Early And Late Ironworking Groups Along The Middle Kavango River In Northern Namibia During The First And Second Millennium AD.

Inaugural-Dissertation zur Erlangung des Doktorgrades der
Philosophischen Fakultät
der Universität zu Köln im Fach Ur- und Frühgeschichte

vorgelegt
von

Eileen Kose

aus
Herrenberg

Köln, 05.04.2016

Erstgutacher: Prof. Dr. Jürgen Richter
Zweitgutachter: Prof. Dr. Ünsal Yalçin
Datum der letzten Prüfung: 12.07.2016

Table of content

Acknowledgement

This doctoral dissertation was financed by the German Science Foundation in the framework of the multidisciplinary collaborative research center ACACIA (SFB 389) of the University of Cologne. After introducing me to the ACACIA research center in 2003 and encouraging me since then to pursue the Kavango archaeology, heartfelt thanks go to my supervisor Professor Jürgen Richter for his many years of support and inspiration on countless occasions. I am very much indebted to my second supervisor Professor Ünsal Yalçin from the German Mining Museum in Bochum whose patience, knowledgeable advice and research interest guided me through the archaeometrical part of this study. Dr. Beatrice Sandelowsky has provided years of friendship and priceless academic as well as logistical support for which I am very grateful. I am indebted to Professor Fred Kamona from the University of Namibia for introducing me to the Kavango geology and to potential iron ore sources of the historical Kavango smelters.

The research could not have gone ahead without generous permission and support from the National Heritage Council of Namibia and the National Museum of Namibia. Thanks must go to Karl Aribeb and Esther Moombolah-Goagoses, to Salomon April and Erica Ndalikokule, to Alma Nankela and Fousy Kambombo. In the same way I am indebted to the authorities of the Kavango region: the Regional Governor of Kavango John Thiguru, Chief Regional Officer Sebastian H. Kantema, and the Kavango Regional Councilor Frieda M. Siwombe who welcomed me in their region and provided me with administrative help during my stays in 2005, 2006 and 2007. Likewise I am very much indebted to the traditional authorities for allowing, supporting and protecting my search of local history: (from west to east) the late Kwangali Hompa Daniel Sitentu Mpasi, Mbunza Hompa Alfons Kaunda, Shambyu Hompa Angelina Matumbo and Chief Advisor Mutero Edward Sikerere, Gciriku Hompa Kassian Shiambiy, and Fumu Mbambo Munika of the Mbukushu. Their recommendations were very important to my work.

I am deeply grateful to the following people who provided me with valuable information about past iron metallurgy in Kavango and southern Angola: Daniel Haikukutu, Jafeti Hainura, Samuel Hausiku, Hidion Karfere, Ndonga Abraham Katara Munganda, Franz Semusi and Paulus Mbundu Siveva, Harupe Paulus Haididira, Mauritius Muyeu Hamtena, Petrus Kudumo Kampanzela, Gerhard Haiugera Kaputungu, Modestus Kashera Shimbiringua, Elius Nangundi Ngomba, the late Nepanda Mbambangandu, Paulus Ndumba, Baltasar Shindimba, Guidion Kayongo Simuma and Paulus Siwoko Simuma, Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Peter Kandjendje, Marcus Kandunda, the late Petrus Kaputura Kashako, Alberto Munoma Makayi, Ndonga Abraham

Katara Munganda, Shiteketa Mbambangandu, Anton Mbamba, Hilda and Roswita Ndumba, and Johannes Kenga Mashela.
This project could not have succeeded without the constant backing from my research assistant Michael Hakusembe, who assisted in fieldwork, organized interviews and translated in the oral history sessions. Heartfelt thanks must also go to Kosmas Kashongo, who assisted and translated in the oral history sessions in the Mbukushu area.
I give thanks to Headwoman Theresia Dona Haupindi, to Headwoman Angelina Runguro Mbangu, to Kletus Likuwa, Josef Kandjimi, Applonia Ghuwanga, and to many more who supported my research on countless occasions.
This project is also the success of those people involved in the fieldwork: Anton Hango, Damiyanu Hausiku, Christina Kempke-Richter, Peter Kudumu, Steven Nependa, John Mandela, Helvi Mbwalala, John Mukoso, Peter Muronga, Renathe Muronga, Clemens Muyeu, Götz Ossendorf, Mukoso Otumato, Boris Schel, and Isabel Schmidt. Special thanks must be given to Muronga and Paulina Heimbili in Ruuga, and to the Hakusembe family in Kapako for supporting our excavations on their ground.

Many thanks are due to my colleagues from the ACACIA research project and the Forschungsstelle Afrika who patiently helped me to overcome academic, administrative as well as technical problems: Ralf Vogelsang, Werner Schuck, Wilhelm Möhlig, Marc Seifert, Barbara Eichhorn, Ulla Tegtmeier, Karin Kindermann, Heiko Riemer, Joris Peters, Friederike Jesse as well as Wolfgang Frank. In the same way I am indebted to Michael Prange, Andreas Ludwig and the staff of the German Mining Museum for their guidance in the laboratory. Greatest thanks must also go to Ed Wilmsen and James Denbow for sharing their finds, findings and ideas with me. I would also like to thank John Kinahan for providing me with data of his Kavango sites. Further, I am grateful to Eugenia Herbert for providing me with the Powell-Cotton Film on Kwanyama ironworking. I am indebted to Anja Rüschmann for her excellent drawings. Many thanks go to Stefan Heidenreich, who assisted me in the lab when the new finds arrived.
A huge thank to my friends and helpers who assisted me with proof reading, database and editing problems, logistical stumbling blocks, photographs, image editing and encouragement over the years: Ahmed Al-Shorman, Franziska Bartz, Wend Ewes, Frank Förster, Marco Hocke, Rosemarie Janisse, David Kelley, Hardy Kose, Carla MacDougall, Monica Nambelela, Adam Newton, Nadine Nolde, Natali Mayer, Michael Scuffil, Christos Vangeltzikis, Chris Waters, Kristin Weber, and Eva Zwissler.
I am grateful to the Catholic Mission in Shambyu for allowing me access to its archaeological collection and for lodging. I give heartfelt thanks to TUCSIN in Windhoek and to the Sarasungu Lodge in Rundu for their overall logistic support of my fieldwork.
Finally, greatest thanks to my parents Gudula and Helmut Kose and to my husband Tshiteya Lubanda for their constant help.

Eileen Kose 2016

Abbreviation index

Al: Aluminum
AMS: Accelerator Mass Spectrometry
As: Arsenic
Ba: Barium
Bi: Bismuth
BL: Bloom
C: Carbon
Ca: Calcium
CL: Clay
CO: Copper artifact
Corg: Organic carbon
Cr: Chromium
Cu: Copper
Dec.: decorated
EFC: Early Farming Communities
EIG: Early Ironworking Groups
Lc: Leucite
LIG: Late Ironworking Groups
LOI: Loss on ignition
LSA: Late Stone Age
Fa: Fayalite
Fe: Iron
FeO: Wustite
Fe_2O_3: Hematite
Fe_3O_4: Magnetite
FL: Furnace lining
FSL: Flow slag
Gl: Glass
GR: Gromp
HA: Hammer scale
Hc: Hercenite
IA: Iron artifact
ICP-OES: Inductively coupled-plasma optical emission spectrometry,
KGS: Kalahari Group sediments
MCC: Munsell color chart
MD: Macroscopic description
Mg: Magnesium
Mn: Manganese
MOD: Modern
Na: Sodium
Ni: Nickel
O: Oxygen
OR: Ore
P: Phosphorus
Pb: Lead
PCS: Polished cross section
PE: Archaeological occupation period
PS: Primary smithing
PSL: Processing slag
PTS: Polished thin section
Quadr.: quadrant
RM: Raw material (RM 1: chalcedony, RM 2: quartzite, RM 23: sandstone), iron raw material
Sb: Antimony
Sc: Scandium
SHB: Smithing hearth bottom
SC: Site catalogue (number)
Si: Silicon
SP: Slag pit
Sp: Spinel
SS: Secondary smithing
SSL: Smelting slag
Ti: Titanium
TY: Tuyere
Undec.: undecorated
USL: Unspcific slag
UDT: Undated
V: Vanadium
Wu: Wustite
XRD: X-ray diffraction
Y: Yttrium
Zn: Zinc
Zr: Zirconium
^{14}C-Radiocarbon dated

1. Introduction

Metallurgy has a significant history in Namibia, yet the advent of metal production is a largely unresearched field in southwestern Africa. This means that the following investigation will be the first academic insight into 1500 years of smelting traditions in Namibia and to some extent in southern Angola. Before this research started, no knowledge about historical iron production had ever been generated in Namibia. Isolated studies exist such as Miller and Kinahan (1993), Miller and Sandelowsky (1999), alongside Miller, Young, Green, Van der Merwe, and Sandelowsky (2005), yet all focusing on copper metallurgy. Besides illuminating metallurgical traditions in northern Namibia, this study also contributes to the understanding of the Divuyu and Nqoma metal assemblages found in the Tsodilo Hills in northwest Botswana, roughly 100 km away from the middle Kavango region. These assemblages have been thoroughly examined by Duncan Miller (1996), yet for many years they were isolated expressions of highly skilled fine smiths in the context of southern Africa's Iron Age cultures (Vansina, 2004; Wilmsen & Denbow, 2010). With this study, the Tsodilo Hills become an integral part of the middle Kavango cultural area and its early metallurgical tradition.

There is a growing body of literature that describes the spread of metallurgy in east and southeast Africa (e.g. Chirikure, 2015), while the same cultural processes are largely unknown in west central and southwestern Africa, even though they are essential for understanding southern Africa's cultural dynamics of the past 2000 years. This lack of knowledge was one of the reasons for choosing this topic as a doctoral thesis, since researching the Kavango region provides an important opportunity to advance understanding of the diffusion of cultural and metallurgical knowledge to southwestern Africa. In northern Namibia, metal artifacts appear in Late Stone Age assemblages between the first and the fifth centuries AD at Geduld (Smith & Jacobson, 1995) and Omungunda (Vogelsang & Eichhorn, 2011), providing evidence for contact between early herders and hunters and iron-producing communities. Most probably, the artifacts found their way to these sites from southern Angola, the Cunene or the Kavango Regions. On the basis of cultural concepts developed for the advent of Iron Age cultures in east and southeastern Africa, where metallurgy, pottery production, agriculture and sedentarism appeared more or less together at a certain moment in history (e.g. Phillipson, 2005; Mitchell, 2002), it is tempting to assume that west central and southwestern Africa underwent a similar cultural change. However, the spread and adoption of these cultural innovations are far from being understood, and cultural developments could be different than expected (e.g. Denbow, 2013, Vansina, 2004). The early as well as the late assemblages investigated along the middle Kavango do not coincide with the archaeological concepts of farmers, herders or foragers commonly applied in a southern African context inasmuch as they are interfaces of theses cultural expressions at the periphery of the Kalahari. Unfortunately, this thesis is unable to encompass the complexity of the early and late interactions of the Kalahari peoples with their neighbors. What is more, due to practical constraints this research work cannot provide a scientific analysis of the faunal remains found in the archaeological assemblages along the middle Kavango River. Nevertheless, an evaluation of the archaeological sites from the past 2000 years provides unique insights into cultural developments along the Kavango, connecting central Angola with the heart of the Kalahari, and adding a missing link to the understanding of the diffusion of cultural knowledge to southwestern and southern Africa.

The archaeological project of the middle Kavango region was realized in the framework of the collaborative research center ACACIA of the University of Cologne, which focused on Holocene cultural dynamics in arid environments. The area was chosen for investigation because it is situated by the first perennial river at the northern limits of the geographical Kalahari, and it displays different cultural trends and developments than the strongly arid regions farther south, which were explored at the same time (Vogelsang, Eichhorn & Richter, 2002; Vogelsang & Eichhorn, 2011). The systematic assessment of the area by Rudolf Kuper, Martin Albrecht and Jürgen Richter from the University of Cologne provided a solid base of sites and finds (Richter, 2005) upon which this research can build. In addition, the thesis also relies on earlier archaeological investigations. Of particular importance are the fieldwork campaigns and the multidisciplinary research approach of Beatrice Sandelowsky from the late 1960ies

(Sandelowsky, 1974, 1979), and the systematic surveys carried out by John Kinahan in the early nineteen-eighties (John Kinahan, 1986). In the framework of my research project, this status of knowledge was then complemented by new and targeted excavations and surveys, carried out in three field seasons. With these additional data and materials, previously formed conclusions were then re-evaluated on the basis of new research questions and approaches. The results of this study rest upon the investigation of a corpus of 60 surveyed or excavated archaeological site-complexes of the Ironworking Groups, including geological sites relevant for the understanding of the raw-material provision of the Kavango peoples. Those sites with evidence of metallurgy receive preferential consideration.

1.1. Aim and structure of this study

This dissertation seeks to reconstruct metallurgical traditions in the middle Kavango region from the early first millennium AD until historical iron production ended in the early twentieth century. The research data are drawn from four main sources: the evaluation of the archaeological assemblages, a sequence of new radiocarbon dates, the scientific examination of ores, metallurgical slags, and iron artifacts and the historical evidence of metallurgy established in the framework of this study. This objective is divided into several research fields:
One important aim is to understand the beginnings of the Early Ironworking Groups and of iron metallurgy in the middle Kavango region. The assemblages of Ruuga (SC 3) and Kapako (SC 4) are investigated to illuminate these processes. With the aid of scientific archaeometallurgical analyses, I reconstruct the metallurgical skills of the first ironworkers of the research area. A second target is to re-evaluate the chronological sequences of the Early and Late Ironworking Groups established in previous studies by Beatrice Sandelowsky (1974, 1979), John Kinahan (1986) and Jürgen Richter (2005). A series of new radiocarbon dates and a higher resolution of the pottery sequences will deepen our understanding of the chronological successions of ironworking peoples along the middle Kavango River.

Another aim is to explore the late metallurgical traditions of the past 500 years. A holistic approach is utilized, integrating cultural archaeological remains, scientific archaeometallurgical analyses and oral history accounts to reconstruct technologies and the significance of iron metallurgy in historical Kavango society. I evaluate the archaeological assemblages from Kapako (SC 4), Vungu-Vungu (SC 12), and Dikundu (SC 30), amongst other sites. The archaeological as well as archaeometallurgical results are contextualized against the background of the region's history and the historical record of ferrous metallurgy. To accomplish the mixed methodological approach, this dissertation also seeks to establish a database of historical knowledge about local iron metallurgy based on oral history interviews. One major research interest influencing the focus of this work comes from the field of African studies, since this study significantly contributes to the correlation of data retrieved from different cultural disciplines to reconstruct the late history of northern Namibia (Seidel, Kose & Möhlig, 2007; Möhlig, Seidel & Seifert, 2009; Seifert, 2009).
Investigating metallurgical tradition also entails investigating the research area's potential ore sources. This means that another concern is an initial assessment of the geological sequences to explore the iron ore sources that were accessible to the Kavango peoples in prehistoric and historical times.

The overall structure of this study takes the form of six chapters, each divided into several sections.
Chapter 1 provides an introduction to this doctoral thesis. The aims and objectives, as well as the structure and the methodological approaches of the research work are outlined. In **section 1.2** a brief consideration of the environment of the middle Kavango region is given, focusing on soil conditions. This is necessary to understand the archaeological site formation and preservation conditions discussed in Chapter 2. In **section 1.3** I sketch the geological background of the middle Kavango region, underpinning my examination of the raw material provision of the Ironworking Groups discussed in the Chapters 2 and 4. **Sections 1.4** and **1.5** are a synopsis of the scientific principles of iron smelting, bloom refining and secondary smithing. Current hypotheses of the technical parameters of bloomery smelting are considered in conjunction with the rich ethnographic record of African ferrous metallurgy. **Section 1.6** describes the archaeological approaches of sampling and slag identification. It discusses the biases of this study resulting from the heterogeneous sampling methods implemented over several

fieldwork campaigns. Furthermore, it briefly describes the scientific laboratory techniques applied in the archaeometrical part of this study, and finishes with a critical reflection on the methodological potential and limitations of scientific slag analyses.

Chapter 2 is a detailed site catalogue of geological and archaeological sites of the Early and Late Ironworking Groups along the middle Kavango. It serves as a reference for this thesis and following studies on other cultural materials, which are only superficially considered in the framework of this research. Individual sites are grouped to site complexes when they appear to aggregate in specific areas along the river. These site complexes are introduced with details on geography and archaeological activities. Whenever information is available, excavation methods, stratigraphy, the dating of the sites and the oral history record are considered. The archaeological assemblages are presented, evaluated and interpreted with a strong focus on the remains of ferrous metallurgy. Results from the archaeometrical analyses of Chapter 4 are presented in conjunction with the findings of the visual slag classification according to the approach presented in section 1.6. If historical accounts exist for the sites (Chapter 5), the findings of the archaeological and metallurgical examinations are discussed against the background of these historical records.

Chapter 3 rests upon the evaluation results of the archaeological assemblages from Chapter 2, and focuses on illuminating and re-viewing the established chronological sequences of the Early and Late Ironworking Groups. It provides insights into the early Kavango sites' temporal placement within the wider geographical context of culturally related assemblages in west central and southwestern Africa. It also addresses the difficulties of positioning the Kavango assemblages in current concepts of the Iron Age or Late Stone Age of southern Africa. Finally, this chapter describes trends in the settlement patterns of the Early and Late Ironworking Groups.

In the archaeometrical part of **Chapter 4**, I present an evaluation the ores (**section 4.1**), slags (**section 4.2**), and metal samples (**section 4.3**) and a discussion of possible ore sources, as well as smelting and refining parameters. Owing to the composition of the slag assemblages on hand, one main issue is the identification of processing steps in post-reduction slags. This chapter also addresses possible furnace designs and the quality and treatments of the iron metal. It concludes with a reconstruction of metallurgical traditions and skilled knowledge for both the Early and the Late Ironworking Groups (**section 4.4**).

In **Chapter 5**, I merge the historical data on metallurgical traditions from the research area and beyond. It starts with an introduction into the complex history of the Late Ironworking Groups, which are the ancestors of the modern Kavango peoples (**section 5.1**). **Section 5.2** outlines the meager state of historical and ethnographic knowledge considering the historical ferrous metallurgy of the Kavango peoples, and seeks to describe the methodological approach to the oral history part of this study. In the following **section 5.3** I give a synthesis of the collected historical data describing the metallurgical traditions of the Kavango peoples based on the narratives and accounts of mining as well as smelting and smithing operations. The chapter highlights the cosmological aspects of ironworking and the sociocultural context of the ironworkers and their metal products. The aim of **section 5.4** is to finally contextualize the results from the previous chapters within a broader cultural perspective of the Kavango peoples, and to reveal the technological traditions alongside the human and spiritual dimensions of iron metallurgy in the Kavango society.

The final **Chapter 6** presents a summary and conclusion of the main findings of this research project, highlighting the new research results of this study and giving some recommendations for future investigations.

All abbreviations used in this study are explained in the Abbreviation Index. Sample numbers (e.g. 4394/06) refer to the registration system of the analytical laboratory of the German Mining Museum at Bochum. These samples are listed with detailed descriptions in numerical order in Appendix 1. The study follows the APA format and citation style.

1.2. The Kavango river environment and soils

The research area stretches for approximately 330 km along the middle Kavango River from Nkurenkuru in the west to the border of Botswana (Figure 1). The middle Kavango region is situated at the

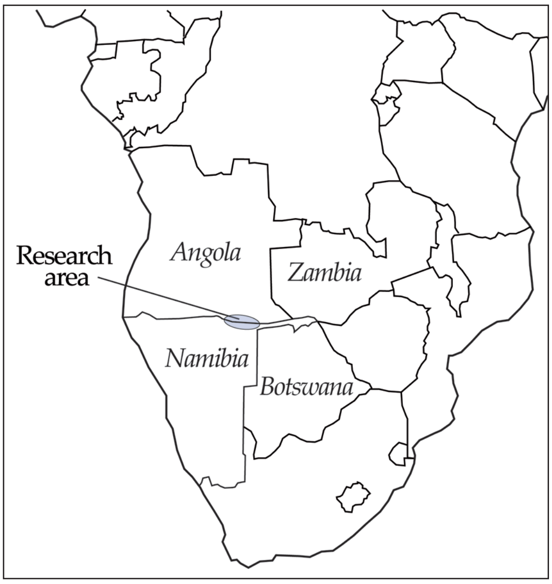


Figure 1: Research area of this study.

northern limits of the semi-arid to arid geographical Kalahari, which is a large sandy desert and savanna (Figure 3). The average rainfall is no more than 400 to 600 mm per year and the evaporation rate is six times higher than the rainfall rate (Mendelsohn & el Obeid, 2004, pp. 12, 26). The Kavango River is part of the Kwito, Cubango (Upper Kavango) and Okavango (Kavango Delta) catchment area (Figure 2). It has its origins in central Angola and ends in the Okavango inland delta in Botswana. It covers a total length of 1860 km. In the semi-arid Kalahari region, the Kavango River and its tributaries have formed linear oases and therefore constituted an attractive ecosystem in the past, and still do in present times (Kgathi, et al., 2006; Mendelsohn & el Obeid, 2004, p. 26). The water of the Kavango originates from wetter regions in central Angola with significantly higher rainfalls than in northern Namibia or northwest Botswana (Steudel et al., 2013) (Figure 2). All the water-carrying tributaries come from the north, while from the south several dry palaeo-riverbeds such as the Omatako or Fontein Omuramba[1] (Figure 158) join the catchment area. The latter carry water in years or periods of higher rainfall and have provided freshwater in waterholes and wells (Figure 145). The Kavango stream gradient constitutes 700 m per 1000 km between the headwater and the Namibian border, and 200 m per 800 km along the middle and the lower Kavango in Namibia and Botswana (Mendelsohn & el Obeid, 2004, p. 40). From Tondoro eastwards the Kavango River develops in a meandering river in a wide valley (Figure 5) with vast floodplains (Figure 4) and sluggishly moving water. The vegetation of the middle Kavango River has been comprehensively described in Kose (2004) as well as Mendelsohn and el Obeid (2004), and will not be repeated in this section.

1.2.1. Soils and find-bearing sequences in the Kavango

Little research has been done to analyze and classify the soils along the middle Kavango River. The general topography allows for categorizing the Kavango soils into arenosols of the sand plateau and alluvial soil forms (mixed with Kalahari sands) on the upper, middle and lower terraces of the river (Mendelson & el Obeid, 2004, p. 43; A.O.C. Technical Services, 1967, pp. 10-12; Groengroeft, Luther-Mosebach, Landschreiber & Eschenbach, 2013). The first are the dominant soil forms in the Kavango region. The term arenosol describes sandy soils that consist of unconsolidated dislocated sand deposits (for instance deposited by wind or water) (Driessen, Decker, Spaargaren & Nachtergaele, 2001, p. 65). They are frequently found in arid regions. In dry zones, these soils hardly display diagnostic soil horizons apart from a beginning A horizon and their texture is loamy sand or coarser (Scheffer, Schachtschabel & Blume, 2002, p. 525). In northern Namibia, 70% of the soil body consists of sand, while clay and silt amount to no more than approximately 10% (Mendelson & el Obeid, 2004, p. 43). In regions formed by shifting dunes, soil profiles do not develop before the dunes are covered and stabilized by vegetation. In arid regions, the organic carbon content of such soils is less than 0.5%, which means that these soils are low in humic matter and other nutrients (Driessen et al., 2001, p. 70; Scheffer et al., 2002, p. 525). Arenosols may appear deep red in desert regions where grains have built up a coating of goethite, and in the Kavango Regions red sands frequently indicate the underlying weathering ferricretes of the Omatako formation (section 1.3.2.10). Due to their porous structure and high permeability, these soils retain little moisture (Schneider, 1987, p. 199). Consequently, there is little run-off of surface water to cause erosion gullies and the relocation of archaeological material. In zones with little vegetation, sand can be blown out from the surface layer due to aeolian activity. This process can affect archaeological open air sites. Without protecting soil layers or vegetation cover, finds of different ages may sink together on a vertical axis and

[1] Herero: dry riverbed.

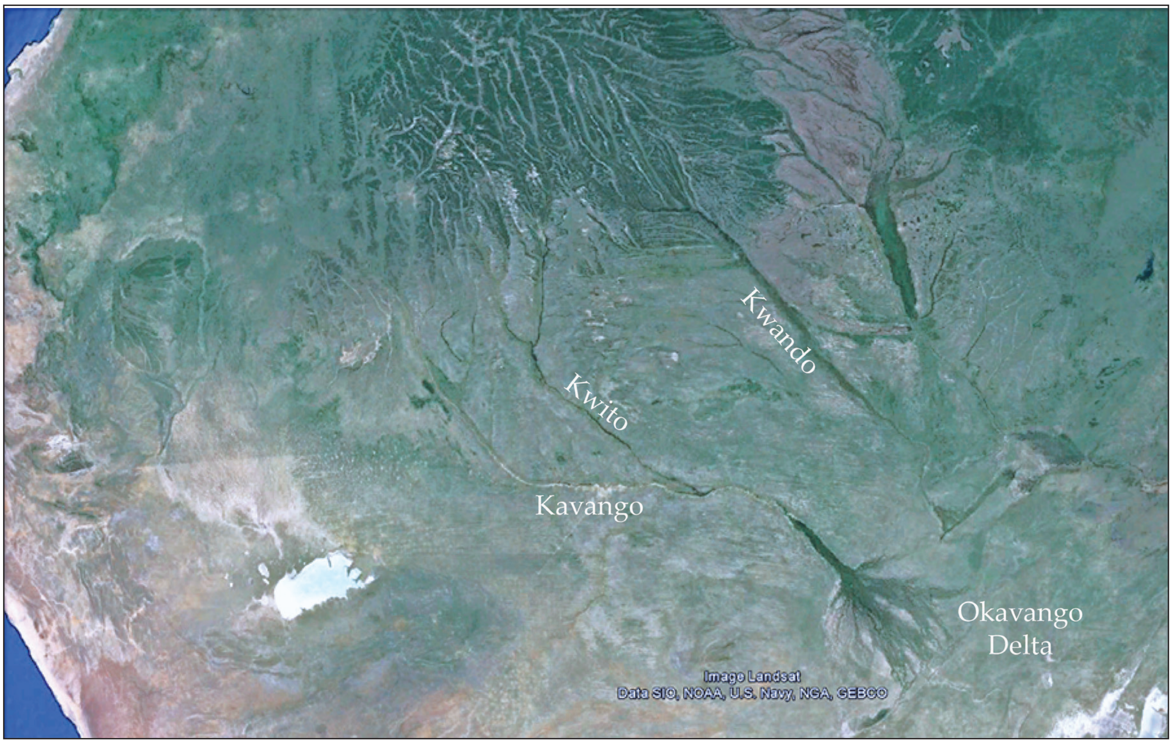


Figure 2: Kavango catchment (image: Google Earth).

appear isochronous later (Holdaway, 2014). The possibility of such deflation processes is discussed in section 2.3.1.2 for the archaeological site Ruuga (SC 3).

Along the braided main river system and its tributaries, young alluvial soil forms have been deposited. Following the description of the reconnaissance soil survey of Kavango soils from 1967 (A.O.C., 1967), the Kavango soils are to be classified into recent alluvia in the floodplains, older loamy soil forms of former floodplains (a mix of clay, silt and sand) on the middle terrace (20 ft. terrace), and remnants of old loamy alluvial soils covered by aeolian sand on the upper river terrace (60 ft. terrace) (see also Groengroeft et al., 2013; Mendelson & el Obeid, 2004, p. 43; Schneider 1987, p. 200). The clay content of these soils varies between 7% and 35%, and increases downhill towards the river (A.O.C., 1967, pp. 10-12). Generally, alluvial soils exhibit a high organic matter and nutrient content, which makes them attractive for agriculture. Due to their alluvial nature, they display a higher internal variability in composition than the arenosols (Groengroeft et al., 2013, p. 108).

Unlike the main river, the fossil tributaries are deeply incised into the inland sand plateau without forming old high terraces (Schneider, 1987, p. 200). At the bottom of these drainage lines as well as in inter-dune valleys, dark, clayey alluvial soils developed similar to those of the upper terrace of the Kavango main river (Mendelson & el Obeid, 2004, p. 44; Schneider, 1987, p. 200), and in places, gleysols have formed (Groengroeft et al., 2013, p. 105) In topographic positions with seasonal waterlogging, plinthic soil forms have developed (see sections 1.3.2.6, 1.3.2.10; Figures 10, 11, 12, 13, 14, and 15). As mentioned, the Kavango soils are highly permeable well-drained sandy soils with low silt and clay contents, except for the clayey fluvisols in the floodplains and on the lowest river terrace (Schneider, 1987, p. 210). The high permeability prevents deeply incised gully erosion that may affect archaeological sites. Conversely, the loose soil consistency favors the dislocation of artifacts owing to wind erosion, human activities and pedoturbation. Moreover, high temperatures, high permeability for oxygen and recurrent humidification cause rapid decay of organic material such as bone and wood (A. Groengroeft, personal communication).

1.3. Geological overview

This chapter aims at giving a short introduction to the geological formations found in the Kavango area in order to establish the background knowledge necessary to assess ore resources, and to understand the depositional nature and constraints of the archaeological sites.

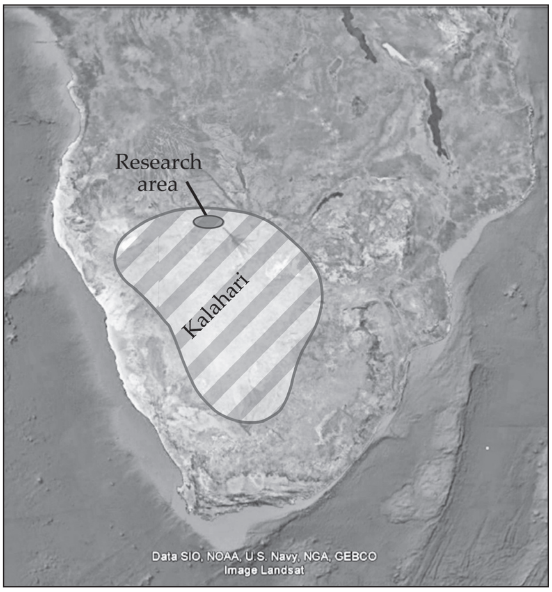


Figure 3: The approximate extension of the arid and semi-arid geographical Kalahari (background image: Google Earth).

1.3.1. The Kalahari: its geological formation and environments

The Kalahari is a very extensive body of sand in central and southern Africa, and there are several views on what the Kalahari actually is. The most popular concepts of the Kalahari are either geological or environmental. The geological Kalahari unit, which is called the Mega Kalahari, extends over an area from Gabon to South Africa and from Angola to Zimbabwe. The environmental definition of the Kalahari Desert describes an arid landscape situated in Botswana and Namibia (Figure 3).

The Mega Kalahari is part of the Kalahari-Cubango-Congo basin that resulted from a large down-warp in the African interior, starting in the mid-Jurassic period approximately 180 million years ago (Haddon, 2000; Haddon & McCarthy, 2005; Thomas & Shaw, 1990; Thomas & Shaw, 1991, pp. 24-27). The geological Kalahari is a vast flat landscape covered by a thick layer of Kalahari sands with few exposures of rocks. Its geomorphology has been formed over millennia and is characterized by dry riverbeds, palaeo-lakes and palaeo-dune formations that indicate a diversified environmental past. Within the Mega Kalahari, there are varying sub-basins into which continental sediments have been deposited since the Jurassic (Haddon, 2000; Haddon & McCarthy, 2005), which are known as Kalahari Group sediments, as will be shown later. In addition, one finds a large variety of climate and vegetation zones. The core area, in the southern part of the Mega Kalahari, is the arid to semi-arid Kalahari Desert that stretches across parts of Botswana, Namibia, and South Africa. It is characterized by low precipitation and by lack of permanent or seasonal watercourses. For most of the year, surface water is extremely rare. To the north, the Kalahari Desert gives way to the Etosha-Okavango-Zambezi swamp zones, while its southern edge is delimited by the Orange River. In the east, the arid landscape ends at a line from the eastern edge of the Okavango swamps down to the Maghadighadi Pan, and roughly along the Kalahari-Limpopo watershed[2] (Thomas & Shaw, 1991, pp. 5-11). To the west, the desert is delimited by the Great Escarpment Mountains.

1.3.2. Geological Sequences

As mentioned above, the Kalahari is a comparatively recent geological landscape. However, Precambrian rocks form the basement of the Kalahari basin, and in most areas Paleozoic to Mesozoic Karoo sediments cover the older strata.

1.3.2.1. The pre-Kalahari sequences

The deeper geological sequences of the Kalahari basin are not well understood. Scholars have proposed that archaic Precambrian rocks form the basement of the Kalahari basin but stratigraphical affinities are still uncertain (Haddon, 2005; Thomas & Shaw, 1991, pp. 39-52). Generally, geologists distinguish two zones of basement rocks (Thomas & Shaw, 1991, p. 40). These zones are located north and south of the Medial Rift that stretches southwest/northeast across the Kalahari Desert region (Haddon, 2005, p. 63). Three groups characterize the northern basement rocks: the Kgwebe Formation volcanics as the oldest, the Ghanzi Group sediments, and younger deposits of the Damara sequence (Thomas & Shaw, 1991, p. 43; see also Hegenberger, 1987). The deposits of the Kgwebe Formation are of volcanic origin and consist of quartz-feldspar porphyrics and diabase. The only outcrop of this formation within the Kalahari is in the Kgwebe Hills, south of the

[2] In an archaeological context, this border is frequently referred to as the transition between the Sandveld and the Hardveld.

Ngami Basin (Thomas & Shaw, 1991, p. 44). The major outcrop of the Ghanzi Group Sediments is the Ghanzi Ridge in the central Kalahari Desert, which is an axis of folding stretching southwest/northeast across the Kalahari Desert. Many faults, grabens, and ridges of similar orientation running across the Kalahari Basin can be seen as an extension of the East African Rift System that developed during the Eocene and Oligocene (Haddon, 2005, p. 216). Ghanzi Group sediments mainly include gritstone, mudstone, and limestone. The Damara Belt (or Katanga sequences in Zambia) extends southwest/northeast through the Kalahari Basin in Namibia, Botswana and Zambia, and exposes only a few outcrops in the Kalahari Desert. Damara Group deposits are mainly formed from quartzite, sandstones, siltstones, limestone, and massive dolomite (Thomas & Shaw, 1991, p. 44).
In the middle and lower Kavango region, the Damara sequence directly underlies the Kalahari Group sediments. Its major exposures are the Aha Hills and in the Nxaunxaun Valley northwest of the Okavango Delta. Also, the Tsodilo Hills and smaller outcrops along the Kavango River valley such as those between Mukwe and the Popa Falls represent the same formation (Hegenberger, 1987, pp. 99-104; Thomas & Shaw, 1991, p. 44).
Beneath most parts of the Kalahari Group Sediments, sequences of the Karoo Formation have occurred. The Karoo Formation comprises five subgroups (Dwyka, Ecca, Beaufort, Stormberg, and Drakensberg), from which the deposits of the lower groups include largely shallow freshwater and terrestrial deposits and some glacial and marine deposits as well (Dwyka Formation). Generally speaking, the oldest of these deposits are of glacial origin, the sequences of the middle Karoo deposits reflect cool temperate conditions, and the upper ones formed under desertic influence. The uppermost Karoo layers, however, consist of volcanic deposits (Stormberg Lavas) (Thomas & Shaw, 1991, p. 45).
In late or post-Karoo times, dolerite dykes formed in many parts of the Kalahari, cutting across the Precambrian deposits and Karoo sediments. Additionally, kimberlite pipes are scattered throughout the Kalahari basin, which are younger than the dolerite dykes (Balfour, Hegenberger, Medlycott & Wilson, 1985; Jelsma et al., 2004; Thomas & Shaw, 1991, pp. 51-52).

1.3.2.2. The Kalahari Sequences

The Kalahari Group sediments date from the Tertiary and Quaternary periods. In the Late Jurassic, during the break-up of Gondwanaland, the edges of the African continent rose, causing the formation of the Great Escarpment around southern Africa. The down-warping of the southern African interior favored the development of a drainage system with few outflows but with large river systems, palaeo-lakes, and swamps in the continental basins, providing the settings for the genesis of the earliest Kalahari Group sediments (KGS) (Haddon, 2000, p. 173; Partridge & Maud, 2000;

Figure 4: Kavango floodplains near Ruuga during the dry season.

Thomas & Shaw, 1990, pp. 189-191; Thomas & Shaw, 1991, p. 34). These drainage systems transported large sediment loads to the interior of the inland basin, and most of the Kalahari sediments therefore accumulated along palaeo-lakes and rivers (Haddon & McCarthy, 2005, pp. 321-324).

The recent river courses of the central and southern Kalahari basin are not what they were in the geological past. Cretaceous to recent earth movements of the southern African cratons along major fault lines and seismic axes caused several alterations in the direction of the fluvial drainage systems of southern Africa (Haddon & McCarthy, 2005, pp. 324-327). The recent course of the Kavango River, for instance, is, according to Haddon and McCarthy (2005, p. 323), the result of two palaeo-rivers. During the Early to Late Cretaceous, one of these rivers was formed by the upper Kavango (Cubango) and Kwito, and drained as far south as the Ghanzi Ridge. From there, it probably continued further east. The middle and lower Kavango, however, together with the palaeo-Kwando River, are believed to have flowed into the palaeo-Limpopo at that time (Haddon & McCarthy, 2005, p. 323). Scholars believe that during the Pliocene the headwaters of the palaeo-middle and -lower Kavango Rivers captured the palaeo-upper Kavango along with the ancient course of the Kwito River owing to seismic activities in the Etosha basin. In the Pliocene and Pleistocene, tectonic movements along the Otavi-Caprivi seismic axis and along the Ghanzi Ridge blocked the Kavango and Kwando rivers on their way to the south (Haddon & McCarthy, 2005, p. 326; Wanke, 2005). These faults and grabens, stretching from the northeast to the southwest, are considered the extension of the East African rift system to the southwest (Haddon, 2000, p. 173; Haddon & McCarthy, 2005, pp. 327-328; Wanke, 2005, pp. 543-545). The Okavango Delta zone, i.e. the seismic axes across the Kalahari Basin, was seismically active until recent times. At their distal ends, the Kavango and Kwito Rivers formed inland deltas or alluvial fans, which developed into unique wetlands.

The Kalahari sediments have accumulated across the continental Kalahari Basin. Strong regional variations developed as a result of geomorphological sub-structures such as the Etosha depression, the Okavango rift systems, and the Maghadighadi depression (Haddon 2000, p. 175; Thomas & Shaw, 1990, p. 191). The thickness of the Kalahari sediments, as far as has been investigated, ranges from about 450 m to less than 30 m, with the thickest stratigraphical sequences occurring in the Etosha depression, the Okavango Rift, and in south-eastern Angola (Haddon & McCarthy, 2005, p. 318). The formation and alteration of the Kalahari Beds is the result of many factors: The diagenesis of the Kalahari Group strata, the weathering of underlying rock, the removal of base elements in solution, the addition of aeolian silica and calcium, the precipitation and re-solution of calcium carbonate and silica, and more recent tectonic activities (Thomas & Shaw, 1991, p. 63). However, it is not always easy to distinguish in the geological record whether the processes at the base of the accumulation of the Kalahari Group sediments in specific regions are due to tectonic activity or to climatic processes (Wanke & Wanke, 2007, p. 315).

The age of these sediments is difficult to determine for many reasons. Concerning the oldest sediments, scholars suggest the deposition of the Kalahari sequences started in the Late Cretaceous period (Thomas & Shaw, 1991, p. 53). Dates from fossil water, pan sediments, and calcrete carbon also indicate Quaternary ages. Generally, scholars distinguish between two groups of Kalahari sediments (Mendelsohn & el Obeid, 2003, p. 28). The first group comprises conglomerates and gravels, marl, sandstone, alluvia, lacustrine deposits and duricrusts. They are considered older than the second group of Kalahari sand deposits (Thomas & Shaw, 1991, p. 60). The characteristic Kalahari dunes formed during the last glacial period and date from the late Pleistocene or Holocene (Lancaster, 2000, p. 77). Generally, the sequences of the depositional strata vary considerably throughout the Mega Kalahari Basin. Although there are general lithological similarities between the varying deposits of the interior basins, local reworking and re-deposition, continuing up to recent times, together with a particular lack of exposed strata of the early Kalahari sequences makes it difficult to establish a supra-regional stratigraphy (Haddon, 2000, p. 175; Thomas, 1988; Thomas & Shaw, 1991, pp. 60-62). Nevertheless, Haddon (2005, pp. 89-117) suggests a schematic idealized stratigraphy of the Kalahari sequences with coarse, basal gravels being the deepest layers, which became covered by finer fluvial gravels. Above these layers, clay deposits are found followed by extensive layers of red, brown, or yellow sand- and gritstone of secondary sedimentary structure. Calcretized or silcretized sediments (duricrusts) cover these sandstone layers, but in some areas, pan sediments form the uppermost strata. Pans contain complex sequences of sediments with contributions from flooding, aeolian activity, groundwater movement, weathering, and duricrusts (Haddon, 2000, p. 178). Most pans are filled by layers of clayey sand, silt, or alkaline calcareous clays, and are characterized by lunette dunes downwind of the pan depression (Haddon, 2005, p. 117). At some locations, diatomaceous pan deposits have developed, which consist of fossilized skeletons of diatoms of microscopic size, and unicellular plants forming a class of algae (Haddon, 2005, p. 118). However, the most common surface unit of the Kalahari Group is unconsolidated sand that covers an area of 2.5 million km² in central southern Africa (Lancaster, 2000, p. 74). In some places, the sand cover reaches a thickness in excess of 300 m (Haddon, 2000, p. 176). In most regions, vegetation covers the surface layers, ranging from scrub savanna and savanna woodland to grassland and tropical forests in the north (Lancaster, 2000, p. 74).

1.3.2.3. The formation of duricrusts

Duricrusts such as calcretes, silcretes, and ferricretes cover huge areas of the Kalahari Basin. They occur at varying stratigraphical levels throughout the Kalahari beds (Haddon, 2000, p. 177) and are also present in the Kavango region. Most of the duricrusts are formed from either groundwater activity or pedogenetic processes within the range of soil moisture fluctuation, and local variation in crust formation is common (Atlhopheng & Ekosse, 2007; Botha, 2000, p. 135). The formation of duricrusts depends largely on the climatic conditions, and the distribution of duricrust types in the Kalahari follows precipitation gradients. Ferricretes are more often found in the northern Kalahari region with higher precipitation, and silcretes and calcretes dominate the arid Kalahari core regions (Atlhopheng & Ekosse, 2007, p. 55; Haddon 2005, p. 101).

1.3.2.4. Calcretes

Calcretes are near-surface accumulations of calcium carbonate in soil profiles, sediments or bedrock that form calcrete horizons. Usually, they develop in arid to semi-arid climatic zones where calcium carbonate, which is generally enriched in drier regions, cannot be moved away during wetter seasons (Wright, 2007, p. 13). Characteristically, calcretes are found near to the surface in varying forms ranging from powdery to highly indurated, depending on their mode of formation (Atlhopheng & Ekosse, 2007, p. 51; Wright, 2007, p. 10). They are formed from either groundwater or pedogenetic activity. The non-pedogenetic calcretes, which are of interest for the area under study, are known as groundwater, phreatic, valley or channel calcretes. Their formation relates to the movement of sub-surface water that could be lacustrine, riverine or from the groundwater table (Atlhopheng & Ekosse, 2007, p. 51). Recent formations of powdery to nodular calcretes indicate that calcretes may still be forming (Haddon 2000, p. 177; Netterberg, 1974, p. 87; Netterberg & Caiger, 1983). Powdery to nodular calcretes were found in the lower layers of the archaeological sites of Ruuga, Kapako and Vungu-Vungu. In addition, the carbonate coating of most of the finds from Ruuga, dating as far back as the third to fourth centuries AD, implies that the crust formation is still ongoing. Commonly, calcretes overlay a sandstone formation, and along the Middle Kavango, they overlay sandstone, silcretes or ferricretes. These sandstones frequently grade upwards from sandstone to calcareous sandstone and a sandy calcrete (Thomas, 1981 as cited after Haddon, 2000, p. 177) and along the middle Kavango, sil-calcretes or calcareous ferricretes occur in zones of transition. In some regions, there is also evidence for alternating sequences of carbonate deposits and sandstone (Wanke & Wanke, 2007, p. 320).

1.3.2.5. Silcretes

Silcretes are silica accumulations in soils, sediments or rocks caused by near-surface weathering processes (Nash & Ullyott, 2007, p. 95). They are defined as containing more than 85wt% SiO_2 (Summerfield, 1983 as cited after Nash & Ullyott, 2007, p. 95), and are also known as surface quartzites (Botha, 2000, p. 137). Silcretes occur in a great number of varying forms depending on the conditions of formation and geomorphological settings (Nash & Ullyott, 2007, pp. 101-105).
The chemical weathering of silicate minerals constitutes the main source for silcrete formation. Silica may be derived from local rocks, sand, or soils. Also, external input of silica may occur in solution through ground-water or surface-water activity, or through silicate-rich and quartz-rich materials that were brought in through wind erosion (Atlhopheng & Ekosse, 2007, p. 51; Haddon, 2005, pp. 97-98; Nash & Ullyott, 2007, p. 117). Silica is weakly

soluble in an acidic and neutral environment. Strong silica solubility mainly occurs at pH above nine, which is common in arid and semi-arid environments as a result of evaporation (Chadwick, Hendricks & Nettleton, 1989 as cited in Nash & Ullyott, 2007, p. 115; Okrusch & Matthes, 2014, pp. 342-343). More often, silica becomes available through the weathering of ferromagnesian minerals, feldspars and the breakdown of clay minerals under acidic conditions in environments with, for instance, high organic productivity. Silcrete formation is therefore frequently attended by laterite formation (Nash & Ullyott, 2007, p. 116; Okrusch & Matthes, 2014, pp. 342-343). Also, there exist a number of important biological silica sources such as plants and bacteria.

Silcretes vary considerably in their consistency depending on their genesis (Atlhopheng & Ekosse, 2007, p. 54; Botha, 2000, p. 139). In many cases, they are associated with former land surfaces, as silicification depends on chemical processes at the surface or near the near surface (Haddon, 2005, p. 97). Silcretes occur in recent fluvial or pan sediments as well as throughout younger and older Kalahari Group sequences (e.g. Botha, 2000, p. 138). In the central Kalahari, near-surface drainage-line silcretes along riverbeds and pan silcretes are common together with other silicified strata or lenses within calcrete profiles (Botha, 2000, p. 138; Netterberg, 1974; Wanke & Wanke, 2007, p. 319). However, as mentioned above, frequently we see gradational associations with ferricretes and calcretes, in the form of ferro-silcretes, sil-calcretes and others, as is the case at many sites in the area under study.

1.3.2.6. Plinthites and laterites

The Kavango smelters used local near-surface secondary ores for iron production up to the early twentieth century. These ores are of high quality and easily accessible for pre-industrial exploitation. Therefore, this chapter gives a short introductory description of the formation and nature of these ores.

The secondary ores that I identified in the Kavango region can be classified either as laterites or plinthites, depending on the describing discipline (geology or pedology). These terms are applied to a wide range of weathering products with high iron and aluminum enrichment. There has been much discussion about the concepts and definition of laterites (e.g. Widdowson, 2007, pp. 47-48; Tardy, 1997, pp. 3-5; Aleva, 1994, pp. 8-17) and different approaches have been made to classify their diverse nature and texture. As they occur in forms ranging from soft, soil-like and slightly indurated iron enrichments to rock-like duricrusts, they do not fit the category of either rocks or soils. To avoid these problems of classification, I base my understanding of laterites on the very broad perception of Tardy (1997, pp. 3-5). However, the most important distinction of these soil products is whether the Fe/Al-enrichment-forming minerals are of autochthonous[3] or allochthonous[4] origin (Widdowson, 2007, pp. 46-49; Cornell & Schwertmann, 2003, p. 421; Fey, 2010, p. 100), and whether the iron oxides segregated into mottles and cemented horizons through groundwater fluctuations (also known as groundwater laterite) or not (Driessen et al., 2001, p. 151; Fey, 2010, p. 100).

Generally, laterites are residual products of the decay of parent rock material. They are typical weathering products under tropical and sub-tropical environmental conditions because high temperatures and humidity favor chemical decomposition and a greater mobility of minerals (Aleva, 1994, pp. 71-73; McFarlane, 1976, pp. 39-45; Okrusch & Matthes, 2014, p. 343; Tardy, 1997, p. 3; Velde & Barré, 2010, p. 25; Widdowson, 2007, p. 46). Typical weathering profiles develop from the chemical alteration processes of minerals of varying solubility and display a characteristic zoning of secondary mineral formations. Less soluble minerals are enriched in the upper near-surface zones of the profile whereas mobile minerals leach to the lower parts (Aleva, 1994, p. 21; Fey, 2010, p. 100; Okrusch & Matthes, 2014, pp. 342-343). Laterite profiles built up on iron-bearing parent materials, and the degree of mineral alteration diminishes with depth. Characteristically, these profiles display several zones of weathered parent-rock material at the bottom, and zones of secondary mineral accumulations at the top (Aleva, 1994, p. 26; Velde & Barré, 2010, 149; Widdowson, 2007, pp. 55-58). The predominant secondary minerals formed during laterization are iron and aluminum oxides (goethite, hematite, kaolinite, gibbsite), because minerals formerly incorporated into silicates change to free oxide phases (Widdowson, 2007, pp. 67-68; Velde & Barré, 2010, p. 225). Enrichment of important minor elements such as chrome, nickel,

[3] Residual, Oxidic Soils after Fey (2010, p. 18).

[4] Imported, absolute, Plinthic Soil according to Fey (2010, p. 18).

manganese, titanium, and others may also occur in different horizons throughout the weathering profile (Aleva, 1994, p. 26; Okrusch & Matthes, 2014, p. 345).

Unlike the residual weathering profiles described above, alteration profiles need an external source of mobilized iron from higher landscape positions, and in some cases, they bear fragments of materials of non-local origin (Fey, 2010, p. 18; Widdowson, 2007, pp. 54-61). Alteration profiles can develop on non-iron-bearing rock types such as limestone, calcretes, sandstone, or sand as a result of the allochthonous (imported) input of ferruginous solutions into a host-material, or mechanically derived iron-bearing substances of non-local origin (Cornell & Schwertmann, 2003, pp. 421-422; Widdowson, 2007, pp. 49-68; Young, 1980, p. 175). Within alteration profiles, Fe-enriched horizons frequently overlay unaltered strata and clearly differ from classical weathering profiles in appearance (Widdowson, 2007, p. 59). In addition, the concentration of Fe is usually higher than in residual laterite profiles (Cornell & Schwertmann, 2003, p. 421). Because of the nature of erosional processes, alteration profiles predominantly develop in topographic depressions such as former lakes, swamps, valley floors, and valley sides. However, well-developed ferricretes may act as a caprock (mesa) later, and will be found in a topographically elevated position when softer material has been eroded away around the duricrust (e.g. Cornell & Schwertmann, 2003; pp. 421-422, 443; Tardy, 1997; pp. 225-229; Widdowson, 2007, p. 54). The mineralogical composition of alteration profiles is inherited from the allochthonous material of origin and the subsequent cementation processes (Widdowson, 2007, p. 68). Nevertheless, the distinction between residual weathering profiles and allochthonus alteration profiles can be difficult, as groundwater chemistry with dissolution and precipitation processes alters the structure of the original soil sequences (Widdowson, 2007, p. 49; Fey, 2010, p. 100). Allochthonus Fe-enrichment horizons exposed to weathering processes may develop a residual weathering profile later (Widdowson, 2007, p. 49). Consequently, at many locations it is difficult to determine whether the ferruginous horizons formed as a result of in situ weathering or from polygenetic factors such as the reworking of former ferricretes, transport through erosion, plant activities, or other geomorphologic processes (Botha, 2000, p. 142).

Most chemical weathering is a result of reactions caused by rain and groundwater together with carbon dioxide or carbonic acid, leading to the breakdown of parent materials with a loss of elements (Okrusch & Matthes, 2014, p. 341; Widdowson, 2007, p. 61).

Iron accumulation and crust formation in soils depend upon the solubility and retention of iron, both of which are influenced by a complex interconnection of redox conditions and pH (Cornell & Schwertmann, 2003, pp. 201-214; Widdowson, 2007, p. 64). For instance, iron in a divalent oxidation state is soluble in water. In a trivalent state, it is only soluble in a strongly acidic environment (Widdowson, 2007, p. 64; Velde & Barré, 2010, p. 148). Thus, horizontal and vertical pH-gradients in soils are just as important for the migration of iron oxides as are the redox conditions (Fey, 2010, p. 101). In most ferromagnesian silicates such as fayalite, iron occurs in a divalent state. In chemical weathering, unstable minerals (for instance high-temperature minerals such as olivine, pyroxenes and others) are rapidly transformed into non-iron-bearing clay minerals, and iron separates from silica if there is enough aluminum to form new clay minerals (Velde & Barré, 2010, p. 45). These newly formed silicate minerals are of low iron content. Under oxidizing soil conditions, which are usually found near the surface, and in deeper horizons of well-aerated soils, the expelled iron oxides change into their trivalent state and form insoluble phases (Velde & Barré, 2010, pp. 45, 148). Thus iron minerals in a trivalent oxidation state such as goethite and hematite are dominant in the final stage of weathering processes. They form soil horizons from slightly indurated mottles to extremely hardened crusts if the enrichment horizon was repeatedly exposed to drying (Cornell & Schwertmann, 2003, p. 422; Fey, 2010, p. 94; Velde & Barré, 2010, p. 147).

Besides the weathering parameters mentioned above, plant activity and bacteria are also important agents in chemical weathering processes and the formation of alteration profiles (plinthites) (Velde & Barré, 2010, pp. 225-227; Fey, 2010). Under anaerobic conditions, bacteria use the oxygen of trivalent iron oxides and reduce them into the bivalent state. Waterlogging accelerates the reduction process by the bacteria, because it slows down the diffusion of oxygen in soils, and organic matter intensifies these processes too (Fey, 2010, pp. 101-102). Under anaerobic conditions, groundwater can transport dissolved iron over long distances

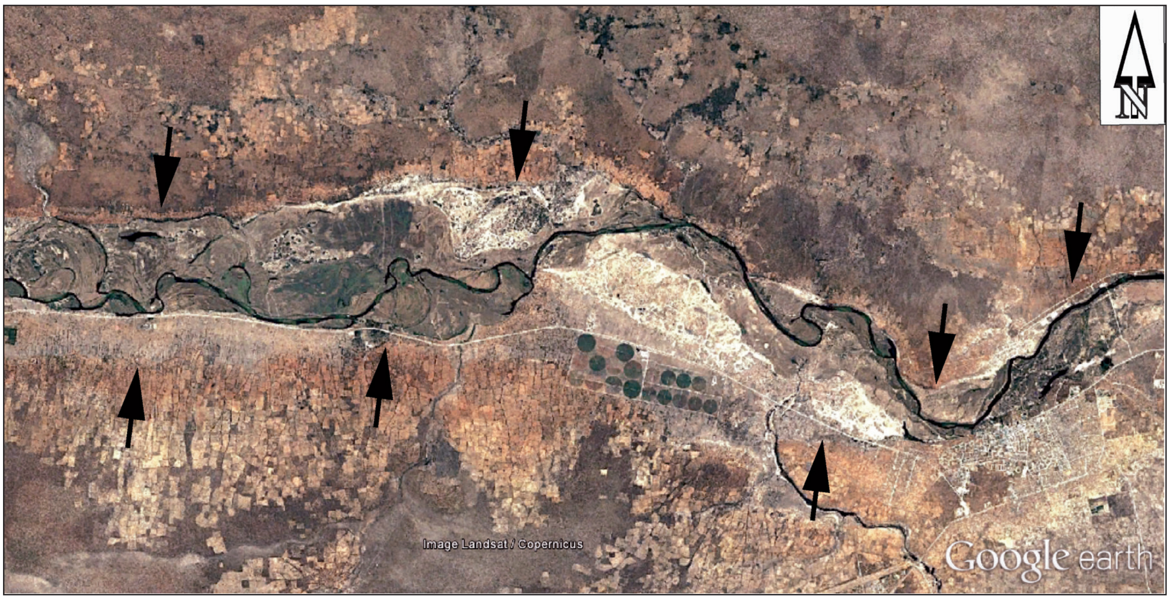


Figure 5: Omatako Formation, weathering outcrop along the Kavango River west of Rundu (backround image: Google Earth).

until it precipitates out in an oxidizing environment and concentrates in the periodically aerated zones of soils (Fey, 2010, p. 100; Widdowson, 2007, p. 64). However, segregated Fe-concentrations are not necessarily imported. They can be formed in situ and by bacteria that increase the rate of oxidation and reduction (Fey, 2010, p. 100). Mobile iron oxides (and other minerals) frequently precipitate along vertical channel walls (i.e. root channels) where oxygen has access to soil, and form pseudomorphs with the original form of the channel (pedotubules) (Fey, 2010, p. 66). Alteration profiles (plinthite) form preferentially in sub-humid climate conditions with well-defined dry and wet seasons, and plinthic soil horizons need cyclic wetting and drying for their formation (Fey, 2010, pp. 94, 100). As mentioned above, one may find them frequently in gentle concave lower slopes where Fe-enriched water accumulates through seepage from the adjacent more elevated areas. In southern Africa, these plinthic catenas where red soils grade via yellow soils on mid-slopes to gray soils in poorly drained bottom lands are common (Fey, 2010, p. 102). The zoning of colors thereby indicates the degree of wetness and the duration of stagnant moisture. Red soil colors (hematite Fe_2O_3) form in drier conditions than yellow ones (goethite $FeO(OH)$). Additionally, goethite is more resistant to dissolution under reducing conditions than hematite (Fey, 2010, p. 97). Gray soil colors associated with the red and yellow zones are considered a result of gleying (groundwater saturation, reducing conditions, impoverished by Fe and Mn) (Fey, 2010, p. 94).

Besides, alteration profiles tend to form on sedimentary rather than igneous rocks owing to a greater lateral movement of groundwater into lower landscape positions (Fey, 2010, p. 100). Additionally, lateral and downward migration of groundwater occurs rather in coarse-textured, permeable soils (Fey, 2010, p. 52). Plinthic horizons harden irreversibly if they repeatedly dry out. As briefly described earlier, in many parts of sub-Sahelian Africa petroplinthites (also known as ferricretes) form thick caps in the landscape and prevent further erosion, and former catenas have changed into elevated topographic positions. As a result, ferricretes or hardened plinthic horizons are commonly found at exposed landscape formations such as mesas and upper river terraces (Driessen et al., 2001, p. 151).

Residual weathering profiles usually display a typical distribution of major and minor elements in their principal horizons (Widdowson, 2007, p. 69). In the weathering horizon immediately above the parent rock (saprolite zone), mobile elements such as Na, Ca, Mg and Sr are leached as a result of the breakdown of feldspars and ferromagnesian minerals. Other elements such as Si and Al are partially retained owing to the formation of new secondary minerals (Okrusch & Matthes, 2014, p. 341; Widdowson, 2007, p. 70). The breakdown of ferromagnesian minerals in this horizon further leads to newly formed Fe-oxides, and causes a loss of Mg and Si. In the mid to

Figure 6: Omatako Formation, weathering ferruginous sandstone at Vungu-Vungu (SC 12).

upper saprolite zone, most primary minerals and some secondary formations are again exposed to weathering (Widdowson, 2007, p. 70). Some metals such as Ni, Cu, Co and Zn, which are leached from the upper horizons, precipitate with secondary Fe-Mn-oxides in the mid to lower saprolite zone. After the breakdown of most primary minerals, Si, Al and Fe, forming kaolinite, quartz, iron oxides and gibbsite, dominate the upper horizons known as mottled zone and duricrust. Because of substitution or co-precipitation, minor elements such as Cr, As, Ga, Sc, K, Ti, V are also commonly present in the upper parts of the geological profile, whereas Ba, Sr, Zn are usually lost to deeper strata (Aleva, 1994, p. 60; Widdowson, 2007, p. 70). Depending on the parent rock material, Mn is found together with Fe and may accumulate in the lower parts of the Fe-rich zone (Aleva, 1994, pp. 38, 61)

The distribution of major and minor elements within ferricrete profiles is less consistent and largely depends on the chemical composition of the host material into which the allochthonous material is transported and infused. Generally, there is no up-profile removal of mobile elements, and in contrast to the residual weathering profiles, they can show stable Si and Al values throughout the entire profile, even though here again a lower Si content is common in the upper horizons (Widdowson, 2007, p. 76). Alteration profiles are usually non-calcareous and dominated by the iron (hydro)oxides goethite, hematite and maghemite. As mentioned above, manganese frequently co-precipitates with the iron oxides (Fey, 2010, p. 97).

Along the Kavango River as along many other active or palaeo-riverbeds in the Kalahari Basin, huge layers of ferricretes occur. They are more common in the northern Kalahari because the mobilization of iron is normally associated with wetter climatic conditions than the processes that lead to the formation of calcretes or silcretes (Haddon, 2000, p. 177; Atlhopheng & Ekosse, 2007, p. 52). As presented earlier in this chapter, the formation of ferricretes depends on varying factors such as the solubility of the components concerned, the original parent rock from which minerals were leached, groundwater fluctuations, microorganisms in specific soils and other landscape dynamics. The ferricretes of the Kalahari are of Tertiary to Pleistocene age and represent former land surfaces (Cornell & Schwertmann, 2003, p. 422). In subtropical and temperate climates, they are considered relict formations from a time when the climate was warmer and wetter (Aleva, 1994, pp. 71-72; Driessen, et al. 2001, p. 151; Young, 1980, p. 157). Geographically, ferricretes are often found along the high terraces of (palaeo-)riverbeds, because, as I pointed out earlier, landscapes covered by ferricretes were protected from erosion during the incision of river valleys.

Petroplinthites were frequently used in traditional iron production. The ferruginous crusts were easy to exploit in pre-industrial times, and were the most common source of iron ore in traditional smelting in Africa and elsewhere (e.g. Avery & Schmidt, 1979, p. 15; Avery, Van der Merwe & Saitowitz, 1988, pp. 268, 272; Brock, 1965, p. 98; Carl & Petit, 1955 as cited after Kense, 1983, p. 76; Childs, 1996, pp. 285-286; Cornell & Schwertmann, 2003, p. 422; Delisle, 1884, p. 469; Housden &

Figure 7: Omatako Formation, weathered silicified sandstone overlain by a ferricrete layer and calcretes at Mupini (SC 6).

Armor, 1959, p. 136; Mapunda, 2010, pp. 155-156; McCosh, 1979, p. 159; Turner, 1952, p. 26; Widdowson, 2007, p. 51).[5] In modern times, petroplinthic material is frequently used for road construction in southern Africa because of its positive properties for road pavements (also known as outklip) (Fey, 2010, pp. 103-104; McNally, 1998, p. 65). Because of this, ferricrete quarries are frequently found along modern highways[6] (e.g. Figure 7) and some of them have destroyed archaeological sites such as Karrangana (SC 2), Gove (SC 17) and Mupapama (SC 25).

1.3.2.7. The Kalahari sand cover

The most common surface unit of the Kalahari Group sediments is unconsolidated sand, which covers an area of 2.5 million km² in central southern Africa, stretching across the continent between the OrangeRiver in the south, and western Congo andGabonto the north (Lancaster, 2000, p. 74). The sand cover extends over a greater area than the underlying Kalahari Group deposits (Haddon & McCarthy, 2005, p. 317). The thickness of the sand bed varies throughout the Kalahari Basin: in some areas it is 20 cm to 30 m in depth, in other places it attains a thickness in excess of 300 m (Lancaster, 2000, p. 74; Thomas & Shaw, 1991, p. 68).

The Kalahari sand consists of fine to medium-sized, rounded to sub-rounded quartz grains. It varies in color, composition, and with respect to the age of origin and deposition. In many areas, the current sand cover has been intensively reworked and re-deposited (Baillieul, 1975; Lancaster, 2000, p. 74). Most of the sand is of aeolian origin or results from the in situ weathering of the underlying rocks; however, fluvial transport and re-deposition also have been important in many areas (Baillieul, 1975, p. 502; Haddon & McCarthy, 2005, pp. 317-321; Kgathi et al., 2006, p. 5; Lancaster, 2000, p. 74). Studies of the composition of the sand indicate that in some areas local sources such as the weathering of the underlying bedrock also played a major role in the release and formation of the sand cover. This led to a spatial grouping of sands of different origins (Baillieul, 1975, p. 502), which might be of interest for provenience studies of pottery.

In the central and southwestern Kalahari, extensive systems of dunes occur (Lancaster, 2000, p. 74; Thomas & Shaw, 1991, pp. 148-151). They formed in a geological period when the Kalahari was considerably more arid than today (Baillieul, 1975, p. 502). The northern dune group, which covers the area under study, developed between the Etosha pan and the Okavango Delta, and reaches as far north as the Shaba plateau in the southern RD Congo. The dunes stretch out from E to W and from ESE to WNW (Lancaster, 2000, p. 75). They can reach a height of 25 m and a spacing of 1.5 km to 2.5 km (Grove, 1969, as cited after Lancaster, 2000, p. 75). Some ridges cover a distance of 200 km (Lancaster, 2000, p. 76), and in some areas gullies and ephemeral channels developed in the interdune corridors (Jaccoberger, 1989, p. 288). There is evidence for multiple periods of dune building during periods of high aridity in the late Pleistocene and Holocene (O'Connor & Thomas, 1999, pp. 52-53; Lancaster, 2000, p. 77; Stokes, et al., 1998, p. 305). These rather short-lived periods of dune formation lasted about 2 ka to 20 ka, and were interrupted by periods of humid conditions for 20 ka to 40 ka (Stokes et al., 1998, p. 318). The youngest re-deposition of local sediment is evident from a time period around 5 ka to 4 ka bp in western Zambia (O'Connor & Thomas, 1999, p. 53). Commonly, a hematite coating of the sand grains gives the Kalahari sand a reddish color. Surface layers are often bleached, mainly in zones that have been reworked by water (Thomas & Shaw, 1991, p. 69). In areas with underlying ferruginous duricrusts or sandstone, the sand can be noticeably red to ocher.

1.3.2.8. The Kalahari sequences in the middle Kavango region

There has been little published on the geological sequences of northeastern Namibia, and the middle Kavango region in particular. From the late 1970s and early 1980s, three unpublished reports exist, describing roughly the Kalahari Group stratigraphy in this region (reports from Albat and McGhee in 1979 and from Balfour in 1981). In the 1980, the South African Committee for Stratigraphy officially adopted the lithostratigraphy of northern Namibia

[5] Hahn (1993, p. 50) describes how women mined nodular pisolites in the soft soil of a dry riverbed. The pisolites were cut in half right at the mining site and inspected for their quality. Only those nodules that were black or blue-black inside were considered good enough for smelting. Pisolites that showed light or yellowish colors inside were of no interest and discarded.

[6] E.g. Popa (SC 48); Mupapama (SC 25); Mashare (SC 22), Gove (SC 17) and Mupini (SC 6).

Figure 8: Omatako Formation, chunks of pisolitic ferricrete scattered at Utokota (SC 16).

Figure 9: Eiseb Formation, outcropping silcretes at Gove-Mbambangandu (SC 17).

proposed in these reports (SACS, 1980, as cited after Haddon, 2005, p. 163). Published studies made in the 1970s exist from the South African geologist Frank Netterberg, who examined duricrusts (Netterberg, 1969, 1974). Later, the Namibian geologist Wulf Hegenberger published a summary of the current state of research in the Kavango region (Hegenberger, 1987) and concluded that not much is known about the geological sequences of this area. He included recent results of the Kalahari Group lithostratigraphy from drill cores taken south of the river in what is known as Bushmanland around Sikereti and Tsumkwe (Balfour et al., 1985). In 2005, the South African geologist Ian Haddon tried within his supra-regional study on the Kalahari Geology to summarize the poor knowledge about the Kalahari Group sequences in this area (Haddon, 2005, pp. 163-165). In 2007, Heike and Ansgar Wanke (Wanke & Wanke, 2007) published new data on the lithostratigraphy of northeastern Namibia. On the basis of surveys of outcrops of the deeper Kalahari sequences, they suggested a new generalized stratigraphic cross section of the Kalahari Group sediments in this area and a basin-wide correlation of Kalahari Group sequences. The denomination of the sequences in northeastern Namibia basically follows Albat's classification into three formation units from bottom to top: the Tsumkwe, the Kalahari, and the Omatako Formation (Albat, 1978, as cited after Hegenberger, 1987, pp. 106-109). McGhee (1979) however, changed the term Kalahari Formation into Eiseb Formation, which is now used in most publications. In 2008, the Namibian geologist Roy McG. Miller published the most up-to-date summary of geological knowledge about northeastern Namibia, but it still reflects the enormous lack of geological research in this area.

Following the stratigraphical suggestions of Haddon (2005, pp. 163-165) and Wanke and Wanke (2007, pp. 322-324), it is in the deepest layers that one may find lime-cemented basal sandy conglomerates and grit of the Tsumkwe Formation that pass upwards into various sandy layers. The overlying Eiseb Formation consists of sandy sediments cemented by silica or carbonates, beds of limestone, and of chalcedony in places. The uppermost unit, the Omatako Formation, consists of ferricretes, ferruginous sandstones and ferruginous soils. However, because there are few detailed boreholes in which the Kalahari Group sedimentary rocks have been accurately analyzed in northern Namibia, the Kalahari Group stratigraphy is still not clearly defined (Haddon, 2005, p. 165). Therefore, Miller (2008, p. 24) provides the best data based on boreholes between Kanovlei in the Omatako Omuramba and Bagani. He identified sands and silicified sands to be the most common units in the Kalahari successions of this region; and calcretes are surface to near-surface deposits, which do not occur in deeper layers of the KGS (Miller, 2008, p. 25).

1.3.2.9. Eiseb Formation

Along the middle Kavango River, sequences of the Eiseb Formation outcrop along the Kavango River. In the Rundu region, a huge bank of fine-grained brownish-gray sandstone lies above a layer of silicified material. The sandstone formation is covered by sandy calcretes of 5 m to 7 m in thickness. The profile of the high terrace at Rundu,[7] documented in 1998, shows the

[7] Rundu (SC 17).

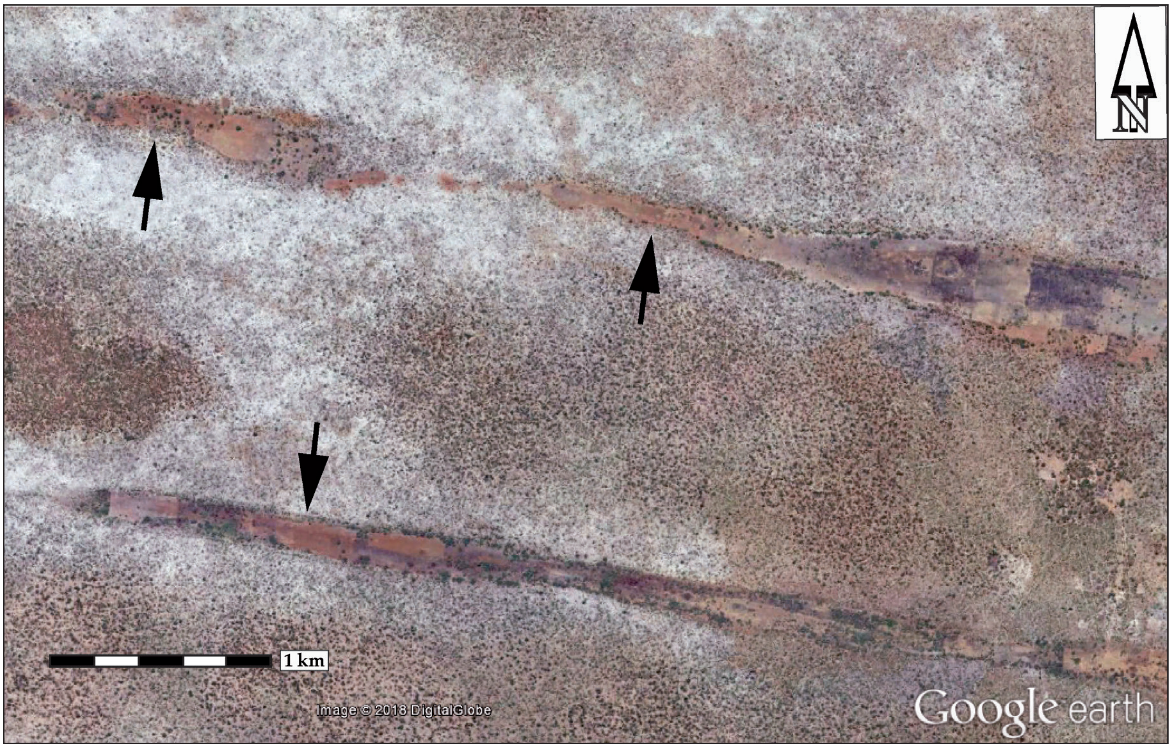


Figure 10: Red soils in the interdune valleys of Dikundu and Karamba indicating iron ore near the surface (background image: Google Earth).

massive sandy calcretes and silicified sandstone layers of the Eiseb Formation covered by highly weathered ferruginous sandstone of the Omatako Formation (Figure 9). Around Mashare, a thick layer of reddish-brown silicified sandstone (6 m to 7 m in thickness) is overlain by a partially silicified greenish-gray sandstone 5 m to 6 m in thickness (Hegenberger, 1987, p. 106). In Shambyu, Hegenberger (1987, p. 107) declared the profile of the alternating calcretes and silcretes to be part of the Eiseb Formation. Furthermore, sandstone in varying degrees of weathering, overlying massive silcretes, stretches from the garden of the Shambyu Mission to the Gove smelting sites[8] and farther. More evidence of silcretes and huge calcretes of the Eiseb Formation come from the Mupini and Kapako area, from around Ruuga, Nkurenkuru, and a number of other sites west and east of Rundu. South of the river, layers of the Eiseb Formation have been observed in an abandoned modern quarry 5 m to 7 m below the present surface at Mapuri.[9] The deepest layers observed consisted of limestone with crystalline calcium carbonate and quartzite inclusion, covered by a layer of quartzite and chalcedony gravel. A thin layer of loose sand with Early Stone Age tools and bones followed the latter, and it graded into an extremely hardened calcareous deposit of sand and silt, 3 m in thickness. The hardened soil passed into a near surface calcrete crust.

1.3.2.10. Omatako Formation

The ferruginous deposits of the Omatako Formation occur in many places along the Kavango River and in the fossil drainage systems north and south of the main stream (Miller, 2008, p. 26) (Figure 5). Residual weathering profiles from ferruginous sandstone to deep-red soils on top of it[10] are present in many places along the middle and upper terraces of the river.[11] In other places, massive pisolitic ferricretes (petroplinthites) developed, protecting the landscape from further erosion (Figure 7 and 161).[12] Nowadays, they are frequently found in middle and upper terrace positions because of relief inversion. In his pioneering geographical

[8] Gove (SC 17).

[9] Mapuri (SC 31).

[10] Hutton Soil Form after Schneider, 1985/87, 209f.

[11] Rundu Ngandu Lodge and Ushivi Road (SC 7), Gove-Mbambangandu (SC 17), Tjeye-East (SC 21).

[12] Ferruginous gravel was further evidenced in the uppermost layers of some boreholes in the Sikereti area (down to a depth of 4 m), approximately 120 km south of the Kavango River (Balfour et al., 1985, pp. 76-77). Its topographic position suggests that the layers belong to the old land surface evident along the Kavango River.

Figure 11: SC 33 Koro, area N07/07, red plinthic soil in the Fontein Omuramba near Koro indicating iron ore near the surface.

work on the Kalahari environment, Passarge (1904, p. 447) gave a detailed description of ferricretes around the Popa Falls. According to his observations, sandstone grades into a pisolitic duricrust, which again pass over into a red clayish soil (Figure 161). At Gove,[13] the old gravel mine (Figure 129) allowed to me to observe the geological sequences of the middle to lower terrace as follows: Under a cover of a reddish sandy terrace deposit of varying thickness, a calcrete layer occurred, approximately 1 m in thickness. The calcrete layer covered a cemented pisolitic ferricrete of more or less 1.5 m in thickness. The upper parts consisted of ferruginous nodules, along with debris of sandstone and silcretes, which became cemented by carbonates. In the lower parts, the duricrust contained iron oxide pisolites cemented by a ferruginous agent (Figure 8). Below the ferricrete, a stratum of strongly weathered and partially ferruginous sandstone is present. The sandstone gradually passes into silicified sandstone, and farther down into a massive reddish silcrete stratum outcropping along the riverbank (Figure 9). At Vungu-Vungu,[14] a fine-grained reddish sandstone formation crops out in the riverbed and weathers into clay of the same color (Figure 6). West of Rundu sequences of the Omatako Formation are exposed in the Mupini quarry[15] within a soil profile of about 6 m in depth (Figure 7). Here the residual weathering process from sandstone to a ferruginous duricrust in the upper horizons can be observed, as well as several phases of silicification in the lower parts of the profile, owing to the downwards leaching of silica.

The geological profiles examined suggest that the pisolitic duricrusts are the product of residual weathering. However, Widdowson (2007, p. 67) argues that sandstone (in particular quartz-rich varieties) does not contain enough iron to form a residual laterite profile, and ferrous duricrusts on sandstone are rather of allochthonus nature. Nevertheless, the profiles examined speak for a residual development but even so, an introduction of allochthonous iron in solution was certainly possible in times when the Kavango River valley was not as deeply incised as it is today, and future research may thoroughly determine the formation history of these crusts. According to oral history (see section 5.3.1), the pisolitic iron crusts along the river were used in traditional iron production. However, as I argue in the sections 4.2.8 to 4.2.13, the chemical fingerprints of the slag material revealed that ores other than the

[13] Gove (SC 17).

[14] Vungu-Vungu (SC 12).

[15] Mupini (SC 6).

Figure 12: SC 30 Dikundu, area N06/04, soil profile at the bottom of the Dikundu valley. The iron ore nodules used in historical smelting originate from the upper, red soil horizon.

Figure 15: Plinthic iron oxide segregations (marked with red arrows) used in traditional smelting.

Figure 13: Plinthic iron ore concretions from the upper, red soil horizon of Figure 12. These nodules were used in historical smelting operations.

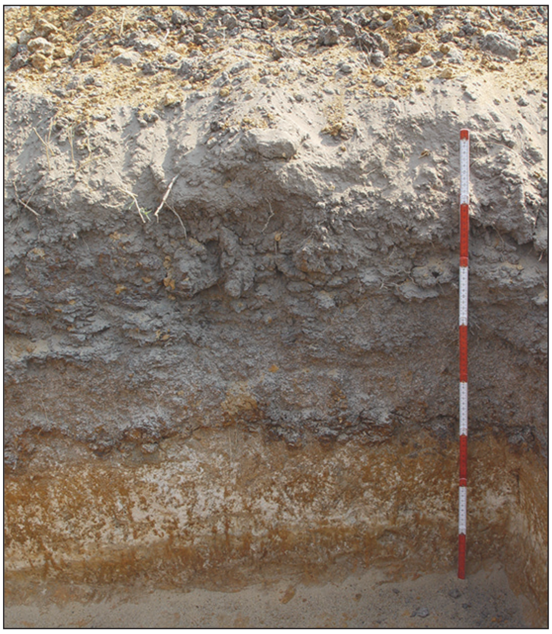


Figure 14: SC 32 Kauti, area N07/03, plinthic hardpan immediately below the surface. This ore was used in historical smelting.

pisolitic ferricretes were preferred, even though the smelting sites were located on ferricrete outcrops.

Turning to the regions south of the Kavango, more evidence of the Omatako Formation comes from palaeo-riverbeds such as the Fontein Omuramba and Omatako Omuramba (Figure 11 and 158) south of the river (Miller, 2008, p. 26). Here, red soils, soft plinthic material, petroplinthites and strongly ferruginous sandstone occur in varying forms in the humid setting of the river valley depression (see also Wanke & Wanke, 2007, p. 320). A thick layer of near-surface fossil petroplinthites is found over a large area of the lower catena at Kauti (Figure 14).[16] The landscape is dry these days. In the same topographic position, red soils (Figure 11 and 160) with hard goethite and hematite segregations (Figure 15) occur throughout the valleys (for instance at Koro[17]). At the seasonally waterlogged bottoms of the fossil valleys, calcareous iron oxides nodules are common.[18] The iron oxides most probably originated in lateral and downward leaching from up-slope iron-enriched horizons, the latter being easily detectable in the valley profile of the Fontein Omuramba. The iron oxides precipitated at different geological periods in the bottomland of the fossil valleys, segregating into nodules and crusts. In the seasonally waterlogged bottomlands of the valley, the formation of plinthic segregations of iron oxides is most probably still ongoing. As mentioned above, reddish valley-attendant soil in the mid- to upper-slope position of the fossil valleys belongs to the old weathered landscape surface

[16] Kauti (SC 32).

[17] Koro (SC 33).

[18] Found for instance at Hamoye (SC 34).

that resisted erosion. Similar to the large fossil drainage lines, smaller seasonally waterlogged inter-dune valleys such as the Dikundu Omuramba and its neighboring valleys show the same pattern of plinthite formation (Figure 10). At the Dikundu mining site (Figures 145 and 146),[19] iron oxides precipitated in the form of soft nodules (Figures 12 and 13) and extremely hardened crusts. In a neighboring valley (Figure 144),[20] numerous small hard nodules of iron oxides are scattered around at the surface. Here again, fossil plinthite formations come together with active iron oxide segregation because of the pronounced dry and wet seasons (e.g. Eze, Udeigwe & Meadows, 2014, p. 161).

1.4. The principles of iron production in the bloomery process

Many scholars have written on the principles of bloomer iron production (e.g. Craddock, 1995; De Rijk, 2007; Fluzin, 2004; Kense, 1983; Kronz & Keesmann, 2005; Osann, 1971; Pleiner, 2000; Rehder, 2000; Rostoker & Bronson, 1990; Schürmann, 1958; Straube, 1996; Van der Merwe & Avery, 1970; Yalçin, 2000; Yalçin & Hauptmann, 1995), and many of them have based their studies on analyses from experimental metal production, archaeological remains and engineering disciplines. Within the framework of this study, I will not be able to provide a comprehensive review of the literature dealing with the reduction of iron in the bloomery process, and many valuable contributions might not be cited. In the following chapters I will nevertheless outline the basic characteristics of bloomery smelting and iron processing. This cursory discussion is set against the background of ethnographic and archaeological evidence from Africa in as far as it helps to better understand my thesis.

The smelting of iron aims at separating iron minerals from non-iron minerals and the gangue respectively, and at reducing the iron minerals to iron metal. The main ingredients in ironmaking consist of iron ores, fuel (charcoal or fresh wood) for the reduction of the oxides and the temperatures required for these reactions, and of other mineral or cosmological supplements. A number of parameters can potentially influence the successful production of soft iron or steel such as the quality and composition of the ore and fuel, the furnace construction, supplements added by the smelters or derived from the furnace wall and the tuyeres. Moreover, temperatures, heat loss, time of reduction, redox conditions and human experience, decision making and beliefs play an important role in successful metal production (e.g. Charlton, Crew, Rehren & Shennan, 2010; Chirikure, 2015; Fluzin, 2004; Kronz & Keesmann, 2003, p. 270; De Rijk, 2007; Rehren et al., 2007). Once metallic iron has been successfully reduced in a smelting operation, the metal can receive further treatment to alter its mechanical properties through alloying elements (carburization or decarburization, dephosphorization etc.). The spongy iron bloom is again heated to furnace temperatures, or even higher, to drain away the enclosed slag and to hammer and weld the bloom to a compacted piece of raw material. Hot elemental iron can further be exposed to an oxidizing atmosphere to remove disturbing alloying elements through oxidation, or it can be exposed to a strongly reducing atmosphere for an intentional intake of alloying agents such as carbon.

Successful iron production depends on many influencing factors that resulted in a highly heterogeneous picture of engineering solutions on a diachronic as well as synchronic scale (e.g. Chirikure, 2015; Kense, 1983). Each group of smelters was obliged to develop an individual solution for the same task, depending on the source materials available and the demand for iron.

For many years, scholars have regarded bloomery smelting only with respect to its alleged inefficiency, and the rate of efficiency has been taken solely from the proportion of iron minerals remaining in bloomery smelting slag, even though bloomery furnaces operated in Europe until the nineteenth century. In remote areas of Africa, bloomery iron was produced until the middle of the twenty-first century, although parallel to this cast iron production was well known and had been practiced for centuries (Chirikure, 2015, pp. 107, 116; Chirikure & Bandama, 2013, p. 14; Haaland, 2004; Kronz & Keesmann, 2003, p. 259; Kronz & Keesmann, 2005, p. 408; Kusimba & Killick, 2003, pp. 106-111; Schmidt Childs, 1995; & De Maret, 2004; Yalçin & Hauptmann, 2003). The advantage of the direct reduction in bloomery smelting is that malleable iron is directly produced in the furnace, and the yielded metal does not undergo further energy consuming decarburization, which is also accompanied by a loss of elemental iron. Moreover, due to the comparatively low reaction temperatures in

[19] Dikundu (SC 30).

[20] Kapongo (SC 29).

bloomery furnaces, less alloying elements dissolute and disturb the quality of the iron. However, as will be discussed below, and in contrast to blast furnace technologies, bloomery smelting requires high-grade ores that were not always available at certain historical moments. In Africa however, rich laterite and plinthite occurrences allowed bloomery smelting traditions to be maintained for a long time, even though the demand for the iron metal in African societies was high.

The following chapters provide an overview of the basic technological dynamics and process operations of iron production and tool production focusing on the procedures and details necessary for the understanding of this study. The division, however, that I make between the cosmological and technological aspects of iron production and processing appears highly arbitrary with respect to the perception that traditional iron masters have and had of their trade (see section 5.3).

1.4.1. Iron ore

As mentioned above, bloomery smelting is known to require high quality ores (Kronz & Keesmann, 2003, p. 272). As I point out below, direct production of soft iron and malleable steel requires slag high in iron oxides because the carburization of the iron metal within the furnace depends upon the partially reduced iron oxides remaining in the slag (Straube, 1996, p. 45). In addition, the low melting temperatures of fayalitic slag require a high percentage of iron minerals. Schürmann (1958, p. 1307) illustrated the interrelations between the initial content of wustite (FeO) found in the ores, FeO that is lost in slag formation and the output of iron metal from the smelt. Following his model, an initial wustite content of 65wt% of the ore for instance, generates about 20% iron metal in dependence of a slag fragment with 60wt% of FeO. The percentage of the yield of iron is higher than would be suggested solely by the reduction of the proportion of the iron oxide quantity between ore and slag. Therefore, typical bloomer slag fragments with FeO contents between 50wt% and 75wt% of FeO are a result of the reduction of ores with more or less 55wt% to 80wt% of FeO. In addition, the impact of the dissolving furnace wall further reduces the ratio of FeO with respect to the other slag components (Kronz & Keesmann, 2003, p. 267).

Apart from the yield of iron oxides, another important property of the iron ores is their reducibility, which means the ease of the iron oxides to release their oxygen to a reducing agent (Yalçin & Hauptmann, 2003, p. 134). Generally, porous ores are easier to reduce in the bloomery process than compact ones, as the carbon monoxide-rich gas can enter the pore spaces and cracks of the ores (Blomgren & Tholander, 1986, p. 158; Tylecote, Austin & Wraith, 1971, p. 359; Yalçin & Hauptmann, 2003, pp. 134-135; Yalçin & Lychatz, 1995, pp. 54-55).[21] Moreover, due to their phase composition and crystal structure, iron ores of sedimentary origin are more reducible than those of igneous and metamorphic formation (Killick & Miller, 2014; Schenk, Schmahl & Funke, 1958, pp. 40-49). Furthermore, hydrogen-containing oxides are preferable ores, as they increase porosity due to the loss of hydrates in the beginning of the smelting process (Avery et al., 1988, p. 264; Kunze, 2006, p. 21). Reducibility may also be increased with a smaller size of the pieces of ore because small-sized ore lumps expose more of the surface to the reducing gas (Blomgren & Tholander, 1986, p. 158; Schenk et al., 1958, p. 50).[22] However, reducibility decreases when the charge of the furnace becomes too compact and prevents the reducing gas from permeating the charge (Maddin, 1985 and Serning, 1979 both cited in De Rijk, 2007, p. 105).

The iron ores suitable for iron production in the bloomery process were in most cases self-fluxing ores (Kronz, 2000). This means that there are sufficient minerals associated to the iron oxides, which react and liquefy at a specific temperature and separate from the metallic iron. The composition of the major and minor elements of the gangue strongly influenced the smelting process and the composition of the slag together with the iron metal (Yalçin, 2000, p. 312). Apart from the iron oxides, silica (SiO_2) is the most important element necessary to form the low-melting

[21] In their detailed study on the reducibility of iron ores, Schenk et al. (1958, pp. 59-64) illustrated how pore sizes influence the reduction. Small pores, for instance, hamper the gas exchange in the reduction process and are of minor influence on the reducibility of the ores. Pore space, however, increases with raising temperatures and advancing reduction as the specific volumes decreases with the loss of oxygen. The cracking of the outer layers of the ores thus allow for a better reducibility even of unfavorable ores (Rostoker & Bronson, 1990, p. 90).

[22] Hahn (1993, p. 51) described how pisolites were crushed to 1 cm size pieces before they were considered usable in a smelt. Kense (1983) provided a number of examples of the chopping and sorting of ore.

fayalite (Fe_2SiO_4) usually found in iron slag, and the two low melting eutectics close to the fayalite composition (Straube, 1996, p. 45 and others) (see section 1.4.6).[23] When silicon (Si) is missing in the gangue it must be added as a flux by the smelters[24] or it must be dissolved from the furnace wall (Killick & Miller, 2014, pp. 251-252; Osann, 1971, pp. 71-75). According to Oelsen and Schürmann (1954, p. 512), the associated gangue should consist of at least 50% silica in order to allow a low melting slag to form. Silica also collects the other associated oxides that cannot be reduced under the temperature and redox conditions present in the bloomery furnace (Pleiner, 2000, p. 136) (see section 1.4.6). Likewise, low-grade ores can be 'fluxed' or upgraded by adding iron-rich fayalitic slag and partially molten materials from previous smelts (Avery et al., 1988, pp. 271, 275).

There are a variety of treatments to improve the chemical and physical properties of ores (Craddock, 1995, pp. 156-169; De Rijk, 2007, p.105; Pleiner, 2000, pp. 106-109; Rostocker & Bronson, 1990, pp. 47-54). Beneficiation is the mechanical treatment of ores by crushing and sorting and it can raise the metal content in relation to the associated minerals. Second, a thermal treatment (roasting) was frequently applied to reduce the hydrogen content of the oxides and to drive off sulphides through chemical reaction, the latter having a negative input on the properties of the metallic iron (Pleiner, 2000, p. 108). Both treatments also improve the accessibility of the reducing gas to the iron oxides (Childs, 1996, p. 286).

1.4.2. The bloomery smelting process

Bloomery smelting is a direct method to produce malleable steel and soft iron. There is also an indirect method of steel production through the decarburization of high carbon cast iron (Pleiner, 2000, p. 131 and others).

In a smelting process, the iron oxides undergo several reduction reactions depending on the temperature, the carbon-monoxide/carbon-dioxide ratio of the atmosphere, and the gas pressure within the furnace (Figure 16). The end-desired product is a malleable iron metal that is separated from the associated minerals of the gangue (De Rijk, 2007, pp. 105-106). As mentioned earlier, iron production in the bloomery process appears inefficient with little output of metallic iron and iron oxide contents of 60wt% to 70wt% in the separated slag. If added fluxes lead to molten slag formation with less iron minerals, slag from bloomery smelts can contain as little as about 40wt% of iron minerals. However, as I mention below, high iron oxide contents are considered a prerequisite for low melting temperature slag and prevent the iron metal produced within the furnace from strong carburization. Only cast iron production creates slag with an iron mineral content of less than 10wt% (Yalçin & Hauptmann, 2003, p. 128).

The main ingredients in bloomery smelting are iron ores, charcoal, furnace lining, and socio-cultural additives. The results are elemental iron, iron-rich slag, and gas. The main reactions need energy input (elevated temperatures) and a reducing agent with a higher affinity to oxygen than what is found in iron, both provided in charcoal (e.g. De Rijk, 2007, pp. 105-106). Depending on temperature, carbon can reduce in a gaseous state (CO) or in the solid state of charcoal (C) (Straube, 1996, p. 41) and the velocity of the reducing reaction depends on its aggregate state (De Rijk, 2007, p. 106). With increasing temperatures, carbon shows a higher affinity to oxygen than iron does and the ratio of carbon monoxide to carbon dioxide also rises (De Rijk, 2007, p. 106; Straube, 1996, p. 41). Contrary to the non-ferrous metal production in pre-industrial times, iron was produced at temperatures below its melting point and separated from the gangue by an early liquefaction of its associated minerals. After the furnace has been charged with fuel and ore, the reaction chain of iron reduction starts with the combustion of charcoal in the furnace:

$$O_2 + C \rightleftharpoons CO_2$$

When CO_2 permeates throughout the charcoal bed inside of the furnace it reacts with the solid carbon to carbon-monoxide:

$$CO_2 + C \rightleftharpoons 2\,CO$$

When more oxygen is added through the tuyeres than is consumed by the combustion the following equation is valid:

$$CO_2 + O_2 \rightleftharpoons 2\,CO + O_2$$

In the reduction process of iron oxides, the latter undergo several steps of reduction. The extraction of oxygen (and hydrogen) from iron hydroxides results in several forms of iron oxides with an increasing ratio of Fe to O, namely hematite (Fe_2O_3), magnetite (Fe_3O_4) and wustite (FeO).[25]

[23] In addition, SiO_2-rich ores seem to crack easily when temperatures rise in the furnace and thus allow for better reduction (Schneider & Koch, 1979 as cited in Kunze, 2006, p. 78).

[24] According to Humphris (2010), crushed quartz was regularly found in association with her smelting features in Rwanda.

[25] Iron to oxygen ratio of iron oxides: hematite (α-Fe_2O_3) 3:5/2:3 (= 0.6/0.666), magnetite (Fe_3O_4) 3:4 (= 0.75), wustite (FeO) 1:1/2:1 (= 1/2).

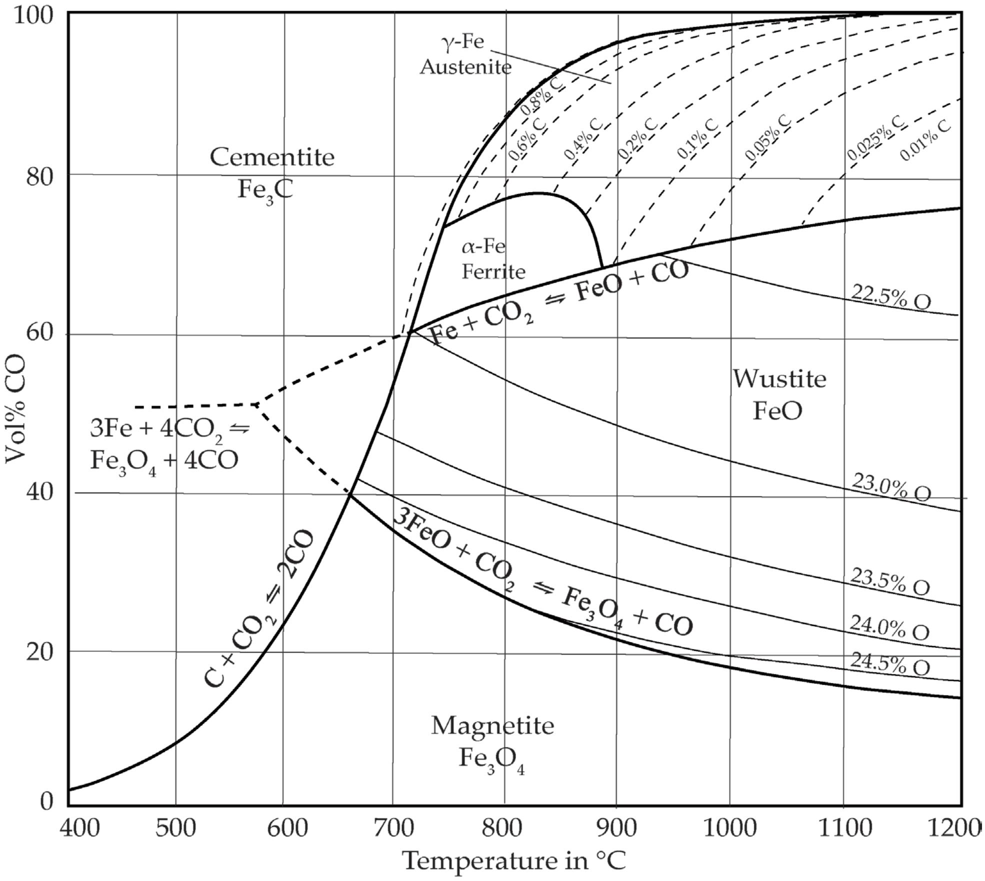


Figure 16: Baur-Glaessner diagram showing the phase equilibrium between iron oxide, iron, carbon monoxide, carbon dioxide, and carbon combined with the Boudouard reaction of a chemical equilibrium of CO and CO_2 at 1 atm.

Taking iron hydroxides (FeOOH) as basic material, the first transformation (dehydroxylation) to hematite, (α-Fe_2O_3) starts at temperatures of about 140 °C (Cornell & Schwertmann, 2003, p. 367):

$$2\ \alpha\text{-}FeO(OH) \rightleftharpoons \alpha\text{-}Fe_2O_3 + H_2O$$

The transformation from hematite to magnetite occurs at a furnace running temperature between roughly 270 °C and 650 °C (Blomgren & Tholander, 1986, p. 151; De Rijk, 2007, p. 106):

$$3\alpha\text{-}Fe_2O_3 + CO \rightleftharpoons 2Fe_3O_4 + CO_2$$

As the chemical bond of the oxygen in the hematite is weaker than that of magnetite or wustite, the limited amount of CO present in the atmosphere of the furnace, and the low temperatures present are enough to allow for the reducing reaction (Osann, 1977, p. 27).

An illustrative outline of the interaction of physical conditions and chemical reactions leading to elemental iron in varying degrees of carburization is given in the projection of the chemical Boudouard equilibrum into the so called Baur-Glaessner diagram (Figure 16) (Blomgren & Tholander, 1986, p. 15; De Rijk, 2007, p. 107; Schürmann, 1958, p. 1302; Straube, 1996, pp. 47-52, Yalçin, 2000, pp. 313-314). It illustrates the chemical reactions and equilibrium conditions ruling the processes in the smelting furnace under idealized conditions above 300 °C. The Boudouard diagram illustrates the equilibrium line of combustion gases (g) and temperature, namely the CO/CO_2 relation in equilibrium with the solid (s) C in a system:

$$C(s) + CO_2(g) \rightleftharpoons 2CO(g)$$

The Baur-Glaessner equilibrium diagrams illustrate the interrelationship of reducing reactions of the oxides and the carburization of the elemental iron (Figure 16). From there it can be assumed that if temperatures exceed 650 °C, and the CO/CO_2 ratio of the reducing gas is about 2:3, magnetite transforms to wustite (Blomgren & Tholander, 1986, p. 151; De Rijk, 2007, p. 107; Straube, 1996, p. 51):[26]

$$Fe_3O_4 + CO \rightleftharpoons 3FeO + CO_2$$

[26] The starting point of a redox reaction depends on the gas pressure, the $CO:CO_2$ ratio of the furnace atmosphere, and the temperature. Given a non-equilibrium situation with CO surplus, or low gas pressure within the furnace, the Fe_3O_4 transformation to FeO can already start at 570 °C. Moreover, the equilibrium line for the magnetite-wustite transformation indicates that by raising temperatures less CO is necessary to release oxygen from the magnetite.

The final breaking of the oxygen bond of the wustite requires higher temperatures and CO concentration in the furnace than seen before. Under idealized conditions, it starts at 723 °C and a $CO:CO_2$ ratio of 3:2, but varies according to the gas pressure and atmospheric conditions (e.g. Blomgren & Tholander, 1986, p. 151; De Rijk, 2007, pp. 106-107; Osann, 1971, p. 800; Schürmann, 1958, p. 1301; Straube, 1995, pp. 49-51):[27]

$$FeO + CO \rightleftharpoons Fe + CO_2$$

However, the conditions leading to the idealized behavior of iron oxides, elemental iron and slag formation illustrated in Figure 16 were rarely found in pre-industrial furnaces (Straube, 1996, p. 53). Non-equilibrium conditions must first be present in order to start the desired reactions and there is reason to assume that most of the non-industrial furnaces operated under conditions far from the equilibrium line (Rehder, 2000, p. 170). The $CO:CO_2$ ratio rather followed the $FeO + CO \rightleftharpoons Fe + CO_2$ equilibrum line than the Boudouard line (Eketorp, 1945 and Eketorp, 1963 cited after Blomgren & Tholander, 1986, p. 153), and the atmosphere in a furnace is considered less reducing than the Boudouard equilibrium promises (Kronz & Keesmann, 2005, p. 406). Moreover, conditions changed from furnace to furnace, from smelt to smelt, and inside the furnace itself (De Rijk, 2007, p. 108; Kronz, 1998, p. 10; Straube, 1996, p. 53). The main reduction to elemental iron occurs in a solid state of the ore, and from iron minerals in the slag bath. Slag formation starts around 1100 °C, when the iron oxides are reduced to a point that allows for the liquefaction of the main slag components (Kronz & Keesmann, 2005, p. 449).

Figure 16 also shows that wustite first transforms to elemental α-iron (ferrite). Due to its specific crystallographic properties, ferrite can only dissolve 0.02wt% of carbon (Schumann & Oettel, 2005, p. 399). If temperatures rise above 911 °C, elemental γ-iron (austenite) will be formed, which has a dissolving capacity of up to 2.06wt% of carbon (Schumann & Oettel, 2005, p. 398).[28] If the austenitic iron remains in the furnace with temperatures above 900 °C, or if the $CO:CO_2$ ratio follows the Boudouard equilibrium already at about 750 °C, austenite may react with the carbon available in the atmosphere including the alloying agent C in its crystal lattice (Figure 16) (Schürmann, 1958, p. 1301; Straube, 1996, pp. 51-52). However, as long as the $CO:CO_2$ ratio of the atmosphere within the furnace follows the $FeO + CO \rightleftharpoons Fe + CO_2$ equilibrum line as suggested above, the iron metal produced incorporates almost no carbon (Blomgren & Tholander, 1986, p. 153). The carbon in the system that is needed to dissolve the oxygen bond of the wustite and for the carburization of the elemental iron is in chemical equilibrium with both of them. The reduction of wustite can hence only begin under non-equilibrium conditions (Straube, 1996, p. 52). Also, as long as there is a high amount of wustite in the system, the carbon of the atmosphere reduces the oxide first. The dissolution of C in elemental iron only starts after a great amount of wustite has been reduced to metallic iron (Osann, 1971, p. 30; Rehder, 2000, p. 107; Schürmann, 1958, pp. 1301-1302; Straube, 1996, p. 53). Therefore, wustite prevents the carburization of the iron metal, and, conversely, a reduced wustite content in the system leads to high carbon elemental iron (Rehder, 2000 p. 125). At 1000 °C a soft iron of 0.01wt% alloying carbon can be produced, or a high carbon steel of 1.15wt% carbon, depending on the ratio of FeO to Fe in the system. The example also shows that the content of iron oxides in bloomery slag can indicate the quality of the steel produced (Straube, 1996, p. 53). However, a reduced wustite content in the smelting system can also be achieved by draining the slag out of the furnace. Presuming enough carbon (charcoal) is still in the furnace, elemental iron can be strongly carburized at the end of a smelting process (Presslinger & Köstler, 1991, as cited in Yalçin & Hauptmann, 1995, p. 293). Moreover, as can be taken from the diagram Figure 16, the iron-carbide phase Fe_3C (cementite) can form, which in turn strongly alters the properties of the iron metal:[29]

$$3Fe + 2CO \rightleftharpoons Fe_3C + CO_2$$ [30]

[27] Schürmann (1958, p. 1302), for instance, illustrates how the conditions for the wustite-ferrite transformation changes when the gas pressure decreases: 0.6 bar less pressure shifts the starting point of the transformation from FeO to Fe down to 650 °C. At the same time, about 3% less CO is needed to start the reduction.

[28] To give but a few examples, phases formed during carburization may be α-$Fe_{16}C$, α-$Fe_{16}C_2$, γ-Fe_8C, γ-Fe_4C and others (Fang, van Huis, Thijsse & Zandbergen, 2012). These phases usually disaggregate into α-Fe and Fe_3C at temperatures below 723 °C.

[29] As will be seen below, cementite (Fe_3C) segregates at temperatures below 723 °C from ferrite or austenite and strongly influences the material properties of steel and other Fe-C alloys. Fe_3C contains 6.67wt% of carbon (Schumann & Oettel, 2005, pp. 572-574).

[30] Direct reduction of wustite in contact with the solid carbon is possible at temperatures above 1000 °C:
$C + FeO \rightleftharpoons Fe + CO$ (Osann, 1971, p. 19; Pleiner, 2000, p. 135).

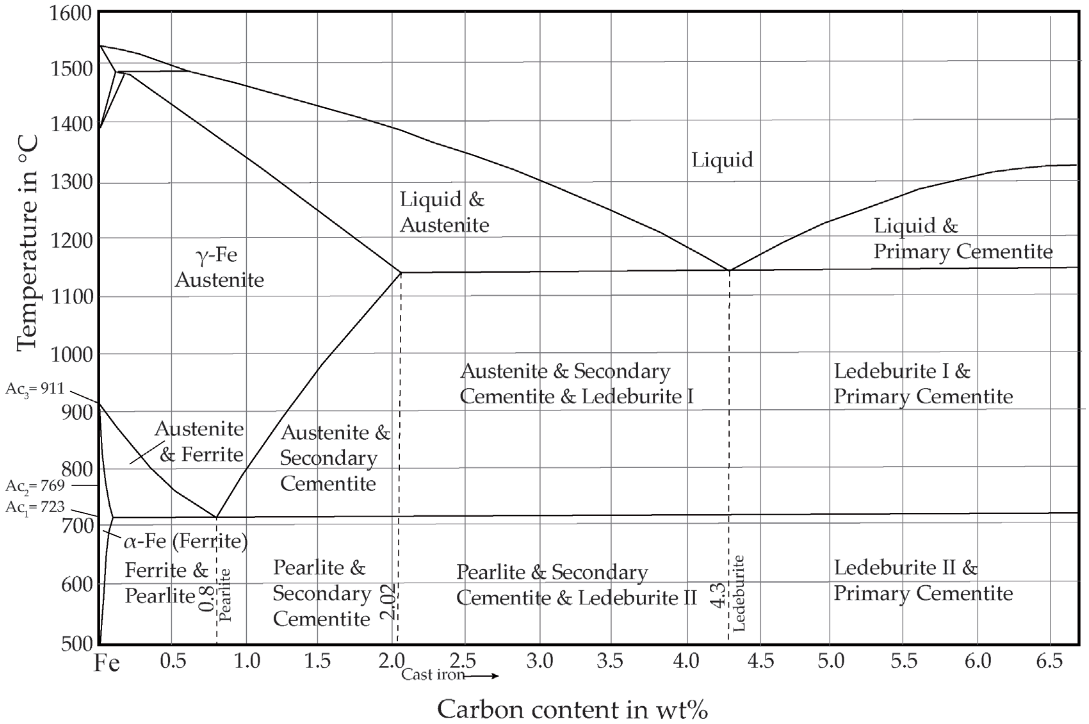


Figure 17: The Fe-C phase diagram (simplified).

Based on smelting experiments, Sauder & Williams (2002, p. 130) even argue that the challenge in bloomery smelting was in keeping the carbon content of the iron as low as possible rather than in producing carbon steel. As can be seen from the iron-carbon-phase diagram in Figure 17, the liquidus line of the iron-carbon alloy changes with its carbon content. The melting point of pure iron lies at 1536 °C and decreases with the increasing content of the carbon alloy. The lowest melting point of the FeC-system (the so called γ-Fe-Fe_3C eutectic) is reached at a composition of 4.26wt% of carbon and a temperature of 1150 °C.[31] Temperatures in bloomery furnaces usually reach 1100 to 1400 °C, and temperatures in low shaft furnaces even reach 1500 to 1600 °C (Blomgren & Tholander, 1986, p. 157; Osann, 1971, p. 32). The melting point analyses of Friede, Hejja & Koursaris (1982, p. 44) of slags from South African sites all revealed melting temperatures between 1100 °C and approximately 1500 °C (see section 1.4.6). Therefore, if the right temperatures and the carbon potential are present, cast iron can easily be produced in bloomery furnaces (Sim, 1998, pp. 10-11; Straube, 1996, p. 52). However, as long as the knowledge of decarburizing the high carbon steel and cast iron was not available, cast iron would have been an undesired side effect in bloomery smelting and frequently discarded at smelting and primary smithing sites (Navasaitis & Selskiene, 2007; Pleiner, 2000, p. 136; Yalçin & Hauptmann, 2003, p. 129).

Low carbon bloomery steel and iron usually retain its solid but pasty state during reduction unless alloys produce metals with lower liquidus temperatures. With the decreasing volume of fuel and ore, and after the gangue had been dissolved and forms liquid slag, the reduced metal particles descend in the furnace together with the slag[32] and accumulates below the entrances of the tuyeres on top of the fuel bed (De Rijk, 2007, p. 109; Rehder, 2000, p. 103; Rostoker & Bronson, 1990, pp. 93-94).[33] There the metallic particles fuse through surface tension forces and form a conglomerated mass of metallic iron and charcoal while most of the slag drains away; other parts of the slag may protect the bloom from re-oxidation (Blomgren & Tholander, 1986, p. 154; Killick & Gordon, 1989, p. 122;

[31] If phosphorus is part of the alloy, the melting temperature of the γ-Fe-Fe_3C-Fe_3P eutectic even descends to 955 °C (Kronz & Keesmann, 1995, p. 271) (section 1.4.6).

[32] Killick and Gordon (1989) suggest that apart from the fusion of particles of elemental iron in liquid slag, the second important process that leads to bloom formation is the reduction of wustite, which is dissolved in the slag, and which reacts with the solid carbon of the charcoal bed.

[33] The particles of metallic iron can be very small and descend with the liquid slag. They successfully separate from the latter and accumulate in the charcoal bed. Many smelting slag fragments contain no metallic iron (Osann, 1971, p. 37).

Killick & Miller, 2014, p. 250; Yalçin & Hauptmann, 1995, p. 292).[34] It is believed that the elemental iron becomes exposed to higher temperatures while descending in the furnace, and that the elevated CO levels in the deeper parts of the furnace cause the carburization of the elemental iron (Blomgren & Tholander, 1986, p. 153).[35] The varying thermo-chemical conditions inside the furnace to which the accumulating elemental iron is exposed, produce an inhomogeneous sponge-like conglomerate of metal ranging from pure iron to carbon steel and cast iron (sections 1.4.9 and 4.3).[36]

1.4.3. Furnace atmosphere, oxygen supply and tuyeres

The mixture of gases inside the furnace varies according to the oxygen supply rate, gas permeability of the charge, fuel to ore ratio, the ongoing reaction processes, the shape of the furnace, in addition to a number of other factors. Successful smelting operations require controlled air supply to the furnace or hearth in order to maintain an optimal atmosphere and temperatures, and to regulate the distribution of the gas plume. The oxygen needed for the combustion process may enter the furnace through natural or forced draft. No matter which method is used, it is most important to create a constant oxygen supply that responds to the needs of the smelting process (Charlton et al., 2010, p. 354; Chirikure, Burrett & Heimann, 2009, p. 207; Craddock, 1995, pp. 174-175). Therefore, air supply in bloomery smelting varies from furnace to furnace.[37]

The atmosphere inside the furnace usually consists of carbon monoxide, carbon dioxide, nitrogen and hydrogen (Osann, 1971, p. 18; Rehder 2000, p. 64).[38] As described earlier, the main reaction of a charcoal combustion is that of oxygen and carbon, which produces carbon dioxide ($O_2 + C \leftrightharpoons CO_2$). This reaction takes place very rapidly and produces a high amount of heat. When the hot gas permeates the fuel bed, the CO_2 reacts with the carbon and produces CO ($CO_2 + C \leftrightharpoons 2\,CO$). The latter reaction is slower than the initial combustion and consumes heat and carbon. For that reason, one may typically find hot oxidizing conditions close to the mouth of the tuyeres and reducing conditions with somewhat cooler temperatures further away from the combustion zone (Osann, 1971, pp. 21-26; Rehder, 2000, pp. 64-65). In addition, the further away from the oxygen supply, the combustion passes incompletely and produces CO rather than CO_2 ($C + ½O_2 \leftrightharpoons CO$) (Straube, 1996, p. 47). The reducing capacity of the atmosphere increases with the rising of temperatures. Since the mixture of gases is in chemical equilibrium with the solid carbon, the latter shows the same reductive power at corresponding temperatures (Straube, 1996, p. 48).

Rehder (2000) provides us with a most detailed study on combustion behavior and reduction processes of charcoal beds in furnaces. He argues that temperatures in the combustion zone in front of the air entrance may reach as much as 1800 °C to 2000 °C, and forced draft furnaces may even reach temperatures up to 1700 °C (Avery et al., 1988, p. 261).[39] Yet heat loss may reduce temperatures of the combustion zone at about 500 °C (Avery et al., 1988, pp. 171-172).

[34] Rostoker and Bronson (1990, pp. 93-94) together with Rehder (2000, p. 109) further suggest that slag accelerates and favors the coalescence (sintering) of dense blooms due to the liquid state of the slag. An illustrative example of sintering of elemental iron in liquid slag is given in Schmidt (1996, pp. 107-109).

[35] Based on a number of experimental smelts, Osann (1971, pp. 49-50) argues that due to the increased level of oxygen close to the mouth of the tuyere, the metallic iron in this part of the bloom is rather decarburized. At the same time, carburizing conditions can be found farther away from the oxygen input.

[36] The carburizing and decarburizing processes within the furnace are not yet fully understood. One group of scholars argue that temperatures within bloomery furnaces were deliberately conducted at low levels in order to produce low carbon elemental iron and iron rich low melting slag (see Schürmann, 1958; Osann, 1971; Yalçin, 2000 and others). Another group assumes that temperatures in bloomery furnaces easily exceed 1200 °C so that primarily high carbon steel as well as cast iron was produced. The high carbon products however would decarburize to malleable iron once they collected in front of the tuyeres (see Blomgren & Tholander, 1986; Straube, 1996 and others). For a summary of opinions see Pleiner (2000, p. 132). Another suggestion came from Rostoker and Bronson (1990, p. 98). They proposed that liquid cast iron droplets could carburize the solid low carbon bloom to steel. For the purpose of this work, the author argues in concordance with Pleiner (2000) that all models apply in one or another thermo-chemical condition inside the furnace.

[37] Small furnaces tend to be over-provided with oxygen and thus the fuel might be exhausted before the final reaction takes place. Large furnaces rather suffer from insufficient air supply which leads to inadequate temperatures for iron reduction (De Rijk, 2007, pp. 107-108).

[38] Hydrogen also serves as a reducing agent of iron oxides: $Fe_2O_3 + 3\,H_2 \leftrightharpoons 2\,Fe + 3\,H_2O$ (Cornell & Schwertmann, 2003, pp. 406-407). In some experimental smelts, the gas content of H2 reached up to 12% of the furnace atmosphere (Rjazancev, 1963 cited after Osann, 1971, p. 24).

[39] Schmidt and Avery (1996, p. 177) for instance recorded temperatures in the combustion zone of a shaft furnace in excess of 1820 °C during their reconstructed traditional smelting experiment in Tanzania.

However, furnace size does not necessarily provide inference for the temperatures at which the smelts were conducted. High shaft furnaces can be operated at temperatures below 1000 °C for several days (Martinelli, 2004, p. 183), whereas low shaft furnaces, which were filled with a mix of ore and slag for fluxing and recycling, operated constantly at temperatures between 1400 and 1500 °C (Schmidt, 1996, pp. 99-104).

When the gas permeates the charcoal bed, temperatures decrease progressively with more distance from the air entrance because of the endothermic reduction processes of the CO_2 to CO, and the initial reduction of the iron oxides (Schmidt, 1996, p. 64; Blomgren & Tholander, 1986, p. 151). The $Fe_3O_4 + CO \rightleftharpoons 3FeO + CO_2$ reduction is an endothermic reaction and further decreases temperatures in the furnace at the beginning of the smelting process whereas the following $FeO + CO \rightleftharpoons Fe + CO_2$ reaction is heat-evolving (exothermic) as is the slag formation reaction of FeO and SiO_2 to fayalite (Blomgren & Tholander, 1986, pp. 151-152). From there it follows that once a certain temperature has been reached, the combustion heat together with exothermic chemical processes maintain the elevated temperatures inside the furnace. Martinelli (2004, p. 183), for instance, reports the rising of temperatures for at least 400 °C after slag formation had started at the end of the reduction process in a high shaft natural draft furnace. However, temperatures should not go below 1000 °C for thermodynamic reasons since the reaction velocity quickly slows down (Rehder, 2000, p. 64)[40] or even becomes inverse below 650 °C ($2\,CO \rightleftharpoons CO_2 + C$) (Osann, 1971, p. 19). For this study, it seems important to mention that in smaller furnaces, in which the time span that combustion products remain in the fuel bed is comparably short, less time for the CO_2 reduction is available, which makes the gas composition less reducing in the furnace (Osann, 1971, p. 26).

As described above, the oxygen supply of a bloomery furnace controls the reduction processes in the furnace and the quality and quantity of the final product. Therefore, a controlled air supply is essential in metal production. Most bloomery furnaces worked with forced draft although African smelters demonstrated how efficient natural draft furnaces could operate (Chirikure & Bandama, 2013) and some smelters make use of both methods at the same time (Avery et al., 1988, p. 275). Pit furnaces and small shaft furnaces, however, need a forced air supply since their natural stack effect is too weak to create sufficient oxygen provision and the required temperatures (Rostoker & Bronson, 1990, p. 29; Straube, 1996, p. 43).

All over the world, bellows of varying sizes and shapes provide the most common air supply. Usually, a refractory tube made of clay (and sometimes metal) is placed into the furnace and protects the bellows from the furnace heat (Craddock, 1995, pp. 180-189; Pleiner, 2000, pp. 196-214; Rostoker & Bronson, 1990, pp. 71-78). The same variety in bellow types and tuyere sizes and materials can be observed in African smelting traditions (e.g. Celis, 1991; Cline, 1937; Chirikure et al., 2009; David, Heimann, Killick & Wayman, 1989; Sandelowsky, 1969). Unfortunately, only the well-burned tips of the tuyeres usually survive in the archaeological record because the unburned parts easily decay (Craddock, 1995, p. 185; Pleiner, 2000, p. 200).

Usually, the distribution of the gas flow in a furnace is highly variable, even in modern furnaces (Rehder, 2000, p. 73). Combustion and high temperatures expand the gas volume six to seven times, and the ensuing reduction of CO_2 to CO again doubles the amount of gas (Rehder, 2000, p. 67). These reactions push the plume towards the open side of the furnace and create isotherms and isolines of specific redox conditions (e.g. Blomgren & Tholander, 1986, p. 152; Pleiner, 2000, p. 134; Tylecote et al., 1971). The quantity of oxygen introduced into the system alters the distribution of temperature and redox conditions. High air input extends the high temperature zone towards the upper part of the furnace. It promotes the reduction from wustite to elemental iron and sets back the beginning of slag formation (Blomgren & Tholander, 1986, p. 158). On the other hand, it extends the influence zone of the less reducing plume, and shortens the time where CO_2 is exposed to the reducing fuel bed. Moreover, it causes rapid fuel consumption and possibly detrimentally high temperatures (De Rijk, 2007, p. 107). Therefore, it is essential in bloomery smelting to keep the flow velocity of the air entering the combustion zone as slow as possible, yet still permitting temperatures high

[40] Rehder (2000, p. 65) argues that within a bed of charcoal the atmospheric CO_2 will be completely reduced to CO within a distance of 10 to 20 times the diameter of the charcoal lump, given a space velocity of 30 m per minute. For fuel lumps of 5 cm in size, this would be in a distance of 50 to 100 cm away from the combustion zone. Osann (1971, pp. 23-26) describes a number of experimental smelts that provided evidence of a CO proportion in the furnace atmosphere of 73% to 96%, 5 to 33 cm away from the tuyere nozzle. Generally, the ratio of carbon dioxide released by the reduction of the iron oxides is estimated at about 10% of the plume (Osann, 1971, p. 25).

enough for a successful reduction and slag formation (Crew & Salter, 1991; De Rijk, 2007, p. 107; Hagfeld, 1966 as cited in Osann, 1971, p. 2; Rehder, 2000, p. 69). Rehder (2000) published a most detailed study about combustion properties and airflow behavior in varying charcoal beds and furnaces. He suggests for pre-industrial furnaces airflow velocities through the orifices of the tuyeres of about 15 to 20 m/sec., given a diameter of 2 to 3.5 cm of the tube. The latter seems to be quite common in the archaeological record (Pleiner, 2000, pp. 198-200; Rehder, 2000, p. 69). Moreover, experimental combustion provides evidence that the blowing pipes are best placed in a 15° angle downwards resulting in a maximum horizontal distribution of the atmospheric gas in the furnace (Shires, 1960 as cited in Rehder, 2000, p. 67). Moreover, the shape of the diameter of the orifice through which the air enters the furnace alters the isolines of the plume (Rehder, 2000, p. 70).[41]

Most bloomery furnaces were operated with more than one air input, although furnaces with only one supply were documented in some regions (Cline, 1937; pp. 44-51; Iles, 2010, pp. 384-385; Pleiner, 2000, p. 200; Prendergast, 1974, p. 257; Rehder, 2000, p. 68; Rowlands & Warnier, 1995, p. 520; Wente-Lukas, 1977, p. 113). Frequently, one can observe four air entrances or even more powering small bowl and shaft furnaces (Celis, 1991). The advantage of using numerous air providers arises from a more homogeneous gas and temperature distribution in the furnace, and markedly less power to maintain the airflow rate needed (Rehder, 2000, pp. 68-69).[42] Mapunda (2010, p. 154) provides evidence of tuyeres sloping down outwards from the furnace serving as slag tapping tubes once a certain level of the liquid slag mass was reached at the furnace bottom. At the same time, horizontally placed pipes permitted a continuous air supply to the furnace. In her detailed study on refractories in the Iron Age in eastern Africa, Childs (1986) found out that clays considered suitable for contemporary tuyere production as well as those used in antiquity were more refractory than the clays suggested and used for furnace construction. Such clays withstood higher temperatures than furnace wall refractories, indicating a selection of raw material for tuyere and furnace wall production. However, other examples have shown that tuyeres were also necessary as fluxing agents of the melt system, and they can strongly erode once they are in contact with the slag bath (Childs, 1986, pp. 469-472) (section 1.4.7).[43]

As mentioned above, the most common device for providing controlled air is to place the bellows that push ambient gas into the furnace in front of the tuyeres. I will not go into detail with respect to variations of bellows since only bowl-shaped bellows are of interest for this study (Chirikure et al., 2009; Friede & Steel, 1986). Bowl-shaped air providers consist of a wooden bowl or clay vessel covered by a diaphragm of varying materials. They are usually used in pairs and air supply is controlled by the strokes per minute (Chirikure et al., 2009; Rostoker & Bronson, 1990, p. 75). Most drum-bellows absorb air backwards, pushing through the outlet that is placed toward the tuyere, but examples are known of bellows with a separate valve-controlled air inlet (Chirikure et al., 2009, p. 202; Otto, personal communication as cited in Friede & Steel, 1986, p. 12). To prevent a disruptive reverse flow of gas from the furnace, the outlet is frequently placed at a certain distance away from the tuyere's outer entrance (e.g. Avery et al., 1988, p. 273; Celis, 1991, pp. 35 & 74; Chirikure et al., 2009, p. 202).[44] Additionally, the pair of air chambers is operated alternately and in doing so the smelters avoid a disruptive air provision to the furnace.

However, as most bellows are made from organic substances, they largely absent from the archaeological record. In addition, bellow types as documented in the ethnographic record do not necessarily correlate with ethnic boundaries and furnace types. Rather, they seem to mirror individual preferences and choices of the smelters (Chirikure et al., 2009, pp. 205-207).

1.4.4. Charcoal and fuel selection

In pre-industrial production, most iron smelting was done with charcoal since charcoal has the highest chemical reactivity

[41] A circular diameter results in a rather vertical gas distribution whereas a rectangular or D-shaped diameter spreads the gas more horizontally. The latter would be useful for bowl-shaped or hearth furnaces (Rehder, 2000, p. 70).

[42] Following Rehder's analyses, two opposite tuyeres already produce a better horizontal uniformity in the spreading of the redox and temperature contour lines. Also using two air providers of the same size instead of one lessens the energy needed to maintain the total flow rate to one quarter of what is necessary with only one supply. If both air suppliers work with the same intensity as before, the air-flow rate would be augmented by 60%. Four tuyeres instead of one would raise the airflow rate by 250% (Rehder, 2000, pp. 68- 69).

[43] The long single tuyere of the Mafa smelters, for instance, reduced for 37.5 cm during the smelt which means 2.5 to 5 cm per hour (David et al., 1989, p. 189; Rehder, 2000, p. 71).

[44] Following Friede & Steel's (1986, p. 14) experimental bellows operation, air output decreases once a certain rate of strokes per minute is exceeded.

of all forms of carbon (Rehder, 2000, p. 60). Charcoal is formed when wood is thermally decomposed under oxygen deficiency. Wood usually contains between 78wt% to 92wt% of carbon depending on the species (Pleiner, 2000, p. 115) and strength, hardness and reactivity alter from type to type (Rehder 2000, p. 56).[45] Generally, with increasing temperatures its content of fixed carbon increases and its chemical reactivity decreases resulting in high quality and long burning charcoal (Rehder 2000, p. 56). The African smelting traditions have shown that charcoal was frequently made from wood of a selected tree species (e.g. Childs, 2000, pp. 217-218; David et al., 1989, pp. 193-194; Goucher & Herbert, 1996, pp. 49-50; Martinelli, 2004, p. 180; Lyaya, 2011, p. 60; Thomas & Young, 1999, p. 224), and the choice of wood was based on experience and traditions (Lyaya, 2011, p. 68). Examples from African smelting practices have shown that people selected tree species according to their ability to deliver high burning values and to produce persistent fires. Moreover, firewood was chosen according to its mechanical stability to prevent crumbling inside the furnace. Additionally, its reducing qualities, its influence on slag formation, and the socio-cultural function of these tree species in societies traditionally influenced the choice (Avery et al., 1988, pp. 272-273; Eichhorn, Robion-Brunner, Serneels & Perret, 2013, p. 439; Lyaya, 2011, p. 60; Lyaya, 2013; Sassoon, 1964, p. 175; Thomas & Young, 1999, pp. 224-225). Also, the age of a tree and the parts that were used in charcoal making had an influence on its quality (Pleiner, 2000, p. 115; Rehder, 2000, p. 57).[46]

The mineral matter that plants extract from soils and water precipitates in wood ashes. The amount of the ashes varies within species and scholars suggest ash proportions ranging from smaller than 1% as high as 12% (Babayemi, Dada, Nwude & Kayode, 2010, p. 1820; David et al., 1989, p. 195; Rehder, 2000, 31; Rostoker & Bronson, 1990, pp. 82-83). Wood ash is usually rich in various oxides such as calcium (CaO), silica (SiO_2), sodium (Na_2O) or soda (Na_2CO_3), phosphorus (P_2O_5), magnesia (MgO), and it commonly contains a high amount of potassium (K_2O) or potash (K_2CO_3). Yet its composition varies from species to species, within the different parts of the tree and within the age range of a tree (Buchwald, 2005, p. 96). For instance, the average CaO content of wood ash from European trees listed in Rostoker and Bronson (1990, p. 83, Tab. 8.2) lies at about 38% and individual species reach up to 75.5%. Potash can reach about 23% and soda around 13%. Killick and Miller (2014, p. 252) mention CaO contents of 90% in South African leadwood (Combretum imberbe) to explain high CaO readings in metallurgical slag. In other African tree species, potash contents as high as 96% are known (Adewuyi, Obi-Egbed & Babayemi, 2008 as cited in Babayemi et al., 2010, p. 1823). Some smelters even added charred reed to the furnace to promote the carbonate and soda input on the molten slag (Avery et al., 1988, p. 273). Although the input of fuel ashes on slag formation is not considered high, fuel ash chemistry is able to alter the properties of a melt and consequently the quality of the elemental iron (Crew, 2000; Kronz & Keesmann, 2003, p. 267; Oelsen & Schürmann, 1954, p. 511; Pleiner, 2000; p. 252; Rehder, 2000, p. 31; Rostoker & Bronson, 1990, pp. 82-83; Thomas & Young, 1999). However, most tree species are selected to provide enough carbon for reduction and stability of the charge to allow the combustion gases to permeate the furnace interior. One ethnographic example attested that some smelters selected tree species only because they provided the smallest amount of fuel ashes after combustion (Juwayeyi, 1995, p. 397).

Another most important impact on the redox conditions during the smelting process is that of the charcoal lump size. Comparable to the optimal ore size, which has been discussed earlier, charcoal quality also benefits from an optimal lump size. The latter allows gas permeability and creates a maximum of surface area exposed for reduction (De Rijk, 2007, p. 107; Osann, 1971, p. 20; Rehder, 2000, pp. 60, 66).

1.4.5. Fuel consumption

It is generally assumed that the fuel to ore ratio influences the amount and quality of the iron produced (e.g. Charlton et al., 2010, pp. 356-357; Childs, 1996, p. 296; Rostoker & Bronson, 1990, pp. 96-97; Tylecote et al., 1971, p. 353). Many experimental smelts have been conducted with a fuel to ore ratio around 1:1 in weight proportions which has resulted in a

[45] Strength and hardness are as important as charcoal stability with respect to its lump size as it sustains the free flow of combustion gases through the charcoal bed (Craddock, 1995, p. 192).

[46] According to Rehder (2000, p. 57), younger trees and younger parts of a tree such as branches have better strength and a reduced reactivity so that they are better suited for iron smelting. Pleiner (2000, p. 115) also refers to the varying components and proportions of mineral matter within the different parts of trees.

much different volume distribution of charcoal and ores (Osann, 1971, p. 8; Rostoker & Bronson, 1990, p. 97; Sassoon, 1964, p. 178),[47] other studies reported fuel to ore ratios from 2:1 up to 20:1 by weight (summarized in Thomas & Young, 1999, p. 228). Usually, it is difficult to derive useful data from the archaeological record because of the fragmentary nature of archaeological data. Therefore, most assumptions are based on experimental smelts (e.g. Tylecote et al., 1971; Rehder, 2000, pp. 149-152) or on information found in the ethnographic record (see below). Obstacles also emerge from the great diversity of often incompatible data due to heterogeneous furnace constructions, variations in heat loss, ore quality, charcoal quality, and the incoherent reference values published in the literature (e.g. Avery et a., 1988, p. 269; David et al., 1989, p. 1999; Goucher & Herbert, 1996, pp. 49-50; Hahn, 1997, p. 136; Humphris, 2010, p. 42; Martinelli, 2004, pp. 184-185; Pleiner, 2000, p. 126-127; Rehder, 2000, pp. 149-152; Rostoker & Bronson, 1990, p. 97; Sassoon, 1964, p. 178; Thomas & Young, 1999, p. 227). Thus I refrain from any further compilation of possible fuel consumption estimations in the framework of this study, except for the ethnohistorical accounts that I collected during fieldwork (section 5.3.3).

1.4.6. Characteristics of bloomery slag

Generally, the formation of metallurgical slag permits the separation of metals from their associated minerals, and it is an important factor for successful metal production. Slag collects all non-reducible parts present in the smelting operation. They protect native metals from re-oxidation and remove unwanted alloying elements. Metallurgical slag commonly consists of silica (SiO_2) and a number of oxides such as FeO, CaO, Al_2O_3, MnO, MgO, P_2O_5, TiO_2 and others. Theses silicates and oxides originate from the associated minerals of the ore, from the furnace lining or other added fluxes, and from the plant resources used in the smelt. The morphological appearance of the slag, its mineralogical microstructure and chemical composition reflect the metal produced, the process conditions of the smelt, the nature of the ore, the chemical and socio-cultural manipulations of the smelting operation, and the weathering symptoms of the slag (e.g. Bachmann, 1982, pp. 9-10; Hauptmann, 2014, pp. 91-92; Kronz & Keesmann, 2005, p. 403; Miller & Killick, 2004; Rehren et al., 2007; Yalçin & Hauptmann, 1995; Straube, 1996, p. 44).

Slag from bloomery smelting and pre-industrial smithing is iron-rich silicate slag. Usually, the iron oxide content exceeds 45wt%, and readings frequently range between 60wt% to 70wt% of iron oxides the samples (Kronz & Keesmann, 2005, p. 405; Yalçin, 2000, p. 313). The principal components of bloomery slag are FeO, SiO_2, CaO and Al_2O_3, and the proportion amongst them indicates the process-related conditions as mentioned above. All over the world, bloomery slag fragments are very homogeneous in chemical composition due to the required physical conditions that are given by the eutectics[48] of the main phases of the multi-component melt system (Hauptmann, 2014, p 100; Kronz, 2000, p. 1005). Slag formation in bloomery smelting benefits from the fact that iron-silica mineral phases have lower melting points than the individual elements involved[49], and the phase diagram FeO-SiO_2 in Figure 18 shows that liquidus temperatures of iron-rich melts can be reached between 1175 to 1180 °C. Yet these melts require high relative FeO-portions between 64wt% and 77 wt% with reference to silica. Moreover, a broader range of melting compositions at temperatures lower than 1200 °C can be achieved when magnetite (Fe_3O_4) is present as partially reduced ore, or by adding hammer scale (magnetite flakes) as a flux (Rostoker & Bronson, 1990, p. 196). All in all, the field of the minimum viscosity is limited by a narrow range of temperature and compositions, and high iron oxide contents are a basic prerequisite for successful slag formation at low average temperatures (Blomgren & Tholander, 1986, p. 152: Fig. 5; De Rijk, 2007, p. 108; Kronz & Keesmann, 2003, p. 259; Straube, 1996, pp. 45-45; Yalçin, 2000, p. 313). As mentioned above, liquefaction starts at the eutectic points of a multicomponent melt system, and the varying components of the charge in non-eutectic

[47] Charcoal has a specific weight of about 200 to 500 kg per m^3, limonite about 2000 kg per m^3 (Osann, 1971, p. 8).

[48] A eutectic is a mixture of chemical compounds or elements in a specific proportional composition that solidifies at a temperature lower than any other possible composition of the system. At the eutectic point, all mineral phases involved solidify at the same moment in what is called a eutectic intergrowth. In non-eutectic compositions, phases solidify one after another when temperature decreases.

[49] Melting point of quartz: 1713 °C, wustite: 1369 °C, elemental iron: 1583 °C.

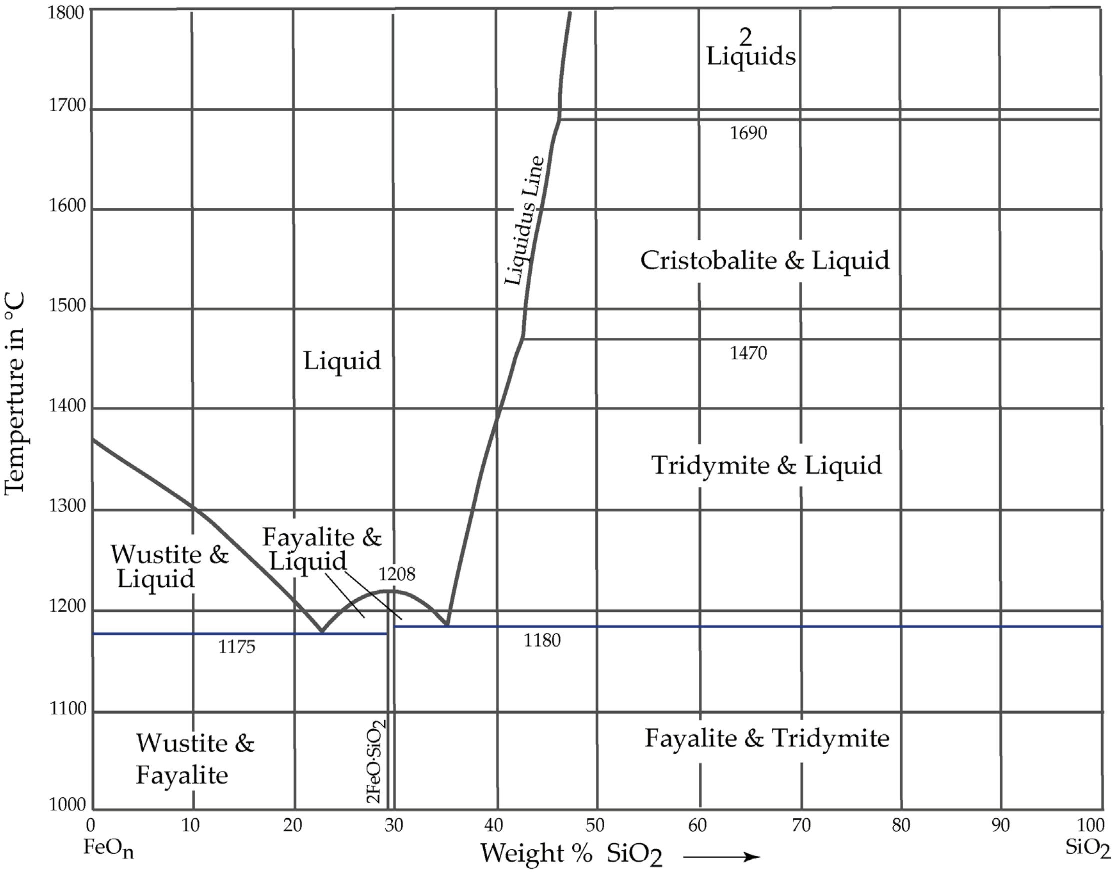


Figure 18: The FeO-SiO_2 phase diagram.

composition partially melt when temperatures and sufficient time for the reaction are provided (Hauptmann, 2014, p. 101; Miller & Killick, 2004, pp. 29-30).[50] Moreover, dissolution of minerals from refractory or biogenetic materials locally alters the slag composition and creates chemical compositions with melting temperatures even lower than seen in the idealized phase diagrams (Rostoker & Bronson, 1990, p. 83; Kronz, 2000, p. 1007) (see section 1.6.4). The most common agents of these processes are potassium, sodium, calcium and iron oxides (Rostoker & Bronson, 1990, p. 82). Besides the eutectics mentioned above, olivines ($(Fe,Mg,Mn,Ca)_2SiO_4$) are the main mineral phases in bloomery slag, in particular the iron-rich fayalite (Fe_2SiO_4). It consists of 70.51wt% FeO and 29.49wt% SiO_2 with a melting point at 1205 °C (De Rijk, 2007, p. 108; Kronz & Keesmann, 2003, p. 259). The main chemical reaction of fayalite formation within the furnace is:

$$2\,FeO + SiO_2 \leftrightharpoons Fe_2SiO_4$$

As this is an exothermal reaction, it keeps the furnace at a consistently high temperature (De Rijk, 2007, p. 108). Apart from fayalite (Fe_2SiO_4), the other main mineral phases are wustite (FeO), varying spinel (such as magnetite and hercynite), leucite ($KAlSi_2O_6$), and varying mainly silica-rich phases and glass (Kronz, 2000, p. 1005).[51] All oxides that stay in their oxygen bond at temperatures and redox conditions present during the smelting operation form the slag together with SiO_2 and FeO (Straube, 1996, p. 56). However, minor and trace elements that become part of the slag frequently form chemical compounds that alter the behavior of slag formation. Therefore, they must be regarded with care (Hauptmann, 2014, p. 99; Kronz & Keesmann, 2005, p. 407). Those

[50] In case that one component is overrepresented in the charge it will stay as a relict phase in the slag and hampers the separation of elemental iron and slag (Hauptmann, 2014, p. 101).

[51] The mineral phase composition within bloomery slag alters according to the redox conditions during solidification and cooling. Reducing conditions produces slag with fayalite, wustite, leucite, hercynite or ulvite-rich spinel, oxidizing conditions result in microstructures with fayalite, magnetite-dominated spinel, leucite and rhönite (Kronz & Keesmann, 2003, p. 263). A very comprehensive analysis of the individual mineral phases in fayalitic slag is provided by Kronz (1998).

elements with oxygen affinities lower than elemental iron or equal to them go into solution with the latter (Kronz & Keesmann, 2005, p. 406). Carbon is only then dissolved in the elemental iron if the aforementioned oxides are completely reduced (De Rijk, 2007, p. 106). Depending on the given redox conditions and temperatures, elements such as nickel (Ni), arsenic (As), cobalt (Co), copper (Cu), zinc (Zn) and lead (Pb) are siderophile and tend to become enriched in the elemental iron. Other elements such as silicium (Si), aluminum (Al), calcium (Ca), potassium (K), zirconium (Zr), titanium (Ti), chromium (Cr), barium (Ba), vanadium (V), strontium (Sr), zirconium (Zr), manganese (Mn) and magnesium (Mg) are lithophile and stay in their chemical bond with oxygen under the given parameters of bloomery smelters and become enriched in the slag mass (Kronz & Keesmann, 2005, p. 424; Kunze, 2006, p. 64; Yalçin & Hauptmann, 1995, pp. 287-288). Phosphorous, which reacts similarly to iron, can be found in both the elemental iron and the slag (Pleiner, 2000, p. 252). Therefore, the temperature at which the elemental iron forms plays an important role for the properties of the iron yielded. Ethnographic records from Mossi smelters in West Africa demonstrated that the smelters were aware of these processes because high shaft furnaces were operated at temperatures below 1000 °C in slow combustion to obtain a low carbon steel bloom with limited disturbing alloying elements (Martinelli, 2004, pp. 181-186).

As mentioned earlier, apart from the main slag-forming agents SiO_2 and FeO, minor components can play an important role in slag formation because their contribution can alter the behavior of a melt.

CaO

Calcium (CaO) is commonly found in elevated percentages in bloomery slag. It may originate from carbonate ores, from calcium-rich refractories or from biogenetic sources. High CaO values are frequently found in the silica-rich glassy matrix, which represents the phase composition with the lowest melting point within the slag (Kronz & Keesmann, 2005, p. 434). The system CaO-FeO-SiO_2 illustrated in Figure 20 exemplifies that minimum liquidus temperatures are reached in the range of 10wt% to 20wt% of CaO in the system. Moreover, CaO is able to replace the iron in the $FeSiO_4$ compound at temperatures above 1100 °C. It sets wustite free for further reduction and it is of great use in high carbon steel and cast iron production (Kunze, 2006, p. 68; Serneels, 1993, p. 17; Yalçin & Hauptmann, 2003, p. 146).

Al

Like calcium, alumina (Al_2O_3) plays an important role in the fayalitic slag composition. The system Al_2O_3-FeO-SiO_2 illustrated in Figure 19 shows that the lowest liquidus temperatures are reached in the range of 7wt% to 10wt% of Al_2O_3 in the system. The aluminum to silica ratio is considered to remain unchanged from ore to slag. Therefore, a change in the ratio may indicate a contribution of alumina from refractories or soil, or that alumina-rich ores were added to the smelt (Kronz, 2000, p. 1006; Craddock, Freestone, Middleton & Van Grunderbeek, 2007, pp. 11-12).[52]

K

Potassium oxides are frequently found in bloomery slag and originate from fuel ashes or eroded refractories used in the smelt. They either form mineral phases of kalsilite ($KAlSiO_4$) or leucite ($KAlSi_2O_6$) and high K_2O contents are also found in the glassy matrix. As mentioned above, potassium alters the liquidus behavior of slag and can be used as a flux (Kronz, 1998, pp. 104-106; Kronz, 2000, p. 1006; Kronz & Keesmann, 2005, pp. 435-436).

Mn

Manganese oxide possesses a higher oxygen affinity than iron and will only be reduced when the iron oxides are completely reduced (Kronz & Keesmann, 2003, p. 262; Straube, 1996, p. 55). Therefore, it is rarely found in bloomery iron but is common in bloomery slag, if manganese-containing ores have been used. Although manganese at moderate percentage slightly raises the liquidus temperature of iron-rich bloomery slag, the positive influence of manganese on the yield of elemental iron comes from its chemical property to replace iron oxides in the Wu-Fe-equilibrium. Therefore, it permits more wustite to become reduced and as its oxygen affinity is higher than that of wustite it promotes further dissolution of carbon in the elemental iron (Iles, 2010, p. 326; Kronz & Keesmann, 2003, p. 262; Kronz & Keesmann, 2005, p. 453; Kunze, 2006, p. 80; Osann, 1971, pp. 66-69; Pleiner, 2000, p. 136; Straube, 1996, p. 45).[53] Some scholars even argue that sophisticated bloomery smelters were most likely able to control carburization through the manganese concentration in their slag (Kronz & Keesmann,

[52] Such a mix of ores ('stone-like' and 'clay-like') was for instance described by Childs (2000, pp. 207-210).

[53] When enough manganese is present in the sample to be significant, melting temperature and efficiency will be calculated with FeO + MnO (Kronz & Keesmann, 2003, p. 262; Oelsen & Schürmann, 1954,p. 510; Straube, 1996, p. 45).

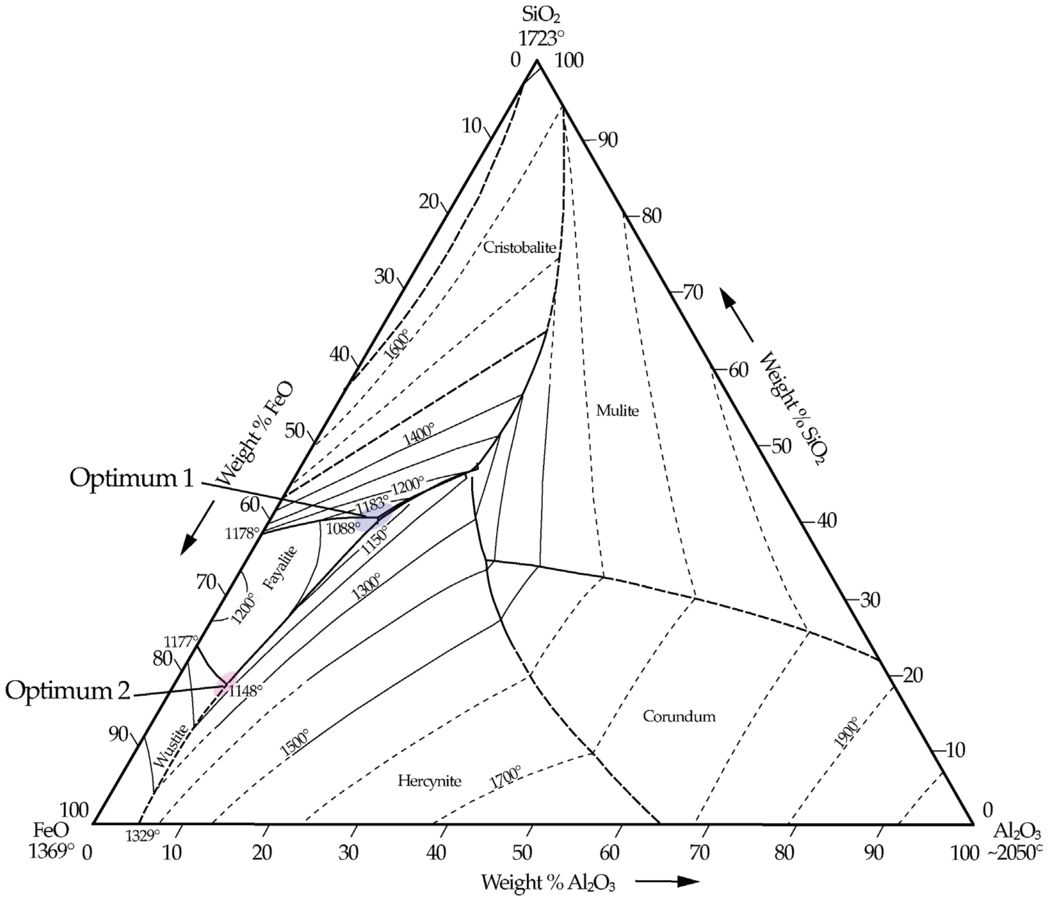


Figure 19: Ternary FeO-Al_2O_3-SiO_2 phase diagram (simplified) with the low-melting eutectics Optimum 1 and Optimum 2.

2005, p. 444). Manganese was probably most effective when added to iron-rich ores as documented in Uganda and discussed in great detail by Iles (2010, pp. 324-354).

Mg

Magnesium is frequently associated with the gangue and the refractories[54], or else it originates from fuel ashes. Contrary to manganese, magnesium oxide (MgO) raises the liquidus temperatures of the fayalite-dominated smelts considerably. As can be gleaned from the FeO-MgO-SiO_2 ternary system (Alibert, 1995, p. 142), the range of possible compositions that allow for melting temperatures around 1200° C is highly restricted, and any minor deviation leads to disadvantageously elevated liquidus temperatures. It is therefore an explicitly negative minor element in bloomery smelting (Kronz & Keesmann, 2005, p. 426; Oelsen & Schürmann 1954, p. 511).[55] However, the proportion of magnesium in fayalitic slag provides valuable information about the furnace operation temperatures.

P

Most iron ores and biogenetic materials contain some phosphorous. Phosphorus enriches in both the iron (here: P) and the slag (here: P_2O_5) since the P_2O_5:P conversion takesplace at temperatures between 900 °C and 1000 °C (Pleiner, 2000, p. 252; Rostoker & Bronson, 1990, p. 82; Kronz & Keesmann, 2003, p. 266; Kronz & Keesmann, 2005, p. 407).[56]

[54] For instance, depending on the deposit, clay from the Kavango River can contain up to 6% of magnesium (sample 4706/06).

[55] It seems as if magnesium is more frequently found in smithing and refining slag than in smelting slag. This might be due to the elevated temperatures that are particularly found in refining than in smelting (Kronz & Keesmann, 2005, p. 426)

[56] To estimate the P content in the bloomery iron produced, Tylecote (1962 and 1986 as cited in Pleiner, 2000, p. 265) suggests values ranging from 0.25% to 0.5% of the phosphorous content found in the slag. Piaskowski (1965 as cited in Pleiner, 2000, p. 265) proposes to multiply the P_2O_5 content of a slag by 0.12 to 0.35 to estimate the P content of the iron produced.

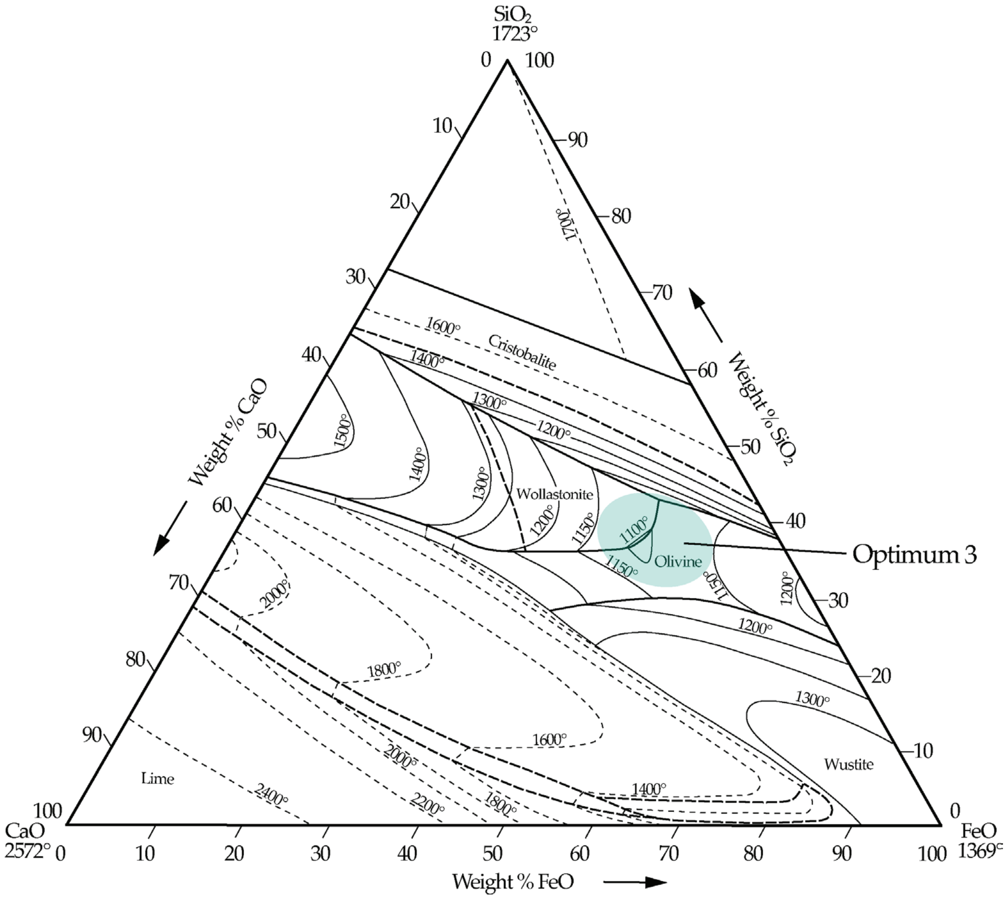


Figure 20: Ternary FeO-CaO-SiO_2 phase diagram (simplified) with the low-melting eutectic Optimum 3.

The P_2O_5:P ratio of slag and bloom therefore reflects the thermodynamic processes in the furnace (Crew & Salter, 1991; Kronz & Keesmann, 2005, p. 441). In modern steel production, phosphorous is an undesired alloying element since it alters the properties of metallic iron (section 1.4.9). However, in direct iron production of bloomery smelters phosphorous decreases the liquidus temperature of fayalitic slag and low temperature smelting operations prevents the elemental iron from phosphorizing (Kronz & Baumeister, 2006, pp. 57, 81; Pleiner, 2000, p. 136).

Glass

Bloomery slag often contains a glassy matrix in which all chemical elements that do not form crystalline mineral phases are collected. They represent the lowest possible liquidus composition of the given phase systems (Kronz & Keesmann, 2005, p. 438.). Due to its high SiO_2 content, the glassy mass does not crystallize under the given thermodynamic conditions in bloomery smelters (Kronz & Keesmann, 2005, p. 436).

Liquid slag collects below the combustion zone of the bloomery furnace and viscosity decreases towards the isotherms of the solidus temperatures of the slag bath (Blomgren & Tholander, 1986, p. 153). As the level of the slag bath rises, smelters may tap the slag to sustain the ongoing smelting operation. In the ethnographic and archaeological record ironworkers created many ways to drain away the slag from the combustion zone (Pleiner, 2000, pp. 141-142). Some furnaces were provided with tap-pits at the bottom to gather the liquid matter; others were constructed with drainage channels (Avery et al., 1988, p. 264). Bowl furnaces frequently had no drainage system and although there was some separation of elemental iron and slag, a great degree of the physical separation was carried out in post-smelting processing steps (Pleiner, 2000, p. 141) (section 1.5). Some smelters did not drain the slag at all because they knew about the obstructing effect of a slag bath on carburization (De Rosemond, 1943, p. 84). In addition, in such furnaces the tuyeres had to be placed far enough above the bottom in order not to become clogged by the growing slag mass (Rostoker & Bronson, 1990, p. 29). As will be discussed later, slag solidifies in varying shapes and conditions and provide valuable information on furnace types and process conditions (section 1.6.2.1).

In most pre-industrial smelting processes, slag formation is considered to be self-fluxing. This means that the gangue, the fuel selection and the refractories allow for a successful separation of the metallic iron and no other fluxes are necessary (Kronz, 2000). The liquidus temperatures present in the ternary systems as referred to above represent only idealized conditions of the complex phase relationships in bloomery smelting. Liquidus temperatures may well drop to about 500 °C below the temperatures given in ternary diagrams (section 1.6.4). Moreover, the amount of FeO in the slag is only a limited indicator of the efficiency of the underlying reduction process. Slag produced from rich ores with less gangue components can show a high wustite portion, although the yield of elemental iron was good. Likewise, slag produced from poor quality ores may show low FeO portions, although the iron output was low (Blomgren & Tholander, 1989, p. 158).

In the ethnographic record fayalitic slag is also known to serve as a flux in subsequent smelts due to its iron-rich low-melting composition (Avery et al., 1988, pp. 273, 275; Celis, 1991, p. 21; De Rosemond, 1943, p. 82; Malcom, 1924, p. 137; Schmidt, 1996, pp. 96-104). Moreover, they provided source material for further iron production (Fowler, 1995, pp. 101-102; Redinha, 1953, p. 132; Schmidt, 1996). Yet whenever residues from former smelts served as a flux in African smelting practices, there was no conceptual separation of technological (fluxing properties) and spiritual function (e.g. Celis, 1991, p. 21).

One so far insufficiently researched field is slag corrosion. From the main slag constituents (wustite, magnetite, fayalites) only wustite reacts with water and forms a product similar to rust. From the minor constituents, potash and soda are soluble in water and affected by weathering. Moreover, slag becomes brittle over time (Rostoker & Bronson, 1990, p. 87). However, the strongest impairment of slag preservation comes from trapped iron inclusions that easily corrode under humid conditions and cause the slag to fall apart (Buchwald, 2005, p. 99).

1.4.7. Technical ceramics

In ancient metal production, adequate technical ceramics are essential for a successful reduction of the ores. Clays of the sort that were used for furnace construction have to withstand the high temperatures and the alternating redox regime of the furnace without breaking down. They also have to resist abrupt changes in temperature without damage and hold heavy charges during the smelt. The chemical, mineralogical and physical properties of these materials determine the stability of the furnace and the tuyeres during the several hours of smelting. Temper was frequently added to manipulate the thermal and chemical quality into the desired direction of function (e.g. Childs, 1996; Freestone, 1989; Martinón-Torres & Rehren, 2014).

Recent research revealed that furnace lining and other clay and silica-rich materials used in bloomery smelting also played an important role in the formation of low-melting slag (Bandama, 2013, pp. 151-152; Craddock et al., 2007; Thomas & Young, 1999; Kronz, 2000; Kronz & Keesmann, 2005, p. 447; Rostoker & Bronson, 1990, pp. 57-60; Paynter, 2006, p. 285). The composition of available ores only sometimes corresponds to the chemical demands for the formation of slag at the intended temperatures (e.g. Iles, 2010, p. 227). Therefore, technical ceramics improve slag formation properties at the expense of a reduced yield of elemental iron from the smelt (Kronz, 2000, pp. 1006-1007). Mass balance analyses indicated that refractory materials contributed between 5wt% and 30wt% of inorganic matter to the slag composition (Kronz, 2000, p. 1007; Kronz & Keesmann, 2003, pp. 268-269; Paynter, 2006, p. 272; Thomas & Young, 1999, p. 163). Moreover, in some regions, furnace sites were associated with the availability of clays and silica rich materials (Kronz & Keesmann, 2005, p. 445). However, most smelters seemed to prefer locally available clay sources even though the refractory qualities were not optimal (e.g. Childs, 1996; Freestone, 1989; Martinón-Torres & Rehren, 2014). Rehder (2000, p. 70) for instance suggested that all clay tuyeres that enter the furnace at more than 10 cm to 20 cm will react with the iron-silica system. The long single tuyere of the Mafa smelters diminished for 37.5 cm in the course of the smelt, which means 2.5 to 5 cm per hour (David et al., 1989, p. 189; Rehder, 2000, p. 71). Rowlands and Warnier (1995, p. 522) mentioned that a tuyere shortened for about 15 cm during an 8-hour-smelt. The Japanese Tatara furnace type provides a most impressive example of the use of refractories in smelting operations. Here, the lower shaft of the furnace wall was intentionally thickened with clay that disappeared during the smelt (Gowland, 1899 as cited in Rostoker & Bronson 1990, p. 136).[57] Examples are known where smelters added sand to the furnace to prevent the erosion of the furnace wall (Hupfeld, 1899 as cited in Cline, 1937, p. 36).

In reconstructing bloomery processes, it is important to recognize whether an ore is self-fluxing, which basically means whether there is enough SiO_2 in the gangue, or not. If not it is necessary to compare the composition of the ore to the components found in the slag in order assess the input of technical ceramics or fluxes. The refractoriness of clay materials strongly depends upon the redox conditions under which clays are exposed to high temperatures. It is known that under furnace running conditions and considering the highly fluxing FeO content of bloomery smelts, technical ceramics behaved less refractorily than expected since the newly formed mineral compositions were chemically more aggressive than the source material (Schmidt & Childs, 1996, p. 229). Analyses of refractories used in ironworking revealed that a reducing atmosphere may lower the melting temperatures of the clays by about 300 °C to furnace operation temperatures at around 1200 °C (Childs, 1986, pp. 148, 156). Therefore, when choosing clay materials for furnace construction, it was important to select substances which did not contain too many melting point reducing agents such as iron and aluminum oxides, potash or soda in order to maintain the structural stability of the furnace (Rostoker & Bronson, 1990, p. 58). However, Kronz and Keesmann (2003, p. 270) argued that the high-temperature silica polymorphs cristobalite and tridymite become enriched in the furnace lining during the smelt and prevent the full erosion of the refractories. Pleiner (2000, pp. 257-259) observed that in European bloomery furnace traditions two different types of refractories were used: one with silica contents at about 60%, about 13% Al_2O_3 and about 9% CaO, and the others with SiO_2 portions up to 90%. The heat resistance of the first type was estimated at approximately 1300 °C, that of the latter range up to 1700 °C. Analyses of recent clay samples designated as suitable material for ironworking purposes by local ironworkers, as well as refractories from archaeological sites in East Africa revealed that the iron masters of the Early and the Late Iron Age preferred fireclays with SiO_2 proportions ranging between 35wt% and 67wt%, Al_2O_3 contents between 20wt% and 42wt % and FeO percentages between 6wt% and 21wt% (Childs, 1986).[58] Here, the relatively high Al_2O_3 readings indicate good refractoriness, the elevated iron mineral contents however may flux the material in a reducing atmosphere already at furnace running temperatures (Hamer & Hamer, 2004 p. 188; Rice, 2005, p. 94). There are known examples in which smelters even temper the clay of the furnace wall with crushed fayalitic slag and thus deliberately decrease the refractoriness of the material (e.g. Iles, 2010, pp. 150, 175; Mapunda, 1995, p. 169) (see also below).

Comparative samples of recent clays from Childs' research area suggested that the chemical composition of the ancient clays was similar to material from termite mounds.[59] Interestingly, all the recent samples analyzed, and in particular the termite clays, showed crumbling and spalling processes already at temperatures between 600 °C and 800 °C under reducing conditions (Childs, 1986, pp. 148, 165, 173).[60] This is an indication that the alumina and silica-rich furnace refractories may already contribute to the composition of the batch at relatively low temperatures. Dugast (1986, pp. 40-41), for instance, reported that the ironworkers in Togo were well aware of the refractory properties of the varying clays. 'White' clays were considered refractory enough to serve as tuyere clays and reddish clays from termite mounds were used in bloom refining. Here they served as a fluxing agent to separate the metallic iron from its slag inclusion. A broader look into the ethnographic record illustrates that all over Africa, termite mounds and termite clays played a special role in furnace constructions, even though other natural clay resources were available (e.g. Avery et al., 1988, pp. 267, 273; Celis, 1991, p. 61; Chaplin, 1961; Childs, 1986, p. 150;

[57] Kronz (2000, p. 1008) exemplifies that during a smelt, in which 5% to 15% of furnace lining is dissolved from the furnace wall, given a furnace of 40 cm in diameter, 125 cm in circumference and a reaction zone of 25 cm in height (and given a charge of 100 kg), the inner radius of the furnace would increase from 0.6 to 3.2 cm.

[58] All data were taken from Childs (1986, p. 334: Tab. 6.9, p. 391: Tab. 6.24) and were rounded.

[59] Termite clay samples from Childs' research area showed SiO_2 readings between 50wt% and 60wt%, Al_2O_3 contents between 26wt% and 35wt%, and FeO proportions of 10wt% to 11wt% (Childs, 1986, p. 153 Tab. 4.6).

[60] More data of technical ceramics from East Africa can be taken from Iles (2010). However, she argues that the high alumina content of these clays makes them highly refractory having little input on slag formation (Iles, 2010, p. 150).

Iroko, 1996, pp. 127-134; Juwayeyi, 1995, p. 396; Lyaya, Mapunda & Rehren, 2012, p. 197; Mapunda 1995; 2010, pp. 67, 71; Read, 1902, p. 45; Redinha, 1953; Robinson, 1961; Schmidt, 1996, pp. 87, 92; Schmidt & Childs, 1995, p. 527; Schmith & Dale, 1920, pp. 203-204; Sandelowsky, 1974; Van Tonder, 1966, p. 264). Termite clays normally vary in composition because they have the mineralogical composition of the sub-soil from which they are built (Hesse, 1955, p. 460). Most termite clays are slightly enriched in alkalis and some show elevated calcium proportions (Adekayode & Ogunkoya, 2009; Wood, 1988, p. 234). Usually, their texture is rather coarse-grained, well-sorted and without supplements suitable for furnace constructions (Childs, 1986, p. 196; 1989, p. 149). The refractoriness of these clays ranges between 1400 °C to 1500 °C under oxidizing conditions, and decreases to 1200 °C to 1400 °C in a reducing atmosphere (Childs, 1986, p. 156: Fig. 4.8). The refractoriness further drops when organic material is naturally present in the clay or added as a temper (Childs, 1989, p. 148; Ndaliman, 2001, p. 45; 2007, p. 160). From there one may conclude that the limited heat resistance of termite clays under temperatures in bloomery smelters was accepted and desired in order to benefit from its fluxing properties. Moreover, there is ethnographic evidence from Africa that smelters used termite clays together with slag from previous smelts to build up their furnaces (Avery et al., 1988, p. 273), which consequently decreases the refractoriness of the furnace walls. This in turn strongly contributed to the slag formation in the furnace. Furthermore, in sand dominated environments such as the Kalahari, termite clays sometimes provide the only clay resource easily accessible to smelters. Some ironworkers even used the hard outer casing of the mound as slabs and bricks for furnace construction (Read, 1902, p. 45; Chaplin, 1961). In addition, the elevated position of the eroded termite mounts was a preferred furnace location (e.g. Halkin, 1911, p. 234) for technical reasons such as preventing the furnace from being damaged during strong rainfalls. Frequently, termite constructions also had a pronounced spiritual function and therefore their vicinity was chosen in smelting for cosmological reasons (Iroko, 1996; Mapunda, 2010, pp. 156-158) (section 5.4). However, even though termite clay refractories have the optimal composition to serve as a flux, the contribution of the furnace lining varies from furnace to furnace and from smelt to smelt.

Refractories in iron smelting, in particular tuyeres, are frequently tempered with organic materials in Africa (e.g. Archinard, 1884 as cited in Cline, 1937, p. 35; Goucher & Herbert, 1996, p. 45; Malcolm, 1924, p. 137; Schmidt, 1996, p. 84) and elsewhere (Craddock, 1995, p. 175; Martinón-Torres & Rehren, 2014, p. 124). Organic materials generally increase the fracture resistance of the clays and improve the thermal insulation (Martinón-Torres & Rehren, 2014, p. 123). Some technical ceramics were tempered with organic material that was charred before being added to the clay and hence contain a high amount of elemental carbon (Rostoker & Bronson, 1990, p. 60). The latter plays an important role in crucible fabrication as it raises the thermal conductivity and thus prevents microcracking due to thermal stress. Furthermore, it increases the thermal and chemical refractoriness together with the tensile strength of the clay material (Martinón-Torres & Rehren, 2014, p. 123; Rostoker and Bronson, 1990, p. 60). However, as described above, un-charred organic temper generally decreases the refractoriness of clays, therefore it is likely that the organic material was not only added for stability reasons, but also to bring about a certain amount of dissolution under the given temperatures.

Other examples revealed that temper was added to increase the refractoriness of the technical clays, in particular when it comes to the stability of the tuyeres. Malawi smelters, for instance, used crushed tuyeres from previous smelts to raise the stability of the freshly produced blowing pipes (Avery et al., 1988, p. 273). The same was true for smelters from Uganda (Childs, 2000, p. 212) since grog temper has a thermal expansion rate comparable to the clays used for the refractories (Childs, 1989, p. 147; Schmidt & Childs, 1996, p. 229). Moreover, Childs (1986) was able to prove that ironworkers selected different and more refractory clays for the production of the tuyeres than for the building of the furnace wall. All in all, technical ceramics play an important role in the various aspects of iron smelting but it seems that the engineering and cosmological choice of refractory materials is subject to strong local variation.

1.4.8. Furnace constructions

As I described above, iron smelting requires a suitable reducing atmosphere, sufficiently elevated temperatures for the desired endothermic reduction reactions, and enough time for the desired reactions to proceed. The main function of furnaces in bloomery smelting is to sustain the temperatures required for the necessary redox conditions and to protect the reducing atmosphere from the oxygen-rich natural environment. Aboveground shaft furnaces, and any other pit or container filled with a deep fuel bed are sufficient with respect to thermodynamics as they reflect the heat radiated by the glowing fuel and the hot furnace walls (Rostoker & Bronson, 1990, p. 25).

All over the world, bloomery smelting furnaces were very heterogeneous in their appearance; both archaeological and ethnographic studies on furnace design largely confirmed the great diversity in the engineering solutions of furnace architecture (Pleiner, 2000, pp. 145-195), but iron-smelting furnace designs are difficult to reconstruct from the archaeological record since most of the upper furnace structures eroded away. On the African continent, furnace design varied from tall shaft furnaces of more than 6 m in height to small superficial smelting hearths (e.g. Avery et al., 1988; Charlton et al., 2010, p. 353; Celis, 1991; Childs, 1991; Chirikure & Bandama, 2014, pp. 296-300; Cline, 1937, pp. 52-53; Collett, 1993, pp. 500-502; Friede & Steel, 1985, 1988; Killick, 1995; Martinelli, 2004; Okafor, 1995, p. 435). Moreover, as will also be demonstrated within this study (section 5.3.3; Figure 218) furnace designs could also vary greatly on a regional level (e.g. Robion-Brunner, Serneels & Perret, 2013). It is a widely held view that furnace design is persistent throughout generations of smelters, even though the smelting recipe may change (e.g. Charlton et al., 2010, p. 354). Nevertheless, because of the pronounced heterogeneity of furnace solutions, the distribution of contemporary furnace types must be approached with caution regarding any diachronic conclusion derived from them (Chirikure et al., 2009).

In pit furnaces and low shaft furnaces, air is usually provided through a forced draft (Chirikure et al., 2009, p. 198; Cline, 1937, p. 52). A natural draft is used where the topography and/or furnace size cause pressure differences of the escaping combustion gas from the furnace between the bottom and the top of the furnace (Avery et al., 1988, p. 264; Killick, 1995).

Smelting duration varies from furnace to furnace and time spans provided in the literature range from 4 hours (Cline 1937, p. 52) to several days (Martinelli, 2004, pp. 178-179), whereas smelting in high shaft natural draft furnaces was the most time-consuming operation (Killick, 1995, p. 61). By increasing height of the shaft, the time span in which the ores were exposed to the reducing atmosphere also increased (De Rijk, 2007, p. 107; Martinelli, 2004, pp. 181-183). Therefore, it is believed that more wustite could be reduced to metallic iron and consequently, less iron oxide was available for slag formation. This would result, according to the FeO-SiO_2-phase diagram shown in Figure 18, in elevated melting temperatures. At the same time as wustite was in chemical equilibrium with the dissolution of carbon in metallic iron, the atmosphere of the furnace would allow for a higher carburization of the bloom (Blomgren & Tholander, 1986, p. 157; Straube, 1996, p. 52). Ethnographic examples, however, attested that in some areas high shaft furnaces operated for several days at temperatures below 1000 °C in order to protect the smelting facility from collapsing, and to produce a low carbon iron (Martinelli, 2004, pp. 181-186). Interestingly, it was more often the small furnaces and in particular the pit furnaces that were susceptible to overheating and as a consequence to an unwanted cast iron formation because the hot combustion gases did not cover a great distance when permeating the bed of fuel and ores (Osann, 1971, p. 43).

The lifespan of the furnaces varied as much as the furnace designs did. In some cases smelting furnaces were used for only one smelt and became destroyed while the bloom was taken out (e.g. Housden & Armor, 1959, p. 137), whereas other furnaces were used repeatedly for several smelting events (Cline, 1937, p. 52; Haaland, 2004, p. 73; Rostoker & Bronson, 1990, p. 30).

1.4.9. Characteristics of bloomery iron

As described earlier, elemental iron precipitates as a spongy conglomerate of varying compactness and varies from smelt to smelt and even within the smelt. Most blooms had to be compacted in a further step of processing (e.g. Schmidt, 1996), and some pieces of blooms went directly to the forge (Avery et al., 1988, p. 272; Housden & Armor, 1959, p. 137) (section 1.5). The quality of the iron depends on multiple physical and chemical parameters of the materials involved in the smelt, as well as the smelters' experience. Generally, direct reduction of iron in bloomery smelters segregates elemental iron in its solid state with limited carburization. The quality

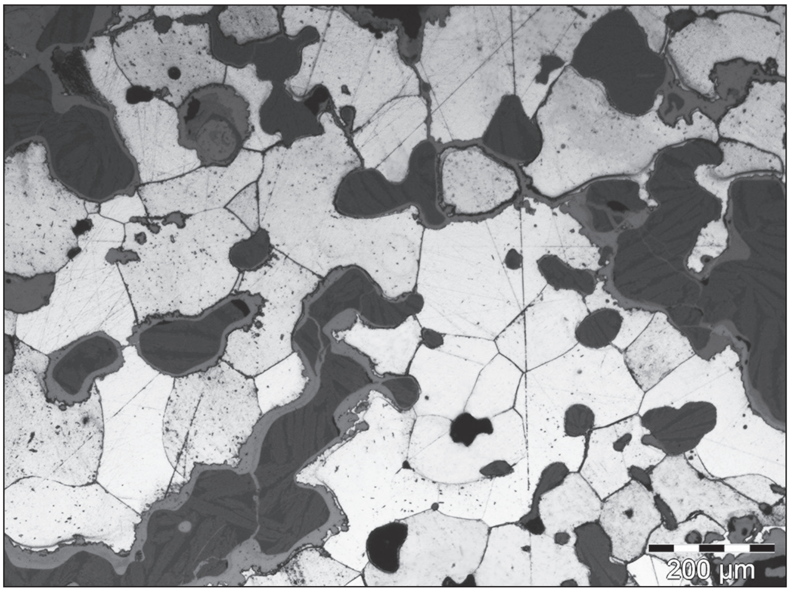


Figure 21: Pure ferrite with a maximum carbon content of 0.02%.

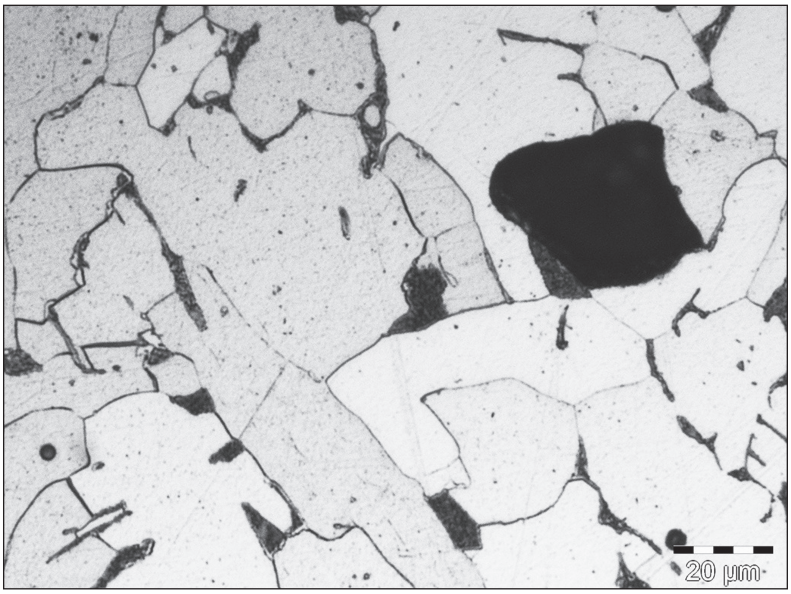


Figure 22: Low carbon steel (ferrite grain with lamellar pearlite in interstices).

of the iron is also largely determined by reaction temperatures only slightly above 1200 °C in order to avoid disturbing the alloying elements to be dissolved in the elemental iron (Kronz & Keesmann, 2005, pp. 405-407).
Iron is an allotropic metal. Under atmospheric pressure, there are three different structural modifications (α-iron, γ-iron, δ-iron) with distinct crystal structures and chemical properties, depending on the prevalent temperatures (Schumann & Oettel, 2005, p. 571). In this study, only α-iron, also known as ferrite, and γ-iron, known as austenite, are of interest since these two modifications determine the principal properties of wrought iron, steel and cast iron due to their capacity to dissolve alloying elements such as carbon, phosphorus and others. Pure ferrite (or pure iron) exists at temperatures below 911 °C[61] and shows a body-centered cubic crystal structure. It is very soft, easily forgeable and referred to as wrought iron in scholarly literature. At temperatures between 912 °C and 1394 °C, ferrite undergoes a phase transformation and changes into austenite that possesses a centered cubic crystal structure and chemical properties different from ferrite. Once temperatures fall below 912 °C, austenite re-transforms to ferrite. The ferrite-austenite-ferrite transformation is not only an important characteristic of the iron metal used to alter its

[61] At a given air pressure of 1 bar.

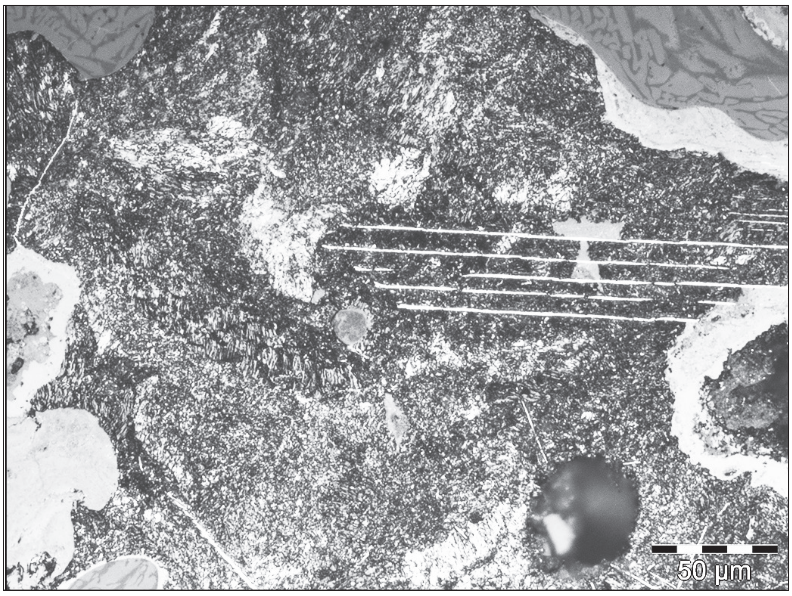


Figure 23: Pearlite (lamellar structures) with the beginnings of cementite segregation (white needles), carbon content slightly above 0.8%.

technical qualities through alloys, but is also the basis of a number of forging and hardening techniques used in pre-industrial and industrial engineering (section 1.5.2). The most important alloying element in pre-industrial and industrial metal production is carbon (Schumann & Oettel, 2005, p. 572). Carbon added to the elemental iron increases the strength, hardness and hardenability of the material (Bramfitt & Benscoter, 2002, p. 3). The phase diagram of iron and carbon in Figure 17 illustrates how the mass percentage of carbon shifts the ferrite-austenite transformation to lower or higher temperatures, and how carbon alters the melting point of iron for about 390 °C. Based on their dissimilar crystal lattice, pure ferrite dissolves only a maximum proportion of 0.02wt% of carbon at 723 °C and it decreases to 10^{-5}wt% at room temperature (Schumann & Oettel, 2005, p. 574) whereas austenite is able to incorporate up to 2.06wt% of carbon at 1147 °C.[62] Generally, carbon occurs in three different conditions in iron and steel: as solid solution in ferrite and austenite; combined with Fe as an independent mineral phase Fe_3C (cementite or iron-carbide); and as graphite or elemental carbon that precipitates from cast iron. Iron-carbide contains as much as 6.67wt% of carbon (Senn-Bischofberger, 2005, p. 41).

Carburization of iron takes place at temperatures above the ferrite-austenite transformation line (Figure 17). The more reducing the atmosphere is, the more carbon dissolves in the austenite (Scott, 2013, p. 40). When the iron cools down from the austenite field, it reverses into a characteristic microstructure depending on the carbon content and cooling rate, which is subject to analyses and interpretation in metallography. On slow cooling, the low carbon phase ferrite crystallizes as large equiaxed polyhedral grains (Figures 21 and 155: 4709/06b and 209: 4410/06b) (Bramfitt & Benscoter, 2002, p. 32; Miller, 1996, p. 31). Carbon in excess of 0.02wt% precipitates along the boundaries of the ferrite grains (also called tertiary cementite) (Figure 22). With increasing carbon content, pearlite forms, which is the eutectoid[63] of ferrite and cementite in lamellar intergrowth (Figure 23) (Bramfitt & Benscoter, 2002, pp. 34-35; Miller, 1996, p. 32). Pearlite preferentially grows as nodule at former austenite grain boundaries or junctures of them and numerous colonies can nucleate in one austenite grain. Pure pearlite contains 0.8wt% of carbon (Figure 17), and the volume fraction of ferrite grains to pearlite determines the carbon content of the iron metal with less than 0.8wt% of carbon (hypoeutectoid steel) (e.g. Figure 55, 4395/06b) (Schumann & Oettel, 2005, p. 578: Fig. 5.9). When carbon is in solution in excess of 0.8%, cementite (also called secondary cementite) segregates in laths during cooling and precipitates in polyhedral structures along former boundaries of the austenite grains, and as needle-like crystals within the pearlitic matrix (hypereutectoid steel) (Figures 23 and 123: 4426/06). When the solution capacity of

[62] Scott (2013, p. 47) mentions a carbon solubility of 2.11wt%.

[63] A eutectoid is a mixture of chemical compounds or elements in a specific proportional composition that forms from a solid solution at a temperature lower than any other possible composition of the system (see Figures 17, 19, and 20).

carbon in austenite has been transcended, excess carbon forms ledeburite and secondary Fe_3C (Figure 142). All alloys with carbon in excess of 2.06wt% are denominated as cast iron, since they are considered not to be forgeable anymore. Ledeburite is the eutectic[64] of austenite and cementite and transforms to pearlite and cementite at temperatures below 723 °C. It consists of 51.4wt% austenite (or in some cases pearlite) and 48.6wt% cementite, and contains 4.3wt% of carbon. In effect, the ratio of pearlite to cementite and to ledeburite determines the amount of carbon in the composition of cast iron (Schumann & Oettel, 2005, p. 585). Pure ledeburite constitutes the eutectic point in the iron-carbon system with the lowest possible melting point at 1147 °C. When the eutectic point has been transcended, only acicular Fe_3C and ledeburite crystallize, until full carburization of the alloy is reached at 6.7wt% C with pure cementite in microstructure (Schumann & Oettel, 2005, p. 585). Cast iron with less than 4.3wt% of iron is termed hypoeutectic, and with more than 4.3wt% of carbon it is hypereutectic. When high carbon alloys cool down slowly, carbon segregates more often as graphite (elemental carbon) than as cementite (Horstmann, 1992, p. 8).

As can be seen in Figure 17, phase transitions of iron are denominated with A_1, A_2, and A_3 (until A_6) (A for French 'arrêt').[65] The temperatures at these points of transformation alter according to the proportion of the alloying element(s). A_1 (also frequently referred to as 'lower critical temperature') describes the temperature line at 723 °C were austenite grains start to develop for the first time. It is also the temperature of the eutectoid austenite-to-pearlite transformation reaction. A_3 (also frequently referred to as 'upper critical temperature') describes the point above which all ferrite is fully transformed to austenite.[66] As I will later show (section 1.5.2) these points of conversion play a dominant role in altering the qualities of the steel through hot working and hardening (Scott, 2013, p. 52).[67] All phase alterations illustrated in Figure 17 refer only to the iron-carbon alloys. If additional alloying elements are involved, phase transformations and properties of the material follow different physical rules (Schumann & Oettel, 2005, pp. 587; Scott, 2013, pp. 42-45).

The iron-carbon alloy is classified into several categories according to its physical properties. Pure iron describes ferrite with a carbon content below 0.02wt%. Plain carbon steel is used to denominate iron-carbon alloys up to 2.06wt % of C. Low carbon steel (also referred to as mild steel) ranges between 0.02 and 0.2wt% of C. Medium carbon steel has carbon proportions between 0.2 and 0.5wt% and high carbon steel (also referred to as hard steel) describes alloys with carbon contents from 0.5wt% up to 2.06wt% (Bramfitt & Benscoter, 2002, p. 2; Samuels, 1999, p. 29). Wrought iron describes material up to 0.03wt% of carbon and it is not hardenable (or only hardenable to a limited extent through cold working), whereas steel is hardenable, which means successfully hot-workable (see section 1.5.2.2), or naturally hard due to its high carbon content (Pleiner, 2006, pp. 21-22; Schumann, 1962, p. 298).[68]

The most workable steels are low carbon steels. They are easily to weld and very ductile. With increasing carbon content, the volume fraction of pearlite (and cementite) also increases and creates a material with higher tensile strength together with decreasing abrasive wear and adhesion, but also decreasing toughness (Berns & Theisen, 2013, pp. 126-127). Medium carbon materials show more hardness and tensile strength, but they are more demanding to process. In modern steel engineering, steel with a carbon content higher than 0.22wt% is considered difficult to weld, because the increased carbon alloy causes heat and shrinkage cracks that lower the quality of the final product (Berns & Theisen, 2013, pp. 126-127). High carbon steel is difficult to handle given that it is rather brittle. Like medium carbon steel, it needs additional heat-treatment before and after welding to retain its physical properties. For instance, metals with a fully pearlitic microstructure are wear-resistant but lack a degree of toughness and formability (Bramfitt

[64] See footnote above.

[65] When referring to phase transitions under rising temperatures, these points of transformation are denominated Ac_1, Ac_3, Ac_5…('c' stands for French 'chauffage'). When referring to phase reversion under descending temperatures, they are denominated Ar_1, Ar_3, Ar_5 and so on ('r' stands for French 'refroidissement') (Samuels, 1999, p. 30).

[66] In hypereutectoid steels, Am (also frequently referred to as 'upper critical temperature') describes the point above which all cementite is fully transformed to austenite.

[67] A_2 (at 769 °C) describes no real phase transformation. It is the temperature in the austenite-ferrite transformation below which the α–iron becomes ferromagnetic. The ferromagnetic transformation temperature of cementite lies at 210 °C (A_0) (Horstmann, 1992, pp. 10-11).

[68] There exist varying classifications of steel as, for instance, discussed in Pleiner (2006, pp. 21-22) and used in Scott (2013, pp. 113-119).

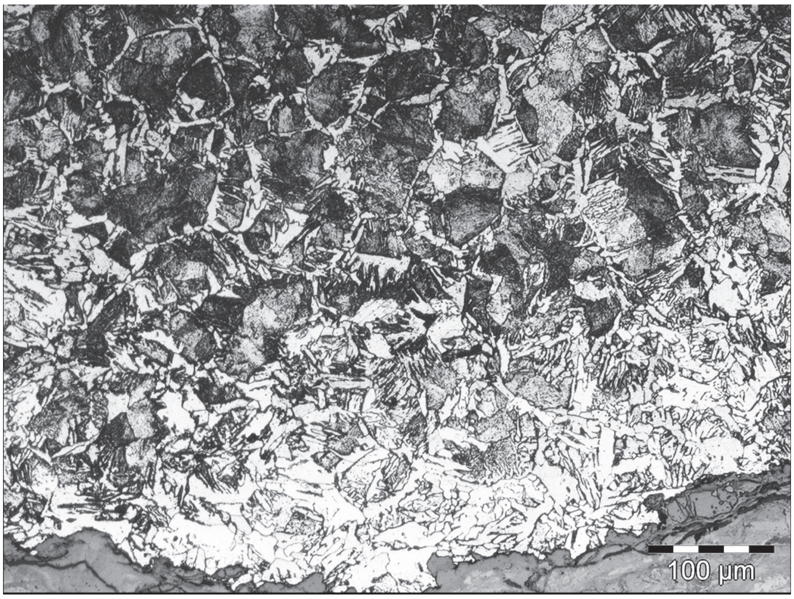


Figure 24: Widmanstätten structure after fast cooling.

& Benscoter, 2002, p. 35). Hypereutectoid steel is used for hard steel products such as cutting tools. However, it needs an elaborate heat treatment to keep its mechanical properties after processing in the forge (Scott, 2013, p. 117).

Austenite is easier to shape mechanically than ferrite. This is one of the reasons why iron is heated in the forge (section 1.5.2) (Scott 2013, p. 46). The properties of iron and steel also depend on the austenite grain size that developed before cooling, because it determines the microstructure and grain sizes of the ferrite, pearlite and cementite. For example, a small grain size results in a material with increased strength, toughness and formability under room temperatures, whereas large austenite grain sizes result in coarse-grained material with better machinability and magnetizability (Samuels, 1999, pp. 200-201). The latter, however, were certainly of minor interest in pre-industrial ironworking. Therefore, controlled heating above Ac_3 and subsequent controlled cooling is the most common practice in ancient and modern metalworking (e.g. Schuman & Oettel, 2005, pp. 623-664). The original austenite grain size may be preserved in grain boundary allotriomorphs of ferrite or cementite, and indicate the temperature at which a specimen was heated (Brick, Gordon & Phillips, 1965, p. 233).

The properties of steel can further be changed through the rate of cooling. Fast cooling from the austenite field shifts the Ar_3 transformation point to lower temperatures and condenses the field of coexistence of γ-iron with α-iron and Fe_3C respectively (the temperature field between Ar_3 and Ar_1) to zero (Horstmann, 1992, p. 14). Therefore, when fast cooling is diagnosed, it would be incorrect to use the phase diagram of Figure 17 for interpretation (Samuels, 1999, p. 30). The effects of fast cooling on steel result from an unbalanced diffusion rate of carbon and a disturbed crystal growth in the transitional phase (Scott, 2013, p. 53-63).

Fast cooling in open air, for instance, produces a picture of fine-grained diffuse lath-shaped ferrites rather than the regular polyhedrals mentioned above (Bramfitt & Benscoter, 2002, p. 51: Fig. 3.3). When the carbon content is raised and more pearlite is present than ferrite, the fast cooling rate prevents a clear separation of ferrite and cementite. The first precipitates along grain boundaries (see above), as well as preferred planes within the parent material austenite before pearlite forms, and produces jagged or acicular ferrite structures (Figures 212: 4475/06b; 213: 4483a/06b and 4476/06b), or what is known as Widmanstätten side plates or sawteeth, and as proeutectoid ferrite and proeutectoid ferrite allotriomorphs (Samuels, 1999, p. 202; Scott, 2013, p. 53). Air-cooling, however, suffices to produce a Widmanstätten structure (Figure 24), which is frequently found in pre-industrial steels. The Widmanstätten structure lowers the quality of the steel since it decreases ductility and limits shock resistance (Scott, 2013, p. 53). The grain boundary ferrite segregation, however, provides evidence of the size of the former austenite grains and the quality of the applied heat treatment. The Widmanstätten structure is indicative of full austenitization of the object in the forge. It may also occur when the hot bloom is removed from the furnace (Schmidt, 1996, p. 106), and most certainly when the bloom is cooled down in water (Rowlands & Warnier, 1995, p. 521). Water cooling (also known as quenching) further alters the quality of steel and produces microstructures known as bainite or martensite, both frequently desired for their hardness at the expense of a reduced ductility (Bramfitt & Benscoter, 2002, p. 35). They are, however, not relevant to this study because I found no traces of such microstructure in my samples.

Bloomery iron from direct reduction usually shows a rather heterogeneous distribution of carbon and is typically wrought iron and steel. Some bloom analyses from smelting re-enactments in Africa revealed carbon fluctuations between less than 0.05wt% and 4wt% C within the same bloom, evidencing that low carbon steel can occur together with cast iron in the same smelt (David et al., 1989, p. 196). Other examples revealed variations in carbon contents ranging from less than 0.02wt% up to 2.0wt% C (Hahn, 1993, pp. 120-121; Schmidt 1996, p. 112; Schmidt & Avery, 1996, p. 180). Products from the same type of furnace but from different smelts revealed carbon proportions between 0.1wt % and 4.5wt% C in the bloom (Childs, 1996, p. 285).

As mentioned earlier (section 1.4.6), the quality of the iron and steel is influenced by further alloying elements that go into dissolution with the elemental iron under temperatures and redox conditions comparable to carbon. In pre-industrial smelting, the dissolution of these minor elements was difficult to control and hard to predict (Rostoker & Bronson, 1990, p. 19). As mentioned, the most common of these siderophile elements are nickel, copper, arsenic, phosphorous and sulfur (Kronz & Keesmann, 2005, p. 406; Straube, 1996, p. 56). Although these elements appear in minor concentrations in iron and steel, they may change the properties of the material markedly (Schumann, 1962, pp. 319-320). Nickel for instance toughens steel at low temperatures but lowers the hardenability of the material (Bramfitt & Benscoter, 2002, p. 3; Rostoker & Bronson, 1990, p. 20). Copper as well as sulfur is not considered desirable in iron and steel. Both elements cause hot-shortness, which means that the bloom, the iron bar or object becomes brittle under hot forging temperatures and tend to break apart (Bramfitt & Benscoter, 2002, p. 3; Pleiner, 2000, p. 108; Rostoker & Bronson, 1990, pp. 20-21). Therefore, sulfur is commonly removed from the ores before smelting. Copper, however, has also a strengthening effect on steel and increases the corrosion resistance of the material. When in solution with elemental iron, sulfur, as well as phosphorous, decreases the melting point of the alloy to temperatures below 1000 °C and hence promote cast iron formation even in bloomery smelting (Kronz & Keesmann, 2003, p. 271; Rostoker & Bronson, 1990, p. 21; Yalçin & Hauptmann, 2003, p. 141). Phosphorous dissolves in ferrite at temperatures between 900 °C and 1000 °C (section 1.4.6), when the present redox conditions allow for it, and is commonly found in bloomery products (Rostoker & Bronson, 1990, p. 22; Straube, 1996, p. 57). Generally, small amounts of phosphorous strengthen iron and steel and wrought iron, for instance, can become as hard as medium carbon steel (Gordon, 1997, p. 15). It also promotes the hardenability of steels via quenching (Rostoker & Bronson, 1990, p. 22). A rising amount of phosphorous, however, causes brittleness, reduces toughness and does not allow for ductile folding of the material in the forge. This phenomenon is also known as cold shortness and increases even with decreasing air temperatures (Rostoker & Bronson, 1990, p. 21; Yalçin & Hauptmann, 1995, p. 291; 2003, p. 143). However, cold shortness caused by phosphorous only affects iron-carbon alloys whereas pure iron benefits from the strengthening effects without embrittlement of the material (Schott, 2013, p. 65). When phosphorous goes into dissolution with ferrite, it shifts the ferrite-austenite transformation towards higher temperatures. Ferrite is able to include 2.8wt% of phosphorous, whereas the dissolution in austenite is restricted to 0.45wt% (Kronz & Keesmann, 2005, p. 442). The rising of the field of stability of the ferrite to higher temperatures simultaneously prevents from carburization of the material and therefore most phosphorous products are ferritic in microstructure (Kronz & Keesmann, 2005, p. 442; Senn-Bischofberger, 2005, pp. 42-43; Straube, 1996, p. 57).Comparably to wrought iron, phosphorous material can be further hardened through cold working (Senn-Bischofberger, 2005, p. 43). A typical feature of low-phosphorous iron (the P contents ranging between 0.1wt% to 0.6wt%) is what is called ghost structures (Figure 25). Ghost structures develop when phosphorous iron is heated to temperatures at which ferrite coexists with austenite. Rapid cooling of such material (for instance air cooling) does not allow the phosphorous to diffuse uniformly, hence, zones of variable P content develop and are visible as ghost structures under the

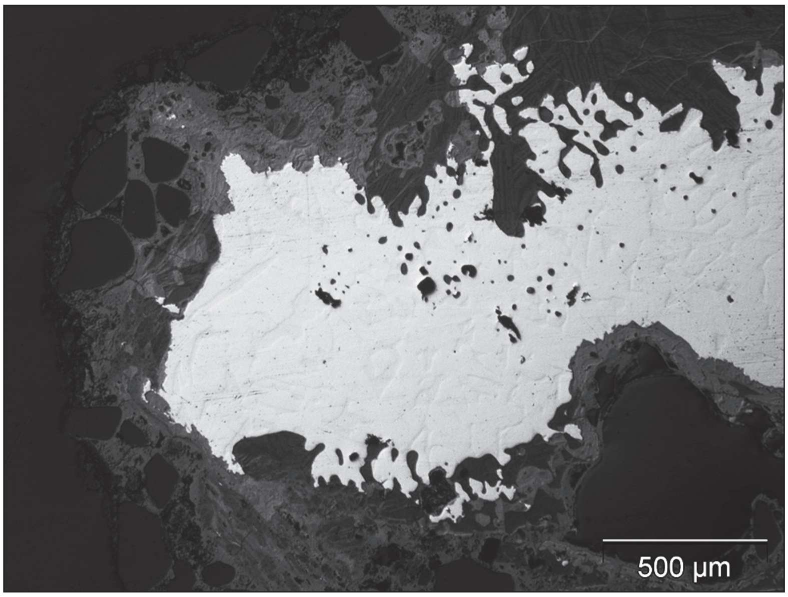


Figure 25: Ghost structure in metallic iron.

microscope (Senn-Bischofberger, 2005, p. 43). Phosphorous also impede the etching of a sample. Therefore, an uneven etching behavior can mirror compositional differences in the material (Miller, 1996, p. 80; Senn-Bischofberger, 2005, p. 43). In the modern iron and steel industry, phosphorous is considered an undesired alloy. However, in pre-industrial iron production, phosphorous is frequently found in materials used for tool and weapon production (Scott, 2013, p. 64, Rostoker & Bramford, 1990, p. 22). Moreover, some African smelters developed an elaborate technique to phosphorize and carburize iron through fuel ashes (Schmidt & Childs, 1995). Nevertheless, when the amount of phosphorous in solution with iron becomes too high, Fe_3P forms, which segregates preferentially long grain boundaries and caused the material to become brittle (Schott, 2013, p. 66). Some scholars also consider acicular phases in ferrite grains to be segregated phosphides (Senn-Bischofberger, 2005, p. 129: Fig. 8, p. 157: Fig. 8).

Another element frequently found in pre-industrial iron is nitrogen. It has the same effect on iron as carbon because it favors hardenability and hardening capacity, but it can also cause brittleness (Rostoker & Bronson, 1990, p. 23). Nitrogen enters the furnace if air is blown into it or if it is heated in the presence of nitrogenous material such as dung (Scott, 2013, p. 114). Nitrides frequently precipitate as acicular structures in ferrite (Miller, 1996, pp. 81, 111: Fig. 61; Scott, 2013, p. 115). However, the interpretation of acicular precipitates in ferrite remains vague because precise analyses are largely absent (Schwab, 2006, pp. 26-27). Depending on the author of a piece of research, they are considered to be phosphides, carbides, nitrides or carbide-nitrides.

A very common feature in non-industrial blooms is a ferrite-pearlite separation, also known as segregational banding. Banding in composition is a phenomenon of low to medium carbon steel where it occurs when both ferrite and pearlite are present, and it indicates a disproportion in the distribution of carbon within a steel bloom or a steel item (Samuels, 1999, p. 112). It first occurs in patchy distribution within the unworked bloom and subsequently in a banded appearance when the item had been hammered. Compositional banding is caused by chemical elements that either increase or decrease the transformation temperature of Ac_3 to the austenite field such as phosphorous and others (Miller, 1996, p. 80; Samuels, 1999, p. 114; Schumann & Oettel, 2005, pp. 634-635). Slow and irregular diffusion of these elements causes variability in the austenite-ferrite-pearlite-transformation and as a consequence in the carbon distribution of the steel, which finally leads to the compositional inhomogeneity (Schumann & Oettel, 2005, pp. 634-635).

As has been mentioned several times in the previous sections, cast iron was frequently an unwanted by-product in bloomery smelting (Blomgren & Tholander, 1986, p. 153; Childs, 1996, p. 285; Pleiner, 2000, pp. 247-250; Yalçin & Hauptmann, 2003, p. 129; Straube, 1996, p. 52). Experimental smelting as well as ethnographic examples both illustrated how easily cast iron can be formed under non-industrial conditions (Crew, 2004; Crew et al., 2011; David et al., 1989). Smelters were vigilant not to produce highly carboniferous products by keeping the furnace-running temperatures low and by controlling carburization through the high wustite buffer of the slag bath. Cast iron can be transformed to malleable iron through decarburization also known as fining, which is basically a reaction of CO_2 and CFe at temperatures between Ac_1 and Ac_3 (Rostoker, 1988, p. 201; Rostoker & Bronson, 1990, pp. 148-150). However, when elemental iron (or iron-carbides respectively) is exposed to CO_2 at high temperatures, the material re-oxidizes to FeO and CO with the result that about 30% of the elemental iron is lost in the slag bath (Osann, 1944 as cited in Kronz & Keesmann, 2003, p. 271). Nevertheless, some African iron masters were proficient in controlled cast iron production and familiar with its mechanical properties and further treatments (Childs, 1991b, pp. 35-36; Chirikure, 2015, p. 116; De Maret, 2004, p. 131; Schmidt & Childs, 1995).

Bloomery iron usually contains numerous slag inclusions even after the refining process. The chemical composition of such slag reflects the smelting system in which the bloom had formed. Therefore, slag inclusions can be used for fingerprinting the source of ore as well as ancient production sites (e.g. Kunze, 2006). The shape of such inclusions provides evidence of the intensity of forging and the forging temperatures (Miller, 1996, pp. 81, 88).

1.5. Principles of bloom refining and fine smithing

Iron working or smithing includes all steps that follow the initial separation of the metallic iron from the gangue during smelting operations. Primary smithing, refining or bloom smithing (terms that I use synonymously) comprises all the steps in cleaning the bloom and consolidating it to a solid piece of quality raw material. Refining can also be used to alter the chemical composition of the metal by adding or removing alloying elements. Secondary smithing includes the forging of tools from primary raw material or from recycled iron artifacts, the carburization or decarburization of iron and steel and the hardening or softening of the iron and steel via mechanical or thermal treatments (Fluzin, 2004; Pleiner, 2006).

1.5.1. Bloom refining processes (primary smithing)

Bloom refining or primary smithing is an important operation on the way to high-quality iron and steel, because the final bar or ingot should not contain more than 1% slag inclusions in order to become forgeable for tool production (Osann, 1971, p. 164). The bloom as taken from the furnace has to be further consolidated by hammering and extracting redundant slag, which is still abundantly present in the spongy material from the smelt. This is done at high temperatures, and Rostoker and Bronson (1990, p. 95) described slag refining as a process 'like squeezing a sponge filled with a liquid'. The high working temperatures also facilitate the welding of the uncompacted iron particles into a solid piece of raw material (Pleiner, 2000, p. 215; Sim, 1998, pp. 11-12).

In the ethnographic record, local smelters from Malawi distinguished between massive iron blooms that were immediately ready for the forging of tools, and blooms of reduced metal content that had to be reheated in a refining furnace first, and thereafter compacted through a mechanical treatment. The selection of the material by the experienced smelters was based on the weight of the pieces, the degree of consolidation, and the more general appearance (Avery et al., 1988, p. 272; Mapunda, 1995, p. 100).[69] Blooms can either be refined directly after smelting (e. g. Cooke, 1966, p. 87; Delisle, 1884, p. 471), or they can be split up and divided amongst the ironworkers who were involved in the smelt, or amongst family members and neighbors (Read, 1902, p. 46; Sassoon, 1964, p. 176; Tessmann, 1913, p. 232). Sometimes, unrefined blooms were stored and only pieces of them were refined when needed (Sassoon, 1964, p. 176). Other ironworkers sold their blooms to foreign blacksmiths (Rostoker & Bronson, 1990, p. 95; Okafor, 1995, p. 439; Sasson, 1964, pp. 176-177; Wente-Lukas, 1977, p. 115), and in some regions of Africa blacksmiths existed who specialized in the refining of blooms (Goucher & Herbert, 1996, p. 51). Therefore,

[69] Blooms ready for forging without refining treatment were also reported from Tanzania without further details (Davison & Mosley, 1988, p. 77).

when analyzing archaeological material, care must be taken as iron blooms can be processed far away from their production sites.

Experimental refining showed that consolidating a bloom until it becomes a solid piece of usable iron is a task that demanded expertise and experience (e.g. Friede & Steel, 1977, pp. 239-240; Sim, 1998). Depending on the quality of the source material, several steps of mechanical and thermal treatments were necessary to produce a compacted piece of primary wrought iron or steel (e.g. Sim, 1998). Fluzin (2004, p. 71) as well as De Rijk (2007, p. 109) distinguished two primary ways to refine a bloom: First, ironworkers may process the hot spongy bloom immediately after the smelt or after having heated it in a refining furnace.[70] Second, a bloom can be cleaned by dividing it into small pieces and sorting them out in a cold state. The small iron fragments will be compacted and welded together afterwards in a smithing hearth. Both steps are well documented in the ethnographic record of African metallurgical traditions. Additionally, Serneels (1993, p. 47) suggested that the whole bloom might be heated in an open, forge-like construction. All in all, the treatment that a bloom underwent on its way to becoming a solid raw material largely depended on its state of compactness when it left the furnace and on the technological traditions that developed in a certain geographical area.

There is evidence that in some regions the hot bloom was cooled down with water when it was removed from the furnace (Cline, 1937, p. 42; Gouillou, 1950 as cited in Essomba, 1992, p. 154; Housden & Armor, 1959, p. 137; Rowlands & Warnier, 1995, p. 521; Sassoon, 1964, p. 176). Pleiner (2000, p. 215) suggested that this treatment may also serve to better separate the iron rich parts of the bloom from the slag material. Other sources reported that the bloom was cut into pieces immediately after it had been removed from the furnace (Celis, 1987a, p. 120; Cooke, 1966, p. 87). Dugast (1955 as cited in Essomba, 1992, p. 380) mentioned that the refined bloom was water cooled after a successful sintering in a refining furnace.

1.5.1.1. Heating after smelting

Consolidating blooms is a task that demanded great expertise in order to maintain the quality of the iron or steel, and to avoid unnecessary losses of the material. Ethnographic examples showed that the consolidation could start in a cold state. The bloom was struck and compacted with a heavy stone hammer first with the intention to keep the many pieces of unconsolidated iron together when the bloom entered the refining furnace or hearth (Housden & Armor, 1959, p.137; Schmidt, 1996, p. 109). This was necessary because refining experiments demonstrated how the sudden loss of slag in the initial stage of refining may cause a bloom to fall to pieces inside the furnace (Crew & Salter, 1991, p. 18; De Rijk, 2007, p. 110). Most blooms were quite spongy when recovered from the smelt. Therefore, the expulsion of the redundant slag was a process of carefully alternating heating to slag-liquidus temperatures with consolidating through hammering (Crew & Salter, 1991, p. 18; Housden & Armor, 1959, p. 137; Wayland, 1931, p. 199). However, blooms with high slag content tend to become brittle when hammered at low temperatures and run the risk of losing a high amount of iron-rich pieces (Avery et al., 1988, p. 270; Crew & Salter, 1991, p. 18; De Rijk, 2007, p. 110). The loss of a certain quantity of such iron rich pieces was an integral part of bloom refining and in scholarly literature they are called 'gromps' or 'crown material'. As described above, the proportion of lost crown material in refining depended on the quality of the bloom, and on the method of refining (Fluzin, 2004, p. 74). Dirty blooms, however, tended to produce more gromps during refining than clean blooms because they required more steps of refinement. One method to keep the loss of bloom material limited was to divide the bloom into small pieces before heating these pieces in the furnace (e.g. Dugast, 1955 as cited in Essomba, 1992, p. 380). Cooke (1966, p. 87) for instance described how a bloom still hot from the furnace was cut into pieces. From this bloom, one piece was then consolidated while the others were kept warm in the furnace. Chaplin (1961, p. 58) also reported that the mass of bloom as extracted from the smelting furnace was broken into small pieces and then added to the glowing charcoal bed in a small refining furnace. A

[70] Within this study I follow the suggestions of Martinón-Torres and Rehren (2014, pp. 110-111) to use the term 'furnace' for structures in which high temperatures under reducing conditions are produced, and the term 'hearth' for open structures with a more oxidizing atmosphere. I therefore use terms like 'refining' or '(primary) smithing furnace' for the initial step of iron processing, and the term 'smithing hearth' or 'forge' for open hearths used in refining or secondary smithing. However, to designate the typical plano-convex slag cake that forms at the bottom of refining furnaces or smithing hearths I prefer to stick with the established term 'smithing hearth bottom' (SHB).

similar treatment was also described by Barndon (2004, p. 89) and Barnes (1926, p. 193; see also Cline, 1937, p. 41). De Rosemond (1943, p. 84) witnessed how the hot bloom fresh from the furnace was crushed into large pieces, which were then pounded on a stone anvil for an initial cleaning. The further refining, however, was done at the blacksmith's shop.

Usually, refining is done at higher temperatures than smelting. Ethnographic examples indicate temperature between 1250 °C and 1350 °C (see below) (Schmidt, 1996, p. 109) and 1300 °C to 1400 °C (Avery et al., 1988, p. 272). Celis (1987a, p. 120; 1987b, pp. 90, 117), De Rosemond (1943, p. 84) and Celis & Coulibaly (2001, p. 116) observed that the bloom was heated until it was glowing 'white'. This implies temperatures above 1250 °C depending on the carbon content of the raw material (De Rijk, 2007, p. 113; Pleiner, 2006, p. 54).

There is variation with respect to details about the time span that blooms were exposed to the heat of the refining hearth or furnace before they were ready for further treatment. Adkinson, (1890 as cited in Rostocker & Bronson, 1990, p. 95) stated that after about 15 minutes in the refining hearth the slag started to flow out of the bloom, and after 30 minutes, the bloom was soft enough to be hammered. Humphris (2010, p. 43) reported that the entire bloom was heated for 40 minutes in a small pit before it was ready for forging. Schmidt (1996, p. 109) described that the bloom was placed on top of a hearth filled with glowing charcoal and heated for 15 minutes at 1250 °C. Subsequently it was hammered so that the liquid slag flew from the bloom. The next step was to heat the same piece to 1300 to 1350 °C in order to expel the impurities that were still trapped in deeper parts of the bloom. The latter treatment was repeated 36 times (Schmidt, 1996, p. 110). Barndon (2004, p. 89) observed that after 15 minutes of heating small pieces of bloom in a hot refining furnace, the first slag was tapped. The actual refining ended when all successively added pieces of the bloom were fused in the furnace. Avery and Schmidt (1979, p. 19) testified that blooms were heated to temperatures above 1200 °C for 40 minutes under oxidizing conditions in a smithing hearth before they were consolidated with a hammer. According to Barnes (1926, p. 193; see also Cline, 1937, p. 41) the bloom lumps remained for about 45 minutes in the refining furnace to generate a compact piece of iron. Only Chaplin (1961, p. 58) mentioned that the bloom stayed for a further 4 hours in a small refining furnace and the now consolidated bloom was considered ready and compact enough for tool smithing. In some areas, blooms were only then treated in small furnaces when the smelt had failed and not all of the iron ore had been transformed to metal (Celis & Coulibaly, 2001, p. 52).

1.5.1.2. Crushing and sorting after smelting

The second refining technique described by Fluzin (2004, p. 71) and De Rijk (2007, p.109) is also well documented in Africa. It is the sorting of crushed blooms in a cold state, and in a second step, the sorted pieces were welded together (e.g. Cline, 1937, p. 43). Rowlands and Warnier (1995, p. 530) as well as Celis and Coulibaly (2001, pp. 26-27) reported that the bloom was hammered in a cold state on a heavy stone anvil until the slag became powdery. The material was then sorted and sifted and the metallic pieces were welded together to form a compact piece of raw material. Sassoon (1964, p. 176) documented that the bloom was first cold-hammered and sorted out. The iron-rich parts were subsequently heated in a smithing hearth for about 30 minutes until they started to adhere. The hot material was thereafter beaten out with a heavy stone hammer until an iron bar was produced which could be used for tool making or as currency. Also Hahn (1993, pp. 132-133) described in detail the initial cold hammering of a bloom with a heavy stone hammer. The slag soon became powdery and the lumps of iron which remained on the anvil were continually compacted. The resulting small lumps of iron-rich material were then coated with clay and heated for one hour in a forge, and hammered and reheated about five times. The final step in primary smithing was to flatten the pieces of compacted iron to a ribbon-like state. Then these pieces were folded over and welded together several times. It most probably served to equalize variation in the chemical composition of the source material (Hahn, 1993, p. 134). David et al., (1989, p. 199) described a very similar way of treating a bloom with a highly variable carbon content. Here small pieces of the bloom were welded together in a crucible to which clay was added (see also Celis & Coulibaly, 2001, p. 147; Pleiner, 2000, p. 215). Other ironworkers used crucibles to refine small bloom fragments, but they did not add clay as a flux (Celis & Coulibaly, 2001, p. 75).

No matter which way of processing was chosen, it seems that after 30 to 60 minutes of heating in a refining hearth or furnace the bloom was hot enough to be hammered and consolidated. The time span during which a bloom had to be heated largely depended on its size. The refining process described by Chaplin (1961, p. 58) worked via further reduction and consolidation of the iron particles in the liquid slag bath. The consolidated metal finally separated from the slag owing to its higher specific gravity.

Many testimonies of African refining report that the initial treatment was done with heavy stone hammers on a stone anvil (e.g. Celis & Coulibaly, 2001, p. 26; Davison & Mosley, 1988, p. 75; Delisle, 1884, p. 471; De Rosemond, 1943, p. 84; Rowlands & Warnier, 1995, p. 530; Schmidt, 1996, p. 109).[71] Only Schmidt (1996, p. 109) pictured more precisely the weight of such a hammer at 16.7 kg. He further specified that hammers of varying sizes and weights were used during the advanced refining. Brock (1965, p. 98) witnessed that only the initial work was done with a heavy stone hammer, and the following finer smithing work with iron tools. However, the frequent use of heavy stone hammers contrasts with statements made by Crew and Salter (1991, p. 18), Fluzin (2004, p. 75), De Rijk (2007, p. 110) and Sim (1998, p. 12) who suggested, based on experimental observations, that heterogeneous blooms were best hammered with a soft material such as wood on a wooden anvil. According to them, soft material prevents the shattering and crumbling of the bloom caused by pronounced shock waves. Their claims find support in Celis's observations in Central and East Africa where pieces of the bloom were initially hammered very carefully and the intensity of the strokes was increased with the growing compactness of the bloom (Celis & Nzikobanyanka, 1976, p. 60; Celis, 1987a, p. 120; 1987b, p. 90). Nevertheless, most ethnographic reports of bloom smithing imply a rather robust way of processing.

As described earlier, many pieces of iron-rich slag or compacted fragments of the bloom went lost during the initial steps of refinement. Examples are known where such gromps were recycled in further smelts (Schmidt, 1996, p. 109) and some ironworkers added them to the main bloom when the latter had become compacted enough (Crew & Salter, 1991, p. 18; De Rijk, 2007, p. 110).

[71] Brock (1965, p. 98) and Sassoon (1964, p. 176) mentioned only the heavy stone hammer and Celis (1987b, p. 172) reported large ovoid stones of 20 cm in diameter for the initial processing of the bloom.

1.5.1.3. Refining furnace

As described earlier, refining needs a furnace or hearth in which a complete bloom or parts of it can be reheated to minimum temperatures of 1200 °C. The refining or primary smithing of a bloom can take place immediately at the smelting site or at any forging location. The method that people used to clean the bloom varied strongly and depended on the quality of the bloom and on traditions that the elders handed down. Refining furnaces (i.e. high temperatures and a reducing atmosphere) are needed in particular to clean what are known as 'dirty blooms' from non-slag-tapping furnaces (Fluzin, 2004, p. 71). Certain ironworkers even used their smelting furnaces, or parts of them, to refine such blooms (Crew & Salter, 1991, p. 18; Roberts, 1993 as cited in Mapunda 1995, p. 106; Rostoker & Bronson, 1990, p. 94), while others built separate small refining furnaces (Barnes, 1926, pp. 192-193; Brock, 1965, p. 98, Chaplin, 1961, p. 58; Cline, 1937, p. 41; Lyaya et al., 2012, p. 198). Mapunda (1995) gave several examples of small refining furnaces that were operated with bellows, while the high-shaft smelting furnaces functioned with natural draft. Furthermore, similar to the constructions of smelting furnaces, termite clay and termite mounds play a special role in their construction (section 1.4.7). All furnaces described by him were small low-shaft facilities producing high temperatures and a reducing atmosphere. Lyaya et al. (2012, p. 200) portrayed how the slag was drained away from such small furnaces, which was, as experimental refining showed, essential in successful bloom processing (Slim, 1998).

Another example of African ironworking attested large clay pots, which were provided with holes in the wall for the entrance of the tuyeres, and a hole from which the slag was tapped at the bottom of the vessel (Cline, 1937, p. 42). A very simple form of a pit furnace of 22 cm in diameter is described by Schmidt (1996, p. 109), and Dugast (1955 as cited in Essomba, 1992, p. 380) mentioned a pit of 70 cm in depth and about 50 cm in diameter, which was provided with a clay lining and a partition. An example of a conical pit of 60 cm in depth is given by Delisle (1884, p. 471). Humphris (2010, p. 43) mentioned a simple small pit filled with charcoal. Chaplin (1961, p. 54) spoke of an open refining furnace without giving further details. De Rosemond (1943, p. 84) reported (without giving further details) that the bloom was heated in a small furnace at a blacksmith's workshop. It is obvious that comparable smelting furnaces can be difficult to distinguish from refining and forging facilities (Kense, 1983, p. 42).[72] Many other ethnographic examples have shown that refining could also be done in an open forge under oxidizing conditions, in particular (but not necessarily) if the bloom was sorted before refining (Avery & Schmidt, 1979, p. 19; Celis & Coulibaly, 2001, pp. 94, 106; Celis & Nzikobanyanka, 1976, p. 60; Celis, 1987a, p. 120; 1987b, p. 90; Cline, 1937, p. 43; Rowlands & Warnier, 1995, p. 530; Sassoon, 1964, p. 176; Schmidt, 1996, p. 109).

During refining, a bloom loses between 12 % to 80 % of its weight depending on the state of fusion and metal content (Craddock, 1995, p. 248; Fluzin, 2004, p. 75; Rostoker & Bronson, 1990, p. 95; Sauder & Williams, 2002, p. 127: Tab. 3). Slim (1998, pp. 31-32) concluded that the loss during refining also largely depended on the method applied. A bloom sorted and cut into small pieces before heating seemed to be easier to handle than refining a complete bloom at once. Crew and Salter (1991, p. 19) stated that during the very initial steps of sorting, when redundant slag was expelled and a billet[73] was formed, blooms lost about 50 % of their original weight. During the second consolidation step, when a bar[74] was formed containing almost no impurities anymore, the weight diminished again by about 40 % of the previous billet. Finally, the bar is shaped into a tool, and the total weight further reduced by about 10 % to 30 % due to the loss of oxidized metal (hammerscale) (see also Fluzin, 2004, p. 78).

1.5.1.4. Refining slag

Refining can produce as much slag as a smelt, or considerably less, depending on the degree of slag tapping during the actual smelt (Fluzin, 2004, pp. 74-75; Kronz & Keesmann, 2005, pp. 404-405). Cleaning dirty blooms with a high amount of fayalitic impurities always produced a large quantity of slag. The same was true for refining operations during which fluxes were applied (Fluzin, 2004, p. 75). It can be argued that in some cases a large slag bath was a deliberately produced instrument in refining because putting a rather loose bloom into a slag bath helped to fuse the metallic iron in it (Sauder & Williams, 2002, p. 129) (section 1.4.6). One ethnographic example testified that smelting slag was recycled to produce a slag bath in a forge (Hatton, 1967 as cited in Prendergast, 1974, p. 258). Also clay that was used for bloom refinement by some smelters served to facilitate the liquefaction of the trapped slag, and contributed to the formation of an adequate slag bath. The smelters were well aware of the different refractory qualities of the clays and deliberately chose material of less refractory quality for fluxing purposes (Dugast, 1986, p. 46). In the same way quartz was added to the workpiece to create a fayalitic slag bath within the refining hearth or forge:

$$Fe_3O_4 + 3\ SiO_2 \rightleftharpoons 3\ Fe_2SiO_4 + O_2$$

$$2\ Fe + SiO_2 + O_2 \rightleftharpoons Fe_2SiO_4$$

Just as iron-rich slag in the smelting process prevented carburization (section 1.4.6), the slag bath has the same function in the numerous steps of refining and smithing, and it controlled the carbon content of the metal and kept it malleable. A high FeO content of the slag bath could easily be maintained by adding hammerscale flakes[75] or iron ore, which kept the slag viscous and in a low-melting composition. A slag bath could also be used to decarburize high-carbon steel blooms because carbon reacts with the available oxides rather than staying in chemical bond with the metallic iron (Kronz & Keesmann, 2005, pp. 407-409; Rostoker & Bronson, 1990, p. 85; Rowlands & Warnier, 1995, p. 521). Therefore, high FeO values of slags are indicative for refining and smithing rather than smelting.[76] During refining in a reducing environment, wustite and other iron oxides can easily transform to metallic iron. As a consequence, the viscosity of the slag alters and allows for a higher carburization of the iron someone was working on. Therefore, even cast iron was produced during refining and lost fragments from the broken-up bloom were further carburized to cast iron prills (Crew & Salter, 1991, p. 20; Fluzin, 2004, p. 71).

When compacting a bloom and when welding pieces of iron together, slag inclusions and iron oxides along the outer surface of the metal often prevented the pieces from connecting with

[72] The example of a smelting pit from Kapongo (SC 29) described in section 5.3.3 is no more than 40 cm in diameter.

[73] Within this study, I follow Slim's definition of a billet being a ‚block of purified iron with only a small quantity of slag present' (Slim, 1998, p. 149).

[74] I also follow Slim's definition of a bar that he described as 'a length of iron […] suitable to be forged into any artifact '(Slim, 1998, p. 149).

[75] Hammerscale flakes show Fe_3O_4 contents of more than 92 wt% (Dungworth & Wilkes, 2009, p. 35).

[76] Slags with FeO readings between 80 wt% and 90 wt% may indicate the fining of cast iron (Kronz & Keesmann, 2003, p. 271).

each other (Rostoker & Bronson, 1990, p. 85; Slim, 1998, p. 11). As described in the previous sections, redundant slag was expelled by heating the workpiece to the liquidus temperatures of the slag and subsequent hammering. Yet heating iron to welding temperatures caused the metal surfaces to oxidize quickly and to form a hematite (Fe_3O_4) skin. The latter is known as hammerscale flakes when they spalled off from the workpiece, and examples of thick layers of hammerscale flakes around forges are known from antiquity (e.g. Dungworth & Wilkes, 2009, p. 34). Disturbing iron oxides could be removed by adding crushed fine-grained quartz as a flux, which reacted with the oxides and formed a film of fayalite. This fayalite film protected the workpiece from further oxidization and could easily be removed by hammering (De Rijk, 2007, p. 112; Young, 2011, pp. 38-40). The use of a silica-rich flux to improve the cohesion of the metal pieces in refining was described by Celis (1987b, p. 117) and Humphris (2010, p. 43) to give but a few examples. As mentioned above, some ironworkers preferred clay (Hahn, 1993, pp. 139-140) most probably because like quartz, it easily reacted with the iron oxides and formed a low-melting alumina-rich slag. Cline (1937, p. 90) reported cases where pulverized tuyeres were recycled to serve as a flux in secondary smithing, or snail shells were powdered for the same purpose. However, Young (2011, p. 39) argued on the basis of his very detailed experimental study on hammerscale formation that slag inclusion in bloomery iron may develop the same protecting quality when heated to welding temperatures as do added fluxes.

1.5.1.5. Carburization

Bloomery iron could be very heterogeneous with respect to its carbon content, and the factors that influenced the carburization of iron within a smelting furnace have been described in detail above (section 1.4.2). The low-melting iron-rich slag field, which can be seen in the SiO_2-FeO phase diagram of Figure 18, indicates that the traditional smelters of the Kavango area produced metallic iron with low carbon content. Pure iron and low-carbon steel was easy to forge and sufficient for the production of ornaments, but it was not wear-resistant or hard enough when it came to cutting tools. Therefore, blacksmiths in historical times developed methods to increase the carbon content of the raw metal or the tools afterwards (e.g. Pleiner, 2006, p. 200; Rostoker & Bronson, 1990, p. 121). To achieve this goal, the iron must again be heated to the austenite temperature field in order to facilitate the intake of carbon into the elemental iron. Moreover, the metal must be in direct contact with charcoal, graphite or carbon in a gaseous state under strongly reducing conditions. Historical blacksmiths carburized tools and bloomery iron in the charcoal bed of forges, hearths and in closed containers (Rostoker & Bronson, 1900, pp. 122-125). Frequently, charcoal was pulverized to increase the contact zone with the metal, nevertheless exposing the iron to gaseous carbon was the most effective way to carburize iron and steel. Carburizing more than a thin layer of elemental iron was a time-demanding task of several hours during which the historical ironworkers had to maintain high temperatures and strongly reducing conditions (Rostoker & Bronson, 1900, pp. 122-125).

1.5.2. Secondary smithing

Secondary smithing comprises all steps of deformation and thermal treatments necessary to form a tool from a bar or ingot, and all processes of recycling worn-out iron items. Secondary smithing techniques and the equipment of the blacksmith's atelier are comprehensively described in Pleiner (2006), and they shall only be considered within the framework of this chapter insofar as they help to understand the interpretation of the material under study.

Despite its impurities, the iron produced in a bloomery furnace and refined afterwards was as malleable as modern industrial iron (Rostoker & Bronson, 1990, p. 96). Generally, the main properties desired in metalworking are a specific hardness, ductility and optical appearance of the material (De Rijk, 2007, p. 111). The principal techniques used are (and were) cold working, hot working including welding, and thermal treatments such as annealing and quenching (e.g. Pleiner, 2006, pp. 53-70). As all procedures that change the shape of an object influence the properties of the material, treatments that determine the final quality are usually conducted at the end of the work process (e.g. De Rijk, 2007, p. 111; Serneels & Perret, 2003, p. 476).

1.5.2.1. Cold working

Cold working describes the shaping (e.g. hammering, bending, drawing, cutting) of metal in a cold solid state or at low temperatures (Schumann & Oettel, 2005, pp. 490-506). In doing so, the ferrite and pearlite grains change their form. Consequently flattened and elongated grain structures in polished cross section indicate mechanical deformation in a cold state. Grain deformation might occur inside foldings, when an item was bent to shape, or along the cutting edges of artifacts that were made from sheet metal (Miller, 1996, p. 81). Also slip-bands might appear in the flattened ferrite grains (Miller, 1996, p. 88). Grain deformation also occurred as use-wear pattern at the strained sections of tools.

Generally speaking, cold working produces a defective crystal lattice, causes internal tensions and alters the chemical, physical and technical properties of iron and steel. For instance, it increases tensile strength and hardness but reduces the ductility of the material (Schumann & Oettel, 2005, pp. 505-506). Therefore, the properties of the material that result from cold working are not always desired. To retrieve the mechanical and chemical properties that the metal had before the alteration, it must be heated to temperatures between 600 °C and Ac_1 to allow new and undisturbed crystals to grow and to replace the damaged structures. The size of the new crystals depends, among other factors, on the degree of deformation, temperatures, the length of time the microstructure is exposed to the anneal, and alloying elements present in the metal (Miller, 1996, p. 80; Schumann & Oettel, 2005, pp. 507-508, 626-627). Therefore, a recrystallized microstructure may appear rather in homogeneous with respect to grain size distribution and compared to microstructures that cooled down from the austenite field (section 1.5.2.4).

1.5.2.2. Hot Working

Hot working is the deformation of metal in a plastic state. As described in section 1.4.9, the temperature of the full ferrite to austenite transformation varies according to the carbon content of the iron and steel. High-carbon steels are worked at lower temperatures than low-carbon steels and wrought iron (Pleiner, 2006, pp. 53-54). Therefore, the use of the optimal temperature for all heat treatments is most important in smithing, and skilled blacksmiths usually rely on the color the workpiece takes when it glows in order to estimate the temperature (De Rijk, 2007, pp. 112-113; Pleiner, 2006, pp. 53-54). Once the right temperature is reached, the object may be shaped into the desired form and the ductility of the hot metal prevents the workpiece from cracking.

In polished cross sections, hot working is evidenced by the banded appearance of compositional inhomogeneities, in particular in pre-industrial ironworking. By the same treatment, slag inclusions become flattened and develop a characteristic inclusion banding (Miller, 1996, p. 88). Deliberate piling of material, applied in the recycling of small metal fragments, create a laminated appearance of the microstructure in cross section (Pleiner, 2006, p. 59). Frequently, the outer margins of a hot-worked artifact are decarburized because it was heated in an oxidizing environment. Smaller items and multiply recycled ones are often of low carbon as a result of hot working. The same phenomenon may also be found around inclusions of slag and oxides (Miller, 1996, p. 81).

1.5.2.3. Welding

In welding, different pieces of iron are connected. The iron is heated to temperatures between 1200 and 1300 °C in the austenite field and then pressed together. As mentioned in section 1.4.9, austenite is easier to shape than ferrite, and the elevated temperatures favor chemical diffusion processes, which cause the metal surfaces to join. It is most important that the parts to be connected are free from surface oxides. Therefore, as seen above, most commonly silica-rich fluxes are used to create a thin film of low-melting slag, which protects the hot surface from oxidation and improves the cohesion of the metal pieces. Other methods to prevent the workpieces from oxidation have been discussed in De Rijk (2007, p. 112) and Serneels and Perret (2003, p. 471), to give but two examples.

In pre-industrial ironworking, welds can frequently be identified by the very dissimilar material found in a single sample (Miller, 1996, p. 88). Elongated inclusions of iron oxides, frequently associated with bands of decarburized ferrite, indicate poorly done welds because surface oxides can become trapped between tow joint pieces, or corrosion products intrude the metal along insufficiently performed seams (Miller, 1996, pp. 80-81, 86).

1.5.2.4. Thermal alterations of microstructures

As I mentioned above when describing the recovering of a cold-worked microstructure, the properties of iron and steel are capable to change at temperatures below the beginning α- to γ- transformation, which means below Ac_1. For instance, if steels are exposed to temperatures between 600 °C and 700 °C for a prolonged period, the cementite plates of the pearlite change and form what is known as degenerated or spheroidized cementite (Miller, 1996, p. 80; Schumann & Oettel, 2005, pp. 628-634). This alteration softens the steel and increases the workability and formability of the material. Usually, it takes hours and days of annealing at the aforementioned temperatures to obtain a fully spheroidized microstructure. The latter, however, changes much faster (within minutes and hours) if the steel was subject to plastic deformation before annealing, because fragmented cementite plates spheroidize easier than unaffected ones (Samuels, 1999, pp. 169-171). Therefore the fastest way to produce spheroidized cementite in microstructures is to treat the material mechanically at temperatures between 600 °C and 700 °C, which causes a constant breakup of cementite plates, and Samuels (1999, pp. 173-173: Fig. 7.3(f)) referred to this treatment as warm working. In pre-industrial ironworking, controlled annealing procedures of many hours at constant subcritical temperatures were rather unlikely. Therefore, most spheroidized microstructures resulted from a comparatively short subcritical anneal after cold working, or developed during mechanical treatment at subcritical temperatures. Since this process was subject to rather uncontrolled conditions, historic steel objects frequently display a range of intermediate structures (Miller, 1996, p. 80). Moreover, variations in the degree of carbide degeneration also develop in chemically inhomogeneous materials (Schumann & Oettel, 2005, p. 632).
Another important thermal treatment was quenching. As briefly described in section 1.4.9, fast cooling can strongly alter the properties of iron and steels and was frequently used in pre-industrial artifact production (Pleiner, 2006, p. 67-69). However, as no signs of deliberate quenching are present in my samples so far, I abstain from any further description of these smithing techniques. The effects of the development of what is known as Widmanstätten structure on the quality of steels were already described in section 1.4.9.
From the previous sections it can be seen that there exist a number of alterations of the physical and chemical properties, which are caused by thermal or mechanical treatments. These alterations can be reset to zero if the iron or steel is heated to temperatures that allow the full α- to γ-transformation above Ac_3 (Figure 17). This treatment is known as austenitization or normalization and is used to remove unwanted properties from the material (Schumann & Oettel, 2005, pp. 638-639). Normalizing usually produces a homogeneous microstructure with respect to crystal growth, which cannot be distinguished from an unaltered microstructure. To identify full austenitization of the material in cross section, grain boundary allotriomorphs and proeutectoid precipitants as described in section 1.4.9 are most useful, because they delineate the former boundary of the austenite grain from which the material cooled down (Miller, 1996, p. 87; Samuels, 1999, pp. 200-202). Whenever a homogenous microstructure appears in worked iron, inclusion and compositional banding indicates as well that the material was mechanically altered before normalization.

1.5.2.5. Secondary smithing residues

As mentioned above, heating iron and steel to temperatures that allow hot working causes the material to decarburize and to form a skin of iron oxides, which flakes away during hammering (hammerscale flakes) (section 1.5.1.4). Fluzin (2004, p. 78) argued that during forging about 10wt% of the original object is lost because of the oxidation of the material. Small items produce small hammerscale flakes, and large objects produce larger ones.
Secondary smithing produces considerably less slag than smelting and refining. It forms only from hammerscale and the fluxing SiO_2 or other substances, when added. Pleiner (2006, p. 113) mentioned that within one hours of smithing, a little smithing hearth bottom of 5 cm in diameter grew in the forge below the tuyere. Some scholars argue that secondary smithing slags are poor in potassium, aluminum, calcium, manganese, phosphorus and barium

compared to smelting and refining slags because these elements mostly derive from the fuel ashes (e.g. Buchwald, 2005, p. 100). Therefore Humphris (2010, p. 257) used the alumina-to-silica ratio to distinguish secondary smithing slag from smelting slag. However, as seen in section 1.4.7, clays can be involved as fluxing agent in secondary smithing and would certainly alter the chemical picture one would expect from the previous considerations. Therefore, here again, only a combination of chemical and morphological features may allow a distinction of secondary smithing slags from other slags.

1.5.2.6. The blacksmith's workshop

Blacksmiths' tools are hardly found in the archaeological record unless they are burial objects, and so far none have been found in the Kavango region. Modern-day ironworkers only give evidence of tools that are used in recent times, which is a mix of traditional and modern forge equipment. Pleiner (2006) gave a most detailed description of traditional forging implements from early European times, which can be found all over the world in comparable composition. Therefore, in this chapter, only a rough summary of the most common forging devices in an African context, except bellows and tuyeres, will be given in a brief reflection of some ethnographic records. This compilation is, however, far from being complete and far from describing the profound knowledge of the skilled African blacksmiths in its entirety.

Most blacksmiths used big stone anvils (e.g. Celis, 1987b, p. 161; Celis & Nzikobanyanka, 1976, pp. 59, 114; Cline, 1937, p. 89; Kita, 1985, p. 93; Laburthe-Tolra, 1970 as cited from Essomba, 1992, p. 589; Lyaya, 2007, p. 22; Wayland, 1931, pp. 199–200) and Hahn (1993, p. 128) described that stone anvils of varying size[77] and shape have been used for different steps of tool making. Some people used stone anvils as well as anvils made out of iron (Wente-Lukas, 1977, p. 115). The first was used for heavy preparatory work and the latter for fine smithing tasks (Cline, 1937, p. 89; Dugast, 1986, p. 33). Many iron anvils were also hammers because they had a thickened end, which could be used both ways, and one conical end, which served as a handle or, if stuck into the ground or drilled into a large piece of wood, as a support base for the anvil (Celis, 1987b, p. 170; Celis & Nzikobanyanka, 1976, p. 64; Dugast, 1986, p. 33; Read, 1902, p. 47). Hammers made from iron were commonly used all over Africa (e.g. Celis, 1987b, p. 161; Celis & Nzikobanyanka, 1976, p. 59) and they had a special cosmological function (e.g. Herbert, 1993, pp. 89-104, 134). Some blacksmiths used a set of iron fashioning implements of varying sizes for the different steps of work (Hahn, 1993, p. 129; Read, 1902, p. 47), and cases are known where one hammer had two dissimilarly shaped ends that could be used for different tasks (Cline, 1937, p. 89). Many examples are known where ironworkers use forging implements made from iron as well as from stone (e.g. Kita, 1985, p. 93; Laburthe-Tolra, 1970 as cited after Essomba, 1992, p. 589; Wayland, 1931, pp. 199-200). Such forging stones could be as heavy as 10 kg, and they were considered to be better suited for certain task than metal ones (Hahn, 1993, pp. 130-131). Some ironworkers used stone hammers for refining only, and iron hammers for the secondary smithing (Celis, 1987b, p. 172). In other ironworking traditions, people used only stone hammers of varying size for the different tasks to be performed at the forge (Celis, 1987b, pp. 174-178; Celis & Nzikobanyanka, 1976, pp. 108, 114; Cline, 1937, 89; Lyaya, 2007, p. 22; Wente-Lukas, 1977, p. 115).

Other standard tools in the blacksmiths' workshops were chisels, because they were essential to divide pieces of raw material into the desired size (Cline, 1937, pp. 91-101; Dugast, 1986, pp. 33, 36; Hahn, 1993, p. 128; Kita, 1985, p. 93). The hot metal was removed from the fire with pincers of varying shapes and made out of different materials such as iron (Cline, 1937, p. 90; Hahn, 1993, p. 129; Kita, 1985, p. 93; Read, 1902, p. 46), bark (Celis, 1987b, p. 161; Celis & Nzikobanyanka, 1976, p. 59) or wood (Cline, 1937, p. 90). Other ironworkers helped themselves with wooden handles into which the hot semi-finished tools were stuck (Cline, 1937, pp. 91-101). Sharpening stones, grinding implements and files also belong to the standard equipment of a forge. They may be made from stone (Celis, 1987b, p. 162; Celis & Nzikobanyanka, 1976; Kita, 1985, 93; Cline, 1937, pp. 91-101) or metal (Cline, 1937, pp. 91-101; Dugast, 1986, p. 36). Other instruments were hand drilling implements (Read, 1902, p. 46), an elongated rod-like objects, which were used as a core to forge steel sleeves for wooden handles (Cline, 1937, pp. 91-101).

[77] The largest one was 50 cm in diameter (Hahn, 1993, p. 128).

1.6. Methods to asses slag materials and a critical assessment of the sources

The knowledge of indigenous iron production and metalworking industries in the Kavango region was never a secret to locals, but it is hardly mirrored in scholarly literature. The time depth of the 'Iron Age' in the archaeological record was first elucidated by Sandelowsky (1979), yet only a few scholars recorded iron production in the historical and ethnographic context (e.g. Fleisch & Möhlig, 2002; Larson, 2001; Van Tonder, 1966). Following the suggestions of the linguist and historian Wilhelm Möhlig, who claimed to have historical evidence for iron production in a hunter-gatherer society in the Kavango region, the archaeological ACACIA research project focused on the identification of ironworking locations, mining sites and a better chronological understanding of archaeological occupation sequences and successions along the Kavango River. The remnants of metalworking collected from these sites became the main source that I consulted for this study to reconstruct the multiple steps in the chaîne opératoire of iron, and to attribute the identified operations to sites and zones of activities (see Chapter 2).

Slag is the most accessible smelting residue for modeling the bloomery formulas used in traditional smelting (e.g. Charlton et al., 2013). It is resistant to weathering and may still be found after millennia, whereas furnaces and forges were eroded away a long time ago. The dominant slag-forming ingredients are ores, fuel ashes, refractories and sometimes fluxes. Their chemical composition helps us to reconstruct the raw materials used, the geological nature of the ores, and furnace-running parameters. In undisturbed sites, the slag distribution can allow for the reconstruction of working zones where smelting, refining, and the tool smithing were performed. It represents at least the location where the waste of such activities was discarded. Slags from disturbed archaeological assemblages or from sites where there is reason to assume that the finds became dislocated for some reason (e.g. Iles, 2010, p. 219) still contain a lot of information about those steps of the chaîne opératoire which produced them. Therefore, slags provide useful information for the archaeologist even from a disturbed context and are worth the archaeometrical examination.

Slags can be analyzed by a number of methods. Most common is an initial macroscopic visual inspection, which permits a basic classification of sites and finds. It is the most important tool in the field to access the site and to select samples for further analyses. Once samples are selected and considered to be relevant to the given research questions, further information can be taken from microscopic (petrographic) examination, bulk-chemical analyses and other tests (e.g. Hauptmann, 2014, p. 95). However, choosing samples for further analyses is bound to certain considerations with respect to the transferability of the results to the given context and the significance of the obtained outcomes.

1.6.1. Sample selection and representativeness of the results

The informative value of all analyses strongly depends on the quality of samples selected as source material. Ideally, series of samples are chosen from each step of production and from each site with a trusted archaeological context. In reality, the available samples hardly fulfill the idealistic aspirations owing to a number of limitations. These constraints are rooted in the quality of the archaeological assemblage, the archaeological sampling method, the chemical and structural inhomogeneities of the piece of slag selected, the section that is chosen for sample preparation and chemical analysis, and the funds available for field and laboratory work. Humphris, Martinón-Torres, Rehren and Reid (2009, p. 359) for instance question the representativeness of samples in general because they are only isolated parts of the original batch which survived under unknown taphonomic conditions. Those samples that are taken to the laboratory are only a selection of the total slag assemblage singled out under more or less controlled conditions. Moreover, only a few grams of these samples are taken to provide us with thin sections and chemical data. Another limitation may arise from the difficulties in assigning slag finds to a specific cultural horizon, in particular at multiply occupied locations. Setting up smelting traditions and technological development in a given research area requires well confined assemblages in time, and establishing the chain of operation requires well excavated and sampled assemblages in space, which are not always given or preserved (e.g. Charlton, Shennan, Rehren & Crew, 2013, p. 290; Lyaya et al., 2009). Moreover, the examples given by Fowler (1995), Schmidt (1996, p. 115), Miller and Killick (2004, p. 31) and others of the extensive reuse of smelting residues sound a note of caution against misinterpreting a highly distorted picture of slag residues.

As described in Chapter 2, the archaeological activities in the Kavango area focused not only on assessing traditional iron production. One main objective was to create an overall chronology of Stone Age and Iron Age occupation sequences and a more systematic approach to the determination of the density of settlements in the archaeological record along the southern side of the Kavango River (Richter, 2005). Therefore, most sites were initially assessed by the systematic sampling of surface finds, and, if promising, test units were investigated to evaluate the soil condition alongside the thickness and succession of the cultural layers. However, from most sites that were not excavated, and also from those sites where test units were carried out, only a few small pieces of slag were collected, to give evidence of ironworking rather than to represent all stages of ironworking activities at these locations. In addition, small samples were favored over large slag blocks in view of the limited funding available for transport. Therefore, none of the surface collections to hand correspond to a representative selection of slag as usually required for a meaningful analysis of metallurgical activities. As a consequence, the macroscopic and microscopic assessment of the collected material revealed that preferentially smithing hearth bottoms and refining slags had been collected, and large slag blocks, indicative for smelting, were ignored for the given reasons.

Most excavated material originated from the 29 m² excavated at Ruuga (N98/39, SC 3), and from 28 m² examined at Vungu-Vungu (N69/01, N96/03-3, N98/32-1, N98/32-2, SC 12). The units excavated at Kapako (N68/01, N68/02, N99/21, SC 4) amount to 12.5 m² and at Dikundu (N69/03, N06/04-1; SC 30) to at least 35 m² but only a few of the finds recovered by Beatrice Sandelowsky in 1969 were assessable in the National Museum of Namibia for this study. From all the sites that were assessed with small test trenches (N99/20, SC 9; N98/27, SC 10; and N98/43, SC 27), only Nyangana-Kangwenu (N98/43, SC 27) showed evidence for metalworking. The three test 1 m² units excavated in Gove-Mbambangandu (N11/02, SC 17) produced only limited insights into ironworking activities, although survey finds from several field seasons along with oral history indicate rich metallurgical activities at this location. For this reason, the study focuses on slag samples from Ruuga (n = 22), Vungu-Vungu (n = 16) and Kapako (n = 11). A further three samples were taken from material from Dikundu (N69/03, N06/04-1; SC 30), and one random sample each was analyzed from Kauti (N07/02-1, SC 32), Utokota (N96/08, SC 16), Tjeye-East (N98/44, SC 21) and Nyangana-Kangwenu (N98/43, SC 27). The nature of archaeological sites in the Kavango area (sandy soils, repeated human occupation, and almost no preservation of features) leads me to assume that the material collected is very heterogeneous and originates from various steps in the chaîne opératoire of iron production and processing. Moreover, all the units excavated are limited in their representativeness because they constitute only a small portion of the whole site. Consequently, the finds from our excavations portray zones of activities within a site rather than representing the entire assemblage. For instance, Kapako, Vungu-Vungu and Gove-Mbambangandu show abundant amounts of heavy slag remains littering the surface, which were not found in the excavated units, and which were not taken for further analysis for the aforementioned reasons. In addition, Ruuga and Kapako bear two horizons of ironworking activities, belonging to the EIG and LIG, which makes it particularly difficult to categorize the surface finds out of context.

1.6.2. Macroscopic identification of slags

All the finds from our excavations and surveys were subject to a macroscopic identification first, before further samples were selected. Many attempts have been made to classify slags according to their morphology and visual appearance (e.g. Bachmann, 1982; Cech & Wallach, 1998; De Rijk, 2007; Lyaya, 2007; McDonnell, 1983; 1988; Miller & Killick, 2004; Oelsen & Schürmann, 1954; Serneels, 1993; Sperl, 1980) and the main attributes used for any sorting are shape, texture, porosity, color, streak, magnetism, inclusions, and corrosion. Slags from pre-industrial iron production and processing can sometimes be difficult to categorize, however, there exist some 'index fossils' left behind by the multiple activities related to iron production and processing, which are easy to identify in the field or in the laboratory by visual inspection.

1.6.2.1. Smelting Slag

Remains from iron smelting are multi-phase compounds with many components. Nevertheless, most iron slags show blackish to dark gray, or greenish to pale gray colors on freshly exposed surfaces. Greenish slags are usually poorer in iron oxides than darker ones, and the color refers to the dominating greenish olivine in the sample, whereas an increasing amount of iron oxides (i.e. wustite) would shift the color of the slag towards dark gray and black (Iles, 2010, p. 163; Modarressi-Tehrani, 2009, p. 35). The ferrous slag usually shows a blackish gray to brownish streak, and with decreasing iron oxide content the color shifts towards pale green or light gray. A number of specimens show a reddish exterior or upper side, which was caused by surface oxidation of the hot slag when it remained in the furnace after the smelt (Crew, 1995, p. 2). More important than colors is the texture of the sample and its internal structure. Slags can appear homogeneous and blocky, or layered and inhomogeneous, and many examples show flow pattern. The degree of crystallization indicates the rate of cooling: A glassy matrix forms under fast cooling, and large blocky, sometimes macroscopic crystals develop under slow cooling conditions (De Rijk, 2007, pp. 124-125; Serneels, 1993, pp. 25-26). Pores within slags range from minute cavities to large circular or elliptical vesicles, and size and arrangement varies with respect to the operation process. Most slags also contain inclusions of refractory materials such as mineral grains, ore remnants, charcoal fragments, and inclusions of elemental metal (Yalçin & Hauptmann, 1995, p. 276). The easiest way to identify elemental iron trapped in a slag specimen is to test the degree of magnetizability of the sample. Even so, slag that formed under oxidizing conditions can show a higher portion of magnetite minerals, which causes these specimens to react more strongly to a magnet than wustite-dominated examples (Bachmann, 1982, p. 5; De Rijk, 2007, p. 119; Miller & Killick, 2004, p. 26). As most slag minerals resist weathering, rusty blistering at the surface or heavy weathering of a slag sample is another way to diagnose metallic iron trapped in a sample (Crew, 1995, p. 3; VATG, 1997, p. 24; Serneels & Perret, 2003, pp. 475-476).

The morphological appearance of smelting slag is highly variable and can change according to different furnace types. Moreover, every smelt produces a number of slags that elude visual classification and can only be identified by microscopic analysis.

The iron bloom is easy to diagnose although rather unusual in the archaeological record. It is commonly a spongy mass, sometimes of plano-convex shape, and it consists of accumulated metallic iron with a considerable amount of slag and in many cases lumps of charcoal (Pleiner, 2000, pp. 230-247). As mentioned above, iron blooms, or fragments of them, are easy to identify because they are highly magnetic and relatively heavy owing to the elevated density (Sperl, 1982, p. 15; Yalçin & Hauptmann, 1995, p. 276).

Smelting slag that was not tapped or drained in or from the furnace is called furnace slag. In particular non-tapping furnaces produce a lot of furnace slag. It manifests a variety of appearances ranging from dense homogeneous blocks to spongy lumps (Crew, 1995, p. 2; De Rijk, 2007, p. 114; VATG, 1997, p. 24). Slags that solidified inside of the furnaces are frequently mixed with fuel, ore remnants, furnace linings, and other refractory materials that did not go into reaction with the overall slag forming ingredients during the smelt (De Rijk, 2007, p. 28; Hauptmann, 2014, p. 101; Sperl, 1980, p. 15). Smelting slag is generally considered dense in structure, the occurrence of voids largely depending on the viscosity and cooling rate of the slag (Bachmann, 1982, p. 4; De Rijk, 2007, pp. 119-120; Serneels, 1995, p. 21; VATG, 1997, p. 24). Undulating upper sides develop when slag cools down while there is still gas ascending in the viscous mass (De Rijk, 2007, p. 116). Furnace slag that cooled down slowly in a protected environment can show large macroscopic crystals and a rather coarse surface texture. Generally, large pieces of slag found in an archaeological context are assigned to smelting, yet many of them are broken because large chunks more usually crack and break to pieces as a result of thermal disequilibria during cooling and clearing out the furnace (De Rijk, 2007, p. 115). Smelting events can also produce microslags, in particular tiny prills and spheres that froze in the charcoal bed of the furnace before the main slag mass accumulated. Unlike the slag spheres that arise from smithing (section 1.6.2.2, microspheres from smelting are filled droplets of slag, and not hollow (Crew, 1995, p. 2; Killick & Miller, 2004, p. 27). Also, furnace slag frequently litters refining sites and originates from the hammering off of redundant slag from the bloom. In non-tapping smelting facilities, a dense slag cake accumulates at the bottom of the furnace, which frequently froze in the shape of the furnace base.[78] The same applies in tapping furnaces, because only parts of the slag were drained

[78] Numerous examples are given in Humphris (2010) and Iles (2010).

away (Oelsen & Schürmann, 1954, p. 508).[79] The examples show there is a potential that slags may mirror the appearance of the smelting furnace. Slags identified to be furnace bottoms are usually round in section and show a convex underside (Crew, 1995, p. 3; De Rijk, 2007, p. 115; Sperl, 1980, p. 15). As they accumulated in the hot furnace, one important diagnostic feature is the circumstance that sand and clayey soils adhered to the underside and went into reaction with the hot slag (Killick & Miller, 2004, p. 24). A number of smelters used slag pits inside or outside of the furnaces in order to collect the molten slag. In some cases, the shape of such slag blocks very much resembles the aforementioned furnace bottoms, others mirror the morphology of a pit, and the weight can range from a few to some hundred kilograms (e.g. Bielenin & Suliga, 2008; Pleiner, 2000, p. 259). These slag blocks are sometimes difficult to distinguish from furnace bottoms but it is generally argued that temperatures in slag pits were not as high as in the charcoal bed of a furnace bottom. From these considerations one can argue that sediment adhering to slag pit bases is, if anything, trapped in the molten slag mass and does not show much structural alteration of the grains (i.e. a thermal reaction). Many smelting procedures generated slag that shows a flow pattern. Such samples help us to comprehend ancient furnace constructions, and to identify ancient smelting sites. Molten material that flowed vertically shows structures like a candle with running droplets, and is called run slag (De Rijk, 2007, p. 116). The term tap slag in contrast describes molten material that flowed more or less horizontally out of a taphole and into a furrow, and the amount of slag can vary from individual runs to accumulated tapping events (Crew, 1995, p. 3). Tap slags can have a smooth surface, horizontal flow structures, runners, and elongated ridges or strings, and sometimes a rippled appearance (Crew, 1995, p. 3; De Rijk, 2007, p. 27; Friede et al. 1982, p. 38; VATG, 1997, p. 24). The smoothness of the surface largely depends on the viscosity of the slag before full solidification. Tap slag is usually dense in texture, and shows but few inclusions. Contrary to run slag, it usually displays a flat underside with unreacted sediment adhering to the specimen, or with impressions and pseudomorphs of the material on to which it flowed (De Rijk, 2007, p. 24; Killick & Miller, 2004, p. 24; Sperl, 1980, p. 15; VATG, 1997, p. 24). Rapid cooling outside of the furnace creates a rather glassy to microcrystalline texture. Under oxidizing cooling conditions, a thin surface skin of magnetite frequently develops and causes tap slag to respond to a magnet in the field (Killick & Miller, 2004, p. 24; Pleiner, 2000, p. 262). However, smelting slag is generally non-magnetic or only weakly magnetic when pulverized, except when metallic iron is trapped in the slag (De Rijk, 2007, p. 119).

1.6.2.2. Post-reduction slags from refining

Iron-rich slags are not only produced through smelting, every step of further processing generates iron-rich slags in varying amounts and shapes. Generally, one must distinguish between slags from refining or primary smithing, and from secondary smithing.

The principle methods of refining as described in section 1.5.1 imply that refining slag can be very diverse in its appearance and composition. It can show characteristics of smelting slag as well as smithing slag. The multiple steps of refining produce slags with characteristic features that allow us to identify more or less precisely the individual production step which generated the sample at hand. As seen in section 1.5.1, blooms can be refined by reheating in a refining furnace, by reheating in an open forge, and by sorting the bloom in cold state and refining smaller pieces in a forge. These examples indicate that refining residues comprise tap and flow type slags, homogeneous and inhomogeneous specimens with and without metal inclusions, slag dominated bloom fragments, smithing hearth bottoms (SHB) and hammer scale of varying size and shape (De Rijk, 2007, pp. 114-117; Fluzin, 2004, p. 71; Lyaya et al., 2012, p. 200; Lyngstrøm, 1997, p. 34). Slags produced by refining can be as big as 50 cm in diameter or no more than 5 cm and even smaller (De Rijk, 2007, p. 114). Frequently, blooms were mechanically treated before any further refining and, as mentioned earlier, shattered smelting slag reflects refining activities (Crew, 1995, p. 3; Fluzin, 2004, p. 71). The experimental cleaning of blooms by Crew & Salter (1991, p. 19) showed that the first step of refining produces large slag cakes in the refining furnace, which must have been removed quite often during the consolidation process. When slag-tapping furnaces are used, slag-draining starts already after 15 minutes (e.g. Barndon, 2004, p. 89) and produces flow-type slags, which are not necessarily

[79] As described in section 1.4.6, the slag bath in a furnace was essential to control the carburization of the iron.

distinguishable from the same slag type produced by smelting, either morphologically or in microstructure or chemistry (Lyaya et al., 2012, p. 200).

Refining in furnaces and hearths creates slag cakes at the bottom of the furnace, and they are called smithing hearth bottoms (SHB). Smithing hearth bottoms are diagnostic for any kind of primary or secondary smithing activity. In smithing, various materials collect at the bottom of the charcoal bed and form a plano-convex or tabular heterogeneous slag cake. Its size largely depends on the quantity and quality of the bloom, iron bars or objects that have been worked (Fluzin, 2004, p. 74; Lyngstrøm, 1997, p. 33; Miller & Killick, 2004, p. 25; Serneels & Perret, 2003, pp. 471-472). Smithing hearth bottoms are round to oval, palm-sized, plano-convex and frequently have the shape of the bottom of the smithing hearth. The upper surface can be even or undulating and some show structures of frozen fluidity. Generally, oxidizing conditions at the upper face of such slag cake lead to the formation of a cooling skin of magnetite, hematite or maghemite (Miller & Killick, 2004, p. 31), whereas the underside frequently shows numerous imprints of the charcoal bed or attached furnace lining. In the main, smithing slag is usually porous and low in density, and smithing hearth bottoms show voids in varying number and size. Typically they contain elongated pores in radial orientation with respect to the upper or lower face of the slag cake (De Rijk, 2007, p. 119). The amount of slag produced decreases during primary smithing. The more advanced the compacting of the bloom is, the smaller and the fewer will be the slag inclusions expelled during hammering. Therefore, any subsequent steps of refining produce slag masses that are not as voluminous as before, and this circumstance is well reflected in the decreasing sizes of SHBs with advanced refining (Crew & Salter, 1991, p. 19). In the late stage of refining, these slag cakes are mainly produced by hammer scale and fluxes (De Rijk, 2007, p. 114: Tab. 5; Gassmann, 2004, p. 76; Pleiner, 2000, p. 216) and they share more similarities with secondary smithing slag than with early refining slag.

Aside from the flow type slag mentioned earlier, one important feature of smithing slags is that they are stratified because of the repeated thermodynamic and mechanical cycles of heating and hammering (Buchwald, 2005, p. 99; Fluzin, 2004, p. 86; Serneels & Perret, 2003, p. 473). The composition of each zone or layer reflects individual smithing events, while fluxes, reactions with fuel ashes, and refractories add to the stratified appearance of the slag (McDonnell, 1991, p. 26; Serneels & Perret, 2003, p. 476). Serneels and Perret (2003, p. 472) further suggest that SHBs form during one single smithing episode. They may reflect a single day's work, or one unit of work. However, the experimental cleaning of blooms by Crew and Salter (1991, p. 19) demonstrated that during the first steps of refining large slag cakes must be removed quite often during the consolidation process. Therefore, Serneels and Perret's suggestion may only be valid for more advanced refining and forging activities.

Besides the typical smithing hearth bottoms, refining produces a high amount of small amorphous slag lumps that consist of individual slag chunks, droplets, hammer scale, and bloom fragments, which litter the blacksmith's workshop (e.g. De Rijk, 1994, p. 31). Such slag debris often accumulates in the charcoal bed of the forge but hardly ever at the bottom of it, and produces various conglomerated lumps of slag (McDonnell, 1988, p. 286; Lyngstrøm, 1997, p. 33).

Small pieces of poorly compacted bloom, or small chunks of compacted iron, repeatedly got lost around the forge and in the slag bath during the various steps of refinement. They are referred to as gromps or crown material. The quality and the compactness of the bloom determined how many such pieces were discarded or during heating and hammering (Avery et al., 1988, p. 270; Crew & Salter, 1991, p. 18; De Rijk, 2007, p. 110; Fluzin, 2004, p. 74; Serneels & Perret, 2003, p. 471; Sperl, 1980, p. 14). Generally, gromps are considered diagnostic for primary smithing activities, in particular for the initial refinement steps when the bloom is still insufficiently consolidated. Because of this, it is argued that SHBs from initial refining contain more gromps than those that accumulated later (Gassmann, 2004, p. 76; Fluzin, 2004, p. 86). Also, gromps from the very first steps of refining can still show the labyrinthine structures of the original bloom, whereas gromps lost during advanced refinement are commonly pieces of compacted iron with signs of cold working or recrystallization. During primary smithing, iron fragments frequently sank down to the bottom of the slag bath because of their higher specific gravity (Rostoker & Bronson, 1990, p. 81).[80] This circumstance also facilitates the identification of smithing hearth bottoms because furnace bottom cakes from smelts accumulate below the bloom, and usually do not contain lumps of (worked) elemental iron in their bottom layers.

80 The density of slag is 3 to 4 g/cm^3, that of iron 7.8 g/cm^3 (Rostoker & Bronson, 1990, p. 81).

Smithing activities produce a high amount of microslags such as thick amorphous or flat hammer scales, or microspheres. They are helpful tools to identify the manufacturing process that generated them, because they vary in size and number depending on the process step performed (e.g. De Rijk, 1994; Dungworth & Wilkes, 2009; McDonald, 1988; Young, 2011). It has been suggested that primary smithing slag from working iron on an anvil is smaller than 5 cm in size, and residues from secondary smithing range from 0.1 mm to 1 cm in diameter (De Rijk, 1994, p. 31; 2007, p. 114). Most of these slags are magnetic because they were exposed to oxidizing conditions at the forge, and since they are small, they were usually not removed from the work place and can be frequently found in situ around a forge. One category of microslags consists of thick hammer scale flakes which are also known as slag flats (after Young, 2011, p. 28). These residues arise during refining and show a slag-like microstructure. Sometimes it shows still the imprints of the hammering tool (De Rijk, 1994, p. 32; Young, 2011, p. 39). These hammer scale flakes with a slag-like microstructure are to be distinguished from flakes that consist of layers of surface oxides only, which formed on the surface of the iron metal under hot oxidizing conditions. Such flakes consist mainly of magnetite, hematite and wustite, depending on the temperature of the workpiece, and they are magnetic. The layering reflects the repeated heating periods before the scale flaked off. Thick oxide flakes are produced under high temperatures and prolonged heating and derive from larger objects that need more time to reach the desired temperature. Consequently, fine small hammer scale flakes are to be associated with the fine smithing of smaller objects (De Rijk, 2007, p. 117; Dungworth & Wilkes, 2009, p. 44; Serneels & Perret, 2003, p. 471; Unglik, 1991, p. 94).

Another diagnostic category is microspheres. They are tiny hollow droplets that were expelled as liquid globules when pieces of iron were to be joined by force. They form from molten slag and usually consist of glass and iron oxides because they solidified too quickly for crystallization (Dungworth & Wilkes, 2009, p. 44; Killick & Miller 2004, p. 27; McDonnell, 1988, p. 286). Microspheres can be globular, spheroid or hemispheric in appearance, and frequently they show a contact surface of the underlay on which they cooled down (De Rijk, 1994, p. 31; Young, 2011, p. 28). They are rather small in size, ranging from 0.1 mm to roughly 6 mm in diameter, and some cemented droplets may form aggregations of slag (De Rijk, 1994, p. 31; Unglik, 1991, p. 92). Experimental smithing has revealed that microspheres form from high temperature welding in particular from temperatures in excess of 1150 °C (Dungworth & Wilkes, 2009, p. 44; McDonnell, 1988, p. 288; Unglik, 1991, p. 94). Here again, larger globules tend to originate from primary smithing activities, whereas minute globules are assigned to fine smithing (De Rijk, 1994, p. 31). Magnetism varies among microspheres depending on their main constituent, which can be either pure fayalite (non-magnetic) or a mixture of fayalite and iron oxides (magnetic).

1.6.2.3. Post-reduction slag from secondary smithing

Secondary smithing slag forms from hot working and welding in the process of tool smithing. The forging of tools produces considerably less slag than refining and, in addition, the amount of slag decreases in the course of the manufacturing process of tools (Gassmann, 2004, p. 73). It has been argued that residues of secondary smithing are more homogeneous than those from primary smithing, because forging objects mainly produces hammer scale flakes and microspheres, small amorphous slag bits and smithing hearth bottoms or tabular slags in the forge (e.g. Lyngstrøm, 1997, p. 34; McDonnell, 1988; 1991). As a rule, smithing hearth bottoms from secondary smithing are rather small, and De Rijk (2007, p. 114) suggested that they do not exceed a maximum size of 15 cm in extension. They mainly form from hammerscale and fluxes and are usually stratified in texture from the repeated heating cycles. Smithing slag may contain all sorts of inclusions such as charcoal or remains of the fluxes used during welding. They can show vitrification at the face that was exposed to the air supply. Frequently sand or clay from the forge adheres to the slags, and flattened surface zones can indicate heat shields (De Rijk, 2007, p. 115). In secondary smithing, redox conditions were not controlled and most slags formed under mixed or, if anything, oxidizing conditions (Gassmann, 2004, p. 76). Oxidizing conditions favor the formation of magnetite (Fe_3O_4) instead of wustite (FeO) and as a consequence, most secondary smithing slags react to a magnet. However, although secondary smithing slag forms in the forge, most residues of this work process scatter around the anvil at a distance of up to 1.5 m and the density

decreases towards the outer margins (De Rijk, 1994, p. 34). Furthermore, metal fragments intended for recycling are also to be expected around and within a forge and can help to identify the workplace of a blacksmith (Fluzin, 2004, p. 90; Serneels & Perret, 2003, p. 471).
Slags from refining and from secondary smithing are sometimes difficult to classify because similar slag types can occur. Nevertheless, there are some distinguishing features, which help to specify the origin of the sample under examination, because the portion of slag types changes from refining to fine smithing (De Rijk, 1994, p. 34). As seen above, refining slag primarily consists of fayalite and wustite, whereas microslags such as hammerscale flakes and spheres contain magnetite and hematite. The latter are produced in increasing number during advanced refining and in secondary smithing. This is another reason why secondary smithing slags tend to be more magnetic than refining slags (Crew & Salter, 1991, p. 19; De Rijk, 2007, p. 117; Dungworth & Wilkes, 2009; Lyngstrøm, 1997, p. 34). However, refining slags frequently contain magnetic crown material, which can be detected through a rather selective reaction to the magnet. Also, refining produces four times more slag than the forging of objects. Moreover, amorphous slag lumps are rather associated with primary smithing whereas fine hammerscale flakes indicate secondary smithing. Additionally, the average size of the residues from refining is larger than the dimension of those from secondary smithing. Consequently, a most important criterion for the distinction of primary from secondary smithing is the size of scale, the amount of scale, the relation of flakes to irregular scale in the assemblage, the size of the microspheres, and finally the size of the smithing hearth bottom (De Rijk, 1994, p. 34; 2007, p. 117; Lyngstrøm, 1997, p. 34).

1.6.3. Laboratory methods

Ninety ore, slag, and iron samples were investigated with scientific laboratory methods and required proper preparation in order to gain reliable results. Bulk chemical analyses were carried out through inductively coupled plasma optical emission spectroscopy (ICP-OES), and mineralogical examination was conducted by optical microscopy and X-ray diffraction (XRD). All the samples were analyzed in the laboratory of the German Mining Museum at Bochum.

1.6.3.1. Sample selection

Samples were selected according to their morphological appearance in order to gain a general assessment of smelting and smithing slag, crown material and iron implements of the research area. In addition, further samples were chosen from Ruuga (SC 3), Kapako (SC 4) and Vungu-Vungu (SC 12) in order to get more information about possible variation between early and late ironworking smelting and processing techniques. As no geological data have been published to which I could refer, I also examined selected samples of iron-rich rocks and soils, expecting to acquire an initial comprehension of possible ore sources.

1.6.3.2. Microscopic examination

The principal method in archaeometry of investigating mineral phases and microstructural properties of slags and iron minerals is petrographic analysis through optical microscopy. All minerals show specific arrangements of atoms, which give them specific optical properties when observed in a microscope in transmitted (polarized) or reflected light (Craig & Vaughan, 1994; Rice, 2005, pp. 375-382; Stoiber & Morse, 1994). For this purpose, thin sections of slag samples and cross sections of iron rich bloom fragments and iron objects were produced. Once the main mineral phases are identified, crystal growth, phase successions and the composition of the microtexture disclose the history of deposition, cooling and redox conditions, temperatures, efficiency, and the process step that led to the formation of the particular slag sample. All the slag sample descriptions are made on the basis of standard literature and classification suggestions, such as Bachmann (1982), De Rijk (2007), Fluzin (2004), Kronz (1997), Kronz & Keesmann (2005), Modarressi-Tehrani (2009) and Serneels (1993). If considered necessary, the relative proportion of the main mineral phases was estimated semi-quantitatively in area percentage at a magnification of 100x. Before an interpretation is suggested, each sample is described in detail in the enclosed sample index with its morphologi cal appearance, macro- and microstructural properties, main mineral phases and phase successions. Elemental iron was described on the basis of metallographic standard literature and very detailed sample descriptions such as Bramfitt (2002), Fluzin (2004), Miller (1996), Samuels (1999); Schumann & Oettel (2005), Scott (1991; 2013) and Senn-Bischofberger (2005).

Thin sections were produced from silica-rich samples, whereas cross sections were made from iron-rich specimens because iron minerals are opaque and can hardly be studied in transmitted light. The samples were transected using a WOCO Conrad low-speed diamond sawing machine in order to produce slices of 1 to 2 mm in thickness. From each slice a sample cross section of approximately 1 cm^2 in area was selected, mounted in bonding epoxy resin and affixed to glass slides or synthetic holders in a vacuum. Thereafter, the samples were ground and polished down to a grain size of 1 μm first with a G&N MPS-2-120 grinding machine and diamond cup wheels, and at the end with a Depireux polishing machine using a lead-antimony polishing wheel and a diamond polish. Thin sections were reduced to a standard thickness of 25 μm. As regards the iron artifacts selected for examination, only cross and no lateral sections were produced from them, because they were all small in size. Thin sections and cross sections were examined under a Zeiss AxioPhot petrological microscope with a maximum magnification of 400x. Digital photographs were produced using the ColorView Soft Imaging System.

1.6.3.3. X-ray diffraction (XRD)

Twelve ore samples were analyzed with X-ray diffraction in order to gain a qualitative identification of mineral phases according to their crystalline structure. In XRD, minerals are identified by being irradiated with X-rays with a precisely defined wavelength, similar to the spacing of the lattice plane of crystals. Since each mineral has a unique arrangement of the atomic lattice, the incident X-rays will be scattered (reflected or diffracted) and produce a series of secondary rays. According to the laws of physics, and depending on their wavelength, these rays cancel one another out through destructive interference, or add to one another in positive interference and produce a sequence of peaks of X-rays with specific wavelengths, emitted at a specific angle from the sample. Both attributes are recorded and interpreted in order to identify the mineral composition of a sample (Rice, 2005, pp. 382-386).

The samples were mechanically cleaned of attached sand and organic matter and then crushed and ground in an agate mortar Fritsch Pulaerisette ball mill to obtain a grain size smaller than 63 μm. The powdered samples were then dried in an oven overnight at 105 °C and approximately 1000 mg of the sample was analyzed using a PANalytical X'Pert PRO X-ray diffractometer.

Parameter of the X-ray-generator: ADS (automatic divergence slit), working power: 1.8 kW, working voltage: 45 kV, working current: 40 mA. The angle array was 5-70° 2-theta with a rate of 0.017°/10 sec, Cu-Kα-radiation of a wavelength of 1.54178 Å.

1.6.3.4. Chemical analyses with inductively coupled plasma optical emission spectroscopy (ICP-OES)

The inductively coupled plasma optical emission spectroscopy (ICP-OES) is what is known as a 'wet chemical' method, which is able to detect the quantity and kind of roughly 70 chemical elements of a compound. 'Wet' refers to the fact that the sample is brought into solution in acid, and the behavior of the components is then observed in controlled laboratory tests. The sample in solution is introduced into argon plasma and the electromagnetic behavior of the elements of the samples is recorded and interpreted. To produce the plasma, argon in its gaseous state is exposed to an electromagnetic field and transferred into an ionized gas first, and subsequently into an argon plasma, which becomes highly conductive and reaches temperatures of roughly between 6000 and 9000 °C. A certain amount of a sample (at least 5 mg) in solution is sprayed into the plasma under controlled conditions. The high temperatures dissociate the molecular bonding of the elements and the atoms can interact with the plasma. Electrons are bound to the electric field of the atomic nucleus with a specific energy that varies from element to element. The lowest-possible energy level is called the ground state. When atoms are exposed to an electromagnetic field, or to free electrons, both of which occur in the argon plasma of the spectrometer, the atom absorbs free energy and the electrons of the atom change their energy level. Any electron that has higher energy than the ground state is called 'excited'. The energy levels an electron can take are variable and depend on the element. As the excited state is not stable, the electron returns to the ground state and the atom releases the energy that was necessary to bring the electron to its excited state. Optical spectrometry makes use of the fact that the energy is emitted as near-ultraviolet or visible light, and is then collected in a detector. The bundle of wavelengths determines the element, and the intensity of the specific spectral pattern changes with the number of atoms and determines the quantity of the elements present in the sample by comparison with calibration standards (Prange, 2001, pp. 24-27; Rice, 2005, pp. 392-393).

Slag samples from the slices used for thin section preparation were chosen for chemical analyses. Pieces from the core area of the slag lumps were preferentially selected to prevent contamination from adhering furnace lining and the slightly sintered calcareous surface of some samples. The ore samples were cleaned of organic material and sand. Each sample was pulverized in a tungsten carbide mill to a grain size < 63 µm, and quartz sand was milled between each sample to avoid cross contamination of the specimens. The samples were subsequently dried in an oven and digested in acid for further treatment. Approximately 100 mg of powdered matter of each sample was digested in a PTFE pressure vessel with 6 ml HCl, 1.75 ml HF and 4.8 ml HNO_3 for 40 min. at 250 °C in a microwave. After the sample had cooled down, 10 ml of boric acid (50g/l) was added and the samples were reheated to 200 °C for 20 min. Finally, the samples were poured into a 50 ml polyethylene volumetric flask, and ultra-pure water was added to the samples to bring the volume up to 50 ml. For the main element analysis, the sample solutions were further diluted with 5% HNO_3 to 1:1000, for the trace element analyses to 1:10. The samples were analyzed using an ICP-OES spectrometer type IRIS AP/HR, TJA. The loss on ignition (LOI) was calculated with standard laboratory procedures at 1050 °C for an ignition time of two hours.

All the elements detected are listed in tables. Major elements (> 1wt%) and minor elements (< 1wt% and > 0.1 wt%) were calculated to their common oxides and listed in weight percentage (wt%). Trace elements (< 0.1wt%) were listed in their elemental state in parts per million (ppm). The iron content of the samples is listed as Fe_2O_3 and if needed converted mathematically to FeO by the standard factor of 0.8998. MnO is converted to Mn by the standard factor 1.2912 and TiO_2 to Ti by 1.6681.

1.6.4. Slag chemistry and its interpretation

Iron production in pre-industrial times required similar technological solutions all over the world. As a consequence, the process produced similar slags, and the range of process-related parameters or choices to generate low-melting slags was limited by the ingredients involved in iron production (e.g. Chirikure & Bandama, 2013, p. 5; Hauptmann, 2014, p. 100; Rehren et al., 2007; Serneels, 1993, p. 14).

As described earlier, slag consists of ore, furnace lining, fuel ash and sometimes fluxes minus the reduced oxides and some volatile elements. Therefore, the chemical composition of slag largely depends on the raw materials, refinements and the thermal process control. However, the basic problem of the chemical examination of slags from iron production sites is their uniform chemistry over long historical periods and large geographical areas (Friede et al. 1982, p. 39; Rehren et al., 2007, p. 212). Slag chemistry is often seen to mirror liquidus temperatures and the efficiency of a smelt according to our Western industrial understanding. Moreover, it can indicate the use of fluxes and the compositional restrictions of the smelting process. As explained earlier in section 1.4.6, temperature and redox conditions are basically responsible for the distribution of elements and whether they are responsive to chemical bonds with the elemental iron or with the slag. However, chemical equilibrium conditions and the proportion of reduced to unreduced elements fluctuate during the smelt, and produce variation in slag composition and also in the quality of the elemental iron produced.

Usually, slags are grouped according to their major, minor and trace elements. The main minerals of iron-rich slags are fayalite, wustite and spinel. Chemical analyses mainly produce compositions where FeO, SiO_2, CaO, and Al_2O_3 constitute at least 80 wt% of the total slag composition. In these series, carbon and sulfur are usually not listed because they evaporate during measuring (De Rijk, 2007, p. 120). These main constituents are used to estimate liquidus temperatures and efficiency (e.g. Chirikure & Bandama, 2013; Rehren et al., 2007; Yalçin & Hauptmann, 1995) and minor and trace elements give evidence of the ore deposits and fluxes that may have been used (Charlton et al., 2010, p. 354; Hauptmann, 2014, p. 99; Joosten, Jansen & Kars, 1997; Kronz & Keesmann, 2005; Kunze, 2006; Paynter, 2006; Yalçin & Hauptmann, 1995, pp. 287-289). Moreover, the clustering of slag compositions around the what is known as Optimum 1 or Optimum 2 (after Rehren et al., 2007) is frequently used to discuss human process control and possible choices (e.g. Humphris et al., 2009) or economic considerations (e.g. Charlton et al., 2013, p. 292). There are many parameters that finally determine the composition of slag, and chemical variations may be due to heterogeneous source materials as well as differences in the production techniques (Bachmann, 1982, pp. 9-10; Charlton et al., 2010, pp. 355-356; Chirikure & Bandama, 2013, p. 5; Friede et al., 1982, p. 39). However, slag composition can vary within a single slag block, within slag blocks from the same site, within slag blocks of a specific region where similar smelting traditions were practiced, and within the same cultural (archaeological) horizon (e.g. Friede et al., 1982, p. 39; Humphris et al., 2009, p. 359; Iles, 2010). Even a single tapping event can produce variation in slag composition, and as the chemical elements and minerals available for chemical reactions change in the course of a smelt, any subsequent tapping event produced a slag of different composition (e.g. Young & Poyner, 2014, p. 93). However, different furnace types can produce very similar slags (Blomgren & Tholander 1986, p. 158). A compilation of slags all over Africa has shown that different furnace types tend to produce different slag compositions, yet there is a large field of slag compositions that escape classification and overlap (Chirikure & Bandama, 2013). From this somewhat contradictory and complex picture it follows that, for all the homogeneity, slags and smelting traditions must be investigated for every region and for every site anew, and results and lines of evolution that may be true for one research area can be completely different for another region. The given examples strongly suggest that a large number of samples are needed to characterize any smelting regime in full at one site and in one area of research (e.g. Hauptmann, 2014, p. 97; Paynter, 2006, p. 275; Young & Poyner, 2014, p. 93).

Attempts have been made as to chemically identifying and classifying smelting, refining and smithing slags (e.g. Charlton, 2007 as cited in Charlton et al., 2013, p. 422; De Rijk, 2007, p. 120; Hjärthner-Holdar, Kresten & Larson, 1997; Lyaya et al., 2012; McDonnell, 1991; Miller & Killick, 2004; Rostoker & Bronson, 1990, p. 87; Serneels, 1993, p. 51). In theory, the different source materials are supposed to be reflected in distinguishable chemical fingerprints of the slag, because refining slag forms from smelting slags, fuel ash, linings, and when required, from fluxes. With increasing compactness of the bloom, more and more iron oxides (hammerscale) dissolve in the refining slag, and the chemical (as well as microstructural) fingerprint shifts towards secondary smithing slag. The latter mainly form from iron oxides that flaked off from the workpiece, and from fluxes. Slags with a higher input of iron oxides (hammerscale) during primary or secondary smithing are assumed to contain more siderophile elements such as Ni, Co and Cu than smelting slag and slag produced during the initial steps of refining. Also, the impact of fuel ash and linings is assumed to be higher in refining slags than in smelting slags, which can lead to elevated readings of elements such as Al, Ca, K, Mg, Na and Ti (Charlton, 2007 as cited in Charlton et al., 2013, p. 422; De Rijk, 2007, p. 120; Lyaya et al., 2009, p. 203; Serneels, 1993, p. 51). However, Humphris (2010, p. 252) was able to associate the highest fraction of fuel ash components with the beginning of a smelt in a furnace that was probably preheated. Therefore, each assemblage must be interpreted anew from the given parameters. Furthermore, the slag studies of Miller and Killick (2004) in southern Africa revealed that at some sites, smelting slag and smithing slag can be chemically identical. As illustrated in section 1.5.1, refining is usually performed at temperatures slightly higher than smelting. As a consequence, elements such as phosphorus, which are bound to the slag under normal furnace running conditions, may go into solution with the metallic iron and may be less present in the slag (Kronz, 1998, p. 118; Kronz & Keesmann, 2003, p. 266). Section 1.5.1 also described a variety of refining techniques that all produce slags of different composition. It can therefore be very difficult to distinguish between smelting and processing slag solely by their chemical fingerprint. When only silica is added as a flux, the smithing slag can consist mainly of FeO and SiO_2, depleted of all other elements (e.g. Humphris, 2010, p. 257). Yet, as seen before, some ironworkers used clays as a fluxing agent, which would produce an aluminum-rich slag with minor and trace elements mirroring the geological fingerprint of the clay, and examples are known where tufa and slags from glass production were used for the same purposes (De Rijk, 2007, p. 112). More contributing materials are mentioned in Serneels and Perret (2003, pp. 472, 473), underlining that smithing slag is extremely heterogeneous in its chemical appearance. Kronz and Keesmann (2005, p. 409) argue that only a combination of macroscopic appearance, microstructure and chemical composition may lead to a satisfying differentiation between smelting and refining slag, because the thermodynamics of both processes are alike and produce chemically similar slags. However, the example given by Lyaya et al. (2012) challenges any slag classification because they were able to show that refining can produce flow-type slags and tap slags, which cannot be distinguished from smelting slag chemically, macroscopically or even on the basis of their microstructure. It is generally believed that high FeO readings of slags are indicative for refining and smithing rather than smelting,[81] yet Serneels and Perret (2003, p. 473) argue that FeO readings of smithing slag can cover the range from 5 to 95wt% of wustite and are not easily identifiable. Therefore, samples of smithing slag should be identified through macro- and microstructure analyses first, to keep them separated from the chemical picture of the smelting slag analyses (Kronz & Keesmann, 2003, p. 262).

The main phases revealed by chemical analyses (usually FeO, SiO_2, Al_2O_3 and CaO respectively) that amount to more than 90 wt% of the total slag components are commonly plotted in ternary phase diagrams (Figures 19 and 20) in order to create a hypothetical framework for the estimation of liquidus temperatures and process-running parameters (e.g. Bachmann, 1982, p. 11; Hauptmann, 2014, p. 99; Young & Poyner, 2014, p. 91). The common procedure to place a slag sample into a phase diagram is to convert the three main components to equal 100 % and to plot these components into the respective ternary diagram. From there one can deduce – according to the common paradigm – whether a slag was workable or not, and, for instance, whether tapping from the furnace started at low temperatures or not. All basic interpretations of thermodynamics, crystallization and forming agents are frequently made on the basis of such plots. However, any plotting of slag compositions into phase diagrams only approximates its compositional parameters, because nothing but the major components is represented by them (e.g. Bachmann, 1982, p. 11; Serneels, 1993, p. 16). Such diagrams can offer only estimations of furnace running parameters since trace elements, which are ignored in such plots, also strongly influence the liquidus and solidus behavior of slags (Hauptmann, 2014, p. 99; Rehder, 2000, p. 112). Slags in the FeO-SiO_2-Al_2O_3 ternary diagram frequently cluster around two low-melting slag compositions with solidus temperatures approximating to 1088 °C and 1148 °C. This plotting behavior has prompted scholars to create the concept of slag optima at specific eutectic slag composition (Optimum 1 and 2) (Figures 19 and 20) (Rehren et al., 2007, p. 212) and it has been suggested that smelters manipulated the furnace parameters (or used what is known as self-fluxing ores) in order to approach the one or the other optimum in composition. In addition, I suggest labeling the low-melting zone in the FeO-SiO_2-CaO system Optimum 3. The broad study of slag compositions presented for instance by Chirikure and Bandama (2013) has shown that the optimum-concept can be helpful for visualizing technical traditions. However, as many parameters influence the final slag composition (e.g. the quality of the ores, the time the slag stays in the furnace, fluxes, refractoriness of the technical ceramics), the concept of slag optima should not mislead us into only seeing a manipulative intention. Nor does the portion of iron oxides within smelting slags necessarily tell us anything about the efficiency or iron yield of the smelt. High-grade ores may produce iron-rich slags and lean ores may produce slags with low iron readings (e.g. Blomgren & Tholander, 1986, p. 158). Moreover, in pre-industrial smelting traditions, the composition of a melt can be quite unpredictable, since raw materials were heterogeneous (e.g. Iles, 2010, p. 225; Lyaya et al., 2012, p. 202) and furnace running conditions were not yet standardized (Bandama, 2013, p. 156; Miller & Killick, 2004, p. 30; Paynter, 2006, p. 272). Because of this, some scholars argue that the Optimum 1 and 2 models hardly reflect the smelting reality (e.g. Charlton et al., 2013, p. 292) and the visualization of slag optima may also mislead us into over-interpreting samples with respect to efficiency versus non-efficiency. In addition, samples from the same batch may cluster in both Optimum 1 as well as Optimum 2 (e.g. Young & Poyner, 2014, p. 93). It is argued that noticeably high wustite content in bloomery slags frequently indicates smithing slags and, if not recognized and separated, such slags may alter phase diagrams in the direction of reduced efficiency of smelting operations. Also samples with high SiO_2 content must be treated with care, because it is believed that they frequently contain a disproportionate amount of refractory materials (Kronz & Keesmann, 2003, p. 262).

As Hauptmann (2014, pp. 100-101) argues, slag formation follows the principle of partial melting, which is characteristic of heterogeneous rock material. Most procedures of extractive metallurgy make use of the fact that mixtures of two or more substances or elements frequently melt at lower temperatures than either of the elements on its own. Since iron ores, fuel and furnace lining behave like a multi-compositional system, those fractions which correspond to the composition of the multi-compositional eutectics of the system

[81] Slags with FeO values between 80 wt% and 90 wt% can indicate the fining of cast iron (Kronz & Keesmann, 2003, p. 271).

(e.g. Optimum 1 and 2) become liquid first, whereas the others remain in a solid state. The composition of the low-melting fraction is first of all determined by its constituents and not by the mineral composition of the source materials. Also, fluxes can change the composition of a batch towards low-melting compositions, and the closer a composition comes to the eutectics of a system, the more, and the more easily, slag can be formed. Moreover, minor and trace element concentration varies throughout the slag and possibly alters the liquidus and solidus behavior of the melt. As has been described in section 1.4.2 and summarized by Young and Poyner (2014, p. 93), temperatures in bloomery furnaces are frequently higher than the lowest melting point derived from the ternary diagram would suggest. The partial-melt model of Hauptmann (2014, pp. 100-101) is reflected in the variation of composition of slag within one slag block or from one tapping event (e.g. Humphris et al., 2009). Therefore, not only slags at optimum conditions represent the smelting event, but also slags that fall into fields of higher solidus temperatures on the ternary diagram (Young & Poyner, 2014, p. 93). Melting experiments have shown that the temperatures between initial melting and the fully molten final phase range from 100 °C to 300 °C (Friede et al., 1982, p. 44). The example suggests that when temperatures were kept at a constant low level, refractive inclusions were quite frequent in bloomery slags (Hauptmann, 2014, p. 101). Experiments also showed that estimations of solidus temperatures deduced from plotted data in a phase diagram could exceed temperatures that were found when testing the real solidus behavior of the same sample for 500 °C (Gale, Papastamataki, Stos-Gale & Leonis. 1985, as cited in Rehder, 2000, pp. 111-112). More skepticism about the reliability of the significance of phase diagrams has been raised by Schiller and Kronz (2004). On the basis of their melting experiments they claimed that pre-industrial melts were frequently manageable at temperatures below 1100 °C, because minor and trace elements can also alter the chemical behavior towards lower liquidus/solidus temperatures, and supercooling effects of SiO_2-rich slags hampered the early solidification of a melt.

Besides the plotting of the main components of samples in ternary diagrams, trace-element ratios can be used as distinctive elements to model groups of slags and groups of ores in binary diagrams, in particular when using lithophile elements (section 4.2.8) (e.g. Yalçin & Hauptmann, 1995; Kronz & Keesmann, 2005). Whenever a representative sample of slag is given from a secured context, multivariate analyses are the best pattern recognition techniques to identify slag clusters and variations in bloomery smelting (e.g. Charlton et al., 2013, pp. 425-428; Iles, 2010). However, it is at the discretion of the scientist to interpret such groupings as the expression of resource variation, or manipulation and technological diversity.

1.7. Classification of lithic material

Retouched artifacts and cores found in the assemblages of the Ironworking Groups were classified according to Richter's classification scheme (Richter, 1990; 1991).

Pieces of raw material were classified to be cores if they showed at least three removal negatives. Six core types were distinguished: single platform cores, conical or cylindrical cores (code 1), discoidal cores (code 2), bipolar cores (code 3), polyhedral cores (code 4), bilateral discoidal cores (code 5), and irregular cores (code 6). The preforms were divided into flakes < 15 mm, flakes > 15 mm and blades. Flakes smaller than 10 mm were considered chips. Debitage comprised material that fell neither into the categories of flakes (identifiable ventral face), nor cores (i.e. at least three removal negatives). The raw material was classified into opaline silica or chalcedony (RM code 1), quartzite (RM code 2), sandstone (RM code 23), quartz (RM code 4), limestone (RM code 9), and unidentified raw material (RM code 99). Chalcedony and quartzite can be subsumed as silcretes and are typical local weathering products as described in section 1.3.2.5. Chalcedony can be found in banded or nodular horizons in local calcrete hardpans, as part of the massive silcrete layers of the Eiseb Formation or as nodular aggregates in matrices of Kalahari sand (section 1.3.2.9) (Netterberg, 1974; 1982). The quality of the material can strongly vary within centimeters from a coarse quartzitic material to opaline silica. The first consists of sand grains in alternating frequency cemented by opaline silica. This coarse material can grade into siliceous deposits with less or no sand grains, described as chalcedony or opaline silica, which make my distinction between chalcedony and quartzite most arbitrary. Material with an estimated area of more than 30% of grainy inclusions was considered quartzite, material with less grainy inclusions was attributed to chalcedony.

2. Site catalogue

2.1. Site catalogue no. 1, Bunya

(Tabel 1, Figure 26)

Site Number: N97/09
Site Name: Bunya
Coordinates: E19°21.441′/S17°51.504′
Constituency: Kapako
Plane Survey Sheet Namibia 1:50000: 1719 CD BUNYA (SAMBUSU)
Survey: 1997
Excavations: -
References: Richter, 2005, p. 86: Catalogue No. 1
Registration Number State Museum Windhoek: B4288
Location: Bunya Catholic Mission, about 250 m east of the girls' hostel building.
Altitude: 1076 m AMSL
Land Owner: Bunya Catholic Mission
Topography: The site is situated at the edge of a lower terrace of the Kavango River. The area is sparsely covered with grass, shrubs, and trees.

Site Appearance: Artifact scatter derived from a cultural layer near the surface of 30 cm to 40 cm in thickness and 100 x 150 m in extension.

Finds: Decorated and undecorated potsherds of the LIG occupation horizon (Tables 4 and 13, Appendix 3).

Pottery Style: Vungu-Vungu style.

Interpretation: This was a settlement site of Late Ironworking Groups.

2.2. Site catalogue no. 2, Karangana

(Tabel 1, Figure 26)

Site Number: N98/40
Site Name: Karangana
Coordinates: E19°24.870′/S17°52.324′
Constituency: Kapako
Plane Survey Sheet Namibia 1:50000: 1719 CD BUNYA (SAMBUSU)
Sub clusters:
N98/40-1(E19°24.903′/S17°52.277′),
N98/40-2 (E19°24.881′/S17°52.271′)
Survey: 1998, 2006
Excavations: -
References: Richter, 2005, p. 86: Catalogue No. 2
Registration Number State Museum Windhoek: B4288
Altitude: 1088 m AMSL
Location: North and south of National Highway B10 from Rundu to Nkurenkuru opposite to the Karangana Gospel Church.

Topography: Flood-free middle terrace of the Kavango River with sparse vegetation cover. In the southern part of the site is an abandoned homestead and agricultural area. The general slope of the area towards the river is 4.7%. The red loamy sandy soil is covered with aeolian sand deposits. There are deep erosion grooves towards the river at the edge of the terrace.

Site Appearance: Surface scatter of artifacts of at least 200 x 200 m in extension. South of the highway, one may expect undisturbed cultural layers at about 50 cm below the present day surface. Quarry work destroyed the northern part of the site. Displaced finds were scattered among the quarry residues and eroded artifacts were concentrated in the erosion gullies towards the river. The site was only sparsely vegetated.

Finds: Thirty-one finds were collected from the surface (Table 4, Appendix 3). The potsherds (Table 13, Appendix 3) were predominantly brittle EIG ware with organic temper. Several shards were found as well. The decorated pottery belonged to the EIG as well as LIG occupation periods. The shards were associated with lithic material. Four chips, one flake and one blade (Table 13, Appendix 3) attested lithic tool production at the site. They were found together with two single-platform cores, one polyhedral core and one bilateral discoidal core. Preforms and cores consisted of very fine opaline silica.

Pottery Style: Kapako/Divuyu and Vungu-Vungu style.

Lithic Typology: Unspecific, perhaps Late Stone Age.

Interpretation: This was a settlement site of the Early Ironworking Groups, which was disturbed by the quarry. The younger pottery of the Late Ironworking Groups may well belong to the contemporary settlement.

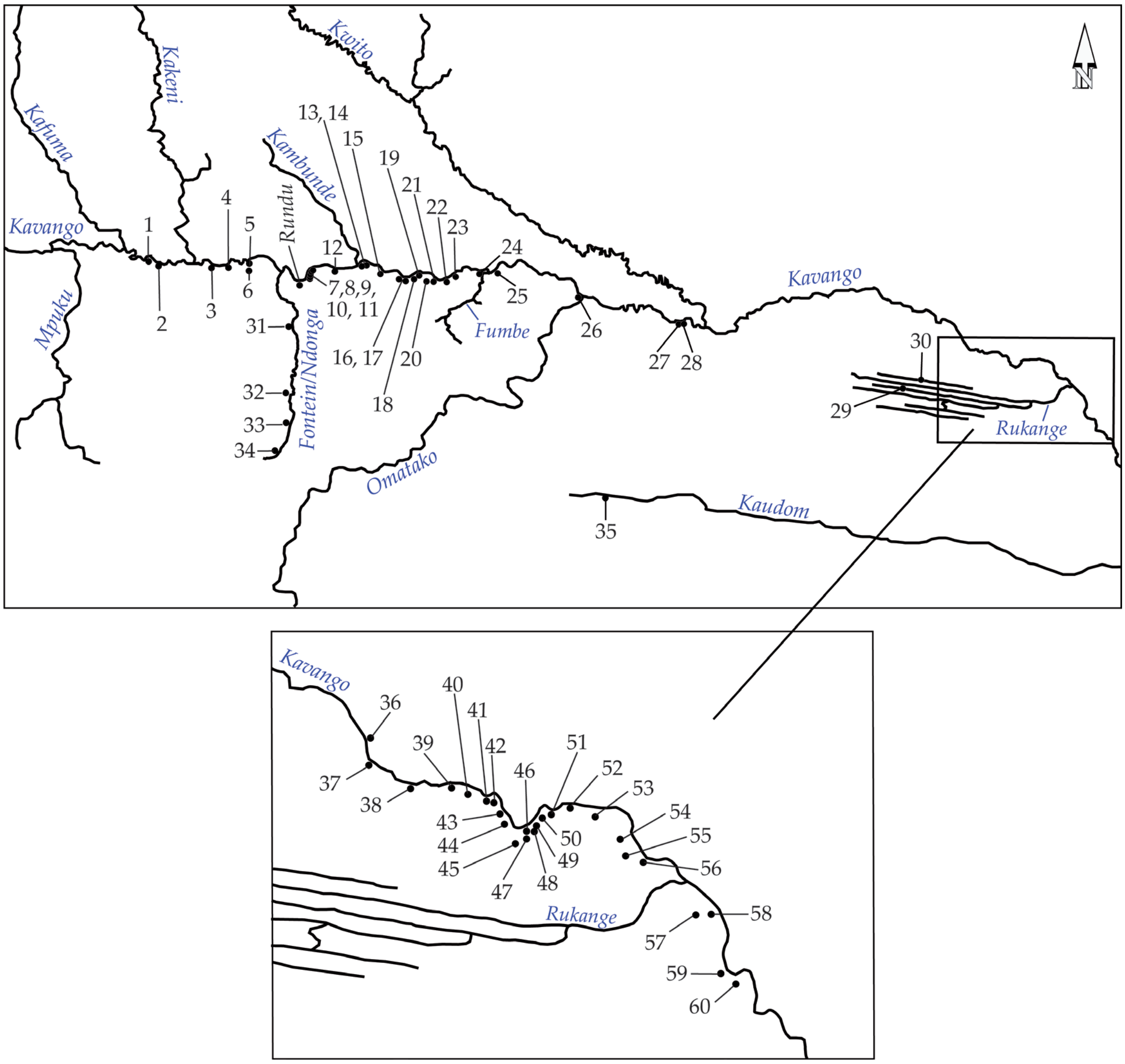


Figure 26: Location of site catalogue nos. SC 1 to 60 in the middle Kavango region.

2.3. Site catalogue no. 3, Ruuga

(Table 1, Figure 26)

Site Number: N98/39
Site Name: Ruuga
Coordinates: E19°31.665'/S17°52.461'
Constituency: Kapako
Plane Survey Sheet Namibia 1:50000: 1719 DC MUPINI
Sub clusters (Figure 27):
N98/39-1 equivalent to N98/39-2 (E19°31.755'/S17°52.360'),
N98/39-3 (E19°31.755'/S17°52.332'),
N98/39-4 (E19°31.665'/S17°52.461'),
N05/01 (E19°31.527'/S17°52.485'),
N05/02 (E19°31.827'/S17°52.342'),
N05/10 (E19°32.026'/S17°52.389')
Survey: 1998, 2006, 2007, 2011
Excavations: 1999, 2005
References: Richter, 2005, pp. 86-87: Catalogue No. 3
Registration Number State Museum Windhoek: B4288
Altitude: 1078 m AMSL
Location: North of National Highway B10 from Rundu to Nkurenkuru
Land Owner: Muronga and Paulina Heimbili

Topography: The archaeological site is situated on a flood-free middle terrace of the river. The terrace inclines approximately 4% towards north and the slope of the excavation area is around 6%. The soil body consists mainly of sand. It is therefore highly permeable and prevents drainage lines of surface water, which may disturb the find-bearing layer. As can be seen in Figure 31, the archaeological material is embedded in a sandy matrix of 110 cm maximum depth. Within the soil body, a

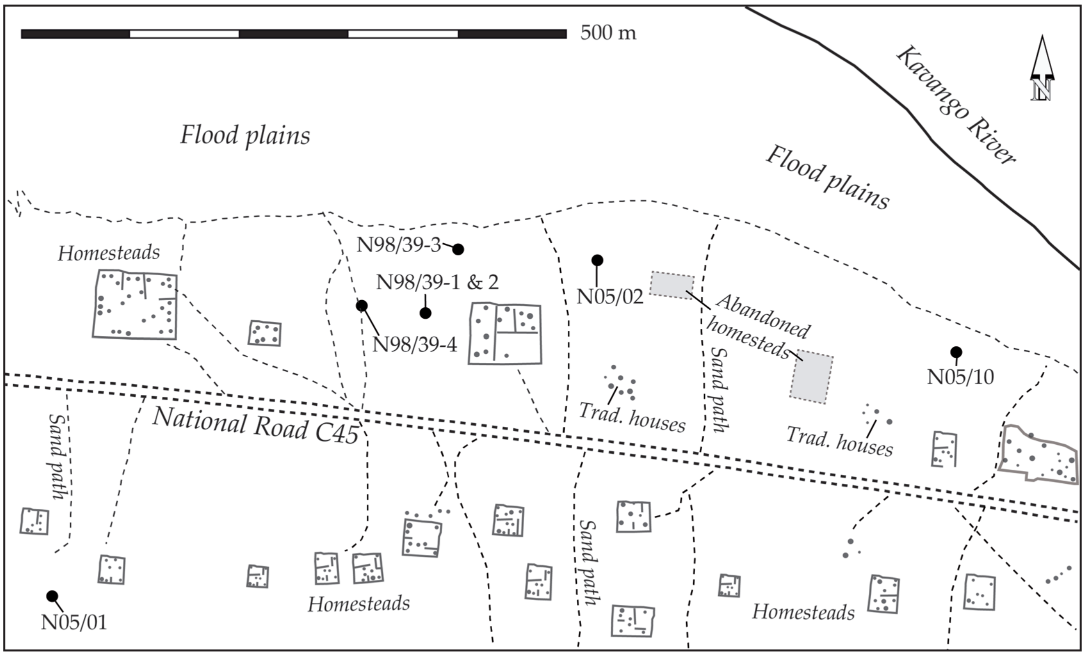


Figure 27: Site layout of SC 3 Ruuga.

massive calcrete crust has formed. The soil cover decreases towards the river owing to erosive processes to a maximum depth of 30 cm above the calcrete hardpan in the northernmost units of the excavation. Strong winds may be one cause of the deflation (e.g. Holdaway, 2014, p. 2087), and frequenting residents and cattle have certainly pushed the sediment farther downhill in modern times. As will be discussed in detail in the stratigraphy section, the vertical mapping of lithics and pottery disclosed that the finds per cubic meter strongly increased 20 to 40 cm below the surface. In the northern units, the main concentration horizons are closer to the underlying calcrete crust than in the southern units (Figure 30). As the total number of finds per unit does not differ from the range of quantities found in the northern units, it is likely that fine-grained material was blown away before the site became covered by new sandy aeolian material. However, the site did not become evenly deflated because the artifacts of the units farther uphill are markedly less condensed.

Site Appearance: The Ruuga site stretched approximately 700 m from east to west along the edge of the river terrace (Figure 27). The extension of the site from the river southwards was difficult to interpret but comprised 100 m or more. The spot was sparsely covered with vegetation. Shrub alignments indicated enclosures of abandoned homesteads. At the edge of the terrace local people mined for calcretes, which was used for house constructions (section 2.3.2, Figure 79). Apart from this, the site seemed to be undisturbed. In several places, artifacts were scattered around, and many of them were found in quarry residues.

2.3.1. Main excavation site N98/39-1 and N98/39-2

2.3.1.1. Excavation method

In 1998, archaeologists from the University of Cologne led by Juergen Richter discovered the site during survey activities along the river. One year later, starting from a shovel test pit, the same team excavated a 2-m² test unit in levels of 20 to 50 cm in thickness (N98/39-1). The excavation revealed a Late Stone Age lithic assemblage mixed with Kapako/Divuyu-Style pottery, slag and iron (Richter, 2005, pp. 86-87). In 2005, a further 29 1-m² units were excavated adjacent to N98/39-1 (Figures 28 and 29). The upper soil layer was removed in two layers of 20 cm in thickness. The next 20 cm was removed in levels of 10 cm until the main artifact-bearing horizon started. From there, the levels were excavated in four quadrants of 5 cm in thickness until the hardpan was reached (Figures 33 to 36). The soil was screened through a 4 mm wire mesh. Based on a grid system, the units were first excavated alternately in order to better assess the site, and to create sections along both axes. Finally, the southern 12 m² were completely excavated because they provided the

Figure 28: SC 3 Ruuga: excavation N98/39-2 in 2005.

best preservation conditions. Soil samples were taken from the western cross section in unit 50/50.

2.3.1.2. Stratigraphy

In the southern units, the find-bearing layer was covered by approximately 50 cm of soil deposits, and it was well protected from modern activities. Krotovinas of small burrowers occurred throughout the units in form of roundish inclusions of pale sand. Several tunnels were unfilled. The vertical mapping of modern materials found at the site (Table 20, Appendix 3, Figures 45 to 47) clearly showed the backfilled test pits of N98/39-1 in the units 50/51d, 50/52c and d, and 50/53c. In the undisturbed units, modern materials are commonly distributed as far down as 50 cm below the surface. The soft soil causes heavier visitors, such as bovines and humans, to sink easily as far as 30 cm into the ground, and thus shift modern material to lower soil regions. Another dislocating factor is certainly burrowers, in particular if plastics and textiles are found below the datum line as can be seen in units 50/51a and b, 50/54 c and d, and 50/55d. Backfilled tunnels may also contain some modern material. In addition, ball-rolling dung beetles were active at the site. Increased ant activity may have affected the stratigraphy of the site to the effect that fine particles were moved to the surface and larger particles such as archaeological artifacts remained in their original position and became covered by the sediment the ants transported upwards (Fey, 2010, pp. 154-158). Another indicator of younger disturbances was the presence of LIG pottery, which possibly derived from an abandoned homestead 70 m west of the site. However, despite the LIG settlement nearby, Vungu-Vungu-style pottery was scarce. Individual pieces were commonly found down to a level of 30 cm below the surface, and in three cases as deep as 50 cm. The highest frequency of LIG pottery occurred in unit 51/53 with six shards in level 370, 30 to 50 cm below the surface.

Fine dune sands dominated the soil body of Ruuga, and the soil formation is weak at the site (Figure 31). The surface layer consisted of more or less 20 cm of gray-brown (MCC 10YR5/2) slightly silty fine sand, loose in consistency and mixed with modern material and eroded artifacts (Figure 30). As described earlier, the surface is only thinly covered with grass. Thin roots penetrated the soil as deep as 1 m below the surface. Beneath the loose surface layer the soil changed gradually into a very

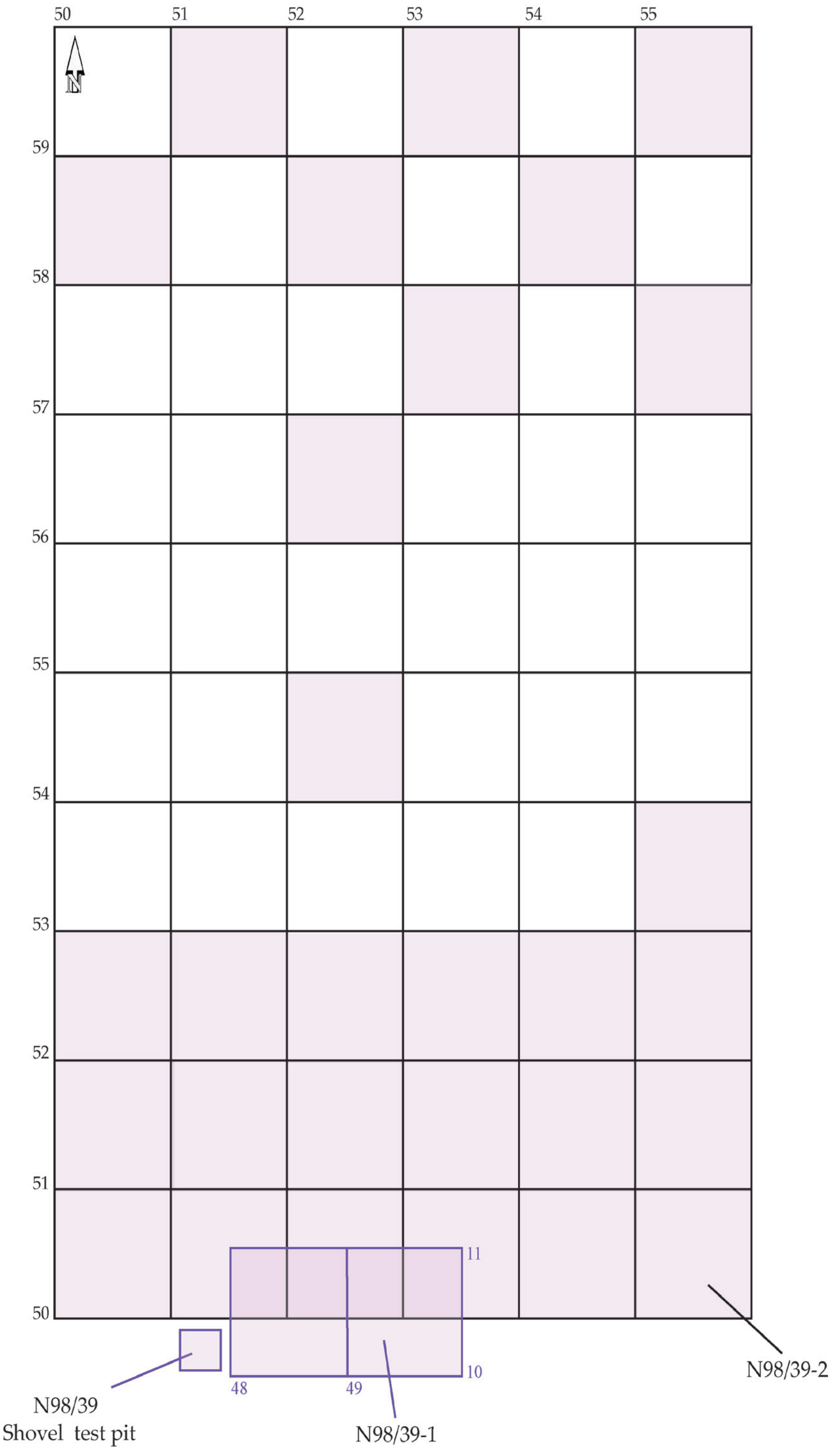


Figure 29: SC3 Ruuga: layout of the excavated areas N98/39-1 and -2 (excavated units marked in pink).

homogeneous silty fine sand of dark grayish brown (MCC 10YR4/2) in color, which was slightly calcareous and hard under dry conditions (Figures 30 and 31). As can be taken from the vertical mapping of the main find categories pottery and lithics in Figures 37 to 44, the archaeological material concentrated mainly from around the datum line to 20 cm below it. However, there was no change in soil color (for instance owing to charcoal concentrations or humic material) that went along with the recorded artifact concentration (Figure 31). It is assumed that during the occupation of the site by the Early Ironworking Groups the soil consistency was not much different than it is today. It is most likely that the discarded artifacts were dislocated by walking individuals in the same way as has been observed in recent times, except that cattle was most probably not present in the area at around 500 AD. Because of this, I consider the main archaeological horizon to be a layer of increased density of finds starting from 10 cm above the datum line to 20 cm below it. Moreover, when interpreting the site, one should keep in mind that the dislocation of finds (for instance lithic chips and cores) could distort the identification of activity zones. At about 70 cm below the surface, the soil changed gradually into an increasingly calcareous horizon with soft, slightly silty fine sand, lighter in color than above (grayish brown, MCC 10YR5/2) with many hard $CaCO_3$ concretions (up to 5 cm in diameter) toward the bottom. The calcareous layer finally bordered on hardpan carbonate of about 3 m in thickness (Figure 32). With increasing depth, most artifacts were covered by a thin $CaCO_3$ coating, which attested that the crust formation is still ongoing. If one looks at the south-north running profiles depicted in Figures 48 and 49, the number of finds in weight and pieces per unit markedly increased towards north. As has been described earlier, the soil body decreased towards the edge of the middle terrace (Figure 30) due to erosive processes, but even so the number of total finds did not

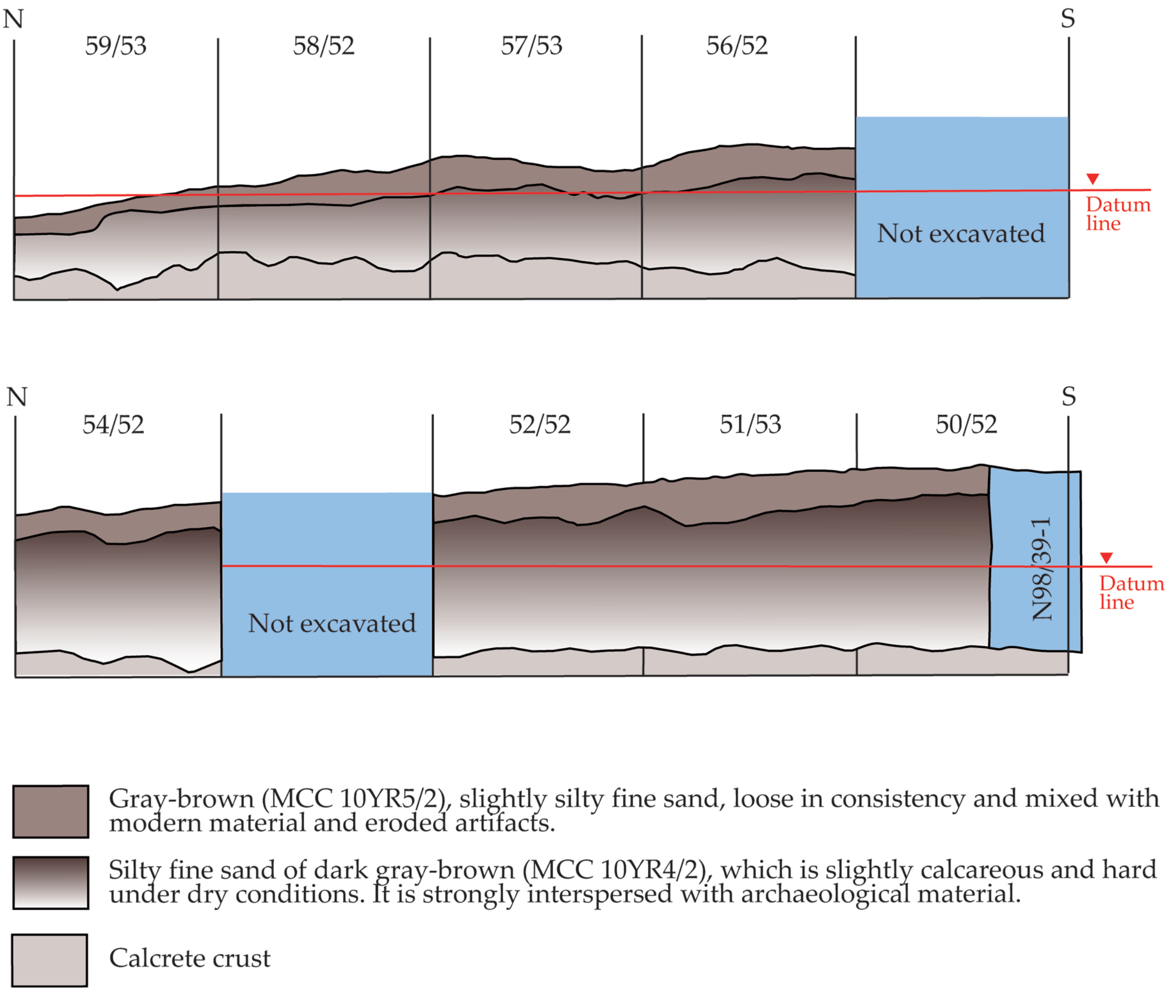


Figure 30: SC 3 Ruuga, area N98/39-2: north-south running cross section.

exceed the frequency of artifacts found in the better preserved units 50/50 to 52/55 (e.g. Figures 64 to 66). Because of this, I consider the assemblage largely complete though condensed into a much smaller soil body than the finds of the southern units. Deflation is also known to create 'mixed' or 'conglomerated' assemblage of archaeological material, which does not belong to the same archaeological time horizon. The result of such deflation processes is known to be rather a geological aggregate than an archaeological site (Holdaway, 2014, pp. 2087-2089, Kelly & Thomas, 2014, p. 57). When analyzing the finds from Ruuga, it naturally followed to suspect the site to be a mixed assemblage because lithics, pottery *and* metallurgical slags were found together. However, the vertical mapping again implied that the finds belong to one occupational horizon because in the southern units with less or no deflation, the three find categories described above occur together. There is no difference in the quantitative ratio among each of the find categories throughout the profile from layer to layer. For instance, lithic material did not appear in a higher frequency in deeper strata than pottery (see vertical index of lithics and pottery in Figures 48 and 49, such as seen in unit 70/45 of Kapako (SC 3, section 2.4.4.5). The pottery is chronologically linked to the metallurgical activities by the radiocarbon-dated tuyere found in unit 51/54c, 55 cm below the surface (COL#2332.1.1, Table 2, Appendix 3), and dating back to roughly the fifth century AD.

2.3.1.3. Radiocarbon dates

In the current state of research, 18 radiocarbon dates are available from the site (Table 2, Appendix 3). First dates have been produced by Juergen Richter from charcoal samples collected from the soil body of the two test units N98/39-1 (Figures 29 and 50). However, as can be taken from Table 2

Figure 31: SC 3 Ruuga, area N98/39-2: soil section of unit 51/55 facing south.

(Appendix 3), the charcoal samples taken from the sediment are not reliable as to the age of the finds. From the four dates (KN-5577, KN-5578, KN-5576, Poz-20669), the oldest (KN-5576) originated from the upper soil levels of the site, and the youngest from a central position within the profile (KN-5577). The latter was the only sample that fell into the same time range as the pottery. Sample Poz-20669, taken from the same vertical position within the profile as KN-5577 (Figure 50), but collected at a distance of some 2 m away from the latter, produced a calendar age roughly 1100 years older than KN-5577 (Figure 162). Owing to these unsatisfactory dates, I decided to date the finds directly by their own C-content. One source of charcoal was the pottery found at the site because most of the shards were tempered with organic substances. Pieces of carburized material of 1 to 2 mm in size were extracted under microscopic magnification for conducting AMS-dating. The 2-sigma calibrated results of eight dates obtained from this procedure ranged from the beginning third century to the turn of the eight century cal AD (Figures 50 and 162, Table 2, Appendix 3, Poz-20675, Poz-20676, Poz-20695, Poz-20696, Poz-20697, KIA28853, KIA28854, Poz-20674). The resulting time frame corresponded to related pottery from other archaeological sites (see section 3.2, Figures 164 and 167). The early smelters produced the blowing pipes in the same way they produced domestic pottery and also tempered them with organic substances and small charcoal particles. The carburized organic sample taken from one tuyere fragment found in unit 51/54c, 55 cm below the surface, dated the metallurgical activities as far back as the fifth to the mid-sixth century cal AD, according to the 2-sigma range of calibration (COL#2332.1.1, Table 2, Appendix 3, Figures 50 and 162). Another alternative appeared to be the direct dating of slags. A trial was made to extract carbon directly from slag samples and to determine the age via AMS-dating (Table 2, Appendix 3, KIA28850, KIA28851). Unfortunately, both samples yielded insufficient organic carbon (< 0.05%), so that the samples' results may be affected by contamination from sedimentary carbon or intruding roots (Pieter M. Grootes, personal communication, 2006). Besides the reduced carbon content, KIA28851 dated back to between the fourth and the second centuries cal BC (2-sigma calibrated result) (Figures 50 and 162), which I consider too old for the assemblage. It is most likely that the extracted material contained carbon from roots enclosed in the ores. This is not surprising because there is a strong possibility that the smelters used ore deposits near the surface (sections 4.1 and 5.3.1). In contrast, sample KIA28850 was dated to the tenth/eleventh century cal AD, which postdates the youngest dates of the pottery assemblage by more or less 150 years, and the tuyere (Table 2, Appendix 3, COL#2332.1.1) by roughly 250 years. It may well be that the site has been used for metallurgical activities up to the tenth or eleventh century, particularly in light of the late dates revealed from Kapako (SC 4) (Figure 162), but it is also possible that the sample became contaminated by some carbon of younger age as suggested by P. Grootes (personal communication, 2006). Another explanation would be that the sample belongs to the LIG metallurgical horizon discussed below, and showed the same distortion by old carbon as sample KIA28851. However, unit 52/54, where the sample was found, was not much disturbed by modern material or LIG pottery, and gave no reason to

Figure 32: SC 3 Ruuga, area N98/39-2: calcrete hardpan at the bottom of unit 52/54.

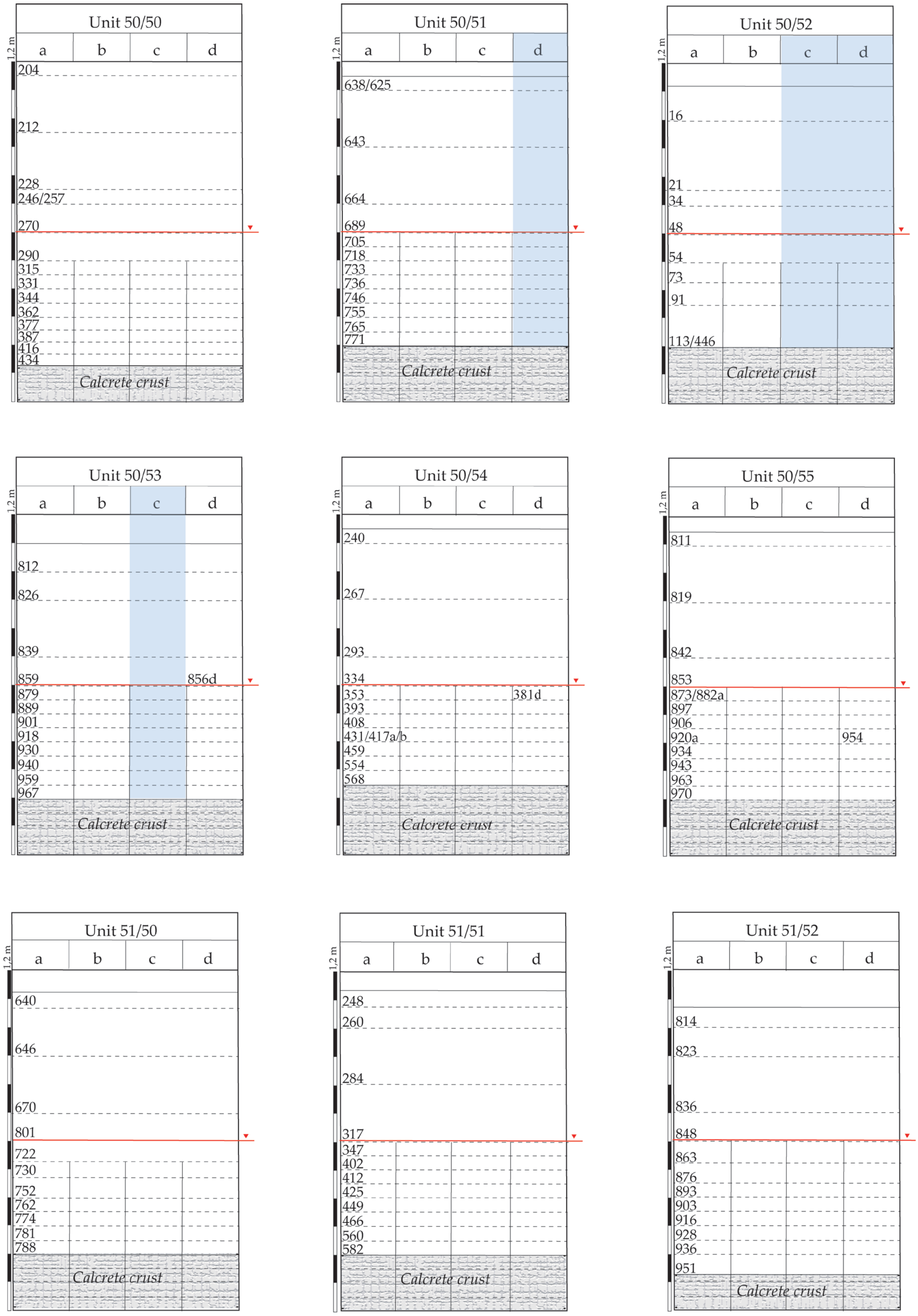


Figure 33: Level index of SC 3 Ruuga, areas N98/39-1 and -2: units 50/50 to 51/52, to be used in conjunction with the Tables 18, 19, 20, 21, and 31 (Appendix 3).

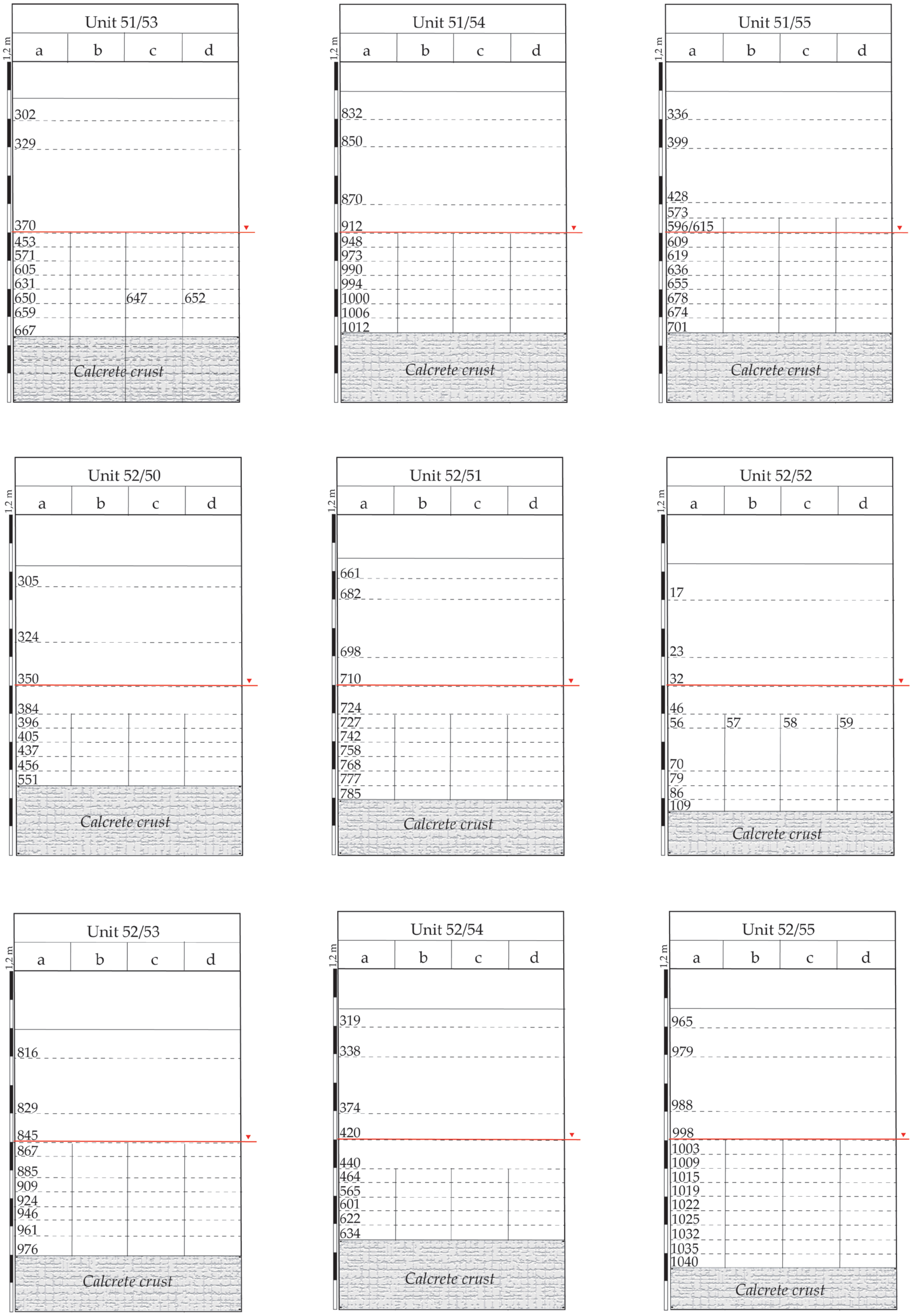


Figure 34: Level index of SC 3 Ruuga, areas N98/39-1 and -2: units 51/53 to 52/55, to be used in conjunction with the Tables 18, 19, 20, 21, and 31 (Appendix 3).

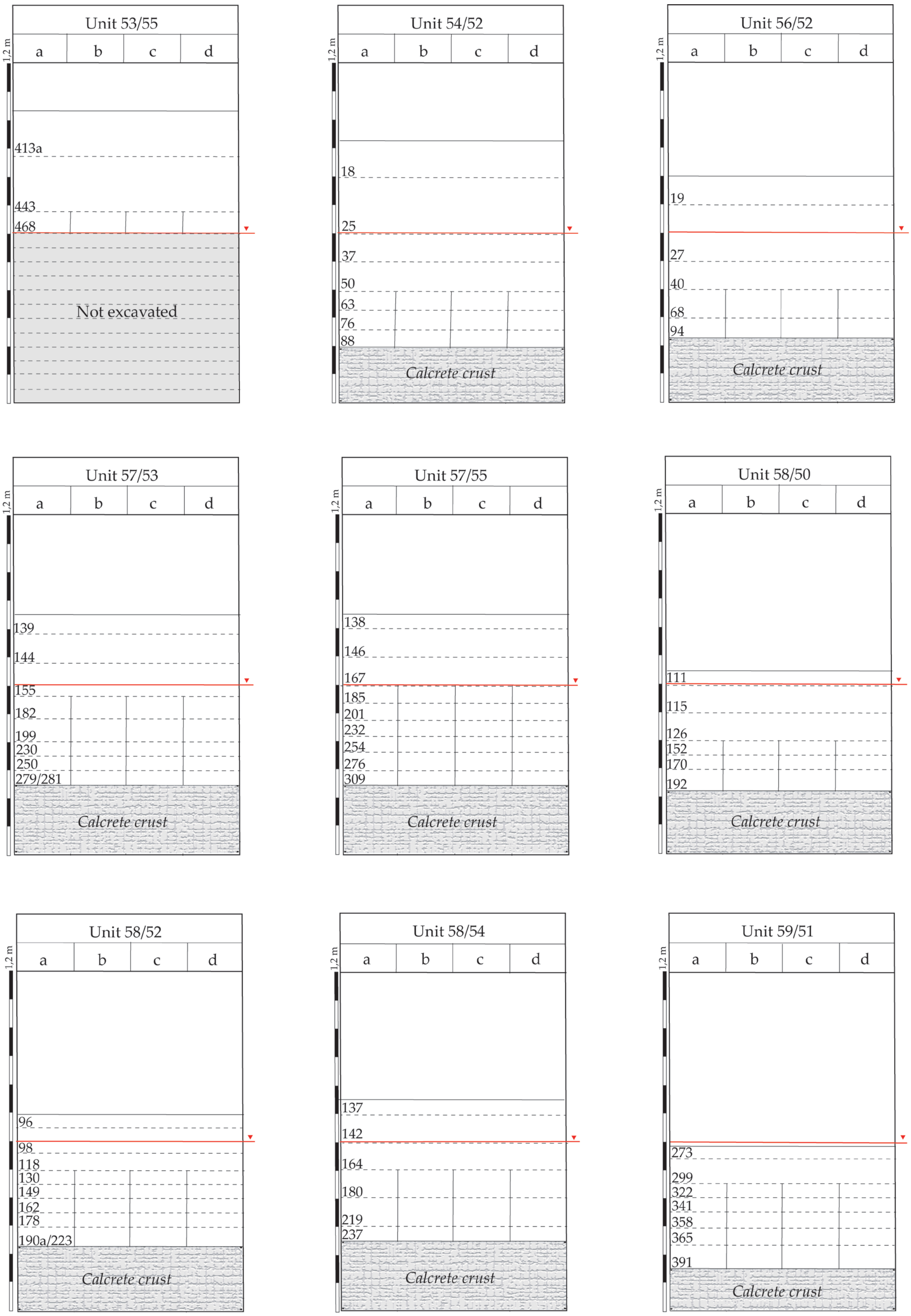


Figure 35: Level index of SC 3 Ruuga, areas N98/39-1 and -2: units 53/55 to 59/51, to be used in conjunction with the Tables 18, 19, 20, 21, and 31 (Appendix 3).

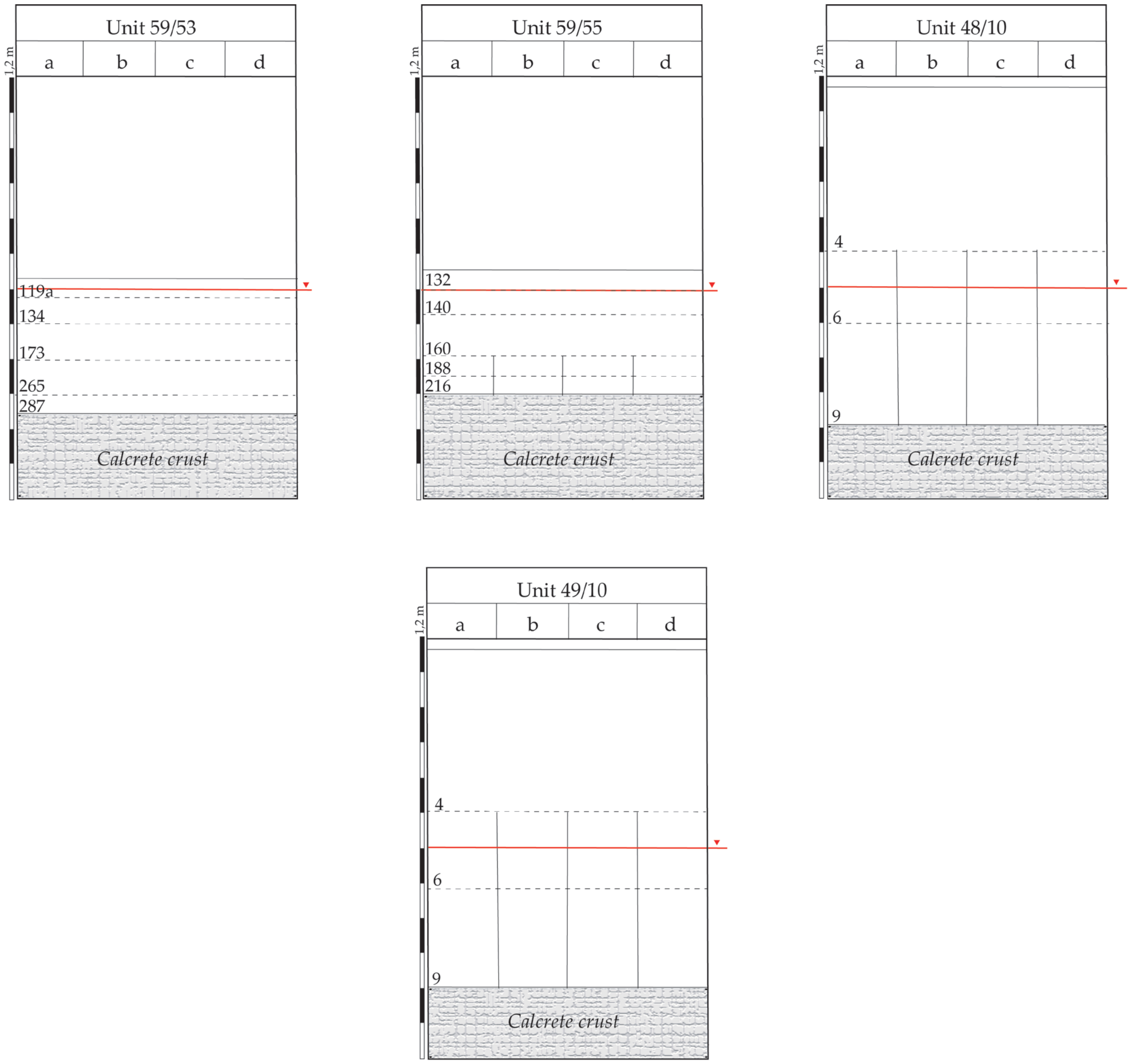


Figure 36: Level index of SC 3 Ruuga, area N98/39-1 and -2: units 59/53, 59/55, 48/10, and 49/10, to be used in conjunction with the Tables 18, 19, 20, 21, and 31 (Appendix 3).

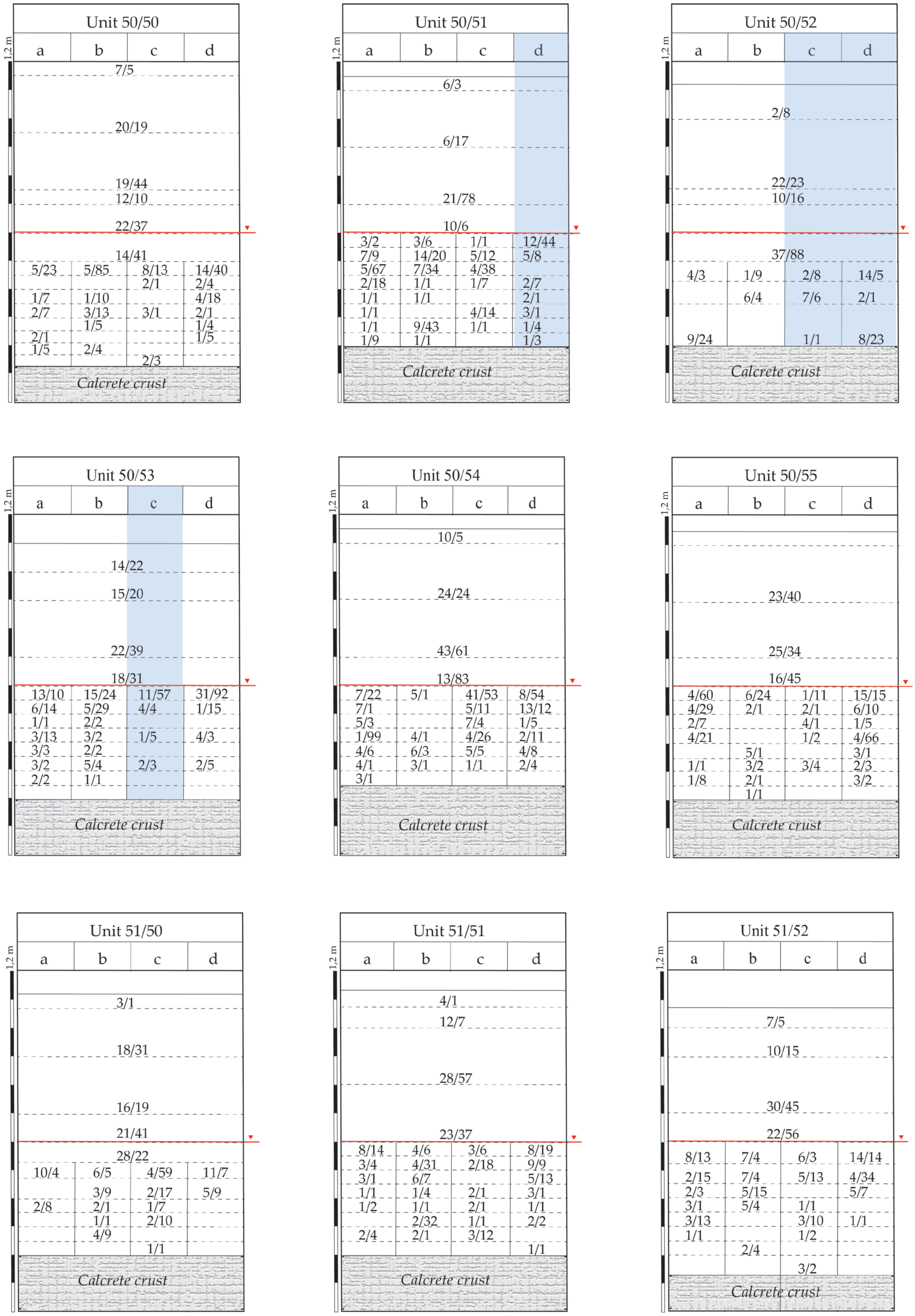


Figure 37: SC 3 Ruuga, area N98/39-1 and -2: vertical pottery distribution in units 50/50 to 51/52 (number/grams).

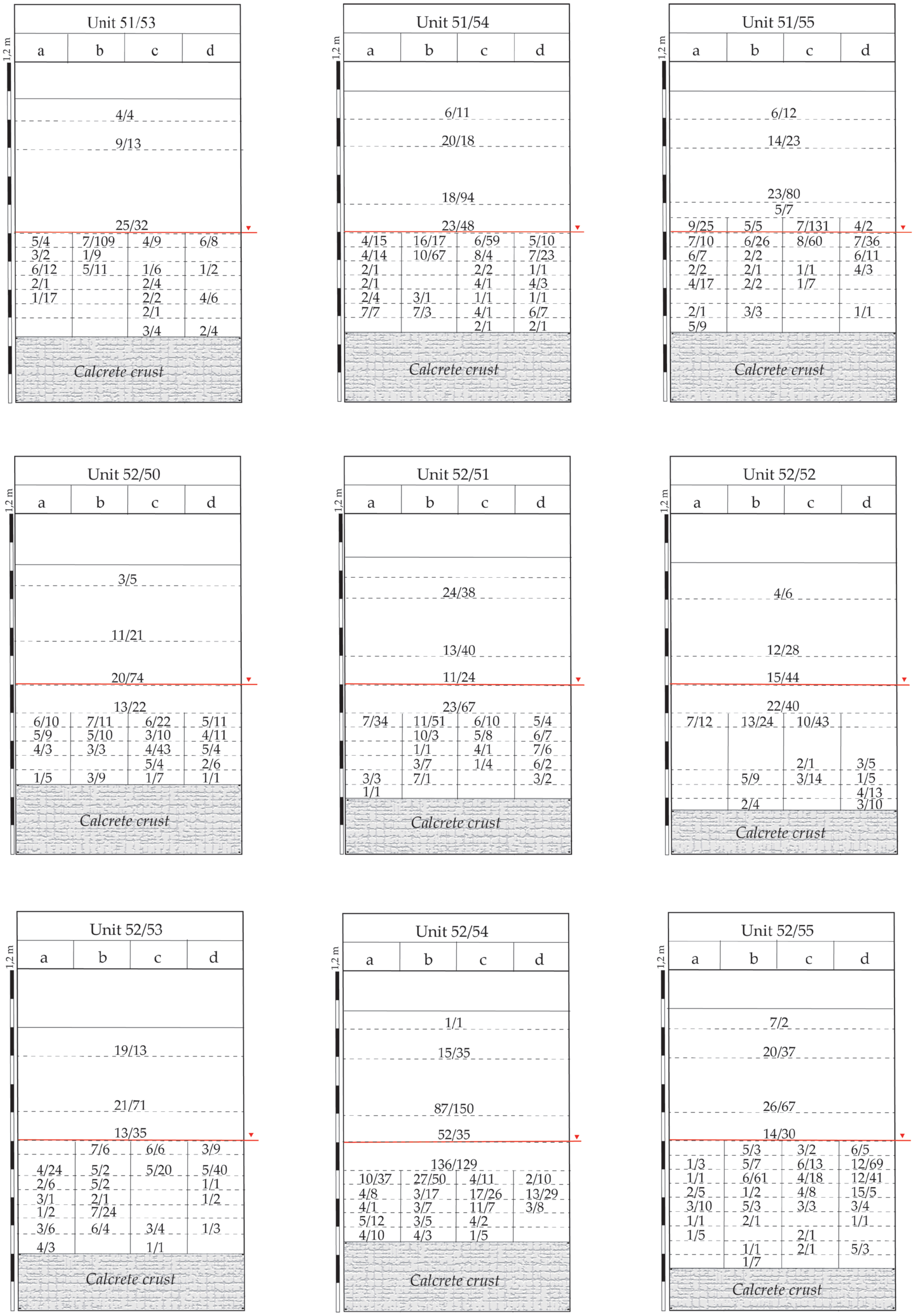


Figure 38: SC 3 Ruuga, area N98/39-1 and -2: vertical pottery distribution in units 51/53 to 52/55 (number/grams).

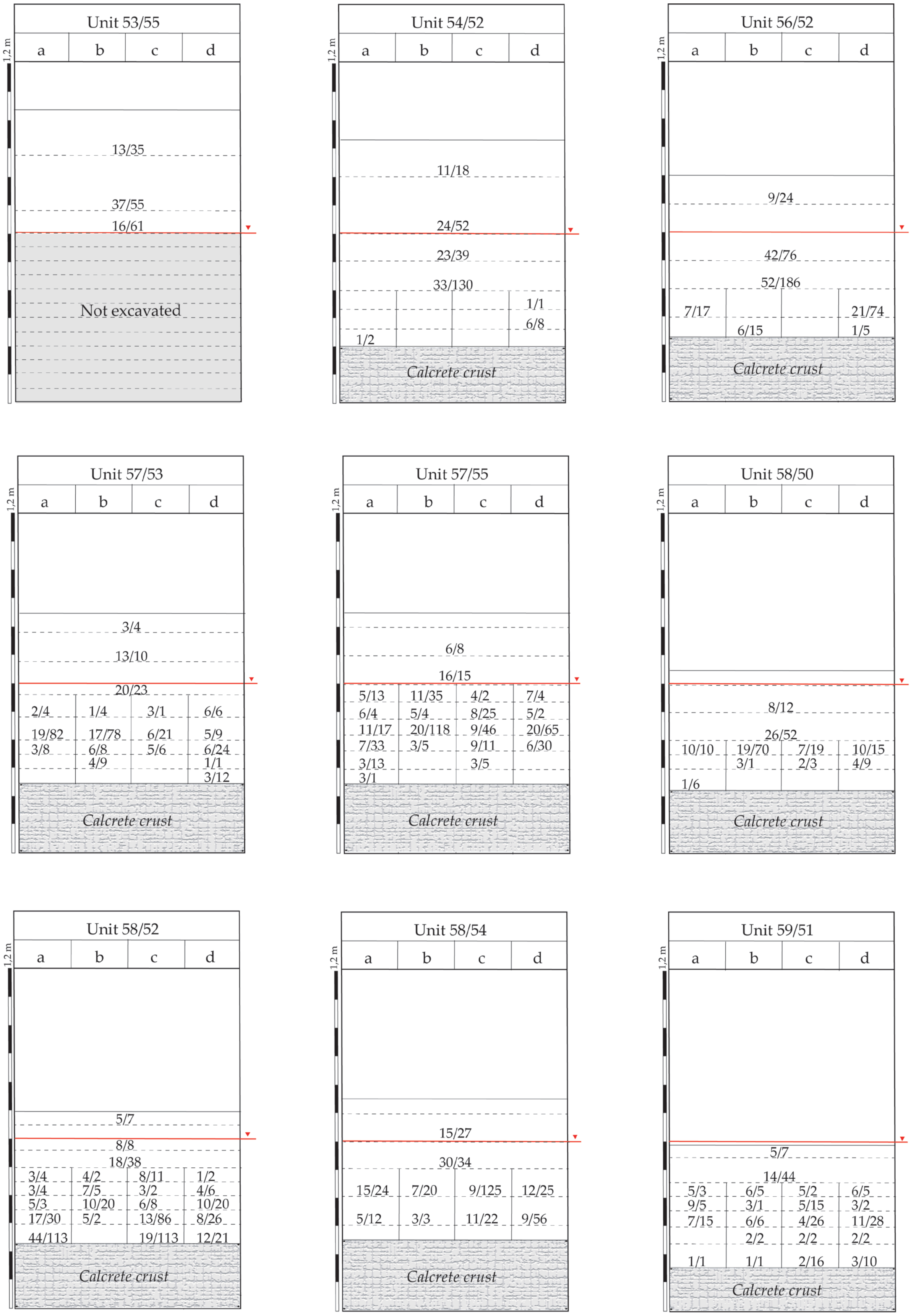


Figure 39: SC 3 Ruuga, area N98/39-1 and -2: vertical pottery distribution in units 53/55 to 59/51 (number/grams).

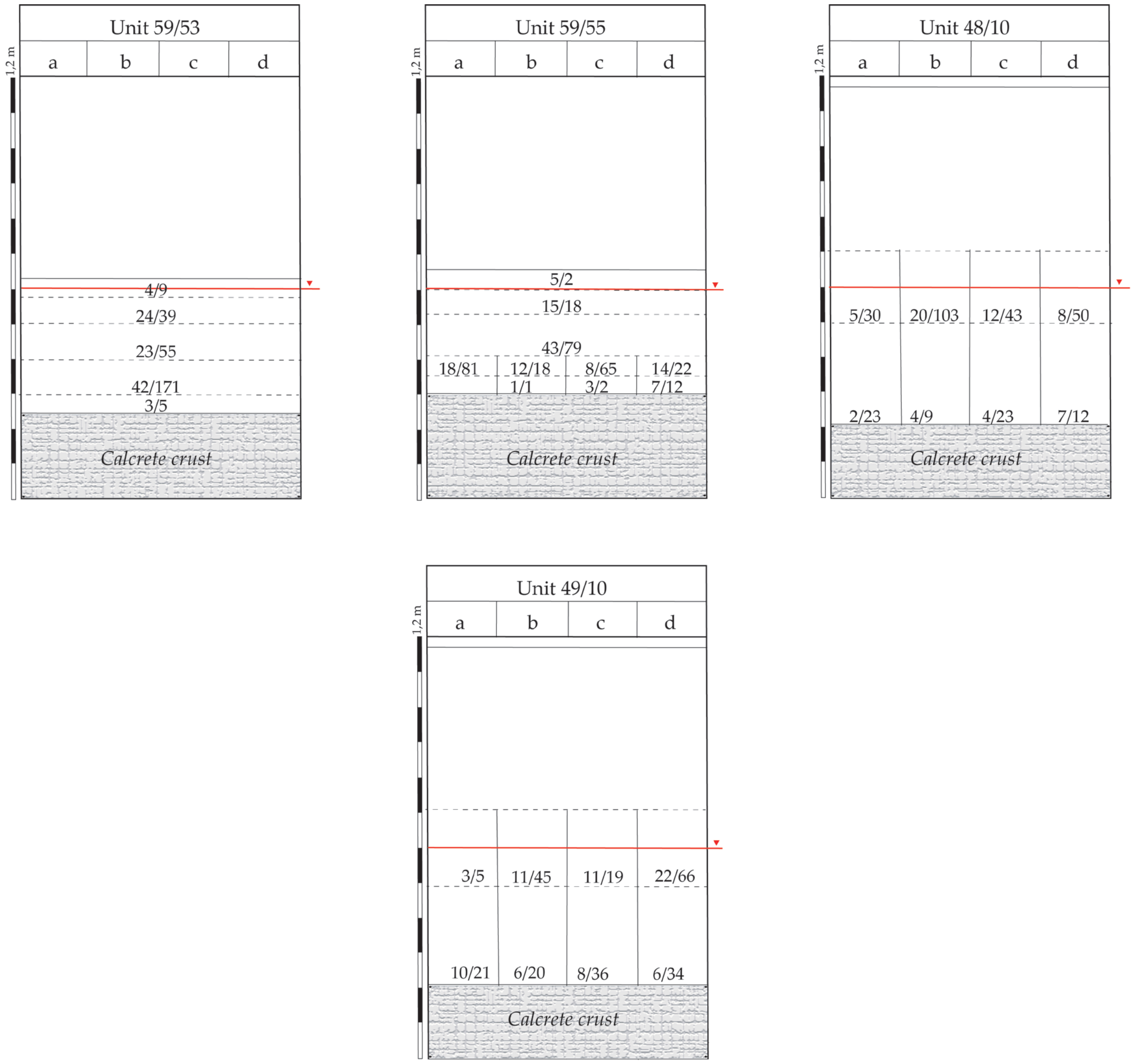


Figure 40: SC 3 Ruuga, area N98/39-1 and -2: vertical pottery distribution in units 59/53, 59/55, 48/10, and 49/10 (number/grams).

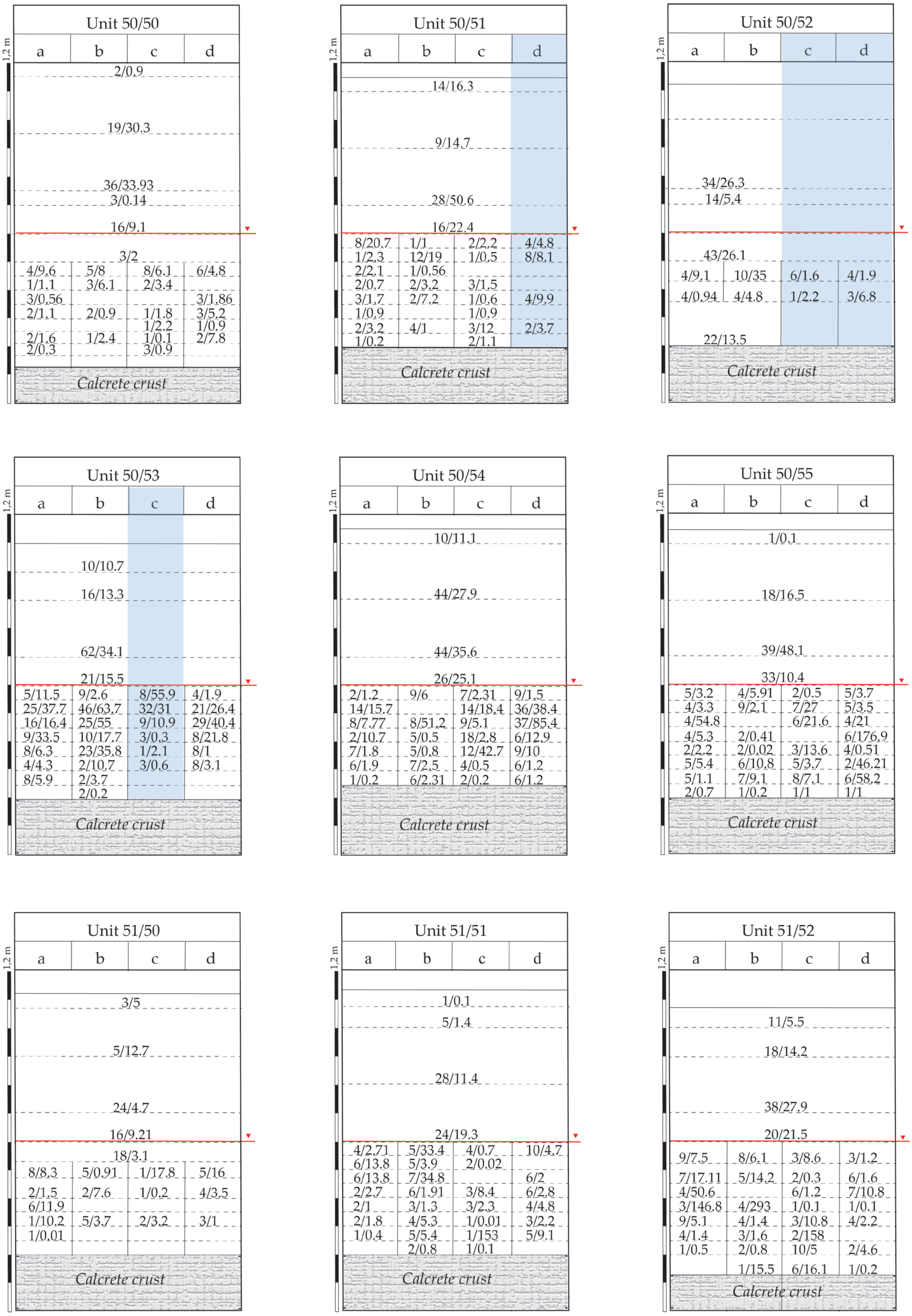


Figure 41: SC 3 Ruuga, area N98/39-1 and -2: vertical distribution of lithics in units 50/50 to 51/52 (number/grams).

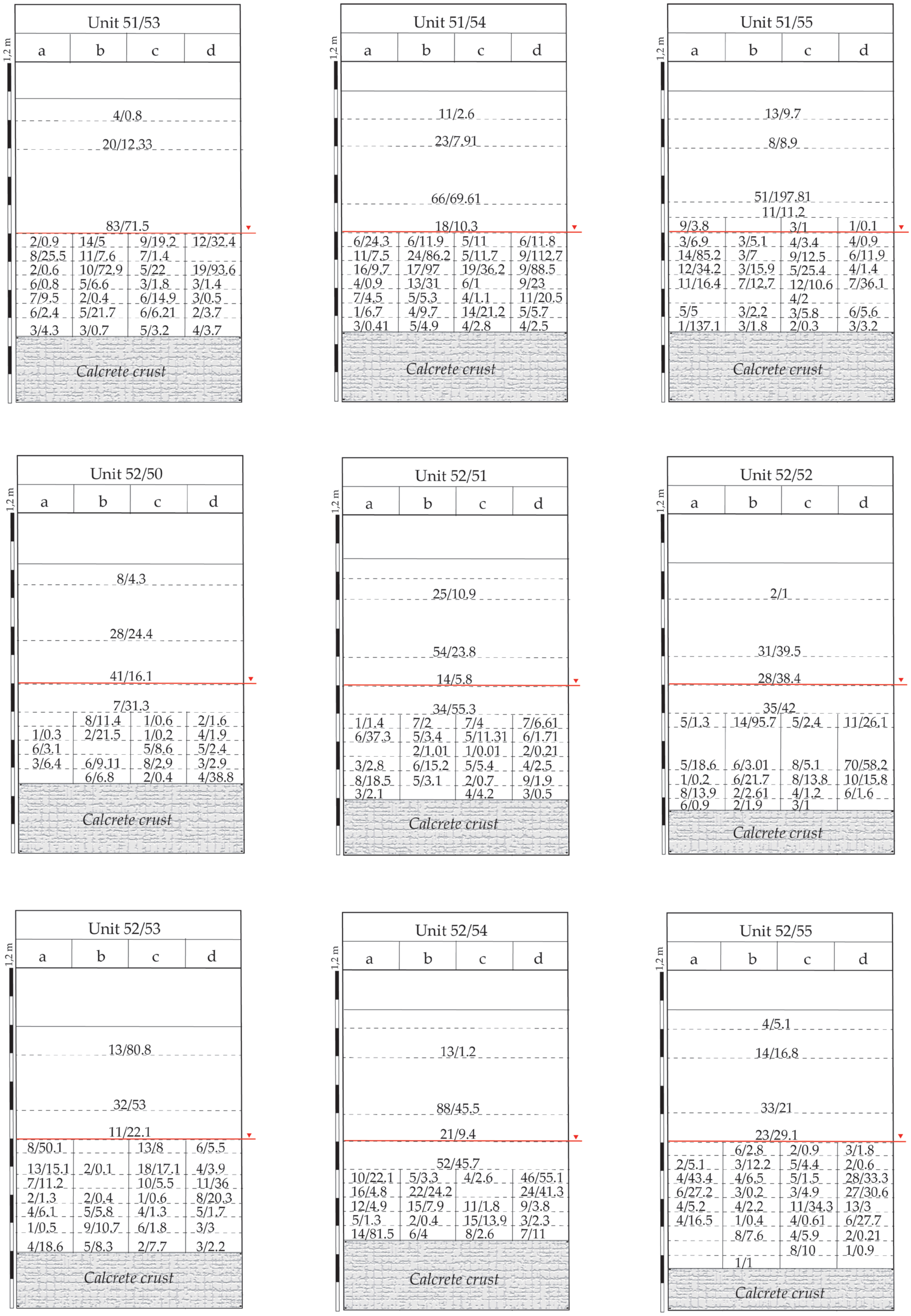


Figure 42: SC 3 Ruuga, area N98/39-1 and -2: vertical distribution of lithics in units 51/53 to 52/55 (number/grams).

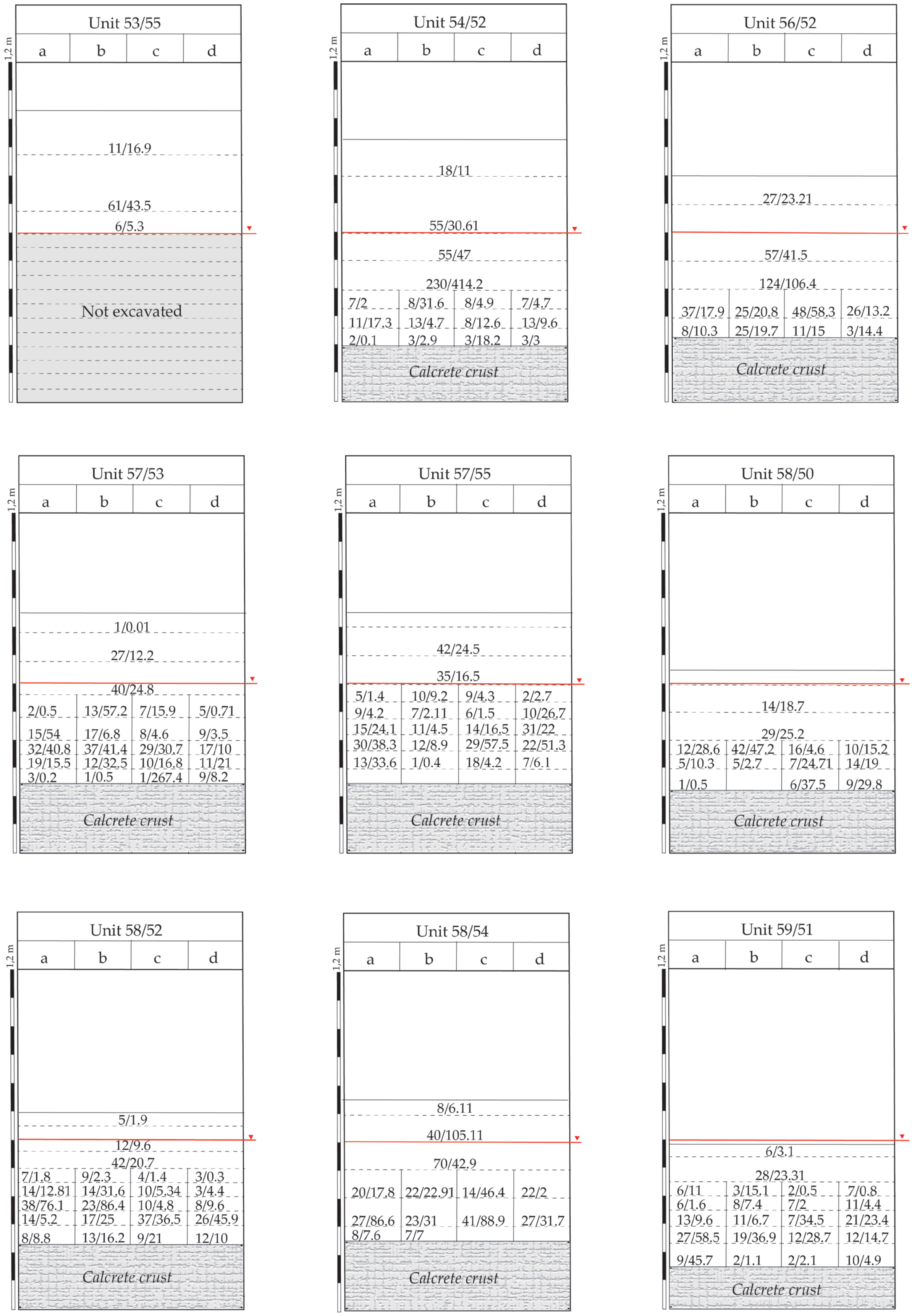


Figure 43: SC 3 Ruuga, area N98/39-1 and -2: vertical distribution of lithics in units 53/55 to 59/51 (number/grams).

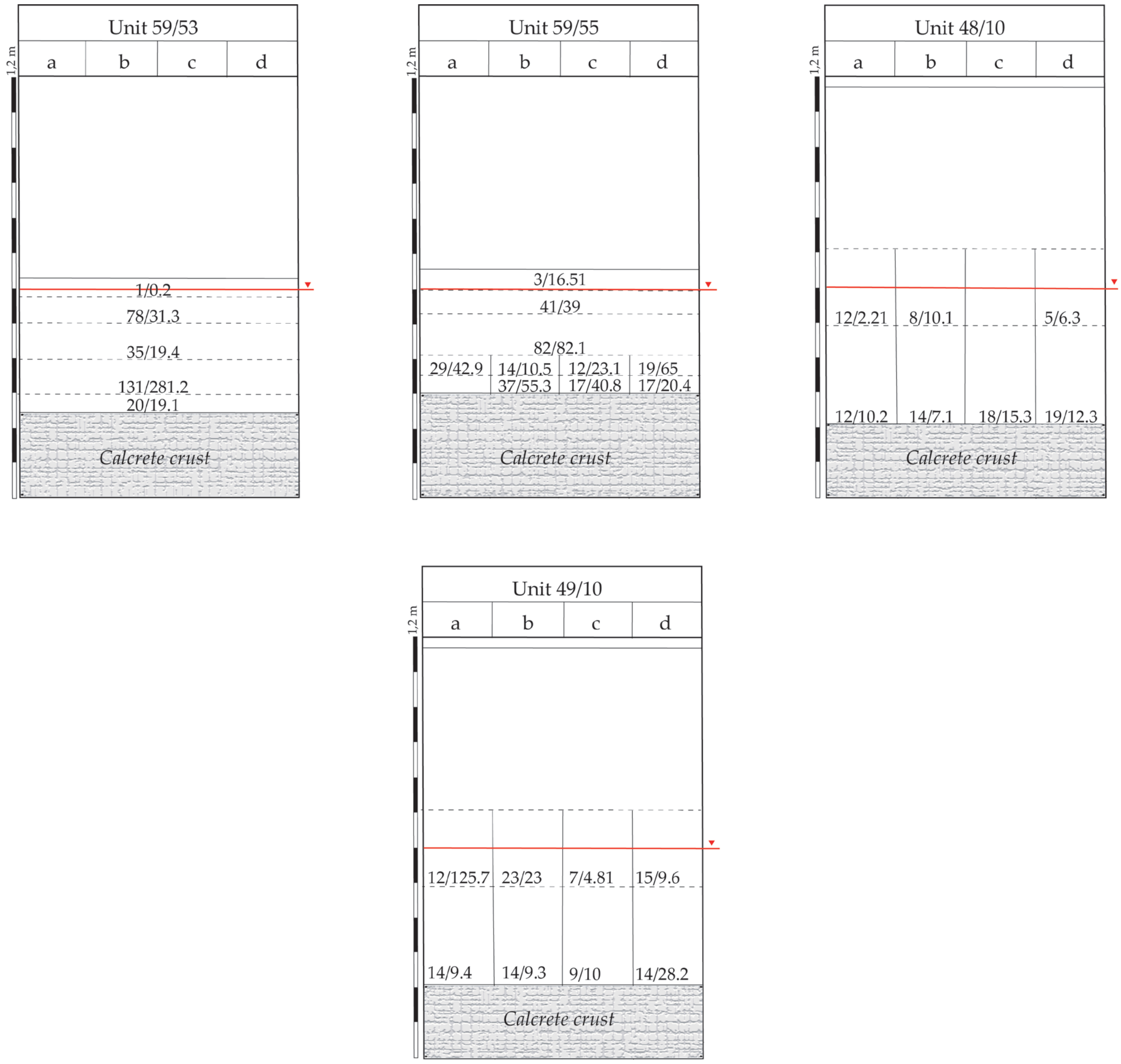


Figure 44: SC 3 Ruuga, area N98/39-1 and -2: vertical distribution of lithics in units 59/53, 59/55, 48/10, and 49/10 (number/grams).

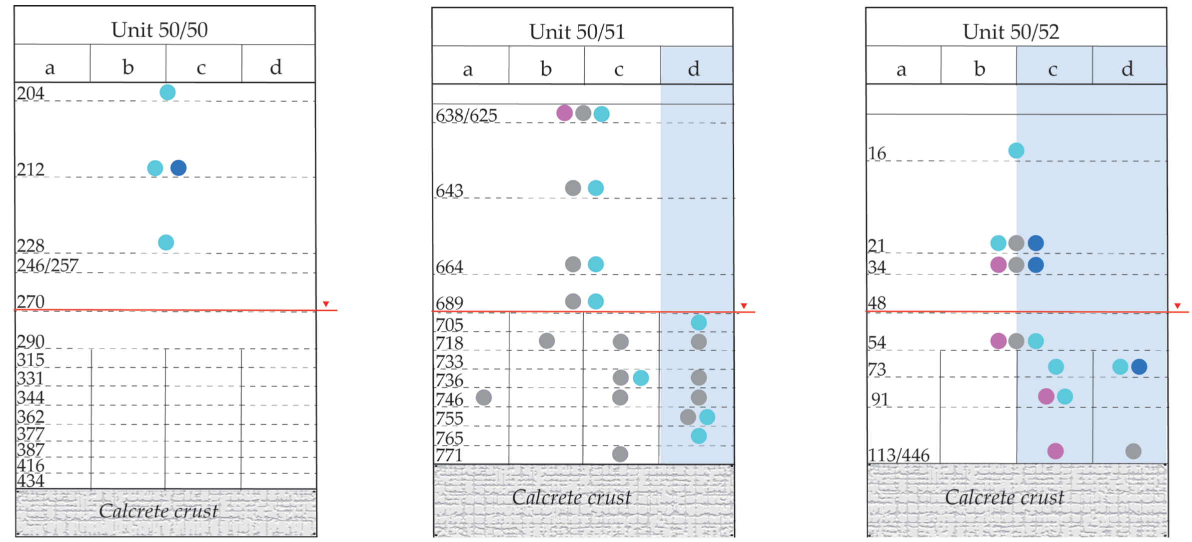


Figure 45 to be continued on next page: SC 3 Ruuga, area N98/39-1 and -2: vertical distribution of modern materials in units 50/50 to 50/52 (gray: plastics; turquoise: glass; pink: textile; blue: industrial metal; black: other modern material).

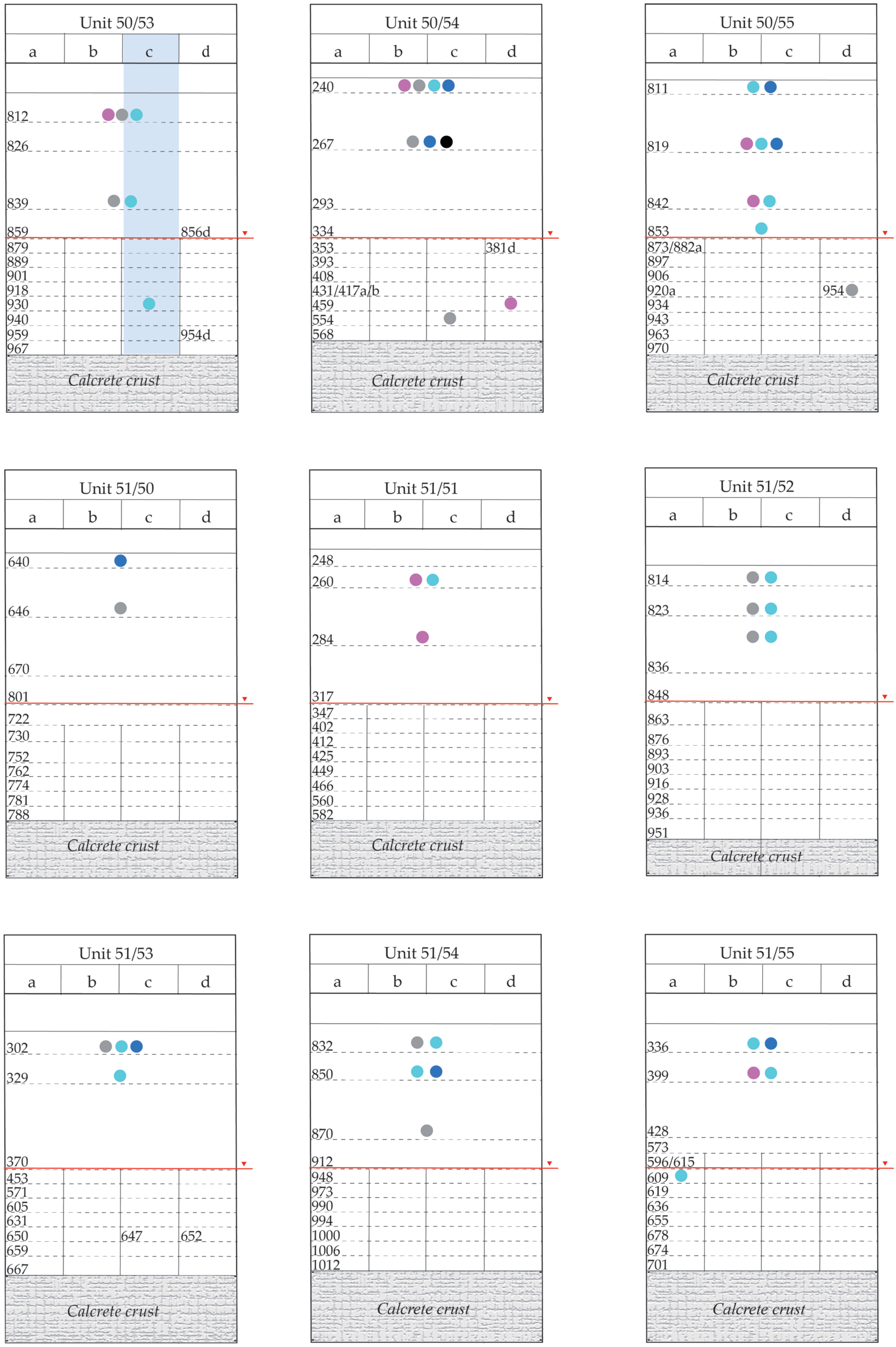


Figure 45 continued from prevoius page: SC 3 Ruuga, area N98/39-1 and -2: vertical distribution of modern materials in units 50/53 to 51/55 (gray: plastics; turquoise: glass; pink: textile; blue: industrial metal; black: other modern material).

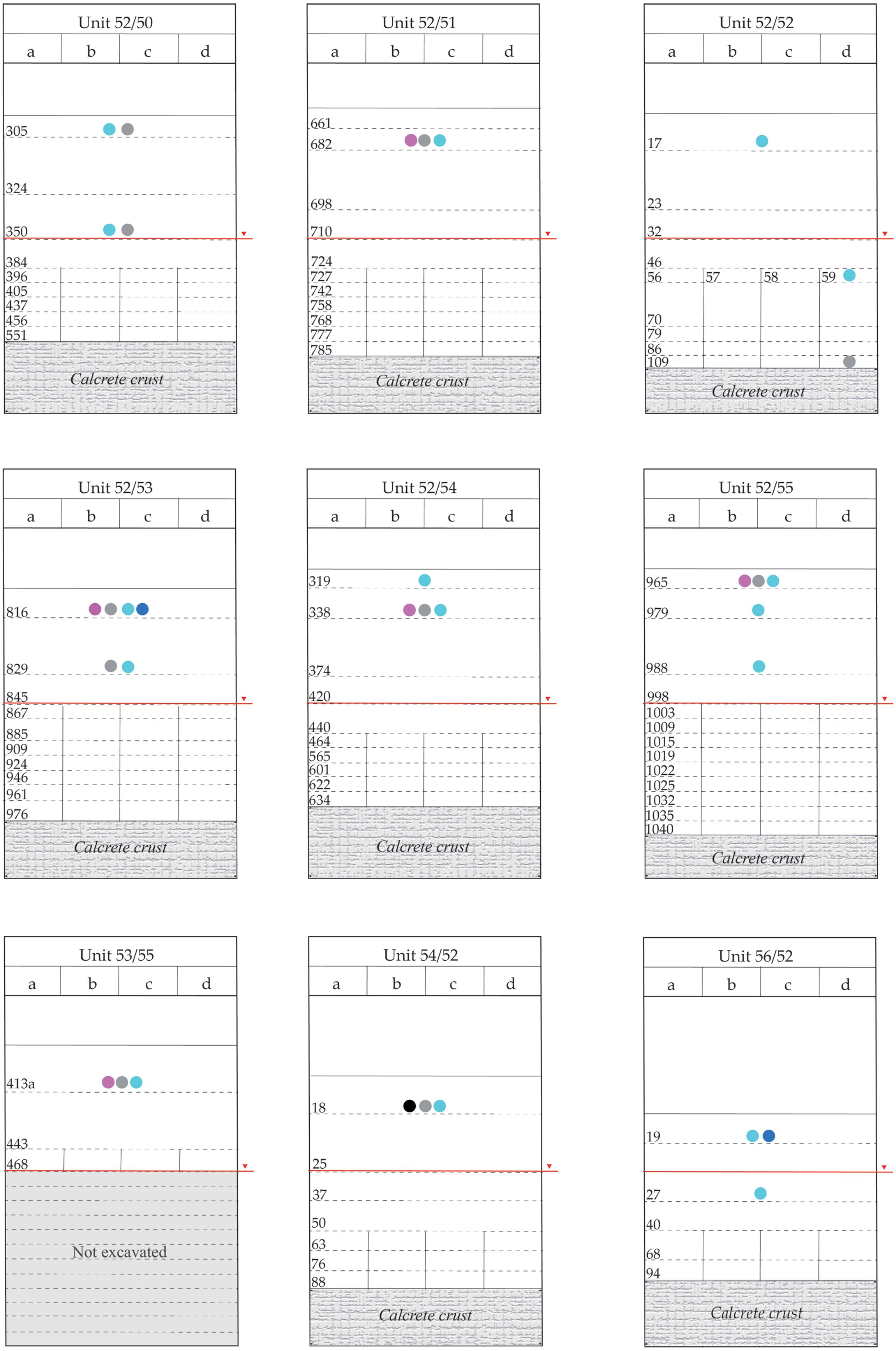


Figure 46: SC 3 Ruuga, area N98/39-1 and -2: vertical distribution of modern materials in units 52/50 to 56/52 (gray: plastics; turquoise: glass; pink: textile; blue: industrial metal; black: other modern material).

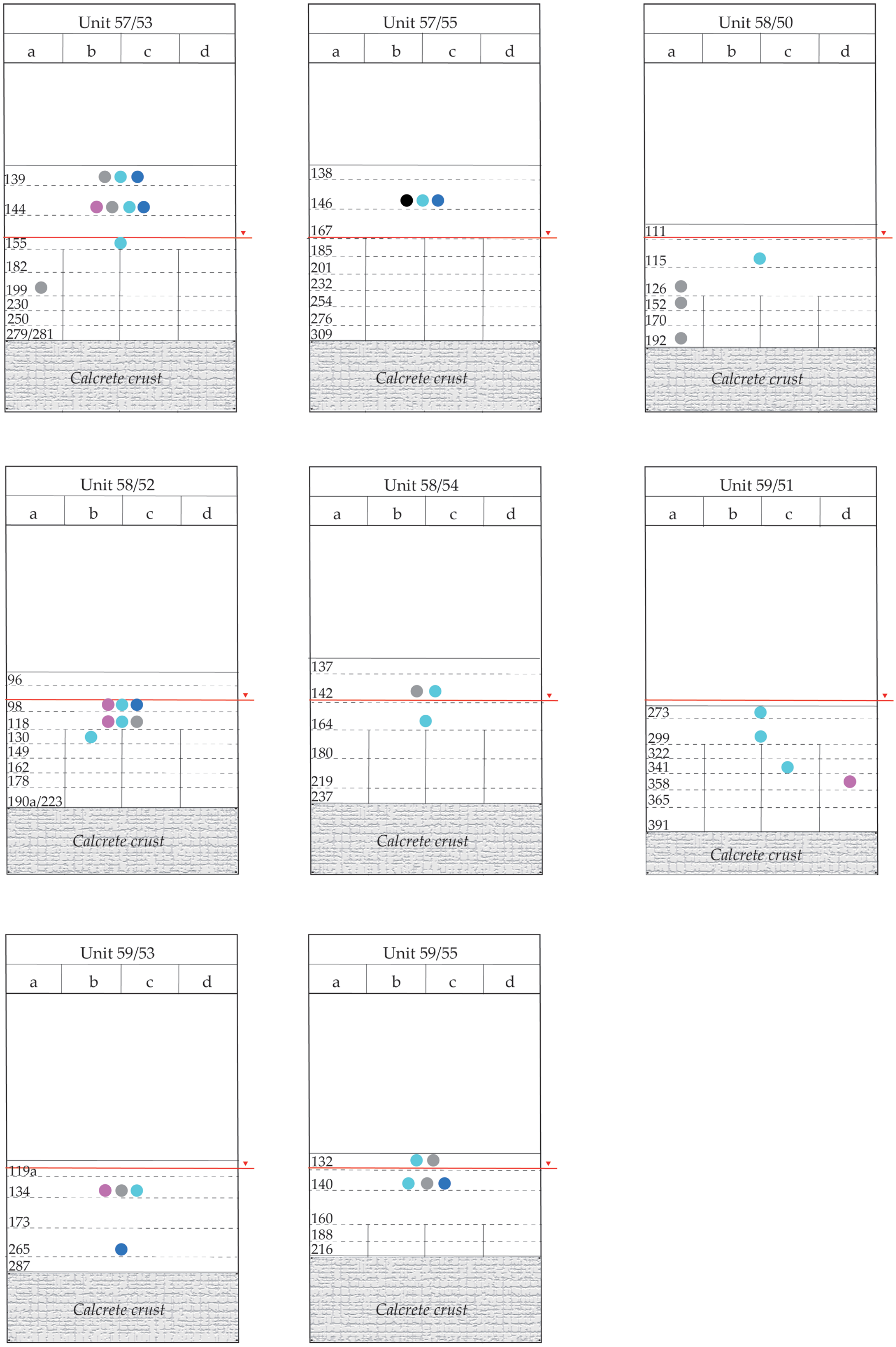


Figure 47: SC 3 Ruuga, area N98/39-1 and -2: vertical distribution of modern materials in units 57/53 to 59/55 (gray: plastics; turquoise: glass; pink: textile; blue: industrial metal; black: other modern material).

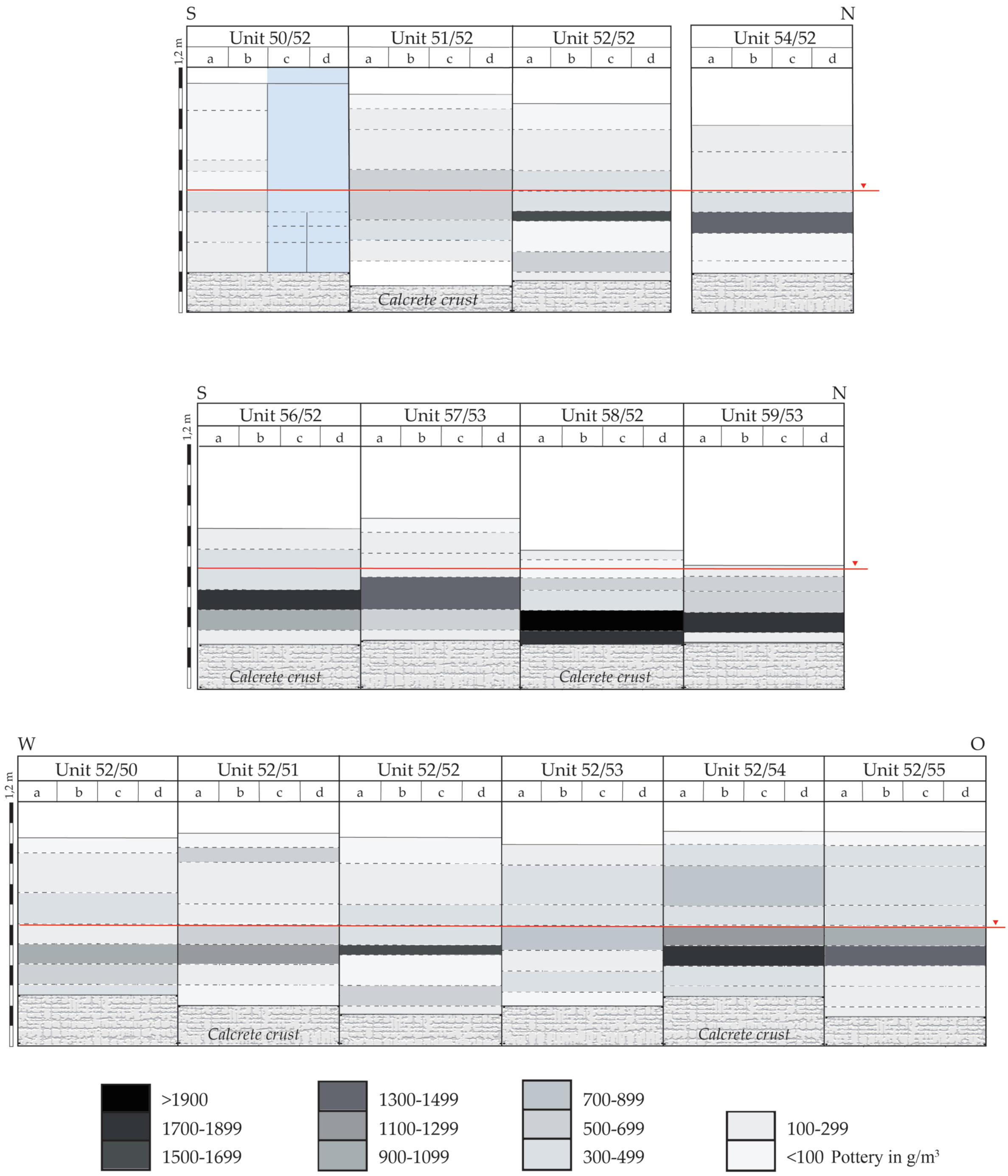


Figure 48: SC 3 Ruuga, areas N98/39-1 and -2: vertical distribution of the relative quantity of pottery in grams per cubic meter.

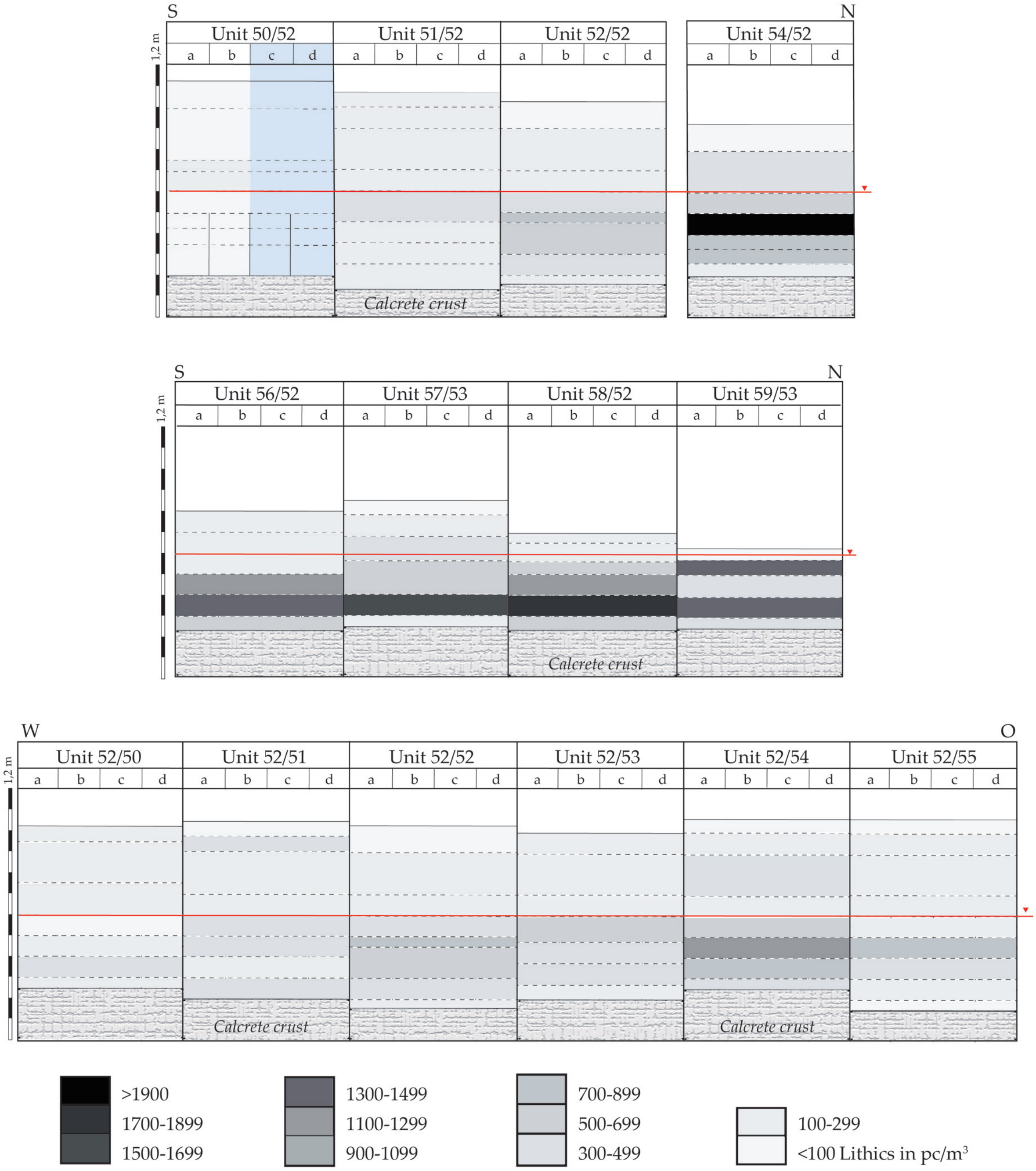


Figure 49: SC 3 Ruuga, areas N98/39-1 and -2: vertical distribution of the relative frequency of lithics in pieces per cubic meter.

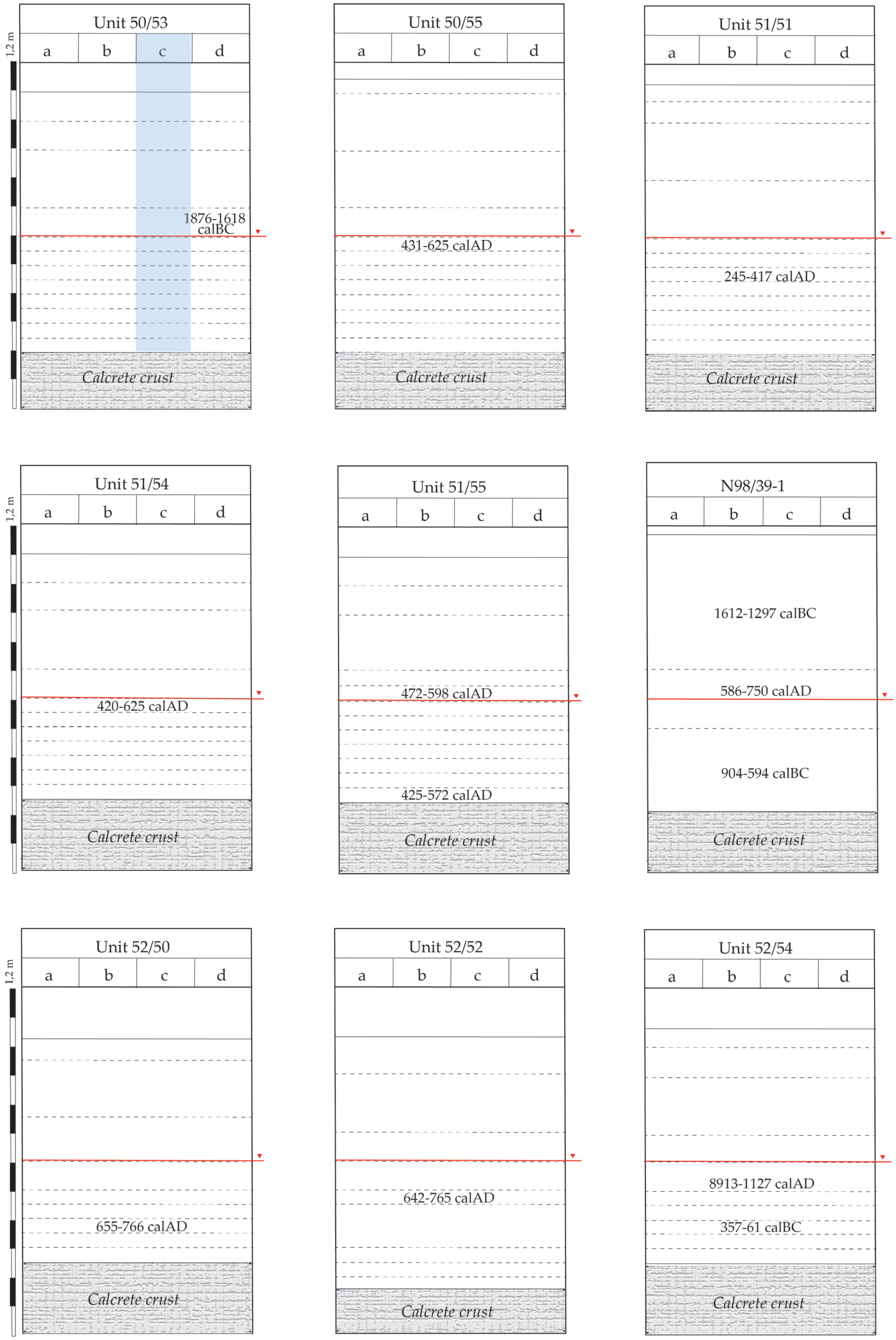


Figure 50 to be continued on next page: SC 3 Ruuga, areas N98/39-1 and -2: vertical distribution of 2-sigma calibrated radiocarbon dates (calibrated with Calib Rev 7.0.4, SHCal13).

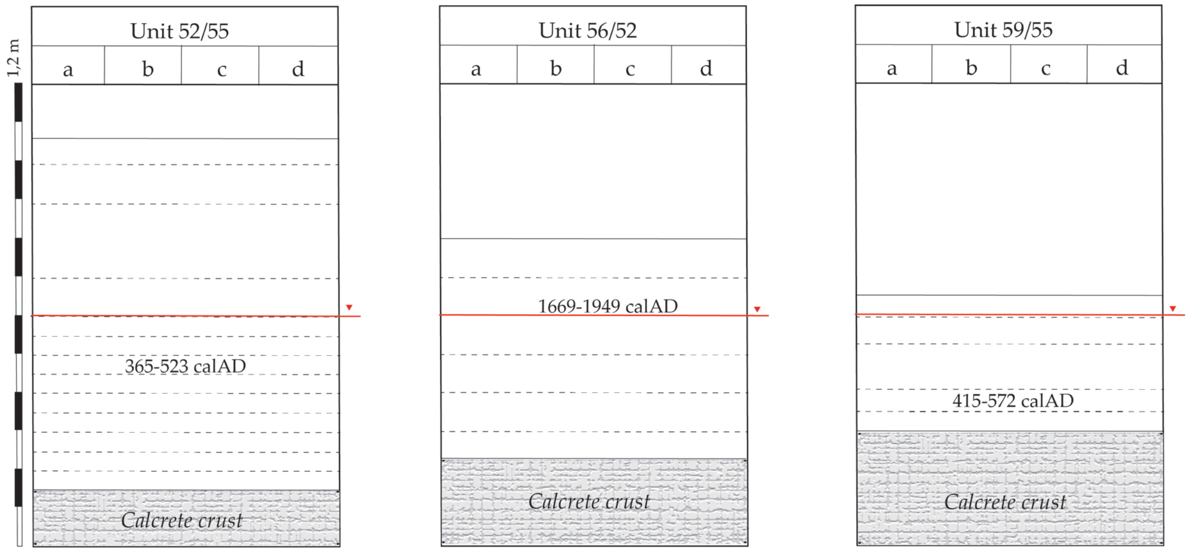


Figure 50 continued from previous page: SC 3 Ruuga, areas N98/39-1 and -2: vertical distribution of 2-sigma calibrated radiocarbon dates (calibrated with Calib Rev 7.0.4, SHCal13).

doubt the affiliation of the sample to the EIG horizon. A further three slag samples were dated by their macroscopic charcoal inclusions (KIA28852, Poz-20698, Poz-20700). However, the slag assemblage provided only a very restricted number of slags with charcoal inclusions large enough to be extracted manually so that finally two samples from the surface were dated(Poz-20698, Poz-20700), and one sample from 10 to 30 cm below the surface (KIA28852). All the three samples were of young age, dating between the fifteenth and nineteenth century (Table 2, Appendix 3, Figure 162), indicating that there exist two ironworking horizons at Ruuga. These young dates were backed up by finds from site N05/01, 400 m farther south (Figures 27 and 56), where slag finds were associated with Vungu-Vungu-style pottery and a clay pipe fragment.

2.3.1.4. Total finds

The excavations from 1999 and 2005 produced a quantity of 18551 archaeological artifacts weighing 28.3 kg in total (Table 5, Appendix 3). In addition, 651 artifacts were collected from the surface totaling to 4.3 kg. The large quantity of finds makes Ruuga the best-examined site of the Early Ironworking Groups in the research area. The main category of finds were lithics (Table 21, Appendix 3) and pottery (Table 18, Appendix 3), amounting to 80.1wt% (n = 22687 g) of the total assemblage (Figure 51). Markedly less frequent were the find categories faunal remains (6.2wt%, n = 1758 g) (Table 19, Appendix 3), charcoal collected from the sediment (5.59wt%, n = 1599 g) (Table 19, Appendix 3), remnants from metal-working activities (slag, ore, and tuyere fragments) (3,76wt%, n = 1066 g) (Table 31, Appendix 3), and modern materials such as glass, plastics and textiles (3,49wt%, n = 989 g) (Table 20, Appendix 3). Metal artifacts (including modern metal remains) amounted only to 0.54wt% (n = 152 g) (Table 31, Appendix 3). More numerous than metal artifacts were ostrich eggshell beads (n = 247 pcs), but owing to their reduced weight they accounted only for 0.1wt% (n = 29 g) of the total assemblage. No more than 0.1wt% (n = 29 g) constituted the finds of burnt clay fragments. Only one unmodified stone was found, which constituted 0.01wt% (n = 2 g) of the assemblage.

2.3.1.5. Remnants of ironworking

The examination of the slag material revealed that the excavated area was part of a bloom refining site, and workplace of fine smithing. A total of two hundred and two pieces of slag provided the basis for the slag study, 184 pieces from the excavations and 18 pieces from the surface, accounting for 905 g (Table 31, Appendix 3). Twenty-two of them were examined via thin sections and bulk chemical analyses (Tables 42, 44, and 45, Appendix 3), and the remaining 180 specimens were visually classified according to the slag characteristics described in the section 1.6.2.1 to 1.6.2.3. From all the slag finds, 49% (n = 99 pcs) fall into the range of processing slags (PSL) (Figure 53) (which

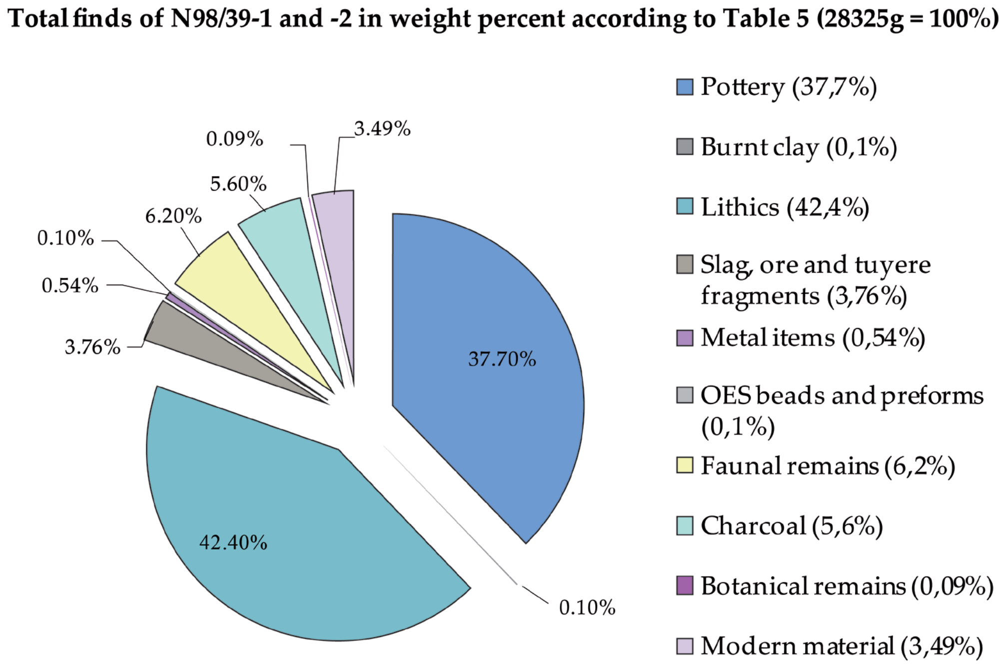


Figure 51: SC 3 Ruuga, areas N98/39-1 and -2: Pie chart of the distribution of find categories in the assemblage.

would correspond to approximately 47wt% of the assemblage) and only 7.9% (n = 16 pcs) were identifiable as smelting remains (SSL). In weight percent, the proportion of smelting remains would however amount to circa 24wt% of the total assemblage. Nine gromps (GR) (4.45%) indicated bloom processing activities and a large amount of slag remained unclassified (USL), accounting for 38.6% (n = 78 pcs) (Figure 53). The latter category contained a high amount of small slag debris, and because of this, the non-diagnostic fraction decreased to approximately 27% of the total slag assemblage in weight.

The vertical distribution of the slag finds is mapped in Figures 58 to 60. It was not possible to separate the two metallurgical horizons at the site because the slag debris displayed no chronologically diagnostic features. By tendency, the slag remains from the surface were larger and heavier than those from the deeper layers (10 of the 18 specimens weighed more than 45 g). However, there was no difference in the frequency of the one or the other slag category signaling different iron-working activities. Furthermore, there were not enough samples analyzed to separate the two horizons by slag chemistry (section 4.2.9). However, out of nine tuyere fragments found at the site (Table 31, Appendix 3, Figure 57) only one is grog-tempered and assignable to the smelters of the Late Ironworking Groups. All the others were organically-tempered, and therefore they belong to the occupation horizon of the Early Ironworking Groups (see also SC 12 for more grog-tempered tuyeres). From the proportion of the organically-tempered tuyeres I consider the influence from the young smelting site farther south (N05/01, Figures 27, 56, and 80) not significant enough to alter the results of the archaeo-metallurgical study of the material from N98/39-1 and 2.

Among the smelting slag debris, there were four samples with flow structures, and one of them showed evidence for a slag pit into which the molten mass was drained (Table 31, Appendix 3). As discussed in section 4.2.15.1, sample 4388/06 contained some attached furnace wall consisting of a silty material (Figure 208), which originated most probably from the furnace wall. Also sample 4403/06 revealed a thick rim of slagged quartz grains, and probably solidified at the sandy bottom of a furnace. In section 4.2.15.1, I discuss the possibility that the slagged sediment was the natural soil found at Ruuga, and that the smelters used pit furnaces without clay lining or superstructure. This interpretation is consistent with the low aluminum readings of the slag samples from the site (Table 44, Appendix 3). Putting all indications together allows me to suggest that people smelted in pit furnaces in the ground, provided with slag tapping facilities such as furrows or a separate pit in order to collect the molten slag mass. However, the exact furnace design and whether or not the people smelted at Ruuga remain unknown.

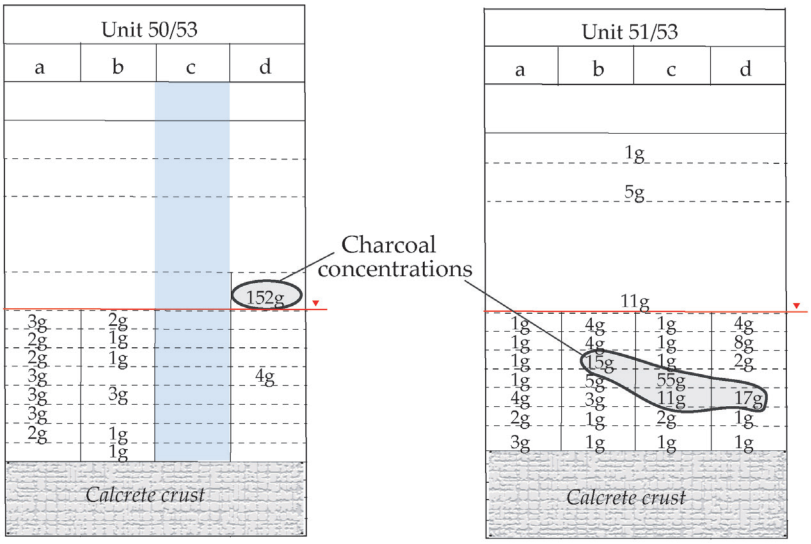


Figure 52: SC 3 Ruuga, areas N98/39-1 and -2: charcoal concentrations in units 50/53 and 51/53.

The smelters mainly produced a soft wrought iron or low carbon steel with a carbon portion of 0.2% or smaller (4389/06, 4395/06, 4404/06, 4407/06, 4409/06, 4410/06, and 4411/06) (Table 49, Appendix 3) (Figure 55). However, two blooms (4394/06 and 4396/06) varied in composition and attested that the whole range from wrought iron to high carbon steel had been produced (Figure 209).

The limited quantity of smelting slag remains (Figure 53) in conjunction with the small uncondensed bloom fragments indicated that the area that we assessed through our excavation was the place where blooms were shattered, sorted and refined. Smelting was performed somewhere else. As described in detail in section 1.5.1, it is likely that the bloom was first compacted in a cold state before it was heated again to slag liquidus temperatures in order to drain away redundant slag and to limit the loss of valuable material through hammering in a cold state. The furnace slag debris, which were comparably small compared to other chunks of furnace slag (e.g. from Vungu-Vungu, Figure 183 or N05/01, Figure 56), in conjunction with the loss of poorly condensed bloom fragments (gromps) supported this interpretation of the assemblage. In addition, the numerous crown material scattering at the site and included in refining slags (see Table 31, Appendix 3) suggested that the starting material was a dirty bloom from a smelt during which metallic iron, slag and fuel did not separate fully in the furnace (section 1.5.1). Blooms frequently contained a certain amount of unreacted ore material, and the small residues of ferrous concretions found in the southern quadrants very well fit the picture of an initial refining site. As discussed in section 4.2.9, the smelters of Ruuga most probably used two different sources of ore and it is likely that they exploited secondary ores in the Kafuma and Kakeni palaeo-riverbeds (Figure 217). The piece of specular hematite found in unit 51/51a (sample 4419/06) was not used in iron production (section 4.2.9). Most probably, it was processed into ocher.

The archaeometrical analyses of 10 samples of processing slag allowed me to prove initial (4393/06, 4396/06, and 4411/06), advanced (4409/06 and 4410/06), and final (4391/06, 4402/06, and 4405/06) refining activities (sections 4.2.3 to 4.2.5). Moreover, fine smithing (secondary smithing) took place at the site (4397/06 and 4400/06) (section 4.2.6). The horizontal distribution of all slag finds (Figure 61) indicated that the center of the smithing zone was in the southern units, because the slags concentrated there. The best indications for a refining furnace or forge are smithing hearth bottoms (SHB) because they must be removed from the smithing facility at regular intervals, in particular during early and advanced refining (section 1.5.1). Clusters of SHBs can consequently indicate a refining furnace or forge nearby. Figure 62 shows that the smithing hearth bottoms were scattered in a semicircular fashion in the southern units, together with all the tuyere fragments found in the excavation. Figure 63 shows the charcoal concentrations of the individual units with the by far highest concentrations of weight per cubic meter in the units 50/53[82] and 51/53. This mapping of charcoal became possible because the soil was very

82 Quadrant 50/53c was not counted since it belonged to area N98/39-1.

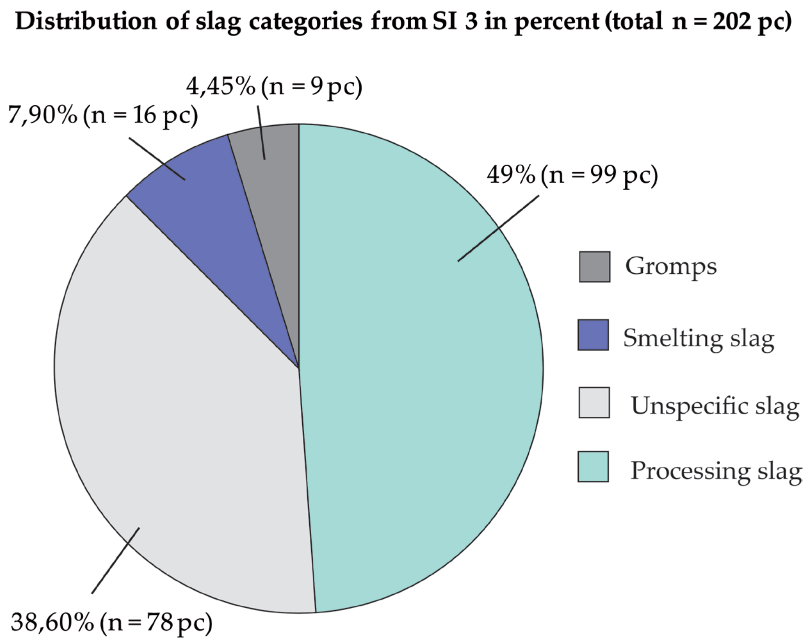


Figure 53: SC 3 Ruuga, areas N98/39-1 and -2: Pie chart of the distribution of slag categories in the slag assemblage.

thoroughly sifted and sampled during the excavation to assess the assemblage as complete as possible. A closer look revealed that the main charcoal concentration occurred 40 to 50 cm below the surface in unit 50/53, and 60 to 75 cm below the surface in unit 51/53 (Figure 52). The SHBs scattered from 15 to 50 cm below the surface, and the tuyeres from 20 to 70 cm. The other slag remains in the southern units scattered throughout the profile and were found in all positions (Figures 58 to 60). As mentioned earlier, it was difficult to define a precise living horizon at the site because the sediment was soft, and a vertical dislocation of artifacts of more or less 30 cm easily occurred by simply walking around.

From the samples 4396/06, 4402/05, and 4406/05 it could be deduced that the refining furnaces were most probably pits in the sandy ground, which certainly did not persist very long once abandoned. The traces that such pit furnaces or forges would leave in the archaeological record are charcoal concentrations surrounded by slags and broken tuyeres. Moreover, modern-day blacksmiths use pits near the forge to store some charcoal. It is therefore most likely that the charcoal concentrations found in the units 50/53 and 51/53 belong to the sphere of a refining pit or forge, but even so, the pattern was not clear enough to interpret the concentration as 'the refining furnace' or 'the forge'. Another problem arose after having dated a sample of charcoal from unit 50/53d. The carburized material was identified to be Acacia wood (*Acacia sp.*, Barbara Eichhorn personal communication, 2006). Unfortunately, the radiocarbon date produced from this charcoal went back to the eighteenth/nineteenth centuries cal BC (Table 2, Appendix 3, Poz-20669) and made the charcoal concentration more or less 1300 years older than the tuyere found nearby (Table 2, COL#2332.1.1) (Figure 50). One possible explanation would be that the iron-workers used the old wood of dead trees, which had not yet decayed at the time of refining. All modern blacksmiths who I interviewed preferred dead trees for charcoal production, and it is likely that this was the same 1500 years ago. In arid and semi-arid environments, the decay of dead trees is slower than under humid climate conditions. Studies from arid zones of

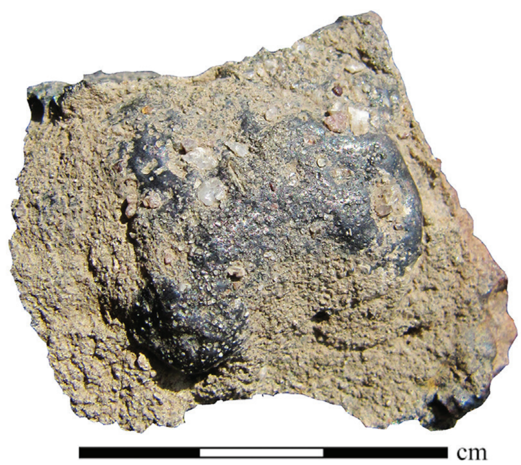


Figure 54: SC 3 Ruuga, areas N98/39-1 and -2, bottom of a SHB from secondary smithing with fine sediment and coarse quartz grains adhering to the specimen (Lab. ID 444, see Table 31, Appendix 3).

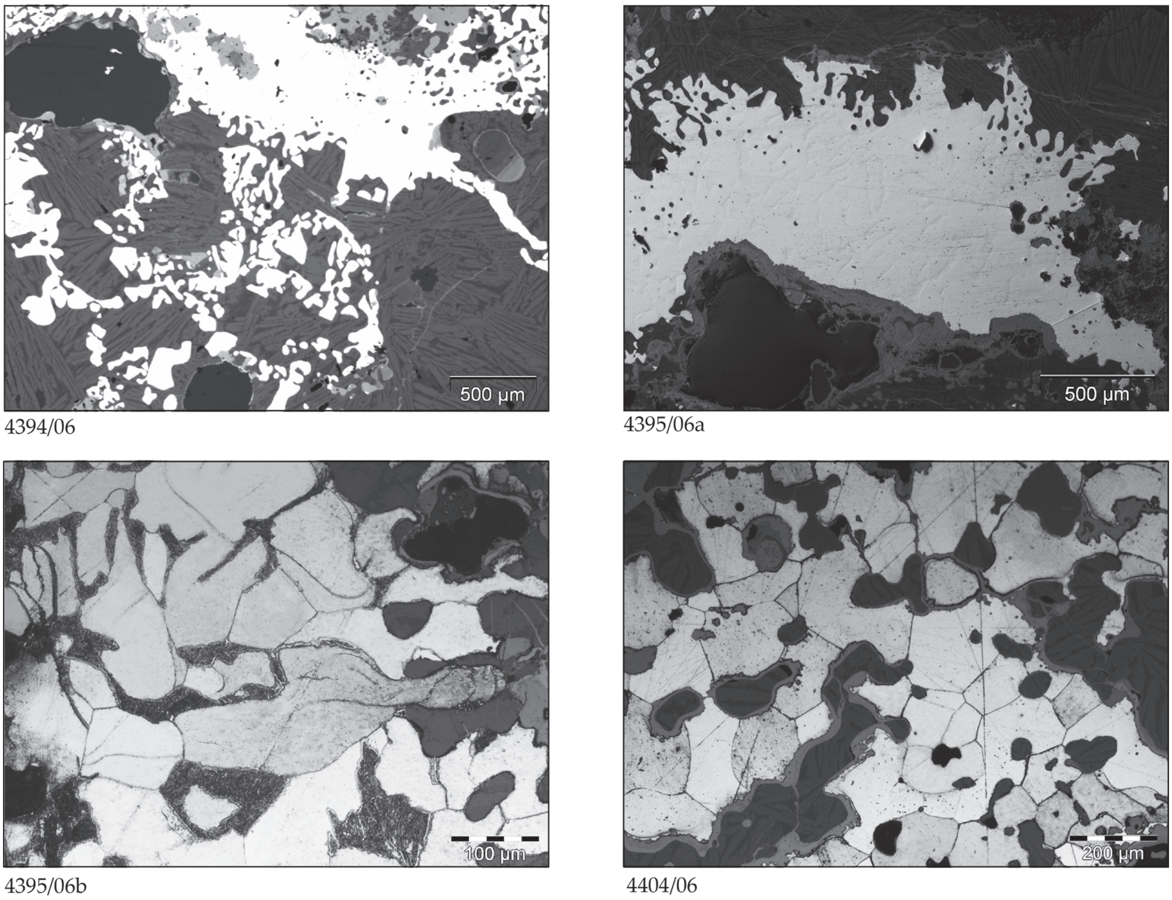


Figure 55: SC 3 Ruuga, areas N98/39-1 and -2, consolidated iron in crown material and bloom fragments from the site. Sample 4394/06: semi-condensed metallic iron (white) in a fayalitic (light gray) slag. Sample 4395/06a: condensed metallic iron (white) with an elevated phosphorous content indicated by the ghost structure in the iron. Sample 4395/06b: medium carbon steel, ferrite (light gray) with pearlite (lamellar dark structures). Sample 4404/06: ferrite grains, wrought iron.

the American continent revealed that dead wood found on the surface could be 1500 years of age (Schiffer, 1986 as cited in Killick, 1987, p. 30) or even dated back to roughly 3000 calendar years before present (Towner & Dean, 2010). In light of such dates, it is not surprising to find charcoal samples associated with material of much younger age, or in confusing stratigraphical positions such as discussed earlier. Another distorting factor would be the use of tree species with a long lifespan. However, scholars attested *Acacia erioloba* to live no more than 300 years of age (Barnes, 2001 as cited after Seymour & Milton, 2003 p. 11),[83] and studies about the lifespan of southern African trees are still scarce. All in all, the confusing picture of the calendar dates produced from the charcoal samples indicated that the people used a range of old wood found in the area. The examples also showed that the old age produced by the sample taken from unit 50/53 (Poz-20669) does not necessarily conflict with the younger age provided by the tuyere (COL#2332.1.1) nearby (Figure 50).

All the refining slags analyzed (Table 42, Appendix 3) (e.g. Figure 184) attested that the ironworkers from Ruuga followed the most common way of bloom refining. After the initial sorting described earlier, the bloom was again heated and redundant slag drained away (sample 4393/06). The bloom became increasingly consolidated through repeated cycles of heating and hammering in a strongly reducing environment, and temperatures and redox conditions in the refining furnaces were comparable to smelting operations.

In the northern units of the site, slag finds were less common. In particular smelting slag debris and undiagnostic slag lumps became less frequent. Nevertheless, one smithing hearth bottom was found in unit 58/52 associated with a number of amorphous or thick flaky hammerscale and gromps. This combination of finds suggested a second workplace where more advanced refining

[83] Which might be different from other *Acacia* species, and even the lifespan of *Acacia erioloba* is not yet comprehensively examined.

Figure 56: SC 3 Ruuga, area N05/01, slag samples collected from a harvested field.

was carried out and where blooms were hammered into compacted pieces of raw metal (section 1.5.1).

Four smithing hearth bottoms were identified to be the residues of secondary or fine smithing (Table 31, Appendix 3) and three of them originated from the excavated units (Figures 61 to 63). Fine smithing generates markedly less slag than refining (section 1.6.2.3), but a forge usually can be identified in the archaeological record by the concentrations of fine flaky hammerscale (section 1.6.2.3). As mentioned earlier, the three specimens were found in the southern units together with the tuyere fragments and the refining slags. Three small hammerscale flakes completed the picture that final tool and jewelry production took place at the same zone where refining operations were performed. However, the limited number of fine hammerscale flakes suggested that the actual forge had not been excavated, and I assume that refining furnace and forge are to be found beyond the southern limits of the excavation. Six samples bore remnants of quartz, which implied that the quartz rich Kalahari sand, or shattered quartz was used as a welding flux (see also samples 4402/06 and 4410/06).[84] From slag sample ID 444 in Table 31 (Appendix 3) one can also deduce that the forge was a shallow depression in the natural soil (Figure 54).

[84] In particular one SHB from secondary smithing (Appendix 3 Table 31, ID 444) showed quartz fragments of larger grain sizes than the natural sand, supporting the assumption that quartz-dominated material served as a welding flux.

As described in section 4.3.3, the site revealed 39 iron artifacts, and two copper beads (Tables 52 and 53, Appendix 3, Figure 211). Only 10 artifacts originated from a reliable archaeological context of the EIG (Figure 211). They comprised typical iron beads made from a thin iron ribbon (Figure 211: 2 and 3) (sample 4439/06 and 4486/06), one chain fragment made of a drawn wire (4475/06) (Figure 211: 9), and a hook that was probably used in fishing (4437/06) (Figure 211: 4). Another find was a small bar of unknown function (4474/06) (Figure 211: 6), an iron plate and an iron ribbon, all serving as starting material for the manufacturing of small items (Table 53, Appendix 3). The assemblage was very similar to the range of metal products recovered from the excavations at Divuyu and Nqoma in the Tsodilo Hills (Miller, 1996). Earlier in the section, I mentioned that the blooms consisted mainly of low carbon steel and wrought iron, yet the metallographic examination of the selected artifacts illuminated that the starting materials was more heterogeneous than previously thought, ranging from wrought iron to high carbon steel, because the products manufactured from bloomery iron usually retain their inherited inhomogeneity. Interestingly, as described in section 4.3.3, only the iron hook was made from low carbon steel (4437/06, Table 50, Appendix 3) (Figure 212). The four other analyzed samples (4439/06, 4474/06, 4475/06, and 4486/06, Table 50, Appendix 3) (Figures 212 and 214) were produced from medium and high carbon steel and it may be that the early ironworkers selected the raw material according to the items

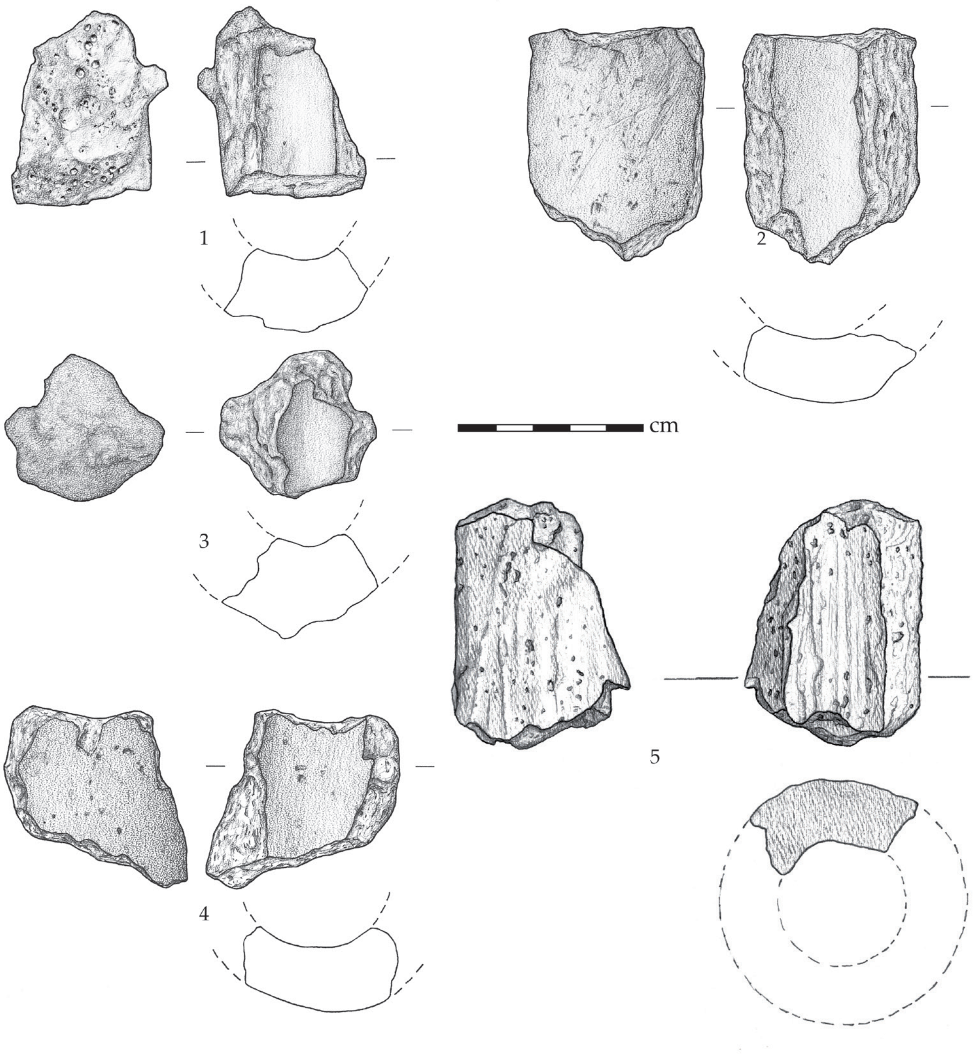


Figure 57: SC 3 Ruuga, areas N98/39-1 and -2: tuyere finds (drawings: Anja Rüschmann).

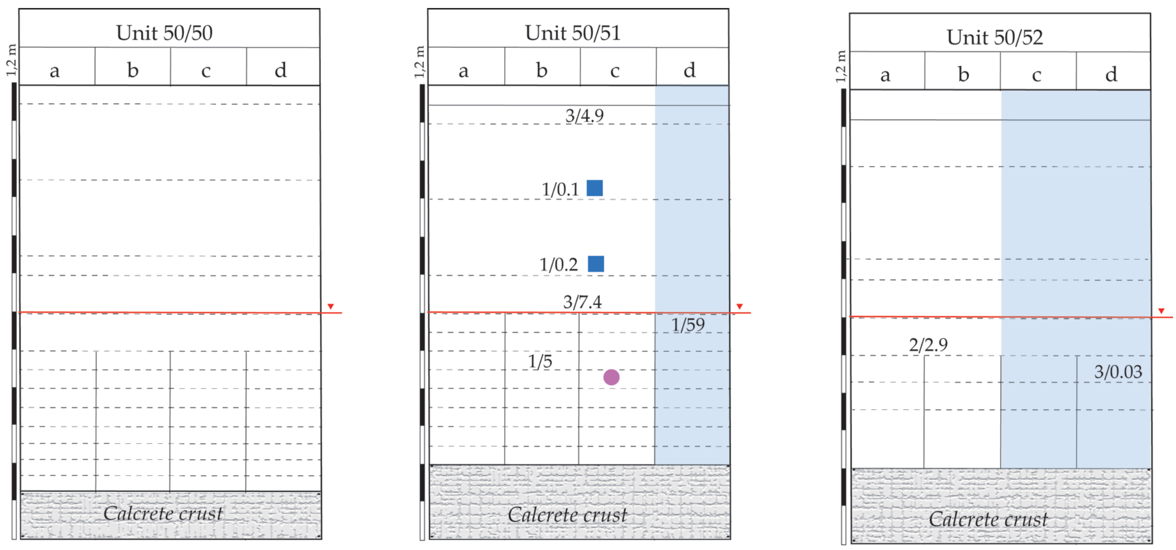


Figure 58 to be continued on next page: SC 3 Ruuga, areas N98/39-1 and -2, vertical distribution of slag, metal artifacts, ore and tuyere fragments in units 50/50 to 50/52 (slag: number/grams; red: copper artifact; gray: undated iron artifact; pink: historical iron artifact; blue: iron ore; black: tuyere fragment).

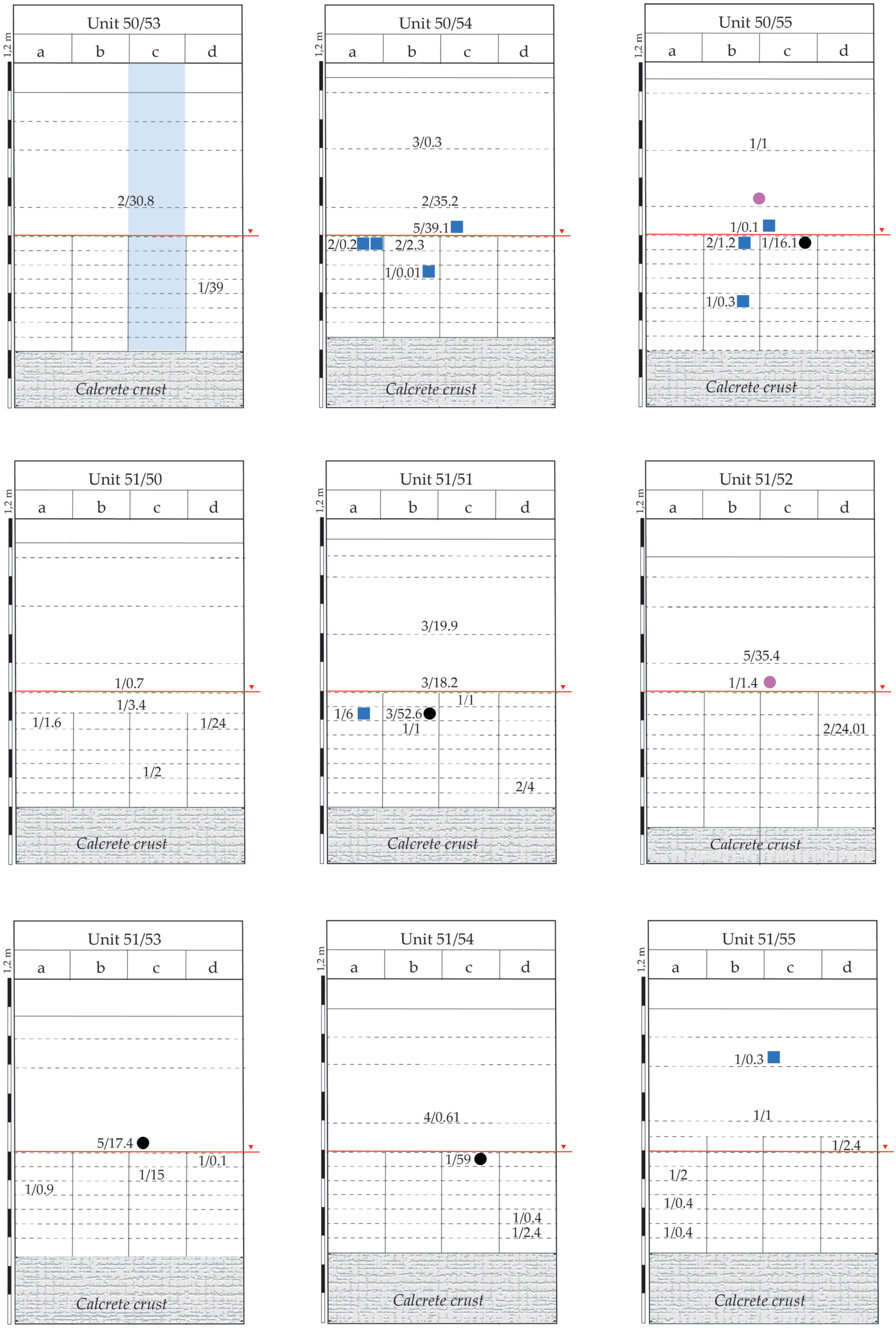


Figure 58 continued from previous page: SC 3 Ruuga, areas N98/39-1 and -2, vertical distribution of slag, metal artifacts, ore and tuyere fragments in units 50/53 to 51/55 (slag: number/grams; red: copper artifact; gray: undated iron artifact; pink: historical iron artifact; blue: iron ore; black: tuyere fragment).

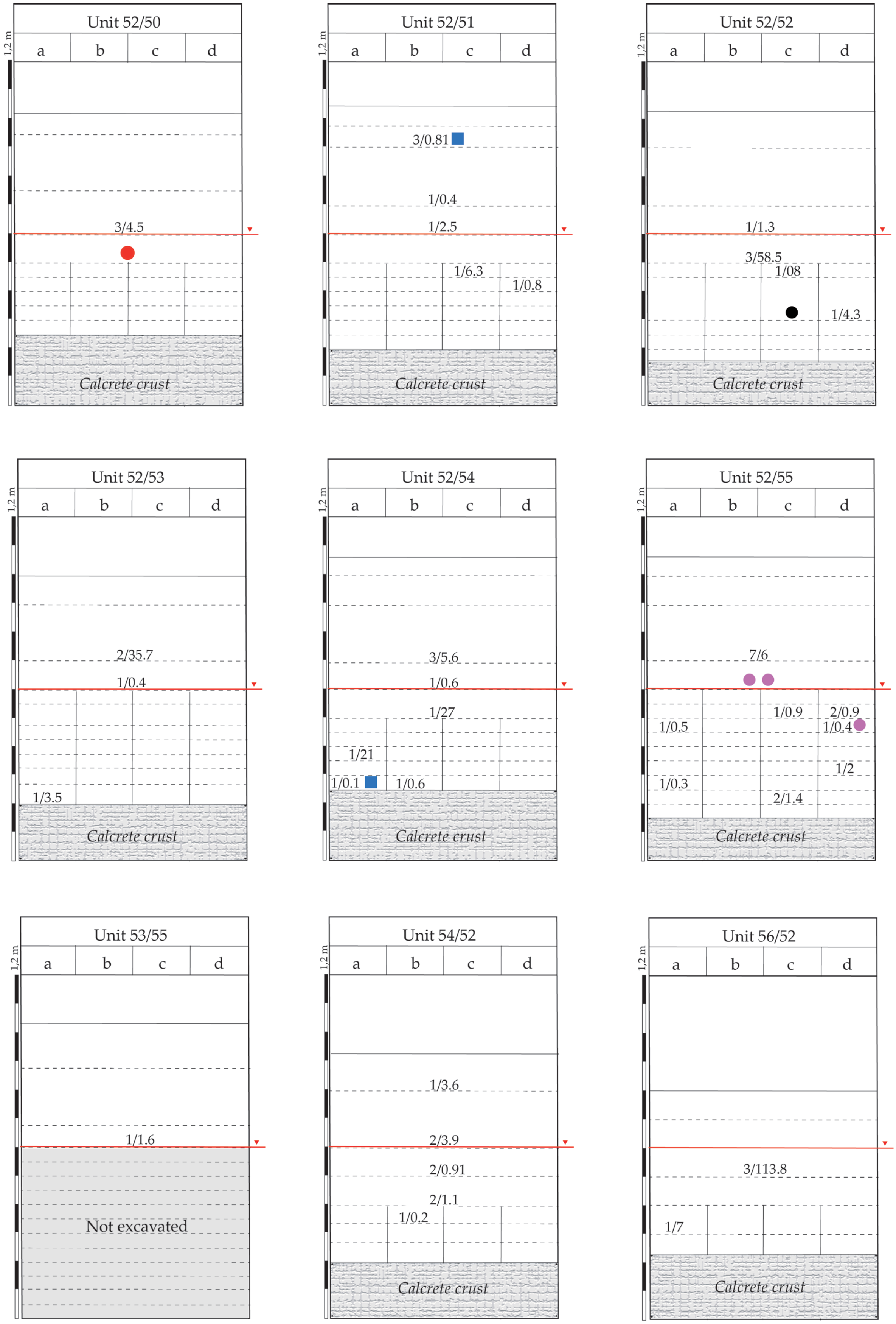


Figure 59: SC 3 Ruuga, areas N98/39-1 and -2, vertical distribution of slag, metal artifacts, ore and tuyere fragments in units 52/50 to 56/52 (slag: number/grams; red: copper artifact; gray: undated iron artifact; pink: historical iron artifact; blue: iron ore; black: tuyere fragment).

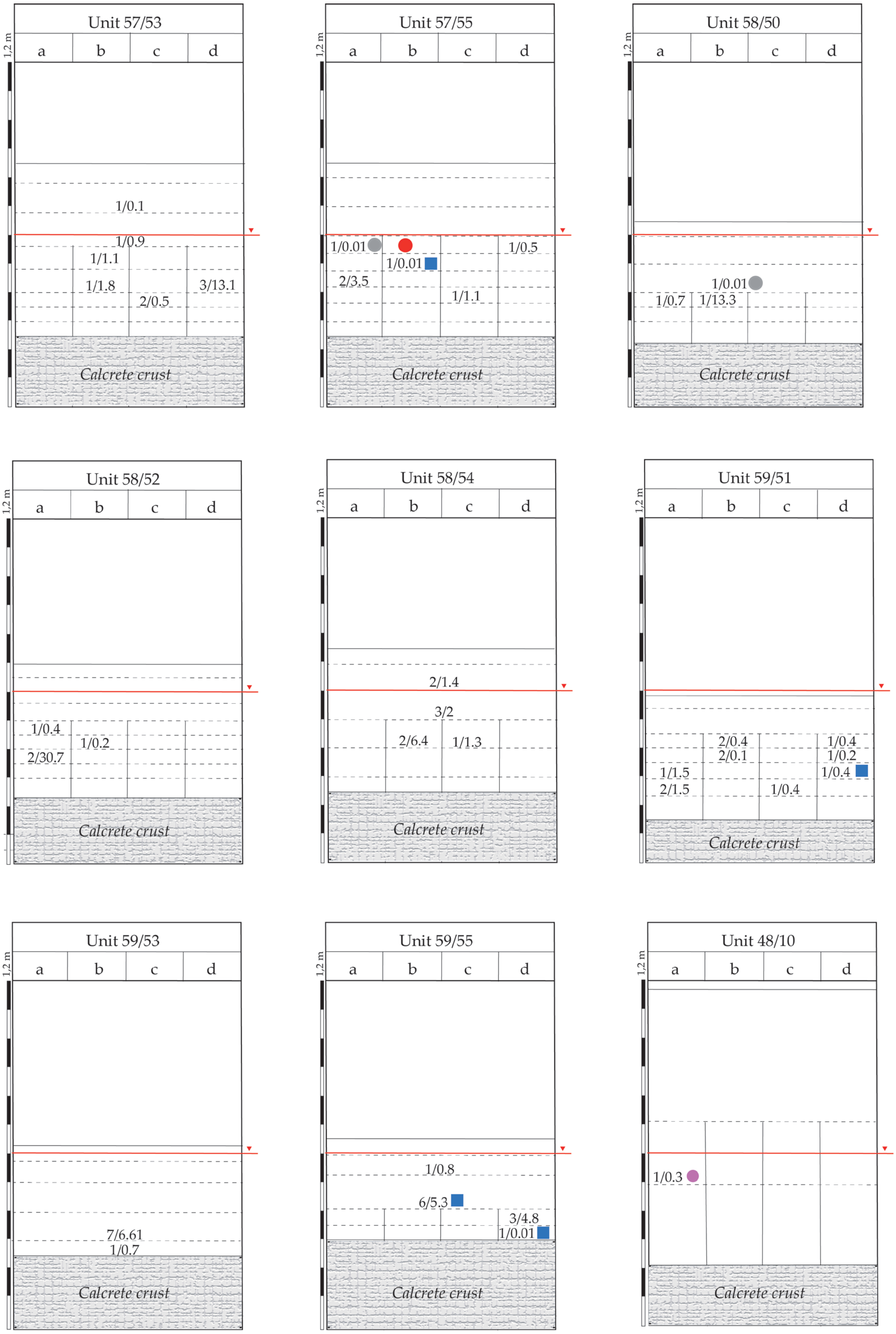


Figure 60: SC 3 Ruuga, areas N98/39-1 and -2, vertical distribution of slag, metal artifacts, ore and tuyere fragments in units 57/53 to 48/10 (slag: number/grams; red: copper artifact; gray: undated iron artifact; pink: historical iron artifact; blue: iron ore; black: tuyere fragment).

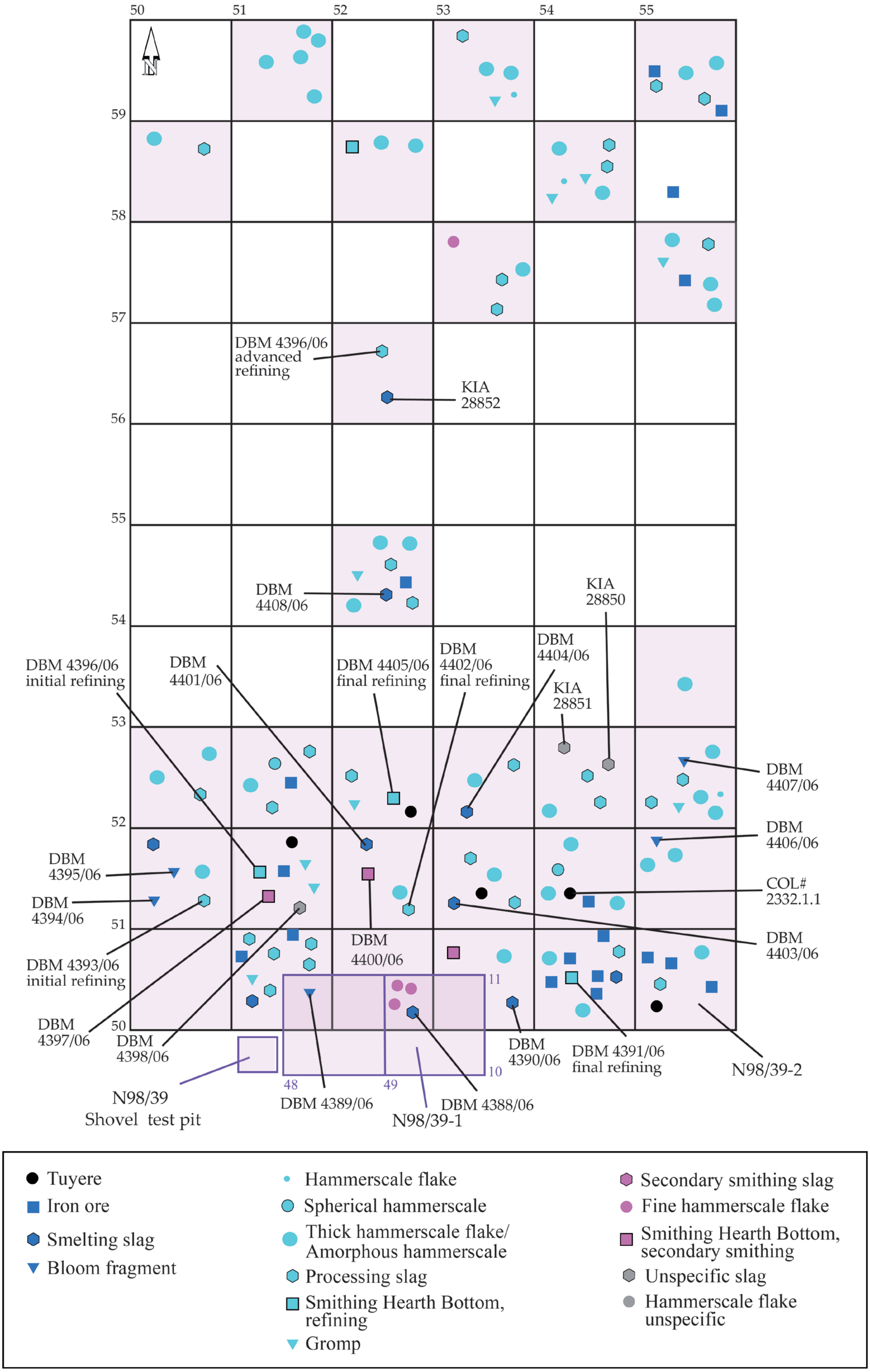


Figure 61: SC 3 Ruuga, areas N98/39-1 and -2, horizontal distribution of diagnostic slag, ore, and tuyere fragments.

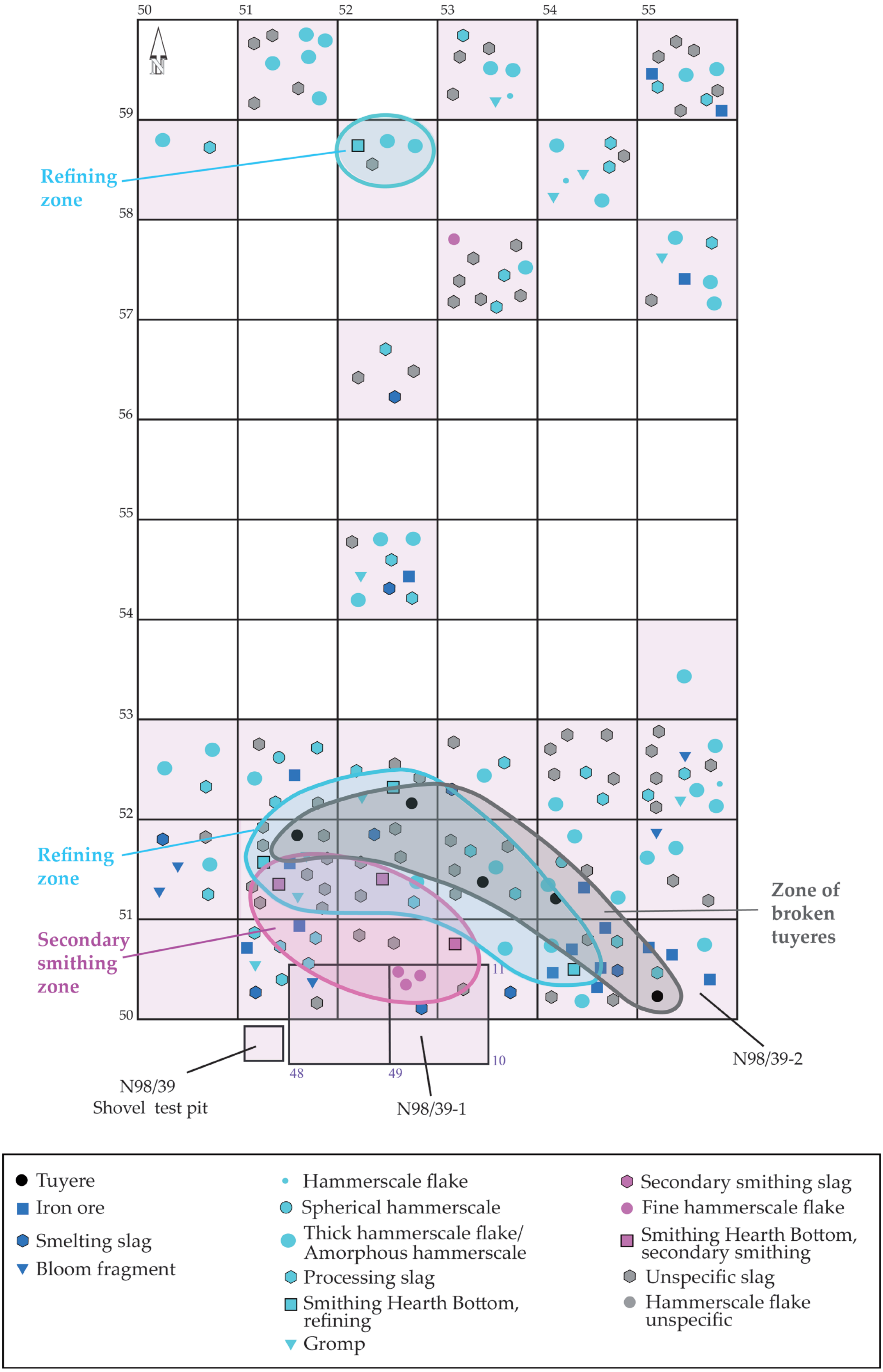


Figure 62: SC 3 Ruuga, areas N98/39-1 and -2, ironworking zones and the spatial patterning of smithing hearth bottoms and tuyere fragments.

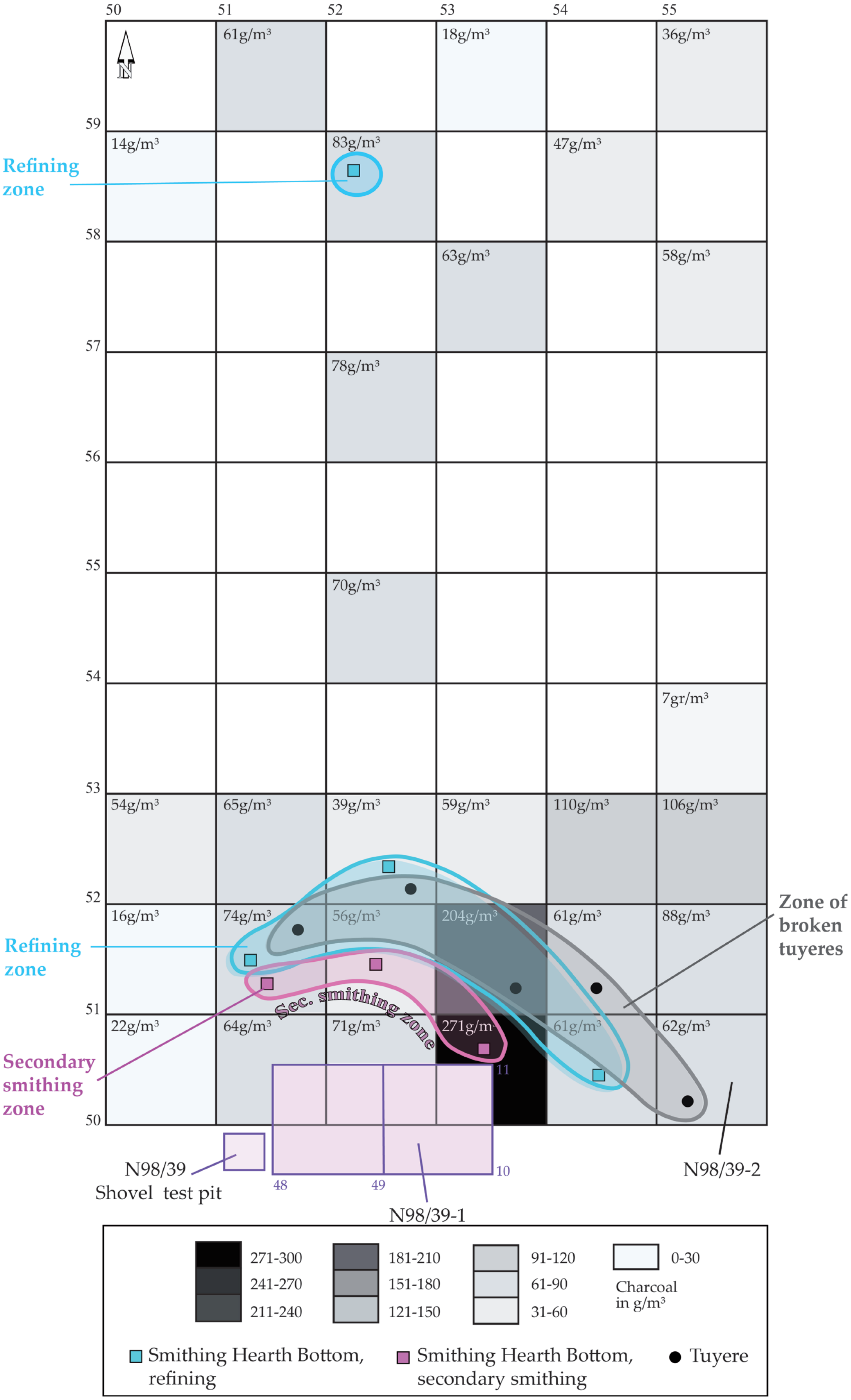


Figure 63: SC 3 Ruuga, areas N98/39-1 and -2, horizontal distribution of the relative quantity of charcoal in conjunction with ironworking zones.

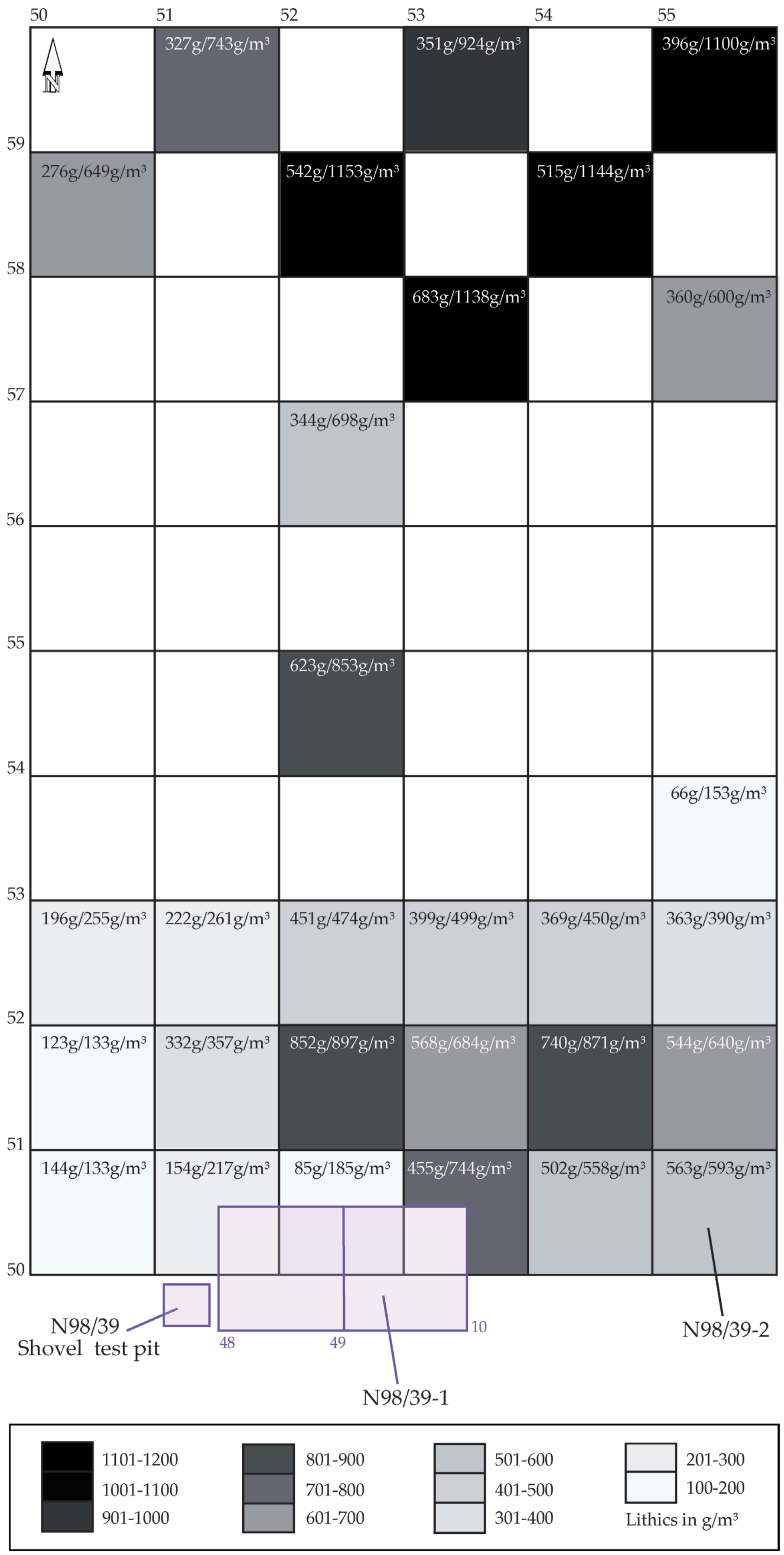


Figure 64: SC 3 Ruuga, areas N98/39-1 and -2, horizontal distribution of lithics, absolute quantity in grams per unit/relative quantity in grams per cubic meter.

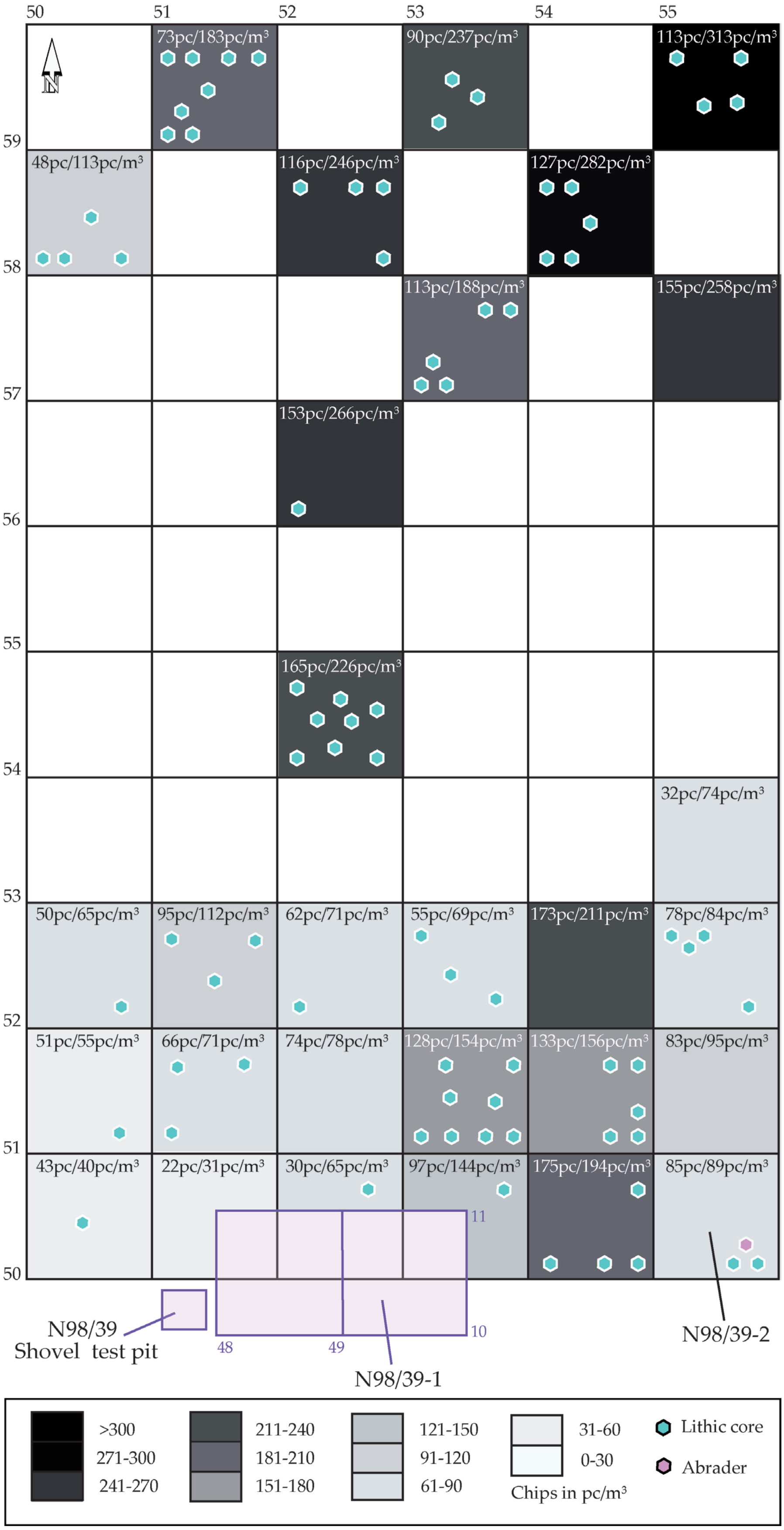


Figure 65: SC 3 Ruuga, areas N98/39-1 and -2, horizontal distribution of lithic chips and cores, absolute quantity of chips in pieces per unit/relative quantity of chips in pieces per cubic meter in conjunction with the absolute number of lithic cores per unit.

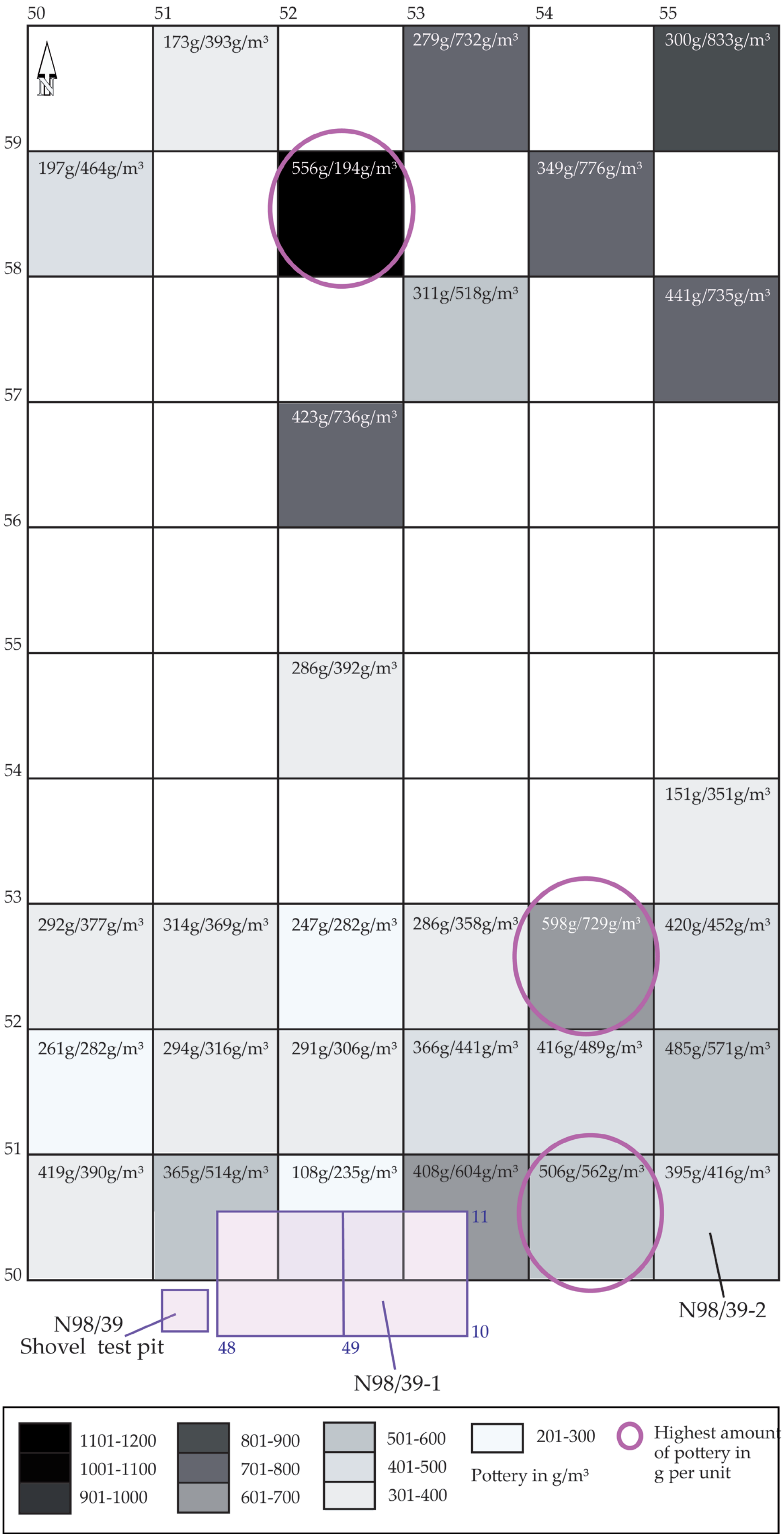


Figure 66: SC 3 Ruuga, N98/39-1 and -2, horizontal distribution of pottery, absolute quantity in grams per unit/relative quantity in grams per cubic meter.

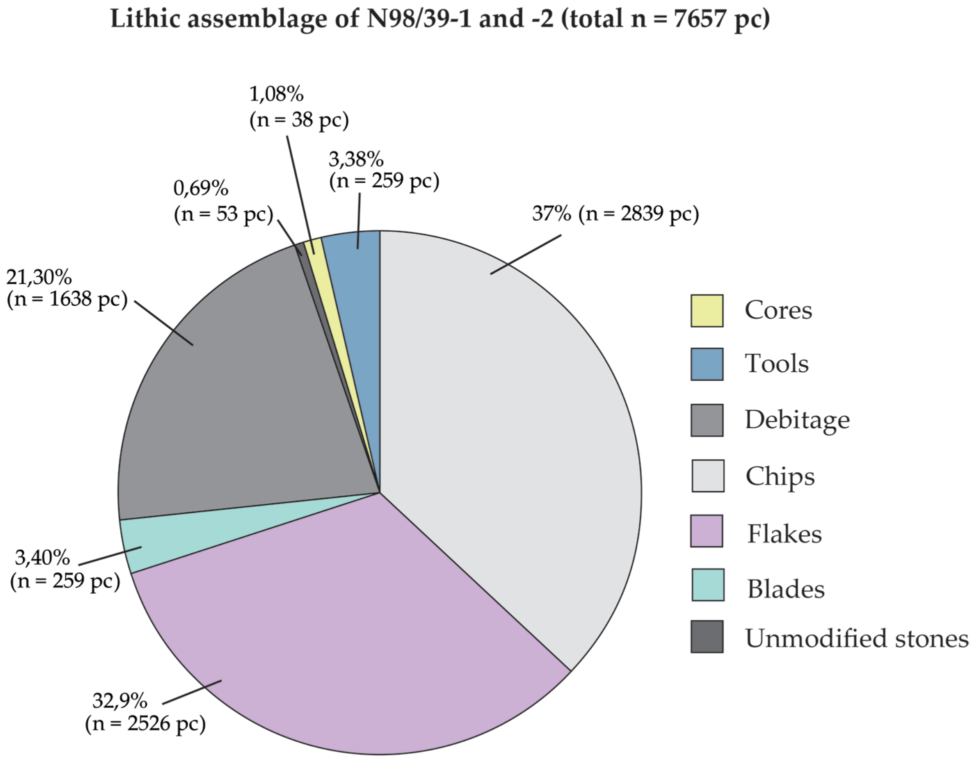


Figure 67: SC 3 Ruuga, areas N98/39-1 and -2, pie chart of the distribution of stone artifact categories in the lithic assemblage.

produced. The blacksmiths of Ruuga thoroughly recycled even the smallest pieces of iron (see samples 4437/06, 4439/06, and 4474/06). Their smithing skills comprised hot working (4437/06, 4439/06, 4474/06, 4475/06, and 4486/06), cold working (4437/06 and 4474/06), warm working (4437/06, 4474/06 and 4486/06), and normalizing of the microstructure (4439/06, 4474/06 and 4475/06). The technologies were described in detail in section 1.5.2. Sample 4437 (Figure 212) was exposed to some annealing at subcritical temperatures, which allowed the damaged crystal structure to recrystallize. The blacksmiths successfully welded materials of varying origin together into new pieces of iron (4437/06 and 4474/06). Nevertheless, the range of products was not as diverse as found at Divuyu, but the technologies applied were the same (Miller, 1996, pp. 83-84). One interesting find was a chain fragment of links made from fine, drawn wire round in cross section (Figures 211: 9 and 212, sample 4475/06). This artifact was found in an undisturbed context in unit 52/55, and it is among the earliest evidence for drawn wire in a

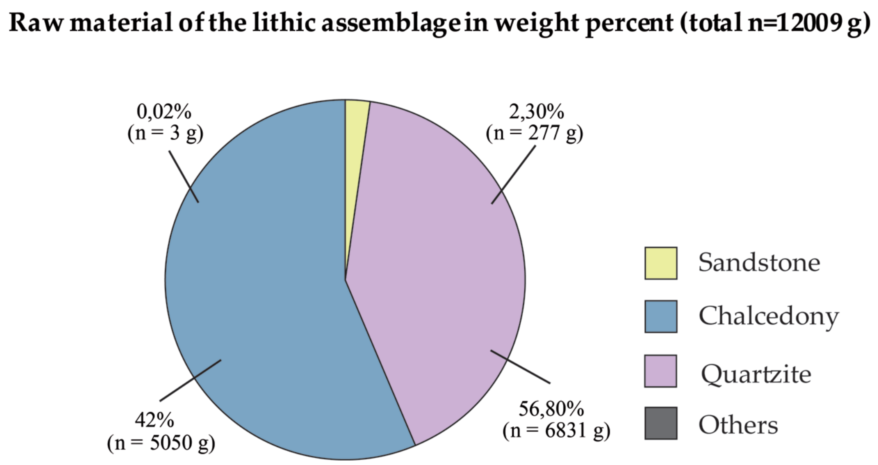


Figure 68: SC 3 Ruuga, areas N98/39-1 and -2, pie chart of the distribution of raw material categories in the lithic assemblage

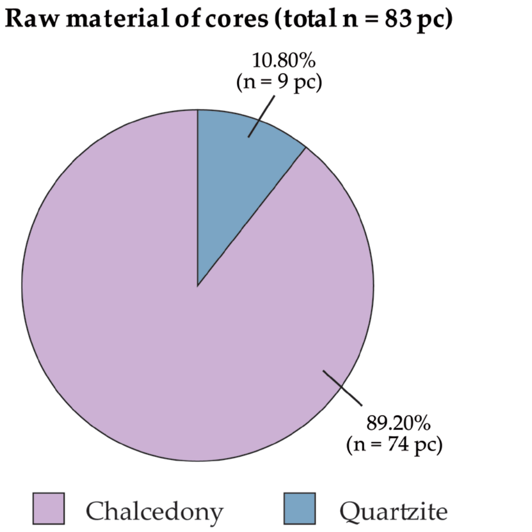


Figure 69: SC 3 Ruuga, areas N98/39-1 and -2, pie chart of the distribution of raw material categories among lithic cores.

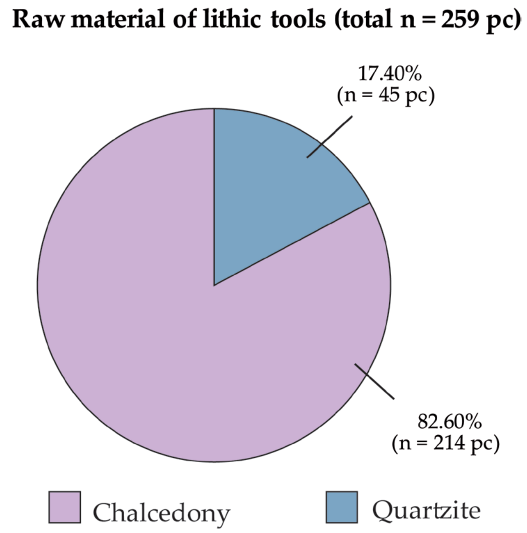
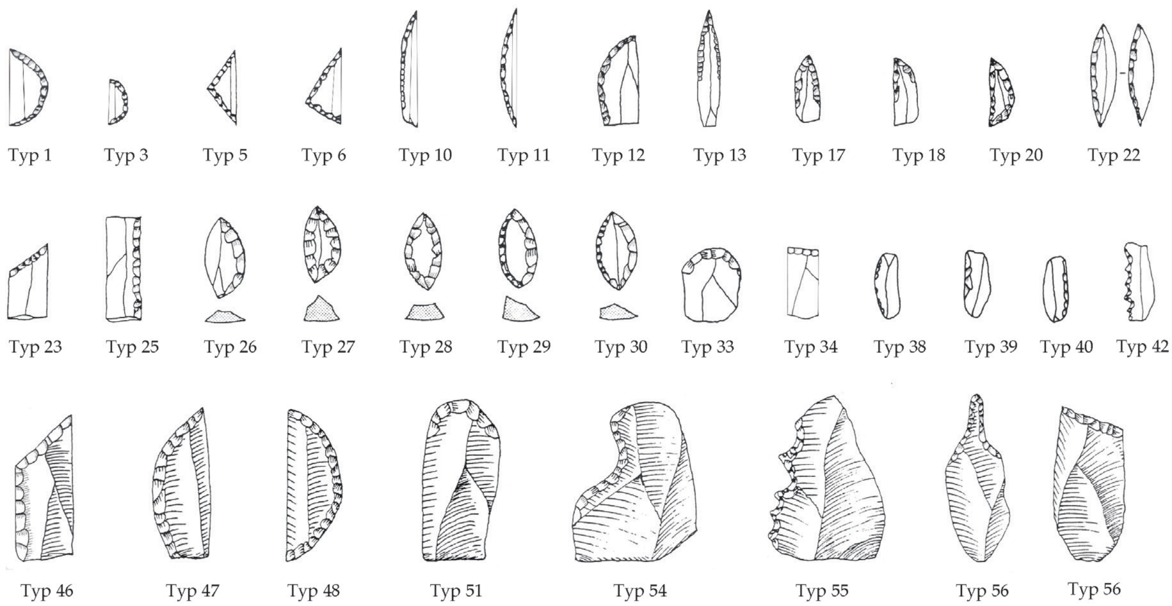
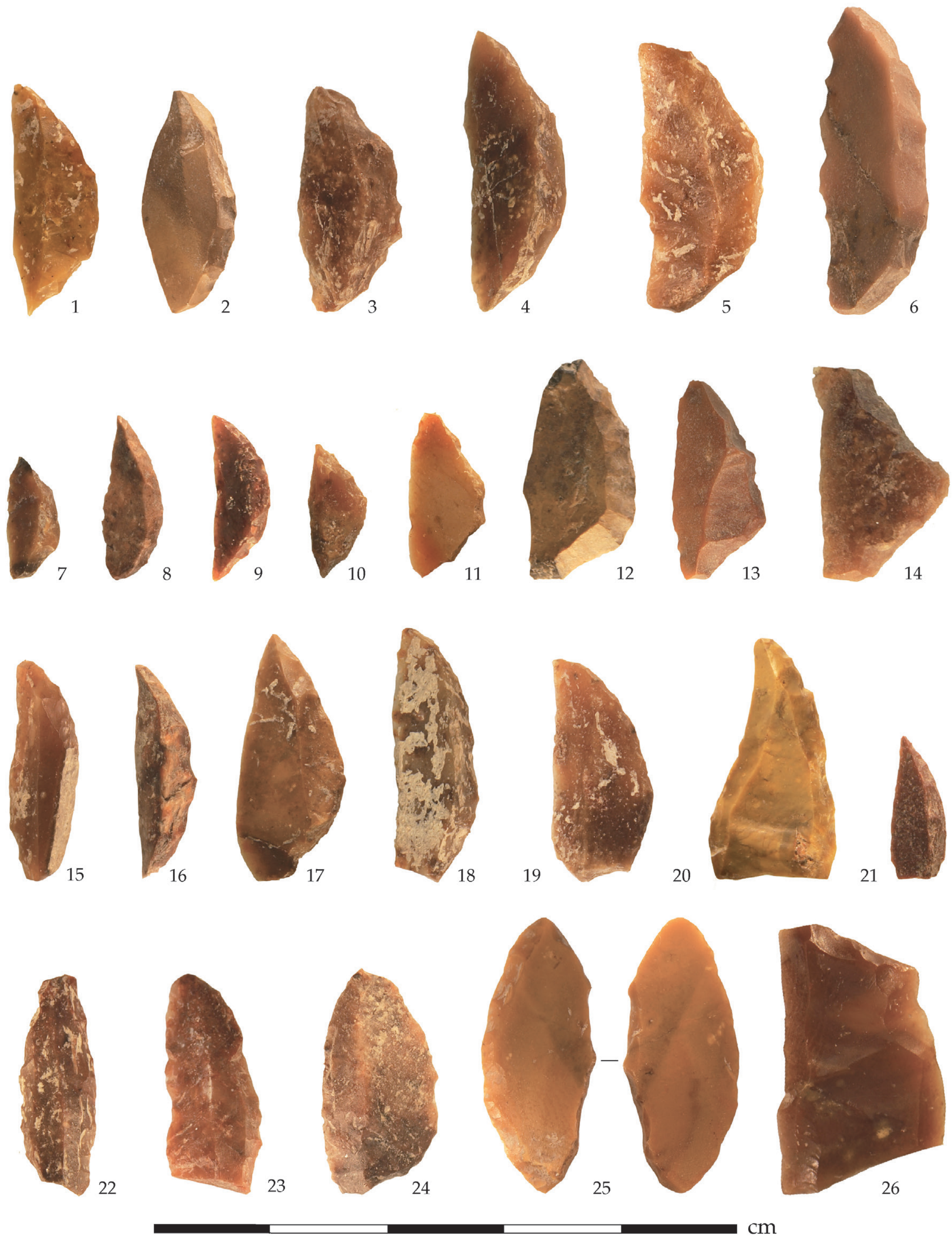


Figure 70: SC 3 Ruuga, areas N98/39-1 and -2, pie chart of the distribution of raw material categories among lithic tools.



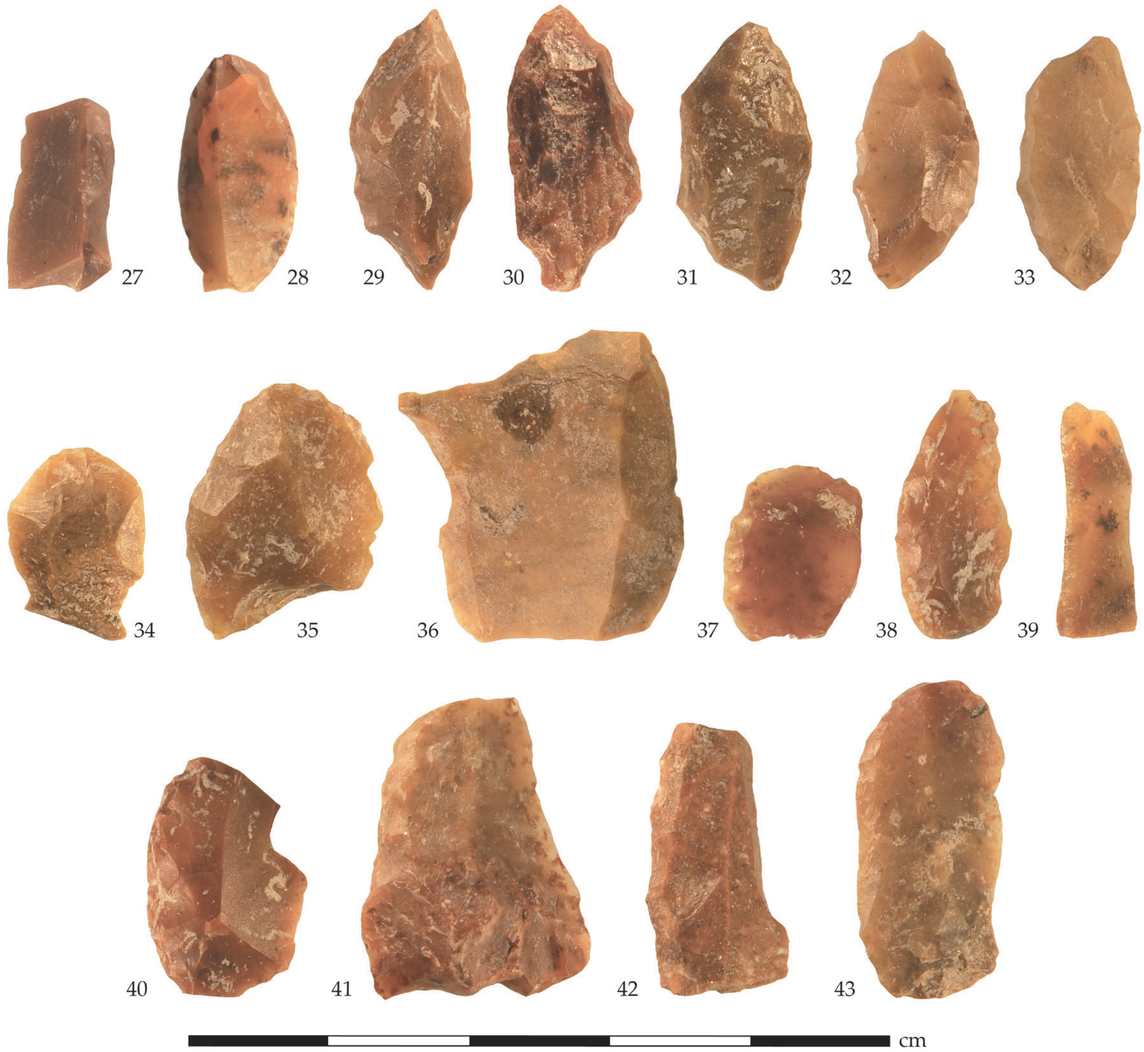
Type 1: Micro-segment < 25mm, Type 3: Micro-segment < 14mm, Type 5: Isosceles triangle, Type 6: Scalene triangle, Type 10: Long micro-point, unilaterally retouched, Type 11: Long micro-double-point, unilaterally retouched, Type 12: Short micro-point, unilaterally retouched, Type 13: Long micro-point, symmetrically bilaterally retouched, Type 17: Short micro-point, symmetrically bilaterally retouchend, Type 18: Short micro-point, asymmetrically bilaterally retouched, Type 20: Short micro-double-point, asymmetrically retouched, Type 22: Alternately retouched micor-double-point, Type 23: Terminally retouched micro-point, oblique, Type 25: Backed bladelet, Type 26: Micro-sidescraper, Type 27: Thick double micro-sidescraper, Type 28: Flat double micro-scraper, Type 29: High-backed micro-sidescraper, Type 30: Low-backed micro-sidescraper, Type 33: Micro-endscraper, Type 34: Terminally retouched straight microlithe, Type 38: Laterally fine retouched microlith, Type 39: Laterally retouched microlith, Type 40: Backed microlith, Type 42: Denticulated microlith, Type 46: Angled backed point, Type 47: Convex backed point, Type 48: Large segment >25mm, Type 51: Endscraper on a blade >25mm, Type 54: Notched flake >25mm , Type 55: Denticulate >25mm, Type 56: Borer >25mm, Type 59: Oblique trunctated flake >25mm.

Figure 71: SC 3 Ruuga, areas N98/39-1 and -2: tool types found in the lithic assemblage (idealized representations compiled after Richter (1990, 1991) to be used in conjunction with Table 22, Appendix 3).



1-6: Micro-segment <25mm (Type 1), 7-9: Micro-segment <14mm (Type 3), 10-11: Isosceles triangle (Type 5), 12-14: Scalene triangle (Type 6), 5: Long micro-point, unilaterally retouched (Type 10), 16: Long micro-double-point, unilaterally retouched (Type 11), 17-21: Short micro-point, unilaterally retouched (Type 12), 22: Long micro-point, symmetrically bilaterally retouched (Type 13), 23: Short micro-point, asymmetrically bilaterally retouched (Type 18), 24: Short micro-double-point, asymmetrically retouched (Type 20), 25: Alternately retouched micor-double-point (Type 22), 26: Terminally retouched micro-point, oblique (Type 23).

Figure 72: SC 3 Ruuga, areas N98/39-1 and -2, lithic tools smaller than 25 mm (digital picutes: Franziska Bartz).



27: Backed bladelet (Type 25), 28: Micro-sidescraper (Type 26), 29: Thick double micro-sidescraper (Type 27), 30: Flat double micro-scraper (Type 28), 31: High-backed micro-sidescraper (Type 29), 32-33: Low-backed micro-sidescraper (Type 30), 34-35: Micro-endscraper (Type 33), 36: Terminally retouched straight microlithe (Type 34), 37-38: Laterally fine retouched microlith (Type 38), 39: Laterally retouched microlith (Type 39), 40-43: Backed microlith (Type 40).

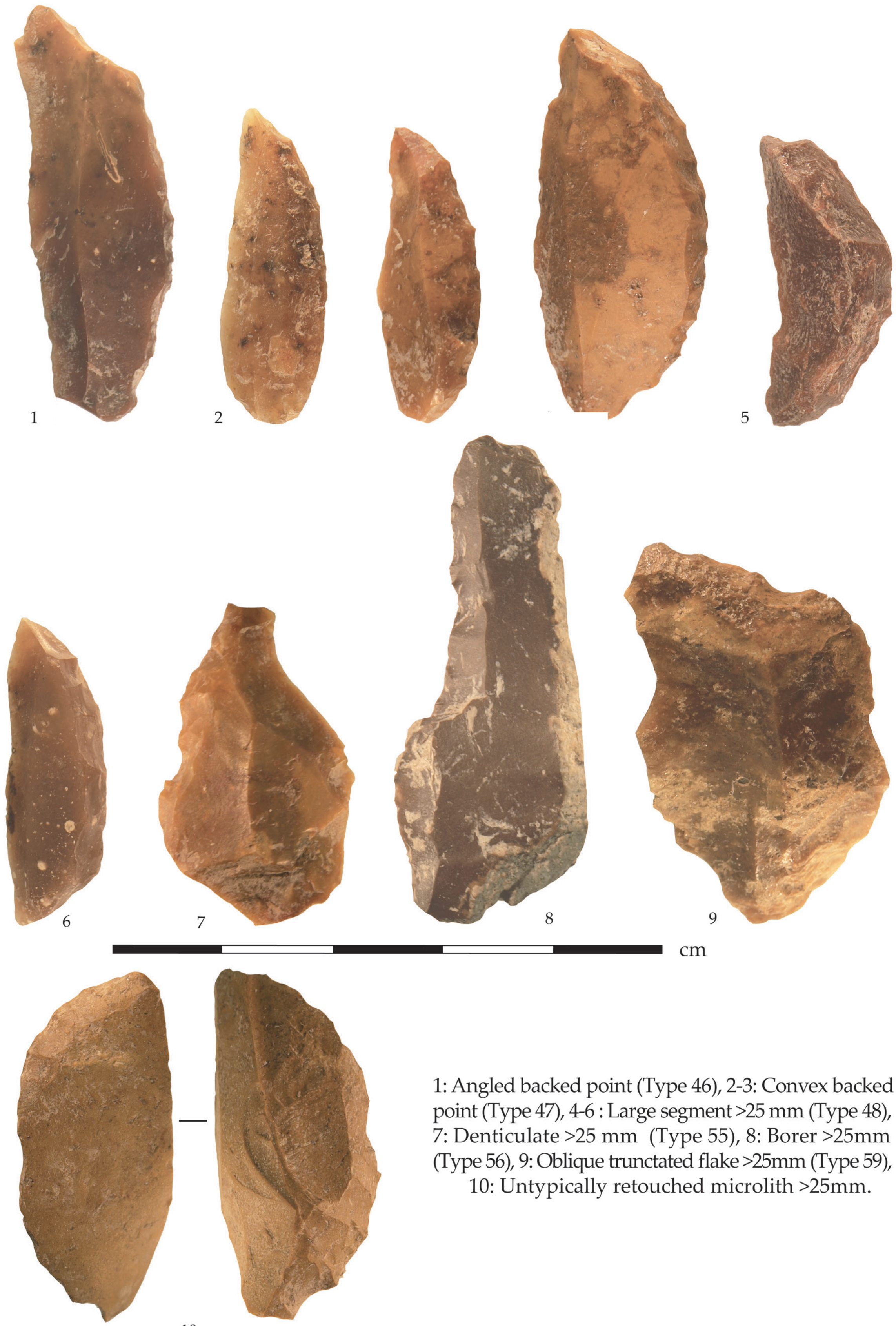
Figure 73: SC 3 Ruuga, areas N98/39-1 and -2, lithic tools smaller than 25 mm (digital picutes: Franziska Bartz).

southern African context (see Miller, 2002, p. 1101). However, there is not enough evidence, such as semi-finished drawn wire or chain links, to claim that the ironmasters produced it at the site. Most probably it was bartered from somewhere else.

All in all, the ironworkers from Ruuga were skilled masters of their craft. They successfully reduced iron oxides to elemental iron of workable quality, and mastered the elaborate steps of refining with simple pit furnaces. The smithing techniques that the ironworkers applied correspond to the technologies used across southern Africa during the Early Iron Age (e.g. Miller, 1996, 2002, p. 1101, Denbow & Miller, 2007, pp. 295-296, Chirikure, 2015, pp. 116-117). The metal artifacts recovered were small tools or jewelry and most likely did not represent to full range of implements produced. Comparing the range of metal artifacts found at LIG sites (Table 53, Appendix 3) with the spectrum of tools handed down in the oral history record (section 5.3.4, Table 56, Appendix 3), the finds made at the tool production sites were in no way representative of the spectrum of implements manufactured in historical times. Most likely the ironworkers of Ruuga produced more than small points and chain fragments, but the full range of tools remains so far unknown.

2.3.1.6. Lithics

Stone artifacts were classified according to the scheme described in section 1.7. As can be seen in Table 5 (Appendix 3), the excavations



1: Angled backed point (Type 46), 2-3: Convex backed point (Type 47), 4-6 : Large segment >25 mm (Type 48), 7: Denticulate >25 mm (Type 55), 8: Borer >25mm (Type 56), 9: Oblique trunctated flake >25mm (Type 59), 10: Untypically retouched microlith >25mm.

Figure 74: SC 3 Ruuga, areas N98/39-1 and -2, lithic tools larger than 25 mm (digital picutes: Franziska Bartz).

Figure 75: SC 3 Ruuga, area N98/39-2, abrader found in unit 50/55 with a small bone fragment.

N98/39-1 and 2 produced 7675 stone artifacts, weighing 12 kg in total. All lithic material was separated according to raw material, retouched pieces (tools), cores, preforms, chips, debitage and unmodified stones (Table 21, Appendix 3). The lithic assemblage comprised the whole range of tool production (Figure 67). Chips accounted for the largest proportion (37%, n = 2839 pcs) of the assemblage, and flakes were present in substantial numbers (32.9%, n = 2526 pcs). Blades occurred only in 3.4% (n = 259 pcs) of the cases. 21.3% (n = 1638 pcs) were classified as debitage, and unmodified raw material added up to only 0.69% (n = 53 pcs). The 83 cores found at the site accounted only for 1.08% and 259 retouched artifacts (tools) amounted to 3.38% of the total assemblage.

People used local raw material for lithic tool production and the main materials were chalcedony (RM 1) and quartzite (RM 2) (Figure 68). The glassy fraction of chalcedony accounts for 56.8wt% (n = 6831 g) of the total assemblage and 42wt% (n = 5050 g) are coarse material of the quartzite fraction. Only 2.3wt% (n = 277 g) of the assemblage was sandstone, and 0.02wt% (n = 3 g) of the lithic raw material found was not identifiable. The stone-knappers of Ruuga were selective in terms of the raw material because 89.2% (n = 74 pcs) of the cores were of opaline silica and only 10.8% (n = 9 pcs) of quartzite (Figure 69). In percentage weight, 75.8wt% (n = 2021 g) of the cores still consisted of chalcedony against 24.1wt% (n = 644 g) of quartzite. A similar distribution occurred with respect to the raw material used for formal tool production: 82.6% (n = 214 pcs) of the retouched artifacts are made from opaline material and only 17.40% (n = 45 pcs) from coarse quartzite (Figure 70).

The vertical distribution of the lithic artifacts can be taken from the Figures 41 to 44. The vertical distribution has already been discussed in section 2.3.1.2. The following discussion addresses now the horizontal distribution of the lithic materials. From Figure 64 it can be seen that one concentration of lithic residues occurred in the area where the ironworking zone has been reconstructed in Figures 61 to 63. The same Figure also illustrates that in the northern units there was another concentration of lithic artifacts, i.e. a zone of activities related to stone knapping. To better understand the activity pattern, the frequency of chips per unit converted to cubic meter was mapped along with the cores (Figure 65). While exhausted cores may be thrown away from the workplace, small chips remain where they are and became trodden into the sandy ground. In the southern non-deflated area, a marked concentration of chips and cores occurred in the units 50/54, 51/53, 51/54, and 52/54. The highest absolute numbers of chips were found in units 50/54 and 52/54. The entire stone-knapping zone differed from the other units in that the latter comprised significantly less

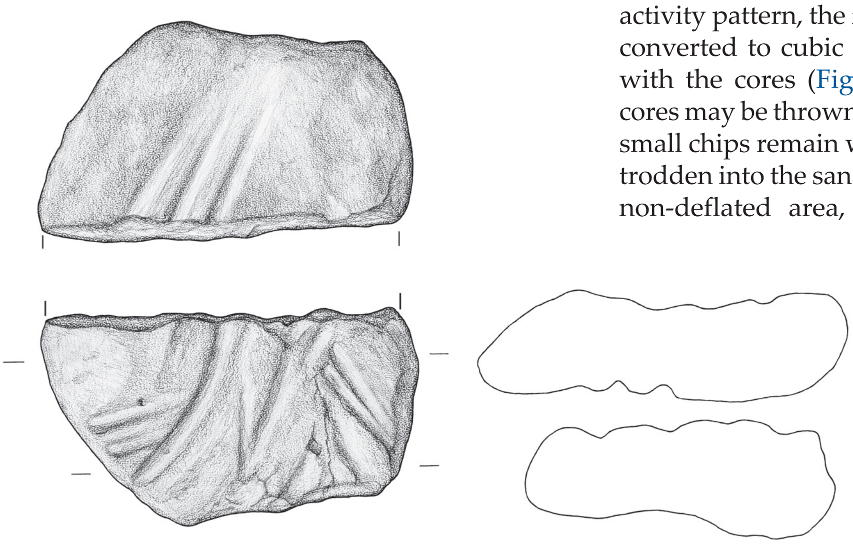
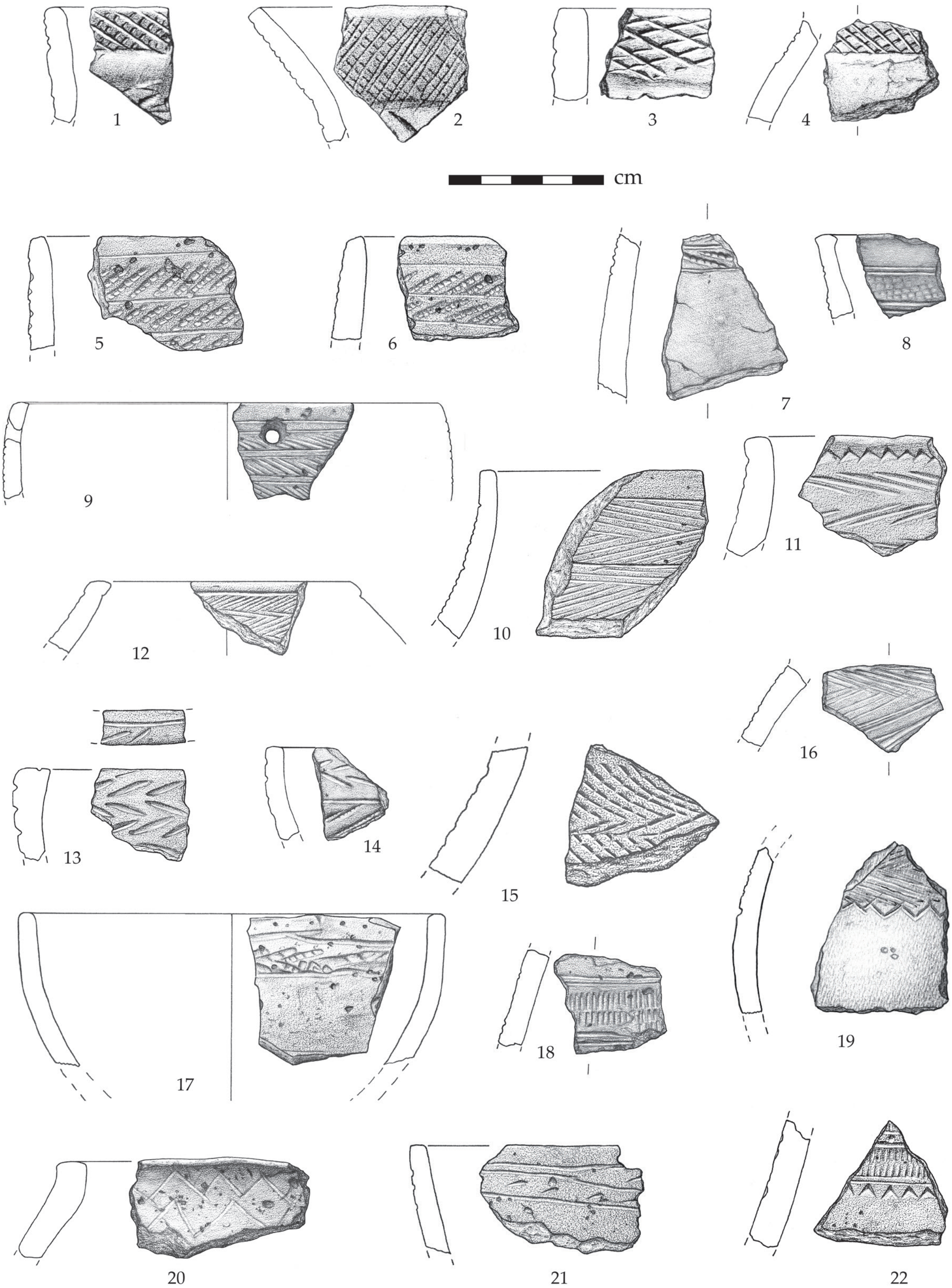


Figure 76: SC 3 Ruuga, area N98/39-2: topside and underside of the abrader found in unit 50/55 (drawing: Anja Rüschmann).



1 to 4: Late Ironworking Groups pottery; 5 to 23: Early Ironworking Groups pottery.

Figure 77: SC 3 Ruuga, areas N98/39-1 and -2, selected pottery finds (drawings: Anja Rüschmann and the author).

Figure 78: SC 3 Ruuga, site N98/39-4 (facing west).

chips and cores, and it overlapped with the ironworking zone as defined in the section above (Figures 61 to 63). Moreover, in unit 50/55 the abrader illustrated in Figures 65, 75, and 76 indicated the production of wooden tools or bone implements, which needed to be straightened or polished. While the waste of slag decreased in the northern units, the presence of chips attested that there was another lithic tool production zone (Figure 65). In particular unit 54/52 attracted attention owing to its high frequency of chips per unit and per cubic meter, and its high amount of cores (n = 8) and retouched tools (n = 20, Table 21, Appendix 3, Figure 65). Together with unit 56/52, it was found to be another workplace of stone-knapping. The high concentration of chips per cubic meter found in the northern units was caused by deflation. However, the absolute frequency of chips per unit was still high, in particular in unit 58/54, and together with the numerous cores found in this section of the excavation it pointed to the existence of another stone working place (Figure 65). Again, this area overlapped greatly with the slag concentrations described in the section above, suggesting that ironworkers and stoneworkers used the same working areas within the settlement.

As illustrated in Figure 67, the preforms produced were mainly flakes (32.9%) whereas blades accounted for only 3.38% of the assemblage. The limited number of the latter is most probably not representative because they were processed into tools. The classification of cores revealed that most preforms were produced from single-platform cores (42.16%, n = 35 pcs) or irregular cores (31.3, n = 26 pcs) (Table 23, Appendix 3). Polyhedral and bilateral discoid cores accounted for 10.84% (n = 9 pcs) each, and in three cases (3.61%) bipolar specimens were found. Only one example of a discoidal core was identified (1.2%). However, from the appearance of the cores it was found that there existed no explicit blade production. Most tools were produced from flakes of various shapes.

The spectrum of the 259 retouched artifacts (Figures 72 and 73) was dominated by micro-segments of Type 1 (24.7%, n = 64 pcs), and short unilaterally retouched micro-points of Type 12 (15%, n = 39 pcs) (Table 22, Appendix 3, Figure 71). The next most frequent tool category was backed microliths of Type 40 with 15 specimens amounting to 5.8%. Taking all laterally retouched microliths together (Type 38, 39, and 40), they accounted for 9.65% (n = 25 pcs). Low-backed micro-sidescrapers of Type 30 were present in

Figure 79: SC 3 Ruuga, site N98/39-3 (facing southwest).

13 cases (5%). Taking all sidescrapers of Type 26, 27, 28, 29, and 30 together, they constituted 9.3% (n = 24 pcs) of the total assemblage (Table 22, Appendix 3). In addition, 2,6% (n = 7 pcs) were found to be micro-points (one angled backed point of Type 46 and six convex backed points of Type 47). Other tool types such as small micro-segments, triangles, micro-points, backed bladelets, endscrapers and denticulate tools were only present in small numbers and are listed in Table 22 (Appendix 3). 9.6 % (n = 25 pcs, Type 43) of the tools did not fit the classification scheme applied here. Artifacts larger than 25 mm (Figure 74) accounted for 9.2% (n = 25 pcs) of the assemblage, 11 of them being large segments (4.2%). The large retouched artifacts appeared not as standardized as the smaller ones, and eight tools (3.1%) did not fit the classification scheme at all. Furthermore, the assemblage of large microliths produced an endscraper on a blade (Type 51), a notched flake (Type 54), two denticulates of Type 55, one borer of Type 56, and one oblique truncated flake of Type 59 (Table 22, Appendix 3).

In summary, the lithic tool assemblage was dominated by micro-segments, micro-points, laterally retouched microliths and micro-sidescrapers (Figures 72 to 74). Because of this, the assemblage could be assigned to the Wilton complex frequently found at Holocene sites in southern Africa. Comparable assemblages were characterized by the occurrence of formal tools such as micro-scrapers and backed micro-tools. Wilton assemblages were preferably made from a fine-grained raw material and tools were manufactured from flakes rather than blades (Mitchell, 2002, p. 145, Parkinson, 2014, p. 131). It is a commonly held view that microliths were used for hunting weapons, in particular as projectile points as reconstructed in Odell (2004, pp. 177-180). Together with the abrader illustrated in Figures 75 and 76, one can argue that projectile production took place in the excavated area. This raises the question whether the ironmasters were also the stone masters, and whether the strong link between iron and hunting as described in section 5.3.4 for the Late Ironworking Groups already existed in earlier times. However, use-wear analyses would be necessary to define precisely the function of the microliths of Ruuga, and to assess whether they were exclusively used in hunting or served other purposes too.

Figure 80: SC 3 Ruuga, site N05/01 (facing north).

2.3.1.7. Ostrich eggshell beads

The excavated units of N98/39-1 and -2 revealed 247 ostrich eggshell products, weighing together no more than 29 g. 89.8% (n = 222 pcs) of them were small well-preserved ostrich eggshell beads, and preforms accounted only for 8.5% (n = 21 pcs). Four specimens were small debris (1.6%). The bead assemblage suggested that there was some bead production at the site but not in the area of the excavated units. Presumably, most of the beads were lost by the residents.

2.3.1.8. Pottery

The excavated areas N98/39-1 and -2 produced a total of 4442 pieces of pottery, weighing 10.6 kg (Table 21, Appendix 3). Like the other find categories, the concentration of pottery raised per unit in the northern squares owing to deflation (Figures 37 to 40 and 66). The pottery assemblage was composed of highly scattered material and almost no refitting of vessel parts was possible. Every unit contained more than 100 g of pottery, most of them produced between 200 and 500 g. Only in the units 50/54, 52/54, and 58/52 was the total amount of pottery between 500 and 600 g per unit. Most likely, the pottery represented discarded material from a settlement nearby and, assuming that the disposal behavior of the inhabitants was similar to that found today, shattered pottery and other remains such as bones were more likely to be concentrated in the precincts of a homestead or living area than in the homestead or living area itself. No structures of houses or shelters have been found at the site so far, but even so one can assume that there existed places at the site where people slept and cooked. The high frequency of pottery in the excavated units suggested that there was a living area nearby, and that the bloom refining as well as the stone knapping took place in the periphery of a zone were families cooked and slept. However, while the first scenario describes a midden, the second indicates a workplace, and it is highly unlikely that iron and stone implements were produced in a rubbish heap. When describing the stratigraphy of Vungu-Vungu (SC 12) I argue that two different

Figure 81: SC 3 Ruuga, site N05/10 (facing east).

occupation horizons became mixed because of the soft soil condition. The same may be true for Ruuga and it is highly likely that the find horizon comprises two different periods of use that interfere with each other. The radiocarbon dates derived from the pottery and the tuyere as discussed above in section 2.3.1.3 however indicate that they cannot be far from each other from a chronological point of view.

The pottery assemblage from the excavated layers was composed of a brittle organically-tempered ware. It is not the aim of this study to provide a detailed analysis of pottery decoration. Briefly described, the prevalent motifs were horizontal bands with incised herringbone patterns or fine comb-stamped ornamentation, and I denominate this pottery Kapako/Divuyu-style ware (Figure 77). Eight charcoal samples were extracted from individual shards for radiocarbon dating (Table 2, Appendix 3) and, as discussed earlier in section 2.3.1.3, they produced 2-sigma calibrated calendar ages between the beginning of the third and the turn of the eight centuries cal AD, indicating that the site was occupied for a period of more or less 500 years (Figure 162). As described earlier, Vungu-Vungu-style pottery was scarce at the site and mainly collected from the surface and the upper soil levels. These finds reflected the settlement activities nearby and belonged to the LIG occupation of Ruuga represented by site N05/01.

2.3.2. Area N98/39-3

Site appearance: Area N98/39-3 (Figure 27) was a calcrete quarry at the edge of the river terrace about 70 m northeast of N98/39-2 (Figure 79). Many finds were recovered from the residues of the quarry through sifting the loose debris and soil.

Finds: As can be seen in the Tables 5 and 21 (Appendix 3), 144 finds of a total weight of 564 g were collected (Tables 5 and 21, Appendix 3). Most of them were lithics (flakes, tools, and cores), attesting the existence of several stone knapping zones in the periphery of the settlement, and that the site extends farther to the east. This is also backed up by one tip of a broken charcoal-tempered tuyere.

Pottery Style: Kapako/Divuyu style

Lithic Typology: Later Stone Age

2.3.3. Area N98/39-4

Site appearance: Area N98/39-4 (Figure 27) was a toilet pit of 2.20 x 2.45 m in extension, reaching down to a depth of 1.5 m below surface (Figure 78). The pit was excavated by the residents roughly 60 m west of N98/39-1 and -2. The freshly excavated soil was sifted and finds were collected. Locals used the soil and calcrete for the construction of a house. Soil samples were taken from the southeastern section.

Finds: From the sifted material, 161 finds were recovered (1027 g) (Tables 5, 18, 19, 21, and 31, Appendix 3). Most of them were potsherds and only five stone artifacts and one processing slag were collected.

Pottery Style: Kapako/Divuyu style

2.3.4. Area N05/02

Site appearance: This was an artifact scatter of 200 x 200 m in an agricultural area, 200 m east of N98/39-2 between two homesteads (Figure 27). The site seemed to be undisturbed.

Finds: Locals collected about 5 kg of potsherds and lithics, but only 33 diagnostic potsherds and nine lithic artifacts were kept (Tables 5, 18, and 21, Appendix 3). The pottery belonged to the Early and Late Ironworking Groups, the latter probably originating from an abandoned homestead nearby.

Pottery Style: Kapako/Divuyu and Vungu-Vungu style.

Lithic Typology: Late Stone Age

2.3.4. Area N05/10

Site appearance: This was a scatter of artifacts comprising 200 x 200 m in an agricultural area, about 600 m east of N98/39-2 and 350 m east of N05/02 (Figure 27). Shrubs of an abandoned homestead enclosed the spot. On the edge of the river terrace artifacts eroded out (Figure 81). The soil cover over the massive calcrete hardpan was only 10 to 15 cm thick. It is likely that in this area most of the site has been eroded away. Farther uphill one may expect the site to be undisturbed.

Finds: Eighteen finds were kept (50 g) (Tables 5, 18, 21, and 31, Appendix 3). Most of them were potsherds, but also stone artifacts and slag fragments were collected.

Pottery Style: Kapako/Divuyu and Vungu-Vungu style.

Lithic Typology: Late Stone Age

2.3.5. Area N05/01

Site appearance: This site consisted of scattered artifacts on a harvested field south of the highway and about 400 m southeast of N98/39-2 (Figure 27). The finds scattered south of Paulina Kausika's homestead who is the owner of the field (Figure 80).

Finds: The finds recovered from this area were smelting and refining slag (Figure 56), potsherds, a clay pipe stem and lithics (Tables 5, 18, and 21, Appendix 3). The slag was not kept. The assemblage implied that there existed a smelting and settlement site of the Late Ironworking Groups south of N98/39-1 and -2. The young slag finds from the latter dating from the late fifteenth to the nineteenth century AD (section 2.3.1.3) were most probably remains from this site.

Pottery Style: Vungu-Vungu style.

Lithic typology: unspecified

2.3.6. Interpretation of site-complex SC 3

Site-complex SC 3 of Ruuga was settlement site of the Early Ironworking Groups, which was occupied between the fourth and the eight centuries AD, and perhaps even longer. The settlement stretched for at least 650 m along the riverbank, comprising the areas N98/39-1, -2, -3, -4, N05/02, and N05/10 Within the settlement there existed several zones of activities and of refuse disposal. The assemblage of Ruuga combined a Wilton microlithic tool assemblage with iron slag and early ceramics.
The areas N98/39-1, 2 and 3 were lithic tool production zones. The raw material was of local origin, but it does not occur at the site. People manufactured formal microlithic tools that belong to the Wilton complex of southern Africa. Besides stone tool production, the residents of Ruuga refined dirty iron blooms in the areas N98/39-1and -2 as early as the in the fifth/sixth centuries AD.

The results of the archaeometrical analyses provided evidence for the first steps of purifying a bloom until the latter became a usable piece of raw material. Whether or not the people smelted on site (i.e. near their habitation location) is unknown. The required ores could have been mined in the Kakeni and Kafuma riverbeds (Figure 217). The ironworkers of the time produced iron and steel, which was processed into artifacts from which only small pieces such as chain links, needles and one hook survived in the assemblage. Small objects of pieced-together material mirrored that iron was valuable and recycled at a high rate. Bloom refining and fine smithing happened at the same workplace most probably performed by the same people. From the archaeological record it would appear that the zone of metal-lurgical activities was also used for lithic tool production. It could be that the same individuals accomplished both tasks, iron and stone working. Perhaps iron was linked to the sphere of hunting right from its introduction into the Late Stone Age societies of the middle Kavango region. As mentioned earlier, the site was occupied for more or less 400 years, or even longer. Whether the residents of the time stayed permanently at the site or whether Ruuga was a location, where a mobile population repeatedly set up their camps for several generations was not apparent from the excavated assemblage. The lack of clays from buildings suggested that people lived in lightweight constructions. Assuming that the environmental conditions were comparable to what is found today, both scenarios are possible. The riverine environment could easily sustain a sedentary hunting and gathering population, but it is just as likely that people were seasonally mobile and exploited the game rich forest zones between the permanent river courses as they still did at the beginning of the twentieth century (section 5.1). The decorative expression of the ceramics links Ruuga with sites like Kapako (SC 4), Divuyu in the Tsodilo Hills (Denbow, 2011; 2013) and Xaro at the banks of the lower Kavango River (Ed Wilmsen, personal communication), which were occupied by herders somewhat later than Ruuga and Kapako (SC 4) (see also section 3.1).

Site-complex SC 3 provided also evidence of a second occupation horizon during the LIG period, particularly a smelting site in area N05/01, some 400 m southeast of the EIG site. Considering the local smelting tradition, there was no local memory about ironworking found among the residents, and the radiocarbon dates suggested that it may belong to an early horizon of the Late Ironworking Groups. The late slag material scattering in area N98/39-1 and -2 most probably originated from this site.

2.4. Site catalogue no. 4, Kapako

(Table 1, Figure 26)

Site Number: N99/21
Site Name: Kapako
Coordinates: E19°34.040'/ S17°52.525'
Constituency: Kapako
Plane Survey Sheet Namibia 1:50000: 1719 DC MUPINI
Sub clusters: N67/01 (-/-),
N68/01 (E19°34'140/S17°52'523'),
N68/02 (E19°33'902'/S17°52'645')
(N74/01 according to Richter, 2005: Catalogue No. 5),
N98/38 (E19°33.382'/S17°52.675'),
N99/21 (E19°34.040'/S17°52.525'),
N06/07 (E19°34.700'/S17°52.615')
Survey: 1967, 1998, 2005, 2011
Excavations: 1968, 1999, 2006
References: Sandelowsky, 1968; Sandelowsky, 1979, pp. 52-55; Richter, 2005, pp. 87-89: Catalogue No. 4-6
Registration Number State Museum Windhoek: B1533 (surface finds), B1534, B1575 (surface finds), B1575A-D (B1575A: material from house foundation, B1575C: material from dump of drainage pit, B1575B: excavation drainage pit, B1575D: material from pit behind pigsty), B1592 (excavation Camp Site N68/02), B4217, B4288
Location: North of National Highway B10 from Rundu to Nkurenkuru. The site starts east of Hompa Leevi Hakusembe's residence at Kapako and stretches along the river side as far west as the well-known Kapande Tree (west of the Kapande In Cuca Shop) (Figure 82).
Land Owner: Hompa Leevi Hakusembe's family, Ebenezer Mission Kapako
Altitude: 1080 m AMSL

Topography: The archaeological site is situated on a flood-proof middle terrace of the river. The modern surface declines towards the river (north) with a slight downward slope of about 2.5%. The high permeability of the soil allows for a good preservation of the cultural horizons because there is little erosion caused by the run-off of surface water. Only close to the edge of the steep bank has soil been eroded away. As can be seen in Figure 89, the archaeological material is embedded in a loamy to sandy soil

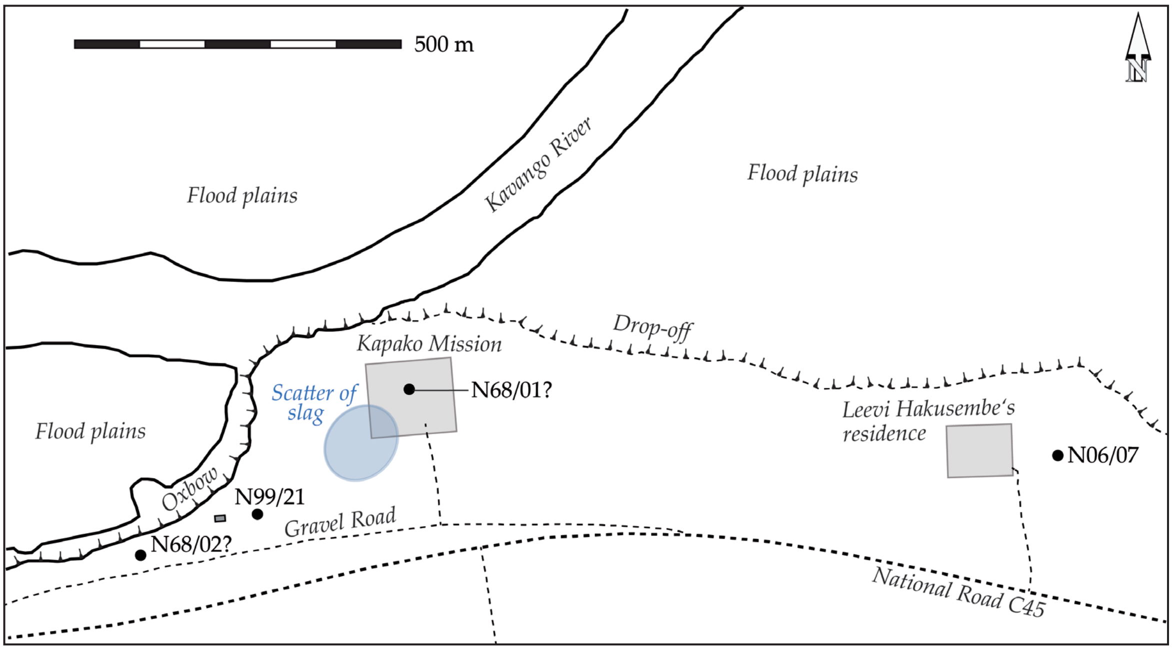


Figure 82: Site layout of SC 4 Kapako.

body of about 220 cm in maximum depth. Within the soil, a massive calcrete crust has formed. The soil cover decreases towards the edge of the terrace to a maximum thickness of about 50 cm and less relative to the crust level. The surface of the calcrete horizon varies for 1.20 m in height relative to the datum and tends to increase towards the river. At site N99/21, there seems to be a sub-surface drop-off of the hardpan of about 1.20 m in height, roughly 40 m away from the edge of the steep bank of the river.

Site Appearance: The archaeological occupation, as far as we were able to identify, stretched from west to east for more or less 2.5 km along the river (Figure 82). The southern limit has not yet been identified. Artifacts were scattered in some places(see sub-clusters), in other places the site seemed to be undisturbed. Along the steep bank down to the river, eroded finds were common. Between Leevi Hakusembe's residence and the mission buildings the place was densely overgrown with Acacia shrubs. Around the mission, agricultural land has been installed. In 2005, a layer of loose, pale fine sand covered the excavation area N99/21 with a sparse grass cover during the rainy season. The top layer was mixed with modern materials such as plastics and cans. Since 2006, the area has been increasingly overgrown with Acacia shrubs. Other parts of the site were fallow land, but several buildings and foundations of abandoned constructions disturb the area.

2.4.1. Radiocarbon dates

So far, 12 radiocarbon dates have been produced from Kapako (Table 2, Appendix 3), most of them were taken to better comprehend the Early Ironworking Groups' occupation period of the site.
The first radiocarbon date published from N68/02 revealed a 2-sigma calibrated calendar age range between the ninth and the twelfth century AD (Pta-234, Table 2, Appendix 3, Figure 162) (Sandelowsky, 1979). This was considerably younger than the dates from Ruuga (SC 3), even though the same ceramic style was present at the site. Therefore, a series of radiocarbon samples was produced from the carburized material found in the sediment and from the charcoal-tempered pottery from the excavations of area N99/21. The best understood unit became N99/21-3 from a chronological point of view. All the 2-sigma calibrated age ranges of samples from the latter (Table 2, Appendix 3, Poz-20668, Poz-20679, Poz-20680, Poz-20682, and Poz-20694) clustered between the first half of the fifth and the second half of the seventh century AD (Figure 91). In particular, the calendar ages obtained from three potsherds from the same level 70 cm below surface (Poz-20679, Poz-20680, and Poz-20694) were very close to one another. What is more, the dates were in chronological order with the oldest being the deepest sample (Poz-20668), and the youngest (Poz-20682) being the uppermost, backing up the assumption that the early occupation horizon of Kapako was well preserved and undisturbed.

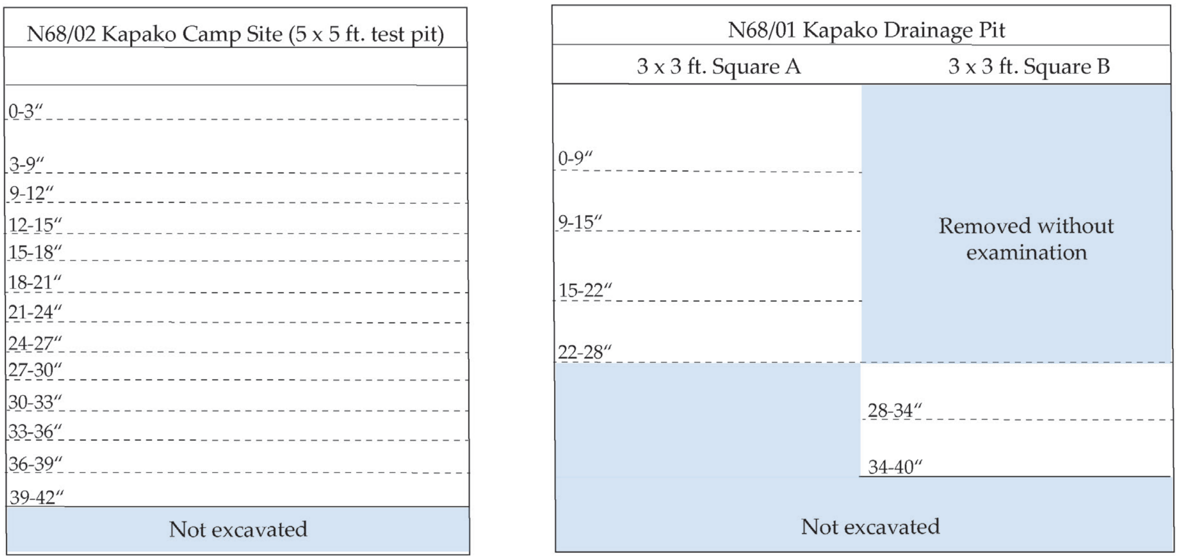


Figure 83: Level index of SC 4, areas N68/01 and N68/0, excavation of B. Sandelowsky in 1968 (Sandelowsky, 1979) to be used in conjunction with Table 24, Appendix 3.

Another date was produced from a charcoal sample taken from a vessel found by Reverend van Niekerk in 1967 on the Kapako Mission's grounds (Poz-20670, Figure 102: 12). According to him, the vessel was recovered 107 cm below the surface near the mission's buildings. Taking the stratigraphy established in area N68/01, which was located somewhere between the mission buildings, as a reference, the vessel must have been found almost 40 cm below the main occupation horizon illustrated in Figure 82, and most probably immediately above the calcrete hardpan in sterile soil. This would be an unusual stratigraphical position, and it may be that it was recovered from the backfill of a pit, which R. van. Niekerk did not recognize as such. The charcoal temper from this vessel produced a 2-sigma calibrated calendar age between the second half of the seventh century to the first half of the ninth century cal AD (Poz-20670, Table 2, Appendix 3, Figure 162).

Turning to N99/21-1, the calibrated radiocarbon dates reflected the doubtful association of finds recovered from this excavation area. Two samples of charcoal collected from the sediment were available (KN-5574 and KN-5575, Table 2, Appendix 3), and three from extracted carburized material from potsherds found in the same layers (Figure 91) (Poz-20677, Poz-20678, and Poz-20693, Table 2, Appendix 3). While charcoal from level 9 produced a calendar age range falling between the late tenth and the middle of the twelfth century cal AD (KN-5575), charred material collected in level 6 showed a calibrated age range in the modern calibration plateau between 1650 and 1950 AD (KN-5574). Both dates are in chronological and stratigraphical order, and the latter could well determine the LIG occupation of the site. However, these samples were associated with EIG pottery dating back to a time span from the early fifth century to the second half of the seventh century cal AD (Poz-20677, Poz-20678, and Poz-20693, Table 2, Appendix 3) (Figure 162). First, these results implied that the occupation zone of the Early Ironworking Groups settlement extended as far west as N99/21-1 (Figure 82). Second, the association of the obtained dates strongly suggested that this area was disturbed, because the finds were no longer deposited in their chronological order. Aside from a possible deflation of the area indicated by the soil body above the calcrete crust, the area was possibly disturbed by the building activities nearby, as indicated in Figure 87.

In summary, Kapako revealed a well-dated occupation horizon of the fifth to seventh century AD, and the entire site was occupied up to

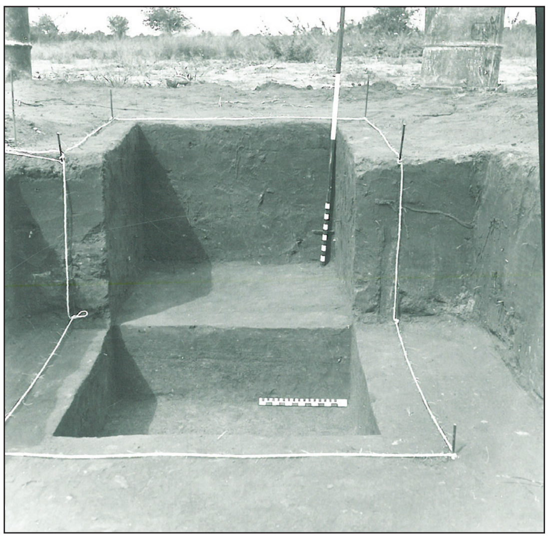


Figure 84: SC 4 Kapako, area N68/01, soil section (image: Beatrice Sandelowsky).

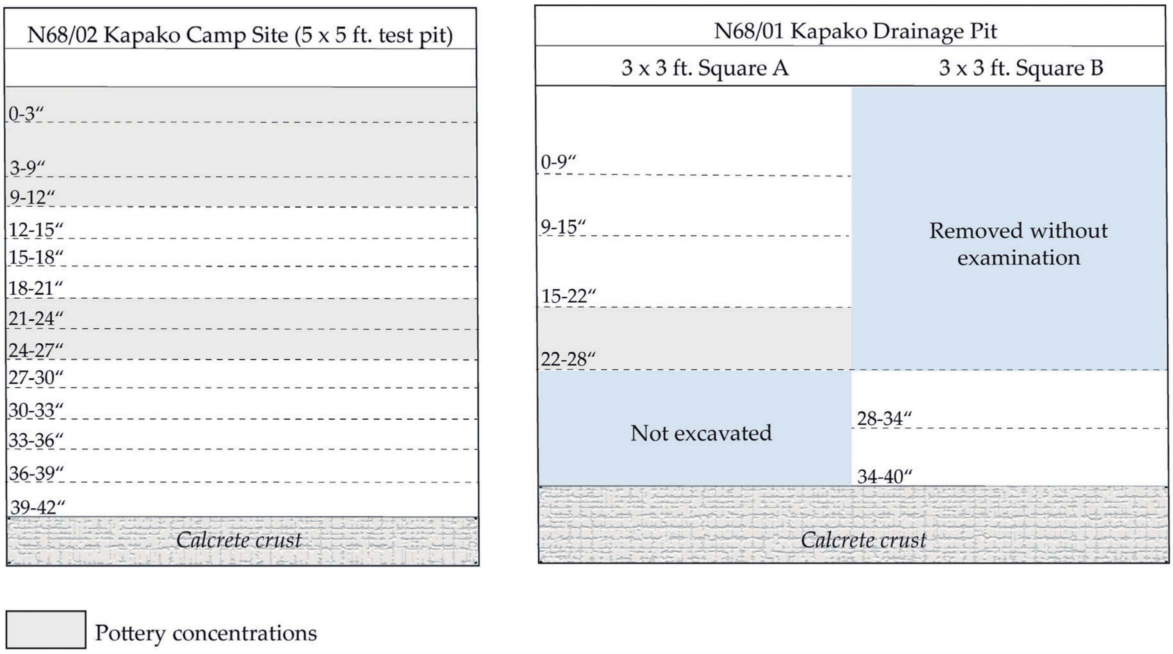


Figure 85: SC 4 Kapako, areas N68/01 and N68/02, vertical occurrence of pottery concentrations (based on Table 24).

the eleventh/twelfth century AD. The only date from the LIG occupation period fell in the calibration plateau of the modern era and was therefore very unspecific. More dates from trusted archaeological contexts would be necessary to assess the time depth of the late occupation period.

2.4.2. Excavation site N68/01

(Figure 82)

2.4.2.1. Excavation Method

The first artifacts from Kapako were reported to the State Museum in the 1950s by Reverend van Niekerk. In 1968, Beatrice Sandelowsky followed up van Niekerk's information on repeated finds around the Mission. Starting from dislocated artifacts recovered during construction activities, she excavated two 1-m² test units in arbitrary layers in a freshly dug drainage trench. In unit 1 (Square D according to Sandelowsky 1968 ms., Square A after Sandelowsky, 1979, p. 53) the upper soil was removed in a level of 20 cm in thickness. From there, the unit was leveled down in steps of 7 or 15 cm to a depth of 71 cm below the surface. Unit 2 (Square E according to Sandelowsky, 1968, Square B after Sandelowsky, 1979, p. 53) started from a level of 71 cm below the surface (bottom of the drainage pit) until a depth of 101 cm was reached (Figures 83 and 84).

2.4.2.2. Stratigraphy

The main occupation horizon was concentrated between 56 and 71 cm below the surface in a variegated soil layer. Slag, iron and lithics occurred from 56 cm to 86 cm below the surface (Table 24, Appendix 3). In the upper layers, only isolated artifacts were recorded. Unfortunately, no material from these units has been dated, but even so the cultural horizon appeared well preserved and undisturbed under a sediment cover of more or less 50 cm, and, judging from the pottery decoration, belonged to the early occupation horizon found at Kapako. One year before B. Sandelowsky undertook her excavations, Reverend van Niekerk reported several finds to the National Museum Windhoek (B1533 and B1534). As mentioned earlier, the potsherds from B1533 originated from a deposit 107 cm below the surface (see above), and they were refitted to a small vessel illustrated in Figure 102:12. As mentioned above, charcoal extracted from the vessel dated to between the late seventh to the ninth centuries cal AD (Table 2, Appendix 3, Figure 162, Poz-20670).

2.4.2.3. Finds

The test pit produced 227 finds (Sandelowsky, 1979, p. 54 Tab. 1) and several slag finds (see also Tables 6, 24, and 32, Appendix 3). More finds were collected from the dump of the drainage pit,[85] which was

[85] Registration Number State Museum Windhoek: B1575C.

dug before B. Sandelowsky assessed the site. Most finds were potsherds, and only two stone artifacts were collected during this excavation. Some faunal remains were also preserved in the cultural layer. From all the finds from the excavation, 50 specimens were accessible and reanalyzed in the framework of this study: 44 potsherds, two pieces of burnt clay, three slag fragments and one iron point (Tables 24, 25, 26, and 32, Appendix 3). The pottery was a brittle charcoal-tempered ware of typical Kapako/Divuyu style, suggesting that this place was a settlement location of the Early Ironworking Groups (Figure 102). Most interesting are the two fragments of burnt clay found in the cultural layer between 45 and 85 cm below the surface (Tables 24 and 26, Appendix 3). One of them showed the negative of a round stick (Figure 103), suggesting that the inhabitants of the site built wattle and daub constructions, which were probably storage facilities or houses. One gromp and one fragment of refining slag with gromps (4412/06) proved that skilled ironworkers lived in the early settlement of Kapako and processed blooms to compacted raw material, and to iron implements. The iron point sample 4476/06 (Figure 211: 7) was made from a piece of fresh raw material (Figures 86 and 213). Even though it was strongly corroded, it attested that the skilled ironmaster normalized the point in a final step of processing to remove disturbing crystal deformation from cold working (section 1.5.2.4). As I have already pointed out for Ruuga (N98/39-1 and -2, SC 3), the pottery and bone fragments indicated that the excavated unit was at the periphery of a living zone or homestead. The slag finds together with the iron artifact suggested that there was an ironworker's workshop nearby.

Pottery Style: Kapako/Divuyu style.

Lithic Typology: unspecified

2.4.3. Excavation site N68/02

(Figure 82)

2.4.3.1. Excavation Method

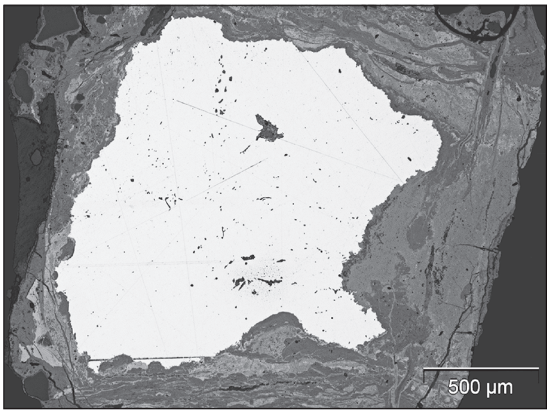
In 1968, Beatrice Sandelowsky excavated another 1.5-m² test unit roughly 50 m east of the mission, close to her campsite. She chose to level the unit down in arbitrary layers of 3 inches (7.62 cm) and 6 inches (15.24 cm) in thickness until she hit an almost sterile layer 106 cm below the surface (Figure 83). The soil was sifted through a 1.5 mm wire mesh.

2.4.3.2. Stratigraphy

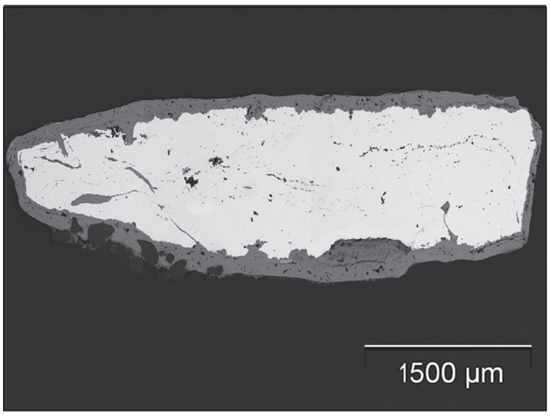
Two occupation horizons occurred. The upper horizon was a dark humic root-penetrated soil matrix of about 40 cm in thickness. Cultural material of the Late Ironworking Groups was scattered vertically from the surface down to a depth of 30 cm, and concentrated between 7 cm and 23 cm (Sandelowsky, 1979, p. 52). From 38 cm below the surface down to 45 cm, a dark gray-black layer of hard soil marked the beginning of the lower occupation horizon. From 45 cm downwards, the number of artifacts of the Early Ironworking Groups increased. The main concentration occurred between 61 and 76 cm below the surface (see Sandelowsky, 1979, p. 53, 5 x 5 ft. test pit) (Figure 85). The soil was dark grayish and hard. Lighter patches were most probably backfilled krotovinas from burrowers. With increasing depth and decreasing number of artifacts, the sediment graded into a looser and light sterile sandy soil at about 106 cm below the surface, covering the calcrete hardpan. A charcoal sample (Pta-234, Table 2, Appendix 3) was collected 60 to 70 cm below the surface from the lower occupation horizon and dated from the late ninth to the middle of the twelfth century cal AD (Figures 91 and 162).

2.4.3.3. Finds

The excavation produced more than 1300 finds, most of which are listed in Sandelowsky (1979, p. 54). However, when writing her paper, B. Sandelowsky overlooked some finds from the site and asked me to fill in the gaps when I reassessed her metallurgical finds. The complete finds are listed in Table 24 (Appendix 3). Of all the finds, 133 were incorporated into this study, in particular the metallurgical remains and the decorated EIG pottery. Altogether, the prevalent find categories from this trench were potsherds and faunal remains. The preservation conditions of the latter were rather good, but faunal analyses are still missing. The upper horizon contained clay pipe fragments, some slag and one iron object. Quartzite debris was scattered throughout the profile as were chunks of the nearby calcrete hardpan. It is likely that the latter were used for some purposes by the residents because calcrete chunks were largely absent in the other units of N68/01 and N99/21. In particular, the upper layer



4476/06



4477/06

Figure 86: SC 4 Kapako, area N68/01, iron artifacts. Sample 4476/06: cross section of an iron point from the EIG horizon. The non-flattened slag inclusions indicated that the artifact was forged from new unrecycled iron. Sample 4477/06: cross section of a piece of iron raw material from the LIG horizon. The inclusion's banding and the corroded weld seam in the left part of the section indicated that the artifact was made from pieces of recycled material.

produced a number of clay lumps, burnt and unburnt, some of which might have been remains of clay-lined buildings.

2.4.3.4. Finds from ironworking activities

Both layers produced a total of 14 slag fragments and two metal objects of which 10 were reassessed in the framework of this study (Table 32, Appendix 3). Eight slags samples turned out to be refining slags, and one specimen was a bloom fragment in smelting slag. Two slags from the lower horizon were analyzed in the laboratory. Sample 4414/06 was a refining slag and was assessed by means of chemical analyses (section 4.2.10). Sample 4413/06 was a piece of unconsolidated bloom. Microstructure analyses revealed that the metal produced was pure iron in a wustite-free fayalitic slag, indicating that it formed under effectively reducing conditions in the furnace. The semi-altered quartz grains present in this sample may be interpreted as erosive processes from the furnace wall, and suggest that the furnace was a pit furnace in the sandy ground.

From the upper layer, only sample 4477/06 displayed the original labeling and could be assigned to the LIG horizon. It was a piece of iron (Figures 86 and 211:10) that consisted of at least two joined pieces of low to medium carbon steel. It had been extensively hot-worked and folded, but the weldseams were poorly performed. It was probably heated to the austenite field in order to restore the crystal lattice of the ferrite grains, and after final cold working held at subcritical temperatures, which led to a partial recrystallization of the ferrite microstructure. The limited size of the piece proved that even the smallest metal fragments were recycled. The smithing techniques applied by the ironworkers of Kapako were the same methods as found at Ruuga (SC 3), Divuyu and Nqoma (Miller, 1996, pp. 82-84) and elsewhere in southern Africa (Miller, 2002, pp. 1100-1101) (section 4.4.5). Besides the technological considerations, the metal fragment attested the presence of a blacksmith at Kapako during the LIG occupation phase.
All the other slag finds were refining slags, and one smithing hearth bottom hinted at a refining furnace nearby. However, as the original labeling has not been preserved, I was not able to assign them to one of the two occupation horizons.

2.4.3.5. Pottery

Only a limited amount of pottery was assessable (Table 25, Appendix 3). All the potsherds belonged to the lower occupation horizon and showed the typical Kapako/Divuyu style (Figures 85 and 102). Most interestingly, Sandelowsky (1979, p. 54, Fig. 2) published three ceramic shards from the upper component of the site, two of which did not belong to what has been defined as typical Vungu-Vungu-style pottery (Kose, 2009b). Rather they belonged to a group of potsherds, which cautiously have been assigned to a kind of 'forager ware' based on their unusual decoration motifs (Kose & Richter, 2007, p. 118, Fig. 11). It is likely that they belonged to an early occupation horizon of the Late Ironworking Groups, i.e. the Tjaube people (sections 5.1.1 and 5.3.2) as will be discussed later in the final interpretation of the site. However, most shard material from the upper horizon was Vungu-Vungu-style pottery.

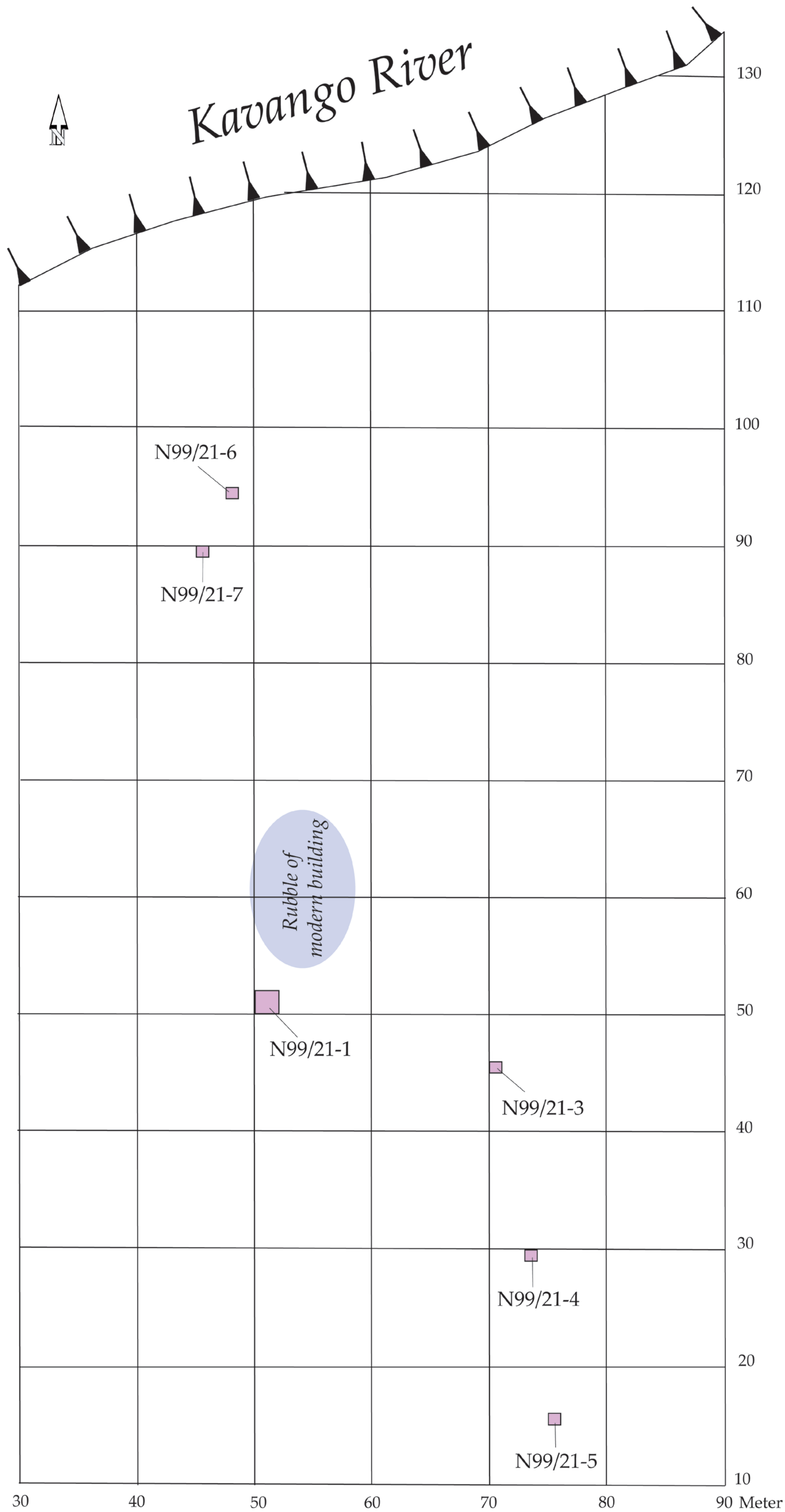


Figure 87: SC 4 Kapako, layout of the excavation areas N99/21.

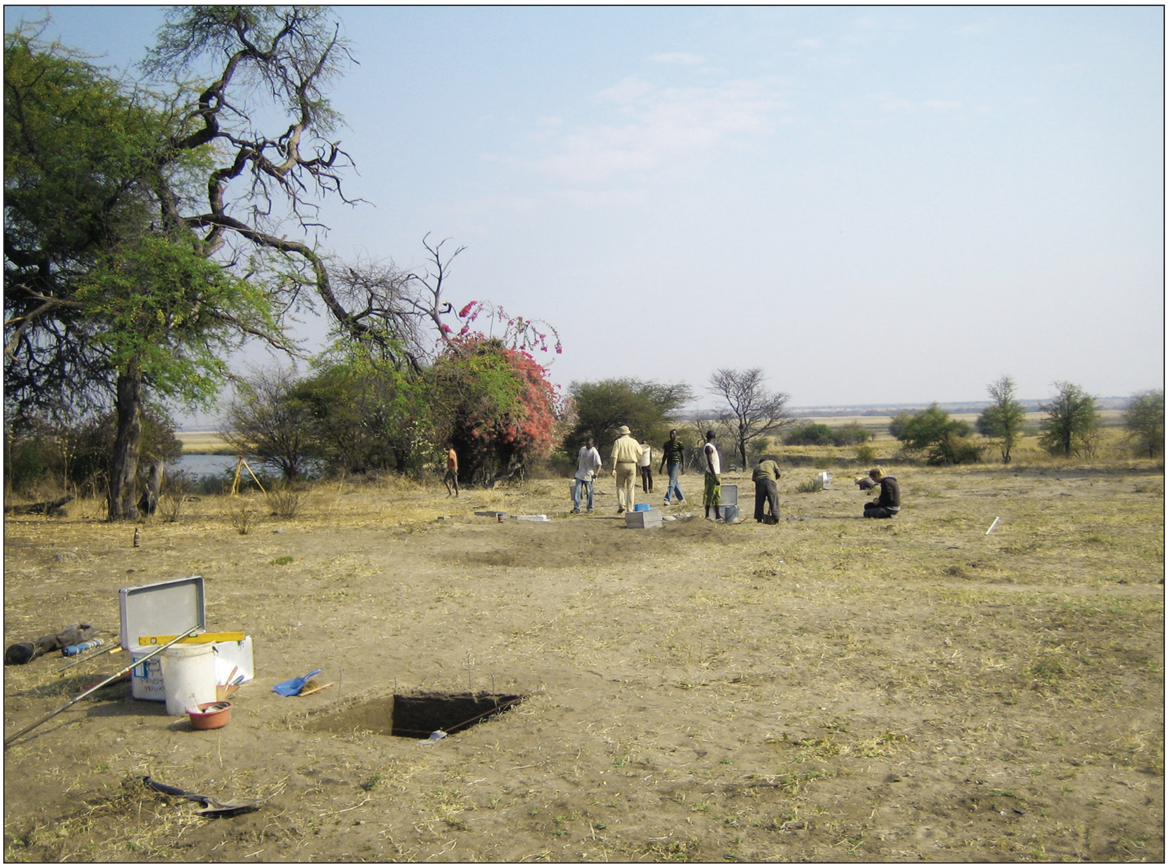


Figure 88: SC 4 Kapako, excavations in area N99/21 in 2006.

2.4.3.6. Lithics

The excavated unit revealed some unspecific lithic material consisting of calcrete chunks and quartzite debitage. The latter were rather thermally fractured than purposefully worked for lithic tool production (Table 27, Appendix 3). The raw material most likely derived from manuports originating the silcretes underlying the calcrete hardpan at the site, which crops out along the steep bank of the river. In the early cultural horizon, there were more flakes present than in the upper layer (Table 27, Appendix 3), which suggested that the inhabitants of the early settlement maintained a targeted production of lithics.

2.4.3.7. Other finds

The site produced a high amount of faunal remains, particularly fish bones (Sandelowsky, 1968). Even though the material has never been analyzed, it is most likely that fishing was an important pillar of subsistence for the late inhabitants of Kapako.

Figure 89: SC 4 Kapako, area N99/21-3, unit 70/45, soil profile (facing south).

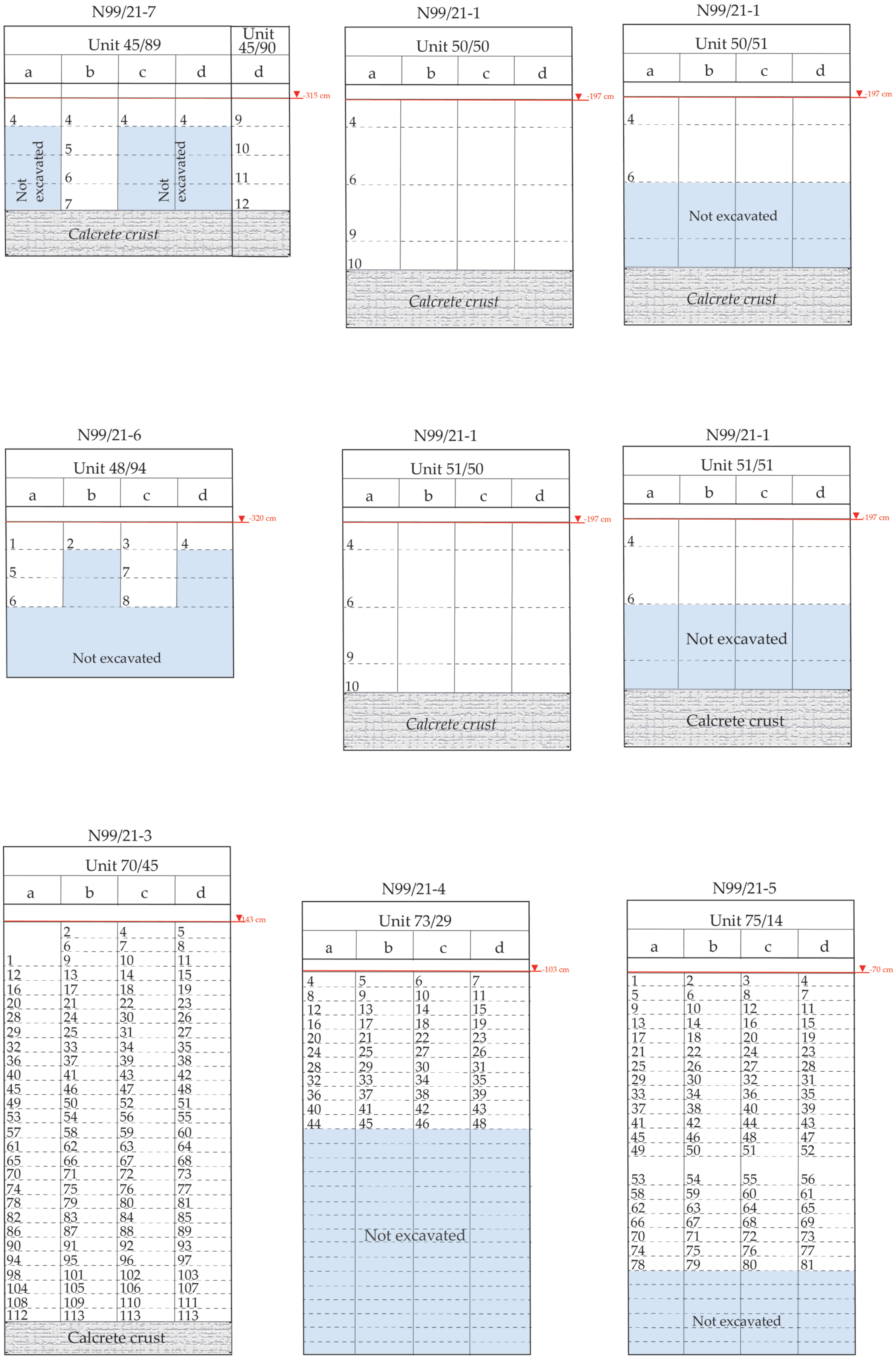


Figure 90: Level index of SC 4 Kapako, areas N99/21, units 45/89, 45/90, 48/94, 50/50, 50/51, 51/50, 51/51, 70/45, 73/29, 75/14 to be used in conjunction with Tables 25, 26, 27, and 32 in Appendix 3.

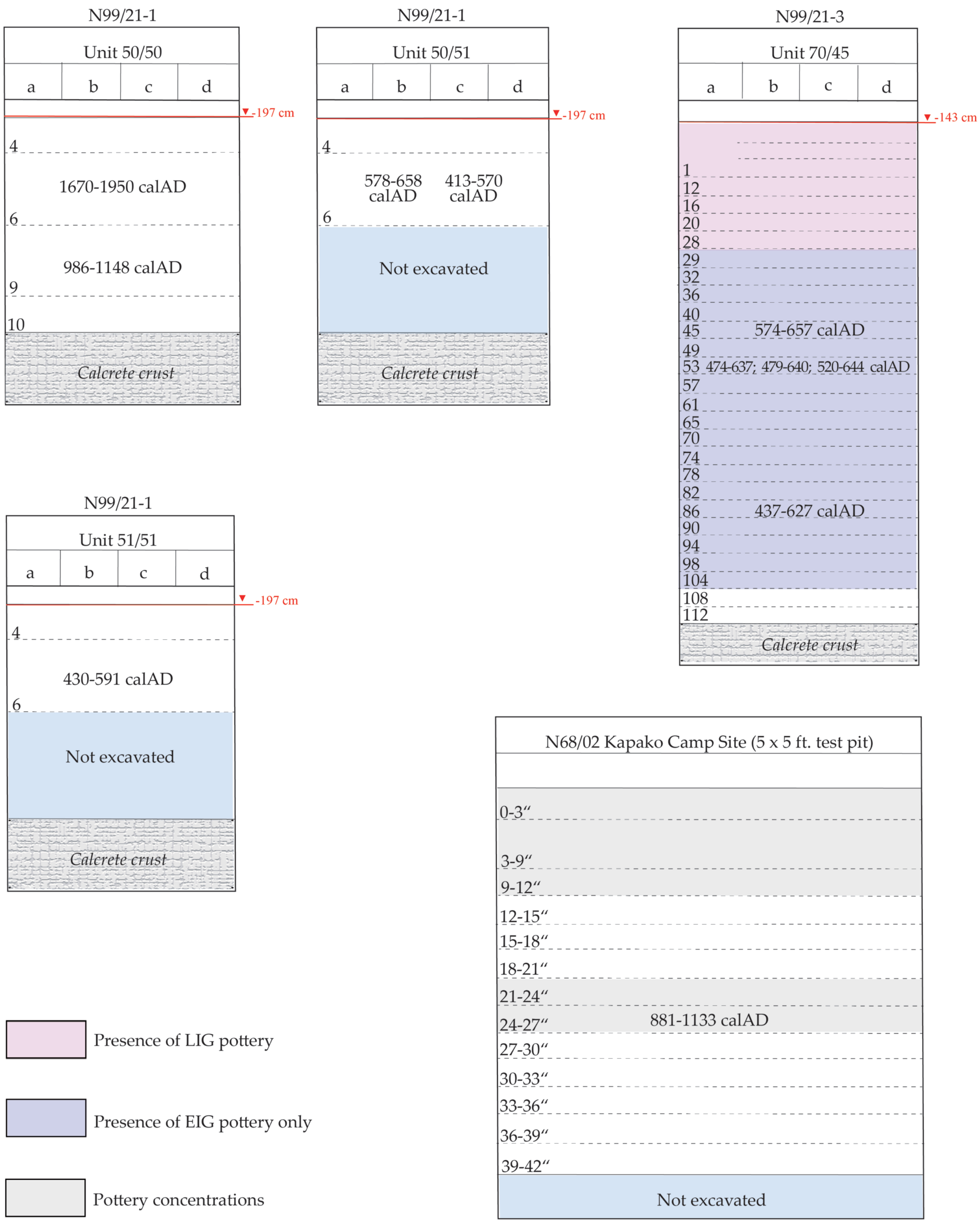


Figure 91: SC 4 Kapako, areas N68/02 and N99/21, vertical distribution of 2-sigma calibrated radiocarbon dates (calibrated with Calib Rev 7.0.4, SHCal13).

2.4.4. Excavation site N99/21

(Figure 82)

2.4.4.1. Excavation method

In 1999, archaeologists of the University of Cologne led by Juergen Richter re-identified the Kapako site excavated by B. Sandelowsky. Starting from a shovel test pit, a 4-m² test unit (N99/21-1) was leveled down in arbitrary layers of 20 cm or 10 cm in thickness. In 2006, the University of Cologne again undertook in a very limited time frame salvage excavation along the course of a trench for a drainage pipe to the river (Figure 88). Three 1-m² units (N99/21-3, N99/21-4, and N99/21-5) were excavated southeast of N99/21-1. A further two 1-m² units (N99/21-6, N99/21-7) were tested 40 m north of N99/21-1 (Figure 87). Units N99/21-3, N99/21-4, and N99/21-5 were leveled down in arbitrary quadrants of 5 cm in thickness (Figure 90). The units N99/21-6 and N99/21-7 were excavated in quadrants and steps of 10 cm in thickness (Figure 90). The soil was sifted through a 4 mm wire mesh. In units N99/21-3, N99/21-6 and N99/21-7 the excavation stopped at the level of the calcrete hardpan. In unit N99/21-4, digging was stopped at a level of 55 cm below the surface and in unit N99/21-5 at 105 cm below the surface, because test drilling disclosed that further finds were not to be expected. Soil samples were taken from the sections facing north in units N99/21-3 and N99/21-5.

2.4.4.2. Stratigraphy

Below the pale sandy surface layer, a horizon of 50 to 70 cm in thickness of dry, dark, clayey, silty fine sand occurred, which increased in hardness towards the top. According to the Munsell Soil Color Charts, soil colors ranged from 5YR3/1 'very dark gray', 10/YR2/2 'very dark brown' to 10YR4/3 'brown' (Figure 89). Clay and silt became increasingly present between 70 and 100 cm below surface. Small nodules of $CaCO_3$ occurred. Grass roots reached as far as 1.5 m below the surface. Roundish pale sand infillings indicated burrower's tunnels and small ant passages were observed. The soil is interspersed with charcoal and other cultural materials. In three excavation units, the excavators observed layers of organic remains and ashes. The upper organic horizon is roughly placed at 10 to 25 cm below the surface. The lower horizon arose in a depth of around 70 cm. Downwards, the dark horizon became increasingly soft, moist and calcareous, and graded into a strongly carbonate-enriched horizon of silt and sand with MCC colors ranging from 10YR5/3 'brown' to 10YR7/2 'light gray' immediately above the calcrete hardpan. Generally, the soil sequence and its loamy appearance suggested old alluvial terrace deposits mixed with aeolian sands. The find-bearing layer of the Early Ironworking Groups was covered with more or less 50 cm of soil and it was not affected by erosion in the units N99/21-3, -4 and -5. The cultural layers slightly sloped towards the north, indicating that the former land surface declined towards the river in the same way as it does today. There is a possibility that area N99/21-3 cut across a midden where people repeatedly discarded organic and inorganic waste. Supposing the radiocarbon dates from the samples collected from the sediment are trustworthy (Poz-20668 and Poz-20682, Table 2, Appendix 3, Figure 91), the soil accreted within a time span of roughly 100 years for 50 cm during the EIG occupation period. However, between the main find concentration of the latter and the LIG occupation horizon, the soil body increased only for 40 cm within more or less 1000 years.

Naturally, the upper cultural horizon of the Later Ironworking Groups is vulnerable to modern disturbances, but glass, plastics (Table 26, Appendix 3) and modern metal artifacts (Figure 93, Table 32, Appendix 3) were only present in the uppermost 20 cm. All in all, the archaeological layers were much better preserved at Kapako than at Ruuga (SC 3) because of the more stable soil body.

The excavations of the areas N99/21-3, -4 and -5 showed the same stratigraphy as N68/02 and N68/01: a well preserved EIG occupation horizon in a depth of 50 to 60 cm below the surface, and a LIG occupation horizon in the uppermost 30 cm of the profile (Figure 101). In N99/21-3, a lithic dominated layer of a ceramic Late Stone Age appeared roughly 110 m below the surface (Figure 97). It marks the beginning of the occupation of the site in the second half of the fourth century. The vertical mapping of LIG potsherds revealed that the younger material did not exceed a depth of 40 cm below the surface in the areas N99/21-3, -4 and -5 (Figure 101). The earlier occupation layers were therefore undisturbed. The vertical mapping of the LIG ware shall also be used to assign the slag finds and lithics to one or the other occupation period.

The stratigraphy of Kapako established with the excavations of N68/02 and N68/01 by Beatrice Sandelowsky, and confirmed in the areas

N99/21-3, -4 and -5, created doubts with respect to the reliability of the association of finds, or the lack of stratigraphy, found in N99/21-1, -6, and -7. Area N99/21-3 showed a soil body of 140 cm above the calcrete hardpan, whereas N99/21-1 had only 60 cm of soil cover above the crust, and N99/21-6 and -7 no more than 40 cm (Figure 90). In area N99/21-1, the main pottery concentrations occurred 10 to 30 cm below the surface, and it was for the most part EIG ware. LIG pottery was present in all levels, which made a separation of two settlement horizons impossible (Figure 100). The same applied to the areas N99/21-6 and -7. One cause of the mixing of the material was a possible deflation towards the edges of the river terrace as has been described earlier for Ruuga (SC 3). Another cause of disturbances, in particular in area N99/21-1, could have been the nearby building as illustrated in Figure 87. Modern material was found in unit 48/94 (Tables 26 and 32, Appendix 3, Figure 93) and in unit 50/51 (Table 32, Appendix 3, Figure 93).

2.4.4.3. Total finds

The excavations from 1999 and 2006 produced a quantity of 4327 archaeological artifacts weighing 8.8 kg in total (Table 6, Appendix 3). In addition, artifacts were collected from the surface totaling 3.5 kg. The main category of finds was pottery, amounting to 63.6wt% (n = 5654 g) of the total assemblage. Markedly less frequent were lithics and manuports (14.1wt%, n = 1196 g), remnants from metalworking activities (slag, ore and tuyere fragments) (10.4wt%, n = 928 g), and faunal remains, accounting for approximately 10wt% of the total assemblage. Other find categories were only sparsely present (Table 6, Appendix 3).

2.4.4.4. Finds from ironworking activities

The excavations of N99/21-3, -4 and -5 produced 36 finds of slag (365 g), metal artifacts and ore fragments (Table 32, Appendix 3) from the EIG horizon (Figure 92). The diagnostic slag finds are mapped in Figure 93. Most of the finds originated from N99/21-3, and even though the number of finds was small, they provided evidence that the early residents were masters at processing a bloom into iron objects. Sample 4720/06 was a semi-sintered piece of a bloom. Unfortunately, the sample got lost before it was fully examined, but it indicated that the ironmasters used quartz-rich sand to manipulate the melting point of the slag, and perhaps as a fluxing agent while processing the bloom. Probably from the same process derived sample 4721/06, an advanced refining slag that contained a high portion of reacted quartz grains. Both samples were found associated with small ore fragments, another gromp, hammerscale flakes and a smithing hearth bottom from refining. Altogether these finds provided evidence that an unworked bloom from the furnace was sorted and compacted in this area. The smithing hearth bottom indicated a refining furnace nearby, but no information as to the layout of the refining facility was found. The mineral phase composition of 4721/06 pointed to hot and reducing furnace-running conditions comparable to those used in smelting. Below this assemblage of refining debris, an iron bar and a small hammerscale flake signaled that fine smithing was performed in the same area, but the finds were few and the forge was most probably farther away from the excavated unit than the refining furnace. Another most interesting find was sample 4719/06, recovered 15 cm below the refining debris assemblage described first. It was classified as an initial refining slag, which cooled down in a separate slag pit. The sample implied that the early metalworkers from Kapako heated the bloom to slag liquidus temperatures and drained away a certain quantity of redundant slag before they started to consolidate the bloom by hammering. In the deeper layer of the EIG occupation horizon, two samples pointed to advanced refining activities, and a fine hammerscale flake attested that a highly compacted bloom was worked, or that iron implements were produced nearby. However, the finds in this layer were scarce and the center of the metallurgical activities was certainly farther away from the excavated unit.

Only four slags were found in the EIG layer of area N99/21-4, two of which were diagnostic (Figure 93). One sample was a refining slag with crown material, representing an initial or advanced step in refining processes. Another sample consisted of small, conglomerated hammerscale spheres, demonstrating that compacted metal was processed into tools (section 1.6.2.3).

Area N99/21-5 produced nine slag samples in the EIG stratum, of which eight were diagnostic finds (Figure 93). Except from one iron clip, all the finds were remnants of initial and advanced bloom refining. Sample 4717/06 revealed that the compacted bloom was heated repeatedly in a hot and reducing environment, and that quartz grains served as a welding flux.

In summary, the metallurgical finds associated with the Early Ironworking Groups attested that the first ironmasters in the Kavango region arrived around the fifth/sixth century with a very sophisticated knowledge of ferrous metallurgy. Like Ruuga (SC 3), it is unknown whether smelting was kept separate from the habitation location or not. The smelting debris found at Kapako belong to the common finds of refining sites, where blooms with adherent smelting slag were shattered and compacted (section 1.6.2.2). As discussed in section 4.2.13, the chemical analyses of five slag samples indicated that the smelters from Kapako and Ruuga used the same source of ore, which was most probably located in the Kakeni or Kafuma River valleys in modern-day Angola (Figure 217).[86] Furthermore, it may be that the early and late smelters of Kapako used the same source of ore, yet the number of analyzed slags was small and further research is required to confirm the assumptions made above.

The excavations of N99/21-3, -4 and -5 produced also 54 (338 g) pieces of slag, metal artifacts[87] and ore fragments, attesting the metallurgical activities of the LIG residents of Kapako. The diagnostic slag finds were mapped in Figure 93. Thirty-five of the LIG slags originated from N99/21-3, and 15 of them were diagnostic (Table 32, Appendix 3). The crown material, iron ore fragments, amorphous hammerscale and the processing slags with metal inclusions attested that blooms were refined nearby (section 1.6.2.2). The thick hammerscale flakes were debris of the consolidation of a semi-compacted bloom, which still contained some slag. Conglomerated flaky hammerscale and micro-spheres provided evidence that the bloom became more and more compacted in a final stage of refinement. The two samples classified as secondary smithing remnants were produced either in the latest steps of bloom refining, or, more likely, they were the waste products of tool smithing on site.
More evidence of bloom refining processes was found in N99/21-4. As illustrated in Figure 93, the unit revealed some iron ore fragments, a piece of smelting slag, processing slag with metal inclusions and amorphous hammerscale, all of which were diagnostic finds for initial bloom refining. The two small hammerscale flakes assigned to secondary smithing indicated a forge somewhere in the precincts of N99/21-4, but the main activity in this area was the initial shattering and consolidation of a bloom. In light of the frequency of finds, it is likely that the center of the refining activities was closer to N99/21-3 and -4 than to N99/21-5.
The LIG layer of N99/21-5 produced five slag finds, of which three showed diagnostic features. One slag was a smelting slag with some bloom inclusions, the other an unspecific processing slag. More interesting was the smithing hearth bottom 4718/06, which formed during final bloom consolidation. The sample consisted of multiple layers of slag, which accumulated during short cycles of heating and hammering. The ironworkers used quartz-rich sand as a welding flux. The smithing hearth bottom formed in a sand bed under hot and reducing conditions. It is therefore likely that the refining furnace was a pit in the sandy ground. However, the limited number of finds from this unit suggested that the center of ironworking activity was farther away, and that area N99/21-5 was located at the outer margins of a slag-dumping zone during the occupation of the Late Ironworking Groups.

The areas N99/21-1, -6 and -7 produced 73 finds of slag, two historical metal artifacts, and two tuyere fragments (Figure 93). I decided to treat these finds separately because their stratigraphical affiliation was not clear, as I have discussed in the stratigraphy section earlier. They may belong to either the early or the late occupation period, or both. However, both tuyere fragments were grog-tempered and belonged to the LIG occupation horizon. That is why I assume that the slag finds are predominantly young.
In area N99/21-7, all the three slag finds attested early refinement activities. Area N99/21-6 produced only one tuyere fragment and the two historical metal artifacts (a copper bead comparable to those illustrated in Figure 211 and an iron point). In area N99/21-1, a high amount of slag was found, but most of them showed no diagnostic features under macroscopic inspection. Those finds that were helpful to assess the metallurgical activities are again mapped in Figure 93. Irrespective of the slag's origin, most specimens derived from initial and advanced refining. Sample 4435/06 provided information about the metal produced by the smelters, ranging from low carbon steel with approximately 0.1wt% of carbon to eutectoid high carbon steel with a carbon content slightly above 0.8wt% (Figure 95). Most probably, it originated from the same bloom.

[86] Surveys in the Matende Omuramba, a southern tributary to the Kavango River between Kapako and Mupini provided no proof for any suitable ore deposit that could have been exploited.

[87] Modern metal artifacts excluded.

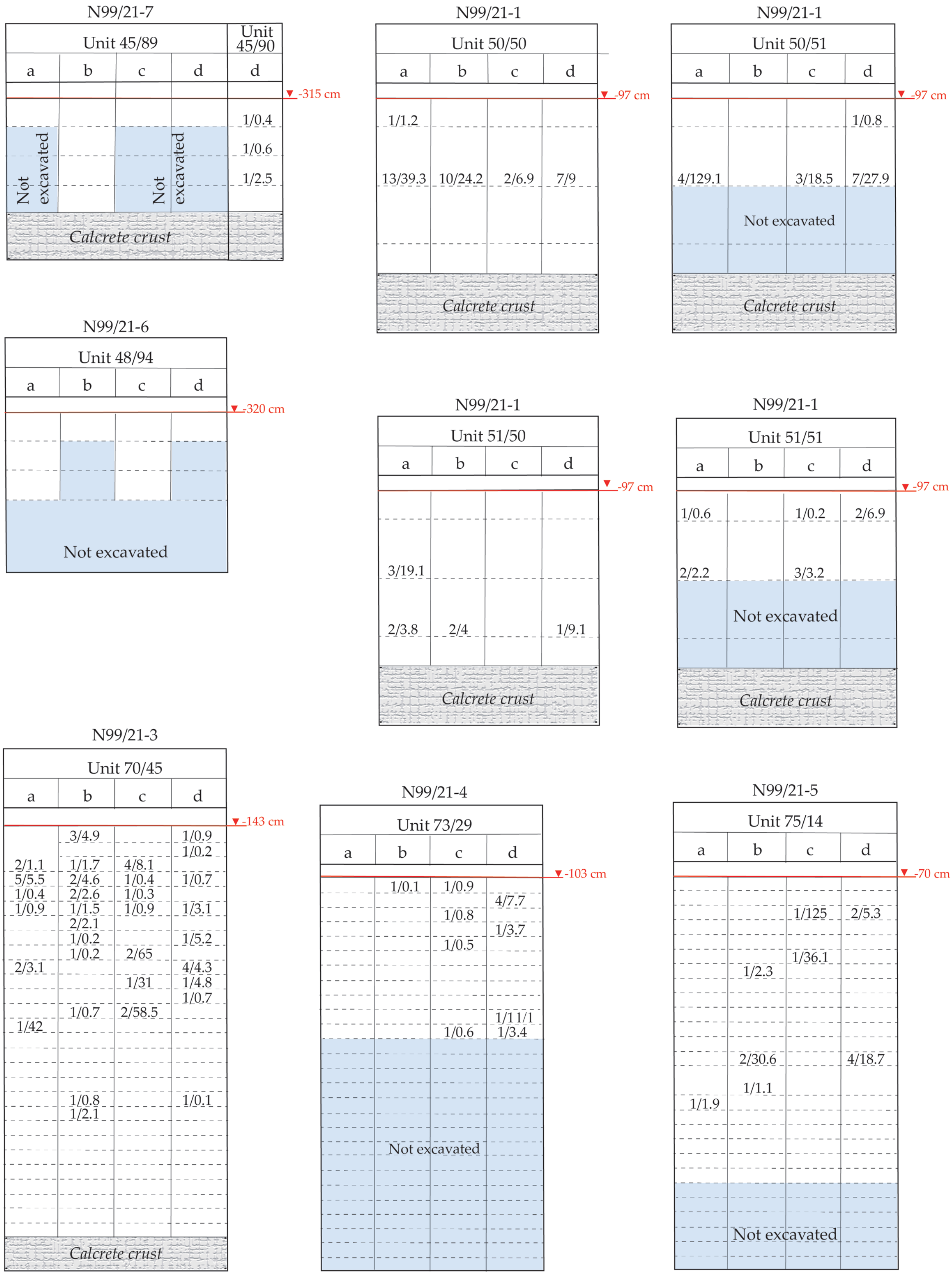


Figure 92: SC 4 Kapako, areas N99/21, vertical distribution of slag finds (pieces/grams).

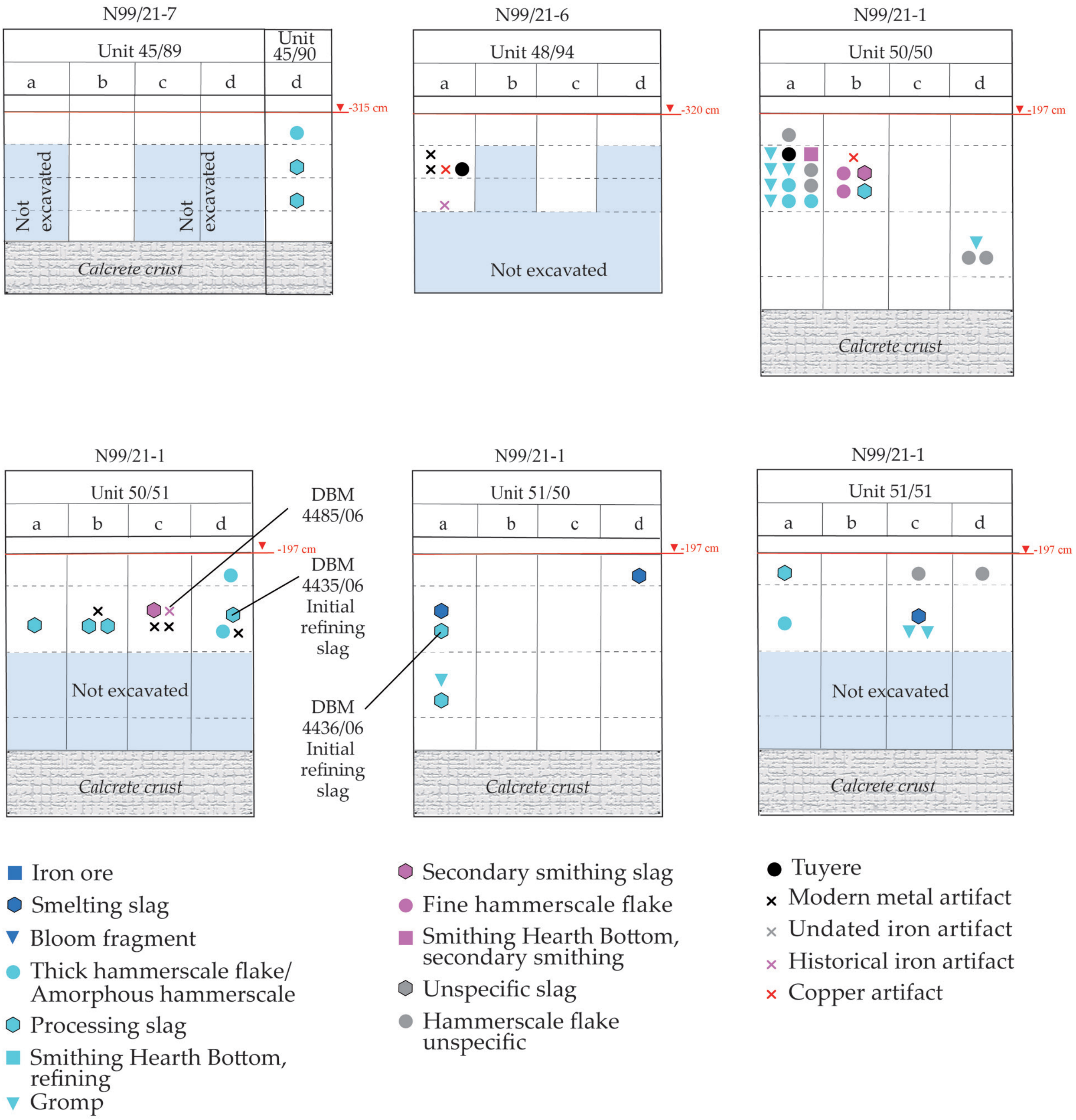


Figure 93 to be continued on next page: SC 4 Kapako, areas N99/21, vertical distribution of diagnostic slag and ore fragments, metal artifacts, and tuyere fragments.

Consequently, the metal must have shown a very inconsistent behavior in the forge. The sample itself was an initial refining slag composed of drained slag and crown material that went lost in the slag bath. It formed under hot and strongly reducing furnace conditions. More insight with respect to the elemental iron produced in the bloomery smelters provided sample 4436/06. The quality ranged from pure soft iron with a carbon content less than 0.02wt% to hypereutectoid high carbon steel with 1.6wt% of C (Figure 96). As discussed in section 1.4.9, medium to high carbon steel displays properties that might not always have been wanted. With increasing carbon content, steel becomes difficult to process because it tends to develop heat and shrinkage cracks during welding. Moreover, with increasing hardness, the material decreases in toughness and formability and therefore requires special heat treatments to decarburize, or soften, the material (section 1.4.9). The high amount of gromps found in N99/21-1 attested that unsuitable material was discarded rather than processed (i.e. decarburized), but owing to the uncertain stratigraphical affiliation of the metallurgical debris they must be interpreted with caution. Sample 4435/06 contained unworked and worked crown material that showed a deformed ferrite grain structure

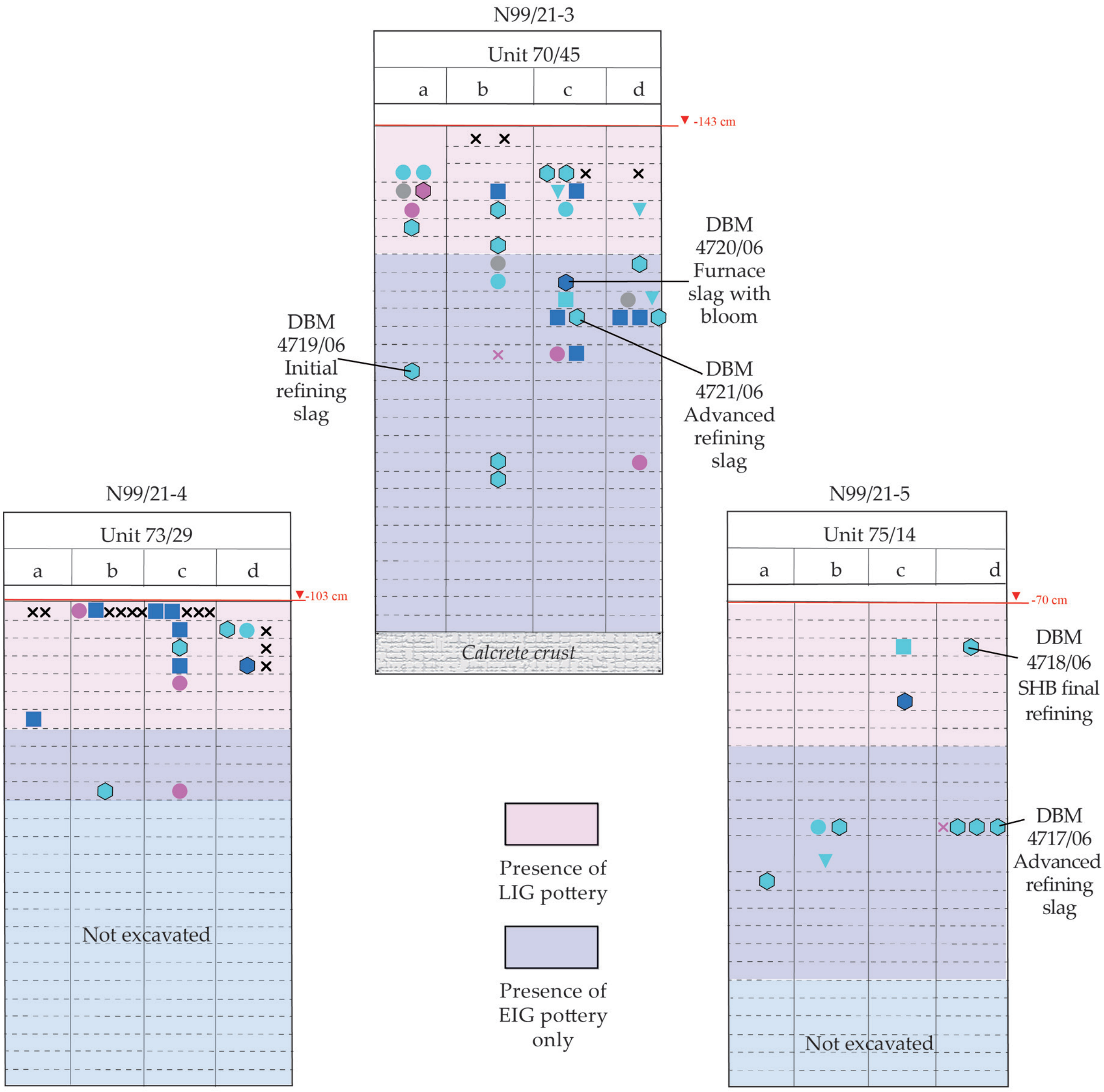


Figure 93 continued from frevious page: SC 4 Kapako, areas N99/21, vertical distribution of diagnostic slag and ore fragments, metal artifacts, and tuyere fragments.

caused by the hammering during bloom consolidating processes. The phase composition of the slag testified that the ironworkers were running their refining furnaces at high temperatures under reducing conditions, which favored the formation of phosphorus-rich cast iron prills in the slag bath. Considering the slag assemblage found in N99/21-1 as belonging together, it is most likely that the smelters refined a dirty bloom with a high amount of slag inclusion. Since there was only little smelting slag found, the place where the bloom was shattered and sorted was probably elsewhere. What is even more diagnostic is the absence of smithing hearth bottoms. Because of this, I assume that the assemblage represents a slag dumping area at a certain distance from the forge or refining furnace. Apart from the early refining slags, units 50/50 and 50/51 revealed slag debris indicating a forge for secondary smithing processes nearby. Sample 4485/06, an iron clip, strongly suggests that the blooms were processed into artifacts on site because the clip consisted of a soft wrought iron to low carbon steel, which had been manufactured from new unrecycled iron.

Several surveys between the mission buildings and N99/21 indicated that there was another center of metallurgical activities roughly 80 m southeast of the mission in a plowed field (Figure 82). As the finds originated from the surface, I consider them to belong to the LIG occupation of the site. Large slag chunks scattered in this area and some were collected for further examination. However, the sample set is not representative because small fragments and large slag chunks were not considered. The

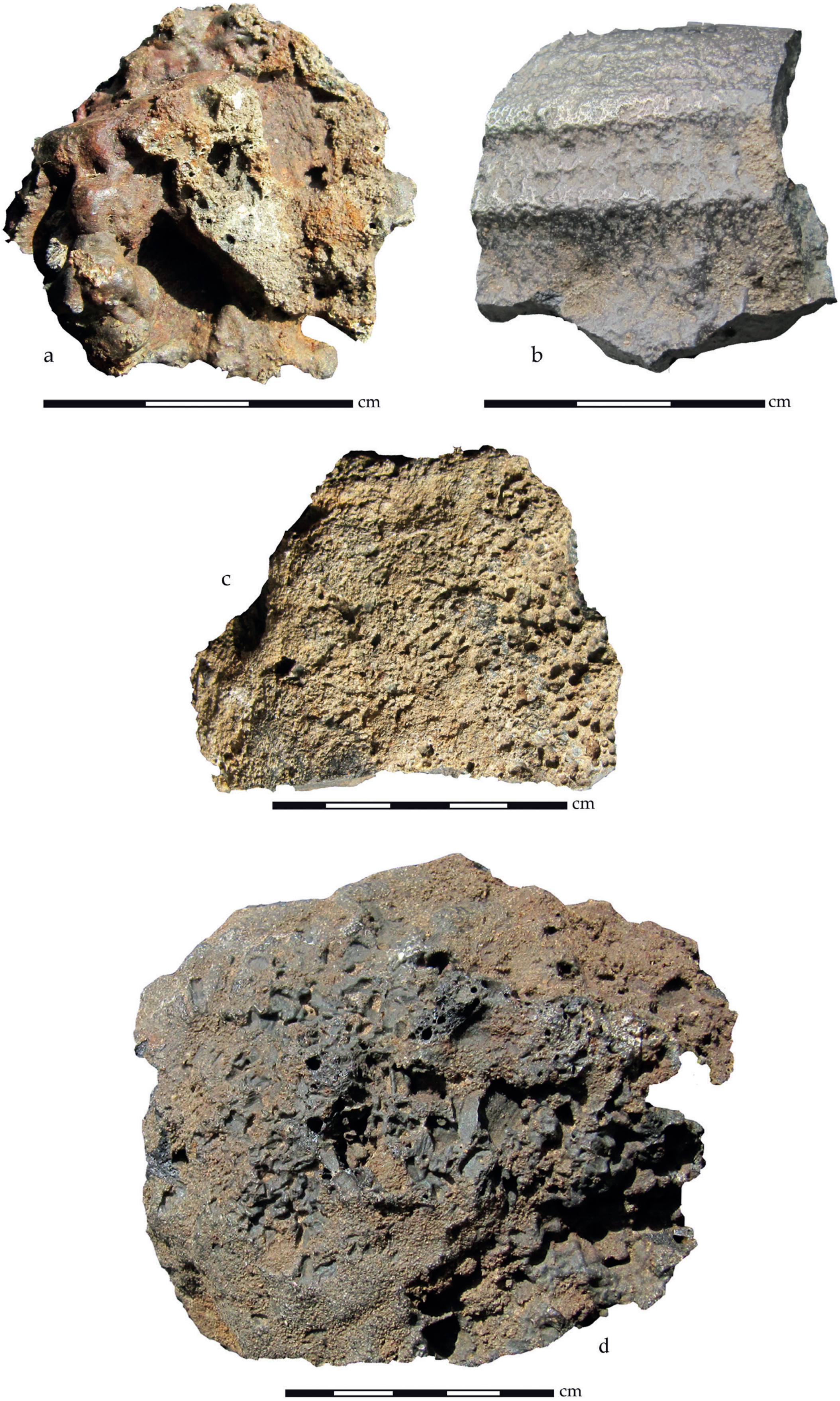


Figure 94: SC 4 Kapako, area N99/21, slag samples a and d: processing slag with adhering natural sediment at the bottom side. c: tap slag with adhering sediment. Area N98/38, slag sample b, a compact tap slag with negatives of the natural soil, indicating that the LIG smelters used slag-tapping furnaces.

collected material showed a high portion of smithing hearth bottoms from refining activities (Table 32, Appendix 3). It also contained furnace slag samples of which one was a tap slag that cooled down in a slag pit (Figure 94c). The only tuyere fragment belonged also to the Late Ironworking Groups' occupation according to its composition. It is not evident from the slag collection on hand whether people smelted on site or not. The tap slag sample however is a good indicator for a smelting facility nearby, because it is unlikely that tap slag was carried along from the smelting site to the refining location together with the bloom. Moreover, the sample proved that people used slag-taping facilities. The picture arising from the surface finds implies that there existed either a large-scale iron production at Kapako, or a repeated use of the site. Even more surprising was the fact that the modern-day residents from Kapako did not remember the historical iron production in their community's past. Iron production must have stopped at the site much earlier than at Vungu-Vungu (SC 12) or Gove (SC 17). The only hint to the Kapako ironworkers came from H. P. H. Kaputungu who stated that Kapako was a smelting site of the Tjaube people (section 5.3.2).[88] Since the Tjaube were most probably the first iron-producing inhabitants of the middle Kavango area during the LIG occupation, this may explain the lack of local memory among the contemporary residents of Kapako.

2.4.4.5. Lithics

The classification of the lithic assemblage followed the same scheme described in section 1.7.

The excavations of N99/21 produced 476 stone artifacts, weighing together 1192 g (Table 27, Appendix 3). The quantity of lithics is small compared to Ruuga (N98/39-2, SC 3), but the good preservation conditions in area N99/21-3 allowed me to distinguish two periods of use of the area within the EIG occupation horizon. Altogether, N99/21-3 provided 184 stone artifacts, making up 331.4 g of lithic material (Figure 98). Chips constituted the largest portion of the assemblage with 57% (n = 104 pcs), followed by flakes amounting to 16.4% (n = 30 pcs). The unit provided only two lithic tools (1.08%) and one core (0.54%). Debitage accounted for 25.5% (n = 47 pcs) of the assemblage, and no blades or unmodified stones were found. Following the distribution of the LIG pottery as discussed in the stratigraphy section above, finds from deeper than 35 cm below the surface were assigned to the Early Ironworking Groups.

The lithics found in N99/21-3 concentrated at 100 to 115 cm below the surface, roughly 40 cm beneath the main concentration horizon of EIG pottery, yet they were scattered as deep as 130 cm (Figure 97). The early lithic horizon is mixed with some EIG pottery (Figure 100), yet the amount of potsherds is significantly less than in the main pottery horizon, 50 to 70 cm below the surface. A charcoal sample collected from the lithic main horizon produced a 2-sigma calibrated calendar age between the middle of the fifth and the mid-seventh century AD (Poz-20668, Table 2, Appendix 3, Figure 91), which was roughly 100 years older than the carburized seed collected 50 cm above (Poz-20682, Table 2, Appendix 3,

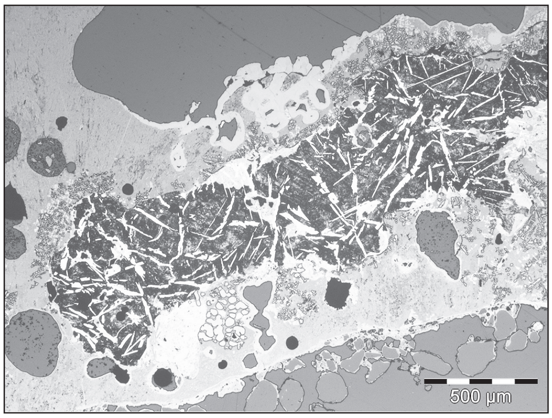


Figure 95: SC 4 Kapako, area N99/21-1, sample 4435/06, a bloom fragment found in an initial refining slag evidencing the high variability of bloomery iron. The quality of this sample ranges from low carbon steel in the left part to eutectoid high carbon steel in the right part.

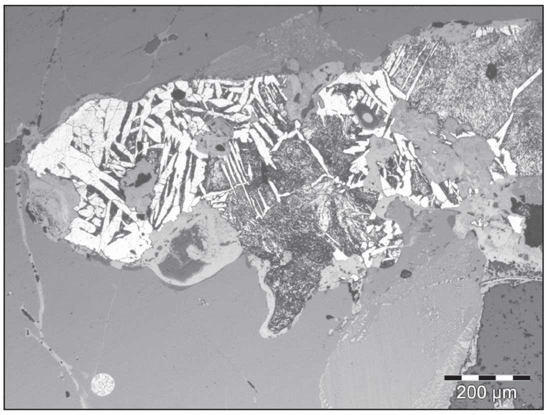


Figure 96: SC 4 Kapako, area N99/21-1, sample 4436/06, a bloom fragment found in a refining slag showing an over-carburized steel fragment with approximately 1.6% of carbon (lamellar pearlite (dark gray) and secondary cementite (white)).

[88] Interview with Harupe Paulus Haididira Kaputungu, Appendix 2.3.

Figure 97: SC 4 Kapako, areas N99/21, vertical distribution lithic artifacts.

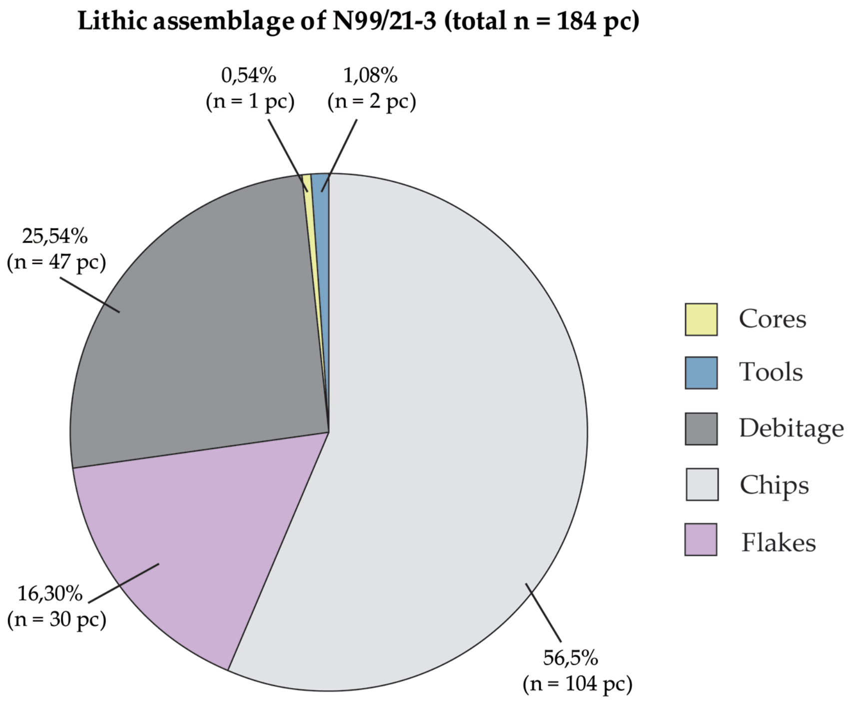
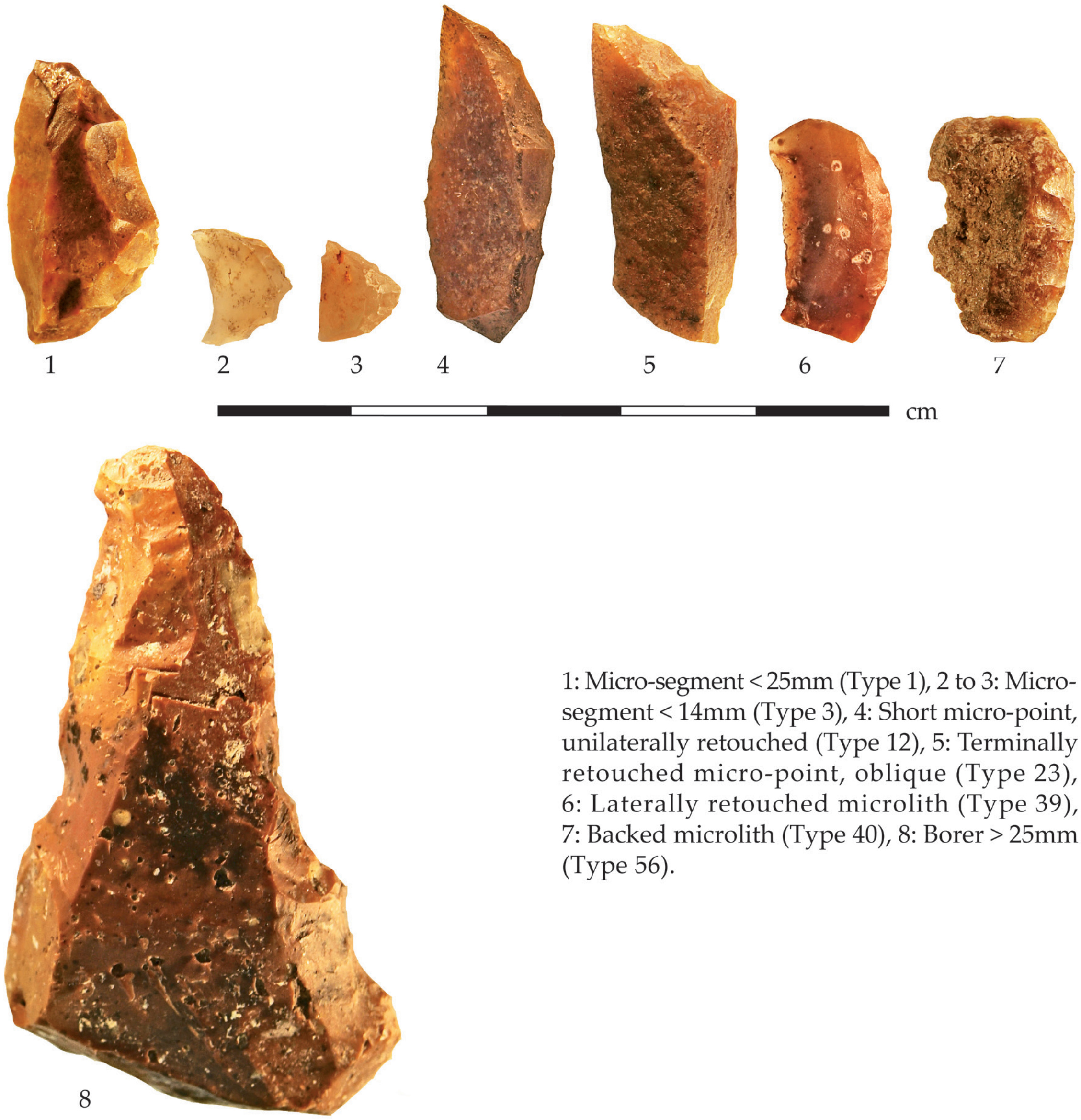


Figure 98: SC 4 Kapako, area N99/21-3, pie chart of the distribution of the lithic artifact categories of unit 70/45.

Figure 91). The raw material as well as the artifact composition of the deeper lithic horizon between 90 and 130 cm below surface was different from what was found between 35 and 90 cm. As can be taken from Table 27 (Appendix 3), in the deeper strata, chalcedony dominated the lithic raw material choice and the assemblage consisted mainly of chips, with some flakes and debitage. In the upper pottery-dominated horizon, significantly fewer stone artifacts were present. Here, quartzite was found to be the main raw material and the lithic assemblage comprised mainly debitage, with some chips and flakes. One interpretation of this change in the lithic assemblage may be that the area was used in two different ways during the fifth to the seventh centuries. The lower lithic assemblage suggested that some stone knapping, i.e. lithic tool production, was performed in this area. The pottery-dominated upper horizon however indicated that the area was a midden in the precincts of a living zone, because the main concentration of faunal remains concurs within the main pottery horizon of the EIG occupation period (see Table 25, Appendix 3). The lithic tools from N99/21-3 were a short asymmetrically bilaterally retouched micro-point of tool Type 18 (Figure 71), and a backed microlith of Type 40 (Figure 71).

Pottery and lithics were found down to a depth of 130 cm. The deepest slag finds, however, were collected from a level of 100 cm below the surface. Therefore, the vertical distribution of the main find categories implies that initially, a ceramic Late Stone Age population occupied the area during the fifth and sixth century AD. These residents were in contact with ironworking people and somewhere in the sixth or seventh century AD they adopted iron production as indicated by the deepest finds of refining slags. With an increasing number of slag finds, the composition of the lithic assemblage changed and became dominated by unspecific debitage, and a coarse quartzitic raw material. Taking the tool assemblage of Ruuga (N98/39-2, SC 3, section 2.3.1.6) as a model, local microliths were preferably produced from chalcedony, and quartzite flakes may have served other purposes. Even though only two tools were found in N99/21-3, the Late Stone Age tool production tradition is reflected in the chalcedony-dominated composition of the assemblage in the deeper levels. A possible explanation of the change of composition in the lithic assemblage may be that after some time of co-existence of lithic tools and iron implements, the first became replaced by iron utensils, in particular the range of hunting weapons.

Stone artifacts were scarce in the EIG horizons of N99/21-4 and -5 (Table 27, Appendix 3, Figure 97) providing little information. In N99/21-5 a laterally retouched microlith of Type 39 (Figure 71 and 99) made of a quartzitic material was found. The finds further suggested that sandstone was worked nearby.



1: Micro-segment < 25mm (Type 1), 2 to 3: Micro-segment < 14mm (Type 3), 4: Short micro-point, unilaterally retouched (Type 12), 5: Terminally retouched micro-point, oblique (Type 23), 6: Laterally retouched microlith (Type 39), 7: Backed microlith (Type 40), 8: Borer > 25mm (Type 56).

Figure 99: SC 4 Kapako, N99/21, selected lithic tools (digital pictures: Franziska Bartz).

The excavations of N99/21-3 and -4 produced 39 stone artifacts associated with the upper settlement horizon of the Late Ironworking Groups. The assemblage consisted mainly of chips (n = 17 pcs), unspecific debitage (n = 18 pcs), and only four flakes were found (Table 27, Appendix 3). Judging by the raw material, people were selective since they mainly used chalcedony, and only a few artifacts were made of quartzite or sandstone (Table 27, Appendix 3). No retouched artifacts were found. However, the lithics found in the younger horizon provided evidence that the LIG residents of Kapako still used and produced stone artifacts even though iron was available to them.

As can be taken from Table 27 (Appendix 3), the excavations of N99/21-1, -6 and -7 produced a total of 258 lithic artifacts. Owing to the difficult stratigraphical affiliation of these finds, only the retouched tools will be mentioned in the following section. As shown in Table 28 (Appendix 3), 15 microlithic tools were found in the three areas. The tool types comprised micro-points (Type 12, 17, 18, and 23), laterally retouched microliths (Type 38, 39, and 40) and segments (Type 1 and 3) (Figures 71 and 99). Retouched artifacts larger than 25 mm were present with one denticulate (Type 55) and one borer (Type 56) (Figures 71 and 99). Furthermore, the assemblage provided a few retouched artifacts that did not fit into the classification scheme used here. Most of the artifacts originated from N99/21-1, -6 and -7 and they were probably dislocated materials from the EIG horizon. The tool assemblage differed from the one found at Ruuga (N98/39, SC 3) in that segments were less common. However, the tool assemblage can hardly be considered representative of the site.

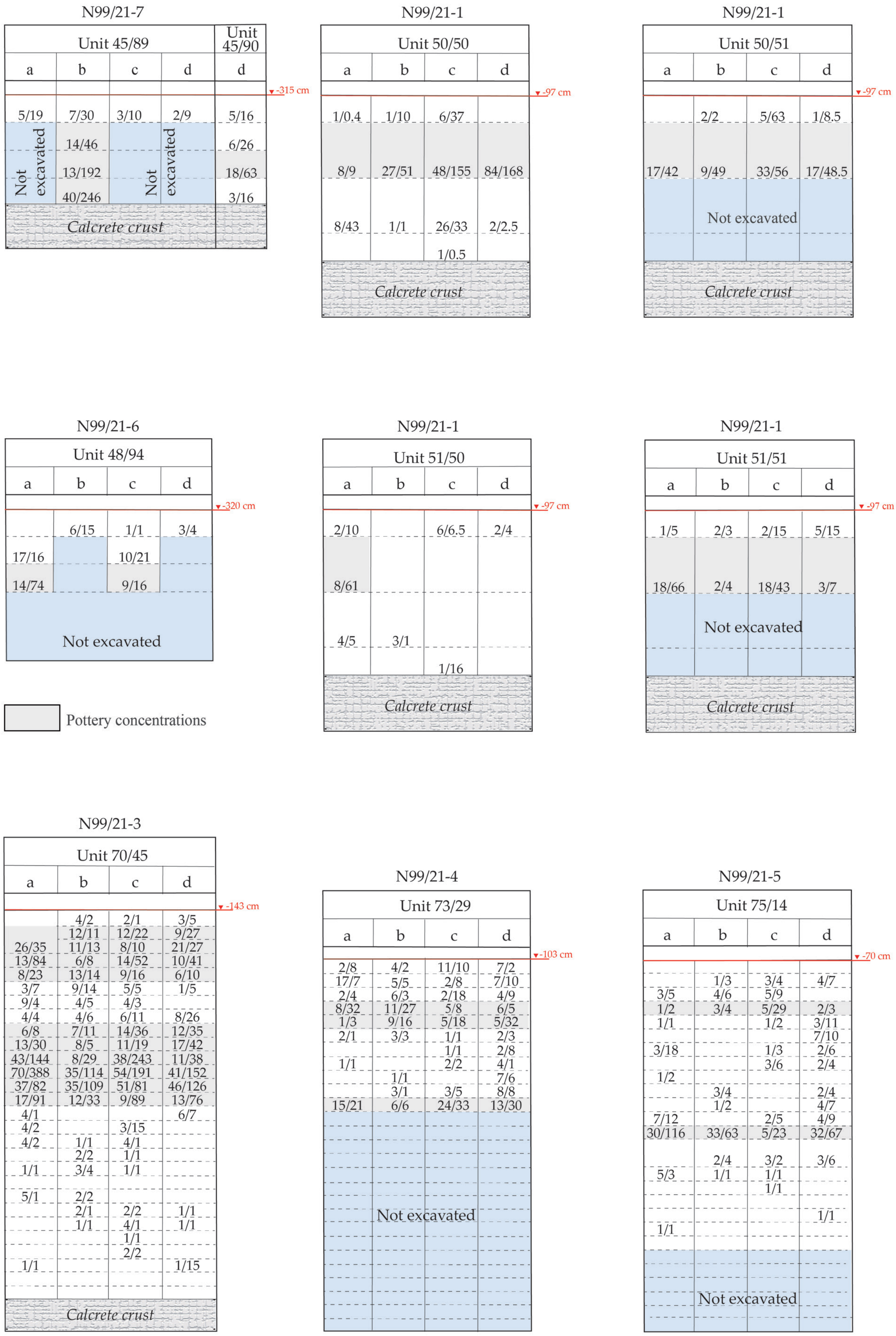


Figure 100: SC 4 Kapako, N99/21, vertical distribution of pottery.

2.4.4.6. Pottery

The excavated areas N99/21-1, -3, -4, -5, -6 and -7 produced altogether 1900 pieces of pottery, weighing 5.6 kg (Table 25, Appendix 3). In the well-preserved units N99/21-3, -4, and -5, the pottery was a useful tool to distinguish between the EIG and the LIG occupation horizon. The pottery of the Early Ironworking Groups was associated with the earliest stone artifacts, but the main concentration occurred between 50 and 70 cm below the surface (Figure 100), together with the main concentration of faunal remains (Table 26, Appendix 3). The early pottery was a prevalent brittle, charcoal-tempered ware. Ceramics were decorated with horizontal bands of incised herringbone motifs, and spaced lines with oblique comb stamping (Figure 102, see also Sandelowsky, 1979, p. 56, Richter, 2005, p. 92). The pottery shows strong stylistic parallels to the ceramics from Ruuga (SC 3) (Figure 77) (Richter, 2005, p. 90) and Divuyu (Denbow, 2013, p. 167). Most likely potsherds and faunal remains represented discarded material from a settlement. Assuming that the disposal behavior of the inhabitants was similar to that found today, both find categories concentrated in the precincts of a homestead or living area because the latter was kept clean.

The upper occupation horizon of Kapako revealed a high amount of typical grog-tempered Vungu-Vungu-style pottery (Figure 102). The LIG pottery scattered to a maximum depth of 40 cm below the surface and provided a helpful tool to distinguish between the early and late occupation horizon (Figure 101). Unfortunately, with only one charcoal sample originating from a disturbed context (KN-5574, Table 2, Appendix 3, Figures 91 and 162), the LIG occupation period is poorly dated. The sample produced a 2-sigma calibrated age range falling in the calibration plateau between 1650 and modern times.

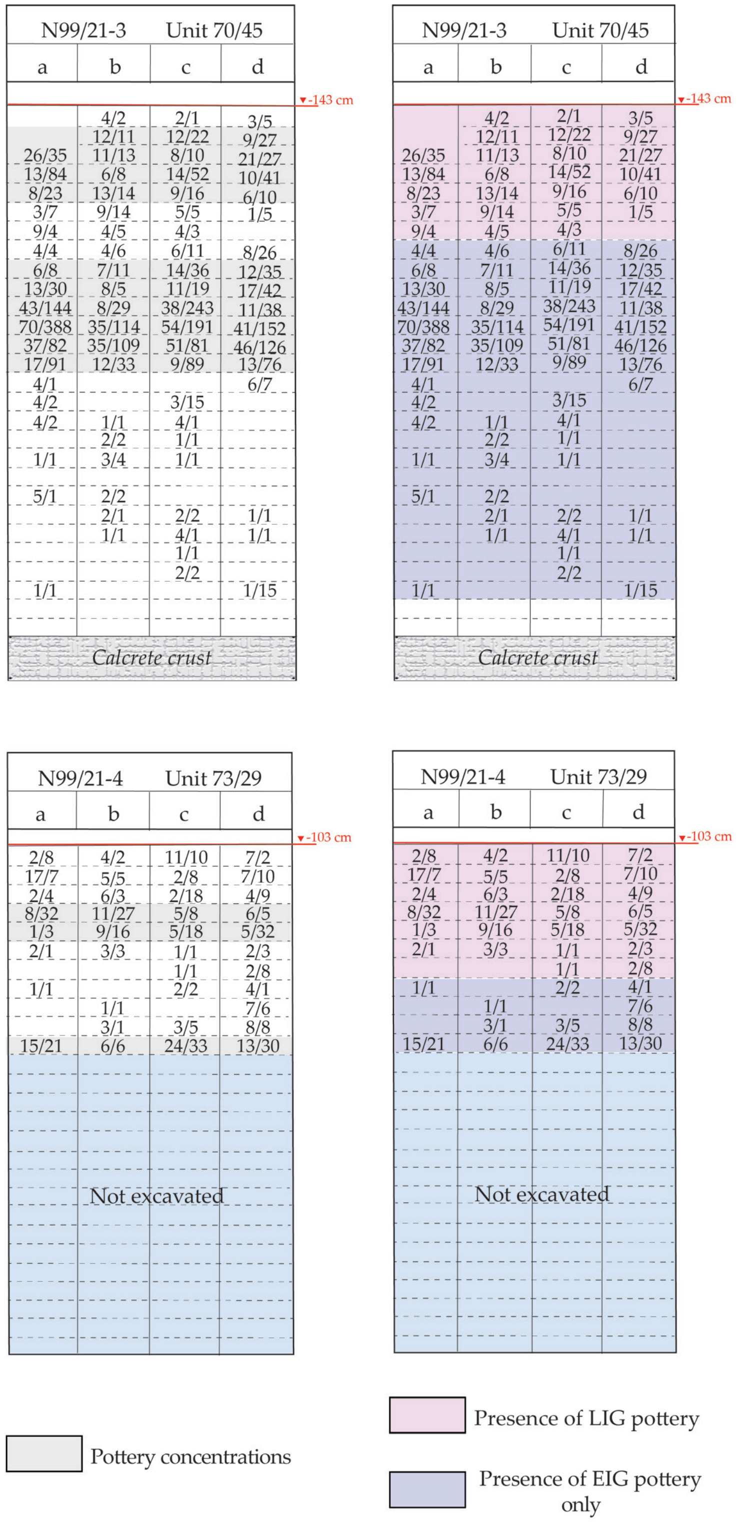


Figure 101 to be continued on next page: SC 4 Kapako, areas N99/21-3, -4 and -5, vertical distribution of chronologically relevant pottery of the Early and the Late Ironworking Groups.

2.4.4.7. Other finds

The excavated units also yielded ostrich eggshell beads and glass beads (Table 26, Appendix 3). Almost all the beads originated from the LIG occupation horizon, or from the unreliable context of N99/21-1, -6 and -7.

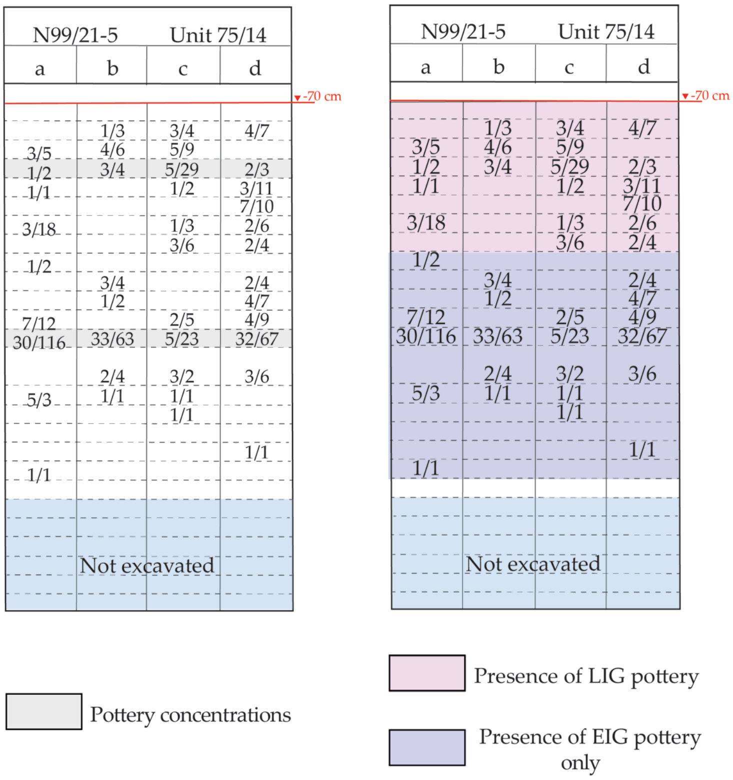


Figure 101 continued from previos page: SC 4 Kapako, areas N99/21-3, -4 and -5, vertical distribution of chronologically relevant pottery of the Early and the Late Ironworking Groups.

A few botanical remains were also recovered, and some modern material in the uppermost levels (Table 26, Appendix 3). Some fragments of burnt clay occurred as well. They were restricted to the LIG horizon, except from the finds from area N99/21-5 (Table 26, Appendix 3) (Figure 103). The latter showed negatives of wooden sticks and in conjunction with the finds of burnt clay described from area N68/01 it appears that the inhabitants of the EIG settlement built wattle and daub constructions, which presumably served as houses.

2.4.5. Area N98/38

(Figure 82)

Site appearance: This was an artifact scatter of 100 x 100 m in extension in an agricultural field, about 1.1 km west of N99/21 and north of National Highway B10 (Figure 82). The place seemed to be an abandoned homestead. Locals mined for calcretes on the edge of the river terrace. Farther uphill one may expect the site to be undisturbed.

Finds: During the survey, LIG pottery was found together with modern glass, slag, and a chalcedony core from lithic tool production. The two slag finds attested that people smelted and refined iron at the site. One piece of compact tap slag (Figure 94) implied that people used smelting facilities with a slag drain. The lithic core most probably originates from a disturbed LSA horizon. No EIG pottery was found.

Pottery Style: Vungu-Vungu style.

Lithic Typology: Unspecified, perhaps LSA.

2.4.6. Area N06/07

(Figure 82)

Site appearance: this is a loose artifact scatter of 600 x 800 m in extension in an uncultivated area, about 300 m west of Hompa Leevi Hakusembe's residence. In the southern part of the area, one can find remnants of abandoned buildings. The place is covered with grass and some shrubs and it seems to be fairly undisturbed.

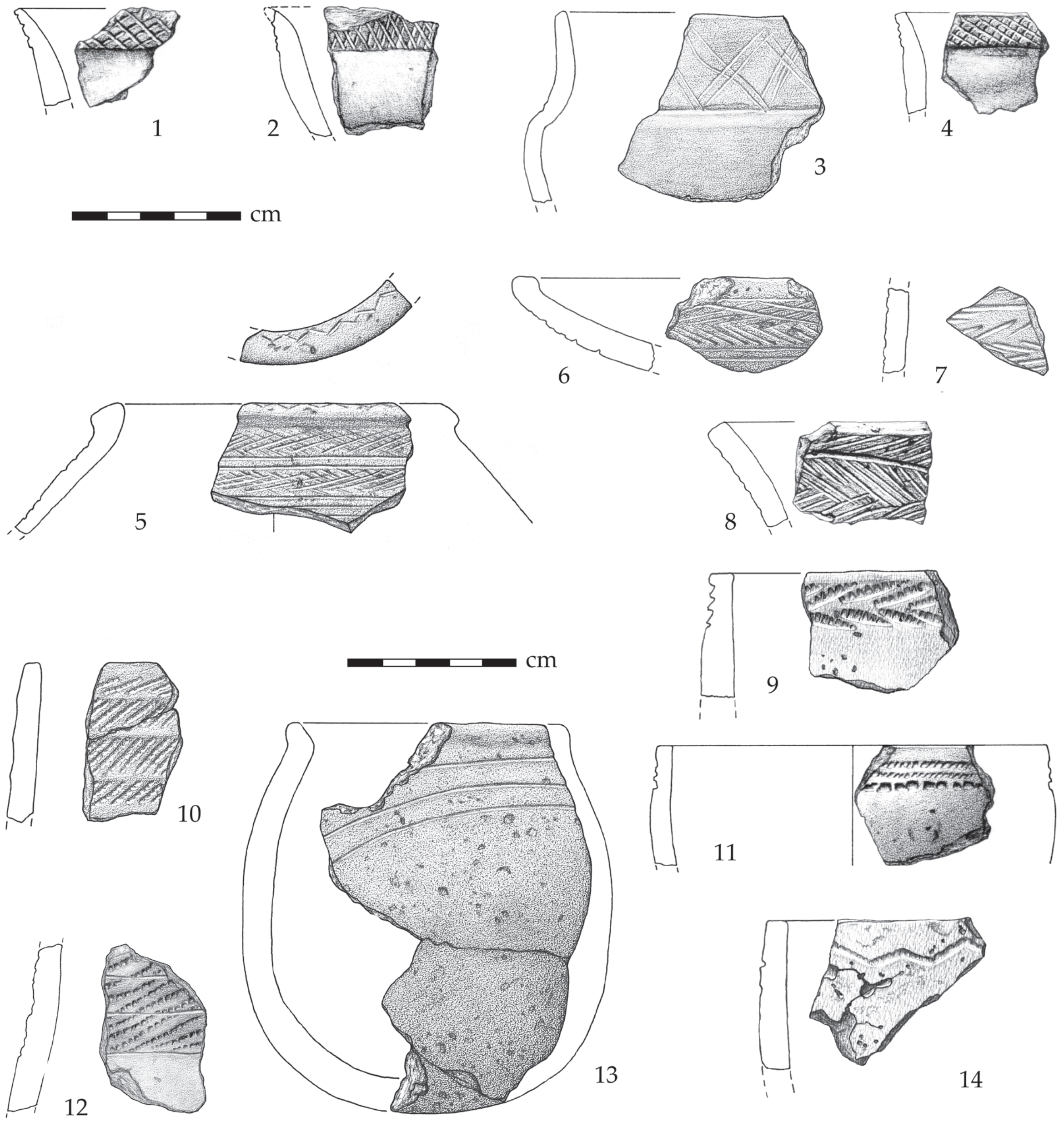
Finds: Unspecific lithics and undecorated organically-tempered potsherds, burnt clay fragments.

Pottery Style: Kapako/Divuyu style.

Lithic Typology: Unspecified, probably LSA.

2.4.7. Interpretation of site-complex SC 4

Kapako was a settlement site of the Early and Late Ironworking Groups. During the EIG period, the settlement site had an extension of at least 1.5 km from east to west along the riverbank. Most likely, there existed several homesteads or living areas, which produced refuse dumps in their periphery and it could be that people lived in buildings made of wattle and daub constructions, or they had stable storage facilities. As the faunal remains are not yet analyzed, they do not allow for the reconstruction of the subsistence strategy of the early residents of Kapako. Within the settlement, people most probably bounded zones by stone-knapping and metallurgical activities.



1 to 4: Late Ironworking Groups pottery; 5 to 14: Early Ironworking Groups pottery.

Figure 102: SC 4 Kapako, selected pottery finds (drawings: Anja Rüschmann and the author).

The radiocarbon dates from the early occupation horizon indicated that the site was occupied between the early fifth and the middle of the twelfth centuries AD. The earliest dates were associated with a ceramic Late Stone Age horizon. In sixth to seventh century AD, the residents began iron production. The smelting site was most probably off-site, whereas refining and fine smithing was performed between the living zones. All the finds related to metallurgy were from bloom refining and fine smithing, and gave the impression that the skilled metallurgical knowledge was introduced to Kapako by experienced ironmasters. Right from the beginning, people were able to clean dirty blooms by sorting the semi-consolidated material. Moreover, blooms were heated to slag liquidus temperatures of roughly 1200 °C in a reducing environment, and most likely redundant slag was tapped from the refining furnace. Iron was a valuable raw material and most of it became recycled. This may explain the limited amount of iron finds in the EIG settlement context. The earliest ceramic LSA layer from area N99/21-3 produced a classical LSA assemblage, possibly belonging to the Wilton complex, with chalcedony chips, preforms and debitage. The upper pottery-

Figure 103: SC 4 Kapako, clay fragments with negatives of sticks or plaster, indicating wattle and daub constructions at the site.

dominated horizon of the EIG showed mainly debitage of a coarse quartzitic material very similar to the stone artifacts found by B. Sandelowsky in N68/02. In N68/01 lithics were largely absent. One can assume that iron implements successively replaced the standardized range of microlithic tools within a range of some 100 years, and that lithic material was largely abandoned towards 1000 AD.

The settlement of the Late Ironworking Groups stretched from the mission as far west as N98/38 for at least 1.5 km along the river. Most probably, it was a compound of homesteads or living areas with different zones of activity. Again, as the faunal remains are not yet analyzed, no assumptions as to the subsistence strategy can be put forward (compare to section 5.1.4). The high amount of fishbone that Sandelowsky (1968) found in the upper LIG horizon attested however that fishing played an important role in the diet of the late residents of Kapako. The people maintained a large iron industry at Kapako and the center of metallurgical activities can be presumed in the western periphery of the mission. The remnants of ironworking covered the range from initial refining residues to fine smithing remains. There is a strong possibility that the refining furnaces were simple pits in the sandy ground and they were operated at strongly reducing conditions. Moreover, the ironworkers used quartz as welding fluxes for bloom refinement. There is some evidence that people smelted on site, but more slag samples are needed to confirm this assumption. Unfortunately, the LIG horizon is not well dated. As local residents did not remember the metallurgical industries at the site, the archaeological remains most probably belonged to an early horizon of the LIG occupation period, comparable to Ruuga (SC 3), and the early occupation horizon of Vungu-Vungu (SC 12) and Gove-Mbambangandu (SC 17). Yet there is some evidence from oral history that Tjaube smelters occupied the site (section 5.3.2).

2.5. Site catalogue no. 5, Mupini

(Table 1, Figure 26)

Site Number: N07/01
Site Name: Mupini
Coordinates: E19°37.540'/S17°51.725'
Constituency: Kapako
Plane Survey Sheet Namibia 1:50000: 1719 DC MUPINI
Sub clusters: -
Survey: 2007
Excavations: -
References: -
Registration Number State Museum Windhoek: -
Location: 180 m northeasterly of the Mupini Mission.
Altitude: 1073 m AMSL

Topography: The archaeological site is situated on middle to lower river terrace situation. The modern surface declines towards the river (northeast) with a slight downward slope of about 3.5%. There is only a minimum sand cover left on a highly eroded gravely calcrete crust. The soil is only sparsely vegetated.

Site Appearance: Loose artifact scatter of eroded finds of about 200 x 200 m in extension. The top soil and upper parts of the hardpan have been eroded away. The finds probably derived from farther uphill where the soil body was still intact above the hardpan.

Finds: Twenty-one finds were collected (Table 4, Appendix 3). The pottery (Table 13, Appendix 3) comprised a brittle charcoal-tempered ware, and grog-tempered shards. The latter belong to the LIG occupation period. Two decorated potsherds were found, one with an untypical motif of the LIG period, and one charcoal-tempered specimen with an undiagnostic motif. The lithics were not very specific. One large quartzite flake, which showed the negative scars of removed flakes, was used as a scraper-like tool, and two large sidescrapers made from chalcedony were found (Table 13, Appendix 3).

Pottery Style: Undiagnostic organically-tempered ware, Vungu-Vungu style.

Lithic Typology: Unspecific, perhaps Late Stone Age.

Interpretation: This was an eroded settlement site of either the Early Ironworking Groups or the early Late Ironworking Groups, because during both occupation periods, organically-tempered pottery was in use. The material was mixed with grog-tempered Vungu-Vungu-style pottery and together with the clay tobacco pipe may well originate from a younger occupation of LIG residents. The main settlement was probably farther uphill, or it has largely been eroded away.

2..6. Site catalogue no. 6, Mupini Quarry

(Table 1, Figure 26)

Site Number: N06/01
Site Name: Mupini Quarry
Coordinates: E19°38.514'/ S17°52.658'
Constituency: Kapako
Plane Survey Sheet Namibia 1:50000: 1719 DC MUPINI
Sub clusters: -
Survey: 2006
Excavations: -
References: -
Registration Number State Museum Windhoek: -
Location: 40 m north of National Highway B10 from Rundu to Nkurenkuru.

Altitude: 1076 m AMSL
Topography: On a middle terrace of the Kavango River. Within a section of about 6 m in height (Figure 7), the residual weathering process from sandstone to ferricretes is exposed. In the upper horizons iron and manganese enrichments occur. These layers grade into several phases of silicification in the lower parts of the section caused by the downward leaching of silica. The iron-enriched upper weathering horizon is covered by a calcrete hardpan, which formed in a sandy middle-terrace soil body.

Site Appearance: Modern silcrete and ferricrete quarry of 650 x 250 m in extension.

Finds: A sample from the iron-rich pisolitic part of the profile was tested (sample 4399/07//4731/06, Table 32, Appendix 3). In thin section the sample contained sand grains (mainly quartz) which were cemented by a matrix of goethite (Figure 172, sample 4731/06). The iron-rich matrix consisted of an accumulation of very fine-grained oxides, which formed depositional bands of varying density. The sample was classified to the Group III ores and showed with 48.1wt% a comparably high reading of Fe_2O_3 (Tables 40 and 41, Appendix 3). It was not suitable for bloomery smelting without beneficiation.

Interpretation: This site displayed the Omatako Formation under a calcrete hardpan and the Kalahari sand cover.

2.7. Site catalogue no. 7, Rundu Ngandu Lodge and Rundu Ushivi Road

(Table 1, Figure 26)

Site Number: N98/22, N98/21
Site Name: Rundu Ngandu Lodge, Rundu Ushivi Road
Coordinates:
N98/22: E19°46.500‘/S17°54.380‘,
N98/21: E19°46.731‘/ S17°54.344‘
Constituency: Rundu Urban
Plane Survey Sheet Namibia 1:50 000: 1719 DD RUNDU
Sub clusters: -
Survey: 1998
Excavations: -
References: Richter, 2005, p. 89: Catalogue No. 11, p. 91: Catalogue No. 16
Registration Number State Museum Windhoek: B4288
Location: Rundu East, north of the Kehemu neighborhood. N98/22 is located north of the Ngandu Lodge, immediately east of the Sarasungu Road. N98/21 is situated 450 m east of N98/22, west of the Sarasungu Road and north of the Ushivi Road.
Altitude: 1079 m AMSL

Topography: High and middle terrace of the Kavango River at a fossil eroding bank of the river. Within a section of about 10 m in height, the residual weathering process from sandstone to red oxidic soils can be observed in the upper horizons. A moderate calcrete crust occurs in the transition horizon from weathered sandstone to the oxidic soil. The lower parts of the section show old massive sandy calcretes and silicified sandstone layers.

Site Appearance: This was an area of abandoned modern quarries of several hundred meters in extension. At the bottom of the quarry occurred artifact scatters of eroded and displaced lithics. The Early and Middle Stone Age occupation is embedded in a hardpan calcrete that formed in the weathered upper layers of the sandstone layer.

Finds: Lithics

Lithic Typology: Early, Middle and Late Stone Age

Interpretation: The site was relevant to this study as it provided insight into the geological Eiseb Formation, which was overlain by the Omatako Formation and a moderate calcrete hardpan. The geological profile exposed Early, Middle and Late Stone Age occupation horizons.

2.8. Site catalogue no. 8, Rundu Sarasungu Lodge

(Table 1, Figure 26)

Site Number: N98/23
Site Name: Rundu Sarasungu Lodge
Coordinates: E19°46.849‘/ S17°53.533‘
Constituency: Rundu Urban
Plane Survey Sheet Namibia 1:50 000: 1719 DD RUNDU
Sub clusters: -
Survey: 1998
Excavations: -
References: Richter, 2005, 91: Catalogue No. 19
Registration Number State Museum Windhoek: B4288

Location: Rundu East, 200 m southwest of the Sarasungu Lodge, about 30 m south of Sarasungu Road.
Altitude: 1070 m AMSL

Topography: The site is situated on a relatively level lower terrace of the Kavango River, about 200 m away from the contemporary floodplains. The area is covered with grass, shrubs and trees.

Site Appearance: Surface artifact scatter of 2 x 2 m in extension on a road attendant dyke.

Finds: Only two fragments of one and the same vessel were collected (Richter, 2005, p. 94: Fig. 16.1) (Tables 4 and 13, Appendix 3). The shards belonged to the grog-tempered ware of the Late Ironworking Groups.

Pottery Style: Vungu-Vungu style.

Interpretation: Settlement site of the Late Ironworking Groups.

2.9. Site catalogue no. 9, Rundu Sarasungu Road

(Table 1, Figure 26)

Site Number: N99/20
Site Name: Rundu Sarasungu Road
Coordinates: E19°46.607‘/S17°53.780‘
Constituency: Rundu Urban
Plane Survey Sheet Namibia 1:50 000: 1719 DD RUNDU
Sub clusters: -
Survey: 1999
Excavations: 1999
References: Richter, 2005, p. 89: Catalogue No. 13
Registration Number State Museum Windhoek: B4288
Altitude: 1071 m AMSL
Location: Rundu East, about 800 m southwest of the Sarasungu Lodge, about 30 m southeast of Sarasungu Road.

Topography: The site is situated on the edge of a level lower terrace of the Kavango River, roughly 40 m away from the contemporary floodplains and about 560 m away from the watercourse. The area declines about 2.7% towards northwest.

Site Appearance: Surface artifact scatter in a eucalyptus plantation of which the original extension has not been identified. The area was covered with shrubs and trees and some grass.

2.9.1. Excavation

In 1999, archaeologists from the University of Cologne (Juergen Richter) excavated a test trench of 2 x 2 m down to a depth of 50 cm and 70 cm below the surface. First, the loose sand cover was removed and the test square was leveled. As finds were few, all the units were excavated to a level of 50 cm in thickness and divided into arbitrary quadrants. From there, only the northern two squares were leveled down for an additional 20 cm until a depth of 70 cm below the surface was reached. The soil was sifted in a 4 mm wire mesh.

2.9.2. Stratigraphy

Below a sandy, slightly hardened surface horizon of pale yellowish orange (MCC 10YR/8/6) a sandy grayish brown horizon occurred (MCC 10YR5/2), which graded in an increasingly calcareous horizon at about 40 cm below the surface of light gray color (MCC 10YR7/2). In the upper 30 to 35 cm below the surface, the soil was interspersed with charcoal and other cultural material. The number of finds decreased with depth. A shallow pit and four postholes were recorded between 10 and 30 cm below the surface. The pit measured about 70 cm in extension and about 20 cm in height. It was backfilled with a highly organic sandy matrix of dark gray color (MCC 10YR4/1). The postholes were round in plan view, 20 cm in diameter and reached about 70 cm below the surface. They were refilled with sandy gray-brown (MCC 10YR3/2) organic soil, which contained also non-organic cultural materials.

2.9.3. Finds

The excavated test square produced 147 finds, weighing 2.45 kg (Table 4, Appendix 3). The finds comprised pottery (n=42 pcs/677 g), lithics (n = 36 pcs/1460 g), glass, metal items, glass beads, and plastics (Table 14, Appendix 3). Most of the finds concentrated in a horizon down to 35 cm below the surface. All the pottery found was grog-tempered ware typical for the LIG occupation horizon. Most shards displayed typical Vungu-Vungu-style decoration, yet some were decorated in an uncharacteristic way for the middle Kavango region (e.g. Kose & Richter, 2007, p. 118). The stone material was mostly sandstone debris and appeared to be fire-broken rocks from a fireplace. The find-bearing layer contained a number of modern materials, in particular white, green and brown industrial glass from bottles. Four pieces of an iron plate (Table 34, Appendix 3) of industrial production were recovered. Some of these pieces were cut into ribbon and attested that the scrap metal was further processed at the site. The site also revealed a copper chain fragment, consisting of eight links of cut wire. The subangular cross section of the wire from which the chain links were produced indicated that it was of traditional production.

2.9.4. Interpretation

The site was a settlement of the Late Ironworking Groups dating to the twentieth century. The four postholes were probably part of a wooden construction, which has not completely been assessed. It may well be that the posts were part of a traditional sun shelter, which commonly consisted of several posts covered by a roof. The function of the pit was not clear. Most probably, the site was part of or near a workshop of a blacksmith, who recycled industrial metal in order to produce objects for the local market. The copper chain fragment might have been stored in order to rework it. The fire-broken rocks were perhaps part of a forge, though diagnostic slag finds were absent from the site. The decorated pottery found at N99/21 suggested that some of the residents came from a neighboring people, most probably from the Ovambo region (see Kose & Richter, 2007, pp. 118-119), or that they were at least in contact with the peoples living west of the Kavango groups.

2.10. Site catalogue no. 10, Rundu Immigration Office

(Table 1, Figure 26)

Site Number: N98/27
Site Name: Rundu Immigration Office
Coordinates: E19°47.444‘/ S17°52.683‘
Constituency: Rundu Urban
Plane Survey Sheet Namibia 1:50 000: 1719 DD RUNDU
Sub clusters:
N98/25 (E19°47.351‘ /S17°52.747‘),
N98/29 (E19°47.491‘/S17°52.685‘)
Survey: 1998
Excavations: 1998
References: Richter, 2005, 91: Catalogue No. 23-25
Registration Number State Museum Windhoek: B4288
Location: Rundu East, about 650 m northeast of the Rundu Immigration Office.
Altitude: 1068 m AMSL

Topography: The site is situated on a relatively level lower terrace of the Kavango River, about 120 m away from the bank of the river. Under a thin cover of fluvial sandy deposit, a calcrete crust crops out. The area is covered with grass, some shrubs and a few trees. In times of moderate flooding, the area constitutes an island in the river.

Site Appearance: Surface artifact scatter of 300 x 100 m in extension with sub-clusters. The vegetation indicated a former homestead. On site were the ruins of a modern military post. The area was covered with grass, some shrubs and trees.

2.10.1. Excavation site N98/27

Excavation method: Around a dense artifact scatter, a 1-m² test unit was laid out. The unit was leveled down in arbitrary layers of 10 and 20 cm in thickness, divided in quadrants, until a level of 50 cm below the surface was reached.

Stratigraphy: Under a sandy layer of gray-yellowish topsoil of 20 cm in thickness, a shallow pit-like feature with gray, strongly hardened sand occurred. The gray soil had a strong smell of bitumen. It was underlain by yellowish strongly hardened sand. The finds were concentrated at the surface, and between 30 and 50 cm below the surface, below the bitumen-smelling layer.

Radiocarbon dates: A charcoal sample was collected from a horizon between 30 and 50 cm below the surface. It produced a 2-sigma calibrated calendar age between 1500 and 1670 cal AD (KN-5190, Table 2, Appendix 3, Figure 162) (Richter, 2005, 86: Tab. 4).

Finds: The site produced 63 potsherds (253 g), one glass bead (0.01 g), and nine stone artifacts (78 g) (Table 4, Appendix 3). The potsherds (Table 15, Appendix 3) from the excavated units were grog-tempered ware of the Late Ironworking Groups (Vungu-Vungu style). The surface finds comprised a certain amount of organically-tempered shards but only three specimens of them showed decoration and belong to the Gove-style ware. The lithics were unspecific and comprised flakes, a chip, a blade and debitage. The prevalent raw material was quartzite. Like the pottery, they originated from the deeper levels below 30 cm, and from the surface (Table 15, Appenidx 3).

Interpretation: This was a settlement site of the Late Ironworking Groups of unknown size. The distribution of finds, concentrating at the surface and from 30 to 50 cm below the surface, and the type of pottery (organically-tempered ware at the surface, grog-tempered ware in the deeper layer) indicated that the site bore some disturbance. Moreover, the bitumen-smelling middle layer hinted at a modern disturbance. One possible interpretation is that a LIG site, represented by the deeper layer, became disturbed in modern times by the intrusion of a bitumen-smelling substance. The organically-tempered Gove-style ware is chronologically older than the grog-tempered material and it may well be that the dense surface scatter was dislocated material from the nearby military building. The lithic remains were undiagnostic and probably belong to the LIG horizon (see Richter, 2005, p. 91, site N98/28 nearby).

2.10.2. Area N98/25

Site appearance: This was a loose artifact scatter of 5 x 5 m in extension in an uncultivated area, about 200 m southwest of N98/27 and 60 m away from the riverbank. Locals frequented the site with cattle and maintained fireplaces.

Finds: Seventeen shards were collected, amounting to 149 g (Tables 4 and 15, Appendix 3). Among them, only one specimen was organically-tempered. One decorated grog-tempered shard showed a typical motif of the Late Ironworking Groups' horizon. One small piece of iron ore was collected as well (Table 34, Appendix 3). It was strongly dyeing and most probably used for cosmetic purposes.

Pottery Style: Vungu-Vungu and perhaps Gove style.

Interpretation: The site belonged to an abandoned settlement of the Late Ironworking Groups.

2.10.3. Area N98/29

Site appearance: This was a loose artifact scatter of 20 x 30 m in extension in an uncultivated area, about 80 m east of N98/27 and 130 m away from the riverside.

Finds: Four potsherds were collected (Tables 4 and 15, Appendix 3) and all of them were undecorated organically-tempered ware. Owing to the decorated shards found at N98/27, they most probably belong to the Gove-style pottery horizon.

Pottery Style: Unspecific, probably Gove style.

Interpretation: This was a settlement site of the Late Ironworking Groups. The pottery suggested that the surface scatter was, together with N98/27, part of a settlement of the early horizon of the Late Ironworking Groups.

2.10.4. Interpretation of site-complex SC 10

All the three sites (N98/25, N98/27, and N98/29) were part of an abandoned settlement. Strikingly, the site-complex is situated in the floodplains of the river and lay only 3 m above the current water level. The area is not occupied with permanent settlements today, except the Rundu Immigration Office nearby. As discussed in section 3.3 the contemporary Kavango settlements are all located farther uphill. This might have been different during the fifteenth/sixteenth centuries when people started to re-occupy the Middle Kavango area and obviously lived closer to the river.

2.11. Site catalogue no. 11, Kaisosi

(Table 1, Figure 26)

Site Number: N98/26, N98/33
Site Name: Kaisosi
Coordinates:
N98/33: E19°47.853'/ S17°52.507',
N98/26: E19°47.930'/S17°52.490'
Constituency: Rundu Rural
Plane Survey Sheet Namibia 1:50 000: 1719 DD RUNDU

Sub clusters: -
Survey: 1998
Excavations: -
References: Richter, 2005, pp. 91-92: Catalogue No. 26-27
Registration Number State Museum Windhoek: B4288
Location: Rundu East, about 2.14 km north-northwest of the Kaisosi Sewage Area and Local Road D3402, north of a eucalyptus plantation.
Altitude: 1068 m AMSL

Topography: The site is situated in the floodplains and on the lower terrace of the Kavango River, about 60 to 100 m away from the bank of the river, 200 m east of an oxbow of the river. Under a thin cover of fluvial sandy deposit, a calcrete crust crops out. During the rainy season N98/33 is flooded.

Site Appearance: This was a loose surface scatter of eroded artifacts varying in number in an area of about 160 x 70 m in extension. The area was covered with grass, some shrubs and a few trees. Locals maintained fireplaces.

Finds: The finds comprised one Early Stone Age tool and unspecific stone artifacts of younger age as well as potsherds (Tables 7 and 15, Appendix 3). One decorated shard collected from N98/26 showed a decoration motif of the Late Ironworking Groups (Vungu-Vungu style). The pottery found at N99/33 comprised grog-tempered and organically-tempered ware. The two decorated shards belonged to the LIG occupation horizon, one showing a crosshatched band, and one an unspecific comb-stamped motif. Both specimens could be assigned to the Gove ware.

Pottery Style: Vungu-Vungu and Gove style.

Lithic Typology: Unspecific and Early Stone Age

Interpretation: This was an eroded settlement site of the Late Ironworking Groups. The pottery types suggested that the site had been occupied during the early horizon of the LIG period (Gove ware), until grog-tempered ware (Vungu-Vungu ware) became common. The extension of the settlement has not yet been identified. Like SC 10, the sites were situated in an area that modern-day locals do not use for setting up permanent settlements because of the risk of flooding.

2.12. Site catalogue no. 12, Vungu-Vungu

(Table 1, Figure 26)

Site Number: N96/03, N98/32
Site Name: Vungu-Vungu
Coordinates: E19°51.389'/S17°53.028'
Constituency: Rundu Rural
Plane Survey Sheet Namibia 1:50 000: 1719 DD RUNDU
Sub clusters: N69/01(-/-), N69/01-1 (-/-), N69/01-2 (-/-),
N96/03-1 (E19°51.188'/S17°53.022'),
N96/03-2 (E19°51.284'/S17°53.002'),
N96/03-3 (E19°51.331'/S17°53.024'),
N96/04 (E19°51.984'/S17°53.006'),
N98/30 (E19°51.401'/S17°52.005')
N98/32-1 (E19°51.374'/S17°53.021'),
N98/32-2 (E19°51.374'/S17°53.028'),
N98/32-3 (E19°51.361'/S17°53.026'),
N98/32-Surf.-1 (E19°51.427'/S17°53.033'),
N98/32-Surf.-2 (E19°51.425'/ S17°53.036'),
N98/32-Surf.-3 (E19°51.405'/ S17°53.035'),
N98/32-Surf.-4 (E19°51.381'/S17°53.019'),
N98/32-Surf.-5 (E19°51.346'/ S17°53.018'),
N98/32-Surf.-6 (E19°51.218'/S17°52.999'),
N98/32-Surf.-7 (E19°51.399'/ S17°53.017'),
N98/34 (E19°51.408'/S17°53.012'),
N98/35 (E19°51.352'/S17°53.014'),
N98/36 (E19°51.283'/S17°53.013'),
N98/37 (E19°51.243'/S17°53.005'),
N06/06-1 (E19°51.254'/S17°53.088'),
N06/06-2 (E19°51.279'/S17°53.017').
Survey: 1968, 1996, 1999, 2003, 2005, 2006
Excavations: 1969, 1996, 1998
References: Sandelowsky, 1968; Sandelowsky, 1969; 1979, pp. 55-60; Richter, 2005, p. 95: Catalogue No. 36-39; Kose, 2004; 2009b
Registration Number State Museum Windhoek: B1577 (N69/01), B1968 (N69/01-1), B1969A-D (N69/01-2), B1970 (N69/01-2), B4288 (N96/03, N96/04, N98/32, N98/34, N98/35, N98/36, N98/37)
Location: North of the Vungu-Vungu dairy, in the northern part of the Vungu-Vungu dairy farm ground. The site stretches for about 1.5 km from east to west along the bank of the Kavango River (Figure 104).
Altitude: 1064 m AMSL
Land Owner: No information, Vungu-Vungu dairy farm.

Oral History: Vungu-Vungu is a well-known historical site because local oral chronicles handed down say that the first Shambyu rulers settled at this location in the eighteenth century and planted a Vungu-Vungu tree, which they

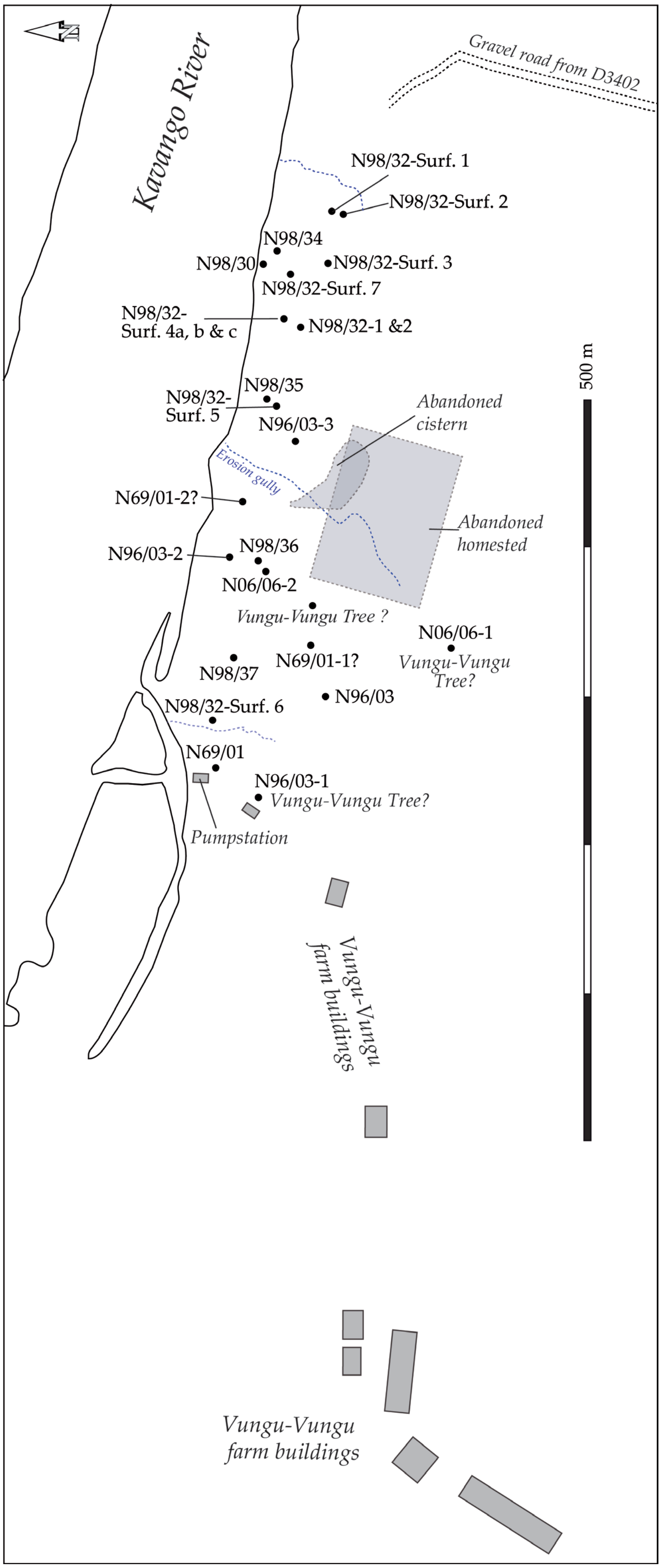


Figure 104: Site layout of SC 12 Vungu-Vungu.

brought along from their country of origin (e.g. Fleisch & Möhlig, 2003, pp. 133-134; Kose, 2004, pp. 14-17; Sandelowsky, 1968). The tree served the Shambyu as a place for sacrifices to the ancestors. The original location of the historical Vungu-Vungu tree as recorded by Beatrice Sandelowsky (1969; 1979, p. 54 Fig. 4) in the late 1960s at this site (Figure 107) could not be re-identified 30 years later.[89] Vungu-Vungu was the residence of the Shambyu royals until the beginning of the nineteenth century, when Queen Mushinga moved the royal court to Gove (SC 17). However, the history of the site goes beyond the Shambyu narratives because Vungu-Vungu is also remembered as a settlement site of the Tjaube people who migrated to the Middle Kavango region some centuries earlier (section 5.1). In their accounts, the place was named Utu. It was a settlement and smelting sites of a certain Lishara, a nephew of the Tjaube King Mankoto. Mankoto resided at Kauti (SC 32) in the Fontein Omuramba, lived on hunting and ivory trade, and set up several settlements along the Kavango River.

[89] Based on information from locals, in 1996 Rudolf Kuper identified a place close to the pump station, about 100 m south of the main river, as the original location of the tree (sub-cluster N96/03-1) (Figure 104). Ten years later, locals stated that the original tree grew about 180 m south of the riverbank on the ground of the Vungu-Vungu dairy (sub-cluster N06/06-1). However, both locationsare too far away from the main river compared to Sandelowsky's photographic andwritten records of her excavation (N69/01-1) (Sandelowsky, 1969; Kose 2004, p. 18: Fig.6). These days, offspring of the tree cluster around the Dairy Farm buildings 70 m north of N96/03-1. It may well be that in former times several offspring of the first Vungu-Vungu tree existed, yet all statements refer to an area between the pump station, the abandoned cistern and the southern limit of the dairy farm grounds.

The youngest oral history narrative is the account of Petrus Kudumo Kampanzela (Appendix 2.1) who described iron smelting of his family at Vungu-Vungu in the early twentieth century. He remembered people smelting in pit furnaces in a fenced-in area inside of the settlement, between the individual homesteads. Despite the smelting site being in the center of a village, people had to create a ritually secluded area to observe the spiritual rules and taboos necessary for successful smelting (section 5.3.2).

Topography: The archaeological site Vungu-Vungu is situated on a lower concave terrace on an eroding bank of the Kavango River. The site is affected by recurrent flooding since it lies only about 3 m to 4 m above the water level during the dry season (Figures 6 and 110). Bank erosion is active. The modern surface of this terrace gently declines towards the river (north) with a downward slope of less than 1%. Due to the high clay content of the alluvial lower and middle terrace deposits, the soil is less permeable than elsewhere along the river. This provokes a number of smaller and larger drainage gullies (Figure 111). Three large main erosional channels cut from higher places towards the river across the area: In the western part immediately east of the pump station, in the eastern part about 90 m west of the prolonged gravel road, leading down to the river from Local Road D3402, and a central channel where site N96/03-3 is located (Figure 104). A general soil description based on studies within the Vungu-Vungu Irrigation Project can be taken from the Report on a reconnaissance soil survey of Okavangoland (A.O.C. 1967, p. 14: Soil Type C). The soil form is classified to be a dark gray brown sandy loam with a clay content of 15 to 35%. It is considered typical for a middle terrace situation in this area and overlies calcretes. Further down the slope red clays occur under the calcrete hardpan (Sandelowsky, 1979, p. 55). The clays can be seen as a weathering product of the outcropping red fine sandstone formation (section 1.3.2.10). Salt crystallizes at the surface along the edge of the river.

Site Appearance: The archaeological occupation stretched from west to east at about 1.6 km along the river (Figure 104). The southern limit has not yet been precisely identified. Towards the river, the find-bearing layer of the Late Ironworking Groups was covered by no more than 10 cm of loose sandy soil. It was poorly protected from erosion, flooding and modern activities. Clusters of finds were frequently found along run-offs of surface water and must be seen as a result of erosive activity (Figure 111). They do not necessarily represent sub-surface archaeological clusters. The area was covered with lower and higher grass and some Acacia shrubs and trees (Figure 106). Fire clearing of trees occurred.
The whole area was used for commercial and traditional agriculture in the 1960s. Today, the northern part along the bank of the river is fallow land and used for fishing, grazing and household activities (Figure 105). Several buildings (e.g. the pump station of the farm, other farm buildings, and a clay brick manufacture) and the ruins of an abandoned cistern disturb the site (Figures 104 and 106). East of the pump station, numerous hardened cement bags are scattered around and the soil seemed to be disturbed. East of the dairy farm, local brick production has taken place using the clay deposits from the river. The top layer was therefore commonly mixed with modern materials such as plastic and canes. As the archaeological site is located on a cut bank of the river, parts of the site have also been lost to soil erosion. Owing to this, the northern part of the backfilled excavation units from 1996 was washed out in 2003.

2.12.1. Stratigraphy

A detailed description of the upper soil horizon from site N98/32 is given in Kose (2004). As the excavations did not exceed 30 cm below the surface, there was little information about the general pedology of the site itself. Better evidence was given in Sandelowsky (1979, p. 55) who reached a depth of 50 cm. Generally speaking the archaeological horizon was found under a thin top layer of loose pale sand, which was strongly mixed with modern material. A soil sample taken from the erosion gully immediately east of the excavated area N98/32 attested to the strong clayey nature of the Vungu-Vungu soil (slightly sandy, silty clay). The color was reddish brown (MCC 5YR4/4) and the matrix slightly calcareous. Small $CaCO_3$ nodules occur throughout the section and reddish and yellowish concretions precipitated under the fluctuating water table. The high clay content caused the great hardness of the archaeological horizon under dry conditions. Depending on the humus, charcoal and ash content, the color of the soil changes towards dark gray colors (Sandelowsky, 1979, p. 55). The hardened layer contained abundant

Figure 105: SC 12 Vungu-Vungu, archaeological site in 2006.

cultural material such as bones, potsherds, charcoal and others. As elsewhere along the river, a calcrete layer bounded the archaeological horizon at the bottom (Figure 109). Soil analysis showed a relatively high organic component (1.5% to 2.8% C_{org}) (H. Scholz in Sandelowsky, 1979, p. 55) of the settlement horizon in relation to local soils with organic C less than 1% (Schneider, 1987, p. 201). Soil samples taken in 2003 produced a carbon-to-nitrogen ratio of 24:1. The high ratio indicates either low biological activity or carbon enrichment of carbon forms that are not easily decomposable such as charcoal. The latter is not surprising because a high charcoal content can be expected in a midden situation such as found in Vungu-Vungu (S. Pätzold, personal communication).

2.12.2. Radiocarbon dates

So far, eight radiocarbon dates exist from Vungu-Vungu (Table 2, Appendix 3), dating the site to the occupation horizon of the Late Ironworking Groups. The dates cluster in two groups: The calibrated results of the first group (Poz-20699, Pta-236, Poz-20671, and Poz-20702) concentrated around the sixteenth century AD (Table 2, Figure 162), the second set of dates is younger (KN-5313, KN-5329, KN-5643, KN-5191, and KN-5330), falling into the calibration plateau between 1650 and 1950 AD. The end-limits of the youngest and oldest ranges of the 2-sigma calibrated dates of both groups overlap in the seventeenth century AD (Figure 162).

According to the age ranges revealed from the site, it seems possible that the occupation of Vungu-Vungu started in the second half of the fifteenth century AD. Three of the early dates were generated from archaeological material associated with the excavations undertaken by Beatrice Sandelowsky in the western part of the site (N69/01-1 and -2, Figure 104 and 162), and one originated from a slag associated with the excavation area N98/32-2.[90] As can be taken from Table 2 (Appendix 3), the materials used for dating derived from different contexts such as a charcoal concentration in a pit (Pta-236), charcoal extracted from pottery (Poz-201671) and charcoal extracted from slag blocks (Poz-20699 and Poz-20702). Altogether, the dates were concordant with each other and represent the early occupation horizon of the Late Ironworking Groups (see section 3.2).

The younger dates were not very significant. All of them were produced from the excavation area N98/32-2 from the units 50/50 to 51/51, and represented no more than that the area was inhabited between circa 1670 and the early twentieth century AD (Figure 162). What is

[90] Sample Poz-20699 originated from eroded material 2 m south of excavation area N98/32.

Figure 106: SC 12 Vungu-Vungu, archaeological site in 1997, in the foreground rubble of abandoned cistern (image: Martin Albrecht).

more, charcoals taken from the sediment must be interpreted with care, because they may well be contaminated by fire clearing of the area after the settlement was abandoned, or by modern fireplaces that people maintained while fishing. The dated bone samples were also uncertain because collagen was only poorly preserved despite the young age of the samples. Moreover, bone material frequently incorporates humic acids from the environment, which may distort the radiocarbon age of the samples (Hajdas, 2008, p. 10).

2.12.3. Area N69/01

(Figure 104)

Survey around the pump station and north of the Vungu-Vungu tree by Beatrice Sandelowsky. Numerous finds eroded out along the river bank and along the erosion gully east of N69/01-2.

Finds: Potsherds, OES and glass beads, faunal remains and a chunk of furnace slag. The pottery was mainly organically-tempered shards with decoration motifs of Gove ware.

Pottery Style: Vungu-Vungu and Gove style.

Interpretation: The finds from N96/03 indicated a midden area around the pump station. It may be that the building of the pump station disturbed some cultural layers. The concentration of Gove-style pottery marked an early settlement area of the Tjaube (see below).

2.12.4. Excavation sites N69/01-1 and -2

(Figure 104)

2.12.4.1. Excavation Method

In 1969, Beatrice Sandelowsky excavated two test squares close to the Vungu-Vungu Tree (Sandelowsky, 1969; 1979). Test trench 1 was located west of the tree and measured 5 x 1.5 m in extension. The soil was removed down to a level of 25 cm below the surface and sifted through a 3 mm wire mesh. Finds were collected according to the individual units (north axis: I to E, east axis: 5 and 6). Test trench 2 was located northeast of the tree and extended 15 x 1.5 m from west to east. The soil was removed down to a level of 25 cm in every second 1.5 m^2 unit (Test unit 2, 4, 6, 8, 10) (Figure 108) and sifted through a 3 mm wire mesh. Around test unit 4 and 6, a square of 5 m side length was laid out and the finds that became

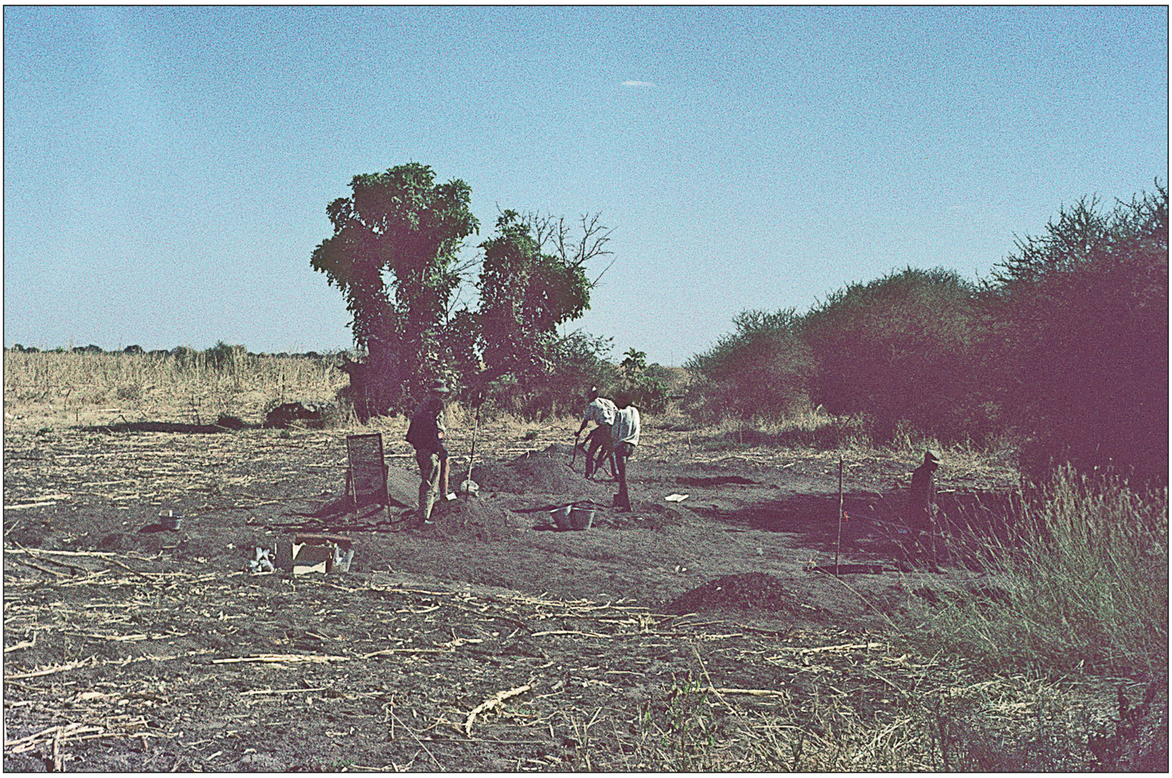


Figure 107: SC 12 Vungu-Vungu, archaeological site in 1969 with the Vungu-Vungu tree. In the foreground excavation area N69/01-2 (image: Beatrice Sandelowsky).

visible below the loose cover of surface sand were mapped. The test trench was then taken down to a level of 15 cm below the surface. Finds were collected according to the individual units (Test 2 to 10). The finds from the 5 x 5 m test area was labeled with 'Surf. scrape 5 sg. m'.

2.12.4.2. Stratigraphy

The occupation horizon in test trench 1 reached no deeper than 25 cm below the surface, and it was bordered by a calcrete crust. Only a few artifacts were found, which were scattered without concentration throughout the deposit. One slag block collected from the surface has been dated to the late fifteenth/ early sixteenth century AD (Poz-20702, Table 2, Appendix 3, Figure 162). In test trench 2, an occupation horizon concentrated between 10 to 15 cm below the surface and eroded out in some places. In test unit 2, a shallow pit was transected 25 cm below the surface and deeper, in which a charcoal concentration appeared. Sandelowsky (1969) interpreted it as a fireplace, and a sample of charcoal produced a calibrated calendar age from the late fifteenth century to the mid-seventeenth century AD (Table 2, Appendix 3, Figure 162, Pta-236). A second radiocarbon date was produced by a charcoal sample extracted from an organically-tempered shard from this test trench and confirmed that the site was occupied during this historical period (Poz-20671, Table 2, Appendix 3). The calcrete crust was hit at 45 cm below the surface (Figure 109).

2.12.4.3. Finds

The excavation from 1969 produced almost 8300 finds (Table 8, Appendix 3), which have been described in Sandelowsky (1979). In test square 1 little was found. The soil contained a few small potsherds, some pieces of slag, glass and ostrich eggshell beads and their preforms. A slag block collected from the surface around test trench 1 produced again a 2-sigma calibrated date between the first half of the fifteenth and the first half of the seventeenth century AD (Poz-20702, Table 2, Appendix 3) Figure 162) (Sample 4415/06, Figure 183). Test square 2 revealed by far more cultural remains. The soil was densely interspersed with potsherds, faunal material, beads made from glass, ostrich eggshells and shells, cowry shells, tobacco clay pipe fragments, some undiagnostic stone artifacts, slag fragments, iron implements and copper beads. The rich pottery assemblage provided the basis for the definition of the late Kavango pottery, because the decoration showed strong similarities to modern traditional pottery (Sandelowsky, 1979, p. 61). However,

Figure 108: SC 12 Vungu-Vungu, excavation area N69/01-2 (image: Beatrice Sandelowsky).

among the shards from N69/01-1 and N69/01-2 along with the surface finds that B. Sandelowsky collected in this area (B1577) there was a high frequency of organically-tempered ware, decorated with various comb-stamped patters and arrangements of single impressions. This pottery has been assigned to the Gove-style ware (Figure 165). When re-assessing the material from both test trenches, nine slag fragments, one piece of a tuyere, five small ore lumps, nine copper beads and three iron artifacts were examined. Most finds from metallurgical activities were found in N69/01-2 and details of these finds will be discussed below in section 2.12.18.

2.12.4.4. Radiocarbon dates

Three dates are available: Pta-236, Poz-20671, and Poz-20702 (Table 2). The 2-sigma calibrated results ranged between the first half of the fifteenth century and the late seventeenth century cal AD (Figure 162).

2.12.4.5. Interpretation

Both test trenches transected an early occupation horizon. The photographs taken by B. Sandelowsky in 1969 (Figure 107) located the test trenches near the old Vungu-Vungu tree. Owing to its high frequency of finds, in particular of faunal remains and potsherds, test trench 2 represented the periphery of a living area where garbage from the homesteads was discharged. The charcoal-filled shallow pit, which Sandelowsky observed in test unit 2 of N69/01-2, together with the smithing hearth bottom from fine smithing (sample 4416/06) and the copper and

Figure 109: SC 12 Vungu-Vungu, area N69/01-2, soil profile (image: Beatrice Sandelowsky).

Figure 110: SC 12 Vungu-Vungu, excavation area N98/32-2 in N1996 (image: Rudolf Kuper).

Figure 111: SC 12 Vungu-Vungu, collecting artifacts along erosion gully in area N98/32-Surf.-4 in 2003.

Figure 112: SC 12 Vungu-Vungu, clay feature in area N98/32-2 (image: Jürgen Richter).

iron artifacts suggested that the area was a working zone of a blacksmith for some while, before it became covered by the domestic refuse of the settlement. Test trench 1, which produced only a few domestic finds, might have been a living area where people slept and cooked. The high frequency of Gove ware among the potsherds from this area, together with the early radiocarbon dates from both test trenches indicated that this part of the site belonged to the Tjaube settlement.

2.12.5. Area N96/03-1

(Figure 104)

According to locals interviewed by Rudolf Kuper in 1996 this was the place were the first Vungu-Vungu tree was planted. The site was about 40 m away from an oxbow and 100 m south of the main river. A few finds were scattered around together with modern refuse. The place is more or less 150 m east of the place where B. Sandelowsky came upon the dead Vungu-Vungu tree in 1969 (see discussion above).

Finds: Potsherds (Vungu-Vungu style), undiagnostic lithics, and slag. No artifacts were collected.

Interpretation: The finds from N96/03-1 indicated the westernmost extension of the entire site-complex of Vungu-Vungu, as far as it has been assessed to this day.

2.12.6. Areas N98/32-Surf. 6 and N98/37

(Figure 104)

Site appearance: Dense artifact scatters in and at the edge of an erosional slope towards the river, about 40 to 80 m east of the pump station. The river bank was strongly eroded and the drainage gully was flooded during the rainy season. Cultural material concentrated around N98/32-Surf. 6, and slags around N98/37.

Finds: Only selected artifacts were collected, comprising decorated and undecorated potsherds, a clay pipe fragment, four stone artifacts, slag, one tuyere fragment and a piece of a copper bracelet. Some bones were also collected. The pottery found is typical grog-tempered Vungu-Vungu-style ware. The lithics comprised retouched flakes and blades, which did not follow the classification scheme applied to this study (section 1.7), and one backed bladelet of Type 25 (Figure 71). The slag finds comprised remnants from refining processes and secondary smithing and will be discussed below (section 2.12.18).

Interpretation: The area has most probably been used as dump in the periphery of a settlement. The slag finds indicated that there may have been a blacksmith's workshop nearby (section 2.12.18). The backed bladelet hinted at a Late Stone Age occupation of the site.

2.12.7. Areas N96/03-2 and N98/36

(Figure 104)

Site appearance: This was an artifact scatter of about 30 x 30 m in extension west of a broad erosion gully, between N69/01-1 and N96/01-2, 10 m to 30 m north of N06/06-2. The area was vegetated with grass and some shrubs and small trees. Towards the river the site seemed to be disturbed by earthworks.

Finds: The overall frequency of artifacts was scarce, and only selected finds were collected, comprising some potsherds and ostrich eggshell beads. Slag was present, but has not been collected.

Interpretation: The area was part of the settlement complex of Vungu-Vungu. It cannot be said for certain whether the limited amount of cultural material scattering at the surface owed to a decreased frequency of finds in general, or because the cultural layer was well protected by soil and vegetation cover.

2.12.8. Area N06/06-2

(Figure 104)

Site appearance: According to the local elder Nangudi Mungomba (personal communication on 7 July 2006), this was the former smelting area of Vungu-Vungu. The site was located east of a broad erosional gully, southeast of the rubble of an abandoned cistern. Big chunks of smelting slag scattered around, other cultural material such as potsherds, beads or faunal remains were scarce.

Finds: No finds were collected.

2.12.9. Area N06/06-1

(Figure 104)

Site appearance: According to the local informant Nangudi Mungomba (personal communication on 7 July 2006), this was the approximate former location of the Vungu-Vungu tree. The site was on the dairy's ground about 180 m south of the bank of the river. The area has not yet been surveyed because it was fenced in. The area was more or less 100 m north of the tree encountered by Beatrice Sandelowsky in 1969 (N69/01-1, Figure 104).

2.12.10. Excavation site N96/03-3

(Figure 104)

Site appearance: In 1996, Martin Albrecht discovered at the east bank of an erosion gully an eroded round pit feature of 1.7 to 2 m in diameter and a depth of about 40 cm below the surface. Charcoal, slag, and potsherds also clustered around the pit (Figure 120).

2.12.10.1. Excavation Method

The surface finds of a test strip of 6 x 0.5 m were sampled for further documentation (units 88/25 to 88/30). Thereafter, a test quadrant (88/26b) was excavated down to a depth of 40 cm in steps of 10 cm, following the slope of the gully bank. An additional quadrant (88/28d) was leveled down to 20 cm (Figure 113).

2.12.10.2. Stratigraphy

In the plan view, slag scattered in the southern two units and in unit 88/26b (Figure 121). Within the latter, no further stratigraphical differentiation was possible. However, the amount of slag increased with depth and concentrated at 10 cm below the surface. Potsherds scattered evenly throughout all the levels. No further remarks existed concerning the condition of the pit, for instance, whether there was any impact of heat to the soil or other characteristics, which may explain the function of it.

2.12.10.3. Finds

The small test units and the surface collection revealed 334 finds, amounting to more than 2 kg of cultural material (Table 8, Appendix 3). By far the largest find category was slag with 257 pieces, weighing 1693 g, followed by 65 pottery fragments accounting for 262 g. Eight stone artifacts (48.8 g), two tuyere fragments (34 g), one ostrich eggshell bead and one bone fragment completed the picture.
Among the 65 potsherds (Table 29, Appemdix 3), 21 displayed some decoration. Most of them could be assigned to typical Vungu-Vungu-style pottery (Figure 114). The lithic finds were mainly unspecific flakes and debitage, made from quartzite or chalcedony (Table 30,

Appendix 3). As described in detail below (section 2.12.18) the slag finds comprised smelting slag, refining slag and secondary smithing slag (Table 33, Appendix 3).

2.12.10.4. Interpretation

Within the site-complex SC 12 of Vungu-Vungu, N96/03-3 represented a workshop of iron-workers where blooms became consolidated and implements were forged. This is the result of the examination of the slag assemblage described in section 2.12.18. The lack of faunal remains and the limited numbers of potsherds showed that the area was not used as a midden. The ironworkers kept the area more or less clean, because they backfilled a pit with material, which usually scatters around an anvil and the refining furnace or forge. The area however raised the question to what extent working areas had been cleared out and whether ironworking debris was discarded together with other cultural material in the precincts of homesteads.

2.12.11. Areas N98/32-Surf. 5 and N98/35

(Figure 104)

Site appearance: This was a dense artifact scatter of about 15 x 15 m in extension on the east bank of a broad erosional gully, 30 m north of N96/03-3. Finds eroded out along the mouth of the gully. A charred tree and chunks of modern charcoal spread around the site.

Finds: Several potsherds, a clay pipe fragment, two stone artifacts and one iron artifact were collected (Tables 8, 29, 30, and 33, Appendix 3). The pottery was of typical Vungu-Vungu style. One stone core and one point of the lithic tool Type 12 (Figure 71) were collected, probably belonging to an LSA occupation of the site.

Interpretation: This area was part of the site-complex SC 12 of Vungu-Vungu. As finds were few despite the erosional activity, it was possibly a living zone or the interior of a homestead. The stone artifacts may belong to an old Late Stone Age occupation of the site (see also sub-clusters N98/32-Surf. 6 and N98/37).

2.12.12. Area N98/32

(Figure 104)

Site appearance: Artifact scatter of about 7 x 4 m in extension, 30 m west of the N98/32-2 excavation site and 30 m east of the large erosional gully. Finds eroded out along an erosion gully towards the riverbank.

Finds: Some pottery of Vungu-Vungu style, faunal remains, OES beads and slags. No finds were collected.

Interpretation: The find scatter probably belonged to the midden area of N98/32-2, which was 10 m to the west.

2.12.13. Excavation site N98/32-1 and 2, and area N98/ 32- Surf. 4a, b and c

(Figure 104)

2.12.13.1. Excavation method

The excavation of this area has been comprehensively described in Kose (2004 & 2009b). In 1996, Rudolf Kuper and his team sampled and excavated an 18 m^2 area with high artifact concentration (N98/32-2). The finds eroded out along the mouth of a deep narrow erosional gully (Figure 111), roughly 250 m east of the place where B. Sandelowsky's test trench 2 must have been located (Figure 104). The area was investigated by sampling the surface finds and sifting the loose sand cover through a 3 mm wire mesh. The finds were documented according to 1-m^2 units subdivided into arbitrary quadrants. Two test units of 1 m^2 (unit 34/23) and 0.5 m^2 (unit 34/23) were excavated in quadrants and artificial layers of 5 cm down to a maximum level of 25 cm and 30 cm below the surface (Figure 113). In 1998, Juergen Richter (2005) re-located the excavated area from 1996 and added a test square of 4 m^2 (N98/32-1) (Figure 121). He removed the loose surface layer and plotted the plan view of the test square. In the southwestern part of it (unit 50/50c and d), a round clay feature appeared (Figure 112). The units were leveled down around the feature to a maximum depth of 30 cm below the surface. For the sake of convenience, all finds, including those from 1996, are listed in this study under N98/32-2.
In 2003, 2005, and 2011, the site again was visited. The northern limits of the refilled excavated squares have been eroding out. Directly north of

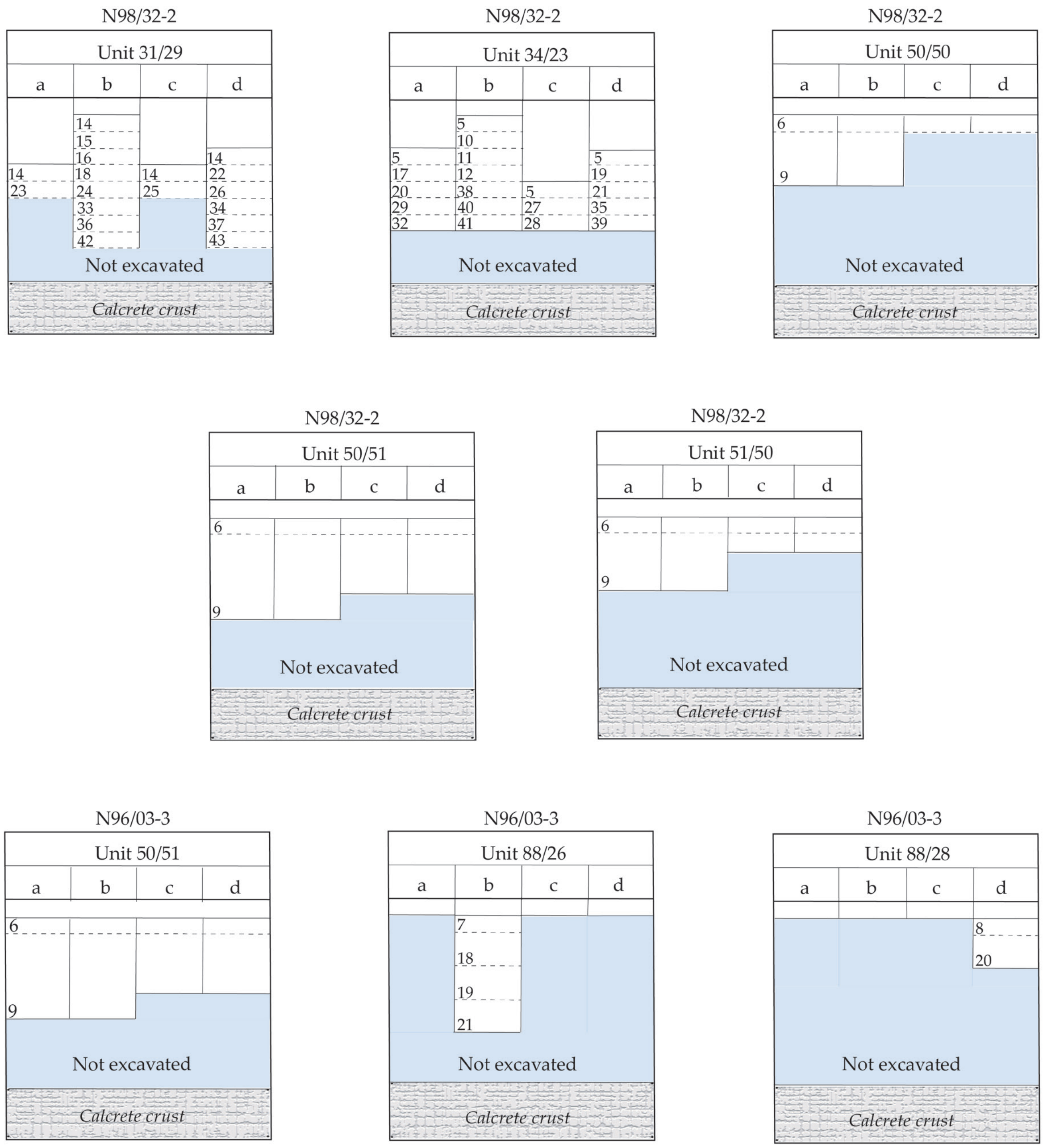


Figure 113: SC 12 Vungu-Vungu, level index of the excavated units to be used in conjunction with Tables 29, 30, and 33.

the former excavation, numerous finds became also exposed at the surface. They were collected under the labeling N98/32-Surface 4b and c. East of the excavation area, an erosional gully cut across the site (Figure 111). Finds from the eastern bank of the mouth of the gully were collected under N98/32-Surface 4a.

2.12.13.2. Stratigraphy

No stratification was recognized in the excavated units and there appeared no significant change in the vertical and horizontal distribution of the finds. The clay feature in unit 50/50c and d consisted of a thick round bottom layer of local red clay with a thick rim of about 10 cm in height (Richter, 2005, p. 97: Fig. 20). A similar feature was observed northeast of test square N98/32-2, on the eroding bank of the river. In unit 50/50, the clay feature was covered with a layer of cultural material, containing potsherds, faunal remains, slags, OES and glass beads. In unit 33/21, the tusk of an elephant appeared on the cleared surface. Some 2 m north of N98/32-2, a smithing hearth bottom (sample 4433/06) eroded out at the bank of the river. The slag was situated in a dense charcoal cluster, which extended towards the south, and the surrounding soil was reddened from fire. Around the slag, numerous potsherds, glass beads and OES beads and their

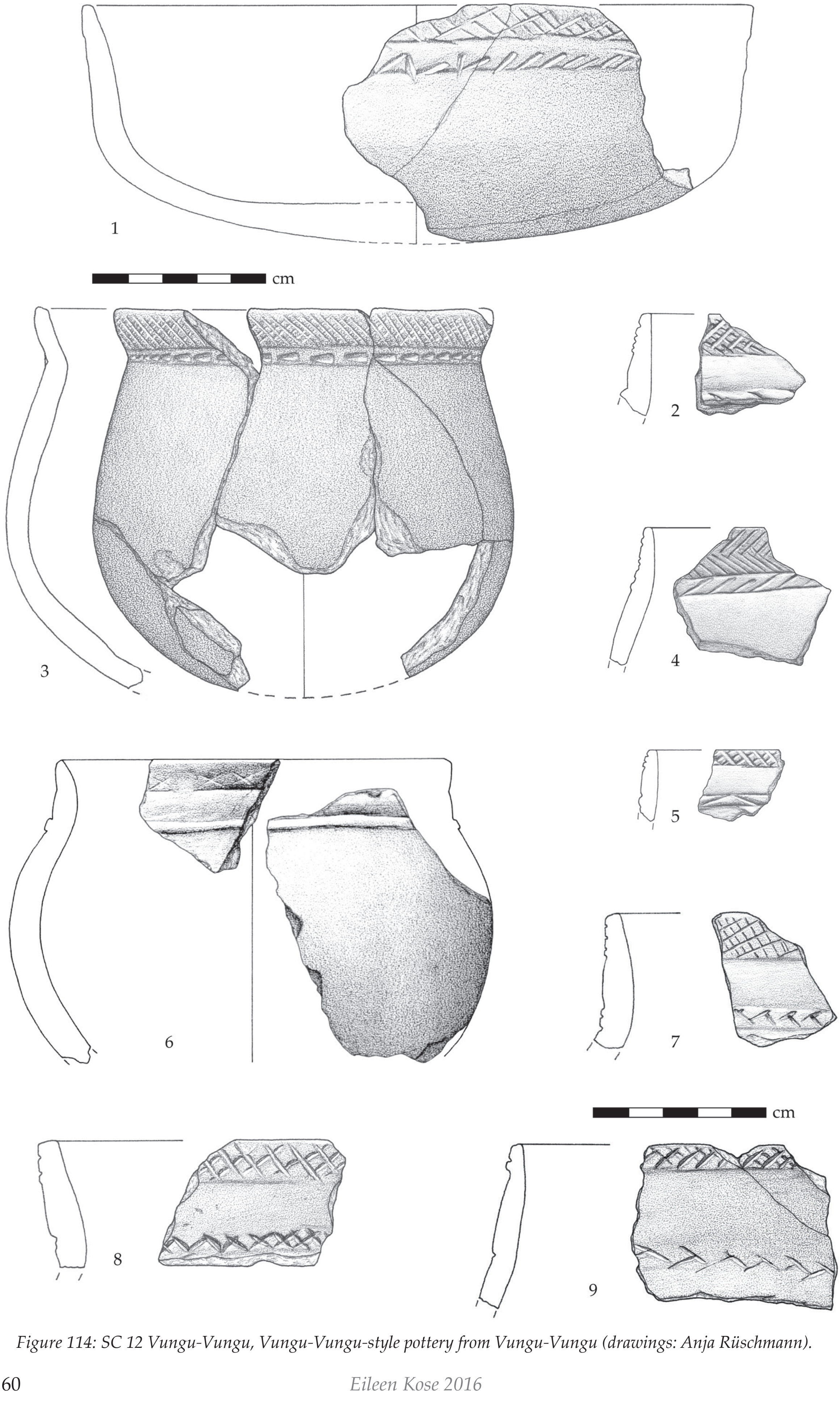


Figure 114: SC 12 Vungu-Vungu, Vungu-Vungu-style pottery from Vungu-Vungu (drawings: Anja Rüschmann).

preforms were scattered. Modern bottle glass and plastics were found in all levels, attesting that the site is contaminated with younger material. This area exemplified the difficulty in interpreting the site because all the features and finds appeared in the same horizon. However, one must assume that the ironworker's workshop was not littered with domestic refuse, nor was it the clay feature of unknown function during its time of use. It is also questionable if the elephant tusk belonged to the time horizon during which the area functioned as a midden. As described in section 5.4, ivory was of greatest value and it is likely that the tusk was hidden in the ground earlier (see below).

2.12.13.3. Finds

The excavations of N98/32-2 produced 4222 finds (faunal remains not included), amounting to 8.8 kg (Table 8, Apprentix 3). From the surface of N98/32-Surf. 4a, b and c, 276 finds were collected (faunal remains not included), weighing 0.9 kg. The pottery, clay pipes and glass beads were listed in detail in Kose (2004). The Tables 29, 30, and 33 (Appendix 3) of this study include finds, which were not considered in Kose (2004). All the excavations at Vungu-Vungu produced a high number of tobacco-clay-pipe fragments compared to other sites from the same period (Figure 115). The 22 examined finds from this area disclosed (together with a further 55 fragments form N69/01-1 and -2) a high variety of decoration patterns and techniques, which went beyond the decoration patterns found on local pottery (e.g. stamped motifs or decoration produced by a roulette) (Kose, 2004, pp. 81-84; Kose & Richter, 2007, pp. 121-122).
In the framework of the archaeological study from 2004, 73 European glass beads from N98/32-2 and -Surf. 4a, b and c were also analyzed (Kose, 2004, pp. 120-121; Kose & Richter, 2007, pp. 122-123). The results showed that most of the beads were early varieties, which were introduced into the African market from the late fifteenth century onwards until the late eighteenth century.
Besides the glass beads, 307 ostrich eggshell beads, their preforms and production debris were recovered from the surface and from the excavated units (Table 29, Appendix 3). They attested that the residents of Vungu-Vungu abundantly produced ostrich eggshell beads.
The area also yielded a number of lithic artifacts (n = 174 pcs/522 g) (Table 30, Appendix 3), which were classified according to the classification scheme described in section 1.7. Most of the lithic material was unspecific debitage (n = 82 pcs, 46.06%), and flakes of various sizes (n = 54 pcs, 30.3%). Chips amount to 12.35% (n = 22 pcs) of the assemblage and only three blades were recovered from the examined area. The dominant raw material was chalcedony (59.55%), followed by quartzite (33.7%). Of interest were five small pieces of quartz, which were most likely not of local origin.
The assemblage yielded a single platform core of chalcedony, a bilateral discoid core and an irregular core both of quartzite. Eleven retouched artifacts were found among the lithic material, all of which were made from flakes. Among them, two pieces were laterally retouched microliths of Type 38 and 39, and one was a borer of tool Type 56 (Figure 71). The other retouched artifacts did not follow the classification scheme applied for this study. Their size ranged between 17 and 63 mm in maximum length. Some flakes of the assemblage showed macroscopic traces of usage. From area N8/32-Surf. 4a, a retouched piece of green bottle glass was collected.
Area N98/32-2 also revealed 2384 pieces of faunal remains, accounting for 3.4 kg of material (Table 29, Appendix 3). Unfortunately, the faunal remains from the research area have only randomly been analyzed, but an initial assessment of the finds indicated that the main categories were antelopes, buffalo, hippopotamus and fish (Joris Peters personal communication June 2006). As mentioned above, most interesting was the discovery of a strongly decayed elephant tusk in unit 33/21.
Eleven pieces of burnt clay were found and some of them showed negatives of wooden sticks (Table 29, Appendix 3). They demonstrated that the residents of Vungu-Vungu built wattle and daub constructions, most probably comparable to modern 'traditional' houses from the area.
One hundred and five slag finds, 16 tuyere fragments, four copper beads and five iron artifacts from this area provided the basis for the reconstruction of the metalworking activities in this part of the site-complex SC 12 of Vungu-Vungu (Table 33, Appendix 3). These finds will be discussed in detail below (section 2.12.18).

2.12.13.4. Radiocarbon dates

Six radiocarbon dates were produced from this area (KN-5191, KN-5313, KN-5329, KN-5330, KN-5643, Poz-20699, Table 2, Appendix 3). Except for Poz-20699, all the dates fall into the calibration plateau between 1650 and 1950 AD (Figure 162).

2.12.13.5. Interpretation

The area N98/32-2 and N98/32-Surf. 4 was difficult to interpret because the examination strongly suggested that it served different functions in the course of the centuries.
It has been assumed that the clay feature mentioned was the remnant of a hearth (Kose, 2004, p. 20), or a furnace used for metallurgical purposes (Richter, 2005, p. 94). However, the clay was certainly not exposed to temperatures around 800 °C and higher, which would be necessary for metalwork. Because of this, other interpretations should be taken into consideration as well. The eroded charcoal concentration around sample 4433/06 was probably the remains of an eroded refining furnace, because the sample has been identified as a smithing hearth bottom from initial refining processes, dating between the mid-fifteenth and the mid-seventeenth centuries cal AD (Poz-20699, Table 2, Appendix 3, Figure 162). The clay feature together with the furnace-like feature suggested that the area was part of a domestic zone and/or a forge and the amount of slag and tuyere fragments discussed below in section 2.12.18 identified this area as part of an ironworker's workshop. Furthermore, the high concentration of ostrich eggshell products indicated that there was a bead production nearby. The buried tusk may belong to the early occupation horizon of the site, and it attested that the residents of Vungu-Vungu were involved in the ivory trade, because the glass bead assemblage provided proof of the early trade relationships of the Kavango peoples with the Angolan coast.
The function of this area changed at an unknown moment in time, and it was then used as dumping area for domestic garbage. The pottery finds belong to this phase of usage. They have been examined in detail in Kose (2004) and Kose (2009b). In combination with complementary data from Beatrice Sandelowsky (1979) the decorated shards provided the basis for the definition of typical Vungu-Vungu-style pottery, which serves as 'index fossils' for the LIG occupation sites (Chapter 3).

The lithics from the sampled and excavated areas strongly suggested that stone artifacts were commonly used during the LIG period for various purposes, and glass fragments provided a most welcome extension of the range of raw materials used. The assemblage, however, largely lacks standardized tools comparable to the microlithic range of tools found on sites of the Early Ironworking Groups or the classical Later Stone Age.

2.12.14. Areas N98/32-Surf. 7, N98/30, and N98/34

(Figure 104)

Site appearance: This area described a loose artifact scatter of about 25 x 20 m in extension, west of excavation site N98/32-1 and -2. The finds eroded out along the bank of the river. The area is inundated during the rainy season.

Finds: Only selected finds were sampled (Table 8, Appendix 3), among them 16 pieces of pottery (Table 29, Appendix 3), decorated with typical Vungu-Vungu-style motifs, and one clay pipe fragment. The area produced also one informal stone tool and five flakes (Table 30, Appendix 3). Nine slag samples were gathered and two tuyere fragments (Figure 116), which bore evidence of bloom refining activities (Table 33, Appendix 3) in this area as will be described in detail below (section 2.12.18).

Interpretation: The area was part of the metallurgical zone N98/32-2 and N98/32-Suf. 4. Unlike the latter, it was not so much used as garbage dump.

2.12.15. Area N98/32-Surf. 3

(Figure 104)

Site appearance: This was a loose artifact scatter north of several fireplaces with modern cattle bones. The fireplaces were embedded in the upper soil stratum. The temporal coherence between artifacts and fireplaces was not clear.

Finds: Only selected artifacts were collected (Tables 8 and 29, Appendix 3). The pottery was of typical Vungu-Vungu style. The faunal material is not yet fully analyzed, but it contained some buffalo, hippopotamus and cattle remains, together with fish bones (Joris Peter personal communication in 2006).

Interpretation: This area was part of the site-complex SC 12 of Vungu-Vungu. It was probably the periphery of a homestead where some garbage was dumped. The modern activities disturbed the area.

2.12.16. Area N98/32-Surf. 1 and N98/32-Surf. 2

(Figure 104)

Site appearance: Loose artifact scatter of 12 x 15 m in extension about 85 m east of excavation site N98/32-1 and -2, 25 m south of the riverbank. Finds have eroded out along small drainage gullies leading to the eastern drainage slope of the site. In places, the site is vegetated with a thin grass cover.

Finds: Only selected finds were collected (Tables 8, Appendix 3), among them some decorated and undecorated potsherds of Vungu-Vungu style (n = 11 pcs) (Table 29, Appendix 3), two clay pipe fragments, an unspecific chalcedony core and a quartzite denticulate (Table 30, Appendix 3), an ostrich eggshell bead and eight glass beads.

Interpretation: This area was part of the site-complex SC 12 of Vungu-Vungu. The lack of slag finds attested that it was outside of the ironworking zone.

2.12.17. Area N96/04

(Figure 104)

Site appearance: This site was located 1.04 km east of the Vungu-Vungu main site, 380 m north of Local Road D3402 and about 35 m away from the cut bank of the river. It was an artifact scatter of about 30 x 30 m in extension on an eroding bank of the river. The finds originated from a dark humous and sandy layer overlying a light sandy deposit.

Finds: Only five pieces of pottery were collected (Tables 8 and 29, Appendix 3). Stylistically, these pieces comprised Gove- and Vungu-Vungu-style ware.

Interpretation: This was a settlement site of the Late Ironworking Groups. The pottery style identified this area to be an early settlement zone within the LIG horizon.

2.12.18. Finds from ironworking activities at the site-complex SC 12 Vungu-Vungu

Four-hundred and thirty pieces of slag, 30 tuyere fragments, 14 copper and 11 iron artifacts provided the basis for this analysis (Table 33, Appendix 3). Of the slag specimens, 289 pieces originate from excavated units (N98/32-2, N96/03-3, N69/01-1 and -2), and 142 fragments from surface collections. Like most slag material collected from the Kavango region during several surveys, the samples at hand are not representative of the range of slag categories present at the site because small pieces were preferentially gathered. The assemblage therefore shows a bias towards processing slags, even though enough smelting remnants could be found at the site. Seventeen of the 431 slags were tested in the laboratory (Tables 42 and 48) and the remaining 414 specimens were examined and classified visually according to the slag characteristics described in the sections 1.6.2.1 to 1.6.2.3.

From the total slag assemblage examined, 44.31% (n = 191 pcs) fell into the range of bloom refining slags (PSL/PS), followed by smelting slag with 9.51% (n = 41 pcs) (Figure 117). Twelve gromps or bloom fragments (GR) were recovered from the site, accounting for 2.8% of the total slag assemblage. The site produced also 17 (3.94%) small pieces of ore (OR). Twenty slag specimens (4.65%) were assignable to processing slag from secondary smithing (PSL/SS). A large portion of the slags however escaped classification (USL) (34.57%, n = 149 pcs). Figure 118 illustrates the slag categories according to their percentage by weight (total n = 5912.8 g). Comparing both diagrams, it can be seen that according to weight proportion smelting slag constituted the main slag category of the assemblage with 38.33wt% (n = 2266.9 g) owing to the heavier weight of the individual pieces. Processing slag from primary smithing accounted for 36.29wt% (n = 2146.3 g). Specimens classified as secondary smithing slags were present with 6.06wt% (n = 358.2 g) and did not differ much in weight proportion from the total slag assemblage in number. Non-diagnostic slag amounted only to 17.35wt% of the total assemblage, while it was 34.57% of the assemblage in number, because unspecific slag remains were comparably small on average and consequently light in weight.

When assessing the metallurgical activities of archaeological sites, both approaches are necessary. The statistical distribution of slag categories in number allows us an enhanced access to those activities producing rather small pieces of slag, while the distribution of categories in weight reflects the metallurgical activities according to the slag masses associated with these working processes.

2.12.18. Finds from ironworking activities at the site-complex SC 12 Vungu-Vungu

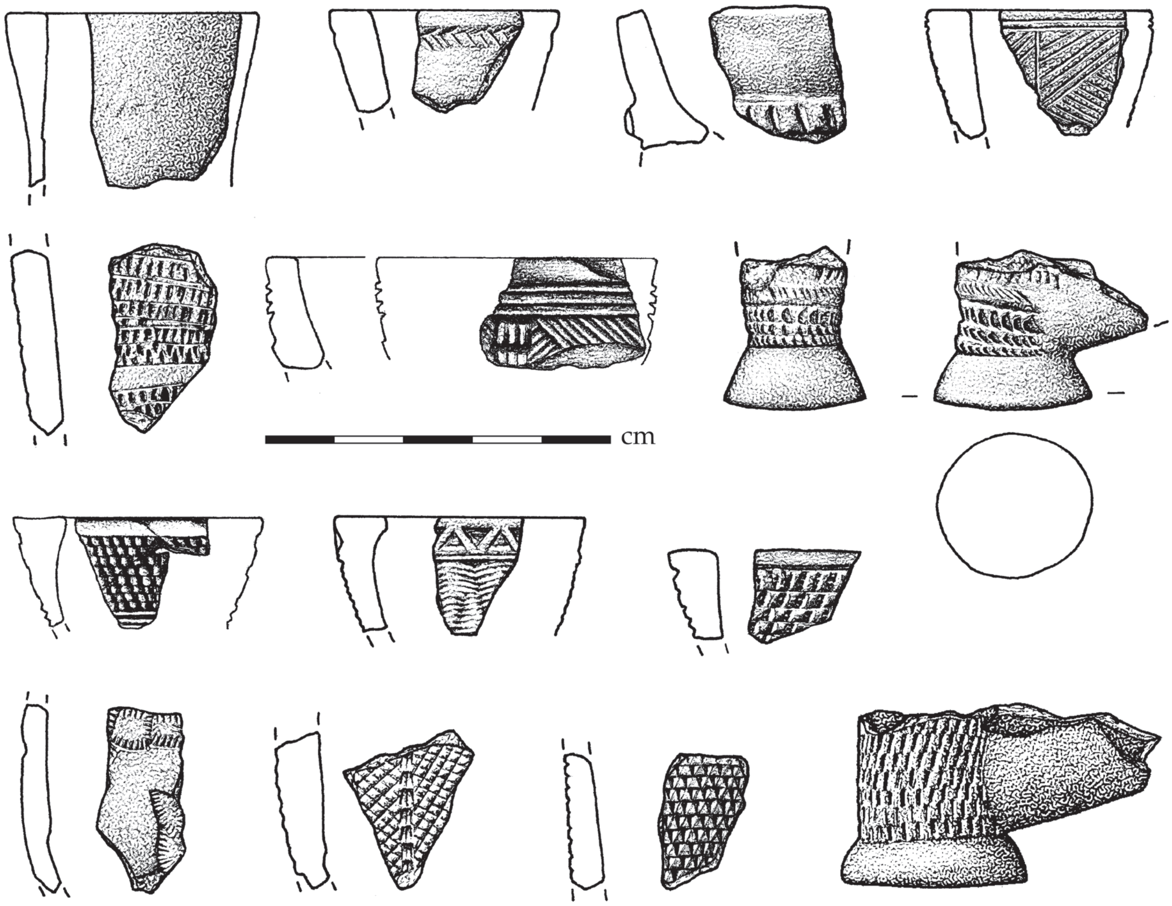


Figure 115: SC 12 Vungu-Vungu, clay pipes from Vungu-Vungu (drawings: Anja Rüschmann).

Ironworking activities started with the first occupation of the site in the fifteenth century (Figure 162). They ended in the twentieth century AD.[91] Even though the metallurgical history of Vungu-Vungu has a time depth of approximately 500 years, the difficult stratigraphy of the annually inundated area, and the low resolution in calendar years of the calibrated radiocarbon dates mean that it is almost impossible to separate early or late ironworking activities. Owing to this, the technological processes reconstructed from the slag assemblage of Vungu-Vungu represent the Late Ironworking Groups' technological traditions as a whole until better stratified archaeological material is available.

The smelting site of Vungu-Vungu was located west of the large erosion gully that runs across the shattered cistern (Figures 104 and 106). This was indicated by large chunks of smelting slag at the surface and charcoal concentration in the sandy soil. Moreover, it was confirmed by the narrations of Nangudi Mungomba (personal communication on 7 July 2006), a local elder from Vungu-Vungu, from H. P. H. Kaputungu (Appendix 2.3), an ironworker of the Vakwandjadi clan, and from P. K. Kampanzela (Appendix 2.1), who is one of the late ironworkers of Vungu-Vungu. The latter recollected the smelting area extending even farther south than indicated by slag scatter at the surface.[92]

All the slag and tuyere finds were concentrated in an area of more or less 100 m in width along the riverbank (Figure 124). Possibly, the finds clustered in this area owing to erosion. Yet it may also be that the workshops of the ironworkers were situated in this area. West of the smelting zone, the finds from N98/32-Surf-6 and N98/37, provided evidence of a refining furnace and a forge, because two smithing hearth bottoms (one of them is sample 4434/06) and a tuyere fragment were found. The latter had cooled down in a sandy pit, indicating that forges were shallow depressions in the ground. One fragment of a copper bangle might have been stored in the workshop for recycling, which was also suggested by the comparably high copper readings of sample 4434/06 (Table 45, Appendix 3).

[91] Interview with Petrus Kudumo Kampanzela, Appendix 2.1.

[92] Petrus Kudumo Kampanzela also stated that the Hompa's palace was situated south of the Vungu-Vungu tree.

Test trench N69/01-1, which must have been close to the smelting zone, provided evidence of bloom refining processes and a chunk of smelting slag (4415/06). The latter has been dated to the fifteenth to seventeenth centuries AD (Poz-20702, Table 2, Appendix 3 Figure 162). Microscopic analyses revealed that the sample was a piece of smelting slag that cooled down in a slag pit. This example indicated that the smelters of Vungu-Vungu used smelting furnaces with slag-tapping facilities.

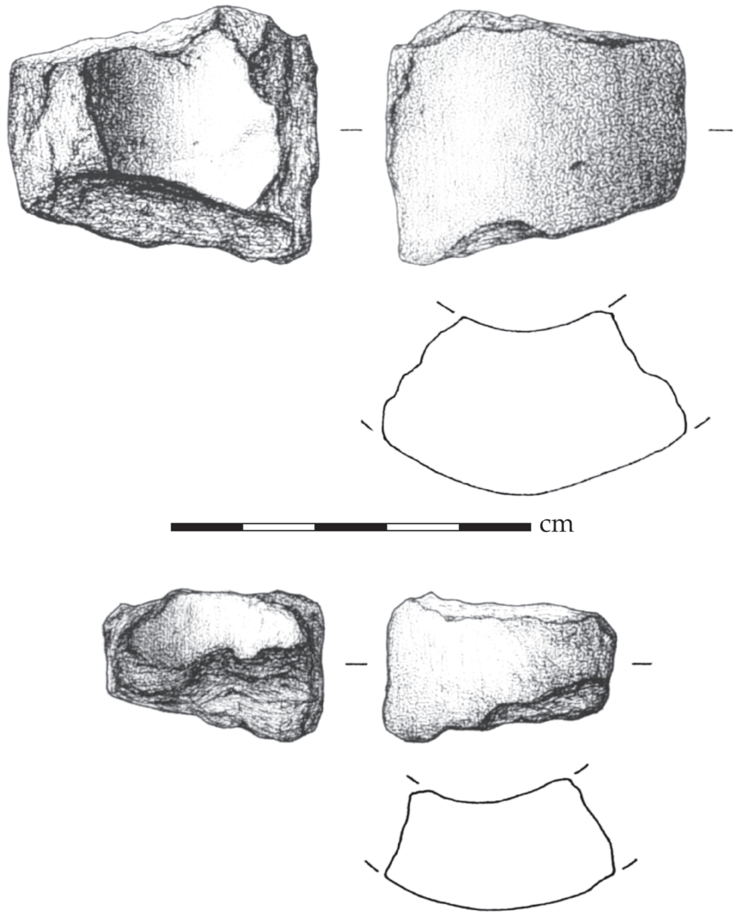


Figure 116: SC 12 Vungu-Vungu, tuyere fragments from Vungu-Vungu (drawings: Anja Rüschmann).

From test trench N69/01-2, 11 diagnostic samples were available for interpretation (Table 33, Appendix 3). The range of slag comprised smelting and bloom refining slag, and five small lumps of a sandy iron-rich material. Such ore lumps in association with refining activities could be seen as unreacted remnants of the smelt. They might have been discarded during initial refining processes, when the metallic iron was separated from impurities such as slag, charcoal and unreacted ore. They may as well be some lost ore material from before the smelt, which was possibly stored near the smelting furnace. One smithing hearth bottom was found, which derived from repeated cycles of heating and cooling in a forge during fine smithing (sample 4416/07). The sample also disclosed that the ironworkers used quartz as a welding flux. It is likely that the shallow pit described earlierwith concentrated charcoal in it was a forge, but unfortunately forge indicators such as fine hammerscale flakes were not reported (compare section 1.6.2.3). As mentioned, a charcoal sample recovered from the fill of this depression and the organic temper from a potsherd found in this test trench dated the area to the mid-fifteenth to the mid-seventeenth centuries AD (Pta-236, Poz-20671, Table 2; Appendix 3). Besides the slag and ore finds, the test trench revealed nine copper beads, eight of them concentrating in and around unit 4. The three iron artifacts were an open ring (sample 4483a/06, Figure 211:11), an iron point (sample 4484b/06, Figure 211:8), and an iron rod with a loop-like end (sample 4483b/06, Figure 211:5). The metallographic examination of the three iron utilities provided insight into the technological skills of the blacksmiths. The iron ring (4483a/06) consisted of high carbon steel, which contained many blocky inclusions (Figures 123 and 213). It was made from freshly produced rather than repeatedly recycled iron. To produce the ring, the iron was hot-worked and normalized at the end. The iron rod 4483b/06 was also made from high carbon steel, but compared to 4483a/06 it was extensively hot-worked and to some extent decarburized (Figures 123 and 213). Like 4483a/06, it was normalized as final step of processing. The iron point (4484b/06) was made from recycled pieces of different quality, ranging from soft wrought iron to high carbon steel. The material showed signs of repeated hot working, and the welds were not always well performed. The point was heated to the austenite field and cooled down quickly. It was subsequently cold-worked and processed at subcritical temperatures, which softened the material to some extent (warm working). The three samples demonstrated that new iron and multiply recycled material circulated at the same time. Together with the copper

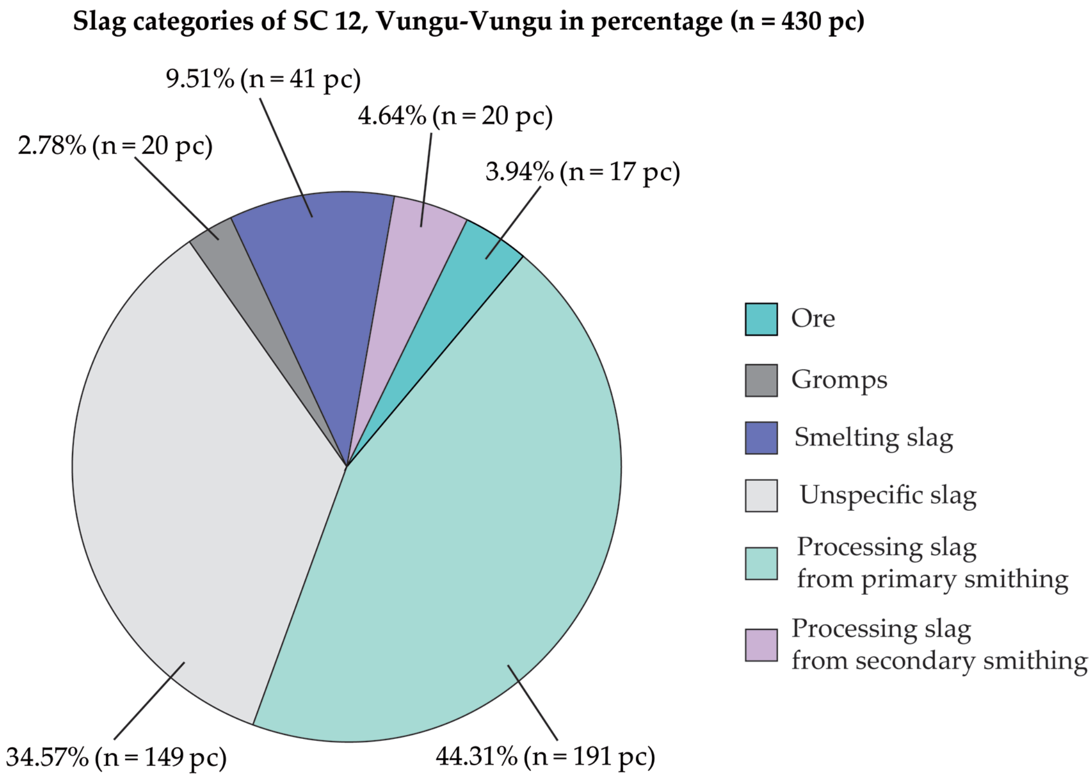


Figure 117: SC 12 Vungu-Vungu, pie chart of the distribution of slag categories from the site-complex in number.

beads (Figure 211), the iron artifacts were probably items that were collected in a blacksmith's atelier for further recycling.

About 80 m east of the smelting zone N06/06-2, the slag finds from N96/03-3 indicated the next refining site (Figures 104, 119, and 124). The slag finds collected from the surface, and recovered from the small test units add up to 257 pieces. Most of them were processing slags from bloom refining processes (n = 59 pcs) and amorphous, thick flaky and spherical hammerscale from the same activity (n = 62 pcs). Among them, 30 fragments of shattered smelting slags were found. Sample 4417/06, one of the smelting slag remains, attested that slag was tapped from the furnace into a slag pit, similar to sample 4415/06 in area N69/01-1 (Figure 122). Such pieces are unusual at refining sites because they are not part of the bloom and of no value. Therefore, there is a possibility that the smelting zone extended farther east to an area that is nowadays disturbed by the broad erosion gully seen in Figure 124. Apart from 4417/06, the other pieces of smelting residues were rather small fragments of slag, typical for working zones where blooms were shattered and sorted during initial refining processes (see section 1.6.2.2). Nine pieces of crown material completed this picture. In the samples 4417/06 and 4426/06, inclusions of metallic iron provided insight into the raw material produced. While 4417/06 contained metallic iron ranging from soft pure iron fragments with less than 0.02% of C to high carbon steel with approximately 0.6% of C detected in several prills, the bloom inclusion found in sample 4426/06 was strongly over-carburized and contained more than 2% of carbon (Figure 123). The latter was not usable without decarburization and probably discarded for this reason. Both samples testified the heterogeneity of the iron and steel produced in bloomery smelters, and the unpredictability of the smelt.
Five refining slag samples were examined by thin section and/or bulk chemistry (4418/06, 4420/06, 4422/06, 4423/06, and 4427/06). The results revealed that the refining furnaces operated under high temperatures and reducing conditions comparable to smelting processes. Sample 4418/06 showed at the bottom side a rim of strongly slagged sand grains demonstrating that the refining furnaces were pits in the sandy ground. Historical bloom consolidation was a process of repeated heating and hammering which could be seen in the layered nature of the analyzed slag. The specimens also contained crown material that went lost in the slag bath during bloom consolidation. Several metal inclusions showed deformations of the ferrite grains caused by the hammering of the bloom at low temperatures. The metal ranged from low to high carbon steel and illustrated again the heterogeneity of the original raw metal

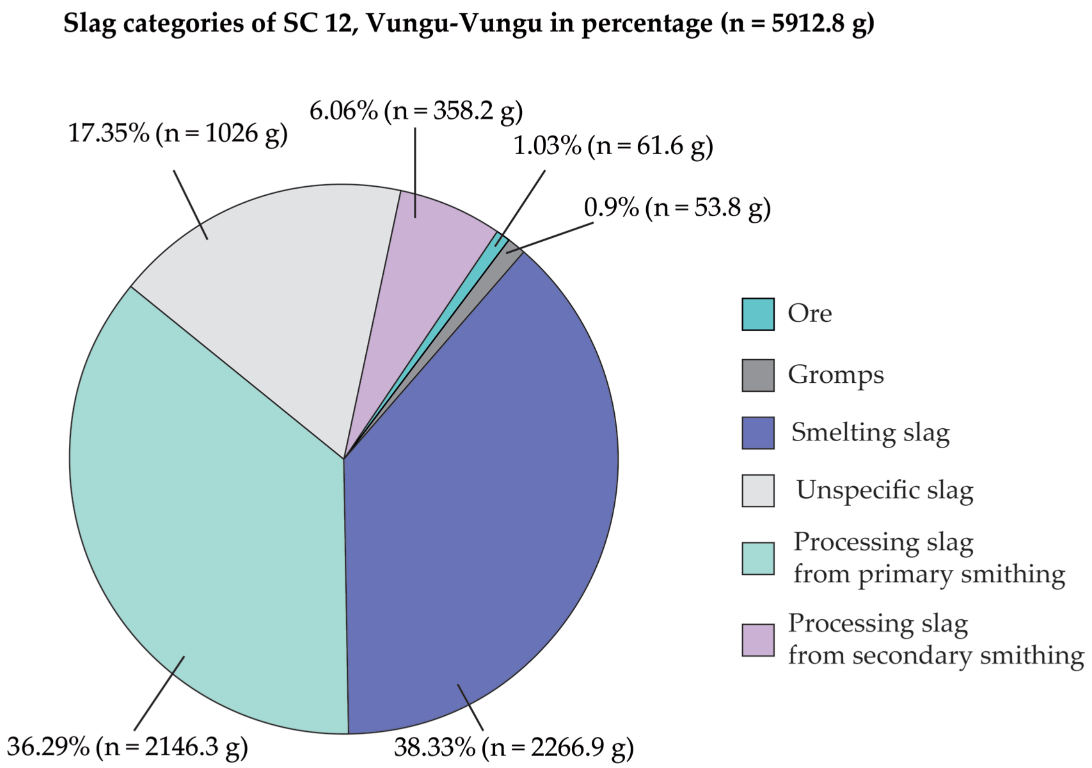


Figure 118: SC 12 Vungu-Vungu, pie chart of the distribution of slag categories from the site-complex in weight.

obtained in bloomery smelters (sections 1.4.9 and 4.3.1). In sample 4420/06, the crown material was associated with powdery charcoal. The carbon content of the metal graded from around 0.1% to 0.8% and it could be that these remnants testified some intentional carburization of the raw material. However, more evidence is needed such as repeated finds of similar appearance to postulate that the ironworkers of Vungu-Vungu carburized iron.

The entire area N96/03-3 was exceptional in that a high amount of hammerscale remained in the ground (Figure 119), suggesting the proximity of an anvil where the bloom became consolidated. Moreover, the three smithing hearth bottoms from the units 88/28d and 88/26d provided evidence of a refining furnace nearby (Figure 119). In addition, four smithing hearth bottoms from fine smithing were found in test unit 88/26b and d, together with several amorphous slag lumps from the same step of manufacturing. Sample 4424/06 disclosed the repeated cycles of heating and cooling under which these smithing hearth bottoms formed. The deeper layers of the sample attested that the bottom of this forge was a strongly reducing environment, while the upper parts were exposed to oxygen. From there one may deduce that the forge was not as closed as the refining furnaces. Altogether, the finds from this test trench indicated the processing of a raw bloom into iron implements, and represented, in my opinion, one processing event. It is tempting to see the pit into which the material was discarded as an abandoned smelting or refining furnace, yet, as long as there is basic information missing concerning the state of the pit's walls (i.e. influence of heat), one must be careful with such an interpretation. Moreover, the fact that the material was backfilled into the pit did not allow me to consider the examined test area as a zone around an anvil or a zone near the refining furnace. Rather, the association of finds and features suggested that a refining zone or an ironworker's workshop nearby was cleared out after a bloom had been processed into new tools.

Some 70 m east of N96/03-3, a large area comprising N98/32-2, N98/32-Surf. 4, N98/30, N98/34 and N98/32-Surf. 7 pointed to another center of iron processing activities (Figure 124). One hundred and fourteen slag and ore fragments were collected, amounting to 922.4 g of metallurgical remains. This was less slag than found in N96/03-3, but 18 tuyere fragments attested a repeated use of this area for metallurgical activities. Only five specimens of smelting slag were found. The largest slag proportion in number (n = 54 pcs) and weight (n = 378.7 g) were non-diagnostic slag pieces, adding up to 41wt% of the total slag assemblage. Processing slag from bloom refining were present with 40.8wt% (n = 377 g),

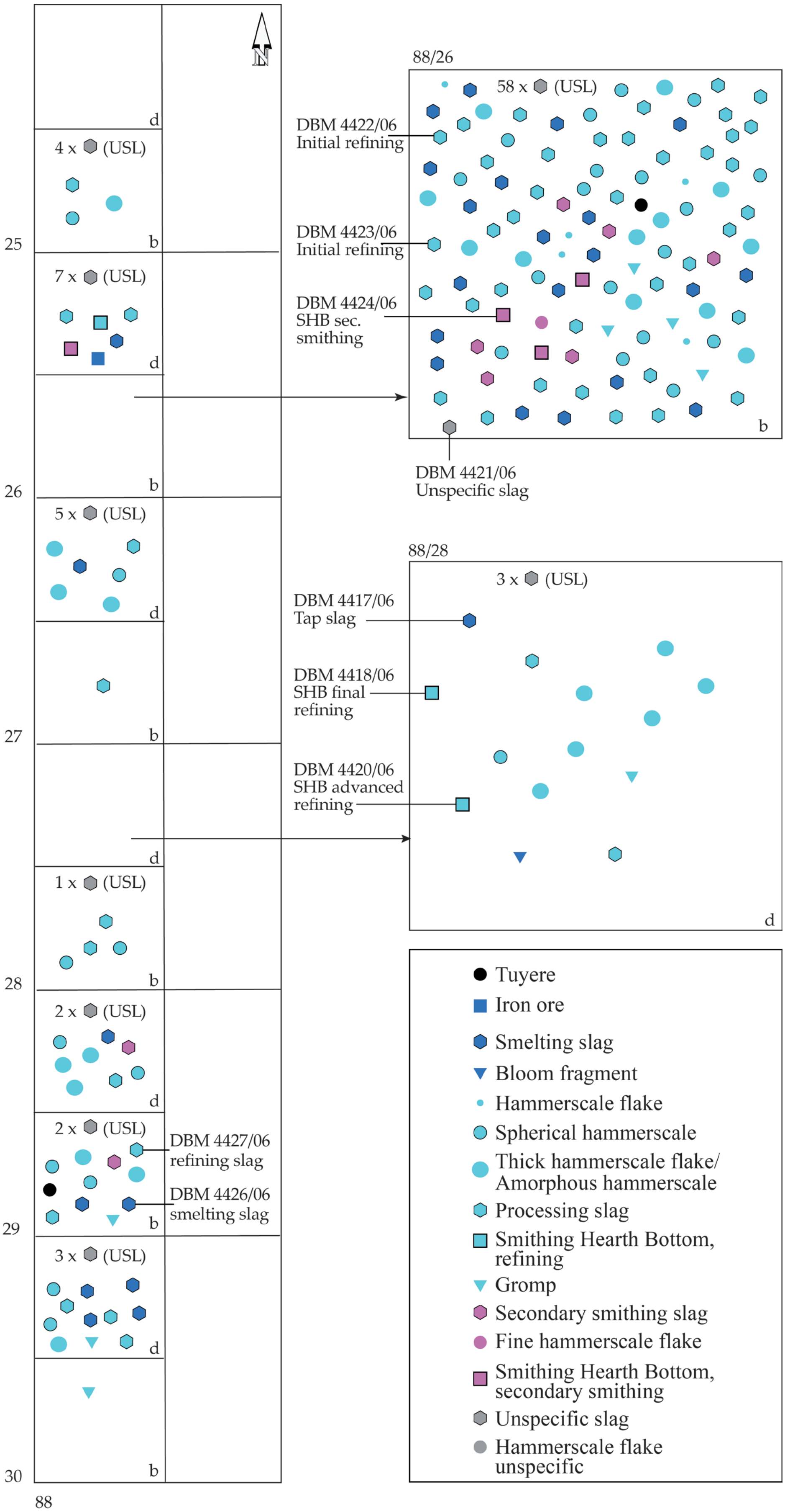


Figure 119: SC 12 Vungu-Vungu, area N96/3-3, horizontal distribution of diagnostic slag, ore, and tuyere fragments.

Figure 120: SC 12 Vungu-Vungu, area N96/3-3, eroding slag and charcoal concentrations before the excavation (image: Martin Albrecht).

accounting for 31 specimens. Only four processing slags from secondary smithing had been identified.

Three smithing hearth bottoms were collected from N98/32-Surf. 4, and, as mentioned, one of them was still in situ in an eroded refining furnace, which marked the center of this ironworking zone. The ongoing bank erosion, however, suggests that parts of the site have already been lost to the river.

Four slag samples were analyzed by thin sections (4428/06, 4429/06, 4430/06, and 4433/06), three of them were bloom refining slags and one a smelting residue. Even though the number was small, they provided valuable insights into the smelting procedure. Sample 4428/06 was a smelting slag with bloom inclusions and partially reduced iron ore (Figure 173). The ore chunks occurred in a fully developed slag bath suggesting that the smelters poured ore into the running furnace in order to increase the yield of iron (section 4.1.7). The angular shape of the ore pieces indicated that the material was crushed in order to increase its reducibility before it entered the furnace (section 1.4.1). However, in this case the furnace was stopped before the batch was fully reduced. More evidence from this unfinished batch was disclosed in the samples 4429/06 and 4433/06 (Figure 175), both initial refining slags. The latter was the in situ smithing hearth bottom from N98/32-Surf. 4c. Both samples contained several inclusions of semi-reacted ore attesting that the bloom was cleaned from unwanted impurities such as slag, charcoal and semi-reacted ore during consolidation. The samples also demonstrated that the ores used by the smelters were fine grained aggregates similar to what was detected in ore sample 4712/06 from Kapongo (SC 29) (section 4.1.7) (Figure 173). Furthermore, small chunks of ore were collected from the excavated units 50/51 and 51/51, which might have belonged to the same batch. However, as discussed in section 4.2.13, the source of ore that the Vungu-Vungu smelters used has not yet been identified. None of the smelters from the other examined sites (e.g. Kapako, SC 4) or Gove-Mbambangandu, (SC 17) used this specific mining area.

Comparing the slag assemblage from N98/32-2 with the one recorded from N96/03-3, the first produced significantly less hammerscale (Figure 121, Table 33, Appendix 3), which is, however, an integral part of bloom refining processes (sections 1.6.2.2 and 1.6.2.3). It is therefore most likely that the anvil was not located in the sampled and excavated area of N98/32-2, even though a refining furnace had been identified. What is more, and again compared to N96/03-3, the amount of slag was

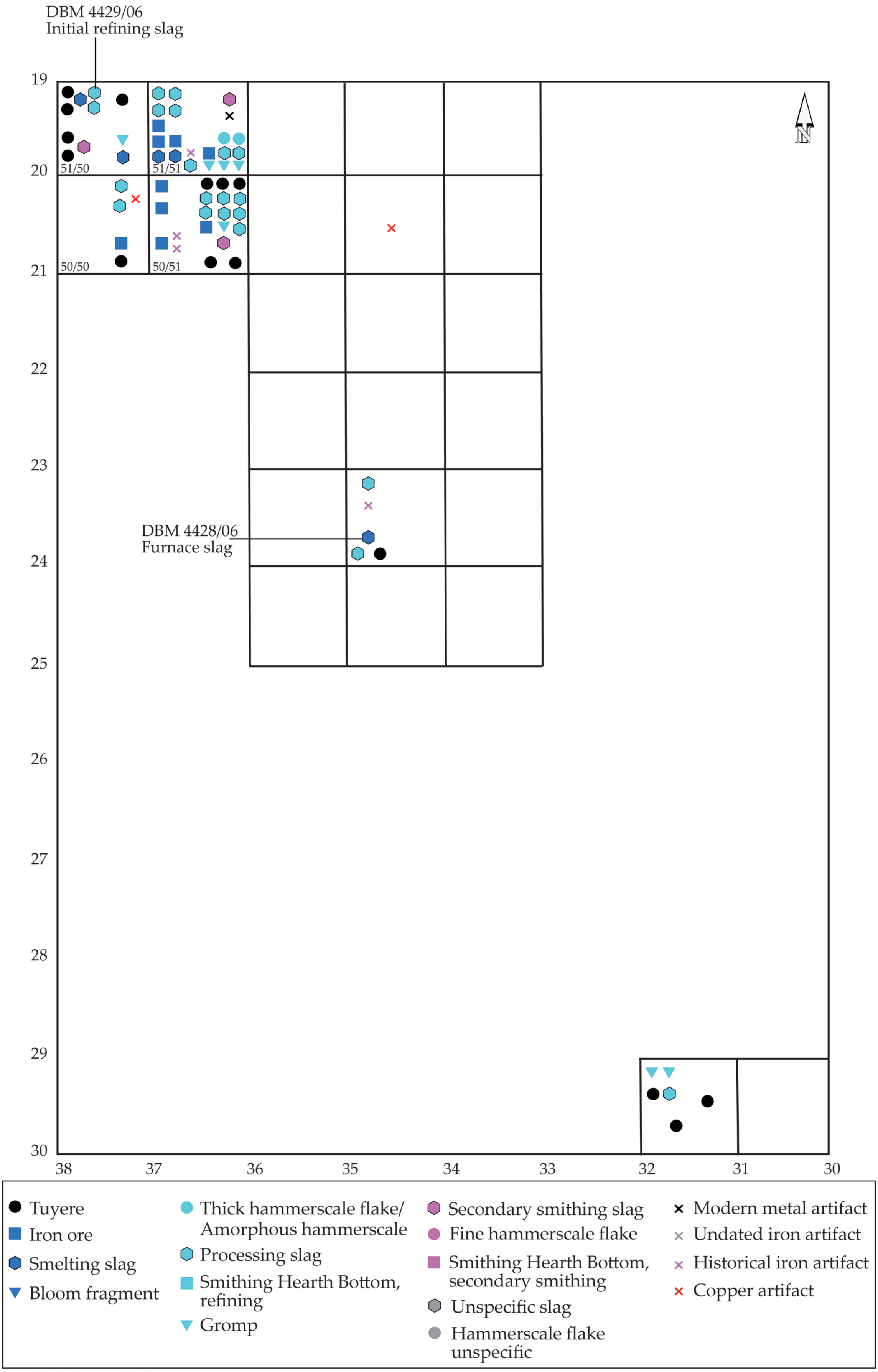


Figure 121: SC 12 Vungu-Vungu, area N98/3-2, horizontal distribution of diagnostic slag, ore, and tuyere fragments together with metal artifacts.

not representative of an area where blooms repeatedly became sorted and consolidated, as indicated by the numerous tuyere fragments. Complementary excavations need to be carried out in order to assess more of the site, and to obtain a better understanding of the layouts of the metallurgical zones at Vungu-Vungu.
From the same ironworking center, four slag specimens were secondary smithing residues, and one tip of a tuyere showed adhering small microspheres typically produced in fine smithing (Figures 121 and 124, Table 33, Appendix 3). One of these slags was a smithing hearth bottom derived from fine smithing. It was unearthed together with the other SHBs from the bloom refining zone N98/32-Surf. 4. This confirmed that in the same area where blooms became consolidated, the metal was processed into tools. Area N98/32-2 and N98/32-Surf. 4 also revealed three copper beads and four historical iron artifacts, a double hook, an unspecific piece of worked iron, an iron ring and a fragment of an iron sheet metal. Additionally, a piece of drawn industrial wire was found which was reshaped into a tweezers-like tool (Tables 52 and 53, Appendix 3). As discussed in section 4.3.3, iron was valuable and subject to a high rate of recycling. Therefore, a raised frequency of metal finds in association with slag, in particular with smithing hearth bottoms, indicated the sphere of a blacksmith's workshop, where implements became repaired and recycled.

The study of the metallurgical remains from Vungu-Vungu has identified six zones of ironworking activities (Figure 125). All of them were situated in the northern part of the former settlement. Zone 2 was the smelting site of Vungu-Vungu, identified by surface slag scatters and oral history. West and east of the smelting zone, concentrations of processing slags indicated bloom refining zones and blacksmiths' ateliers. While the finds of Zone 1 and 3 allowed no more than interpreting these areas as locations where some refining and fine smithing took place, Zone 4 allowed for the interpretation of the area as a blacksmith's workshop. Here, blooms were refined and transformed into tools, and iron and copper items became recycled. More important than Zone 4 must have been Zone 6. The high frequency of tuyere fragments strongly suggested a high intensity of metalworking in this zone, perhaps over several generations. Zone 6 provided the only evidence of a refining furnace in the eroded bank of the river, which was a pit in the sandy ground. Like Zone 4, Zone 6 included a blacksmith's workshop where blooms were not only compacted and processed into tools, but where skilled ironworkers most probably stored metal items for recycling purposes. Zone 5 revealed a most interesting assemblage comprising the complete range of slag materials that accumulate during bloom refinement processes and when raw metal is worked into tools. It is highly likely that the slag residues represented only one refining event. All the slag was discarded into one pit, which might have been a smelting or refining furnace.
The slag study has also shown that people smelted in furnaces where slag tapping facilities drained away the molten mass into external pits (e.g. Figure 207). The appearance of these furnaces cannot be reconstructed either from the slag assemblage or from the archaeological features found. However, the overall lack of shattered refractories (i.e. clay fragments exposed to high temperatures) indicated that these smelting facilities were pits in the sandy ground without superstructure. This assumption found also support in the slag chemistry discussed in section 4.2.1 (see also Table 44, Appendix 3), because the slag was poor in aluminum suggesting that clay refractories did not significantly contribute to the slag composition (section 1.4.6). The metal produced in these furnaces was a heterogeneous material, ranging from soft wrought iron to high carbon steel, and in certain cases over-carburized metal, which was no longer processable.
Refining was carried out in pit furnaces under hot and strongly reducing conditions, which were comparable to smelting operations. The shattered smelting slag uncovered in association with refining slags implied that blooms first became mechanically cleaned from redundant slag, and were subsequently re-heated in the hot refining furnace to expel disturbing slag inclusions. The layered nature of the refining slags demonstrated that bloom consolidation was a process of repeated heating and hammering until a solid piece of iron emerged. The new raw metal implements were shaped by hot and cold working. The blacksmiths also recycled even the smallest pieces of iron. The unwanted changes in the properties of the metal from cold working were obliterated by heating the implement above Ac_3 (Figure 17) and allowing the damaged crystal structure of the iron to be restored by slow cooling. There was some evidence of warm working in the examined metal samples, yet it cannot be said for certain whether the changes in the properties of the material that occurred by hammering the

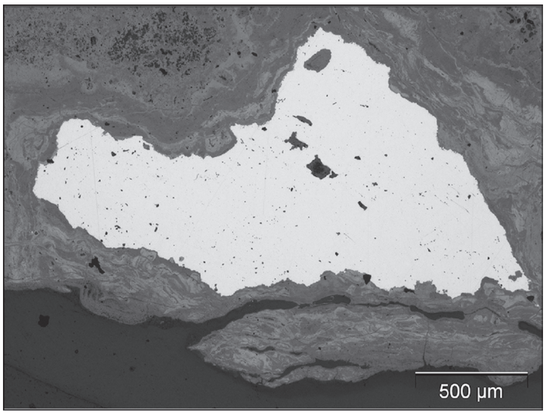
Figure 122: SC 12 Vungu-Vungu, bottoms of the smelting slag samples 4415/06 and 4417/06 with adhering sediment evidencing that the slag was drained from the furnace into a pit in the ground.

metal at sub-critical temperatures were wanted (section 1.5.2). Most probably, the metalworkers also recycled copper items, which were traded to this area from neighboring peoples.

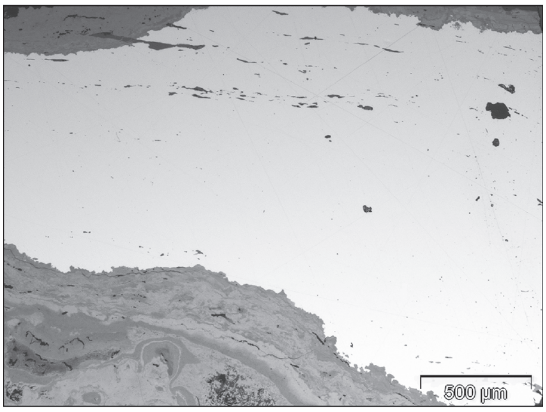
2.12.19. Ironworking at Vungu-Vungu in the oral history record

As mentioned, Vungu-Vungu was a smelting site since the earliest reoccupation of the middle Kavango region by the Late Ironworking Groups. The early Tjaube people lived off hunting and fishing and were involved in ivory trade. At Utu (Vungu-Vungu), they produced iron and manufactured hunting weapons. According to the chronicle, people used ores from Fumbe and Taratara (Fleisch & Möhlig, 2002, pp. 41-42). The first mining area is roughly 30 km southeast of Vungu-Vungu, the second more or less 60 km away from it. The Tjaube chronicle however does not answer the question why people bothered to carry the heavy ore to the river instead of smelting at the mining sites (see also Gove, SC 17). The Shambyu immigrants were also involved in iron production, yet no sites are listed in their oral chronicles (version published by Fleisch & Möhlig, 2002). Fortunately, the interview with Petrus Kudumo Kampanzela (Appendix 2.1) revealed many details with respect to the smelting practice of Vungu-Vungu. According to him, iron production was of high status and performed at Vungu-Vungu to honor the early Shambyu sovereigns. After the rulers had left the location under Queen Mushinga, iron smelting was still practiced at Vungu-Vungu until the reign of Hompa Mbambangandu II ended in 1948. The settlement was abandoned when the Vungu-Vungu dairy farm was installed. At that time, it comprised ten homesteads.

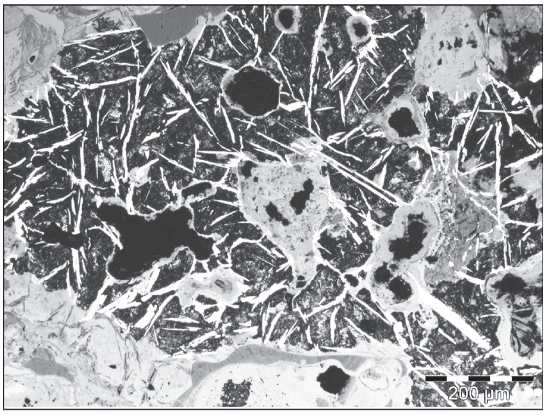
The smelting site was a fenced-in area of roughly 20 m² and it was laid out between the individual homesteads around a big tree. The group of smelters could determine a new area to be a smelting site. People smelted in circular pits in the sandy ground. These furnaces were approximately 1 m in diameter and knee deep. Some were provided with a clay lining at the bottom. The furnaces were filled with charcoal and ore in alternating layers, and were operated with four bellows. The smelt took approximately 12 hours. A successful smelt resulted in the slag being separated from the iron and collected at the bottom of the furnace. Following P. K. Kampanzela, the new iron consisted of numerous individual pieces recovered from the furnace. The waste of a smelt was slag and ashes, which were



4483/06a



4483/06b



4426/06

Figure 123: SC 12 Vungu-Vungu, iron artifacts. Sample 4483a/06: cross section of an iron ring with angular slag inclusions. Sample 4483b/06: cross section of small iron rod showing flattened inclusions and inclusion banding. Sample 4426/06: bloom fragment in smelting slag with over-carburized hypereutectoid steel.

discarded around the furnace. People used the smelting facilities for one season, which means one to three smelts, and sometimes longer. They only changed the smelting location when the area became too polluted. The pieces of iron were consolidated in a forge (i.e. refining furnace), no more than 5 to 10 m away from the smelting site.

Contrary to Tjaube chronicle, P. K. Kampanzela stated that the late smelters from Vungu-Vungu collected ore at M'pupo in contemporary Angola, roughly 40 km away from Vungu-Vungu (Figure 217). M'pupo was a smelting site of the Nyemba people, who recommended this raw material to the ironworkers from Vungu-Vungu. The ores were hard concretions that people collected in a dry riverbed. For one smelt, they needed 4 to 10 bags of raw material. Whenever they needed more iron, the smelters visited M'pupo for a second time in order to collect more. The whole iron manufacturing process took two weeks starting from collecting the ore until the metal was melted.

As described in the sections 5.3.6 and 5.4, iron production was subject to many taboos, and particularly women of fertile age were considered a danger to the smelting process. Therefore, the smelting zone was a secluded area, even though it was laid out inside a settlement. During the time of the smelt, the ironworkers were supposed to stay at the smelting site in order to avoid sexual contact with women. For this reason, they built traditional houses at the furnace site for sleeping. Every blacksmith of Vungu-Vungu had its own working area, which they repeatedly used. These ateliers were near their homesteads, but always outside of the outer fence in order to protect women from being ritually harmed (section 5.3.6). It was important to always leave the forge at the same place so that the women living in the settlement could avoid them.

2.12.20. Archaeological record and oral history – is there a correlation?

According to oral chronicles Vungu-Vungu was a settlement and smelting site of the first group of invaders in the modern era who practiced iron production, the Tjaube people (section 5.1) (Fleisch & Möhlig, 2002; Hartman, 1987). Although the chronicle recounts exactly the migration route of these people from the east, it has not been possible to date their migration by historical means. The oral chronicles of the Shambyu mentioned first Shambyu rulers occupying the site during the late eighteenth century (Fleisch & Möhlig, 2002). Both groups, the Tjaube and the Shambyu were involved in ivory trade and iron production at the site.
The radiocarbon dates obtained from Vungu-Vungu (Table 2, Figure 162) attested an early occupation horizon from the fifteenth to the late seventeenth centuries, and produced a series of

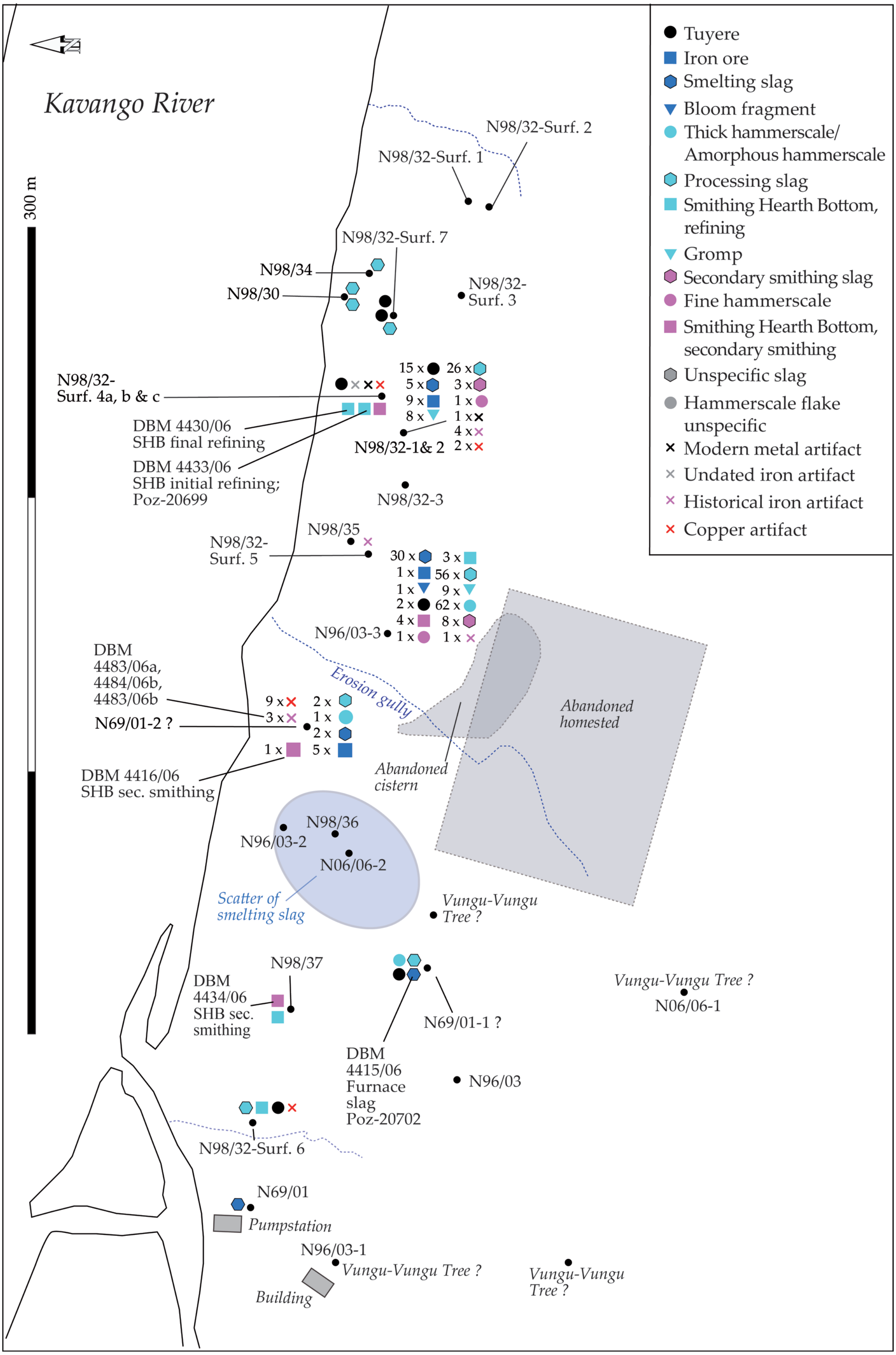


Figure 124: SC 12 Vungu-Vungu, horizontal distribution of diagnostic slag, ore, and tuyere fragments together with metal artifacts at the site complex.

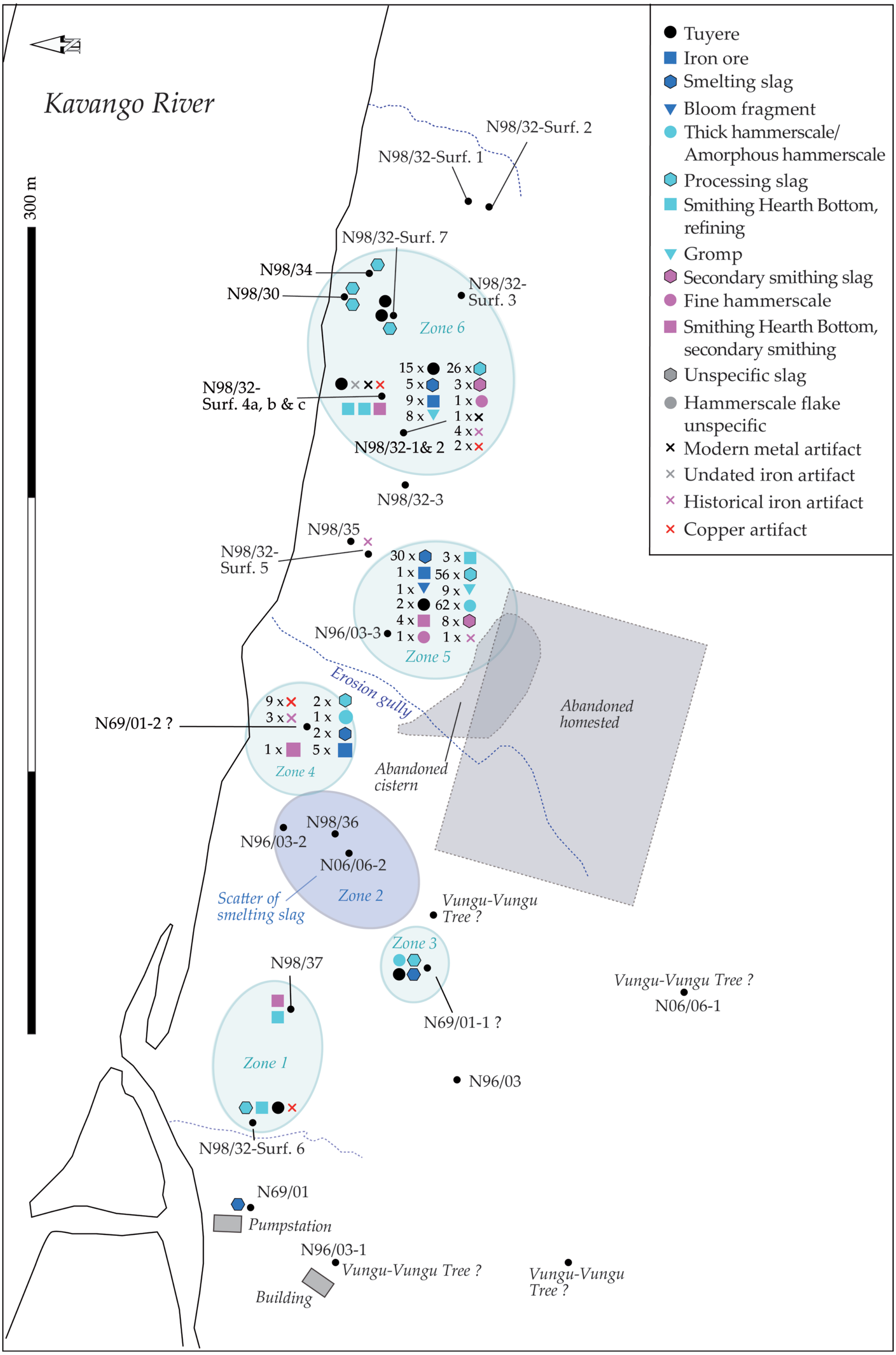


Figure 125: SC 12 Vungu-Vungu, reconstructed ironworking zones at the site complex.

later dates that were not very significant because they fell within the modern calibration plateau. Nevertheless, the ^{14}C-dates confirmed that the site was older than deduced from the Shambyu chronicle. The dates also suggested two main occupation horizons, but owing to the calibration problem no better resolution by means of radiocarbon dating was possible. However, the first occupants predated the Shambyu by some 200 years, and it is likely that these early dates reflected the occupation of the site by a group of Tjaube settlers.
Another indicator for early occupation of the site was the numerous finds of Gove-style ceramics. In conjunction with the spacial distribution of the radiocarbon dates, two areas could be defined within the site-complex to represent the early Tjaube settlement (Figure 162). One area stretched from the broad erosion gully (east of the smelting site) to the pump station (Figure 126), and the second could be identified in area N96/04, 1.04 km east of the main site.

Another historically interesting find category was the rich European trade bead assemblage from area N96/01-2 and N98/32-2. Most beads were types that were introduced into the African market between the fifteenth and the late eighteenth centuries (Kose, 2004, pp. 125-126; Kose & Richter, 2007, p. 122-123). Accordingly, they were traded in a period before the Shambyu arrived following the chronology established by Fleisch and Möhlig (2002, p. 175), or during the first generation of Shambyu rulers at Vungu-Vungu. The evidence from the glass beads attested that the early residents of Vungu-Vungu were part of supra-regional trade networks, which connected them to the Angolan coast even though it contrasts with the oral chronicles where no trade relationships are mentioned. However, the strong focus of both the Tjaube and the Shambyu chronicles on elephant hunting is indirect evidence of the Kavango peoples being involved in the international ivory trade that affected all Africa at that time (sections 5.3.5 and 5.4). The Tjaube chronicle tells that ivory from elephants and rhinos had to be delivered to the King Mankoto at Kauti who owned a legendary amount of tusks (see also SC 17, section 2.17.12). From there one may conclude that ivory was stored somewhere in the residence until it was sold to the ivory traders. It is not clear why the decayed tusk found in N98/32-2 was kept at the site and became forgotten. It did though provide good evidence that the residents from Vungu-Vungu participated in the ivory trade. More evidence for the supra-regional trade relationships was the cowry-shells found in N69/01-2.
Besides the glass beads and the tusk, the excavations at Vungu-Vungu provided an exceptionally high number of clay pipe fragments (Kose & Richter, 2007, pp. 120-121; Sandelowsky, 1979, pp. 59-60). With the trans-atlantic trade of the Portuguese, tobacco and tobacco pipes spread across Africa and found their way to the Kavango region. Smoking tobacco was a sign of wealth and prestige (Kose, 2004, pp. 103-104) and the clay pipe fragments (Figure 115) underline the importance of Vungu-Vungu in early times.
Besides its importance in the supra-regional trade, Vungu-Vungu must be one of the earliest smelting sites within the LIG settlement horizon according to the oral chronicles. Slag samples 4415/06 and 4433/06 produced 2-sigma calibrated dates between the mid-fifteenth and the mid-seventeenth centuries and represented these early smelting activities mentioned in the chronicles. From the narrative given by P. K. Kampanzela (Appendix 2.1), one can assume that there existed several smelting sites and only the youngest amongst them could be identified. It is likely that other sites were on the farm grounds in the present day and have not yet been located. People used the smelting sites until they became too polluted by slag and ashes. Instead of clearing the area, they moved the smelting zone to a different location. Over the years and over the centuries, this may have created a diffuse pattern of smelting slag scattering all across the settlement and mixing with the domestic remains. What is more, the refining zones, which were 5 to 10 m away from the smelting furnace, also shifted through the entire settlement area leaving behind the same diffuse slag scatter of bloom refining slags. Moreover, assuming that a smelting zone with its adjacent refining areas was used for 5 years, there is a possibility that the area became a dump for domestic waste such as bones and pottery once it was abandoned by the ironworkers. In such cases, archaeologists will hardly be able to separate both sequences of usage by the sole analysis of the distribution of finds. Rather the finds appear as a dumping horizon where slag became discarded together with domestic garbage. The sandy soil and recurrent flooding would do the rest. Moreover, homesteads were certainly abandoned or newly set up during the course of the centuries as well. Perhaps, new homesteads were built on old smelting sites, or smelting areas were laid out in abandoned homesteads. Without historical

records, archaeologists can easily misinterpret sites like Vungu-Vungu. They may postulate that people not only smelted inside a settlement, but also within their homestead compounds. In the end, the distribution of the finds from which archaeologists would draw their conclusions would obliterate any traces of rituals, taboos and the seclusive nature of the smelting zones.

Another interesting aspect to compare against each other was the smelting facility described by Petrus Kudumo Kampanzela and what has been reconstructed from the slag. According to P. K. Kampanzela people smelted in pit furnaces without slag tapping facilities. The slag finds however suggested that there existed another and probably older smelting solution at the same site, in which slag was tapped from the furnace into separate pits. A slag tapping smelting method has been described by Modestus Kashera Shimbiringua for Gove (Appendix 2.2), and there is a possibility that the smelters of the Tjaube tradition used this method also at Vungu-Vungu (section 5.3.1) (Figure 218). Therefore, the contradiction in the archaeological and historical records would simply refer to different occupation periods of the same location.

From an archaeological point of view, no smelting furnace has been identified so far and no slagged refractories have been found except from the tuyere fragments. This archaeological signature is not surprising when taking the evidence from oral history into account. What traces could a smelting pit leave in the sandy ground once abandoned and collapsed, and washed away by summertime strong rainfalls and flooding? There is better archaeological evidence of refining furnaces because several smithing hearth bottoms preserved a bottom of strongly slagged sand, and one of them was even found in a charcoal concentration surrounded by soil reddened from heat. However, I have no precise description of refining facilities from the oral history interviews. The slag assemblage from N96/03-3 gives the impression of being the remains of a single bloom-refining event, which survived erosion because it was discarded in a pit. The shifting smelting and refining zones described in the interview with P. K. Kampanzela confirm this interpretation.

Besides the smelting and refining zones, there existed working areas of the blacksmiths near their homesteads and owing to spiritual reasons, theses workplaces were not moved. Therefore, there must be markedly less zones with traces of fine smithing than of refining and smelting. Among the six ironworking zones shown in Figure 125, two ateliers of fine smiths have been recognized based on corresponding slag finds and concentrations of lost metal artifacts. However, all of them provided plenty of refining slag too, together with some smelting slag. This association of finds indicated that the blacksmiths' ateliers were also used for refining. This is not confirmed in P. K. Kampanzela's interview (Appendix 2.1), but it is backed up by the other interviews as summarized and discussed in section 5.3.3. However, taking the shifting zones of metallurgical activities into account it seems also likely that a permanent workplace of an ironworker was set up at a place that was used for smelting or primary smithing processes some decades earlier, or vice versa.

From the historical record, one can deduce that the slag formed from three different ore sources (Fumbe, Taratara and M'Pupo, Figure 217). This was not reflected in the slag chemistry discussed in section 4.2.11, because the selected samples were far from being representative of the site. Moreover, the link from Vungu-Vungu to its mining sites would only have been detected in a large-scale geological study of plinthic deposits in a radius of 40 km or more.

In summary, the archaeological study confirmed the occupation history of the site as described in the chronicles. The oral chronicles revealed a strong focus on elephant hunting of the early Kavango peoples. This indicated that the people were involved in the international ivory trade, which was not mentioned in the chronicles, but received support in the elephant tusk found at Vungu-Vungu. The archaeological assemblage gave clear evidence that the early residents of Vungu-Vungu were wealthy people and part of a supra-regional trade network which provided them with European goods.

This study also confirmed that archaeological and archaeometrical methods were suitable tools for reconstructing smelting traditions, and for identifying steps in the process of iron production and processing performed at a specific archaeological site. The same methods also allowed me to investigate technologies that went beyond the time frame of local memory. On the contrary, archaeology and archaeometry failed to decode the spiritual and ritual background of iron metallurgy at Vungu-Vungu. Moreover, without oral history accounts, no information would have been available as to the smelting furnaces, the raw materials, the range of tools produced, and the number of people involved in smelting.

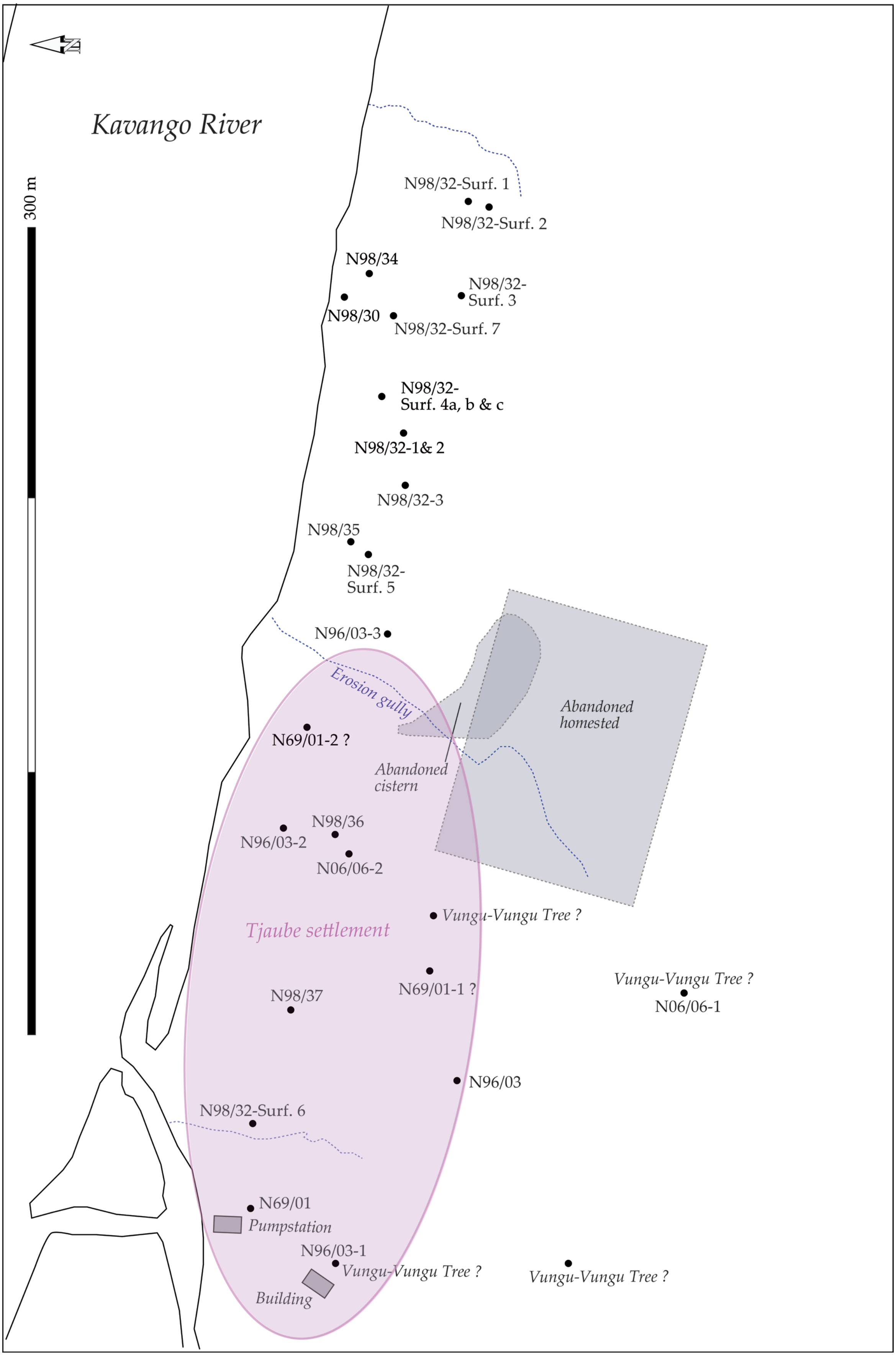


Figure 126: SC 12 Vungu-Vungu, reconstructed settlement area of the Tjaube people at the site complex.

2.12.21. Interpretation of site-complex SC 12 Vungu-Vungu

Vungu-Vungu is the largest site of the Late Ironworking Groups that has been examined so far. The settlement existed between the mid-fifteenth and the mid-twentieth centuries for more or less 500 years. Two different groups mentioned in the chronicles occupied the site: the Tjaube people and the Shambyu. Both groups could be identified by their pottery and based on this, in conjunction with the early radiocarbon dates, two areas have been identified to bear witness of the occupation period of the Tjaube people. Most probably at the end of the seventeenth century, the first Shambyu sovereigns settled at Vungu-Vungu.

The archaeological assemblage implied that Vungu-Vungu flourished in particular during what is known as the Early Contact Period from the late fifteenth to the late eighteenth centuries. The rich game resources of the Kavango River system provided the source of wealth of the Kavango peoples because Tjaube and Shambyu were involved in the international ivory trade. The tusk found at the site along with the rich glass bead assemblage and the high rate of tobacco clay-pipes attested that Vungu-Vungu was a center of ingoing and outgoing goods. During the Tjaube occupation period, the site may have been a commercial post at the main trading route along the Kavango River. This may also explain why the first Shambyu rulers chose to settle at Vungu-Vungu. Following the oral chronicles, Tjaube and Shambyu still maintained friendly relationships during that time. The Shambyu royals moved to Gove (SC 17) in the early nineteenth century under Queen Mushinga (Fleisch & Möhlig, 2002, p. 137) and Vungu-Vungu was abandoned by its residence in the middle of the twentieth century. Vungu-Vungu is also the best analyzed site of the LIG horizon in terms of ferrous metallurgy. The radiocarbon dates indicated that smelting started with the occupation of the site in the fifteenth to seventeenth centuries, and according to oral history it ended in the middle of the twentieth century. As shown in Figure 125, Zone 2 has been identified to be the historical smelting site, which was, according to oral history, near the Vungu-Vungu tree. The early residents smelted in slag tapping furnaces of unknown appearance, while the later ironworkers used bowl furnaces in the sandy ground without slag tapping. The ores used by the smelters were structurally similar to those utilized at Kapongo (SC 29). Only oral history provided information of mining areas in the Fumbe and Omatako Omuramba, and near the M'Popa falls of the Kwito River. All these mines were in a radius some 45 km away from Vungu-Vungu. The ores were crushed into small pieces to increase their reducibility and this study provided evidence that ore was added to the running furnace in order to increase the yield of a smelt. Unfortunately it was not possible to detect the mines from where the source material originated by archaeometrical means. At Vungu-Vungu, the furnace site was surrounded by several zones of bloom refining and secondary smithing activities (Figure 125). The slag assemblage of Zone 5 provided good evidence of a single work process from bloom to tools in the periphery of the smelting Zone 2. Zone 4 has been interpreted to be a blacksmith's workshop, probably belonging to the early occupation period of the site between the fifteenth and the seventeenth century. The largest center of iron processing was Zone 6: Area N98/32-Surf. 4c provided evidence for a refining furnace, which was also a simple pit in the ground and the whole area was probably used for metallurgical activities over a long period of time. Like in Zone 4, there was probably a blacksmith's atelier, too. The metal produced was a heterogeneous material, ranging from soft wrought iron to high carbon steel and iron was intensively recycled. The blacksmiths mastered cold and hot working, welded bloom fragments and scrap metal together, and normalized the finished implements at high temperatures. Perhaps they used warm working to alter the quality of the steel.

2.13. Site catalogue no. 13 Mayana-N'Kwazi

(Table 1, Figure 26)

Site Number: N96/06
Site Name: Mayana-N'Kwazi
Coordinates: E19°54.585'/S17°51.784'
Constituency: Rundu Rural
Plane Survey Sheet Namibia 1:50000: 1719 DD RUNDU
Survey: 1996
Excavations: -
References: Richter, 2005, p. 95: Catalogue No. 38
Registration Number State Museum Windhoek: B4288

Location: 3.03 km north-northeast of Mayana and of Local Road D3402, about 500 m, northeast of the N'Kwasi Lodge.
Altitude: 1065 m AMSL

Topography: The site is situated on a shallow elevation in the floodplain of the river.

Site Appearance: Four clusters of potsherd in grayish soil mixed with charcoal.

Finds: Three undecorated grog-tempered potsherds (Tables 7 and 16, Appendix 3) were collected (Vungu-Vungu style).

Interpretation: The site might be a temporarily used area where people cooked while fishing or gardening in the floodplains. Most probably it belonged to a young phase of the occupation horizon of the Late Ironworking Groups.

2.14. Site catalogue no. 14 Mayana

(Table 1, Figure 26)

Site Number: N96/SW1
Site Name: Mayana
Coordinates: E19°56.035'/S17°52.071'
Constituency: Rundu Rural
Plane Survey Sheet Namibia 1:50000: 1719 DD RUNDU
Survey: 1996
Excavations: -
References: Richter, 2005, p. 95: Catalogue No. 39
Registration Number State Museum Windhoek: B4288
Location: 4.08 km northeast of Mayana and Local Road D3402, about 480 m east of the Mayana Lodge.
Altitude: 1065 m AMSL

Topography: The site is situated on the lowest river terrace.

Site Appearance: Artifact scatter of 5 x 5 m in extension in an agricultural area near the river-bank, east of a shallow drainage channel.

Finds: Undecorated unspecific potsherds and bones. No finds were collected.

Pottery Style: Unspecific

Interpretation: The finds probably belonged to an undated abandoned settlement, or a temporarily occupied zone near the bank of the river.

2.15. Site catalogue no. 15 Muhopi

(Table 1, Figure 26)

Site Number: N96/07
Site Name: Muhopi
Coordinates: N96/07 (E19°18.582'/S17°53.404')
Constituency: Mashare
Plane Survey Sheet Namibia 1:50000: 1719 DD RUNDU
Survey: 1996
Excavations: -
References: Richter, 2005, p. 95: Catalogue No. 41
Registration Number State Museum Windhoek: B4288
Location: 2.3 km north of Local Road D3402 at Muhopi.
Altitude: 1066 m AMSL

Topography: Edge of a level lower terrace of the river on a cutting bank. The average slope of the terrain is about 0.6 %.

Site Appearance: This was an artifact scatter of about 15 m in diameter from a dark gray cultural layer, which was 70 cm in thickness. The finds eroded out along a cutting edge on the river-bank. The area was vegetated with a loose trees and shrubs. There was some fire clearing at the site from burning uncut trees.

Finds: Three pieces of decorated and undecorated Vungu-Vungu-style pottery and two tuyere fragments (Tables 7 and 16, Appendix 3) were collected. One tip of the tuyeres was exposed to great heat (Table 34, Appendix 3).

Pottery Style: Vungu-Vungu style.

Interpretation: This was an eroding midden of an abandoned settlement, belonging to the occupation horizon of the Late Ironworking Groups. There was ironworking at the site.

2.16. Site catalogue no. 16 Utokota

(Table 1, Figure 26)

Site Number: N96/08 and N96/08-1
Site Name: Utokota
Coordinates:
N96/08 (E20°1.188'/S17°54.515'),
N96/08-1 (E20°1.453'/17°54.529')
Constituency: Mashare
Plane Survey Sheet Namibia 1:50000: 1720 CC MASHARE
Survey: 1996, 2006

Excavations: -
References: Richter, 2005, 95: Catalogue No. 42
Registration Number State Museum Windhoek: B4288
Location: About 1 km west of Shambyu Mission, 230 m north of Local Road D3402.
Altitude: 1072 m AMSL

Topography: Edge of a middle terrace of the river with deeply red old terrace soils and near surface pisolitic ferricretes (Figure 8) overlying ferruginous sandstone (see also Gove-Mbambangandu (SC 17).

Site Appearance: Artifact scatter of 500 x 150 m in diameter in an agricultural area on the edge of the river terrace. The average slope of the terrace is 5%. Slag and chunks of pisolitic ferricretes were scattered around. The area was only sparsely vegetated. The soil seemed to be well permeable because there were only marginal shallow drainage channels towards the river.

Finds: Slag and iron ore (Table 34, Appendix 3). Only selected finds were collected. The association of slag and chunks of the ferruginous crust suggested that Group III ores as defined in section 4.1.3 were smelted at the site. Therefore, an ore sample (4723/06//5196/07) (Tables 40 and 41, Appendix 3) and one slag sample (4722/06) (Tables 44 and 45, Appendix 3) were analyzed. XRD-analysis of sample (4723/06//5196/07) revealed that the crust consisted mainly of goethite and quartz. Bulk chemistry indicated a moderate Fe_2O_3 content of 43.90wt% (Table 40, Appendix 3), which would demand beneficiation or a strongly fluxing supplement to be usable in bloomery smelting. Furthermore, a comparison of minor and trace elements attested that in no case of the analyzed slags were the local ferricretes used for smelting. The slag sample 4722/06 was a smithing hearth bottom from advanced refining and provided insight as to the iron produced and the refining techniques applied. The site has not been dated so far but I assume it to be part of the Gove smelting complex (SC 17). The thin section examination showed that refining was a process of several cycles of heating the bloom so that slag could separate from the metal, and of hammering and compacting the metal. The atmosphere in the refining furnace was strongly reducing with temperatures comparable to smelting, because cast iron formed in the course of refining. The lost bloom fragments were of low carbon steel quality. So far, neither the smelting site where the bloom was produced, nor the source of ore has been identified.

Pottery Style: -

Interpretation: This was a geological site where the Omatako Formation cropped out (section 1.3.2.10). It was also an undated bloom refining site and most probably belonged to the smelting complex of the Late Ironworking Groups at Gove-Mbambangandu (SC 17), 2.5 km farther east.

2.17. Site catalogue no. 17 Gove-Mbambangandu

(Table 1, Figure 26)

Site Number: N96/05 and N11/02
Site Name: Gove-Mbambangandu
Coordinates: S17°54.078'/E20°2.493'
Constituency: Mashare
Plane Survey Sheet Namibia 1:50000: 1720 CC MASHARE
Sub clusters:
N96/05 (E20°2.545'/S17°54.002'),
N96/05-1 (S17°53.982/E20°2.541'),
N96/05-2 (E20°2.416'/S17°54.100),
N96/05-3 (E20°2.381'/S17°54.142'),
N96/12 (E20°2.620'/S17°53.936'),
N97/02 (E20°2.543'/S17°54.007'),
N06/09 (E20°2.262/S17°54.254'),
N11/02-1 (E20°2.426'/S17°54.124'),
N11/02-3 (E20°2.437'E/17°54.088'),
N11/02-5 (E20°2.471'/S17°54.119'),
N11/02-6 (E20°2.493'/S17°54.078'),
N11/02-7 (E20°2.483'/S17°54.055'),
N11/02-8 (E20°2.440'/S17°54.096').
Survey: 1996, 1997, 1998, 2006, 2007, 2011
Excavations: 2011
References: Richter, 2005, p. 97: Catalogue No. 49.
Registration Number State Museum Windhoek: B4288
Location: 1.2 km east of the Shambyu Mission, about 700 m north of Local Road D 3402 at Gove. East of the royals' graveyard.
Altitude: 1070 m AMSL

Oral History: The site is mentioned in the Tjaube chronicle as a settlement site, where Kapilika, a nephew of the Tjaube King Mankoto, settled. The Tjaube produced iron on site and manufactured hunting weapons. The ore was mined at Fumbe and Taratara (Figure 217) (Fleisch & Möhlig, 2002, pp. 41-42). In the early nineteenth century, Gove became the residence of the Shambyu rulers under Queen Mushinga (Fleisch & Möhlig, 2002, p. 137). As described in section 5.3.2, Gove remained an iron production center under the rule of the Shambyu because the royal palace was there.

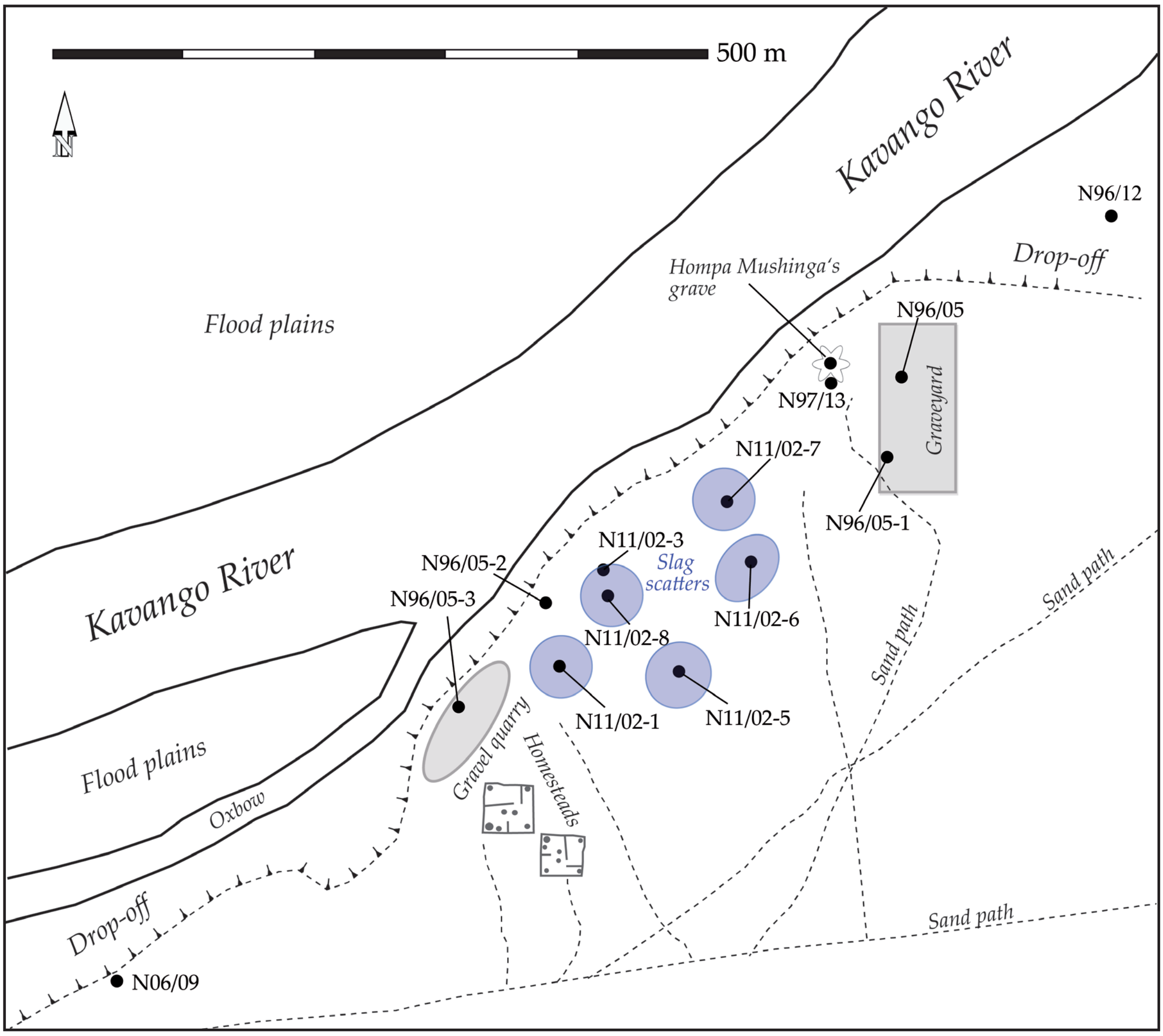


Figure 127: Site layout of SC 17 Gove-Mbambangandu.

Smelting at Gove has been described by Modestus Kashera Shimbiringua (Appendix 2.2). He recollected that the homestead of Kapilika was north of the modern-day royal graveyard. The ancient smelting site has been identified in N11/02-5 on a shallow hill. M. K. Shimbiringua recollected that the smelting site was in a secluded area from which women and children were banned, approximately 800 m away from the homesteads. A large tree provided shade. People smelted on top of the shallow hill. Here they stockpiled charcoal and ore and cut several small channels in the ground of the hill to drain the liquid slag away. Harupe Paulus Haididira Kaputungu (Appendix 2.3) recounted that iron tools were the property of the sovereigns and kept in the royal residence. Queen Mushinga owned a pit at Gove in which all the iron weapons and tools were stored together with the most valuable items of the country. The honorable Queen passed away in this pit and was buried with all her wealth (Figure 128).

Topography: The archaeological site is situated on a flood-proof edge of the middle terrace of the Kavango River. The modern surface declines towards the river (north) with a downward slope of about 6%. The high permeability of the soil allows for a good preservation of the cultural horizons as there is little erosion caused by the run-off of surface water. The site is situated on a cutting bank of the river and provides insight into the geological Eiseb Formation, which underlies the ferruginous Omatako Formation under a late calcrete horizon. In undisturbed places, the soil body comprises at least 2 m of silty sand on calcrete. Generally, soil formation is weak at the site. The upper horizon is light yellowish brown (MCC 2.5YR6/4) mixed with few organic materials and ash where former smelting activities took place. The upper horizon is about 20 to 30 cm thick and grades into a soft, moist, silty sandy B horizon of reddish yellow (MCC 7.5YR7/8) in color. The soil body is deflated towards the edges of the steep

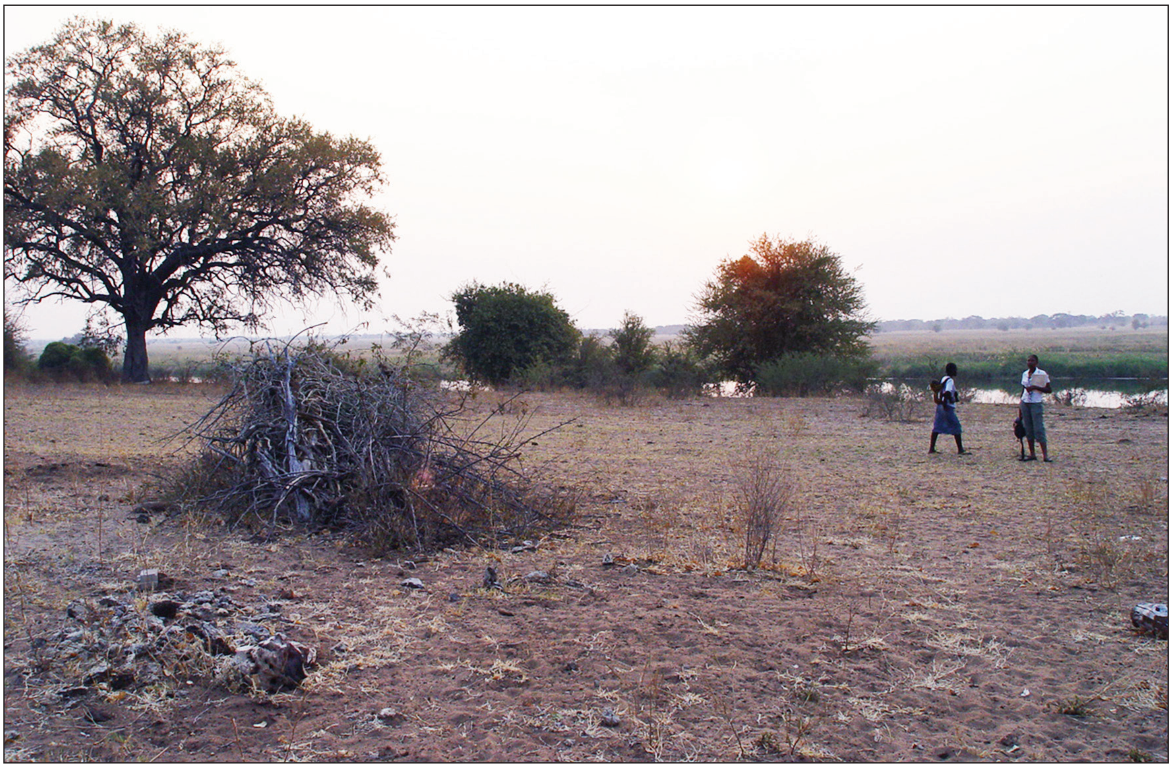


Figure 128: SC 17 Gove-Mbambangandu, archaeological site, in the foreground the grave of Hompa Mbambangandu, in the background the grave of Hompa Mushinga under the big tree.

riverbank. A calcrete crust of about 1 m in thickness borders the sandy deposits on the bottom without showing a transitional soft calcic horizon above. The calcrete hardpan covers a pisolitic ferricrete of about 1.5 m in thickness (section 1.3.2.10). Below the ferruginous horizon, strongly weathered and partially ferruginous sandstone occurs. The sandstone gradually passes into silicified sandstone and further down into a massive reddish silcrete stratum.

Site Appearance: The archaeological occupation of the Late Ironworking Groups stretched about 500 m from west to east along the river and about 200 m towards south from the edge of the river (Figure 127). The southern limit has not yet been precisely identified. Acacia shrubs scattered across the terrace and grass and other lower-growing plants were common. Some parts of the site were used for agriculture. In the 1950s, ferricrete exploitation for road construction destroyed the western parts of the location (N96/05-3) (Figure 129). From the same time, digging activities of the locals in search of silcretes heavily disturbed the northern part of the site (N96/05-2, N11/02-2, and N11/02-3) (Figure 130). In addition, locals recently transferred the uncultivated land into a crop field and have used the 'dark soil' of the historic smelting sites as fertilizer (N11/02-1). Frequenting residents and cattle caused further removal of the topsoil towards the edge of the terrace and the steep bank of the river. All over the site, burrowing animals have been highly active and helped archaeologists to identify the ancient smelting sites (Figure 132).

2.17.1. Area N96/09

(Figure 127)

Site appearance: 500 m east of the mission, in an area stretching about 500 m from east to west along the edge of the middle terrace, a heavily weathered ferruginous sandstone of the Omatako Formation eroded out at the steep bank of the river, together with chunks of the pisolitic ferricrete. The weathered sandstone may be the parent material of the ferricrete. Numerous lithics also occurred.

Finds: Several stone artifacts were collected. Two samples were taken, one from the ferruginous sandstone (4725/06) and a thick pisolite from the ferricrete (4726/06//4401/06//5197/06) (Tables 40 and 41, Appendix 3). In thin section the iron-enriched part of the sandstone 4725/06 consisted predominantly of quartz grains, which were cemented by a goethitic matrix with colloform growth banding (Figure 172). The sand matrix also contained several subangular grains of

Figure 129: SC 17 Gove-Mbambangandu, abandoned modern quarry N96/05-3.

Figure 130: SC 17 Gove-Mbambangandu, recent non-industrial silcrete quarry N11/02-3 with scattering lithic debris.

hematite. The chemical analysis revealed only 25.7wt% of Fe_2O_3 (Table 40, Appendix 3), and the material was not suitable for iron production. The pisolite 4726/06 showed in thin section mainly quartz grains, which were cemented by depositional successions of alternating ferrous or siliceous matrices (Figure 172). The ferrous matrix consisted of granular aggregates of iron oxides of varying concentration. In some areas, the structure was rather unspecific granular-like, in others the oxides segregated into layered and sometimes concentrically formed growth bands. XRD analyses disclosed that it was composed of quartz and hematite. The sample contained 40.06wt% of Fe_2O_3 and was taken because it was thought to be the source material of the iron production on site. However, as discussed in section 4.1.3, this study made clear that the sample belonged to the Group III ores that were not used for local iron production.

Pottery Style: -

Lithic Typology: Early, Middle and Late Stone Age

Interpretation: Stone Age occupation site, geological outcrop.

2.17.2. Area N96/05-3

(Figure 127)

Site appearance: According to locals, an abandoned modern quarry for ferricrete of 80 x 45 m in extension (Figures 127 and 129). Debris from the mining was scattered around. Numerous big chunks of the calcrete hardpan along with blocks of pisolitic ferricretes cemented by $CaCO_3$ were found. Slag was scattered in the eastern part of the quarry and attested a destroyed smelting location. Several Middle Stone Age flakes occurred embedded in the calcrete. The geological successions encountered in the quarry were described in the topography section above.

Finds: A number of pieces of smelting slag were found (Figure 138), yet they were not collected. A sample of iron-rich pisolitic ferricrete was analyzed (4724/06//5199/07//5202//07) (Tables 40 and 41, Appendix 3) because, as mentioned earlier, they were originally thought to provide the source material for the smelts. XRD analyses showed that the crust consisted of quartz and goethite. However, the sample contained only around 30wt% of Fe_2O_3 (Table 40, Appendix 3) and was not suitable for iron smelting without beneficiation. It belonged to the Group III ores discussed section 4.1.3.

Pottery Style: -

Lithic Typology: Unspecific, perhaps Middle Stone Age.

Interpretation: The lithics found in the calcretes indicated a Middle Stone Age occupation. The slag belonged to the LIG horizon, possibly to N11/02-1. The site was disturbed by a modern quarry, which provided insight into the geology of the region.

2.17.3. Excavation site N11/02-1

(Figure 127)

Site appearance: The area was a roundish feature of gray sandy soil, which appeared as a shallow, hardly noticeable elevation

Figure 131: SC 17 Gove-Mbambangandu, smelting site N11/02-5 on the shallow elevation.

in the general topography of the site. Finds scattered in particular in the northern zone of the feature and to the north of it.

2.17.3.1. Excavation method

Based on a concentration of surface finds, three 1-m² test-units were excavated where artifacts were scattered. The site appeared as a roundish feature of grayish soil, 35 x 35 m in extension. A spade hole was started in the southern part of the feature in a shallow depression that was dug by locals in order to obtain 'dark soil' for agriculture (unit 3). The unit was leveled down in steps of 10 cm and 15 cm to a depth of 1.60 m below the surface in order to get a general impression of the nature of the stratification of the site. The excavated soil was sifted through a 10 mm wire mesh. Unit 2 was laid out in the western outer zone of the feature, and so was unit 1 further downhill on the northern outer zone. unit 2 and unit 3 were leveled down in artificial quadrants and layers of 5 cm in thickness down to a depth of 1.10 m (unit 1) and 1.20 m (unit 2). The removed soil was sifted through a 3 mm wire mesh.

Figure 132: SC 17 Gove-Mbambangandu, smelting site N11/02-5, den of a burrower unearthing charcoal remains of the smelting site.

2.17.3.2. Stratigraphy

At the current state of writing, the finds from the N11/02-1 excavations are still under examination in Windhoek. Therefore, only some preliminary results will be considered here.

The surface layer consisted of 20 to 30 cm of slightly silty fine sand, pinkish gray (MCC 7.5YR6/2) in color, loose in consistency and mixed with modern material and few eroded artifacts. The surface was covered with grass. Roots penetrated the soil as deep as 1.5 m below the surface with decreasing density. Beneath the loose surface layer the soil changed gradually into a soft silty fine sand of patchy dark red-brown to very dark gray-brown (MCC 5YR2.5/5 to 10YR3/2). Pottery, bone, lithics, crushed low quality ore, several tuyere fragments and slags concentrated abundantly together with charcoal in this horizon. The dark layer varied in thickness (10 to 20 cm) and filled a pit-like feature in

Figure 133: SC 17 Gove-Mbambangandu, smelting site N11/02-6 on the shallow elevation.

unit 2 (Figure 134). In unit 1, a 10 to 20 cm thick layer of a highly ashy fine sand, reddish gray in color (MCC 2.5YR7/1), underlay the dark layer. At about 50 to 60 cm below the surface, the dark grayish soil changed into an increasingly variegated brownish to reddish yellow horizon with soft, slightly silty fine sand, lighter in color than above (MCC 7.5YR4/2 to 7.5YR6/8 and 7.5YR8/6). In this layer, a second horizon with pottery, lithics, faunal remains, crushed ore, and slag occurred. In the lower levels, the archaeological remains decreased in number and changed into a lithic dominated assemblage, but crushed ore, some slag, and pottery was still present. In unit 1, the soil color changed into pale red (MCC 10R/7/2) near the calcrete crust and the soil became slightly calcareous. Small $CaCO_3$ nodules increased in number towards the bottom of the units. In unit 1, lenses of small silcrete and calcrete nodules occurred near the crust. Only in unit 1 was the calcrete crust reached. Open and backfilled burrows of up to 30 cm in diameter were common all the way through the soil body. It was obvious that the archaeological horizons were strongly disturbed in several places (Figure 135). Therefore, the interpretation of the assemblage must be conducted with caution.

2.17.3.3. Finds

The excavation produced some 7000 finds, among them a high amount of potsherds, faunal remains, slag, iron ore, tuyere fragments, several ostrich eggshell beads and glass beads, an iron implement, and lithics. The inventory is still under study. The pottery was an organically-tempered ware, which provided the basis for the definition of the Gove ware as shortly described in Chapter 3. The tuyere fragments were all grog-tempered, attesting that in the horizon of the Late Ironworking Groups tuyeres belonging to the early horizon cannot be cannot be distinguished from late ones on the basis of their temper. In unit 2, a Middle Stone Age lithic assemblage formed the bottom of the unit immediately above the calcrete crust. In unit 3, the deeper strata produced several LSA stone artifacts.

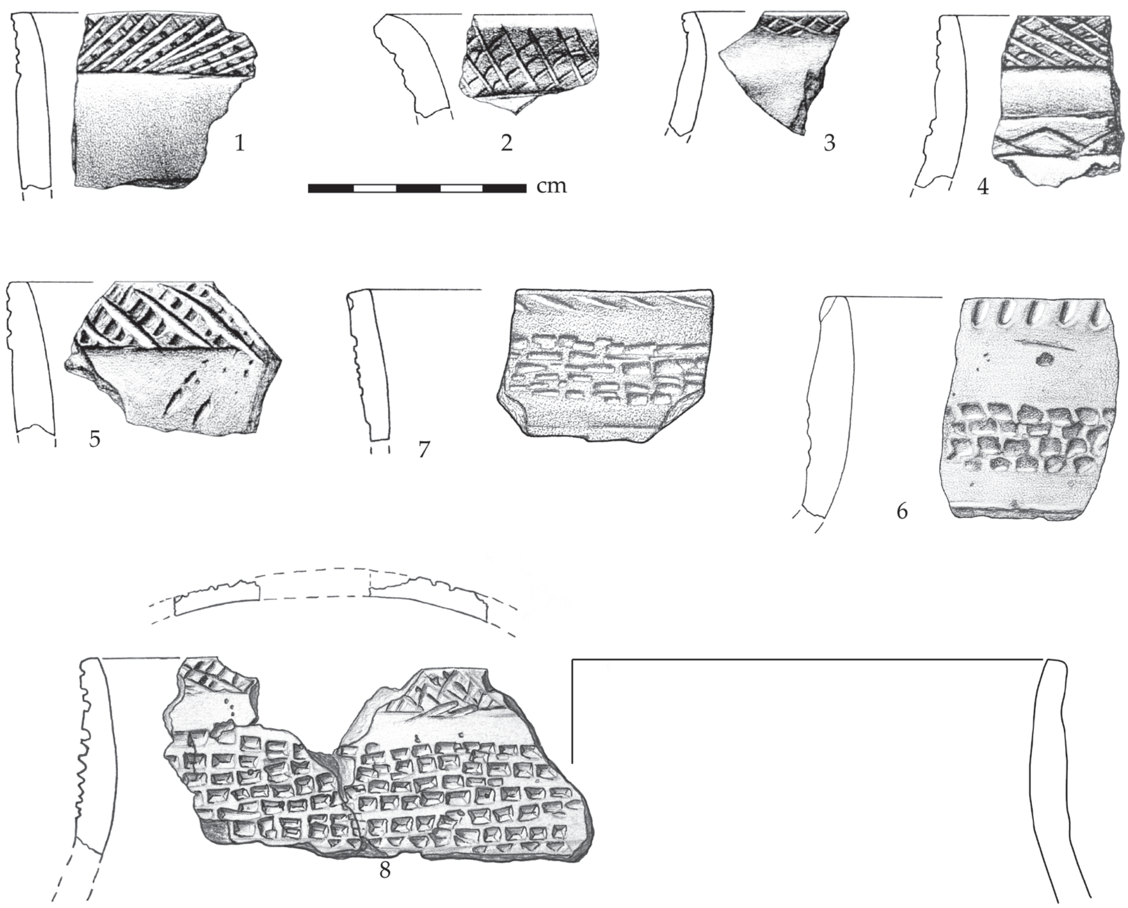
2.17.3.4. Radiocarbon dates

Two radiocarbon dates were produced from charcoal extracted from two well stratified decorated vessel fragments (Table 2, Appendix 3) While the potsherd from

Figure 134: SC 17 Gove-Mbambangandu, N11/02-1 soil section of unit 2 (facing east).

Figure 135: SC 17 Gove-Mbambangandu, N11/02-1 soil section of unit 3 (facing north).

the deeper level produced a calendar age falling between the mid-fifteenth and the mid-seventeenth century cal AD (COL#2330.1.1., Table 2), the 2-sigma calibrated results of charcoal extracted from the upper vessel fragment (COL#2331.1.1., Table 2) fell between the fourth to the mid-sixth century cal AD (Figure 162). At first sight, the latter result fit well into the EIG occupation horizon dated at Ruuga (SC 3) and Kapako (SC 4). However, stylistically, the potsherd was an early representative of the late Kavango pottery with its characteristic crosshatching (Figure 136). Moreover, sample COL#2331.1.1 was found in a stratigraphically younger position than COL#2330.1.1. The latter date is backed up the calendar age produced by an organically-tempered shard from Vungu-Vungu (Poz-20702, Table 2), also



1-4- Late Ironworking Groups pottery (Vungu-Vungu-style), 5-8- Late Ironworking Groups pottery (Gove-style).

Figure 136: SC 17 Gove-Mbambangandu, pottery finds from the site complex (drawings: Anja Rüschmann and the author).

dating between the mid-fifteenth to the mid-seventeenth century cal AD (Figure 162). It is therefore most likely that sample COL#2331.1.1 points to the same problem of 'old wood' as discussed earlier for Ruuga (SC 4), which can heavily distort the chronologies established by radiocarbon dates in arid environments.

12.17.3.5. Interpretation

The excavation of N11/02-1 revealed a Middle Stone Age open air site, and the area was frequented during the Late Stone Age. The upper layers provided evidence of an eroded smelting site, dating to a period between the fifteenth and the seventeenth century cal AD. The ceramic assemblage (Figure 136) confirmed that another pottery style existed in the middle Kavango area during the occupation of the Late Ironworking Groups, which was assignable to the Tjaube people described in oral chronicles. In the framework of this study this pottery tradition was named 'Gove ware' (section 3.2).

2.17.4. Area N96/05-2

(Figure 127)

Site appearance: This was a concentration of large chunks of slag, some 45 m north of N11/02-1, on the edge of the river terrace. Most probably, they were dislocated finds originating from N11/02-1 or N11/02-8.

Finds: Slag. No finds were collected.

Interpretation: Eroded smelting site of the Late Ironworking Groups.

2.17.5. Area N11/02-8

(Figure 127)

Site appearance: Roundish feature of a gray, ashy soil, 25 m in diameter which appeared as a shallow, barely noticeable elevation in the general topography of the site. The tunnels of large burrowers exposed an ashy layer of at least 30 cm in thickness with chunks of charcoal. Slag and partially reacted ore were scattered around. The site seemed to be disturbed and cut by people and cars frequenting the riverside.

Finds: Slag, charcoal. No finds were collected.

Interpretation: Eroding smelting site of the Late Ironworking Groups.

2.17.6. N11/02-3

(Figure 127)

Site appearance: Modern mining area for silcretes of about 60 x 30 m in extension. High concentration of unspecific lithic debitage occurred together with several ESA and MSA tools and flakes (Figure 130). Most probably the miners dislocated Early and Middle Stone Age material during their activities. Not far from the mining area, an Early Stone Age hand ax was found (N11/02-2). Locals used the silcretes in the 1950s and ‘60s to produce hand axes for the Shambyu mission in exchange for sweets and clothes. These tools are stored in the Shambyu Museum.

Finds: Lithics, pottery, some slag. No finds were collected.

Interpretation: Early (?) and Middle Stone Age open air site, modern silcrete quarry.

2.17.7. Area N11/02-5

(Figure 127)

Site appearance: This was a circular shallow elevation in the general topography of the site, 40 m in diameter and 1 m high (Figure 131). The soil was gray, ashy and sandy. The tunnels of large burrowers exposed a thick ashy matrix of the site with chunks of charcoal (Figure 132). Slag and pottery were scattered around. Besides the burrowers the site seemed to be undisturbed.

Finds: Only some pottery was collected (Tables 10 and 16, Appendix 3). The area produced a number of organically-tempered Gove ware, but also grog-tempered Vungu-Vungu ware.

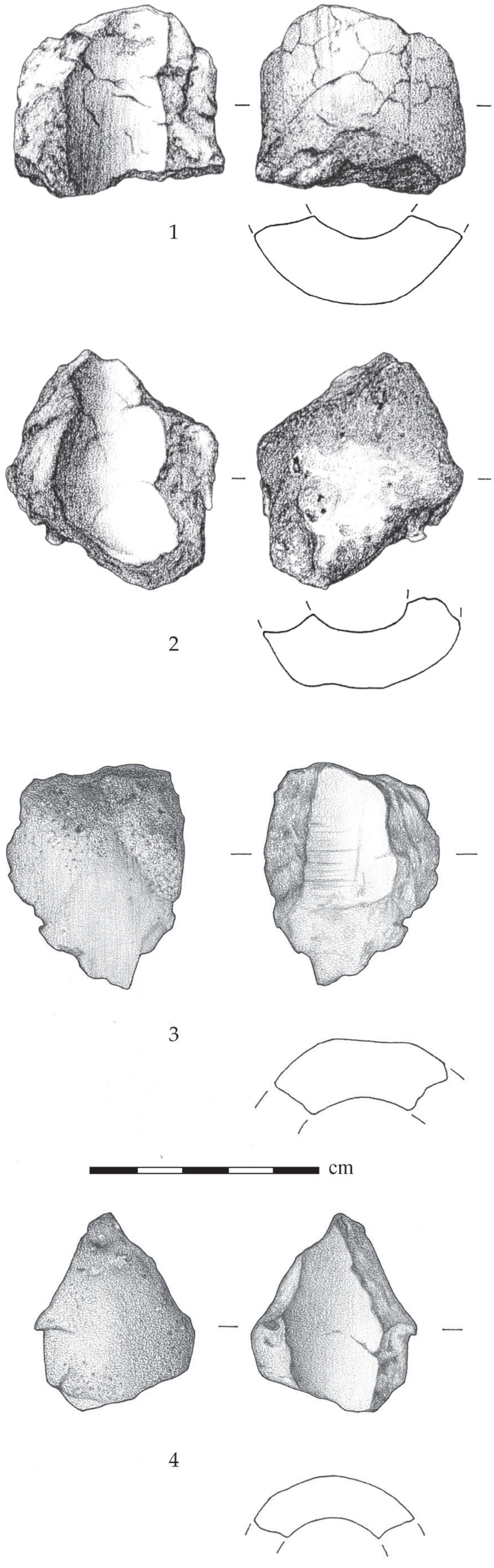


Figure 137 :SC 17 Gove-Mbambangandu, tuyere finds from the site complex (drawings: Anja Rüschmann).

Oral History: Modestus Kashera Shimbiringua (Appendix 2.2) showed me the site in 2007 and explained how the iron-workers of the Vakwandjadi clan used to smelt on top of the hill. The site was no longer in use when M. K. Shimbiringua was a child in the 1930s.

Interpretation: This was a smelting site of the Late Ironworking Groups. It could be assigned to the smelters of the Vakwandjadi (Falcon/Rain) Clan (section 5.1).

2.17.8. Area N11/02-6

(Figure 127)

Site appearance: This was an elongated shallow elevation in the general topography, 60 x 35 m in diameter and 1.5 m high (Figure 133), roughly 80 m northeast of N11/02-5. The site consisted of a zone of gray, ashy sandy soil. The tunnels of large burrowers exposed the ashy soil matrix of the site. Slag and pottery were scattered around. The site was disturbed because it was part of a crop field. Parts overgrown with shrubs were cleared by fire.

Finds: Slag, pottery, charcoal. No finds were collected.

Interpretation: This was a disturbed smelting site of the Late Ironworking Groups, comparable to N11/02-5.

2.17.9. Area N11/02-7

(Figure 127)

Site appearance: This was an artifact scatter of 45 x 30 m in extension, north of N11/02-6, on the edge of the middle terrace. In the northwestern part the soil was gray and ashy. Numerous chunks of slag and some pottery were spread around. Due to the high concentration of artifacts I considered the area to be an eroded smelting location.

Finds: Slag, pottery, charcoal. No finds were collected.

Interpretation: This was a disturbed smelting site of the Late Ironworking Groups, comparable to N11/02-5.

2.17.10. Areas N96/05, N96/05-1, N97/02, and N97/13

(Figure 127)

Site appearance: Large loose artifact scatter of roughly 120 m or more in diameter east of Hompa Mushinga's grave, and north and northeast of the graveyard of Hompa Mbambangandu. The area was vegetated with some shrubs and small trees, some parts were used for agriculture. This place is said to be Hompa Mbambangandu's palace until the 1940s and it extended farther to the east.

Finds: Pottery, tuyere fragments (Figure 137), slag, and several stone artifacts (Tables 10 and 34). Only selected finds were collected. The pottery (Table 16, Appendix 3) was dominated by Vungu-Vungu ware, yet some Gove ceramics were present too.

Interpretation: The area showed the pattern of an eroded ironworking site. The pottery finds indicated a settlement area nearby, which dated to the late occupation period of the LIG horizon. However, future research is necessary to better assess the layout of the site.

2.17.11. Area N96/12

(Figure 127)

Site appearance: About 180 m northeast of the graveyard of Hompa Mbambangandu's family, stone artifacts, slag and iron ore were recorded in the profile of a pit. The site is situated on the lower terrace of the Kavango River.

Finds: Slag, stone artifacts, two tuyere fragments (Tables 10 and 34, Appendix 3).

Pottery Style: -

Lithic Typology: Unspecific.

Interpretation: This site was part of the site-complex SC 17. The finds indicated another ironworking site. However, they might also have been eroded material from farther uphill.

2.17.12. Archaeology and oral history, is there a correlation?

Site-complex SC 17 is not yet well assessed by archaeological and archaeometrical means. However, the assemblages found in the

Figure 138: SC 17 Gove-Mbambangandu, area N96/05-3, slag finds (group to the right) and chunks of the ferricrete (group to the left).

three excavated units of area N11/02-1, together with the identification of the smelting areas from surface finds provided valuable information with respect to the history of the site. From an archaeological point of view, Gove-Mbambangandu is one of the largest smelting sites so far identified in the middle Kavango area. Furthermore, it was the first archaeological site that provided unequivocal evidence of the existence of an early ceramic horizon within the Late Ironworking Groups, which pre-dated the Vungu-Vungu-style pottery (Figure 136, section 3.2). One radiocarbon date produced from this pottery (COL#2330.1.1, Table 2) together with one dated potsherd from Vungu-Vungu (Poz-20671, Table 2) proved that this ware was older than the Vungu-Vungu-style pottery (see also Chapter 3).

Turning to oral history, the Tjaube chronicle describes that the area was occupied from the south by a group of hunters, who settled in the Ndonga Omuramba at Kauti (Figure 215) (section 5.1). From there, they established settlements along the Kavango River such as Gove and Vungu-Vungu (Fleisch & Möhlig, 2002, pp. 40-42). The chronicle further describes both sites as iron and weapon production sites. As has been portrayed for Vungu-Vungu in section 2.12.20 and later in section 5.4, the Tjaube were involved in the international ivory trade. There exist different versions in terms of who the first Shambyu immigrants were.[93] Following the Shambyu chronicle as published by Fleisch and Möhlig (2002, pp. 133-137), two generations of kings settled at Vungu-Vungu (King Kapinga and King Nyumba). Queen Mushinga of the third generation moved to Gove. According to the same chronicle, she ruled between 1820 and 1858 (Fleisch & Möhlig, 2002, p. 137). Queen Mushinga appears in the Tjaube chronicle as the antagonist of King Mankoto, who usurped the Tjaube kingdom and enslaved Mankoto's commoners and descendants (section 5.3.5.3).[94] The latter chronicle describes the Queen to be the first Shambyu ruler in the country. Vungu-Vungu is not mentioned as royal residence. Gove again became the residence of a sovereign under Hompa Mbambangandu II who ruled the country between 1925-1948.

The archaeological assessment of the site-complex SC 17 Gove-Mbambangandu allowed me to define an early pottery phase within the settlement horizon of the Late Ironworking Groups. This pottery was denominated Gove ware and has been assigned to the Tjaube people (section 3.2). The calibrated calendar ages of this pottery ranged between the fifteenth and the seventeenth century cal AD. The archaeological investigation also confirmed that Gove-Mbambangandu was a large smelting site where people produced iron for several generations. Area N11/02-1 combined smelting remains with Gove ware and could therefore be linked to the description given in the Tjaube chronicle according to which Gove was an iron and tool production site of the Tjaube people (Fleisch & Möhlig, 2002, pp. 41-42). Unfortunately, the palace of Queen Mushinga from the nineteenth century has not yet been identified archaeologically. The youngest smelting area N11/02-5 could be linked to ironworkers of the Vakwandjadi clan in the early twentieth century, who smelted in Gove in honor of Hompa Mbambangandu II. His palace was remembered east of the graveyard. Like Queen Mushinga's domicile, the residence of Hompa Mbambangandu has not yet been identified archaeologically. However, in the eastern part of the site-complex SC 17, Vungu-Vungu-style pottery dominates the surface finds whereas in the western part Gove ware is the most frequent. From there one can assume that the younger settlement was somewhere between N11/02-7, N11/02-6 and the drop-off towards the flood plains, east of the graveyard (Figure 127). Queen Mushinga's grave still exists and is marked by a tombstone under a large tree (Figure 128).

[93] For the discussion see Fleisch and Möhlig (2002, pp. 125-131).

[94] For this fight see Fleisch and Möhlig (2002, pp. 48-51). A different version with emphasis on the role of iron weapons in this conflict was told by Harupe Paulus Haididira Kaputungu (Appendix 2.3)

2.17.13. Interpretation of site-complex SC 17 Gove-Mbambangandu

The site-complex Gove-Mbambangandu was a center of iron production of the Late Ironworking Groups. Five smelting areas have been identified so far, others were probably destroyed by the modern quarry (Figure 127). While smelting area N11/02-1 could be assigned to the Tjaube smelters prior to the arrival of the Shambyu, area N11/02-5 represented the youngest smelting area used in the early twentieth century by the smelters of the Vakwandjadi clan under Hompa Mbambangandu II. Site-complex SC 17 also revealed the first undisturbed ceramic assemblage of Gove ware and provided evidence for an early occupation horizon within the history of the Late Ironworking. Together with the evidence from Vungu-Vungu, Gove provided substantial archaeological support for the historical veracity of the Tjaube chronicle, i.e. that the area was occupied by a group of settlers with culturally different roots from the San people as well as the later Kavango peoples such as Shambyu, Gciriku and their neighbors (see section 5.1).
The settlement of Gove came into focus under Queen Mushinga in the middle of the nineteenth century. The latter lived in the peak time of the ivory boom (see Von Oppen, 1993, p. 63) and King Mankoto's immense richness of 18 heaps of elephant tusks aroused desires (section 5.4). After the conquest of the Tjaube territory, all the smelters and all the hunting weapons became controlled by the sovereign. Queen Mushinga died at Gove in a pit full of iron weapons and the most valuable items of the country, which were most probably elephant tusks at that time. Her grave is situated in the north-western part of the site-complex SC 17. Her palace and the legendary pit have not so far been identified archaeologically. However, in light of the extended trade relationships of this historical period, one can expect a rich archaeological assemblage reflecting the international level of the commercial activities.

2.18. Site catalogue no. 18 Gove-East

(Table 1, Figure 26)

Site Number: N96/10
Site Name: Gove-East
Coordinates: N96/10 (E20°3.326'/S17°54.092')
Constituency: Mashare
Plane Survey Sheet Namibia 1:50000: 1720 CC MASHARE
Survey: 1996
Excavations: -
References: Richter, 2005, p. 97: Catalogue No. 51
Registration Number State Museum Windhoek: B4288
Location: About 380 m north of Local Road D3402 and 1.3 km east of the graveyard of Hompa Mbambangandu's family.
Altitude: 1065 m AMSL

Topography: The site is situated on a lower terrace of the river on the southern bank of an oxbow, 1.2 km southeast of the main river.

Site Appearance: Artifact scatter of unknown extension in sandy soil.

Finds: Unspecific lithics and pottery were found. No finds were collected.

Interpretation: Undated site of the Ironworking Groups.

2.19. Site catalogue no. 19 Gove-North

(Table 1, Figure 26)

Site Number: N96/11
Site Name: Gove-North
Coordinates: N96/10 (E20°3.326'/S17°54.092')
Constituency: Mashare
Plane Survey Sheet Namibia 1:50000: 1720 CC MASHARE
Survey: 1996
Excavations: -
References: Richter, 2005, p. 97: Catalogue No. 52
Registration Number State Museum Windhoek: B4288
Location: About 2 km north of Local Road D3402 and 2.2 km northeast of the graveyard of Hompa Mbambangandu's family.
Topography: This site is situated on a lower terrace of the river on the west bank of an oxbow, 95 m southwest of the main river. The area is affected by flooding.
Altitude: 1066 m AMSL

Site Appearance: Artifact scatter of 10 m in diameter in sandy soil. The area was vegetated with trees and shrubs.

Finds: Pottery, decorated and undecorated (Tables 7 and 16, Appendix 3). Only selected finds were collected.

Pottery Style: Vungu-Vungu style.

Interpretation: This was probably a settlement only used temporarily during the dry season. It dated to the late period of the occupation horizon of the Late Ironworking Groups.

2.20. Site catalogue no. 20 Tjeye

(Table 1, Figure 26)

Site Number: N98/41
Site Name: Tjeye
Coordinates: N98/41 (E20°5.041'/S17°54.586')
Constituency: Mashare
Plane Survey Sheet Namibia 1:50000: 1720 CC MASHARE
Survey: 1998
Excavations: -
References: Richter, 2005, p. 97: Catalogue No. 53
Registration Number State Museum Windhoek: B4288
Location: About 50 m south of Local Road D3402, and 400 m northwest of the Tjeye Junior Primary School.
Altitude: 1073 m AMSL

Topography: Middle terrace of the river 1.9 km south of the main river.

Site Appearance: This was a loose artifact scatter of 50 m in diameter in a reddish sandy soil. The area was vegetated with trees and shrubs. Finds of modern lids and cans indicated an abandoned homestead. Chunks of calcretes with silcrete nodules and lithic artifacts occurred. The broken calcretes derived most probably from modern quarry work in the course of the road construction.

Finds: Stone artifacts, undecorated grog-tempered pottery (Vungu-Vungu style) (Tables 7 and 16) and two pieces of slag were collected (Table 35). The stone artifacts indicated a Middle Stone Age occupation of the site. One piece of a flow slag and one tuyere fragment were found (Table 35).

Interpretation: This was a late settlement site of the Late Ironworking Groups, where iron had been worked or smelted. Below the young settlement, there was a Middle Stone Age occupation horizon.

2.21. Site catalogue no. 21 Tjeye-East

(Table 1, Figure 26)

Site Number: N98/44
Site Name: Tjeye-East
Coordinates: N98/44 (E20°5.953'/S17°54.539')
Constituency: Mashare
Plane Survey Sheet Namibia 1:50000: 1720 CC MASHARE
Survey: 1998, 2003
Excavations: -
References: Richter, 2005, p. 97: Catalogue No. 54
Registration Number State Museum Windhoek: B4288
Location: About 200 m north of Local Road D3402, and 250 m south of the main river.
Altitude: 1069 m AMSL

Topography: At the edge of a middle terrace of the river, there is an outcrop of ferricretes of the Omatako Formation near the surface, overlying ferruginous sandstone. The average slope of the area is 4%. The soil consists of well-permeable oxidic middle terrace soils with little surface water run-off in erosional channels.

Site Appearance: This was a scatter of slag and chunks of ferricretes and weathered sandstone of 150 x 200 m in diameter or more. The site was situated in an agricultural area. One hundred and fifty meters east of the site were two small modern ferricrete quarries. North of the site, a dense scatter of dislocated ferricrete remnants indicated further mining activities, which probably disturbed an ironworking site. Lithic artifacts were scattered across the area.

Finds: A slag block, several ferricrete chunks and lithics were collected (Tables 7 and 35, Appendix 3). The bulk chemistry of an iron-rich sandstone was tested (sample 4728/06) (Tables 40 and 41, Appendix 3) but it revealed only 4.07wt% of Fe_2O_3. The slag block 4727/06 was a smithing hearth bottom from advanced and finial refining. The furnace-running condition of the refining facility was hot and reducing, comparable to smelting. The slag contained iron inclusions ranging from low to high carbon steel, evidencing that the bloom consisted of a heterogeneous material. The iron showed signs of cold working from the physical consolidation of the bloom. A high proportion of fuel was recognized within the sample and together with the metal inclusions it might have been that the ironworkers carburized some raw iron. However, more evidence is needed to confirm this impression. Besides the slag, several MSA stone artifacts were collected.

Interpretation: This was an undated bloom refining site that was disturbed by modern mining activities. Most probably, it belonged to horizon of the Late Ironworking Groups. The site provided also evidence of a Middle Stone Age occupation horizon.

2.22. Site catalogue no. 22 Mashare and Mashare-West

(Table 1, Figure 26)

Site Number: N98/45 and N98/45-1
Site Name: Mashare, Mashare-West
Coordinates:
N97/08 (E20°07.357'/S17°54.428'),
N98/45 (E20°7.247'/S17°54.488'),
N98/45-1 (E20°7.023'/S17°54.621')
Constituency: Mashare
Plane Survey Sheet Namibia 1:50000: 1720 CC MASHARE
Survey: 1998, 2006
Excavation: -
References: Richter, 2005, p. 97: Catalogue No. 55
Registration Number State Museum Windhoek: B4288
Location: About 190 m north of Local Road D3402, and about 60 m south of the main river.
Altitude: 1069 m AMSL

Topography: This is an outcrop of ferricretes of the Omatako Formation, which overlies ferruginous sandstone, and reddish and yellowish silcretes of the Eiseb Formation. It is situated at the edge of a middle terrace of the river. The average slope of the area is about 10%. The soil consists of permeable oxidic middle terrace soils with several shallow erosional channels. Towards the river, alluvial clayey deposits occur. A calcrete crust has formed in the soil body.

2.22.1. Area N98/45

Site appearance: A modern ferricrete quarry produced a scatter of ferricretes, ferruginous sandstone, calcrete and silcrete chunks, 220 x 90 m in extension. Numerous Middle Stone Age artifacts were scattered around. Fifty meters west of the mined area locals dug for clay. In the profile of these extraction pits, Middle Stone Age lithic tools and flakes occurred in a silty and clayey soil deposit.

Finds: Several chunks of sandstone, ferricretes and lithics were collected (Tables 7 and 35, Appendix 3). Bulk chemistry of a sample of ferruginous sandstone (sample 4729/06) was tested (Tables 40 and 41, Appendix 3). It contained 12wt% Fe_2O_3 and was probably the parent material of the ferricrete.

Lithic Typology: Middle Stone Age

Interpretation: This was a geological outcrop of the Eiseb and Omatako Formations. It was disturbed by a modern quarry. The clayey deposits near the river, but also the eroding geological formation farther uphill provided evidence for a Middle Stone Age occupation.

2.22.1. Area N98/45-1

Site appearance: 350 m west of N98/45, an artifact scatter was noticed of unknown extension in an agricultural area on the edge of the river terrace. The site seemed to be undisturbed because surface finds were scarce.

Finds: One organically-tempered but undecorated potsherd was collected (Tables 7 and 16, Appendix 3) and dated (Poz-20673, Table 2). It produced a 2-sigma calibrated calendar age between the mid-fifth and the mid-seventh century cal AD (Figure 162).

Pottery Style: Kapako/Divuyu style.

Interpretation: The potsherd indicated an undisturbed settlement site of the Early Ironworking Groups, which has not been located so far.

2.23. Site catalogue no. 23 Mashare-East

(Table 1, Figure 26)

Site Number: N96/15
Site Name: Mashare-East
Coordinates: N96/15 (E20°8.969'/S17°53.869')
Constituency: Mashare
Plane Survey Sheet Namibia 1:50000: 1720 CC MASHARE
Survey: 1996
References: Richter, 2005, p. 98: Catalogue No. 58
Registration Number State Museum Windhoek: B4288
Location: 50 m north of Local Road D3402, and 300 m south of the main river.
Altitude: 1065 m AMSL

Topography: Lower terrace of the river with alluvial deposits. The average slope of the area is 1%. Calcretes have formed in the soil body.

Site Appearance: This was a modern quarry that produced a scatter of artifacts of 30 x 20 m in extension. The quarry stretched along the road for 800 x 150 m.

Finds: Potsherds of uncommon decoration and unspecific stone artifacts were recorded but only selected finds were collected (Tables 11 and 16, Appendix 3). The decorated potsherd was not of local origin.

Interpretation: Undated Stone Age and Ironworking Groups occupation site.

2.24. Site catalogue no. 24 Mashare Agricultural College

(Table 1, Figure 26)

Site Number: N06/05
Site Name: Mashare Agricultural College
Coordinates: N06/05 (E20°13.310'/S17°53.230')
Constituency: Mashare
Plane Survey Sheet Namibia 1:50000: 1720 CC MASHARE
Survey: 2006
Excavations: -
References: -
Registration Number State Museum Windhoek: -
Location: About 1.05 km north of Local Road D3402, and about 1 km northeast of the Mashare Agricultural College.
Altitude: 1064 m AMSL

Topography: At the edge of a middle terrace of the river there is an outcrop of ferricretes of the Omatako Formation, which overlies ferro-silcretes.

Site Appearance: This was an abandoned modern ferricrete quarry that produced a scatter of chunks of ferricretes and ferro-silcretes. The mining area stretched at least 1.3 km x 600 m in extension.

Finds: No finds or samples were collected.

Interpretation: This was a modern ferricrete quarry for road construction, which displayed the geological Omatako Formation.

2.25. Site catalogue no. 25 Mupapama-North

(Table 1, Figure 26)

Site Number: N97/07 and N98/46
Site Name: Mupapama-North
Coordinates:
N97/07 (E20°15.313'/S17°53.109'),
N98/46 (E20°15.195'/S17°53.110')
Constituency: Mashare
Plane Survey Sheet Namibia 1:50000: 1720 CD MABUSHE (TAKWASA)
Survey: 1997, 1998
Excavations: -
References: Richter, 2005, pp. 99-100: Catalogue Nos. 60 and 61
Registration Number State Museum Windhoek: B4288
Location: About 680 m north of Local Road D3402 at Mupapama.
Altitude: 1062 m AMSL

Topography: At the edge of a middle terrace of the river is an outcrop of sandstone, ferricretes and ferro-silcretes of the Omatako Formation.

Site Appearance: Abandoned modern ferricrete quarry that produced a scatter of chunks of ferruginous sandstone, ferricrete, ferro-silcrete and some dislocated calcrete. The mining area stretches at least 250 m in diameter. Stone artifacts were scattered all over the place. In the eastern part some pottery was found. The original spread of the archaeological remains was not clear. A heavy silcrete hammer (Richter, 2005, p. 100: Fig. 25) indicated traditional mining activities at the site.

Finds: A sample of the ferricrete and several lithics were collected (Tables 11 and 35, Appendix 3). The ferricrete sample (4730/06) was classified to the Group III ores (see section 4.1.3), but it contained only 11.03% of Fe_2O_3 (Tables 40 and 41, Appendix 3) and was not suited for bloomery iron production.

Lithic Typology: Middle Stone Age

Interpretation: This was an abandoned modern ferricrete quarry, which exposed geological sequences of the Omatako Formation. There might have been traditional mining activities. The lithics found belonged to a Middle Stone Age occupation horizon.

2.26. Site catalogue no. 26 Ndonga

(Table 1, Figure 26)

Site Number: N96/13, N98/48
Site Name: Ndonga
Coordinates:
N96/13 (E20°28.329'/ S17°57.003'),
N98/48 (E20°28.455'/S17°57.101')
Constituency: Ndyona
Plane Survey Sheet Namibia 1:50000: 1720 CD MABUSHE (TAKWASA)

Survey: 1996, 1998
Excavations: -
References: Richter, 2005, p. 100: Catalogue Nos. 62 and 64
Registration Number State Museum Windhoek: B4288
Location: West (N96/13) and east (N98/48) of the confluence of the Omatako with the Kavango. N96/13 is 230 m north of Local Road D3402, N98/47 is 110 m north of the latter.
Altitude: 1050 m AMSL

Topography: The site is situated at the edge of an almost level lower terrace of the Kavango River, which is cut through by the valley of the Omatako. The soil is a loamy alluvial deposit with a few erosional channels at the surface.

Site Appearance: This was an artifact scatter along the erosional edges of the river terrace and farther inland. N96/13 extended about 100 x 50 m, N98/48 more or less 10 x 5 m. The area was vegetated with trees and shrubs. N96/13 stretched across a modern homestead and agricultural land.

Finds: The site produced potsherds, several unspecific lithics and faunal remains (Tables 11 and 16, Appendix 3). The pottery showed Gove and Vungu-Vungu style. Two potsherds showed decoration motifs that were unusual for the middle Kavango region.

Interpretation: This was a settlement site of the Late Ironworking Groups, which went back to the early occupation period of the LIG horizon. It was disturbed by modern homesteads.

2.27. Site catalogue no. 27 Nyangana-Kangwenu

(Table 1, Figure 26)

Site Number: N98/43
Site Name: Nyangana-Kangwenu
Coordinates:
N98/43 (E20°28.455′/S17°57.101′)
Constituency: Ndyona
Plane Survey Sheet Namibia 1:50000:
1820 BA
Survey: 1998
Excavations: 1998
References: Richter, 2005, p. 102: Catalogue No. 72
Registration Number State Museum Windhoek: B4288
Location: 75 m north of Local Road D3402, 2.5 km southeast of the Nyangana Mission.
Altitude: 1052 m AMSL

Topography: The site is situated at the edge of a middle terrace of the Kavango River on a steep cut bank. The average slope of the area is 4.2% and increases towards the steep bank of the river. The archaeological horizon is covered by a layer of a hardened, sandy deposit of 40 cm in thickness. It covers a banded sandy deposit that follows the incline of the riverbank. The soil body is underlain by a thick calcrete hardpan (see Richter, 2005, p. 102). Deeply incised erosional channels occur.

Site Appearance: The site appeared as artifact scatters of varying density along the erosional edge of the river terrace, 60 x 30 m in extension. The site was covered with trees and shrubs. Drainage water from the surface cut erosional channels through cultural layers and older deposits. Numerous finds were washed out. At the surface, an eroded roundish feature appeared which was related to a slag scatter. The slag, however, was no longer there when I reassessed the finds in 2005. Two Levallois flakes were collected from the surface.

2.27.1. Excavation area N98/43-1

2.27.1.1. Excavation method

A test unit of 1.5 m² was laid out in an erosional channel around an almost completely washed out clay pot (Figure 141). In consideration of the downward slope of the

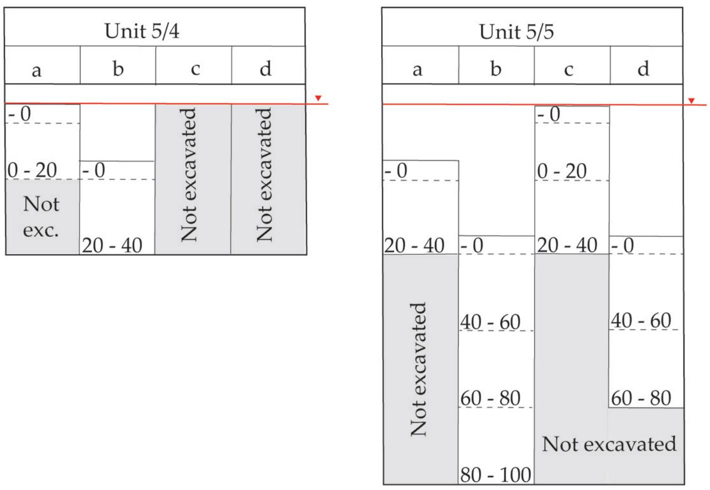
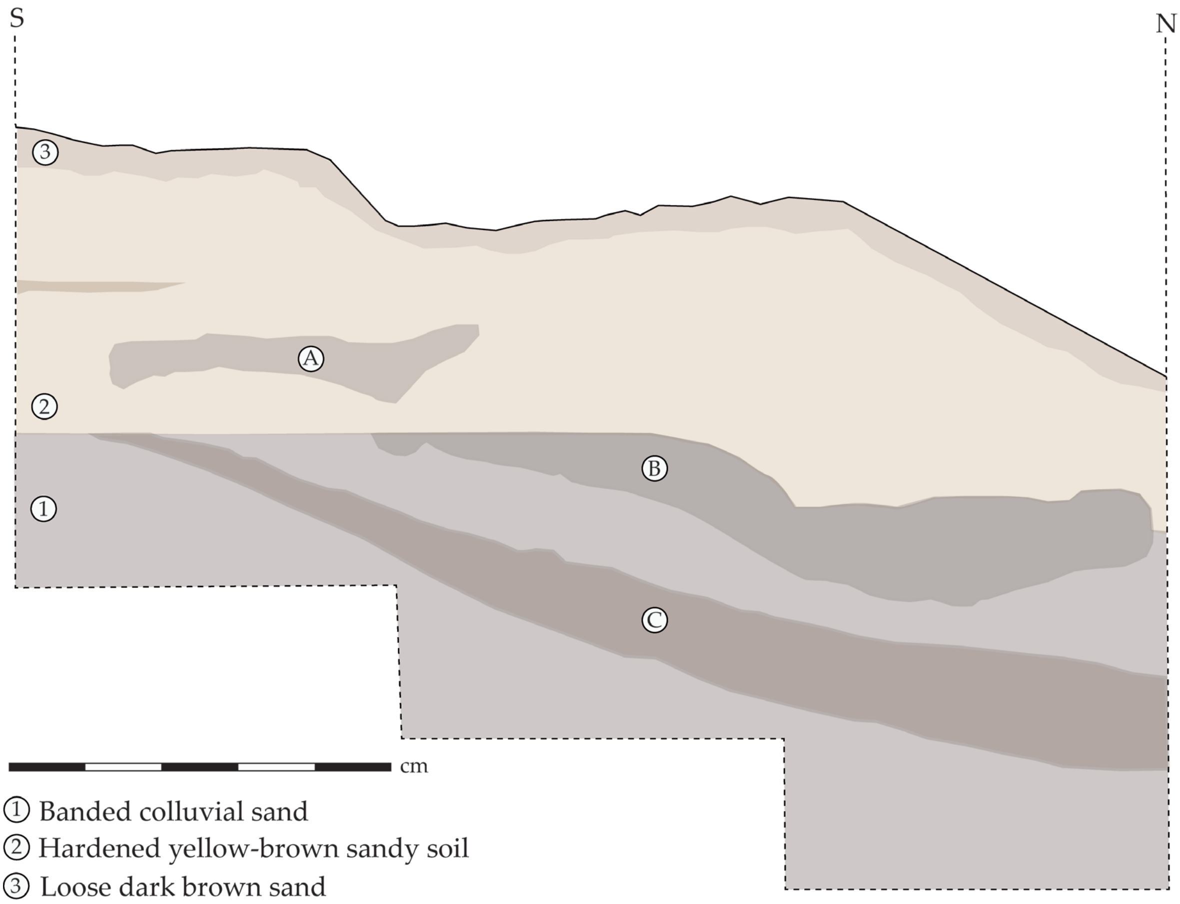


Figure 139: SC 27 Nyangana-Kangwenu, level index of the excavated area N98/43-1 to be used in conjunction with the Tables 17 and 35.



① Banded colluvial sand
② Hardened yellow-brown sandy soil
③ Loose dark brown sand
Ⓐ Dark gray sandy humic soil mixed with charcoal and cultural material
Ⓑ Dark gray sandy humic soil mixed with charcoal and cultural material
Ⓒ Dark brown sandy humic soil mixed with charcoal and cultural material

Figure 140: SC 27 Nyangana-Kangwenu, south-north running cross section facing east (simplified after Richter, 2005, p, 103).

channel the units were leveled down in quadrants and in artificial steps of 20 cm in thickness until sterile soil was encountered. The latter occurred at 40 cm below datum in the southwestern quadrant, and at 100 cm below datum in the northeastern quadrant. The datum line was defined as the highest surface elevation of the test trench (southwest corner of the excavation) (Figure 139).

2.27.1.2. Stratigraphy

Three cultural layers were identified (Figure 140). Layer A, the youngest deposit, was a small horizontal band of a dark gray sandy deposit mixed with charcoal and humic matter. It was embedded in a sterile hardened sandy soil matrix. Layer B occurred farther down the slope roughly 30 cm below surface. It was gray sandy humic deposit similar to Layer A, 5 cm to 15 cm in thickness. In this layer, the clay pot illustrated in Figure 141 was found, containing bones, slag and an unidentified substance. Layer C occurred approximately 10 cm below Layer B. They were separated from each other by sterile colluvial bands of sand. Layer C was an extensive deposit of dark brown sandy material, interspersed with charcoal and artifacts. It occurred about 60 cm below the current surface.

2.27.1.3. Radiocarbon dates

Three samples of charcoal from Layers A, B, and C were dated (Layer A: KN-5375, Layer B: KN-5377, Layer C: KN-5376, Table 2) (see also Richter, 2005, p. 86: Tab. 4). The calendar ages of the 2-sigma calibrated results ranged from the first half of the sixteenth to the mid-twentieth century cal AD (Figure 162). Even though the calendar ages of KN-5376 and KN-5377 fell between the years 1650 and 1800 cal AD (instead of 1950 cal AD), there is no satisfactory resolution possible with respect to the age of the site.

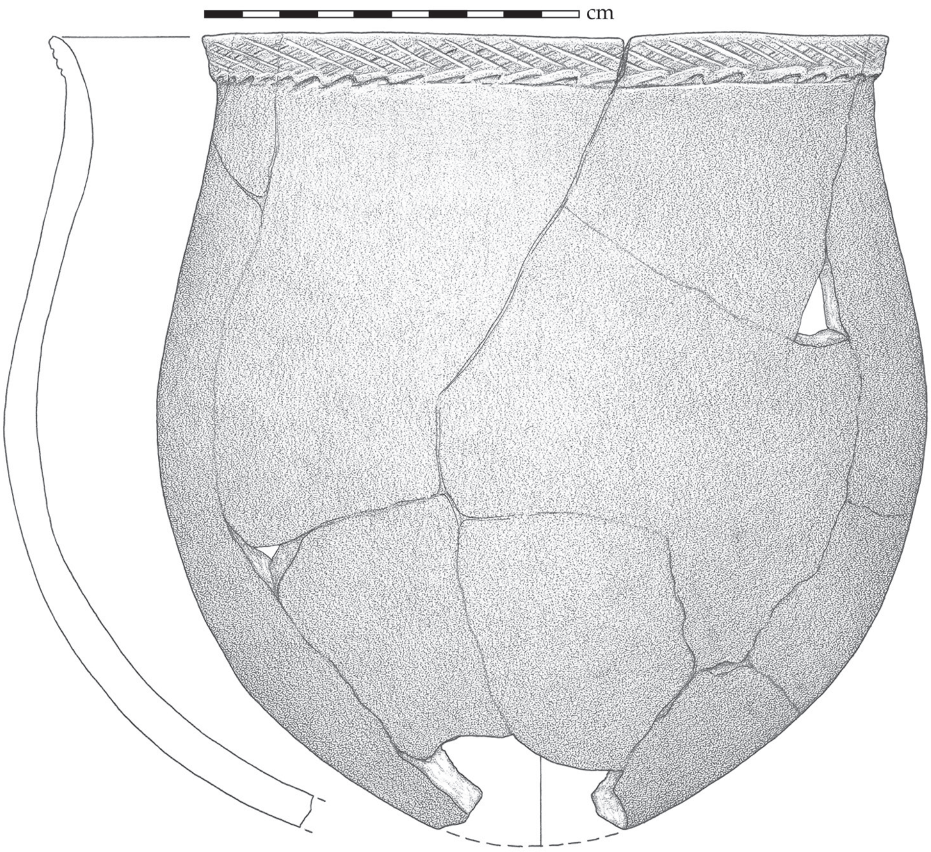


Figure 141: SC 27 Nyangana-Kangwenu, N98/43-1 Vungu-Vungu-style vessel (Drawing: A. Rüschmann).

2.27.1.4. Finds

The excavation revealed 38 pieces of pottery, accounting for 1781 g, an uncounted number of faunal remains, a stone artifact and 10 pieces of slag, adding up to 76.7 g. Another 52 potshards were collected from the surface, amounting to 464 g (Table 11, Appendix 3). All the ceramics (Table 17, Appendix 3) from the excavated units were typical grog-tempered Vungu-Vungu-style pottery. Organically-tempered ware was infrequent and derived only from surface collections.

All the slag finds were small pieces of processing slag from bloom consolidation (Table 35, Appendix 3). The limited number and the small size indicated that these finds originated from the sphere of a refining site. However, the finds represented only a small fraction of the anticipated spectrum of slag, in particular compared to the slag assemblage from N96/03-3 found at Vungu-Vungu (SC 12). One fragment of crown material was analyzed in polished cross section (sample 4440/06). The examination revealed that the sample was a compact piece of iron. It consisted of a mix of eutectoid steel and hypoeutectic cast iron. Furthermore, it contained phosphide inclusions (Figures 142 and 209). Both the high carbon content and the raised proportion of phosphorous indicated that the material was too hard and brittle for having been forged and processed. This was most probably the reason why it became discarded. However, sample 4440/06 demonstrated well that cast iron could be produced in the local bloomery smelters.

2.27.1.5. Interpretation

Nyangana-Kangwenu was a settlement site of the Late Ironworking Groups. The surface finds suggested that ferrous metallurgy was associated with the settlement. Area N98/43-1 was most probably a refuse dump at the edge of the river terrace. The slope and the nature of the layers embedded in sterile material suggested a midden situation, interrupted by erosional events. The midden deposit contained a few small slag remains, which attested that blooms were refined somewhere at the site. Most likely the eroding feature that was noticed when assessing the site was the ironworking zone of the settlement. The slag assemblage from N98/43-1 also provided evidence that local bloomery smelters could produce over-carburized steel and some cast iron. However, local ironworkers did not process iron of this quality. The excavation produced the best-dated site of the late occupation horizon within the Late Ironworking Groups. The cultural layers were well preserved under a cover of consolidated sand. The radiocarbon dates revealed that the occupation of the site was not from before 1650 AD.

2.28. Site catalogue no. 28 Shikoro

(Table 1, Figure 26)

Site Number: N98/42
Site Name: Shikoro
Coordinates: N98/42 (E20°43.094'/S18°00.880')
Constituency: Ndyona
Plane Survey Sheet Namibia 1:50 000: 1820 BA
Survey: 1998
Excavations: -
References: Richter, 2005, p. 102: Catalogue No. 73
Registration Number State Museum Windhoek: B4288

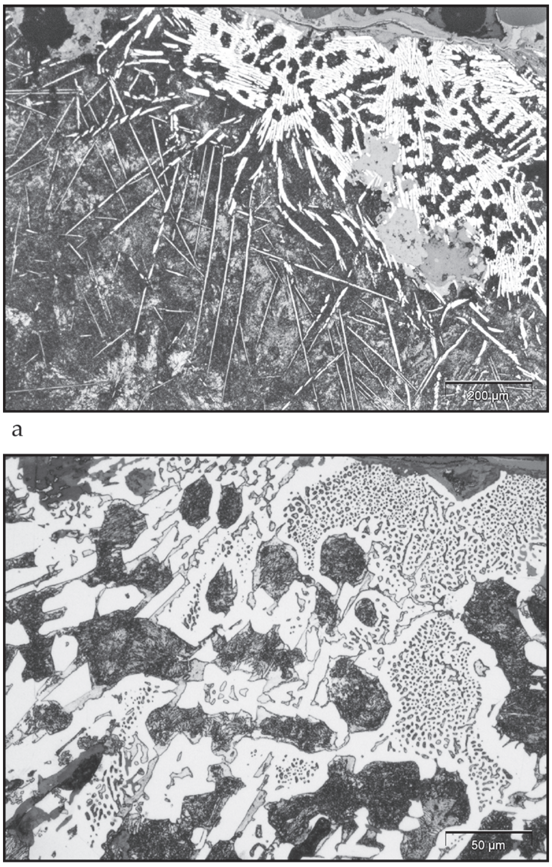


Figure 142: SC 27 Nyangana-Kangwenu, N98/43-1, discarded bloom sample 4440/06, a: Transition from slightly hypereutectoid steel (left corner, pearlite with secondary cementite) to hypoeutectic cast iron (right corner, ledeburite with pearlite islands). b: Hypoeutectoid cast iron (ledeburite and pearlite) with approximately 2.5% carbon.

Location: Immediately north of Local Road D3402 at Shikoro, 200 m east of the Shikoro Supermarket, 1.05 km east of the Shikoro Primary Junior School.
Altitude: 1051 m AMSL

Topography: The site is situated at the edge of middle terrace of the Kavango River on a cut bank of the river. The average slope of the terrace north of the road is about 6%.

Site Appearance: This was a scatter of potsherds roughly 300 x 300 m in extension. The area was uncultivated and vegetated with some trees.

Finds: The site produced some decorated and undecorated pottery (Tables 11 and 17, Appendix 3). Only selected finds were collected.

Pottery Style: Vungu-Vungu style.

Interpretation: This is a LIG settlement site of the late occupation period.

2.29. Site catalogue no. 29 Kapongo

(Table 1, Figure 26)

Site Number: N69/02, N06/02, N06/02-1
Site Name: Kapongo
Coordinates: N69/02 (-/-), N06/02 (E21°15.374'/S18°9.292), N06/02-1 (E21°17.039'/S18°9.622')
Constituency: Mukwe
Plane Survey Sheet Namibia 1:50000: 1821 AB and 1721 CD ANDARA (MUKWE)
Survey: 1969, 2006
Excavations: -
References: -
Registration Number State Museum Windhoek: B1973
Location: About 15 km south of National Highway B8, about 4 km southwest of Dikundu and about 2.5 km northwest of Havo in the Kapongo Omuramba (Figure 143).
Altitude: 1064 to 1066 m AMSL

Topography: Southeast-northwest stretching interdune valley in the Sandveld between fossil Kalahari dunes. The vertical height between the bottom of the valley and the top of the dunes is 15 m to 20 m. The dunes are densely vegetated and stable. The clayey silty soils of the valley bottom cause water stagnation during the rainy season. Climatic and topographic circumstances suggest active plinthite formation, although the

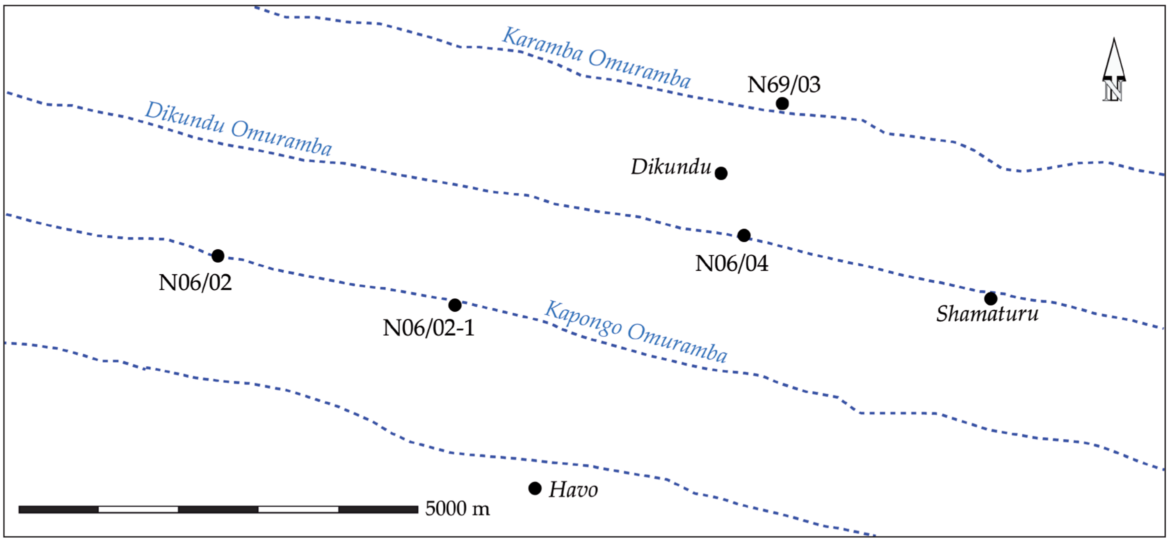


Figure 143: SC 29 Kapongo and SC 30 Dikundu, layout plan of sites.

ore nodules used in traditional smelting are fossils (see section 1.3.2.1). Places with efflorescent salt occur in the valley.

2.29.1. Area N69/02 and N06/02

(Table 1, Figure 143)

Site appearance: In a depression of the valley dense scatters of iron ore nodules occurred at the surface of several hundreds of meters in extension (Figure 144). The area was uncultivated and vegetated with some grass. Burrowers were very active and transported soil from deeper levels to the surface. The shape of the nodules suggested that they originally precipitated along insect and root channels in the soil, and weathered out later, perhaps due to the burrowers' activities.

Finds: Three samples recommended by the local ironworkers were analyzed (samples 4710/06, 4711/06, and 4712/06) (Tables 11 and 36, Appendix 3). The samples were assigned to the Group I ores discussed in section 4.1.1. The Fe_2O_3 content of the samples ranged between approximately 72wt% and 80wt%, while the silica proportions varied from approximately 6wt% to 15wt% (Tables 40 and 41, Appendix 3). The samples contained a high proportion of organic matter which increased porosity and made these ores best suited for iron production (section 1.4.1). Sample 4712/06 was analyzed in thin section and revealed that the nodules were aggregates of microgranular iron hydroxides. The matrix showed banded depositional sequences and cloud-like structures (Figure 171). The sample also contained cellular root channel structures, which were replaced by iron oxides. XRD analyses revealed that the main minerals were hematite, goethite, and quartz (samples 5191/07 and 5192/07).

Oral History: Ores and mining have been described by Petrus Kashako Kaputura (Appendix 2.5), who witnessed the iron production of Kapongo as a child. According to him, the ore nodules were collected from the surface of the bottom of the Kapongo Omuramba. They were not crushed or beneficiated before the smelt (section 5.3.1). Kapongo has also been described by Headman Kavinja in 1969 (Appendix 2.7). He recollected that ironworkers from the Mashi region smelted red sand from the Kapongo Omuramba.

Interpretation: Site N06/04 was a mining area of the Mbukushu people. It was also exploited by people living beyond the Kavango River. The ore was best suited for bloomery smelting. However, the time depth of the use of the resources from this site is not yet well understood.

2.29.2. Area N06/02-1

(Figure 143)

Site appearance: 3 km east-southeast of N69/02, on the southern edge of the Kapongo valley there was a group of some 30 fossil termite hills. The area was covered with trees and shrubs and opens towards the valley. People use the place for agriculture. The termite

Figure 144: SC 29 Kapongo, N06/02, historic mining area in the bottom of the Kapongo Omuramba after a bush fire in 2006 with Headman M. B. Tovero.

hills were used for traditional smelting and lots of slag was scattered around. The extent of the site had not been recorded. The termite hills were weathered, but some of them still seemed to have their original height. Others were removed by locals when they cleared the area for agricultural purposes.

Finds: No finds were collected.

Oral History: Smelting at Kapongo has been described by Petrus Kashako Kaputura (Appendix 2.5), who witnessed the iron production of Kapongo as a child. According to him, the smelting furnaces were hollowed-out termite hills of up to 1.80 m in height, in which the ironworkers produced cast iron. The furnaces were used several times and the waste from the smelts was discarded in the precincts of the smelting site, roughly 20 m away. Smelting sites were supposed to be situated at least 500 to 600 m away from the next homestead for cosmological reasons (section 5.3.6). The entire interview is reproduced and discussed in the ethnography Chapter 5 of this study.

Interpretation: Kapongo was a large smelting center of the Late Ironworking Groups. It seems as if the area has been assessed by smelters from the Mashi region in search of new mining grounds with quality ores. Later, it became a smelting center of the local Mbukushu population. It is not clear when smelting started at the site and future research will be necessary to illuminate the temporal and spatial dimension of Kapongo.

2.30. Site catalogue no. 30 Dikundu

(Table 1, Figure 26)

Site Number: N69/03, N06/04
Site Name: Dikundu
Coordinates:
N69/03 (N06/04-1) (E21°19.338'/S18°8.268'),
N69/03-1 (-/-),
N06/04 (E21°19.042'/S18°9.165')
Constituency: Mukwe
Plane Survey Sheet Namibia 1:50000: 1821 AB and 1721 CD ANDARA (MUKWE)
Sub clusters: N69/03-1(-/-)

Figure 145: SC 30 Dikundu, N06/04, well at the bottom of the Dikundu Omuramba in 2006. Behind the well starts the ancient mining area.

Figure 146: SC 30 Dikundu, N06/04, ancient overgrown mining area. In front of the donkeys traces of an old ore extraction pit (image: Götz Ossendorf).

Survey: 1969, 2006
Excavations: 1969
References: Sandelowsky 1974; 2004; Kose, 2009
Registration Number State Museum Windhoek: B1973
Location: About 13 km south of the National Highway B8. N69/03 is situated 1.25 km northeast of Dikundu, at the northern edge of the Karamba Omuramba, N06/04 is located 1.1 km southeast of Dikundu in the Dikundu Omuramba, east of a well (Figure 143).
Altitude: 1061 to 1067 m AMSL
Land Owner: N69/03: Marembo Bernardo Tovero

Topography: Southeast-northwest stretching interdune valleys in the Sandveld between fossil Kalahari dunes. The vertical height between the bottom of the valley and the top of the dunes is 17 m. The dunes are densely vegetated and stable. Clayey silty soils of the valley bottom cause water stagnation during the rainy season. Climatic and topographic circumstances suggest active plinthite formation. Therefore, geologically young ores occur together with fossil ores (section 1.3.2.10).

2.30.1. Area N06/04

(Figure 143)

Site Appearance: Site N06/04 was a mining area of about 1000 x 200 m in extension in a depression of the Dikundu valley (Figure 145). In this area, deeply red soil occurred with soft iron ore concretions immediately below the sod (Figure 12). These soft nodules (Figure 13) were said to be used in traditional smelting. Shallow depressions from traditional mining activities could be seen in the landscape. Today the area was overgrown with grass, trees and shrubs.
Two small test trenches were excavated in order to reveal more information about the thickness and nature of the ore-bearing horizon (Figure 12). Five to 15 cm below the surface, dry, soft sandy, silty clay occurred. The soil was plastic and sticky, and the color ranged from MCC 5YR4/4 reddish brown, MCC 5YR4/6 yellowish red to MCC 7.5YR4/6 strong brown. The soil was non-calcareous to very weakly calcareous. Within this horizon many soft nodules of iron oxides occurred of 3 cm to 5 cm in diameter (Figure 13). They were slightly hard, friable, roundish in shape, porous and penetrated by grass roots. The color ranged from 2.5YR2.5/3 very dusky red to MCC 2.5YR3/6 dark red. Locals considered the nodules good quality ore. At 15 cm to 25 cm below the surface, the soil changed into a dry, soft, slightly clayey and silty fine sand, non-plastic, slightly sticky and black in color (MCC 7.5YR2.5/1). Small, slightly hard amorphous iron oxide concretions occurred, yellowish brown in color (10YR5/6). This horizon was non-calcareous. The dark horizon graded into an increasingly yellowish horizon with irregular patches of gray and yellowish soil material.
In the eastern part of the recorded valley depression (Figure 146), an extremely hard sub-surface plinthic hardpan was found at about 10 cm below the current surface. The crust was 20 cm to 30 cm in thickness, the color ranged from MCC 2.5YR4/6 dark red, 7.5YR5/8 yellowish red to 10YR4/4 dark yellowish brown. The structure was porous and vesicular and the crust was non-calcareous. However, thin bands of crystallized calcite occurred. Chunks of the crust were found at the surface. They were the remnants of traditional mining activities because locals considered the crust being unsuitable as ore. The yellowish color indicated that goethite was the dominant mineral of the crust. No soil section was made to analyze the crust in situ.

Finds: Three samples recommended by the local ironworkers were analyzed (samples 4713/06, 4714/06, and 4715/06) and one sample of the ferruginous soil in which the iron segregations occurred (4716/06) (Tables 12 and 36, Appendix 3). The samples were assigned to the Group I ores discussed in section 4.1.1. The Fe_2O_3 content ranged between 61.8wt% and 76.1wt%, while the silica proportions varied from 2.94wt% to 8.16wt% (Tables 40 and 41). More interesting than the silica content was the high CaO proportion between 5.95wt% and 13.7wt%, making the ores most attractive for smelting. The samples also contained a high proportion of organic matter, which increased porosity and made these ores best suited for iron production (section 1.4.1). The soil sample 4716/06 revealed only 27.1wt% of Fe_2O_3. XRD analyses revealed that the main minerals were hematite, goethite, quartz and calcite (samples 5193/07 and 5194/07).

Oral History: Ores and mining have been described by Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje (Appendix 2.6), whose families were involved in the iron production at Dikundu. During the interview, they recollected

Figure 147: SC 30 Dikundu, N69/03, excavating the iron smelting furnace in 1969 (image: Beatrice Sandelowsky).

Figure 148: SC 30 Dikundu, N69/03, eroded iron smelting pit of Angolan smelters in the foreground, some 5 m away from the eroded shaft furnace in the termite hill in 1969 (image: Beatrice Sandelowsky)

Figure 149: SC 30 Dikundu, N69/03, leveling down the iron smelting pit from Figure 148 (image: Beatrice Sandelowsky).

Figure 150: SC 30 Dikundu, N69/03, partially bisected iron smelting pit from Figure 148 disclosing the black soil interspersed with charcoal, ashes and slags (image: Beatrice Sandelowsky).

that people living along the Kavango River came to the dry riverbeds in the Dikundu area in order to mine the ore and to smelt on site, or near their villages along the river. The interviewees remembered that the soft nodules were mined and smelted, and that there existed different qualities of ores, which were distinguished by color. Most ore was collected from the surface. However, people also extracted the material from pits of 1 to 1.2 m in depth (section 5.3.1).

Interpretation: Site N06/04 was a mining area of the Mbukushu people. The ore was best suited for bloomery smelting. The time depth of the use of the resources from this site is not yet well understood.

2.30.2. Area N69/03 (N06/04-1)

(Figure 143)

Site Appearance: On the northern edge of the Karamba Omuramba there was a fossil termite hill with a dense scatter of slag and ashes of at least 30 m in diameter (Figure 153). The dimension of the termite hill itself was about 6 m in diameter and 1 m in height. Around the hill, B. Sandelowsky identified several small heaps of clay, slag and remnants of deeply red iron ore, which formed a pronounced contrast to the surrounding soil. Immediately west of the termite hill, a shallow elevation of ashes, charcoal and slag occurred, also about 6 m in diameter. In 1969, the whole area was densely vegetated with trees and shrubs (Figure 147). Today, the hill was flattened but still visible in an agricultural area (Figure 153). The original hill was disturbed by backfilled or recent krotovinas. In 2006, the site was again visited and the area used as a crop field. The furnace in the termite heap was still visible as a shallow elevation in the field. Abundant slag littered the area and some samples were collected.

2.30.2.1. Excavation method

In 1969, a grid system of 1-m² units was laid out measuring 12 x 16 m in extension. The concentrations of surface finds were plotted. Two test trenches were excavated in order to obtain more information about the overall stratigraphy of the site. The first test trench (of unknown size) bisected one patch of red soil roughly 5 m away from the termite hill. The second trench bisected a shallow elevation near the anthill consisting of slag, charcoal and clay (Figures 148, 149 and 150). Locals remembered the latter to be a smelting pit of Angolan ironworkers. As the excavated test units revealed no clear structure and stratigraphy, the excavation was extended for an area of 7 x 5 m in extension, covering the southwestern quarter of the termite hill alongside with the slag heap. The units were leveled down to 1.25 m below datum (1.2 to 0.6 m below the surface) in artificial layers of 10 to 15 cm in thickness. Finds were collected according to the 1-m²-units. The north-south running section cut across the furnace in the center of the termite hill. Therefore, a trial was made to uncover the original surface of the furnace from its eastern side in natural layers. However, as the soil of the termite hill turned out to be too hard to be removed by trowel, this part of the excavation remained unfinished.

2.30.2.2. Stratigraphy

Four cultural layers were identified together with the actual furnace. The whole area seemed to be underlain by dark sandy soil, which appeared in some parts right at the surface, in other parts it was covered by cultural deposits. Thick layers of sandy ashy sediment interspersed with slag lumps, charcoal and fragments of burnt clay occurred around the termite construction, which was the center of the site and revealed the actual furnace. Also, patches with red soil were found around the furnace. The furnace shaft consisted of a wall of vitrified hardened termite clay, reddish to grayish in color and roughly 15 cm in thickness (Figures 151 and 152). The interior diameter of the shaft was approximately 65 cm. The furnace was preserved for about 1.20 m in height. The interior of the furnace was filled with a light consolidated sandy deposit, only at the bottom was a slag cake found in a charcoal bed from which a sample was taken for radiocarbon dating (section 2.30.2.4). In front of the furnace a deep small and a larger shallow depression filled with ashy material and charcoal were found. The shaft of the furnace was embedded in extremely hard consolidated material of the termite construction.

2.30.2.3. Finds

For this study, 24 slag samples were examined, amounting to 947.9 g (Tables 12 and 36, Appendix 3). The metal quality of two bloom fragments were analyzed in polished cross section (4708/06 and 4709/06)

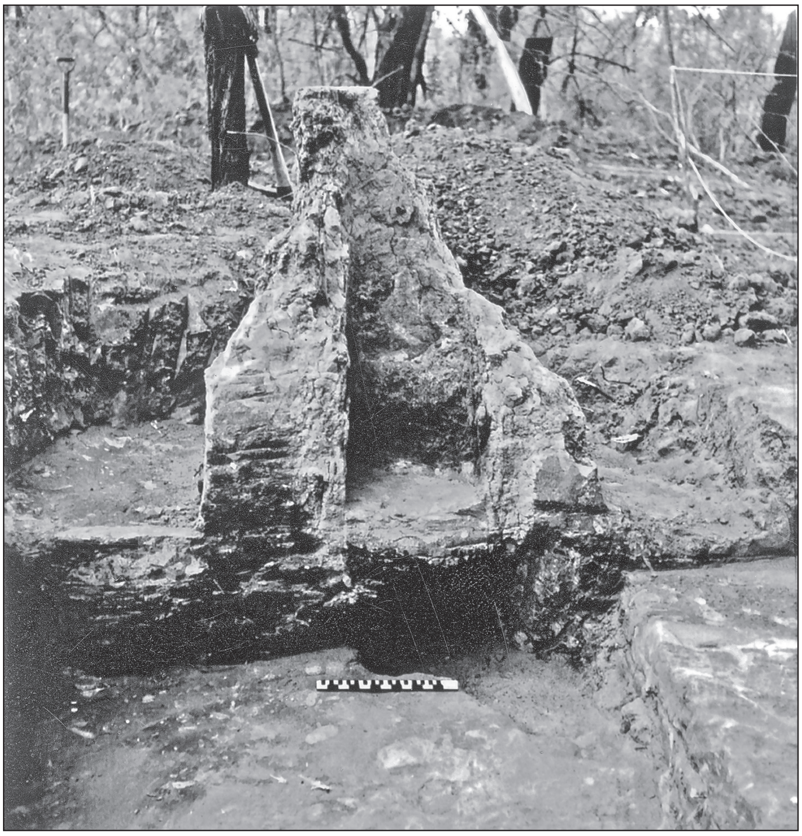


Figure 151: SC 30 Dikundu, N69/03, bisected iron smelting shaft furnace in the anthill (image: Beatrice Sandelowsky).

Figure 152: SC 30 Dikundu, N69/03, backside of the bisected iron smelting shaft furnace in the anthill (image: Beatrice Sandelowsky).

Figure 153: SC 30 Dikundu, N69/03, eroded iron smelting shaft furnace in the anthill from 1969 in 2006, still visible as a shallow elevation in a harvested crop field (image: Götz Ossendorf).

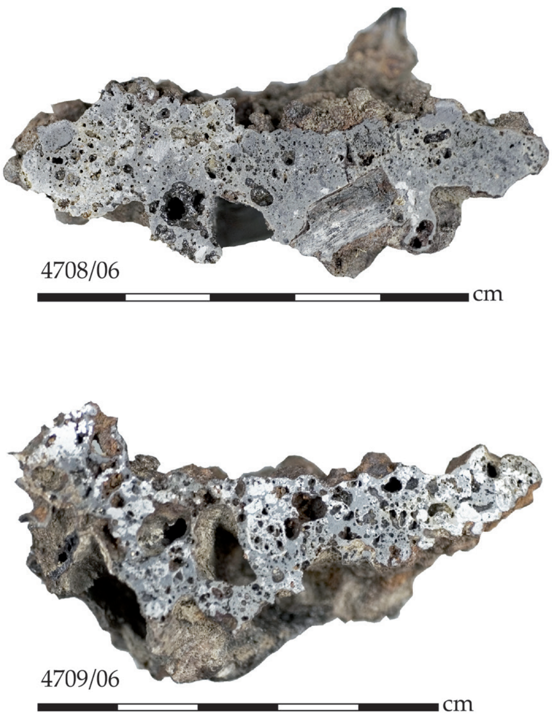


Figure 154: SC 30 Dikundu, N69/03, bisected blooms from the site, metallic iron is indicated by light gray to white colors.

(Figures 154 and 155), and the microstructure of the slag block found in situ in the furnace in 1969 was examined in thin section (4438/06) (Figure 185). Of the collected material, 20 specimens were flow slags from smelting and two bloom fragments were found. Two specimens remained unclassified. The slag scatter around the eroded furnace indicated that N69/03 was a smelting site. However, the slag block 4438/06 at the bottom of the furnace suggested that this furnace was used for refining processes at a certain moment in history. The slag analyses indicated that the ironworkers heated a bloom in the furnace in order to sinter it and to drain away redundant smelting slag (section 4.4.4). Sample 4708/06 from the precincts of the furnace revealed a partially sintered iron bloom in smelting slag, which contained several unreduced lumps of ore (Figure 174). The combination of a fully developed fayalitic slag with successfully reduced elemental iron and unreduced ore can be taken as evidence that the running furnace was replenished with ore (and probably fuel) to increase the yield of iron (section 4.1.7). The quality of the metal varied from pure iron to low carbon steel.

Sample 4709/06 was also a semi-condensed iron bloom in smelting slag (Figure 156). The quality of the metal ranged from pure iron to high carbon steel and was again evidence of the inhomogeneous distribution of carbon in iron produced in bloomery smelters (section 1.4.9).

2.30.2.4. Radiocarbon dates

A charcoal sample was taken in 1969, 75 cm below the surface from the bottom of the furnace (Pta-235, Table 2). Another sample of extracted charcoal from slag sample 4438/06 found in situ at the bottom of the furnace was analyzed for re-dating the site (Poz-20703, Table 2). Pta-235 produced a radiocarbon age of 120±20 years BP, while Poz-20703 resulted in 320±30 years BP. Both samples can be assigned to one and the same smelting or refining event, because the first came from the charcoal bed in which slag block 4438/06 solidified. The 2-sigma calibrated calendar age of Poz-20703 lay between the early sixteenth and the mid-seventeenth century cal AD, while Pta-235 fell into the modern calibration plateau between 1650 and 1950 (Figure 162). The discrepancy between the ages of the samples from the same event can be best explained by the use of wood from different trees. All dates from metallurgical sites must be treated with care because there is a tendency that charcoal was produced from old trees that could bias radiocarbon dates towards an older age (e.g. Killick, 1987, pp. 29-30) (see also section 5.3.3.6). N69/03 was therefore a good example of the dating problems metallurgical sites frequently bring about. Finally, only a series of dates from different sources such as provided to some extent at Vungu-Vungu (SC 12) allows one to establish a reliable chronological time frame of an ironworking site.

2.30.2.5. Oral History

The interview with Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus

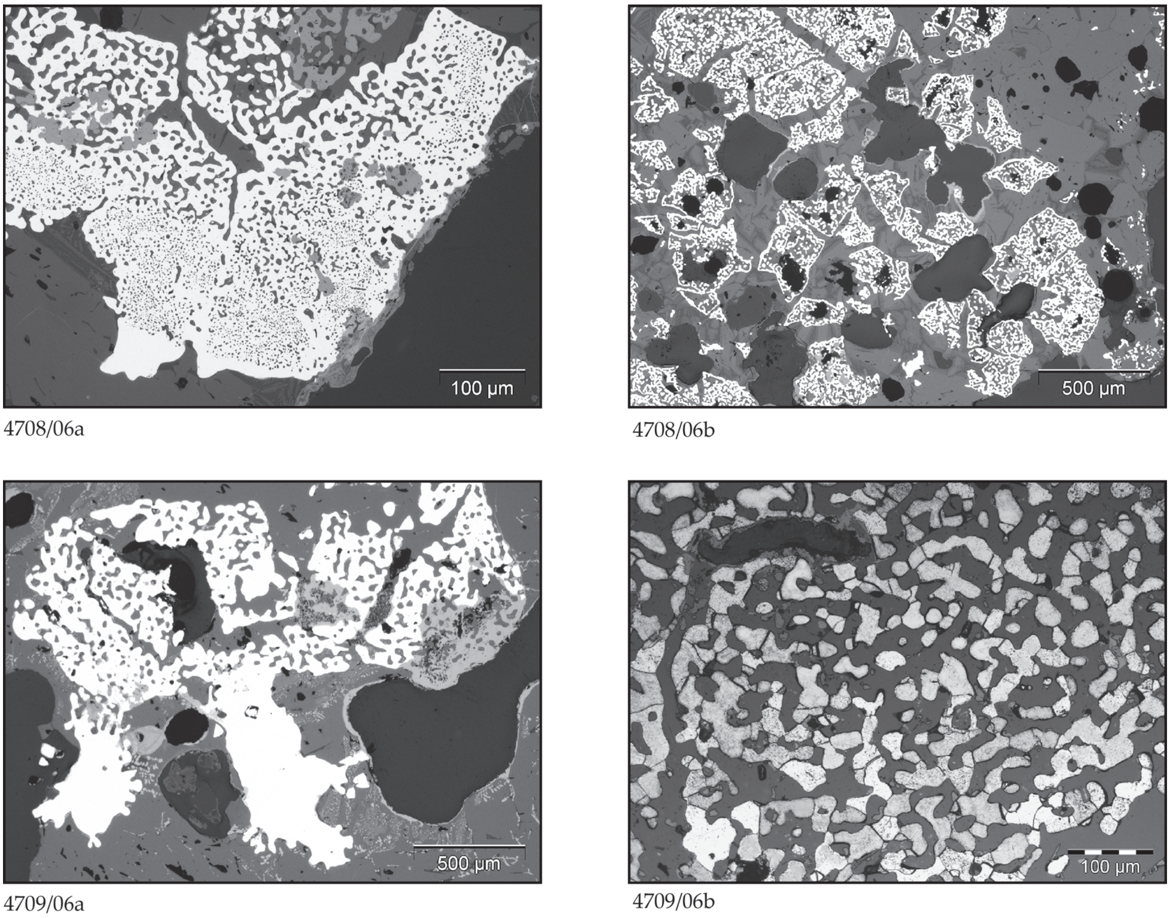


Figure 155: SC 30 Dikundu, N69/03, polished sections of the blooms of Figure 154. Sample 4708/06 a & b: Condensed and semi-condensed elemental iron (white) in fayalitic slag (light gray). Sample 4709/06a: Condensed metallic iron (white). Sample 4709/06b: Uncondensed wrought iron in a fayalitic slag. The iron consists of ferrite mono- and polycrystals with isolated tertiary cementite segregations along grain boundaries.

Figure 156: SC 30 Likundu, N69/03-1, smithing hearth bottom generated during refining processes. The attached sand evidences that the refining hearth was a pit in the sandy ground.

Kandunda and Peter Kandjendje (Appendix 2.6) provided valuable insights into the smelting traditions of Dikundu (see Chapter 5). According to them, smelting sites were secluded areas for spiritual reasons. The smelting site N69/03 was approximately 1 km away from the nearest homesteads. Like in Kapongo, people used hollowed-out termite hills and provided the furnace with drains for the molten iron. People usually used only one furnace at a time even if there was a high need for new iron. These furnaces were used for many years. Normally people smelted during the dry season, and every family (i.e. homestead) owned skilled ironworkers who formed one group of smelters during the smelting period. The smelters produced cast iron that was collected in furrows leading away from the furnace and that was treated in the forges of the ironworkers near their homesteads. The slag and ashes were dumped in a radius of 10 m around the furnace site.

Another account of smelting techniques was handed down by Headman Kavinja in 1969 (Appendix 2.7). He recollected that people from the Mashi region mined ore in the Kapongo valley but smelted in Dikundu. Their furnaces were small pits in the sandy ground and produced what is known as dirty blooms (section 1.5.1). These blooms were refined in a shallow open pit nearby. The places where the ore was stored before being smelted were still visible as red patches in the light and sandy soil in 1969.

2.30.2.6. Oral history and archaeology – is there a correlation?

In oral history it is handed down that people smelted in shaft furnaces as well as in small pits at the site (section 5.3.3.5). The archaeological investigations of Beatrice Sandelowsky at Dikundu revealed the remains of a shaft furnace in an eroded termite hill surrounded by a scatter of flow slag. During her excavation, Beatrice Sandelowsky was able to identify zones of reddened soil where high quality ore of local origin was stored before being processed. She also identified an area with a high amount of charcoal, slag and clay fragments. The latter was remembered by locals to be the remains of a smelting pit at the bottom of the termite heap containing the furnace. Although B. Sandelowsky succeeded in identifying the shaft furnace, which was situated in the fossil termite heap, the remains of the smelting pit would not have been recognized as such without the help of local memory. The extension of the zone, where slag can be found these days, is larger than the area remembered in the interview (Appendix 2.7). However, taking a certain dislocation of

finds into account owing to the agricultural activities at the site, the slag scatter still indicated the old furnace site.
The bloom fragments that were found and analyzed demonstrated that the people produced soft iron to high carbon steel. However, according to oral history people produced cast iron in the shaft furnaces, and a typical dirty bloom in the smelting pits (section 5.3.3.8). No archaeological or archaeometrical evidence of cast iron production has been found so far. Nevertheless, one must bear in mind that only a fraction of the site and the smelting techniques of the Mbukushu people has been examined so far (section 5.3.3.5). The analyzed blooms provided evidence of typical products from bloomery smelter: an inhomogeneous material ranging from soft pure iron and high carbon steel. Surprisingly the slag block 4438/06 found at the bottom of the furnace in 1969 indicated that the smelting furnace was also used as refining facility. What is more, the microstructure of the analyzed sample implied that a refining technique was applied, which was not mentioned in the interview with Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje in Appendix 2.6. The slag might have been formed from a secondary bloom sintering process comparable to what Van Tonder (1966, p. 264) described (see section 5.3.3.5). The interviewees from Dikundu however recollected that other people from more distant Mbukushu settlements used the area for smelting as well. This may explain the find, but more research is needed to better fathom the heterogeneity of the site.

Following the oral history interview (Appendix 2.6), people also refilled their shaft furnaces with ore and fuel in order to increase the yield of iron. This information found confirmation in the archaeometrical study in sample 4708 (section 2.30.2.3). As reported in section 5.3.3.5, one group of smelters used one furnace for several years. From the Mashi smelters, Headman Kavinja (Appendix 2.7) remembered that every smelter smelted his own ore, but he did not hand down whether they used several pits or only one furnace one after another. However, considerably more archaeological work will need to be done to determine the service life of one furnace and the time depth of a furnace site. Up to the present, the archaeological furnace site is a remote place from the village.

2.30.2.7. Interpretation

N69/03 was a smelting site of the Mbukushu and their neighbors from the Mashi region. It belongs to the settlement horizon of the Late Ironworking Groups. The shaft furnace and the smelting pit excavated by B. Sandelowsky are the only smelting facility, which have so far been identified in the archaeological record of the Kavango region. The history of the site was heterogeneous and at least two different smelting techniques were practiced by the smelters. In light of the finds from N69/03-1, it can be assumed that there were also two different refining techniques applied. However, more research is necessary to investigate the time depth and the spatial dimension of the site.

2.30.3. Area N69/03-1

Site Name: Likundu
Site Appearance: In an unknown distance away from smelting site N69/03 a scatter of slag was found around a burnt tree. The finds concentrated on one side of the tree. The area was densely vegetated with trees and shrubs.

Excavation method: A grid of 8 x 8 m was laid out around the burnt tree. The surface of the area was cleared and the removed soil sifted. The finds were plotted and collected according to the grid system.

Stratigraphy: Slag was mainly found in the units G8, G9, and G10. In the units G9 and G10, clay tuyere fragments occurred. In unit E/F10, two metal fragments were collected. According to locals, the tree burnt down during a bush fire.

Finds: An uncounted number of slag, tuyere, and metal fragments were recovered from the site. Nine pieces of slag (380 g) and two tuyere fragments (34.5 g) were available for this study (Tables 12 and 36, Appendix 3). Only one fragment of smelting slag was found. All the others were refining slag and three unclassified pieces. Among the processing slag, three fragments of a large smithing hearth bottom attracted attention (Figure 156). They provided evidence that the refining hearth was a simple pit in the sandy ground. Two of the fragments also contained tuyere remains. The ankles of the tuyere fragments suggested that the pit was rather shallow. From the limited amount of finds analyzed one could deduce that N69/03-1 was a refining site.

Interpretation: This was a refining site in the periphery of smelting site N69/03. The examined slag provided evidence that the slag was refined in a shallow small pit in the sandy ground. Most probably, the refining procedure was similar to what has been described by Headman Kavinja in the interview in Appendix 2.7 (see also section 5.3.3). The site is not yet dated, but there is a strong possibility that it belonged to the occupation period of the Late Ironworking Groups.

2.31. Site catalogue no. 31 Mapuri

(Table 1, Figure 26)

Site Number: N99/14
Site Name: Mapuri
Coordinates: E19°44.400'/S17°58.900'
Constituency: Rundu Rural
Plane Survey Sheet Namibia 1:50000: 1719 DC MUPINI
Survey: 1999
Excavations: -
References: Richter, 2005, p. 89: Catalogue No. 7
Registration Number State Museum Windhoek: B4288
Location: 10 m east of Local Road D3400, 1.6 km north of the Mavandje Senior Primary School in the Ndonga Omuramba.
Altitude: 1083 to 1088 m AMSL

Topography: The site is situated in a catena of a fossil tributary to the Kavango. The quarry cuts through the area in a toe and depression of the valley. The area is seasonally waterlogged in years with strong rainfall. The site provides evidence of the Eiseb Formation. Under a thick layer of dark gray fluvial upper soil of up to 1 m in thickness, a near surface calcrete hardpan occurred, 50 cm in thickness, which graded into a softer, nodular calcareous horizon of about 30 cm in thickness. The latter transitioned into a semi-consolidated calcareous deposit of sand and silt, 3 m in thickness, with an increasing hardness and proportion of $CaCO_3$ nodules downwards. The consolidated horizon overlies an unconsolidated calcareous sandy deposit with bands of gravelly chalcedony. The deepest horizon observed in the section consists of limestone with crystalline calcium carbonate and quartzite inclusion.

Site Appearance: This was a modern quarry for road construction approximately 600 x 250 m in extension. The quarry displayed a profile of the geological formation of the valley's bottom, 6 to 7 m in height. Within the area, two ponds had formed. Stone artifacts were found 4 m below the surface in the lower part of the thick, semi-consolidated calcareous deposit of sand and silt. Dislocated bones and lithics were collected next to the section from the bottom of the quarry.

Finds: Several lithics and bones were collected. The stone artifacts belong to the Early Stone Age.

Pottery Style: -

Lithic Typology: Early Stone Age.

Interpretation: This was a modern gravel quarry, which provided insight into the Eiseb Formation (section 1.3.2.9). The stone artifacts were evidence of an Early Stone Age occupation of the area. The stratigraphic affiliation of the faunal material was uncertain.

2.32. Site catalogue no. 32 Kauti

(Table 1, Figure 26)

Site Number: N07/02, N07/03, N07/06
Site Name: Kauti
Coordinates:
N07/02 (E19°45.251'/S18°6.803'),
N07/02-1 (E19°45.350'/S18°6.801'),
N07/03 (E19°44.733'/S18°6.990'),
N07/06 (E19°45.407'/S18°7.491')
Constituency: Rundu Rural
Plane Survey Sheet Namibia 1:50000: 1819 BB NCUNCUNI (SHIMPANDA)
Survey: 2006, 2007
Excavations: -
References: -
Registration Number State Museum Windhoek: -

2.32.1. Area N07/02

(Figure 157)

Location: 40 m east Local Road D3400 at Kapupahedi in the Ndonga Omuramba. Coming from Rundu, the site is situated west of a sharp left hand bend in the road, in the bottom of the valley.
Altitude: 1097 m AMSL

Topography: The fossil Ndonga valley cuts about 30 m deep into the landscape. The site is situated in a depression of the bottom of the fossil valley (Figure 158). Here, a fossil tributary

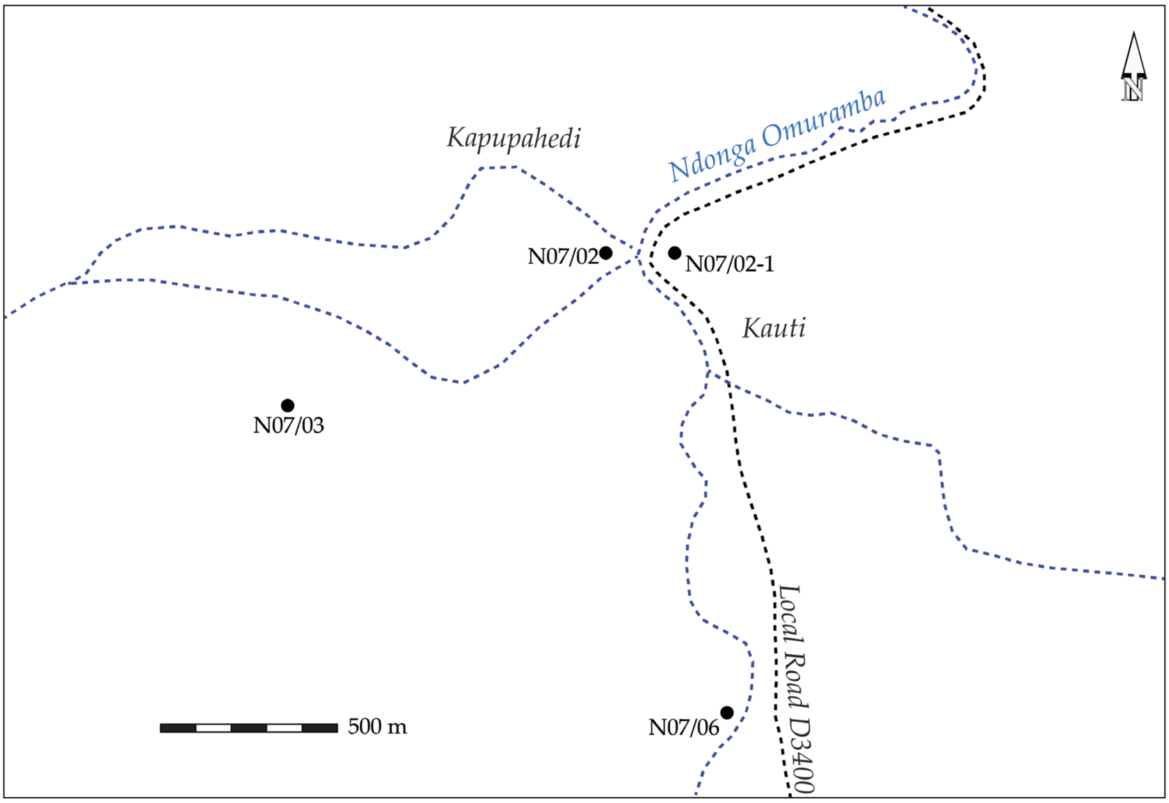


Figure 157: SC 32 Kauti, layout plan of sites.

joins with the main valley from the west. The area is slightly concave. In climatic periods with strong rainfall, the valley was filled with perennial water. In climatic periods with less rainfall, the dark gray clayey fluvial deposits of the valley bottom cause water stagnation during the rainy season and favor plinthite formation in zones of seasonal waterlogging. Therefore, active plinthite formation can be expected as well as fossil deposits (section 1.3.2.10). Although no sample was taken, I expect the same type of ore that was found 1.3 km south in a similar topographic position (see N07/06 and N07/07-1, SC 33 and N99/15, SC 34).

Site Appearance: In an area of about 300 x 400 m, the bottom of the valley was covered with shallow depressions of 1 to 2 m in diameter and about 50 cm and less in depth, between small heaps of soil. The area was remarkably different from the usual flat and even bottom of the valley. The entire extension of the site has not been recorded. The site was densely overgrown with grass and used for grazing.

Oral history: According to residents, this was a historical mining area belonging to smelting site N07/02-1. No further investigations were carried out.

Finds: No finds were collected.

Interpretation: Presumably traditional mining area of N07/02-1.

2.32.2. Area N07/02-1

(Figure 157)

Location: 40 m east of Local Road D3400 at Kapupahedi in the Ndonga Omuramba. Coming from Rundu, the site is situated in a sharp left hand bend of the road, on the east bank of the fossil valley.
Altitude: 1104 m AMSL

Topography: The site is situated in a lower slope position on a slip-off-slope of a fossil tributary to the Kavango River, about 6 m above the bottom of the valley. The area declines about 1.3% towards west. Well-aerated loose light-gray sandy soil prevents the surface water from forming drainage channels towards the bottom of the valley. The soil forms a pronounced contrast to the dark clayey soil of the nearby valley bottom.

Site Appearance: Scatter of slag and some chunks of charcoal approximately 80 to 50 m in extension west of a modern homestead (Figure 158). The area was vegetated with some trees and grass. The complete extension

Figure 158: SC 32 Kauti, smelting site N07/02-1 in the foreground. In the background the valley bottom of the Ndonga Omuramba where mining area N07/02 is situated.

of the site has not been identified. The modern homestead and the activities of the residents disturbed the archaeological pattern.

Finds: Seven slag specimens (1093.7 g) were collected and visually examined (Tables 12 and 37, Appendix 3). The finds comprised smelting and processing slag. One specimen remained unclassified. Two specimens of smelting slag contained small particles of unreacted ore at the bottom. Bulk chemistry of one sample was analyzed (sample 5190/07) (Tables 44 and 45, Appendix 3). It revealed a high fraction of iron oxide, which may owe to the unreduced ore, and showed a chemical signature which linked the sample to the ore source of N07/03 (section 4.2.12). However, more research would be needed to illuminate the mining, smelting, and settlement activities of Kauti.

Pottery Style: -

Interpretation: This was a smelting site of the Late Ironworking Groups. The source of the ore probably was the plinthic hardpan assessed at site N07/03.

2.32.3. Area N07/03

(Figure 157)

Location: 1.2 km west of Local Road D3400 at Kapupahedi in the Ndonga Omuramba, roughly 900 m west-southwest of N07/02.

Topography: The site is situated in a slightly concave toe of slope position where a fossil tributary from the west joins with the main valley. The area lies 2 m above the average altitude of the bottom of the valley, and 28 m below the upper edge of the fossil valley. It declines 0.6% towards east-northeast.
The iron hardpan found is a near-surface accumulation and segregation of imported iron oxides in a toe of slope position (Figure 14). The composition of reddish soil nearby grading into grayish soil indicates different degrees of drainage and aeration under which the iron oxides segregated (Fey, 2010, p. 102). The thick iron crust most probably precipitated under poorly drained conditions with pronounced recurrent cyclic wetting and drying. The iron oxides originated from the lateral and downward leaching of up-slope iron-enriched horizons of the Omatako

Figure 159: SC 32 Kauti, smelting site N07/03 smelting experiment in 2007 in a shaft furnace under the guidance of the Chokwe ironworker Johannes Mashela Kenga, using the ores from Kauti.

Formation, which are well detectable in the general topography of the valley (section 1.3.2.10). In light of its topographic position within the catena, it must have happened in climatic periods with higher rainfall than today during which elevated topographic positions within the valley were affected by seasonal waterlogging.[95] Another explanation would be that the plinthic horizon segregated in times when the valley bottom was not as deeply incised, as it is today. Today, the area is dry all year round. As the hardpan occurs immediately below the modern surface I assume that the plinthic soil horizon in which the hardpan originally formed has eroded away. The thin sand cover only seems to be a secondary top layer.
Altitude: 1097 m AMSL

Site Appearance: The iron hardpan occurred in an area of a minimum 200 m in diameter. The entire extension of the occurrence has not been assessed. Strongly red loamy soil comparable to Koro (N07/07, SC 33) occurred west and south of the site in topographic positions that were slightly higher than N07/03. The area was used for crop cultivation and was scarcely vegetated with some shrubs, trees, and crops. Chunks of the iron hardpan were scattered around in plowed areas. No signs of mining were detected.

Stratigraphy: A 1.5 x 1.5 x 0.8 m square was excavated in order to gain iron ore for experimental smelting. The section of the pit revealed the following soil sequences (Figure 14): Under a thin upper soil horizon of pale, grayish slightly silty sand, a plinthic hardpan occurred of about

[95] Climatic conditions of such a kind are handed down in the Tjaube chronicle (Fleisch & Möhlig, 2002, p. 40).

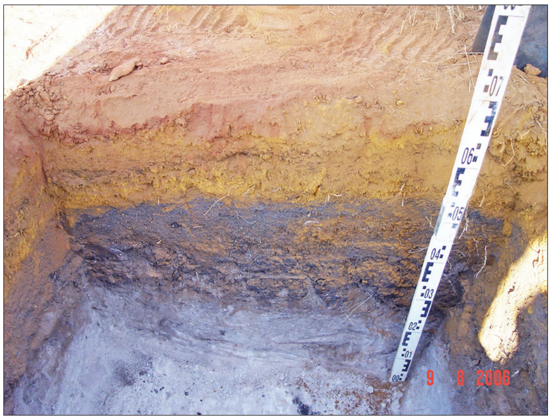


Figure 160: SC 33 Koro, N07/07, soil section.

40 to 50 cm in thickness. It overlay a pale layer of fine sand with vertical structures of iron oxide segregations, probably along root channels.

Oral history: According to locals, comparable ore was used in traditional smelting.

Finds: Iron ore sample (5202/07//5188/07, Tables 12 and 37, Appendix 3).

Interpretation: Iron ore occurrence, mining site for our smelting experiment in 2007 (Figure 159).

2.32.4. Area N07/06

(Figure 157)

Location: 60 m west of Local Road D3400 at Madudu in the Ndonga Omuramba, 1.3 km south of N07/02.
Altitude: 1100 m AMSL

Topography: At the bottom of the fossil valley, where a fossil tributary joins the main valley from the east, dark gray calcareous iron oxide segregations occur in a near-surface horizon. The area is slightly concave. The formation of comparable iron segregations has been described earlier under N07/02 (see also Koro, N07/07-1, SC 33 and Hamoye, N99/15, SC 34).

Site Appearance: In an area of about 250 m in diameter, dense surface scatters of dark gray nodules of calcareous iron oxides occurred, in particular in cultivated areas. The entire extension of the occurrence has not been recorded. The site was densely overgrown with grass and used for crop cultivation in some parts.

Oral History: According to locals, this type of ore was used in traditional smelting

Finds: Iron ore (Tables 12 and 37, Appendix 3), no samples were analyzed.

Interpretation: Iron ore occurrence.

2.33. Site catalogue no. 33 Koro

(Table 1, Figure 26)

Site Number: N07/07, N07/07-1
Site Name: Koro
Coordinates:
N07/07 (E19°45.494'/S18°11.671'),
N07/07-1 (E19°45.722'/S18° 11.545')
Constituency: Rundu Rural
Plane Survey Sheet Namibia 1:50000: 1819 BB NCUNCUNI (SHIMPANDA)
Survey: 2006, 2007
Excavations: -
References: -
Registration Number State Museum Windhoek: -

2.33.1. Area N07/07

Location: 85 m east of Local Road D3400 at Koro in the Ndonga Omuramba.
Altitude: 1123 m AMSL
Topography: The site is situated in a slightly concave toe of slope position, 2 m above the average altitude of the bottom of the valley. A small fossil tributary joins the main valley from the west. The area declines 2.2% towards east. Red and yellow soil covers the area (Figure 11) comparable to Site N06/04 (SC 29) in the Dikundu Omuramba. As mentioned previously, the fossil valley was filled with perennial water in times of strong rainfall in geologically younger periods. In climatic phases with less rainfall, the area was affected by seasonal waterlogging, which favored plinthite formation (section 1.3.2.10). Today, the area is dry all year round.

Site Appearance: In an area of about 200 m in extension, strongly yellowish-red soil occurred at the surface. The entire extension of the occurrence has not been recorded. The site was partly overgrown with grass and used for grazing (Figure 11).

Stratigraphy: A test unit of about 50 x 50 x 70 cm in dimension was excavated and revealed the following soil horizons (Figure 160): The upper horizon consisted of a 10 cm deep non-calcareous slightly sandy silty clay, reddish brown (MCC 5YR3/4) to dark brown (MCC 7.5YR3/4) in color. Slightly hard small segregations of iron-(hydro) oxides, strong brown in color (MCC 7.5YR5/8), occurred commonly in this horizon. The red horizon was followed by a silty to clayey horizon, 20 cm thick and yellow in color (MCC 2.5Y7/8), with numerous small slightly hard amorphous iron oxide segregations. From 30 to 55 cm below surface, a soft, slightly sandy silty clay horizon followed, reddish black in color (MCC 2.5YR2.5/1). This horizon was non-calcareous and with a few rusty iron-(hydro) oxide precipitations along pore spaces. The latter were strong brown in color (MCC 7.5YR5/8). The deepest recorded horizon of the test section was a soft sandy deposit white in color (MCC N8).

Finds: A sample of iron-rich soil was taken (5203/07) (Tables 12 and 37, Appendix 3). It was classified to the Group I ores (section 4.4.1) and it contained 66.7wt% of Fe_2O_3 (Tables 40 and 41, Appendix 3). The mineral composition of the soil according to the XRD analysis was quartz, goethite, and siderite.

Interpretation: Iron ore occurrence at the surface of a paleo-riverbed. This was an accumulation and segregation of imported iron oxides in a toe of slope position. The red, yellow and black colors indicated different degrees of drainage and aeration under which the iron oxides precipitated (section 1.3.2.10). The iron oxides originated from the lateral and downward leaching of up-slope iron-enriched horizons of the Omatako Formation, which were well detectable in the general topography of the valley.

2.33.2. Area N07/07-1

Location: 400 m east of Local Road D3400 at Koro in the Ndonga Omuramba, 450 m northeast of N07/07.
Altitude: 1110 m AMSL

Topography: The potential iron ore occurs at the bottom of the fossil valley. The area is slightly concave.

Site Appearance: In an area of at least 700 x 300 m, dark gray nodules of iron oxides were found in the clayey dark gray upper soil horizon. Numerous iron nodules were scattered at the surface in cultivated areas. The entire extension of the occurrence has not been recorded. The deepest and wettest part of the valley bottom was densely overgrown with high reddish reed.[96] According to Johannes Kenga Mashela, a Chokwe ironworker from Vungu-Vungu, this type of reed is considered an indicator of iron ore. Other parts of the valley were overgrown with grass, and used for crop cultivation and grazing.

Stratigraphy: A shovel test pit was excavated of 30 x 30 x 50 cm in dimension. It revealed dark gray clayey soil with common hard, coarse, vesicular nodules of iron hydroxides. The bottom of the dark soil horizon was not reached.

Oral History: According to locals, this type of ore was used in traditional smelting

Finds: Iron ore sample (Tables 12 and 37, Appendix 3).

Interpretation: Iron ore occurrence. A formation of comparable iron ore segregations has been described earlier for Kauti (N07/02, SC 32, N07/06, SC 32, and Hamoye, N99/15, SC 34).

2.34. Site catalogue no. 34 Hamoye

(Table 1, Figure 26)

Site Number: N99/15
Site Name: Hamoye
Coordinates: E19°44.141'/S18°14.097'
Constituency: Rundu Rural
Plane Survey Sheet Namibia 1:50000: 1819 BA NCAGCU (NKUTU), 1819 BB NCUNCUNI (SHIMPANDA)
Survey: 1999, 2006
Excavations: -
References: Richter, 2005, p. 102: Catalogue No. 71
Oral History: -
Registration Number State Museum Windhoek: B4288
Location: 360 m west of Local Road D3400 and 370 m east of the Forestry Station at Hamoye in the Ndonga Omuramba.
Altitude: 1120 to 1124 m AMSL

Topography: The site is situated in the upper Ndonga valley where three fossil tributaries merge into the main valley. The area declines 1.7% towards southeast. Red and yellow clayey soils occur in the toe of slope position and grade into dark gray soils towards the bottom of the valley. The bottom of the valley is affected by seasonal waterlogging. The toe of slope area is dry all year round. The site displays near-surface accumulations and segregations of imported iron oxides at the bottom of the catena. Similar topographic conditions were encountered at Kauti (SC 32) and Koro (SC 33) and are described in detail there.

Site Appearance: Iron ore nodules occurred abundantly throughout the valley in an area of about 700 x 200 m in extension. The entire extension of the occurrence has not been assessed. The deepest and wettest part of the valley was densely overgrown with high reddish reed comparable to that at Koro (N07/01-1, SC 33). Large parts of the valley were used for agriculture. For reasons unknown the whole area has been disturbed by pits and dislocated topsoil. Chunks of strongly ferruginous sandstone were found in the dislocated soil.

Finds: Iron ore sample, ferruginous sandstone of the Omatako Formation (Tables 12 and 37, Appendix 3). No samples were analyzed. The site produced also several fragments of burnt clay. No slag was recorded and the interpretation as an ironworking site as suggested by Richter (2005, p. 100) could not be confirmed in the following assessment of the site.

Interpretation: Iron ore occurrence, undated settlement site.

2.35. Site catalogue no. 35 Tamsu

(Table 1, Figure 26)

Site Number: N99/19
Site Name: Tamsu
Coordinates: E20°33.89'/S18°35.110'
Constituency: Ndyona
Plane Survey Sheet Namibia 1:50000: 1820 DA
Survey: 1999
Excavations: -
References: Richter, 2005, 102: Catalogue No. 71
Registration Number State Museum Windhoek: B4288
Location: 120 m south of Local Road D3411 in the Khaudom Omuramba. Topography: The site is situated in the upper Khaudom valley in the slightly concave bottom of the valley. Sandy and clayey deposits are overlain by a calcareous hardpan. The bottom of the valley is affected by seasonal waterlogging.

[96] Unfortunately, I was not able to identify this type of reed botanically.

Altitude: 1092 m AMSL

Site Appearance: Artificial waterhole in the bottom of the valley. The pit exposed a soil section of 2.60 m. Giraffe bones together with glass beads were scattered around the waterhole. Traces of elephants have been found.

Finds: Nine white glass beads were found and several faunal remains (Tables 12 and 17, Appendix 3). The beads were small barrel-shaped specimens and corresponded to Kinahan's Variety 2 and Variety 5 (Kinahan, 2000, p. 108). As discussed in Kose (2004, p. 124), size and shape placed these varieties into Kinahan's Middle and Late Contact Period in the nineteenth and twentieth centuries.

Interpretation: The site was a temporarily occupied area at a waterhole in the Khaudom Omuramba. The beads dated the site to the late occupation period of the Late Ironworking Groups. As no pottery was found, I assume that hunter-gatherer groups occupied the site. They maintained exchange relationships with the people of the middle Kavango region and gained access to European trade beads (see Kose, 2009b, pp. 142-145).

2.36. Site catalogue no. 36 Andara Island

(Table 1, Figure 26)

Site Number: N68/03
Site Name: Andara Island
Coordinates: Around 18°03'S/21°26'E
Constituency: Mukwe
Plane Survey Sheet Namibia 1:50000: 1821 AB and 1721 CD ANDARA (MUKWE)
Survey: 1968
Excavations: -
References: -
Registration Number State Museum Windhoek: B1590
Location: Island close to the Andara Catholic Mission, no exact localization possible.
Topography: On an island in the Kavango River, about 3 m to 5 m above the current water table.
Altitude: Around 1025 m AMSL

Site Appearance: Scatter of potsherds and glass beads. The area was densely vegetated with trees and shrubs.

Finds: Approximately 30 finds were collected from the site, among them pottery, a stone implement and a glass implement, burnt clay, glass beads and ostrich eggshell beads. Eight potsherds adding up to 187 g were reassessed in the framework of this study. Among them typical grog-tempered Vungu-Vungu-style ware. Two specimens were decorated with uncommon motifs, yet they did not belong to the Gove-style ceramics. The artifact scatter also included seven ostrich eggshell beads, seven white glass beads and one pink specimen. All the glass beads were small barrel-shaped specimens and correspond to Kinahan's Variety 2, Variety 5 and Variety 21 (Kinahan, 2000, pp. 108, 110). Size and shape placed these varieties into Kinahan's Middle and Late Contact Period between the nineteenth and twentieth centuries (see also Kose, 2004, p. 124).

Pottery Style: Vungu-Vungu style and unidentified.

Interpretation: This was an occupation site of the Late Ironworking Groups of the nineteenth or early twentieth century. The uncommon motifs that some of the pottery was decorated with may hint at influences from neighboring groups. The extension of the site has not been assessed because of the dense vegetation.

2.37. Site catalogue no. 37 Andara South

(Table 1, Figure 26)

Site Numbers: N83/01
Site Name: Andara South
Coordinates: 18°04.259'S/21°26.924'E
Constituency: Mukwe
Plane Survey Sheet Namibia 1:50000: 1821 AB and 1721 CD ANDARA (MUKWE)
Survey: 1983
Excavations: -
References: Kinahan, 1986
Registration Number State Museum Windhoek: B2694
Location: Approximately 1.07 km south of the Andara Catholic Mission, 50 m east of Local Road D 3402.
Altitude: 1028 m AMSL

Topography: The site is situated on a middle terrace, about 190 m away from the main river. The area declines about 4% towards northeast.

Site Appearance: Surface scatter of artifacts.

Finds: Two shards were collected, one of them being a decorated organically-tempered specimen. The shard showed a comb-stamped decoration motif (Kinahan, 1986, Fig. 3.1) but its chronological association to the EIG occupation period or the early LIG pottery horizon is not clear.

Pottery Style: Unspecific.

Interpretation: The potsherd may indicate a settlement site of the Ironworking Groups.

2.38. Site catalogue no. 38 Dryogha

(Table 1, Figure 26)

Site Numbers: N83/02
Site Name: Dryogha
Coordinates: 18°04.986'S/21°29.178'E
Constituency: Mukwe
Plane Survey Sheet Namibia 1:50000: 1821 AB and 1721 CD ANDARA (MUKWE)
Survey: 1983
Excavations: -
References: Kinahan, 1986
Registration Number State Museum Windhoek: B2695
Location: Approximately 700 m east-southeast of the Frans Dimbare Youth Centre, 890 m north of Local Road D 3402.
Altitude: 1020 m AMSL

Topography: The site is situated in a low to middle terrace position, 190 m away from the river. The area declines about 1.5% towards east-northeast.

Site Appearance: Surface scatter of artifacts.

Finds: One undecorated grog-tempered pottery was collected.

Pottery Style: Vungu-Vungu style.

Interpretation: The potshard may indicate a settlement site of the Late Ironworking Groups.

2.39. Site catalogue no. 39 Kake

(Table 1, Figure 26)

Site Numbers: N83/03
Site Name: Kake
Coordinates: 18°05.304' S/21°30.978' E
Constituency: Mukwe
Plane Survey Sheet Namibia 1:50000: 1821 BA and BC
Survey: 1983
Excavations: -
References: Kinahan, 1986
Registration Number State Museum Windhoek: B2696
Location: The site is situated at Kake, about 200 m north of Local Road D 3402.
Altitude: 1014 m AMSL

Topography: The site is situated on a lower terrace of the river, 90 m away from the river. The area declines about 1.6% towards north.

Site Appearance: Surface scatter of artifacts.

Finds: One decorated and seven undecorated potsherds were collected together with two glass beads. One red barrel was identified as Variety W3 after Kinahan (2000, p. 114) and one blue barrel corresponded to Variety 39 after Kinahan (2000, p. 112). Both specimens could be assigned to eighteenth century bead assemblages.

Pottery Style: Vungu-Vungu style.

Interpretation: The surface finds indicated a LIG settlement site of the late occupation phase. The beads suggested that it existed into the eighteenth century.

2.40. Site catalogue no. 40 Kake-West

(Table 1, Figure 26)

Site Numbers: N83/04
Site Name: Kake-West
Coordinates: 18°05.574'S/21°31.410'E
Constituency: Mukwe
Plane Survey Sheet Namibia 1:50000: 1821 BA and BC
Survey: 1983
Excavations: -
References: Kinahan, 1986
Registration Number State Museum Windhoek: B2697
Location: Between Kake and Divundu, 260 m south of Local Road D 3402, 900 m southeast of Site N83/03.
Altitude: 1025 m AMSL

Topography: The site is situated in a middle terrace position, about 500 m south of the river. The area declines about 1.25% towards north.

Site Appearance: Surface scatter of artifacts.

Finds: Fifteen potsherds were found, all of which were typical grog-tempered Vungu-Vungu-style pottery.

Pottery Style: Vungu-Vungu style.

Interpretation: The surface scatter indicated a LIG settlement site of the late occupation phase.

2.41. Site catalogue no. 41 Divundu North

(Table 1, Figure 26)

Site Numbers: N83/05
Site Name: Divundu North
Coordinates: 18°05.754′ S/21°32.802′E
Constituency: Mukwe
Plane Survey Sheet Namibia 1:50000: 1821 BA and BC
Survey: 1983
Excavations: -
References: Kinahan, 1986
Registration Number State Museum Windhoek: B2698
Location: About 690 m northeast of the Divundu Combined School at Divundu, 390 m north of the junction of Local Road D 3402 and National Highway B8.
Altitude: 1010 m AMSL

Topography: The site is situated on a lower terrace, about 160 m south of the river. The area declines about 2.3% towards northeast.

Site Appearance: Surface scatter of artifacts.

Finds: Four undecorated grog-tempered potsherds were collected.

Pottery Style: Vungu-Vungu style.

Interpretation: The pottery indicated a LIG settlement site of the younger occupation phase.

2.42. Site catalogue no. 42 Divundu South

(Table 1, Figure 26)

Site Numbers: N83/06
Site Name: Divundu South
Coordinates: 18°06.192′S/21°32.928′E
Constituency: Mukwe
Plane Survey Sheet Namibia 1:50000: 1821 BA and BC
Survey: 1983
Excavations: -
References: Kinahan, 1986
Registration Number State Museum Windhoek: B2699
Location: About 460 m south of the junction of National Highway B8 and Local Road C48/D 3403 at Divundu, 30 m east of the Rukonga Vision School.
Altitude: 1020 m AMSL

Topography: The site is situated on a middle terrace of the Kavango River, 710 m away from the watercourse. The area declines approximately 2.1% towards northeast.

Site Appearance: Surface scatter of artifacts derived from a plowed field. A new school building probably disturbed the site.

Finds: Two undecorated grog-tempered potsherds were collected.

Pottery Style: Vungu-Vungu style.

Interpretation: The potsherds indicated a settlement of the younger phase of the LIG occupation horizon.

2.43. Site catalogue no. 43 Ndongo-North

(Table 1, Figure 26)

Site Numbers: N83/07
Site Name: Ndongo-North
Coordinates: 18°06.534‘S/21°33.384‘E
Constituency: Mukwe
Plane Survey Sheet Namibia 1:50000: 1821 BA and BC
Survey: 1983
Excavations: -
References: Kinahan, 1986
Registration Number State Museum Windhoek: B2700
Location: About 750 m southeast of the Rukonga Vision School, 50 m east of Local Road C48/D 3403.
Altitude: 1013 m AMSL

Topography: The site is situated in middle to lower terrace position, about 140 m away from the watercourse. The area declines about 1.6% towards east.

Site Appearance: Surface scatter of artifacts from a plowed field.

Finds: Three non-diagnostic undecorated potsherds were collected.

Pottery Style: Unspecific.

Interpretation: The pottery indicated an undated settlement site.

2.44. Site catalogue no. 44 Ndongo-South

(Table 1, Figure 26)

Site Numbers: N83/08
Site Name: Ndongo-South
Coordinates: 18°06.972'S/21°33.672'E
Constituency: Mukwe
Plane Survey Sheet Namibia 1:50000: 1821 BA and BC
Survey: 1983
Excavations: -
References: Kinahan, 1986
Registration Number State Museum Windhoek: B2701
Location: About 1.91 km southeast of the Rukonga Vision School, 90 m east of Local Road C48/D 3403.
Altitude: 1014 m AMSL

Topography: The site is situated in a middle terrace position, about 190 m away from the river. The area declines about 1.6% towards northeast.

Site Appearance: Surface scatter of artifacts.

Finds: Twelve undecorated organically as well as grog-tempered potsherds were collected. While the latter attested an occupation during the late phase of the LIG occupation horizon, the first may belong to an EIG occupation or an early LIG period.

Pottery Style: Vungu-Vungu style and unspecific.

Interpretation: The potsherds indicated a settlement site during the younger phase of the LIG horizon. The site has also been occupied prior to this archaeological horizon.

2.45. Site catalogue no. 45 Popa South

(Table 1, Figure 26)

Site Numbers: N83/09
Site Name: Popa South
Coordinates: 18°08.436'S/21°34.350'E
Constituency: Mukwe
Plane Survey Sheet Namibia 1:50000: 1821 BA and BC
Survey: 1983
Excavations: -
References: Kinahan, 1986
Registration Number State Museum Windhoek: B2702
Location: At Popa 1.7 km south of Local Road C48/D 3403.
Altitude: 1033 m AMSL

Topography: The site is situated on the high terrace of the Kavango River, about 1.8 km south of the watercourse. The area declines about 0.6% towards north.

Site Appearance: Surface scatter of artifacts.

Finds: One undecorated grog-tempered shard was collected.

Pottery Style: Vungu-Vungu style.

Interpretation: This was presumably a settlement site of the young phase of the LIG occupation horizon.

2.46. Site catalogue no. 46 Popa-West

(Table 1, Figure 26)

Site Numbers: N83/10
Site Name: Popa-West
Coordinates: 18°07.536'S/21°34.968'E
Constituency: Mukwe
Plane Survey Sheet Namibia 1:50000: 1821 BA and BC
Survey: 1983
Excavations: -
References: Kinahan, 1986
Registration Number State Museum Windhoek: B2703
Location: About 600 m south of the southern edge of Popa Falls, 80 m south of Local Road C48/D 3403.
Altitude: 1022 m AMSL

Topography: The site is situated on the middle terrace of the Kavango River, about 420 m southeast of the watercourse. The area declines about 0.7% towards northwest.

Site Appearance: Surface scatter of artifacts.

Finds: Three undecorated grog-tempered potsherds were collected.

Pottery Style: Vungu-Vungu style.

Interpretation: This was probably a settlement site of the young phase of the LIG occupation horizon.

2.47. Site catalogue no. 47 Popa Southeast

(Table 1, Figure 26)

Site Numbers: N83/11
Site Name: Popa Southeast
Coordinates: 18°08.046′S/21°34.980′E
Constituency: Mukwe
Plane Survey Sheet Namibia 1:50000: 1821 BA and BC
Survey: 1983
Excavations: -
References: Kinahan, 1986
Registration Number State Museum Windhoek: B2704
Location: At Popa 1.03 km south of Local Road C48/D 3403, 950 m south of site N83/10.
Altitude: 1030 m AMSL

Topography: The site is situated on the high terrace of the Kavango River, about 1.52 km south of the watercourse. The area declines approximately 0.4% towards north.

Site Appearance: Surface scatter of artifacts.

Finds: Thirteen grog-tempered undecorated potsherds were collected.

Pottery Style: Vungu-Vungu style.

Interpretation: The potsherds indicated a settlement site during the younger phase of the LIG horizon.

2.48. Site catalogue no. 48 Popa

(Table 1, Figure 26)

Site Number: N07/04
Site Name: Popa
Coordinates: E21°35.187′/S 18°7.518′
Constituency: Mukwe
Plane Survey Sheet Namibia 1:50000: 1821 BA and BC
Survey: 2007
Excavations: -
References: -
Registration Number State Museum Windhoek: -
Location: Immediately south of National Highway C48/D 3403 at Popa, about 800 m southeast of the Popa Falls
Altitude: 1021 m AMSL

Topography: The site is situated on the upper terrace of the Kavango River. Red loamy soils overlie a massive semi-consolidated gravel layer of the Omatako Formation (Figure 161). The gravel mainly consists of ferro-silcrete nodules.

Site Appearance: Gravel quarry for road construction 250 m to 300 m in extension.

Finds: An iron ore sample was taken and analyzed in the laboratory (sample 5201/07) (Table 37, Appendix 3). The pisolitic ferricrete was assigned to the Group III ores. The sample was taken for a preliminary assessment of the consistency of the massive ferricretes along the Kavango River. XRD analyses revealed that it is composed of goethite, muscovite, and quartz. The sample contained 36.7wt% Fe_2O_3 and 51.1wt% SiO_2 (Tables 40 and 41, Appendix 3). It was not suitable for bloomery smelting.

Interpretation: Modern gravel quarry, geological outcrop of the Omatako Formation.

Figure 161: SC 48 Popa, area N07/04: soil section showing pisolitic ferricrete of the Omatako Formation.

2.49. Site catalogue no. 49 Popa North

(Table 1, Figure 26)

Site Numbers: N83/12
Site Name: Popa North
Coordinates: 18°07.104'S/21°35.400'E
Constituency: Mukwe
Plane Survey Sheet Namibia 1:50000: 1821 BA and BC
Survey: 1983
Excavations: -
References: Kinahan, 1986
Registration Number State Museum Windhoek: B2705
Location: About 460 m south of the Divava Lodge at Popa, 460 m north of Local Road C48/D 3403.
Altitude: 1021 m AMSL

Topography: The site is situated on the middle terrace of the Kavango River, about 370 m southeast of the watercourse. The area declines about 0.8% towards northwest.

Site Appearance: Surface scatter of artifacts.

Finds: The site produced one organically-tempered undecorated potshard and one stone artifact.

Pottery Style: Unspecific.

Interpretation: The combination of a lithic tool with organically-tempered pottery suggested a settlement site of the EIG horizon. However, the site could just as well date to the early horizon of the Late Ironworking Groups, or both.

2.50. Site catalogue no. 50 Bagani-West

(Table 1, Figure 26)

Site Numbers: N83/13
Site Name: Bagani-West
Coordinates: 18°06.570'S/21°35.832'E
Constituency: Mukwe
Plane Survey Sheet Namibia 1:50000: 1821 BA and BC
Survey: 1983
Excavations: -
References: Kinahan, 1986
Registration Number State Museum Windhoek: B2706
Location: About 530 m southeast of the Nunda Lodge at Popa, 780 m northwest of Local Road C48/D 3403.
Altitude: 1014 m AMSL

Topography: The site is situated on the middle terrace of the Kavango River, about 460 m east of the watercourse. The area declines about 0.7% towards east.

Site Appearance: Surface scatter of artifacts.

Finds: Seventeen undecorated potsherds were collected, among them two with organic temper. All the others were grog-tempered ware. Two decorated shards showed motifs of the Vungu-Vungu style. One white barrel-shaped glass bead corresponded to Kinahan's Variety 5 (Kinahan, 2000, p. 108).

Pottery Style: Vungu-Vungu style and unspecific.

Interpretation: The find assemblage indicated a settlement site of the younger occupation horizon of the Late Ironworking Groups. The organically-tempered shards were difficult to place chronologically.

2.51. Site catalogue no. 51 Bagani

(Table 1, Figure 26)

Site Numbers: N83/14
Site Name: Bagani
Coordinates: 18°06.432'S/21°36.624'E
Constituency: Mukwe
Plane Survey Sheet Namibia 1:50000: 1821 BA and BC
Survey: 1983
Excavations: -
References: Kinahan, 1986
Registration Number State Museum Windhoek: B2707
Location: About 850 m north of the Bagani Combined School at Bagani, 370 m north of Local Road C48/D 3403.
Altitude: 1003 m AMSL

Topography: The site is situated in the floodplain of the Kavango River.

Site Appearance: Surface scatter of artifacts.

Finds: Two undecorated grog-tempered potsherds were collected.

Pottery Style: Vungu-Vungu style.

Interpretation: This was presumably a settlement site of the young phase of the Late Ironworking Groups occupation horizon.

2.52. Site catalogue no. 52 Bagani Northeast

(Table 1, Figure 26)

Site Number: N83/15
Site Name: Bagani Northeast
Coordinates: 18°06.270'S/21°37.728' E
Constituency: Mukwe
Plane Survey Sheet Namibia 1:50000: 1821 BA and BC
Survey: 1983
Excavations: -
References: Kinahan, 1986
Registration Number State Museum Windhoek: B2708
Location: Northeast of Bagani, 550 m northeast of Local Road C48/D 3403 at the sharp bend towards south.
Altitude: 1006 m AMSL

Topography: The site is situated on the lower terrace of the Kavango River, about 200 m south of the watercourse. The area declines about 0.8% towards north.

Site Appearance: Surface scatter of artifacts.

Finds: Four undecorated grog-tempered potsherds were collected.

Pottery Style: Vungu-Vungu style.

Interpretation: This was presumably a settlement site of the young phase of the LIG occupation horizon.

2.53. Site catalogue no. 53 Bagani-East

(Table 1, Figure 26)

Site Number: N83/16
Site Name: Bagani-East
Coordinates: 18°06.816'S/21°38.424'E
Constituency: Mukwe
Plane Survey Sheet Namibia 1:50000: 1821 BA and BC
Survey: 1983
Excavations: -
References: Kinahan 1986
Registration Number State Museum Windhoek: B2709
Location: 1.12 km east of the Bagani Airstrip and about 890 m east of Local Road C48/D 3403.
Altitude: 1011 m AMSL

Topography: The site is situated on the middle terrace of the Kavango River, about 940 m south of the watercourse. The area declines about 0.9% towards north.

Site Appearance: Surface scatter of artifacts.

Finds: One unspecifically decorated potsherd was collected.

Pottery Style: Unspecific.

Interpretation: This is an undated settlement site of the Ironworking Groups.

2.54 Site catalogue no. 54 Kamutjonga

(Table 1, Figure 26)

Site Number: N83/17
Site Name: Kamutjonga
Coordinates: 18°08.418'S/21°39.630'E
Constituency: Mukwe
Plane Survey Sheet Namibia 1:50000: 1821 BA and BC
Survey: 1983
Excavations: 1983
References: Kinahan, 1986
Registration Number State Museum Windhoek: B2710
Location: At Kamutjonga, 560 m east of Local Road C48/D 3403.
Altitude: 1009 m AMSL

Topography: The site is situated on the middle terrace of the Kavango River, about 2.26 km west of the watercourse. The area declines about 0.4% towards east.

Site Appearance: Dense surface scatter of artifacts.

Excavation method: No information.

Finds: Kamutjonga produced 244 decorated and undecorated potsherds, all belonging to the Vungu-Vungu-style horizon. From the material, two large vessel fragments could be refitted to Vungu-Vungu-style ceramics (Kinahan, 1986, Fig. 2) Moreover, faunal remains, a tanged iron awl point of 138 g, lead seal (27 g), and the wooden head of an axe handle were collected. A charcoal sample (Pta-3758, Table 2, Appendix 3) and organic carbon extracted from bone (Pta-3745, Table 2, Appendix 3) were taken for radiocarbon dating. Unfortunately both samples were not very significant as they fell into the calibration plateau between 1650 and 1950 AD.

Pottery Style: Vungu-Vungu style.

Radiocarbon dates: Pta-3745, Pta-3758 (Table 2, Appendix 3)

Interpretation: This is a plowed-over midden of a LIG settlement. The latter was occupied during the younger occupation period of the LIG horizon.

2.55. Site catalogue no. 55 Kamutjonga South

(Table 1, Figure 26)

Site Number: N83/18
Site Name: Kamutjonga South
Coordinates: 18°09.240'S/21°39.960'E
Constituency: Mukwe
Plane Survey Sheet Namibia 1:50000: 1821 BA and BC
Survey: 1983
Excavations: -
References: Kinahan, 1986
Registration Number State Museum Windhoek: B2711
Location: In the southern part of Kamutjonga, 140 m west of Local Road C48/D 3403, 2.31 km northwest of the Kamutjonga Fisheries Institute. Topography: The site is situated on the middle terrace of the Kavango River, about 2.32 km west of the watercourse. The area declines about 0.4% towards southeast.
Altitude: 1009 m AMSL

Site Appearance: Surface scatter of artifacts.

Finds: The site produced 11 undecorated grog-tempered potsherds. Furthermore, an iron spear point of 82 g was recovered. Very uncommon finds for this area were two sheets of schist because there is no geological source for it. Twenty three barrel-shaped white glass beads were recovered at the site, some of which were exposed to fire. Twenty-two of them corresponded to Kinahan's Variety 2 and one could be assigned to Variety 1 (Kinahan, 2000, p. 108). The beads were from the eighteenth century or younger.

Pottery Style: Vungu-Vungu style.

Interpretation: The numerous finds indicated a midden area of a settlement, dating to the young occupation period of the LIG horizon.

2.56. Site catalogue no. 56 Kamutjonga Southeast

(Table 1, Figure 26)

Site Number: N83/19
Site Name: Kamutjonga Southeast
Coordinates: 18°09.378'S/21°41.316'E
Constituency: Mukwe
Plane Survey Sheet Namibia 1:50000: 1821 BA and BC
Survey: 1983
Excavations: -
References: Kinahan, 1986
Registration Number State Museum Windhoek: B2712
Location: 250 m northeast of the Kamutjonga Fisheries Institute, 1.9 km west of Local Road C48/D 3403.
Altitude: 1005 m AMSL

Topography: The site is situated on a lower terrace of the Kavango River, about 500 m away from the watercourse on a shallow elevation.

Site Appearance: Surface scatter of artifacts.

Finds: An undecorated rim shard of unusual texture was found.

Pottery Style: Unspecific.

Interpretation: This is an undated settlement site of the Ironworking Groups.

2.57. Site catalogue no. 57 Mahango Central

(Table 1, Figure 26)

Site Number: N83/20
Site Name: Mahango Central
Coordinates: 18°12.330'S/21°43.248'E
Constituency: Mukwe
Plane Survey Sheet Namibia 1:50000: 1821 BA and BC
Survey: 1983
Excavations: -
References: Kinahan, 1986
Registration Number State Museum Windhoek: B2713
Location: 5.15 km southeast of the northern entrance gate of the Mahangu Game Reserve, 1.63 km east of Local Road C48/D 3403, within the Game Reserve.
Altitude: 1007 m AMSL

Topography: The site is situated on a middle terrace of the Kavango River, about 3.71 km west of the watercourse. The area is almost even.

Site Appearance: Surface scatter of artifacts.

Finds: One undecorated potsherd was collected.

Pottery Style: Unspecific.

Interpretation: The potsherds indicated an undated settlement site of the Ironworking Groups.

2.58. Site catalogue no. 58 Mahango South

(Table 1, Figure 26)

Site Number: N83/21
Site Name: Mahango South
Coordinates: 18°12.372‘S/21°44.832‘E
Constituency: Mukwe
Plane Survey Sheet Namibia 1:50000: 1821 BA and BC
Survey: 1983
Excavations: -
References: Kinahan, 1986
Registration Number State Museum Windhoek: B2714
Location: In the central part of the Mahango Game Reserve, 7.75 km southeast of the northern entrance gate of the Mahangu Game Reserve, roughly 4.39 km east of Local Road C48/D 3403, within the Game Reserve.
Altitude: 999 m AMSL

Topography: The site is situated in the floodplains of the river, 970 m west of the watercourse. The area declines about 0.4% towards east.

Site Appearance: Surface scatter of artifacts.

Finds: Eleven decorated and undecorated potsherds were found and one stone artifact. Ten of the shards were grog-tempered Vungu-Vungu-style ware. One specimen however was an organically-tempered potsherd with a typical Kapako/Divuyu-style herringbone motif (Kinahan, 1986, Fig. 3.21).

Pottery Style: Vungu-Vungu and Kapako/Divuyu style.

Interpretation: The finds indicated an Early and a LIG occupation site. It is, however, not clear to which degree the material was eroded from farther uphill.

2.59. Site catalogue co. 59 Thinderuvu Water Mouth

(Table 1, Figure 26)

Site Number: N83/22
Site Name: Thinderuvu Water Mouth
Coordinates: 18°14.592‘S/21°45.084‘E
Constituency: Mukwe
Plane Survey Sheet Namibia 1:50000: 1821 BA and BC
Survey: 1983
Excavations: -
References: Kinahan, 1986
Registration Number State Museum Windhoek: B2715
Location: In the southern part of the Mahango Game Reserve, about 2.07 km north-northeast of the Mohembo Border Control, about 610 m east of Local Road C48/D 3403, within the Game Reserve.
Altitude: 1003 m AMSL

Topography: The site is situated on a lower terrace of the Kavango River, more or less 1.54 km west of the watercourse. The area is almost even.

Site Appearance: Surface scatter of artifacts.

Finds: One undecorated organically-tempered shard was found.

Pottery Style: Unspecific.

Interpretation: The potsherd indicated a settlement site of the Ironworking Groups.

2.60. Site catalogue no. 60 Mohembo Border Control

(Table 1, Figure 26)

Site Number: N83/23
Site Name: Mohembo Border Control
Coordinates: 18°15.210‘S/21°45.780‘E
Constituency: Mukwe
Plane Survey Sheet Namibia 1:50000: 1821 BA and BC
Survey: 1983
Excavations: -
References: Kinahan, 1986
Registration Number State Museum Windhoek: B2716
Location: In the southern part of the Mahango Game Reserve, about 530 m northeast of the Mohembo Border Control, 900 m east of Local Road C48/D 3403, within the Game Reserve.
Altitude: 1003 m AMSL

Topography: The site is situated on a lower terrace of the Kavango River, about 1.31 km away from the watercourse. The area declines about 0.8% towards east.

Site Appearance: Surface scatter of artifacts.

Finds: Fifty-five potsherds were collected from the site. Most of the shards were a brittle organically-tempered ware. Unfortunately, only one decorated rim shard and one poorly preserved decorated body shard were available. Some of the vessel fragments were exposed to fire. Among the shards, seven specimens belonged to the grog-tempered Vungu-Vungu-style ware. Additionally, eight stone artifacts were collected and one glass bead. The latter was a small blue barrel corresponding to Variety 39 after Kinahan (2000, p. 112).

Pottery Style: Vungu-Vungu style, perhaps Divuyu/Kapako or Gove style.

Lithic Typology: Unspecific.

Interpretation: This is a two-phase settlement site. The collected assemblage of Mahango South is difficult to classify chronologically because the only available decoration motif is non-diagnostic. The site might have been occupied during the EIG horizon as well as during the early settlement interval of the LIG horizon. Easy to identify from the Vungu-Vungu-style pottery was the late horizon of the LIG occupation period from the eighteenth century or younger.

3. Definition, chronology and settlement pattern of the Ironworking Groups

3.1. Definition of the Ironworking Groups

The purpose of this chapter is to outline the cultural and chronological background of the Ironworking Groups, and to explain why the concept 'Iron Age' or 'Farming Communities' is not appropriate in the context of this study. Both concepts are commonly used in the archaeological discourse of southeastern Africa to describe the rise of farming and iron producing communities in the past 2500 years (e.g. Mitchell, 2002, pp. 259-299, 345-379; Phillipson, 2005, pp. 249-269; Segboye, 1998, pp. 101-111; Van Waarden, 1998, pp. 115-152). It is a commonly held view that iron metallurgy spread to southern Africa in association with crop cultivation, animal husbandry and a sedentary way of life. These cultural innovations have been called the Chifumbaze Complex owing to their homogeneous appearance in the archaeological record over large regions of eastern and southeastern Africa (summarized in Phillipson, 2005, p. 249; Mitchell, 2002, pp. 261-264). Scholars have linked the Chifumbaze Complex to the spread of Bantu-speaking settlers, whom it is believed were the ancestors of the contemporary Eastern Bantu language speakers in southern Africa (summarized in Mitchell, 2013, pp. 657-666). Analogously, archaeologists and historians have envisioned that a comparable development and spread of pottery traditions and cultural innovations took place in the largely non-researched regions of south-central and southwestern Africa, and that this movement must find expression in what is known as western-stream pottery tradition (Phillipson, 1977, pp. 128-140) (Figure 163). The idea that there existed an eastern and western pottery tradition is based on Guthrie's classification of contemporary Bantu languages into East and West Bantu, and was adopted by archaeology and history despite the meager state of research in large parts of sub-equatorial Africa (summarized in Eggert, 2005, pp. 307-309). The earliest ceramic facies associated with the Chifumbaze Complex is Urewe ware. This pottery has been found in east Africa in the Great Lakes region and dated back to the mid-first millennium BC. From there the Chifumbaze Complex spread to southern Africa. On the basis of ceramic traditions, scholars classified the diffusion of the Chifumbaze Complex into an eastern Nkwale branch and a central Nkope branch (Phillipson, 2005, pp. 249-261; Mitchell, 2013, p. 658). Besides the pottery facies of the Nkwale and Nkope branches, a third pottery tradition became manifest in southern Africa. It was called the Kalundu tradition and was associated with Iron Age or Early Farming Communities settlements in the western parts of southeast Africa (Huffman, 1989, p. 114). While Phillipson in his early papers cautiously suggested that the Zambian Early Iron Age was influenced by or introduced from the northwest (Phillipson, 1968), the same pottery assemblages were declared 'western-stream' pottery later and were believed to represent the migration of speakers of West Bantu languages to the south (Phillipson, 1977, pp. 128-142, 220-222). Furthermore, he suggested that 'western-stream' pottery possibly represents a derivative of the east African Urewe ware. Huffman (1989), who renamed the 'western-stream' ceramic assemblages as the 'Kalundu pottery tradition', perpetuated Phillipson's hypothesis. He again assigned them to speakers of an East Bantu language, who introduced what is known as the Central Cattle Pattern to central and west central Africa and from there via Zambia to southern Africa. One main diagnostic feature of pottery of the Kalundu tradition takes the form of horizontal bands on the vessels' necks and shoulders. These bands are filled with incised lines arranged into herringbone patterns or interlocked triangles, together with comb-stamped motifs, or bands of ladder stamping, which are uncommon among facies derived from eastern pottery traditions (Huffman, 2007). In Zambia, early representative settlements of 'western-stream' origins which provided evidence of metalworking are Kapwirimbwe, Dambwa and Chondwe (Fagan, 1967; Fagan, Phillipson & Daniels, 1969; Mills & Filmer, 1972; Phillipson, 1968).

In the nineteen seventies, Dos Santos Junior and Ervedosa (1970) published pottery that was found in an extensive shell midden in northern Angola near Luanda on the Atlantic coast. The site, Benfica, dated back to the early first millennium AD (Table 3, Appendix 3), and the pottery, showing a crosshatched pattern, incised herringbone motifs and comb-stamped decoration (see also De Sousa Martins, 1973), was declared to mark the arrival of Bantu speakers in northern Angola. Furthermore, it was considered ancestral to the 'western stream' pottery of the Kalundu tradition (Huffman, 1989, p. 114), despite the absence of any archaeological evidence between Benfica and Zambia (summarized in Clist & Lanfrachi, 1991, pp. 219-223). However, in light of the new research by Valdeyron and Da Silva Domingos (2009), the finds from Benfica must be taken with caution because their stratigraphical affiliation seems to be uncertain, and, as a consequence, also their age. Moreover, Benfica was a shell midden and cannot be used to explain the spread of farming or a Central Cattle Pattern from the Atlantic coast into southern Africa as concluded by Huffman (1989. p. 114). While the Kalundu tradition is seen as an expression of East Bantu speakers coming from the west, early pottery assemblages found near Lubumbashi along the Naviundu River (Anxieaux de Faveau & De Maret, 1984) and related pottery assemblages from Zambia were envisioned as cultural remains of speakers of a West Bantu language (Huffman, 1989, p. 114).[97] The finds from Naviundu are associated with early copper production. Contrary to the decoration motifs of the Kalundu tradition, Naviundu pottery shows a variety of stamped motifs, produced by combs, metal bracelets or single impressions. During the past twenty-five years, more information has become available from archaeological sites along the Atlantic coast of sub-equatorial Africa (Denbow, 1990; 2012; 2013). These sites produced inventories of a ceramic Late Stone Age and of Iron Age occupations, which help to shed better light on the origin of 'western stream' ceramic assemblages found in the southern parts of Africa. Of particular interest are sites where an early herringbone-decorated ware was found, such as BP 113 and Kayes, and sites with pottery showing spaced curvilinear motifs such as Mandingo-Kayes and Lac Ndembo. All the sites dated to the late first millennium BC, and the early first millennium AD (Denbow, 2012, pp. 389). Without going into details, suffice it to say all the four styles, herringbone-decorated ceramics, ware with spaced curvilinear motifs, pottery in the Naviundu tradition and Kalundu-style ceramics are relevant to this study because the Kavango pottery of the Early Ironworking Groups as illustrated in Figure 165 combines elements from all of these ceramic styles. The same is true for the assemblage from Divuyu and Xaro, which shows the closest ties to the early pottery of the middle Kavango (Denbow, 2011, pp. 89-91; 2013, pp. 166-170, Ed Wilmsen, personal communication). However, the purpose of this chapter is not to discuss the stylistic links of the Kavango pottery with their northern and eastern neighbors in detail, because a comprehensive pottery study is in preparation. Rather the sites mentioned here will help to place the early Kavango assemblages in a broader historical frame of reference.

Unlike the better-researched pottery assemblages, the early beginnings of iron metallurgy in southern Africa are not well understood. As discussed above, the spread of iron metallurgy is generally linked to the spread of the Chifumbaze Complex, but archaeologically there is little information available as to the earliest smelts in southern Africa (Miller, 1995, p. 233; Mitchell, 2002, pp. 276-279). One main problem is the lack of precise descriptions and archaeometrical slag analyses, which would allow the assignation of slag samples to one of main process steps necessary to produce iron. Most publications, in particular those from Zambia, content themselves with mentioning slag, tuyere fragments and metal objects, and postulating that a high proportion of slag in the assemblage indicates smelting, while a reduced number of slag finds implies fine smithing at a site. This information is however not enough to identify smelting sites in the absence of the material evidence of a furnace, or to assess the ironworking activities performed in, or in the precincts of, a settlement. Therefore, the only site to which I can compare my findings from Ruuga (SC 3) and Kapako (SC 4) is Divuyu because of its thorough archaeometrical analyses (Miller, 1996), which, though it was a settlement of highly skilled blacksmiths, lacks evidence of smelting and refining.

Over the past decades, most research concerning the introduction of pottery, animal husbandry, farming and metal production has contrasted prevalent lithic Late Stone Age assemblages with non-lithic Early Iron Age assemblages, implying that these sites belong to different 'ages' that succeeded each other, rather than emphasizing the concurrence of these assemblages over more than 1000 years in southern African history (Sadr & Sampson, 2006; Sadr, 2008). As a result, discordances in the appraisal of sites of one or the other composition have led to confusion with respect to the classification and denomination of archaeological assemblages and the cultural affiliation and subsistence strategy behind them. The same complexity arose in the Kavango region and the problems connected with the adequate naming

[97] Even though these sites are located east of the assumed spread of the East Bantu speakers from Benfica to Zambia.

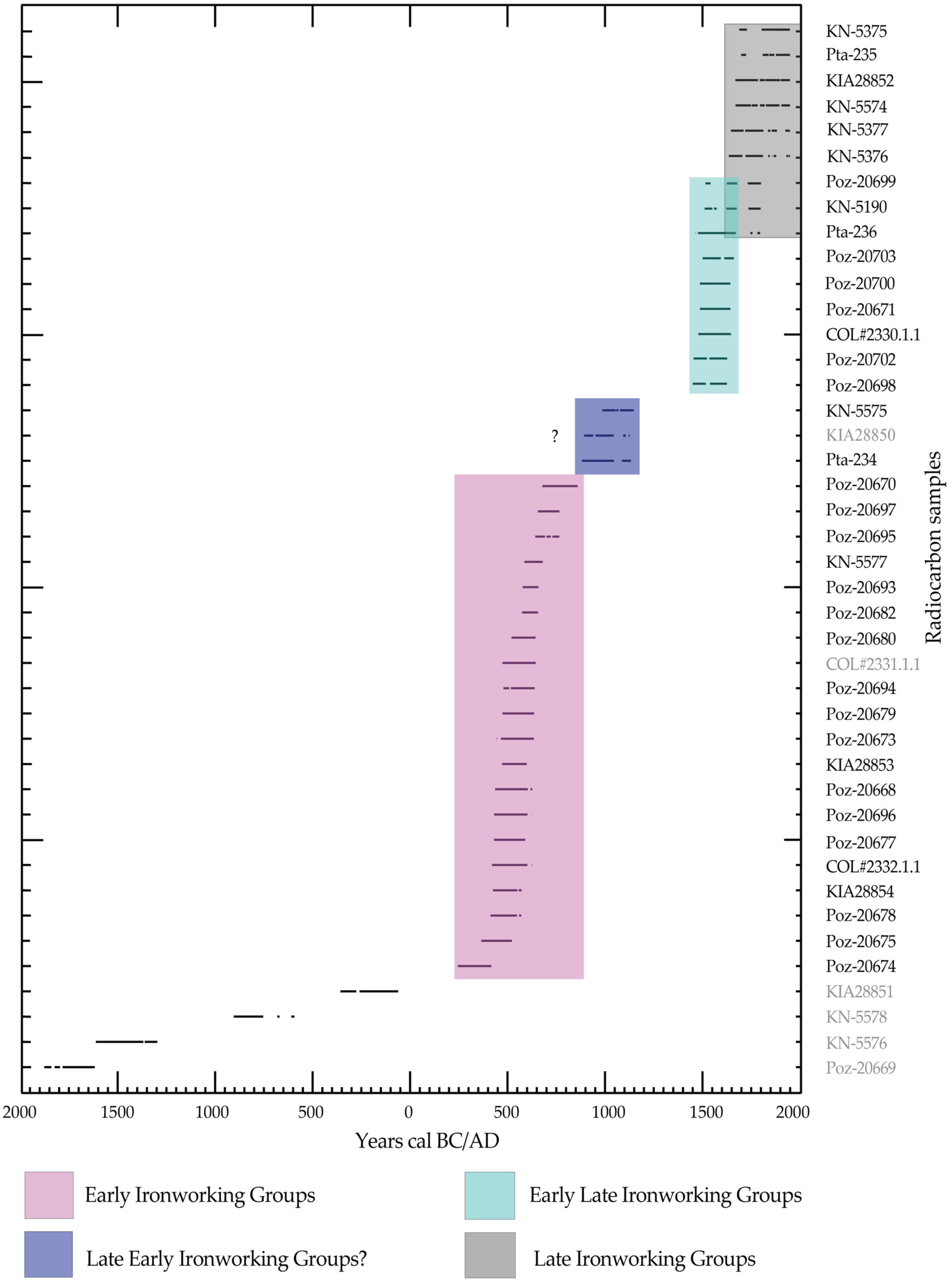


Figure 162: Two-sigma calibrated calendar age ranges of radiocarbon dates from the middle Kavango region (Table 2, Appendix 3). Problematic samples are written in gray (calibrated with Calib Rev 7.0.4, SHCal13).

of the early and late sites found along the middle Kavango River have already been addressed in earlier publications by the present author (Kose, 2009a; 2009b). One major shortcoming of this study is that faunal analyses are not available yet, apart from the data published by Sandelowsky in 1979 from Vungu-Vungu (SC 12). Consequently, caution must be applied when it comes to the naming of the assemblages and cultural horizons under study. In addition, no botanical or pollen analyses have ever been carried out to investigate the environmental

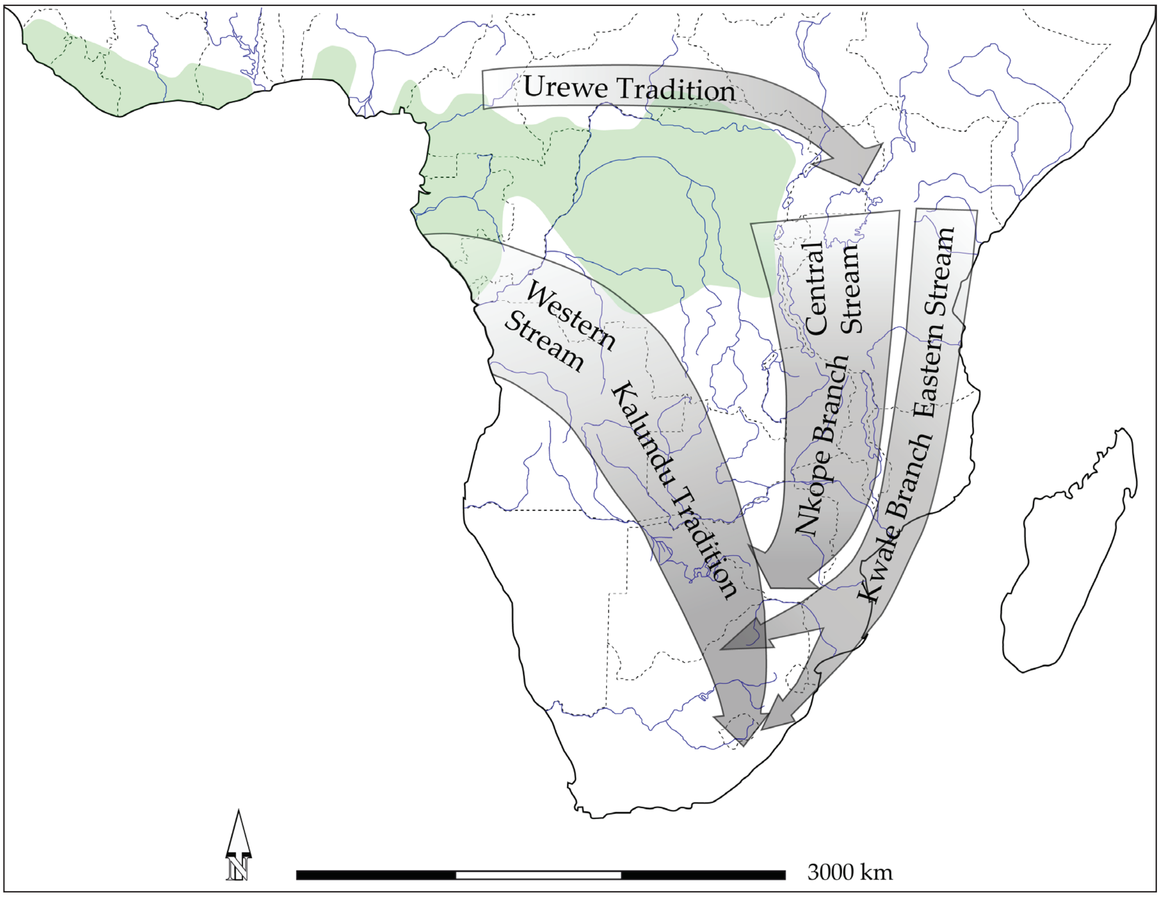


Figure 163: Early Iron Age movements in central and southern Africa

conditions of the past 2000 years along the middle Kavango, and to assess the extent to which crops were present in the precincts of the archaeological sites. In the 1970s, Sandelowsky (1979) still saw the archaeological assemblage of Kapako as the cultural expression of an Early Iron Age. Later, in light of the new finds from Ruuga (SC 3) and Karrangana (SC 2), Richter (2005, p. 81) suggested a ceramic Late Stone Age preceding the Early Iron Age. Since then, targeted excavations at Ruuga (SC 3), Kapako (SC 4) and Gove-Mbambangandu (SC 17), the re-assessment of Sandelowsky's finds, and a series of new radiocarbon dates allows for an enhanced access to the occupation history of the middle Kavango area over the past 2000 years. As can be gathered from the site descriptions of Ruuga (SC 3) and Kapako (SC 4), both sites are in a Late Stone Age tradition and for that reason there is a strong possibility that these peoples followed a foraging subsistence strategy rather than herding or mixed farming.

No smelting site and no smelting furnace have been identified from the early settlement sites so far, but in my opinion, the identification of bloom-refining processes together with some smelting slag recovered from the assemblages both sites provides enough evidence for the smelting activities of the same people. Moreover, the archaeometrical examination of the slag assemblages revealed that the refining furnaces operated under similar temperatures and redox conditions as smelting facilities would have done (section 4.4.4). This demanded the skilled knowledge of ironworkers who were certainly also proficient in smelting.

As far as the late occupation horizon is concerned, ethnographers or archaeologists assigned all the more recent archaeological sites to a farming population because the contemporary Kavango peoples speak Bantu languages and practice mixed farming. A closer look into oral history however reveals that the latter seems to be a recent innovation of the nineteenth century, and the scarce evidence for domesticated bovines in the faunal material from Vungu-Vungu (Sandelowsky, 1979, pp. 58 and 61) underlines the strong foraging subsistence traditions of the forefathers of the modern Kavango peoples. A detailed picture of the historical and ethnic background of the modern Kavango peoples is provided in section 5.1 to introduce the historical part of this study.

In summary, the archaeological concepts of the farming communities used in eastern and southeast Africa are not applicable to the archaeological situation along the middle Kavango because I assume that animal husbandry and crop farming did not exist prior to the nineteenth century. The early sites are in a microlithic Late Stone Age tradition and the late sites must be seen in the foraging traditions of the modern Kavango peoples as handed down in oral chronicles (section 5.1). Therefore, future research could usefully focus on researching the subsistence strategies over the past 2000 years with better-suited methods than mere assumptions. However, owing to this lack of information, I prefer to name the early and late archaeological assemblages with evidence of iron use and production the Early Ironworking Groups (EIG) and the Late Ironworking Groups (LIG) to avoid associations with the archaeological concepts used in east and southern Africa. Moreover, I am not in the position to assign any of the Ironworking Groups to a language family spoken in the area today, except for the late phase of the Late Ironworking Groups, who are the ancestors of the modern Bantu-speaking population. Linguistic suggestions for the early phase of the Late Ironworking Groups are sketched in section 5.1.

3.2. Chronology

In the current state of research, 51 radiocarbon samples are available from the middle Kavango region (Table 2, Appendix 3). This sample set markedly enhances the understanding of the settlement history of the Ironworking Groups, though some intervals still ask for more clarification. The history of archaeological research in the Kavango region has already been published by the author in an earlier paper (Kose, 2009b) and will not be repeated here. As mentioned above, Sandelowsky (1979) was the first scholar who conclusively recognized an Early and a Late Iron Age occupation horizon based on her excavations at Kapako (SC 4) and Vungu-Vungu (SC 12). In 1987, Leon Jacobson published a short state of research concerning the archaeology of the Kavango region in which the chronological depth of the occupation history from the Early Stone Age up to modern times became apparent. Between 1996 and 1999 archaeologists of the University of Cologne assessed and re-investigated 73 archaeological sites in the middle Kavango region. On this basis, Richter (2005, p. 81) established a more detailed chronological framework of the region, confirming that the middle Kavango region was populated from the Early Stone Age up to modern times. In terms of the past 2000 years, Richter (2005, p.81) suggested an occupation succession from a Late Stone Age to a ceramic Late Stone Age, represented by Ruuga (SC 3) and Karangana (SC 2), which was then followed by an Early Iron Age occupation around 1000 AD, as has been found at Kapako (SC 4). Furthermore, he backed up Sandelowsky's findings of a Late Iron Age occupation exemplified by the assemblage from Vungu-Vungu (SC 12), starting in the fifteenth century AD, and added a modern occupation horizon with sites such as Rundu Immigration Office (SC 10). A series of new data from excavations and surveys between 2005 and 2007, also undertaken by the University of Cologne and focusing on sites of the Ironworking Groups, allows me now to propose some new interpretations and specifications of the existing chronology framework of the past 2000 years (see also Kose, 2009a; 2009b).

The next section analyzes the chronological succession of the sites. All specifications as to the calendar age of radiocarbon samples are made according to the 2-sigma calibrated age ranges provided by Calib Rev. 7.0.4, calibrated with the SHCal13 calibration curve for southern hemisphere terrestrial samples.

The bar plot of the 2-sigma calibrated calendar ages of all available samples from the middle Kavango region in Figure 162 revealed that four samples fell in a time span between 2000 and 50 cal BC. These dates are suspiciously early and they will not be considered when discussing the chronology of the Ironworking Groups of the Kavango region. All the four samples originate from Ruuga (SC 3). They are however problematic with respect to their integrity, as has been discussed in section 2.3.1.3 when the chronological frame of the site was described. Among the remaining samples, two discrete sets of dates emerge: first, a group of early calendar age ranges older than the twelfth century cal AD, second, a sample set of late calendar ages younger than the fifteenth century cal AD (Figure 162). The two sets are separated by a hiatus of 350 to 400 years. The first group of 23 samples represents the occupation period of the Early Ironworking Groups, while the other set of 22 samples constitute the presence of the Late Ironworking Groups in the research area until the twentieth century. However, in Figure 162 the calendar age ranges of only 17 of the late samples are

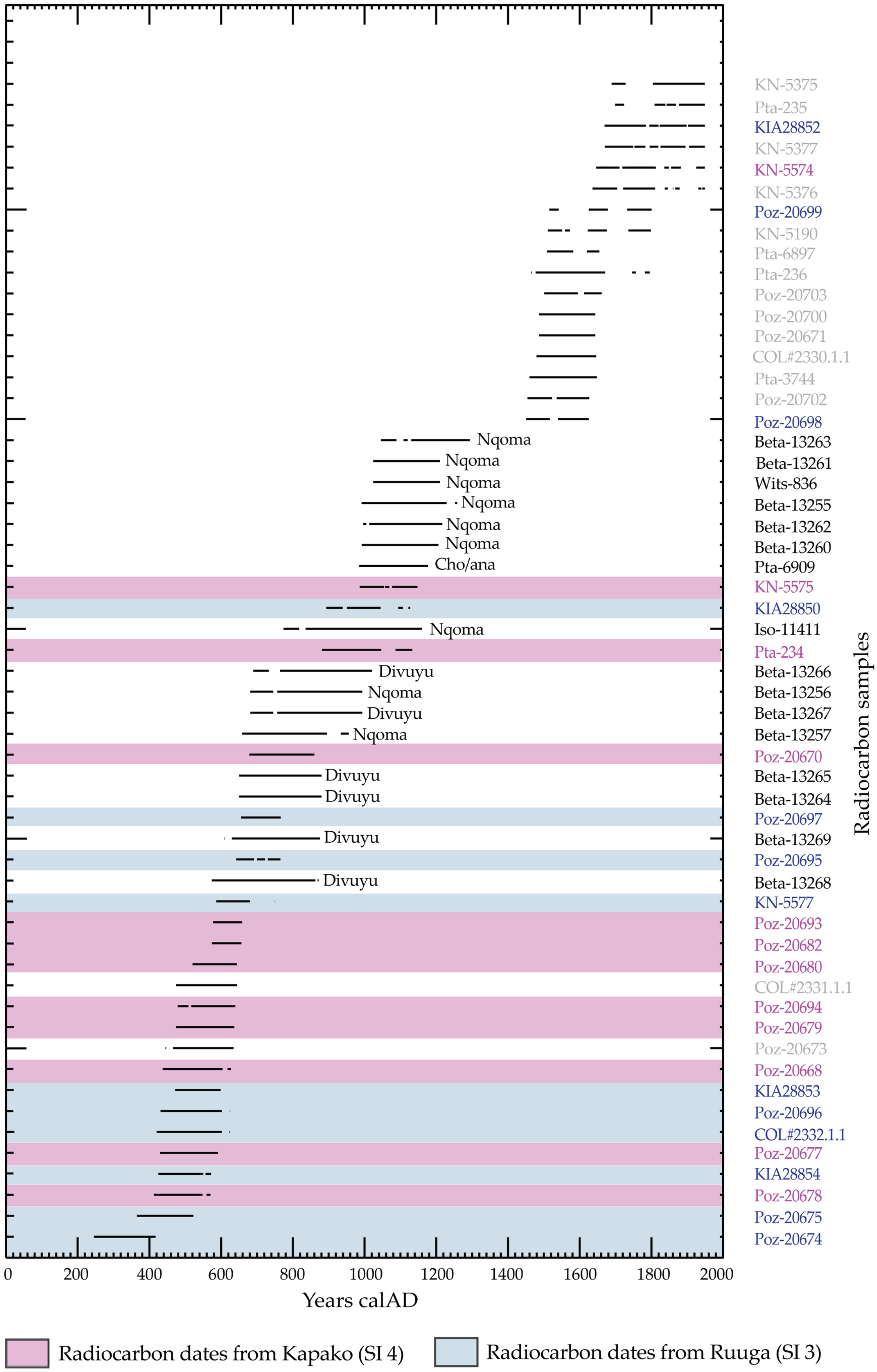


Figure 164: Two-sigma calibrated calendar age ranges of radiocarbon dates from the middle Kavango region and from Divuyu and Nqoma (Tables 2 and 3, Appendix 3) (dates BC not considered) (calibrated with Calib Rev 7.0.4, SHCal13).

illustrated, because radiocarbon ages younger than 120 years were not processed by the calibration program mentioned above.

Turning to the Early Ironworking Groups, the oldest limit of the 2-sigma calibrated calendar age ranges was found the year 245 cal AD (Poz-20674). The latest sample of the Early Ironworking Groups (KN-5575) had its youngest limit in the year 1148 cal AD. However, out of the 23 samples, a group of 15 dates showed 2-sigma calibrated age ranges between the early fifth and the middle of the seventh century cal AD (sample Poz-20678 to KN-5577 in Figure 162). This distribution indicates that the main occupation period occurred between the fifth and the mid seventh century AD, even though there are samples that pre- or post-date this group. A closer look at the early dates revealed that all samples between laboratory number Poz-20674 and Poz-20670 overlapped each other in the 2-sigma calibrated age ranges, whereas samples Pta-234 to Kn-5577 were somehow set aside because they were younger, and the calibrated age ranges did not overlap with the set of the earlier dates. Among the three latter samples, it was found that KIA28850 is not very trustworthy for the reasons discussed in the site catalogue when addressing the stratigraphy and dating problems of Ruuga (see site description SC 3, section 2.3.1.3). Nevertheless, these dates constitute a late phase of the Early Ironworking Groups, but much more research needs to be done before we can really illuminate how the transition from the early to the late occupation phase took place. All in all there is strong evidence that the middle Kavango area was occupied by the Early Ironworking Groups between the third and the ninth century AD, and there is some evidence that this occupation continued until the eleventh to twelfth centuries. Besides the radiocarbon data set available from this early occupation horizon, the main diagnostic feature of EIG sites was the pottery from these assemblages. Most of the EIG ceramics are tempered with organic matter, and decorated with horizontal bands of incised or comb-tamped motifs on the vessel's neck and shoulder. Herringbone motifs are most common, as well as horizontal bands filled with oblique lines of comb-stamping. Some characteristic prototypes are illustrated in Figure 165. More pottery of the Early Ironworking Groups has been published in Richter (2005) and a detailed pottery study is in preparation. In the framework of this study, I designated all ceramic found at EIG sites Divuyu/Kapako-style pottery.

Besides their characteristic pottery, the early assemblages such as Ruuga, the lower layers of Kapako, and most probably Karangana were in a Late Stone Age tradition, combining microlithic Wilton stone inventories (Figures 72 to 74) with ironworking and a large amount of pottery, which was most probably produced locally. A look at the radiocarbon sample sets from Ruuga (SC 3) and Kapako (SC 4) in Figure 162 indicated that the calendar ages produced from Ruuga (SC 3) started and were concentrated somewhat earlier than those from Kapako. Six out of the 10 samples outlining the early occupation horizon of Ruuga (SC 3) were concentrated in a time interval from the mid third century (Poz-20674) to the end of the sixth century cal AD (KIA28853). At Kapako however, six out of 11 relevant samples were concentrated in a time interval from the early fifth century (Poz-20668) to the mid seventh century cal AD (Poz-20693). While all the dates produced from Ruuga (SC 3) were associated with Wilton microlithic tool assemblage and ironworking activities (see site description SC 3, section 2.3), there seems to be evidence for the transition from a ceramic Late Stone Age to an ironworking ceramic Late Stone Age during the fifth to the mid seventh century cal AD at Kapako (see site description SC 4, section 2.4). Interestingly, the layers excavated by Sandelowsky in the late nineteen sixties (Sandelowsky, 1979) produced no lithic LSA inventory anymore, even though some stone artifacts were found (see site description SC 4, section 2.4). The only dated charcoal sample from her excavations fell in the 2-sigma calibrated calendar age range from the late ninth to the early twelfth century cal AD (Pta-234), which gives us a terminus post quem for the abandonment of classical Wilton stone tool production in the Kavango region. If one omits sample KIA 28850 from these considerations because of its lack of reliability (see site description SC 3, section 2.3), the youngest date from Ruuga that was still associated with a Wilton lithic tool assemblage would be sample Poz-20697, which provided a span of calendar years from the early sixth to the middle of the eighth century cal AD. Turning to Divuyu (Figure 166) (Denbow, 2011), the nearest and most closely related site to the early middle Kavango assemblages, it became apparent that the main occupation phases of Ruuga (SC 3) and Kapako (SC 4) pre-dated the main occupation interval of Divuyu. The latter comprised a span of 2-sigma calibrated calendar years between the late sixth century and the early eleventh century cal AD (Figure 164). Unfortunately, the dates from Divuyu showed a great age uncertainty

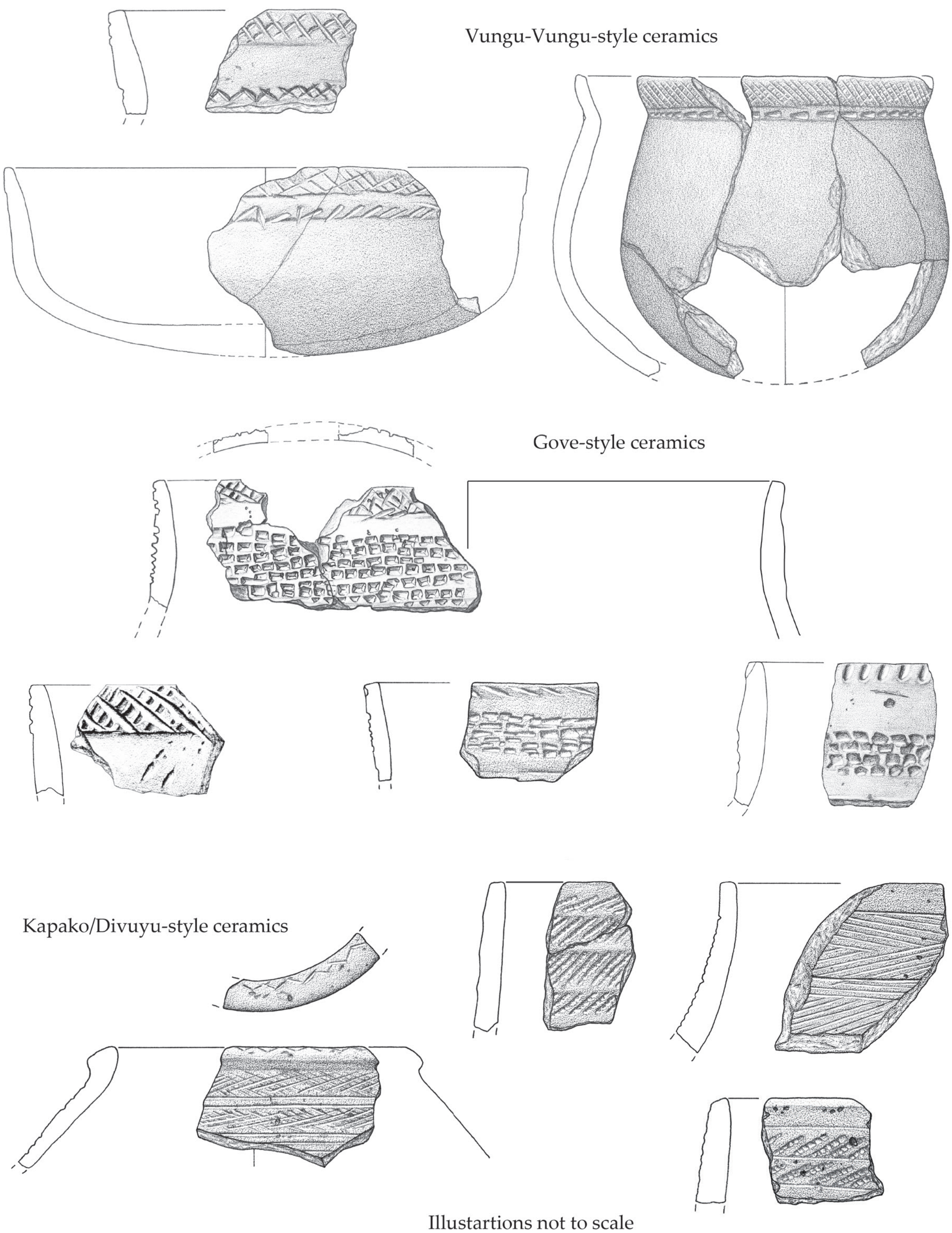


Figure 165: Pottery styles/traditions of the middle Kavango region. Early Ironworking Groups: Kapako/Divuyu style; Late Ironworking Groups: Gove style (early) and Vungu-Vungu style (late) (drawings: Anja Rüschmann and the author).

(see Table 3, Appendix 3), which strongly limits resolution of the chronological succession. The main occupation horizons of Divuyu produced only a limited amount of formal lithic tools and pre-forms, but a large number of iron artifacts (Denbow, 2011, p. 78; Miller, 1996). This association is surprising in light of the fact that the settlement interval of Divuyu overlapped with the late dates from Ruuga associated with a Wilton lithic tool industry as mentioned. Apparently, the moment in history when people abandoned standardized tool production varied locally. What is more, it seems as if the transition from the standardized lithic tool era to the non-lithic Early Ironworking Groups may have taken two to three hundred years or even longer. This raises the question whether the earliest iron products were meant to replace standardized lithic tools in their fields of activities, or whether the earliest metal products were mainly ornaments as suggested by the finds from Divuyu (Denbow, 2011, p. 78; Miller, 1996), and were necessary to satisfy the needs for body decoration and probably prestige. Another interesting aspect of the Divuyu assemblage is that the people in the Tsodilo Hills practiced a mixed subsistence strategy of herding and hunting (Denbow, 2011, p. 86) to meet their demands for meat. However, as the faunal analyses of the Kavango assemblages are not yet available, I refrain from any assumptions concerning the subsistence strategy behind the assemblages from the middle Kavango. Up until the late thirteenth century, the Tsodilo Hills continued to be occupied by people producing a slightly different pottery than before, which became known as Nqoma-style ceramics (Hendrickson, 1986; Denbow, 2013, pp. 168–170, Wilmsen & Denbow, 2010, pp. 76–78). The occupation interval of Nqoma covered a period from the late seventh century (Beta-13257) to the end of the thirteenth century cal AD (Beta-13263). It overlapped with the younger dates from the middle Kavango assemblages but most probably post-dated them by roughly 100 calendar years. However, in terms of pottery style, there were only very limited parallels between the ceramics of the middle Kavango assemblages and those of Nqoma.

In Figure 167 I put together radiocarbon dates from Early Ironworking Group assemblages in a wider frame of reference of selected well-dated early sites located in the Republic of Congo, Angola, the Democratic Republic of Congo, and Zambia (Figure 166) (Table 3, Appendix 3). These sites have already been introduced earlier in this chapter: BP 113, Mandingo-Kayes, Kayes and Lac Ndembo in the Republic of Congo, Benfica in what is today Angola, Naviundu in the Copper Belt of the Democratic Republic of Conge, and Kapwirimbwe, Dambwa along with Chondwe in Zambia. At this point, I do not want to go into details as to the stylistic nuances of the ceramics of all these sites, or how exactly they are related to the Divuyu/Kapako-style pottery. It was more interesting to assess how these sites are placed chronologically with respect to the Early Ironworking Group assemblages from the middle and lower Kavango. It turned out that one major shortcoming of such a chronological projection was the considerable uncertainty of many of the radiocarbon dates obtained from published studies. As can be seen from Figure 167, some samples cover a 2-sigma calibrated calendar age range of more or less 400 years and produced a considerable lack of clarity as to the chronological successions of the sites.Nevertheless, certain trends became visible from the resulting picture: The oldest site of this compilation was clearly BP 113 on the Atlantic Coast of what is today the Republic of Congo. The 2-sigma calibrated age ranges reached beyond the Christian era and the latest limit fell in the beginning fifth century AD (Tx-7016). BP 113 is followed by the dates from Benfica, covering an age range between the second and the early fifth centuries cal AD. Furthermore, Mandingo-Kayes belongs to this group of early sites, yet the great age uncertainty of both samples from the site (Tx-5958 and Tx-5957) placed it somewhere between mid second and the mid sixth centuries cal AD. All these sites overlapped temporally with the earliest dates from Ruuga, but lay, except for Mandingo-Kayes, before the main occupation phase of the middle Kavango region between the early fifth and the mid seventh centuries cal AD as described above. Overlapping with this early group of sites was also the oldest sample from Kayes (Tx-6691). The second group of sites, which I consider contemporaneous with the main EIG occupation horizon of Ruuga (SC 3) and Kapako (SC 4), comprised Kayes on the Atlantic coast in the Republic of Congo, Naviundu in the Copper Belt of the Democratic Republic of Congo, Kapwirimbwe and the oldest layers of the Chondwe site, both situated in what is today Zambia. From the available dates a third group of younger sites ccould be defined, which were contemporaneous with the main occupation phase of Divuyu, and the younger dates from Ruuga and Kapako. This group included Lac Ndembo in the Republic of Congo along with Dambwa and Chondwe in Zambia. Due to the indicated age uncertainty of certain samples, the calibrated calendar age ranges from Dambwa overlapped with the previous group of sites, but the main possible age range run parallel was is the youngest site of the early Kavango sequence, existed concurrently with the late phases of Chondwe in Zambia. Most interestingly, the assemblage from Chondwe combined a microlithic tool industry with metallurgical slag, pottery related to the Naviundu tradition and faunal remains of game (Mills & Filmer, 1972). The youngest dates from Chondwe ranged between the eleventh and the fourteenth centuries cal AD (Beta-13261 and GX-1330). These circumstances again back

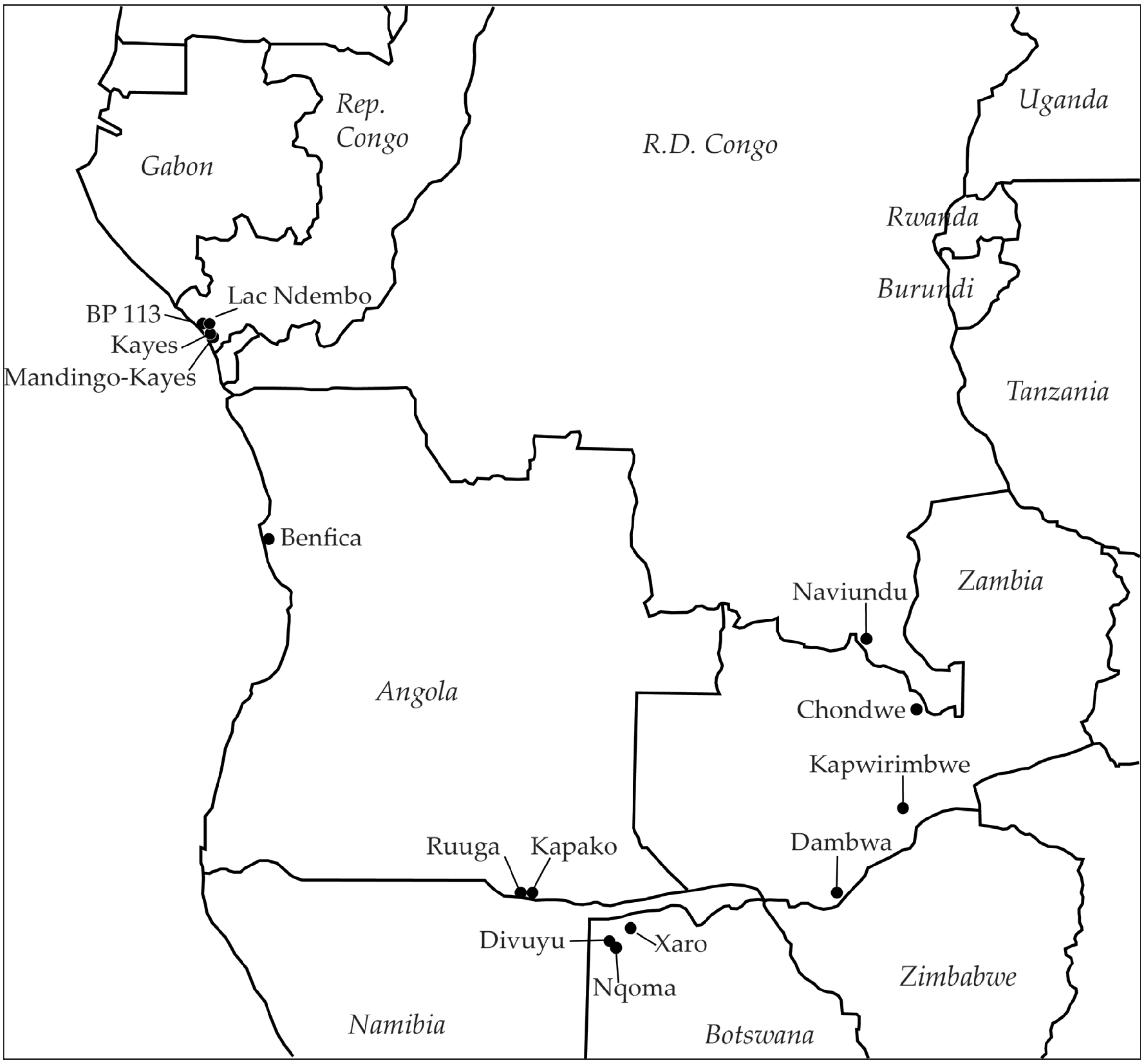


Figure 166: Early Iron Age sites with related pottery traditions mentioned in Chapter 3.

up my earlier assumption that there existed strong regional variations with respect to the historical period in which standardized microlithic tool production was abandoned. The availability of metal was obviously not crucial for abandoning neither formal stone tool production nor a hunting subsistence economy, because the people of Chondwe were surrounded by farming people with metal tool industries.

Overall, a set of new available radiocarbon dates allowed me to better place the Early Ironworking Groups in a wider frame of reference of related sites. These dates also threw new light on the chronological succession of certain sites and the spread of technological knowledge throughout south-western Africa. As a result, only BP 113 and Benfica can still be seen to be earlier than the main occupation interval of the early Kavango sites, but the dates from Ruuga disturb this picture since they are too close to Benfica and to BP 113 for beeing explicitly younger. What is more, the dates from Mandingo-Kayes do not distance themselves clearly enough from the early Kavango sites temporally. The main occupation phase of Ruuga and Kapako runs parallel to the existence of Kayes, Naviundu and Kapwirimbwe. Even though related in pottery tradition, neither of these sites can be considered ancestral to the other. Consequently, the question is who were then the common ancestors of all these sites? The answer largely depends on how much time we allow people for the transport of proficient metallurgical knowledge and a certain pottery style over a distance of, in the case of Benfica, more or less 1000 km, and in the case of the Congo sites roughly 1600 km across the continent, to arrive at the middle or lower Kavango and western Zambia.

Turing now to the Late Ironworking Groups, no archaeological sites have been identified so far dating from the twelfth to the fourteenth

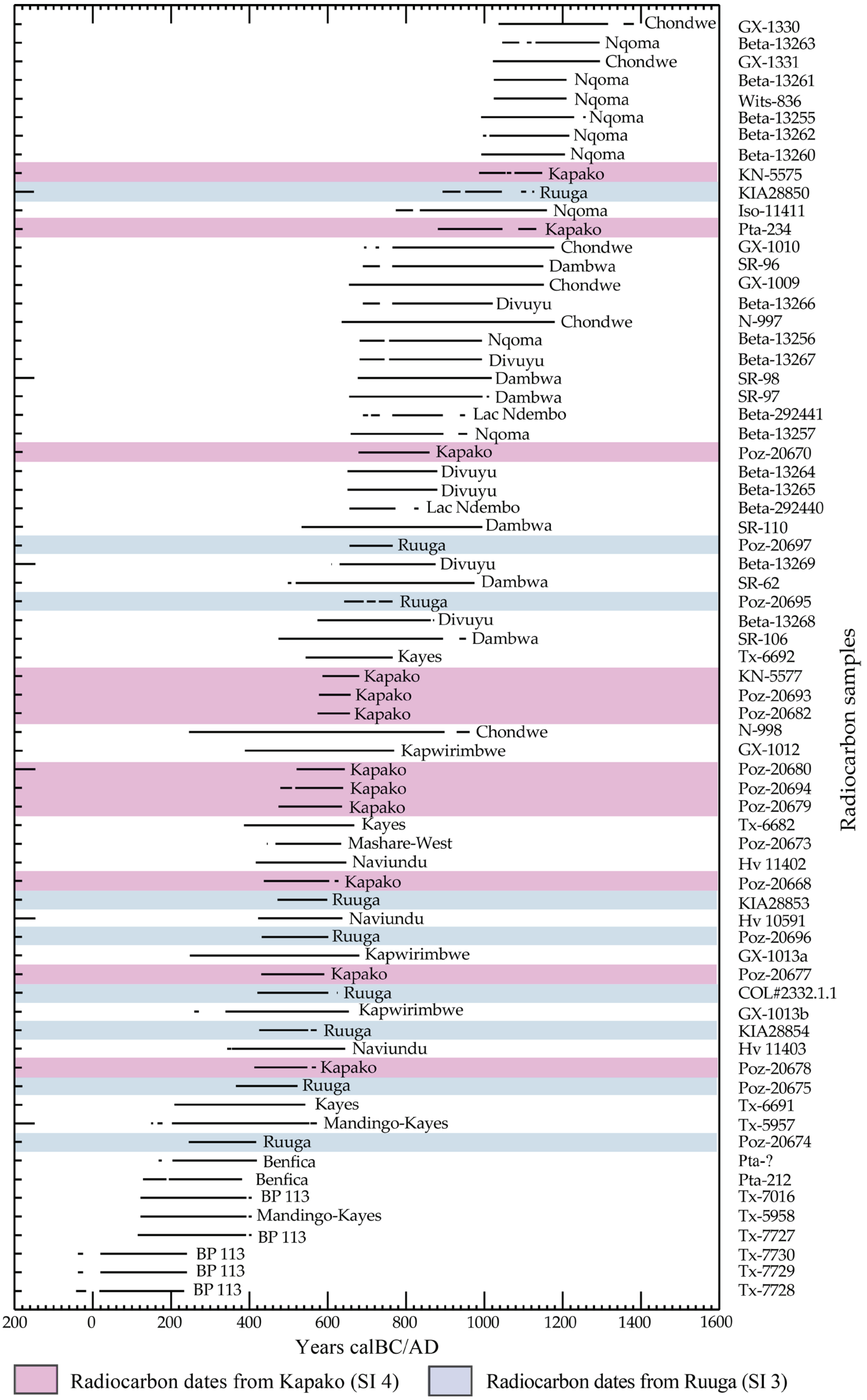


Figure 167: Two-sigma calibrated calendar age ranges of radiocarbon dates from the middle Kavango region and from sites with related assemblages in west central, south central and southwestern Africa (Tables 2 and 3, Appendix 3) (dates BC not considered) (calibrated with Calib Rev 7.0.4, SHCal13).

centuries The reason for this hiatus is still unknown. There may well be sites from this historical period farther inland that have escaped our survey activities, or sites with a prevalent lithic assemblage. The 2-sigma calibrated radiocarbon sample set from the younger occupation period indicated that from the middle of the fifteenth century onwards, ceramics-using people came back to the area. As can be seen from Figure 162, two clusters of radiocarbon dates are apparent. First, a group of seven early dates with calibrated age ranges between the first half of the fifteenth century and the middle of the seventeenth century cal AD. Second, a group of 13 younger dates falling in the calibration plateau between 1650 AD and the present, of which only six are shown in Figure 162 for the reasons explained earlier (sample KN-5376 to KN-5375, Table 2, Appendix 3). The calendar ages of two samples (Poz-20699, KN-5190, Table 2, Appendix 3) overlapped with both groups. On the basis of this distribution, I distinguish between an early Late Ironworking Groups (early LIG) phase, and a late phase of the Late Ironworking Groups (late LIG). Four of the seven early samples originated from slag and might be biased towards an older age owing to the old wood effect as discussed for Dikundu (SC 30) in section 2.30.2.4. However, they all originated from different sites and find support in two charcoal samples extracted from pottery (COL#2330.1.1 and Poz-20671, Table 2, Appendix 3) along with dated charcoal from a shallow pit (Pta-236), and are therefore trustworthy.

The idea that there existed an early and a late occupation phase along the middle Kavango was mainly inspired by local chronicles, which hand down that there existed a group of iron-producing hunters who migrated from the southeast to the area. These people are remembered as the Tjaube people, and they constitute the ancestors of what is today the Vakwandjadi Clan among the Kavango peoples. During the eighteen century, small groups of the ancestors of the modern Kavango peoples established small polities along the river and conquered the Tjaube territory. A detailed description of the historical processes behind the amalgamation of the Kavango peoples is given in section 5.1. The two migration waves however are well mirrored in the sequence of radiocarbon dates. The re-assessment of Beatrice Sandelowsky's pottery assemblage from Vungu-Vungu (SC 3, section 2.12.3) provided new evidence of a ceramic ware that differed from the characteristic late Kavango pottery in that the shards are organically tempered and brittle. The motifs are mainly

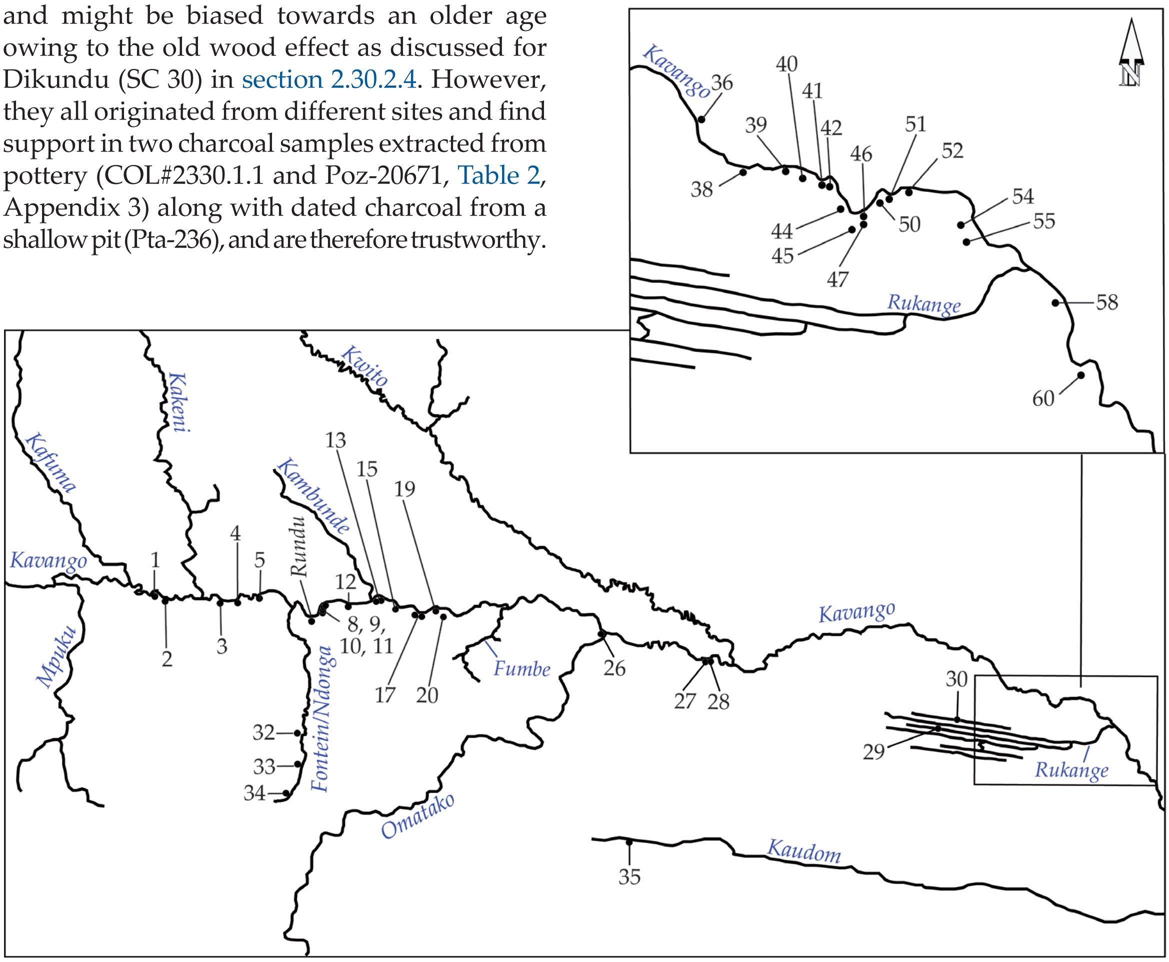


Figure 168: Archaeological sites of the Early Ironworking Groups of the middle Kavango region with Kapako/Divuyu style ceramics.

coarse comb-stamped designs in horizontal bands, or bands of alignments of various single impressions, and surprisingly, bands of cross-hatching. Some prototypes of the early ware are illustrated in Figure 166. Test excavations at Gove-Mbambangandu (SC 17) confirmed the existence of such early pottery assemblages. The site became eponymous with this early pottery, which I named Gove ware. The younger pottery, which has been well described by Sandelowsky in 1979, and was re-analyzed by the present author (Kose, 2004; 2009) was named Vungu-Vungu ware. It differs from Gove ware in that the potsherds a hard and mainly grog-tempered. Diagnostic motifs are a horizontal band of cross-hatching along the rim, and a protruding band with single impressions on the neck or shoulder of the vessel. Some examples of typical Vungu-Vungu-style pottery are given in Figure 165. Since Gove ware was found at settlement sites mentioned in the Tjaube Chronicle, it is highly likely that they coincide with the presence of the Tjaube people in this area (section 5.1), and the two charcoal samples extracted from pottery mentioned earlier confirmed this assumption. The late Vungu-Vungu-style pottery is still produced in the area and can consequently be assigned to the ancestors of the five Kavango groups (Kwangali, Mbunza, Shambyu, Gciriku, and Mbukushu) as described in detail in section 5.1. Another most interesting clue with respect to the settlement history of the middle Kavango region came from the European glass beads found at the LIG settlement sites. While Vungu-Vungu (SC 3) produced a rich glass bead inventory of the early contact phase with European trade goods, dating between the fifteenth and the eighteenth centuries, the sites discovered by Kinahan (1986) east of Andara revealed bead finds solely of the middle and late contact phases dating to the nineteenth and twentieth centuries (see SC 37 to SC 60). This circumstance allows two possible interpretations: first, that the western part of the middle Kavango region was re-settled earlier during the Late Ironworking Groups occupation period, or second, this area was in contact with European goods from the Atlantic at an earlier date.

In summary, this section has reviewed the occupation patterns of the Late Ironworking Groups. It became apparent that the area was probably re-occupied by ceramics-using people from the fifteen century onwards. Two settlement intervals exist, and the early interval coincides with the historical account of the Tjaube people. A second period of migration occurred from the seventeenth century on and it correspond to the migration of the contemporary Kavango peoples to the middle Kavango region.

3.3. Settlement density

In the current state of research, five sites are assignable to the Early Ironworking Groups horizon. These sites are Karangana (SC 2), Ruuga (SC 3), Kapako (SC 4), Mashare West (SC 22),

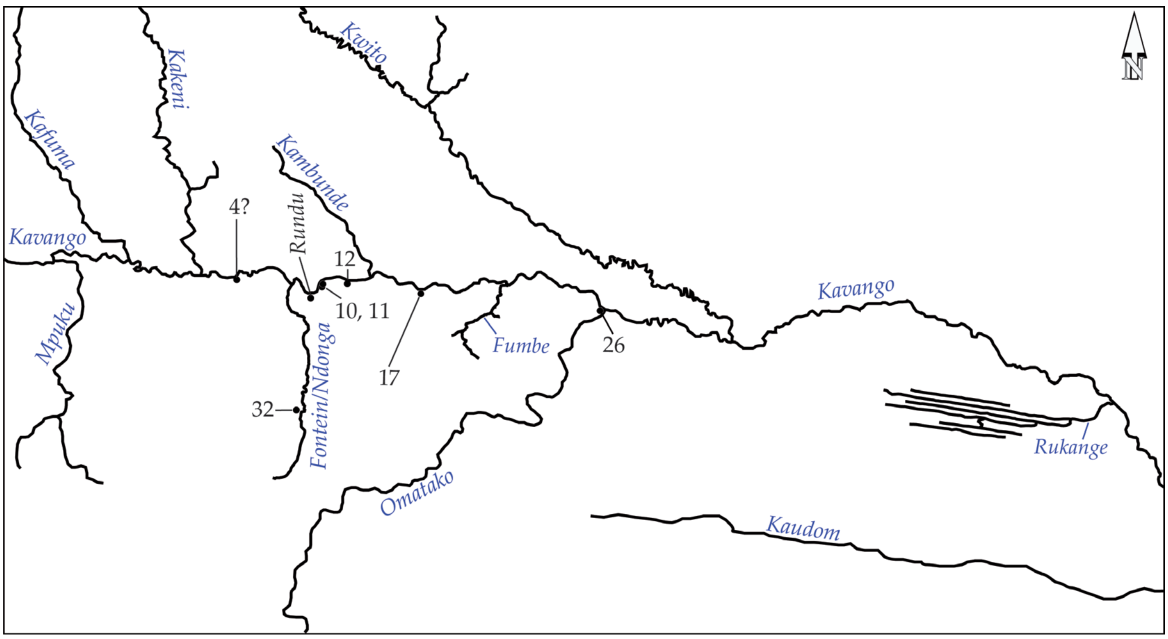
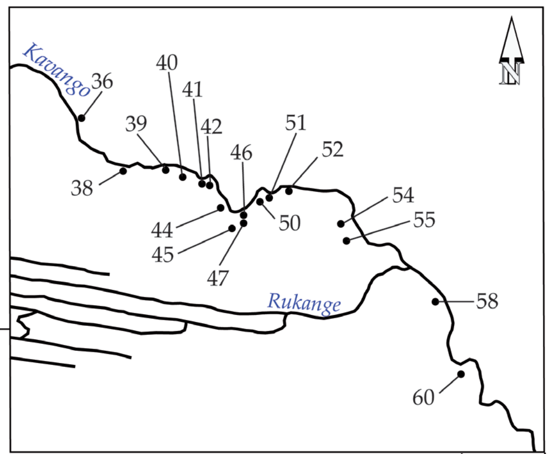


Figure 169: Archaeological sites of the Late Ironworking Groups of the middle Kavango region with Gove style ceramics.

and Mahango South (SC 58) (Figure 168). The site Mohembo Border Control (SC 60) produced many organically tempered potsherds, yet only two of them were decorated with poorly preserved non-diagnostic motifs. It is highly unlikely that the limited number of sites is representative with respect to the population density of the Early Ironworking Groups occupation period. All representations that reconstruct settlement patterns and density based on the archaeological record are biased by the fact that only the southern Namibian side of the Kavango River has been surveyed and assessed. Moreover, the surveys concentrated on a small band between the national highway running parallel to the river, and the riverbank itself. It can therefore be said for certain that an incalculable number of sites are missing in the maps of Figure 168 to 170. Karangana (SC 2), Ruuga (SC 3), Kapako (SC 4) and Mashare West (SC 22) are situated on the high terrace of the river, suggesting that the settlers of the EIG period preferred a place out of the reach of flood. All these find-bearing horizons were covered by approximately 50 cm of soil deposit and were well protected. All the sites became known only because of modern soil-disturbing activities: Karangana because of quarry work, Kapako because of the construction of the mission, Ruuga owing to the calcrete quarry, and Mashare West was collected from a ploughed-over field. Therefore, I assume that there are still some undiscovered assemblages; however, settlement density was most likely not as high as it is today, and further research is necessary to illuminate the settlement pattern of the EIG occupation horizon. Interestingly, towards the lower Kavango River, sites move closer to the river and to lower regions because Mahango South (SC 58) and Mohembo Border Control (SC 60) are situated on the lower river terrace. Approximately 30 km further south, in what is today Bostwana, the site Xaro, which has not been entirely published so far, is situated on a peninsula and belongs to the same occupation horizon of the EIG (Ed Wilmsen, personal communication). One explanation could be that waterline fluctuations of the lower Kavango were less pronounced in the Okavango panhandle than farther west.

Turning to the early occupation period of the Late Ironworking Groups, only five sites are explicitly identified to belong to this horizon by their pottery assemblage (Figure 169). These sites are Rundu Immigration Office (SC 10), Kaisosi (SC 11), Vungu-Vungu (SC 12), Gove-Mbambangandu (SC 17), and Ndonga (SC 22). Kauti (SC 32) can also be assigned to this occupation period on the basis of oral history, just like Kapako (SC 4), but the latter still lacks



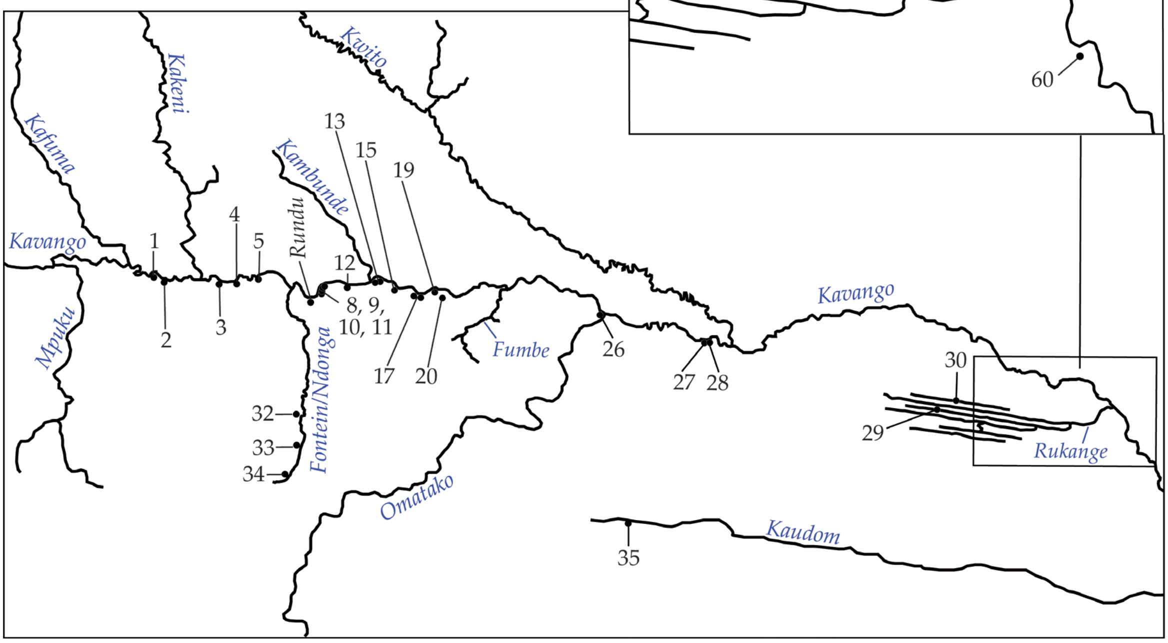


Figure 170: Archaeological sites of the Late Ironworking Groups of the middle Kavango region with Vungu-Vungu style ceramics.

convincing archaeological evidence in the pottery assemblages examined. Interestingly, the sites at Rundu Immigration Office, Kaisosi, Vungu-Vungu and Ndonga are all located in the floodplains and on the lowest river terrace, and are affected by recurrent flooding under the current climatic conditions. In contrast, modern-day settlements are all laid out farther uphill on the middle terrace of the river. A possible explanation for this might be that the average water level of the Kavango River from the fifteenth to the eighteenth centuries was not as high as it is today, and the rainfalls were moderate during the rainy season farther north. Only Gove-Mbambangandu lies on a high terrace of the river. What is more, the sites with identifiable Gove-ware are situated in an area where the Shambyu and Gciriku polities became established later. This also roughly coincides with the Tjaube territory handed down in the chronicle mentioned above (section 5.1, Fleisch & Möhlig, 2002). Settlement density seemed to have been low, but one must expect that some sites have already been eroded away, while other sites with unspecific organically tempered ceramic finds are still not identified (e.g. Mupini (SC 5), Nyangana-Kangwenu (SC 27), and maybe Mohembo Border Control (SC 60) farther east). Furthermore, the range of decorations of the Gove-style ware is not well understood yet, and some of the potsherds with unusual decorations found among younger shard material may indicate an older occupation horizon of the same sites. The reflections show that more targeted future research would be necessary to assess the full number of early LIG sites along the river.

With regard to the late phase of the Late Ironworking Groups horizon, Figure 170 shows that the number of well-identified archaeological sites markedly increased. So far, 39 sites have been confirmed by means of diagnostic pottery or by oral history. However, as discussed in section 5.1, the northern riverside was even more populated during the late occupation phase of the LIG horizon than its southern counterpart (see also Kose, 2004, pp. 6-7). Many of the late LIG sites are located on the lower river terrace or even in the floodplains, and Vungu-Vungu is the best example of a large settlement laid out in a topographic position which is uninhabitable today. Other sites however, were laid out on the middle or even upper river terrace. As I mentioned earlier, the present settlements are all situated at least on the middle terrace. It is not clear if the different topographic positions of the settlements reflect a temporal succession. The dates from Nyangana-Kangwenu (SC 27), from Rundu Immigration Office (SC 10), Vungu-Vungu (SC 12) as well as the assemblages from Gove-Mbambangandu (SC 17) and Kapako (SC 4) strongly suggest that late LIG sites existed simultaneously in different topographic positions. Perhaps the shift of the communities towards the middle terrace is a recent development during the twentieth century and may be influenced by the modern traffic routes, too. What is more, some of the archaeological sites situated in the floodplains could have been only temporary domiciles during the dry season.

Altogether, and despite all uncertainty as to the source material, there is a strong possibility that the middle Kavango River was rather sparsely populated during the EIG occupation period. The same is true for the early LIG times. However, what is missing in this reconstruction are lithic-dominated non-ceramic assemblages of the same historical periods, which escape my perception because they have not been dated. With the arrival of the modern Bantu-speaking immigrants, the middle Kavango River became densely populated. Nonetheless, much more research needs to be done before we are able to fully fathom the settlement dynamics of this region.

4. Archaeometrical analyzes of ore, slag, and metallic iron from the middle Kavango region

4.1. Iron ore deposits in the middle Kavango region

To understand past metal production, it is important to know the raw materials people used. Many scholars have succeeded in tracing back old mining sites, and reconstructing ancient process parameters by identifying and comparing the chemical signature of ores, slags, refractories and the metal itself. Thus far, the geological resources of the Kavango area have been of limited interest for industrial exploitation and no research on the quantity and quality of iron ores has ever been done. Likewise, soil analyses are largely lacking. To assess potential ore sources used in pre-industrial smelting, surveys were carried out along the southern riverside covering an area between Nkurenkuru and Bagani. The primary aim of these surveys was to detect and to sample potential deposits in the vicinity of archaeological smelting sites, and to get an initial idea of the quality and composition of iron-rich rocks and soil deposits in the research area. Additionally, I followed the recommendations of local ironworkers and sampled ore sources that people remembered from historical smelting. However, there was no time for large-scale surveys, nor was funding available for analyzing a representative number of samples. Because of this all I can present in this section is a preliminary picture of possible near-surface ore resources, far away from any significant geological study. The results will be discussed against the background of the analyzed slag samples in section 4.2, and the oral history study in section 5.3.1.

Bulk chemistry and mineral-phase composition of 24 samples were analyzed through inductively coupled plasma-optical emission spectroscopy (ICP-OES), and mineralogical and microstructural examination was conducted by optical microscopy on polished thin sections (PTS) and X-ray diffraction (XRD) (Table 38, Appendix 3). The results of these analyses allowed me to distinguish four groups of potential iron ores based on their geological setting, their texture, and their FeO-SiO_2-ratios:

Group I:	Plinthic soil with nodular segregations
Group II:	Plinthic hardpan
Group III:	Pisolitic ferricrete
Group IV:	Specular hematite

4.1.1. Group I ores: Plinthite

Eight samples of plinthic soils and concretions were assigned to the Group I ores (Table 39, Appendix 3). As described in detail earlier (section 1.3.2.10), these ores were soft or hard concretions that precipitated in plinthic soils in seasonally waterlogged depressions of palaeo-river and inter-dune valleys (Figures 13 and 15). Plinthic soil horizons represent what are known as alteration profiles, and, as one would expect, the distribution of elements is inhomogeneous and largely depends on the parent material that went into solution in the groundwater (section 1.3.2.6). The thin section of sample 4712/06 disclosed that the concretions were cemented aggregates of fine-grained amorphous precipitates of iron hydroxides and sometimes pseudomorphs of plant material (Figure 171: 4712/06a-f). Groundwater fluctuations during the period of plinthite formation were visible in banded sequences of varied iron oxide content (Figure 171: 4712/06d and e). According to XRD analyses, the main mineral phases of these soils were goethite (FeO(OH)) and hematite (Fe_2O_3) (Table 39, Appendix 3), commonly found in secondary ore formations. In one case (sample 5203/07), siderite ($FeCO_3$) was detected.
The iron oxide content (Fe_2O_3) of the concretions fluctuated from 61.8wt% to 80.09wt% and the silica portion ranged between 6.02wt% and 15.52wt% (Table 40, Appendix 3) (Figure 177). Alumina (Al_2O_3) was barely present in these samples and ratios of alumina to silica ranged between 1:59 and 1:294. Two samples (4716/06 and 5203/07) of the red soil horizons in which the nodules formed were analyzed too. They largely consisted of silica and iron oxides in varying proportions, and alumina did not exceed 3wt%. More interesting with respect to the ore properties was that three samples (4713/06, 4714/06, and 4715/06) showed calcium oxide (CaO) values ranging between 5.94wt% and 13.7wt%. This variability can cause an inhomogeneous slag picture such as seen in the samples from Ruuga (SC 3) and discussed in section 4.2.9. Barium and

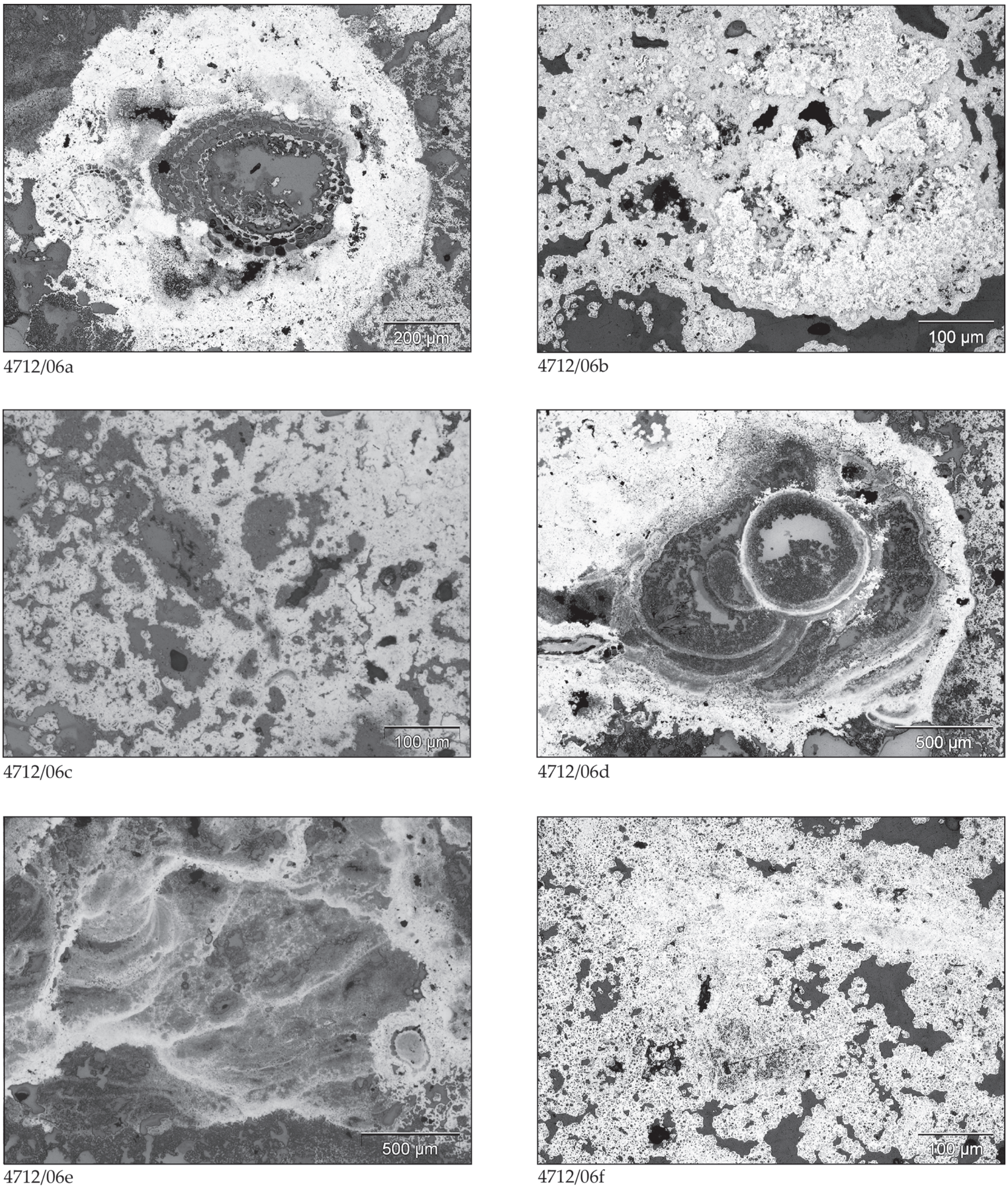
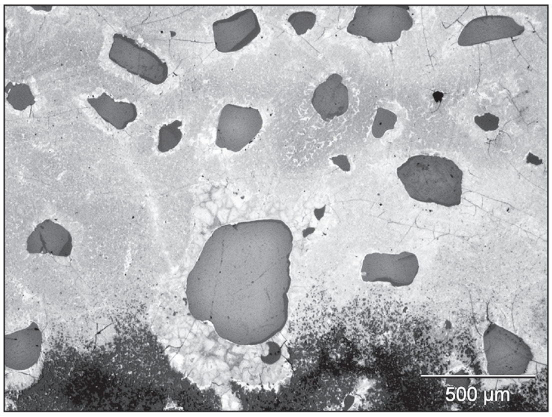


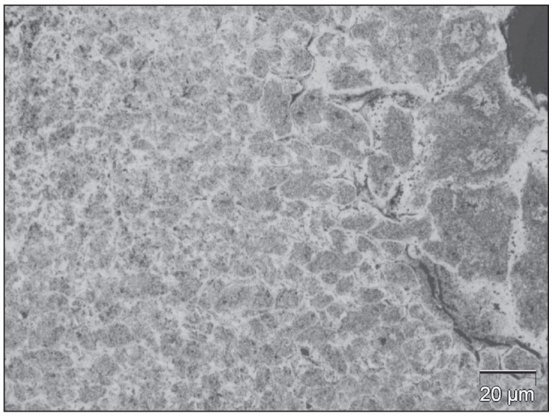
Figure 171: Polished section of Kavango ores. Sample 4712/06, Group I ore nodule from Kapongo (SC 29), N06/02.

strontium values were higher in the material from Dikundu (SC 30) than in those samples collected at Kapongo (SC 29), and reflected variation in the process of formation commonly found in plinthic segregations. All nodules analyzed produced high losses on ignition, indicating a high proportion of organic material and other volatile elements.

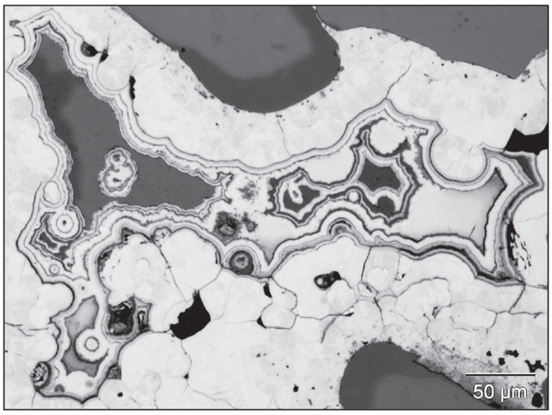
Most samples of the Group I ore were collected following the recommendations of local iron-workers. The rough chemical characterization of these concretions with an average content of 73wt% Fe_2O_3, 8wt% of SiO_2 and 5wt% of CaO (Table 40, Appendix 3) places them among what are known as self-fluxing ores (section 1.4.1). Moreover, as described in section 1.4.1, escaped volatile elements and burnt-out organics add to the porous structure of these ores once a certain temperature is reached, which permits an easy penetration of the reducing gases. The ethnographic information collected in the oral history study (section 5.3.1) underlines that for preference, raw material comparable to the Group I ores was processed. Mines with high quality ores attracted smelters from far away and from various ethnic groups.



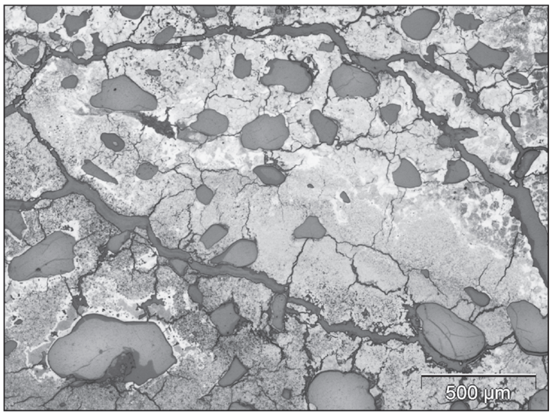
4726/06a



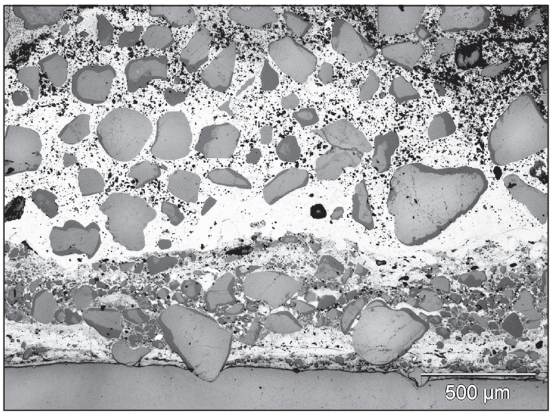
4726/06b



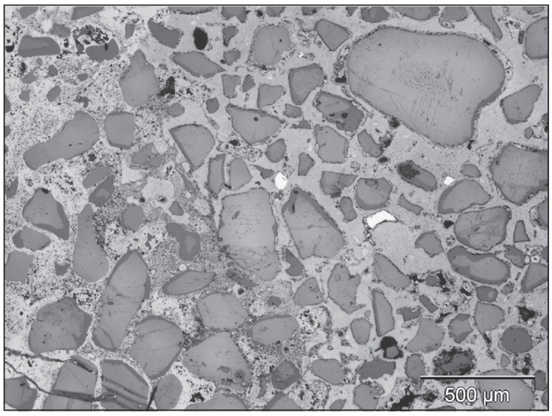
4725/06



4726/06c



4731/06a

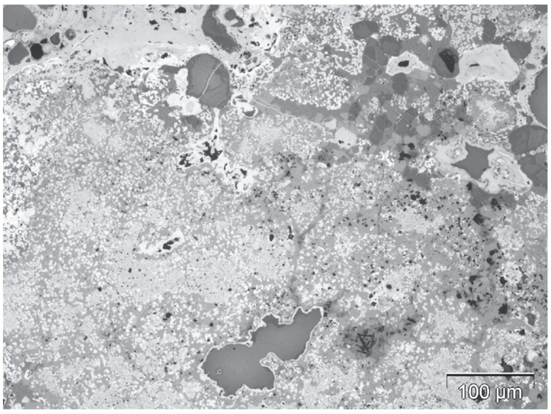


4731/06b

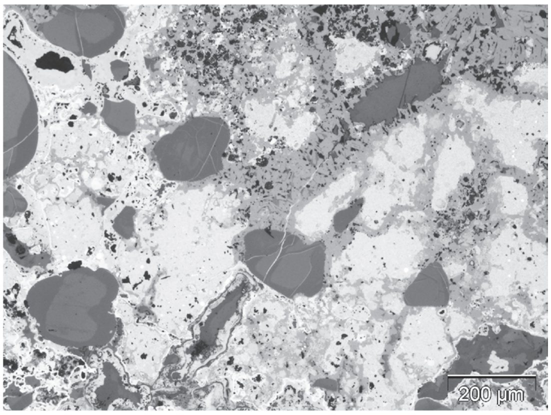
Figure 172: Polished section of Kavango ores. Sample 4725/06, ferruginous sandstone from Gove-Mbambangandu (SC 17), N06/09. Sample 4726/06, Group III ore from Gove-Mbambangandu (SC 17), N06/09. Sample 4731/06, Group III ore from Mupini-Quarry (SC 6), N06/01.

4.1.2. Group II ores: Plinthic hardpan

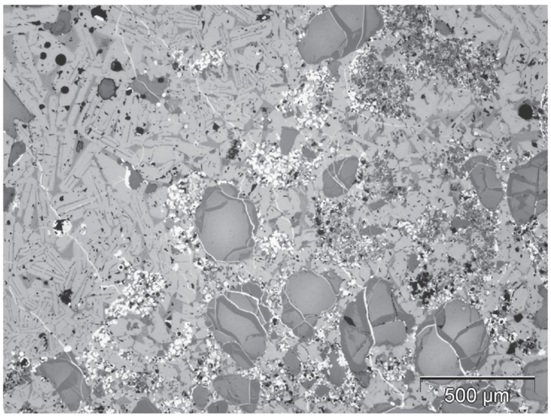
Only two samples of a plinthic hardpan were analyzed (5188/07 and 5202/07), and they were taken from the same chunk of ore. This plinthic hardpan was shown to me by people living in Kauti (SC 32), and was referred to as the raw material historical smelters exploited. Knowing that two samples cannot characterize the ore deposits around Kauti in full, the geomorphological setting, the soil sequences, and their chemical signature prompted me to declare these samples a separate ore group, even though they belong like the Group I ores to plinthic soil formations. The hardpan investigated in Kauti was 50 cm in thickness and composed of successions of thin horizontal bands and sponge-like aggregations of iron oxides (Figure 14). XRD analysis revealed that the main constituent was goethite (FeO(OH)). Bulk chemical analyses disclosed that Fe_2O_3 was present with



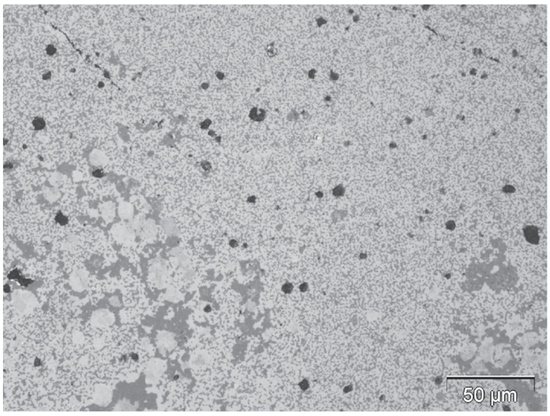
4428/06a



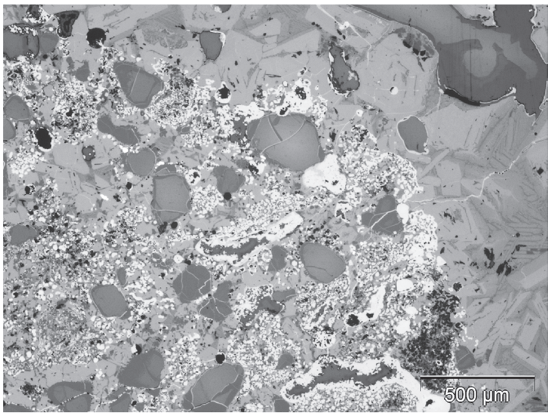
4428/06b



4428/06c



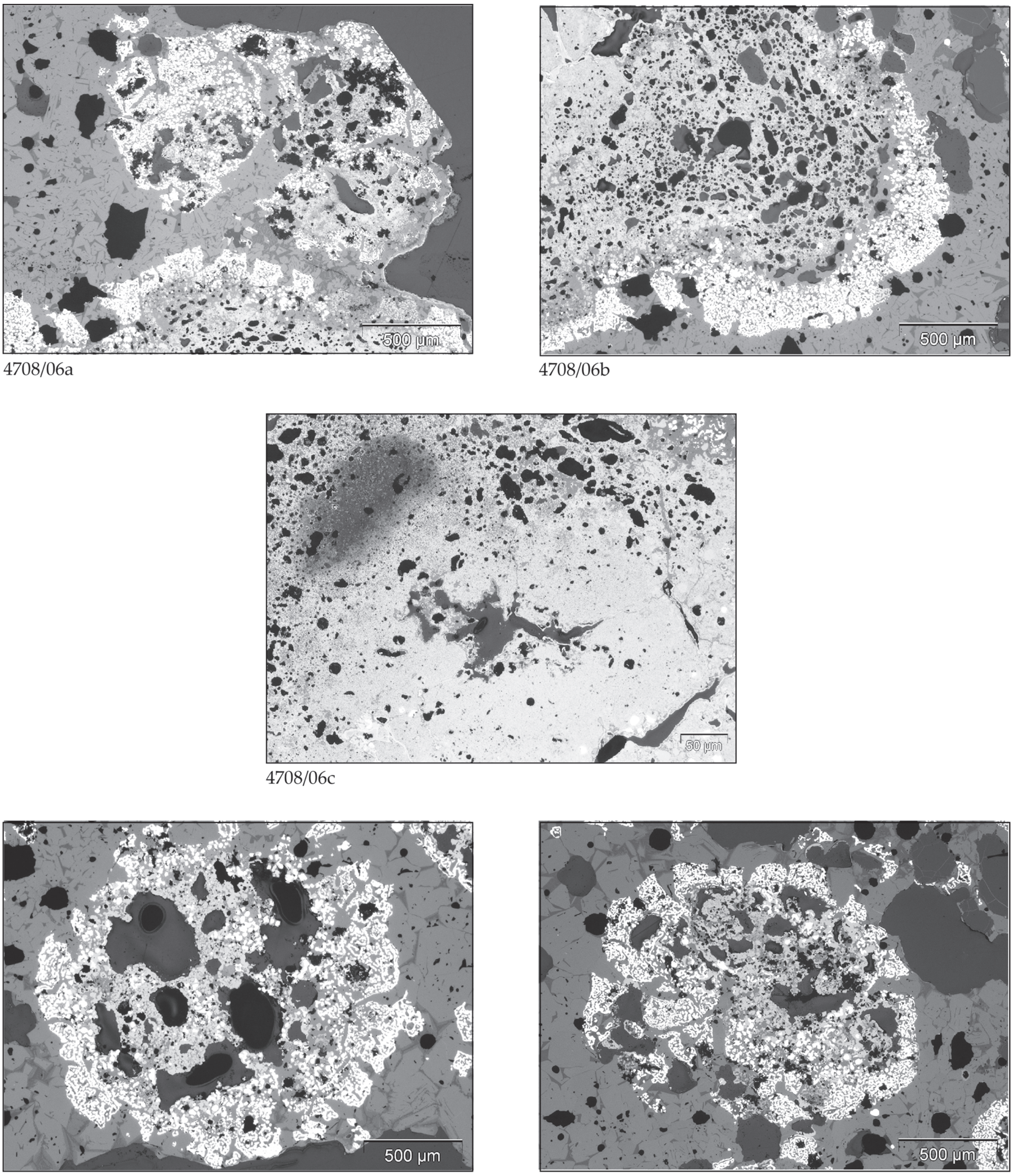
4428/06d



4428/06e

Figure 173: Polished section of semi-reduced ores in slags: Sample 4428/06, bloom in smelting slag with semi-reacted ore inclusions from Vungu-Vungu (SC 12), N98/32-2.

73.4wt%, SiO_2 with 18.3wt% (Table 40, Appendix 3) (Figure 177). Alumina readings were low and the alumina to silica ratio fluctuated from 1:18 (sorted material) to 1:27 (unsorted sample). Most minor elements listed in Table 40 (Appendix 3) occurred only in insignificant quantities and played no major role in slag composition, although the two samples produced elevated values of bismuth, copper, and nickel, which might have affected the quality of the iron produced. The porous and spongy nature of the crust meant that sand became trapped in the pore space. Sample 5188/07 was a trial to improve the iron-to-silica ratio by simple manual sorting and separating sand grains from the dark crust fragments. However, the iron oxide proportion increased only by roughly 2wt% at the expense of silica (Table 40, Appendix 3). Both samples analyzed showed high losses on ignition, indicating a high proportion of organic material and other volatile elements. This implied a porous and reduction-friendly texture of the ore.



4708/06a

4708/06b

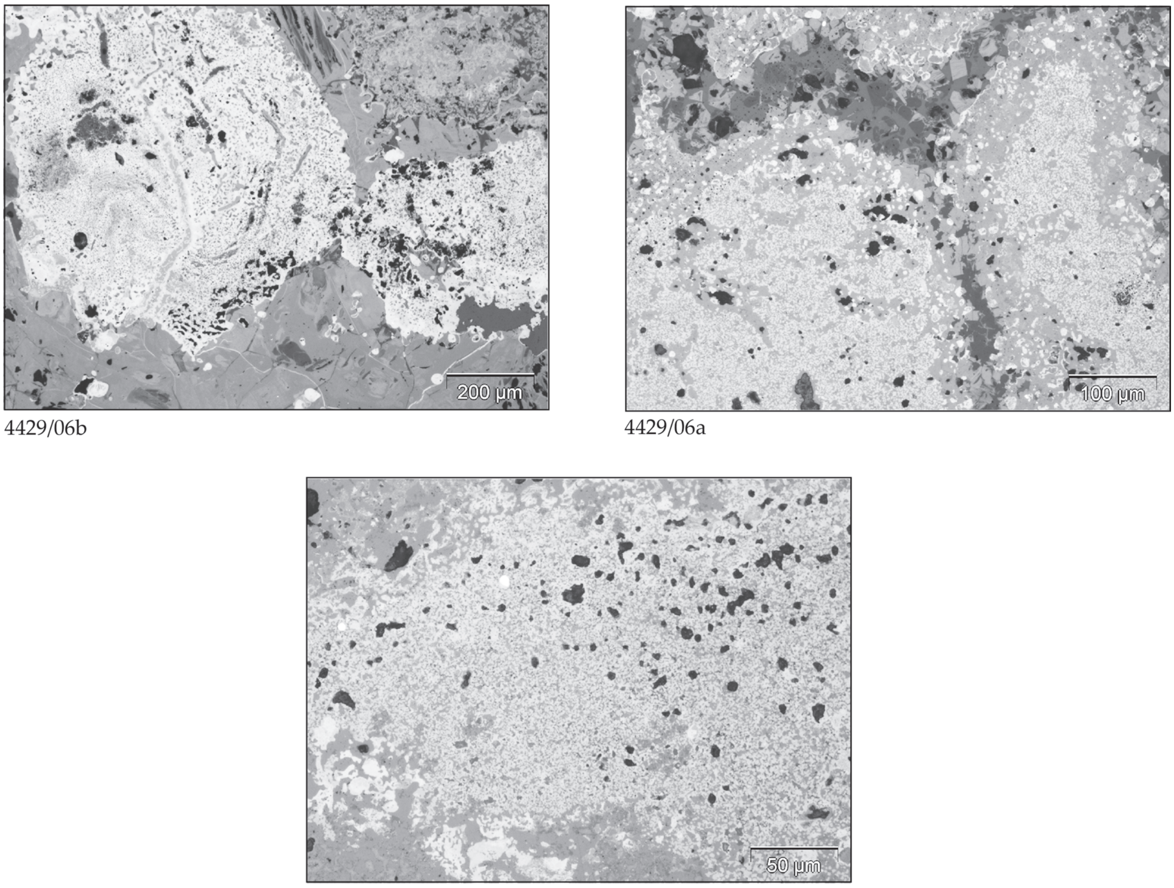
4708/06c

4708/06d

4708/06e

Figure 174: Polished section of semi-reduced ores in slags: Sample 4708/06, bloom in smelting slag with semi-reacted ore inclusions from Dikundu (SC 30), N69/03.

As stated earlier, the Group II ore was collected following recommendations of local ironworkers, and it was used in an experimental smelt, which unfortunately failed. The ore could hardly be improved by simple sorting, but the high silica content permitted the formation of a low-melting fayalitic slag without the need of fluxes (section 1.4.1). The geomorphological setting of the ores from Kauti (see SC Nos. 32-34) suggested that the oxide deposits produced heterogeneous chemical fingerprints (see also sections 1.3.2.6 and 1.3.2.10). The internal variability of the element distribution was already detectable in the Ba, Cr and Ni distribution of only the two samples 5188/07 and 5202/07 (Table 41, Appendix 3). This implies that comparable ores may create a rather inhomogeneous chemical slag picture even though the raw material was taken from the very same extraction pit. The identification of comparable mining areas solely by a comparison of chemical fingerprints of slags becomes all the more difficult when extraction zones are not well identified, either archaeologically or through oral history.



4429/06b

4429/06a

4433/06a

Figure 175: Polished section of semi-reduced ores in slags. Sample 4429/06, initial refining slag with semi-reacted ore inclusions from Vungu-Vungu (SC 1 2), N98/32-2. Sample 4433/06, SHB from initial refining processes with semi-reacted ore inclusions from Vungu-Vungu (SC 12), N98/32-Surf. 4c.

4.1.3. Group III ores: Pisolitic ferricrete

Seven samples of pisolitic ferricretes (Figure 8) from different locations along the southern riverbank were analyzed (Tables 39 and 40, Appendix 3). As described in detail earlier (see section 1.3.2.10), Group III ores are thick layers of hard pisolitic concretions that built up on iron-rich sandstone by residual weathering when the northern Kalahari had a more tropical climate.

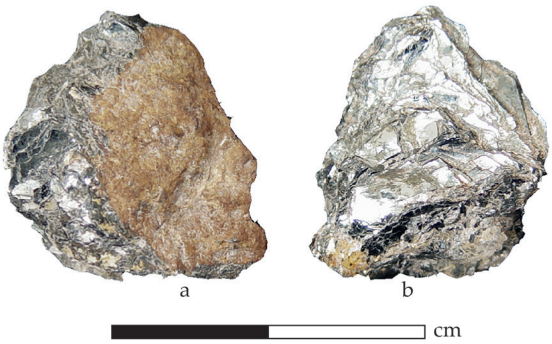


Figure 176: Ruuga (SC 3), N98/39-2, sample 4419/06, Group IV ore specular hematite.

All the samples were taken randomly from different locations. Because of this, they cannot represent the full chemical picture of the local residual weathering profiles. As seen in section 1.3.2.6, residual weathering profiles differ from plinthic horizons in that they show a rather typical distribution of elements according to the various stages of weathering throughout the geological profile. The iron-rich ferricretes are the uppermost zone of the laterite profile, and the typical main components are Fe, Si and Al and rather immobile minor and trace elements such as V, Cr, As, Ti. Depending on the parent rock material, co-precipitants such as manganese may be found as well.

Thin sections of two samples were produced (4726/06 and 4731/06) in order to obtain information about the ore structure. Both samples consisted of rounded sand grains (mainly quartz) varying in grain fraction, which were cemented by distinguishable depositional successions of ferrous or siliceous matrices (Figure 172: 4726/06a-c and 4731/06a-c). The ferrous matrices consisted of fine granular

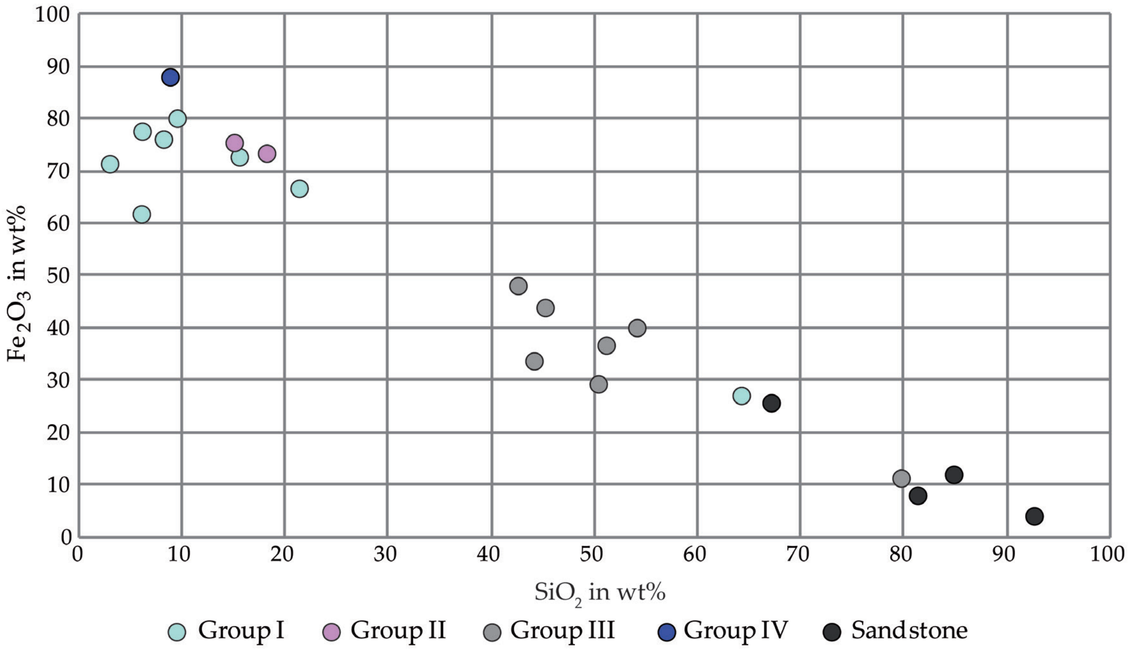
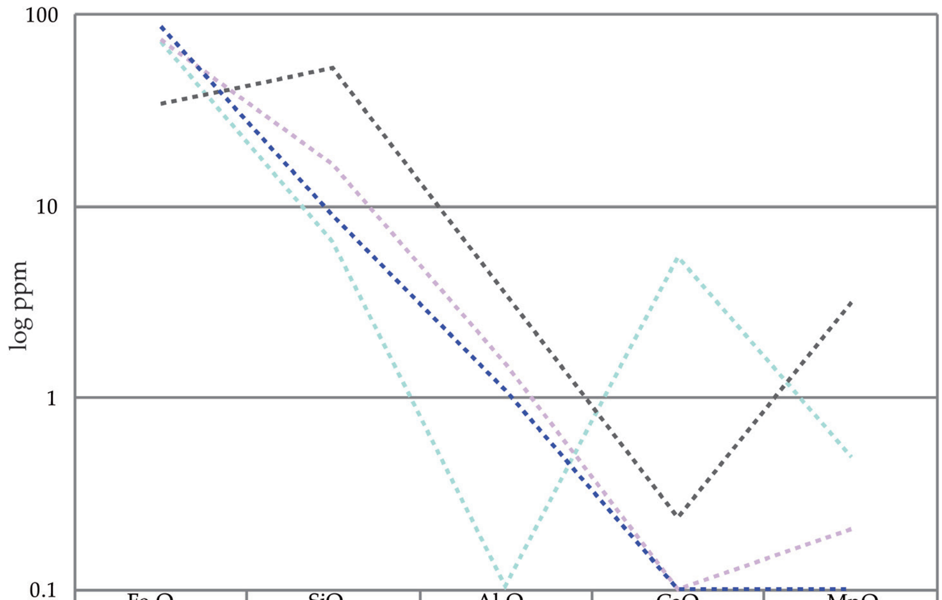


Figure 177: Fe_2O_3 versus SiO_2 proportions in the Kavango ores of the Groups I to IV and ferruginous sandstone.

aggregates, which could form bands of distinct density and showed concentric structures in some cases. The samples also contained some subangular hematite grains (Figure 172: 4731/06a-b). Sample 4731/06 revealed cellular root-channel structures that were replaced by iron oxides. The quartz and hematite grains were probably relics of the parent rock, and the cementation successions reflected climatic cycles. According to XRD analysis, the main mineral phases of the samples were goethite (FeO(OH)) and quartz (SiO_2), while sample 5203/07 revealed also muscovite $KAl_2(AlSi_3O_{10})(F,OH)_2$) (Table 39, Appendix 3). The iron oxide content (Fe_2O_3) of the samples fluctuated between 11.3wt% and 48.1wt%, and silica ranged between 42.54wt% and 79.7wt% (Table 40, Appendix 3) (Figure 177). More alumina (Al_2O_3) was present in these samples than in the ore groups described before, ranging between 2wt% and 6wt% (Table 40, Appendix 3). The ratio of alumina to silica lay between 1:8 and 1:48. CaO and Mg were hardly present, as is commonly the case in the upper zones of residual weathering profiles (see section 1.3.2.6). More interesting was the elevated manganese fraction in sample 4724/06 and 5205/07, because manganese replaces iron in fayalitic slag formation (see section 1.4.6) and purposeful selection may improve the quality of these ores. As discussed in section 1.3.2.6, manganese is present in ferricretes depending on the composition of the parent rock, and on the position within the geological profile. This may explain why samples 4726/06 and 4723/06 contained only limited manganese, since they were taken from the uppermost stratum of the crust. The porous nature of the ferricretes also meant that sand became trapped in it. Sample 5205/07 was therefore a trial to improve the iron-to-silica ratio by simple manual sorting and separating sand grains from the dark crust fragments. However, the iron content increased only by roughly 4wt% at the expense of silica, and the latter decreased by about 6wt% (Table 40, Appendix 3).

Group III ores revealed a different chemical profile than the Group I and II ores. As is to be expected in the upper horizon of a residual weathering profile, vanadium,chromium and titanium are enriched, whereas the average strontium proportion is lower than in Groups I and II (Table 41, Appendix 3). All the samples showed variable barium readings, and in samples 4724/06, 5205/07, and 4730/06 the elements were markedly more present than in the average of the remaining samples. All the samples examined produced losses on ignition between 3wt% and 8wt%, indicating a high proportion of organic material and volatile elements.

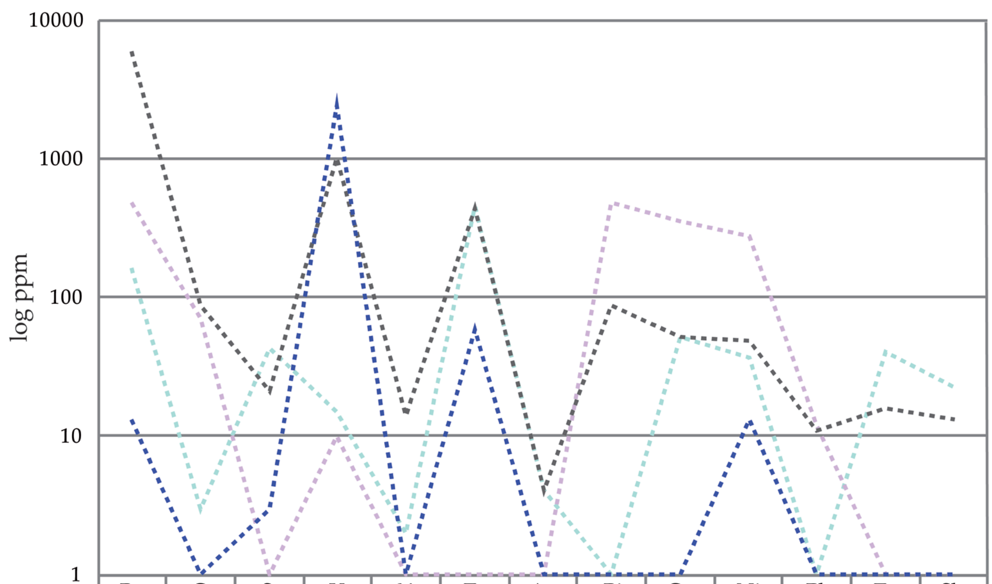
The material of the Group III ores was collected because smelting sites were associated with them (N96/05 (SC 17); N96/08-1 (SC 16); N98/44 (SC 21)), and oral history has it that they were used in traditional smelting by certain smelters (section 5.3.1). However, the composition of these crusts with an average content of 35wt% of Fe_2O_3, and 52wt% of SiO_2 (Table 40, Appendix 3) makes them unsuitable for



	Fe_2O_3	SiO_2	Al_2O_3	CaO	MnO
I	73.3	6.5	0.1	5.5	0.49
II	74.4	16.7	1.51	0.1	0.21
III	34.4	52.4	3.46	0.24	3.18
IV	88.2	8.99	1.1	0.1	0.1

Major elements

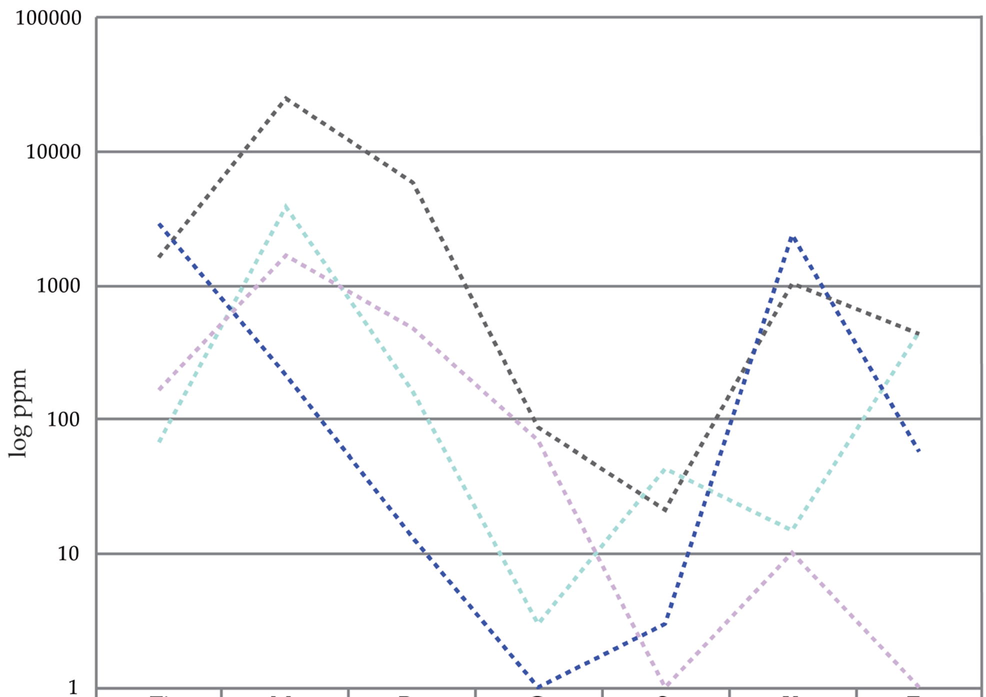
Figure 178: Average proportions of major and minor elements in the Kavango ores of Group I to IV.



	Ba	Cr	Sr	V	Y	Zr	As	Bi	Cu	Ni	Pb	Zn	Sb
I	161	3	43	15	2	452	4	1	52	37	1	40	22
II	483	70	1	10	1	1	1	482	349	277	12	1	1
III	5861	86	21	1019	14	434	4	88	51	49	11	16	13
IV	13	1	3	2397	1	58	1	1	1	13	1	1	1

Trace elements

Figure 179: Average proportions of trace elements in the Kavango ores of Group I to IV.



	Ti	Mn	Ba	Cr	Sr	V	Zr
I	67	3843	161	3	43	15	452
II	164	1657	483	70	1	10	1
III	1605	24647	5861	86	21	1019	434
IV	2901	212	13	1	3	2397	58

Lithophile elements

Figure 180: Average proportions of lithophile elements in the Kavango ores of Group I to IV.

bloomery smelting without pre-treatment. Consequently I suggest that the Group III ores could have been used only after thorough beneficiation or with a rich calcium or manganese flux (see section 1.4.1), but they certainly could have been used to flux rich ores with insufficient gangue.

4.1.4. Group IV ore: Specular hematite

The Group IV ore was represented by a single piece of specular hematite (4419/06) (Figure 176) (Table 39, Appendix 3). It was found at Ruuga (SC 3) in an EIG archaeological context. It contrasted with the ores of Groups I to III because it was a primary ore and was not indigenous to the research area. Chemical analysis revealed iron and silica to be the main constituents (Fe_2O_3: 88.2wt%; SiO_2: 8.99wt%) (Table 40, Appendix 3) (Figure 177), and that the sample had a high vanadium fraction (Table 41, Appendix 3). The ore was suitable for smelting, and reducibility could be facilitated by adding fluxing components.

4.1.5. Ferruginous sandstone

Four samples of sandstone were analyzed, which were found associated with ferricretes (4725/06, 4728/06, and 4729/06), or sandstone outcrops elsewhere in the region (4707/06) (Table 38, Appendix 3). All the samples were weathered and leached and probably constituted remnants of the parent rock material within the local laterite profile of the Omatako formation. The Fe_2O_3 readings ranged from approximately 4wt% to 25wt% (Table 40, Appendix 3). The sedimentary nature of the rock was best visible in the thin section of sample 4725/06. It revealed that the iron-rich zone was composed of sand (mainly quartz) of various grain fractions, which was cemented by a matrix of iron hydroxides with colloform growth banding (Figure 172: 4725/06a). Some subangular grains of hematite were embedded in the matrix, as well as unspecific organic inclusions. All in all, the chemical signature varied among the rock samples but the number of samples was too small to draw any further conclusion.

4.1.6. Chemical characteristics of the Kavango ores

All the groups defined here differed in their chemical signatures. I am aware that the number of samples taken to define these groups cannot be representative, that the sample taking was random, that one sample cannot characterize a deposit, and that the resulting picture is therefore incomplete and biased. Nevertheless, I use the data to carve out some characteristics of these ores that may help to illuminate the preferences of the Kavango smelters, and I leave it to future research to accept or reject my suggestions.

I calculated the average of the major oxides and trace elements of each group (Tables 40 and 41, Appendix 3), and plotted them in diagrams of Figures 178 and 179. A look at the major elements revealed that apart from the striking difference in the Fe_2O_3 proportions between Group III ores and the others, Group I ores produced raised CaO values. The latter add to the iron content when it comes to fayalite formation, and would increase the yield of the smelt (see section 1.4.6). The same is true for the elevated manganese content of the Group III material, but even so the average content of manganese is not enough to make this ore attractive for bloomery smelting. Group II and Group IV ores were similar in their signature with respect to the major element average illustrated in Figure 178. A closer look at the average trace-element fractions revealed that Group III contained considerably more trace elements of all kinds tested for here than the other groups, and it contrasted markedly with the other ores through high Ba, V and Zr values (Figure 179). The signatures of Group I and Group II ores were not as overlapping as seen before in Figure 178, and they particularly diverged in Cr, Sr, Zr, Bi, Cu, and Ni. The Group IV ore produced the highest vanadium reading of all groups, and the smallest quantities of the remaining other elements compared to the Group I to III ores.

In identifying ancient mining areas, the lithophile elements are of major interest because temperature frequently was not high enough and redox conditions not reducing enough in bloomery smelting to break the chemical bond of these elements with the oxygen. Therefore, such elements are commonly found unchanged in the slag. As described in section 1.4.6, lithophile elements are manganese, titanium, barium, chromium, vanadium, strontium and others. A plot of these elements in Figure 180 illustrated that Group III and Group IV differed considerably from each other, except for vanadium. However, working with the average mass proportion of elements such as manganese and barium in Group III is somehow misleading because, as discussed earlier and as seen in the Tables 40 and 41 (Appendix 3) there is considerable internal mass variance of the individual elements in such deposits. As can seen from Table 40 (Appendix 3), only three samples showed manganese values above 1wt%, and the average of the remaining four samples would bring Group III ores close to Group II. Despite these constraints, I suggest that titanium, chromium, strontium, vanadium, and barium are suitable Group III indicators. Group I ores produced considerably less internal variation in trace element fractions, which is certainly due to their geographical proximity and their similar history of deposition.

4.1.7 Ore remains found in slag samples

Four samples (4428/06, 4429/06, 4433/06 and 4708/06) of smelting and initial refining slag revealed inclusions of unreduced or partially reduced iron ore (Figures 173 to 175). Polished cross section examination of these inclusions showed that a porous (Figure 175: 4429/06b, Figure 174: 4708/06a-c) and fine-grained (Figure 173: 4428/06a and c, Figure 174: 4708/06c, Figure 175: 4429/06a and 4433/06a,) ore was preferred. The fragments detected in sample 4429/06 (Figure 175: 4429/06b) and 4708/06 (Figure 174: 4708/06a and b) indicated that the ore was nodular in shape. The angular contour of some remnants found in sample 4428/06 (Figure 173: 4428/06b) attested that the ore had been crushed into fine lumps before it entered the furnace. Samples 4428/06 and 4429/06 disclosed quartz grains in various states of thermal alteration associated with the ore remains, and the formation of new fayalite could be observed. However, one could not tell from the microstructure whether the sand grains were part of the ore as seen in Figure 172: 4726/06a, or whether they were added separately for fluxing purposes. Yet the presence of strongly altered quartz grains next to unaltered ones as seen in Figure 173: 4428/06a justifies the interpretation that sand had been added step by step to the running furnace to facilitate the slag formation and to maintain a certain slag fluidity (see section 1.4.6). All in all the structural appearance of the ores found in these slag samples indicated that a source material comparable to sample 4712/06, which belonged to the Group I ore, was favored. However, high quality ore of Group III as seen in Figure 172: 4726/06a may have been used as well, as indicated by the crushed ore fragments in sample 4428/06 (Figure 173: 4428/06b). Samples 4428/06 and 4708/06 were smelting slag remains that exhibited unreduced ore fragments in a fully developed fayalitic slag bath (Figures 173 and 174). From a procedural point of view, such combination can only occur if ore was added to a furnace which had been running for several hours, and in which a fully reacted fayalitic slag bath had had enough time to develop from the iron oxides and the gangue. Therefore both samples can be seen as evidence for the refilling of a running furnace with fresh ores.

4.2. Slag analyses

Fifty-seven samples were chosen for microscopic and chemical examination (Table 42, Appendix 3). Following morphological criteria as described in the sections 1.6.2.1 to 1.6.2.3, in combination with microstructure examination on thin sections and polished cross sections, the slag finds were classified into eight categories of smelting slag, refining slag and secondary smithing slag:

Group I: Furnace slag, smelting
Group II: Flow slag, smelting
Group III: Bloom with slag, smelting
Group IV: Initial bloom refining slag
Group V: Advanced bloom refining slag
Group VI: Final bloom refining slag
Group VII: Secondary smithing slag
Group VIII: Unspecific slag

From Figure 181, it can be seen that 49.1% (n = 28) of the 57 samples analyzed turned out to be refining slag, whereas 19.3% (n = 11) were smelting slag, and the same percentage (19.3%, n = 11) were remnants of unrefined blooms. Secondary smithing slag fragments accounted for 8.8% (n = 5) of the samples and two specimens (3.4%) remained unclassified.
As seen above, a closer classification of the samples on hand allowed me to define eight sub-categories or slag groups that represented varying steps in iron production and subsequent processing (Figure 182). 12.1% (n = 7) of the samples could be classified as furnace slag whereas 7% (n = 4) fell into the range of flow slag. The major portion of refining slag divided out into 19.3% (n = 11) of residues from initial bloom refining, 17.5% (n = 10) of remnants from advanced refining, and 12.3% (n = 7) of slag that formed during the final refining processes of a bloom. Again, secondary smithing slag accounted for 8.8% (n = 5) of the samples, and two specimens (3.4%) remained unclassified.

4.2.1. Furnace Slag (Group I) and slag associated to blooms (Group III)

All the samples listed in Table 42 (Appendix 3) were classified according to the characteristics described in sections 1.6.2.1 to 1.6.2.3. Most samples that were assigned to furnace slag or bloom were either greenish medium gray (n = 6) or medium gray (n = 5) in color. Dark gray was observed three times. As seen in section 1.6.2.1, green colors indicate that these samples were dominated by green olivine (fayalite), and slag samples of medium gray contained less iron oxide than those of dark gray. The exterior of the samples was frequently of a rusty brown, or of the same color as the interior. Rusty brown minerals are formed when hot slag is exposed to oxidizing conditions, perhaps in a furnace after the bloom had been removed from it (section 1.6.2.1).
All the samples of furnace slag were fractured. In addition, the bloom fragments did not show the original surface of the bloom in the furnace, except for samples 4708/06 and 4409/06 (Figure 154). As far as can be reconstructed, the shapes of the slag ranged from amorphous to tabular and plano-convex. Sample 4403/06 possessed a thick rim of slagged sand grains and probably solidified at the bottom of a furnace. Sample 4415/06 and 4417/06 gave reason to assume that they cooled down in a slag collecting pit because they had thick rims of sand that became trapped in liquid slag without showing much thermal reaction (Figure 122). A cooling skin was documented in two samples (4428/06 and 4709/06). The density of the slag texture varied, ranging from very dense to sponge-like. Magnetism was tested on all the samples, but it was not a helpful tool because the selected slag fragments were variably magnetic due to inclusions of elemental iron.
Thirteen samples of furnace slag and bloom remains were available for microstructure analyses (Table 42, Appendix 3). Among them, polished thin sections were produced from three furnace slag fragments (4415/06, 4417/06,

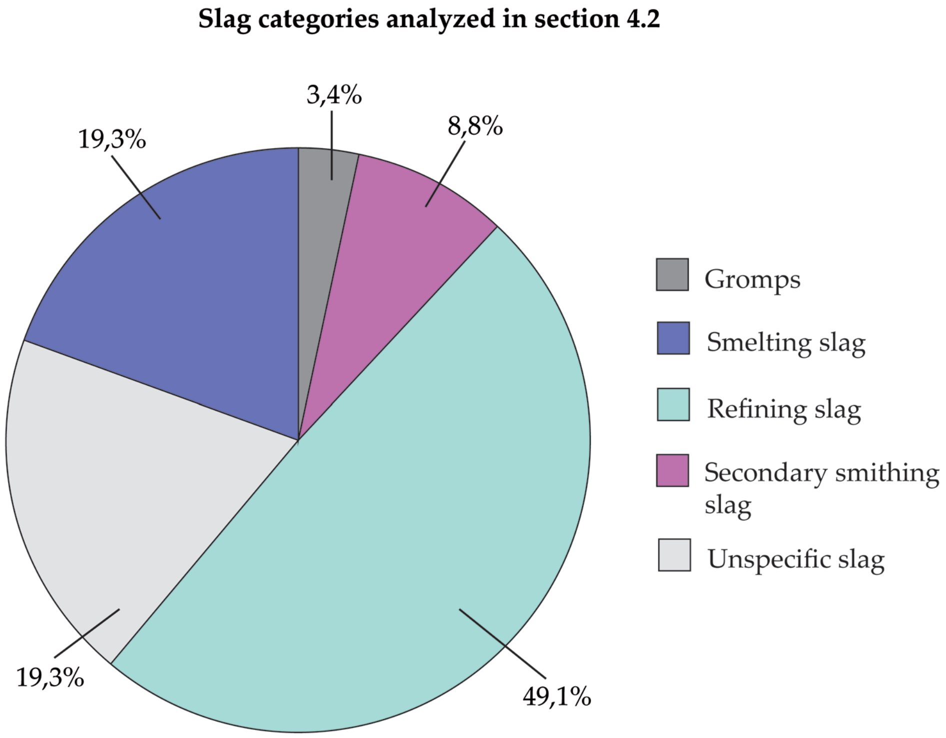


Figure 181: Pie chart of the slag categories analyzed in section 4.2.

and 4428/06), and from 10 bloom samples that showed enough slag remains for phase analyses of cross sections to be made (4389/06, 4394/06, 4395/06, 4404/06, 4407/06, 4413/06, 4426/06, 4708/06, 4709/06, and 4720/06).

Microtexture examination in reflected and transmitted (polarized) light revealed that most samples (n = 5; 4404/06, 4407/06, 4413/06, 4426/06, and 4708/06) consisted of fayalite and interstitial glass (Table 43, Appendix 3). Two samples (4389/06 and 4428/06) showed fayalite as the first phase that crystallized, followed by a fayalite/leucite eutectic in interstices. In addition to the aforementioned phase successions, sample 4394/06 and 4395/06 provided proof of a final glassy matrix. Only three of the samples contained wustite (Table 43, Appendix 3). In sample 4417/06, fayalite crystallized first, followed by wustite and a fayalite/wustite eutectic, and sample 4709/06 showed in addition to this phase succession a final glassy matrix. Sample 4415/06 was the only evidence found in smelting/furnace slag where wustite appeared as the first phase, followed by fayalite, a fayalite/wustite eutectic and a final glassy matrix (Figure 183). One layer of this sample consisted of a fayalite/wustite eutectic only. A rather exceptional sample was 4720/06 because silica-rich mineral phases formed first before fayalite and a ternary eutectic of leucite/fayalite/spinel solidified. Unfortunately, this sample was lost before I could finish my examination, and I was not able to identify the first phase.

To summarize, one can state that the investigated samples were all fayalite-dominated slag, and excess wustite was successfully reduced to metallic iron. Leucite ($K(AlSi_2)O_6$) also played a dominant role in these furnace slag samples and its formation was probably favored by a K_2O input from fuel ashes and refractories. As mentioned in section 1.4.6, potassium is known to lower liquidus temperatures of slag compositions in bloomery smelting and consequently is most favorable in a melt. However, as K_2O identification of my bulk chemical analyses was only done at random, and since I analyzed neither refractories nor fuel compositions, I must leave it to future research to elucidate the role of potassium in these smelts.

All the samples displayed a regular microstructure with a homogeneous distribution of the individual mineral phases, and gradual transitions when the composition changed. The samples 4415/06, 4417/06, 4428/06, 4708/06, and 4709/06 showed large blocky fayalite

Slag sub-categories analyzed in section 4.2

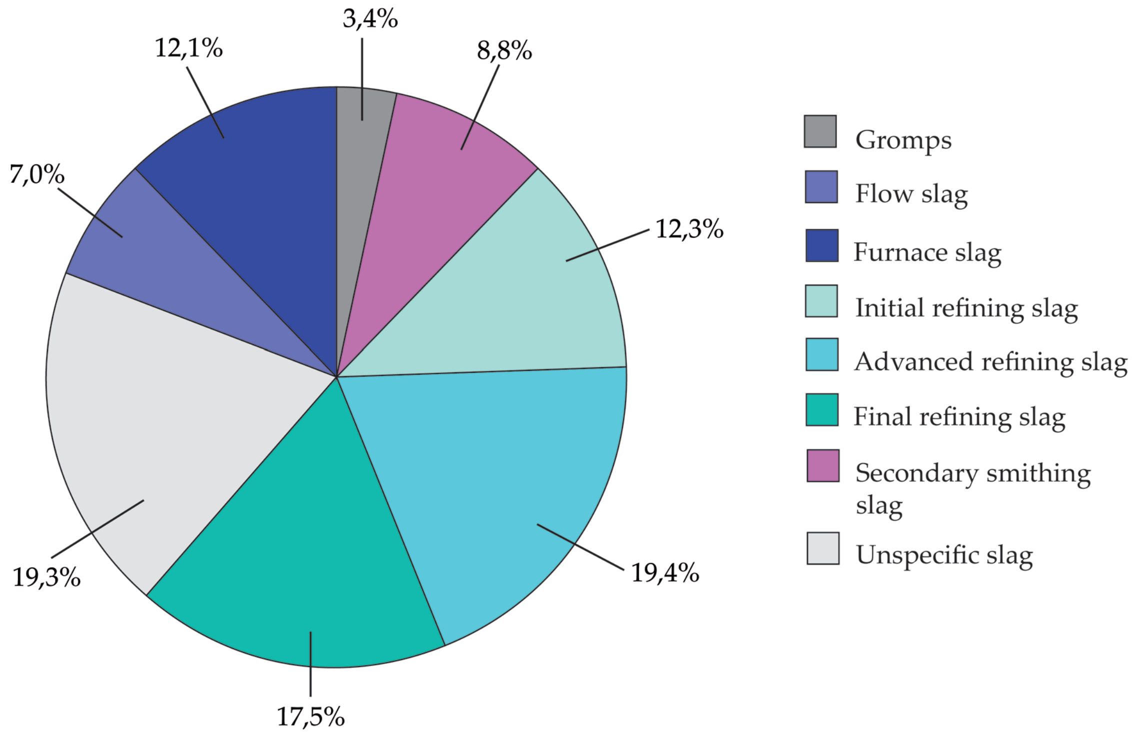


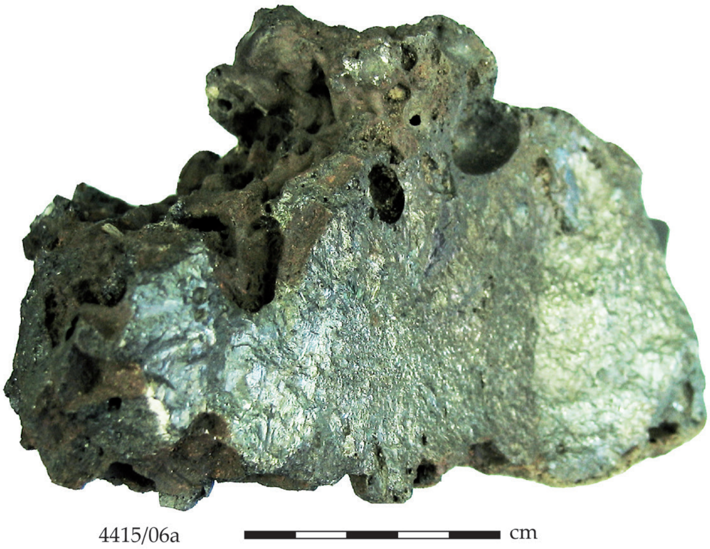
Figure 182: Pie chart of the slag sub-categories analyzed in section 4.2.

crystals, which had enough time to develop during slow cooling, and some of these samples show crystals of the second and third generation. By contrast, samples 4389/06, 4394/06, 4404/06, 4407/06, 4413/06, and 4426/06 revealed fayalites that had hardly had time to evolve from the melt, indicating that the bloom was removed from the hot furnace and exposed to fast cooling. As mentioned above, in samples 4415/06 and 4417/06 rims of sand grains were detected that became trapped in the slag. The grains showed little thermal stress reactions. This circumstance led me to assume that the specimens cooled down in an environment below furnace running temperatures, probably a separate slag pit. Erosive processes of a smelt, probably from a furnace wall, occurred in sample 4413/06 with fractured sand grains in transition to new silica-rich mineral phases. In sample 4428/06, sand grains were associated with partially reduced ore (see section 4.1.7) in a well-developed slag bath (Figure 173: 4428/06d-e). These quartz grains exhibited varying degrees of alteration and certainly entered the furnace at different moments during the smelt. This might have been in association with the ore, or as fluxes to facilitate slag formation.

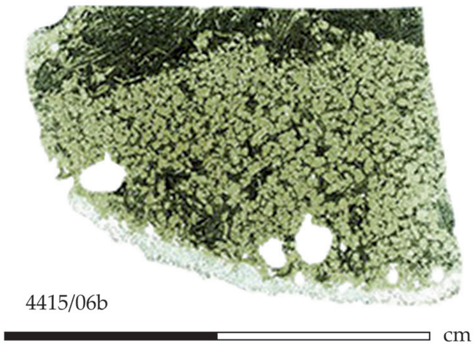
4.2.2. Flow slag (Group II)

Four samples were assigned to flow-type slag (4388/06, 4390/06, 4401/06, and 4406/06) (Table 42, Appendix 3). All the samples showed a smooth exterior and flow structures. The inner color did not differ from the colors of the exteriors of the samples. It ranged from light greenish gray to dark and blackish gray, indicating variation in the iron-oxide content. Runners and droplet-like structures along the surfaces further suggested that these samples were all run slag that descended inside of a furnace (see section 1.6.2.1). Sample 4388/06 even suggested that it cooled down along a furnace wall.

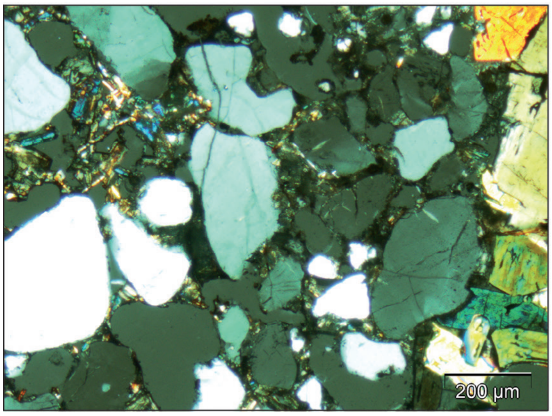
Only one sample of flow slag was examined in thin section (4390/06). It showed a homogeneous microstructure of large fayalite and spinel (magnetite) crystals, both present in two generations (Table 43, Appendix 3). Spinel (magnetite) developed first in an oxidizing environment and fayalite and the crystals of the second generation succeeded it. A glassy matrix filled the crystal interstices. The sample provided proof of several flow successions and its macro-crystalline development indicated that it cooled down in a furnace.



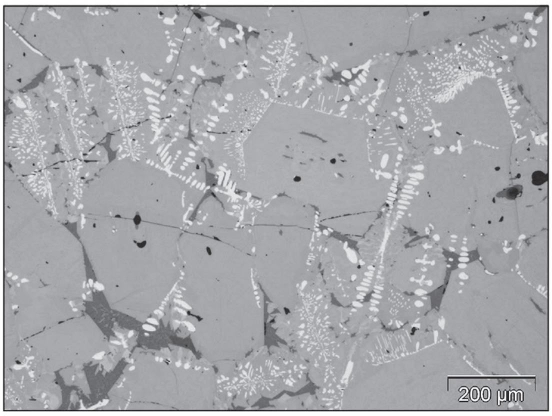
4415/06a



4415/06b



4415/06c

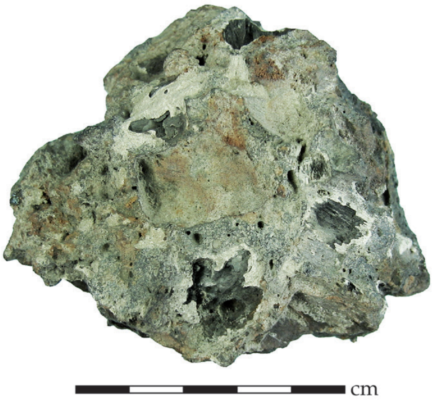


4415/06d

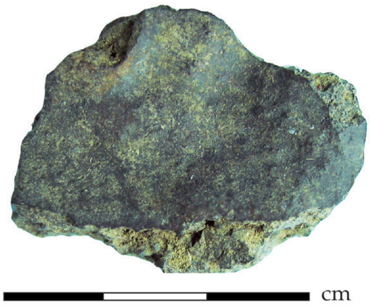
4415/06a: Dense smelting slag.
4415/06b: Thin section showing macrocrysallline fayalitic slag in light green in conjunction with opac dark gray parts where wustite dominates the slag composition.
4415/06c: Unfractured quartz grains (medium gray to white colors) in a fayalitic slag bath (polichromatic crystals) in polarized light.
4415/06d: Slag composition showing wustite dendrites as first phase (light gray) followed by blocky fayalites (medium gray), an fayalite/wustite eutectic and in interstices a glassy matrix (dark gray) in reflecting light.

Figure 183: Smelting slag block samole 4415/06 from Vungu-Vungu (SC 12), area N69/01-1.

4411/06a

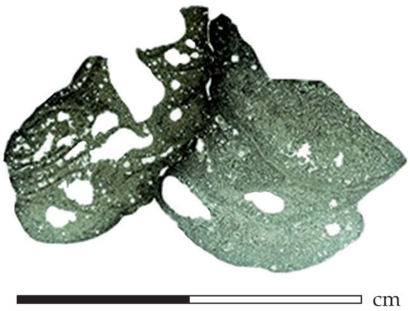


4411/06b



4396/06a

4396/06b



4393/06a

4393/06b

4429/06

4411/06a: Smithing hearth bottom from initial refining processes with surface skin.
4411/06b: Bottom side of the SHB indicating that the slag cooled down in a charcoal bed.
4396/06a: Smithing hearth bottom from initial refining processes with surface skin.
4396/06b: Bottom side of the SHB indicating that the slag cooled down in a sand bed.
4429/06: Amorphous initial refining slag with trapped bits of charcoal.
4393/06a: Thin section of flow slag from initial refining showing repeated flow events in its layered texture.
4393/06b: Initial refining with flow structures.

Figure 184: Initial refining slags from the Kavango sites. Samples 4393/06, 4396/06, and 4411/06, Ruuga (SC 3), area N98/39-2. Sample 4429/06, Vungu-Vungu (SC 12), area N98/32-2.

4.2.3. Initial bloom refining slag (Group IV)

Initial bloom refining slag that was analyzed accounted for 10 samples (Table 42, Appendix 3). The main properties that I used for the classification of this group were the presence of unworked and partially worked bloom fragments, crowded wustite patterns indicating amorphous hammerscale, and a possible layered appearance. All the samples were of dark to medium gray color and exhibited rusty brown parts. The interior of theses slag types was also dark to medium gray and most of them showed a silvery luster. Most samples contained corroded iron, which produced patches of brown rust at the surface.

All the slag samples were fractured but most specimens showed parts of their original top and bottom sides. Five samples (4393/06, 4423/06, 4429/06, 4435/06, and 4436/06) were amorphous refining slag as described in section 1.6.2.2 (Figure 184: 4393/06 and 4429/06), two specimens were plano-convex (4411/06 and 4433/06) (Figure 184: 4411/06) and one was convex-convex (4719/06) in vertical section. Another two samples (4396/06 and 4422/06) were tabular (Figure 184: 4396/06). Seven samples provided proof that the slag cooled down either in a sand bed (4396/06, 4429/06, 4433/06, and 4719/06) (Figure 184: 4396/06b), in a charcoal bed (4431/06) or in a charcoal bed that was placed in sand (4411/06 and 4436/06) (Figure 184: 4411/06b). A cooling skin was regularly present on the top side of the samples (4393/06, 4396/06, 4411/06, 4422/06, 4423/06, 4429/06, 4435/06, 4436/06, and 4719/06) (Figure 184: 4411/06a and 4396/06a), indicating that one side was exposed to cold oxidizing conditions. Density of the slag varied and ranged from a compact and solid texture to a pumice-like appearance. Pore size varied from minute to large pores up to 3.5 cm in diameter. Only one sample (4433/06) showed radiating oblong pores that are considered characteristic for smithing-hearth bottoms (see section 1.6.2.2). Magnetism was highly variable due to the inclusions of elemental iron in varying sizes and stages of weathering, and due to the magnetic cooling skin.

The microstructure was examined on polished cross and thin sections of 10 samples of initial bloom refining slag (Table 42, Appendix 3) and the analyses revealed the layered and sometimes conglomerated nature of these samples. Most specimens were composed of several layers of slag and in polished section it became clear that these layers could vary considerably in composition and, as a consequence, in crystal phase successions (4429/06, 4435/06, and 4719/06). Furthermore, examples were found where phase successions gradually changed throughout the section without a clear structural boundary (4422/06, 4429/06, 4433/06, 4435/06, and 4436/06). Wustite occurred most frequently as first phase, succeeded by fayalite and a fayalite/wustite eutectic, and in some cases glass solidified in interstices as final phase (4393/06, 4396/06, 4411/06, 4422/06, 4423/06, 4433/06, 4435/06, and 4719/06) (Table 43, Appendix 3). Only one example displayed the succession wustite, fayalite and glass (4433/06). Two specimens were found where wustite was followed by a fayalite/wustite eutectic as second phase (4435/06 and 4436/06) and one sample (4719/06) revealed a layer that consisted of a fayalite/wustite eutectic only. Four samples exhibited layers or zones in which fayalite crystallized first (4422/06, 4429/06, 4435/06, and 4719/06), followed by a fayalite/wustite eutectic, wustite or glass. One example had wustite as second phase (4719/06). Four of these multi-compositional slag fragments showed a fayalite/leucite eutectic as the final phase of solidification (4429/06, 4435/06, 4436/06, and 4719/06) (Table 43, Appendix 3).

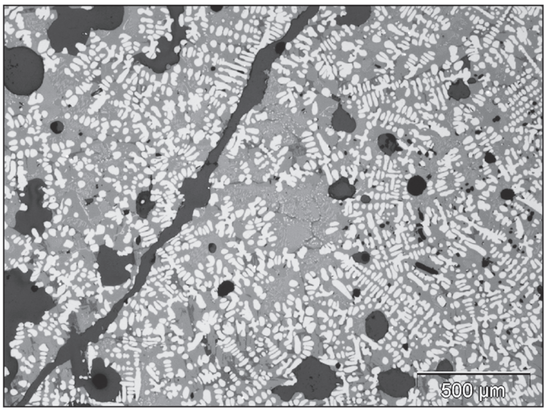
The wustite-headed phase successions of the initial refining slag samples mirrored the increasing fraction of iron oxide found in these remains. The hammerscale that became lost in the slag bath during the consolidation of the bloom explains this. As discussed in section 1.6.2.2, in initial refining processes one can expect a mixture of smelting slag along with re-oxidized elemental iron that forms amorphous lumps of iron-rich slag. These slag remains are also called amorphous hammerscale. The latter produces crowded insular wustite agglomerations of unspecific shape in the slag bath that tend to dissolve if they stay long enough in the liquid slag. They are, however, indicative of early refining activities, in particular if they are associated with unrefined bloom fragments. The characteristics of the analyzed samples and their phase successions suggested that iron oxides were abundantly present in these slag fragments due to the amorphous hammerscale produced during the initial hammering, and unlike the smelting slag described earlier, a low-melting fayalite/wustite eutectic appeared most frequently. Those zones in which fayalite crystallized first were close to the phase composition of smelting slag and commonly

they displayed a fayalite/leucite eutectic as final phase. Most probably, these slag remains reflected a very early processing step in refining when the bloom was heated and smelting slag had been drained away before consolidation.
A look at the size and shape of the crystals revealed that three samples cooled down rather quickly (4393/06, 4396/06, and 4429/06) (section 1.6.2.1), and four samples provided evidence of slow cooling in a protected environment (4411/06, 4422/06, 4423/06, and 4431/06). However, three slag samples (4433/06, 4435/06, and 4719/06) exhibited layers of variable crystal growth suggesting each layer formed not only under chemically different preconditions but also in thermally alternating circumstances.
All the mineral phases found in the samples formed under reducing conditions comparable to those present in smelting operations. Moreover, seven specimens (4393/06, 4396/06, 4411/06, 4422/06, 4423/06, 4435/06, and 4436/06) provided proof that redox conditions and temperature permitted wustite to become reduced to elemental iron in the refining hearth or furnace. Only sample 4393/07 revealed some spinel (magnetite), which needed more oxygen to form. However, as described earlier, most samples displayed a cooling skin on the upper side of the specimen, indicating oxidizing conditions at the end of the working process. Sample 4422/06 even contained several cooling skins, which were covered by new slag layers and subsequently became reduced to wustite. Samples 4429/06 and 4433/06 contained partially reduced ore (section 4.1.7), which was most probably chipped off from the bloom during refining. These inclusions showed well that not all ore present in a furnace was always transformed to elemental iron and slag.
As reported earlier, most samples cooled down in a sand bed or a charcoal bed resting upon sand (4396/06, 4411/06, 4429/06, 4431/06, 4433/06, 4436/06, and 4719/06 (e.g. Figure 184). The sand grains found in these specimens became trapped in the slag and were hardly thermally altered. Because of this, I assume that most of the slag collected in a cooler part of the refining hearth or furnace. However, in sample 4396/06 the trapped sand grains exhibited some thermal alteration attesting that they were exposed to high temperatures and had enough time to react with the liquid slag before the latter cooled down at the bottom of a refining hearth. Evidence of a separate slag pit can be seen in sample 4719/06. Its rim of trapped sand with little thermal grain alteration implied that the slag had been deliberately drained into a slag pit, probably in the course of the very first steps of refining, during which a large amount of slag leaked from the hot bloom.

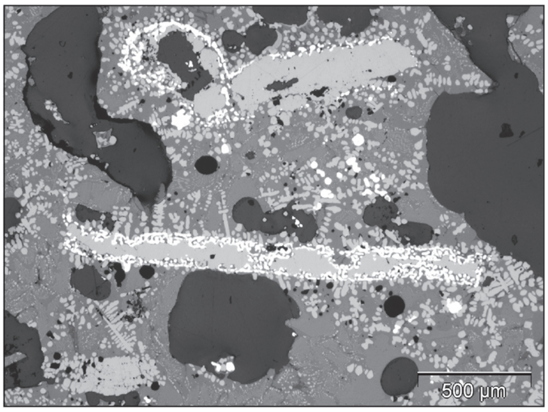
4.2.4. Advanced bloom refining slag (Group V)

Eleven samples were considered advanced bloom refining slag (Table 42, Appendix 3). The main diagnostic features that I used for their classification were a conglomerated layered appearance, the presence of partially worked bloom fragments as well as tabular and unspecific crowded wustite patterns in the microstructure. The combination of these features implies that the bloom was consolidated enough to generate tabular hammerscale flakes but still contained enough slag to produce amorphous hammerscale. Moreover, the semi-consolidated state of the bloom caused some gromps to get lost. Apart from that, those samples of refining slag from which no polished sections were made were also collected in Group IV because they contained gromps but were by definition not assignable to Group III.

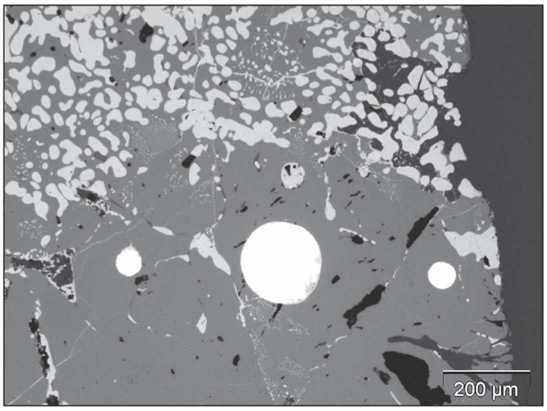
The exterior face of the Group IV samples varied in color. It ranged from blackish dark gray to greenish medium gray and beige, and most samples showed rusty brown parts caused by corroded elemental iron. The interior hue of the specimens ranges from blackish dark gray to light gray, sometimes with a greenish undertone, and certain samples exhibited a silvery luster.
Eight out of 11 samples were fractured, but these samples still exhibited parts of their original top and bottom sides. Eight samples (4409/06, 4410/06, 4412/06, 4414/06, 4427/06, 4431/06, 4717/06, and 4721/06) were amorphous refining slag as described in section 1.6.2.2, whereas three specimens were plano-convex in vertical section (4420/06, 4438/06, and 4722/06). The surface structure of six samples suggested that they cooled down in a sand bed (4409/06, 4410/06, 4414/06, 4420/06, 4438/06, and 4717/06), another two solidified in a charcoal bed (4427/06 and 4431/06) and one (4722/06) showed imprints of charcoal that must have rested on sand. Nine of 11 specimens displayed a cooling skin on their upper faces (4409/06, 4410/06, 4414/06, 4420/06, 4427/06, 4431/06, 4438/06, 4717/06, and 4722/06) indicating that one side of these slag samples was in contact with a cool oxidizing environment. The texture of the analyzed residues could be of high, medium or low density. Pore sizes were rather small to medium



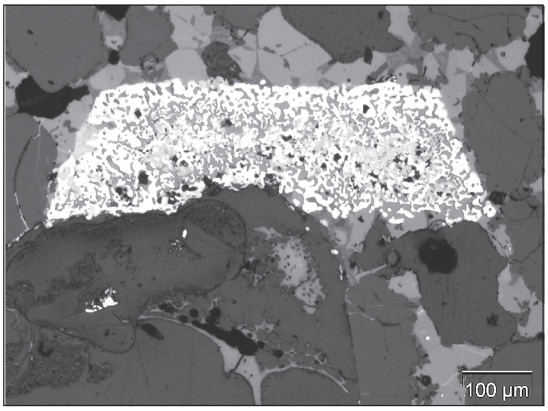
4410/06a



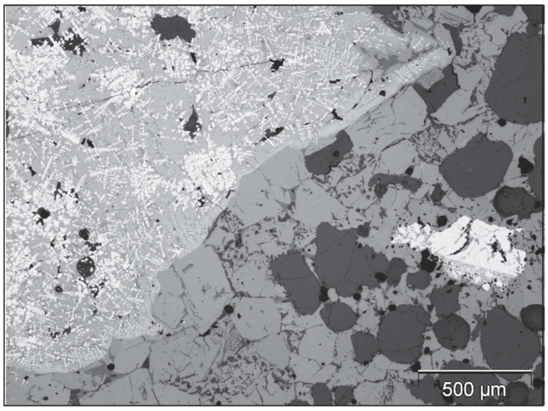
4410/06b



4722/06



4438/06a



4438/06b

4410/06a: Iron-rich slag, wustite (light gray) followed by an wustite/fayalite eutectic and intersticial glass (dark gray).

4410/06b: Tabular and amorphous hammerscale structures consisting of wustite (light gray) and which are partially reduced to metallic iron (white).

4722: In the upper part an iron-rich zone dominated by granular wustite (light gray) and in the lower part a fayalite dominated zone (medium gray) with metallic iorn prills (white).

4438/06a: Tabualar hammerscale reduced to metallic iron (white) in a fayalitic slag (medium gray) with slightly thermally altered quartz inclusions (dark gray).

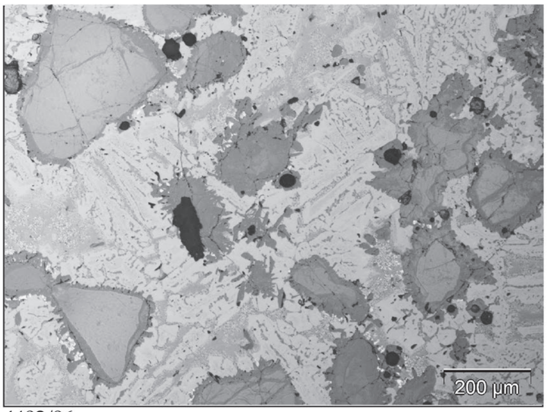
4438/06b: In the left part wustite dominated slag with irregular hammerscale structures (light gray), in the right part fayalite dominated slag with a tabular hammerscale inclusion (light gray) and slightly thermally altered quartz grains (dark gray).

Figure 185: Advanced refining slag from the Kavango sites. Ruuga (SC 3), area N98/39-2: sample 4410/06. Dikundu (SC 30), area N69/03: sample 4438/06. Utokota (SC 16), area N96/08-1: sample 4722/06.

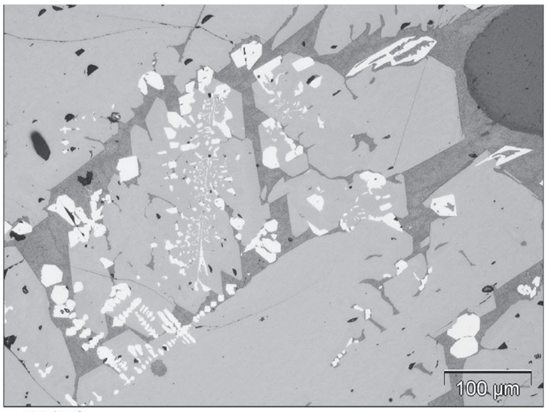
and exceeded a diameter of 1 cm only in one case (4722/06). Three samples (4410/06, 4420/07, and 4722/06) exhibited radiating oblong pores and two of them (4420/06 and 4722/06) showed the typical plano-convex shape of smithing hearth bottoms. Magnetism was highly variable because of the gromps in the material and the magnetic cooling skins.

Polished cross and thin sections of seven specimens of advanced refining slag were available for microstructure analyses (Table 42, Appendix 3). The results of these analyses underlined the heterogeneous composition of the samples, since they revealed a high variety of crystal phase successions (Table 43, Appendix 3). In all the specimens except sample 4721/06, the phase successions changed gradually throughout the sections without clear structural boundaries, and the samples were dominated by various eutectic compositions. The most frequent phase succession was wustite followed by a fayalite/wustite eutectic and optionally a by glassy matrix in the remaining interstices (4409/06, 4410/06, 4420/06, 4438/06, and 4717/06). Additionally, in samples 4409/06 and 4717/06 areas existed in which wustite was followed by fayalite and a fayalite/wustite eutectic. Sample 4722/06 revealed the same three mineral phases at the beginning, but within the sample the fayalite/wustite eutectic could be followed by a wustite/leucite eutectic, which was again succeeded by a fayalite/leucite or leucite/spinel eutectic (Table 43, Appendix 3). It is, however, sometimes difficult to detect whether the eutectics solidified one after another or whether they formed in parallel. Four samples revealed fayalite-dominated parts in the section: sample 4410/06 contained an area of fayalite in a fayalite/wustite eutectic and in sample 4438/06 fayalite could be followed by the latter but also by a fayalite/leucite or fayalite/leucite/spinel eutectic (Table 43, Appendix 3). Sample 4409/06 included zones in which fayalite was followed by interstitial wustite and glass, and in sample 4717/06 areas existed in which fayalite was followed by a glassy matrix only, or by a neogenetic silica-rich phase. Samples 4721/06 and 4722/06 contained more leucite than any other specimen and in some places it occurred as idiomorphic crystals. Four samples (4409/06, 4410/06, 4420/06, and 4717/06) showed a markedly high wustite concentration in microstructure examination (Figure 185: 4410/06a). In sample 4722/06, wustite-rich zones alternated with areas of considerably less wustite (Table 43, Appendix 3).

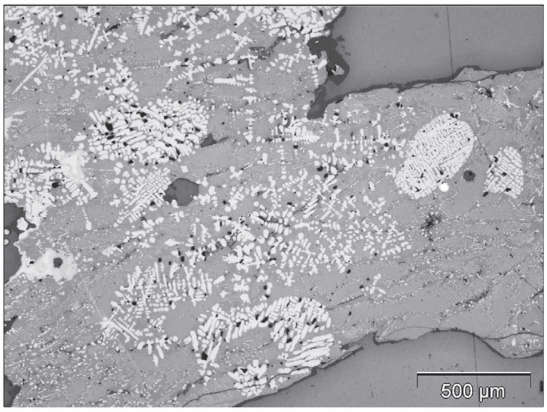
As summarized in section 1.6.2.2, slag from advanced refining activities developed from a mixture of redundant smelting slag expelled from the semi-consolidated bloom, from hammerscale that dissolved in the slag bath, and from fluxes that might have been be used in bloom consolidation. These slag samples still contained fragments of elemental iron that fell off the semi-consolidated bloom (e.g. sample 4409/06), and frequently the microstructure of these gromps exhibited traces of cold and hot working (e.g. 4420/06). Advanced refining processes leave typical smithing hearth bottoms behind in the refining hearth or forge together with amorphous slag lumps that accumulated in the charcoal bed. In addition, one can expect an increasing number of microslags precipitating around the forge and in the slag bath. All the slag specimens analyzed here reflected their heterogeneous origin in changing phase succession throughout the samples. One may assume that slag viscosity also permanently changed in the course of the refining process owing to the alternating chemical composition. Moreover, on the basis of the microstructural picture found one can argue that eutectic compositions, which are those compositions of a multi-component system with the lowest possible solidus temperature, were most wanted. Furthermore, compared to the early bloom refining slag, leucite was increasingly involved in the slag formation and can be seen as input of fuel ashes to the melt. Three samples (4410/06, 4717/06, and 4721/06) gave reason to assume that sand was added to the workpiece or to the slag bath as a fluxing agent. In samples 4410/06 and 4721/06, fractured quartz grains were associated with lost bloom fragments. This combination indicated that sand was used as a welding flux in bloom consolidation, whereas in sample 4717/06 sand might have been added to the slag bath in order to maintain the fluidity of the latter. Here the high iron proportion recognized in the slag might have shifted the melting point unfavorably towards higher temperatures. However, in advanced refining, an iron-rich slag buffer in the hearth or furnace was necessary in the same way as it was in initial refining in order to prevent the bloom from carburizing while being reheated before further consolidation.
A look at the size and shape of the crystals revealed that four samples cooled down slowly (4410/06, 4414/06, 4438/06, and 4717/06) in a protected environment of a furnace or hearth, two samples (4409/06 and 4722/06) provided evidence of an alternating thermal environment, and another two samples (4420/06 and 4721/06) cooled down fast. Furthermore, the mineral



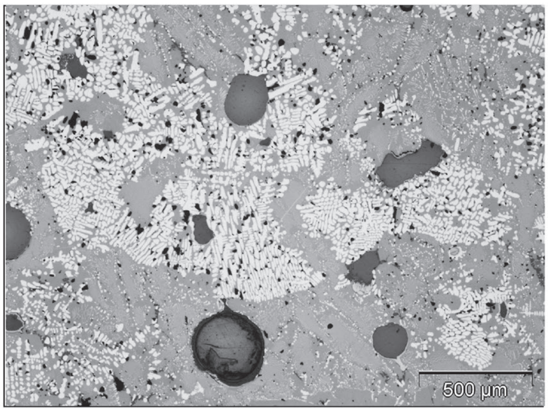
4402/06a



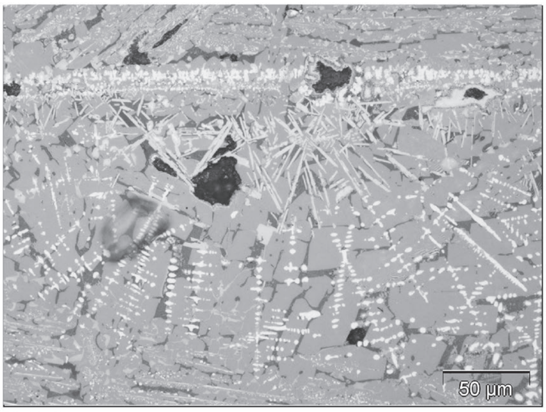
4402/06b



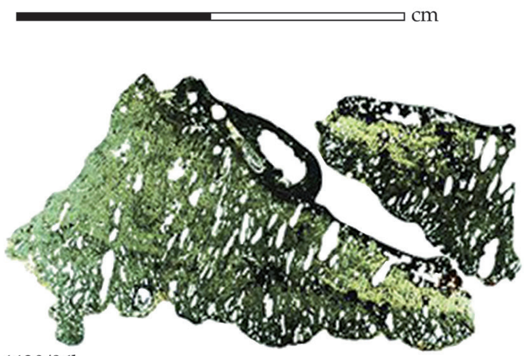
4405/06a



4405/06b



4430/06a



4430/06b

4402/06a: Quartz grains (dark to medium gray) in various stages of alteration in a glassy slag mass.
4402/06b: Blocky fayalite crystals (medium gray) with idiomorphic and dendritic spinel crystals (magnetite) (light gray) and various eutectic compositions in interstices.
4405/06a: Spherical hammerscale (light gray), partially in dissolution, in a wustite/fayalite eutectic.
4405/06b: Amorphous hammerscale sturcutres (light gray) in a wustite/fayalite eutectic.
4430/06a: Spinel (magnetite) cooling skin (linear structure), acicular iscorite (light gray), and dendritic wustite (light gray) in a fayalitic slag (medium gray) with intersticial glass (dark gray).
The cooling skin was covered by a layer of a wustite/fayalite eutectic.
4430/06b: Thin section of the sample, showing the layered composition and the varying content of iron oxides (opac, dark gray sections). The sample shows radiating oblong pores typical for smithing hearth bottom.

Figure 186: Final refining slag from the Kavango sites. Ruuga (SC 3), area N98/39-2: samples 4402/06 and 4405/06. Vungu-Vungu (SC 12), area N98/32-Surf. 4a: sample 4430/06.

phases found in the examined specimens attested that in advanced refining processes a reducing regime was wanted. In addition, five of nine samples (4410/06, 4420/06, 4438/06, 4717/06, and 4722/06) disclosed that the given redox conditions and high temperature favored the reduction of some wustite to elemental iron (Figure 185: 4410/06b and 4438/06a). However, as seen earlier, the increasing presence of cooling skins among specimens in this group demonstrated that these slag types were more often exposed to an oxidizing and cool environment than the initial refining slag, but the composition of the main slag mass clearly spoke for an enclosed structure in which a reducing atmosphere was maintained during refining.

As mentioned earlier, most samples cooled down in a sand bed. The sand grains could appear trapped in slag and were hardly thermally altered (4410/06, 4414/06, and 4717/06), or they were strongly slagged and fractured (4420/06, 4438/06, and 4722/06). The first three samples were amorphous slag, which probably accumulated in the charcoal bed and sagged down to the sandy bottom of the hearth where they slowly cooled down. The latter were all typical smithing hearth bottoms and formed under prolonged high temperatures as indicated by the fractured sand grains. This backed up the assumption that in advanced bloom refining the same high temperatures were needed as used in initial bloom refining in order to expel the decreasing slag inclusions from the semi-compacted bloom.

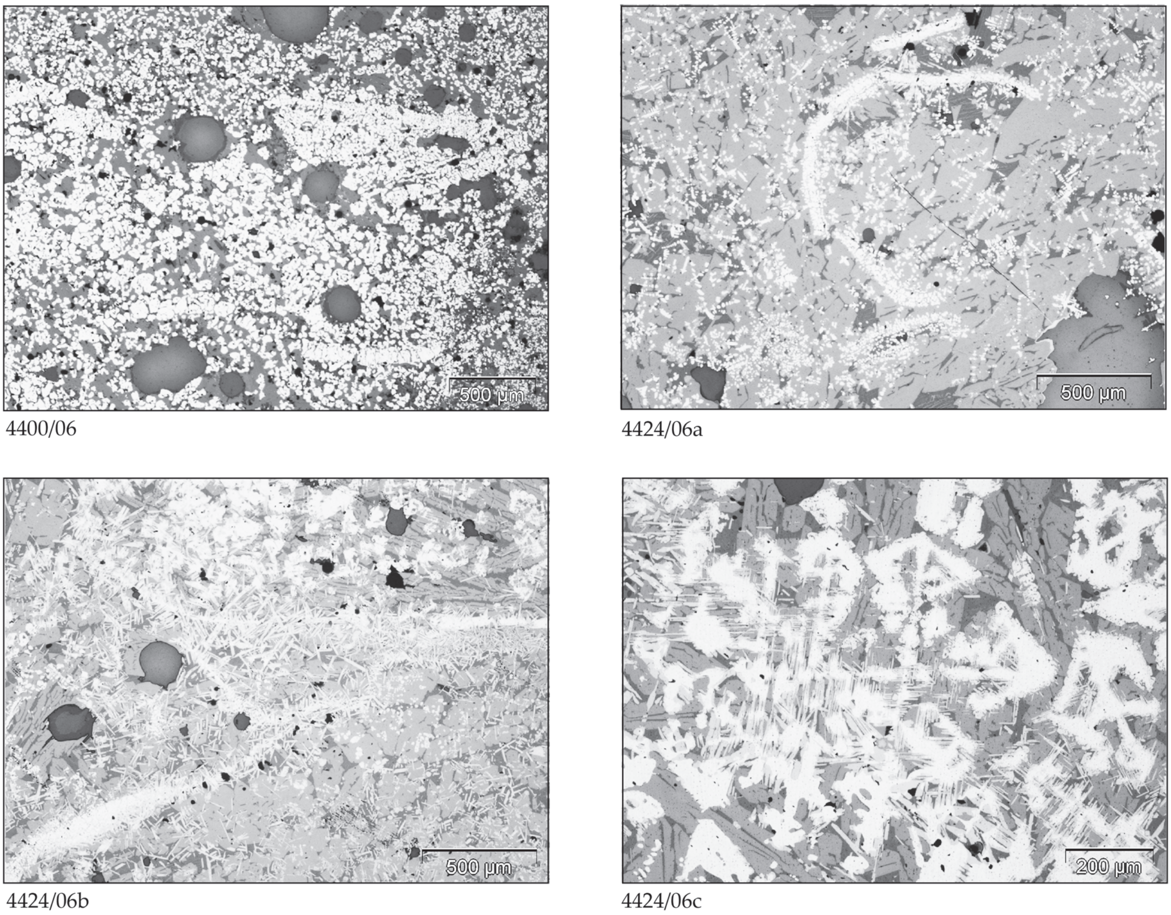
4.2.5. Final refining slag (Group VI)

Final bloom refining slag accounted for seven samples (Table 42, Appendix 3). The main properties used for classification were a conglomerated layered appearance, microslag inclusions such as spherical and tabular hammerscale and a few small compacted fragments of elemental iron, or the absence of the latter. The combination of these features indicates that the bloom is already strongly consolidated and produces mainly tabular hammerscale flakes or microspheres (see section 1.6.2.2), but small fragments of worked iron can still get lost during this final refinement process.

The surface of the Group V samples was variable in color. It ranged from blackish dark gray to greenish medium gray and light gray, and most samples had rusty brown zones caused by corroded elemental iron. The scope of colors of the interior of the samples comprised mainly blackish to dark gray and sometimes medium gray, indicating high iron oxide levels. Only one sample showed a green hue.

All the specimens were fractured except sample 4718/06, and all of them showed parts of their original top and bottom sides. Five samples were plano-convex in vertical section (4405/06, 4418/06, 4430/06, 4718/06, and 4727/06) (Figure 186: 4430/06b), and represented what is known as smithing hearth bottoms (see section 1.6.2). Two samples (4391/06 and 4402/06) were amorphous refining slag with beginning flow structures. Four samples cooled down in a sand bed (4402/06, 4405/06, 4418/06, and 4718/06) and one sample (4727/06) had imprints of charcoal on its bottom side. Only one sample (4430/06) exhibited both impressions of charcoal chunks and sand at the bottom. Five of seven samples developed a cooling skin at the surface (4391/06, 4405/06, 4418/06, 4430/06, and 4727/06) because one side was in contact with a cool oxidizing environment. The texture of the final refining slag fragments varied between high and low density, but most specimens were of medium compactness. Pore sizes were small to medium and only one sample (4391/06) had pores larger than 2 cm in diameter. Five samples (4391/06, 4418/06, 4430/06, 4718/06, and 4727/06) showed radiating oblong pores indicative for smithing hearth bottoms (see section 1.6.2.2) (Figure 186: 4430/06b) and one of these specimens (4391/06) was amorphous in shape suggesting that smithing hearth bottoms varied in their appearance. Sample 4405/06 in turn exemplified that typical plano-convex smithing hearth bottoms did not necessarily have zones with radiating oblong pores. The magnetism in this slag group was rather weak except for those specimens that contained gromps (4727/06 and 4405/06) or had magnetic cooling skins.

Polished thin sections and cross sections of seven samples were available for microstructure analyses (Table 42, Appendix 3). All samples except 4418/06 revealed a highly heterogeneous composition and alternating crystal phase successions (Table 43, Appendix 3). Commonly, the phase composition gradually changed throughout the sections without clear structural boundary, and frequently random microzones of varying crystal growth formed. Only three samples (4405/06, 4430/06, and 4727/06) revealed definable layers in their sections. Various eutectic compositions and small-scale compositional changes dominated the micro-structure of all the samples from the final bloom refining processes.



4400/06: Iron-rich slag showing a broken cooling skin and tabular hammerscale (linear structures) in a matirx of densely crowded spinel (magnetite) crystals in light gray.
4424/06a: Broken cooling skins (linear strucktures) with dentritic spinel (magnetite) crystals (light gray), blocky fayalite (medium gray) and interstitial glass (dark gray).
4424/06b: Several generations of cooling skins (linera structures) consisting of spinel (magnetite) (white-gray), followed by acicular iscorite crystals (light gray). In the background blocky fayalites with intersticial glass. In the upper section large hypidiomorphic spinel crystals.
4424/06c: Spinel dominated slag, forming skeletal magnetite crystals (white-gray). Acicular scorite appears as second phase (light gray). In the background skeletal fayalite with intersticial glass.

Figure 187: Secondary smithing slag samples from the Kavango sites. Ruuga (SC 3), area N98/39-2: sample 4400/06. Vungu-Vungu (SC 12), area N96/03-3: sample 4424/06.

The overall picture gained from the characteristics of final refining slag suggested that redox conditions and temperatures were comparable to those applied in smelting and the earlier refining processes, but not always necessary during the final steps of bloom consolidation. The numerous small-scale compositional variations resulted from short variable smithing events and the frequent change of crystal sizes within individual samples mirrored the inconsistent temperatures in the hearth. Trapped sand grains with little or without thermal alteration were detected in two samples (4402/06 and 4718/06) (Figure 186: 4402/06a), whereas another two specimens revealed strongly slagged and fractured grains (4405/06 and 4418/06), indicating high temperatures at the bottom of these slag cakes. From these four samples, three were classified as smithing hearth bottoms (4405/06, 4718/06, and 4418/06) and one was an unspecifically amorphous slag (4402/06).

4.2.6. Secondary smithing slag (Group VII)

Generally, secondary smithing slag forms from hammerscale and fluxes (see section 1.6.2.3). The main properties used for classification were a fine-layered and conglomerated appearance and a small size of the complete sample. Fine microslag inclusions such as spherical and tabular hammerscale can be expected, and possibly

The most frequent phase composition was a fayalite/wustite eutectic, which was present in every sample and constituted the main slag mass (Table 43, Appendix 3). Four of seven specimens revealed a fayalite/leucite eutectic in addition to the fayalite/wustite eutectic. Only one sample (4718/06) displayed a leucite/wustite eutectic, which was, as described earlier, prevalent in slag composition of the Group V specimens (Table 43, Appendix 3). The binary eutectic of leucite/spinel and a ternary variation consisting of fayalite/leucite/spinel could be found as final phase in three samples (4402/06, 4405/06, and 4718/06) (Table 43, Appendix 3).
The prevalent phase succession found in these specimens was wustite as first phase, followed by fayalite and a fayalite/wustite eutectic, or wustite that was immediately followed by the latter. There was more variation among the final phases found in these samples than in the slag groups described before: It could be another eutectic (e.g. 4405/06 and 4718/06), leucite (4405/06, 4718/06, and 4727/06) or most commonly a glassy matrix (Table 43, Appendix 3).
The iron oxide content could strongly alter throughout the analyzed samples and five specimens (4402/06, 4405/06, 4430/06, 4718/06, and 4727/06) showed isolated layers with reduced iron oxide contents in which fayalite was the first phase that separated from the melt. However, the phase successions in fayalite-dominated zones were variable. Fayalite could be succeeded by interstitial wustite or spinel, depending on the redox conditions, or by a eutectic composition or glass. Also, it seemed as if fayalite/leucite or fayalite/leucite/spinel eutectics were by tendency (but not exclusively) associated with fayalite dominated layers and zones (Table 43, Appendix 3).
Most samples exhibited strong variation with respect to their wustite content. The latter occurred in highly irregular distribution and dissolution in the slag (Figure 186: 4405/06a-b). The increasing number of microslag structures such as tabular or spherical hammerscale found in all the specimens reflected the high compactness of the metal that had been worked close to the hearth. When redox conditions allowed for it, such as in the uppermost layers of some specimens, spinel (magnetite) formed instead of wustite (4402/06 and 4430/06) (Figure 186: 4402/06a). In addition to magnetite, sample 4430/06 contained iscorite (Fe_2+5Fe_3+2SiO_{10}) (Figure 186: 4430/06a) as second phase in the uppermost zone of the smithing hearth bottom (Table 43, Appendix 3).

In section 1.6.2.2 I concluded that slag remains from final refining activities developed from a mixture of fluxes and hammerscale, and still contained some smelting slag expelled from the consolidated bloom. The increasing portion of leucite found in the samples of the analyzed slag group also implied that also potassium-rich fuel ashes contributed to the slag formation, most probably resulting in comparatively low solidus temperatures (see section 1.4.6). Moreover, the high compositional variation discovered in the specimens was a result of short processing events under different compositional circumstances (e.g. added fluxes, varying portion of slag in hammerscale, varying types of hammerscale lost etc.). Like Group V slag, the eutectic compositions found were most probably wanted and maintained. Also slag viscosity and thermodynamics must have changed permanently in the course of the refining process. Only one sample occurred consistently in a microcrystalline or glassy state (4418/06), and another showed crystal sizes that suggested slow cooling (4727/06).

Three samples (4391/06, 4402/06, and 4718/06) suggested that sand was used as welding flux (Figure 186: 4402/06a), or to maintain a specific viscosity of the slag bath. Specimen 4391/06 contained unaltered sand grains that must have fallen into the slag bath, and sample 4402/06 (Figure 186: 4402/06a) as well as 4718/06 revealed quartz grains in varying degrees of thermal alteration and phase transformation. In final refining, an iron-rich slag buffer in the hearth or furnace was beneficial in order to avoid a carburization of the elemental iron during the time of reheating before further consolidation. In addition, all the samples formed under reducing conditions except for the two samples mentioned above (4402/06 and 4430/06). Moreover, in six of seven samples prills of elemental iron were detected, suggesting that redox conditions and high temperature permitted some wustite to become reduced to elemental iron. As mentioned earlier the analyzed slag specimens were exposed to an oxidizing and cool environment at the end of the working process and developed cooling skins (Figure 186: 4430/06a). In some cases, the cooling skins became reduced to wustite or elemental iron once they were covered with new slag, or once they were exposed to high temperatures and reducing conditions (4391/06, 4405/06, and 4430/06).

small compacted fragments of elemental iron. The combination of these features provides evidence that metal was cold and hot-worked in a forge.
Five samples were identified as secondary smithing slag (Table 42, Appendix 3). The surfaces of the Group V samples were variable in color and ranged from dark to medium gray, and most samples exhibited zonal brownish hues as well. The interior of these samples was mainly dark gray, indicating a high iron oxide content, and only one sample (4434/06) had a dark gray-green hue.
Four of the five samples fell into the category of plano-convex smithing hearth bottoms (4397/06, 4416/06, 4424/06, and 4434/06) and one specimen (4404/06) was amorphous in shape. Only one sample (4424/06) was preserved in full, yet all the specimens showed parts of their original top and bottom sides.
The imprints detected on the bottom sides of the samples revealed that four of them cooled down in a sand bed (4397/06, 4404/06, 4424/06, and 4434/06) and one (4416/06) solidified in a charcoal bed. On all the specimens a cooling skin on the upper face of the slag was found, which provided evidence that one side was in contact with a cool and oxidizing environment (Figure 187). The texture of the secondary smithing slag was of medium to low density and only in one case pores larger than 1 cm were found (4416/06).
Interestingly, only one of the five samples (4424/06) contained radiating oblong pores, otherwise indicative for smithing hearth bottoms (see section 1.6.2.2), but even so the macro- and microstructure analyses disclosed that all the samples must have been formed at the bottom of a forge. In addition, one of them was amorphous in shape pointing again to the variability in appearance of secondary smithing slag. Magnetism was rather weak to moderate, except for specimens with inclusions of metallic iron.

Three thin sections were available for microstructure analyses (Table 42, Appendix 3), revealing a layered composition of the specimens, but the microtexture was not as heterogeneous as among the final bloom refining slag group. Compositional variation changed according to the layers rather than to random microzones, and the phase compositions found displayed clear structural boundaries for the most parts. What is more, several generations of cooling skins trapped in the slag mass were found in each sample (Figure 187), attesting to repeated heating and cooling. The phase compositions indicated that two samples formed in an oxidizing environment (4400/06 and 4424/06) (Figure 187) and one (4416/06) under reducing conditions.
Although the number of analyzed specimens was small, the phase compositions observed suggested changing redox conditions in the course of the slag formation. In sample 4400/06, spinel (magnetite) was the first phase that crystallized (Figure 187: 4400/06). It was followed by both fayalite and glass, or by hercynite (Fe_2+Al_2O_4) and a spinel/leucite eutectic. Sample 4424/06 was more heterogeneous. Here spinel (magnetite) was succeeded by iscorite (Fe_2+5Fe_3+2SiO_{10}), fayalite and glass within the top layer (Figure 187: 4424/06b and c). The mineral phases of the middle and bottom layer of this sample reflected reducing conditions, because the main slag mass was dominated by wustite as first phase, which could be followed by fayalite before a fayalite/wustite eutectic formed or directly by the latter eutectic. The final phase was a glassy matrix. The phase succession wustite-fayalite-glass was also present in places (Table 43, Appendix 3). Towards the silica-rich bottom, fayalite crystallized first in a glassy matrix, or it was followed by interstitial wustite and a fayalite/wustite eutectic. Sample 4416/06 revealed wustite instead of spinel as the first phase. It was followed by a fayalite/wustite eutectic and in some zones, fayalite crystals developed before the eutectic. The final phase was mostly glass and in places a fayalite/leucite eutectic (Table 43, Appendix 3). However, the phase successions described for Group VII slag samples certainly give an incomplete picture due to the limited number of samples. All the samples revealed pronounced variation in their spinel and wustite content (Table 43, Appendix 3). The oxides occurred in very irregular distribution, and fine tabular or spherical hammerscale was observed in all states of dissolution in the slag, attesting that sound metal was worked in these forges. The overall high proportion of iron oxides found suggested that slag fluidity together with the presence of a slag bath in the hearth to keep chemical equilibrium with carbon and iron was probably not important for the task. In samples 4416/06 and 4424/06 wustite became reduced to elemental iron indicating high temperatures and reducing conditions in some forges. Yet the varying crystal size of these samples underpinned the picture of rather inconsistent thermal conditions. Moreover, in each sample examined in thin section several generations of cooling skins were found, which builtup during short

repeated cycles of slag accumulation and subsequent cooling. However, there existed high temperatures at the bottom of the forge because three of the samples with sandy bottoms revealed slagged and fractured sand grains (4400/06, 4424/06, and 4434/06).

In conclusion, redox conditions, temperature, slag fluidity and chemical properties of secondary smithing slag seemed not to have been as important as those of refining slag samples. One can assume that in secondary smithing, temperatures in the hearth were as high as in refining, yet it was not important to maintain a reducing environment. The analyzed samples formed during short repeated heating and smithing cycles, but they showed less compositional variability than the Group VI slag from final bloom refining processes. Only one sample (4416/06) revealed fractured quartz grains, which permitted one to think of a welding flux.

4.2.7. Slag chemistry

Of the 57 samples, 37 were selected for chemical analysis. Most of them were taken from the assemblages of Ruuga (SC 3) (n = 14), Vungu-Vungu (SC 12) (n = 12) and Kapako (SC 4) (n = 5) (Table 42, Appendix 3). The remaining five samples originated from Kauti (SC 32), Utokota (SC 16), Tjeye-East (SC 21) and Dikundu (SC 30). Due to the rather selective gathering of the slag collection in the course of several field campaigns (see section 1.6.1), only a few specimens of furnace slag were available for analysis. Most samples were refining and smithing slag. Therefore, only 10 samples of furnace and flow slag were examined (27% of all samples) against 25 samples of refining and secondary smithing slag. Two specimens were in the end not assignable to either of the slag groups (Table 42, Appendix 3).

The main phases of the analyzed slag samples were plotted in ternary diagrams of the FeO-SiO_2-Al_2O_3 and FeO-SiO_2-CaO-systems although these plots can only be seen as a mere approach to real furnace running conditions for the reasons that have been discussed earlier (see section 1.6.4). Projecting furnace and flow slag samples into the FeO-SiO_2-Al_2O_3 system (Figure 188) revealed that the contribution of alumina to the system was low. None of the samples contained enough alumina to approach the Optimum 1 or 2. Most samples clustered in the field of fayalite with suggested melting temperatures between 1177 °C and 1200 °C. Interestingly, the leanest samples with FeO readings of less than 60wt% (samples 4408/06, 4388/06, and 5189/07, Table 44, Appendix 3) fell in a zone of liquidus temperatures between 1200 °C and 1400 °C, which backed up the assumption that a lean slag was not always the best choice (see sections 1.4.6 and 1.6.4). A closer look at the samples in the FeO-SiO_2-CaO-system confirmed the impression that most of them concentrated in the fayalite field, and CaO did not contribute much to the smelting system either (Figure 188). Again two samples of the three lean slag specimens with FeO proportions below 60wt% fell in the range of melting temperatures above 1400 °C. Only one of them (4388/06) approached the Optimum 3 with melting temperatures less than 1100 °C because of its comparatively high CaO reading (Table 44, Appendix 3). The latter was probably contaminated with furnace wall materials, because it solidified along a furnace wall. Sample 5189/07 was taken from a failed experimental smelt and may contain unreacted ore, only sample 4408/06 gave no indication for any possible contamination that could explain the high liquidus temperatures.

Plotting the major elements of the refining slag samples (Table 44, Appendix 3) into the ternary diagrams (Figure 189) revealed that the initial bloom refining slag samples also concentrated in the fayalite field, whereas the total of the refining slag was more scattered than this group. Yet none of the samples left the low melting temperature field of iron-rich fayalitic slag. Only those samples that showed FeO readings higher than 75wt% approximated Optimum 2 in the FeO-SiO_2-Al_2O_3 system; still these samples did not contain enough alumina to fully reach the eutectic composition. In the FeO-SiO_2-CaO system only one sample (4393/06) approached a composition close to the Optimum 3. Summing up, all the refining slag samples examined attested that alumina and calcium played no role in slag formation.

A closer look at the average alumina-to-silica ratio between the slag groups revealed changes from group to group:

Slag Groups:	**Al_2O_3:SiO_2:**
Group I:	1:32 (1:12,5)
Group II:	1:14,5
Group IV:	1:15,5
Group V:	1:20
Group VI:	1:25
Group VII:	1:13

Furnace slag (Group I) contained the highest silica portion, whereas flow (Group II) and initial bloom refining (Group III) slag indicated an input of alumina to the composition.

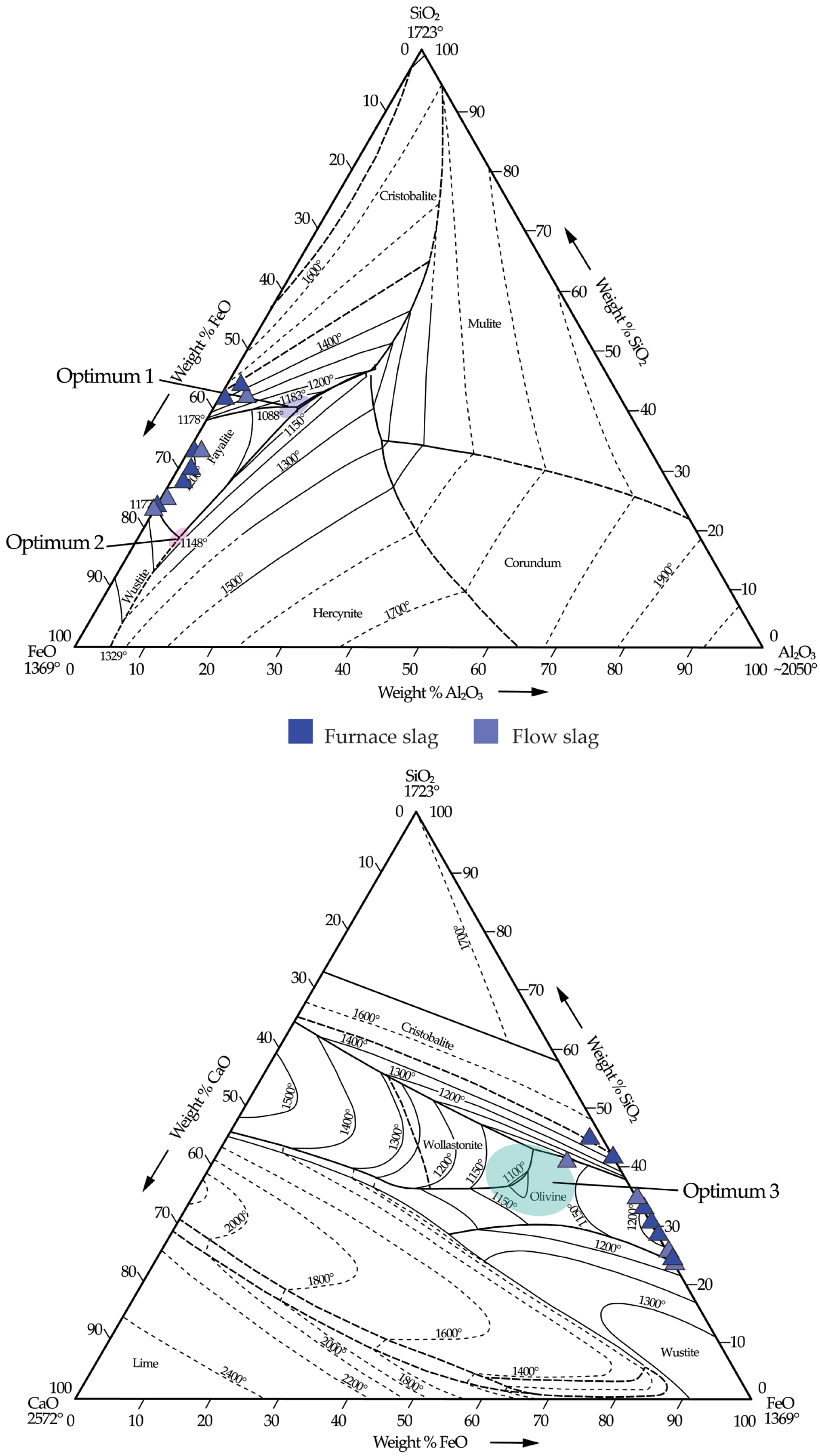


Figure 188: Above the ternary FeO-Al_2O_3-SiO_2 phase diagram with the low-melting eutectics Optimum 1 and Optimum 2 and plotted smelting slag samples from the research area. Below the ternary FeO-CaO-SiO_2 phase diagram with the low-melting eutectic Optimum 3 and plotted smelting slag samples from the research area.

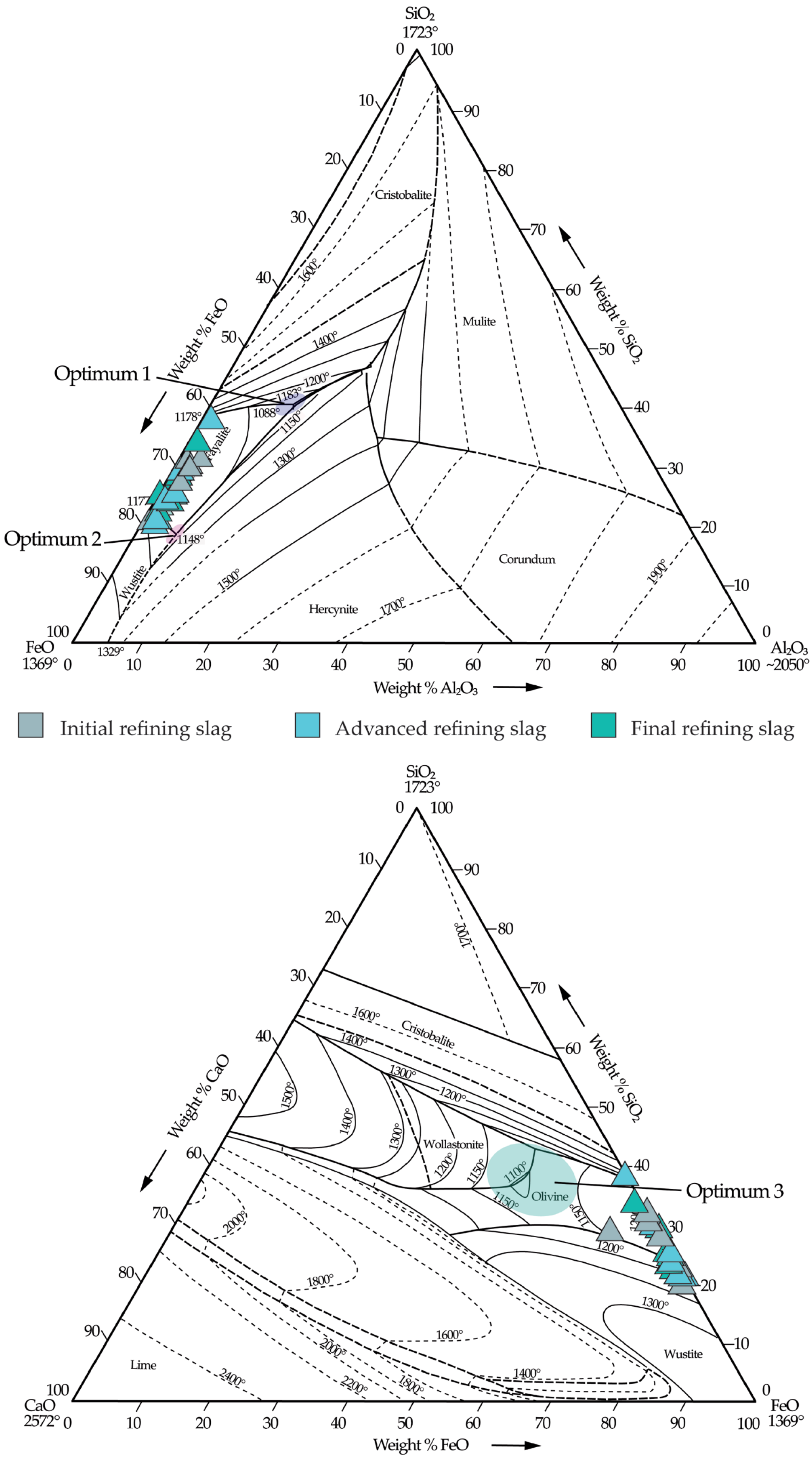


Figure 189: Above the ternary FeO-Al$_2$O$_3$-SiO$_2$ phase diagram with the low-melting eutectics Optimum 1 and Optimum 2 and plotted refining slag samples of the research area. Below the ternary FeO-CaO-SiO$_2$ phase diagram with the low-melting eutectic Optimum 3 and plotted refining slag samples of the research area.

However, omitting the two samples from Kauti from Group I because they cannot be considered representative (sample 5189/07 from a failed experimental smelt, sample 5190/07 contained unreacted ore) revealed that the alumina-to-silica ratio constantly decreased towards final refining activities from 1:12.5 in the Group I samples to 1:25 in the Group VI samples. It is likely that this change mirrored the fact that initial refining slag was still close to smelting slag in its composition, whereas final refining slag basically formed from microslags and fluxes, which were in this case most probably quartz-rich sands. However, there was a clear difference between final refining (Group VI) and secondary smithing (Group VII) slag, although theoretically they formed from similar activities such as fire welding and the shaping of consolidated iron. Secondary smithing slag showed an alumina-to-silica ratio comparable to smelting slag, which brought them closer to the Optimum 1 and 2 eutectics than any other of the slag groups. At this point, it was not clear what caused the alumina-to-silica ratio to increase particularly in secondary smithing, since temperatures were comparable to refining processes, only the cycles of heating and cooling seemed to be shorter (see section 1.6.2.3).

In summary, the picture gained from these plots was that the smelters intended an iron-rich, low-melting slag around fayalitic composition. Aluminum and calcium played no major role in slag formation. From this it follows that only rich iron ores could have been used, since they allowed a gain of elemental iron and the formation of a fayalitic slag with a FeO portion of around 70wt%.

4.2.8. Ore and slag – is there a correlation?

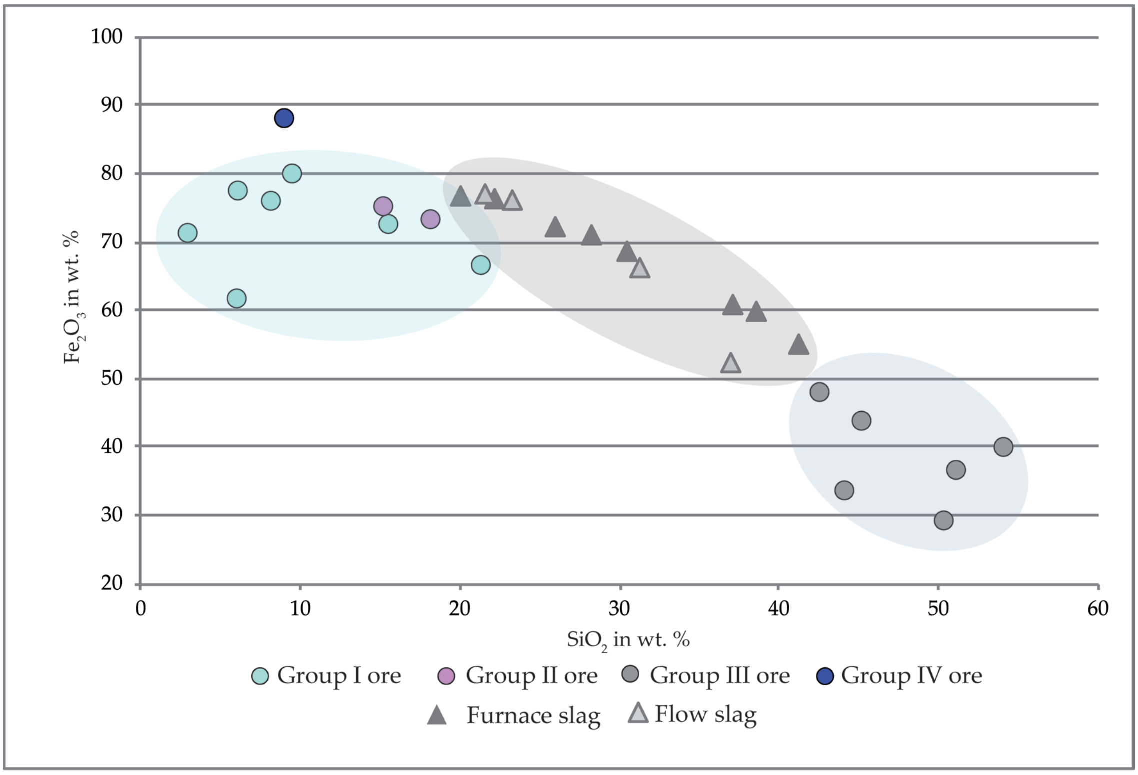
One question of my slag examination was to identify the ore sources that were used by the former smelters. As outlined in section 4.1, I sampled and analyzed some iron ores from the Kavango region in order to gain chemical fingerprints of possible ore deposits in the vicinity of the historic smelting sites. In the following, the four groups of ores defined will be compared with the slag samples from those sites from which a more or less representative number of samples were available. These sites were Ruuga (SC 3), Vungu-Vungu (SC 12), and Kapako (SC 4).

The Fe_2O_3-SiO_2 diagram Figure 190 illustrates that the furnace and flow slag samples overlapped with the Group I and II ores with respect to their iron-oxide content, but they were significantly shifted towards a higher silica proportion. Assuming that ore types of comparable quality to Group I and II were used, the shift of the slag readings was caused by the gain of elemental iron and probably the input of a siliceous fluxing agent. The latter was necessary to generate a low-melting fayalitic slag (Figure 18). The gain of metallic iron, however, was little unless the old Kavango smelters used an ore of higher quality than those classified as Group I and II ores. Group III ores may not have contributed to the smelts in light of the high FeO readings of the slag samples and as long as no evidence of an elaborate beneficiation of the ores is found.

The plot of all bloom refining slag specimens into the same Fe_2O_3-SiO_2 diagram (Figure 190) showed that the samples concentrated in the field of high iron oxide but lower silica proportions than the smelting slag. The average of the initial refining slag seemed to be the closest to furnace and flow slag with comparably low Fe_2O_3 values and high silica proportions. The advanced refining slag shifted closer to ore compositions and some samples had iron oxide readings even higher than their probable source material. The group of final refining slag showed slightly lower Fe_2O_3 readings than the advanced refining slag, but their iron oxide content is in each case still close to the ore composition of Group I and II.

The secondary smithing slag divided into two groups (Figure 191): two samples revealed elevated Fe_2O_3 values and a similar silica content to the potential ore of origin, and two samples were noticeably lean with high silica readings. Those samples with an elevated Fe_2O_3 content certainly represent extreme iron oxide enrichments in the slag through hammerscale inclusions, whereas the lean slag samples probably attested the influence of siliceous welding fluxes on the slag composition.

The fayalite-dominated slag composition allowed me to plot the FeO-to-SiO_2 ratio of all the slag samples in a binary phase diagram. From Figure 192 one can see that furnace and flow slag specimens concentrated in a low-melting area between the two eutectics and fayalite. The three lean slag samples that fell into zones of high liquidus temperatures were already described earlier (see section 4.2.7). The same phase diagram illustrates that the wustite-to-silica ratio of the Group I, II and IV ores was concentrated in an area of 15 to 25 rel. wt% less



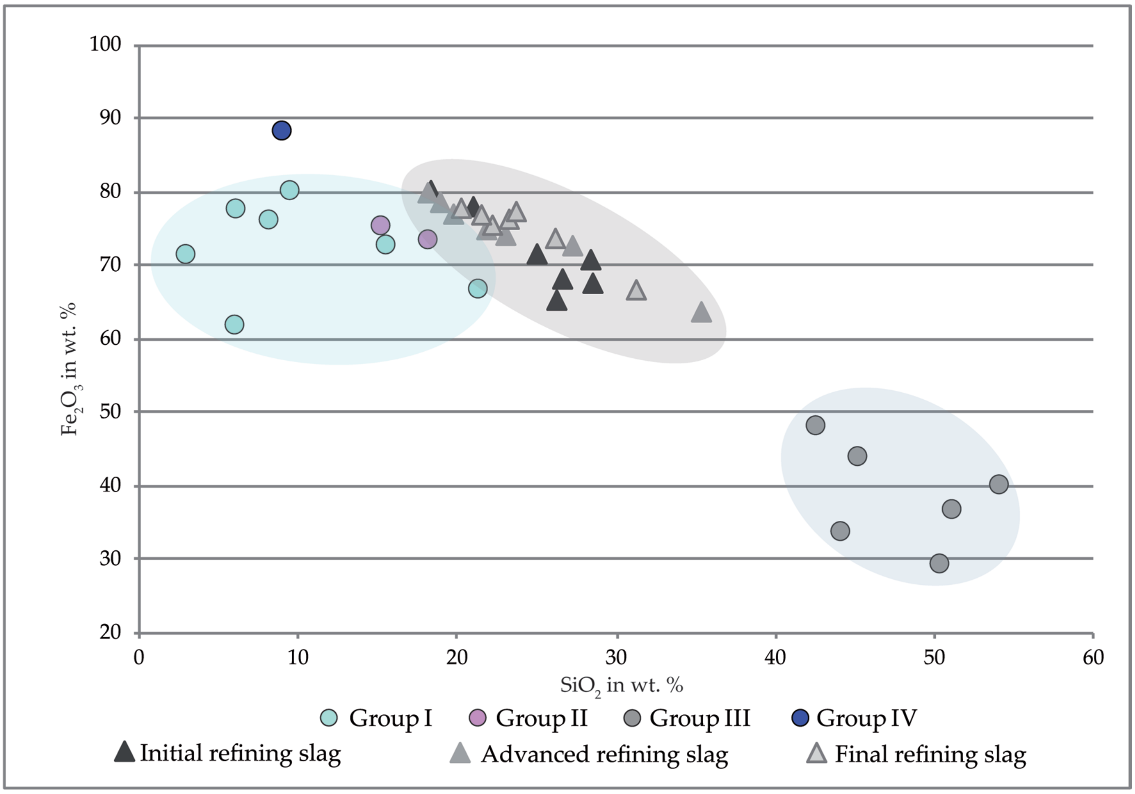


Figure 190: Above Fe_2O_3 versus SiO_2 proportions in the ore samples of the Groups I to IV together with smelting slag samples from the research area. Below Fe_2O_3 versus SiO_2 proportions in the ore samples of Groups I to IV together with refining slag from the research area.

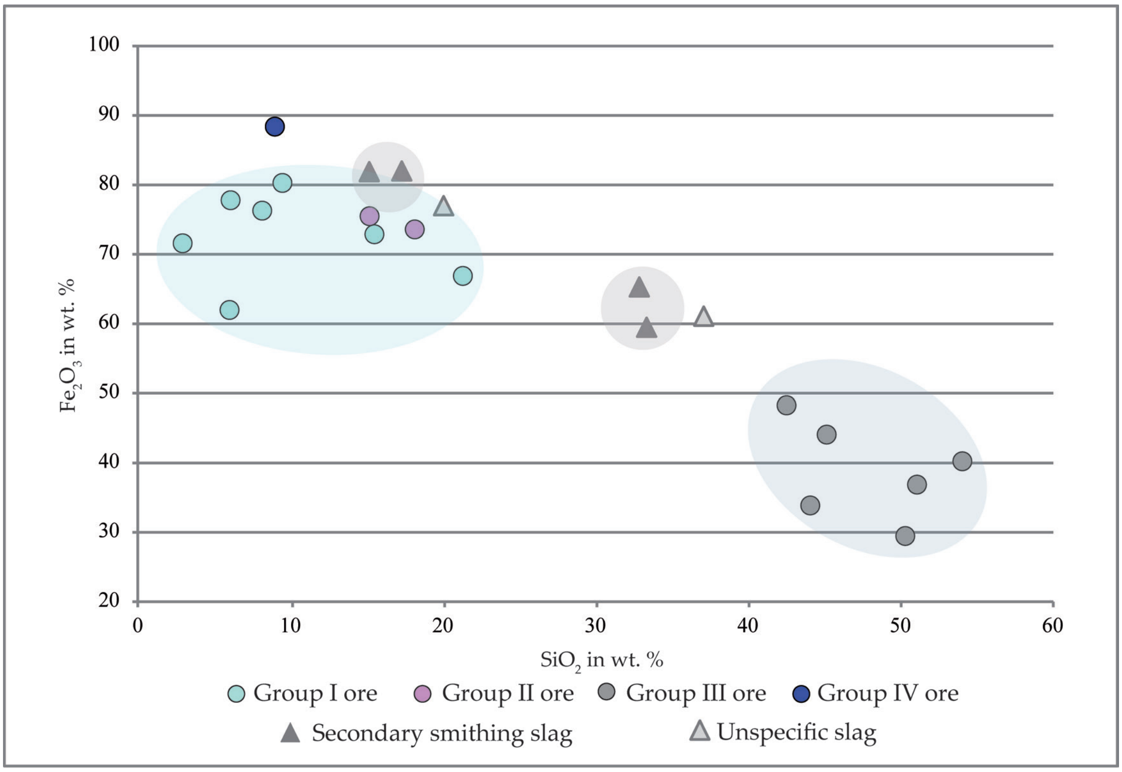


Figure 191: Above Fe_2O_3 versus SiO_2 proportions in the ore samples from the research area of Groups I to IV together with secondary smithing slag samples.

silica than the average flow and smelting slag samples, yet some ore samples approached the first eutectic of the FeO-SiO_2-system in relative composition. This means that approximately 15 to 25 rel. wt% of wustite was available for reduction before the batch reached the eutectic and fayalitic compositions from which a low-melting slag could form. Provided that an average ore contained 65 abs. wt% of FeO, less than 16 abs. wt% of it would have been available for reduction. Converting 16wt% of wustite to elemental iron[98] revealed that the average gain of metallic iron did not exceed 12wt% of the available iron oxides. Besides the limited quantity of metallic iron generated from these ores, Figure 192 also demonstrate that refining used the same low-melting compositional field as iron smelting, but the slag composition shifted closer to the iron-rich first eutectic. This chemical situation was well reflected in the most common phase succession of the refining slag samples, in which wustite constituted the first phase and was followed by a fayalite/wustite eutectic. Furthermore, Figure 192 shows that secondary smithing slag did not necessarily fall in the range of low-melting compositions. One can assume that this was because in secondary smithing a slag buffer was not used as a tool to prevent the iron from carburization.

One way to identify possible ore sources of ancient smelters is to compare the lithophile elements of the ore and slag samples. As mentioned in section 1.4.6, lithophile elements are those elements that are hardly reduced by bloomery smelting techniques, but are part of the slag mass. In theory, these elements become relatively enriched in the slag since elemental iron is separated from the batch during the smelt.[99] However, refractories and fluxes that contributed to the melt may influence the slag composition in an unpredictable way and can change the chemical profile of the slag in an unknown direction (e.g. Kronz & Keesmann, 2005, p. 424-425). As long as not all the ingredients of a specific smelt in a specific geographical area are analyzed and known, suggestions concerning possible enrichments or depletions are better expressed with care.

In section 4.1, I tried to define four groups of ores based on the available samples, their geological setting and chemical composition. These groups are far from being representative of the research area and describe no more than an initial attempt to classify potential prehistoric ore sources. To continue my analyzes, I selected those lithophile minor

[98] By the standard conversion factor 0.7773.

[99] Yalçin and Hauptmann (1995, p. 288) suggest an enrichment factor of 1.5 for bloomery smelting operations.

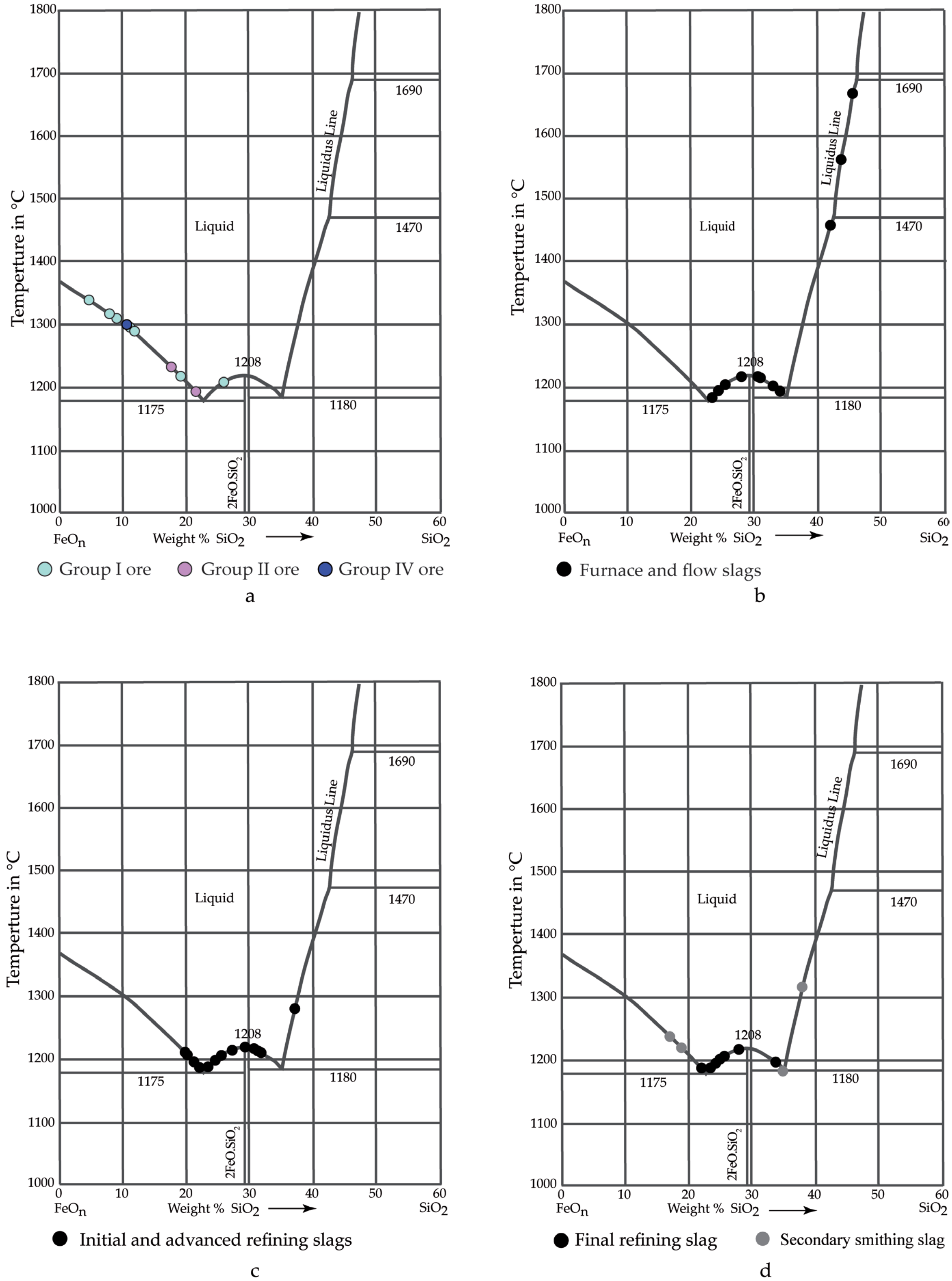


Figure 192: The FeO-SiO$_2$ phase diagrams with plotted ore and slag samples from the research area showing the shift in the relative FeO-SiO$_2$ ratio among slag groups and ore types.

and trace elements for comparison with the slag samples that turned out to vary the most between the ore deposits and ore groups. These elements were titanium, manganese, barium, vanadium and strontium. Since the number of analyzed furnace and flow slag samples is limited and hardly representative, I increased the number of samples for comparison by assuming the group of initial bloom refining slag to be largely identical in composition with the groups of smelting slag.

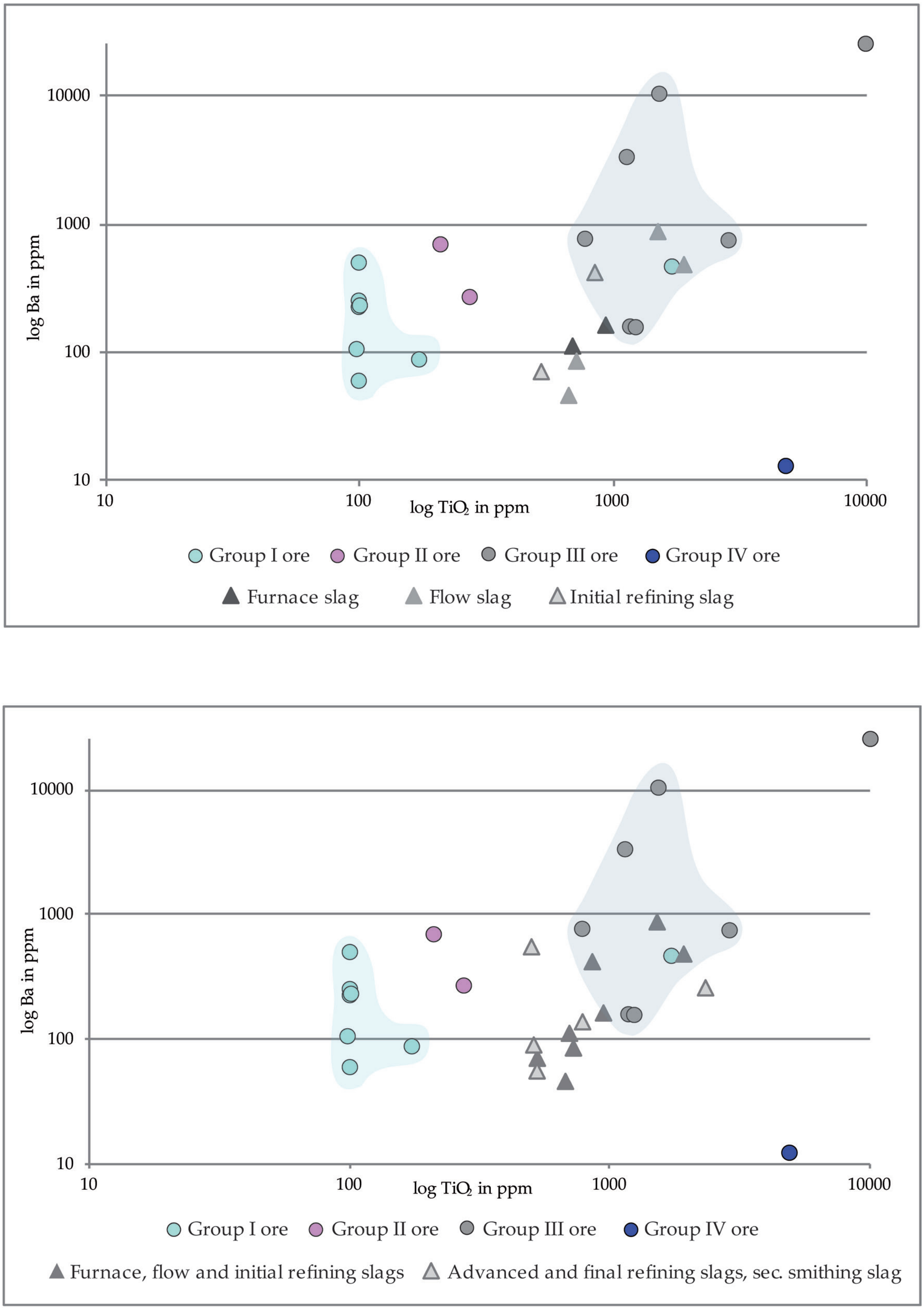
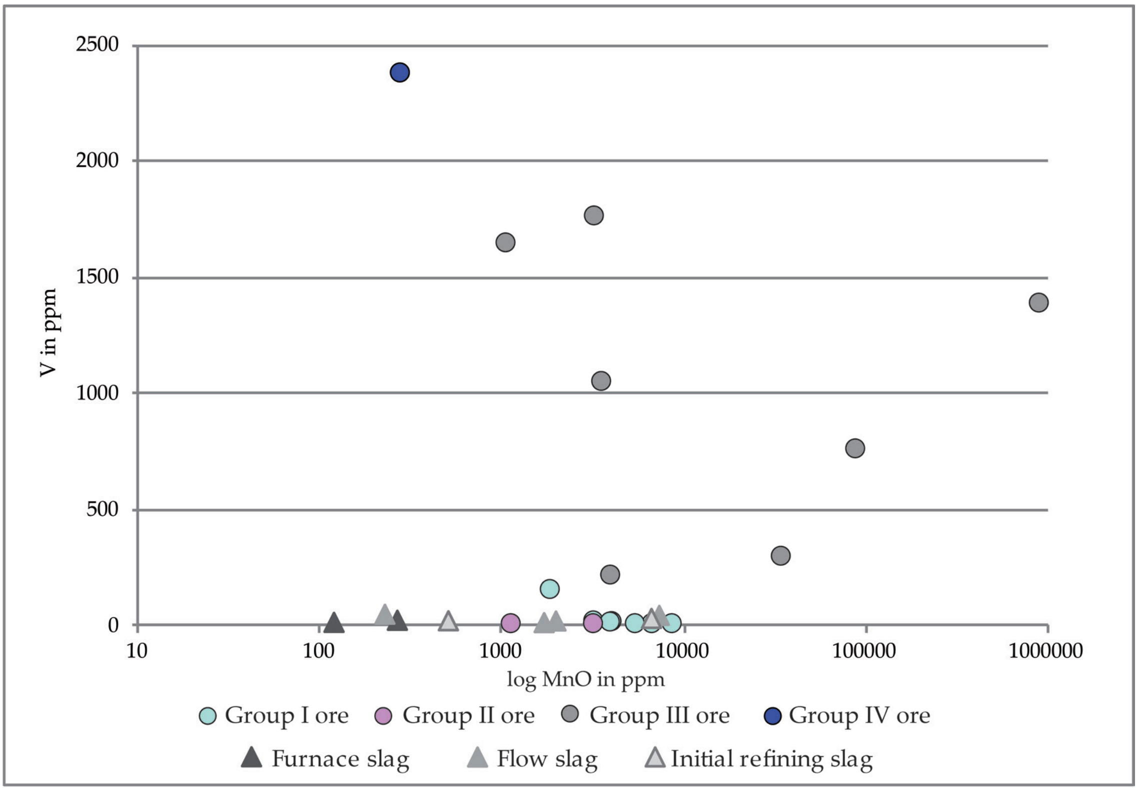


Figure 193: A plot of Ba against TiO_2 of the ore samples from the research area together with smelting and processing slag samples from Ruuga (SC 3).



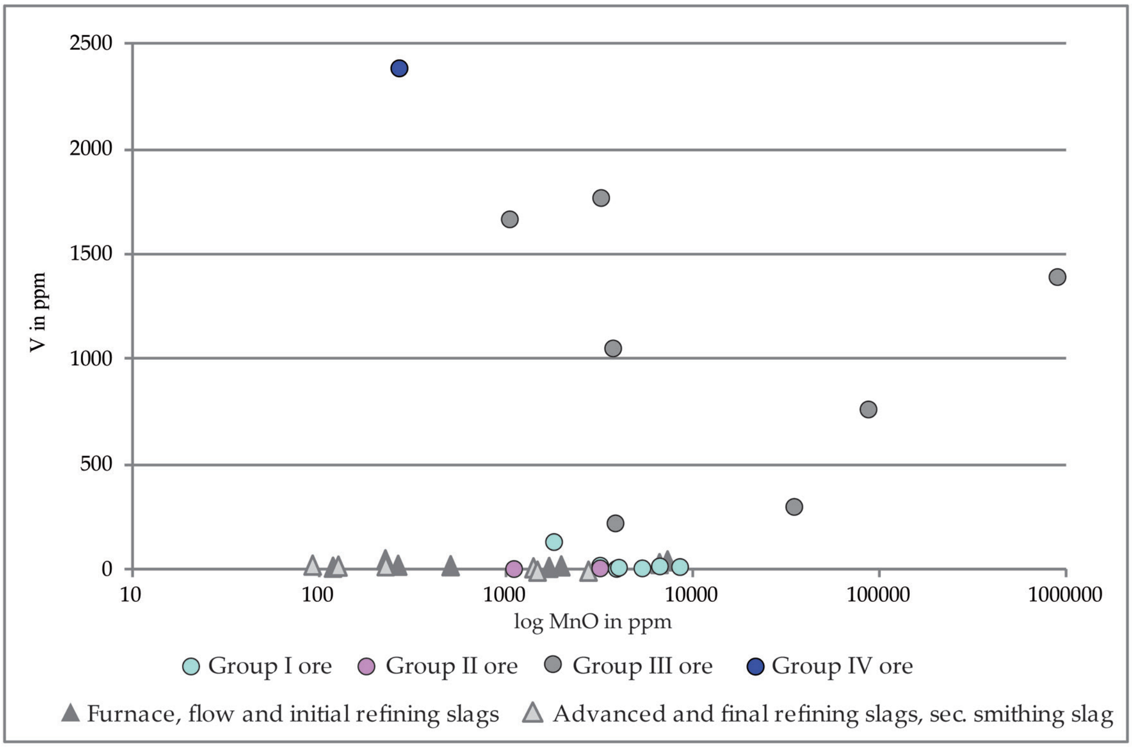
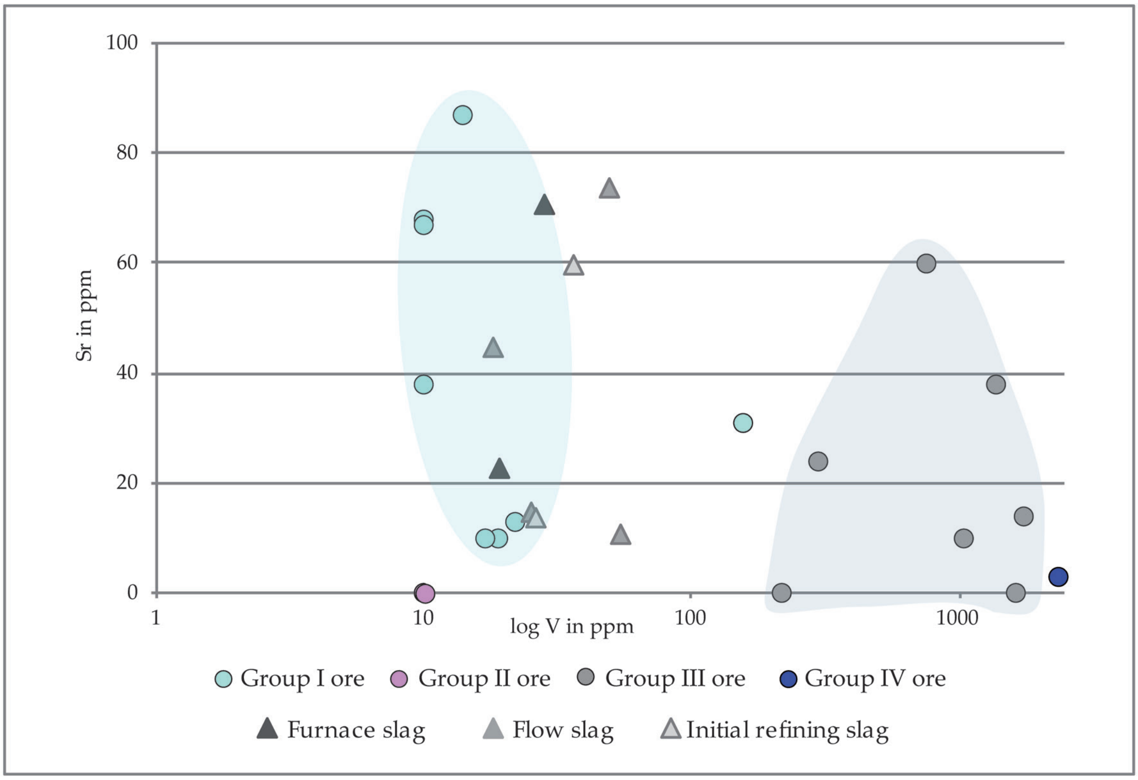


Figure 194: A plot of MnO against V of the ore samples from the research area together with smelting and processing slag samples from Ruuga (SC 3).



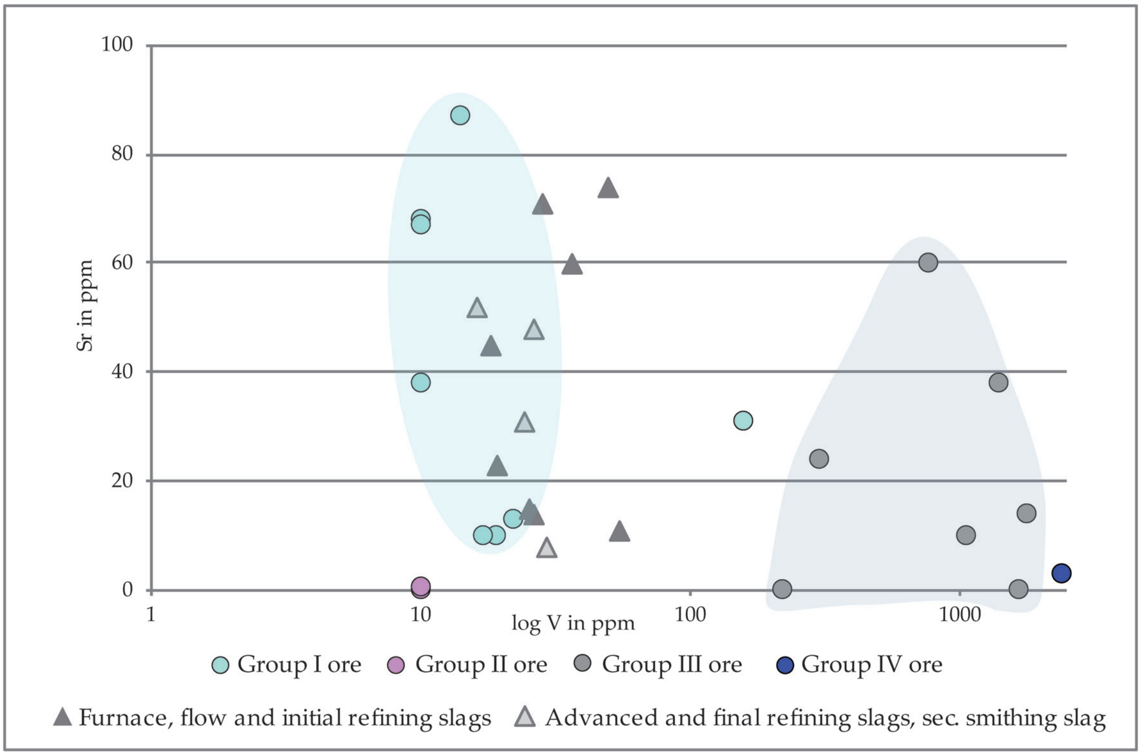


Figure 195: A plot of Sr against V of the ore samples from the research area together with smelting and processing slag samples from Ruuga (SC 3).

4.2.9. Slag samples from Ruuga

Chemical data of 14 slag samples (Table 46, Appendix 3) were available for comparison from Ruuga (SC 3) (Tables 44 and 45, Appendix 3). A plot of Ba against TiO_2 of the ore groups, furnace, flow and initial refining slag in Figure 193 brought to light that the slag samples significantly differed in the TiO_2 fraction against the ore types. However, the Ba readings fluctuated within the range of the Group I ores, and overlapped with those of the Group II ores. The Group III ores showed a raised TiO_2 fraction and were highly diverse in Ba, which certainly reflected the random and incomplete sampling of these ores (see section 4.1). Yet some of the Ruuga slag samples overlapped with those of the Group III ores that had moderate Ba values, whereas other samples clearly lay below both barium and titanium oxide. Adding all the refining and secondary smithing slag samples to the picture (Figure 193) did not change the overall slag distribution within the diagram. Rather they added to the impression that there existed two groups of slag: one with high Ba values and one with lower ones. In conclusion Group I as well as Group II ores could be excluded as a possible source due to the low TiO_2 values. Furthermore, a comparison of vanadium and manganese in Figure 194 revealed that the Group III ores could not be considered as possible ore sources either, because the V fraction differed greatly from those of the slag samples. Rather the latter overlap with the Group I and II ores in both the vanadium and manganese fractions. However, here again the slag samples seem to divide into two groups, one with low manganese readings and one with raised ones. Only the latter approached the Group I and II ores samples. Comparing those elements with each other where the two slag clusters became the most apparent made it clear that there existed one cluster low in Ba and MnO, which correlated with none of the ore groups, and another cluster with raised Ba and in particular elevated MnO readings, which overlapped with Group I and II ores. As samples from all slag groups were present in one or the other slag cluster, I presume that the ironworkers from Ruuga used two different sources of ores. However, I found no stratigraphic clue in the slag assemblage that would justify any diachronic interpretation of this chemical peculiarity. A plot of strontium against vanadium in Figure 195 again confirmed that Group III ores were not taken for iron production, also Group II was out of the question. On the contrary, the slag cluster partially coincided with the Group I ores. Certain samples from Ruuga (4388/06, 4393/06, 4400/06, and 4408/06) displayed elevated CaO values, yet only samples 4388/06 and 4393/06 contained enough CaO to produce a significantly lower melting temperature than the other samples. For this reason, I assume that the fluctuations of CaO in these specimens from the site were if anything incidental, because the soil was affected by an active calcrete crust formation (section 2.3.1.2). Another consideration would be that the ore used in smelting had fluctuating CaO fractions such as were found in the Group I ore samples.

In summary, the slag specimens from Ruuga produced a chemical profile of a source material comparable to the Group I and II ore. The Group III ore is highly unlikely to have been used. The chemical profile of the specularite sample 4419/06 of Group IV, which had been found at Ruuga, did not fit the slag chemistry of the site at all, and can be excluded as possible source material. However, there was weak evidence that the ironworkers from Ruuga possibly used two different iron ore deposits.

The analyses of the slag assemblage showed that there was no great difference in chemical composition from furnace to secondary smithing slag. It is therefore likely that all type of slag found represented various processing steps of one specific source material. It can thus be suggested that even final refining and secondary smithing slag from one site can be an adequate representative of a furnace slag chemistry with respect to the lithophile elements found in these samples.

4.2.10. Slag samples from Kapako

Slag chemistry of no more than six samples (Table 47, Appendix 3) was available from Kapako (SC 4) (Tables 44 and 45, Appendix 3). These samples are not representative, but still I decided to contrast them with the ores analyzed from the area.

A comparison of the barium and titanium oxide fraction of ore and slag samples produced a comparatively closely spaced cluster outside of the distribution zones of all the four ore groups (Figure 196). A plot of vanadium against manganese oxide (Figure 197) produced a pattern with low V values and a MnO fraction that scattered in the same area as the readings of the slag samples from Ruuga. These samples slightly overlapped with the Group I and II ores, but significantly differed from the distribution pattern of the Group III and IV ores. Comparing vanadium against strontium attested that the

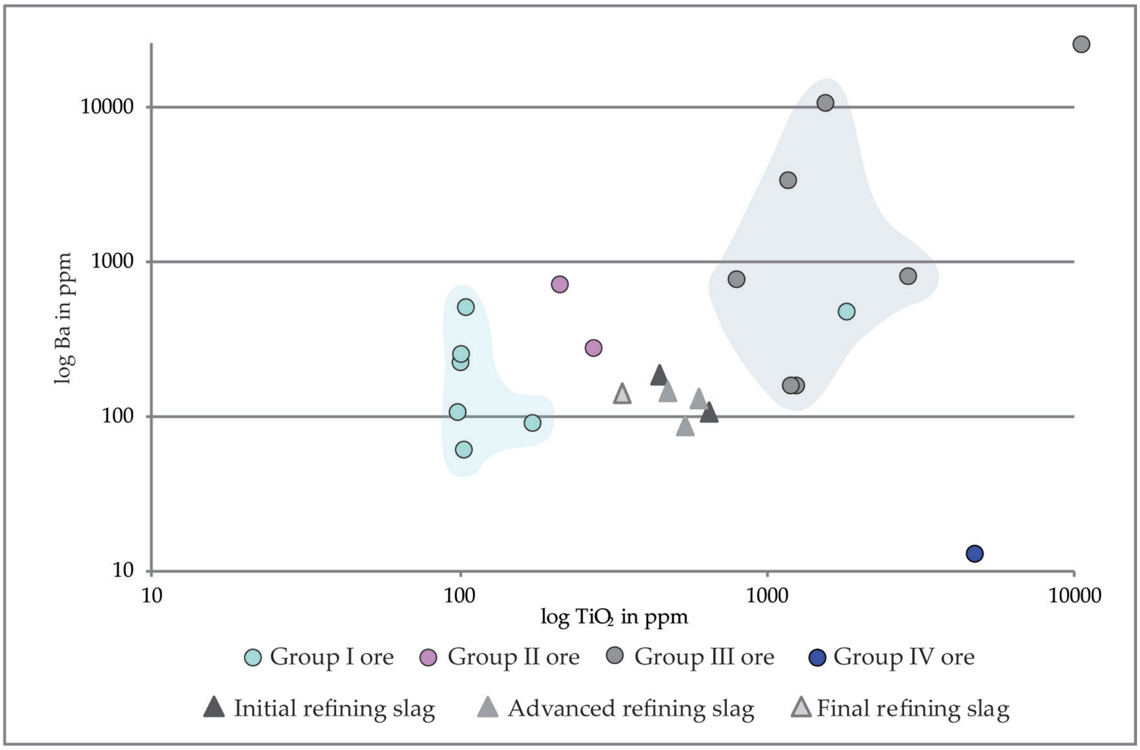


Figure 196: A plot of Ba against TiO_2 of the ore samples from the research area together with processing slag samples from Kapako (SC 4).

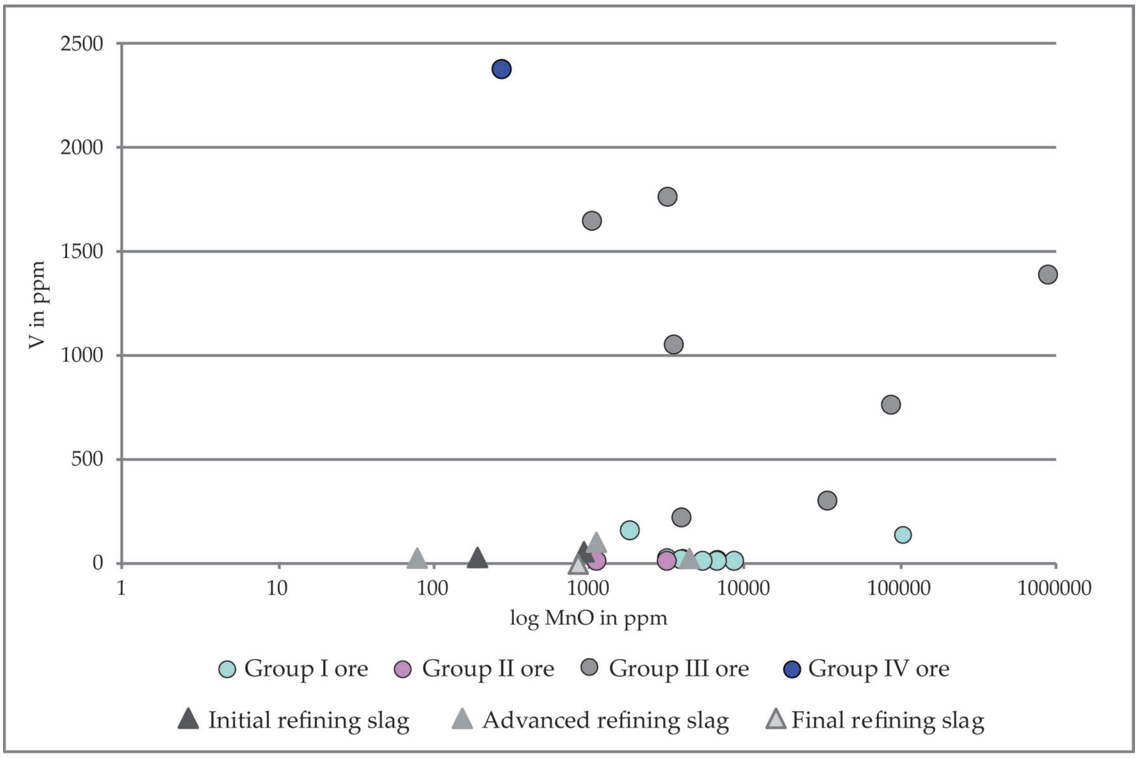


Figure 197: A plot of MnO against V of the ore samples from the research area together with processing slag samples from Kapako (SC 4).

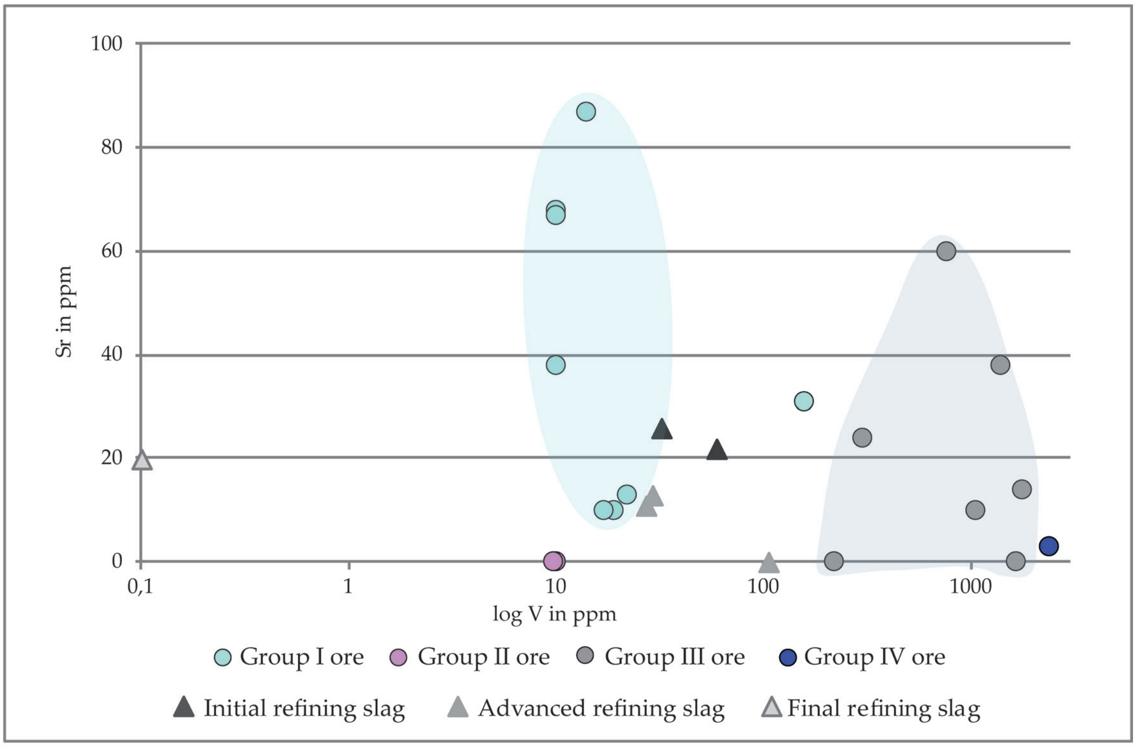


Figure 198: A plot of Sr against V of the ore samples from the research area together with processing slag samples from Kapako (SC 4).

source material was low in both Sr and V and insofar it differed from the Group I, III and IV ores (Figure 198).

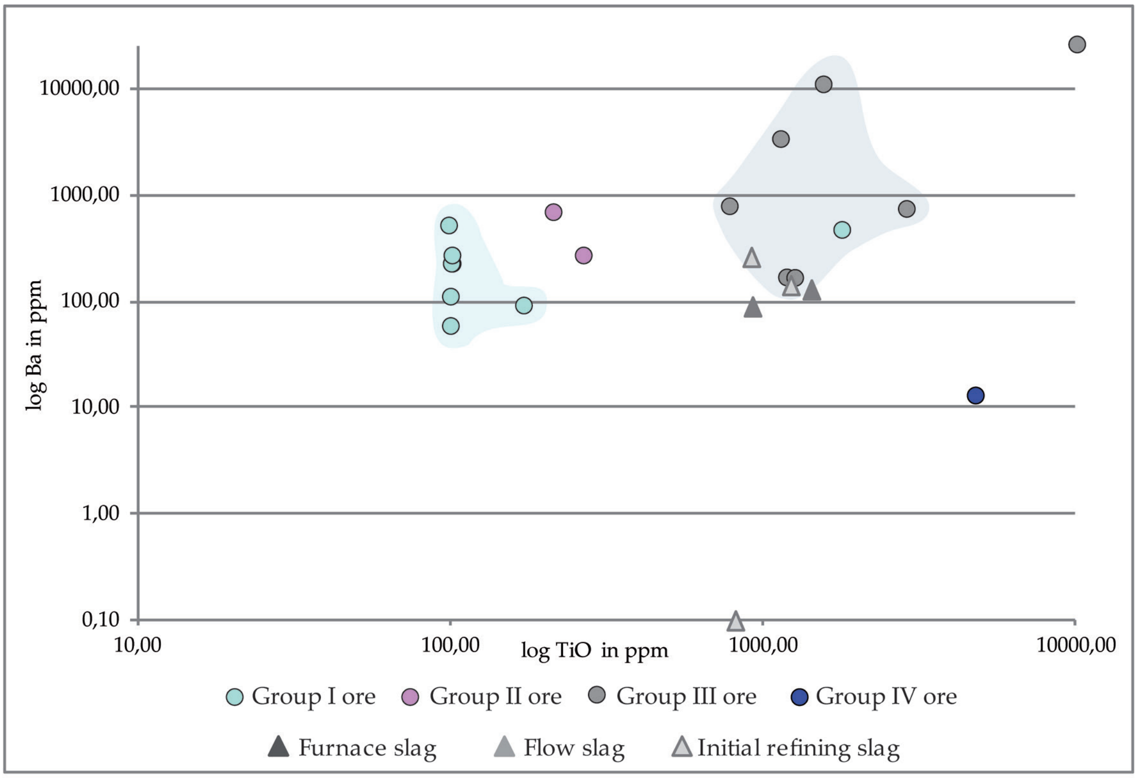
In summary, the chemical profile provided proof that none of the ore samples analyzed was the starting material for the slag specimens found at Kapako. However, the chemical profile suggested that ore had been used comparable to that of Group I and II.

4.2.11. Slag samples from Vungu-Vungu

Twelve samples (Table 48, Appendix 3) from Vungu-Vungu (SC 12) were chemically analyzed (Tables 44 and 45, Appendix 3). On the basis of the similarities in chemical composition found across the different slag groups from Ruuga (section 4.2.9) I premise that the refining and secondary smithing slag samples from Vungu-Vungu also represent the chemistry of the smelt with respect to the weight fraction of the lithophile elements.

A plot of barium and titan oxide of the Kavango ore groups and the slag samples from Vungu-Vungu in Figure 199 revealed a picture similar to the slag samples from Ruuga. The Ba fraction varied within the range of the Group I ore and overlapped with the readings of the Group II ore. Some of the slag samples also fell in the distribution zone of the Group III ore with moderate Ba reading, whereas other samples lay below both the barium and titanium oxide fractions of the Group III ore. All the slag samples showed titanium oxide fractions close to Group III ore and except the Group I as well as Group II ores as possible starting material owing to their low TiO_2 proportions. However, a comparison of vanadium against manganese (Figure 200) indicated that both the V and MnO readings of the Group III ore samples strongly differed from those of the slag specimens, and therefore these ores had not been used for smelting. The vanadium fraction of the slag samples was as low as observed in the Group I and II ores, but the slag readings formed a cluster in an area of low MnO, which was notably set aside from all the ores analyzed. A plot of strontium against vanadium again confirmed that neither Group III nor Group II ores were utilized for iron production (Figure 201).

In summary, the chemical profile of the slag samples from Vungu-Vungu indicated an unknown source material comparable to the Group I and II ores. The Group III ores were highly unlikely as starting material and the signature of the specularite sample of Group IV did not fit the slag chemistry of Vungu-Vungu at all.



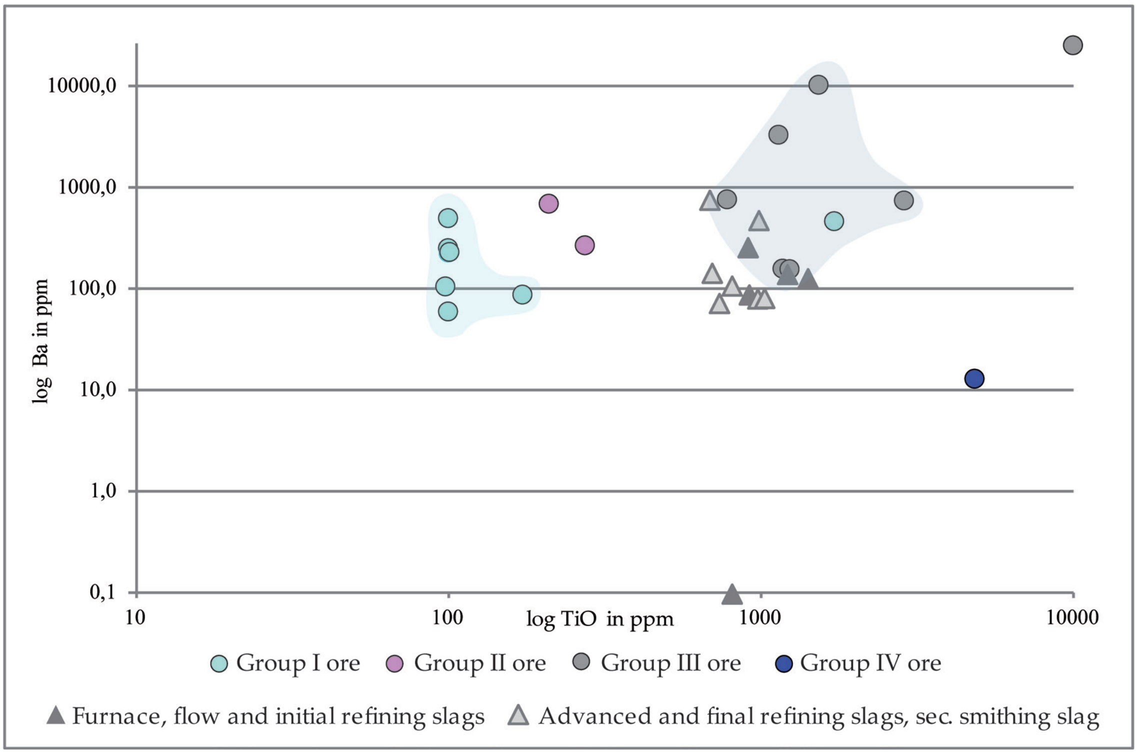
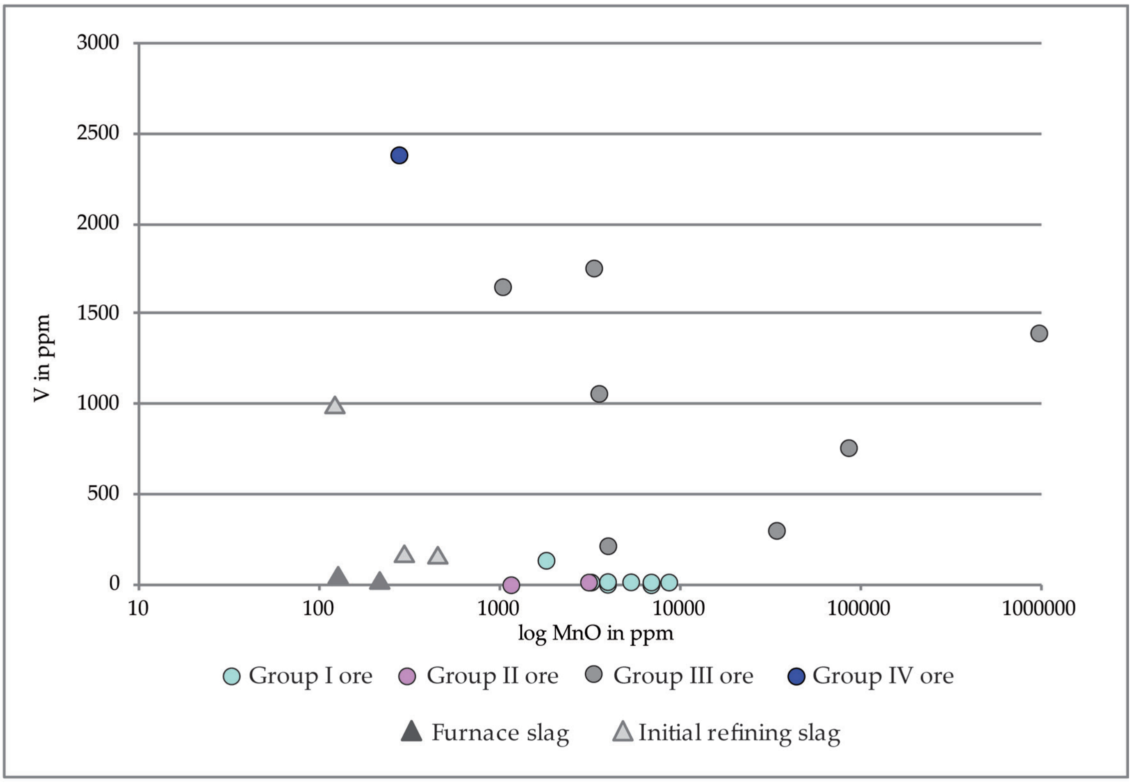


Figure 199: A plot of Ba against TiO_2 of the ore samples from the research area together with smelting and processing slag samples from Vungu-Vungu (SC 12).



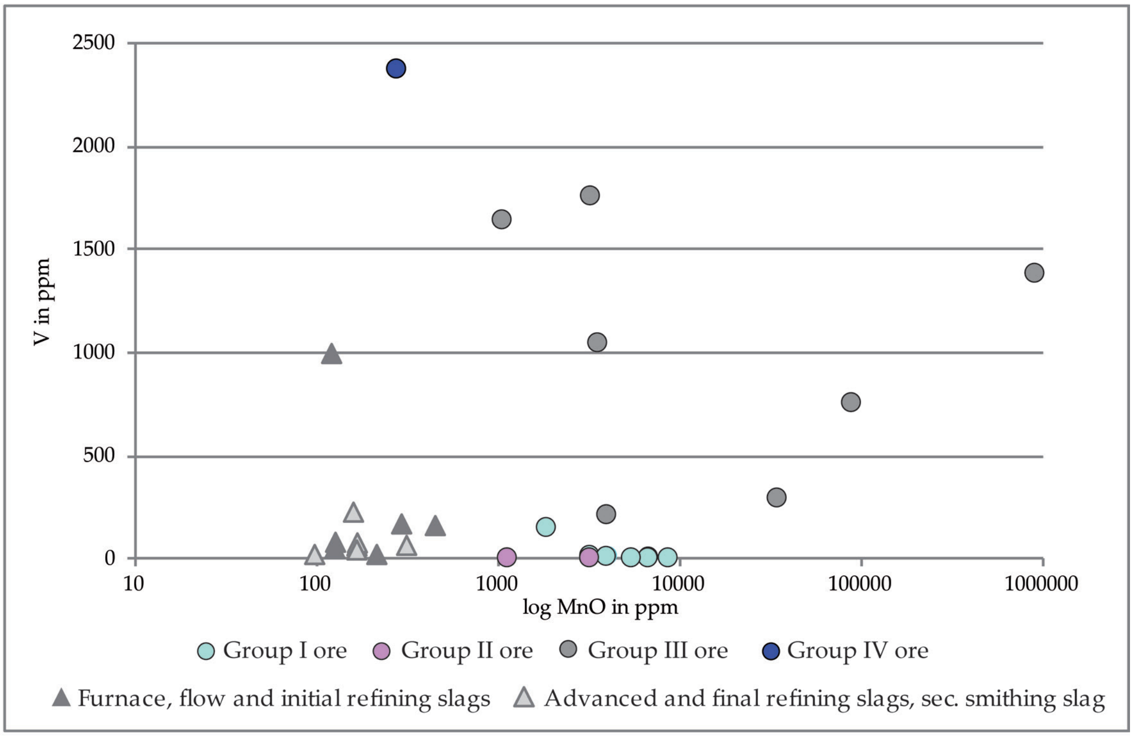
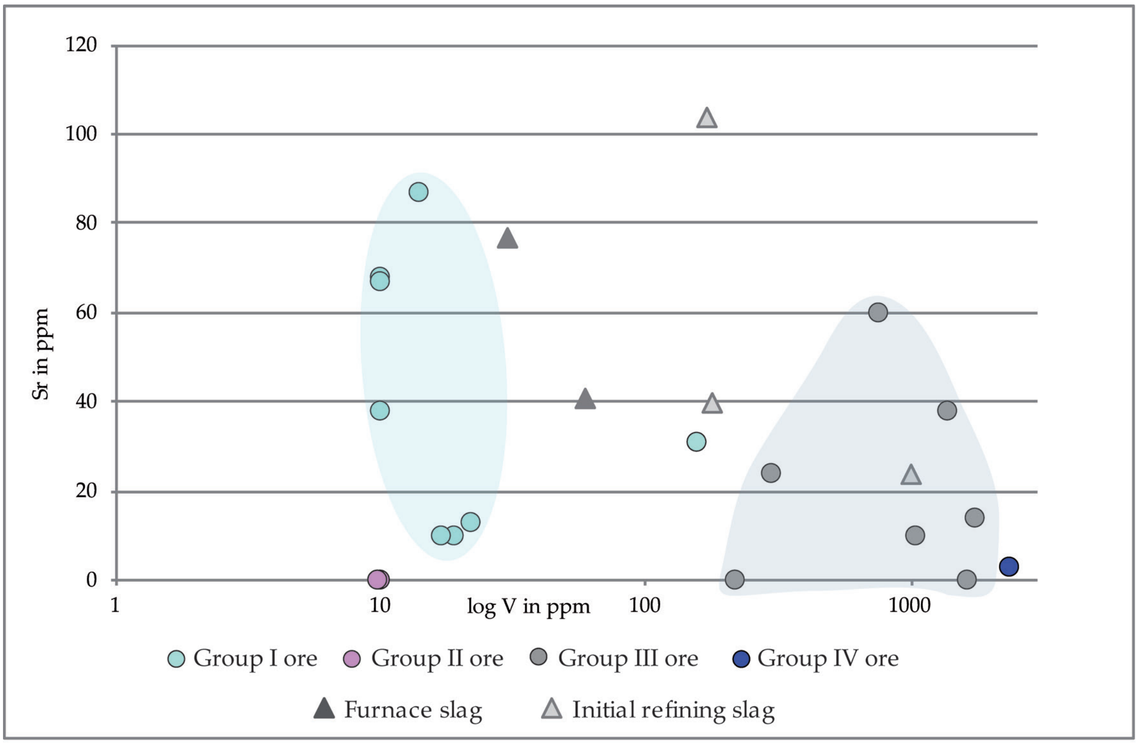


Figure 200: A plot of MnO against V of the ore,samples from the research area together with smelting and processing slag samples from Vungu-Vungu (SC 12).



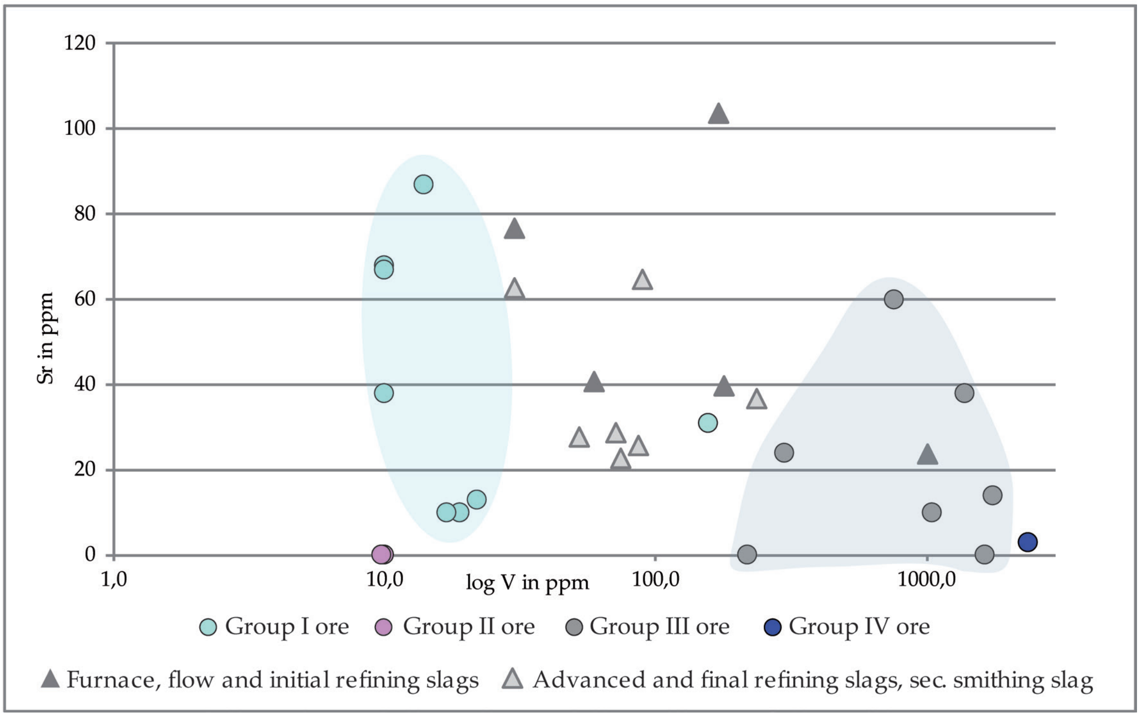


Figure 201: A plot of Sr against V of the ore samples from the research area together with smelting and processing slag samples from Vungu-Vungu (SC 12).

In none of the diagrams did sample 4422/06 from the refining site N96/03-3 correlate with the overall slag cluster form Vungu-Vungu, in particular because of its low barium and high vanadium readings (Table 45, Appendix 3). Since this sample is an initial refining slag, it may well mirror the slag chemistry of the smelt. However, the three other samples from N96/03-3 (4418/06, 4421/06, and 4427/06) did not differ from the overall range of slag chemistry from the site, providing that 12 samples can be considered representative for one site.

One possible explanation might be that the chemistry was changed by refractory material, or, that sample 4422/06 formed from the consolidation of a bloom that had not been produced from the same source material as the other slag samples from Vungu-Vungu.

4.2.12. Slag samples from Dikundu, Tjeye-East, Utokota and Kauti

Only two samples from Kauti (SC 32) and one sample each from Dikundu (SC 30), Utokota (SC 16) and Tjeye-East (SC 21) were analyzed (Tables 44 and 45, Appendix 3) due to our limited funding resources. Although not representative, I plotted them against the sampled ores because all of them were found associated with these ore deposits. As expected, the diagrams of Figures 202 to 204 disclose that the slag sample from Dikundu (4438/06) appeared close to the Group I ores from Dikundu and Kapongo. More interesting were the two samples from Kauti. Sample 5189/07 was taken from an experimental smelt in 2007, which was conducted with the Group II ores from Kauti (SC 32), and sample 5190/07 originated from a historic smelting site nearby. In all three diagrams (Figures 202 to 204), the lithophile elements of sample 5190/07 plotted closer to the two ore samples of Group II than sample 5189/07, although the source material of the latter was taken from the same square meter of deposit as were the analyzed ore samples. This divergence may reflect the compositional variability of the deposit, which I was not able to describe in full due to the limited number of samples, or else it might express the input of the refractory material (termite clay refractories). The two remaining samples from Utokota (4722/06) and Tjeye-East (4727/06) behaved in the diagrams as if they formed from the same source material, and the two sites are only 9 km apart as the crow flies. Both samples were found at sites from which ore samples of Group III were taken and in diagram Figure 204, they plotted in the field of the Group III ores with respect to their vanadium and strontium fraction. Hence, their position in the diagram suggested at first sight that these ores were the starting material of the two slag samples. However, a comparison of vanadium with manganese oxide (Figure 203) and barium with titanium oxide (Figure 202) revised the initial impression, and again the Group III ores could not have contributed to the smelting activities of the historic Kavango smelter at these two sites.

4.2.13. How many ore sources were there?

The comparison of the ore samples with the slag specimens from Ruuga (SC 3), Kapako (SC 4), Vungu-Vungu (SC 12), Utokota (SC 16) and Tjeye-East (SC 20) provided evidence that ore types different from those sampled for this study were used. The question is now whether the smelters at all these sites used the same source material or not. However, the position of the two samples from Utokota and Tjeye-East in the ore-slag-comparison diagrams (Figures 202 to 204) have already clearly indicated that these smelters used a completely different ore deposit than those from Vungu-Vungu, Kapako and Ruuga. The proportion of trace elements of the slag samples from the latter three sites overlapped in their distribution in the one or the other diagram. Because of this, those lithophile elements that contrasted significantly with each other in proportion were plotted against each other. Projecting strontium against barium and against titanium oxide (Figure 205) illustrated that the slag samples from Kapako concentrated in a field of low Sr, Ba and TiO_2. They differed from those from Vungu-Vungu, which were higher in Sr and in TiO_2. The slag specimens from Ruuga showed a fraction low in Sr, Ba and TiO_2, which overlapped with the readings of the slag samples from Kapako, and a more scattered fraction of specimens with higher ratio of all the three elements. Providing that the hypothesis about the two different ore sources used in Ruuga is right and that the samples are representative, it would appear that the smelters from Kapako and Ruuga used the same deposit of iron ore. The samples from Vungu-Vungu were close to the high TiO_2 fraction of the slag specimens from Ruuga, but most of them were low in Ba, indicating that the two slag assemblages did not have the same starting material. How many ore sources were there then? Trusted ore deposits are those of Group I and Group II based on ethnographic evidence (section 5.3.1). However, ignoring the oral traditions, only the one sample of Dikundu (SC 30) fell chemically into the field of its starting material, whereas the two samples from Kauti (SC 32) would not necessarily be linked to the Group II ores without the ethnographical knowledge. Vungu-Vungu (SC 12) has its own unknown source of ore, although the latter and Utokota (SC 16) for instance are only 17 km apart. The ironworkers of Kapako (SC 4) used the next unidentified

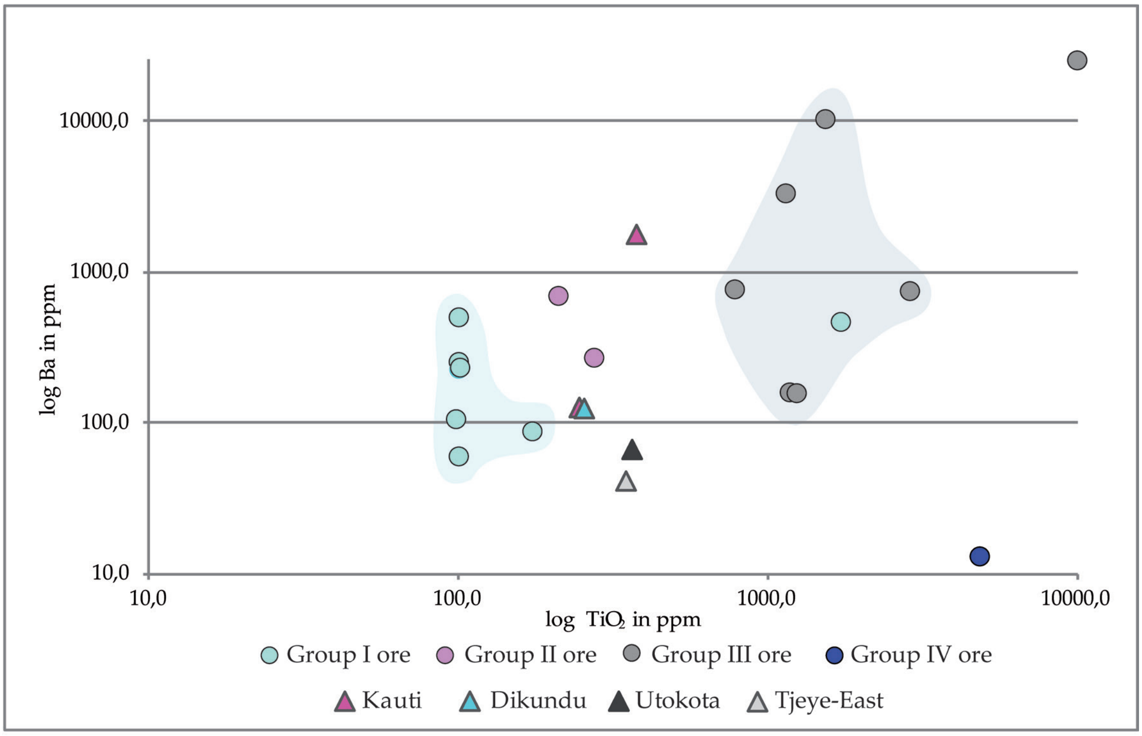


Figure 202: A plot of Ba against TiO_2 of the ore samples from the research area together with slag samples from Utokota (SC 16), Tjeye-East (SC 21), Dikundu (SC 30), and Kauti (SC 32).

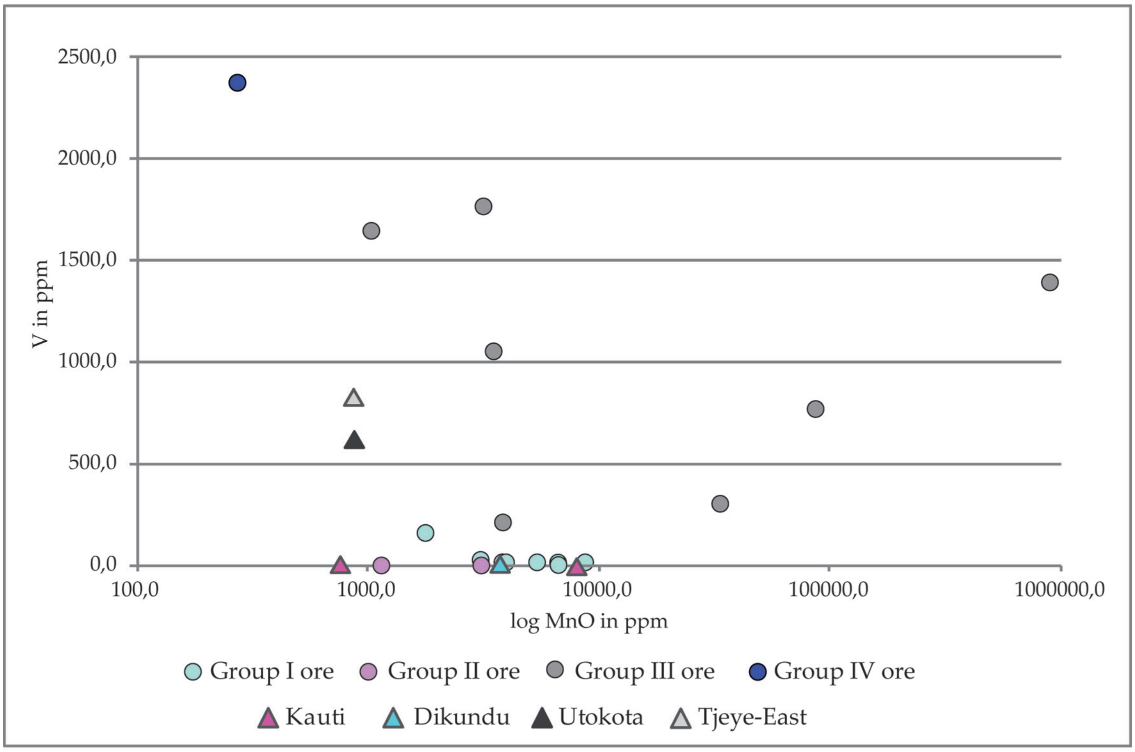


Figure 203: A plot of MnO against V of the ore samples from the research area together with slag samples from Utokota (SC 16), Tjeye-East (SC 21), Dikundu (SC 30), and Kauti (SC 32).

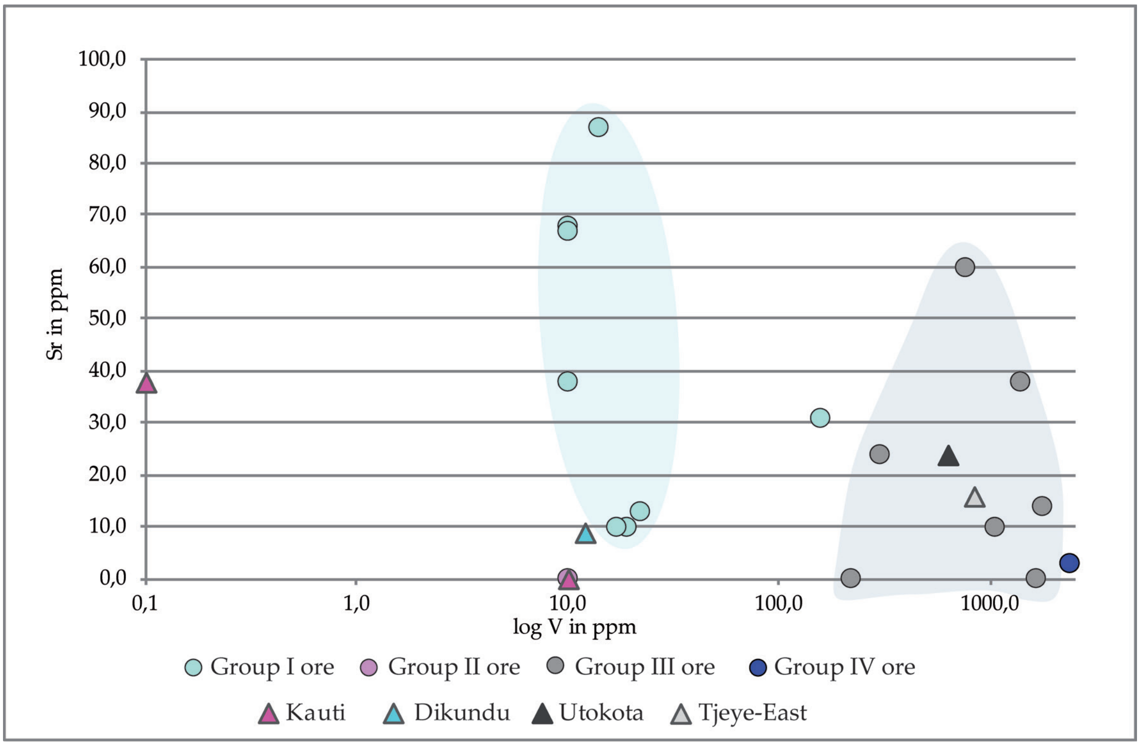


Figure 204: A plot of Sr against V of the ore samples from the research area together with slag samples from Utokota (SC 16), Tjeye-East (SC 21), Dikundu (SC 30), and Kauti (SC 32).

deposit and most probably, they shared their source of raw material with their counterparts from Ruuga (SC 3) who lived only 5 km away. However, assuming that the latter exploited material from two different deposits, again an unknown ore deposit may play a role in the smelting traditions of the Kavango region.

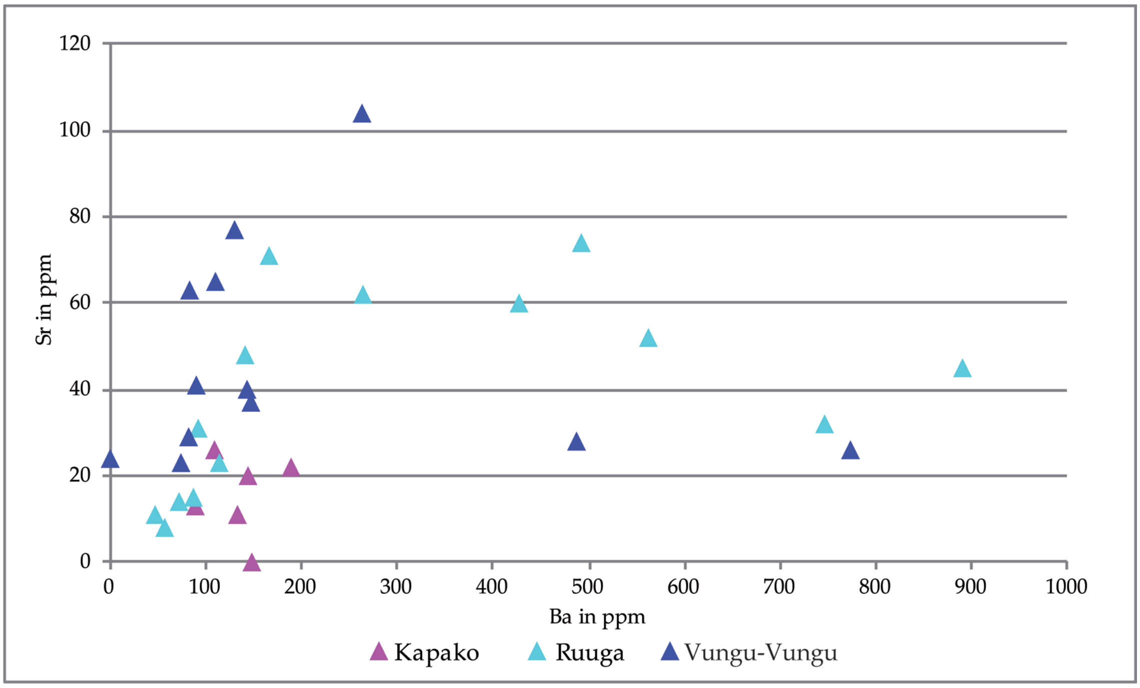
In summary the slag and ore analyses showed that the seven archaeological smelting and ironworking sites that I investigated expressed the chemical fingerprints of seven different ore deposits, of which only two are known so far. The ferricretes along the river terrace were not of interest for the ancient smelters, nor was the specularite found in the archaeological assemblage of Ruuga. Moreover, the smelters of the Early Ironworking Groups did not use the same ores as their counterparts of the Late Ironworking Groups. Within the later settlement horizon, a very heterogeneous picture of local ironworking and smelting traditions became apparent.

4.2.14. Siderophile elements of the slag samples

As pointed out earlier in my thesis, siderophile elements become reduced to their elemental form in the furnace-running conditions necessary for iron production in bloomery smelting (section 1.4.6). They accumulate as alloying elements in the elemental iron, thus they are hardly found in smelting slag samples. However, following common slag formation models as described in section 1.6.4, siderophile elements are expected at least in principle to be present in processing slag because of the increasing input of hammerscale that contains a high amount of re-oxidized iron.

Generally, the slag samples at hand were poor in siderophile elements. As above, I ignored samples 5189/07 and 5190/07 from Kauti (SC 32), because I consider both to be contaminated with unreacted material. Both samples were considerably higher in Bi, Cu, Pb and Ni than the average of the remaining specimens (Table 45, Appendix 3). However, samples 4429/06 and 4433/06 from Vungu-Vungu (SC 12) also contained partially reacted ore, yet only the first showed an elevated Zn fraction (Table 45, Appendix 3). Apart from that, none of the samples from Vungu-Vungu differed much from the other slag specimens and so I included them in my reflections.

Nickel was found in 30 of 32 samples that I was able to assign to one of the slag groups (Table 45, Appendix 3), and it was the most common siderophile element. In Figure 206 I plotted the average content of siderophile elements of the individual slag groups against



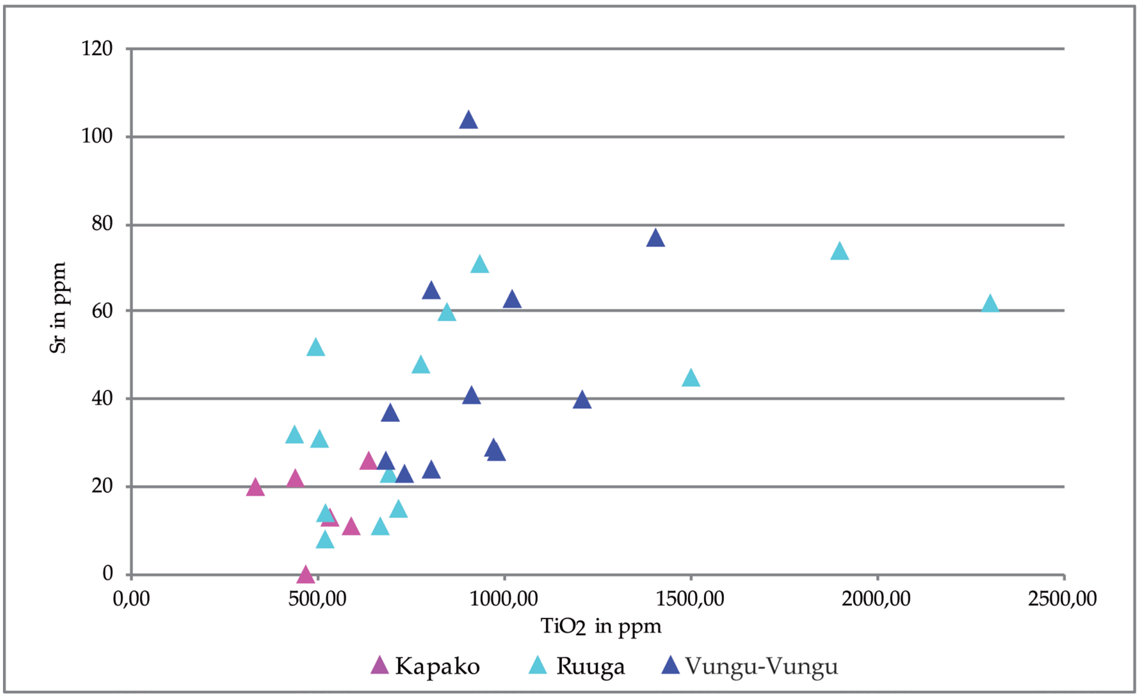
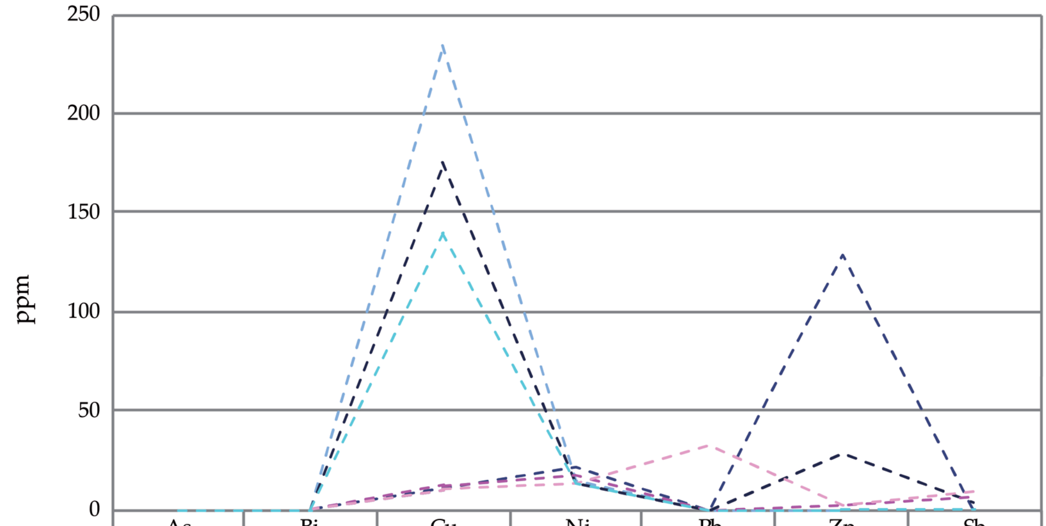


Figure 205: Above: a plot of Sr against Ba of the slag samples from Ruuga (SC 3), Kapako (SC 4), and Vungu-Vungu (SC 12). Below: a plot of Sr against TiO_2 of slag samples from the same sites.

each other, but the average nickel fraction did not significantly change throughout these groups. Copper was detectable in 16 samples of the 32, and flow slag (Group II), initial refining slag (Group IV) and secondary smithing slag (Group VII) were noticeably higher in copper than the other three slag groups. The data in Table 45 (Appendix 3) indicated that there were some individual samples with elevated copper readings compared to the other specimens, yet I was not able to detect any regularity that would link these slag samples to a common source or treatment.



	As	Bi	Cu	Ni	Pb	Zn	Sb
I	0	0	10	22	0	129	0
II	0	0	235	15	0	0	0
IV	0	0	175	13	0	28	4
V	0	0	12	17	0	2	6
VI	0	0	10	14	33	2	9
VII	0	0	140	14	0	0	0

Siderophile elements

Figure 206: Average proportions of siderophile elements in the Kavango slag samples of Group I to VII.

Zinc was detected in six of the 32 samples and antimony only in five of them. Here again, individual samples raised the average of these elements as shown in Figure 206, and no regularity seemed to be behind this inconsistent chemical picture. Only one sample contained any lead. Arsenic as well as bismuth were below detection limit in all the samples.

In summary, the siderophile elements of the samples at hand revealed a rather inconsistent chemical profile, and no relative or absolute enrichment of these elements could be found throughout the individual slag groups. However, as I pointed out earlier, the traditional smelters used several ore deposits which I was not able to detect and from which I have no chemical fingerprint that would allow for a comprehensive comparison of ore, slag and metallic iron. The comparison of nickel against copper in slag and ore samples underlined the heterogeneous picture. The bulk of slag specimens showed Ni and Cu readings below those of the ore deposits and one can only assume that most of the siderophile elements accumulated in the elemental iron. Most slag samples from Ruuga were very poor in copper, whereas those from Vungu-Vungu had a slightly higher average of it. However, both sites provided individual samples with copper proportions considerably above those found in the ores (Table 45, Appendix 3). As these amounts of copper in slag samples seemed to occur sporadically, I assume that the iron-workers processed some of the imported copper items in their forges.

4.2.15. Reconstructing furnace types: a morphological approach

4.2.15.1. Smelting furnaces

The overall lack of furnace remains such as slagged refractories or other archaeological features visible in the ground made a reconstruction of possible smelting facilities very difficult. The only furnace identified was the shaft furnace investigated by Beatrice Sandelowsky at Dikundu (Figure 151 and 152) (SC 30). Similar smelting facilities can be expected inside of the eroded termite mounds at the smelting site of Kapongo (SC 29); these have not yet been examined. Martin Albrecht recorded in 1996 in Vungu-Vungu (SC 12, N96/03-3) a pit 1.7 m to 2 m in diameter and 40 cm in depth, full

Figure 207: Vungu-Vungu (SC 12): tap slag, surface find.

of charcoal and slag debris, but frustratingly the test squares excavated revealed no clear indication about the original function of this pit. In 1998 Juergen Richter (Richter, 2005, p. 86) detected at the same site a round clay feature associated with charcoal and refining slag fragments (SC 12, N98/32-2) (Figure 112), but the refractory material was not slagged as much as would be expected at temperatures above 800 °C and its function might not have been linked to ironworking. From the obvious lack of slagged and refractory furnace remains at the investigated smelting and refining sites it appears that no furnaces with clay superstructures had been operating along the middle Kavango, except from the LIG smelting tradition in the Mbukushu area (sections 2.30 and 5.3.3).

Turning to the slag debris that provided indirect evidence of the smelting constructions through their shape or adhering refractories, only seven specimens of smelting slag bore any morphological features reminiscent of the furnace architecture. Two samples from Vungu-Vungu (SC 12) (4417/06 and 4415/06) (Table 33, Appendix 3) (Figure 122) and one collected at Kapako (SC 4) solidified in a pit (Table 32, Appendix 3, N99/21-2, ID 348), and displayed a flat bottom with hardly slagged sand adhering to it (Figure 94c). Another sample from Vungu-Vungu (SC 12) was typical dense flow slag that solidified in a cold environment (Figure 207, Table 32, Appendix 3). Similar pieces of such slag were collected at Kapako (SC 4) (e.g. Figure 94b) and Ruuga (SC 3). Together the evidence from the archaeological sites of the Kavango region suggested that two furnace types were in use. In the eastern part of the research area, shaft furnaces in termite constructions were common. To judge by the amount of flow slag surrounding the furnace at Dikundu, the slag was tapped from these facilities. In the western part, I argue that pit furnaces without clay lining were used, owing to the fact that no furnace mantle material has been found so far. The assumption is backed up by the remarkably low aluminum content in the furnace slag samples (Table 44, Appendix 3). However, sample 4388/06 from Ruuga (SC 4) revealed some attached furnace wall consisting of a silty material (Figure 208). With all caution, this may be interpreted as a furnace lining, but alternatively it could be the naturally occurring clayey component of the Kavango soils. The smelting pits were provided with a slag tapping facility such as an additional slag pit at the bottom of the furnace and probably slag collecting drains, because the slag samples described above all showed trapped sand grains with little thermal alteration, or only pseudomorphs of the substrate on which they solidified. Both cases indicate an environment that was certainly cooler than the bottom of a furnace below the charcoal bed. Still the evidence is not enough to reconstruct these furnaces graphically.

Figure 208: Ruuga (SC 3), area N98/39-1: sample 4388/06, flow slag that solidified along a furnace wall with some attached sediment.

4.2.15.2. Refining furnaces

Reconstructing refining furnaces in the research area is as difficult as reconstructing smelting furnaces. The mineral phases found in primary smithing slag samples undoubtedly implied a strongly reducing refining environment and furnace running conditions comparable to those during smelting. Owing to this, it seems justified to argue that the refining furnaces were similar to smelting furnaces in their function and most probably in their construction, too. Sample 4438/06 from Dikundu provided indirect evidence of the re-use of a smelting furnace for refining purposes. Furthermore, the sample suggested that a lot of smelting slag drained from the bloom in one go. In this case, only a few amorphous hammerscale inclusions contributed to the slag whereas flat hammerscale flakes, which derived from a compact piece of iron, appeared more frequently trapped in the slag. This sample lacked the refining intervals that produce layered slag lumps and amorphous hammerscale through repeated cycles of heating and hammering. It would therefore appear that the finds from Dikundu are linked to a refining procedure during which the bloom was sintered in the furnace for an extended time period (i.e. longer than 40 minutes) and left the furnace afterwards as a compact piece of raw material. By contrast the refining assemblage found at Likundu (SC 30, N69/03-1) (Figure 156), which was not far from the site of Dikundu (SC 30), provided proof that a shallow open pit was utilized to heat the bloom. Both examples demonstrate that technology and technological style can be quite heterogeneous even in the same area. The consolidation technique used at Likundu was the same as has been reconstructed at most of the other refining sites in the research area. Apart from 4438/06, all primary smithing slag samples showed repeated cycles of heating, slag draining, and hammering and that the bloom had been successively consolidated after the smelt. All smithing hearth bottoms with adhering material from the furnace wall suggested that the refining furnaces were pits in the sandy ground, too, which were filled with fuel (Figure 184). Certain samples had sediment residues finer than sand adhering to them(e.g. Figure 94a and d) but the evidence was not enough to interpret them as furnace lining remains. As discussed earlier, a more silty natural soil would probably produce the same picture. Sample 4719/06 from Kapako (SC 4) even suggested that slag tapping was practiced during refining. As a result, refining furnaces seem to differ from smelting furnaces only in that less evidence for slag-tapping constructions has been found so far.

4.3. Metallographic analyzes of crown material and iron artifacts

One aim of my study is to reconstruct both the quality of iron that had been produced and the processing techniques that the ironworkers used to forge jewelry and tools. For this purpose, 44 polished cross and thin sections were made from iron artifacts, blooms, gromps, and smithing slag remains that were expected to contain remnants of metallic iron (Tables 49 and 50, Appendix 3). In addition, a number of smithing slag fragments contained small iron prills that formed during primary smithing, indicating the furnace or hearth running conditions during the refining activities. Of the 44 available samples, 11 were not etched because the content of elemental iron was too little or too corroded. Fourteen of the etched samples originated from Ruuga (SC 3), six from Kapako (SC 4), eight from Vungu-Vungu (SC 12), two from Dikundu (SC 30) and one from Utokota (SC 16), Nyangana-Kangwenu (SC 27) and Tjeye-East (SC 21) each (Tables 49 and 50, Appendix 3). No chemical analyses were made from the elemental iron, and consequently only those alloying element could be described which were detectable by optical microscopic microstructure analyses. Not surprisingly, the most important alloying element found was carbon, and certain samples contained phosphorous. Acicular intragrain inclusions were commonly present in the ferrite grains of the samples, yet their interpretation in scholarly literature is vague and ranges from iron-phosphides, iron-carbides, iron-nitrides to carbide-nitrides (section 1.4.9). Most bloom fragments, gromps and artifacts were corroded to varying degrees and sometimes decomposed. Those iron fragments that were enclosed in slag were still in good condition.

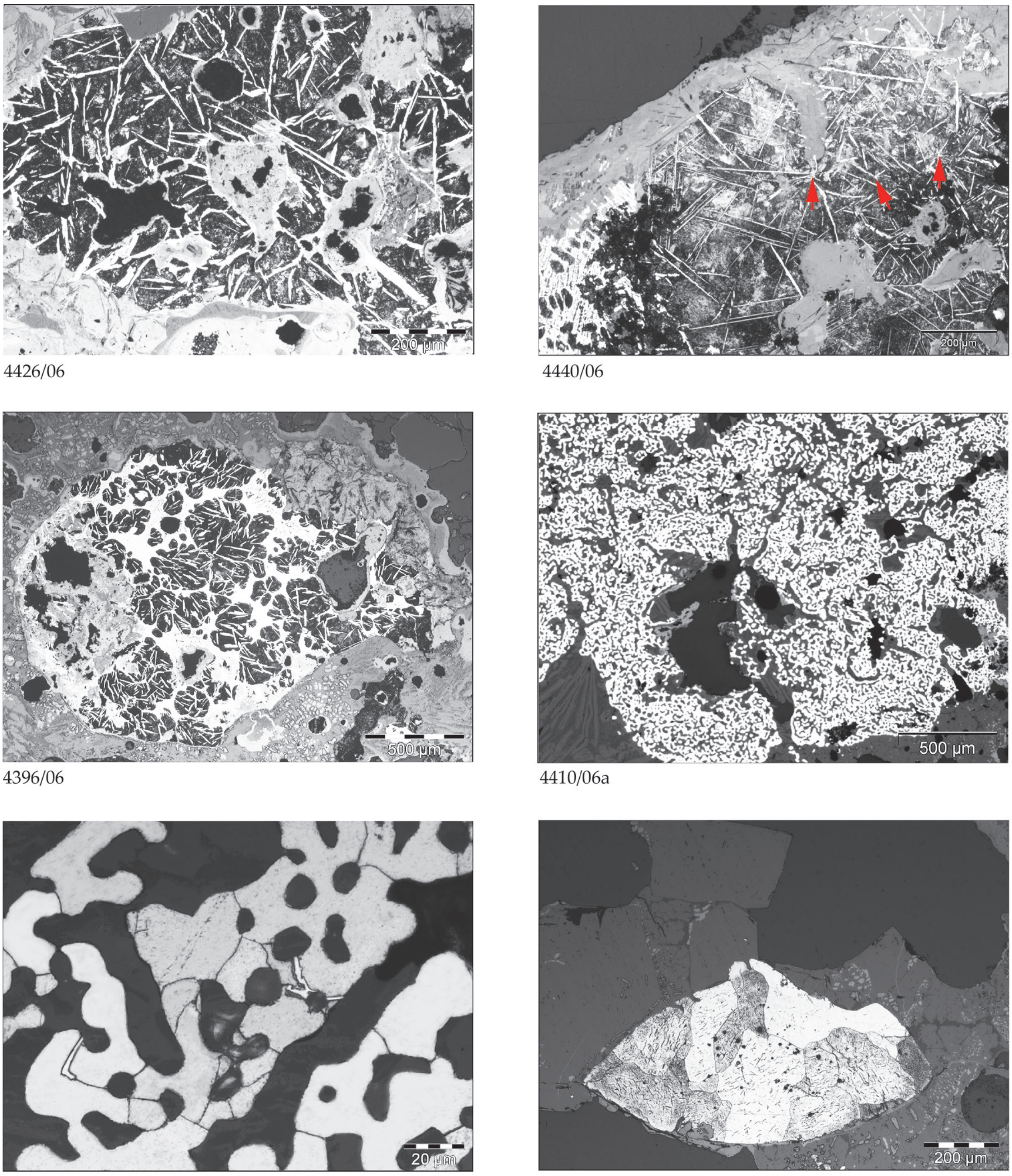
4.3.1. Blooms

Eleven samples of bloom fragments were examined (Table 49, Appendix 3). They originated from Ruuga (4389/06, 4394/06, 4395/06, and 4404/06), Kapako (4413/06 and 4720/06), Vungu-Vungu (4426/06 and 4417/06), Nyangana-Kangwenu (4440/06) and Dikundu

(4708/06 and 4709/06). Most of these samples were associated with smelting slag and probably became lost during the very initial step of sorting and refining after the smelt (sections 1.5.1.1 and 1.6.2.2). All blooms and bloom fragments were unconsolidated and occurred in loose coral-like structures (e.g. Figure 155: 4708/06b and 4709/06b, see also Figure 209: 4410/06a). Only a few were condensed into a more solid piece of iron (e.g. Figure 55: 4394/06 and 4395/06a and Figure 155: 4708/06a and 4709/06a). After etching, most samples displayed microstructures with a low carbon content. The quality of this material ranged from pure ferrite (pure iron) (4389/06 and 4404/06) (Figures 21 and 209: 4410/06b) to low carbon steel with carbon proportions in the region of 0.02wt% to 0.2wt% (4395/06, 4404/06, 4407/06, and 4413/06) (Figure 22). Nevertheless, four samples provided evidence that pure iron could be produced in the same bloom along with low, medium, and high carbon steel with up to 0.8wt% of C (Figure 23) (4394/06, 4708/06, 4709/06, and 4417/06). It was found that two samples were clearly over-carburized and were probably discarded for this reason: Sample 4426/06 consisted of hypereutectoid steel (Figure 209: 4426/06) with a carbon content in the region of 2wt% to 2.06wt%, and sample 4440/06 that varied extremely from eutectoid steel (0.8wt% C) to eutectic white cast iron (4.3 wt% C) (Table 49, Appendix 3) (Figure 142).
A diachronic look at the bloom fragments suggests that the smelters of the Early Ironworking Groups preferentially produced pure iron and low carbon steel (Table 49, Appendix 3). Moreover, the analyzed finds implied that the early ferrous material was more homogeneous than the blooms produced later. The samples collected from smelting sites of the Late Ironworking Groups varied greatly in carbon content (Table 49, Appendix 3) and it would appear that two different technological approaches to smelting were both possible. However, as will be discussed below, the etched sections of the iron objects associated with the EIG context revealed that the early blacksmiths preferred medium to high carbon steel for tool production (Table 50, Appendix 3), which proved that the low carbon blooms did not represent the full spectrum of iron and steel produced.
Two specimens revealed phosphorous in the alloy: Sample 4395/06, low carbon steel, displayed a ghost structure in polished section (Figures 25 and 55: 4395/06a) and behaved unresponsively towards etching. As described earlier, ghost structures develop in low phosphorous iron (P contents between 0.1wt% to 0.6wt%) under fast cooling conditions, and the observed etching behavior is characteristic of phosphorous in the material (section 1.4.9). The over-carburized sample 4440/06 revealed two-phase phosphides (Figure 209: 4440/06). Phosphorous is also known to lower the melting point of iron (section 1.4.9), yet without more detailed chemical analyses the extent to which it contributed to the formation of the cast iron detected in sample 4404/06 remains unknown. However, in both cases it made the iron harder than one could deduce from the sole presence of the carbon in the specimen. Samples 4389/06 and 4394/06 revealed small intragrain inclusions, which permitted variable interpretations, as can be seen above.
All the bloom fragments were unconsolidated and no traces of hammering or cold working could be detected. Those samples that were consolidated enough to contain slag inclusions - rather than being iron labyrinths in slag - exhibited no deformation of the inclusions, which suggested that they had not yet been manipulated. However, variation in ferrite grain sizes such as seen in sample 4389/06, ranging between ASTM 1 to 7, could indicate recrystallization after grain deformation of a physical treatment.

4.3.2. Iron fragments in smithing slag

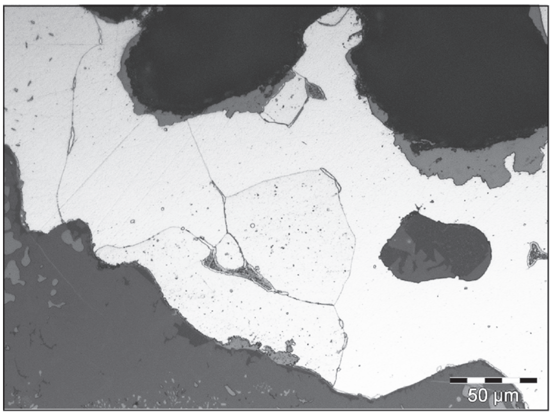
Cross sections of 22 specimens of the refining slag revealed bloom fragments and prills of elemental iron (4391/06, 4393/06, 4396/06, 4402/06, 4405/06, 4409/06, 4410/06, 4411/06, 4416/06, 4418/06, 4420/06, 4422/06, 4423/06, 4429/06, 4430/06, 4435/06, 4436/06, 4438/06, 4719/06, 4721/06, 4722/06, and 4727/06). Eleven of these samples were not etched because the amount of iron was too small or too corroded. Of the 11 etched samples (Table 49, Appendix 3), four originated from Ruuga (4396/06, 4409/06, 4410/06, and 4411/06), two from Kapako (4435/06 and 4436/06), three from Vungu-Vungu (4418/06, 4420/06, and 4423/06), one from Utokota (4722/06) and one from Tjeye-East (4727/06). Most inclusions of metallic iron were found in pieces of initial and advanced refining slag (section 1.6.2.2) and they consisted of unconsolidated and consolidated bloom fragments. Sometimes it was difficult to decide whether inclusions of unconsolidated elemental iron were lost gromps from a bloom, or whether they became reduced within the slag itself during refining (e.g. 4423/06).



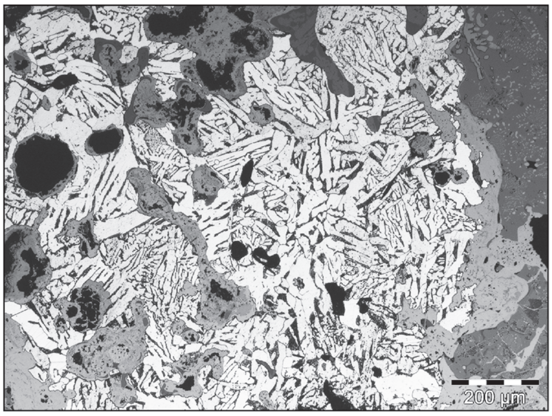
4426/06 | 4440/06 | 4396/06 | 4410/06a | 4410/06b | 4411/06

4426/06: Hyperoitectoid steel (lamellar pearlite in dark gray with acicular secondary cememtite).
4440/06: Hypereutectoid steel with phosphide inclusions indicated by the red arrows, in transition to cast iorn in the left section.
4396/06: Cast iorn prill with approximately 3% of carbon.
4410/06a: Semi-condensed iron bloom.
4410/06b: Wrought iron (ferrite with isolated tertiary cementite segregations along grain boundaries).
4411/06: Acicular ingragrain inclusions in ferrite.

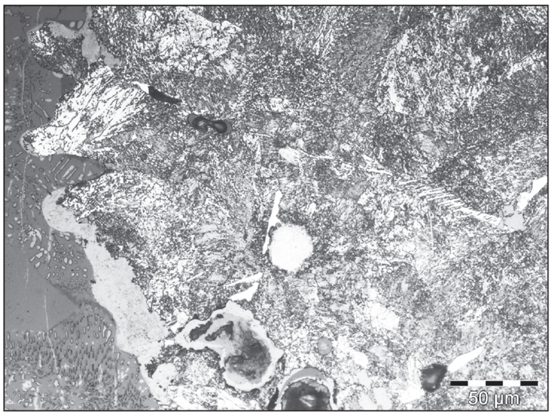
Figure 209: Polished cross section of blooms and crown material in smelting and refining slag. Ruuga (SC 3), N98/39-2 and surface finds: samples 4396/06, 4410/06, and 4411/06. Vungu-Vungu (SC 12), area N96/3-3: sample 4426/06. Nyangana-Kangwenu (SC 27), area N98/43-1: sample 4440/06.



4418/06



4423/06



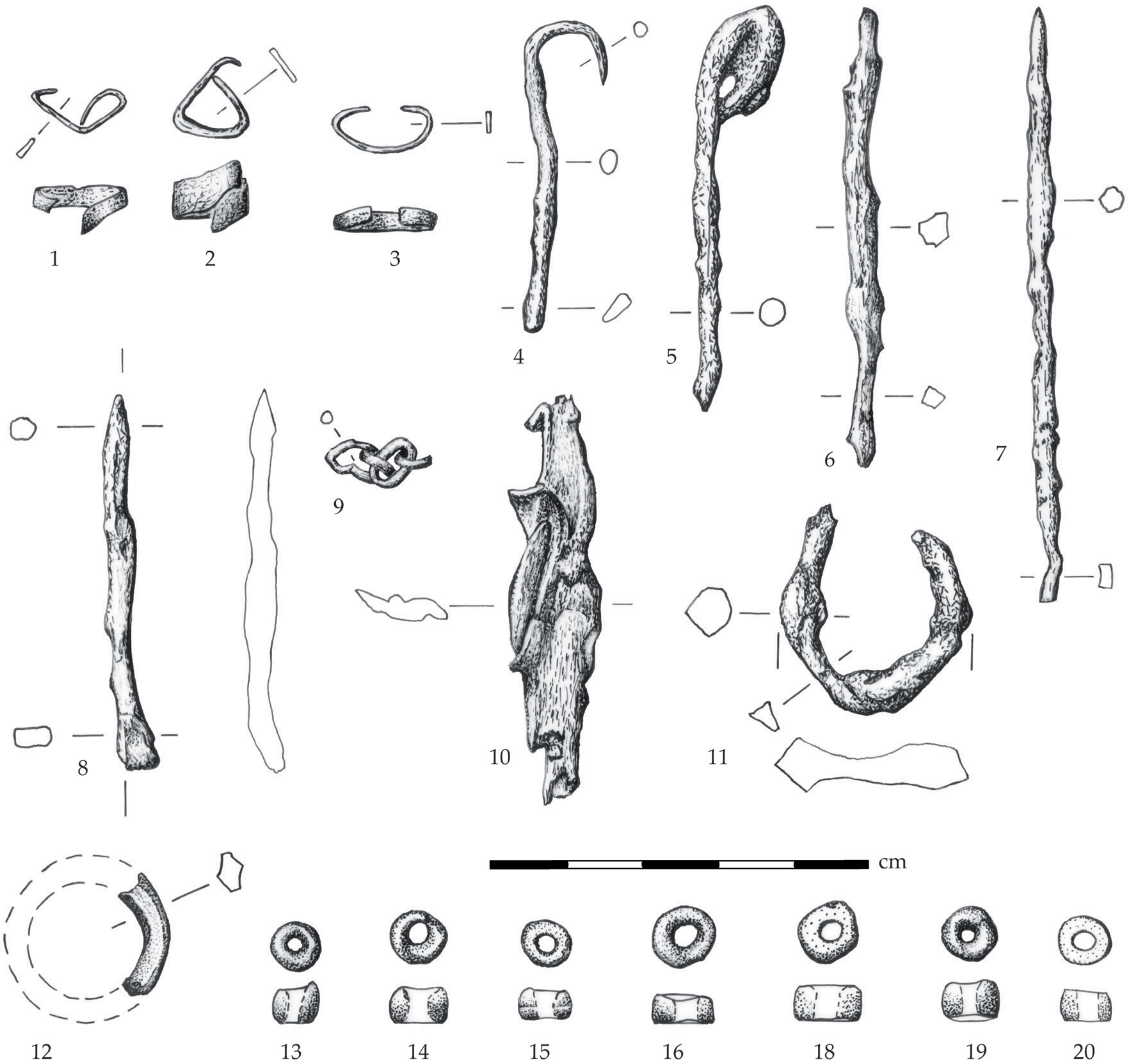
4420/06

4418/06: Low carbon steel with approximately 0.03% carbon. Ferrite with tertiary cementite along grain boundaries and perlite islands.
4423/06: Medium carbon steel with lath-shapted ferrite grains (Widmanstätten structure) indicating rapid cooling.
4420/06: Eutectoid steel, lammelar pearlite (0.8% C).

Figure 210: Vungu-Vungu (SC 12), area N96/3-3: blooms and crown material in refining slag. Samples 4418/06, 4420/06, and 4423/06.

The iron metal found in these samples was very heterogeneous and mirrored the variability already found in the bloom fragments examined earlier. Five samples (4410/06, 4411/06, 4418/06, 4423/06, and 4722/06) consisted of pure iron and low carbon steel with less than 0.02wt% to 0.2wt% of C (Figure 209: 4410/06b and 4411/06), whereas six samples (4396/06, 4409/06, 4420/06, 4435/06, 4436/06, 4727/06) had heterogeneous inclusions of iron ranging from pure iron to hypereutectoid high carbon steel which did not exceed 0.85wt% of carbon (Figure 95) (Table 49, Appendix 3). Only samples 4436/06 and 4727/06 revealed some over-carburized steel gromps with carbon contents in the region of 1.1wt% to 1.6wt% (Table 49, Appendix 3). There was no evidence for elevated phosphorous in the specimens, yet chemical analyses or micro-hardness testing might have changed this picture. Only in three samples were iron fragments found with intragrain inclusions in the ferrite grains (Figure 209: 4411/06), which were, as mentioned above, difficult to interpret (section 1.4.9).

Deformation of grain morphology provided evidence in five samples (4420/06, 4423/06, 4436/06, 4722/06, and 4727/06) that the bloom had been hammered and cold-worked. More indirect evidence of cold working was deduced from the grain size variations found in the microstructures of six samples (4418/06, 4420/06, 4435/06, 4436/06, 4722/06, and 4727/06), indicating a recrystallized microstructure. Ferrite grains varied between five to seven ASTM grain size classes within individual bloom fragments (e.g. Figure 22) and represented crystal microstructures that did not fully recover after a certain degree of cold working (section 1.4.9). In seven samples (4396/06, 4409/06, 4410/06, 4411/06, 4423/06, and 4727/06), the compacted gromps had slag inclusions that provided indirect evidence of the mechanical and thermal treatments that the bloom underwent because they were angular and subangular in section. Four samples displayed a Widmanstätten structure (4396/06, 4420/06, 4423/06, and 4435/06) (Figure 210: 4423/06), indicating that these gromps cooled down rapidly from the austenite field above critical temperatures, probably in the air (section 1.4.9).



1- Iron clip, Kapako (SC 4), sample 4485/06; 2- Iron clip, Ruuga (SC 3), sample 4486/06; 3- Iron clip, Ruuga (SC 3), sample 4439/06, 4- Iron hook, Ruuga (SC 3), sample 4437/06; 5- Iron rod with loop-like end, Vungu-Vungu (SC 12), sample 4483b/06; 6- Iron bar, Ruuga (SC 3), sample 4474/06; 7- Iron point, Kapako (SC 4), sample 4476/06; 8- Iron point, Vungu-Vungu (SC 12), sample 4484/06; 9- Iron chain fragments, Ruuga (SC 3), sample 4475/06; 10- Iron, piece of recycled material, Kapako (SC 4), sample, 4477/06; 11- Open iron ring, Vungu-Vung (SC 12), sample 4483a/06; 12- Copper ring fragment, Kapako (SC 4); 13- Copper bead, Ruuga (SC 3); 14-19- Copper beads, Vungu-Vungu (SC 12).

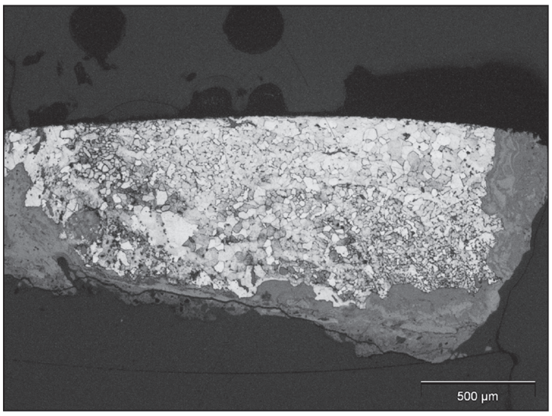
Figure 211: Metal artifacts from the middle Kavango region.

4.3.3. Iron artifacts

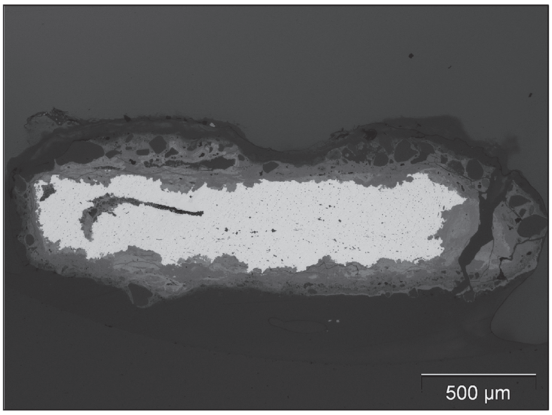
A total of 79 iron artifacts have been collected from five archaeological sites (Table 52, Appendix 3). Most of these artifacts were considered modern, such as numerous fragments of tin cans, pieces of industrial wire, industrial iron plates, a screw, a blade of a hacksaw, and a crown cup. All of these artifacts were either surface finds or they originated from the upper soil horizon, which was mixed with modern residues. These finds will not be discussed.

Of the 83 artifacts, only 27 originated from archaeological deposits that were associated with traditional ironworking and were the work of indigenous blacksmiths. Most of the artifacts from the EIG horizon were found at Ruuga (SC 3) and in the deeper layers of Kapako (SC 4). The LIG artifacts mostly came from Vungu-Vungu (SC 12), from the upper layers of Kapako (SC 4) and from Gove (SC 17) (Table 53, Appendix 3).

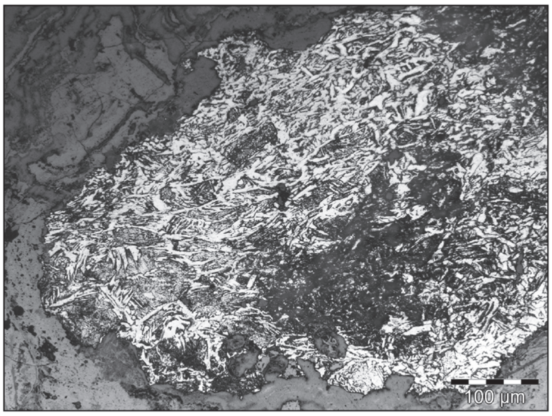
Iron clips (Figure 211: 1-3) were the most common finds (n = 6) and were probably used as beads that were bent around an organic core. Two iron rings (Figure 211: 11) and one chain



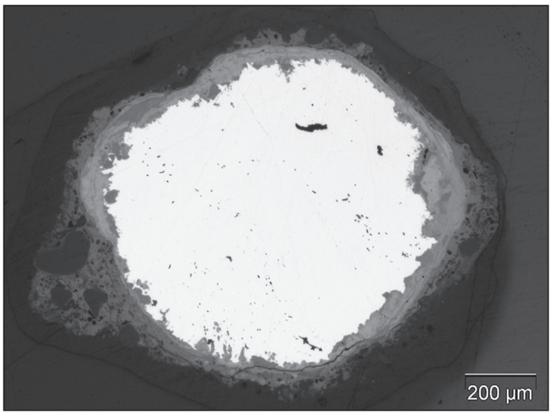
4437/06



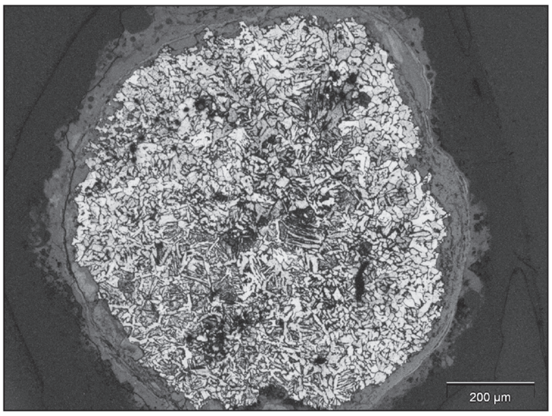
4439/06



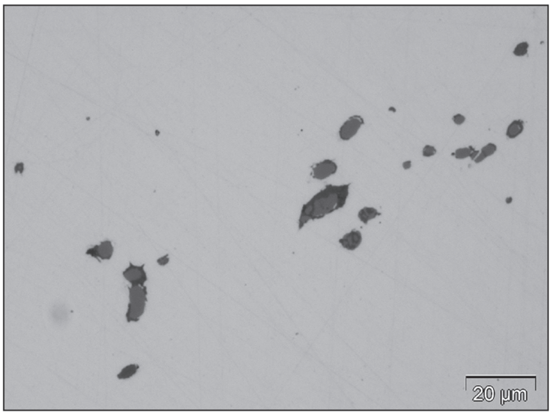
4474/06



4475/06a



4475/06b



4475/06c

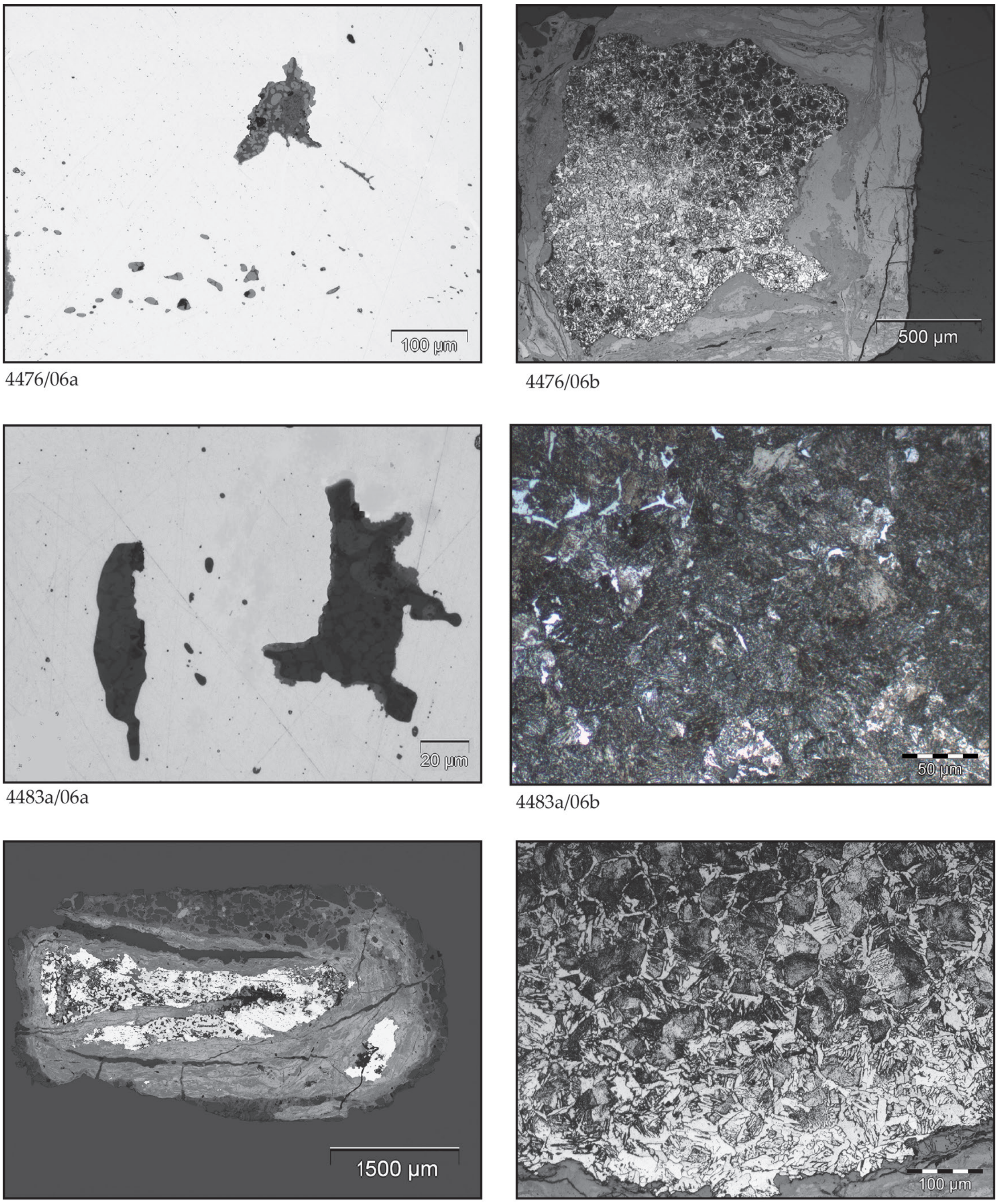
4437/06: Low carbon steel showing strong ferrite grain size variation indicating recrystallization after coldworking.
4439/06: Unetched cross section showing numerous inclusion in the artifact and a corrosion line in the metal indicating a poorly performed weldseam.
4474/06: Widmanstätten strucutre with grain deformation after coldworking.
4475/06a: Cross section of drawn wire showing slag inclusion and some corrosion.
4475/06b: Widmanstätten structure in the center of the artifact and decarburization towards the outer margin.
4475/06c: Slag inclusions in the artifact with granular wustite crystals.

Figure 212: Polished sections of iron artifacts from Ruuga (SC 3), samples 4437/06, 4439/06, 4474/06, and 4475/06.

fragment (Figure 211: 9) were also classified as ornaments. Three finds were rods with pointed ends, and one rod had a loop-like end (Figure 211: 5). Two hooks (Figure 211: 4) from Ruuga (SC 3) and Vungu-Vungu (SC 12) might have been used in fishing. From Vungu-Vungu (SC 12) a tweezers-like object was collected, which was made from a recycled industrial wire. One small iron bar (Figure 211: 6) and a piece of recycled raw material (Figure 211: 10) were probably used as starting material by a blacksmith. The same applied to one piece of ribbon, a piece of sheet metal, and a plate (Table 53, Appendix 3). Sample 4477/06 (Figure 211: 10) consisted of welded and fused small fragments of sheet metal and provided insight into the recycling habits of the LIG blacksmiths. Three objects were too unspecific and corroded for identification. If one wishes to differentiate between the products of the Early and the Late Ironworking Groups, it seems that the EIG blacksmiths focused on producing ornaments since there were only two non-decorating artifacts collected from this horizon: a hook (Figure 211: 4) and a point (Figure 211: 7). The LIG blacksmiths seem to have crafted both tools and ornaments in equal amounts. However, there is reason to assume that the range of iron artifacts found in the assemblages was highly biased due to the high rate of recycling. In particular large artifacts such as spear heads and axes were absent and the range of tools recorded during the oral history interviews (section 5.3.4) was not represented in the archaeological assemblages at all.

Of 27 iron artifacts from a reliable archaeological context, 11 were chosen for microscopic examination through polished cross sections (Table 50, Appendix 3). Six samples were associated with EIG material (4437/06, 4439/06, 4474/06, 4486/06, 4475/06, and 4476/06) and five artifacts were associated with the LIG occupation (4477/06, 4483a/06, 4483b/06, 4484b/06, and 4485/06). Most items were moderately to severely corroded (e.g. Figure 213: 4476/06b and 4484b/06, and Figure 214: 4486/06c), which affected the etching behavior of some samples. It was found that the composition of the iron and steel from which the artifacts were made was quite heterogeneous but less variable than the gromps found in the smelting slag residues. The microstructure of the majority of the objects indicated that the blacksmiths preferred medium to high carbon steel for jewelry and tool production with carbon proportions above 0.2wt% (Table 50, Appendix 3). Hypereutectoid steel was undesirable, and it was most probably the difficult forging behavior of the material that made it unattractive for the blacksmiths. Only two samples (4437/06 and 4485/06) were made of a homogeneous soft material in transition from pure iron to low carbon steel (Figure 212: 4437/06). Sample 4484b/06, a strongly corroded point, showed low carbon steel zones in combination with eutectoid high carbon steel. However, in this sample the etching response was difficult and over-etched sections occurred together with scarcely affected ones. As mentioned earlier in the section, this indicated compositional variation in the material and made the properties of the material difficult to predict (also see section 1.4.9). Although the examined samples were small, all but three specimens (4437/06, 4475/06, and 4485/06) disclosed compositional inhomogeneities indicated by the fluctuating carbon content (Figure 213: 4476/06). These inhomogeneities occurred in random distribution or banded, and the latter is believed to attest that the material had been heavily worked (section 1.4.9). Most transitions from one composition to another were gradual, only in samples 4437/06 and 4484b/06 were the boundaries sharp. The diversity of iron and steel found in the smithing slag described earlier attested that the chemical variations of the artifacts were inherited from the starting material. In addition, extensive hot working caused decarburization as did iron hydroxide inclusions, and both contributed to the variable compositional nature of the historical iron objects. As mentioned above, the greatest variability occurred in sample 4484b/06, which was made of material from low carbon to eutectoid high carbon steel (Table 50, Appendix 3).

The morphology of the ferrite grains and the pearlite was another source of information. As described in section 1.5.2.1 earlier in this study, variation in grain dimensions (e.g. Figure 212: 4437/06) is indicative of recrystallization after grain deformation and can also be influenced by alloying elements. There was a wide range of grain sizes found in the material, and the latter ranged between ASTM 3 and ASTM 10. Only three samples were homogeneous with respect to the ferrite grain size distribution (4439/06, 4474/06, and 4476/06), whereas the other objects showed internal variations of five to six ASTM grain size classes. Six samples (4474/06, 4475/06, 4476/06, 4483a/06, 4483b/06, and 4484b/06) developed a Widmanstätten structure in zones with adequate carbon content (Figure 212: 4475/06 and Figure 213: 4476/06 and 4483a/06). As seen in section 1.4.9, proeutectoid ferrite on grain boundaries of former austenite grains alongside ferrite saw teeth penetrating the pearlite field could only develop when the material was heated to the austenite field and was rapidly cooled afterwards. The size of the former austenite grains, which was visible in the contour of the ferrite allotriomorphs, ranged from ASTM 4 to 9 within the sample set and corresponded to austenitization temperatures roughly between 850 °C and 930 °C (after Brick, Gordon & Phillips, 1965, p. 234). When artifacts are subject to plastic deformation at temperatures



4476/06a   4476/06b

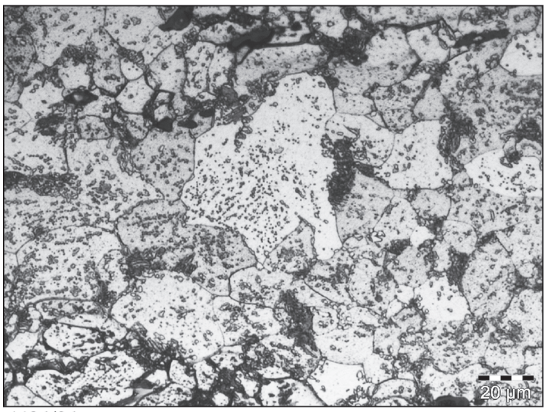
4483a/06a   4483a/06b

4484b/06   4483b/06

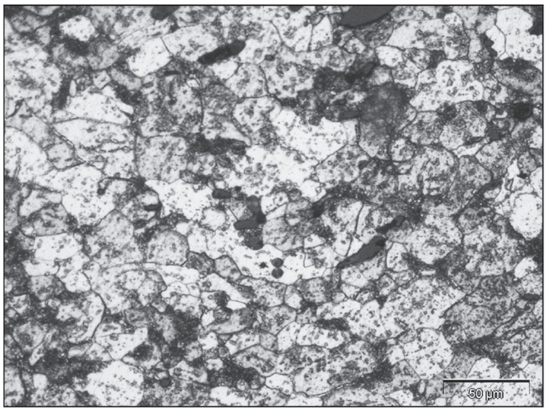
4476/06a: Angular slag inclusions in iron showing wustite crystals.
4476/06b: Gradual transition from low to high carbon steel in a small artifact.
4483a/06a: Large angular slag inclusions in elemental iron with crowded wustite crystals.
4483a/06b: Pearlite near the eutectic composition.
4484b/06: Heavily corroded artifact. The line of corrosion in the artifact indicates a poorly performed weldseam.
4483b/06: High carbon steel which developed a Widmanstätten structure. The artifact is decarburized towards the outer margin.

Figure 213: Polished sections of iron artifacts from Kapako (SC 4), area N68/01 (sample 4476/06) and Vungu-Vungu (SC 12), area N69/01-2 (samples 4483a/06, 4483b/06, and 4484b/06).

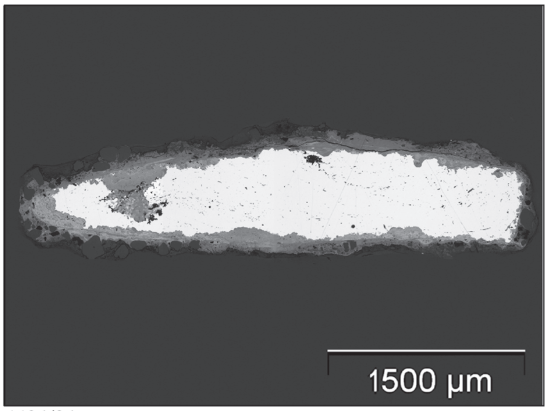
between 600 °C and 700 °C below the beginning α- to γ- transformation of Ac_1, fragmented cementite plates easily spheroidize (section 1.5.2.4). Spheroidized cementite has been observed on four objects (4437/06, 4474/06, 4484b/06, and 4486/06) in varying states of degeneration, and the latter largely depended on the degree of warm working, the length



4486/06a



4486/06b



4486/06c

4486/06a and b: Ferrite grains with pearlite islands and spheroizided cementite.
4486/06c: Unetched cross section showing strong inclusion banding.

Figure 214: Ruuga (SC 3): Polished sections of iron artifact sample 4486/06.

of time the object was held at subcritical temperatures, and the chemical composition of the material (Figure 214).

All the artifacts contained numerous inclusions, which are characteristic of products made from bloomery iron. Most of them were two- or three-phase slag inclusions consisting of wustite, fayalite and glass (Figure 212: 4475/06 and Figure 213: 4437/06 and 4483a/06). Frequently, small voids were associated with bloomery iron in places where liquid slag was expelled from the bloom during the refining process, and the pores were not properly closed during subsequent consolidation. Some artifacts displayed small fuel inclusions that caused unintended carburization around them while the object had been hot-worked. Voids, fissures and welds were typical zones of damage through corrosion in the interior of an object (Figure 212: 4439/06 and Figure 213: 4484b/06). Because of this, poorly performed welds frequently developed into zones of vulnerability of an object (4439/06, 4474/06, 4477/06, and 4484b/06). Most informative was the alignment and shape of the inclusions since they changed with the degree of hot working, and became oval and flattened (section 1.5.2.2) (Figure 212: 4439/06). The more the iron became recycled, the more flattened and banded appeared the inclusions. Thus, inclusions that displayed an angular to sub-angular shape indicated a material that was still close to the original bloom, in particular if the inclusions appeared in random distribution or in swarms (4476/06, 4483a/06, and 4485/06) (Figure 213: 4476/06 and 4483a/06). One artifact (4437/06) provided evidence that both new and recycled iron had been joined. Furthermore, laminas of inclusion bands indicated the piling and welding of small metal pieces in order to get a larger piece of raw material to produce a new object. In total eight samples provided indirect evidence for hot working because of their elongated impurities (4437/06, 4439/06, 4474/06, 4475/06, 4477/06, 4483b/06, 4484b/06, and 4486/06). Of them, the microstructures of the samples 4439/06, 4474/06, and 4477/06 attested that their starting materials were iron sheets which were folded and welded because they contained curved bands of corrosion and inclusions. The laminated inclusion bands of the samples 4474/06, 4477/06 and 4483b/06 indicated piling and recycling of small metal objects. However, the evidence for hot working from compositional banding was weak. As seen earlier, most objects showed variation in composition, yet none of the samples exhibited a pronounced banding of such inhomogeneities. Better proof of forging at elevated temperatures came from the decarburized zones along the outer margin of an object because it had been heated in an oxidizing environment in which the carbon reacted with the available oxygen (4439/06, 4475/06, 4477/06, 4483b/06, and 4486/06). As described earlier, four samples (4437/06, 4474/06, 4484b/06, and 4486/06) revealed that the items were forged at subcritical temperatures (warm-worked) because the pearlite transformed to ferrite and spheroidized cementite. However, the small number of analyzed samples and the inconsistent degree of spheroidization, which resulted in an inconsistent alteration of the properties of the steel (section 1.5.2.4), did not permit the conclusion that specific warm working was an integral part of the technological knowledge of the blacksmiths.

There was direct and indirect evidence of cold working. Four samples (4474/06, 4477/06, 4484b/06, and 4485/06) displayed deformed grain structures as a result of a physical treatment below temperatures at which iron crystals would recover. As summarized in section 1.5.2.1, the alterations of the properties of the iron and steel after cold working were not always desired. To bring back an undisturbed crystal microstructure, the deformed material needed to be heated to temperatures between 600 °C and Ac_1. Yet the final dimensions of recrystallized grains depended on numerous factors, which frequently resulted in a barely predictable microstructure of unequal ferrite grain-size distribution, in particular in traditional iron-working. Based on these considerations, and as mentioned earlier, the wide range of grain sizes found in the material indicated that six samples (4437/06, 4474/06, 4477/06, 4484b/06, 4485/06, and 4486/06) were annealed after cold working, and the four samples with grain deformation revealed in some parts of the cross section a beginning of or complete recrystallization.

Another way to obliterate microstructural alterations from the physical or thermal treatments of iron and steel was to heat the material to the austenite field (above Ac_3) and completely reestablish the microstructure (section 1.5.2.5). The newly formed normalized microstructure was uniform in grain size distribution and was found in the samples 4439/06, 4474/06, and 4476/06. Frequently, under uncontrolled traditional ironworking conditions, a Widmanstätten structure developed during rapid air cooling of small items, as could be seen in the samples 4474/06, 4475/06, 4476/06, 4483a/06, 4483b/06, and 4484b/06. However, sample 4474/06 exemplified that the material was normalized first, probably during recycling, then cold-worked (deformed Widmanstätten structure in Figure 212: 4474/06) and subsequently warm-worked. This resulted in some recrystallization of ferrite grains along the decarburized margin of the object, and the initial spheroidization of some cementite. Sample 4477/06 was also normalized before some minor grain deformation stimulated some parts of the microstructure to recrystallize at corresponding temperatures. Likewise, sample 4484b/06 exhibited a uniform normalized microstructure at its base, which had first been cold-worked (grain deformation) and was thereafter warm-worked for a short period of time, which allowed some fe rrite grains to recrystallize and some cementite to spheroidize. The three samples provided evidence that the blacksmiths did not always practice full intentional final normalization or recrystallization.

4.3.4. Iron prills and refining furnace running conditions

Fourteen samples of refining and secondary smithing slag revealed in polished cross section what is known as iron prills (4391/06, 4393/06, 4396/06, 4402/06, 4405/06, 4411/06, 4416/06, 4436/06, 4409/06, 4410/06, 4420/06, 4430/06, 4438/06, and 4722/06). Nine of them were etched to analyze the microstructure of them (Table 51, Appendix 3). Iron prills are small round iron inclusions that form under hot and reducing conditions within the slag bath during the refining process. They are indicators of the conditions in which the slag formed, and their presence already implies a strongly reducing and hot environment comparable to smelting operations. The analysis of the iron prills in the samples revealed that some had a similar (low) carbon content compared to the gromps found in the same specimens (4410/06, 4411/06, and 4420/06), or they could differ considerably from them (4396/06, 4405/06, 4436/06, and 4722/06). As seen in Figure 192, the refining slag samples showed elevated FeO readings, which usually helped to prevent the ferrite from carburization during the refining procedure. Whenever iron prills with an elevated carbon content occurred in these specimens, the atmosphere and the temperature needed to be continuously reducing and hot to produce such prills. The low carbon prills most probably formed under furnace running conditions with an effective wustite buffer in the slag bath, and the ferrite probably did not have enough time to absorb more carbon. Those prills, however, that show a significantly high carbon content had enough time, the appropriate temperatures in the austenite field, and a greatly reducing environment, to dissolve a high amount of carbon, despite the high wustite proportion present in the slag bath. The hypereutectic cast iron prill in sample 4722/06 (Table 51, Appendix 3) indicated temperatures of 1153 °C and higher, whereas the white cast iron prills of sample 4396/06 with approximately 3wt% C (Figure 209) attested furnace running temperatures above 1300 °C. These highly carburized iron prills were most probably kept much longer in the hearth than any of the iron and steel bloom fragments with which they were associated to in the samples. Overall, these results provided insight into refining technologies, which were very similar to the applied smelting solutions in terms of redox conditions and temperatures.

4.4. Reconstructing ironworking technologies

Section 4.3 has described in detail the quality of the iron produced in the bloomery smelters and the smithing techniques of the ancient blacksmiths. In the next section, I will present a synthesis of the archaeological and archaeometrical results in order to reconstruct the historical ironworking processes practiced in the middle Kavango region.

The evaluation of all the archaeological and archaeometrical data permits one to outline a picture of technological expertise and style over the past centuries. Slag material from eight sites was considered in this study but unfortunately the material at hand provided only a reduced information base because of inconsistent sampling procedures across the various field campaigns. Nevertheless, this section addresses iron fabrication traditions and technologies as far as they can be reconstructed from the material taken into consideration.

4.4.1. Ores and mining

The pronounced climatic fluctuations between dry and wet seasons provided numerous deposits of high quality secondary ores in the Kavango region, in particular in seasonally waterlogged riverbeds, interdune valleys and depressions (section 1.3.2.10). Moreover, thick pisolitic ferricretes that formed under past tropical climate conditions stretch across the area underground. As presented in section 4.1, preliminary chemical analyses of ore samples from the research area revealed that the ore deposits have differing chemical signatures. These chemical differences are likely to be detected by chemical analyses of the slag material. Nevertheless, the internal fluctuation of the chemical element distributions within the deposits has not yet been properly analyzed. An assessment of the most distinctive lithophile trace elements in section 4.1.6 revealed that the smelters of seven archaeological sites exploited seven different ore deposits. Furthermore, the chemical fingerprints of the slag could vary within a radius of 17 km or less. Traces of historical mining activities have only been detected in Kauti (SC 32) and Dikundu (SC 30). Both sites belong to the LIG occupation horizon, and at a rough estimate, the digging for ore did not exceed a depth of 50 cm below the surface, but even so, the original outlines of the extraction pits have been largely obliterated over the course of the past decades and centuries (section 2.30). Because of the geological setting it is assumed that no substantial sub-surface mining was necessary or even possible in the sandy regional soils. The microstructural examination of remains of unreacted ore in some slag samples from Vungu-Vungu and Dikundu in section 4.1.7 revealed textures similar to the Group I ores, indicating that the traditional smelters, at least those belonging to the Late Ironworking Groups, preferred near-surface plinthic ore deposits. Conversely, the entire sample set that was analyzed backed up the suggestion that the massive ferricretes were not attractive to the historical smelters, even though some smelting sites were associated with outcrops of the ferrous crust (sections 1.3.2.10, 2.16, and 2.17). Turning to the pre-treatment of the ore before it entered the furnace, only weak evidence exists, but the size and morphology of the ore fragments found in slag fragments from Dikundu and Vungu-Vungu together with some ore pieces found in the archaeological assemblages attested that they were crushed into lumps of less than 1 cm in diameter.

4.4.2. Smelting

Hardly any archaeological evidence for smelting furnaces has been found so far, even though abundant scatters of smelting slag residues were recorded. Only the shaft furnace from Dikundu (SC 30) was excavated (Figures 15h and 15i). The smelting area of Kapongo (SC 29) with its numerous eroded furnaces in termite mounds promises interesting results for future studies but has not yet been investigated. West of the Mbukushu area, there was a striking lack of slagged furnace lining debris from all smelting sites, and the only refractory material associated with smelting activities took the form of tuyere fragments and sand. Occasional evidence came from slag specimens that bore the shape of a furnace bottom or a furnace wall. Consequently a reconstruction of furnace types appeared rather difficult. However, the little evidence available nevertheless justifies the conclusion that people smelted in pits of unknown size in the ground. Most likely these pits were not lined with clay because all the smelting slag investigated was noticeably poor in aluminum. Some slag specimens contained attached sediments finer than the naturally occurring sand and may indicate furnace clay refractories. Yet it seems more plausible to consider these finds as the naturally occurring clayey component of the Kavango soils. Vungu-Vungu (SC 12) as well as Kapako (SC 4) and Ruuga (SC 3) produced some evidence for slag tapping (Figures 94 and 207) from the furnace into a slag pit and into a drain of unknown shape, yet reconstructing the overall appearance of these pit furnaces was not possible given the current state of research.

4.4.3. Reconstructing smelting processes

It was not possible to reconstruct the smelting system in full because important contributing substances, such as ores, refractories and a representative collection of furnace slag debris, were not available nor had they been investigated, but the evaluation of the slag illuminated some major aspects of the smelting systems performed by the Kavango smelters.

All the samples analyzed reinforced the conclusion that the Kavango smelters aimed at producing a fayalite-rich low-melting slag because the dominant ingredients, by far, of the slag specimens were iron oxides and silica. All smelting systems benefit from a certain input of refractory material to act as a fluxing agent, in particular from aluminum from the furnace walls (section 1.4.7), yet the aluminum proportion of the sample set was strikingly poor when compared to other smelting systems in general (e.g. Iles, 2010; Humphris, 2010). Figure 188 illustrates well that silica was the main fluxing agent and contributed significantly to the system. It supports the assumption that an extremely silica-rich furnace wall supplemented the smelt, and additional evidence came from some samples that exhibited erosive slag-forming processes from a sandy environment. Under these circumstances, a clayey furnace lining appeared to be unnecessary to improve a smelt. On this basis, I conclude that west of the Mbukushu area people smelted in pit furnaces without clay linings, because the natural siliceous sandy soil deposits of the region had a most favorable impact on the smelting system. It is likely, as the samples 4428/06 from Vungu-Vungu (SC 12) and 4720/06 from Kapako (SC 4) indicated, that the smelters deliberately added naturally occurring quartz-rich sand to promote the slag formation in the furnace (see section 1.4.1). However, the smelting slag examined also disclosed that a fayalite/leucite eutectic frequently solidified as final phase, so that the 'real' solidus temperatures might have been lower than one would infer from the phase diagrams of Figure 188. Some slag material from Ruuga produced elevated CaO readings, but they were inconsistent and thus could not support the idea that lime was added as a fluxing agent on purpose. A possible explanation would be that calcium entered the system from the wall of the smelting pit and that the readings reflected the calcareous soil of Ruuga (SC 3) (see section 2.3). Alternatively one could consider the fluctuating CaO proportions to be inherited from the ore, which has been observed in the Group I ores from Dikundu and Kapongo. The slightly elevated aluminum proportion seen in flow slag fragments in Table 44 (Appendix 3) most probably stemmed from eroded tuyeres, or it reflected the input of the sparse clayey component present in the sandy Kavango soils. All iron oxides in excess of those necessary for the fayalite formation were successfully reduced to elemental iron, but even so, the yield of iron was rather poor. Taking the ore samples recommended by local ironworkers as a reference, no more than approximately 12wt% of the available iron oxides were converted to metallic iron. This looks inefficient by modern standards, but was normal in bloomery smelting (section 1.4.1). There is a possibility that the smelters from Vungu-Vungu and Dikundu refilled the running furnaces with fuel and ore in order to increase the total yield of metal. Moreover, one can argue that the Kavango smelters used the chemical equilibrium that came into existence between the furnace atmosphere, the iron-rich slag bath, and the soluble carbon in the elemental iron to protect the iron from over-carburization (section 1.4.2), but it is not evident to what extent they were able to control the carburization process. The prevailing moderate carbon content below 0.2wt% found in the unmodified bloom fragments (Table 49, Appendix 3) corresponded to the high FeO proportions found in the smelting slag. Yet larger bloom fragments such as sample 4708/06 and 4709/06 exemplified clearly that the generated blooms were very heterogeneous and contained material ranging from soft pure iron to hard high-carbon steel. This certainly required special skills and knowledge on the part of the ironworkers, because they subsequently had to master the sorting and homogenizing of blooms that behaved most challenging in the forge. An even greater variance of iron and steel was evident in the lost or discarded iron gromps found in the refining slag fragments, some of which were certainly too carbonaceous to be processed (C > 1wt%). In addition, bloomery smelting always carried with it the danger that alloying elements other than carbon would go into solution with the iron metal, changing the properties of the material in an unwanted way (section 1.4.9). It is believed that phosphorus and phosphide/nitride inclusions frequently found in bloomery iron was not always wanted and that the historical smelters were at the mercy of the unpredictability of their bloomery products (see section 4.3.1, samples 4395/06 and 4440/06). Nevertheless, some scholars argue that the contribution of alloying elements other than carbon was fostered and intended (e.g. Iles, 2010, p. 162; Schmidt & Childs, 1995). The challenge in bloomery smelting was certainly to control the furnace-running conditions in such a way as to generate a homogeneous product of predictable quality. Two bloom samples (4426/06 and 4440/06) (Figures 123 and 209) attested that there was always a risk of the smelt getting out of control and cast iron being formed, which was useless to ironworkers without the knowledge of how to decarburize hypereutectoid steel and cast iron. All in all, the large amount of refining slag residues of all stages of cleaning, and the numerous gromps that have been found at the sites investigated so far, indicated that the final outcome after a smelt was a dirty bloom full of slag, fuel remains and semi-reacted ore.

4.4.4. Reconstructing refining processes

Almost every site that yielded slag remains bore evidence of bloom refining activities. Unfortunately, no tools related to the refining activities have been found. Consequently, this study relied on the slag finds themselves and a few archaeological remains to reconstruct the working processes of primary smithing. First of all, the shattered furnace slag fragments and the numerous pieces of poorly consolidated bloom that were recovered reinforced the picture that the initial step in refinement was to crush the bloom in a cold state, and to chip away those parts that the ironworkers considered not valuable enough for further treatment. Some bloom fragments were associated with slag in a glassy state, which indicated fast cooling outside of a furnace. Because of this, it is likely that these specimens were chipped off or became lost during the first step of heating and hammering while the bloom was still full of slag and fuel remains (section 1.5.1 and 1.6.2.2).

Refining facilities were as elusive as smelting furnaces in the research area. The best evidence was the eroded furnace from Dikundu (SC 30, N69/03), in which a block of refining slag was found in situ. This association indicated that a smelting furnace also served as a refining facility, probably after parts of the shaft had collapsed. Weak evidence came from Vungu-Vungu (SC 12) where a pit and a round clay feature were associated with abundant refining slag debris. However, the function of these features could not be positively linked to any refining or even smelting activities. From the morphology of the smithing hearth bottoms, one could infer that except for the evidence from Dikundu the refining facilities were pits with a shallow concave or convex bottom. Like smelting furnaces, these pits were filled with charcoal and there was reason to assume that the blooms or pieces of the bloom were placed in the middle of the charcoal bed and probably covered with fuel. The ethnographic and experimental evidence compiled in section 1.5.1.1 suggested that blooms were scarcely heated longer than 40 minutes, and sometimes only 15 minutes, which was considered long enough to bring the slag enclosed in a bloom fragment to liquidus temperatures. The large quantity of layered refining slag of all steps of the bloom cleaning process reinforces my view that refining in this region was a multi-step process of alternating heating and consolidation and the whole procedure lasted for several hours. By contrast, the in situ refining slag block from Dikundu (SC 30) supported the interpretation that a different refining technology was applied, because the microstructure and phase composition of sample 4438/06 implied that the bloom was consolidated through sintering in a furnace for a period of probably several hours. The finds from nearby

Likundu (section 2.30.3) illustrated how varied technological style or practice could be in a radius of just a few kilometers, and much more research is needed to shed light on the technological variations practiced by the ancestors of the Mbukushu people (see section 5.3.3.5). The historical Kavango ironworkers preferred a strongly reducing environment in their refining hearths. The phase composition of the slag samples attested that the temperatures and redox conditions were comparable to iron smelting, and frequently iron oxides became reduced to elemental iron even during refining. As mentioned above (section 4.3.4), some furnaces operated in a way that allowed cast iron to form.

Within the sample set, the overall chemical composition of the refining slag shifted towards higher iron oxide readings compared to smelting slag samples, and some samples even overlapped with the analyzed ores. It is most likely that the ironworkers deliberately kept the slag bath at the bottom of the furnace in the low-melting field between fayalite and the fayalite/wustite eutectic with high iron oxide proportions in the binary FeO-SiO_2 system of Figure 192. The microscopic microstructure analyses of these slag samples also disclosed that eutectic compositions in general played a dominant role in the formation of refining slag (Table 43, Appendix 3), and since leucite is again involved in some eutectic compositions, liquidus temperatures may have been lower than one would infer solely from the phase diagrams of Figure 189. The multiple layers and changing main phase successions found in these samples mirrored well the processing cycles of primary smithing, and many cycles of heating were needed to create a clean ingot. Initial refining slag showed comparably thick slag layers with uniform phase successions in each case, but with increasing compactness of the bloom, the slag layers became thinner. Eventually, in final refining slag samples frequently only small zones (instead of layers) of a specific composition remained and each cycle of heating and hammering created a micro-event with changing slag chemistry, liquidus temperatures, and redox conditions. The alumina-to-silica ratio decreased with every step of bloom consolidation. Finds of quartz sand in varying stages of alteration indicated that the siliceous natural sand was the only flux that the ironworkers used in the course of the welding and compacting processes, and to maintain the fluidity of the slag bath. Eroded tuyeres or clayey additives played no detectable role in the refining technologies of the Kavango region. Bulk chemistry of the slag specimens from Ruuga (SC 3), Vungu-Vungu (SC 12) and Kapako (SC 4) exemplified how little compositional variation there was across the sample sets with respect to the stage of processing. Within the framework of this study, it is therefore justified to also consider the chemical signature of refining slag samples as representative of the original batch (section 4.2.8). When the process of consolidation was completed, the charcoal bed with its slag remains was probably left exposed and cooled down, because all refining slag fragments developed pronounced cooling skins at their upper faces. It is likely that large slag blocks were removed from the furnace pits before the ironworkers continued with their work but small amounts of slag that had been accumulating at the bottom of the furnaces frequently remained in the pit until the furnace was again activated. This was exemplified in the numerous cooling skins that became buried under new slag layers, in particular during the more advanced steps of refining. Also, among the final refining slag specimens, some evidence could be found that the furnaces were not always running at a strongly reducing regime, since some samples revealed mineral phase successions that need a higher level of oxygen to form (section 4.2.5).

4.4.5. Reconstructing metalworking

Forty-nine iron objects of indigenous production were recovered during the archaeological field seasons. These items were mainly small implements and ornaments. In addition, 22 copper ornaments from a trusted archaeological context have been found, which must have been imported from other places because copper ores do not occur in the middle Kavango region. However, some elevated copper readings in slag samples (4390/06, 4393/06, and 4434/06) could stem from copper smithing, and it is likely that the blacksmiths repaired or recycled some copper artifacts.

Metallographic examination has been performed on iron artifacts from the EIG and LIG occupation horizon. As mentioned previously, the raw material that the Kavango smelters generated in their furnaces was very heterogeneous in composition and hardness, ranging from soft pure iron to cast iron unsuitable for processing. Such heterogeneous material was the typical product of bloomery smelting. It was all the more interesting to observe that the ironworkers were selective with respect to the quality of the material for their ornaments and tools. Although the number of analyzed samples was small, there was a trend towards the use of medium-to-high-carbon steel, though carbon content did not exceed 0.8 wt%. Many artifacts still revealed an inherited compositional variance. It was not clear from the material analyzed whether the historical ironworkers practiced carburizing or decarburizing techniques, but the high proportion of pure iron and mild steel found in the blooms and the refining slag samples was not reflected in the iron objects. The same applied to hypereutectoid steel, which was certainly difficult to process, but it remained uncertain whether the latter had been discarded or not. Perhaps future research into ironworking traditions in this area will lead to a better comprehension of these aspects. The raw material was consolidated in refining furnaces capable of producing temperatures above 1200 °C, and the phase compositions of secondary smithing slag implied that temperatures at around the same level were reached in the forge as well. The average of the secondary smithing slag samples revealed a higher aluminum proportion than the final refining slag, and it seems possible that clay-lined smithies or clayey fluxes were used. However, due to the small number of samples caution must be applied as to their interpretation. All objects were hot-worked, and the degree of forging and recycling was indicated by the flattening of the inherited inclusions alongside with the banding of the inherited compositional variations. Based on these indicators, it is assumed that several objects were fabricated from a piece of compacted bloom, whereas other objects were made from extensively recycled material. A few artifacts exhibited signs of decarburization along the outer margins, which was also indirect evidence for hot working. Some artifacts disclosed features implying that they were warm-worked or briefly annealed after cold working at subcritical temperatures, which softened the steel and increased the workability and formability of the material. Yet there was not enough evidence to consider warm working a deliberately induced treatment. Evidence for cold working was very limited owing to the annealing to which the artifacts were exposed afterwards, and which restored the damaged crystal structures. A number of these objects were heated to temperatures in the austenite field so that all traces of cold or warm working were completely obliterated. Small items cooled down fast at air temperatures and because of this the material developed in some cases a certain brittleness and hardness (Widmanstätten structure). However, the objects examined revealed no evidence of quenching.

Iron must have been valuable because the historical blacksmiths recycled even the smallest pieces of it. A number of artifacts attested that they were produced from folded and welded fragments of sheet metal, which were joined to form a larger piece of raw material. The historical blacksmiths accomplished most welds thoroughly, yet some joints developed into weak points of the objects because corrosion entered the material along the weld seams. The raw material was hammered into small bars, rods or sheets of metal, which served as the primary material for the ornaments and implements. The basic forms were then hot-worked into shape, or alternatively they were most probably cut and bent into the desired shape in a cold state. Most chain remains were made out of links of thin bent metal sheets. Chain fragment sample 4475/06 was exceptional because it was made from a drawn wire, but this single piece is not enough evidence to claim that the wire was produced locally in the middle Kavango region.

4.4.6. Diachronic aspects

It is barely possible to draw conclusions with regard to diachronic aspects from the investigated sites because the material that has been used for this study was insufficient for contrasting the iron smelting and fabrication techniques of the Early Ironworking Groups against those of the Late Ironworking Groups. Nevertheless, this study aims to lay the foundations on which future research can be built. There is some evidence that the EIG smelters at Ruuga (SC 3) produced iron and steel that was more homogeneous than what was fabricated later and the first drawn wire appeared in the assemblage. As for the technology of the Late Ironworking Groups, two differing engineering solutions for smelting and refining became apparent. In the western part of the research area, a pit-furnace technological tradition dominated the picture, whereas in the eastern part a shaft-furnace tradition with variable refining technologies became visible. However, there are not yet enough sites known to profoundly contrast early and late technologies and traditions, and to compare eastern and western styles.

5. Iron metallurgy in historical sources of the Kavango region

The interest in historical aspects of ironworking traditions along the middle Kavango arose in the course of our geological and archaeological survey in 2006, during which I followed the recommendations of locals in order to identify potential indigenous mining sites, and to assess the ore resources of the region. The survey revealed that there existed a shared knowledge about historical mining and smelting, which has so far scarcely been documented in either ethnographic studies or historical accounts for whatever reason (section 5.2.1). The following oral history interviews revealed that iron production stopped when the first missions were established along the river in the 1930s, and when itinerant workers brought back industrial iron from their stays in South African or South West African mines. Surprisingly, the people of southern Angola practiced iron production up to the middle of the twentieth century because scrap metal was scarce in these remote parts of the country. The constant migration of Angolan citizens to northern Namibia in the nineteenth and twentieth century means that many modern-day blacksmiths in Namibia have a Nyemba or Chokwe family background from Angola (Kose, 2009a, p. 141). These blacksmiths provided an inexhaustible source of information, from which my time frame only allowed me to investigate superficially the rich ironworking traditions north of the Kavango River.

5.1. Historical and ethnic context of the Kavango peoples

Before proceeding with the results of my oral history study, it will be necessary to provide a short introduction into the history of the Kavango peoples, and an evaluation of written historical and anthropological sources, which will complement this study. This section shortly describes the ethnic situation of the modern-day Kavango peoples and their historical background during roughly the past 250 years. This is of much relevance for the study because the archaeological sites assigned to the Late Ironworking Groups overlap with the time depth of local oral chronicles, oral history and early European travelers' accounts.

Research on the history and ethnography of the Kavango peoples has long been neglected. Most information came from early European travelers, missionaries, colonial servants and South African ethnographers (section 5.2.1). Among them, only one study was made by a researcher of local origin about the Kwangali people (Kampungu, 1966). The first systematic and comprehensive study that included all available historical and ethnographic data from the middle Kavango region was published by Gibson, Larson and McGurk in 1981, and it became a reference book of Kavango history and ethnography. It took more than 25 years before the next systematic compilation was published with Pröpper's commented bibliography on ethnographic research literature from the Kavango region (Pröpper, 2007). In recent years, particularly after Namibian independence, the number of cultural and historical studies increased and the area attracted attention from scholars of local origin (e.g. Akuupa, 2015; Likuwa, 2012; Mbambo, 2002; Shiremo, 2010) and researchers from abroad (e.g. Eckl, 2004; Fleisch & Möhlig, 2002; McKittrick, 2008; Seifert, 2007).

It is a widely held view that the Kavango area is inhabited by five Bantu-speaking ethnic groups: the Kwangali, Mbunza, Shambyu, Gciriku and Mbukushu (Figure 215). Local chronicles of their royal clans hand down that the modern-day Kavango peoples moved to this area from the seventeenth century onwards. They originated from the Mashi region, which denominates one part of the Kwando River in western Zambia and the Caprivi (Fleisch & Möhlig, 2002; Fisch, 2005). However, a deeper look into history disclose a complex and multilayered history of clans, families, and groups of hunters of various backgrounds, who migrated into the middle Kavango region, mixed with San people and amalgamated into what is known the Kavango peoples of today (McKittrick, 2008). In his recent study, Akuupa (2015, pp. 55-57) emphasized that the common concept of the five Kavango groups is strongly biased. He discussed in detail how ethnic groups belonging historically to the Kavango peoples and living along the Kavango River became excluded in the colonial discourse, and were later on not recognized as people belonging to the riverine environment by the colonial administration of South West Africa.

During the colonial ethnographic discourse, anthropologists created a concept of 'real locals' (i.e. the five Kavango peoples) versus 'immigrants' from Portuguese West Africa in disfavor of a Nyemba population, which has been contributing to the region's history in the same way as the 'real' Kavango peoples did. What is more, anthropologists and administrators of the Kavango Homeland defined territories in which the 'real' locals lived thus denying the existence of other ethnic groups living in these territories. This ethnic picture was contrasted against a diffuse concept of a Bushmanland north and south of the river, associated with various groups of San people, and depleted of Bantu-speakers. However, while San peoples were acknowledged to be part of the South West African ethnic groups, the Nyemba as well as the Chokwe and the Luchazi were denied any contribution to early Namibian history and remained intruders from central Angola (see also Gordon, 1992, p. 126). Although focused on a very restricted topic, the following oral history study about ironworking traditions in northern Namibia and southern Angola revealed the shared history of all ethnic groups frequenting the middle Kavango region, and unintentionally challenged the static and biased picture of ethnicity and history, which still can be found in most modern-day scholarly and popular publications.

In the following sections of the oral history study, I describe the local metallurgical traditions according to the political division made by the indigenous population, i.e. in accordance with the historical Kavango polities including the Nyemba and the scant information available about San metalwork. I do not, however, describe the Chokwe ironworking traditions, even though Chokwe ironworkers were present among the Kavango peoples in the late nineteenth and early twentieth century.

5.1.1. The origins of the Kavango peoples

The purpose of this section is to provide a short introduction to the complex origin of the Kavango peoples, which is necessary to understand the oral history part of this study. The ethnic genesis of the population is also of relevance when discussing the archaeological evidence against the data revealed through oral history and ethnography.

Each Bantu-speaking ethnic group living along the middle Kavango posses oral chronicles describing the migration of their royal clans to the Kavango area. Most chronicles refer to the Mashi as their country of origin, which is a region along the southern Kwando River in modern-day Zambia, Namibia (Caprivi) and Botswana (Figure 215). These chronicles are backed up by linguistic studies indicating a close relationship of the Kavango languages with those spoken in western Zambia by peoples living between the Zambezi and the Kwando rivers (Maho, 2009, p. 65).[100] Furthermore, genetic analyses placed the Kavango people with ethnic groups living in the northern precincts of the Okavango Delta, namely the Luyana, Subiya and Mashi (Nurse & Jenkins, 1975, p. 57). In local memories, however, aside from official chronicles of the royal clans, conflicting versions exist about from where the Kavango peoples truly came. While one version of Kwangali chronicles claims that the founding sisters of the Kwangali migrated from the Mashi to their present-day territory (Fleisch & Möhlig, 2002, pp. 237, 275), other competing chronicles see them as descendants of the Handa groups in southwest Angola (Fleisch & Möhlig, 2002, pp. 179-180; see also Kampungu, 1965, pp. 38-39). A third version of narratives claims that Kwangali and the Ovambo groups have common roots (Akuupa, 2015, p. 66; Fleisch & Möhlig, 2002, p. 300). This contradicts the linguistic situation, but cultural contact is not restricted to language and strong cultural links to the peoples living west of the Kwangali developed during several historical events and in particular owing to frequent intermarriages (Akuupa, 2015, p. 58; Kampungu, 1965, pp. 37-38). East of the Kwangali, the Mbunza polity developed (Figure 215). Local chronicles also state that Kwangali and Mbunza have common roots and share a common founding mother, but as could be seen among the Kwangali, it is not clear whether the Mbunza really originated from the Mashi region to the east, or whether they are descendants from peoples living west of them (Gibson et al., 1981, pp. 83-84; Fleisch & Möhlig, 2002, pp. 181, 289-290). Linguistically, modern-day Mbunza people speak Rukwangali, which connects them to their western Kwangali neighbors, though some scholars stated that the original Mbunza language was closer to Rumanyo, the language

[100] Maho (2009, p. 65) classified the Kavango languages in his K30 Luyana Group together with fourteen small languages in western Zambia. At this point I do not follow Vansina's suggestion that the Kavango languages are most closely related to Umbundu in central west Angola (Vansina, 2004, p. 184). Vansina's perspective has been discussed against the new research results from African studies and archaeology in Seidel et al. (2007).

spoken by the people living in the Shambyu and Gciriku polities east of the Mbunza territory (Kampungu, 1965, p. 40). This picture is confusing, and the entire process that eventually resulted in the pre-colonial Mbunza polity was most probably a complex and multi-layered historical development of several hundred years. Traces of this process can still be found in oral chronicles, such as those told by the Mbunza elders of the Vakwanyatji (Buffalo) Clan who claim that they lived in the area prior to the arrival of the ruling Vakwasipika (Hyena) Clan (McKittrick, 2008, p. 793). Furthermore, as will be discussed in the following section, oral traditions also contend that the Tjaube people, who are the forefathers of the Vakwandjadi (Falcon/Rain) Clan, also settled in the Mbunza area earlier than the Vakwasipika (Hyena) Clan, which again underlines the heterogeneous origin of what is today called the Mbunza people.

East of the Mbunza polity, the Shambyu and Gciriku established their kingdoms. Both groups are remembered to have been one people in the Mashi region in both the early days and in the course of their shift to the Kavango River.[101] It is believed that they migrated to the Kavango area in the late eighteenth and nineteenth centuries from southern Angola and established new feudal states along the river (Fleisch & Möhlig, 2002, p. 134; Kose, 2012, pp. 211-212; Mbambo, 2002, pp. 46-52; Seidel et al., 2007, pp. 154-155). The Shambyu settled east of Rundu and the Gciriku west of Nyangana (Figure 215). This narrative of settlement history, however, contrasts with the archaeological evidence which dates the arrival of the Kavango peoples back to the sixteenth century (Kose, 2009a). As Shiremo (2010, pp. 38-43) pointed out, the oral chronicles found in the Kavango region are oral traditions of individual family clans rather than chronicles representing the history of the entire population. Each clan has its own oral tradition, i.e. its own history of migration, but only the chronicles of the ruling clans became official. The bias in local representations of history can be best exemplified in the oral chronicles handed down by Shambyu and Gciriku. Today, both polities are governed by descendants of the Vakafuma (Frog) Clan, who provide the official version of chronicles describing the origin of the peoples from the Mashi. The members of the Vakwandjadi (Falcon/Rain) Clan, however, trace their origins in the maternal line back to an ethnic group remembered as the Tjaube people (e.g. Fleisch & Möhlig, 2002; Hartmann, 1987). The Tjaube considered themselves Bushmen (though not San) and migrated to the river from the south-east decades or even centuries earlier than the Vakafuma (Frog) Clan.[102] The oral history study with ironworking descendants of the Vakwandjadi (Falcon/Rain) Clan that will be presented in the following sections revealed that the Tjaube people possessed a profound knowledge about the natural resources found in the region south of the Kavango River (Figure 215). This region is much drier than the Kavango valley and people depended on the water resources found in the palaeo-riverbeds, such as the Omatako and Fontein Omiramba. However, the detailed knowledge about natural resources from their oral chronicles, and found in the oral history interviews (Fleisch & Möhlig, 2002; Hartmann, 1987), indicated that the Tjaube stayed in this region for several generations. It seems likely that they were culturally associated with the Bantu-speaking Yeyi people living in and around the Okavango Delta, and who frequented the region as far south as Karakuvisa in the nineteenth century (Shiremo, 2010, p. 40). Fleisch and Möhlig (2002, p. 33), on the other hand, placed them in the context of Khoe-speakers from the same area in modern-day southern Zambia and northwestern Botswana. As will be further discussed in section 5.3.2.3, the Tjaube people were conquered by the new Shambyu rulers who came in search of new hunting grounds. Yet their ironworking and hunting skills, together with the spiritual control over the country, proved to be indispensable for the new rulers. As a consequence, the latter bound the descendants of the Tjaube peopleto the royal court in order to stabilize their leadership (McKittrick, 2008, p. 792; Kose, 2012, p. 214).[103] Besides the chronicles of the Vakwandjadi (Falcon/Rain) Clan, other families hand down that they came for various reasons such as intra-family or societal conflicts and Shiremo (2010, p. 39) suggested that they too arrived earlier than the ruling Vakafuma (Frog) Clan. Some accounts describe a split between generations in royal lineages, when young clan members were no longer willing to accept the old rulers once they arrived in the new country (Akuupa, 2015, p. 64). The complex migration

[101] Köhler (1989, p. 334) described a version of oral chronicles in which the Shambyu migrated along with the Mbukushu.

[102] A discussion about the time depth of the chronicles against the background of recent archaeological evidence is provided in Kose (2009a) and section 2.12.20.

[103] The migration history of the Manyo people, their separation into two groups, and the amalgamation process of the Tjaube people has been extensively discussed in Fleisch and Möhlig (2002, pp. 29-37), Akuupa (2015, pp. 62-64), McKittrick (2008), and Kose (2009a, pp. 144-146).

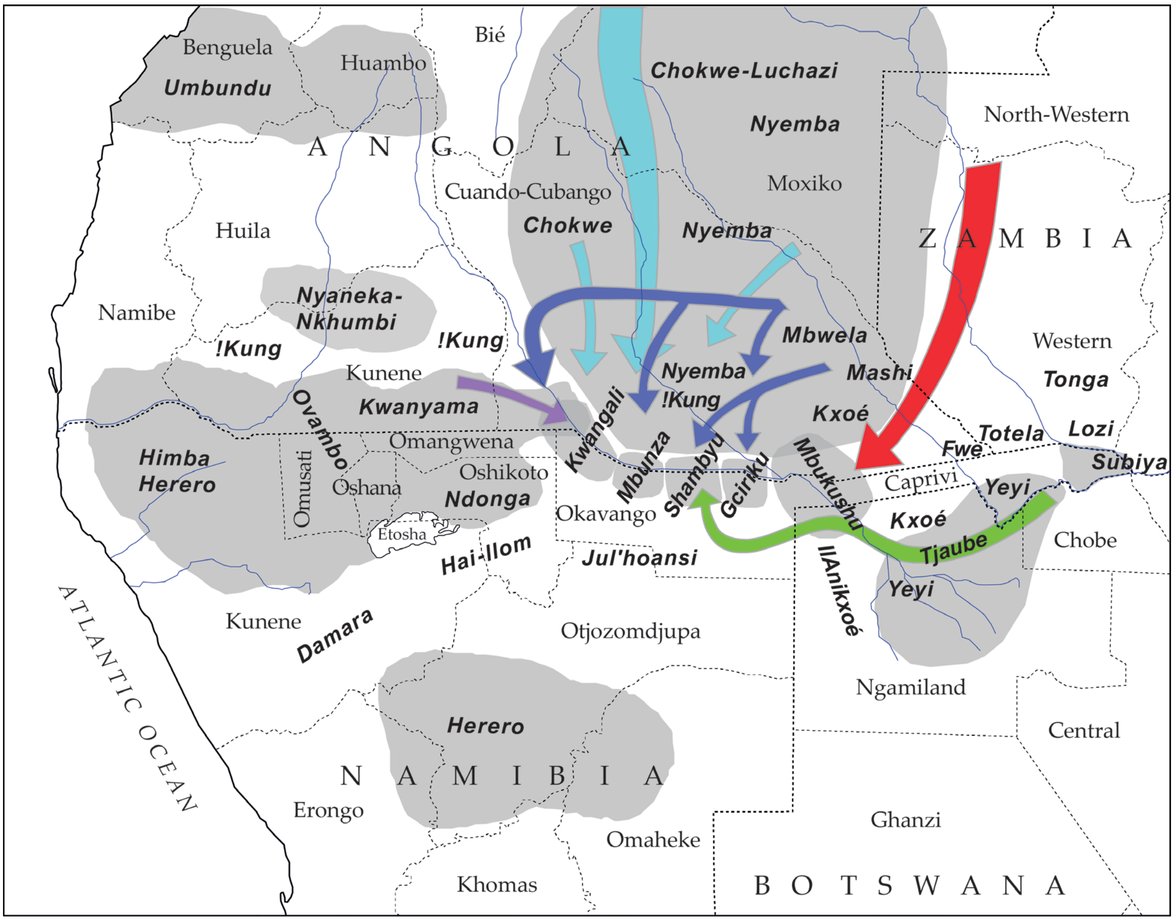


Figure 215: Migration history of the Kavango peoples.

history handed down in the Kavango chronicles caused some writers to propose that the Kavango peoples were refugees from well-established polities in western Zambia or central Angola, who brought along their own cultural identities and set up new kingdoms (McKittrick, 2008, p. 788; Vansina, 2004, pp. 183-186). However, most chronicles describe that the first arrivals were elephant hunters or at least hunters exploring the Kavango area, and thus the motor of the movement of people seemed not so much the escape from something but rather the opening of new hunting grounds and a movement towards new options and wealth. As will be discussed in section 5.4, ivory trade for the European market caused major shifts of population and power all across Africa (Von Oppen, 1993, pp. 62-77) and opened immense new options for people excluded from political power in the periphery of well-established polities (Likuwa, 2012, pp. 27-32; Möhlig, 2007; Seifert, 2009, p. 279).

East of Shambyu and Gciriku, the Mbukushu kingdom formed (Figure 215). Nowadays, the Mbukushu live in Namibia as well as Botswana, Zambia and Angola (Maho, 2009, p. 65). Similar to the other Kavango peoples, the Mbukushu trace their origins back to the Mashi region to a place called Musuma at the confluence of the Kabompo and Zambezi rivers (Van Tonder, 1966, p. 37). Likewise, their migration to the Kavango formed a complex multilayered historical period, accelerated by multiple political and economical circumstances during the past 250 to 300 years, in which elephant hunting was only one aspect of their shift to other regions (Larson, 2002, pp. 50-60; Fisch, 2005). Once established along the river, the Mbukushu rulers became famous rainmakers and were highly respected and feared among their neighbors, but the power to control the water supply of the country misled some sovereigns to exploit their own people and more distant polities, who paid tributes to the Mbukushu sovereigns (e.g. Larson, 2002, pp. 315, 338-343; Salokoski, 2006, p. 225).

Attempts have been made to stratify the royal genealogies and to evaluate the time depth of the oral chronicles handed down along the middle Kavango (e.g. Fleisch & Möhlig, 2002). McKittrick (2008, p. 789) gave the apt description that the oral traditions are straightened narratives of a long multilayered historical process. An attempt to synchronize the existing oral traditions and recent archaeological research disclosed that the reoccupation of the middle Kavango area started at least some 500 years ago, whereas suggestions based on oral traditions only reach a time depth of roughly 250 years (section 2.12.20; Kose, 2009a). This discrepancy is not surprising considering the approaches that tried to analyze how memory organizes temporal sequences and reschedules events (Vansina, 1985, pp. 176-178). It is one of the main advantages of the present multidisciplinary study that data from both fields are available.

Turning to the Nyemba people living north of the five Kavango polities described above, few written sources can be found as to their existence in the southernmost parts of Angola. Serpa Pinto (1881, p. 117) visited the upper reaches of the Kavango, Kwito, Kwatato and Kucha rivers in central Angola in the nineteenth century and mentioned a vast territory of several groups belonging to the Nyemba people. De Almeida (1912, pp. 73-78) described them as various groups living between the Bihé plateau and the Zambezi along the various river courses and roughly as far south as modern-day Katwitwi in Namibia. These groups appear in the literature as Nyemba, Nhemba, Ganguella, Ngangela, Mbwela or Ambuella. For the sake of convenience, I refer to them as Nyemba because the interview participants referred to themselves as Nyemba.[104] The geographical area inhabited by Nyemba groups stretched across the Angolan provinces Bihé, Moxico and Cuando-Cubango (Figure 215). Serpa Pinto (1881, p. 117) observed that all Nyemba groups shared a common language and similar customs. The political system, however, seemed to vary according to the individual groups. Some polities were described as centralized kingdoms whereas other polities were portrayed as associated confederations of independent communities (De Almeida, 1912, pp. 73-77). Today, Nyemba speakers cover most of south central and southeastern Angola attesting the large area the Nyemba speaking people inhabit (Maho, 2009, p. 63).[105] Linguistically, Nyemba is related to other languages stretching north-south in eastern Angola and along the western fringes of the DR Congo. No published material was available to me about the origin of the Nyemba people. Only A. M. Makayi[106] stated in his interview that their country of origin was Tshitauwe, a region found along a tributary of the Kwito River. As mentioned earlier, and as will be described in the following sections, the Nyemba and Kavango polities have strong historical ties (Köhler, 1989, p. 334; Likuwa, 2012, p. 33; Shiremo, 2010, pp. 72-73), and it has been suggested that Nyemba groups were present along the middle Kavango as early as the other clans and groups described above (Akuupa, 2015, p. 56; Mbambo, 2002, p. 34). The time depth of their historical interconnection also became apparent in certain oral traditions of the Kavango peoples, which hand down that the descendants of the Vakangombe (Cattle) Clan see their origins among the Nyemba people (Shiremo, 2010, p. 42), and that Kwangali and Nyemba have the same founding mother (Fleisch & Möhlig, 2002. p. 299).

The middle Kavango was always frequented by San[107] peoples, who are considered the earliest inhabitants of the Kavango area (Akuupa, 2015, p. 56; Jacobson, 1987, pp. 151-152; Köhler, 1989, pp. 179-181, 204; Larson, 2002, pp. 15-16). San people do not occur in the oral traditions of the ruling Bantu-speaking clans, which claim that the territory was found empty of people, denying the San people the status of being the first owners of the Kavango region (McKittrick, 2008, p. 794). It has been argued that among many African cultures the first owners of a country keep a strong spiritual position in society even after they have been conquered by another people (Kopytoff, 1987, pp. 57-58). Akuupa (2015, p. 62) suggested that this lack of representation in local oral traditions of the Bantu-speakers is owing to the fact that San people only passed through the area but did not set up permanent settlement camps. On the other hand, Shiremo (2010, pp. 77-78) stated it was shared knowledge among the Gciriku that San people have lived along the river since the arrival of the first Bantu-speaking groups. This supports Köhler's testimony of the long history of San people living along the river, which is also handed down in the oral traditions of the Mbukushu people (Köhler, 1989, pp. 332-333). Moreover, there was an awareness among the Khoe of Dikundu that the region around Nyangana was originally the territory of the Bush-!Kung (Köhler, 1989, p. 349). The presence of San groups is also undeniable from place names found in the Kavango region. What is more,

[104] Some scholars also suggested that the Mbunda of east Angola and west Zambia should be considered as part of the Nyemba people because of their close linguistic relatedness (Baumann, 1975, p. 545; Köhler, 1989, p. 372).

[105] Maho (2009, p. 63) classifies Nyemba to his K10 Ciokwe-Luchazi Group

[106] Interview with Alberto Munoma Makayi, Appendix 2.8.

[107] Within this study, ‚San' is used to generally describe the speakers of a Khoisan language.

Rumanyo in particular, the language spoken by the Shambyu and Gciriku, shows a strong linguistic influence from Khoisan languages in semantic fields of riverine subsistence economy (Köhler, 1989, p. 188; Möhlig, 2007; Seidel et al., 2007, p. 153). The loan words associated with fishing activities do not originate from any of the modern Khoisan languages spoken around the Kavango River. Köhler (1989, p. 329) proposed them to have originated from the Khoisan languages of the Mashi region, whereas Möhlig (2007, p. 140) explained them as a linguistic heritage of the Tjaube people (see above). Vansina (1985, p. 102-103) argued that politically motivated biases were frequently found in oral traditions owing to their function of justifying a new ruling system or to claim land rights. Such distortion can be seen in the oral traditions of the Mbukushu, which describe how the rainmaking charm was found by a Mbukushu hunter in a springhare warren in the bush (Larson, 2002, p. 317). The same account was told by the Khoe people living in the same area, who say that this powerful charm was stolen from them by Mbukushu men (Köhler, 1989, pp. 390-391). Kopytoff (1987, p. 54) suggested that in regions with several groups of first-comers the history was frequently shortened to a specific point at the beginning of the history. In their own chronicles of the Tjaube people, the members of the Vakwandjadi (Falcon/Rain) Clan claim this zero point in the occupation history of the Kavango for themselves (Fleisch & Möhlig, 2002, pp. 51-52). However, officially they are denied the first-comer's status in the ruling clans' traditions, but they still held a special role in the ancestral evocation and in rainmaking ceremonies among the Bantu-speaking Kavango groups (section 5.3.7.3). This is though denied to the San people from this area. The far-reaching historical relationship between Bantu and San also becomes apparent in the oral traditions of the Vakayovhu (Elephant) Clan, whose members claim to be of San (Khoe) descent from the Mashi region (Shiremo, 2010, p. 39). San and Bantu frequently intermarried (Akuupa, 2015, p. 64; Köhler, 1989, p. 396; Shiremo, 2010, p. 60; Van Tonder, 1965, p. 45) because both lived in close exchange relationships, and San people assisted their Bantu neighbors in time-intense tasks, such as the harvest, or worked as professional hunters for the Kavango sovereigns (Gordon, 1992, pp. 125-126). The same close relationship existed between San groups, the southern Nyemba, and other Bantu-speaking groups of southern Angola (e.g. Biesele, 2002, p. 60; De Almeida, 1912, pp. 74-75; Estermann, 1977, pp. 12-13; Köhler, 1989, p. 427).

5.1.2. Settlement pattern

In 1886, the middle Kavango River was declared the political boundary between Portuguese Angola and German South West Africa. However, the Kavango peoples never perceived the river as a boundary and settled on both sides depending on the political or economic circumstances. As mentioned above, the territories as defined today are constructs of the colonial administration of South West Africa. In pre-colonial and early colonial times, the Kavango clans lived in Angola, sharing the territory with Nyemba, Mbunda and other groups (Likuwa, 2012, p. 33). What is more, people preferred the northern bank of the river because it was considered more fertile than the southern side (McKittrick, 2008, p. 799). From the nineteenth century and the turn of the twentieth century, Anderson (1863, p. 128) and Jodtka (1902, p. 546) reported the main settlements to be situated along the northern bank of the river, whereas the southern riparian countryside was used for agriculture. According to Eckl (2007, p. 20), people did not move progressively to the south side of the Kavango before the Portuguese started to fortify the border along the river at the beginning of the twentieth century (see De Almeida, 1912). However, settlement sites such as Rundu Immigration Office (SC 27), Vungu-Vungu (SC 12), Gove-Mbambangandu (SC 17), Nyangana-Kangwenu (SC 27), and the late horizon of Kapako (SC 4) pre-date the nineteenth century and provide evidence that both sides of the river were inhabited during the Late Iron-working Groups occupation horizon. At the beginning of the German colonial era, each polity was estimated to comprise roughly 1500 inhabitants (McKittrick, 2008, p. 798).[108] The Shambyu kingdom stretched approximately 48 km along the Kavango (Couceiro, 1982 as cited after Gibson et al., 1981, p. 100) and the territories of the Kavango polities did not seem to extend 25 km south of the river (Eckl, 2007, p. 25). The riverbanks were densely populated because, as Seiner (1909, p. 101) stated, in the early nineteenth century villages comprising fifty to sixty individuals were within earshot from each other.

[108] Fleisch & Möhlig (2002, p. 26) estimate that one polity comprised only 500 to 800 individuals.

5.1.3. Social organization

The societal system of all of the Bantu-speaking populations along the middle Kavango is matrilineal, which means that children belong to the mother's clan. The mother's brother acts as the social father and can make far-reaching decisions concerning the life of his sisters' offspring. As previously mentioned when illuminating the origins of the Kavango peoples, there exist twelve clans among the five 'Namibian' Kavango peoples, nine of them transcending the entire population because people were encouraged to marry outside of their clans (Shiremo, 2010, pp. 30-32). Each Bantu-speaking Kavango polity was governed by an absolute ruler (Rukwangali and Rumanyo *Hompa*, Thimbukushu *Fumu*, Chinyemba *Mwene*). The queens and kings were supported by respected elders of their clan and polity, and leant upon a network of principals in each village and community, who were appointed by the rulers or were members of the royal clans (Eckl, 2007, p. 31; Gibson et al., 1981, pp. 71, 142, and 196; Mbambo, 2002, pp. 90-91). Like clan affiliation, the mother's clan passed (and still passes) on kingship, and local chronicles provide valuable insights into the succession conflicts of the royal lineages over the past 250 years (e.g. Fleisch & Möhlig, 2002; Fisch, 2005; Larson, 2002). The queens and kings provided the ethnic affiliation that made commoners belong to one of the Kavango groups by allocating land to people who wished to settle in their kingdom (Likuwa, 2012, p. 33). This was another important factor contributing the heterogeneous nature of the entire Kavango population. The Kavango sovereigns were absolute rulers and masters over the life and death of their commoners. They were the unfettered owners of the country and everything in their country. Their absolute power led to early European and African traders exploiting the Kavango polities by exchanging European goods with the sovereigns for slaves and ivory from their kingdoms (Shiremo, 2010, p. 98-100; Likuwa, 2012, pp. 28-30). This is of relevance in the following sections because the sovereigns also controlled the game resources of their countries along with the hunting weapons and the producers of these weapons.

5.1.4. Subsistence strategies

In most scholarly literature, the Kavango peoples have been described as agriculturalists because nowadays they subsist on mixed farming (e.g. Gibson et al., 1981). However, cultivation of the land and animal husbandry seem to be a rather recent form of existence, perhaps no older than 150 years. The faunal remains of Vungu-Vungu (SC 12) revealed strikingly small quantities of bone material from domesticated animals (Sandelowsky, 1979, p. 58). Sandelowsky (1979, p. 61) carefully suggested that some of the identified bovids from Vungu-Vungu may well be cattle, but a detailed evaluation of the faunal material is lacking to this day. A surface collection of eroded faunal remains in 2003 mainly supplied evidence of game, in particular from antelopes adapted to the riverine environment as well as species that live in the bush. There was only little *bos taurus* bone material present, and neither the number of individual animals nor their age or gender justified the suggestion of animal husbandry being practiced among the Kavango peoples or the existence of a long herding tradition (J. Peters, personal communication in 2004). In addition, oral traditions, such as those told by the Mbunza elders of the Vakwanyatji (Buffalo) Clan, claimed that in the old days people lived exclusively on foraging (McKittrick, 2008, p. 793) and it seems likely that bovines were bartered from cattle breeding neighbors. People living in the northern periphery of the geographical Kalahari developed a variety of subsistence strategies. It was commonly the case that Bantu-speaking communities of different ethnic affiliation settled along the main rivers such as the Kavango, Kwito, and Kwando as well as their tributaries, whereas San people occupied the bush and dense forest between the water lines (De Almeida, 1912, p. 78). Some Bantu communities or polities had a strong mixed farming tradition, whereas others were hunters, fishers and only seasonal crop cultivators (Baumann, 1975, p. 572; De Almeida,1912, pp. 73-77). A similar diversity developed among Khoisan-speakers, who could live as sedentary foraging agro-pastoralists (Köhler, 1989, p. 190-194; Vossen, 2007, pp. 178-179), while other communities preferred a mobile foraging subsistence strategy without agriculture. There existed also San communities who hunted only and exchanged game for domestic crops with their neighbors (Biesele, 2002, p. 60). According to oral chronicles, crop farming was not introduced into the Kavango area before the end of the eighteenth century (Fleisch & Möhlig, 2002, p. 138). Linguistic studies of the semantic fields of hunting and agriculture revealed a highly diversified vocabulary for hunting, along with a strong link to religious concepts, whereas for agriculture there seemed no long-standing roots in either Kavango languages or cosmologies (Hüttenberger, 1997, pp. 87-88). The mixed economy of the Kavango peoples of hunting, fishing, a few bartered bovines, and seasonal crop cultivation combined with the gathering of wild fruits, as described in the early records of European visitors, is nothing exceptional in a broader geographical frame of reference. Nevertheless, it is most probably a more recent development and more archaeological and archaeobotanical research is necessary to shed light on the time depth of certain subsistence strategies of the region.

5.2. Historical sources and method

5.2.1. Literature review

If one looks into oral traditions such as the oral chronicles from the Kavango region, only limited information on iron smelting or forging is handed down, such as given in the Shambyu Chronicle (F. J. Haushiku in Fleisch & Möhlig, 2002, pp. 135-136). This might be due to the very nature of oral chronicles, often serving royal clans to justify their rule rather than describing the skilled crafts and trades of past societies. Only the Tjaube chronicle mentioned mining locations, smelting sites, and skilled ironworkers in detail (R. Haushiku in Fleisch & Möhlig, 2002, pp. 29-55).

Not many written sources are available to document the historical iron production of the peoples living along the middle Kavango. A short review of relevant literature has already been provided in Kose (2004) and (2008) and shall not be repeated here in detail. The earliest contributions came from European travelers such as Anderson (1863), Schulz and Hammar (1897) and Seiner (1909 and 1910),[109] from missionaries (e.g. Bierfert, 1938; Wüst, 1938) and German colonial civil servants (e.g. Eggers, 1900; Jodtka, 1903; Volkmann, 1901).[110] In the 1960s, a number of South African anthropologists researched the cultural life of the Kavango peoples, influenced by the South African volkekunde, and provided a basis for the implementation of the Odendaal Plan.[111] What all reports, accounts and studies have in common is that the rich smelting traditions of the Kavango peoples remained unnoticed except from Van Tonder's and Larson's studies on the Mbukushu (Van Tonder, 1966; Larson 2002). It is not clear whether this lack of perception was arrived at by coincidence, or whether it was politically motivated to reduce most of the Kavango peoples to blacksmiths with no smelting skills. However, this bias in cultural records started long before South African rule. For instance, Passarge (1905a and 1905b; see also Wilmsen, 1997, p. 10) concluded that the Mbukushu peoples had no iron producing industries because of a lack of ores. This is all the more surprising in the context of Passarge's thorough geographical studies, because he must have traveled through the ore-rich valleys around Dikundu (SC 30) and Kapongo (SC 29) (see Wilmsen, 1997). Other travelers and ethnographers stated that the people bartered raw metal and implements from their neighbors instead of producing them on their own (e.g. Otto, 1987, p. 195), notwithstanding the existing local iron production and the mentioning of these trade skills in the oral chronicles (Fleisch & Möhlig, 2002). Only Pater Bierfert (1938) from the Nyangana Mission briefly described the traditional iron production of the Gciriku people. Because of the obvious bias in the early non-indigenous records, this study relies first of all on the oral history accounts collected. Yet in certain cases early written documents provided useful accompaniments to the information gathered from the interviews. Early accounts about the ironworking industries of the Nyemba exist only from the central parts of Angola (Johnston, 1893; Serpa Pinto, 1881). These accounts are comparably detailed and contributed to a more comprehensive picture of the Nyemba metallurgical traditions.

5.2.2. Collecting oral history

As pointed out above, iron production traditions in northern Namibia and southern Angola are a greatly under-researched topic. This lack of published historical and anthropological data together with the temporal overlapping of local memories and the late archaeological sites motivated me to create a database of oral historical knowledge that can be used to compare and

[109] A compilation of early Portuguese travelers to the Kavango can be found in Gibson, Larson and McGurk (1981, p. 24).

[110] A comprehensive commented compilation of relevant literature was given by Pröpper (2007), relevant sources on the early colonial time under German rule were discussed in Eckl (2004).

[111] For a critical discussion see Akuupa (2015, pp. 75-82).

contrast archaeological assemblages with the historical records, since both disciplines claim to reconstruct history. The major research questions were: Do there still exist people who witnessed iron smelting at the youngest archaeologically investigated smelting sites? How many smelting and mining sites existed in the area, which have still not yet been detected? What were the mining and smelting techniques and what furnaces were used? Moreover, I sought to know what were the main products (i.e. tools and ornaments) that the ironworkers produced? Finally, I was interested in the social and cosmological context of ironworking. In light of the very limited records available, oral history interviews were the only method to answer these questions, and to complement the meager evidence.

The oral history method is well established among historians who write about the African past since early written records are scarce, in most cases crafted by individuals of European descent, and as a consequence, strongly biased and partial. However, oral history is also rarely objective, and the pros and cons have been extensively discussed among historians (summarized in Egger, 2013). Therefore, in the following section only some major limitations shall be considered.

It is commonly accepted that oral history is the testimony of eyewitnesses of a specific event in the past, whereas oral traditions are common knowledge handed down in families, communities or societies (Leavy, 2011, p. 4; Thompson, 2000, p. 25; Vansina, 1985, p. 13). The latter can be defined as institutionalized group accounts, such as the chronicles existing in each of the Kavango polities, passing down the origin of the peoples and the succession to the throne of the royal clans. Oral traditions and chronicles are considered a fused memory of earlier narratives told by numerous peoples to numerous peoples (Vansina, 1985, pp. 30-31). Due to these definitions, the following study transcends the boundary between oral history and oral traditions since it uses eyewitness accounts together with information gathered from oral chronicles, and handed down family knowledge about iron smelting traditions recounted by descendants of smelters, belonging, by definition, to the field of oral tradition.

Eyewitnesses to certain events in history are the most valuable source of information. In my case this would be skilled smelters and assistants in historical iron production. However, recollections of the past are never objective because individuals have a personal and subjective relationship to their memories, and reminiscence depends on many factors that influence the quality and the accuracy of it (Egger, 2013, p. 84). As described in detail by Thompson (2000, pp. 129-132), memory depends on the comprehension of, and the personal intrinsic interest in, an event or in craftsmanship. Memory undergoes permanent selection and discarding processes. The more significant something was to the individual, the more likely it is to be remembered. Moreover, recurrent processes, such as the repeated operations of iron production, are much better remembered than single events (Thompson, 2000, p. 158). Nevertheless, every reconstruction of a past event (or skilled work) is an approximation of it, because memories - whether pleasant memories or not - are produced in the present, and culture, social status, age, gender, and many other factors influence and bias accounts in oral history (Egger, 2013, p. 84). The examples mentioned show that oral history accounts and oral traditions must be reassessed and evaluated in the same way that written historical evidence has to be assessed to judge the representativeness of the provided information. Apart from the potential biases generally given in oral history interviews, one important criterion for judging the value of the account given is its internal consistency, and the confirmation of the same event in other sources, such as interviews with other participants, about the same topic (Egger, 2013, p. 56; Thompson, 2000, p. 119; Vansina, 1985, p. 48). The further back interviews go in time, the greater is the possibility of distortion. Moreover, every account given is an interpretation of perceptions and memories according to personal expectations, knowledge, and what individuals consider the logic of certain events to be (Vansina, 1985, p. 4). I faced this source of bias in many interviews as numerous informants claimed that liquid iron was drained away from the furnaces (section 5.3.3). It might be that this collective memory of iron smelting goes back to the beginning and the middle of the twentieth century, when some smelter generated cast iron in order to produce gun barrels. From the same time and earlier, people produced bloomery iron in slag tapping smelting facilities. Yet the high prestige of guns and gun production possibly distorted the exact reproduction of a local smelting history. All drained material recollected is, from a present day memory, interpreted and considered to be molten iron. This is clearly an interpretation of historical events based on personal expectations, knowledge and the assumed logic of certain informants. To resolve this problem, only a few questions were necessary to assess whether the informants were aware that cast iron must be decarburized in order to produce steel implements. However, in some cases it was not possible to separate 'truth' from 'fiction'. To avoid further biases, I compiled all the examples given without judging them. I leave it to the reader to form his/her own view and future research may disclose more details about this topic.

5.2.2.1. Developing an interview guide

Before I started with my oral history study, I decided to use structured interviews as defined by Leavy (2011, p. 14). Structured interviews are one possible method in oral history to gather information that guarantees a high level of comparability between the individual participants. Such interviews allow the researcher to generate standardized information, what I considered necessary to reconstruct ironworking traditions in a broader geographical area. To generate such dates, I developed an interview guide first, and each session followed the same scheme. This proved to be useful because the informants were very often uncertain about the details that would be of interest to me. Without the interview guide, many details of technology and cosmology would not have been recounted and thus not recorded.

I chose 127 questions focusing on smelting and mining locations, the spatial organization of mining and smelting, a description of raw materials, bellows, furnace constructions and smelting techniques, efforts in material and time, rituals, taboos and concepts of seclusion, the forging and trading of iron items, and the socio-cultural role of ironworkers. The outline of the questionnaire was based on ethnographic studies such as the one published by Childs (2000). The interview guide mainly comprised open-ended questions and if necessary, follow-up questions were asked to specify a thematic area of interest. During the session, the participants had the opportunity to review and change prior statements. The detriment of this procedure was that the depth of the topic sometimes fell victim to the breadth of the interview. Many details and new aspects that arose during the interviews, such as a detailed description of refining techniques, the deeper meaning of the songs performed at the smelting sites, rituals and taboos in a wider cultural context, the use and social role of the iron implements, were neglected in order to acquire as much comparable information as possible in the given time frame. Some aspects such as the songs were revised later with the interviewees, but many aspects remained unanswered and may inspire future research.

5.2.2.2. Locate participants and setting up interviews

All information was gathered in 2006 and 2007 in the frame of two three-month field stays. The access to appropriate informants turned out to be difficult because of the limited pool of still-living smelters and descendants of ironworkers who were familiar with the skilled knowledge of the craft. Often, local authorities recommended potential informants, and the personal network of those ironworkers who I approached was most helpful finding new participants. In this way, 32 people were contacted. Whenever a person presented broad knowledge of the technological details relevant to traditional iron smelting, an interview of several hours was arranged. Michael Hakusembe, son of the deceased Mbunza Hompa Leevi Hakusembe, assisted and translated most of the interviews because he was well acquainted with my archaeological work and known and respected among locals. In the Mbukushu area, Cosmas Kashongo assisted and translated the interviews because he had already participated in previous linguistic and historical research projects undertaken by the University of Cologne. My own language skills were restricted to English, whereas most elderly people were fluent in Rukwangali, Rumanyo, Thimbukushu and Afrikaans.

All interviews took place in the participants' homes. Only in two instances was a group interview organized. Generally, I tried to refrain from group interviews because, according to Vansina (1985, p. 62), the output of the individual informants in such sessions is subject to what all the participants can agree on. However, under some circumstances it could not be avoided.

Eight interviews of several hours were recorded on videotape, and from short assessing interviews, notes were taken while the participants recounted. The interview sessions lasted from 30 to 240 minutes, depending on the available time frame of the participant, his concentration and state of health. Before continuing with the next interview session, I transcribed the initial part of the interview and discussed those aspects that were not clear to me in the next session.

5.2.2.3. Writing up and interpreting oral history interviews

The interpretation of all the interview dates will be undertaken in the following sections. The written records listed above in section 5.2.1 will complement the reconstruction of historical ironworking. If different versions exist, I treat them equally and describe every version on its own, even if they are conflicting with each other. I try to avoid fusing them into one version that follows my ideas of what is plausible or not, because in most cases there is not enough historical evidence available to select and rate them according to their historical representativeness. Readers may judge on their own which version they wish to follow or not. However, some statements found in the interviews remained ignored, in particular when there was enough evidence against it (e.g. statements like 'the Shambyu people did not smelt'), but readers will find these statements in the appended interviews in full length.

The information gathered becomes permanent and testimony when recorded and published in scholarly studies. Regardless of how valuable the gathered information is, it represents only a fraction of the whole knowledge existing in a society or ethnic group (Egger, 2013, p. 55). Owing to this, the main problem that arose during this study was the limited pool of possible informants. One aim in oral history research is to gather information from a cross-section of a specific generation, social class or society in order to obtain representative dates (Thompson, 2000, p. 145). For the purpose of this study, the optimum case would have been a cross section of all the ironworkers who were eyewitness to traditional iron smelting. However, the composition of the participants was rather random because firstly, I did not have enough time to assess the number of potential participants that were still alive, and second, most ironworkers of their generation had already passed away. Another restricting factor, particularly in the Shambyu area, was a certain distrust against me as a foreigner because of historical events dating back to German colonial times. Moreover, people suspected that my interviews would be followed up by mining companies who would exploit the deposits the people recollected without sharing the benefit with the local population. Only during my last field season of 2007, did it become possible to interview certain Vakwandjadi ironworkers because people started to consider me trustworthy. Another disadvantage of this study is that it cannot claim to outline the Kavango ironworking traditions in full since it addresses only randomly the technological knowledge and traditions of metallurgy among the San people living in the same region. Even though Köhler (1997) gave an extensive testimony of Khoe ironworking traditions in the Mbukushu area, I was not able to find suitable San participants in the given time frame. The study remains therefore biased.

As pointed out earlier, the historical evidence collected in oral history interviews can be tested and supported when several versions of accounts of the same event or, in my case, from the same smelting site or ethnic group exist. However, before I started with my interviews, I was unaware how diverse historical iron smelting traditions were among the Kavango peoples because of the overall lack of previous research in this area. The output of this study was that almost every interview stood on its own and could not be falsified since there existed no commonly acknowledged standard ironworking tradition in each polity or ethnic group to which I could compare the interviews. It is hence difficult to judge from the sole interviews how far they are representative of a region, an ethnic group, or sometimes even of a smelting area. Yet the technical details that participants recollected clearly distinguish skilled ironworkers from participants who provided second-hand information. The depth of technical descriptions was therefore my main argument for considering an interview as representative of historical smelting traditions of at least an ironworking family and a specific smelting site. With this bias in mind, I tried to reconstruct the iron smelting traditions of the Kavango peoples as accurately as possible. Already the first interview revealed that many data could be gathered about sites that have not yet been assessed archaeologically, in particular those from Angola. As a result, this study became an archive of information that lays the foundations upon which future research can be built.

5.3. Ironworking in historical sources

5.3.1. Mines and ores

5.3.1.1. Kwangali and Mbunza

All the smelting sites that the people remembered in the interviews about the Kwangali and Mbunza iron smelting traditions were located in modern-day Angola. These sites were always connected to rich iron ore deposits and located along the Kwito River and its tributaries, in the precincts of Makuzu and Tondoro and in the Kafuma valley depression (Kose, 2009a, pp. 142-143). One well-known mining and smelting district was situated in the area of Kafuma and frequented by Kwangali, Kwanyama, and Nyemba.[112] The Kafuma Omuramba (i.e. dry riverbed) runs north-south for a distance of approximately 100 km in southern Angola and widens at the Kavango River valley at Bengo and Kasivi, roughly 40 km west of Rundu (Figure 217). The smelting sites were situated approximately 80 km north of the Kavango. Turning to the location of Makuzu, it is handed down that the settlement was the first residence of the Kwangali people close to the Kavango River on their southwards migration (section 5.1.1) (Fleisch & Möhlig, 2002, p. 180; Kampungu, 1965, p. 37). According to Kampungu (1965, p. 37), Makuzu was situated approximately 150 km away from Nkurenkuru in what is today Angola on the banks of the Kavango River (see also Fleisch & Möhlig, 2002, p. 276) (Figure 216).[113] In the Tjaube Chronicle it is mentioned that some of the captured Tjaube ironworkers continued smelting in a place called Ukuyu, which later became Makuzu.[114] However, it was not possible to gather any further information about the ironworking sites and the geological settings. Another possible source of ore[115] was remembered in the Mpungu Omuramba, more or less 50 km west of Nkurenkuru, yet it is not clear whether the Kwangali smelters made use of these deposits.[116] People smelted together with the Kwanyama, Umbundu and Nyemba groups and shared their mines.[117] Apparently, different types of ores were used: Some smelters smelted red sands (*kasira*), which were not available south of the Kavango River, while others used heavy[118] red and black stones. The ironworkers gathered the ore from the surface, yet at certain sites they were supposed to dig for suitable material. Usually, only skilled individuals were able to recognize ore of suitable quality. Some ironworkers collected the ore themselves, others had people to gather it for them, which were rewarded with a piece of raw metal later. People put the ore on a handbarrow (*sitali*) and carried the material to the smelting site.[119]

Farther east, historical smelting sites of the Mbunza people were not remembered, even though the slag samples from Ruuga and Kapako indicated iron production for the last four centuries in this area (sections 2.3.1.3 and 2.4.1). Some residents of Chokwe and Nyemba origin recollected that their families installed new smelting sites along the river at the turn of the twentieth century when they settled at Rupara, Sikondo and Mupini (Kose, 2009a, pp. 143-144). First, the immigrant smelters went to mining areas in the Kafuma and Kakeni valley and brought the ore on oxen sleights to their new residences in order to smelt it there. With the increasing border conflicts between Portuguese and Germans, the smelters learned from the local population how to use the hard crust ores from Kauti (SC 32) and so mined there (sections 1.3.2.10 and 4.1.2).[120] The ore was brought to their residences, although Rupara for instance lies 75 km away as the crow flies from Kauti. H. P. H. Kaputungu[121] claimed that Kapako was a smelting site of the Tjaube people (see below), so that the statements of all the interviewees that there existed no smelting sites of the Kwangali or Mbunza ethnic groups along the Kavango River seemed to be correct. Besides, it may also explain why local residents of Kapako did not remember any smelting in the precincts of their settlement.

---

112 Interview with Hompa Daniel Sitentu Mpasi, conducted by Eileen Kose, August 2, 2006 in Nkurenkuru. Manuscripts.

113 Akuupa (2015, p. 55) referred to this place as Makuzu gaMuntenda in south-western Angola. According to oral chronicles, Makuzu was also the place where the Handa people taught the Kwangali how to keep cattle (Fleisch & Möhlig, 2002, p. 182). Another place called Makuzu is known from Namibia immediately west of Namuntundu (Fleisch & Möhlig, 2002, p. 272), which is not the former Kwangali residence.

114 Interview with Harupe Paulus Haididira Kaputungu, Appendix 2.3.

115 Deposits of red sands called *kasira*.

116 Interview with Headman Samuel Hausiku, conducted by Eileen Kose, August 3, 2007 in Sauyemwa. Manuscripts.

117 Interview with Hompa Sitentu Mpasi, conducted by Eileen Kose, August 2, 2006 in Nkurenkuru; with Headman Paulus Mbundu Siveva, August 9, 2006 in Sikarosompo; with the Headmen Daniel Haikukutu, Jafeti Hainura, Samuel Hausiku, Hidion Karfere and Franz Semusi, August 6, 2007 in Nkurenkuru.

118 I.e. as heavy as slag.

119 Interview with Hompa Sitentu Mpasi, conducted by Eileen Kose, August 2, 2006 in Nkurenkuru; with Headman Paulus Mbundu Siveva, August 9, 2006 in Sikarosompo; with the Headmen Daniel Haikukutu, Jafeti Hainura, Samuel Hausiku, Hidion Karfere and Franz Semusi, August 6, 2007 in Nkurenkuru.

120 Interview with Headman Ndonga Abraham Katara Munganda, conducted by Eileen Kose, August 3, 2007 in Kasote; with Headman Samuel Hausiku, August 3, 2007 in Sauyemwa; with George Kahiata, October 7, 2007 in Karrangana. Manuscripts.

121 Interview with H. P. H. Kaputungu, Appendix 2.3.

5.3.1.2. Nyemba

As described above, the Kafuma and Kakeni dry riverbeds were well-known mining and smelting areas in southern Angola, and several ethnic groups exploited the rich iron ores. In the Kafuma Omuramba, A. M. Makayi[122] recollected mining sites in Mukundu[123] and Sindenga, which is north of Cantana (Figure 217).[124] The people mined deposits of a rich iron ore of clay-like consistency, because this material showed most favorable properties in smelting.[125] This material was found at the surface or immediately below it. Only experienced adult men older than 20 years were involved in the mining and smelting, and depending on the available manpower, the material was mined with digging sticks from extraction pits of 5 m in diameter and of hip height.[126] The ironworkers cut the clay into bricks the size of a lower leg and carried them to the furnace site on wooden dishes. One person carried only four of them at a time. For one smelt, 50 to 100 of such bricks were needed. Besides the adult ironworkers, boys were also allowed to assist in the preparation of the smelt in order to obtain some skilled knowledge.[127]
Another smelting site was in Kwango, in central Angola, where Chokwe and Nyemba groups exploited the same mines.[128] Nevertheless, it was not possible to collect any information about this location from people of Nyemba origin. A further testimony of Nyemba iron production provided Johnston (1893, p. 99) in his report on the mining and smelting sites that he observed along the upper course of the Kwanza River in central Angola. He described the mines as extraction pits of roughly 3 m in diameter and 2.5 m in depth. Serpa Pinto (1881, p. 118) witnessed large extraction sites along the upper Kavango River with extraction pits measuring 3.5 to 3.9 m in diameter, and roughly 2 m in depth. Nyemba mining and smelting sites were also located along the Kwito River in southeastern Angola, in particular around M'pupo,[129] which is roughly 30 km north of the Kavango. Schönfelder (1935, p. 50) noticed at the beginning of the twentieth century the abundant iron ore deposits along the Kwito River, which were associated with slag heaps from indigenous smelting in the region of the Maleo and around the M'pupo falls. Another mining site of Nyemba smelters was in Rumono[130] west of Nyangana in what is today Angola.[131] Shiremo (2010, p. 73) informed us that Nyemba smelters traveled through the Gciriku kingdom in order to mine at Dampundja.[132]

5.3.1.3. Manyo (Gciriku & Shambyu) and Tjaube

As discussed earlier (sections 5.1.1), in the settlement area of the contemporary Rumanyo speakers different technological and cultural smelting traditions overlapped and became fused. Only a few mining sites were remembered from this area: The ironworkers from Vungu-Vungu (SC 12) collected ore in the M'pupo mining sites (Figure 217) described above. The mines were situated in a dry riverbed close to the Kwito main stream,[133] more or less 40 km northeast of Vungu-Vungu in linear distance. However, ironworkers of the Vakwandjadi clan living in Vungu-Vungu claimed that people collected ore in the Kakeni Omuramba.[134] The Kakeni Omuramba runs north-south for a distance of more or less 75 km in southern Angola and widens at the Kavango River valley at Shinsogoro, roughly 6 km west of Ruuga and 40 km west of Vungu-Vungu (Figure 217). However, I was not able to collect more information about the mining areas in this dry river valley than the mere statement that there were mines there. The Gove (SC 17) smelting site was provided from mines in the Fumbe Omuramba near

122 Interview with Alberto Munoma Makayi, Appendix 2.8

123 Probably 20 to 30 km north of the Kavango River.

124 Probably 50 to 60 km north of the Kavango River.

125 Interview with Alberto Munoma Makayi, Appendix 2.8.

126 Interview with Alberto Munoma Makayi, Appendix 2.8.

127 Interview with Alberto Munoma Makayi, Appendix 2.8.

128 Interview with Johannes Mashela Kenga, conducted by Eileen Kose, July 26 and 31, 2007 in Vungu-Vungu. Manuscripts. Unfortunately, I was not able to locate the site on a map of Angola.

129 Interview with Petrus Kudumo Kampanzela, Appendix 2.1.

130 Unfortunately I was not able to locate Rumono more precisely.

131 Interview with Paulus Ndumba, Appendix 2.4.

132 Unfortunately, I was not able to exactly locate Dampundja.

133 Interview with Petrus Kudumo Kampanzela, Appendix 2.1.

134 Interview with the blacksmiths Paulus Siwoko Simuma, Mauritius Muyeyu Hamtena and Guidion Kayongo Simuma, August 22, 2006 in Vungu-Vungu.

Rujaja[135] and Mungunda[136] as well as at Taratara in the Omatako Omuramba (Fisch, 1980; Fleisch & Möhlig, 2002, pp. 41-42). Rujaja is roughly 15 km southeast from Gove (Figure 216), though Taratara, however, is 45 km away as the crow flies (Figure 217). South of the river, the smelter of Kauti (SC 32) (Figure 217) used the local ores. However, the mining site was not in the main valley of the Fontein Omuramba. People exploited deposits in the Kangomba Omuramba, which is a tributary of the main valley coming from the east.[137]

According to local recollection, the Gciriku smelted only in their territory north of the river and the mining sites were at Kashivi (Figure 217), which was situated approximately 5 km[138] west of the Nyangana Mission, and in Okekete near Katere.[139] At Kashivi in southern Angola, ore was available at several locations, but people did not mix these ores. They preferred the raw material from only one locality for their smelts. The mining area had a dimension of roughly 10 x 10 m, and the ore was indicated by the red colors of the sandy soil, and by burrowers who transported some ore to the surface through their activities in the ground. The ore was comparable to the plinthic crust of Kauti (Figure 14) and occurred immediately below the topsoil. Four to five ironworkers and some helpers extracted the hard material with axes and dug extraction pits of approximately 1.5 to 2 m in diameter, and of knee to waist depth. Three *cukuma*-baskets of 60 to 80 cm in diameter and of knee height were necessary for one smelt, and two individuals carried one basket full of ore, hanging from a bar to the furnace site.[140]

Gciriku ironworkers also went to exploit the M'pupo mines at the Kwito River, yet they never smelted in this region,[141] probably because the M'pupo mines belonged to the Nyemba territory. According to P. K. Kampanzela,[142] Nyemba traders told the ironworkers from Vungu-Vungu about the mines near the Kwito River. It is possible that Gciriku smelters from Nyangana also exploited the ore deposits around Dikundu and Kapongo, which were used by Mbukushu and Mashi groups, and carried the raw material to their smelting sites at the river.[143] Nyangana is more or less 60 km away from this deposit as the crow flies.

At M'pupo, the ironworkers from Vungu-Vungu (SC 12) collected hard nodular ore from a near surface deposit.[144] The color and weight indicated the quality, and the pieces of ore could be as large as brick-size. The nodules could be found at the surface, or else people used digging sticks to extract material from below. Six to eight men were enough to bring sufficient ore for one smelt to Vungu-Vungu (SC 12). Four to ten leather bags were necessary for one furnace charge and the collecting took the ironworkers three days: two days for the journey to the mines and one day for gathering sufficient material. In case the people needed more iron than produced from one smelt, the ironworkers went again into the mines and repeated the whole procedure.[145] As handed down in the Tjaube Chronicle (Fleisch & Möhlig, 2002, p. 42) there lived some Tjaube smelters at Vungu-Vungu prior to the Shambyu. It could be that they used the same mines in the Fumbe Omuramba or at Taratara like their Tjaube colleagues from Gove, but only limited details of the mines near Rujaja were remembered (Figure 217). Apparently, the ironworkers mined stones (i.e. hard nodular ores), which people contrasted in their memory with the red sands (*katira*) (Fisch, 1980), yet the mines seemed to be exhausted.[146]

Perhaps this was the reason why people decided to mine at Taratara. The ore was sifted out through a braided fish trap and carried in fur bags (Fisch, 1980). Only the strongest of the ironworkers went into these mines and brought the ore to the smelting sites along the river. The ore was transported on sleights, which were pulled by the miners, who sang some songs on their way to and from the mines. The ore was then hidden near the

[135] Interview with Modestus Kashera Shimbiringua, Appendix 2.2, and with Harupe Haididira Kaputungu, Appendix 2.3; with Headman Nependa Mbambangandu, conducted by Eileen Kose, August 5, 2006, in Gove.

[136] According to Fisch (1980), there existed several mining sites in the dry riverbeds south of the Kavango river.

[137] Interview with Modestus Kashera Shimbiringua, Appendix 2.2. Unfortunately, I was not able to locate these sites precisely on a map.

[138] Within a walking distance of 1 hour.

[139] Interview with Paulus Ndumba, Appendix 2.4.

[140] Interview with Paulus Ndumba, Appendix 2.4.

[141] Interview with Petrus Kudumo Kampanzela, Appendix 2.1.

[142] Interview with Petrus Kudumo Kampanzela, Appendix 2.1.

[143] Interview with Headman Kavinja conducted by Beatrice Sandelowsky, Appendix 2.7.

[144] Interview with Petrus Kudumo Kampanzela, Appendix 2.1.

[145] Interview with Petrus Kudumo Kampanzela, Appendix 2.1.

[146] Interview with Headman Nependa Mbambangandu, conducted by Eileen Kose, August 5, 2006, in Gove.

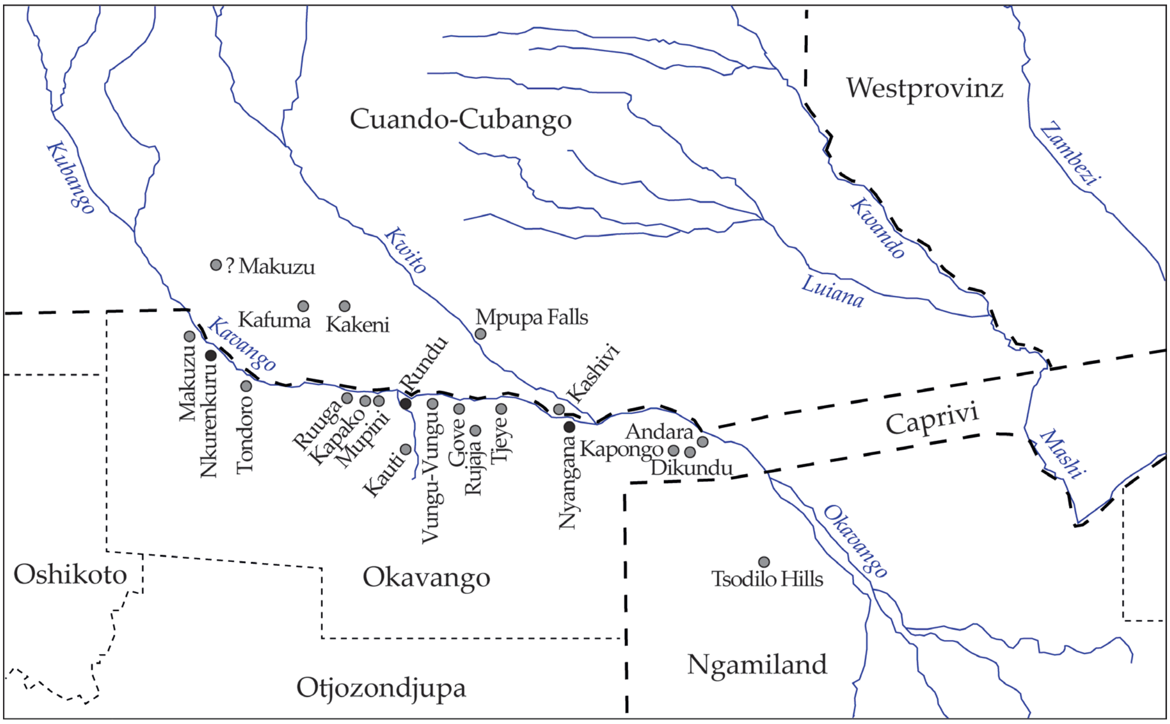


Figure 216: Smelting sites mentioned in Chapter 5 (as far as they were traceable).

smelting sites before the actual smelt was started to protect the raw material from the negative influence of fertile (i.e. menstruating) women on it (section 5.3.6).[147] At Kauti (SC 32), small red stones exposed at the surface indicated the ore, but the main deposit was somewhat below the ground level. In the Tjaube smelting traditions, boys collected the ore at Kauti and the experienced elderly smelters were only responsible for the actual smelting process.[148] The plinthic hardpan[149] sampled during our surveys was not the source material referred to above, yet locals claimed that it was used in historical smelting too. As pointed out earlier, the Kauti mines attracted ironworkers from the Kavango River from as far away as 70 km[150] and it is most likely that they used a variety of deposits in this area. Mines such as Kauti, Taratara and Rujaja, which are mentioned in the Tjaube Chronicle, and which are remembered by the ironworkers of the Vakwandjadi clan, reflect a profound knowledge of the landscape south of the river, which was considered the territory of San people.

5.3.1.4. Mbukushu

We can be certain that there existed numerous mining sites of the ancient Mbukushu people and only a few of them found their way into this study. Those mining areas of the Mbukushu that I surveyed were situated in the Dikundu (SC 30) and Kapongo (SC 29) Omuramba (Figure 217), as well as other interdune valleys in the same area (sections 1.3.2.10, 2.29, and 2.30). Those mining areas with adjacent smelting sites were in Dikundu, Shamaturu, Kapongo, Havo and Shividi.[151] Farther north, Mandhingwe (Ndjesha) close to Andara is remembered as another iron production site where people mined and smelted the pisolitic ferricretes along the river (section 4.1.3).[152] Ore of good quality was only available at specific locations, and people recollected that hunters discovered the ores in

[147] Interview with Headman Nependa Mbambangandu, conducted by Eileen Kose, August 5, 2006, in Gove; with Harupe Paulus Haididira Kaputungu, Appendix 2.3; with Modestus Kashera Shimbiringua, Appendix 2.2.

[148] Interview with Modestus Kashera Shimbiringua, Appendix 2.2.

[149] Sample 5188/07 and 5202/07.

[150] Interview with Headman Ndonga Abraham Katara Munganda, conducted by Eileen Kose, August 3, 2007 in Kasote; with Headman Samuel Hausiku, August 3, 2007 in Sauyemwa; with George Kahiata, October 7, 2007 in Karrangana, and with Gerhard Hainguera, August 8, 2006 in Ncuncuni.

[151] Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6, and with Petrus Kashako Kaputura, Appendix 2.5.

[152] Fumu Erwin Mbambo Munika, personal communication October 11, 2007 in Mukwe.

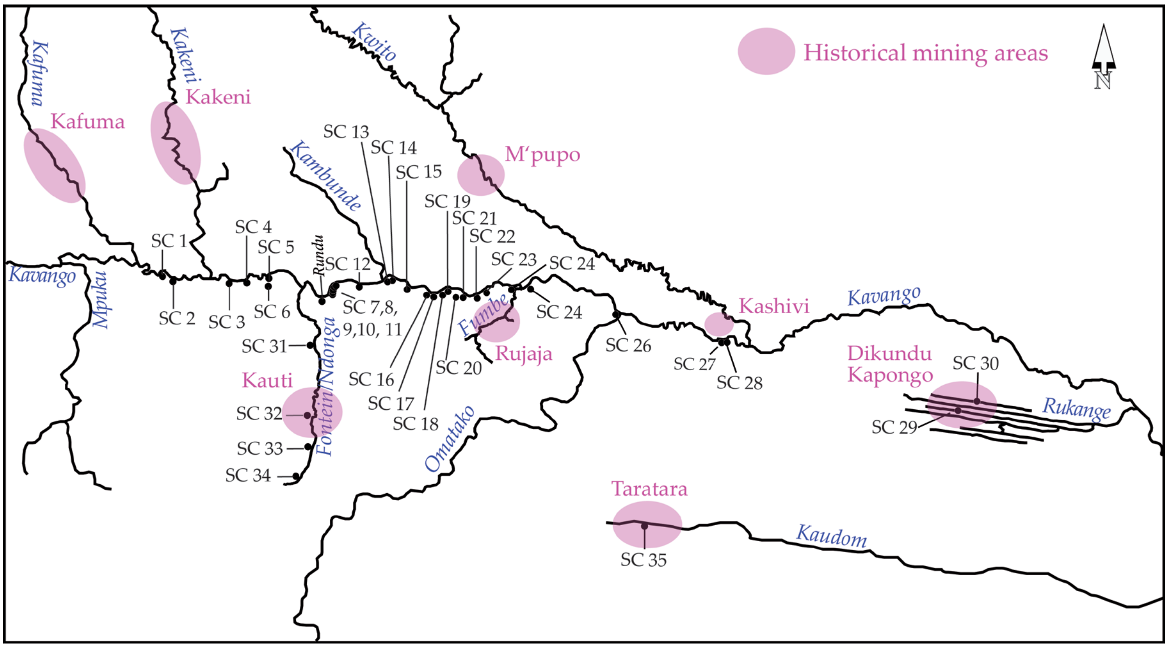


Figure 217: Mining sites mentioned in Chapter 5.

the Dikundu region. In historical times, the Mbukushu settled exclusively along the Kavango River and went into the bush in order to smelt whenever they needed new iron. San groups occupied the area around Dikundu and maintained wells in the Dikundu and Shamaturu riverbed (Köhler, 1989, pp. 299-302). The ore deposits are located at about 20 km south of the Kavango River, but people came from areas as far away as Nyangana and from the Mashi (Kwando) Islands in what is today Angola in order to exploit the rich material of this region.[153] The Mashi people belonged to the Mbukushu ethnic group (Köhler, 1989, p. 382) and usually, they smelted along the Kwando River near their settlements, using ore from depressions in the dry riverbeds (Köhler, 1989, pp. 383-384). It is not clear why they went smelting south of the Kavango at a given moment in history, but they used the rich iron ore deposits of Dikundu (SC 30) and Kapongo (SC 29) before the Mbukushu settled in this area. The Mashi smelters paid tributes to the local sovereign in return for the access to the mines,[154] which indicates that the Mbukushu considered the mines as their territory. Seemingly, the ores from Kapongo were of better quality than those found in the Dikundu valley (Köhler, 1989, p. 387). The Mashi ironworkers stayed in Dikundu for roughly two months and returned to Angola with new tools.[155] The local communities from the Kavango River only exploited the mining fields in this area but smelted near their settlements along the river. Some people were remembered to have come from the south in order to collect material. When the area became occupied by Mbukushu farmers, the local communities from the river paid millet and cattle to the farmers in order to gain access to the mines.[156]

Among the Mbukushu who are these days settled around Dikundu and Kapongo it is remembered that exclusively married men were allowed to be involved in mining since only they were considered responsible enough to conduct a smelt. The size of the group varied from 12 to 20 individuals, depending on their need for new iron. Every village community mined on its own. People collected hard nodular ore from the surface and exploited the hard plinthite horizons down to a depth of roughly 1 to 1.20 m in the Dikundu Omuramba. The ore was described as stone-like but soft (i.e. soft nodules). The quality was differentiated by color: red implied good quality, brown ore was less attractive though still usable, whereas the yellowish parts of the plinthic deposits have not been used in historical smelting.[157] The mining work was carried out with axes, hoes, and digging sticks. People crushed the ore to a maximum of the size of a fist because it was easier to be smelted in lumps

[153] Interview with Headman Kavinja, Appendix 2.7.

[154] Interview with Headman Kavinja, Appendix 2.7.

[155] Interview with Headman Kavinja, Appendix 2.7.

[156] Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6.

[157] Samples 4713/06 (5193/07), 4714/06, 4715/06 (5194/07), and 4716/06.

of limited size. The ironworkers transported the ore in heavy leather bags on their shoulders or on their heads to the furnace site, and the quantity they collected depended on the amount of iron they wanted.[158] In the Kapongo Omuramba (SC 29), the ironworkers collected only the nodular ore from the surface. These plinthic segregations were red, black and brown and judged to be very hard.[159] They were used as they were found and not selected. Ten full *thimbamba*-baskets were needed for one smelt; one basket was of knee height and roughly 1 m in diameter.[160] It was remembered that the pile of ore stacked up next to the furnace was 6 to 7 m in diameter and of chest height of an adult man.[161]

While this section focused on the information gathered about mines and ore, the following section moves on to describe the smelting sites handed down and their layout. This is of particular interest since smelting sites were subject to many taboos and were established in ritually secluded areas.

5.3.2. Smelting sites

It is generally assumed that smelting sites all over Africa were laid out separately from settlement sites since in African cosmologies there were as many esoteric as physical rules to be followed in order to succeed in smelting. One major concern was that smelting sites must be ritually secluded from the domestic areas where women of reproductive age lived (section 5.3.6). Therefore, this section focuses on the spatial disposition of smelting sites and settlement zones, and on the layout of smelting locations, as far as information was available. Those sites that were traceable by the author are mapped in Figure 216.

5.3.2.1. Kwangali and Mbunza

The Kwangali smelting sites have already been discussed in the previous section when describing their mining traditions. Unfortunately, not much information has been collected so far about the layout of the Kwangali smelting areas as such. What was found is that it was not allowed to smelt inside of a village, yet the smelting areas could be close to settlements or homesteads. Iron production sites were remembered to have been fenced in zones in order to protect the technical and spiritual processes from the influence of fertile women, which will be discussed in detail in section 5.3.6.[162]

5.3.2.2. Nyemba

Generally, it is remembered the Nyemba people preferred to smelt near or at their mining sites and people lived close to the iron production locations. A smelting site could be at a distance of 3 km from the permanent settlements, or even closer. If necessary, iron could be produced near a homestead, as long as the production site was approximately 100 m away from what was considered the village. However, it was prohibited to smelt inside of a settlement in order to maintain the seclusive character of the smelt.[163]

As described earlier (section 5.3.1), the Nyemba people maintained several important smelting centers. One was located along the Kwito River around the M'pupo falls, others were in Rumono west of the Nyangana Mission, and in Simbaranda, estimated to be 100 km north of Nyangana.[164] Farther west, several smelting and mining centers existed in the Kafuma valley. One of them was the location of Mukundu at a one-day walking distance from the Kavango. Another smelting site was Sitave[165], where the ores from the previously described mines at Sindenga were processed, and it was roughly 2 km away from the mining site.[166] A. M. Makayi recollected that at the smelting sites in the Kafuma valley, people used only one furnace at a time.[167] The smelting zone as such was roughly 10 x 10 m in dimension and it was protected

[158] Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6.

[159] Ore samples 4710/06, 4711/06 (5191/07), and 4712/06 (4400/07, 5192/07).

[160] One basket contained approximately 0.13 m³ of ore, provided an estimated height of 0.5 m and an average diameter of 1 m. Ten baskets full of ore would amount to 1.3 m³ for one batch.

[161] Interview with Petrus Kashako Kaputura, Appendix 2.5.

[162] Interview with the Headmen Daniel Haikukutu, Jafeti Hainura, Samuel Hausiku, Hidion Karfere, and Franz Semusi, conducted by Eileen Kose August 6, 2007 in Nkurenkuru.

[163] Interview with Alberto Munoma Makayi, Appendix 2.8, and with Headman Shiteketa Mbambangandu, conducted by Eileen Kose, July 30, 2006 in Ndonga.

[164] Interview with Paulus Ndumba, Appendix 2.4, with Petrus Kudumo Kampanzela, Appendix 2.1

[165] Sitave is also called Situwe.

[166] Interview with Alberto Munoma Makayi, Appendix 2.8.

[167] Interview with Alberto Munoma Makayi, Appendix 2.8.

with a reed mat fence, or with shrubs that were placed at a safe distance from the fire to keep animals or playing children away. Smelting sites were a taboo zone for women and other non-ironworking men but it seemed as if the rules of seclusion were not strictly applied out of season though visitors were not welcome either. As mentioned in the previous section, Johnston (1893, p. 99) described iron manufacturing of the northern Nyemba from the upper course of the Kwanza River in central Angola. Apparently, the smelting sites were camps near the mines with several furnaces and forges that were protected by sheds. It is most likely that these smelters were submitted to the rule of seclusion and sexual abstinence because they were staying in these camps far away from the villages during the entire smelting season. Likewise, Serpa Pinto (1881, p. 118) reported that in June and July Nyemba smelters left their communities and set up large camps near their mines between the upper Kavango and Cuchi rivers. He further stated that the ironworkers stayed in these camps for several weeks and worked night and day until enough new tools for another year had been produced.

5.3.2.3. Manyo (Gciriku and Shambyu) and Tjaube

The picture evolving from Gciriku and Shambyu reflects two smelting traditions: One associated with the Tjaube smelters, and one influenced by the southern Angolan smelting practices. There is little known about the layout of the early smelting sites of the Tjaube group which provided the first ironworkers settling in this area after the chronological hiatus between the Early and Late Ironworking Groups (Chapter 3 and section 5.1). The spatial outline of the smelting sites that people described and remembered in the interviews possibly reflects a later development, which occurred during the past 200 years as a result of the historical events described below.

The Tjaube followed the concept of seclusion in the same way as did the Shambyu and Gciriku smelters later. People could smelt near the villages or close to the mines. The earliest smelting sites mentioned in the local chronicles were Kauti (SC 32), Utu (Vungu-Vungu) (SC 12) and Gove (SC 17) (Fleisch & Möhlig, 2002, pp. 41-42) (Figure 216). It is likely that the LIG smelting horizon of Kapako (SC 4) was also part of the Tjaube network.[168] Generally, it was prohibited to smelt inside of a settlement, but a distance of 800 m was considered far enough away to protect the smelt from the presence of fertile women and playing children.[169] Smelting sites were preferably laid out where people found large trees, for instance at Gove (SC 17),[170] and Vungu-Vungu (SC 12)[171] because these trees provided some shade for where the demanding tasks were carried out.

As described in section 5.1, the first Shambyu arrivals were groups of specialized hunters who settled along the Kavango River. Even though they originated from iron producing communities, their knowledge of iron production became lost because, apparently, only specialized hunters migrated to the river (section 5.3.5.3) (Kose, 2010, p. 145; 2012). For an unknown period of time, the Tjaube were the dominant ethnic group in this area and tolerated the Shambyu immigrants. But oral chronicles contend that the tide turned when the Shambyu found support from the Kwangali farther west. During the conquest of the Tjaube territory by the Shambyu people, it seems as if the availability of iron weapons finally turned the war in favor of the Shambyu. For this reason, the control over ironworkers, smelting activities, iron tools and weapons became a central task of the ruling Shambyu sovereigns.[172] The smelting sites were from then on installed close to the Hompa's residence to honor the ruler[173] and the ruler performed control over the implements that were produced by his or her subjects.[174] The early smelting site of Vungu-Vungu (SC 12) was remembered as being close to the sacred Vungu-Vungu tree,[175] only later could people choose whatever area they wanted as long as it was outside of a homestead. However, the smelting zone of Vungu-Vungu (SC 12) was inside the settlement area and fencing of reed mats maintained its seclusive character during iron

[168] Interview with Paulus Haididira Kaputungu, Appendix 2.3.

[169] Interview with Nependa Mbambangandu, conducted by Eileen Kose, August 5, 2006 in Gove; with Modestus Kashera Shimbiringua, Appendix 2.2.

[170] Interview with Modestus Kashera Shimbiringua, Appendix 2.2.

[171] Interview with Paulus Haididira Kaputungu, Appendix 2.3; with Petrus Kudumo Kampanzela, Appendix 2.1.

[172] Interview with Harupe Paulus Haididira Kaputungu, Appendix 2.3.

[173] Interview with Petrus Kudumo Kampanzela, Appendix 2.1.

[174] Interview with Harupe Paulus Haididira Kaputungu, Appendix 2.3.

[175] Interview with Harupe Paulus Haididira Kaputungu, Appendix 2.3.

production. Before and after this, the area was accessible to the whole community.[176] It is not clear from the memories of the Vakwandjadi elders whether the smelting sites of the Tjaube ironworkers were fenced in too. However, it appears that in early times the concept of seclusion was implemented by the distance of the smelting site from the village rather than by fencing off an area inside of a settlement.

In the framework of this study, three iron production sites of the Gciriku around Nyangana have been remembered. One site was in Rucara in what is today Namibia, and another site was in Skekete near Dcirico between the Kavango and Kwito rivers in contemporary Angola.[177] P. Ndumba described another location of iron making at Kashivi, which was situated west of Nyangana north of the Kavango (Figure 216). Generally, people preferred to smelt close to the mines. In Kashivi all smelters seem to have used the same sources of ore but every family had its own furnace site. As several families smelted around the mines, one can expect a large area with smelting remnants. Kashivi is most probably the location mentioned by Pater Bierfert when describing the Gciriku iron production near the Nyangana mission in early twentieth century (Bierfert, 1938, p. 15). P. Ndumba recollected that the smelting sites were approximately 800 m away from the permanent settlements and were not protected with a fence.[178] Four to five individuals formed the core team of smelters at the Kashivi sites. Furthermore, it has been remembered that several additional assistants were necessary to perform a smelt, who were later paid in tools for their service. Each group of smelters chose a working zone of approximately 10 x 10 m under a large tree, and built a traditional house with open walls. Similar to Vungu-Vungu, the smelting site only became a secluded zone during the mining and smelting period. During this time, access was denied in particular to fertile women of twelve years of age and older. Likewise, P. Ndumba recalled that ore could be stored in the settlement yet during the smelting period only the ironworkers were allowed to touch it.[179]

[176] Interview with Petrus Kudumo Kampanzela, Appendix 2.1.

[177] Interview with Paulus Siwoko Simuma, Mauritius Muyeyu Hamtena, and Guidion Kayongo Simuma, conducted by Eileen Kose, August 22, 2006 in Vungu-Vungu.

[178] Interview with Paulus Ndumba, Appendix 2.4.

[179] Interview with Paulus Ndumba, Appendix 2.4.

5.3.2.4. Mbukushu

From the interviews and the published ethnographic studies one can deduce that the Mbukushu people smelted either near their mines or in the precincts of the settlement where the smelting family lived. All smelting sites recollected in the interviews were associated with the mining areas described above in the Dikundu and Kapongo Omiramba (SC 29 and 30) (Figure 216). Originally, before the Dikundu area was provided with boreholes, these smelting sites were far away from the places of residence along the river and every village had its own smelting area. Later, when Mbukushu farmers started settling around the boreholes, the smelting sites were 500 to 1000 m away from the permanent settlements. This was considered far enough away from the villages in order to respect the requirements of seclusion. The smelting locality itself was remembered as an open space of approximately 10 to 15 m in diameter, or smaller. It was not fenced in, but people respected and avoided the furnace site even outside of the smelting season, when no-one (not even the ironworkers) was allowed to approach this specific zone.[180] As mentioned earlier in section 5.3.1.4, Mashi people from the Kwando River also frequented the Dikundu region in order to smelt on the spot, but no information was available as to the layout of their smelting sites. Köhler (1989, p. 387) however provided some information stating that the Mashi smelters collected their ore in the Kapongo Omuramba, but smelted in the Shamaturu riverbed.

Taken together, the information presented in section 5.3.2 provided important insights into the spatial order of mining, smelting and living. All the dates disclosed that the furnace sites were secluded areas near the mines or near the permanent settlements of the people. Most smelting sites were laid out within a maximum radius of 1000 m around the villages despite their seclusive character. Smelting localities could be very close to individual homesteads as long as people considered this area to be outside of what was perceived to be ‘the settlement’. Some ironworkers deemed it necessary to fence off

[180] Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6, and with Petrus Kashako Kaputura, Appendix 2.5.

the furnace location to keep unwanted visitors away (see also section 5.3.6), other communities achieved seclusion whereby individuals respected the taboo zone in space, and did not approach the precincts of the furnace site. However, the seclusion of a smelting site was not a static concept that found expression only in the spatial relationship between villages and the smelters' camp. The Shambyu example indicated that smelting sites could be installed inside a place of residence and that people found strategies to maintain the spiritually remote character of the furnace site despite the spatial proximity of people who possessed power to threaten the success of the smelts (section 5.3.6). As will be argued later in section 5.3.5.3, the Shambyu installed their furnace sites near the royal court because their sovereigns wished to have full control over the implements produced in the country. This is another example showing that, if necessary, cosmological solutions were found to adapt the taboos essential to fulfill a smelt to the sovereign's need for control.

5.3.3. Smelting techniques and furnace design

What follows in this section is a description of furnace solutions and smelting techniques as provided by the informants I had been interviewing and as reported in some published accounts observed by anthropologists or early European travelers. The accuracy in the technical details of the gathered data varied considerably and for that reason some skilled solutions are comprehensively described whereas others remained vague.

5.3.3.1. Kwangali

The evidence collected about the Kwangali smelting practices was scant but yielded some helpful information. Unfortunately it was not possible to collect any information about the size of working groups nor about furnace constructions and the quality of the iron produced. The furnace solutions remembered were made in eroded termite mounds in which a pit had been dug. The furnace was equipped with one furrow cutting down into the mound in which the iron could be tapped from the furnace.

Bellows provided oxygen. People smelted from sunset until the next morning. In local memory, the piece of molten iron that the smelters obtained was as thick as an adult's arm.[181] Another smelting technique remembered from the Kwito region was to pile up the ore and the charcoal above the ground and supply air into the heap using three bellows. As soon as the metal started to separate from the slag, people dug a furrow to drain away the liquid slag. Thereafter people covered the heap with sand and waited until it cooled down. Some smelters put out the fire with water.[182]

5.3.3.2. Nyemba

Moving on to the Nyemba iron production traditions, it has been recollected that people smelted up to three times a year in the Kafuma valley, always during the dry season.[183] The group of smelters consisted of thirty individuals or more, headed by the oldest of them. The Nyemba furnace constructions were large box-shaped pits, measuring roughly 10 m in length and 1.5 to 2 m in width (Figure 218). These furnaces were knee-deep and excavated by the ironworkers with digging sticks in the sandy ground and then provided with slag tapping furrows on the long edges.[184] If the rainy season began earlier than expected, the smelters protected their furnaces with a roof. The smelters charged their furnaces with a layer of ore at the bottom, a layer of charcoal in the middle and again a layer of ore at the top.[185] In addition, S. M. Mbambangandu recollected a final charcoal layer covering the ore.[186] According to A. M. Makayi,[187] the ironworkers placed two bellows at the narrow edges of the furnaces and lit the fire from this side. One smelt took approximately 12 hours and lasted from sunset to dawn. Inside the pit, A. M. Makayi remembered a liquid melt with

[181] Interview with Hompa Daniel Sitentu Mpasi, conducted by Eileen Kose, August 2, 2006 in Nkurenkuru; with Headman Paulus Mbundu Siveva, conducted by Eileen Kose, August 3, 2006, in Sikarosompo.

[182] Interview with the Headmen Daniel Haikukutu, Jafeti Hainura, Hidion Karfere, Franz Semusi, conducted by Eileen Kose, August 6, 2007 in Nkurenkuru.

[183] Interview with Alberto Munoma Makayi, Appendix 2.8.

[184] Interview with Alberto Munoma Makayi, Appendix 2.8; with Headman Shiteketa M. Mbambangandu, conducted by Eileen Kose July 30, 2006, in Ndonga.

[185] Interview with Alberto Munoma Makayi, Appendix 2.8.

[186] Interview with Headman Shiteketa M. Mbambangandu, conducted by Eileen Kose July 30, 2006, in Ndonga.

[187] Interview with Alberto Munoma Makayi, Appendix 2.8.

the metal concentrating at the bottom of the pit and the slag on top of it. Despite the two furrows in which some slag could escape, there was still plenty of it in the main pit. After the furnace had been cooled down for an hour, the smelters removed the bloom with their hands and the best metal was remembered to have been at the bottom of the furnace. They also cleared out the other waste from the pit and discarded theslag near to the furnace. The furnaces were used repeatedly, sometimes for one or two years, sometimes even longer. A slightly different smelting procedure was remembered by N. A. K. Munganda,[188] whose family also used to smelt in Kafuma. He stated that the box-shaped pits were filled with two layers of charcoal with one layer of ore in between. The two bellows only operated on one narrow edge. They started with the smelt in the morning hours and operated the bellows until the melt became liquid in the evening, then covered the furnace with a layer of sand and waited until the next morning before they removed the bloom. Similar to the account of A. M. Makayi, Johnston (1893, p. 99) reported from central Angola that Nyemba people smelted during the coldest months of the year in the dry season and stayed at the smelting sites until they had enough iron and new implements for their needs. They built clay furnaces of unknown appearance, which were protected by sheds. It may well be that several of them operated at once, because Johnston spoke of sheds and furnaces in the plural. Obviously, these furnaces were destroyed after the smelt, assuming that Johnston's descriptions of broken clay furnaces and crucibles did not in fact refer to several generations of old broken smelting facilities. A similar description was handed down by Serpa Pinto (1881, p. 118), who observed among the Nyemba people pit furnaces that operated with only one bellow. Like Johnston, he described ironworkers staying at their smelting camps until they had enough new tools for another year. This, however, differed from the descriptions given about the Kafuma smelting sites seen earlier. A. M. Makayi recollected that the expenditure of time necessary for the entire process, starting from the production of charcoal and the collection of ore until the raw metal was generated, was one month.[189] The tools were made later (see section 5.3.4.2).

[188] Interview with Headman Ndonga Abraham Katara Munganda, conducted by Eileen Kose, August 3, 2007 in Kasote.

[189] Interview with Alberto Munoma Makayi, Appendix 2.8.

5.3.3.3. Shambyu and Tjaube

Several technical solutions for furnace constructions were known from the Tjaube and the Shambyu, and the practices that locals recollected painted a picture whereby each smelting site possessed its own technological tradition.

According to M. K. Shimbiringua's account from Gove (SC 17), the ironworkers chose a shallow hill and smelted above the ground without protecting the furnace construction. The fire was started in a bottom layer of charcoal and then covered with a pile of ore up to knee-height (Figure 218). The pile of ore was then completely covered with charcoal and supplied with air by three bellows which were set up in a semicircle. Beneath the heap of ore and charcoal, the ironworkers dug some furrows in the ground opposite the bellows in order to drain the slag away from the furnace. People smelted from the afternoon hours until dawn, which comprised roughly 12 hours.[190] Another smelting solution recollected in the Shambyu region were pit furnaces with iron [slag?] tapping furrows on one side. [191, 192] Opposite the drains, two bellows provided air. Here again the furnace was covered with sand as soon as the batch became molten and the iron was then removed from the furnace the next day.[193] Apparently, there also existed pit furnaces without tapping facilities, which were operated by two bellows. Smelting in these pits also took twelve hours, yet people could perform their smelts either during daytime or during the night.[194] P. K. Kampanzela gave a detailed description of these simple pit or bowl furnaces operating at Vungu-Vungu (SC 12).[195] The ironworkers created knee-deep bowl furnaces of roughly 1 m in diameter with a digging stick and the bottoms of these furnaces were sometimes covered with a clay lining. Air was provided by four bellows, which were placed around the depression. People charged the furnace with three to four alternating

[190] Interview with Modestus Kashera Shimbiringua, Appendix 2.2.

[191] Interview with Headman Nependa Mbambangandu, conducted by Eileen Kose, August 5, 2006 in Gove.

[192] I assume that the interviewee in fact meant slag because he remembered that the iron was removed from the furnace the next day.

[193] Interview with Headman Nependa Mbambangandu, conducted by Eileen Kose, August 5, 2006 in Gove.

[194] Interview with Gerhard Hainguera, conducted by Eileen Kose, August 8, 2007 in Ncuncuni.

[195] Interview with Petrus Kudumo Kampanzela, Appendix 2.1.

layers of charcoal and ore starting with a fuel layer at the bottom. One crew of smelters comprised 12 to 13 individuals, who used only one pit at the same time. On the night of the smelt, more manpower was needed to keep the bellows running because each bellows was operated by four individuals who took turns throughout the night. P. K. Kampanzela further stated that during a successful smelt, molten slag developed and descended to the bottom of the pit. According to him, the good quality iron was found on top of the slag. Slag and ashes were discarded a short distance away from the furnace site. The smelt was carried out during the night and lasted for approximately twelve hours. People sometimes smelted two to three times a year, in the winter, and used their furnace pits only once in the following year. Occasionally they protected their furnaces from heavy rainfall with shelters. When the furnace site became too polluted with ashes and slags, the ironworkers moved the smelting area to a new location and built a new pit furnace. Altogether, in this example the iron manufacturing process seemed to take no more than two weeks, starting from collecting the ore until the metal was produced. Maria Fisch (1980) recorded that people smelted in shallow pits in which ore was placed on top of the charcoal. Four bellows were placed around the pit, at the bottom and halfway up the pit. The furnace site was surrounded by walls made from dried reeds to protect it from the cold winter winds and curious visitors. The molten iron was collected at the bottom of the pit in a furrow which was lined with burnt clay.

5.3.3.4. Gciriku

From the Gciriku area, two technological smelting solutions were handed down: B. Shindimba remembered, without giving further details, that pit furnaces with drains for molten iron were used, which functioned with only one bellows.[196] Pater Bierfert (1938, p. 15) from the Nyangana Mission only briefly described that furnaces driven by four to five bellows were used. P. Ndumba contributed a more in-depth insight into the smelting furnace construction from iron production at Kashivi.[197] According to him, the ironworkers excavated elongated box-shaped smelting pits with axes and hoes. These furnaces measured roughly 2 m in length, 30 cm in width and were as deep as the thigh of an adult man (Figure 218). The smelting pit was charged with a bottom layer of fuel, a middle layer of ore and again covered with a layer of fuel. Two long tuyeres each with one bellows were placed at a 90° angle to each other below the bottom layer of fuel, one at the narrow edge and one at the broad edge. The ironworkers then lit the fire from the narrow edge of the furnace where the bellows were placed. As soon as the melt became liquid at that end of the pit, people changed the position of tuyeres along with the bellows and placed them at the opposite end of the pit. The ironworkers preferred to smelt from the evening hours until the early morning so to benefit from the agreeable nighttime temperatures. It was the master smelter who decided that a smelt was over when the slag had fully been formed. According to P. Ndumba, this usually happened after roughly twelve hours, but the smelters left the melt in the furnace for another day until it had fully cooled down before they retrieved the bloom. Usually, the slag, ashes and failed smelts were discarded on a dump 5 to 10 m away from the furnace. The discarded slag was remembered as being rather fragmentary. Occasionally, the ironworkers refilled their furnace with soil or protected them with thorny boughs for another smelt, others left the smelting pits as they were. The entire iron production procedure from start to finish took two to two and a half weeks. If necessary, people smelted up to ten times a year during all seasons as long as it did not rain.[198]

5.3.3.5. Mbukushu

Among the Mbukushu in the Dikundu area (SC 29 and SC 30), it has been handed down that the headman of the community and the heads of a families decided when it was time to smelt.[199] They also chose the men who were allowed to carry out the iron production. People smelted at any time of the year apart from the rainy season and if necessary, this could be up to three times a year. A crew of five to more than 20 individuals were involved in the smelting and the size of the group depended on the need for iron of the

[196] Interview with Headman Balthasar Shindimba, conducted by Eileen Kose, July 30, 2007 in Nyangana.

[197] Interview with Petrus Ndumba, Appendix 2.4.

[198] Interview with Petrus Ndumba, Appendix 2.4.

[199] Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.5; with Petrus Kashako Kaputura, Appendix 2.5.

individual families because each homestead in need of new raw material provided skilled married men for the working crew. During the period of iron production, the ironworkers were busy with the preparation of the smelt all day long and could not pursue other activities. It could take two months to collect all the materials required to produce new iron.[200] This same duration of the smelting process was remembered from the Mashi people who frequented the Dikundu area prior to the establishment of permanent settlements there.[201]

Oral and written records have it that among the Mbukushu various engineering smelting solutions existed. Larson (2003, p. 250) described the following from his years of research among the Mbukushu in Botswana: '*Iron was melted down by Hambukushu blacksmiths by building a fire of hardwood or charcoal over a depression. The iron at the bottom ran off through two long slabs molded by a potter or it collected under the fire. While it was still hot it was cut out with an ax into the desired shapes. When an implement was to be made, the iron was reheated then tempered by dipping into cool water*.' Van Tonder (1966, pp. 262-263) documented the following details about the Mbukushu iron smelting practice: A suitable place on a flat anthill was selected for the melting. Four furrows, approximately four feet[202] long and six inches[203] wide and about two inches[204] apart, were chopped out of the anthill soil. The first furrow was filled with coals, the second one with iron ore, the third with coals and the fourth with iron ore. The fifth and last furrow was again filled with coals. The furrow with the coals in them were as twice as deep as the furrows with the iron in them. Two bellows were then placed at opposite ends with the nozzles of each pair of bellows serving a coal furrow. The center furrow then had two nozzles at each end. The coals and iron ore were covered by a further layer of coals and smeared shut with a thick layer of anthill clay. The blowing usually started in the late afternoon, and was continued until the early hours of the next morning. The workers were also smeared with clay to protect them against the intense and continuous heat. The furnaces remembered in Dikundu (SC 30)[205] and Kapongo (SC 29)[206] were tall shaft furnaces carved out from large termite mounds because people wanted to protect the fire from strong winds. The smelters cut the tip of the mound to a height of 1.7 to 1.8 m and hollowed it out with digging sticks (*munyondo*) or axes so that an adult person could fit inside (Figure 218). Below the bottom of the termite hill, the smelters installed a furrow in order to drain the molten iron. Laterally and level with the ground, they carved out small holes through the furnace walls and installed two to four bellows around the it. The furnace was charged with three layers of charcoal and two layers of ore, starting with a layer of charcoal from the bottom. Additionally, a medicine[207] was put into the furnace in order to protect those who did not belong to the crew of smelters from getting burnt by the iron. The furnace was not closed during the smelt[208] and one side stayed open from which further materials were supplied. The ironworkers lit the fire at sunset with a piece of wood from the top and sometimes the smelt continued during the next day. Usually, after having operated the furnace for approximately seven hours, the molten iron flowed out before the slag came and the furnace was stopped when the channel was filled with metal. The ironworkers waited until the iron solidified after approximately one hour and removed the hot piece of raw material from the furrow with their bare hand, which were protected by a liquid medicine of unknown composition. Subsequently, they cleaned the furnace and filled it again and whilst still hot the crew ran the furnace for 24 hours until all the collected ore was used up. People normally used only one furnace at a time even if twenty individuals wished to produce new iron. In the latter case, people took turns and the furnace was run for an entire week. During such smelts, they supplied the furnace with new ore while the molten iron poured out. Generally, these furnaces were used for many years.[209]

200 Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.5; with Petrus Kashako Kaputura, Appendix 2.5.

201 Interview with Headman Kavinja, Appendix 2.7.

202 1.22 m

203 15.24 cm

204 5.1 cm

205 Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6, with Petrus Kashako Kaputura, Appendix 2.5.

206 Interview with Petrus Kashako Kaputura, Appendix 2.5.

207 Unfortunately P. K. Kaputura could not remember the ingredients of their medicine.

208 Interview with Petrus Kashako Kaputura, Appendix 2.5.

209 Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6

The interviewees recollected that the waste from the smelt was black, brownish and red much like rusty iron. It looked like small chunks of charcoal or even smaller. They dumped the waste of the smelt roughly 10 to 20 m away from the furnace site and cleaned out the working area when the smelt was over. If the iron ore had not been reduced to iron the smelt was unsuccessful. The ironworkers were able to recognize a problematic smelt from the noises of the airflow that the bellows produced. In such a case, the ironworkers stopped the furnace the next morning and tried to find the one that had caused the failure of the smelt. Thereafter, they cleaned out the furnace and tried again.[210]

While the Mbukushu smelted in high shaft furnaces, the Mashi who frequented Kapongo smelted in small pit furnaces of 30 to 45 cm in diameter that were provided with two furrows leading into the furnace depression in which the bellows were placed.[211] Headman Kavinja recalled that one smelt took roughly 24 hours after which the iron would have collected in the middle of the furnace and was covered by slag. After the furnace cooled down, the Mashi smelters removed the bloom and knocked off the redundant slag material. The bloom was remembered as being a big chunk of metal with lots of waste adhering to it.[212] Another furnace type was observed by Köhler (1989, p. 388). He stated that the Mashi smelters in the Shamaturu Omuramba used low shaft furnaces made from termite clay, which were operated by four bellows.

5.3.3.6. Fuel

The predominant fuel used in iron production was charcoal of the Camel Thorn Tree (*Acacia erioloba*, syn. *giraffae*), the Ambo Teak (*Erythrophleum africanum*), Rhodesian Teak (*Baikiaea plurijuga*), the Silver Terminalia (*Terminalia sericea*) and the Red Syringa (*Burkea Africana*). The Mbukushu smelters used all five species whereas the Nyemba ironworkers preferred the Ambo Teak only (Table 54, Appendix 3). Moreover, there is evidence that the Mbukushu also used non-carburized fresh wood in the smelting furnaces (Larson, 2002, p. 250).[213]

All tree species were selected because they produced embers that lasted well in the furnace and at high temperatures. Generally, the charcoal was produced in the bush where suitable material was found of preferably dead and dry trees. From the Kwangali area it is remembered that the ironworkers collected charred trees after forest fires. Also, they preferred to collect suitable wood close to the smelting site and produced charcoal there.[214]

Generally, all members of the smelting team were involved in charcoal making. However, the Nyemba ironworkers also accepted charcoal produced by the neighboring villagers and exchanged fuel for new iron from the smelt.[215] In Vungu-Vungu (SC 12), boys from the village helped the experienced smelters with this task[216] but in Kashivi, charcoal production was restricted to the group of ironworkers.[217] In the Dikundu area (SC 30), the experienced smelters of the team were responsible for the quality of the charcoal and while producing the fuel material, the ironworkers had to follow the requirements of seclusion (section 5.3.6). It was remembered that ironworkers were also subject to sexual taboos and had to abstain from women, otherwise they would not have been able to detect the right tree species in the bush. In addition, ignoring to the taboos would also cause fire accidents during charcoal production.[218]

The amount of fuel needed for the individual smelts varied and was difficult to estimate because the material was measured in baskets whose morphology I was not familiar with, and statements regarding dimensions were made in the width and length of parts of the human body. Nevertheless, in the following section some estimation will be attempted. From Kashivi, P. Ndumba recollected that two to three *cukuma*-baskets of charcoal were needed for one smelt and the amount of fuel exceeded the volume of the furnace pit.[219] One basked measured approximately 60 to 80 cm in diameter and was of knee height. Taking 50 cm as a basis for knee height, and 70 cm as

[210] Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6, with Petrus Kashako Kaputura, Appendix 2.5.

[211] Interview with Headman Kavinja, Appendix 2.7.

[212] Interview with Headman Kavinja, Appendix 2.7.

[213] Fumu Erwin Mbambo Munika personal communication, October 11, 2007 in Mukwe.

[214] Interview with the Headmen Daniel Haikukutu, Jafeti Hainura, Hidion Karfere, Franz Semusi, conducted by Eileen Kose, August 6, 2007 in Nkurenkuru.

[215] Interview with Alberto Munoma Makayi, Appendix 2.8.

[216] Interview with Petrus Kashako Kaputura, Appendix 2.5.

[217] Interview with Petrus Ndumba, Appendix 2.4.

[218] Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6, with Petrus Kashako Kaputura, Appendix 2.5.

[219] Interview with Petrus Ndumba, Appendix 2.4.

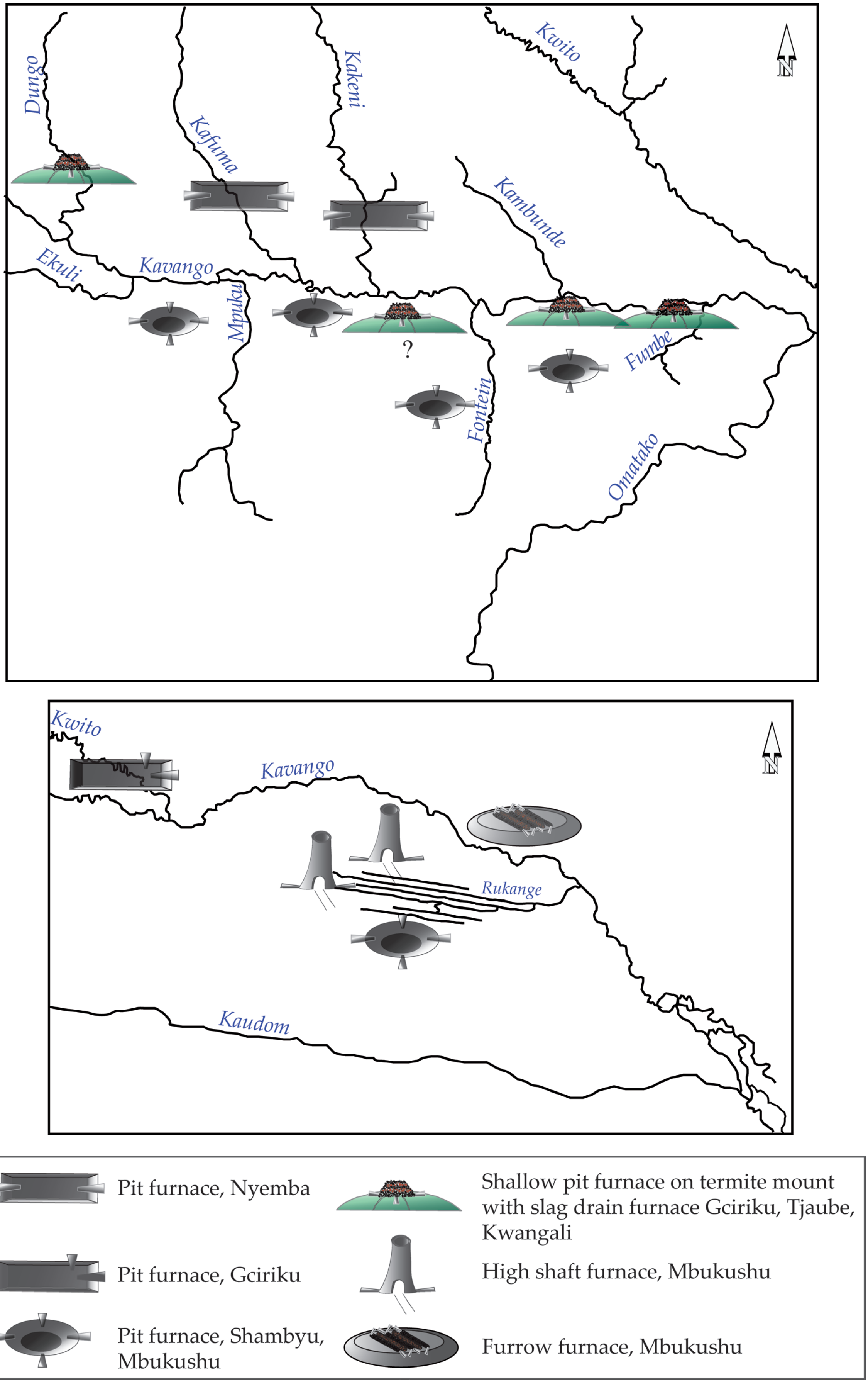


Figure 218: Furnace types of the middle Kavango region as reconstructed in Chapter 5.

the average diameter, this would amount to 0.384 to 0.577 m^3 of charcoal per smelt. The furnace pit was estimated at 0.43 to 0.48 m^3 in volume[220] (section 5.3.3.4). Assuming that one third (i.e. 0,152 m^3) of the furnace fill was ore, 0.056 to 0.299 m^3 of fuel remained available for replenishing the furnace during the smelt. In Kapongo (SC 29), the ironworkers collected a heap 2 to 3 m in diameter and 1.8 to 2 m in height,[221] which amounted to 1.8 to 4.7 m^3 of charcoal. Assuming a furnace dimension of 1.75 m in height and of 1 m in inner diameter (see section 5.3.3.5), it would have had a volume of more or less 1.4 m^3. P. K. Kaputura[222] also remembered that ten *thimbamba*-baskets of ore were required for one smelt. One basket was approximately 1 m in diameter and of knee height. Again taking 50 cm as a basis for knee height, this would amount to 3.9 m^3 of ore for one smelt. The ore to charcoal ratio seemed not to have gone greatly below one, but the amount of fuel and ore recollected for one smelt surpasses the estimated volume of the furnace significantly. I believe that the amounts of raw material remembered reflected a long non-stop smelting episode during which ore and charcoal were continuously refilled, or that the descriptions referred to repeated single smelting episodes remembered to be 'one smelt' (section 5.3.3.5). The smelters of Sitave in the Kafuma valley needed 35 to 40 baskets of charcoal for one smelt; however, the baskets varied in size and an exact estimation of the amount of fuel was therefore not possible.

5.3.3.7. Bellows and tuyeres

All the bellows were made from the wood of the Wild Teak Tree (*Pterocarpus angolensis*) (Table 55, Appendix 3) because it was lightweight, easy to shape and resilient, and it is still commonly used in modern-day wood carving (Curtis & Mannheimer, 2005, p. 239). The bellows consisted of two wooden cups with one air channel each, and the cups were covered with soft flexible hides of small game or domestic animals because they allowed for a good compression of the air in the cups. From Kashivi it was remembered that each bellow consisted of two cups on a bottom board. The jars measured 25 to 30 cm in height, and each jar displayed an approximate diameter of 30 cm. The air channels were roughly 30 cm in length.[223] The same cup dimension was recollected from the Mbukushu smelters, only the air channel was markedly longer measuring approximately 1 to 1.20 m in length.[224] The sticks for operating the bellows were made out of thin branches of the Sandpaper Raisin Bush (*Grewia flavescens*) or of the Camel Thorn Tree (*Acacia erioloba*) (Table 55, Appendix 3) because these branches were considered resilient. They were chest-high and allowed the smelters to operate the bellows either standing upright or while they were sitting.

The tuyeres were made from river clay and connected the bellows' wooden air channels with the furnaces in order to protect them from fire and heat. The Nyemba and Gciriku smelters used long pipes measuring up to 1 m in length, 10 cm in diameter at the edge facing the bellows, and 3 to 5 cm in diameter at the air outflow into the smelting pit.[225] The blowing pipes used by the Mbukushu smelters of Dikundu measured only 30 to 50 cm in length. The edges that met with the bellows were roughly 20 cm in inner diameter whereas the edges that were placed towards the furnace were 10 cm in inner diameter. Moreover, these tuyeres were fired before they were used.[226] Contrary to the Mbukushu living in the Dikundu area, the visiting Mahsi ironworkers who smelted in Kapongo used termite clays to fabricate their blowing pipes.[227] Köhler (1997, p. 265) provided indirect evidence that in former times some Mbukushu also used termite clay tuyeres because the Khoe living in the Dikundu area copied this technology from them.

There existed several techniques of how to operate the bellows: P. K. Kampanzela[228] stated that pumping both cups simultaneously produced a strong airflow. Pumping the cups alternately produced a lighter airflow but this method was not as tiring for the ironworkers as the one mentioned before. From the Nyemba smelters in Sitave it is remembered that they used a specific pumping technique to avoid a blast of hot air that would burn the wooden

[220] At a given length of 1.8 to 2 m, a width of 0.3 m and a depth of 0.8 m (thigh height).

[221] Interview with Petrus Kashako Kaputura, Appendix 2.5.

[222] Interview with Petrus Kashako Kaputura, Appendix 2.5.

[223] Interview with Petrus Ndumba, Appendix 2.4.

[224] Interview with Petrus Kashako Kaputura, Appendix 2.5.

[225] Interview with Petrus Ndumba, Appendix 2.4; with Alberto Munoma Makayi, Appendix 2.8.

[226] Interview with Petrus Kashako Kaputura, Appendix 2.5; with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6.

[227] Interview with Headman Kavinja, Appendix 2.7.

[228] Interview with Petrus Kudumo Kampanzela, Appendix 2.1.

bellows.[229] Pumping the bellows for several hours was remembered to be a demanding task and for this reason only the strongest men among the ironworking crew operated them in Sitave. During the night of the smelt, ten to twelve individuals had to take turns at the two bellows.[230] At the Mbukushu smelting sites, every worker was expected to operate them to keep the furnace running.[231] At Kashivi, the master smelter started the operation of the bellows and was replaced by other members of his team. If not enough ironworkers were available, the smelters invited children to assist, yet it was not clear how many people were finally involved in the actual smelt.[232]

5.3.3.8. Iron and Refining

The following section summarizes the information on the metallic iron produced and its treatment after the smelts. The bloom that the Gciriku smelter obtained from one smelt was recalled as an elongated chunk of metal mixed with slag of the size of a lower leg of an adult person.[233] A bad smelt would generate a bloom as big as a lower arm. If the smelt failed, people were left with only numerous small pieces of iron approximately 1 cm in diameter, or the reduction of ore to elemental iron completely failed. Such poorly consolidated blooms and failed smelts were discarded in the same way as the slag. After the smelt, the bloom was taken to the forge near the homesteads and metal and slag were separated by beating the bloom out.[234]

From Vungu-Vungu (SC 12) it was remembered that the metallic iron precipitated in numerous thin longish pieces up to 15 cm in length.[235] It seems as if there was no consolidated big bloom. According to P. K. Kampanzela, one smelt could generate more than 100 small pieces of raw metal, but more commonly the yield of iron was less than that. Smelts below 30 pieces of metal were considered bad smelts. The numerous pieces of iron were consolidated in a forge near the furnace, no more than 5 to 10 m away from the furnace site.[236] Both P. Ndumba and P. K. Kampanzela stated that iron of good quality was hard, heavy and shiny. Iron of poor quality was brittle, light in weight and flaky. It is likely that the most disruptive loss of quality was not from the over-carburization of the elemental iron as discussed in section 1.4, but rather the lack of sintering in the furnace, which resulted in a bloom fragment of reduced weight and a brittle nature in the forge owing to too many slag inclusions. Refining treatments were also recollected from the Mashi smelters in Kapongo.[237] The blooms that they generated in their smelting pits were blocks of metal mixed with slag and probably fuel. Adhering slag was removed by hammering and once the bloom was sufficiently consolidated the iron was repeatedly heated and hammered to soften it.[238] 'Soft' in this case could refer to an increased ductility owing to less disruptive slag inclusions, and it certainly described a treatment of homogenizing and decarburizing the material in a forge. Van Tonder (1966, p. 264) documented another sophisticated bloom refinement technique that utilized a non-tapping smelting solution applied by some Mbukushu smelters: 'By the next morning the iron ore had melted together. They were then again hammered into smaller pieces. The pieces were then placed in a hole, approximately one foot deep, and covered with a thick layer of coals. Clay was again smeared on top of this and blowing started once more. This was continued until a sound like the hiss of a snake was heard, when they knew that the iron was finally 'coming together and leaving the stone'. It was then removed from the fire and beaten until only a pure bar of iron was obtained.' The procedure described here is the second step of bloom sintering in a small refining furnace (section 1.5.1.1). By doing this, the smelters avoided the initial refining steps, which frequently caused a high loss of poorly sintered crown material (section 1.5.1.2). The clay cover promoted a reducing environment and most probably served as a fluxing agent at the same time.

As illustrated in section 5.3.3, many participants of the oral history interviews recollected furnaces with slag tapping facilities. The most detailed description of the quality of the iron produced in a furnace of such kind was given by A. M. Makayi.[239] One average smelt produced five to six pieces of unrefined iron,

229 Interview with Alberto Munoma Makayi, Appendix 2.8.

230 Interview with Alberto Munoma Makayi, Appendix 2.8.

231 Interview with Petrus Ndumba, Appendix 2.4.

232 Interview with Petrus Ndumba, Appendix 2.4.

233 Interview with Petrus Ndumba, Appendix 2.4.

234 Interview with Petrus Ndumba, Appendix 2.4.

235 Interview with Petrus Kudumo Kampanzela, Appendix 2.1.

236 Interview with Petrus Kudumo Kampanzela, Appendix 2.1.

237 Interview with Headman Kavinja, Appendix 2.7.

238 Interview with Headman Kavinja, Appendix 2.7.

239 Interview with Alberto Munoma Makayi, Appendix 2.8.

and in exceptional cases up to ten of them. The sizes of the blooms varied. Big blooms were as large as half a loaf of bread, small ones could be the size of a cigarette box. Large blooms usually contained iron of better quality, which accumulated in the middle of the furnace pit, whereas iron of poorer quality collected along the furnaces walls. Small pieces tended to be brittle and light in weight, but it was not clear whether the brittleness owed to an over-carburization of the metal, or because it was not sintered enough and contained too many slag inclusions. A. M. Makayi further stated that good quality iron was heavy, which certainly referred to its compactness. A successful smelt generated three to four blooms of good quality and two of poorer consistency. Fewer than four pieces of raw material was considered a disappointing result. The ironworkers called the iron of poor quality *manyana*, which is a term generally used for slag and waste. It was given to the assistants of the smelt in reward for their help whereas the iron of good quality (*tshitima sha utale*) was kept by the smelters. Only those assistants who participated repeatedly in the production of iron were rewarded with metal of good quality. When the smelt was over, the ironworkers carried the raw iron to their homesteads and consolidated the bloom in a forge. A. M. Makayi recalled that to refine a bloom, it was necessary to again heat it up to high temperatures until it was glowing red, and it was then divided into smaller pieces with a large iron chisel. The consolidated smaller pieces of iron were then transformed to tools.[240] M. K. Shimbiringua[241] remembered too that the iron generated from the smelts at Gove (SC 17) was of varying quality. Hard metal was used for tool production whereas soft iron was used for jewelry. A smelt was regarded unsuccessful if the reduction of ore to elemental iron failed, or if the bloom did not sinter enough so that the metal remained unforgeable. Among the Kwangali ironworkers, brittleness during forging was also remembered as the main reason to discard iron. Iron of such bad quality was called *ruka*.[242]

It is very striking in the collective memory of iron production in the Kavango region that many participants of the interviews were convinced that their ancestors produced cast iron. Out of eleven interviews in which tapping furnaces were mentioned, seven reported that liquid iron was tapped from the furnace instead of slag and additional evidence comes from the unpublished manuscript of Maria Fisch (1980). As seen above the most detailed accounts were collected from the Mbukushu area (section 5.3.3.5). As cited earlier, Larson (2002, p. 250) was the first to document the existence of smelting facilities that produced cast iron. The interviews in Appendix 2.5[243] and 2.6[244] generated some more evidence and details: The iron was remembered as being viscous or liquid and of silvery color. It poured into a furrow leading away from the furnace (section 5.3.3.5) and solidified as one piece of metal 60 to 70 cm in length and as thick as the forearm of an adult man. After a couple of hours the ironworker removed the raw iron from the drain. It was also remembered that they were able to touch the hot iron because they had dipped their hands into a medicine before they started the smelt. From Dikundu (SC 12) it has been reported that the raw iron was taken to the forge in the village and the new iron was then divided into smaller pieces while it was yet to solidify. The first piece of metal that was cut was shaped into a big chisel and used to cut all subsequent chunks of iron. The remaining chunk was then reheated in the forge in order to soften and divide it into six smaller pieces. After the metal had been heat-treated, it was ready to be forged into tools. However, the given descriptions of the refining process were not very precise, most probably because I failed to insist on technical details during the interviews. The iron of local production, however, was remembered as being hard. Some contradiction arose with respect to the quality of the iron from Dikundu because the interviewees stated that there was no variation in quality, but in the same interview poor quality iron was described as brittle and light in weight.[245] In my opinion, this description would better apply to bloomery iron than to cast iron and most

[240] Interview with Alberto Munoma Makayi, Appendix 2.8; Interview with Headman Shiteketa M. Mbambangandu, conducted by Eileen Kose July 30, 2006, in Ndonga.

[241] Interview with Modestus Kashera Shimbiringua, Appendix 2.2.

[242] Interview with the Headmen Daniel Haikukutu, Jafeti Hainura, Hidion Karfere, Franz Semusi, conducted by Eileen Kose, August 6, 2007 in Nkurenkuru. Manuscript.

[243] Interview with Petrus Kashako Kaputura, Appendix 2.5.

[244] Interview with Petrus Kashako Kaputura, Appendix 2.5; with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6.

[245] Interview with Petrus Kashako Kaputura, Appendix 2.5; with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6.

probably people produced both bloomery and cast iron. Another most interesting contribution came from Fumu Mbambo Munika[246] who recollected how people used to cast metal tubes. According to him, the liquid iron was drained into a furrow into which a wooden stick was placed. The stick entirely carburized while the metal solidified and left a hole in the material. Another allusion to cast iron was found in the Shambyu area. According to N. Mbambangandu, during the smelt, the iron collected in the furrows that lead away from a pit furnace and it was covered with sand in order to cool down.[247] After one day, people removed the raw iron from the drain and cut it into smaller pieces. P. K. Kampanzela recollected that the blacksmiths hammer was made from a piece of cast iron that collected in an elongated depression at the bottom of the furnace.[248] Moreover, P. H. Kaputungu stated that the Shambyu people also cast muzzle-loaders, which were remembered as 'traditional guns' or *uta* (see section 5.3.4.3) (Bosch, 1964, p. 302).[249] Most likely, the tubes produced by the Mbukushu smelters described earlier served the same purpose. Cast iron production was also remembered from among the Kwangali,[250] yet without further details concerning the treatment and use of it (section 5.3.3.1).

5.3.4. Forging and the implements produced

Having described furnace design and technical smelting solutions on the previous pages, this section presents the forges and the range of implements and ornaments the local ironworkers produced. From the several stages of production in local historical iron production, only forging survived the introduction of European metal products (section 5.3.8). It appears that blacksmiths and their products were more visible to early European travelers and ethnographers than smelting because there exist considerably more descriptions of the blacksmiths' products and the forges than of mining and smelting. Yet in some areas, particularly among the Kwangali and Mbunza, the knowledge of iron production and procession was possibly lost as early as during their migration to the Kavango River in the seventeenth or eighteenth century (see section 2.4.7) and local demands became fulfilled by immigrant Nyemba and Chokwe blacksmiths.[251] Because of this, more research is needed to elucidate the historical ironworking traditions of the Kwangali and Mbunza, in particular among those people living in southern Angola and around Makuzu (section 5.3.1.1).

Modern-day smithies in the Kavango area consist of a small fire in a shallow pit or even on the ground, and a small pit or a bag in which some charcoal is stored. Moreover, modern ironworkers use bellows with a blow pipe, an anvil of local or European appearance, a hammer, pliers, and a container with water. When the mobile implements are removed, the place is no longer recognizable as a blacksmith's forge for someone of non-local origin.

5.3.4.1. Kwangali

The little information that I gathered from the Kwangali described that black-smiths were free to choose a workplace either inside or outside of homesteads. They bought refined iron from the smelters and forged their tools. As can be seen from Table 56 (Appendix 3), Kwangali blacksmiths produced standard tools such as axes, knives, spears, hoes, arrowheads and small implements for fishing and basketry, razors and fire strikers (flint and steel), and a type of copper bracelet called *musere*.[252] A similar range of products was described by Eedes (1933, as cited in Gibson, Larson & McGurk, 1981, p. 49). P. M. Siveva[253] also recalled iron jewelry such as necklaces and bracelets as part of the range of products, though as I said earlier, it was difficult to obtain any further information because today it is mainly Nyemba and Chokwe blacksmiths that practice skilled metalwork along the river west of Rundu.

[246] Fumu Erwin Mbambo Munika, personal communication, October 11, 2007 in Mukwe.

[247] Interview with Headman Nependa Mbambangandu, conducted by Eileen Kose, August 5, 2006, in Gove.

[248] Interview with Petrus Kudumo Kampanzela, Appendix 2.1.

[249] Interview with Paulus Haididira Kaputungu, Appendix 2.3.

[250] Interview with Hompa Daniel Sitentu Mpasi, conducted by Eileen Kose, August 2, 2006 in Nkurenkuru.

[251] Interview with the Headmen Daniel Haikukutu, Jafeti Hainura, Hidion Karfere and Franz Semusi, conducted by Eileen Kose, August 6, 2007 in Nkurenkuru.

[252] Interview with the Headmen Daniel Haikukutu, Jafeti Hainura, Hidion Karfere and Franz Semusi, conducted by Eileen Kose, August 6, 2007 in Nkurenkuru.

[253] Interview with Headman Paulus Mbundu Siveva, conducted by Eileen Kose, August 3, 2006, in Sikarosompo. Manuscripts.

5.3.4.2. Nyemba

Similar to the Kwangali, it seems as if among the Nyemba people blacksmiths could establish a forge close to or even inside of a homestead. It largely depended on whether there were small children around or not.[254] Alfred Schachtzabel, however, described that villages owned one shared forge, which were laid out at a certain distance from the homesteads and were protected with a shelter. Every skilled man of the village could use the public forge (Heintze, 1995, p. 217). An even more economic description was provided by Johnston (1893, p. 99). As mentioned earlier he stated that all implements were produced right at the smelting site and people would not leave their temporary camps until enough new tools were forged for everyone's needs. A. M. Makayi described that to produce a tool the blacksmiths took a piece of refined iron and heated it in the forge until it glowed red.[255] Then they divided it into smaller pieces and shaped it into the desired form. The most important blacksmith's tools were an iron hammer, iron pliers called *rumana*, an anvil that consisted of an iron head or hammer, which was set in a large chunk of wood, an iron chisel, two types of sharpening stones and one bellows with a blow pipe measuring roughly 50 cm in length. Cold water was used to harden their tools. As can be seen in Table 54 (Appendix 3), the blacksmith used charcoal from the same type of tree as they did for smelting. The hammer scale produced during forging was called *manyana utale*. The implements produced by the Nyemba blacksmiths were mainly hunting weapons (Table 56, Appendix 3).[256] The range of tools comprised two types of spears, four types of arrowheads all used for hunting game, birds, and large fish, a single and a double edged knife, harpoons for fishing, hoes, and two types of ax. The *kakundu* ax was used for domestic and hunting purposes, whereas the *mutaka* type was an ornamented war ax for beheading (Heintze, 1995, p. 135).[257] The same range of tools was observed by Johnston (1893, p. 99) who also mentioned iron snuff spoons. Some blacksmiths also manufactured iron jewelry (e.g. foot bangles called *tshinjede*[258]) (Heintze, 1995, p. 218). In addition, Serpa Pinto (1881, p. 119) documented the production of what he called shovels and nails. The Nyemba ironworkers were also skilled at producing guns[259] and bullets for muzzleloaders (Heintze, 1995, p. 218; Serpa Pinto, 1881, p. 120). Apparently, the iron was softened with the fat of oxen and salt in order to make it suitable for the manufacturing of weapons of such kind, yet Serpa Pinto (1881, p. 120) gave no deeper description of the technical details of this treatment. Like Johnston (1893, p. 99), he claimed that the ironworkers lived in separate camps during the smelting period and worked several weeks for 24 hours until all work was completed and enough new tools had been produced. From the Kafuma and Kakeni region there is some evidence that people also manufactured copper jewelry, yet it is not known from where the raw copper originated.[260]

5.3.4.3. Shambyu

Among the Shambyu people, blacksmiths established their forges close to but always outside of their homesteads at a place that they repeatedly used. The charcoal was made from the same tree species as in smelting (Table 54, Appendix 3).[261] The blacksmiths fabricated their charcoal in the bush where they found suitable trees, which were cut down, split and burnt for charcoal. If the fire made from these tree burnt red, people put soil on the burning wood to stop the fire. After one day, the charcoal was ready to be used in the forge. In the past, the ironworkers used a big piece of raw iron as an anvil, and today, they often use a European-style implement. The most important tool was an iron hammer, which they cast at the bottom of a smelting pit, as has been described above. Whenever they needed a new hammer in the forge, they dug an elongated depression into the bottom of the furnace and had the liquid iron collect there. This piece of raw iron was later used as a blacksmith's hammer but sometimes they simply used a big piece of well-consolidated iron. Additionally, the blacksmiths equipment consisted of a sharpening stone and one or two bellows depending on the number of people who forged. The hot iron items were touched and

[254] Interview with Alberto Munoma Makayi, Appendix 2.8.

[255] Interview with Alberto Munoma Makayi, Appendix 2.8.

[256] Interview with Alberto Munoma Makayi, Appendix 2.8.

[257] Interview with Alberto Munoma Makayi, Appendix 2.8.

[258] Heintze (1995, p. 279).

[259] Unfortunately, Serpa Pinto (1881, p. 120) did not describe the type of gun.

[260] Interview with Alberto Munoma Makayi, Appendix 2.8.

[261] Interview with Petrus Kudumo Kampanzela, Appendix 2.1.

moved with wooden sticks.[262] Tools were hardened in cold water.[263, 264] Most items produced by the Shambyu blacksmiths were used in hunting. People remembered three types of knives, four types of spears, five types of metal arrowheads and a fishing spear (Table 56, Appendix 3). Harpoon-like hunting weapons were used in traps for elephant and hippopotamus hunting. Axes and adzes were used in hunting and in other crafts, particularly in woodcarving (Fisch, 2008, p. 24). People also crafted guns (see also Bosch, 1964, p. 202; Gibson et al., 1981, p. 109). Gibson et al. (1981, p. 129) further stated that people manufactured copper rifles but unfortunately they gave no further information as to the production process of them. As described in section 5.3.3.8, another type of gun was breechloaders, named *uta* and analogous to the traditional hunting bow (Fisch, 2008, p. 36).[265] Gunsmiths were also reported from central Angola in the middle of the nineteenth century and there was obviously a great need for local gun production and repair (Travassos Valdez, 1861, p. 329; Von Oppen, 1993, pp. 170-175). The role of firearms in Kavango society is briefly mentioned in Shiremo (2010, p. 62). According to him it was a privilege to own them and only a few people, in particular sovereigns, had access to them. Firearm ownership garnered respect, power and fear. However, the Act of Brussels from 1890 prohibited the sale of European firearms to Africans (Shiremo, 2010, p. 99). It was a big economic loss to numerous local hunters and certainly threatened the dominion of many African rulers. It seems possibly that this interdiction motivated the Kavango peoples to start their own local gun production.

For agricultural tasks, only one type of hoe was produced, and a special knife-like needle was needed in basketry. Personal items among the range of tools were razors, fire striker (steel and flint) and the blacksmiths' hammers and anvils (Table 56, Appendix 3) (see also Bosch, 1964, pp. 302-303).[266] It appears as if the ironworkers selected the raw material according to its quality and soft iron was used for the manufacturing of bracelets and foot bangles.[267] Some detailed descriptions of the making of wooden handles can be found in the attached interview with P. K. Kampanzela.[268]

5.3.4.4. Gciriku

According to Pater Bierfert's account, the forges were located outside of the village under a shady tree (Bierfert 1938, p. 15). Furthermore, P. Ndumba stated that the forges were supposed to be outside of the precincts of the smelting sites, but he did not remember the reason why.[269] The blacksmith's tools consisted of an iron hammer (*tshindoma*) and an anvil (*liyundo*) that consisted of a piece of iron set in a large chunk of wood, and of iron pliers (*tshimana*). The fire of the forge was ignited by one bellows (*muduye*) together with one blowpipe (*likera*). Furthermore, a blacksmith's shop needed a sharpening stone called *liwe ya kurora* (see also Bierfert, 1938, p. 15; Gibson et al., 1981, p. 171). The Gciriku had the same selection of implements as the Shambyu and most of them were hunting tools (Table 56, Appendix 3). However, Gibson et al. (1981, p. 171) stated that blacksmiths also forged leg ornaments out of copper and brass. Another important tool was the fishing spear *musho*. On the one hand it served to lancinate larger fishes and on the other hand it was used to burn shaft holes into the wooden handles of axes and adzes. The charcoal was made from the same tree types as for smelting because, according to P. Ndumba, the embers would last and produce high temperatures.[270]

5.3.4.5. Mbukushu

It seems as if the forges among the Mbukushu were always located within the precincts of a village. Blacksmiths always worked outside of the fenced in zone of the homesteads under a tree because a forge put children at risk and brought fire hazards to the

262 Interview with Petrus Kudumo Kampanzela, Appendix 2.1.

263 Interview with Modestus Kashera Shimbiringua, Appendix 2.2.

264 According to Fisch (1980), the Shambyu used no hardening or other upgrading techniques in smithing. This is the reason why iron tools made by the Totela in southwestern Zambia were considered more valuable than the local ones.

265 Interview with Paulus Haididira Kaputungu, Appendix 2.3.

266 Interview with Petrus Kudumo Kampanzela, Appendix 2.1; Interview with Modestus Kashera Shimbiringua, Appendix 2.2.

267 Interview with Modestus Kashera Shimbiringua, Appendix 2.2.

268 Interview with Petrus Kudumo Kampanzela , Appendix 2.1.

269 Interview with Petrus Ndumba, Appendix 2.4.

270 Interview with Petrus Ndumba, Appendix 2.4.

homesteads. Every homestead had its own workplace and at least one person who knew how to forge.[271]

Blacksmiths of the Mbukushu used an iron hammer (*mweto*) and an anvil (*dyundo*), which consisted of a conical piece of iron with a flattened end set in a large chunk of wood. Additionally, blacksmiths used large stones as an anvil, which they collected along the river and brought to the sandy areas in the hinterland (Köhler, 1997, p. 270). Pliers (*mayura*) were made out of two pieces of tree bark. Before touching the hot iron, the ironworkers dipped the pliers into water. Blacksmiths also used fine-grained sandstones from the river to sharpen their tools. Bellows (*mwandhe*) were used to ignite the fires and were connected to the forge by a clay tuyere (*dikera*). Cold water was used to harden the tools. The charcoal was made from the same tree species as used in the smelting process because these charcoals produced a hot glow. It was (and still is) also important to use the correct type of wood, otherwise the iron would loose its quality and become brittle.[272] Van Tonder (1966, p. 246) reported that the ironworkers' tools were bequeathed within a family and neither given to another blacksmith nor sold.

Like their neighboring groups, the Mbukushu fabricated mainly hunting and fishing implements, and it seems noteworthy that they had five different types of spear (Table 56, Appendix 3). Only hoes were used in agriculture (Table 56, Appendix 3) (see also Larson, 1975, pp. 109-110; Larson, 2002, pp. 250-251; Schulz & Hammar, 1897, pp. 208-209). Mbukushu blacksmiths also crafted guns (see section 5.3.3.8), which were probably a type of muzzleloader (Gibson et al., 1981, p. 230). Axes and adzes were used for hunting and wood work, and a specific chisel-like tool was made exclusively for woodcarving. According to Köhler (1997, p. 255), Mbukushu and Khoe copied the *mutaka* war ax of the Nyemba and wore them as personal weapons. Iron razors for men and cosmetic knives for women belonged to the personal sphere of an individual. Moreover, people crafted iron and copper jewelry. Among the latter, copper leg rings were seen as sign of wealth and prestige (Van Tonder, 1966, p. 270) and were made from copper acquired from Ovambo copper traders (Passarge, 1905b, pp. 299).

Altogether, the range of products described in section 5.3.4 is probably incomplete. It appears to me that some implements escaped the memories of the informants because they are not used anymore, in particular when it comes to jewelry or specific hunting weapons. However, the implements are representative as to the fields of activities for which they were, and still are, produced.

5.3.5. Trade and exchange

The next sections describe the role and value of the iron implements in the Kavango societies. Questioning the people in the research area about trade and price rates soon made it clear that European notions of the value of things were more than misleading. Every interviewee informed me that in former times prices in a modern sense did not exist. People lived in reciprocal exchange relationships with family members and neighbors, and produced iron mainly for their own need. The exchange values that the informants remembered were vague and only given because I insisted on having at least some reference values. Many things were given away free of charge, yet the currency behind the ‚free of charge information' was the expectation of getting something in return on another occasion. Only those who traded with neighboring Bantu-speaking peoples fixed exchange rates to some extent. Table 57 (Appendix 3) shows some equivalent values in domestic animals or portions of plant food. However, the compilation is misleading in that it was not strictly required to pay the blacksmiths with these goods.

5.3.5.1. Kwangali

The Kwangali people produced iron largely for their own needs, but there is evidence that they sold implements to their neighbors too (Andersson, 1861 as cited in Otto, 1987, p. 195).[273] Other visitors to the Kwangali region at the turn of the twentieth

[271] Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6, and with Petrus Kashako Kaputura, Appendix 2.5.

[272] Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6, and with Petrus Kashako Kaputura, Appendix 2.5.

[273] Interview with Hompa Sitentu Mpasi, conducted by Eileen Kose, August 2, 2006 in Nkurenkuru, and with the Headmen Daniel Haikukutu, Jafeti Hainura, Hidion Karfere and Franz Semusi, August 6, 2007 in Nkurenkuru.

century mentioned that they bought implements from neighboring peoples (Jodtka, 1902, p. 591; Volkmann, 1901, p. 867), for instance from the Ovambo and San (Laubschat, 1903, p. 680). What all the reports from early European travelers had in common is that they did not describe either places or the circumstances under which the iron tools were purchased. The overall lack of smelting sites in the modern-day settlement area of the Kwangali (Figure 216), along with my difficulties finding skilled informants suggests that iron production was no longer performed when the Kwangali settled along the southern banks of the Kavango River (section 5.3.2.1).[274] As will be described later, P. Ndumba[275] stated in his interview that Gciriku blacksmiths from Nyangana sold their tools in Nkurenkuru to the Kwangali. P. M. Siveva remembered that although the Kwangali had their own iron production, they purchased implements from the Nyemba. For one cow, one would get 10 to 12 axes or hoes.[276]

5.3.5.2. Nyemba

All over the Kavango, the Nyemba people were known to be skilled ironworkers. Historical accounts described blacksmith traders traveling to their southern neighbors to sell tools and refined iron (Otto, 1987, p. 195). However, there existed regional variation as to the range of implements produced and sold. Serpa Pinto (1881, p. 23) observed that certain Nyemba groups produced only specific types of arrowheads, bullets and knives, whereas shovels (hoes?) were bought from other Nyemba neighbors. In addition some Luchazi living close to them provided them with war axes, other types of arrowheads and spears. From the Kafuma smelters it was remembered that some items such as axes, hoes, knives and spears were exchanged for goats, chickens or a certain quantity of millet (Table 57, Appendix 3).[277] A. M. Makayi provided equivalent values in centavos (Table 57, Appendix 3), which probably referred to the Angolan currency Angolar, valid from 1928 to 1958. However, he gave contradictory information as to the values of the tools. An adult bovine had an equivalent value ranging from two hoes and one ax to 10 hoes or 10 axes.[278] Irrespective of the exchange value that he remembered, iron had the lowest value among the Nyemba people compared to other communities living along the river. The blacksmiths also lent out tools for free. Another currency was charcoal or labor. The Nyemba blacksmiths exchanged the heads of harpoons (*mumba*) only for charcoal for the forge. From one bag of charcoal they were able to manufacture two harpoon heads: one was for the customer, the other for the ironworker. Customers could also pay with field labor or assistance in the smelts whenever they were in need of new arrowheads. For one day's work, people obtained two to three arrowheads, depending on their commitment to work. The ironworkers also exchanged three arrowheads for one chicken. Fire strikers cost two days of labor. A man who intended to marry was expected to pay one cow to his future in-laws. Alternatively, he could offer four hoes and one ax, which he could earn from the blacksmith by working in the field. Unrefined pieces of the bloom were only provided to the smelting assistants. A. M. Makayi recollected that smelting attracted many people owing to the opportunity to obtain some iron. According to him people came from Kuji, Ilonga, Tshithimba, Tshiwambi, Luntovu and Cahema, all places about 30 to 50 km away from Sitave.[279]

5.3.5.3. Shambyu

Among the Shambyu, ironworkers mainly produced tools for their own families and friends. People from other households or neighboring settlements could barter the tools that they needed. However, as mentioned earlier, there existed no fixed price rates in the modern sense. The blacksmith gave tools free expecting a service in return later, yet some blacksmiths sold to the Nyemba, Kwangali, or Mbukushu people. In the case that iron items were sold to an outsider, they made sure someone in the community or region knew the buyer. They never traded implements to unidentified individuals since they feared foreign people would use the iron weapons against them.[280] The most high-priced items were spears because they were considered the hunter's pride and means to kill game.

[274] For a brief description of their migration see Kampungu, (1965, pp. 36-39) and Fleisch and Möhlig (2002).

[275] Interview with Petrus Ndumba, Appendix 2.4.

[276] Interview with Headman Paulus Mbundu Siveva, August 9, 2006 in Sikarosompo.

[277] Interview with Alberto Munoma Makayi, Appendix 2.8.

[278] Interview with Alberto Munoma Makayi, Appendix 2.8.

[279] Interview with Alberto Munoma Makayi, Appendix 2.8.

[280] Interview with Modestus Kashera Shimbiringua, Appendix 2.2; with Petrus Kudumo Kampanzela, Appendix 2.1.

Spears had an equivalent value of one bovine, alternatively eight chickens, or three female goats together with one male goat, or 50 kg of *mahangu*. Tools associated with less status than spears were, according to a western understanding, disproportionately cheap. Hoes,[281] axes, knives, and fishing spears could be given away for two chickens or one young goat. Alternatively, one could provide 12 kg of millet. According to P. K. Kampanzela, all these implements were traded for the same price, even though knives, for instance, consisted of less metal than axes and hoes. For one bovine, one could get three axes or hoes, five knives or one spear (Table 57, Appendix 3).[282]

H. P. H. Kaputungu[283] stated that in the early days of the Shambyu kingdom, all iron implements legally belonged to the sovereign and iron tools and weapons were stored in the royal residence. People thought that in the event of warfare all weapons were available at once in the palace. The Hompa lent implements out to his commoners, particularly for agricultural work, and private users had to bring them back to the residence after work. Furthermore, hunting weapons had to be returned to the ruler, which allowed her or him complete control over the hunting activities of the commoners. This was necessary to defeat illegal trade with elephant tusks without the sovereign's knowledge (see section 5.4).[284] H. P. H. Kaputungu further remembered that another reason to centralize all the weapons in the royal court was the war of the Kwanyama and Kwangali against the Tjaube King Mankoto. This military campaign was instigated by the Shambyu Queen Mushinga and her sister Nashira in order to conquer the Tjaube polity, and the availability of iron weapons was the key to victory (section 5.3.7.3). When Queen Mushinga took over rule of the Tjaube country and all its skilled ironworkers in the first half of the nineteenth century,[285] people decided to dig a large pit at Gove (SC 17) in order to hide the most important and valuable goods of the community, and to protect them from pillage in the event of war.[286] It is said that the elderly and blind Queen committed suicide while she examined the goods that were stored there. This was believed a bad omen and Queen Mushinga was buried with all the goods in the pit.[287], [288] It is not clear whether the centralization of iron implements happened only under the rule of Queen Mushinga or whether it was continued by her successors. As described above, the ownership of implements remembered by M. K. Shimbiringua and P. K. Kampanzela was more liberal, yet trading iron tools to foreigners was not accepted. It might be possible that the monopolization of implements became less important with the decline of the ivory trade due to overhunting at the end of the nineteenth century, but more research is needed to support this assumption.

5.3.5.4. Gciriku

Contrary to the Shambyu, it has been remembered that the Gciriku blacksmiths sold their implements to the neighboring villages.[289] Some blacksmiths even traveled as far as Nkurenkuru in order to sell their tools to the Kwangali and the journey took them 2 weeks or more. At this time, the Kwangali around Nkurenkuru produced no iron (see section 5.3.5.1). P. Ndumba recollected that those blacksmiths who traveled repeatedly to Nkurenkuru acquired a second wife in one of the villages along the route in order to have a place to sleep over on their journey. Usually, the blacksmiths traveled with assistants, which were mostly young men. Each assistant had to carry five to 10 hoes, 10 axes and some knives. The Gciriku blacksmiths also maintained trade

[281] These days, a hoe without handle costs about 50 N$, with handle it costs about 70 N$.

[282] Interview with Petrus Kudumo Kampanzela, Appendix 2.1.

[283] Interview with Harupe Paulus Haididira Kaputungu, Appendix 2.2.

[284] According to Shiremo (2009, p. 100) the killing of an animal owned by the ruler was prosecuted with a fine of 15 bovines.

[285] According to Fleisch & Möhlig (2002, p. 137) Queen Mushinga ruled from 1820 to 1858.

[286] In the Shambyu chronicle Kwangali and Mbunza were said to have frequently attacked the Shambyu during the rule of the very early King Shakampiringi, and to have robbed them of their hoes and other belongings (Fleisch & Möhlig, 2002, p. 132). The rule of King Shakampiringi is not well documented and he might have lived three generations before Queen Mushinga. There is also some contradiction in these records because King Sakampiringi is associated with crops and hoes, i.e. agriculture. Yet the same chronicle stated that agriculture did not start before the rule of Queen Mushinga (Fleisch & Möhlig, 2002, p. 138).

[287] Interview with Harupe Paulus Haididira Kaputungu, Appendix 2.2.

[288] According to the Shambyu chronicle as F. J. Hausiku (in Fleisch & Möhlig 2002, pp. 139-140) told it, the elderly Queen Mushinga moved to a solid pit house, after having lost her sight, in which she passed away. The Tjaube chronicle, however, handed down that she committed suicide (Fleisch & Möhlig 2002, p. 51; see also Hartmann, 1987).

[289] Interview with Paulus Ndumba, Appendix 2.4.

relationships with Mbukushu communities nearby.[290] Most probably it was easier for those communities to get the implements from their neighbors than from their own smelters. It seems as if the ironworkers from the Nyangana area had clearer defined exchange rates (Table 57, Appendix 3), yet a number of implements were inalienable for various reasons. Only hoes, large axes, knives and the *liwonga*-type spear were given to foreigners. The first had an exchange value of a medium sized goat or a big basket of millet. Knives were given away for varying quantities of millet depending on their size but always for one chicken or 20 ct., yet it was not clear to which time and currency the 20 ct. referred to. Spears were exchanged for one or two chickens or the same number of small baskets of millet, corn, nuts or beans. According to P. Ndumba's account it was most profitable to participate in a smelt. The small axes were given to the assistants of the ironworkers in return for their services.[291] They belonged to the standard hunting gear of every man (Fisch, 2008, pp. 23-24). The *karumbi*-type spear was considered a personal weapon, which protected its owner.[292] A smelting assistant could acquire them in return for their services at a furnace or forge, and friends could borrow *karumbi* spears from the ironworkers or their helpers. Another advantage was to receive arrowheads for their services because blacksmiths forged them for the smelters from the new raw material. Some helpers earned a fishing spear, which otherwise was only provided to male family members. Razors and fire strikers were lent out or provided free of charge by the blacksmiths to friends, family members and helpers.[293] It seems that among the Gciriku, assisting in smelting or forging was a most profitable undertaking because those associated with the skilled ironwork had access to the desired hunting tools, and both were affiliated to status and prestige.

5.3.5.5. Mbukushu

Among the Mbukushu, the trade customs strongly varied. The informants from Dikundu (SC 30) stated that every village and family produced for their own needs. Occasionally, people sold implements to communities that were not in possession of a smelting location.[294] These people had to exchange goods in order to get the implements they needed. Axes and hoes were the most expensive items because they had an exchange value of one bovine, two to five goats, or a large quantity of millet. Knives were exchanged for one goat, one to three chickens or a small quantity of millet, depending on the size of the tool. An adz could be bartered for one chicken. Some ironworkers sold spears for one goat, others considered it a personal weapon, which they would never sell. People did not give away arrowheads and fishing spears. They were provided free of charge, expecting a service in return later. Cosmetic knifes and razors were considered personal and not even lent to other people. Another private implement owned by a family were the hooks for hunting crocodiles though they were lent to neighbors. Comparing the exchange rates of the Mbukushu ironworkers to those of the Gciriku blacksmiths, it was cheaper for a Mbukushu community to buy from their neighbors than from their own ironworkers. Schulz and Hammar (1897, p. 210), for instance, observed in the nineteenth century that certain Mbukushu bought implements from people north of the Zambezi River, which misled them to conclude that the Mbukushu had no local iron production at all. Quite the contrary, Passarge noticed at the beginning of the twentieth century that the Mbukushu traded locally manufactured iron implements along the Kavango River to the Ovambo and Tawana. In exchange, they obtained copper jewelry and raw copper from Ovambo traders and the latter was processed into ornaments by local blacksmiths (Passarge, 1905a, p. 701; 1905b, pp. 295, 299; Wilmsen, 1997, pp. 293, 299). Both descriptions conflict with the evidence of local iron production on the one hand, and the statement that every community produced for its own needs on the other hand. Again, Larson (2002, p. 251) reported that the Mbukushu of Botswana were sophisticated blacksmiths and their tools were in great demand among the neighboring peoples. According to Köhler's compilation of narratives provided by the Khoe around Dikundu (SC 30), the ore deposits of the site were originally only used by Mashi smelters who produced iron implements in the bush, and sold them to Mbukushu living in Mukwe (Köhler, 1989, p. 388). Headman Kavinja

[290] Interview with Paulus Ndumba, Appendix 2.4.

[291] Interview with Paulus Ndumba, Appendix 2.4.

[292] Interview with Paulus Ndumba, Appendix 2.4.

[293] Interview with Paulus Ndumba, Appendix 2.4.

[294] Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6, and with Paulus Ndumba, Appendix 2.5.

described a similar scenario.[295] From the given examples it is not entirely clear when the Mbukushu living along the main river started to use the deposits around Dikundu, and which were the local iron production centers in other parts of the Mbukushu territory. However, the gathered evidence suggests that there existed strong local variations as to the commercial habits of the people.

5.3.5.6. Trade and exchange with San people

A most important exchange partner of the Kavango groups were the San peoples of northern Namibia and southern Angola. The intense trade relationships between these ethnic groups have been discussed in Kose (2009b, pp. 142-145) for the middle Kavango region, and in a wider geographical context in Wilmsen (1989; 2003), Gordon (1984) and Shapera (1963, p. 146). The Kavango groups provided San people with pottery, metal implements, agricultural products such as millet and milk, tobacco, glass beads and other things, and received meat, honey, animal skins, ostrich products, and wild fruits in return (Scott, 2003, pp. 25-28; Wilhelm, 1954). The information gathered during the interviews suggested that considerably more items from the Bantu-speaking Kavango groups found their way to the San people than to their Bantu-speaking neighbors. With respect to iron implements, locals remembered that San people worked for the Kwangali and received knives and axes in return for their service, or else they exchanged wooden bows and arrows for iron implements.[296] Others stated that the Kwangali furnished many things free of charge knowing that they would obtain something in return later.[297] San people also lived in close interrelationship with their Bantu neighbors in Angola (e.g. Biesele, 2002, p. 60; De Almeida, 1912, pp. 74-75; Estermann, 1977, p. 12-13; Köhler, 1989, p. 427) and were involved in the iron smelting of the Kwanyama people (Herbert, 2001; Kose, 2009a, pp. 136-140). A. M. Makayi remembered that in Nyemba communities, axes were given away for meat and honey.[298] According to J. M. Kenga, Chokwe communities also maintained close relationships with San groups and sometimes they lived together in the same household. Knives were provided for free and axes were exchanged for meat and honey. The Chokwe also provided traveling San with food, if necessary.[299] Beyond the exchange of goods and implements described here, the Shambyu provided San groups with refined iron, which they worked into arrowheads.[300] The Mbukushu informants from Dikundu recollected that San received arrowheads and axes from them.[301] Oswin Köhler's thorough studies of Khoe communities in the Mbukushu area are valuable testimonies of the close interrelationships between both peoples (Köhler, 1989; 1997). In these interviews, his informants stated that the Khoe people learned the iron trade from the Mbukushu and Nyemba (Mbwela). Mashi people provided the Khoe with hammers, anvils and refined raw iron (Köhler, 1997, pp. 258-261). The latter carved bellows like those of the Mbukushu, fashioned tuyeres from hard termite clays and copied the products bartered from their neighbors (Köhler, 1997, pp. 264-276).

5.3.6. Rituals, taboos and cosmologies

In most African societies, crafts and every aspect of live have been embedded in a coherent cosmological system that structured and explained the world and human existence. Metallurgy has not only been seen as a succession of physical and chemical processes, rather it was and still is understood as an interplay of spiritual force, practical experience and the compliance to cosmological rules and prohibitions to avoid grievance and misfortune in life (e.g. De Barros, 2000, p. 164). Because of this, a full description of metallurgical traditions must reflect both the technology and anthropology of smelting (e.g. Chirikure, 2015, pp. 87-92; Herbert, 1993; pp. 1-5; Iles & Child, 2014, pp. 195-196). Among the many interviews that I conducted, most descendants of ironworkers remembered

[295] Interview with Headman Kavinja, conducted by Beatrice Sandelowsky, Appendix 2.7.

[296] Interview with Hompa Daniel Sitentu Mpasi, conducted by Eileen Kose, August 2, 2006 in Nkurenkuru and with Headman Paulus Mbundu Siveva, August 9, 2006 in Sikarosompo.

[297] Interview with the Headmen Daniel Haikukutu, Jafeti Hainura, Hidion Karfere and Franz Semusi, conducted by Eileen Kose, August 6, 2007 in Nkurenkuru.

[298] Interview with Alberto Munoma Makayi, Appendix 2.8.

[299] Interview with Johannes Mashela Kenga, conducted by Eileen Kose, July 26 and 31, 2007 in Vungu-Vungu.

[300] Interview with Petrus Kudumo Kampanzela, Appendix 2.1; with Modestus Kashera Shimbiringua, Appendix 2.2.

[301] Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6 and with Petrus Kashako Kaputura, Appendix 2.5.

the cosmological aspects of iron smelting, i.e. the rituals and taboos, in detail, while technological descriptions often lacked precision. In my opinion, this imbalance in the collective memory reflects the importance of cosmological, or cognitive-symbolic parameters in iron smelting, and suggests that the fulfillment of these parameters was more important than any technological requirement.[302] All over Africa, iron smelting was highly ritualized and the complicated technologies and transformations of iron production were seen on the same lines as other processes of life and nature. The metamorphosis of stones to metal was perceived as analogous to human reproduction and childbirth, and was subject to similar beliefs, norms and taboos (Herbert, 1993, pp. 78-85). One important taboo demanded sexual abstinence of the smelters prior and in particular during the smelt, because their legal wives were considered competitors to the female furnace, and sexual activity was equivalent to committing adultery. In many African societies, it was believed that adultery provoked accidents of the legal partners, and caused pregnant women to abort. Consequently, the sexual abstinence of the ironworkers prevented the furnace from miscarrying, and women were banned from the precincts of mining and smelting in order not to seduce the male ironworkers (Childs & Killick 1993, p. 327; De Barros, 2000, p. 169; Herbert, 1993, pp. 80-82). Another important reason to ban fertile women from smelting and mining sites was seen in menstruation blood, which was considered a contaminating force on many aspects of daily life. Menstrual blood represented a failure to conceive and consequently the presence of menstruating women could cause a smelt to fail (Herbert, 1993, pp. 85-88). The requirement of the spiritual seclusion of smelting sites as it has been practiced in many African societies goes back to the reasons described before. Yet seclusion could take on many forms and it was implemented in a variety of ways (Chirikure, 2015, pp. 88-92).

In most African societies, power and knowledge was (and is) linked to a person's age. Elderly people received respect because of their spiritual and practical expertise. The most influential position in an age hierarchy is granted to the ancestors of a family, clan, or landscape, who were believed to control and manipulate success or failure in many aspects of societal life. The support from the ancestors was also a key in successful metallurgy and as significant as the tangible and spiritual ingredients of a smelt. However, despite the seclusive character of smelting sites, smelts failed from time to time and this was explained by transgressions of the sexual taboos, the presence of women, the viciousness of neighbors and by displeased ancestors (summarized in De Barros, 2000, pp.164-167).

Ironworkers held a special position in most African societies owing to their esoteric ability to communicate with the spirit world. Frequently, they were also healers and sorcerers. Because of this, in many African cultures metalworkers were perceived as dangerous competitors to rulers, not only because of their ability to manipulate spiritual powers, but also because of their esoteric and physical skills to produce dangerous weapons. Many African societies handled this danger by including ironworking into concepts of political power. Frequently, sovereigns were seen as blacksmiths or descendants of a mythical blacksmith king, and in many African monarchies, royal regalia included iron objects. In some polities, only the royal clans carried out iron production, in other countries, sovereigns strongly controlled the ironworking families or clans (De Barros, 2000, pp. 161-164; De Maret, 1985; Herbert, 1993, pp. 132-150). Usually, only adult mature men were involved in smelting because it was believed that expertise and responsibility in all fields of smelting increased with a person's age (Childs & Killick, 1993, p. 326).

Most publications on iron cosmologies have focused on taboos found in the sphere of smelting, but comparably little attention has been paid to the cosmologies of forging. Scholars have frequently believed that the sphere of forging was (and still is) less ritualized or less loaded with esoteric beliefs because it was less secluded compared to the smelting process (e.g. De Barros, 2000, p. 167). However, collecting information about the skilled knowledge of the blacksmiths from the Kavango region revealed that smithing did not and still does not exist in a cosmological vacuum. It was embedded in the same rules and taboos that surrounded iron smelting and brought about the same mutual and complex cosmological interrelationship of the procreative power of man and woman as seen in iron production.

On the following pages, I provide a detailed account of the rituals and taboos remembered by the local informants with respect to iron and tool production. In section 5.4, I intend to embed these rules and beliefs into a broader

302 The importance of non-technological additives in successful smelting is well described in Dupré & Pinçon (1997, pp. 133-134).

cosmological framework of the Kavango peoples, and to interpret them against the background of the far-reaching cosmological concepts of Africa discussed in Herbert (1993).

5.3.6.1. Kwangali

The Kwangali interviewees remembered only fragmentarily information on rituals, taboos and cosmology. However, all taboos belonged to the general concept of seclusion, which banned women from mining and smelting activities. The ironworkers were not allowed to sleep at their homesteads during the mining and smelting period because any contact with women would impair the quality of the tools produced. Furthermore, women were not allowed to touch the ore. Moreover, it was believed that the fire from the smelting furnace would affect women's health and was thought to produce headaches when taken to the homesteads. The same was true for embers from the forge. Generally, women could be present at the smithy but it was not allowed for them to cross the bellows.[303]

5.3.6.2. Nyemba

There was not enough information available to describe the rituals and taboos of the Nyemba in full and the sparse historical reports from the northern groups suggested that some ritual differences existed amongst them. In the Kafuma valley, the smelting sites were near the places where people permanently lived, but ordinary people had to respect the seclusive nature of these camps.[304] It was not entirely forbidden to visit, but it was not welcomed either. The smelting camp was particularly a taboo zone for fertile women because they were considered a threat to the success of a smelt, yet post-menopausal women were not believed to be dangerous anymore. Furthermore, the smelt was carried out at night to avoid visitors who might have had the power to influence the outcome of the smelt in a negative way. The ironworkers also had to abstain from sexual contact with women during the smelting season. Breaking the taboo of sexual abstinence was thought to cause fire accidents and to affect the quality of the metal so that it became brittle. Even the tools forged from such iron were thought to break more easily. Moreover, sexual contact would prevent the ore from transforming into metallic iron. Once a person was found guilty of transgressing the rules and taboos, the whole community would condemn and abandon the guilty individual.[305] Likewise Serpa Pinto (1881, p. 120) mentioned from Nyemba smelting sites in central Angola that no women were allowed to approach the camps of the ironworkers because otherwise the metal would have been spoiled. The charcoal used in smelting was spiritually powerful and it was not allowed to use it for fires in the homesteads. Every individual ironworker asked his ancestors for assistance before they started the smelt. During the smelting period, the crew subsisted on the game and fish they had hunted themselves since they rejoiced in their work so much that they did not feel like killing domestic animals. They drank alcoholic beverages and milk. The ironworkers were expected to dress up like elderly women with game hides and blankets. Those ironworkers who operated the bellows wore a headdress of ostrich feathers to express that they were rejoicing in their work. Around midnight, the smelting crew started to drink alcoholic beverages in order not to get tired and the people from the villages shouted and sang encouragement from there. If the smelt was successful, everybody celebrated the smelt. Those ironworkers who operated the bellows sang specific songs the whole night through. These songs were believed to supply mental and physical power preventing the ironworkers from becoming exhausted during the demanding work. One song was the praise song of Ndungulume:

Tumuyeveye Ndungulume wadhala
kantjala kumutwe.

Let us operate the bellows for Ndungulume
who puts a headdress on [his] head[306].

(Nyemba; A. M. Makayi; text collected by E. Kose, translation by H. & R. Ndumba and W. J. G. Möhlig).

[303] Interview with Headman Paulus Mbundu Siveva, conducted by Eileen Kose, August 3, 2006, in Sikarosompo, and with the Headmen Daniel Haikukutu, Jafeti Hainura, Hidion Karfere and Franz Semusi, conducted by Eileen Kose, August 6, 2007 in Nkurenkuru.

[304] Interview with Alberto Munoma Makayi, Appendix 2.8, and with Headman Shiteketa M. Mbambangandu, conducted by Eileen Kose July 30, 2006, in Ndonga.

[305] Interview with Alberto Munoma Makayi, Appendix 2.8, and with Headman Shiteketa M. Mbambangandu, conducted by Eileen Kose July 30, 2006, in Ndonga.

[306] Literally, it means: let us operate the bellows for Ndungulume who spreads out a small mat on [his] head (W. J. G. Möhlig, personal communication).

In Nyemba society, this song is a welcome song for the local authorities and kings and Ndungulume stands for an important person who wore a headdress or crown of honor on his head. Figuratively, the ironworkers of Kafuma praised their bellows like the important Ndungulume because they were believed to bring prosperity to the people (Kose, 2008, p. 152). The bellows were considered the most important tools of the smelting process, since they possessed the vital power to generate iron. Another song that was sung at the furnace while the ironworkers operated their bellows was an eland praise song:

Lishefu lyange, lishefu lyange,

My eland, my eland,

ya thiha Mukonda muna Ghumba wa
Ndala – va nanee!

Who was injured by Mukonda,[307] [son]
of Ghumba and grandchild of Ndala
– my mother!

Ndina hono kukava Kangovo mukalu,

I cannot follow Kangovo,[308] he is the
difficult one,[309]

Kangovo wa mukalu kumushikula –
lishefu lyange,

Kangovo is difficult to be followed –
my eland,

Kangovo wa mukala kumulandula –
lishefu lyange,

Kangovo is difficult to be followed by
his footsteps – my eland,

Lishefu lyange,

My eland,

Lya thiha Mukonda muna Ghumba wa
Ndalee-ee!

Who was injured by Mukonda, [son]
of Ghumba and grandchild of Ndala
– my mother!

Ndjina hono kukava Kangovo wamukalu.

I failed to follow him because
Kangovo is a difficult person.

(Nyemba; A. M. Makayi, text collected by E. Kose, translation by H. & R. Ndumba and W. J. G. Möhlig)

This song was performed because the smelting process was considered to be as difficult as following a wounded eland antelope through the bush. The smelters identified themselves with the heroic hunter and applied spiritual hunting techniques in order to succeed in metal fabrication (section 5.4) (Seifert, 2009, pp. 285-286). However, the song is seemingly more commonly applied in initiation ceremonies of boys and girls in the Nyemba society.[310] It is also part of healing rituals that were performed to cure a certain mental illness, which caused individuals to run away from their community into the bush.[311] Another more hidden meaning of this song is the complaint of a wife who knew that her husband was following a concubine. The wife, however, could not catch him doing something wrong because, like the injured eland in the song, he was so difficult to pursue.[312] In Kavango societies the eland was the property of the ruler, and it was even identified with the sovereign. Eland fat was believed to possess spiritual forces. It was used to empower hunters, and to anoint new rulers or individuals who married into the ruling clan (section 5.4) (Gibson et al., 1981, p. 199; Fisch, 2008, pp. 155-161). This song exemplifies well the cosmological link between smelting, hunting, transformation and kingship, as discussed in Herbert (1993, pp. 164-166), Seifert (2009, p. 386) and at the end of this section.

In Nyemba society taboos against women were not as exclusionary at the forge as in smelting because they were allowed to approach and watch the working blacksmiths. However, it was prohibited for women to touch anything at the workplace or to cross the fire of the forge. Only girls could operate a bellow without getting problems.[313] Contrary

[307] Mukonda is the name of a mythical hunter.

[308] According to Fisch (2008, p. 188), Kangovo is the Nyemba praise name of the eland antelope.

[309] Which means to be difficult to find.

[310] Hilda Ndumba personal communication, October 6, 2007 in Rundu.

[311] Hilda Ndumba personal communication, October 6, 2007 in Rundu.

[312] Hilda Ndumba, personal communication, October 6, 2007 in Rundu.

[313] The term 'problems' refers to health problems.

to the statements of the ironworkers from the other Kavango peoples, it was possible to use charcoal from the forge for fires in the homesteads.[314]

5.3.6.3. Shambyu

Among the Shambyu, the same taboos and rules of seclusion were practiced as among Kwangali and Nyemba. Women of fertile age were not allowed to visit the smelting site and touch the ore. Fisch (1980) described that the ironworkers avoided contact with individuals that were considered ritually unclean, which meant women and foreigners. In addition to an overall sexual abstinence that was required, no alcohol consumption was permitted to the smelters during the smelting period.

From Vungu-Vungu P. K. Kampanzela remembered that men, small children of both sexes along with elderly women were tolerated at the smelting site since the latter were regarded as men after their menopause.[315] The ironworkers had to abstain from sexual contact with their wives during the entire smelting period, otherwise the smelts would fail either because the ore would not melt, or because the pieces of raw iron would be so small that they would not be forgeable. To avoid temptations, the ironworkers had to sleep at the smelting site. It was also forbidden to take charcoal or embers from the smelting site to the homesteads.[316] The ironworkers wore their habitual dress, but it was remembered that in former times, smelters and blacksmiths always wore a headdress during their work. At the beginning of a smelt, the crew slaughtered a goat or bovine to honor the ancestors. The heart of the animal was taken out and moved around the smelting pit to prevent the ironworkers from accidents during the smelt. The crew was supposed to finish off the meat of these animals during the smelt because it was prohibited to take leftovers of this meat to their families when the smelt was over. After a meal, the bones were thrown into the river to protect the smelters from becoming tired and sick during their work. In the event that they were running short of food, boys or elderly women could provide them with additional food from the village.[317] People remembered several songs that were sung at the furnace while the smelters operated the bellows. These songs were called *kisi*:

NyaKasereke Ntungurume wazara kazara komutwe, NyaKasekere

Mother of Kasekere [said] Ntungurume who puts a headdress on his head[318], mother of Kasekere

(Kwangali; P. K. Kampanzela; text collected by E. Kose, translation by J. Kandjimi, K. Likuwa, W. J. G Möhlig)

This song is a Kwangali version of the Nyemba song described earlier in praise of Ndungulume - the bellows or important man - who brought prosperity to the people (see also Kose, 2009a, p. 153). However, it is not clear to whom or to what the first part NyaKasereke might refer. The next song invoked a pregnant woman who avoided demanding work because she was close to delivery or immediately after it.:

Kumona maherekadi ayee (2x), kangere

To see the shirker woman (?) ayee, fry for [him/her?]

Nimusumba kapi anitu ayee (2x), kangere

I am pregnant (this is why) I cannot pound, fry for [him/her?]

Nimwali kapi ani hompo aye (2x) kangere

I have just delivered a baby I cannot start to winnow, ayee, fry for [him/her?]

(Mixture of Kwangali and another dialect close to it; P. K. Kampanzela; text collected by E. Kose, translation by J. Kandjimi, K. Likuwa, W. J. G. Möhlig)

The song clearly refers to the procreation paradigm as will be described in section 5.4, and the smelters, who operated the bellows, identified themselves with a delivering woman. The next song is meant to encourage the ironworkers to hold out at the bellows. Like the song in honor of Ndungulume, it also appeals

[314] Interview with Alberto Munoma Makayi, Appendix 2.8.

[315] Interview with Petrus Kudumo Kampanzela, Appendix 2.1.

[316] Interview with Modestus Kashera Shimbiringua, Appendix 2.2, and with Nependa Mbambangandu, conducted by Eileen Kose, August 5, 2006, in Gove.

[317] Interview with Petrus Kudumo Kampanzela, Appendix 2.1.

[318] Literally it means ‚Mother of Kasekere (said) Ntungurume who spreads out a small mat, mother of Kasekere.

to the outstanding spiritual power of the bellows to transform and to fluidify stones, and to metamorphose the ore to metal.

Yenu kuno, tuyadukute ndenga,[319]

You over there, let us operate with
bellows the iron ore

Kutanta ashi, yenu kuno tuyadukute
mawe ghakare vikuhlo ngatu
rughaniteko.

It means: you over there let us operate
with bellows the old stones we will
treat them over there.

(Gciriku; M. K. Shimbiringua, translation by K. Likuwa, W. J. G. Möhlig & S. Nependa)

P. K. Kampanzela recollected that when a smelt succeeded, the ironworkers celebrated their triumph. If a smelt failed, it was seen as a sign that one of the ironworkers had transgressed the sexual taboos and brought ill luck to the group. The culprit was one of those who had been absent from the smelting site for some time and his punishment was to pay a cow.[320]

The smithies have always been located outside of the homesteads because people did not (and still do not) want to put women in danger.[321] In former times, women were excluded from the forge, but in modern days and in the course of gender equality, they have started watching the work at the forge and nowadays they are allowed to touch the blacksmith's bellows and tools.[322] However, if a woman crossed the forge or the bellows, she would get permanent menstrual bleeding, even if she were not at the time of her regular menses. Modern medicine would not be able to heal this sickness, only traditional healers could.[323] To heal an affected woman, the healer would dig up a pit at sunset and put some traditional medicine in it. To stop the bleeding, the woman has to sit naked above the smoking medicine for 2 hours. The medicines that traditional healers use are special leaves of the Manketti tree (*Ricinodendron rautanenii*). Manketti trees frequently have small holes and depressions in which some water collects. At these spots, the tree sprouts small twigs with leaves. These leaves are used as a remedy for the discomfort described above. Also, if women used charcoal or embers from the forge, they would suffer from headaches. In turn, the charcoal had no negative influence on men when they wished to use it elsewhere.[324]

5.3.6.4. Gciriku

Among the Gciriku, fertile women were also banned from the precincts of mining and smelting. People even mistrusted men who did not belong to the work crew because they could spoil the smelt in the event that they had had sexual contact with a woman the night before. It was much safer to keep all people away from the smelting site, yet small children were tolerated as long as they had not yet reached the age of puberty. As soon as people started preparing a smelt, nobody other than the ironworkers was allowed to touch the iron ore.[325] The iron ore was also believed to cause sicknesses among women who had come into contact with it.[326] Contrary to the strict requirement of a long absence from home during the entire smelting period as seen among the other Kavango groups, the ironworkers of Kashivi were allowed to visit their families and fetch food from home.[327] Therefore, it was necessary that only men older than 25 years were involved in smelting because they were considered responsible and obedient, and would not put the success of the smelt at risk.[328] All the food was provided by the ironworkers' families and it was prohibited to kill at the smelting site, yet it was authorized to eat meat.[329] The smelters drank alcoholic beverages in order to work faster and avoid becoming tired. They wore their habitual dresses but in the night during the smelt they

[319] *Ndenga* is a Nyemba term (W. J. G. Möhlig, personal communication).

[320] Interview with Petrus Kudumo Kampanzela, Appendix 2.1.

[321] Interview with Petrus Kudumo Kampanzela, Appendix 2.1; Interview with Modestus Kashera Shimbiringua, Appendix 2.2;

[322] Also, in former times women were not allowed to touch guns.

[323] Interview with Petrus Kudumo Kampanzela, Appendix 2.1; Interview with Modestus Kashera Shimbiringua, Appendix 2.2;

[324] Interview with Petrus Kudumo Kampanzela, Appendix 2.1.

[325] Interview with Paulus Ndumba, Appendix 2.4.

[326] Interview with Headman Balthazar Shindimba, conducted by Eileen Kose, July 30, 2007, in Nyangana. Manuscript.

[327] Interview with Paulus Ndumba, Appendix 2.4.

[328] Interview with Headman Balthazar Shindimba, conducted by Eileen Kose, July 30, 2007, in Nyangana.

[329] Interview with Paulus Ndumba, Appendix 2.4.

decorated their heads with the feathers of chickens. No special sacrificial ceremony was performed at the furnace site, but the master smelter always put some secret medicine on the ore before they lit the furnace. The master smelter, however, kept medicine and ritual secret.[330] The ironworker sang one specific song during the smelting process:

Yeveyeni ndenga

Operate [with bellows] the ore!

Yakakutambura kamuye voyo ndenga.

Those who can help me with my song,
come now, those who own iron ore

Yeveyeni ndenga.

Operate [with bellows] the ore!

Tuvapekere[331] *Ndungurume wazala*
katjara kumtwe.

(Not understood) Ndungurume who
spreads out a small mat on [his]
head.[332]

(Nyemba; P. Ndumba; text collected by E. Kose, translation by W. J. G. Möhlig)

According to P. Ndumba, this song was performed to keep the ironworkers awake and motivated. It was performed in Chinyemba by the Gciriku smelters even though they did not understand the meaning of the song. Moreover, as seen earlier, other versions existed of the first part of this song in Rugciriku, and of the second part in Rukwangali. As can be clearly seen, it is a combination of the two songs in honor of the spiritual force of the bellows described earlier, and which were performed by Nyemba and Shambyu ironworkers. The feather headdress of the smelter of Kashivi is reminiscent of the headdress of the smelters from Kafuma (see also Kose, 2009a, pp. 152-153). The ironworkers celebrated a successful smelt. When the smelt failed, the master smelter thoroughly interrogated the members of his group to find the culprit. The latter was thereafter excluded from any further smelts. Yet P. Ndumba admitted that some smelts failed without detectable human influence.[333]

Women were allowed to be present in the precincts of the forge but the same ailments would occur as seen among the Shambyu if women crossed the fire and bellows of the smithy. Moreover, if women were to use charcoal or embers from the forge in their homesteads it is believed that they would get the same menstrual bleeding at infinitum as from the crossing of the forge. The source of this dangerous impact was seen in the fact that the bellows ignited the embers. Wherever the embers from a forge were used, women would react to them in the same way, whereas men could use them without being compromised.[334]

5.3.6.5. Mbukushu

Also among the Mbukushu the smelting site was a zone with restricted access. Only married men who already had children, or unmarried men of advanced age were allowed to enter the smelting zone. Women were banned from this area because they were believed to spoil the smelt.[335] Furthermore, women were not permitted to become in visual or physical contact with the ore once the ironworkers had started with the mining. For this reason, collected ore was kept away from the villages.[336] The same was true for bellows, which were always stored outside of the homesteads. Men were expected to be sexually abstinent during the entire smelting period because otherwise the smelts would fail. To better control each other, the workers stayed at the smelting site and slept under a tree. The individuals also had to abstain from women during the making of new bellows and charcoal. The ironworkers ate self-prepared meals. Before the smelt started, their wives slaughtered chickens and goats to provide them with sufficient food for the coming weeks. As soon they were running out of food, the smelters slaughtered a goat or hunted some game by themselves since they tried to

[330] Interview with Paulus Ndumba, Appendix 2.4.

[331] The term *tuvapekere* is understood in neither Nyemba nor any Kavango language (W. J. G. Möhlig, personal communication).

[332] Figuratively it means that he puts a headdress on his head.

[333] Interview with Petrus Ndumba, Appendix 2.4.

[334] Interview with Petrus Ndumba, Appendix 2.4.

[335] Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6, and with Petrus Kashako Kaputura, Appendix 2.5.

[336] Interview with Petrus Kashako Kaputura, Appendix 2.5.

avoid people with a negative influence from approaching the furnace site. Only men and elderly post-menopausal women were allowed to provide some food from the village. They were supposed to leave it half the way to the smelting site, to hide behind shrubs and trees, and to call the ironworkers so that they could fetch it themselves from this neutral location.[337]
It is remembered that the ironworkers performed no specific ceremonies at the beginning of the smelting period and that they wore no specific dress. Only the master smelter prepared a liquid medicine from the roots of a specific tree. He put these roots on a plate in some water and every ironworker could dip his hands into the liquid, which prevented them from getting burned.[338] Van Tonder (1966, p. 264) reported that the ironworkers smeared themselves with clay to protect them from the heat of the furnace, yet it is not clear if it too held a ritual meaning. In the night of the smelt, the smelters sang songs while they operated the bellows because they rejoiced in their work and wanted to hold out during the whole night. Other crew members started dancing to stay awake. Some of these songs were in Chinyemba, even though the smelters did not understand their meaning; other songs were in their own language. Two songs with a Mbukushu background were remembered:

[The ogre asks]:
Kupi kutughunwa?

Where can I get something to drink?

Kaghundongo-ndongo,

Feeling of being thirsty,

Mutjima toko mutjima kaghuru ngunda.

The heart [of the ogre] is hurt the heart is burning.

(Mbukushu; M. B. Tovero, Y. J. Matende., M. F. Mukura, M. Kandunda; text collected by E. Kose, translation by C. Kashongo)

This song is part of a well-known tale of an ogre known as *dikithi*. In the tale, the ogre threatened individuals and entire countries because he ate people and villages.[339] As discussed in Kose (2009a, p. 149) and in Seifert (2007, pp. 293-295; 2009, pp. 275-278), the song appealed to the spiritual power of the iron-workers, their bellows and the fire ignited by them. Today, several versions of the *dikithi*-tale exist among the Kavango and Ovambo groups, and most of them refer to a hero blacksmith who provoked the giant ogre to swallow him, his bellows and the charcoal. The fire was then ignited in the stomach of the giant and maintained by the bellows, which caused the ogre to become thirsty, but in the tale, the lakes and wells that he visited in search of water all dried up as soon as he arrived. The ogre finally died of thirst and the swallowed people escaped his stomach. In this tale, the hero blacksmith not only killed a menace to society, he also had the power to control and manipulate the water supply of the country. In Mbukushu society, rainmaking and water control is exclusively in the hands of the ruling sovereign. Consequently, the hero blacksmith not only overcame the powerful ogre, the tale also symbolizes the removal of an old and obsolete ruling system and the making of a new sacred king (Seifert, 2007, p. 335; 2009, pp. 275-278). This is not surprising because ironworkers were frequently seen as powerful competitors to the rulers. In their song, the ironworkers of Dikundu repeated the words of the giant in search of water, in order to mock the ogre. They identified with the hero blacksmith of the tale because they operated powerful bellows and produced the spiritual force to metamorphose stones to metal. It is important to be aware that the interviewees stated that only a fire ignited by bellows had the spiritual force to kill the ogre.[340]
The second song remembered referred to ironworkers who were thirsty from hard labor. They went fetching water from a well but the well was dry, then they imitated the sound of an empty calabash to symbolize their thirst (see also Kose, 2009a, p. 149). The song was performed at many occasions in daily life when people were expected to hold out and to continue with their work, even if they were thirsty. It was not restricted to the ironworkers and was meant to encourage them to work hard and to persist at the furnace and the bellows:

337 Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6, and with Petrus Kashako Kaputura, Appendix 2.5.

338 Interview with Petrus Kashako Kaputura, Appendix 2.5.

339 The complete tale is published in Seifert (2006, pp. 50-55).

340 Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6.

Tuyende kumeyu mahupa,

We are going to fetch water with a calabash,

Ngwaranga.

(The sound of an empty calabash).

(Mbukushu; M. B. Tovero, Y. J. Matende., M. F. Mukura, M. Kandunda; text collected by E. Kose, translated by C. Kashongo)

The whole community celebrated with the ironworkers when a smelt succeeded. If it failed, the head of the family summoned a meeting and tried to identify the culprit. The guilty one could be one of the ironworkers who was then accused to have violated the requirement of sexual abstinence, or an unauthorized person such as a woman, who was suspected to have approached the furnace site. The culprit was not specifically punished or fined, but the community disregarded and ostracized him or her. However, the informants admitted that the smelters were not always able to identify a person to be blamed.[341]

Smithies were always located outside of homesteads. It was and still is believed that the fire of a forge had supernatural power and was dangerous for the women living close by. Because of this, the latter were not welcome in the sphere of the forge. Among the Mbukushu, crossing the smithy would cause the same unhealthy menstrual bleeding to women as described from the other Kavango peoples.[342] According to P. K. Kaputura,[343] people treated this illness with shoots of the *ghunyondo* tree (*Combretum imberbe*, Leadwood)[344] and *ghushi* tree (*Guibourtia coleosperma*).[345] Traditional healers prepared the leaves of the tree and gave it to the unlucky women to drink until they recovered. Furthermore, embers from the forge would cause sickness among women when used for domestic purposes. In turn, the presence of fertile (i.e. menstruating) women at the forge could spoil the quality of the tools. Whenever women brought something to eat, they were expected to keep a certain distance. Moreover, the fire of a smithy was never lit with embers from the fire of a homestead that had been used by menstruating women. Such embers were also believed to spoil the tools.[346]

5.3.7. Ironworkers and their socio-cultural context

This section describes the position of ironworkers within their society based on the interviews and the little information published in scholarly literature. A short description of the role of blacksmiths and smelters in the Kavango societies has already been published in Kose (2008) and (2009a). In their accounts, all the interview participants stated that the historical ironworkers were part-time specialists and subsisted more on hunting, gathering, and farming than on ironworking. This describes the conditions in the early twentieth century and most probably the late nineteenth century (section 5.1.4). There were no societal restrictions for them with respect to apprenticeship and marriage, yet smelters and blacksmiths tended to come from ironworking families. Only the ironworkers of the Vakwandjadi clan had a strong clan or lineage affiliation.

5.3.7.1. Kwangali

The Kwangali ironworkers were farming part-time specialists and highly regarded. Every able-bodied man who was interested was welcome to learn the necessary skills. The iron trade was specialized to some extent, which implies that the Kwangali had a long ironworking tradition, even though its traces have become obliterated in modern times. It seems as if there existed miners, smelters and blacksmiths. The latter bought their raw material from the smelters. It was remembered that some ironworkers smelted and forged,

[341] Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6, and with Petrus Kashako Kaputura, Appendix 2.5.

[342] Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6, and with Petrus Kashako Kaputura, Appendix 2.5.

[343] Interview with Petrus Kashako Kaputura, Appendix 2.5.

[344] According to Curtis & Mannheimer (2005, p. 481) *Combretum imberbe* is regarded as having mythical properties among the Herero and Ovambo groups. It has also numerous medicinal applications.

[345] According to Curtis & Mannheimer (2005, p. 205) *Guibourtia coleosperma* is used for many secular purposes, and various parts are used medicinally.

[346] Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6, and with Petrus Kashako Kaputura, Appendix 2.5.

others were only blacksmiths or miners. Smelters were the most highly respected because they were capable of transforming stone into metal, but all men involved in iron or implement production were highly esteemed. However, ironworkers were as wealthy as any other member of their communities, and they maintained farms and other subsistence strategies.[347] The respect shown towards them was because of their technical and spiritual skills.

5.3.7.2. Nyemba

Among the Nyemba living close to the Kavango River, smelting and smithing were separate part-time occupations, and most of the ironworkers were also engaged in farming in order to subsist. A. M. Makayi recollected that every man who was interested in the iron trade could learn it at the smelting sites of Kafuma.[348] Ironworking was not restricted to clans or families, yet smelters and blacksmiths tended to come from ironworking families. Both of them were highly regarded because of their spiritual force for producing iron, yet smelters received more respect than blacksmiths. Some blacksmiths were also healers, but healing skills were not implicit to the iron trade. Ironworkers were wealthier than other members of their communities since they exchanged iron implements for domestic animals. What is more, they hunted and cultivated fields in order to make a living. In accordance with their social status and like other high-ranked men, they could have up to three wives, whereas farmers could mostly afford only one or two of them.[349]

5.3.7.3. Shambyu

In the Shambyu society there existed professional smelters and blacksmiths, who were equally respected. It appears as if in the early days, the knowledge about iron production was kept secret by the royal clan of the Tjaube people (section 5.3.5.3). Later, the population grew and the royal clan had to share its knowledge in order to provide enough tools and weapons for the people.[350] The knowledge and the apprenticeship of the iron trade was restricted to ironworking families and was strongly monopolized. As the clan membership was inherited from the mother's side, the male members of the matriclan guarded the secret knowledge. According to H. P. H. Kaputungu, a man who married into an ironworking family was expected to prove his integrity first for a period of two or three years, before his brothers-in-law introduced him to the iron trade.[351] The historical scenario described in the Tjaube chronicles draws the picture of a skilled foraging and ironworking society superior to the arriving Shambyu hunters (Fleisch & Möhlig, 2002, pp. 37-54). The war that arose between the two antagonists was a conflict about hunting grounds. It is said that the Shambyu were not able to conquer the Tjaube territory because they lacked iron weapons. In the following attack, it is remembered that the Shambyu were armed with the latter from their Kwangali and Kwanyama neighbors, and won the second fight. The ironworkers of the Tjaube people, however, were most required as skilled craftsmen and some of them were given to the Kwangali in order to work for them at Makuzu (section 5.3.1.1) (Fleisch & Möhlig, 2002, p. 50).[352] Oral tradition also contends that men from the royal clan married into the Tjaube female line (McKittrick, 2008, p. 797), which is certainly the strongest alliance between two clans, and the ironworkers of the Tjaube became morally bound to the royal clan through their father's line. The descendants of the Tjaube became part of the Shambyu and Gciriku society. Nowadays they form the Vakwandjadi clan, which by now transcends all the Kavango polities. Following Bosch's (1964, p. 130) suggestion, one third of the total population belonged to this clan in the 1960s, and Hartmann (1987, p. 87) stated that it is the most populous clan among all Kavango groups.[353] Originally, all ironworkers of the Shambyu and Gciriku belonged to this clan because, as described above, access to the knowledge of ironworking was only held by certain families. Even today, most blacksmiths in the Shambyu area belong to the Vakwandjadi clan and can trace their

[347] Interview with the Headmen Daniel Haikukutu, Jafeti Hainura, Hidion Karfere, and Franz Semusi, conducted by Eileen Kose, August 6, 2007 in Nkurenkuru.

[348] Interview with Alberto Munoma Makayi, Appendix 2.8.

[349] Interview with Alberto Munoma Makayi, Appendix 2.8.

[350] Interview with Harupe Paulus Haididira Kaputungu, Appendix 2.3.

[351] Interview with Harupe Paulus Haididira Kaputungu, Appendix 2.3.

[352] Interview with Harupe Paulus Haididira Kaputungu, Appendix 2.3.

[353] He did not mention the Nyemba.

pedigree back to their common Tjaube ancestor King Mankoto of Kauti. Originally, the Vakwandjadi clan also owned the rainmaking charm even though they were subjects to the new rulers. In modern day Namibia they still play a special role in evocation ceremonies for the ancestors (Gibson et al., 1981, p. 191; Hartmann, 1987, p. 87; Kampungu, 1965, p. 465; see also Kose, 2009a, pp. 144-147). Together with the metallurgical knowledge, the hunting skills, the rainmaking charm and the spiritual ties to the ancestors, the Vakwandjadi clan possessed all qualities required from African rulers. As discussed in the introductory section 5.1.1, they were also in the strong position of being the first owners of the land. Firstcomers are thought to master the spiritual power of the country and its ancestors, which is a force that cannot be extinguished through conquest (McKittrick, 2008, p. 790). This is probably the reason why they became tied to the new ruling clan of the Shambyu, and even iron production sites were moved to the immediate precincts of the royal palace (section 5.3.2.3). However, the Vakwandjadi clan kept a strong competing position against the ruling Vakafuma clan because oral tradition tells that two Gciriku rulers were killed through witchcraft by Vakwandjadi descendants of the Tjaube people (Shiremo, 2010, pp. 194-195) (see also section 5.4). Furthermore, it has been handed down that the Shambyu and the descendants of the Tjaube people smelted together in Vungu-Vungu when the war was over.[354] The scenario above somewhat contradicts the liberal picture that P. K. Kampanzela remembered from the early twentieth century around Vungu-Vungu. Most probably it changed under the influence of other ironworkers in this area. According to him, every interested person could learn the iron trade. Smelters and blacksmiths were respected members in their communities, yet they were no wealthier than other people. They hunted and farmed in order to make a living. Some blacksmiths were healers, but healing skills were not associated with ironworking skills.[355]

5.3.7.4. Gciriku

Following P. Ndumba, the knowledge of ironworking was not restricted to families or clans, and every able-bodied man was allowed to learn smelting or forging. It seems that besides the Vakwandjadi smelters, other ironworking families such as those living at Kashivi established their craft with fewer monopolizing structures. Smelters and blacksmiths were not considered separate professions, but some people were specialized on forging only. Generally, smelters were more respected than blacksmiths because they were able to transform stone into metal. P. Ndumba also stated that ironworkers were wealthy members of their society since they sold tools for cattle and crops all across the Kavango region.[356]

5.3.7.5. Mbukushu

Among the Mbukushu, trade specialization varied as did smelting technology and commercial habits. Most craftspeople were part-time specialists, and every married man farmed in order to make a living. In the Dikundu area, every family had its own ironworkers and each homestead had at least one trained person.[357] The number of ironworkers in a community depended on the size of the village. Usually the knowledge was passed on within the family from the most skilled experts to their male relatives. Only in exceptional cases were people trained by neighbors.[358] Van Tonder (1966, p. 263) documented that only a small number of people were specialists in the iron field. The skilled knowledge stayed within the family and was passed on to the younger brothers of the senior blacksmith. Generally, smelting and forging were not perceived to be separate trades (see also Larson, 1975, p. 111; Van Tonder, 1966, p. 263).[359] However, a slightly different picture was sketched by Larson (2002, p. 251). He reported that there existed specialized blacksmiths who worked on a seasonal as well as full-time basis and their work input largely depended on the demand of implements by the neighboring groups (section 5.3.4.4).

[354] Interview with Paulus Haididira Kaputungu, Appendix 2.5.

[355] Interview with Petrus Kudumo Kampanzela, Appendix 2.1.

[356] Interview with Petrus Ndumba, Appendix 2.4.

[357] Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6, and with Petrus Kashako Kaputura, Appendix 2.5.

[358] Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6, and with Petrus Kashako Kaputura, Appendix 2.5.

[359] Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6, and with Petrus Kashako Kaputura, Appendix 2.5.

Ironworkers were wealthier than other individuals of their communities because they owned metal and commonly had more cattle and fields than others. They were highly respected and frequently became the heads of their families because they possessed a broad knowledge. [360]

5.3.8. Origin and decline of ironworking

One aim of my interviews was to find out whether there existed a historical concept of the time before any of the ethnic groups adopted iron production. However, the effort was not very fruitful because it was obviously not important to hand down from whom and why they learned the necessary skills. Only among the Nyemba people did ironworking seem to be associated to the very early founder of the Nyemba kingdom (see below). Asking the informants about the technologies of their neighbors, the answers strongly diverged against the background of the archaeological, anthropological and historical evidence. Some informants gave detailed descriptions, whereas others remembered only their own iron production. It did not become clear whether this blind spot in the memory of certain interviewees is from a personal lack of knowledge or a commonly applied societal or political strategy in order not to acknowledge spiritual and technological skills of one's neighbors. The best example is provided by the Shambyu Chronicle (Fleisch & Möhlig, 2002, pp. 132-175), which does not mention the important input from the Tjaube hunters and ironworkers to stabilize the ruling Shambyu clan. The possible biases in oral history have already been discussed in section 5.2.2, and it is strongly suggested statements about the expertise of neighboring people should be treated with care.

5.3.8.1. Kwangali

The Kwangali elders who were interviewed did not recollect from whom the people might have acquired their expertise in iron making.[361] Following Otto (1987, p. 195), the Kwangali learned it from the Nyemba, with whom they were in close contact under Hompa Himarwa at the turn of the twentieth century. However, the material presented in the previous sections describes a society with a well-established ironworking tradition and specialization, the roots of which I believe to be much older than the late nineteenth and early twentieth century. Hompa Daniel S. Mpasi stated that local ironworking was prohibited by the German colonial administration for fear of local weapon production,[362] though it is not clear from the accessible information whether or not the Kwangali had established local gun production (section 5.3.3.8). Another factor was the increasing availability of European scrap metal, which rendered iron smelting dispensable.[363]

5.3.8.2. Nyemba

Not much information was available from the Nyemba groups. A. M. Makayi stated that they received the knowledge about iron production from their ancestors in order to end the suffering of the people. The country of origin of the Nyemba founders was to the north and was called Tshitauwe. Tshitauwe was also a tributary of the Kwito River and the founder kings knew the secrets of iron production. A. M. Makayi further stated that the Nyemba look back on many thousands of years of smelting, whereas the Kwangali, Mbunza, Shambyu, and Mbukushu only forged, but never smelted. Furthermore, Nyemba blacksmiths maintained trade relationships with many polities around them, which led A. M. Makayi to assume that Ovambo, Kwanyama, Herero, Gciriku, Umbundu and San possessed no metallurgical knowledge at all. His statements certainly do not reflect historical reality, but witnesses the extended supra-regional commerce in which the Nyemba groups were involved. Most interesting was his statement that people used to smelt in the Kafuma area until the mid 1970s since access to scrap metal was very limited in this region during the independence war of Angola. This may be one reason why traditional smelting procedures were so well remembered among the Angolan immigrants in Namibia.

[360] Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6, and with Petrus Kashako Kaputura, Appendix 2.5.

[361] Interview with the Headmen Daniel Haikukutu, Jafeti Hainura, Hidion Karfere and Franz Semusi, conducted by Eileen Kose, August 6, 2007 in Nkurenkuru.

[362] Interview with Hompa Daniel Sitentu Mpasi, conducted by Eileen Kose, August 2, 2006 in Nkurenkuru.

[363] Interview with Headman Paulus Mbundu Siveva, conducted by Eileen Kose, August 3, 2006, in Sikarosompo.

5.3.8.3. Shambyu

There exists no common memory about the time depth of the iron production of the Tjaube and Shambyu. Oral history and chronicles tell that the Tjaube people brought the expertise with them from their country of origin,[364] which is assumed in modern-day Botswana or Zambia (section 5.1). Likewise, P. K. Kampanzela[365] did not remember how long the Shambyu people had been involved in iron production. He recollected that Kwangali, Mbunza, Gciriku, Shambyu, and Nyemba were iron-producing polities. San people only forged and developed this technology by themselves. According to him, people stopped smelting after the arrival of Europeans, in particular when people started to work at the mines of Tsumeb and Kombat. It was easier to obtain iron (i.e. scrap metal) from there than to smelt. Another important factor adding to the decline of skilled ironworking was the fear of local weapon production. After World War II, the South Africans as well as the Portuguese prohibited local blacksmiths from working because of their skills in the production of guns.[366] Fisch (1980) collected local memories stating that the Nyemba husband Mpote of Queen Mushinga brought along the knowledge of iron production to the Shambyu. However, she also mentioned that ironworking Tjaube men were kept at the same time in Mushinga's settlement after the war against King Mankoto at Kauti (see section 5.3.7.3)

5.3.8.4 Gciriku

The origins of Gciriku iron smelting practices were not explicitly remembered. P. Ndumba assumed that the Gciriku might have learned it while they were still settled along the Kwando River before they migrated to the Kavango area.[367] His knowledge as to the ironworking skills of the neighboring polities was restricted because he stated that only Nyemba and Gciriku smelted in the past, whereas the other peoples did not know how to produce iron. According to him, San people knew how to forge but not how to smelt. People stopped smelting in the 1920s because none of the local smelters wanted to continue with such demanding work when European scrap metal became available. When the Nyangana mission was established, the bishop distributed European tools among the people and also instigated the decline of local iron production.[368]

5.3.8.5. Mbukushu

The Mbukushu consider themselves self-taught smelters and blacksmiths who were involved in iron production for a long time. However, details concerning the time depth of smelting sites such as Dikundu (SC 30) or Kapongo (SC 29) could not be provided.[369] According to the interviewees, every polity around them such as Kwanyama, Kwangali, Mbunza, Gciriku, Shambyu, Nyemba, Chokwe, Tswana and Haruyi (Caprivi) produced their own iron. It is believed that the San learned the iron trade from the Mbukushu, but that they did not smelt. The production of iron ceased when the white explorers and missionaries arrived in the area in the 1920s since they provided them with European tools.[370] Another important factor was that people stated to process scrap metal from industrial productions once they started to work in the mines of Johannesburg (Köhler, 1989, p. 388).

5.4. Reconstructing ironworking from the historical sources

The following is a recapitulation and discussion of the information gathered about the historical ironworking described in the section 5.3.

From summing up the evidence from the interviews and the little published scholarly material, every group of the Bantu-speaking Kavango peoples had its own smelting tradition. While technical details and furnace design varied among them, rituals and taboos surrounding iron production and forging were

[364] Interview with Modestus Kashera Shimbiringua, Appendix 2.2.

[365] Interview with Petrus Kudumo Kampanzela, Appendix 2.1.

[366] Interview with Harupe Paulus Haididira Kaputungu, Appendix 2.3; with Headman Nependa Mbambangandu, conducted by Eileen Kose, August 5, 2006 in Gove.

[367] Interview with Petrus Ndumba, Appendix 2.4.

[368] Interview with Headman Balthasar Shindimba, conducted by Eileen Kose, July 30, 2007 in Nyangana.

[369] Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6; with Petrus Kashako Kaputura, Appendix 2.5.

[370] Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6; with Petrus Kashako Kaputura, Appendix 2.5.

largely the same. San people living in and around the precincts of the Bantu-speaking communities also practiced metalwork, yet I was not able to assess whether they were involved in smelting in historical times too.

From the given accounts it is evident that the Kavango smelters preferred near surface ore deposits, which were easily accessible to them. The descriptions of the mining sites strongly suggested that these ores were of plinthic nature. Only in one case was the pisolitic ferricrete remembered as a source of ore (sections 1.3.2.10 and 4.1.3). Ore was extracted from pits, ranging between 2 and 5 m in diameter, and reaching a maximum depth of 2.5 m. Yet some ore was only collected from the surface. No pre-treatment of the ore was necessary except for some sorting. A comparison of the data gathered from the accounts revealed that two spatial solutions existed with respect to the relationship between mines and smelting sites: Smelting sites could be laid out in the precincts of the mines, being away from the habitation locations, or in the precincts of the settlements at a certain distance from the mines. Both spatial solutions occurred independently of ethnicity and the mining area. Interestingly, none of the smelting sites situated on the banks of the Kavango River was associated with a nearby mining area. Ironworkers from all these settlements mined either in the hinterland or along the Kwito. The data collection also discloses that people accepted walking distances between 15 and 75 km to acquire quality ore, which is, assuming a daily walk of 20 km, a one to four-day-walk in one direction.

One advantage of researching iron production in Africa is that we do not only have the mineral remains but also that ethnography and history provide uncountable documents of the spiritual dimension of metal production (e.g. Cline, 1937; Chirikure, 2007, 2015; Barndon, 2004; De Barros, 2000; De Maret, 1980; Herbert, 1993; Mapunda, 2010; Schmidt, 1996; Seifert, 2009).

The rituals and taboos described in section 5.3.6 revealed that the Kavango peoples shared (and still share) cosmological concepts with many other peoples from across Africa where taboos and offerings were considered important for maintaining good relationships of an individual with god, the ancestors and the supernatural. Violating any of the cosmological agreements would result in illness, accidents and a personal ritual uncleanness that would harm fellow human beings and bring bad luck to the entire community.

The exclusion of women of reproductive age and the sexual abstinence of the smelters were the most important rules to be followed. Similar to many African societies, menstruating women and menstrual blood was considered a powerful negative force among the Kavango peoples, said to be able to bring illness and death to humans and domestic animals, to weaken men and to spoil tools. Herbert (1993, p. 95) argued that in societies in which reproduction is highly desired, menstruation is the failure to conceive and a powerful tool for destroying productivity and any task seen analogous to reproduction or procreation. From the Kwangali it has been handed down that women were expected to stay within their homesteads during their menstruation. Whenever a woman lost menstrual blood in the sphere of a neighboring homestead, be it intentional or not, she put an evil spell on her fellow human beings who were believed to fall ill because of her. Menstrual blood was considered one of the main causes of severe sicknesses among the people (Kampungu, 1966, p. 122). Similar beliefs apply to the Nyemba since women were perceived as ritually unclean once a month, and were not allowed to cook (Heintze, 1995, p. 250). Among the Shambyu, affected women were forbidden from offering food to anyone for fear of causing a deadly cough (Gibson et al., 1981, p. 103). The cooking taboo certainly referred to the beliefs that anything women touched during menses would spoil and be infected with the negative energy. For instance, drinking from the same cup as a menstruating women could weaken a man with hunting ambitions and consequently all hunters had to keep away from women during hunting expeditions (Fisch, 2008, p. 79). Mbambo (2002, pp. 118-124) provided a thorough description of concepts of sickness among the Gciriku. Taboo related sicknesses were known as *shidira* and, in contrast to other diseases, they were contagious and transmitted by ritually polluted people, infected objects and places. *Shidira* finds expression in the recurrent statements of the ironworkers described in section 5.3.6 that women were not allowed to touch anything involved in iron or tool production. Affected women would spoil a smelt together with the quality and power of the hunting weapons produced from it. It was even prohibited for them to touch guns.[371] The influence was far reaching because, as described earlier from the Mbukushu, when used to light the fire of the

[371] Interview with Modestus Kashera Shimbiringua, Appendix 2.2.

forge the embers from the fire of a homestead where menstruating women lived would permanently spoil the blacksmith's products. Menstrual flow had also a deadly influence on domestic animals and consequently affected women were banned from the cattle kraals (Gibson et al., 1981, p. 103; Larson, 2002, p. 167). Another highly important taboo was to abstain from sexual intercourse during the said period, otherwise it was believed that the husband or the family's cattle would die (Gibson et al., 1981, p. 156; Larson, 2002, pp. 163-164, 167). Menstrual power did not only affect those directly affected by it, it also rendered offerings to the ancestors and the higher beings effectless. Consequently, women of the reproductive age had to stay away from the offering stocks of people (Gibson et al., 1981, p. 156).

As said before, Herbert (1993, p. 226) concluded that menstruation is a metaphor for sterility and failed conception as much as it is indispensable for impregnation, fertility, and procreation. However, the same ambivalent female power that strongly affected the health and success of fellow human beings could turn against women when coming into contact with its antagonist, the likewise ambivalent procreative masculine power. Although the latter is little analyzed among the Kavango peoples, reproduction is considered an act of men and women. This dichotomy can be tracked to the furnace site where smelters behave like husbands to their furnaces, which will be discussed later in the same section. A special role was assigned to the bellows who were praised in the songs of the smelters as procreators in the process of iron production, owing to their ability to transform stone into metal, and to give embers the spiritual force of creating iron and successful tools. Among the Kavango peoples, bellows were clearly associated with the procreative male part in iron production, and similar beliefs have been observed in other African smelting traditions (Herbert, 1993, pp. 37, 123). Genderization was also part of the ironworking traditions of the Khoe living in the Dikundu area because they used a male hammer consisting of a large piece of iron, and a female anvil that was a piece of iron inserted into a log of wood (Köhler, 1997, pp. 368-270). As all ironworking technologies were adopted from the neighboring Mbukushu, one may assume that the genderization was adopted from them too. The procreative masculine power was as contagious as its female counter-part because those things influenced by the bellows air outflow, such as the embers of a furnace or a smithy, were infected by the male energy produced by the bellows. The male power is as dangerous to women as is their menstrual blood to men. One aspect of this can be seen in the prohibition to use embers from the smelting furnace, or from the forge, to light fires in homesteads, which are considered the sphere of women. The details given in the interviews disclosed that among Kwangali, Nyemba, and Mbukushu it was believed that such embers would cause sicknesses among women and pain in their heads. A similar conviction is found among the Gciriku where the same influence was ascribed to ore when touched by women. However, it is not always clear from the interviewees' statements whether women were prohibited from touching ore in order to protect them from the negative masculine power, or in order to protect the ore from the negative energy of women; both might be possible. The reciprocity of the dualism between feminine and masculine power becomes strikingly apparent in taboos concerning the smithy that were, and still are, maintained to protect women from the danger of the bellows and the forge. While the physical presence of women at the forge was thought to spoil the blacksmith's work, the most negative influence of masculine procreative power manifested itself when women crossed the bellows and the forge. All interviewees stated that this would heavily distort the women's monthly cycle and caused immediate menstrual bleeding ad infinitum, which caused and still causes miscarriages and puts women in life-threatening conditions. The crossing of bellows can therefore be seen as analogous to adultery of women during pregnancy, which is believed to be the cause of stillborn children and the death of mothers during childbirth (Gibson et al., 1981, p. 187; Larson, 2002, p. 122). The spiritual dimension of these menacing blood flows becomes evident through the testimony of the interviewees, which state that modern biomedical treatments would not be able to relieve the affected women from their discomfort, only traditional medicine could. Similar to the taboos about smithies, women of reproductive age had to follow many food taboos in order to maintain health and fertility. One taboo was to avoid the meat of dangerous animals. Interestingly, the spleen and meat from the armpit of animals that were considered evil by the Kavango peoples would cause the same menstrual abnormality and spontaneous abortion among women as could be caused by the forge (Fisch, 2008, p. 80). However, my cultural knowledge is too restricted in this case to integrate these animal parts into the overall cosmological concepts of genderized power. An interesting analogy has been described in Herbert (1993, p. 85) from the Lopanzo in the DR Congo where women were also believed to develop a continuously menstrual flow in the event that they approached the smelting furnace.

The negative power of women started with menarche and ended with menopause. Generally, post-menopausal women were exempt from the numerous taboos around menstruation and fertility, and gained access to social areas that were considered the men's domain (Gibson et al., 1981, p. 124). Some examples on the previous pages showed that preadolescent girls and post-menopausal women were tolerated in the sphere of ironworking and production, yet in some cases they still had to maintain a certain spatial distance.

As mentioned in the introduction to section 5.3.6, most African societies have genderized iron production and perceive it as analogous to human reproduction. The furnace has been seen as analogous to the pregnant wife, the bloom to the new born child, and smelters adopted the roles of husbands and fathers to the bloom-child. As such, in historical times it was essential for them to follow the same cosmological instructions and taboos required as when their human wives were pregnant. Although no interviewee explicitly denominated their smelting furnaces to be female, and none of them compared iron production to human reproduction, all smelters abode by the same taboos found in the sphere of pregnancy.

Among the Mbukushu, sexual intercourse was forbidden for pregnant women and the taboo extended several months after childbirth. However, husbands were allowed to maintain relationships with legal concubines during this time, which would not be judged as adultery (Gibson et al., 1981, p. 255; Larson, 2002, p. 123). This was important because adultery usually had severe consequences for the adulterer and his or her partner. Among the Kwangali, every person involved in extramarital sexual relationships was considered a threat to the whole community (Kampungu, 1966, pp. 122, 127). Not only among the Kwangali, an unfaithful pregnant women would die at childbirth. Furthermore, a cheating husband was likewise believed to cause the death of the mother (i.e. his wife) and child, particularly when the child was not able to be delivered (Gibson et al., 1981, p. 187; Kampungu, 1966,p. 129; Larson, 2002, p. 122, Mbambo, 2002, pp. 123-124). Also among the Shambyu, taboos against adultery of both sexes were strongest around the time of childbirth (Gibson et al., 1981, p. 121).

The cosmological link between iron smelting and human reproduction became most prominent in the song performed by the smelters of Vungu-Vungu described earlier, in which the ironworker imitated the complaint of a pregnant women around delivery (section 5.3.6.3). It might be that the Nyemba smelters dressing up like elderly women symbolized the midwives at the furnace, because delivering women were frequently supported by their grandmothers. Also, the consequent sexual abstinence required from the smelters was analogous to marital live when the legal wive was carrying a child. The utmost importance to follow this taboo appeared in the statements about failed smelts. Hardly any other explanation of failure, or miscarriage, was imaginable besides the violation of sexual taboos during the smelting period. However, the act of adultery not only affected the partner of an individual and his child, but every person who violated sexual taboos could infect other people with their negative spell. For instance, it was believed that an infant would die when touched by someone who had committed an illegal sexual act (Kampungu, 1966, 127; Larson, 2002, p. 123). In less dramatic cases, the child would catch a heavy abdominal flu (Gibson et al., 1981, p. 112). The violation of the sexual taboos by one of the smelters would not only cause the smelt to fail, it would also put a negative spell on everything he touched. Consequently, he was a multiple threat to the other smelters and the furnace. Eventually, every person from outside the secluded and controlled smelting camp was a menace to the fragile transformation process of stone into metal for various reasons. Most informants stated that it was important to keep every visitor away from the secluded zone.

It has been stated that ironworking had a cosmological link to hunting and political power, since it belonged to the sphere of masculine power and prestige (Herbert, 1993, pp. 165-170). The bush in which hunting took place was as much a cosmological landscape as it was a geographical area. Frequently, hunters were bound to esoteric beliefs reminiscent of smelting, because success in hunting was, and still is, seen as a more spiritual than physical venture (Herbert, 1993, pp. 165-170). From the Kavango region Hüttenberger's linguistic study on the hunting terminology in Rugciriku emphasized the strong religious nature of the success and failure of the hunter (Hüttenberger, 1997, p. 88), which explains that among the Kavango peoples hunting was subject to the same stringent sexual taboos as for smelting and pregnancy. Infidelity before or during the hunt was a severe offence and manifested itself negatively, particularly in the hunting of large game such as elephants, buffaloes and hippopotamus. Furthermore, a hunter was believed to die on a hunting or fishing expedition when his wife was unfaithful (Fisch, 2008, p. 77; Gibson et al., 1981, pp. 156, 187; Larson, 2002, p. 166). For instance, the attack of a carnivore was seen as the animal's natural pugnacity, but the antagonistic and malevolent behavior of herbivores was seen as a spiritual act of discontent caused by the transgression of a taboo by a hunter or one of his family members (Fisch, 2008, p. 77). Similar to smelting, men who were considered irresponsible and unreliable with respect to the control of their sex drive were not welcome as hunting companions, and analogous to the camps of the smelters, hunting camps were a forbidden zone for women (Fisch, 2008, pp. 71, 79). Among the Kavango peoples, many taboos other than sexual ones were required from the relatives of a hunter during his expedition (Fisch, 2008, pp. 79-80), yet I cannot say for certain whether the families of the smelters had to follow the same restrictions in domestic life during the smelting period. The most apparent link between smelting and hunting among the Kavango smelters can be seen in the praise song for the eland sung by the Nyemba smelters at the bellows (section 5.3.6.2). The ironworkers identified themselves with hunters who pursued the difficult path of an injured eland. As pointed out earlier, the eland antelopes belonged to the kingly game among the Kavango peoples and its fat was used in the coronation ceremonies of a new queen or king (Seifert, 2008, p. 286). It was of great prestige and honor to hunt down the antelope, and the arrival of a hunter who delivered the fat to the palace was seen as analogous to the arrival of a chief (Fisch, 2008, p. 155). The song, however, closes the circle to the praise song of Ndungulume, a chief, or wealthy man, who brought prosperity to the people. Both songs are metaphors for the high standing of smelters, who considered themselves as both hunters of the highest status and chiefs because they provided well-being to the people. Moreover, it links the hunter to the sovereign, the bellows and to the masculine procreative power. The latter accomplished the transformation from stone into iron, and from iron into hunting tools, which brought death and fertility because the meat of hunted game guaranteed prosperity and reproduction (Herbert, 1993, pp. 169-170), in particular to hunting societies such as those found along the Kavango River. The many songs in honor of the power of the bellows found in the interviews stress the bellows' role as the most important instrument in the whole process of transformation. At first sight, these songs sound harmless, yet in a wider cosmological context the bellows is a strong manifestation of spiritual procreative masculine energy, which injects its power into the ore, the charcoal, the iron and the hunter's spear (Dupré & Pinçon, 1997, p. 127). Nevertheless, the question remains why the Kavango smelters performed songs that they heard from their Nyemba colleagues. I suspect that the adoption took place because the Kavango smelters desired to increase their supernatural power and hunting success, but I cannot say for certain why the esotericism of the Nyemba iron production were so attractive to their neighbors. It is a widely held view that ironworkers are linked to political masculine power in large parts of central Africa (De Barros, 2000, pp. 157-164; De Maret, 1985; Herbert, 1993, pp. 131-135). Some scholars also argued that women banned from the sphere of iron production were also banned from economic wealth and political power (e.g. Goucher & Herbert, 1996, p. 54). However, among the Kavango peoples political power is not restricted to men. All the Kavango peoples have in common a matrilineal descent system and except from the Mbukushu, they can look back at a long list of female leaders and foundresses of states (e.g. Kampungu, 1966, Fleisch & Möhlig, 2002; Gibson et al., 1981, p. 156), whose power did not depend on spiritual and material success in metallurgy. The queens and kings of the Kavango peoples were the spiritual leaders of the country, but their power was linked to the ability to provide rain and be successful hunters (e.g. Gibson et al., 1981; Mbambo, 2002, pp. 247-248; Seifert, 2007, pp. 46-50). Rainmaking guaranteed the esoteric supremacy over commoners and neighboring peoples (e.g. Gibson et al., 1981; 258-259; Salokoski, 2006; p. 225; Larson, 2002, pp. 315-316) and success in hunting ensured spiritual power and economic wealth because profitable game was monopolized by the rulers (Kose, 2012, p. 214; Seifert, 2009, pp. 278-280). Eventually, in the Kavango societies it was the success of the individual male hunter who warranted the economic power of the ruling clan and the female leaders. Only the Nyemba sovereign was hunter, healer and blacksmith all in one.[372]

[372] Interview with Alberto Munoma Makayi, Appendix 2.8.

However, the topos of the hero blacksmith as discussed in Seifert (2007, pp. 325-365; 2009, pp. 275-278) has occurred in tales from all over northern Namibia and southern Angola, and comes from their common Bantu heritage in central Africa (De Maret, 1985; Herbert, 1993, pp. 132-135). It finds expression in kingship only among the Nyemba, and, although most ethnographers have not associated the Mbukushu Fumu with smelting or forging, the interviewees from Dikundu stated that the Mbukushu rulers knew the techniques of iron production even if they never performed a smelt themselves.[373] As mentioned earlier in this section, the tale of the giant ogre, which the Kavango peoples share with their neighbors, was performed in Dikundu at the smelting furnace (section 5.3.6.5). The smelters saw themselves in the tradition of the hero blacksmith who killed the giant ogre *dikithi* with the deadly power of their bellows and the instruments infected with its energy. The hero blacksmith also controlled the water supply of the country and overthrew the threatening rule of the ogre. Interestingly, the ogre *dikithi* was also the king of the antelopes (Fisch, 2008, p. 159). As Seifert (2007, p. 48) pointed out, the ritual regicide was a much better suited and powerful way of transferring the spiritual leadership of an obsolete sovereign – here the ogre – to a new ruler than the natural death of a queen or king. In the end, the blacksmith hero unified all the qualities necessary for a powerful new ruler, ready to act as intermediary between the spiritual and physical world of his people. Another interesting spiritual aspect may be recognized in the use of termite clays or termite mounds in smelting. Besides the physical and chemical advantages of termite clay refractories described in section 1.4.7, all over Africa, termites, termite mounds and termite clays are associated with supernatural forces. Considering that in historic smelting the spiritual ingredients and supernatural forces were perceived as more important than suitable charcoal and ore, the role of termite clays becomes even more important. Iroko (1996) described at length the role of termites and termite constructions in African cosmologies, which were seen as gateways between human beings and the spirit world. In many cultures, termite mounds are seen as the origin of mankind, and termites are linked to human kingship and incorporated into the enthronement ceremonies of new rulers (Iroko, 1996, pp. 171-178, 183-185). Termite constructions connected the ancestral world with the living descendants and were located between live and death. They could be homes to gods, ancestors, and spirits. Termite mounds were frequently used as burial sites of individuals such as sorcerers, twins, stillborn children, disabled people or foreigners, who were perceived as a menace to their community because of their negative energy (Iroko, 1996, pp. 202-206). There is only little information available for this study with respect to the role of termiteria among the Kavango peoples. Most ethnographic records refer to them as burial sites in which spiritually contaminated individuals were laid to rest. Among the Mbunza, albinos and deformed children were put to death and buried in a termite mound (Gibson et al., 1981, p. 84). The Shambyu buried miscarriages and women who died during childbirth in termite constructions (Gibson et al., 1981, pp. 126-127). Apparently, termiteria were able to protect relatives and the whole community from the detrimental energy of the deceased. Interestingly, Kwangali and Mbukushu used termite mounds and termite clays in smelting. If one wishes to consider them as spiritual gateways between life and death, and between the supernatural and the physical world, smelters could use no better place to deal with both spheres. Termites and termiteria are also frequently linked to fecundity (Iroko, 1996, p. 220), however, further information from the Kavango area is needed to illuminate the full function and meaning of termiteria in local cosmology and smelting traditions. The strong cosmic power, the outstanding role, and the various functions of such places are much better documented among the Ovambo groups, where termiteria were a place of outstanding esoteric power used in enthronement ceremonies of new rulers (Salokoski, 2006, pp. 16, 202) and in initiation ceremonies of new diviners (Salokoski, 2006, pp. 154-155). Moreover, termiteria were also considered to be the place where God created the first human beings (Salokoski, 2006, p. 77).

From the previous section 5.3.6 it can be seen that among the Kavango peoples the most important rules to obey were first to exclude women of reproductive age from the smelting processes because of the negative influence of menses, and second the sexual abstinence of the ironworkers was required during the entire smelt. As discussed above, the transgression of both taboos was considered to be the main cause for a failed smelt. Because of these prohibitions, the furnace sites were spiritually and spatially

[373] Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda, and Peter Kandjendje, Appendix 2.6.

secluded areas in most African societies, where women were banned from, and where the ironworkers stayed during the smelting period. However, each community and each people had its own notion of how to implement in practice the concept of seclusion in order for a successful iron production (De Barros, 2000, pp. 186-190; Chirikure, 2015, pp. 88-90). As described earlier (section 5.3.2), smelting sites were laid out near to either the mines or the permanent settlements of the Kavango peoples. From the interviews one can conclude that most smelting sites were set up within a radius of 1000 m around the villages. Smelting sites could be very close to individual homesteads as long as people perceived this area as 'outside of the settlement' or spiritually 'secluded'. Some ironworkers deemed it necessary to fence in the furnace site to keep unwanted visitors away. Other communities achieved seclusion due to the fact that individuals respected the taboo zone and did not approach the precincts of the furnace site. However, the seclusion of a smelting site was not a static concept that found expression only in the spatial relationship between villages and the smelters' camp. The Shambyu example showed that smelting sites could be installed inside of habitation locations, and that people found strategies to maintain the ritually seclusive character despite the spatial proximity to people who possessed the spiritual power to threaten the success of the smelts. One reason to set up furnaces inside of settlements was the wish of the Shambyu rulers to have full control over the implements produced in their country. Another reason was that iron production was of high prestige and honored the ruler in whose settlement the stones were transformed into metal. Obviously, the Shambyu found a cosmological solution for adapting the taboos that were essential to fulfill a smelt necessary for the sovereign's desire for control and prestige.

As seen above, the spiritual requirements were as important as the physical preconditions in African iron smelting. In the following, I will focus only on furnace design and smelting technology. Both varied among the Kavango peoples and most interestingly, these technical features transcended political boundaries and were not linked to the expression of ethnic identity (see also Chirikure, 2015, p. 141). Most smelters preferred bowl or pit furnaces, some smelted even without a protecting furnace superstruction. Others preferred bellow driven high shaft furnaces, and one example of a low shaft furnace was found (section 5.3.3). The same diversity of furnace designs can be found among the neighboring peoples in what is today Angola and Zambia (e.g. Barnes, 1926; Chaplin, 1961; Herbert, 2001; Maluma, 1979; McCosh, 1979; Turner, 1952; see also Chirikure, 2015). The Kavango smelters preferred furnaces with tapping facilities, but even so, furnaces that operated without slag tapping existed. Refractory material used for furnace walls was either the natural quartz-rich sandy soil, or termite clays. As pointed out in section 1.4.7, termite clay refractories can have a most favorable influence on a melt as they contribute to low-melting slag compositions. The smelting solution described by Van Tonder (1966, p. 264) operated with an additional termite clay cover in both smelting and refining, which certainly significantly contributed to early slag formation. Termite clays were also used by the neighboring peoples in what is today Angola and Zambia (e.g. Bastin, 1974; Barnes, 1926; Chaplin, 1961; Read, 1902). Among the Kavango peoples only the tuyeres seemed to have been made preferentially from alluvial clay deposits although termite clays were available. Perhaps the alluvial clays were more refractory than the latter, which prevented the tuyeres from collapsing during the smelt. Nevertheless, much more archaeometrical research is needed to shed light on such technological details. Those furnaces that operated in the natural soil without a clay lining could take advantage of the fluxing properties of the high quartz fraction of the Kalahari sands as has been discussed in the archaeometrical section of this study (section 4.4.4).

As expected, non-slag tapping and slag tapping furnaces produced bloomery iron of varying quality. From the interviews it was found that the main challenge was to create a large densely sintered bloom and to avoid small pieces of metal becoming interspersed with slag. The most challenging result was certainly the fragmentary bloom described from Vungu-Vungu (section 5.3.3.8), but every group of craftsmen found their own individual technical solution for creating new iron and steel of satisfactory quality. The most common refining technique found in the memories of the ironworkers was to consolidate the bloom by heating and forging. However, such treatment produced the highest losses of crown material compared to other refining techniques, since poorly sintered material was not processable solely by heating and hammering (section 1.5.1.2). The most sophisticated refining technique was certainly the two-step solution observed among the Mbukushu. Sintering a bloom in a second step as seen in section 1.5.1.1 allowed people to utilize even low quality material, which would have been discarded during the refinement procedure as described from the other sites. Moreover, as mentioned above, it is most likely that the clay cover of the refining furnace promoted a slag bath with low melting temperatures and thus facilitated the bloom sintering (section 1.4.2). Three examples provided in section 5.3.3 attested that some furnaces were covered with sand after the full melt had developed. Under this cover, the furnace was left to cool down for about 12 hours. Such treatment certainly advanced the carburization of the bloom, particularly when the slag had been previously tapped from the furnace. Parallel to methods for producing more selective carbon steel, people also applied procedures for decarburizing steel and cast iron, yet the descriptions provided lack technical details. It is not clear when cast iron production started in the research area, but it contributed to the great variety of smelting solutions that already existed in the Kavango region. However, more archaeological research is needed regarding the furnace constructions, refractories, temperatures and fining techniques applied by the people to deepen our knowledge about the skills of the late ironworkers living along both sides of the river. Interestingly, none of the technical solutions seemed to have been perceived as superior to the other because they co-existed even though the smelters knew of each other and of the technical variation. The best example is provided by the Mbukushu smelters who applied, as exemplified earlier in this chapter, three different smelting methods, and by the Dikundu area where high shaft furnaces operated at the same time as simple bowl furnaces along with low shaft furnaces, and each group of smelters retained their methods and styles. Chirikure (2015, pp. 140-141) discussed this phenomenon in a wider African context. He suggested that the conservative attitude towards adopting new smelting technologies might be the result of specialization which leads to smelters retaining their culturally accepted norms for producing iron.

The Kavango peoples needed iron to produce implements that belonged mainly to the sphere of men and hunting. The subordinate position of crop-cultivation becomes apparent in that only one implement, a hoe, was produced for this sphere of activity. However, hoes were used by both genders because farm work was performed by men and women (Bierfert, 1938, pp. 17-19; Bosch, 1964, p. 194; Gibson et al., 1981, pp. 168-169; Larson, 2002, p. 203). Apart from hoes, some tools were made for basketry, which was also performed by both genders (e.g. Gibson et al., 1981, p. 171; Larson, 2002, p. 256). Only the cosmetic knifes manufactured by the Mbukushu were explicitly for women. As briefly described in section 5.1.4, it is believed that agriculture was not introduced prior to the nineteenth century and people lived largely as foragers before that time (see also Kose, 2009b, p. 131). A similar scenario has also been described from parts of the Nyemba in remote areas up until the middle of the nineteenth century (Silva Porto, 1886 as cited in Von Oppen, 1993 p. 188). As pointed out in section 5.1, the oral chronicles of the Kavango polities described their ancestors as skilled hunters who occupied the middle Kavango area because of the rich hunting grounds they found. In particular, it was the abundance of elephants that made this region attractive. It is consequently unsurprising that people were specialized in the production of high-quality hunting tools. Maria Fisch (2008) thoroughly documented the Kavango hunting traditions, focusing especially on the hunting methods, hunting weapons, and beliefs. Her documentary evidence contributed significantly to the reconstruction of the late migration history of the Kavango peoples as suggested in Seifert (2009), and later in Kose (2012). Turning to classes of artifacts, axes and knifes were used for woodworking and to butcher animals (Fisch, 2008, pp. 22-24). The *mutaka* ax of the Nyemba was considered a personal weapon and used in rituals and warfare, and was also known among their Chokwe neighbors (Heintze, 1995, p. 135).[374] Spears were both personal weapons and hunting implements.[375] They were the pride of their owners and were carried during journeys as well as taken along while working in the fields (Fisch, 2008, pp. 24-25). In particular the ceremonial spear *mupembe* was carried as a sign of high status, whereas the *karumbi*-type spear was used in self-defense.

In the foraging societies of northern Namibia, people did not depend on metallurgy to ensure food production. Subsistence hunting and fishing was performed with an elaborate range of trap systems. Small animals caught in traps along with fishing contributed to a large portion to the subsistence of the people, and was also performed by women and children

[374] Interview with Johannes Mashela Kenga, July 26 and 31, 2007 in Vungu-Vungu.

[375] Interview with Headman Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje, Appendix 2.6, and with Paulus Ndumba, Appendix 2.4.

(Fisch, 2008, pp. 37-45; Larson, 2002, pp. 217-224). Yet these activities were of low prestige and did not enhance the esteem of the hunters. Similar observations from other African regions are described in Herbert (1993, p. 165). Iron hunting weapons were mainly found associated with those men considered mature, and hunting methods and animals that promoted the standing of the hunters in society (Kose, 2012, p. 212; Seifert, 2009, p. 281). Furthermore, Hüttenberger (1997, p. 87), analyzing the semantic field of hunting in Rugciriku, argued that hunting enhanced not so much the economic capital of men as their social status. Young men were acknowledged and initiated as hunters after their first successful antelope hunt. After initiation as a hunter, the young man was considered able to provide for a family, marry, and engage in public matters (Fisch, 2008, p. 74). The distinction between boys and men also became apparent in the type of arrowheads used: boys exercised and hunted with a range of wooden arrowheads whereas acknowledged hunters used variations made from iron (Fisch, 2008, p. 29).

The personal hunting equipment of men was the most precious possession of a Kavango hunter. It consisted of both types of knives, a small ax, a wooden throwing club, two to three types of spears, and a bow and arrows together with a quiver. As described above, spears were the most prestigious weapons because they served for personal protection and hunting (Fisch, 2008, pp. 22-28; Kose, 2012, pp. 212-213).[376] People distinguished between subsistence hunting, hunting for reasons of status, and ritual hunting (Fisch, 2008, pp. 30-36; Seifert 2009, pp. 280-281). Status hunting demanded special physical and mental skills of the individual hunter who stalked down an animal with a spear. Above all elephants and hippopotamuses were highly dangerous to kill, and raised the prestige of a successful hunter enormously (Fisch, 2008, p. 32; Kose, 2012, p. 213). Together with the eland, all hippopotamuses belonged to the ruling sovereign and the fat of both animals was desired for its nutritional and spiritual value (Fisch, 2008, pp. 124, 161).[377] Elephants were not as monopolized as eland and hippopotamus, yet oral chronicles suggest that they were one important reason for certain kin groups to move to the Kavango River and to found new polities. From the same historical period, groups of men specialized in hunting elephants were also reported from the central parts of Angola (Magyar, 1857 as cited in Von Oppen, 1993, p. 67). As has been described in detail in Von Oppen (1993, pp. 66-77), Möhlig (2007, pp. 134-135), Seifert (2009, pp. 278-281) and Kose (2012, pp. 211-212), the European need for ivory caused major population shifts in the interior of Africa when skilled hunters searched for new hunting grounds. Similarly, the San people of the Kalahari were actively involved in the ivory trade and exchanged tusks for other goods with their Bantu neighbors (Wilmsen, 1989, pp. 116-120). However, the Kavango region was not only attractive to local hunters. Shiremo (2010, pp. 102-103) and Likuwa (2012, pp. 27-28) described the mass killing of elephants in the nineteenth century by Europeans, and how local sovereigns issued hunting rights to foreigners in exchange for European goods such as guns and ammunition, blankets and glass beads. In particular the dry palaeo-riverbeds south of the Kavango River turned out to be a hunter's paradise. These regions were frequented and occupied by the Tjaube kin group and the increased need for ivory was certainly the motivation for the migration of the Tjaube people to the middle Kavango region (see section 5.1). Oral chronicles and oral history provided evidence that elephant tusks and rhinoceros horns were already the property of the Kavango rulers under King Mankoto in the early nineteenth century. As a consequence, each following sovereign in this area tried to bind successful hunters to their clan through marriage or appointing them to an office (Fisch, 2008, p. 30; Fleisch & Möhlig, 2002, p. 42; Gibson et al., 1981, p. 199). The historical record explains why the elephant tusk found at Vungu-Vungu (SC 12) is the most convincing archaeological evidence for a royal residence of the late Kavango peoples (section 2.12.20). Due to the developments on the international ivory marked, the latter became of great value to the local Kavango population. During a political intrigue about the succession on the throne at the end of the nineteenth century, the donation of one tusk prompted Hompa Mbambangandu to march against his neighbor Hompa Nyangana with the intention to kill him (Shiremo, 2010, p. 50).The Kavango peoples were always connected to the widespread trading networks of West Central Africa (e.g. Gibson et al., 1981, p. 230; Likuwa, 2012, pp. 28-32; Miller, 1988, p. 220 ; Seifert, 2009, p. 279; Wilmsen, 1989, pp. 76-77; 2003, pp. 82-88;

376 Interview with Paulus Ndumba, Appendix 2.4.

377 The outstanding role of hippopotamuses in the Kavango languages was analyzed by Hüttenberger (1997).

Vansina, 2004, p. 185; Von Oppen, 1993, p. 188).[378] Glass beads found at Vungu-Vungu indicated that European trade articles were already available during the early contact phase between the fifteenth and the eighteenth centuries (Kose & Richter, 2007, p. 123). In the following centuries, ivory and slaves became the most wanted export products from the Kavango area and confirmed the dominion of the leading clans (Likuwa, 2012, pp. 28-32; Shiremo, 2010, pp. 98, 148). The strong economical aspect found in the historic hunting activities of the Kavango peoples reaches beyond sole subsistence hunting and the European voracity for ivory encountered African societies in which hunting for status and prestige had a long tradition. The commercial exploitation of animal resources could easily become integrated in existing social structures. Finally, to keep up with competing communities and polities, the hunters needed weapons of first-class physical and spiritual quality.

Despite the fact that the Kavango peoples were involved in the international trade, the trade customs of iron implements greatly varied locally (section 5.3.5). Generally speaking, people mainly produced iron for their own needs, i.e. the needs of their families or communities. On the other hand, ironworkers traded implements to neighboring communities or groups. As said earlier, every Kavango polity had its own iron production, but it seems as if the Kwangali and Mbunza depended the most on the iron supply from their neighbors, particularly those who settled on the southern bank of the Kavango River, though I cannot say for those who stayed in what is today Angola. It is not entirely clear why Kwangali and Mbunza abandoned their own metal industry. As illustrated in section 5.3.5.2, Nyemba and Chokwe smelters filled this shortage around the turn of the twentieth century. A completely different picture unfolded from the Shambyu farther east. Here, people treasured local iron production and smelted to honor the ruler. Iron was produced for local use only and it was not acceptable to sell iron implements to foreigners, particularly to unknown individuals. Another special attribute was that ironworkers provided iron artifacts for their communities in exchange for various services, which a person could compensate for later. Fixed price rates were uncommon, yet people had an idea of the value of the implements. The value came from the raw materials used and the spiritual importance of the implement. Among the Gciriku it appears that some implements, such as big axes, hoes, knives and certain types of spears, were produced for the supra-regional trade, while others, such as small axes, the *karumbi*-type spear, arrowheads and other small items, were restricted to local use. The latter implements were earned through assisting in the smelts. It would be interesting to further investigate the spiritual dimensions of these inalienable items, which might comprise hunting success and personal protection. Farther east, as described in section 5.3.5.4, there is convincing evidence that the Mbukushu ironworkers were involved in the supra-regional trade of metal implements. It seems as if there existed large-scale iron artifact production centers with trading blacksmiths who satisfied the demand for high-quality tools among neighboring peoples. However, at the same time in other parts of the Mbukushu polity, smelters produced mainly for the demands of their own families. All in all, it became apparent that the Nyemba were the most active traders. Nyemba-speaking groups lived in large parts of central and southern Angola (Figure 215), and accordingly trade customs varied among them. In some areas, blacksmiths specialized on specific tool types, in other regions, there was no such specialization. In some area, Nyemba were provided with tools by neighboring people, in other regions, Nyemba blacksmiths furnished their neighbors with implements. However, many ways existed to pay a blacksmith for his tools. Besides barter, it was very common to provide manpower, such as assisting in either the smelt or in fieldwork. Charcoal for the forge was also an accepted currency. One interesting finding is that there seemed to be no difference as to the sophistication of the iron smelting techniques between those regions that produced beyond local requirements and those that satisfied the moderate need for implements of their own families. All the Mbukushu smelters along the Kavango performed advanced smelting technologies, no matter how high the yearly output of iron was. It seems to me that it was not only among the Mbukushu that furnace design and smelting technology did not coincide with the amount of iron produced. Looking west of the Kavango polities, the Kwanyama were strongly involved in supra-regional trade on a large scale and always produced iron beyond their needs (Kose, 2008, 2009a,

[378] Interview with Headman Paulus Mbundu Siveva, conducted by Eileen Kose, August 3, 2006, in Sikarosompo; with Interview with the Headmen Daniel Haikukutu, Jafeti Hainura, Hidion Karfere, Franz Semusi, conducted by Eileen Kose, August 6, 2007 in Nkurenkuru; with Headman Balthazar Shindimba, conducted by Eileen Kose, July 30, 2007, in Nyangana.

Angebauer, 1927; Estermann, 1936, Herbert, 2001; Travassos-Valdez, 1861. Nevertheless, the Kwanyama smelters used the simplest bowl furnaces consisting of small shallow unlined pits in the sandy Kalahari soil. Obviously, both the quality and quantity of the generated iron was sufficient for them. The examples given remind us that furnace design and the assumed sophistication behind it does not necessarily synchronize with the actual demand for iron, and the extent to which a society was involved in supra-regional trade.

The previous descriptions of the Kavango peoples portrayed a society in which iron was dispensable for a subsistence economy. Rather, iron tools appear in a segmental sphere of hunting and masculine status. The total need for iron was comparably low because people smelted primarily for their own demands. The respect given to smelters and in the second instance to blacksmiths was because of their spiritual and technological skills and not so much because of their economic wealth. People smelted during the dry season, in particular from April to June, and forged new tools before the rainy season started in October. Trade specialization varied among the Kavango peoples. The Kwangali considered miners, smelters and blacksmiths to be different crafts. It cannot be said for certain whether the division of labor is a result of a long and intense large-scale iron production or not, since De Barros (2000, p. 152) observed that a division of labor could also be found among small-scale producers. Supposedly, the iron industries were as varied and diverse as among the Nyemba or Mbukushu. The Nyemba distinguished between smiths and smelters, which may be because they occupied a large geographical area where iron ore was not always locally available, or because they were involved in regional and supra-regional trade. The latter had been found among the Mbukushu where ironworkers developed into full-time blacksmiths when involved in far reaching trade relationships, while in other regions smelting and smithing was a part-time occupation where every family produced only for their own demands. The unfolding picture is more or less in accord with the situation that Childs and Killick (1993, p. 329) sketched for unstratified societies. They further argued together with De Barros (2000, p. 154) and other scholars that in small-scale acephalous societies, or what are known as 'big-man systems', iron production was in the hands of clans or lineage heads, whereas in more complex societies iron production was controlled by the central power. According to them, this was considered necessary because ironworkers were regarded as competitors to rulers. However, the Kavango polities somehow elude such classification. All Kavango polities of Bantu-speakers have a similar genesis, a comparable political organization and social stratification. Nonetheless one finds the iron craftsmanship loosely tied to certain families owing to tradition among the Kwangali, Nyemba and Gciriku, while it was the common knowledge of each family or lineage among the Mbukushu. In turn, iron and tool production was restricted and strongly monopolized by one clan among the Shambyu, and controlled by their rulers. Among all Bantu-speaking Kavango groups, the Shambyu have the strongest egalitarian traditions as exemplified in section 5.3.5.3 when describing their trade customs. Yet it seems as if societies could develop features attributed to stratified societies in some fields of societal life such as clan affiliation, the control of ironworkers by the central power, and the monopolization of ivory trade, whereas other fields retained the structures rather typical of egalitarian forager societies.

There was no local memory found with respect to the time depth of iron production in the Kavango region except for the Nyemba and the account of the Tjaube migration. In both cases, the iron craft is associated with their country of origin, yet the true time-depth escapes remembrance. Iron production declined in the first half of the twentieth century for two main reasons: first, the availability of European tools and scrap metals, and second, owing to the suppression of the craftsmanship by the colonial administration. Skilled blacksmiths were considered dangerous to the German and South African (and Portuguese) colonial administration because potentially they were able to re-arm the people. The control of weapons, particularly of guns was a main concern of the colonial administrations. All the guns had to be registered and examples of the struggle for ownership are given in Eckl (2004, pp. 152-153) and Fisch (2004, pp. 78-80). However, more historical research is needed to fully assess the competing role of the iron-workers in the struggle for power during the early colonial period. Supposedly, the suppression of the craft is the main reason why nowadays local expertise became lost in large areas along the Kavango River, and local ironworkers have been replaced by skilled blacksmiths from Angola.

6. Summary and Conclusion

This dissertation set out to investigate the archaeology and metallurgy of ironworking peoples in the middle Kavango region in northern Namibia, covering a period from the 3rd century to the early 20th century AD. It is the first academic work to illuminate 1500 years of metallurgical tradition in southwestern Africa, adding significantly to the state of knowledge about historical ironworking traditions in this region.

My research focused on an enhanced understanding of the chronological sequences of the Early and Late Ironworking Groups with special consideration to their iron metallurgy. To understand metallurgical traditions and to reconstruct the technological processes on prehistoric and historic sites, I have carried out an archaeometallurgical study of ore and slag material alongside iron artifacts from the Early and Late Ironworking Groups assemblages. One major concern was to identify metalworking processes in the archaeological record and to increase our knowledge about the specific metallurgical activities at the archaeological sites under study. Another purpose of this work was to create a database of oral history knowledge about ironworking traditions from the middle Kavango region to document a vanishing technology and to put the more recent archaeological sites in a historical context.

The middle Kavango region was selected because it provided a corpus of 60 surveyed or excavated archaeological site complexes dating to the Ironworking Groups occupation periods, or contributing information of relevant geological formations. On 14 of these sites, remains of metalworking have been found of which no scientific archaeometallurgical analyses existed at that time. Geographically, the middle Kavango region is part of the Kavango River system that connects central Angola with the extremely arid environment of the Kalahari in Botswana. The Kavango River is the first perennial river at the northern fringe of the geographical Kalahari, and presumably it was an important route for the exchange of goods and ideas in prehistoric times, as it has been in historical times.

My research project started with new fieldwork focusing on the earliest sites that was assumed would yield new and additional evidence of early metallurgy. From these sites, in particular from Ruuga (SC 3) and Kapako (SC 4), roughly 22 000 new finds were incorporated into this study. Additionally, my pursuit of new information, connections and interpretations led me to reassess parts of the archaeological assemblages excavated by Beatrice Sandelowsky in the late 1960s (Sandelowsky, 1974; 1979), and some of the cultural materials collected by John Kinahan in the early 1980s (Kinahan, 1986).

Another focus in the field was to sketch the geological sequences of the research area, because studies that have addressed the geology of the middle Kavango region are scarce. This was particularly important in order to comprehend the sources of iron ore that were accessible to the Kavango peoples in prehistoric and historical times. Sites that were potentially old mining sites were located and sampled, and the samples were analyzed in the laboratory in addition to ore samples recommended by modern local ironworkers.

When selecting the slag and metal samples from the archaeological assemblages for the archaeometrical study, priority was given to the most important sites Ruuga (SC 3), Kapako (SC 4), and Vungu-Vungu (SC 12). In addition, selected samples from less researched locations were added to obtain a broader state of information concerning the metallurgical traditions in the area. The samples were analyzed with wet-chemical, mineralogical, and metallographic standard methods.

The third objective of my research work, the oral history study, was started from almost zero. Only from the Mbukushu area had ethnographic and historical accounts of iron production existed previous to this investigation. For my interviews, I followed the recommendations of the local authorities to trace informants with historical knowledge about metal production. In addition, blacksmiths were approached and their family background was investigated. I found structured interviews to be the best historical method to create a database of comparable information. For this purpose I developed an interview guide that covered the metallurgical fields of mining, smelting, forging, trade customs, rituals and taboos alongside the social position of ironworkers.

As mentioned above, the major contribution of this study has been that it is the first academic work to illuminate 1500 years of metallurgical tradition in southwestern Africa. The earliest metallurgical remains from Namibia are among the earliest evidence of iron production and processing in southwestern Africa in general and started in a Late Stone Age context. Therefore this study was also a systematic archaeometallurgical examination of slag remains and metals found in Late Stone Age assemblages. Probably until the late 19th century the Kavango peoples subsisted mainly on hunting, fishing and gathering with little or no input from crop cultivation and animal husbandry. Hence the investigation of the recent archaeological assemblages could also deepen our knowledge about the role of iron in societies with less pronounced agricultural roots. What is more, this work provides the first standardized compilation of historical knowledge on metallurgical traditions along the middle Kavango River and it became a key strength of this study to combine the archaeometallurgical approach with well-dated archaeological assemblages and a database of historical information about ironworking traditions from the research area.

The new fieldwork revealed the earliest evidence of ironworking in Namibia at the Ruuga (SC 3) archaeological site. Together with new evidence from the Kapako (SC 4), this study provides an important contribution to the understanding of the spread of metallurgical knowledge to southwestern Africa and sheds new light on what has been discussed as 'Western Stream Iron Age' in scholarly literature. The evaluation of the archaeological assemblages confirmed and improved upon previous conclusions whilst also adding new information on the chronological framework of the Ironworking Groups along the middle Kavango River. The study also illuminated some aspects of the transition from the Late Stone Age to the Iron Age and encourages new interpretive approaches. It lays the foundation, in particular together with Duncan Miller's thorough examination of metal artifacts from the Tsodilo Hills (Miller, 1996), for future archaeometrical projects to be conducted in Namibia, Botswana or Angola.

In the course of this research, the Early Iron Working Groups period has been defined, on the basis of the pottery style from these assemblages (Sandelowsky, 1979; Richter, 2005), to be an occupation period between the 3rd and the 12th centuries AD along the middle Kavango River. Only five sites were assignable to the Early Ironworking Groups occupation period and I assume that the limited number of sites is not representative of the settlement density of this period. The archaeological assemblages of Ruuga (SC 3) and Kapako (SC 4) provided the first insights into iron production and processing practices during the first millennium AD. The investigation revealed that the earliest metal production in Namibia started in a Late Stone Age context during the 5th and the 6th centuries AD. From the archaeological record it would appear that Ruuga (SC 3) is older than Kapako (SC 4), but even though the latter is younger, the new finds from Kapako supported the results from Ruuga that iron metallurgy arose in a classical Late Stone Age context around the middle of the first millennium AD. Unfortunately, neither the smelting nor the mining locations of the Early Ironworking Groups have been detected. Most probably, the smelters of the time mined in the Kafuma or Kakeni Omiramba in present-day Angola, and the slag analyses suggested that the smelters from Ruuga (SC 3) and Kapako (SC 4) probably used the same mining grounds for some time. Neither Ruuga nor Kapako provided evidence of a smelting site. The smelting slag remains uncovered at both sites fell in the typical range of slag that can be found at refining sites. It is unknown what type of fuel the early ironworkers used, or the way in which iron production and processing were organized. It could be that people lived in different locations from the smelting sites, but more research is necessary to illuminate the spatial arrangement of the processing steps of early metallurgy. Likewise, the spiritual aspects of early metal production remained unknown, since they are barely visible in the archaeological record. Very little concrete evidence of the furnace designs became available. The chemical slag signature attested that no clay refractories contributed significantly to the melt. Rather it appeared that the quartz-rich Kalahari sand contributed to the overall smelting parameters. As some slag samples showed slagged rims of the natural soil, this could indicate such a possibility as unlined pit furnaces in the ground. Furthermore, the generated archaeometrical and morphological data indicated that these furnaces possessed slag-tapping facilities.

In both investigated areas at Ruuga (SC 3) and Kapako (SC 4), the ironworkers performed bloom-refining. Here they purified the new iron material and forged it into the desired artifacts. The technical and artistic skills mirrored in the slag compositions from pictured ironworkers who mastered the transformation from dirty blooms into compact pieces of raw metal. These processes included the mechanical sorting of iron-rich parts of the bloom, the reheating of such pieces above slag-liquidus temperatures in a strongly reducing environment, the mechanical compacting of these bloom fragments and the fusing of these pieces into bars of raw metal.

The ironworkers used siliceous fluxes whilst compacting the iron. Unfortunately the refining furnaces of the time were as elusive as the smelting furnaces, but the extracted morphological and archaeometrical data indicated that they were small unlined pits in the ground. There is a possibility that they had slag-tapping facilities, too. However, reconstructions of both smelting and refining furnaces remain to be confirmed by future archaeological research.
This study has been able to show that the generated iron was heterogeneous, the quality ranging from wrought iron to high carbon steel. However, the range of evidence from the metallographic analyses suggested that the ironworkers of the time preferred medium to high carbon steel for artifact production. The skills of the smiths involved cold and hot working as well as knowledge of the effects of normalizing and annealing the artifacts at subcritical temperatures to restore the material's properties. It cannot be said for certain whether warm working was a deliberately induced treatment, either. The range of artifacts found was restricted to small jewelry items or tools, which are most probably not representative of the spectrum of artifacts produced, because iron was subject to a high rate of recycling. Interestingly, Ruuga (SC 3) provided the earliest evidence of a drawn iron wire in southern Africa, yet it was probably not of local origin since other traces of wire fabrication were absent in the assemblage. Presumably, copper was also worked at these sites, since individual slag samples showed high copper readings. The level of technological knowledge that became visible in the course of this study strongly suggested that the artisan skills of iron production were introduced into this region as a package of skilled knowledge. From the changes in the lithic assemblage of Kapako (SC 4) during the 5th to the 7th centuries it would appear that the iron products successively replaced the spectrum of formal lithic tools, but the late phase of the Early Ironworking Groups is not yet well illuminated.

The decorative expression found on pottery from the Early Ironworking Group period indicated closest cultural links to sites like Xaro situated on the lower Kavango River and Divuyu in the Tsodilo Hills, both of which were more recent than the middle Kavango sites investigated in this study. Since Divuyu was a habitation location of highly trained blacksmiths (Miller, 1996), it is likely that the Kavango smelters delivered some raw metal or iron products to them. The connection to the Tsodilo Hills is backed up by a piece of specular hematite found at Ruuga (SC 3) mirroring the trade relationships that were maintained by the inhabitants of the middle Kavango region with the hematite miners of the Tsodilo Hills (Robbins, Murphy, Campbell, & Brook, 1998; Wilmsen, Campbell, Brook, Robbins & Murphy, 2013). However, the specular hematite was most likely used for coloring or other spiritual purposes and not for iron production, since it did not contribute to the chemical fingerprints of the slag fragments analyzed. The Early Ironworking Groups made their first appearance sometime between the 3rd and 4th centuries AD with Late Stone Age peoples using and probably producing pottery for the first time. The results of this study also attested that metallurgy appeared between the 5th and 6th centuries AD among the same people. While in the early phases of the EIG horizon lithic tool production still played a major role, the assemblages changed in a later phase of the EIG period and stone working lost its importance. Unfortunately, there is not much known about the late phase of the Early Ironworking Groups or how and why they vanished around the 12th century. Perhaps climatic constraints forced the people to leave the area because only in the Tsodilo Hills and in the Okavango Delta region was evidence for human occupation beyond the 12th century AD found.
Moving on to the chronological position of the Early Ironworking Groups in a wider frame of reference, the newly produced sequence of radiocarbon dates proved that the beginnings of the EIG occupation in the middle Kavango region were contemporaneous with other Early Iron Age sites in south central and west central Africa, where related pottery styles and/or evidence for metallurgy were found. These sites are Kapwirimbwe, Dambwa, and Chondwe in what is today Zambia, Naviundu in the Democratic Republic of Congo as well as Kayes and Mandingo-Kayes in the Republic of Congo. Only Benfica on the Atlantic coast in Angola and the site BP 113 in the Republic of Congo are slightly antecedent to these sites. This means that the dynamics of the spread of metallurgical knowledge and pottery styles to southwestern as well as south central Africa are far from being understood in the current state of research. They may well be different from that previously acknowledged and the results of this study strongly recommend looking for new common roots and new approaches to the cultural history of the past two millennia between the Congo, the Copper Belt and the Kavango. Nevertheless, although archaeological evidence is still lacking,

I assume that metallurgy spread from central or west central Africa to the middle Kavango region. With Ruuga being the oldest of the Kavango sites, followed by Kapako and Divuyu the pottery traditions as well as the metallurgical knowledge appeared to have made their way from west to east along the Kavango River until they reached the peoples living in the Tsodilo Hills.

After a hiatus in the archaeological record of approximately 300 years, the Kavango region underwent reoccupation by pottery-using and ironworking peoples from the late 15th and 16th centuries AD onwards, the Late Ironworking Groups. The area might still have been frequented all along by mobile groups of foragers, but the archaeological assemblages of non-pottery-using and non-ironworking groups of the past two millennia are only poorly understood in the current state of research. The LIG period has been defined to be a period between the late 15th and the 20th centuries AD and it has been established on the basis of the prevalent pottery style found in these late assemblages, which is known as typical Kavango pottery or Vungu-Vungu-style ceramics.
One significant new finding of this study was that there existed an early occupation phase within the Late Ironworking Groups with an as yet unknown pottery tradition first observed in the context of this dissertation. It emerged from the reassessment of Beatrice Sandelowsky's finds from Vungu-Vungu (SC 12) in conjunction with new finds from the site complex Gove-Mbambangandu (SC 17) and radiocarbon dates generated from carburized organic temper extracted from ceramics. A comprehensive definition of this new pottery style, which I denominated 'Gove ware', will be provided in a coming study on the ceramics from the area. Only five sites could be attributed to this period, yet all these sites provided pottery that in style and manufacture was quite different from the Vungu-Vungu pottery tradition. It cannot be said for certain whether these few sites are representative of the settlement density of this period during the beginnings of the LIG period, and hopefully in the future a more coherent picture of this early occupation phase will be developed. The significance of this finding derives from the oral chronicles and narratives handed down in the middle Kavango area, providing an account of an ironworking foraging population who settled along the river and in its southern fossil tributaries prior to the arrival of the ancestors of the modern Kavango peoples. These settlers are remembered as the Tjaube people. It has long been assumed that the account of the Tjaube, their migration history and the conquest of their polity is fictional, yet the evidence outlined in this dissertation could well suggest that the Tjaube were living along the middle Kavango for some 200 years or even longer before the ancestors of the modern Kavango peoples arrived in the late 18th century.

Regarding the late phase of the Late Ironworking Groups, 39 sites were assignable to this period, reflecting a steadily increasing settlement density over the past 200 years. Metallurgy activities were detected at 14 of these sites. The most important assemblages that contributed to the archaeometallurgical study came from the upper layers of Kapako (SC 4), from Vungu-Vungu (SC 4), and Dikundu (SC 30).
The assemblage of the upper settlement horizon of Kapako (SC 4) provided insights into iron production and processing during the Late Ironworking Groups period, but unfortunately the most recent occupation phase is insufficiently dated at the site. The amount and distribution of the archaeological slag material delineated a center of ironworking and probably iron production, which was though difficult to fathom in the current state of research. The remnants of metallurgy comprised initial refining residues (including some smelting slag) and fine smithing remains. From the faunal assemblage it appeared that the subsistence of these settlers was mainly dependent upon fishing.
Vungu-Vungu (SC 12) is the largest site of the Late Ironworking Groups to be hitherto investigated. Besides the rich cultural remains already published (Sandelowsky, 1979; Richter, 2005, Kose & Richter, 2007; Kose, 2009b), here too special attention was given to the metallurgical residues. Another challenge was to link existing oral chronicles with the archaeological remains of Vungu-Vungu (SC 12).The archaeological investigations revealed a multi-component site spanning roughly 500 years of history. Combining these data with the historical records suggested that Vungu-Vungu was first a trading post of the Tjaube people, where ivory and probably other local goods were exchanged for European trade items. It was possible to localize two areas related to the early Tjaube occupation within the site complex. The site continued to be connected to the supra-regional trading networks when it became the royal court of the first Shambyu in the late 18th century. The subsistence of both groups of settlers depended on hunting and fishing

alongside some bartered cattle, and might have been complemented by crop farming in the 19th century. Oral accounts that metallurgy started with the first settlers at the site found confirmation in the archaeological study, and the occupation ended in the early 20th century. Based on the macroscopic as well as microscopic examination of the slag samples in conjunction with the oral history record I have been able to reconstruct six zones of metallurgical activities inside the historical settlement, amongst them one smelting zone and five areas where bloom refining processes and fine smithing were accomplished. Most interesting was the fact that the smelting site was located inside the settlement. Many African societies performed iron production according to the reproductive paradigm as described by Herbert (1993), and smelting was carried out in spatial seclusion outside of settlement and habitation zones. The historical Shambyu smelters however moved the smelting activities close to their royal residences in order to honor the sovereign and found new solutions for maintaining a ritual seclusion in an area that was spatially only minimally separated from the living zones of the inhabitants.
The third important site mentioned, Dikundu (SC 30), contained the archaeological and historical evidence of various smelting and refining practices. The area was first investigated by Beatrice Sandelowsky (1974) and together with the new reassessment of the site the whole dimension and diversity of iron metallurgy of the late Kavango peoples together with their high standard of technological knowledge became visible.

As mentioned, a geological survey needed to be employed to locate potential historical mining sites and to generate a preliminary chemical picture of potentially exploited iron ores. The data of these ore samples were then compared with the chemical fingerprints of the slag material. The results of this study clearly indicate that neither the specular hematite found at Ruuga (SC 3) contributed to the melts nor the massive ferricretes outcropping along the upper and middle terrace of the Kavango River. Slag and ore chemistry in conjunction with semi-reacted ore remains found in several slag samples strengthened the assumption that near-surface plinthic ore formations such as those identified at Kauti (SC 32) , Dikundu (SC 30) and Kapongo (SC 29) were the prevalent raw material used in historical smelting operations. This result found confirmation in the oral accounts of local ironworkers outlining the importance of near-surface (plinthic) deposits in palaeo-riverbeds in the historical smelts. An interesting aspect found in the narratives is the transport distance of the raw material: In order to obtain high-quality material for their smelts, the historical smelters transported iron ore over distances of up to 70 km.

Moving on to the metallurgical record of the Late Ironworking Groups, there appeared no significant change in furnace style from the Early to the Late Ironworking Groups. Reconstructions from slag morphology indicated that slag-tapping pit furnaces without superstructure still prevailed. The chemical slag signatures revealed that clay refractories did not significantly contribute to the melt and the overall silica-rich slag chemistry suggested that quartz-rich material (i.e. the natural soil) added to the slag formation. A new furnace type took the form of shaft furnaces carved from and located in abandoned termite mounds as identified at Dikundu (SC 30) and Kapongo (SC 29). However, despite extensive investigation in the course of this research work in the middle Kavango region, the furnace of Dikundu, excavated by Beatrice Sandelowsky in 1969, continues to be the only archaeologically investigated smelting facility in this area. The performance and the outcome of the smelts could hardly be determined on the basis of the metallurgical record. However, evidence has been found in the assemblages from Vungu-Vungu (SC 12) and Dikundu (SC 30) that the running furnaces were replenished with iron ore (and probably fuel) in order to increase the total yield of iron. Calculations of the shift in the $FeO:SiO_2$ ratio from ores to slag indicated that no more than 12wt% of the available iron oxides in the ores were transformed to iron metal. The main portion of iron oxides was necessary to produce the iron-rich but low-melting slag composition in the fayalite field from which all bloomery smelters benefited.

Refining was a process of repeated heating and hammering of an iron bloom. The examined slag material indicated that refining furnaces were small pits in the sandy soil. In the case of Dikundu (SC 30), the ironworkers used an abandoned shaft furnace from smelting operations for refining. The investigated areas at Kapako (SC 4) and Vungu-Vungu (SC 12) showed that refining was done in habitation locations. Remnants of the bloom purification were frequently associated with the waste from fine smithing processes and apparently both procedures were performed in the same working zone. Reconstructing the technical skills of the ironworkers showed that blooms were mechanically sorted first, and the iron-rich parts were reheated under hot and strongly reducing conditions to slag-liquidus temperatures. The large quantity of layered refining slag residues of all steps of the bloom-cleaning process reinforced my view that in this region refining was a multi-step process of alternate heating and consolidation lasting several hours. The physical compaction of the hot bloom was mirrored in the deformed microstructure of metal inclusions found in the refining slag samples. The ironworkers used siliceous fluxes to fuse the bloom fragments into a piece of solid raw material. However, the examination of the slag block recovered from the bottom of the furnace at Dikundu (SC 30) suggested a different technological approach. Here it appeared that the bloom was re-heated and the slag reliquefied in a furnace to provoke the sintering of the iron metal in the liquid slag bath. This technology would save several steps of heating and hammering.

The metallographic examination of iron inclusions in slag remains and of several iron artifacts has been able to show that the bloomery iron was a heterogeneous material, ranging from wrought iron to high carbon steel, and in certain cases over-carburized cast iron was identified. The ironworkers of the time welded pieces of quite different qualities together and forged them into new tools. Iron was valuable and there was a high rate of recycling. For this reason only small items were found in the archaeological assemblages, including small implements such as a hook, rings, small points and a small iron bar. From the archaeological record it would appear that these small objects were the main goal of production, yet the historical record provided clear evidence that mainly hunting weapons such as spears and arrowheads were manufactured. This contradiction points most probably to meticulous recycling. There was no apparent difference between the forging techniques identified in the EIG assemblages of Kapako (SC 4) and Ruuga (SC 3), and those traced back in the LIG artifacts examined for this study. The fabrication technique involved cold and hot working to give an implement the desired shape. Some artifacts were normalized, i.e. heated to the austenite field in order to restore the properties of the material and several objects were left in an annealed state. Warm working has been identified, too, but there was not enough evidence to argue that this treatment was intended by the ironworkers to alter the material's properties. No evidence was found that techniques of strengthening or hardening the material were practiced, yet this outcome may be distorted owing to the strongly limited and biased range of artifacts that were found. Presumably, copper was also worked and recycled by the ironworkers of the time because the iron artifacts were found in association with small and sometimes damaged copper artifacts.

This study has found that there was no apparent difference in the smelting, refining and fine smithing technology of the metalworkers of the Early Ironworking Groups and the Late Ironworking Groups. This result confirmed the conclusions previously made by Miller (1996, pp. 95–96) who has attributed a rather conservative attitude towards metalworking to the ironworkers of southern Africa, with no dramatic technological innovations once iron metallurgy was established in the area.

Besides the archaeometallurgical investigation of the archaeological material, another purpose of this study has been to collect local memories of historical iron metallurgy. The oral history study significantly enhanced our insight into historical metallurgical practices of the Kavango peoples and beyond, since it has generated information on the social and cosmological aspects of metallurgy, together with valuable data about historical smelting and mining sites and a range of technical details. Moreover, the oral history collection constitutes a start for the documentation of the historical metallurgical traditions of the Nyemba people in southern Angola.

Comparing the oral history record with the archaeological data, it seems that considerably more smelting sites existed during the past 500 years than were remembered in local memories. This might be explained by the high mobility of the local population during the past 100 years, obliterating the historical traces of iron production at several locations, or because local memories do not reach further back than the late 19th century. Conversely, the oral history interviews produced information about historical sites that have not yet been identified archaeologically.

Another discovery of the oral history study has been that there existed a greater variety of furnace styles and technical solutions than one would assume from the archaeological record. People operated pit furnaces of varying dimensions with or without slag-tapping facilities, various pit furnaces on shallow elevations

such as eroded termite mounds with slag-tapping facilities, and high shaft furnaces. A very interesting finding was that smelting techniques transcended political and ethnic boundaries on the one hand, while on the other hand technical performances of the same process could vary significantly within polities, ethnic groups and even at one and the same smelting site. The reason for this diversity might be attributed to cultural and not resource-related dynamics owing to the heterogeneous genesis of the contemporary Kavango peoples. Migration movements into the middle Kavango region took place from the Okavango Delta, from what is today west Zambia, as well as from central and south Angola, and presumably contributed to the heterogeneous picture of the Kavango smelting traditions.
The historical data collection disclosed that the Kavango smelters produced bloomery iron and cast iron. Cast iron was produced by the Mbukushu and was processed into hunting and household implements in the forge. There is also historical evidence that the ironworkers along the middle Kavango River cast muzzle loaders. It cannot be said for certain when cast iron production started in the middle Kavango region, but I assume that it appeared not before the 19th century. Further studies to illuminate the start of cast iron production and additional technical aspects in this field would be worthwhile.

The historical study has also been able to explore process-related parameters such as the time needed for preparing and performing a smelting operation, the number of people involved, the amount of fuel and ores needed, and the yield of new iron per smelt. Ironworking was primarily performed by mature men who were considered responsible enough to follow the most important taboo of sexual abstinence during the smelting period. It was carried out during the dry season and a group of workers could comprise between five and more than 20 individuals, depending on the amount of new iron required. In the early 20th century all the ironworkers were part-time farming specialists, while in earlier times they presumably were part-time hunting and fishing metalworkers. Only among the Shambyu was metalworking restricted to a specific clan. In other regions families specialized to some extent in ironworking out of tradition, while the trade skills were accessible to every responsible male member of the society. Among the Mbukushu highly specialized ironworkers existed in some parts of their polity, providing the whole region with metal implements, while in other regions every extended family had its own ironworkers and every settlement maintained its own smelting site. Merging the data on trade customs showed that most groups smelted for the demands of their communities or families. However, the Nyemba and to some extent the Gciriku and Mbukushu produced iron implements beyond their needs and traded them with their neighbors. A most interesting finding was the buoyant flow of iron implements from the Bantu-speaking communities to their San-speaking neighbors. Pulling together all the historical data it appeared that considerably more material goods found their way from the Kavango communities to the San peoples than to their Bantu neighbors.

All over Africa cosmological concepts that have explained human existence as well as the universe have also explained and above all regularized iron production. The historical research confirmed that iron production and iron processing was (and still is) located between the conceptual poles of procreative feminine and masculine power. In the Kavango societies, smelting operations were procreative processes analogous to human reproduction. The same ritual and taboos associated with pregnancy and childbirth surrounded the smelters and the furnace. One important rule was the ironworkers' sexual fidelity in their relationship to the smelting furnace, and any transgression would cause the smelt to fail. Another menace was the destructive power of menstruating women, whose presence was believed to cause sickness amongst their communities, and to weaken and spoil in particular masculine activities such as metal and tool production. These were the main reasons why smelting operations were always kept separate from habitation locations, yet people found pragmatic spatial and spiritual solutions to the performance of iron production no more than 100 m away from the living zones or, as mentioned earlier, even inside the settlement itself. The collection of historical data also unveiled the significant role of the bellows in all smelting and tool-production processes. It could be seen that bellows were believed to embody the procreative masculine power, which eventually transformed the stone to metal. Moreover, the bellows transferred spiritual power to defensive arms to protect their owners. The Kavango peoples look back on a long hunting tradition. Accordingly, the ironworkers manufactured mainly hunting weapons. Here again the bellows were thought to transfer esoteric power to the hunting gear during the production of the iron implements, and finally their spiritual force provided the hunters' success and prosperity for the people.

This work has also shown that the Kavango smelters were predominantly small-scale iron producers, in contrast with the economic wealth that the application of the iron hunting weapons produced. Several historical studies (Likuwa, 2012; Seifert, 2009; Shiremo, 2009; Von Oppen, 1993) have illuminated that once the Europeans arrived on the coast of Angola, the Kavango region experienced increasing trade with the Atlantic coast and became part of the transatlantic market. Ivory, slaves, ostrich products, bees wax, rubber and many other things were traded along the river in exchange for European trade goods such as glass beads, tobacco, textiles, and guns. The Kavango peoples introduced significant amounts of ivory to the international market and served as intermediate agents between the Kalahari and the Atlantic. Their trade relationships find expression in the rich archaeological assemblage of Vungu-Vungu (SC 12). The results of this research in conjunction with the historical studies mentioned and the oral chronicles of the Kavango polities strongly suggest that the increasing impact of the ivory trade motivated the Kavango peoples to migrate to the Kavango River, which still provided a rich source of ivory at the time. New rulers established their dominion on the basis of these ivory resources and the European luxuries that they received in return. Yet every sovereign depended on productive hunters, and a hunter's success is based on a first-class hunting gear in terms of its physical and in particular spiritual properties. Finally, only with this broader historical approach was it possible to explore the importance of iron, iron implements and ironworkers in the history of Kavango society.

This study confirms that a broad multidisciplinary approach to a research topic is most fruitful when it comes to understanding prehistoric and historic dynamics, even though, owing to this broad approach, it may lack depth in the one or the other respect. It is unfortunate that only limited faunal analyses of the investigated Kavango sites were available at the time this study was finished, and it would be a fruitful area for further work. It is recommended to complement this study with more data, considering potential iron ore deposits and focusing on smelting slags to deepen the understanding of smelting practices. My investigations also showed that there is a potential for more early metallurgical sites along the Kavango River, which could move the debate on the spread of early metallurgy in west central and southwestern Africa significantly forward. It would also be a valuable contribution to the region's history to concentrate future research also on the northern riverside inwhat is today Angola, and to move the focus farther upstream. Another future challenge would be to pursue the historical data given in the oral chronicles more thoroughly from an archaeological perspective. The interviews and narratives about local iron production collected in the context of this study could guide future research to targeted historical investigations in this area. Finally, no efforts should be spared in these times of growing economy and traffic in northern Namibia to protect these important sites.

Bibliography

Adekayode, F. O., & Ogunkoya, M. O. (2009). Comparative study of clay and organic matter content of termite mounds and the surrounding soils. *African Crop Science Conference Proceedings, 9*, 379-384.

Aleva, G. J. J. (1994). *Laterites. Concepts, geology, morphology, and chemistry.* Wageningen: International Soil Reference and Information Center.

Akuupa, M. (2015). *National culture in post-apartheid Namibia - state-sponsored cultural festivals and their histories.* Oxford: Basler Afrika Bibliographien.

Allibert, M. (1995). *Slag atlas.* Düsseldorf: Stahleisen.

Anciaux de Faveaux, E., & de Maret, P. (1984). Premières datations pour la fonte du cuivre au Shaba (Zaïre). *Bulletin de la Société Royale Belge d'Anthropologie et de Préhistoire, 95*, 5-20.

Anderson, C. (1863). *Der Okavango Strom. Entdeckungsreisen und Jagdabenteuer in Südwest-Afrika.* Leipzig: Wolfgang Gerhard.

Angebauer, K. (1927). *Ovambo. Fünfzehn Jahre unter Kaffern, Buschleuten und Bezirksamtmännern.* Berlin: Scherl.

A.O.C Technical Services (1967). *Report on a reconnaissance soil survey of Okavangoland with particular reference to the riparian land.* Report for the South West African Administration Water Affairs Branch, Johannesburg.

Atlhopheng, J. R., & Ekosse, G.-I. E. (2007). Mineralogical appraisal of sediments of duricrust suites and pans around Jwaneng area, Botswana. *Journal of Applied Sciences and Environmental Management, 11*(1), 51-56.

Avery, D. H., van der Merwe, N. J., & Saitowitz, S. (1988). The metallurgy of the iron bloomery in Africa. In R. Maddin (Ed.), *The beginning of the use of metals and alloys. Papers from the second international conference on the beginning of the use of metals and alloys, Zhengzhou, China, 21 - 26 October 1986* (pp. 261-282). Cambridge: MIT Press.

Avery, D. H., & Schmidt, P. (1979). A metallurgical study of the iron bloomery, particularly as practiced in Buhaya. *Journal of Metals, 31*(9), 14-20.

Babayemi, J. O., Dauda, K. T., Nwude, D. O., & Kayode, A. A. A. (2010). Evaluation of the composition and chemistry of ash and potash from various plant material - a review. *Journal of Applied Science, 10*(16), 1820-1824.

Bachmann, H. G. (1982). *The identification of slags from archaeological sites.* London: Institute of Archaeology.

Baillieul, T. A. (1975). A reconnaissance survey of the cover sands in the Republic of Botswana. *Journal of Sedimentary Petrology, 45*(2), 494-503.

Balfour, D. J., Hegenberger, W., Medlycott, A. S., & Wilson, K. J. (1985). Kimberlites near Sikereti, north-eastern South West Africa/ Namibia. *Communications of the geological survey South West Africa/Namibia, 1*, 69-78.

Bandama, F. (2013). *The archaeology and technology of metal production in the Late Iron Age of the southern Waterberg, Limpopo Province, South Africa.* (Doctoral dissertation).Retrieved from http://uctscholar.uct.ac.zaPDF/166016_Bandama_Foreman.pdf

Barndon, R. (2004). *An ethnoarchaeological study of iron-smelting practices among the Pangwa and Fipa in Tanzania.* London: Archaeopress.

Barnes, H. B. (1926). Iron smelting among the Ba-Ushi. *The Journal of the Royal Anthropological Institute of Great Britain and Ireland, 56*, 189-194.

Bastin, M. L. (1974). Le haut fourneau ‚Lutengo': opération de la fonte du fer et rituel chez les Tshokwe du nord de la Lunda (Angola). *In memoriam António Jorge Dias / Instituto de Alta Cultura, 3*, 59-69.

Bauermeister, J., & Kronz, A. (2006). Phosphorreiche Erze: Ein Problem für die frühe Eisenverhüttung ? - Kaiserzeitliche Eisenverhüttung im Kreis Leer. *Archäometrie und Denkmalpflege 2006, Kurzberichte der Jahrestagung an der Staatlichen Akademie der Bildenden Künste Stuttgart*, 55-57.

Baumann, H. (1975). *Die Völker Afrikas und ihre traditionellen Kulturen Allgemeiner Teil und südliches Afrika.* Wiesbaden: Steiner.

Berns, H., & Theisen, W. (2013). *Eisenwerkstoffe - Stahl und Gusseisen.* Berlin, Heidelberg: Springer.

Bielenin, K., & Suliga, I. (2008). The ancient slag-pit furnace and the reduction process in the light of a new archaeological concept and metallurgical research. *Metallurgy and Foundry Engineering, 34*(1), 53-78.

Bierfert, A. P. (1938). *25 Jahre bei den Wadiriku am Okawango.* Hünfeld: Oblaten.

Biesele, M. (2002). Ein Abriss zur Ethnographie der !Xun. In M. Szalay, & M. Biesele (Eds.), *Der Mond als Schuh: Zeichnungen und Aquarelle von Diä!kwain, /Han≠Kass'o, !Nanni,Tamme, /Uma und Da* (pp. 53-66). Zürich: Scheidegger und Spiess.

Blomgren, S., & Tholander, E. (1986). Influence of the ore smelting course of the slag microstructures at early ironmaking, usable as identification basis for the furnace process employed. *Scandinavian Journal of Metallurgy, 15*, 151-160.

Bosch, J. L. (1964). *Die Shambiu van die Okavango; 'n volkekundige Studie.* (Doctoral dissertation, University of Stellenbosch, Stellenbosch).

Botha, G. A. (2002). Paleosols and duricrusts. In T. C. Partridge, & R. R. Maud (Eds.), *The Cenozoic of southern Africa* (pp. 131-144). Oxford: Oxford University Press.

Bramfitt, B. L., & Benscoter, A. O. (2002). *Metallographer's guide - practices and procedures for irons and steels.* Materials Park, Ohio: ASM International.

Brick, R. M., & Gordon, R. B., & Phillips, A. (1965). *Structure and properties of alloys - the application of phase diagrams to the interpretation and control of industrial alloy structures.* New York: McGraw-Hill.

Brock, B. P. W. G. (1965). Iron working amongst the Nyiha of southwestern Tanganyika. *The South African Archaeological Bulletin, 20*(78), 97-100.

Buchwald, V. F. (2005). *Iron and steel in ancient times.* Copenhagen: Det Kongelige Danske Videnskabernes Selskab.

Cech, B., & Walach, G. (1998). Feldmethoden zur Bewertung historischer Schmiedeschlacken. Methodik und erste Ergebnisse. *Archäologie Österreichs, 9*(2), 72-78.

Celis, G., & Nzikobanyanka, E. (1976). *La métallurgie traditionelle au Burundi. Techniques et croyances.* Archives d'Anthropologie 25, Tervuren: Musée Royal de l'Afrique Centrale.

Celis, G. (1987a). Fondeurs et forgerons ekonda (Equateur, Zaïre). *Anthropos, 82*(1-3), 109-134.

Celis, G. (1987b). *Introduction a la metallurgie traditionelle au Rwanda - Techniques & Croyances.* Butare: Institut National de Recherche Scientifique.

Celis, G. (1991). *Eisenhütten in Afrika. Beschreibung eines traditionellen Handwerks.* Frankfurt a. M.: Stadt Frankfurt Dez. Kultur u. Wissenschaft.

Celis, G. R., & Coulibaly, Y. T. (2001). *Métallurgies traditionelles du fer Sénoufo, Malinké et Somono Côte d'Ivoire, Burkina Faso et Mali.* Archives d'Anthropologie 32, Tervuren: Musée Royale de l'Afrique Centrale.

Chaplin, J. H. (1961). Notes on traditional smelting in northern Rhodesia. *South African Archaeological Bulletin, 16*(2), 53-60.

Charlton, M. F., Crew, P., Rehren, T., & Shennan, S. J. (2010). Explaining the evolution of ironmaking recipes - an example from northwest Wales. *Journal of Anthropological Archaeology, 29*, 325-367.

Charlton, M., Crew, P., Rehren, T., & Shennan, S. (2013). Measuring variation in iron smelting slags: an empirical evaluation of group-identification procedures. In J. Humphris, & T. Rehren (Eds.), *The world of iron* (pp. 421-430). London: Archetype.

Charlton, M., Shennan, S., Rehren, T., & Crew, P. (2013). Evolutionary analysis of ironmaking slag. In J. Humphris & T. Rehren (Eds.), *The world of iron* (pp. 288-295). London: Archetype.

Childs, S. T. (1986). *Style in technology: A view of African early Iron Age smelting through its refractory ceramics.* Ann Arbor: UMI University Microfilms International.

Childs, S. T. (1989). Clays to artifacts: Resource selection in African early Iron Age iron-making technologies. In G. Bronitsky (Ed.), *Pottery technology, ideas and approaches* (pp. 139-164). Boulder: Westview Press.

Childs, S. T. (1991a). Style, technology, and iron smelting furnaces in Bantu-speaking Africa. *Journal of Anthropological Archaeology, 10*, 332-359.

Childs, S. T. (1991b). Transformations: Iron and copper production in central Africa. In P. D. Glumac (Ed.), *Recent Trends in Archaeo-metallurgical Research, 8*(1) (pp. 33-46). Philadelphia: MASCA Research Pappers in Science and Archaeology.

Childs, S. T., & Killick, D. (1993). Indigenous African metallurgy: Nature and culture. *Annual Review of Anthropology, 22*, 317-337.

Childs, S. T. (1996). Technological history and culture in western Tanzania. In P. S. Schmidt (Ed.), *The culture and technology of African iron production* (pp. 277-320). Gainesville: University Press of Florida.

Childs, S. T. (2000). Traditional iron working: A narrated ethnoarchaeological example - the sociocultural context. In M. S. Bisson, S. T. Childs, P. de Barros, A. F. C. Holl, & J. O. Vogel (Eds.), *Ancient African metallurgy* (pp. 199-276). Lanham: Alta Mira Press.

Chirikure, S. (2007). Metals in society. *Journal of Social Archaeology, 7*, 72-99.

Chirikure, S., Burrett, R., & Heimann, R. B. (2009). Beyond furnaces and slags: A review study of bellows and their role in indigenous African metallurgical processes. *Azania 2009, 44*(2), 195-215.

Chirikure, S. (2013). The archaeology of African metalworking. In P. J. Mitchell, & P. Lane (Ed.), *The Oxford Handbook of African Archaeology* (pp. 132-143). Oxford: Oxford Univesity Press.

Chirikure, S. (2015). *Metals in past societies - a global perspective on indigenous African metallurgy.* Cham: Springer.

Cline, W. (1937). *Mining and metallurgy in negro Africa.* Menasha: George Banta Publishing Company.

Clist, B., & Lanfranchi, R. (1991). Angola. In B. Clist, & R. Lanfranchi (Eds.), *Aux origins de l'Afrique centrale* (pp. 219-223). Paris: Sépia.

Craddock, P. T. (1995). *Early metal mining and production.* Washington, D.C.: Smithsonian Inst. Press.

Craddock, P., Freestone, I., Middleton, A., & van Grunderbeek, M.-C. (2007). Early Iron Age iron-smelting debris from Rwanda and Burundi, east Africa. *Journal of the Historical Metallurgy Society, 41*, 1-14.

Collett, D. P. (1993). Metaphors, and representations associated with precolonial iron-smelting in eastern and southern Africa. In T. Shaw, P. Sinclair, B. Andah, & A. Okpoko, (Eds.), *The archaeology of Africa: Food, metals and towns* (pp. 499-511). London, New York: Routledge.

Cooke, C. K. (1966). Account of iron smelting techniques once practiced by the Manyubi of the Matobo District of Rhodesia. *The South African Archaeological Bulletin, 21*(82), 86-87.

Cornell, R. M., & Schwertmann, U. (2003). *The iron oxides - structure, properties, reactions, occurrences and uses.* Weinheim: Wiley-VCH.

Craig, J. R., & Vaughan, D. J. (1994). *Ore microscopy and ore petrography.* New York, NY: Wiley.

Crew, P., & Salter, C. J. (1991). Comparative data from iron smelting and smithing experiments. In K. Radwański (Ed.), *From bloom to knife*: international symposium of the Comité pour la Sidérurgie Ancienne de l'UISPP; Kielce-Ameliówka, 18-22 September 1989 (pp. 15-23). Kraków: Muzeum Archeologiczne.

Crew, P. (1995). Bloomery iron smelting slags and other residues. *Historical Metallurgy Society/ Archaeology Datasheet No. 5.* Retrieved from http://histmet.org/hmsdatasheet05.pdf

Crew, P. (2000). The influence of clay and charcoal ash on bloomery slags. In C. C. Tizzoni, & M. Tizzoni (Eds), *Iron in the Alps. Deposits, mines and metallurgy from antiquity to the XVI century* (pp. 38-48). Bienno: Comune di Bienno.

Crew, P. (2004). Cast Iron from a bloomery furnace. *Historical Metallurgy Society News / HMS news, 57*, 1-2.

Crew, P., Charlton, M., Dillmann, P., Fluzin, P., Salter, C., & Truffaut, E. (2011). Cast iron from a bloomery furnace. In J. Hošek, H. Cleere, L. Mihok, & R. Pleiner (Eds.), *The archaeometallurgy of iron. Recent developments in archaeological and scientific research; dedicated to Professor Radomír Pleiner* (pp. 239-262). Prague: The Institute of Archaeology of the ASCR.

Curtis, B., & Mannheimer, C. (2005). *Tree atlas of Namibia.* Windhoek, Namibia: National Botanical Research Institute, Ministry of Agriculture, Water and Forestry.

Davison, S., Mosley, P. N. (1988). Iron-smelting in the upper north Rukuru basin of northern Malawi. *Azania 23*, 57-99.

David, N., Heimann, R., Killick, D., & Wayman, M. (1989). Between bloomery and blast furnace: Mafa iron-smelting technology in north Cameroon, *The African Archaeological Review, 7*, 183-208.

Delisle, F. (1884). La fabrication du fer dans le Haut Ogowé. *Revue d'ethnographie 3*, 465-473.

De Almeida, J. (1912). *Sul d'Angola. Relatório de um governo de distrito (1908 - 1910).* Lisboa: Div. de Publ. e Biblioteca, Agência Geral das Colónias.

De Barros, P. (2000). Iron metallurgy: Sociocultural context. In M. S. Bisson, S. T. Childs, P. de Barros, A. F. C. Holl, & J. O. Vogel (Eds.), *Ancient African metallurgy* (pp. 147-198). Lanham: AltaMira Press.

De Maret, P. (1985). *The smith's myth and the origin of leadership in central Africa.* Oslo: Norwegian University Press.

De Maret, P. (2004). *Central Africa: Knowing iron - new light on its antiquity; west and central Africa.* Paris: UNESCO Publishing.

De Martins, R. S. (1973). A estação arqueológica da antiga Banza Quibaxe: Dembos - Angola. *Contribuições para o Estudo da Antropologia Portuguesa, 9*(4), 245-329.

Denbow, J. (1990). Congo to Kalahari: Data and hypotheses about the political economy of the Western Stream Early Iron Age. *The American Archaeological Review, 8*, 139-176.

Denbow, J., & Miller, D. (2007). Metal working at Bosutswe, Botswana. *Journal of African Archaeology, 5*(2), 271-313.

Denbow, J. (2011). Excavations at Divuyu, Tsodilo Hills. *Botswana Notes and Records, 43*, 76-94.

Denbow, J. (2012). Pride, prejudice, plunder and preservation: archaeology and the re-envisioning of ethnogenesis on the Loango coast of the Republic of Congo. *Antiquity, 86*, 383-408.

Denbow, J. (2013). *The archaeology and ethnography of central Africa.* New York: Cambridge University Press.

De Rijk, P. (1994). Das Schmieden von Luppe und Eisen. Eine Schlackenbeschreibung. *Historisk-Arkaeologisk Forsøgscenter Lejre, Research Report, 46*, 30-34.

De Rijk, P. (2007). De scoriis Eisenverhüttung und Eisenverarbeitung im nordwestlichen Elbe-Weser-Raum. *Probleme der Küstenforschung im südlichen Nordseegebiet, 31*, 95-242.

De Rosemond, C. C. (1943). *Iron smelting in the Kahama District*. Tanganyika Notes & Records, 16, 79-84.

Dos Santos Júnior, J. R., & Ervedosa, C. (1970). A estação arqueológica de Benfica: Luanda - Angola. *Ciencias Biológicas (Luanda), 1*, 31-51.

Driessen, P., Deckerz, J., Spaargaren, O., & Nachtergaele, F. (Eds.). (2001). *Lecture notes on the major soils of the world*. Rom: Food and Agriculture Organization of the United Nations.

Dugast, S. (1986). La pince et le soufflet: deux techniques de forge traditionelles au Nord-Togo. *Journal des africanistes, 56(2)*, 29-53.

Dungworth, D., & Wilkes, R. (2009).Understanding hammerscale: The use of high-speed film and electron microscopy. *Journal of Historical Metallurgy Society, 43*, 33-46.

Dupré, M.-C., & Pinçon, B. (1995). La métallurgie du fer: technique, symbolique et sémantique: symbolique obstétrique et dynamique de la contradiction en Afrique centrale. *Cahiers des Sciences Humaines, 31(4)*, 825-848.

Eckl, A. E. (2004). *Konfrontation und Kooperation am Kavango (Nord-Namibia) von 1891 bis 1921*. (Doctoral dissertation). Retrieved from http://kups.ub.uni-koeln.de/1321/

Eckl, A. (2007). The accumulation of knowledge of Kavango and its peoples by the German colonial administration 1891-1911. *Journal of Namibian Studies, 1*, 7-37.

Egger, M., & Schöpfer, G. (2013). *Der kleine Oral History Ratgeber*. Graz: Universität Graz, Institut für Wirtschaft und Sozialgeschichte.

Eggers, L. (1900). Über eine Reise nach dem Okavangogebiet. *Mittheilungen aus den Deutschen Schutzgebieten, 13*, 185-188.

Eggert, M. (2005). The Bantu problem and African archaeology. In A. B. Stahl (Ed.) *African archaeology: A critical introduction* (pp. 301-326). Malden: Blackwell Pub.

Eichhorn, B., Robion-Brunner, C., Serneels, V., & Perret, S. (2013). Fuel for iron - wood exploitaion for metallurgy on the Dogon plateau, Mali. In J. Humphris, & T. Rehren (Eds.), *The world of iron* (pp. 435-442). London: Archetype.

Essomba, J.-M. (1992). *Civilisation du fer et sociétés en Afrique centrale - Le cas du Cameroun meridional: histoire ancienne et archéologie.* Paris: L'Harmattan.

Estermann, C. P. (1977). *Ethnographie du Sud-Ouest de l'Angola - Les Peuples non Bantous et le groupe ethnique Ambo.* Paris: Académie des sciences d'outre-mer.

Estermann, R. P. G. (1936). Les forgerons Kwanyama. *Bulletin de la Société Neuchâteloise de Gógraphie, 44*, 1-8.

Eze, P. N., Udeigwe, T. K., & Meadows, M. E. (2014). Plinthite and its associated evolutionary forms in soils and landscapes: A review. *Pedosphere,24*(2), 153-166.

Fagan, B. M. (1967). *Iron Age cultures in Zambia: Kalomo and Kangila.* London: Chatto & Windus.

Fagan, B. M.; Phillipson, D. W., & Daniels, S. G. H. (1969). *Iron Age cultures in Zambia - Dambwa, Ingombe Ilede, and the Tonga.* London: Chatto & Windus.

Fang, C. M., van Huis, M. A., Thijsse, B. J., & Zandbergen, H. W. (2012). Stability and crystal structures of iron carbides: A comparison between the semi-empirical modified embedded atom method and quantum-mechanical DFT calculations. *Physical Review B, 85*, 54116-1-054116-7.

Fey, M. V. (2010). *Soils of South Africa.* Cambridge: Cambridge University Press.

Fisch, M. (1980). *Ganze Gciriku und Shambyu Geschichte.* Unpublishd Manuscripts.

Fisch, M. (2004). *Die südafrikanische Militärverwaltung (1915-1920) und die frühe Mandatszeit (1920-1936) in der Kavango-Region/Namibia.* Cologne: Köppe.

Fisch, M. (2005). *The Mbukushu in Angola (1730-2002) - a history of migration, flight and Royal rainmaking.* Cologne: Köppe.

Fisch, M. (2008). *The World of the traditional hunters along the Kavango River.* Windhoek: Macmillan.

Fleisch, A., & Möhlig, W. J. G. (2002). *The Kavango peoples in the past - local historiographies from northern Namibia.* Cologne: Köppe.

Fluzin, P. (2004). The Process chain in iron and steel-making: archaeological materials and procedures. In H. Bocoum (Ed.), *The origins of iron metallurgy in Africa: new light on its antiquity; west and central Africa* (pp. 65-96). Paris: UNESCO Publishing.

Fowler, I. (1995). The Oku iron industry in its regional setting: A descriptive account. *Baessler-Archiv, Neue Folge, 43*, 89-126.

Freestone, I. C., & Tite, M. S. (1986). Refractories in the ancient and preindustrial world. W. D. Kingery (Ed.), *High-technology ceramics. Past, present, and future. The nature of innovation and change in ceramic technology* (pp. 35-53). Westerville/Ohio: American Ceramic Soc.

Freestone, I. C. (1989). Refractory materials and their procurement. In A. Hauptmann, A. Pernicka, E.; Wagner, & A. Günther (Eds.), *Archäometallurgie der Alten Welt: Beiträge zum Internationalen Symposium „Old World Archaeometallurgy", Heidelberg 1987* (pp. 155-162). Bochum: Selbstverlag des Deutschen Bergbau-Museums.

Friede, H. M., & Steel, R. H. (1977). An experimental study of iron-smelting techniques used in the South African Iron Age. *Journal of the South African Institute of Mining and Metallurgy, 77*, 233-242.

Friede, H. M., Hejja, A. A., & Koursaris, A. (1982). Archaeometallurgical studies of iron smelting slags from prehistoric sites in Southern Africa. *Journal of the South African Institute of Mining and Metallurgy, 82*, 38-48.

Friede, H. M., & Steel, R. H. (1985). Iron Age iron smelting furnaces of the western/central Transvaal: Their structure, typology and affinities. *The South African Archaeological Bulletin, 40*(141), 45-49.

Friede, H. M., & Steel, R. (1988). Notes on an iron smelting pit furnace found at Bultfontein Iron Age Site 41/85 (central Transvaal) and on general features of pit furnaces. *The South African Archaeological Bulletin, 43*(147), 38-42.

Gassmann, G. (2004). ‚Schmiedeabfälle' - Aspekte ihrer naturwissenschaftlichen Untersuchung. In W. Melzer (Ed.), *Schmiedehandwerk im Mittelalter und Neuzeit. Beiträge des 6. Kolloquiums des Arbeitskreises zur Archäologischen Erforschung des Mittelalterlichen Handwerks* (pp.71-80). Soest: Westfälische Verlags-Buchhandlung Mocker und Jahn.

Gibson, G. D., Larson, T. J., & McGurk, C. R. (1981). *The Kavango peoples*. Wiesbaden: Steiner.

Gordon, R. B. (1997). Process deduced from ironmaking wastes and artefacts. *Journal of Archaeological Science, 24*, 9-18.

Gordon, R. J. (1992). *The Bushman myth. The making of a Namibian underclass*. Boulder: Westview Press.

Goucher, C. L., & Herbert, E. W. (1996). The blooms of Banjeli: Technology and gender in west African Ironmaking. In P. R. Schmidt (Ed.), *The culture and technology of African iron production* (pp. 40-73). Gainesville: University Press of Florida.

Groengroeft, A., Luther-Mosebach, J., Landschreiber, L., & Eschenbach, A. (2013). Mashare-Soils. In J. Oldeland, C. Erb, M. Finckh, & N. Jürgens, (Eds.), *Environmental assessments in the Okavango region* (pp. 105-108). Hamburg: BEE, Biocentre Klein Flottbek and Botanical Garden.

Haaland, R. (2004). Iron smelting a vanishing tradition: Ethnographic study of this craft in southwest Ethiopia. *Journal of African Archaeology, 2*(1), 65-80.

Haddon, I. G. (2000). Kalahari Group sediments. In T. C. Partridge, & R. R. Maud (Eds.), *The Cenozoic of southern Africa* (pp. 173-181). Oxford: Oxford University Press.

Haddon, I. G. (2005). The sub-Kalahari geology and tectonic evolution of the Kalahari Basin, southern Africa. (Doctoral dissertation) Retrieved from: http://www.the-eis.com/data/literature/The%20sub_Kalahari%20geology%20and%20tectonic%20evolution%20of%20the%20Kalahari%20Basin.pdf.

Hahn, H. P. (1993). Eisentechnik in Nord-Togo. Münster: LIT.

Hajdas, I. (2008). Radio carbon dating and its applications in quaternary studies. *Quaternary Science Journal, 57*(1-2), 2-24.

Halkin, J., & Viaene, E. (1911). *Les Ababua (Congo Belge)*. Bruxelles: de Wit.

Hamer, F., & Hamer, J. (2004). *The potter's dictionary of materials and techniques*. London: Black Publishers.

Hartmann, B. (1987). Die Tjaube, eine Vorbevölkerung im Kavangogebiet. *Journal South West African Scientific Society, 40/41*, 75-95.

Hauptmann, A. (2014). The investigation of archaeometallurgical slag. In B. W. Roberts, & C. Thornton (Ed.), Archaeometallurgy in global perspective: Methods and syntheses (pp. 91-105). New York, NY: Springer New York.

Hegenberger, W. (1987). Stand der geologischen Kenntnisse über das Kavangogebiet. *Journal South West African Scientific Society, 40/41*, 97-113.

Heinzte, B. (1995). *Alfred Schachtzabels Reise nach Angola 1913-1914: und seine Sammlungen für das Museum für Völkerkunde in Berlin - Rekonstruktion einer Ethnographischen Quelle.* Cologne: Köppe.

Hendrickson, A. A. B. (1986). *Early Iron Age ceramics from northwestern Botswana: The evidence from Matlapaneng, N!oma, and Divuyu.* (Master's dissertation, University of New York, New York).

Herbert, E. W. (1993). *Iron, gender, and power: rituals of transformation in African societies.* Bloomington: Indiana University Press.

Herbert, E. W. (2001). *Kwanyama iron working.* Retrieved from http://www.era.anthropology.ac.uk/era_resources/Era/P-C_Museum/herbert.html.

Herrmann, E., Milton, S., & Seymour, C. (2003). *A collation and overview of research information on combretum imberbe warwa (combretaceae) and identification of relevant research gaps to inform protection of the species.* Unpublished report, Department of Water Affairs & Forestry, Pretoria.

Hesse, P. R. (1955). A chemical and physical study of the soils of termite mounds in east Africa. *Journal of Ecology, 43*(2), 449-461.

Hjärthner-Holdar, E., Kresten, P., & Larsson, L. (1997). From known to unknown Application of well-known experimental iron production results on archaeological materials. In L. C. Nørbach (Ed.), *Early iron production: archaeology, technology and experiments* (pp. 15-25). Lejre: Historical-Archaeological Experimental Centre.

Holdaway, S. (2014). Deflation archaeology. In *Encyclopedia of Global Archaeology* (Vol. 3, pp. 2087-2089). New York, NY: Springer New York.

Horstmann, D. (1992). *Das Zustandsschaubild Eisen-Kohlenstoff und die Grundlagen der Wärmebehandlung der Eisen-Kohlenstoff-Legierungen.* Düsseldorf: Stahleisen.

Housden, J., & Armor, M. (1959). Indigenous iron smelters at Kalabo. *Northern Rhodesian Journal, 4*(4), 135-138.

Huffman, T. N. (1989). *Iron age migrations. The ceramic sequences of southern Zambia.* Johannesburg: Witwatersrand University Press.

Huffman, T. N. (2007). *Handbook to the Iron Age - the archaeology of pre-colonial farming societies in southern Africa.* Scottsville, South Africa: University of KwaZulu-Natal Press.

Humphris, J., Martinón-Torres, M., Rehren, T., & Reid, A. (2009). Variability in single smelting episodes - a pilot study using iron slag from Uganda. *Journal of Archaeological Science, 36*, 359-369.

Humphris, J. (2010). *An archaeometallurgical investigation of iron smelting traditions in southern Rwanda.* (Doctoral dissertation). Retrieved from http://discovery.ucl.ac.uk/20461/

Hüttenberger, J. (1997). *Zur Beziehung zwischen Sprache und Kultur anhand der Jagdterminologie im Gciriku (Kavangosprache)*. (Master's dissertation, University of Cologne, Cologne).

Iles, L. E. (2010). *Reconstructing the iron production technologies of western Uganda: Reconciling archaeometallurgical and ethnoarchaeological approaches.* (Doctoral dissertation). Retrieved from http://discovery.ucl.ac.uk/1306719/

Iles, L. E., & Childs, S. T. (2014). Ethnoarchaeological and historical methods. In B. W. Roberts, & C. Thornton (Eds.), *Archaeometallurgy in global perspective: Methods and syntheses* (pp. 193-211). New York, NY: Springer New York.

Iroko, A. F. (1996). *L'homme et les termitières en Afrique.* Paris: Editions Karthala.

Jacobberger, P. A. (1989). Reflectance characteristics and surface processes in stabilized dune environments. *Remote Sensing of Environment, 28,* 287-295.

Jacobson, L. (1987). The archaeology of the Kavango. *Jounal South West African Scientific Society, 40/41*, 149-157.

Jelsma, H. A., de Wit, M. J., Thiart, C., Dirks, P. H. G. M., Viola, G., Basson, I. J., & Anckar, E. (2004). Preferential distribution along transcontinental corridors of kimberlites and related rocks of southern Africa. *South African Journal of Geology, 107*, 301-324.

Jodtka, P. (1902). Reise des Asistenzarzte Jodtka nach dem Okavango. *Deutsches Kolonialblatt, 20*, 493-495; *21*, 524-526; *22*, 546-548; *23*, 590-592.

Johnston, J. (1893). *Reality versus romance in south central Africa.* New York: Fleming H. Revell Company.

Joosten, I., Jansen, B., & Kars, H. (1997). The use of a model to describe bloomery production in the Netherlands. In L. C. Nørbach (Ed.), *Early iron production: Archaeology, technology and experiments* (pp. 37-46). Lejre: Historical-Archaeological Experimental Centre.

Juwayeyi, Y. M. (1993). Iron age settlement and subsistence patterns in southern Malawi. In T. Shaw, P. Sinclair, B. Andah & A. Okpoko (Eds.), *The archaeology of Africa: Food, metals and towns* (pp. 391-398). London: Routledge.

Kampungu, R. (1965). *Okavango marriage customs investigated in the light of ecclesiastical legislation.* (Doctoral Dissertation, Pontificia Universitas Urbaniana de Propaganda Fide Roma, Rome).

Kelly, R. L., & Thomas, D. H. (2013). *Archaeology*. Belmont: Wadsworth/Cengage Learning.

Kense, F. (1983). *Traditional African ironworking.* Calgary: Department of Archaeology University of Calgary.

Kgathi, D. L., Kniveton, D., Ringrose S., Turton, A.R., Vanderpost, C.H.M., Lundqvist, J., & Seely, M. (2006). The Okavango; a river supporting its people, environment and economic development. *Journal of Hydrology, 331*, 3-17.

Killick, D., & Gordon, R. B. (1989). The mechanism of iron production in the bloomery furnace. In R. M. Farquhar, R. G. V. Hancock & L. A. Pavlish (Eds.), *Proceedings of the 26th international archaeometry symposium, held at University of Toronto, Toronto, Canada, May 16th to May 20th 1988* (pp. 120-123) Toronto: University of Toronto.

Killick, D. (1987). On the dating of African metallurgical sites. *Nyame Akuma, 28*, 29-30.

Killick, D. (1995). *Variation in African ironsmelting practice: Implications for the study of prehistoric iron technology in Europe.* Paris: Vulcain.

Killick, D., & Miller, D. (2014). Smelting of magnetite and magnetite-ilmenite iron ores in the northern Lowveld, South Africa, ca. 1000 CE to ca. 1880 CE". *Journal of Archaeological Science, 43*, 239-255.

Kinahan, J. (2000). *Cattle for beads: The archaeology of historical contact and trade on the Namib coast.* Uppsala: University of Uppsala, Department of Archaeology & Ancient History.

Kinahan, J. (1986). Settlement patterns and regional exchange: Evidence from recent Iron Age sites on the Kavango river, northeastern Namibia". *Cimbebasia, Series (B) 3*, 109-116.

Kita, K. M. (1985). La technique traditionelle de la métallurgie du fer chez le Balega de Pangi (Zaïre). *Muntu, 3*, 85-99.

Köhler, O. (1989). *Die Welt der Kxoé-Buschleute im südlichen Afrika, eine Selbstdarstellung in ihrer eigenen Sprache - Die Kxoé-Buschleute und ihre ethnische Umgebung.* Berlin: Reimer.

Köhler, O. (1997). *Die Welt der Kxoé-Buschleute im südlichen Afrika, eine Selbstdarstellung in ihrer eigenen Sprache - Materielle Ausrüstung: Werden und Wandel.* Wohnplatz und Buschlager Berlin: Reimer.

Kopytoff, I. (1987). *The African frontier. The reproduction of traditional African societies.* Bloomington: Indiana University Press.

Kose, E. (2004). *Vungu-Vungu. Eisenproduzenten und Jäger am Kavango in Namibia.* (Master`s thesis. University of Cologne, Cologne).

Kose, E. (2008). ,We are not looking for diamonds, we are looking for red stones'. Archaeology of iron in Kavango. In C. Limpricht & M. Biesele (Eds.), *Heritage and cultures in modern Namibia - in-depth views of the country* (pp. 37-46). Windhoek: Hess.

Kose, E. (2009a). A sketch of pre-colonial metalworking in northern Namibia and southern Angola. In W. J. G. Möhlig, F. Seidel & M. Seifert (Eds.), *Forgotten words. Contact scenarios, speaker strategies and language change in Africa* (pp. 127-157). Cologne: Rüdiger Köppe.

Kose, E. (2009b). New light on ironworking groups along the middle Kavango in northern Namibia. *South African Archaeological Bulletin, 64(190),* 130–147.

Kose E. (2012). The role of iron in foraging societies of northern Namibia in the 15th to the 20th century AD. In C. Robion-Brunner & B. Martinelli (Eds.), *Métallurgie du fer et Sociétés africaines* (pp. 209-216). Oxford: Archaeopress.

Kose, E., & Richter, J. (2007). The prehistory of the Kavango people. In W. J. G. Möhlig (Ed.), *Cultural changein the prehistory of arid Africa. Perspectives of archaeology and linguistics* (pp. 103-129). Cologne: Köppe.

Kronz, A. (1998). *Phasenbeziehungen und Kristallisations-mechanismen in fayalitischen Schmelzsystemen - Untersuchungen an Eisen- und Buntmetall-schlacken.* Friedland: Bielefeld.

Kronz, A. (2000). Self-mixing melt compositions in fayalitic slags - a key in understanding early metal production. In D. Rammlmair, J. Mederer, Th. Oberthür, R. B. Heimann, & H. Pentinghaus (Eds.), *Applied mineralogy in research, economy, technology, ecology and culture: Proceedings of the 6th international congress ICAM 2000, Gottingen, 13-21 July 2000* (pp. 1005-1008). Rotterdam: A Balkema Publishers.

Kronz, A., & Keesmann, I. (1995). Die vorneuzeitliche Eisentechnologie im Lahn-Dill-Gebiet: Chemische und mineralogische Untersuchungen. In B. Pinsker (Ed.), *Eisenland : Zu den Wurzeln der nassauischen Eisenindustrie. Begleitkatalog zur Sonderausstellung der Sammlung Nassauischer Altertümer im Museum Wiesbaden, 29. Januar - 23. Juli 1995* (pp. 215-234). Wiesbaden: Verl. des Vereins für Nassauische Altertumskunde und Geschichtsforschung.

Kronz, A., & Keesmann, I. (2003). Fayalitische Schmelzen und die Effektivität des metallurgischen Verfahrens. In T. Engel (Ed.), *Abbau und Verhüttung von Eisenerzen im Vorland der mittleren Schwäbischen Alb* (pp. 259-274). Stuttgart: Theiss.

Kronz, A., & Keesmann, I. (2005). Fayalitische Schmelzsysteme - Ein Beitrag zur vorneuzeitlichen Eisen- und Buntmetalltechnologie im Dietzhölzetal (Lahn-Dill-Gebiet, Hessen). In A. Jockenhövel & C. Willms (Eds.), *Das Dietzhölzetal-Projekt: Archäometallurgische Untersuchungen zur Geschichte und Struktur der mittelalterlichen Eisengewinnung im Lahn-Dill-Gebiet (Hessen)* (pp. 403-472). Stuttgart: Steiner.

Kunze, R. (2006). *Archäometallurgische Untersuchungen zur frühen Eisenverhüttung und -gewinnung in der Hallstatt- und Latènezeit am Beispiel von Eisenfunden der Hunsrück-Eifel-Kultur.* München: GRIN.

Kusimba, C. M., & Killick, D. (2003). Ironworking on the Swahili coast of Kenya. In C. M. Kusimba & S. B. Kusimba (Eds.), *East African archaeology: Foragers, potters, smiths, and traders* (pp. 99-116). Philadelphia: University of Pennsylvania Museum of Archaeology and Anthropology.

Lancaster, N. (2000). Eolian deposits. In T. C. Partridge & R. R. Maud (Eds.), *The cenozoic of southern Africa* (pp. 73-87). Oxford: University Press Oxford.

Larson, T. J. (1975). Craftwork of the Hambukushu of Botswana. *Botswana Notes & Records, 7*, 109-121.

Larson, T. J. (2001). *Hambukushu rainmakers of the Okavango.* San Jose: Writers Club Press.

Laubschat, A. (1903). Bericht des Baumeisters Laubschat über eine Reise nach dem Norden des deutsch-südwestafrikanischen Schutzgebietes. *Deutsches Kolonialblatt, 22*, 614-616, 641-646; 24, 678-682.

Leavy, P. (2011). *Oral history, understanding qualitative research.* Oxford: Oxford University Press.

Likuwa, K. M. (2012). *Voices from the Kavango: A study of the contract labour system in Namibia, 1925-1972.* (Doctoral dissertation). Retrieved from: http://nrfnexus.nrf.ac.za/handle/20.500.11892/102138

Lyaya, E. C. (2007). *The physical properties of metalliferous slag: A comparison between smelting and smithing*. Master's dissertation, University of Dar es Salaam, Dar es Salaam).

Lyaya, E. C. (2011). Bio-archaeometallurgy, technology, and spatial organization of ironworking at Mjimwema, Njombe, Tanzania. *Papers from the Institute of Archaeology, 21*, 59-79.

Lyaya, E. C. (2013). Use of charcoal species for ironworking in Tanzania. In J. Humphris & T. Rehren (Eds.), *The world of iron* (pp. 444-453). London: Archetype.

Lyaya, E., Mapunda, B. B., & Rehren, T. (2012). The bloom refining technology in Ufipa, Tanzania (1850-1950). In C. Robion-Brunner & B. Martinelli (Eds.), *Métallurgie du fer et sociétés africaines: bilans et nouveaux paradigmes dans la recherche anthropologique et archéologique* (pp. 195-207). Oxford: Archaeopress.

Lyngstrøm, H. S. (1997). The borderland of archaeology - experimental forging. In L. C. Nørbach (Ed.), *Early iron production: Archaeology, technology and experiments* (pp. 27-35). Lejre: Historical Archaeological Experimental Centre.

Maho, J. F. (2009). *The online version of the new updated Guthrie List, a referential classification of the Bantu languages.* Retrieved from http://goto.glocalnet. net/mahopapers/nuglonline.pdf

Malcom, L. W. G. (1924). Iron-working in the central Cameroon. *Man, 24*, 136-138.

Maluma, E. (1979). Chongwe and Kanakantapa iron smelting furnaces. *Goodwin Series, 3*, 7-13.

Mapunda, B. B. (1995). *An archaeological view of the history and variation of ironworking in southwestern Tanzania.* (Doctoral dissertation). Retrieved from http://ufdc.ufl.edu/AA00003202/00001

Mapunda, B. B. (2010). *Contemplating the Fipa ironworking. Kampala:* Fountain Publishers.

Martinelli, B. (2004). On the threshold of intensive metallurgy: The choice of slow combustion in the Niger River Bend (Burkina Faso and Mali). In H. Bocoum (Ed.), *The origins of iron metallurgy in Africa: new light on its antiquity; west and central Africa.* Paris: UNESCO Publishing.

Matinón-Torres, M., & Rehren, T. (2014). Technical ceramics. In B. W. Roberts & C. Thornton (Eds.), *Archaeometallurgy in global perspective: Methods and syntheses* (pp. 107-131). New York: Springer New York.

Mbambo, S. K. (2002). *„Heal with god": Indigenous healing and religion among the Vagciriku of Kavango region, Namibia.* Utrecht: Unitwin Network for Southern Africa.

McCosh, F. W. J. (1979). Traditional ironworking in central Africa with some reference to the ritualistic and scientific aspects of the industry. *Zambezia, 7*, 155-170.

McDonnell, J. G. (1983). Tap slags and hearth bottoms or, how to identify slags. *Current Archaeology, 86*, 81-83.

McDonnell, J. G. (1987). Ore to artefact - a study of early ironworking technology. In E. A. Slater & J. O. Tate (Eds.), *Science and archaeology Glasgow 1987 - proceedings of a conference on the application of scientific techniques to archaeology, Glasgow, September 1987* (pp. 283-293). Oxford: Archaeopress.

McDonnell, J. G. (1991). A model for the formation of smithing slags. *Materiały Archeologiczne, 26*, 23-27.

McFarlane, M. J. (1976). *Laterite and landscape.* London: Academic Press.

McKittrick, M. (2008). Landscapes of power: Ownership and identity on the middle Kavango river, Namibia. *Journal of Southern African Studies, 34*(4), 785-802.

McNally, G. H. (1998). *Soil and rock construction materials.* London: E & FN Spon.

Mendelsohn, J., & El Obeid, S. (2003). *Sand and water. A profile of the Kavango region.* Cape Town: Struik Publishers & RAISON.

Mendelsohn, J., & El Obeid, S. (2004). *Okavango river: The flow of a lifeline.* Struik Publishers & RAISON.

Miller, D. (1996). *The Tsodilo jewellery: Metal work from northern Botswana.* Rondebosch: UCT Press.

Miller, D. (1995). 2000 years of indigenous mining and metallurgy in southern Africa - a review. *South African Journal of Geology, 98*(2), 232-238.

Miller, D. (2002). Smelter and smith: Iron age metal fabrication technology in southern Africa. *Journal of Archaeological Science, 29*, 1083–1131.

Miller, D., & Killick, D. (2004). Slag identification at southern African archaeological sites. *Journal of African Archaeology, 2*(1), 23-47.

Miller, D., & Sandelowsky, B. (1999). Smelting without ceramics: the Drierivier copper smelting site near Rehoboth, Namibia. *The South African Archaeological Bulletin, 54*(169), 28-37.

Miller, D. E., Young, S. M., Green, W. A., Van der Merwe, N. J., & Sandelowsky, B. (2005). Sourcing the ore from the Drierivier copper smelting site in central Namibia, using lead isotope fingerprinting. *South African Journal of Science, 101*, 344-346.

Miller, R. McG. (2008). *The geology of Namibia, Upper Palaeozoic to Cenozoic.* Windhoek: Ministry of Mines and Energy, Geological Survey.

Mills, E. A. C., & Filmer, N. T. (1972). Chondwe Iron Age site, Ndola, Zambia. *Azania, 7*, 129-145.

Mitchell, P. (2002). *The archaeology of southern Africa.* Cambridge: Cambridge University Press.

Modarressi-Tehrani, D. (2009). *Untersuchungen zum früheisenzeitlichen Metallhandwerk im westlichen Hallstatt- und Frühlatènegebiet.* Rahden: Leidorf.

Möhlig, W. J. G. (2007). Linguistic evidence of cultural change. The case of the Rumanyo speaking people in northern Namibia. In W. J. G. Möhlig (Ed.), *Cultural change in the prehistory of arid Africa. Perspectives of archaeology and linguistics* (pp. 131-154). Cologne: Köppe.

Möhlig, W. J. G., Seidel, F. & Seifert, M. (2009). Language contact, language change and history: Based on language sources in Africa. In W. J. G. Möhlig, F. Seidel & M. Seifert (Eds.), *Language contact, language change and history based on language sources in Africa* (pp. 11-29). Cologne: Köppe.

Nash, D. J., & Ullyott, S. J. (2007). Silcrete. In D. J. Nash, J. David & S. J. McLaren (Eds.), *Geochemical sediments and landscapes* (pp. 95-143). Malden: Blackwell Publisher.

Ndaliman, M. B. (2001). Some studies on refractory properties of termite hills in Nigeria. *Nigeria Journal of Education and Technology, 1*(1/2), 44-46.

Ndaliman, M. B. (2007). Refractory properties of termite hills under varied proportions of additives. *AU Journal of Technology, 10*(3), 159-162.

Navasaitias, J., & Selskienė, A. (2007). Metallographic examination of cast iron lump produced in the bloomery iron making process. *Materials Science, 13*(2), 167-173.

Netterberg, F. (1969). The interpretation of some basic calcrete types. *South African Archaeological Bulletin, 24*, 117-122.

Netterberg, F. (1974). Calcretes and silcretes at Sambio, Okavangoland, South West Africa. *South African Archaeological Bulletin, 29*, 83-88.

Netterberg, F. (1982). Calcretes and their decalcification around Rundu, Okavangoland, south west Africa. *Palaeoecology of Africa, 15*, 159-169.

Netterberg, F., & Caiger, J. H. (1983). A geotechnical classification of calcretes and other pedocretes. In R. C. L. Wilson (Ed.), *Residual deposits: Surface related weathering processes and materials* (pp. 235-243). London: Geological Society Publishing House.

Nurse, G. T., & Jenkins, T. (1976). The Kavango peoples. *Journal of the South West African Scientific Society, 30*, 55-58.

O'Connor, P. W., & Thomas, D. S. G. (1999). The timing and environmental significance of late quaternary linear dune development in western Zambia. *Quaternary Research, 52*, 44-55.

Odell, G. H. (2004). *Lithic analysis.* New York: Kluwer Academic/PlenumPublishers.

Oelsen, W., & Schürmann, E. (1954). Untersuchungsergebnisse alter Rennfeuerschlacken. *Archiv für das Eisenhüttenwesen, 25*(11/12), 507-514.

Okafor, E. E. (1998). Iron working refractories. *Nsukka Journal of the Humanities, 9*, 116-120.

Okrusch, M., & Matthes, S. (2014). *Mineralogie - Eine Einführung in die spezielle Mineralogie, Petrologie und Lagerstättenkunde.* Berlin: Springer Berlin Heidelberg.

Osann, B. (1971). *Rennverfahren und Anfänge der Roheisenerzeugung - zur Metallurgie und Wärmetechnik der alten Eisengewinnung.* Düsseldorf: Verein Deutscher Eisenhüttenleute.

Otto, A. (1987). Einführung in die traditionelle materielle Kultur der Kwangali. *Jounal South West African Scientific Society, 40/41*, 159-198.

Parkinson, J. (2014). The later stone age of southern Africa. In C. Renfrew & P. Bahn (Eds.), *The Cambridge World History 1, Africa, south and southeast Asia and the Pacific* (pp. 131-150). New York: Cambridge University Press.

Partridge, T. C., & Maud, R. R. (2000). Macroscale geomorphic evoltion of southern Africa. In T. C. Partridge & R. R. Maud (Eds.), *The Cenozoic of southern Africa* (pp. 3-18). Oxford: Oxford University Press

Passarge, S. (1904). *Die Kalahari. Versuch einer physisch-geographischen Darstellung der Sandfelder des südafrikanischen Beckens.* Berlin: Reimer.

Passarge, S. (1905a). Das Okawangosumpfland und seine Bewohner. *Zeitschrift für Ethnologie, 37*(5), 649-716.

Passarge, S. (1905b). Die Mambukushu. *Globus, 87*(13), 229-234, 295-301.

Paynter, S. (2006). Regional variation in bloomery smelting slag of the iron age and romano-british periods. *Archaeometry, 48*, 271-292.

Phillipson, D. W. (1968). The early iron age site at Kapwirimbwe. Lusaka. *Azania, 4*, 87-105.

Phillipson, D. W. (1977). *The late prehistory of eastern and southern Africa*. London: Heinemann.

Phillipson, D. W. (2005). *African archaeology.* Cambridge: Cambridge University Press.

Pleiner, R. (2000). *Iron in archaeology. The European bloomery smelters.* Praha: Archeologický ústav AVČR.

Pleiner, R. (2006). *Iron in archaeology. Early European blacksmiths.* Praha: Archeologický ústav AVČR.

Prange, M. (2001). 5000 Jahre Kupfer im Oman - Vergleichende Untersuchungen zur Charakterisierung des omanischen Kupfers mittels chemischer und isotopischer Analysenmethoden. *Metalla, 8*(1), 1-126.

Prendergast, M. D. (1974). Research into the ferrous metallurgy of Rhodesian Iron Age societies. *Journal of the South African Institute of Mining and Metallurgy, 74*, 254-264.

Proepper, M. (2007). *Der ethnographische Forschungsstand zum Kavangogebiet in Nordost Namibia 2006 - eine kommentierte Bibliographie.* BAB Working Paper/ Basler Afrika Bibliographien 1. Retrieved from http://baslerafrika.ch/wp-content/uploads/WP_2007_1_Proepper.pdf

Read, F. W. (1902). Iron smelting and native blacksmithing in Ondulu-Country, south-east Angola. *African Affairs, 2*, 44-49.

Redinha, J. (1953). *Subsídios para a história, arqueologia e etnografia dos povos da Lunda: Campanha Etnográfica ao Tchiboco (Alto-Tchicapa).* Lisboa: Museo do Dundo.

Rehder, J. E. (2000). *The mastery and uses of fire in antiquity.* Montreal: McGill-Queen's University Press.

Rehren, T., Charlton, M., Chirikure, S., Humphris, J., Ige, A., & Veldhuijzen, H. A. (2007). Decisions set in slag: the human factor in African iron smelting. In S. LaNiece, D. R. Hook, and P.T. Craddock (Eds.), *Metals and Mines - Studies in Archaeometallurgy* (pp. 211-218). London: Archetype/British Museum.

Rice, P. M. (2005). *Pottery analysis - a sourcebook.* Chicago: University of Chicago Press.

Richter, J. (1990). Messum 1, Zentrale Namib Prähistorische Jäger in extrem arider Umwelt. *Beiträge zur allgemeinen und vergleichenden Archäologie, 9/10*, 281-358.

Richter, J. (1991). *Studien zur Urgeschichte Namibias.* Cologne: Heinrich-Barth-Institut.

Richter, J. (2005). The archaeology along the Kavango river/Namibia. *Southern African Field Archaeology, 11/12*, 78-104.

Robinson, K. R. (1961). Two iron-smelting furnaces from the Chibi Native Reserve, southern Rhodesia. *The South African Archaeological Bulletin, 16*(61), 20-22.

Robbins, L. H., Murphy, M. L., Campbell, A. C., & Brook, G. A. (1998). Intensive mining of specular hematite in the Kalahari ca. A.D. 800-1000. *Current Anthropolgy, 39*(1), 144-150.

Robion-Brunner, C., Serneels, V., & Perret, S. (2013). Variability in iron smelting practices: Assessment of technical, cultural and economic criteria to explain the metallurgical diversity in the Dogon area (Mali). In J. Humphries & T. Rehren (Eds.), *The world of iron* (pp. 257-265). London: Archetype.

Rostoker, W. (1988). The ancient heat treatment of white cast iron. In R. Maddin (Ed.), *The beginning of the use of metals and alloys. Papers from the second international conference on the beginning of the use of metals and alloys, Zhengzhou, China, 21 - 26 October 1986* (pp. 200-204). Cambridge, Mass.: MIT Press.

Rostoker, W., & Bronson, B. (1990). *Preindustrial iron, its technology and ethnology.* Philadelphia: Archeomaterials.

Rowlands, M., & Warnier, J.-P. (1993). The magical production of iron in the Cameroon grassfields. In T. Shaw, P. Sinclair, B. Andah, & A. Okpoko (Eds.), *The archaeology of Africa: Food, metals and towns* (pp. 512-550). New York: Routledge.

Sadr, K. (2008). An ageless view of first millennium AD southern African ceramics. *Journal of Archaeological Science, 6*(1), 103-129.

Salokoski, M. (2006). *How kings are made - how kingship changes. A study of rituals and ritual change in pre-colonial and colonial Owamboland, Namibia.* Helsinki: University of Helsinki.

Samuels, L. E. (1999). *Light microscopy of carbon steels.* Materials Park: ASM International.

Sandelowsky, B. H. (1968). *Excavation at Kapako.* Unpublishd Manuscriptes/Fieldnotes.

Sandelowsky, B. H. (1969). *Vungu-Vungu excavation and Dikundu furnace site.* Unpublished Manuscripts/ Fieldnotes.

Sandelowsky, B. H. (1974). Prehistoric metalworking in South West Africa. *Journal of the South African Institute for Mining and Metallurgy, 74*(10), 363-366.

Sandelowsky, B. H. (1979). Kapako and Vungu-Vungu: Iron Age sites on the Kavango river. *Goodwin Series, 3*, 52-61.

Sandelowsky, B. H., & Pendleton, W. C. (1969). Stone tuyères from south west Africa. *The South African Archaeological Bulletin, 93*, 14-20.

Sassoon, H. (1964). Iron-Smelting in the hill village of Sukur, north-eastern Nigeria. *Man, 64*, 174-178.

Sauder, L., & Williams, S. (2002). A practical treatise on the smelting and smithing of bloomery iron. *Historical Metallurgy, 36*(2), 122-131.

Schenk, H., Schmahl, N. G., & Funke, G. (1958). Die Reduzierbarkeit von Eisenerzen. Wiesbaden: Springer Wiesbaden.

Scheffer, F., Schachtschabel, P. & Blume, H-P. (2002). *Lehrbuch der Bodenkunde.* Heidelberg: Spektrum Akademie Verlag.

Schiller, M., & Kronz, A. (2004). *Kristallisationsexperimente an historischen Schlackenschmelzen.* Archäometrie und Denkmalpflege - Kurzberichte, 2004, 167-169.

Schmidt, P. R. (1996). Reconfiguring the Barongo: Reproductive symbolism and reproduction among a work association of iron smelters. In P. R. Schmidt (Ed.), *The culture and technology of African iron production* (pp.74-127). Gainesville: University Press of Florida.

Schmidt, P. R., & Avery, D. H. (1996). Complex iron smelting and prehistoric culture in Tanzania. In P. R. Schmidt (Ed.), *The culture and technology of African iron production* (pp.172-185). Gainesville: University Press of Florida.

Schmidt, P. R., & Childs, T. S. (1995). Ancient African iron production. *American Scientist, 83*, 524-533.

Schmidt, P. R., & Childs, T. S. (1996). Actualistic models for interpretation of two early iron age industrial sites in northwest Tanzania. In P. R. Schmidt (Ed.), *The culture and technology of African iron production* (pp. 186-233). Gainesville:University Press of Florida.

Schneider, M. (1987). Notes on terrace soils of the Okavango river, northern S.W.A./Namibia. *Journal South West African Scientific Society, 40/41*, 199-213

Schönfelder, E. (1935). Südost-Angola und der westliche Caprivi-Zipfel. *Petermanns Geographische Mitteilungen, 2*, 49-52, 87-89.

Schürmann, E. (1958). Die Reduktion des Eisens im Rennfeuer. *Stahl und Eisen, 78*(19), 1297-1308.

Schulz, A., & Hammar, A. (1897). *The new Africa. A journey up the Chobe and down the Okovango rivers; a record of exploration and sport; with newly drawn map of Hitherto unexplored parts of the country.* London: Heinemann.

Schumann, H. (1962). *Metallographie.* Leipzig: VEB Deutscher Verlag für Grundstoffindustrie.

Schumann, H., & Oettel, H. (2005). *Metallografie*. Weinheim: Wiley-VCH.

Schwab, R. (2004). *Technologie und Herkunft eiserner Werkzeuge und Waffen aus dem spätkeltischen Oppidum von Manching.* (Doctoral dissertation). Retrieved from http://www.qucosa.de/fileadmin/data/qucosa/documents/2393/Werkstoffwissen-schaftenSchwabRoland320708.pdf.

Scott, D. A. (1991). *Metallography and microstructure of ancient and historic metals.* Marina del Rey: The J. Paul Getty Trust.

Scott, D. A. (2013). *Ancient metals: Microstructure and metal-lurgy - Vol. IV: Iron and steel.* Los Angeles: CSP.

Scott, M. (2003). *Ju/'hoansi bushmen of G/am, Namibia, and their pastoralist neighbours: Contact, Hxaro, crisis of identity, and implications for the past.* (Master's thesis, University of Cape Town).

Segobye, A. (1998). Early farming communities. In P. Lane, A. Reid & A. Segobye (Eds.), *Ditswammung. The archaeology of Botswana* (pp. 101-114). Gaborone: Pula Press and the Botswana Society

Seidel, F., Kose, E., & Möhlig, W. J. G. (2007). Northern Namibia - overview of its historio-graphy based on linguistic and extralinguistic evidence. In O. Bubenzer, A. Bolten & F. Darius (Eds.), *Atlas of cultural and environmental change in arid Africa* (pp. 150-153). Cologne: Heinrich-Barth-Institut.

Seifert, M. (2006). *Narrations of the Kavango: Folktales and documentary texts from northern Namibia and southern Angola.* Cologne: Köppe.

Seifert, M. (2007). *„Derjenige, der sich selbst erschaffen hat…" Motivuntersuchungen zu Heldenerzäh-lungen aus Nordnamibia und Südangola.* (Doctoral dissertation, University of Cologne, Cologne).

Seifert, M. (2008). Folktales as a source for historical traces: The reintroduction of iron working along the central Kavango. In W. J. G. Möhlig, F. Seidel & M.Seifert (Eds.), *Language contact, language change and history based on language sources in Africa* (pp. 265-296). Cologne: Köppe.

Seiner, F. (1909). Ergebnisse einer Bereisung des Gebietes zwischen Okawango und Sambesi (Caprivi-Zipfel) in den Jahren 1905 und 1906. *Mitteilungen aus den Deutschen Schutzgebieten, 22*(1).

Seiner, F. (1910). Die Buschmänner des Okawango- und Sambesigebietes der Nord-Kalahari. *Globus, 97*(22/23), 341-345, 357-360.

Senn-Bischofberger, M. (2005). *Das Schmiedehandwerk im nordalpinen Raum von der Eisenzeit bis ins frühe Mittelalter.* Rahden: Leidorf.

Serneels, V. (1993). *Archéométrie des scories de fer. Recherches sur la sidérurgie ancienne en Suisse occidentale.* Lausanne: Cahiers d'archéologie romande.

Serneels, V. (1995). A propos de quelques scories: Le fer en Suisse romande. In P. Benoit & P. Fluzin (Eds.), *Paléométallurgie du fer & cultures: actes du symposium international du Comité pour la Sidérurgie Ancienne de l'Union Internationale des Sciences Préhistoriques et Protohistoriques 1995* (pp. 21-28). Belfort Cedex: Vulcain.

Serneels, V., & Perret, S. (2003). Quantification of smithing activities based on the investigation of slag and other material remains. In Associazione Italiana di Metallurgia (Ed.), *Archaeometallurgy in Europe: Proceedings of the International Conference Archaeometallurgy in Europe : 24, 25, 26 September 2003, Milano, Italy; 1* (pp. 469-478). Milan: Associazione Italiana di Metallurgia.

Serpa Pinto, A. (1881). *Wanderung quer durch Afrika.* Leipzig: Hirt.

Seymour, C., & Milton, S. (2003). *A collation and overview of research information on Acacia erioloba (Camelthorn) and identification of relevant research gaps to inform protection the species.* Report to the Department of Water Affairs and Forestry, Pretoria.

Shapera, I. (1963). *The Khoisan peoples of South Africa. Bushmen and hottentots.* London: Routledge & Kegan Paul.

Shiremo, S. (2010). *The reign of Hompa Nyangana over the Vagciriku, relations with neighbouring kingdoms, politics and challenges to his leadership: An era of hostility and violence, 1874-1924.* (Master's thesis) Retrieved from http://wwwisis.unam.na/theses/shiremo2009.pdf

Sim, D. (1998). *Beyond the bloom: Bloom refining and iron artifact production in the roman world.* Oxford: Archaeopress.

Smith, E. W., & Dale, A. M. (1920). *The Ila-speaking peoples of northern Rhodesia.* London: Macmillan.

Smith, A., Jacobson, L. (1995). Excavations at Geduld and the appearance of early domestic stock in Namibia. *South African Archaeological Bulletin 50,* 3-14.

Sperl, G. (1980). *Über die Typologie urzeitlicher, frühgeschichtlicher und mittelalterlicher Eisenhüttenschlacken.* Vienna: Verlag der Österreichischen Akademie der Wissenschaften.

Steudel, T., Göhmann, H., Mosimanyana, E., Quintino, M., Flügel, W.-A. & Helmschrot, J. (2013). Okavango Basin - Hydrology. In J. Oldeland, C. Erb, M. Finckh, & N. Jürgens, (Eds.), *Environmental assessments in the Okavango region* (pp. 19-22). Hamburg: BEE, Biocentre Klein Flottbek and Botanical Garden.

Stokes, S., Haynes, G., Thomas, D. S. G., Horrocks, J. L., Higginson, M., & Malifa, M. (1998). Punctuated aridity in southern Africa during the last glacial cycle: The chronology of linear dune construction in the northeastern Kalahari *Palaeogeography, Palaeoclimatology, Palaeoecology, 137*, 305-322.

Stoiber, R. E. & Morse, S. A. (1994). *Crystal identification with the polarizing microscope.* Boston: Springer US.

Straube, H. (1996). *Ferrum Noricum und die Stadt auf dem Magdalensberg.* Vienna: Springer Vienna.

Tardy, Y. (1997). *Petrology of laterites and tropical soils.* Rotterdam: Balkema.

Tessmann, G. (1913). *Die Pangwe. Völkerkundliche Monographie eines westafrikanischen Negerstammes. Ergebnisse der Lübecker Pangwe-Expedtion 1907-1909 und früherer Forschungen 1904-1907.* Berlin: Wasmuth.

Thomas, D. S. G. (1988). The nature and depositional setting of arid and semi-arid Kalahari sediments, southern Africa. *Journal of Arid Environments, 14*, 17-26.

Thomas, D. S. G., & Shaw, P. A. (1990). The deposition and development of the Kalahari Group Sediments, central southern Africa. *Journal of Earth Sciences, 10*(1/2), 187-197.

Thomas, D. S. G., & Shaw, P. A. (1991). *The Kalahari environment.* Cambridge: Cambridge University Press.

Thomas, G., & Young, T. (1999). The determination of bloomery furnace mass balance efficiency. In M. A. Pollard (Ed.), *Geoarchaeology: Exploration, environments, resources* (pp. 155-164). London: The Geological Society.

Thompson, P. R. (2000). *The voice of the past: Oral history.* Oxford: Oxford University Press.

Towner, R., & Dean, J. (2010). *Archaeological chronology development and the old wood problem on the northern Colorado plateau.* Retrieved from http://grantome.com/grant/NSF/BCS-1026422

Travassos-Valdez, F. (1861). *Six years of a traveller's life in western Africa.* London: Hurst & Blackett.

Turner, V. W. (1952). *The Lozi peoples of north-western Rhodesia.* London: International African Institute.

Tylecote, R. F., Austin, J. N., & Wraith, A. E. (1971). The mechanism of the bloomery process in shaft furnaces. *Journal of the Iron and Steel Institute, 209,* 342-363.

Unglik, H. (1991). Observatios on the structures and formation of microscopic smithing residues from Bixby Blacksmith Shop at Barre Four Corners, Massachussetts,1824-55. *Journal Historical Metallurgy Society, 25*, 92-98.

Valdeyron, N., & Da Silva Domingos, S. L. (2009). Nouvelles données sur la Préhistoire récente angolaise: le gisment de Cabolombo à Benfica revisité. In M. Barbaza & J. Guilaine (Eds.), *De Méditerranée et d'ailleurs. Mélanges offerts à Jean Guilaine* (pp. 737-749). Toulouse: Archives d'écologie préhistorique.

Van der Merwe, N. J., & Avery, D. H. (1982). Society pathways to steel: Three different methods of making steel from iron were developed by ancient peoples of the Mediterranean, China, and Africa. *American Scientist, 70*(2), 146-155.

Vansina, J. (1984). Western Bantu expansion. *Journal of African History, 25*, 129-145

Vansina, J. (1985). *Oral tradition as history.* Madison: University of Wisconsin Press.

Vansina, J. (2004). *How societies are born. Governance in west central Africa before 1600.* Charlottesville: University of Virginia Press.

Van Tonder, L. L. (1966). *The Hambukushu of Okavangoland: an anthropological study of a south-western Bantu people in Africa.* (Doctoral dissertation, University of Port Elizabeth, Port Elizabeth).

Van Waarden, C. (1998). The Late Iron Age. In P. Lane, A. Reid & A. Segobye (Eds.), *Ditswammung. The archaeology of Botswana* (pp. 115-160). Gaborone: Pula Press and Botswana Society.

Vereinigung des Archäologisch-technischen Grabungspersonals der Schweiz (VATG) & Schweizerische Arbeitsgruppe für Eisenarchäologie (SAGEA). (1997).*Technique des Fouilles; Grabungstechnik. Minerai, scories, fer; Erze, Schlacken, Eisen.* Basel: VATG.

Velde, P. & Barré, P. (2010). *Soils, plants and clay minerals. Mineral and biologic interactions.* Berlin: Springer.

Vogelsang, R. & Eichhorn, B. (2011). *Under the Mopane tree. Holocene settlement in northern Namibia.* Cologne: Heinrich-Barth-Institute.

Vogelsan, R., Eichhorn, B. & Richter, J. (2002). Holocene human occupation and vegetation history in northern Namibia. *Die Erde, 133*, 113-132.

Volkmann, R. D. (1901). Reise von Grootfontein nach dem Okavango. *Deutsches Kolonialblatt, 12*, 866-870.

Von Oppen, A. (1993). *Terms of trade and terms of trust. The history and contexts of pre-colonial market production around the upper Zambezi and Kasai.* Munster: Lit.

Vossen, R. (2007). Languages of the desert... and what they can tell us about the economic history of southern Africa. In W. J. G. Möhlig (Ed.), *Cultural change in the prehistory of arid Africa - perspectives of archaeology and linguistics* (pp.175-185). Cologne: Köppe.

Wanke, H. (2005). The Namibian Eiseb graben as an extension of the East African Rift: evidence from Landsat TM 5 imagery. *South African Journal of Geology, 108*, 541-546.

Wanke, H., & Wanke, A. (2007). Lithostratigraphy of the Kalahari Group in northeastern Namibia. *Journal of African Earth Sciences, 48*, 314–328.

Wayland, E. J. (1931). Preliminary studies of the tribes of Karamoja. *The Journal of the Royal Anthropological Institute of Great Britain and Ireland, 61*, 187-230.

Wente-Lukas, R. (1977). Fer et forgeron au sud du lac Tchad (Cameroun, Nigeria). *Journal des africanistes, 47*, 107-122.

Widdowson, M. (2007). Laterite and ferricrete. In D. J. Nash & S. J. McLaren (Eds.), *Geochemical sediments and landscapes* (pp. 46-94). Malden: Wiley-Blackwell.

Wilhelm, J. H. (1954). Die !Kung-Buschleute. *Jahrbuch des Museums für Völkerkunde zu Leipzig, 12*, 91-189.

Wilmsen, E. N. (1989). *Land filled with flies - a political economy of the Kalahari.* Chicago: University of Chicago Press.

Wilmsen, E. (1997). *The Kalahari ethnographies (1896 - 1898) of Siegfried Passarge - Nineteenth century Khoisan- and Bantu-speaking peoples; translations from the German.* Cologne: Köppe.

Wilmsen, E. N. (2003). Further lessons in Kalahari ethnography and history. *History in Africa, 30*, 327-420.

Wilmsen, E. N., Campbell, A. C., Brook, G. A., Robbins, L. H., & Murphy, M. (2013). Mining and moving. Specular haematite in Botswana, ca. 200-1300 AD. In J. Humphris & T. Rehren (Eds.), *The world of iron* (pp. 35-45). London: Archetype.

Wilmsen, E., & Denbow, J. (2010). Early villages at Tsodilo: The introduction of livestock, crops, metalworking. In A. Campbell, L. Robbins & M. Taylor (Eds.), *Tsodilo Hills: Copper bracelet of the Kalahari* (pp. 72-81). East Lansing: Michigan State University Press.

Wood, T. G. (1988). Termites and the soil environment. *Biology and Fertility of Soils 6*(3), 228-236.

Wright, P. V. (2007). Calcrete. In D. J. Nash & S. J. McLaren (Eds.), *Geochemical sediments and landscapes* (pp. 10-45). Malden: Wiley-Blackwell.

Wüst, J. (1938). Ein sterbendes Volk. *Monatsblätter der Oblaten der unbefleckten Jungfrau Maria 45*(12), 325-329.

Yalçin, Ü. (2000). Zur Technologie der frühen Eisenverhüttung. *Arbeits- und Forschungsberichte zur sächsischen Bodendenkmalpflege, 42*, 307-382.

Yalçin, Ü. & Hauptmann, A. (2003). Archäometallurgie der früh- und hochmittelalterlichen Eisenverhüttung im Vorland der Schwäbischen Alb. In Landesdenkmalamt Baden-Württemberg (Ed.), *Abbau und Verhüttung von Eisenerzen im Vorland der mittleren Schwäbischen Alb* (pp. 127-158). Stuttgart: Konrad Theiss.

Yalçin, Ü., & Hauptmann, A. (1995). Zur Archäometallurgie des Eisens auf der Schwäbischen Alb. In Landesdenkmalamt Baden-Württemberg (Ed.), *Beiträge zur Eisenverhüttung auf der Schwäbischen Alb* (pp. 269-309). Stuttgart: Konrad Theiss.

Yalçin, Ü., & Lychatz, B. (1995). Früh- und hochmittelalterliche Eisengewinnung im Vorland der mittleren Schwäbischen Alb: Naturwissenschaftlich-technologische Aspekte zur Rekonstruktion der Eisenverhüttung. *Metalla, 2*(2), 53-61.

Young, T. (2012). Some preliminary observations on hammerscale and its implications for understanding welding. *Historical Metallurgy, 45*(1), 26-41.

Young, T., & Poyner, D. (2014). Two medieval bloomery sites in Shropshire: The adoption of water power for iron smelting. *Historical Metallurgy, 46*(2), 78-97.

List of figures

List of tables

Appendix 1: Sample catalogue

All abbreviations used are listed in the abbreviation index.

Lab.-Number: DBM 4388/06
Site catalogue number: 3
Site name: N98/39-1
Unit: 49/10
Quadrant: a
Level: 6
Object: Slag
Size: 11.5 x 8.20 x 2.2 cm, incomplete.
Weight: 41 g
Illustrations: Figure 208
Methods of analyses: MD, ICP-OES
Magnetism: Non-magnetic
Macroscopic description: The exterior and interior of the specimen was light green-gray. The slag was amorphous, sponge-like in shape. Flow structures occurred. The density was low and the texture was frothy, showing small round pores. Fine-grained sediment adhered to one side of the specimen. The flattened shape of one side together with the flow patterns implied that the slag cooled down along a furnace wall. There were no signs of corrosion.
Microscopic description: -
Identified mineral phases: -
Chemical composition:

Fe_2O_3	52.60
SiO_2	36.90
Al_2O_3	3.33
CaO	7.16
MnO	0.72
TiO_2	0.19
MgO	0.62
Na_2O	0.05
P_2O_5	0.05
Total	101.62
	wt%

Ba	492
Cr	n.d.
Sr	74
V	49
Y	n.d.
Zr	54
As	n.d.
Bi	n.d.
Cu	n.d.
Ni	16
Pb	n.d.
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Early Ironworking Groups
Interpretation: This was a silica-rich flow slag, which probably originated from a furnace. The shape of the specimen showed the structure of the furnace wall. The slag probably reacted with the furnace wall. The chemical picture differed from the other samples of flow and furnace slag in that its composition approached Optimum 3 in the FeO-SiO_2-CaO system (Figure 188), indicating solidus temperatures below 1100 °C.

Lab.-Number: DBM 4389/06
Site catalogue number: 3
Site name: N98/39-2
Unit: 50/51
Quadrant: d
Level: 705
Object: Slag
Size: 11.3 x 4.3 x 3.0 cm, complete.
Weight: 59 g
Illustrations: -
Methods of analyses: MD, PCS
Magnetism: Variable, predominantly strongly to very strongly magnetic, in parts only weakly magnetic.
Macroscopic description: The exterior of the specimen was medium gray and rusty brown. In cross section, it was dark gray and metallic silver. The shape of the slag lump was amorphous and sponge-like. The density was medium to high and the texture showed minute to small round to amorphous-angular pores. There was some charcoal powder in the pores. Sand adhered to the specimen due to the slag flow and to corrosion. Patches of strong corrosion were present.
Microscopic description: In cross section, the sample was a homogeneous fayalitic slag with metallic iron. Fayalite appeared as weakly developed blocky crystals with blurred boundaries in an amorphous glassy mass of a fayalite/leucite eutectic. The sample contained a number of fractured and slagged quartz grains, which formed acicular neogenetic silica-rich mineral phases. Almost no wustite was present in the sample. The content of metallic iron was about 25area%. It occurred in unfused and loose, coral-like structures throughout the whole sample. Some corals of elemental iron still showed patterns of the preceding phase wustite, and in some parts the transformation from wustite to metallic iron could be observed. After etching with 3% Nital, the elemental iron revealed a purely ferritic microstructure of ferrite mono- and polycrystals without any grain boundary segregations. The grains contained a number of small intragrain inclusions (minute round etch pits and some acicular structures). A pronounced cooling skin of wustite and magnetite with some acicular iscorite formed along the outer margin of the slag. In some parts a rim of slagged sand grains adhered to the slag, together with small lumps of iron oxide.[379] Some of the iron bloom as well as the cooling skin showed signs of corrosion (goethite).

[379] In a corroded environment it can be difficult to distinguish goethitic iron ore from the neogenetic iron hydroxides of the sample.

Identified mineral phases: Fayalite, leucite, ferrite, wustite, spinel (magnetite), goethite, iscorite, quartz, silica-rich phases, glass.
Chemical composition: -
Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Early Ironworking Groups
Interpretation: This was a piece of an unsintered soft iron bloom in smelting slag from the furnace. The appearance of the elemental iron represented the first stage of α-iron formation before carburization took place. The sample also implied that wustite was effectively reduced to metallic iron during the smelt. The cooling skin and the amorphous appearance of the mineral phases present in the slag suggested that the sample cooled down rapidly outside of the furnace. The intragrain inclusions were usually considered iron-nitrides, iron-carbide-nitrides or phosphides. It was probably discarded during initial refinement because the bloom was not sintered enough for further treatment.

Lab.-Number: DBM 4390/06
Site catalogue number: 3
Site name: N98/39-2
Unit: 50/53
Quadrant: d
Level: 918
Object: Slag
Size: 10.3 x 6.4 x 1.7 cm, complete.
Weight: 39 g
Illustrations: -
Methods of analyses: MD, PTS, ICP-OES
Magnetism: Weakly magnetic.
Macroscopic description: The interior and exterior of the slag lump was greenish medium gray. The shape was amorphous and the sample showed layered and droplet-like flow patterns. The exterior was smooth. The density was medium to high and the texture showed minute to small round to amorphous-roundish pores. Some pores were filled with charcoal powder. There were no signs of corrosion.
Microscopic description: In thin section, the specimen consisted of about 75 to 90area% of fayalite and of 10 to 25area% of magnetite-dominated spinel in a glassy groundmass. The sample was of macrocrystalline texture. Magnetite appeared as the first phase and solidified in idiomorphic skeletal rhombic singular crystals. Around these magnetite crystals, fayalite grew as large blocky, skeletal crystals. In interstices, secondary magnetite dendrites occurred together with small, lath-like fayalites of the 2nd generation. A glassy matrix solidified last. Some flow boundaries showed crystal intergrowth.
Identified mineral phases: Fayalite, magnetite, glass.
Chemical composition:

Fe_2O_3	66.50
SiO_2	31.20
Al_2O_3	2.22
CaO	0.66
MnO	0.17
TiO_2	0.15
MgO	0.19
Na_2O	0.06
P_2O_5	0.06
Total	101.22
	wt%

Ba	890
Cr	n.d.
Sr	45
V	18
Y	n.d.
Zr	68
As	n.d.
Bi	n.d.
Cu	941
Ni	19
Pb	n.d.
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Early Ironworking Groups
Interpretation: This was a multilayered flow slag, probably from a smelting event. The whole sample suggested slow cooling under oxidizing conditions, probably within the furnace after the bloom had been removed, or close to the mouth of a tuyere.

Lab.-Number: DBM 4391/06
Site catalogue number: 3
Site name: N98/39-2
Unit: 50/54
Quadrant: -
Level: 293
Object: Slag
Size: 2.7 x 1.9 x 1.0 cm, incomplete
Weight: 35 g
Illustrations: -
Methods of analyses: MD, PTS, ICP-OES
Magnetism: Weakly magnetic.
Macroscopic description: The exterior of the specimen was medium gray. In cross section, it was dark gray. The slag lump showed a layered texture with the beginnings of flow structures. The density varied from medium to high with round to oblong minute to large pores up to 2 cm in diameter. Oblong pores in divergent order formed along the underside of the specimen. Only minimal signs of corrosion occurred.
Microscopic description: In cross section, the sample appeared layered and inhomogeneous. Large opaque sections indicated a high content of iron oxides and layers of high wustite content alternated with layers of low wustite content. The latter crystallized as first phase. It was somewhat crowded in appearance and in places formed dense xenomorphous accumulations of amorphous hammerscale.

Depending on the composition of the layer, wustite was followed by an amorphous fayalite/wustite eutectic with poor crystal development, or, in some areas with acicular and divergently oriented crystal growth. In some zones, blocky fayalites crystallized before the eutectic. If present, interstices were filled with a glassy matrix and only a few fayalites of the 2nd generation occurred. Plane flow boundaries between the various layers occurred as well as slightly intercrystallized flow limits. In some parts a magnetitic and/or hematitic cooling skin formed along the outer margins of the slag and was partially reduced. The sample showed only a few small prills of pure iron. Some of them were corroded. A few quartz grains were present in the sample without thermal alteration. Some quartz grains adhered to the specimen due to corrosion.

Identified mineral phases: Fayalite, wustite, magnetite, hematite, goethite, metallic iron, quartz, little glassy groundmass.

Chemical composition:

Fe_2O_3	73.70
SiO_2	26.12
Al_2O_3	1.13
CaO	0.63
MnO	0.15
TiO_2	0.04
MgO	0.16
Na_2O	0,01
P_2O_5	0.07
Total	102.01
	wt%

Ba	746
Cr	n.d.
Sr	32
V	n.d.
Y	n.d.
Zr	48
As	n.d.
Bi	n.d.
Cu	n.d.
Ni	19
Pb	n.d.
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -

Absolute age: -

Occupation horizon: Possibly Early Ironworking Groups.

Interpretation: The macroscopic appearance (oblong pores in divergent order, cooling skin, multilayered texture) implied that this was a small smithing hearth bottom which had been formed from short repeated iron working cycles, although only little of the original slag survived. The sample was highly ferrous, and the crowded but rather fussy distribution of wustite suggested that hammerscale fell into the slag bath and had enough time to dissolve. Under reducing conditions it cooled down slowly from temperatures comparable to smelting operations. The absence of bloom fragments and the multilayered texture, indicating short repeated smithing events, together with the high amount of hammerscale led me to suggest that this sample formed during final refining.

Lab.-Number: DBM 4393/06
Site catalogue number: 3
Site name: N98/39-2
Unit: 51/50
Quadrant: d
Level: 730
Object: Slag
Size: 3.0 x 1.9 x 0.9 cm, incomplete.
Weight: 2 g
Illustrations: Figure 184
Methods of analyses: MD, PTS, ICP-OES
Magnetism: Variable, from non-magnetic to moderately magnetic.

Macroscopic description: The interior and exterior of the slag lump was medium gray. The shape was amorphous and it showed flow patterns. The exterior was smooth. The density was medium and the texture showed minute to medium-sized round to amorphous-angular pores up to 0.8 cm in diameter. Some pores were filled with powdery fuel. There were no signs of corrosion.

Microscopic description: This was a multilayered slag with multiple flow boundaries with and without crystal intergrowth. The composition of the various layers, however, remained largely the same.

Wustite and magnetite-dominated spinel crystallized as first phase in regular dendrites or granular-like individual crystals across the sample. Some small crowded agglomerations of wustite occurred. Fayalite appeared as second phase as acicular to small blocky and lath-like crystals. It was followed by a fayalite/ wustite eutectic. The sample contained only little glassy matrix in interstices. A hematitic cooling skin formed in some parts of the slag layers. Only a few small angular fragments and prills of pure iron were present in the specimen. The sample contained powdery charcoal or fuel ashes. Pores were small, mainly angular and in some layers in radiating order.

Identified mineral phases: Fayalite, wustite, spinel (magnetite), glass, hematite, metallic iron.

Chemical composition:

Fe_2O_3	65.30
SiO_2	26.20
Al_2O_3	1.78
CaO	6.45
MnO	0.65
TiO_2	0.08
MgO	0.48
Na_2O	0,02
P_2O_5	0,04
Total	101.01
	wt%

Ba	427
Cr	n.d.
Sr	60
V	36
Y	n.d.
Zr	48
As	n.d.
Bi	n.d.
Cu	1154
Ni	15
Pb	n.d.
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Early Ironworking Groups
Interpretation: This was an initial refining slag. The microstructure indicated that there were numerous repeated flow events of liquid slag in a hot environment (low viscosity, intercrystallized flow boundaries). The occurrence of wustite and magnetite-dominated spinel suggested that the liquid slag was drained away from the refining furnace into a cooler and more oxidizing environment (magnetite, cooling skin, acicular and mostly small crystals). Since there was only little discarded material from hammering, such as amorphous hammerscale and fragments of metallic iron, I suggest that the slag was probably generated during the initial heating of a bloom in order to drain away the redundant slag. A plot of the major components in the ternary system FeO-SiO_2-CaO revealed that the composition of this sample approached the low melting temperature field of Optimum 3 (Figure 189).

Lab.-Number: DBM 4394/06
Site catalogue number: 3
Site name: N98/39-2
Unit: 51/50
Quadrant: c
Level: 774
Object: Slag/bloom
Size: 10.3 x 6.4 x 1.7 cm, complete.
Weight: 39 g
Illustrations: Figure 55
Methods of analyses: MD, PCS
Magnetism: Very strongly magnetic.
Macroscopic description: The exterior of the slag lump was rusty brown to medium gray and the interior was greenish medium gray to metallic silver. The shape was amorphous. The density was middle to high and the texture showed minute to small round to amorphous-roundish pores. Charcoal powder was trapped in pores. A rind of corrosion enveloped the specimen with adhering sand grains.
Microscopic description: In cross section the specimen consisted of about 70area% fayalite and 20area% unconsolidated iron bloom with interstitial glass. The fayalite appeared mainly as long columnar to lath-shaped crystals, which were rather poorly developed. In interstices, fayalite appeared in eutectic intergrowth with leucite, or they were filled with a glassy matrix only. Metallic iron occurred from labyrinthine to fused structures. When etching with 3% Nital, the sample revealed iron and steel with carbon contents from below 0.02wt% up to 0.7wt%. The pure iron and low carbon steel parts revealed irregular polygonal ferrite of varying grain size with cementite segregations along grain boundaries and small pearlite islands. The grain size ranged between ASTM 1 to 7. The sample graded into high carbon steel, which developed Widmanstätten side plates and saw teeth in a pearlitic matrix. Some of the ferrites exhibited small acicular intragrain precipitants that can be iron phosphides, iron carbides, or nitrides. The metal inclusions showed round unaltered pores.
Identified mineral phases: Fayalite, metallic iron (ferrite, pearlite, cementite), glass, goethite.
Chemical composition: -
Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Early Ironworking Groups
Interpretation: This was a bloom fragment in smelting slag. The composition of the sample indicated effectively reducing conditions in the furnace and a low-iron slag. The inhomogeneity of the carbon distribution evidenced variations of the material produced within less than 1 cm of the bloom. The piece was probably lost during refining and was exposed to air-cooling. The range of grain sizes might indicate that the bloom had already been mechanically altered (hammering) and recrystallized.

Lab.-Number: DBM 4395/06
Site catalogue number: 3
Site name: N98/39-2
Unit: 51/50
Quadrant: -
Level: 801
Object: Slag, bloom
Size: 1.1 x 0.8 x 0.3 cm, complete.
Weight: 0.7 g
Illustrations: Figure 55
Methods of analyses: MD, PCS
Magnetism: Very strongly magnetic.
Macroscopic description: The exterior of the slag lump ranged from rusty brown to medium gray and the interior from medium gray to metallic silver. The slag was of tabular shape. The density was high and the texture showed minute amorphous-roundish pores. The specimen was partly corroded with sand grains trapped in the rust.
Microscopic description: In cross section, the specimen consisted of about 50area% fayalite, 30area% metallic iron, iron hydroxides and interstitial glass. Fayalites of two generations appeared as medium-sized columnar crystals with interstitial leucite in eutectic intergrowth with fayalite. In some parts, interstices were filled with glass. The metallic iron appeared layered in labyrinthine structures or in complete fusion. The non-etched section showed a ghost structure which was indicative of phosphorus in the steel. When etching with 3% Nital, the sample was rather unresponsive to the etching material. The microstructure showed polygonal ferrite, interstitial pearlite and some grain boundary cementite. The carbon content might be around 0.2wt%. The pores of

the consolidated elemental iron were round and unaltered. The metallic iron was partially corroded and powdery fuel or fuel ashes were associated with some of the elemental iron.
Identified mineral phases: Fayalite, leucite, metallic iron (ferrite, pearlite, cementite), goethite.
Chemical composition: -
Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Early Ironworking Groups
Interpretation: This was a low carbon steel bloom in smelting slag. The layered appearance of the elemental iron provided evidence of the mechanism of the deposition and accumulation of elemental iron while the slag drained away to deeper parts of the furnace. The absence of wustite further suggested effectively reducing conditions. The acicular nature of the fayalites indicated fast cooling, probably when the bloom was taken out of the furnace while it was still hot. The piece of steel was probably lost during refining (gromp). Both the ghost structure and the lack of response towards etching indicated an elevated phosphorous content of the elemental iron. Therefore, the low carbon steel was probably harder than one would expect solely based on the carbon content.

Lab.-Number: DBM 4396/06
Site catalogue number: 3
Site name: N98/39-2
Unit: 51/51
Quadrant: -
Level: 284
Object: Slag
Size: 3.5 x 2.0 x 1.2 cm, incomplete.
Weight: 16 g
Illustrations: Figures 184 and 209
Methods of analyses: MD, PCS, ICP-OES
Magnetism: Variable, magnetic surface skin.
Macroscopic description: The exterior of the slag lump was medium gray to light grayish brown and the interior was dark gray. The slag was of tabular shape and it solidified in a sand bed. A cooling skin formed at the upper side of the slag. The texture was of medium density and showed minute to large round and amorphous-roundish pores up to a diameter of 2 cm. There was a high content of powdery fuel or fuel ashes in the sample. The exterior of the specimen was only minimally corroded.
Microscopic description: In cross section, the sample showed an inhomogeneous structure and abundant iron oxides (wustite). Wustite crystallized as first phase within the sample and formed dense irregular and crowded agglomerations of granular-like to dendritic crystals. The hammerscale occurred in different degrees of dissolution and some sections showed large wustite dendrites in a well-oriented order. A few fayalites appeared as second phase with medium-sized blocky crystals. The main slag mass consisted of a fayalite/wustite eutectic with poorly developed columnar and lath-like crystals. Only little interstitial space was present in the sample, which was filled with a glassy matrix. In a few zones, a fayalite/leucite eutectic was present.
Small round and subangular pieces of compacted metallic iron occurred and some of them showed an acicular cast iron structure. Etching with 3% Nital revealed a small fragment of low carbon steel (about 0.2wt% C) with a ferritic Widmanstätten structure and some interstitial pearlite. The corrosion pattern around this fragment was rectangular in section. Additionally, some fragments of eutectoid high carbon steel (0.8 to 0.85wt% C) were found, which showed a pearlitic microstructure and, in a few zones, grain boundary cementite. All of these fragments showed subangular pores and inclusions. Furthermore, small prills of metallic iron were obviously reduced within the slag itself. They consisted of white cast iron and exhibited a microstructure of pearlite, ledeburite, and secondary cementite. The carbon content was estimated to be in the region of 3wt%, which indicated working temperatures above 1300 °C. All metallic iron showed corrosion. The bottom side of the sample had a slagged coating with slightly fractured quartz grains. Some unfractured quartz grains adhered to the inner surface of pores due to corrosion.
Identified mineral phases: Fayalite, metallic iron (ferrite, pearlite, cementite), wustite, goethite, quartz.
Chemical composition: -

Fe_2O_3	78.00
SiO_2	20.96
Al_2O_3	1.14
CaO	0.31
MnO	0.05
TiO_2	0.05
MgO	0.12
Na_2O	0.01
P_2O_5	0.06
Total	100.70
	wt%

Ba	72
Cr	n.d.
Sr	14
V	26
Y	n.d.
Zr	55
As	n.d.
Bi	n.d.
Cu	5
Ni	13
Pb	n.d.
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Perhaps Early Ironworking Groups.
Interpretation: This was a primary smithing hearth bottom with gromps. Amorphous hammerscale was found together with gromps and implied that the slag formed during an initial step of refining. The

hammerscale in dissolution together with the cast iron prills provided evidence that the slag bath remained liquid for a long period of time under hot reducing conditions. The inhomogeneous nature of the lost steel fragments evidenced the highly varying source material that was processed. The pore alterations of these fragments derived from hammering, as did the relict rectangular shape of one of the fragments.

Lab.-Number: DBM 4397/06
Site catalogue number: 3
Site name: N98/39-2
Unit: 51/51
Quadrant: -
Level: 317
Object: Slag
Size: 5.8 x 5.6 x 3.9 cm, incomplete.
Weight: 15 g
Illustrations: -
Methods of analyses: MD, ICP-OES
Magnetism: Very weakly magnetic.
Macroscopic description: The exterior of the slag lump was medium brown-gray and the interior was dark gray. The shape was plano-convex and the specimen solidified in a sand bed with sand adhering to the under side. The horizontal outline suggested that the specimen formed in a small pit of less than 10 cm in diameter. A cooling skin was present at the upper side and the maximum thickness did not exceed 2 cm. The texture was microcrystalline, layered, and of medium density. It showed minute to small amorphous-roundish pores. There were no signs of corrosion.
Microscopic description: -
Identified mineral phases: -
Chemical composition:

Fe_2O_3	82.00
SiO_2	17.23
Al_2O_3	1.17
CaO	0.24
MnO	0.01
TiO_2	0.05
MgO	0.13
Na_2O	n.d.
P_2O_5	0.11
Total	100.92
	wt%

Ba	57
Cr	n.d.
Sr	8
V	29
Y	n.d.
Zr	53
As	n.d.
Bi	n.d.
Cu	26
Ni	8
Pb	n.d.
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Early Ironworking Groups
Interpretation: This sample was a small smithing hearth bottom. The limited size, together with the high content of iron oxide and the lack of gromps implied that this was a residue from secondary smithing.

Lab.-Number: DBM 4398/06
Site catalogue number: 3
Site name: N98/39-2
Unit: 51/51
Quadrant: b
Level: 402
Object: Slag
Size: 8.2 x 6.4 x 1.7 cm, incomplete.
Weight: 18 g
Illustrations: -
Methods of analyses: MD, ICP-OES
Magnetism: Moderately magnetic.
Macroscopic description: The exterior of the slag was brown medium gray to medium gray and the interior was medium gray. The shape was amorphously flat and the specimen showed some flow structures. The slag solidified in a sand bed and grains adhered to the underside. The texture was glassy to microcrystalline and of high to medium density. It showed minute to medium-sized round and amorphous-roundish pores up to 0.6 cm in diameter. There were no signs of corrosion.
Microscopic description: -
Identified mineral phases: -
Chemical composition:

Fe_2O_3	61.10
SiO_2	37.03
Al_2O_3	1.77
CaO	1.30
MnO	0.02
TiO_2	0.08
MgO	0.32
Na_2O	0.04
P_2O_5	0.15
Total	101.80
	wt%

Ba	141
Cr	n.d.
Sr	48
V	26
Y	n.d.
Zr	54
As	n.d.
Bi	n.d.
Cu	12
Ni	17
Pb	n.d.
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Early Ironworking Groups
Interpretation: This slag cooled down at the bottom of a pit. The low iron oxide content implied that it was a smelting slag (or initial refining slag) and its magnetism suggested that it cooled down

under oxidizing conditions. The interpretation, however, was difficult without microscopic examination.

Lab.-Number: DBM 4400/06
Site catalogue number: 3
Site name: N98/39-2
Unit: 51/52
Quadrant: -
Level: 836
Object: Slag
Size: 3.3 x 1.8 x 1.2 cm, incomplete.
Weight: 23.7 g
Illustrations: -
Methods of analyses: MD, PTS, ICP-OES
Magnetism: Very strongly magnetic.
Macroscopic description: The exterior of the slag was medium gray and the interior was dark gray. The shape was amorphous. The slag solidified in a sand bed with a partially slagged rim of sand grains adhering to the irregular underside. A cooling skin formed on the upper side of the lump. The texture of the slag was layered and of medium density and minute to small round pores were present. There was almost no charcoal in the sample. The specimen was only minimally corroded along the outer margin.
Microscopic description: In cross section, the sample revealed an inhomogeneous and layered structure. The main mineral phases were spinel (magnetite and hercynite) and fayalite. Magnetite crystallized as first phase and occurred in four generations. Most of the crystals were idiomorphic, rhombic or dendritic. In some sections, smaller magnetite occurred in well-oriented dendritic patterns. Additionally, magnetite appeared as highly condensed tabular elongated structures of flat hammerscale. On the upper side of the specimen, a pronounced cooling skin formed and remnants of several generations of broken cooling skins were present. Fayalite crystallized as second phase. Depending on the layer, it could be glassy, lath-like or medium-sized blocky in appearance. Where blocky fayalites developed, blocky hercynite crystals occurred as third phase. Interstitial space was filled with a leucite/spinel (hercynite and magnetite) eutectic. In layers of different composition, fayalite was followed by a glassy matrix in interstices in which some minute spinel crystals grew. The underside exhibited a coating of sand grains trapped in the slag and some of them were fractured due to thermal stress.
Identified mineral phases: Magnetite, fayalite, hercynite, leucite, quartz, glass.

Chemical composition:

Fe_2O_3	59.50
SiO_2	33.28
Al_2O_3	3.21
CaO	3.30
MnO	0.27
TiO_2	0.23
MgO	0.41
Na_2O	0.10
P_2O_5	0.11
Total	100.42
	wt%

Ba	264
Cr	n.d.
Sr	62
V	n.d.
Y	n.d.
Zr	57
As	n.d.
Bi	n.d.
Cu	n.d.
Ni	22
Pb	n.d.
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Perhaps Early Ironworking Groups
Interpretation: This was a small smithing hearth bottom from secondary smithing. The slag cooled down under oxidizing conditions in a sand bed in a thermally alternating environment. Although it was only 1.2 cm in thickness, the cooling skins within the sample evidenced several cycles of heating and cooling. The very compacted magnetite dominance of the section together with the tabular inclusions of flat hammerscales strongly suggested that elemental iron had been hot-worked near the forge. Based on its limited size, the high amount of magnetite and the tabular hammerscale inclusions I consider it a secondary smithing slag.

Lab.-Number: DBM 4401/06
Site catalogue number: 3
Site name: N98/39-2
Unit: 51/52
Quadrant:
Level: 836
Object: Slag
Size: 4.2 x 4.1 x 1.7 cm, incomplete.
Weight: 3.9 g
Illustrations: -
Methods of analyses: MD, ICP-OES
Magnetism: Weakly magnetic.
Macroscopic description: The exterior and interior of the slag was dark gray. The shape of the slag lump was amorphous and it showed flow structures with a smooth exterior. The texture was microcrystalline and of medium density. Minute to small round pores up to 0.4 cm in diameter were present. There were no signs of corrosion.
Microscopic description: -

Identified mineral phases: -
Chemical composition:

Fe_2O_3	76.40
SiO_2	23.21
Al_2O_3	1.27
CaO	0.26
MnO	0.19
TiO_2	0.07
MgO	0.14
Na_2O	0.01
P_2O_5	0.07
Total	101.63
	wt%

Ba	87
Cr	n.d.
Sr	15
V	25
Y	n.d.
Zr	59
As	n.d.
Bi	n.d.
Cu	n.d.
Ni	13
Pb	n.d.
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Perhaps Early Ironworking Groups
Interpretation: This was a shattered flow type slag probably from smelting.

Lab.-Number: DBM 4402/06
Site catalogue number: 3
Site name: N98/39-2
Unit: 51/52
Quadrant: d
Level: 876
Object: Slag
Size: 3.0 x 1.8 x 1.3 cm, incomplete.
Weight: 24 g
Illustrations: Figure 186
Methods of analyses: MD, PTS, ICP-OES
Magnetism: Weakly magnetic.
Macroscopic description: The exterior and interior of the slag lump was medium grayish green. The slag was of amorphous shape and showed the beginnings of a flow structure. The slag solidified along a sandy furnace or pit wall. The texture was of high density and showed minute to medium-sized round pores up to a diameter of 0.3 cm. The specimen had no sign of corrosion at the surface.
Microscopic description: In thin section the sample revealed an inhomogeneous structure of a fayalitic slag with low wustite and magnetite content. The slag had glassy regions as well as macrocrystalline sections. In one area, wustite crystallized as first phase, followed by a fayalite/wustite eutectic and interstitial glass. Here, wustite appeared as a crowded accumulation of dendritic to granular-like crystals. In zones of less iron-oxide concentration, fayalite was the first phase, followed by a fayalite/leucite and a fayalite/leucite/spinel eutectic. In places with higher iron-oxide concentration, idiomorphic spinel (magnetite) crystallized after the fayalite as second phase. The magnetite was less concentrated than the wustite seen before, but also irregular in its distribution. The wustite-rich area of the sample was glassy in its microstructure whereas the fayalite-dominated layers can be glassy as well as macro-crystalline with large skeletal blocky to lath-like crystals. The sample contained about 30area% of fractured quartz grains with varying stages of thermal alteration and incipient forming of neogenetic silica-rich phases as well as fayalite. Some fractured quartz zones were surrounded by clouds of small spinel crystals. A medium content of powdery fuel or fuel ashes was present. Some minute prills of metallic iron were scattered throughout the sample.
Identified mineral phases: Fayalite, wustite, magnetite/spinel, leucite, quartz, neogenetic silica-rich phases, glass.
Chemical composition:

Fe_2O_3	66.70
SiO_2	31.20
Al_2O_3	1.36
CaO	1.10
MnO	0.14
TiO_2	0.05
MgO	0.26
Na_2O	0.03
P_2O_5	0.14
Total	100.98
	wt%

Ba	562
Cr	n.d.
Sr	52
V	16
Y	n.d.
Zr	47
As	n.d.
Bi	n.d.
Cu	n.d.
Ni	18
Pb	n.d.
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Early Ironworking Groups
Interpretation: This was a heterogeneous slag from final refining. The crystal structure of the sample showed layers that cooled down slowly. These layers were overlain by layers with a rather glassy texture that formed during rapid cooling. They represent repeated cycles of heating and processing of an iron bloom. The slag solidified along the sandy wall of a furnace, indicating that the refining furnace was a pit in the sandy ground. The presence of magnetite and wustite signaled alternating redox conditions. The small amorphous hammerscale inclusions suggested that iron was processed at a stage when some slag was still present in the raw material. The high amount of silica in varying phases of alteration, however, implied that the iron material was comparably clean and the ironworkers needed to add quartz as a flux

to protect the surface from too much oxidation. The high portion of the fayalite/leucite eutectic within the sample suggested that liquidus temperatures of the slag were low. Also, the absence of bloom fragments hinted at a rather late stage in bloom refinement.

Lab.-Number: DBM 4403/06
Site catalogue number: 3
Site name: N98/39-2
Unit: 51/53
Quadrant: c
Level: 571
Object: Slag
Size: 7.1 x 4.2 x 1.4 cm, incomplete.
Weight: 15 g
Illustrations: -
Methods of analyses: MD, ICP-OES
Magnetism: Non-magnetic.
Macroscopic description: The exterior and interior of the slag was greenish medium gray. The shape of the slag was amorphous with flow structures. The exterior of the specimen was smooth. The slag solidified in a sand bed because a rim of partially reacted quartz grains, which became trapped in the slag, formed on one side of the sample. The texture was crystalline and of medium density and had small to medium-sized round to amorphous-roundish pores. There were no signs of corrosion.
Microscopic description: -
Identified mineral phases:
Chemical composition:

Fe_2O_3	71.30
SiO_2	28.17
Al_2O_3	1.54
CaO	0.49
MnO	0.01
TiO_2	0.07
MgO	0.11
Na_2O	0.02
P_2O_5	0.08
Total	101.80
	wt%

Ba	114
Cr	n.d.
Sr	23
V	19
Y	n.d.
Zr	58
As	n.d.
Bi	n.d.
Cu	n.d.
Ni	14
Pb	n.d.
Zn	670
Sb	n.d.
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Early Ironworking Groups
Interpretation: The sample was not easy to interpret. It was non-magnetic, which means that it contained no metallic iron or magnetite and it lacked a cooling skin along the upper side of the specimen. Moreover, it showed flow structures and a thick rim of slagged quartz grains along the underside. Taking these features together, I suggest that the slag formed under prolonged hot and reducing conditions, which can usually be found during a smelting process, and it solidified at the bottom of a furnace.

Lab.-Number: DBM 4404/06
Site catalogue number: 3
Site name: N98/39-2
Unit: 51/55
Quadrant: a
Level: 619
Object: Slag, bloom
Size: 1.1 x 1.0 x 0.9 cm, incomplete.
Weight: 2 g
Illustrations: Figure 55
Methods of analyses: MD, PCS
Magnetism: Strongly magnetic.
Macroscopic description: The exterior of the slag lump ranged from rusty brown to medium gray and the interior was from light to dark gray and metallic silver. The slag was amorphous in shape. The density was high and the texture showed minute and small amorphous-angular pores. The specimen was strongly corroded with numerous sand grains trapped in the rust.
Microscopic description: In cross section the specimen consisted mainly of about 75area% of fayalite, 20area% of metallic iron and iron hydroxides. Fayalite crystallized as first phase in two generations in medium-sized columnar crystals. Interstices were filled with glass. The metallic iron appeared in coral-like and labyrinthine pattern as well as in complete fusion. The metallic iron was strongly corroded. After etching with 3% Nital, the microstructure consisted of polygonal ferrite with little grain boundary cementite and the beginnings of pearlite formation. Carbon was estimated to be approximately 0.02wt%. The grain sizes of the ferrite grains varied between ASTM 1 to 5. The elemental iron contained globular slag inclusions which were not affected by any mechanical treatment. Fractured quartz grains occurred, forming neogenetic silica-rich mineral phases. Only a few inclusions of fuel were present.
Identified mineral phases: Fayalite, metallic iron (ferrite, pearlite, cementite), goethite, quartz, silica-rich phases, glass.
Chemical composition: -
Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Early Ironworking Groups
Interpretation: This was a piece of low carbon steel bloom in smelting slag. The bloom was probably lost while the main bloom was removed from the furnace, or during the initial sorting of the bloom. The fine acicular microstructure of the fayalite suggested that the slag cooled in air outside of the furnace.

Lab.-Number: DBM 4405/06
Site catalogue number: 3
Site name: N98/39-2
Unit: 52/52
Quadrant: -
Level: 46
Object: Slag
Size: 7.4 x 5.8 x 1.9 cm, incomplete.
Weight: 56 g
Illustrations: Figure 186
Methods of analyses: MD, PTS, ICP-OES
Magnetism: Variable, most of the sample is weakly magnetic, strongly magnetic at rusty spots.
Macroscopic description: The exterior of the slag lump was light gray and the interior was blackish gray. The slag was flat in shape with a slightly convex bottom and small slag lumps adhering to it. It solidified in a sand bed forming a rim of sand grains trapped in slag on the underside. A cooling skin formed at the upper face of the slag lump. The texture was of low density and had minute to medium-sized round and amorphous-angular pores. There was a high amount of charcoal powder in the pores. The specimen was partially corroded.
Microscopic description: In thin section the sample revealed an inhomogeneous layered and conglomerated structure. The slag consisted mainly of wustite and fayalite and exhibited a high area portion of iron oxides. Zones with high wustite content alternated with zones of low wustite content and the latter crystallized predominantly as first phase within the slag. Wustite was present in irregularly crowded and insular patterns of large dendritic and amoeba-like crystals. Some of these dense wustite patterns showed well-confined round and tabular structures of globular and flat hammerscale. Most layers found in microstructure were dominated by the phase succession of wustite, fayalite and a fayalite/wustite eutectic. However, layers differed in that the final phase could be leucite, a fayalite/leucite ora fayalite/leucite/spinel eutectic. The top layer exhibited less iron oxide and showed the crystallization succession of fayalite, wustite and a fayalite/leucite eutectic in interstices. The different slag layers did not only vary in composition, they also attested that cooling conditions changed with each new layer. Fayalite appeared from micro- to macrocrystalline condition in blocky or lath-like crystals of varying size. In some sections, small secondary wustite dendrites grew in interstices. The bottom side of the sample showed a coating of trapped sand grains with incipient reaction rims around them. The sand was trapped in a macrocrystalline slag mass with spinel crystals as first phase followed by small fayalites and then leucite in a glassy matrix. Small pieces of fused metallic iron occurred and were probably remnants of the gorged iron that fell into the refining furnace. Additionally, small prills of metallic iron were obviously reduced from wustite in the slag itself. Moreover, the cooling skin had been reduced to wustite and metallic iron, which corroded later. Both prills and the reduced cooling skin implied high temperatures and reducing conditions in the refining furnace. Generally, the metallic iron present in the specimen was highly corroded.
Identified mineral phases: Fayalite, wustite, metallic iron, goethite, leucite, quartz, glass.
Chemical composition:

Fe_2O_3	77.80
SiO_2	20.20
Al_2O_3	0.99
CaO	1.15
MnO	0.01
TiO_2	0.05
MgO	0.45
Na_2O	0.02
P_2O_5	0.10
Total	100.77
	wt%

Ba	92
Cr	n.d.
Sr	31
V	24
Y	n.d.
Zr	57
As	n.d.
Bi	n.d.
Cu	n.d.
Ni	32
Pb	n.d.
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Early Ironworking Groups
Interpretation: This was a smithing hearth bottom from a final step of bloom refining. The phase composition and the elemental iron reduced within the slag suggested high temperatures and reducing conditions. The appearance of amorphous, globular and tabular hammerscale together with the angular chunks of elemental iron implied that the bloom still contained some slag, but was already consolidated metal. The slag intruded a sand bed and the trapped grains showed thermal alteration.

Lab.-Number: DBM 4406/06
Site catalogue number: 3
Site name: N98/39-2
Unit: 52/53
Quadrant: -
Level: 829
Object: Slag
Size: 2.1 x 1.7 x 1.5 cm, incomplete.
Weight: 34 g
Illustrations: -

Methods of analyses: MD, ICP-OES
Magnetism: Weakly magnetic.
Macroscopic description: The interior of the slag was very dark gray. The original exterior was not preserved. The slag showed flow structures and several layers of slag were separated by fine lines of small pores. The texture was macrocrystalline and of high density with minute to small round and oblong pores. There were no signs of corrosion.
Microscopic description: -
Identified mineral phases:
Chemical composition:

Fe_2O_3	77.30
SiO_2	21.50
Al_2O_3	1.43
CaO	0.27
MnO	0.02
TiO_2	0.07
MgO	0.07
Na_2O	n.d.
P_2O_5	0.09
Total	100.75
	wt%

Ba	47
Cr	n.d.
Sr	11
V	54
Y	n.d.
Zr	59
As	n.d.
Bi	n.d.
Cu	n.d.
Ni	12
Pb	n.d.
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Perhaps Early Ironworking Groups
Interpretation: This was a flow-type slag. The high iron oxide content might indicate a refining slag. Nevertheless, the interpretation was difficult without microscopic examination.

Lab.-Number: DBM 4407/06
Site catalogue number: 3
Site name: N98/39-2
Unit: 52/55
Quadrant: -
Level: 988
Object: Slag, bloom
Size: 1.4 x 0.6 x 0.5 cm, complete.
Weight: 3 g
Illustrations: -
Methods of analyses: MD, PCS
Magnetism: Very strongly magnetic.
Macroscopic description: The exterior of the slag lump was rusty brown to medium gray and the interior was greenish medium gray and metallic silver. The slag was amorphous in shape. The density was low and the texture showed minute to large amorphous-roundish pores up to 2 cm in diameter. Some powdery fuel was trapped in the pores. The specimen was partially corroded and sand grains were trapped in the rust.
Microscopic description: In cross section the specimen consisted of about 55area% fayalite, and 35area% metallic iron. Fayalite solidified as an almost glassy mass with only poor incipient and diffuse crystal formation in a glassy matrix. Metallic iron largely appeared in coral-like structures. Only some parts were more compacted and they exhibited labyrinthine to incipiently fused patterns. The metal was partially corroded. After etching with 3% Nital, the sample revealed ferrite mono- and polycrystals with little grain boundary cementite segregations. The carbon content was estimated to be less than 0.02wt%. The grain sizes of the ferrite ranged between ASTM 1 and 2 in the fused part of the bloom, the monocrystals were smaller. The slag inclusions within the fused structures were round and unmodified.
Identified mineral phases: Fayalite, metallic iron (ferrite, tertiary cementite), goethite, glass, quartz.
Chemical composition: -
Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Early Ironworking Groups
Interpretation: This sample was a piece of a low carbon steel bloom in smelting slag. It was probably discarded during initial refining because the bloom was not sintered enough. The lack of wustite in the sample implied the effective reduction of the smelt. The poor crystallization suggested that the bloom cooled down rapidly.

Lab.-Number: DBM 4408/06
Site catalogue number: 3
Site name: N98/39-2
Unit: 54/52
Quadrant: -
Level: 37
Object: Slag
Size: 2.1 x 1.9 x 1.7 cm, incomplete.
Weight: 0.9 g
Illustrations: -
Methods of analyses: MD, ICP-OES
Magnetism: Weakly magnetic.
Macroscopic description: The interior and exterior of the slag was brownish medium gray. The slag was of amorphous shape and sand adhered to the specimen. The texture was macrocrystalline and of medium density. It showed minute to medium-sized round and amorphous-roundish pores up to 0.3 cm in diameter. There were no signs of corrosion.
Microscopic description: -
Identified mineral phases:

Chemical composition:

Fe_2O_3	55.30
SiO_2	41.15
Al_2O_3	1.84
CaO	2.08
MnO	0.03
TiO_2	0.09
MgO	0.52
Na_2O	0.06
P_2O_5	0.16
Total	101.25
	wt%

Ba	166
Cr	n.d.
Sr	71
V	28
Y	n.d.
Zr	63
As	n.d.
Bi	n.d.
Cu	18
Ni	22
Pb	n.d.
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Early Ironworking Groups
Interpretation: Shattered furnace slag. The plot in the FeO-SiO_2-Al_2O_3 and FeO-SiO_2-CaO system indicated a high solidus temperature and the sample was probably contaminated with siliceous matter.

Lab.-Number: DBM 4409/06
Site catalogue number: 3
Site name: N98/39-2
Unit: 56/52
Quadrant: -
Level: 27
Object: Slag
Size: 7.9 x 4.7 x 3.4 cm, incomplete.
Weight: 78 g
Illustrations: -
Methods of analyses: MD, PCS
Magnetism: Weakly magnetic.
Macroscopic description: The exterior of the slag lump was brownish dark gray and rusty brown and interior was a dark gray. The slag was amorphous in shape and solidified in a sand bed with a rim of sand grains trapped in the slag on the underside. An irregular cooling skin formed on the upper face of the specimen. The texture was of medium density with minute roundish pores. The specimen contented a high amount of powdery charcoal with small bits of it in pores. Some areas of the specimen were corroded.
Microscopic description: In cross section the sample had an inhomogeneous layered and conglomerated structure predominately of wustite and fayalite. The sample was very rich in wustite, which consequently crystallized as first phase in most parts of the sample. It appeared in irregular crowded agglomerations of dendritic and granular crystals. Some highly compacted agglomerations showed a pattern of tabular and amorphous hammerscale.
The slag varied in composition and zones of different crystallization successions grade into one another. One area showed wustite followed by a poorly crystallized fayalite/wustite eutectic with interstitial glass. Depending on its composition, fayalite crystals developed as second phase in some zones. In parts with less iron oxide content, a crystal phase succession of large blocky fayalite followed by wustite and interstitial glass could be observed. Within the sample, secondary wustite and fayalite developed in interstices. A hematitic cooling skin formed along the surface.
Within the whole sample, elemental iron appeared from individual prills to coral-like and semi-consolidated labyrinthine compacted structures. The coral-like structures were associated with wustite-free slag zones and could be considered as bloom inclusions with some adhering smelting slag. The iron prills were most probably reduced from the main slag mass during refining. After etching with 3% Nital, the compacted elemental iron revealed a ferritic microstructure of soft iron with only a few segregations of tertiary cementite. The carbon content was below 0.02wt%. The pores of the spongy iron were round and unmodified. Some individual prills were ferritic-pearlitic in microstructure and reached carbon contents of up to approximately 0.5wt %.
Identified mineral phases: Fayalite, wustite, metallic iron (ferrite, pearlite, cementite), goethite, glass, quartz, hematite.
Chemical composition: -
Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Early Ironworking Groups
Interpretation: This sample was an amorphous slag from advanced refining since it contained unmodified bloom fragments together with hammerscale residues that implied the hot working of compact metal. The redox conditions and thermodynamics were comparable to those during smelting operations and the high wustite buffer prevented the wrought iron bloom from further carburization. However, the prills of elemental iron showed that temperatures, time and redox conditions in the refining furnace allowed the reduction of elemental iron and its carburization.

Lab.-Number: DBM 4410/06
Site catalogue number: 3
Site name: N98/39-2
Unit: -
Quadrant: -
Level: 42 (Surface)
Object: Slag
Size: 4.5 x 4.1 x 2.7 cm, incomplete.

Weight: 51 g
Illustrations: Figure 209
Methods of analyses: MD, PCS, ^{14}C
Magnetism: Variable, weakly magnetic, in some sections strongly magnetic.
Macroscopic description: The exterior of the slag was medium gray and the interior was dark gray. The slag was amorphous in shape and cooled down in a sand bed. An irregular cooling skin formed on the upper side of the specimen. The texture was of low to medium density with minute to small roundish, angular, and elongated pores in divergent order. The specimen contained powdery charcoal and small bits of it were in pores. Some parts were corroded.
Microscopic description: In cross section the sample revealed an inhomogeneous layered and conglomerated structure. It mainly consisted of wustite, fayalite and metallic iron.

Wustite occurred most abundantly, and it was the first phase to crystallize in the slag. It appeared in crowded structures of medium-sized dendritic or granular crystals. Some highly compacted tabular structures indicated flat hammerscale flakes. Wustite was followed by a fayalite/wustite eutectic that developed the beginnings of medium-sized lath-like to blocky crystals. Interstices were few and filled with a glassy matrix and in some parts idiomorphic leucite formed. Less frequently, the wustite was followed by a fayalite/leucite eutectic only. Some areas of the slag exhibited the crystallization succession of wustite followed by fayalite and interstitial glass.

The sample contained fragments of iron bloom in compacted labyrinthine structures. These fragments were associated with a wustite-free zone of lath-like fayalites that evolved from a fayalite/leucite eutectic. Some labyrinthine bloom was associated with partially reacted quartz grains in transition to new silica-rich phases in a microcrystalline fayalitic mass. Within the whole sample numerous prills of elemental iron occurred. Also, some of the wustite hammerscale structures were partially reduced to metallic iron along the outer margins. Etching with 3% Nital revealed that the iron prills and the partially reduced hammerscale structures mainly consisted of pure ferrite to low carbon steel (ferrite and some interstitial pearlite). However, the bloom revealed a purely ferritic microstructure with little grain boundary cementite, indicating a carbon content below 0.02wt%. Most of the bloom and some of the prills showed intragrain precipitates after etching. The pores and inclusions of the iron sponges were round and unmodified. The pores of the entire sample were subangular to angular due to the crystal growth and some powdery fuel was present in the section.
Identified mineral phases: Fayalite, wustite, metallic iron (ferrite, pearlite, cementite), goethite, leucite, glass, quartz.
Chemical composition: -
Mineralogical composition from XRD: -
Absolute age: 355±30 BP (Poz-20700, Table 2)
Occupation horizon: Late Ironworking Groups
Interpretation: This was a primary smithing hearth bottom that formed from advanced refining activities. The macro- and microstructure revealed several features that were typical for ironworking slags such as pores in radiating order, a pronounced cooling skin, crowded and irregular wustite under reflecting light together with reduced hammerscale structures. The macrosize of the crystals indicated that the slag cooled down slowly in a furnace. The loss of fragments of elemental iron hinted at bloom refining activities. The first were associated with slag that showed phase characteristics of smelting slag. The bloom lumps were of wrought iron quality and the high wustite content of the slag bath prevented from carburization during refining. The intragrain ferrite precipitates might be iron-nitride-carbides, which generally increases the hardness of the material. The reduction of wustite to elemental iron in other parts of the sample suggested thermodynamics and redox conditions comparable to iron smelting. The quartz grains found in the sample implied the use of sand as a fluxing agent. This might have been necessary, as the sample had a very high wustite content, which would have raised the liquidus temperature of the slag unfavorably. It is also possible that the sand grains were used as welding fluxes during bloom compaction. However, with respect to the sandy environment I may be mistaken because sand can easily fall into the refining furnaces accidentally. The tabular hammerscale structures indicated that parts of the bloom were already consolidated into a sound piece of iron.

Lab.-Number: DBM 4411/06
Site catalogue number: 3
Site name: N98/39-2
Unit: -
Quadrant: -
Level: 1046 (Surface)
Object: Slag, bloom
Size: 9.1 x 6.4 x 3.4 cm, incomplete.
Weight: 190 g
Illustrations: Figures 184 and 209
Methods of analyses: MD, PCS, ^{14}C
Magnetism: Variable, along the exterior weakly magnetic, in cross section strongly magnetic gromps.
Macroscopic description: The exterior of the slag lump was of dark gray to rusty brown and the interior was of medium gray and metallic silver. The slag was plano-convex in shape. The density was medium and the texture had minute large round and amorphous-roundish pores up to 3.5 cm. The upper side was smooth with many small craters. Numerous charcoal imprints on the underside suggested that the slag

cooled down in a charcoal bed. In addition, sand adhered to the slag due to the slag flow. Some areas of the sample were corroded.

Microscopic description: In cross section the specimen consisted mainly of fayalite, wustite and elemental iron. Wustite crystallized as first phase with larger dendrites and granular crystals in slightly crowded distribution. It was followed by large blocky fayalites in a mass of a poorly crystallized fayalite/wustite eutectic.

Metallic iron was present in different states of consolidation. Unconsolidated coral-like structures occurred in the same way as increasingly compacted labyrinthine and completely fused pattern. Some iron showed an angular shape. Also, small individual iron prills were scattered throughout the sample. After etching with 3% Nital, the metal inclusions revealed ferrite polygons with some segregations of tertiary cementite along grain-boundaries. The carbon content was below 0.02wt%. Some of the metal fragments contained pronounced small acicular inclusions and round etch pits which were considered to be iron nitrides, carbides or nitride-carbides. The iron prills contained no more than 0.02wt% of carbon. The pores of the iron inclusions were round and unaltered. The elemental iron concentrated in the lower part of the sample. Most probably they sunk down to the bottom of the sample in a liquid slag bath.

Identified mineral phases: Fayalite, wustite, metallic iron (ferrite, cementite), quartz.

Chemical composition: -

Mineralogical composition from XRD: -

Absolute age: 410±30 BP (Poz-20698, Table 2), charcoal extracted from the sample.

Occupation horizon: Late Ironworking Groups

Interpretation: This was a primary smithing slag with fragments of a soft iron bloom from initial refining. The overall appearance of the microstructure suggested that the slag formed under prolonged hot and reducing conditions allowing for some iron to be reduced within the slag bath, and allowing the lost gromps to sink down to the bottom of the slag cake. Moreover, hammerscale seemed to have been largely dissoluted and appeared only slightly crowded. The gromps found in the sample were of wrought iron quality although the iron-nitride inclusions suggested an increased hardness of the iron than one would expect solely from the carbon content.

Lab.-Number: DBM 4412/06
Site catalogue number: 4
Site name: N68/01
Unit: B1575B
Quadrant: -
Level: 15-22’’
Object: Slag, bloom
Size: 4.7 x 2.4 x 2.1 cm, incomplete.
Weight: 27 g
Illustrations: -
Methods of analyses: MD, ICP-OES
Magnetism: Weakly to moderately magnetic.

Macroscopic description: The exterior of the slag was of dark gray to brownish gray and the interior was dark gray. The slag was amorphous in shape with flow structures. It was conglomerated in composition. Small rusty lumps adhered to the specimen. The density was medium and the texture showed small to medium-sized round to amorphous-roundish pores up to 0.5 cm in diameter. The specimen was partially corroded with sand grains trapped in the rust.

Microscopic description: -

Identified mineral phases: -

Chemical composition:

Fe_2O_3	78.60
SiO_2	18.89
Al_2O_3	1.05
CaO	0.35
MnO	0.43
TiO_2	0.06
MgO	0.11
Na_2O	n.d.
P_2O_5	0.07
Total	99.57
	wt%

Ba	133
Cr	n.d.
Sr	11
V	27
Y	n.d.
Zr	53
As	n.d.
Bi	n.d.
Cu	n.d.
Ni	12
Pb	n.d.
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -

Absolute age: -

Occupation horizon: Early Ironworking Groups

Interpretation: This was most probably a refining slag because of its conglomerated appearance and variability in magnetism. Moreover the sample displayed rusty parts indicating elemental iron and a high iron oxide content. It has been classified to advanced refining slags because it was not possible to assign it to initial or final refining activities without microstructure analysis.

Lab.-Number: DBM 4413/06
Site catalogue number: 4
Site name: N68/02
Unit: B1592
Quadrant: -
Level: 24-30’’
Object: Slag, bloom
Size: 4.7 x 2.4 x 2.1 cm, incomplete.
Weight: 27 g
Illustrations: -
Methods of analyses: MD, PCS

Magnetism: Very strongly magnetic.
Macroscopic description: The exterior of the slag lump was of a rusty grayish brown and the interior was medium gray and metallic silver. The slag was tabular in shape. The density was high and the texture showed minute to large round and elongated pores. The specimen contained powdery fuel or fuel ashes in the pores. The exterior and interior were strongly corroded and sand grains were trapped in the rust.
Microscopic description: In cross section the specimen consisted mainly of fayalite and strongly corroded metallic iron. Fayalite appeared as poorly developed, slightly lath-shaped crystals in a glassy matrix. The metallic iron was strongly corroded and in some parts the iron hydroxides still showed a relict coral-like structure. After etching with 3% Nital, the limited remains of elemental iron revealed an unspecific ferritic microstructure of pure iron containing less than 0.02wt% of carbon. Along the outer margin strongly altered quartz grains occurred in transition to new dark silica-rich phases. The sample contained no wustite. It had some cracks.
Identified mineral phases: Fayalite, goethite and other iron hydroxides, metallic iron (ferrite), quartz, silica-rich phases.
Chemical composition: -
Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Early Ironworking Groups
Interpretation: The composition of the sample suggested that this was a fragment of a poorly sintered bloom of pure iron. The dominance of fayalite and the absence of wustite indicated liquidus temperatures around 1200 °C, and the quartz grains in transformation might be regarded as evidence for erosive processes along the furnace wall. The bloom seemed to have been quickly removed from the hot furnace since the fayalite could not fully develop. The fragment was probably discarded during primary smithing because it was not compacted enough.

Lab.-Number: DBM 4414/06
Site catalogue number: 4
Site name: N68/02
Unit: B1592
Quadrant: -
Level: 24-30''
Object: Slag
Size: 3.7 x 3.6 x 1.3 cm, incomplete.
Weight: 19 g
Illustrations: -
Methods of analyses: MD, ICP-OES
Magnetism: Variable, from non-magnetic to strongly magnetic.
Macroscopic description: The exterior of the slag was of brownish medium gray and the interior was medium gray. The slag was amorphous in shape and solidified in a sandy environment with sand grains adhering to the exterior. In some parts a cooling skin formed on the upper side of the specimen. The texture was macrocrystalline and conglomerated and some gromps adhered to the exterior. Its density was medium and it showed minute to small round and amorphous-roundish pores. The specimen was partially corroded.
Microscopic description: -
Identified mineral phases: -
Chemical composition:

Fe_2O_3	63.70
SiO_2	35.29
Al_2O_3	1.34
CaO	0.31
MnO	0.01
TiO_2	0.05
MgO	0.09
Na_2O	0.01
P_2O_5	0.13
Total	100.94
	wt%

Ba	89
Cr	n.d.
Sr	13
V	29
Y	n.d.
Zr	53
As	n.d.
Bi	n.d.
Cu	3
Ni	14
Pb	n.d.
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Early Ironworking Groups
Interpretation: The accumulated appearance of the slag together with the cooling skin and the small adhering gromps suggested that this was a primary smithing slag. It has been classified to advanced refining slags because it was not possible to assign it to initial or final refining activities without microstructure analysis.

Lab.-Number: DBM 4415/06
Site catalogue number: 12
Site name: N69/01-1
Unit: B1968
Quadrant: -
Level: Surface
Object: Slag
Size: 10.7 x 10.2 x 6.1 cm, complete.
Weight: 1002 g
Illustrations: Figures 122 and 183
Methods of analyses: MD, PTS, ICP-OES, ^{14}C
Magnetism: Non-magnetic.
Macroscopic description: The exterior of the specimen was dark greenish gray, medium grayish beige and brownish orange. In cross section it was of dark green-gray. The shape of the slag was plano-convex, with an undulating and vesicular upper side.

It solidified in a bed of sand and charcoal because it had a thick coat of sand grains at the bottom side together with imprints of charcoal lumps. The density was high and the texture showed mainly large amorphous-roundish pores up to 2 cm in diameter. Some patches of a weak corrosion occurred.

Microscopic description: In cross section the sample consisted mainly of fayalite and wustite. It showed two layers. The lower layer consisted of a fayalite/wustite eutectic. Within the upper layer, wustite crystallized as first phase and formed large dendrites in regular distribution. It was followed by large blocky fayalites in a poorly crystallized eutectic of fayalite and wustite. Some granular poorly developed wustite crystals appeared in interstices. The latter were filled with a glassy groundmass. At the bottom side sand grains became trapped in liquid slag. The grains exhibited little thermal reaction. Close to the quartz coat, blocky individual crystals of spinel (hercynite) were present. The cross section revealed only a few minute prills of metallic iron. Most of them occurred within the sandy coat along the underside of the specimen.

Identified mineral phases: Fayalite, wustite, quartz, spinel (hercynite), glass, metallic iron.

Chemical composition:

Fe_2O_3	63.70
SiO_2	35.29
Al_2O_3	1.34
CaO	0.31
MnO	0.01
TiO_2	0.05
MgO	0.09
Na_2O	0.01
P_2O_5	0.13
Total	100.94
	wt%

Ba	89
Cr	n.d.
Sr	13
V	29
Y	n.d.
Zr	53
As	n.d.
Bi	n.d.
Cu	3
Ni	14
Pb	n.d.
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -

Absolute age: 400±30 BP (Poz-20702, Table 2), charcoal extracted from the sample.

Occupation horizon: Late Ironworking Groups

Interpretation: This was a wustite-rich slag, which cooled down slowly. The thick coat of little fractured sand grains suggested that the slag solidified in a slag pit. The regular, even distribution of crystal growth found in the sample implied that it was a smelting slag.

Lab.-Number: DBM 4416/06
Site catalogue number: 12
Site name: N69/01-2
Unit: B1969A
Quadrant: Test 10
Level: 0-25 cm
Object: Slag
Size: 7.0 x 4.8 x 2.9 cm, incomplete.
Weight: 189 g
Illustrations: -
Methods of analyses: MD, PTS, ICP-OES
Magnetism: Weakly to moderately magnetic.

Macroscopic description: The exterior of the slag was dark gray and rusty brown and the interior was dark gray. The slag was plano-convex in shape and it cooled down in a charcoal bed. Sand adhered to the slag's exterior due to corrosion. A cooling skin formed on the upper side of the specimen. The texture was of medium to high density and had small to large, round to roundish pores, up to 1.2 cm in diameter. The specimen contented powdery charcoal in pores. The slag showed a coat of corrosion.

Microscopic description: In thin section the sample revealed an inhomogeneous layered and conglomerated structure of a wustite-rich fayalitic slag. Wustite crystallized as first phase and formed dendritic or granular crystals in crowded structures. In some zones, structures of fine tabular and some very small spherical hammerscale were present. The main slag mass consisted of a fayalite/wustite eutectic with poorly developed crystal structures or in a glassy state. The latter layer contained numerous quartz inclusions showing thermal alterations. Interstices were, if present, filled with a fayalite/leucite eutectic or with a glassy matrix. The sample contained fragments of broken cooling skins. Tiny prills of metallic iron were present and most of them were corroded. Quartz grains were trapped in a goethitic matrix of corrosion along the exterior of the sample.

Identified mineral phases: Fayalite, wustite, quartz, metallic iron, goethite, glass, hematite

Chemical composition:

Fe_2O_3	81.90
SiO_2	15.09
Al_2O_3	1.47
CaO	0.25
MnO	0.02
TiO_2	0.07
MgO	0.08
Na_2O	< 0.01
P_2O_5	0.13
Total	99.01
	wt%

Ba	773
Cr	n.d.
Sr	26
V	86
Y	n.d.
Zr	57
As	n.d.
Bi	n.d.
Cu	21
Ni	12
Pb	n.d.
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Late Ironworking Groups

Interpretation: This was a smithing hearth bottom, which formed under hot reducing conditions. The small size of the flat hammerscale structures suggested that the sample formed during the smithing of metal artifacts. The multiple cooling skins represented cycles of iron processing in the forge. The quartz inclusions can be seen as fluxes used during hot working. The sample most probably formed during secondary smithing, though in this case, it evidenced thermodynamics similar to primary smithing.

Lab.-Number: DBM 4417/06
Site catalogue number: 12
Site name: N96/03-3
Unit: 88/28
Quadrant: d
Level: 8
Object: Slag
Size: 9.3 x 9.2 x 3.2 cm, incomplete.
Weight: 383 g
Illustrations: Figure 122
Methods of analyses: MD, PCS, ICP-OES
Magnetism: Mainly non-magnetic, in some parts weakly magnetic.
Macroscopic description: The exterior of the specimen was of brownish medium gray. In cross section the color of the sample was of green medium gray. The shape of the slag was plano-convex with a flat irregular upper side on which a cooling skin formed. It solidified in a sand bed and it showed a thick coat of sand grains adhering to the underside. The density was medium to high and the texture had small to large roundish voids up to 2.3 cm in diameter. Some patches of corrosion occurred at the exterior.
Microscopic description: In cross section the sample consisted mainly of fayalite (about 70area%) and wustite (about 20area%). Fayalite was the first phase to crystallize and mainly appeared as macrocrystalline blocky crystals. Wustite dendrites developed between the large blocky fayalites. Interstices were filled with a fayalite/wustite eutectic, or with a glassy matrix in which fayalites of the 2nd and 3rd generation were present. The sample exhibited some loose coral-like formations of unconsolidated bloom. After etching with 3% Nital, the corals revealed a ferritic microstructure of monocrystals or sintered polygonal grains and some segregated tertiary grain boundary cementite. The carbon content was less than 0.02wt%. In some sections the metallic iron was more compacted and formed some prills. Here the carbon content was higher, ranging between 0.3wt% and 0.6wt% of carbon. The microstructure was ferritic-pearlitic with lath-like ferrite grains. At the bottom side sand grains, which exhibited only little thermal reaction, became trapped in liquid slag. The latter consisted of micro-fayalites in a glassy matrix.

Identified mineral phases: Fayalite, wustite, quartz, metallic iron (ferrite, pearlite, cementite), goethite.
Chemical composition:

Fe_2O_3	68.90
SiO_2	30.40
Al_2O_3	1.36
CaO	0.70
MnO	0.02
TiO_2	0.14
MgO	0.25
Na_2O	0.03
P_2O_5	0.07
Total	101.87
	wt%

Ba	130
Cr	n.d.
Sr	77
V	30
Y	n.d.
Zr	71
As	n.d.
Bi	n.d.
Cu	n.d.
Ni	36
Pb	n.d.
Zn	103
Sb	n.d.
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Late Ironworking Groups
Interpretation: This was a smelting slag from a furnace. The thick coat of almost unfractured sand grains suggested that the slag cooled down in a slag pit. The loose iron bloom and the prills found in the sample were probably drained away with the slag during the smelt. The globular nature of the steel indicated high temperatures in the austenite field. The lath-shaped ferrite attested that the steel was exposed to rapid cooling, probably when the slag solidified in a cool environment. The sample also provided evidence of the co-production of soft wrought iron and high carbon steel in the same smelt.

Lab.-Number: DBM 4418/06
Site catalogue number: 12
Site name: N96/03-3
Unit: 88/28
Quadrant: d
Level: 8
Object: Slag
Size: 8.2 x 6.1 x 2.5 cm, incomplete.
Weight: 127 g
Illustrations: Figure 210
Methods of analyses: MD, PCS, ICP-OES
Magnetism: Weakly magnetic.
Macroscopic description: The exterior of the slag was very dark to dark gray together with rusty brown and gray-beige and the interior was very dark to dark gray. The slag was plano-convex in shape and it solidified in a sand bed. Slagged sand adhered to the underside. A cooling skin formed on the upper side of the slag and some hammerscale flakes adhered to the sample. The texture was of medium to high

density and showed minute to medium-sized round, amorphous-angular and oblong pores up to a diameter of 0.8 cm. The latter occurred in divergent order. There was a high content of charcoal powder or fuel ashes in the sample. The specimen was partially corroded at the exterior.

Microscopic description: In cross section the sample revealed a rather homogeneous composition. The main slag mass consisted of wustite and a glassy fayalite/wustite eutectic. Wustite crystallized as first phase and appeared in insular agglomerations of large dendritic and granular-type crystals. Some of them formed densely crowded structures of amorphous hammerscale, others were less concentrated and in dissolution. The next phase was a glassy fayalite/wustite eutectic, which developed in some sections of the sample hypidiomorphic lath-like crystals. Only a few interstices were present and were filled with a glassy matrix. Prills of metallic iron occurred. Additionally, a few loose coral-like structures as well as round and subangular pieces of fused metal were present. After etching with 3% Nital, the elemental iron exhibited a microstructure of ferrite mono- and polycrystals with grain boundary cementite segregations and some insular pearlite in interstices. The carbon content was estimated at about 0.03%. Some of the compacted iron pieces showed strong variation in ferrite grain size.

Identified mineral phases: Fayalite, wustite, metallic iron (ferrite, pearlite, cementite), goethite, glass, quartz.

Chemical composition:

Fe_2O_3	75.50
SiO_2	22.16
Al_2O_3	1.80
CaO	0.82
MnO	0.01
TiO_2	0.10
MgO	0.15
Na_2O	0.02
P_2O_5	0.08
Total	100.64
	wt%

Ba	83
Cr	n.d.
Sr	63
V	30
Y	n.d.
Zr	69
As	n.d.
Bi	n.d.
Cu	14
Ni	14
Pb	n.d.
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -

Absolute age: -

Occupation horizon: Late Ironworking Groups

Interpretation: This was a smithing hearth bottom which formed during final refining activities. It consolidated under a reducing regime comparable to smelting operations. High temperatures were indicated by the round ferrite prills that reduced within the slag, as well as the slagged sandy bottom of the specimen. Some of the rather angular small pieces of metallic iron were probably lost in the slag bath during smithing and grain-size variation indicated recrystallization after cold working. The flake-like hammerscale adhering to the upper side of the slag flaked away while sound metal had been hammered. All in all, the sample suggested that it developed in a hot and strongly reducing environment. Since there was only little metallic iron lost in the sample, together with the hammerscale flakes which derived from the hammering of sound metal (and not a mix of slag with metal inclusions), the slag can be regarded as the waste of a final refining step of an already cleaned bloom.

Lab.-Number: DBM 4419/06

Site catalogue number: 3

Site name: N98/39-2

Unit: 51/51

Quadrant: a

Level: 402

Object: Iron ore

Size: -

Weight: 7 g

Illustrations: -

Methods of analyses: MD, ICP-OES

Magnetism: Very strongly magnetic.

Macroscopic description: This was a bladed and flaky hematite aggregate, silvery in color with metallic luster, in a thin layer of an unidentified parent rock material.

Microscopic description: -

Identified mineral phases: -

Chemical composition:

Fe_2O_3	88.20
SiO_2	8.99
Al_2O_3	1.10
CaO	0.04
MnO	0.03
TiO_2	0.02
MgO	0.48
Na_2O	n.d.
P_2O_5	0.01
Total	98.88
	wt%

Ba	13
Cr	n.d.
Sr	3
V	2379
Y	n.d.
Zr	58
As	n.d.
Bi	n.d.
Cu	n.d.
Ni	13
Pb	n.d.
Zn	n.d.
Sb	n.d.
S	n.d.
	ppm

Mineralogical composition from XRD: -

Absolute age: -

Occupation horizon: Early Ironworking Groups

Interpretation: Specular hematite, probably for ocher production in an Early Ironworking Group context.

Lab.-Number: DBM 4420/06
Site catalogue number: 12
Site name: N96/03-3
Unit: 88/28
Quadrant: d
Level: 8
Object: Slag
Size: 3.2 x 2.5 x 2.1 cm, incomplete.
Weight: 31g
Illustrations: Figure 210
Methods of analyses: MD, PCS
Magnetism: Very strongly magnetic.
Macroscopic description: The exterior of the slag lump was blackish to dark gray together with rusty brown and grayish beige and the interior was blackish to dark gray. The slag was plano-convex in shape. It solidified in a sand bed and slagged sand adhered to the underside. A cooling skin formed on the upper side of the slag with some trapped flat hammerscale flakes. The texture was of medium to high density and it showed minute to medium-sized round, amorphous-angular and oblong pores up to a diameter of 0.8 cm. The latter occurred in divergent order. The sample contained a high amount of charcoal powder or fuel ashes. The specimen was partially corroded at the exterior face.
Microscopic description: In cross section the sample revealed a highly inhomogeneous and layered microstructure. The first layer mainly consisted of crowded wustite crystals, fayalite and metallic iron. Wustite crystallized first and occurred in an irregular and crowded distribution with large dendritic and granular crystals. Some compacted wustite crystals showed structures of tabular hammerscale flakes. Wustite was followed by a fayalite/wustite eutectic that developed hypidiomorphic columnar to lath-like crystals. Little interstitial space was present in the sample and it was filled with a glassy matrix. The second layer was less ferrous and exhibited wustite as first phase followed by small to medium sized fayalite and a glassy matrix in interstices with some secondary fayalite. The sample included a large fragment of metallic iron of a compacted and fused nature, as well as numerous prills and loose coral-like structures of iron. Etching with 3% Nital revealed a piece of low carbon steel with irregular polygonal ferrite and interstitial pearlite. The carbon content was estimated at about 0.1wt%. The grain size varied between ASTM 3 to 8 and some of the polygons exhibited grain deformation. The microstructure changed with gradually increasing carbon content until it was completely pearlitic with a carbon portion of 0.8wt%. Where possible, a Widmanstätten structure developed.
The pores of the slag sample were angular to subangular and contained powdery fuel and ashes. Furthermore, the sample included a number of individual prills of elemental iron with carbon contents in the region of 0.5 to 0.8wt%. They were reduced from wustite within the slag itself. Also, uncondensed loose coral-like structures of ferritic low carbon steel were present, which still showed structures of the original wustite and in cases the tabular appearance of flat hammerscale. The elemental iron was partially corroded.
Identified mineral phases: Fayalite, wustite, metallic iron (ferrite, pearlite, cementite), goethite, glass.
Chemical composition: -
Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Late Ironworking Groups
Interpretation: This sample was a smithing hearth bottom from advanced primary smithing because bloom fragments occurred together with hammerscale flakes. The bloom fragment found in the sample revealed evidence of hammering and recrystallization. The gradually increasing carbon content of this fragment, together with the many fuel inclusions raised the question if it could be judged as evidence of carburization. The eutectoid nature of the prills, which formed within the slag, implied that thermodynamics and redox conditions for high carbon steel formation were present in the refining furnace.

Lab.-Number: DBM 4421/06
Site catalogue number: 12
Site name: N96/03-3
Unit: 88/26
Quadrant: b
Level: 18
Object: Slag
Size: 2.7 x 1.7 x 1.3 cm, incomplete.
Weight: 11 g
Illustrations: -
Methods of analyses: MD, ICP-OES
Magnetism: Weakly magnetic.
Macroscopic description: The interior of the slag was dark brownish gray and the exterior was dark gray. The slag was of amorphous shape and showed some flow structures around charcoal impressions. The texture was macrocrystalline, of medium density and had minute to small round and amorphous-roundish pores. There were no signs of corrosion.
Microscopic description: -
Identified mineral phases: -
Chemical composition:

Fe_2O_3	77.00
SiO_2	19.97
Al_2O_3	2.16
CaO	0.51
MnO	0.02
TiO_2	0.10
MgO	0.16
Na_2O	n.d.
P_2O_5	0.10
Total	100.02
	wt%

Ba	487
Cr	n.d.
Sr	28
V	52
Y	n.d.
Zr	67
As	n.d.
Bi	n.d.
Cu	11
Ni	13
Pb	n.d.
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Late Ironworking Groups
Interpretation: Unspecific slag.

Lab.-Number: DBM 4422/06
Site catalogue number: 12
Site name: N96/03-3
Unit: 88/26
Quadrant: b
Level: 18
Object: Slag
Size: 6.1 x 3.3 x 2.4 cm, incomplete.
Weight: 44 g
Illustrations: Figure 185
Methods of analyses: MD, PTS, ICP-OES
Magnetism: Weakly magnetic.
Macroscopic description: The exterior of the slag was dark gray and rusty brown and the interior was dark gray. The slag was tabular in shape. Some flow structures formed around charcoal impressions on the underside. A cooling skin developed on the upper side. The texture was of medium density and showed minute to medium-sized roundish, amorphous-angular and oblong pores up to a diameter of 0.7 cm. Bits of charcoal and powdery fuel or fuel ashes were present in pores. The specimen was strongly corroded at the exterior and sand was trapped in the rusty coat.
Microscopic description: In cross section the sample revealed an inhomogeneous layered and conglomerated structure. Wustite crystallized as first phase in dendritic or granular crystals. It was rather unspecifically crowded yet irregular in its distribution. Wustite was followed by large blocky fayalites and interstices were filled with a fayalite/wustite eutectic. In zones of poorer iron oxide content, fayalite solidified as first phase in a glassy matrix and formed secondary crystals in interstices. Within this layer drop-like inclusions of wustite-rich slag occurred. All layers were intercrystallized. Several generations of cooling skins were present in the sample. They were covered by new slag layers and subsequently reduced to wustite.
The sample contained strongly corroded iron bloom inclusions. Some of these structures still exhibited the coral-like pattern of unconsolidated bloom while other pieces occurred consolidated. However, as most of the metal was corroded to iron hydroxides, little information could be taken from them. The section also contained lumps of charcoal. The sand grains that adhered to the specimen were embedded in a matrix of hydroxides.
Identified mineral phases: Wustite, fayalite, metallic iron, goethite, quartz, hematite.

Chemical composition:

Fe_2O_3	71.59
SiO_2	24.96
Al_2O_3	1.66
CaO	0.37
MnO	0.01
TiO_2	0.08
MgO	0.17
Na_2O	n.d.
P_2O_5	0.10
Total	98.94
	wt%

Ba	n.d.
Cr	n.d.
Sr	24
V	1004
Y	n.d.
Zr	53
As	n.d.
Bi	n.d.
Cu	n.d.
Ni	14
Pb	n.d.
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Late Ironworking Groups
Interpretation: This was a slag from bloom refining. Its layered appearance represented repeated steps in bloom processing and small fragments of bloom were lost in the slag. It formed from during an early step of bloom refining because gromps were present, but no tabular or somehow compacted hammerscale appeared yet.

Lab.-Number: DBM 4423/06
Site catalogue number: 12
Site name: N96/03-3
Unit: 88/26
Quadrant: b
Level: 21
Object: Slag
Size: 4.8 x 3.7 x 2.1 cm, incomplete.
Weight: 35 g
Illustrations: Figure 210
Methods of analyses: MD, PCS
Magnetism: Magnetism varied from weakly to strongly magnetic.
Macroscopic description: The exterior of the slag was medium gray and rusty brown and the interior was dark gray and metallic silver. The slag was amorphous in shape. A cooling skin was present in a small zone of the exterior. The texture was of medium density and showed minute to medium-sized round and amorphous-roundish pores up to a diameter of 0.7 cm. There was a high content of charcoal bits and powdery fuel or fuel ashes in the sample. The specimen was strongly corroded inside and outside with a high amount of sand grains that became trapped in the coat of rust.

Microscopic description: In cross section the sample exhibited an inhomogeneous, layered and conglomerated structure. It mainly consisted of wustite, fayalite and metallic iron in varying portions. Layers of high wustite content alternated with layers of rather low wustite content. Wustite crystallized first within the sample. It appeared as amorphous, crowded and compacted structures of granular to dendritic crystals. In some sections, blocky fayalites crystallized as second phase. However, the main slag mass constituted a glassy and sometimes slightly columnar crystallized mass of fayalite in eutectic intergrowth with wustite. Interstices were filled with glass and in some sections small secondary wustite dendrites or fayalites were present.
Within the sample, the main part of the metallic iron occurred in angular compacted fragments with angular pore spaces. After etching with 3% Nital, the microstructures of the metal inclusions revealed pure iron to low carbon steel with carbon contents estimated to range between 0.02wt% and 0.1wt%. The first appeared as irregular polygons with signs of grain deformation, or in strongly varying grain sizes. Little tertiary cementite segregated from the ferrite along grain boundaries. The low carbon steels exhibited either a ferritic microstructure with insular pearlite and signs of grain deformation, or in zones of higher carbon content lath-like to acicular ferrite in pearlite of a poorly developed Widmanstätten structure. Some loose coral-like structures of ferrite monocrystals occurred as well and were probably reduced within the slag itself. However, most of the iron and steel inclusions were corroded and the microstructure was not visible anymore under the microscope. The metal inclusions were strongly interspersed with powdery charcoal or fuel ashes. A hematitic cooling skin formed along the outer margin of the sample. It was also partially reduced to metallic iron. The sample contained sand grains that were trapped in corrosion products.
Identified mineral phases: Wustite, fayalite, goethite, metallic iron (ferrite, pearlite, cementite) quartz, hematite.
Chemical composition: -
Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Late Ironworking Groups
Interpretation: The layered structure together with the crowded amorphous wustite aggregations suggested that this was an ironworking slag from initial bloom refining. It contained wrought iron and low carbon steel fragments that were subject to cold working as indicated by grain deformations. The specimen cooled down from austenite field temperatures as evidenced by the Widmanstätten structure. The pore space of the iron fragments indicated that these gromps were lost in the slag bath during one of the several steps of bloom refinement. The slag formed in a refining furnace under strongly reducing conditions and the crystals of the second generation attested slow cooling.

Lab.-Number: DBM 4424/06
Site catalogue number: 12
Site name: N96/03-3
Unit: 88/26
Quadrant: b
Level: 21
Object: Slag
Size: 5.2 x 4.5 x 1.4 cm, complete.
Weight: 33 g
Illustrations: -
Methods of analyses: MD, PTS
Magnetism: Weakly to moderately magnetic.
Macroscopic description: The exterior of the slag was medium to dark gray and the interior was dark gray with a light gray underside. The slag was tabular in vertical section with a slightly convex underside, and roundish in view from above. It solidified in a sand bed and displayed a rim of sand grains with bits of charcoal trapped in the slag on the underside. A cooling skin was present at the upper surface of the slag. The texture was of medium to high density with minute to small roundish and oblong pores up to 0.3 cm in diameter. The latter occurred in divergent order along the underside of the specimen. Powdery fuel was present in pores. Some parts of the sample were corroded, and some hammerscale flakes were trapped in the rim of corrosion.
Microscopic description: In thin section the sample exhibited a layered structure. The layers differed in composition. The bottom layer consisted of sand grains, which were trapped in slag. Some of them showed reactions to thermal stress. Fayalite crystallized as first phase and was followed by interstitial glass in one section of the examined sample. In this part, wustite was absent and secondary fayalites developed in interstices. In other sections of the bottom layer fayalite was followed by dendritic wustite and a fayalite/wustite eutectic in interstices. Goethitic structures indicated that metallic iron was originally present. Some of these structures were tabular and of coral to labyrinthine structure, indicating that tabular hammerscale was reduced to metallic iron within the slag bath.
The middle layer exhibited a higher iron oxide content than the bottom layer. Wustite developed as first phase and was followed by a few blocky fayalites. Wustite appeared in irregular and crowded patterns of dendritic to granular agglomerations of crystals. The main slag mass consisted of a fayalite/wustite eutectic with a poorly developed lath-like crystal structure. Interstices were filled with a glassy matrix. In some zones, the composition changed so that a wustite, fayalite, glass succession developed, in other parts wustite was immediately followed by the fayalite/wustite eutectic.
Towards the upper side of the sample, the wustite dominated composition changed. Wustite gradually changed into magnetite-dominated spinel, which was

the first phase to crystallize in the top layer. Acicular iscorite became more and more present in some parts of the section and solidified as second phase. It particularly grew along cooling skins. Blocky fayalites appeared as third phase with interstitial glass and some fayalites of the next generation in interstices. The magnetite-dominated spinel crystals occurred in compacted structures along the cooling skins, but also as large individual idiomorphic blocky or dendritic skeletal crystals. Some amorphous highly compacted magnetite agglomerations reflected hammerscale inclusions in dissolution. Moreover, several generations of cooling skins were present in the sample, which were repeatedly covered by new slag layers. They were sometimes fractured and were scattered throughout the sample.

Identified mineral phases: Wustite, spinel (magnetite), fayalite, iscorite, goethite, metallic iron, glass, quartz.

Chemical composition: -

Mineralogical composition from XRD: -

Absolute age: -

Occupation horizon: Late Ironworking Groups

Interpretation: This was a small smithing hearth bottom from secondary smithing. The layered appearance with compositional changes and several generations of cooling skins implied repeated ironworking cycles. The trapped fine hammerscale flakes showed that the slag formed in the periphery of an anvil. Although the specimen was very thin (only 1.4 cm in maximum height) and only approximately 5 cm in diameter, the sample evidenced redox conditions and temperatures that allowed for iron reduction in the lowest layers of the slag cake. Moreover, the crystal phase succession illustrated the heterogeneous nature of even small smithing slags. The mineral composition changed towards the upper side of the specimen, which evidenced the increasingly oxidizing atmosphere under which the slag cake formed. Nevertheless, the size of the crystals attested that the slag cooled down slowly, which would be provided in a protected environment such as the bottom of an open forge.

Lab.-Number: DBM 4426/06

Site catalogue number: 12

Site name: N96/03-3

Unit: 88/29

Quadrant: b

Level: 13

Object: Slag

Size: 1.6 x 1.5 x 0.9 cm, complete.

Weight: 12 g

Illustrations: Figures 123 and 209

Methods of analyses: MD, PCS

Magnetism: Strongly magnetic.

Macroscopic description: The exterior of the specimen was dark gray and rusty brown. In cross section it was of medium gray, metallic silver and rusty brown. The shape of the slag was amorphous. The density was medium to high and the texture showed minute to small amorphous-roundish pores. Bits of charcoal and powdery fuel were trapped in pores. The specimen showed strong corrosion inside and outside. Sand grains, bits of charcoal and slag were trapped in the coat of corrosion.

Microscopic description: In cross section the specimen consisted mainly of fayalite, metallic iron and corrosion products. Fayalite appeared as fine columnar crystals which were sometimes poorly developed. Interstices were filled with glass. There was no wustite in the sample. Metallic iron occurred as very loose coral-like structures, or as completely fused pieces of iron. Without being etched, most of these inclusions exhibited the acicular habitus of cementite. After etching with 3% Nital, the elemental iron exhibited the structural pattern of hypereutectoid steel with a pearlitic matrix that contained acicular and grain boundary cementite. The carbon content was estimated to range between 2.0 and 2.06wt%. The size of the former austenite grains was estimated to vary between ASTM 2 to 4, indicating temperatures above 900 °C. The metallic iron was strongly corroded and prevented further analyses. The whole sample was highly interspersed with powdery fuel remains. The adhering quartz grains were not exposed to thermal stress. Small angular slag fragments, bits of charcoal and fuel ashes were trapped in the rim of corrosion.

Identified mineral phases: Fayalite, metallic iron (pearlite, cementite), goethite, hematite, quartz, glass.

Chemical composition: -

Mineralogical composition from XRD: -

Absolute age: -

Occupation horizon: Late Ironworking Groups

Interpretation: This was a bloom fragment in smelting slag. The sample consisted of pieces of over-carburized hypereutectoid steel close to cast iron. The slag cooled down rapidly, probably in air. The angular fragments of slag adhering to the specimen suggested that the piece was discarded during primary smithing, because the steel was too hard to be forged. The slag itself showed no signs of an ironworking slag (layering, hammerscale structures) and therefore I considered it to be smelting slag.

Lab.-Number: DBM 4427/06

Site catalogue number: 3

Site name: N96/03-3

Unit: 88/29

Quadrant: b

Level: 13

Object: Slag

Size: 5.2 x 3.3 x 2.0 cm, incomplete.

Weight: 26 g

Illustrations: -

Methods of analyses: MD, ICP-OES

Magnetism: Weakly magnetic.

Macroscopic description: The exterior of the slag was dark gray and rusty brown and the interior was medium gray. The slag was amorphous-flat in shape and developed a smooth surface skin at the upper face. It cooled down in a charcoal bed. The texture was micro- to macrocrystalline, of medium density and it contained charcoal inclusions. It showed minute to small roundish, elongated and amorphous-angular pores. Two-thirds of the specimen was corroded and sand grains were trapped in the coat of rust.
Microscopic description: -
Identified mineral phases: -
Chemical composition:

Fe_2O_3	74.12
SiO_2	22.99
Al_2O_3	1.94
CaO	0.31
MnO	0.02
TiO_2	0.10
MgO	0.16
Na_2O	n.d.
P_2O_5	0.09
Total	99.74
	wt%

Ba	82
Cr	n.d.
Sr	29
V	71
Y	n.d.
Zr	59
As	n.d.
Bi	n.d.
Cu	17
Ni	13
Pb	n.d.
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Late Ironworking Groups
Interpretation: This was an amorphous smithing hearth bottom, which formed in the charcoal bed of a refining furnace. It produced a high iron oxide reading and the included gromps were completely corroded. It was classified to the group of advanced refining slags because it was not possible to assign it to initial or final refining activities without microstructure analysis.

Lab.-Number: DBM 4428/06
Site catalogue number: 12
Site name: N98/32-2
Unit: 34/23
Quadrant: b
Level: 41
Object: Slag
Size: 4.4 x 3.6 x 1.7 cm, incomplete.
Weight: 19 g
Illustrations: Figure 173
Methods of analyses: MD, PTS
Magnetism: Moderately to strongly magnetic.
Macroscopic description: The exterior of the specimen was green medium gray and rusty brown. In cross section it was greenish medium gray. The shape of the slag was flat to tabular. A cooling skin formed on the upper side of the slag. The density was high and the texture showed minute to small round to roundish pores. The sample was strongly corroded and sand grains, iron ore and charcoal bits were trapped in the coat of corrosion.
Microscopic description: In cross section the slag consisted mainly of fayalite and corroded metallic iron with partially reduced iron ore. Fayalite crystallized first. It appeared mainly as medium-sized blocky or lath-like skeletal crystals and fayalites of the 2^{nd} and 3^{rd} generation formed in interstices. Most of the inter-crystal space was filled with a eutectic of fayalite and leucite, yet interstices could also be filled with a glassy matrix. Within the sample, zones of partially reduced iron ore occurred. The chunks of ore were angular in shape and were associated with a high amount of powdery charcoal or fuel ashes. Wustite appeared as zones of dense micro-granular crystals still showing the structural properties of the ore. These structures were only partially reduced to metallic iron along the outer rim. Metallic iron also occurred in individual droplets and in coral-like structures. The metallic iron in this sample, however, was strongly corroded and complicated the distinction between ore structures and neogenetic phases of iron hydroxides. In some areas, the partially reduced ore was associated with numerous quartz grains. They were strongly altered by thermal stress and formed new silica-rich phases and small fayalites.
Identified mineral phases: Fayalite, leucite, wustite, metallic iron, goethite, quartz, silica-rich mineral phases.
Chemical composition: -
Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Late Ironworking Groups
Interpretation: This was a smelting slag with inclusions of bloom and partially reduced iron ore. The fayalitic composition suggested that the batch was effectively and successfully reduced. The appearance of ore chunks and fuel in the slag bath together with the formation of new fayalite indicated that both, ore and fuel, were poured in successively in the course of the smelt to increase the yield of iron. The clouds of partially reacted quartz implied that either a sandy ore was used, or that quartz was added deliberately to promote slag formation. The ore chunks were angular in shape and suggested that they had been crushed before placing them inside of the furnace. They exhibited a fine-grained ore structure comparable to sample 4712/06.

Lab.-Number: DBM 4429/06
Site catalogue number: 12
Site name: N98/32-2
Unit: 51/50
Quadrant: a

Level: 9
Object: Slag
Size: 5.2 x 2.7 x 1.6 cm, incomplete.
Weight: 22 g
Illustrations: Figures 175 and 184
Methods of analyses: MD, PTS, ICP-OES
Magnetism: Moderately magnetic.
Macroscopic description: The exterior of the specimen was dark gray and rusty brown. In cross section it was dark gray. The shape of the slag was amorphous-flat and it cooled down in a sand bed. The density was low and the texture had minute to small roundish to amorphous-angular pores. The whole sample appeared very inhomogeneous with a high amount of fuel inclusions. The sample was strongly corroded and sand grains together with charcoal bits were trapped in the coat of corrosion.
Microscopic description: Thin section examination revealed the conglomerated and layered nature of the sample. The main slag mass appeared as a glassy fayalite/wustite eutectic. Wustite crystallized as first phase in irregular distribution as granular crystals or in weakly developed dendrites and it was followed by the fayalite/wustite eutectic. A second layer developed which was free of wustite. Here, blocky medium-sized fayalites crystallized first and interstices were filled with glass or a fayalite/leucite eutectic. Throughout the sample, and in particular in the wustite-free zones, coral-like and highly compacted labyrinthine structures of metallic iron were present. These metal inclusions were strongly corroded and did not allow for further analyses. In addition, the sample contained lumps of partially reduced iron ore. The latter exhibited a fine granular structure and a nodular morphology comparable to the plinthite segregation 4712/06. The ores were reduced to wustite and in parts already to elemental iron, in particular the outer zones of the nodules. The elemental iron however was corroded to iron hydroxides. Inclusions of sandy quartz showed varying degrees of grain alteration due to thermal stress and some grains formed new fayalites. The outer margin of the sample was highly corroded.
Identified mineral phases: Fayalite, goethite, wustite, metallic iron, quartz, leucite, silica-rich mineral phases.
Chemical composition:

Fe_2O_3	68.18
SiO_2	26.57
Al_2O_3	2.14
CaO	1.01
MnO	0.04
TiO_2	0.09
MgO	0.21
Na_2O	0.08
P_2O_5	0.24
Total	98.75
	wt%

Ba	263
Cr	n.d.
Sr	104
V	170
Y	n.d.
Zr	54
As	n.d.
Bi	n.d.
Cu	18
Ni	12
Pb	n.d.
Zn	114
Sb	n.d.
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Late Ironworking Groups
Interpretation: This was an amorphous processing slag from the first stage of bloom refining. It formed under hot reducing conditions and cooled down slowly in a sand bed. It contained patterns of amorphous hammerscale and numerous small bloom inclusions. Most of them were only partially reduced to elemental iron and still exhibited ore structures. These gromps were discarded in the primary process of cleaning and consolidating the bloom. They also reflected the heterogeneous nature of a bloom and proved that the reduction process was not always fully completed when the furnace ceased. The wustite free layer showed compositional properties of smelting slag.

Lab.-Number: DBM 4430/06
Site catalogue number: 12
Site name: N98/32-Surface 4a
Unit: -
Quadrant: -
Level: Surface
Object: Slag
Size: 5.3 x 4.6 x 2.2 cm, incomplete.
Weight: 34 g
Illustrations: **Figure 186**
Methods of analyses: MD, PTS
Magnetism: Weakly magnetic.
Macroscopic description: The exterior of the specimen was dark gray to reddish brown. In cross section it was dark gray. The slag was plano-convex in shape and solidified in a bed of charcoal and sand with imprints of both at the bottom side. A pronounced cooling skin formed on the upper side of the slag. The density was medium and the texture showed minute to medium-sized roundish and oblong pores. The latter solidified in divergent order relative to the upper and underside of the specimen. Only a few signs of corrosion were present.
Microscopic description: In thin section the sample appeared as a layered and inhomogeneous slag with about 45area% fayalite and wustite in each case, and layers of high wustite content alternated with layers of low wustite content. Some layers were intercrystallized. The bottom layer mainly consisted of a fayalite/wustite eutectic with poorly developed crystal structures. Here, wustite crystallized as first phase and it appeared in crowded medium-sized granular to dendritic crystal agglomeration. Some of these agglomerations exhibited

structures of amorphous and spheroid hammerscale. Interstices were poorly developed and filled with a glassy matrix. This microtexture graded into an area in which the crystal succession changed: large blocky fayalites developed first, followed by interstitial wustite in a fayalite/leucite eutectic. Towards the upper parts of the sample, the composition changed again and well-oriented evenly spread wustite dendrites occurred together with spinel (magnetite) before fayalite developed. The top layer of the sample formed under oxidizing conditions. It showed spinel (magnetite) as first phase followed by iscorite and fine, well shaped columnar fayalite crystals. Interstices were filled with glass. Several generations of magnetitic cooling skins were present in the upper layer, which were covered by new arriving slag. Some were reduced to wustite. Throughout the sample, small droplets of metallic iron occurred, which became reduced from wustite present in the slag. They were surrounded by wustite-free zones and some lost angular particles of iron. Clouds of corrosive mineral phases indicated that there was originally some more metallic iron in the sample. Only little fuel was present in the slag.
Identified mineral phases: Wustite, magnetite, iscorite, fayalite, glass, metallic iron.
Chemical composition:

Fe_2O_3	76.30
SiO_2	23.21
Al_2O_3	1.53
CaO	0.38
MnO	0.03
TiO_2	0.07
MgO	0.18
Na_2O	0.01
P_2O_5	0.10
Total	101.80
	wt%

Ba	74
Cr	n.d.
Sr	23
V	74
Y	n.d.
Zr	53
As	n.d.
Bi	n.d.
Cu	n.d.
Ni	13
Pb	n.d.
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Late Ironworking Groups
Interpretation: This was a small smithing hearth bottom from a final step of bloom refinement or iron bar smithing. It had a characteristic plano-convex appearance, radiating oblong pores and several generations of cooling skins in the top layer. The sample reflected refining steps under strongly reducing conditions (formation of iron prills), which generated amorphous and spheroid hammerscale from a bloom still containing some slag. Subsequently, the consolidated bloom was hot-worked and further consolidated in an oxidizing environment with repeated cycles of processing (several generations of cooling skins) and only limited new slag formation.

Lab.-Number: DBM 4431/06
Site catalogue number: 12
Site name: N98/32
Unit: -
Quadrant: -
Level: Surface
Object: Slag
Size: 4.9 x 4.2 x 2.4 cm, incomplete.
Weight: 58 g
Illustrations: -
Methods of analyses: MD, ICP-OES
Magnetism: Variable, from weakly to strongly magnetic.
Macroscopic description: The exterior of the specimen was rusty brown and dark gray. In cross section it was dark gray and metallic silver. The slag was amorphous-flat in shape and solidified in a bed of charcoal. A cooling skin formed on the upper side of the slag. The density was medium to high and the macrocrystalline texture showed small round, roundish and oblong pores. Some bits of charcoal and metallic iron were present in the sample. Some parts of the slag were corroded and sand was trapped in the rusty coat.
Microscopic description: -
Identified mineral phases: -
Chemical composition:

Fe_2O_3	79.90
SiO_2	18.10
Al_2O_3	1.80
CaO	0.68
MnO	0.01
TiO_2	0.08
MgO	0.12
Na_2O	0.07
P_2O_5	0.13
Total	100.89
	wt%

Ba	110
Cr	n.d.
Sr	65
V	89
Y	n.d.
Zr	62
As	n.d.
Bi	n.d.
Cu	11
Ni	19
Pb	n.d.
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Late Ironworking Groups
Interpretation: This was a primary smithing slag with gromps. The macrocrystalline texture indicated that the slag cooled down in a furnace. It has been classified to advanced refining slags because it was not possible to assign it to initial or final refining activities without microstructure analysis.

Lab.-Number: DBM 4433/06
Site catalogue number: 12
Site name: N98/32-Surface 4c
Unit: -
Quadrant: -
Level: Surface
Object: Slag
Size: 8.0 x 5.0 x 2.9 cm, incomplete.
Weight: 122 g
Illustrations: Figure 175
Methods of analyses: MD, PTS, ICP-OES, ^{14}C
Magnetism: Very weakly to weakly magnetic.
Macroscopic description: The exterior and interior of the specimen was dark gray and rusty brown. The shape of the slag was plano-convex and it cooled down in a sand bed. The density was low and pumice-like. The texture was layered and conglomerated. It showed minute to large roundish to amorphous-angular and oblong pores up to 2.3 cm in diameter. Small oblong pores in divergent order formed along the bottom of the specimen. Powdery fuel or fuel ashes and big bits of charcoal were embedded in the sample. The slag was strongly corroded and sand grains together with charcoal bits were trapped in the coat of corrosion.
Microscopic description: In cross section the sample revealed an inhomogeneous conglomerated and layered structure. Wustite solidified as first phase and formed granular to poorly developed dendritic crystals in irregular distribution pattern. Wustite was followed by blocky fayalites and interstices were filled with a fayalite/wustite eutectic, or a glassy matrix. The bottom layer consisted of columnar radiating crystals of fayalite in eutectic intergrowth with wustite.
Within the whole sample, sponge-like inclusions of corroded corals and labyrinths of metallic iron were present. Only little non-corroded iron had been preserved. Some of the labyrinthine structures developed around fine-grained and granular wustite concentrations which structural features of iron ore. Some of the corroded iron sponges were associated with highly fractured quartz in transition to minute fayalites and other silica-rich mineral phases. In addition, the sample contained inclusions of quartz grains which were only slightly exposed to thermal stress.
Identified mineral phases: Fayalite, wustite, goethite, metallic iron, quartz, silica-rich mineral phases.
Chemical composition:

Fe_2O_3	67.60
SiO_2	28.47
Al_2O_3	2.31
CaO	0.49
MnO	0.03
TiO_2	0.12
MgO	0.16
Na_2O	0.11
P_2O_5	0.19
Total	99.49
	wt%

Ba	143
Cr	n.d.
Sr	40
V	178
Y	n.d.
Zr	60
As	n.d.
Bi	n.d.
Cu	n.d.
Ni	14
Pb	n.d.
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -
Absolute age: 270±30 BP (Poz-20699, Table 2), charcoal extracted from the sample.
Occupation horizon: Late Ironworking Groups
Interpretation: This was a smithing hearth bottom from the first steps of bloom consolidation. The macroscopic appearance and the radiating oblong pores along the underside were indicative of smiting hearth bottoms. The layered texture reflected repeated iron processing cycles from which material accumulated in the refining furnace. The mineral composition indicated that it formed under hot reducing conditions. The sample contained bloom fragments, which were only partially reduced to metallic iron and still exhibited granular structures of the iron ore. They were discarded during the first steps of bloom consolidation and proved that reduction was not always fully completed when the furnace ceased. The sand grains, displaying varying stages of thermal alteration, could have been fallen into the slag accidentally, or they were added to promote slag formation.

Lab.-Number: DBM 4434/06
Site catalogue cumber: 12
Site name: N98/37
Unit: -
Quadrant: -
Level: Surface
Object: Slag
Size: 6.2 x 4.8 x 2.5 cm, incomplete.
Weight: 70 g
Illustrations: -
Methods of analyses: MD, ICP-OES
Magnetism: Weakly magnetic.
Macroscopic description: The exterior of the upper side of the slag was dark gray to brownish medium gray. The underside was brownish-beige medium gray. In cross section it was greenish dark gray. The slag was concave-convex in shape and solidified in a sand bed within a shallow pit. A pronounced rim of both slagged and unmodified sand grains adhered to the bottom side. A cooling skin formed on the upper side of the slag. Some charcoal was embedded in the slag. The density was medium to high and the macrocrystalline texture showed minute to medium-sized roundish and round pores up to 0.6 cm in diameter. Minute and small tabular, amorphous and spherical hammerscale flakes were trapped in the sandy underside of the slag. Only a few rusty zones occurred.

Microscopic description: -
Identified mineral phases: -
Chemical composition:

Fe_2O_3	65.30
SiO_2	32.80
Al_2O_3	1.78
CaO	0.49
MnO	0.02
TiO_2	0.07
MgO	0.14
Na_2O	0.01
P_2O_5	0.14
Total	100.74
	wt%

Ba	147
Cr	n.d.
Sr	37
V	235
Y	n.d.
Zr	53
As	n.d.
Bi	n.d.
Cu	515
Ni	14
Pb	n.d.
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Late Ironworking Groups
Interpretation: This was a smithing hearth bottom from secondary smithing. It cooled down in a shallow sandy pit. The fine flaky hammerscale trapped in the bottom of the sample suggested that it formed in the periphery of an anvil on which sound metal had been worked.

Lab.-Number: DBM 4435/06
Site catalogue number: 4
Site name: N99/21
Unit: 50/51
Quadrant: d
Level: 6
Object: Slag
Size: 1.7 x 1.5 x 1.4 cm, incomplete.
Weight: 17 g
Illustrations: Figure 95
Methods of analyses: MD, PCS, ICP-OES
Magnetism: Strongly magnetic.
Macroscopic description: The exterior of the specimen was dark grayish brown. In cross section it was dark gray to greenish medium gray and metallic silver. The shape of the slag was amorphous. A cooling skin formed on the upper side of the slag. The density was medium to low and the texture showed minute to small roundish and round pores up to 0.5 cm in diameter. Some parts of the sample were corroded and sand grains were trapped in the coat of rust.
Microscopic description: In cross section the sample revealed two very different layers of slag. The bottom layer consisted of a fayalite dominated mass with inclusions of metallic iron. Fayalite appeared as first phase mainly as very big blocky crystals in a fayalite/wustite eutectic with blocky and columnar crystal structures. Interstices were filled with small and incompletely developed wustite crystals and/or with fayalite in eutectic intergrowth with leucite. Within this layer, pieces of metallic iron occurred in a compacted completely fused state with inclusions of powdery charcoal or fuel ashes. The upper layer of the sample was wustite dominated. It crystallized as first phase within the slag mass and appeared as medium-sized, granular to dendritic crystals in crowded amorphous patterns. The main slag mass was a glassy to poorly crystallized fayalite/wustite eutectic. Only a few interstices developed and they were filled with a glassy matrix. Some prills of metallic iron were present within this layer and were obviously reduced within the slag itself. After etching the sample with 3% Nital, the pieces of metal appeared as medium to high carbon steels with carbon contents ranging between 0.3wt% and slightly above 0.8wt%. The first exhibited a ferritic-pearlitic microstructure with acicular ferrite and in places a poorly developed Widmanstätten structure in pearlite. The latter were mainly eutectoid-pearlitic in microstructure with some grain boundary secondary cementite. The steel was slightly corroded. One larger piece of completely fused and compacted metallic iron was associated with a high amount of powdery fuel. The microstructure was that of low carbon steel dominated by irregular ferrite polygons with pronounced grain boundary cementite and small pearlite islands in interstices. The overall carbon content was estimated at 0.1wt% C. The grain size varied distinctively between ASTM 3 and 9. Some unidentified etch pits were present in the ferrite grains. The overall content of fuel residues was rather low within the whole sample.
Identified mineral phases: Fayalite, wustite, metallic iron (ferrite, cementite, pearlite), leucite, goethite.
Chemical composition:

Fe_2O_3	80,20
SiO_2	18.29
Al_2O_3	1.37
CaO	1.16
MnO	0.02
TiO_2	0.06
MgO	0.08
Na_2O	0.01
P_2O_5	0.18
Total	101.37
	wt%

Ba	109
Cr	n.d.
Sr	26
V	32
Y	n.d.
Zr	63
As	n.d.
Bi	n.d.
Cu	n.d.
Ni	9
Pb	n.d.
Zn	79
Sb	n.d.
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Late Ironworking Groups

Interpretation: This was a primary smithing slag. The lower layer could be regarded as remnants of the initial heating of the bloom and the draining away of redundant smelting slag since signs of forge working (hammerscale structures, high FeO content) were absent. The second layer structurally attested the forging activities of the bloom consolidation. The mineral composition and the iron prills of the sample proved the hot reducing regime of the refining furnace. The wide range of grain sizes of the bloom fragments indicated that the ferrite recrystallized after having been cold-worked (hammered, consolidated). The wide range of carbon distribution found in the iron fragments documented the variability of pre-industrial metal.

Lab.-Number: DBM 4436/06
Site catalogue number: 4
Site name: N99/21
Unit: 51/50
Quadrant: a
Level: 6
Object: Slag
Size: 4.7 x 3.7 x 1.8 cm, incomplete.
Weight: 16 g
Illustrations: Figure 96
Methods of analyses: MD, PCS
Magnetism: Variable, moderately to strongly magnetic. Macroscopic description: The exterior of the specimen was reddish brown-gray. In cross section it was dark gray and metallic silver. The shape of the slag was amorphous-flat. The slag solidified in a bed of charcoal and sand. A cooling skin formed on the upper side of the specimen. The density was medium and the texture showed minute to medium-sized roundish and round pores up to 0.7 cm in diameter. A high amount of powdery fuel or fuel ashes was trapped in the slag. The sample was partially corroded and sand adhered to the slag due to corrosion.
Microscopic description: In cross section the sample revealed an inhomogeneous conglomerated structure. Wustite crystallized first and it occurred in crowded agglomerations of medium-sized, granular to dendritic crystals. Highly compacted zones of wustite crystals exhibited structures of undissolved amorphous hammerscale. The main slag mass consisted of a fayalite/wustite eutectic in a glassy state, or in partially columnar and lath-like developed crystals. Only a few interstices developed that were either filled with a fayalite/leucite eutectic or a glassy matrix.
Metallic iron was present from loose coral-like structures to labyrinthine and completely fused and compacted zones. Etching with 3% Nital revealed that the quality of the metal varied from soft iron to hypereutectoid steel. The hypereutectoid steel showed a pearlitic microstructure with cementite segregation along former austenite grain boundaries and secondary acicular cementite. The carbon content was estimated at about 1.6wt%. Furthermore, fragments of compacted low carbon steel and soft iron occurred. Some of them displayed a ferritic microstructure with small pearlite islands in interstices and some tertiary cementite along grain boundaries. The carbon content ranged between 0.02 to 0.025wt%. Grain sizes varied from ASTM 2 to 6. The other pieces of consolidated iron had a ferritic microstructure of soft iron with less than 0.02wt% C, and some tertiary cementite was segregated along grain boundaries. The grain sizes ranged between ASTM 1 and 7, and the crystals took the form of irregular polygons, which exhibited grain deformation. All low-carbon iron fragments showed numerous small acicular intragrain inclusions. The pores and inclusions of these metal fragments were round to subangular. Most of the compacted zones were associated with a high amount of powdery fuel or fuel ashes. In some parts, the wrought iron had been carburized to low carbon steel of about 0.1wt% of carbon. Additionally, the sample revealed labyrinthine and coral-like structures of metallic iron of an unconsolidated bloom. They also consisted of soft iron to low carbon steel with a ferritic microstructure, grain boundary cementite and some pearlite islands. Some individual prills within the slag showed a higher carbon content (> 0.8wt%) and one prill consisted of white cast iron with an iron-phosphide inclusion (> 2.06wt%).
Identified mineral phases: Fayalite, wustite, metallic iron (ferrite, pearlite, iron phosphide, cementite), goethite, quartz.
Chemical composition: -
Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Late Ironworking Groups
Interpretation: This was a primary smithing slag with inclusions of bloom fragments. The amorphous hammerscale structures evidenced that it was generated during an initial step of refining. The gromps were unmodified or showed evidence of cold working (hammering) and were partially recrystallized as indicated by the highly alternating ferrite grain sizes. The pieces of high carbon steel were not suitable for processing without decarburization and became therefore discarded. The wide range of carbon distribution of the iron fragments documented the variability of pre-industrial metal. The formation of high phosphorous cast iron indicated elevated temperatures in the refining furnace and redox conditions comparable to smelting operations that facilitated the phosphorization of the iron. The phosphorous might have been already present in the smelting slag discarded in the refining furnace, or it was introduced through the fuel material. Some of the

iron fragments exhibited acicular intragrain inclusions, which were usually considered iron-nitrides, iron-carbide-nitrides or phosphides. Both alloying elements increased the hardness of the material. The metal fragments were probably too small to be recovered from the furnace.

Lab.-Number: DBM 4437/06
Site catalogue number: 3
Site name: N98/39-2
Unit: 52/55
Quadrant: -
Level: 998
Object: Single hook, iron
Size: 4 x 1.09 x 0.32 cm, incomplete.
Weight: 1.1 g
Illustrations: Figure 212
Methods of analyses: MD, PCS
Magnetism: Very strongly magnetic.
Macroscopic description: This hook was made out of an iron wire. The wire was approximately 0.3 cm in diameter and of subangular cross section. One end of the hook was tapering and pointed. The exterior was a rusty brown, and the interior was metallic silver and rusty brown. The artifact was moderately corroded.
Microscopic description: In cross section, the sample revealed a homogeneous microstructure with some compositional variation. The carbon content was estimated to be from below 0.02wt% to 0.05wt%. The microstructure consisted of ferrite grains with grain boundary cementite and pearlite islands in interstices. The ferrite was variable in appearance and grain sizes ranged from ASTM 3 to 8. Pearlite became more present with the increase of carbon in the sample and in some zones the lamellas exhibited degeneration and spheroidized cementite. The boundaries of the alternating composition within the microstructure developed both gradationally and sharp. They were not clearly associated with lines of inclusions. The artifact contained many non-iron inclusions. Four types of inclusions were identified: There were two-phase inclusions of dendritic wustite in a glassy matrix, corrosion products, unspecific dark two to three phase inclusions and a larger blackish zone of powdery fuel. There was local carburization around the fuel inclusion. Around this zone, oxides and slags mainly appeared as swarms of very angular, non-flattened to slightly flattened inclusions of varying orientation. In other zones, inclusions took the form of elongated stringers, and were arranged in lines parallel to the extension of the material and in slightly concentric order.
Chemical composition: -
Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Early Ironworking Groups
Interpretation: The artifact consisted of at least two joined pieces of different source material. The nature of the non-flattened swarms of inclusions together with remnants of fuel indicated that one piece originated from a primary piece of bloom. The carburization in this part of the object seemed to have been unintentional. The other material showed microstructural characteristics (inclusion banding) of metal that had been extensively hot-worked. The strongly varying size of the ferrite grains with coarse grain formation indicated that the material recrystallized after cold working. The degeneration of some pearlite (globular cementite) implied warm working at subcritical temperatures because I consider it unlikely that the item was exposed to prolonged annealing of several hours.

Lab.-Number: DBM 4438/06
Site catalogue number: 30
Site name: N69/03
Unit: B1973
Quadrant: Furnace hole
Level: -
Object: Slag
Size: 10.1 x 9.8 x 4.3 cm, incomplete.
Weight: 350 g
Illustrations: **Figure 185**
Methods of analyses: MD, PCS, ICP-OES, ^{14}C
Magnetism: Mainly non-magnetic, magnetic surface skin, weakly magnetic around metallic iron inclusions.
Macroscopic description: The exterior of the specimen was brownish and greenish medium gray. In cross section it was of greenish medium gray and light gray. The shape of the slag was plano-convex and the dimension of it corresponded to the shape of the bottom and wall of a furnace pit. The slag was conglomerated in appearance. It solidified in a sand bed and formed a pronounced rim of slagged and unslagged sand grains. A cooling skin formed on the upper side with some hammerscale flakes trapped in it. The density was high and the texture had round minute to large pores up to 1 cm in diameter. A high amount of bits of charcoal and powdery fuel or fuel ashes was trapped in the slag. Some areas of the specimen were corroded.
Microscopic description: In cross section, the slag revealed of a silica-rich and fayalite dominated matrix with some inclusions of wustite-rich slag. The sample mainly consisted of large blocky fayalite, which crystallized as first phase. The interstices were filled with varying compositions: a fayalite/wustite, fayalite/leucite or a fayalite/leucite/spinel eutectic. The fayalite/wustite eutectic could be followed by a fayalite/leucite eutectic. Some larger crystals of dendritic wustite and magnetite-dominated spinel grew in interstices as well. Still, the overall composition was very poor in wustite. Within this macrocrystalline

fayalite-dominated slag mass, small inclusions of wustite-dominated slag were present. Within these zones, wustite occurred as first phase and formed crowded zones of medium-sized dendritic to granular crystal agglomerations. It was followed by a glassy to weakly crystallized fayalite/wustite eutectic. Only a few interstices existed, which were filled with a glassy matrix. The microstructures of these inclusions clearly differed from the overall slag matrix.

Along the outer zones of the sample, a rim of fayalite dominated slag with many sandy quartz inclusions developed. The fayalites took the form of medium-sized blocky crystals. The quartz grains were strongly fractured due to thermal stress and in transformation to silica-rich mineral phases. This silica-rich zone of the sample included tabular and amorphous hammerscale flakes, which were partially reduced to metallic iron. Moreover, the sample contained some small angular fragments of iron and some prills.

Identified mineral phases: Fayalite, quartz, wustite, leucite, magnetite/spinel, goethite, metallic iron, unidentified silica-rich mineral phases, glass.

Chemical composition: -

Fe_2O_3	72.70
SiO_2	27.20
Al_2O_3	0.64
CaO	0.50
MnO	0.37
TiO_2	0.03
MgO	0.14
Na_2O	n.d.
P_2O_5	0.04
Total	101.61
	wt%

Ba	127
Cr	n.d.
Sr	9
V	12
Y	n.d.
Zr	48
As	n.d.
Bi	n.d.
Cu	n.d.
Ni	16
Pb	n.d.
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -

Absolute age: 320±30 BP (Poz-20703, Table 2), charcoal extracted from the sample.

Occupation horizon: Late Ironworking Groups

Interpretation: This was a furnace bottom from initial and advanced refining activities. The slag originated from the furnace hole of the termite mount excavated by B. Sandelowsky in 1969 (Figure 151). The macrocrystalline main body and the overall shape of the slag indicated that it cooled down in the furnace. The main slag body was poor in wustite and, together with the reduced hammerscale flakes, reflected effectively reducing conditions comparable to what one may expect from successful smelting operations. The wustite-rich inclusions clearly contrasted with the overall slag matrix. Due to their different succession of crystallization and inhomogeneous microstructure, I considered them smithing slags that fell into the slag bath. The hammerscale found included in the sandy rim as well as in the surface skin together with the small angular iron fragments provided evidence of the processing of a compact piece of metal. The slag bath was most probably of necessity to prevent the iron from carburization during refining. The high temperatures and redox-conditions were comparable to the smelting process, although the surface was exposed to cool oxidizing conditions. The interpretation of this sample was difficult because (unrefined) gromps were absent. The phase succession of the main slag mass and the amount of slag suggested that the slag formed during an early step in refining from drained smelting slag. The wustite rich inclusions probably formed in the charcoal bed during bloom consolidation and sunk down to the bottom of the refining furnace. The residues of more advanced smithing (hammerscale flakes, angular iron fragments) indicated that the bloom was processed to a compacted piece of sound metal. The furnace bottom must have been exposed to oxidizing conditions (perhaps the tuyere entrance zone) as some magnetite was present in the slag. A possible explanation for this unusual slag picture may be the use of a different method of bloom refinement during which the latter was sintered in a furnace for several hours, producing a rather homogeneous slag. The sintered piece of raw material then was subsequently hammered, causing the typical hammerscale flakes.

Lab.-Number: DBM 4439/06
Site catalogue number: 3
Site name: N98/39-2
Unit: 50/54
Quadrant: c
Level: 459
Object: Clip, iron
Size: 1.49 x 0.68 x 0.28 cm, complete.
Weight: 0.02 g
Illustrations: Figure 212
Methods of analyses: MD, PCS
Magnetism: Strongly magnetic.

Macroscopic description: This clip was made of a thin uniform ribbon of sheet metal. It measured about 0.1 cm in thickness. Its ends were bent inwards. The exterior was a rusty brown and the interior was metallic silver and rusty brown. The artifact was moderately corroded and some sand grains adhered to the specimen.

Microscopic description: In cross section, the sample revealed homogeneous steel with minor compositional banding. The content of carbon was estimated to range between 0.7wt% and 0.8wt%. The microstructure was fine grained and consisted mainly of fine lamellar pearlite with a few ferrite

polygons. The latter had grain sizes of about ASTM 7. The steel was slightly decarburized towards the outer margin.
There was one thick noticeable band of corrosion permeating the artifact. It was bent at one end. Other inclusions were mainly dark, roundish, elongated or angular voids, and small light gray remnants of corrosion products, which were oriented in loose bands and lines. A thick rim of corrosion with trapped sand grains enveloped the object.
Chemical composition: -
Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Early Ironworking Groups
Interpretation: This artifact was hot-worked (elongated inclusions) and the bent shape of the trapped band of surface corrosion provided evidence of the deliberate folding of the starting material. The lack of any traces of cold working together with the homogeneous microstructure and grain sizes indicated that the piece was successfully normalized at the end. The pronounced corrosion was probably responsible for the slight decarburization along the outer margin of the remaining steel.

Lab.-Number: DBM 4440/06
Site catalogue number: 27
Site name: N98/43
Unit: 5/5
Quadrant: d
Level: 60 – 80 cm vessel contents (Gefäßinhalt).
Object: Slag and bloom
Size: 1.8 x 1.7 x 0.9 cm, complete.
Weight: 1.5 g
Illustrations: Figures 142 and 209
Methods of analyses: MD, PCS
Magnetism: Strongly magnetic.
Macroscopic description: The exterior of the slag lump was rusty brown-gray and the interior was metallic silver. The shape was amorphous. The density was very high and the texture showed minute roundish and amorphous-angular pores. A rind of corrosion products, in which some sand grains were trapped, enveloped the specimen.
Microscopic description: The specimen consisted of about 90area% of metallic iron with little fayalite and some goethite. The metal was completely fused and it took the form of acicular crystals of cementite towards its outer margin. After etching with 3% Nital, the metallic part of the sample revealed mainly eutectoid to slightly hypereutectoid steel with the beginnings of the precipitation of secondary cementite along grain boundaries of the former austenite grains. The grain size of the former austenite was ASTM 1 to 2 and indicated temperatures above 950 °C. Moreover, a number of two-phase phosphide inclusions were present in the sample. Towards the outer margin of the nodule, the amount of acicular secondary cementite precipitates increased in relation to the pearlite, and in some zones, ledeburite appeared. According to the ratio of pearlite, secondary cementite, and ledeburite, the carbon content of this sample ranged from 0.8wt% to the eutectic point. The surrounding corrosion products took the form of some relict oxide structures of the secondary cementite and ledeburite.
Identified mineral phases: Metallic iron (pearlite, cementite, ledeburite, phosphide), fayalite, goethite.
Chemical composition: -
Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Late Ironworking Groups
Interpretation: This was a piece of a discarded iron bloom. The material ranged from hard eutectoid steel to hypoeutectic cast iron. The phosphide inclusions indicated that the material was much harder than one might estimate solely from the carbon content. This could also have been the reason why it was discarded. The sample proved the high variety of carbon contents in bloomery iron.

Lab.-Number: DBM 4474/06
Site catalogue number: 3
Site name: N98/39-2
Unit: 50/55
Quadrant: -
Level: 842
Object: Bar, iron
Size: 5.98 x 0.49 x 0.45 cm, incomplete.
Weight: 2.5 g
Illustrations: Figure 212
Methods of analyses: MD, PCS
Magnetism: Strongly magnetic.
Macroscopic description: This was a longish iron bar of rectangular cross section. It varied in thickness and was irregular in shape. The exterior was rusty brown and light brown-gray and the interior was metallic silver and rusty brown. It was strongly corroded and rusty scale flaked off. Some sand grains were trapped in the corrosion layer. A layer of calcareous sinter gave it its light gray color.
Microscopic description: The transverse section revealed strongly corroded iron with numerous non-iron inclusions. The original outline of the artifact was not visible anymore. Three areas of metallic iron withstood corrosion. They were separated bya pronounced band of corrosion and their microstructures exhibited different histories of treatments. The carbon content was in the region from 0.3wt% to 0.6wt%. Two carburized zones were present around fuel inclusions. The microstructure mainly consisted of a Widmanstätten structure with proeutectoid grain boundary ferrite and Widmanstätten side plates in lamellar pearlite. The

size of the former austenite grains approximated ASTM 8 to 9, indicating austenitization temperatures below 900 °C. With decreasing carbon content, the microstructure graded into a ferritic-pearlitic texture that took the form of lath-like to polygonal ferrite and interstitial pearlite islands. The grain sizes of the ferrite varied between ASTM 6 and 8. The whole microstructure exhibited grain deformation from cold working. Some of the ferrite in the low carbon zones seemed to have been recrystallized. All pearlite was slightly degenerated and displayed some globular cementite of varying distribution.
The object contained abundant small inclusions. Most of them were distinctly elongated and oval in shape. Most inclusions were aligned in bundles of wavy bands, and some of these bundled bands were bent reversely. The inclusions consisted of corrosion products, minute globular voids and unspecific two- to three-phase inclusions. Blackish zones of fuel inclusions caused minor carburization around them. The object was severely corroded. Iron hydroxides intruded into the object along poorly performed welds and along cracks.
Chemical composition: -
Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Perhaps Early Ironworking Groups
Interpretation: This artifact consisted of hypoeutectoid medium to high carbon steel. It was hot-worked (elongated inclusions) and the reverse pattern of the course of the inclusion banding indicated deliberate folding of the starting material. The thick lines of corrosion along cracks that run across the object were signs of poor welding. The microstructure of the object also preserved evidence of normalizing (heating to the austenite field) and subsequent fast cooling, which created the Widmanstätten and other lath-dominated grain structures. The steel was then repeatedly exposed to hot and cold working. Warm working at subcritical temperatures most probably caused the lamellar pearlite to slightly alter. However, variation in the degree of degeneration of the pearlite in the warm working process could reflect compositional segregations within the steel. The final step of working seemed to have been cold hammering, which left behind a number of strongly degenerated grains.

Lab.-Number: DBM 4475/06
Site catalogue number: 3
Site name: N98/39-2
Unit: 52/55
Quadrant: d
Level: 1015
Object: Chain, iron
Size: 1.72 x 0.5 x 0.42 cm, incomplete.
Weight: 0.4 g
Illustrations: Figure 212
Methods of analyses: MD, PCS
Magnetism: Strongly magnetic.
Macroscopic description: This was a chain fragment consisting of four iron links. The exterior was rusty brown and light gray and the interior was metallic silver and rusty brown. One link measures about 0.7 by 0.51 cm in length and width, and 0.12 cm in height. The links were made of pieces of fine, round iron wire of about 0.1 cm in diameter. These pieces were bent into oval rings, and their ends were not closed. The artifact was heavily corroded and the links stuck together. Sand adhered to the specimen. Calcareous sintering gave the chain fragment its light gray color.
Microscopic description: In cross section, the metal appeared inhomogeneous. The carbon content was estimated at about 0.4wt% and the steel exhibited decarburization towards the outer margin. A Widmanstätten structure was present in the center of the wire with ferrite grain boundary allotriomorphs and Widmanstätten side plates penetrating the degenerated pearlite region. The alignment of the grain boundary ferrite indicated former austenite grain sizes of ASTM 4 to 5, suggesting austenitization temperatures above 900 °C. Towards the outer margins, the microstructure changed with the decreasing carbon content into polygonal ferrite and pearlite. Grain sizes of the ferrite varied from ASTM 6 to 10.
The object contained some small inclusions and a few voids. The inclusions consisted of corrosion products and two-phase slag inclusion of globular wustite in a glassy matrix. The inclusions took the form of loose swarms and lines. A rim of corrosion products enclosed the artifact and intruded into the metal along cracks. Changes in colors of the corrosion product demarcated the original outline of the artifact.
Chemical composition: -
Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Early Ironworking Groups
Interpretation: The sample consisted of hot-worked hypoeutectoid medium carbon steel. The occurrence of a Widmanstätten structure was indicative of full austenitization and rapid cooling from above, probably through air-cooling.

Lab.-Number: DBM 4476/06
Site catalogue number: 4
Site name: N68/01
Unit: B1575B, Kapako drain
Quadrant: -
Level: 20-34’’
Object: Point, iron
Size: 7.62 x 0.31 x 0.3 cm, incomplete.
Weight: 2 g

Illustrations: Figures 86 and 213
Methods of analyses: MD, PCS
Magnetism: Strongly magnetic.
Macroscopic description: This was a severely corroded iron point. The exterior displayed a rusty brown color and the interior was metallic silver and rusty brown. It was made from a small iron bar and had a squarish cross section. Rust scale flaked off the artifact. Sand was trapped in the coat of corrosion.
Microscopic description: The sample revealed an inhomogeneous microstructure and the carbon content ranged between 0.3wt% and 0.7wt% C. It consisted mainly of ferrite polygons and laths with lamellar pearlite islands Areas of higher carbon content took the form of pearlite with ferrite allotriomorphs. The grain sizes of the ferrite were in the region of ASTM 7 to 8. In the zones of higher carbon content, Widmanstätten saw teeth indicated rapid cooling from above Ar_3. Compositional variations occurred in banded and areal carbon segregations. The starting material used for this artifact was impure and contained numerous larger and small inclusions. Many of these impurities were remnants of multiphase slag inclusions with globular wustite. Other inclusions were voids, corrosion products and some remnants of fuel. The impurities occurred both in elongated oval and flattened forms and in very angular non-flattened appearance. They were aligned in swarms rather than in bands and were not in association with the chemical segregation patterns. The object was strongly corroded and covered by an envelope of iron hydroxides. Changes in the colors of the corrosion products demarcated the original outline of the artifact.
Chemical composition: -
Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Early Ironworking Groups
Interpretation: The sample consisted of hypoeutectoid medium to high carbon steel. The steel was hot-worked but the random distribution and the rather non-flattened nature of the inclusions suggested that the source material originated from a primary bloom. It was successfully normalized and most probably air-chilled. Variation in the degree of carburization was due to the compositional variability and segregations inherited from the smelting nodule.

Lab.-Number: DBM 4477/06
Site catalogue number: 4
Site name: N68/02
Unit: B1592
Quadrant: -
Level: 3-9''
Object: Piece of raw material, iron
Size: 5.25 x 1.4 x 1.5 cm, incomplete.
Weight: 5.3 g
Illustrations: Figure 86
Methods of analyses: MD, PCS
Magnetism: Strongly magnetic.
Macroscopic description: This piece consisted of several small iron plates that were hammered together. It exterior was a rusty brown and the interior was metallic silver and rusty brown. It was mildly corroded.
Microscopic description: In transverse section the metal consisted of two parts with different texture. The larger zone of them showed a fine-grained ferritic-pearlitic microstructure with lath-like ferrite and interstitial pearlite. The carbon content was approximately 0.3wt% and the object displayed a decarburized margin. Grain sizes of the ferrite varied between ASTM 6 to 8. Towards the outer margin, the ferrite grains generally increased in size and became somewhat equiaxed. The second and smaller part consisted of a ferritic microstructure with only little interstitial pearlite and some grain boundary cementite. The carbon content was approximately 0.1wt%. Grain sizes of the ferrite varied considerably and ranged from ASTM 3 to 8.
The object contained numerous impurities. Inclusions occurred in wavy lines parallel to the flat side of the sheet metal. There were numerous elongated slag and glass inclusions and some blocky, fissured voids, which in some cases contained trapped remnants of fuel. A few of them caused zonal carburization around them. Thick bands of corrosion run across the object and were associated with decarburization. It separated the zone of low carbon steel from that of medium carbon steel. They probably developed either from trapped surface oxides from poorly performed welds or when the metal had been folded over in the forging process. The artifact was covered by corrosion products.
Chemical composition: -
Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Late Ironworking Groups
Interpretation: This was a piece of recycled raw material for further processing. The metal consisted of at least two pieces of hypoeutectoid low to medium carbon steel. It had been extensively hot-worked (inclusion banding and decarburization along the margins) and folded. The internal lines of corrosion provided evidence of poor welding or folding of the material. It was normalized and air-chilled (fine grained lath-dominated microstructure). It was subsequently cold-worked in some parts and the grains were fully recrystallized.

Lab.-Number: DBM 4483a/06
Site catalogue number: 12
Site name: N69/01-2
Unit: Test 2

Quadrant: -
Level: 25-35 cm
Object: Open ring, iron
Size: 2.55 x 1.8 x 0.4 cm, incomplete.
Weight: 3.4 g
Illustrations: Figures 123 and 213
Methods of analyses: MD, PCS
Magnetism: Strongly magnetic.
Macroscopic description: This was a heavily corroded open iron ring made from an iron bar. The exterior was a rusty brown and light gray and the interior was metallic silver and rusty brown. Corrosion has obliterated the original surface. In cross section (transverse section), a rectangular core of metallic iron was visible. Sand adhered to the artifact.
Microscopic description: The artifact consisted of hypoeutectoid to eutectoid steel with approximately 0.7 to 0.8wt% of carbon. The microstructure was largely homogeneous and consisted mainly of fine lamellar pearlite with proeutectoid grain boundary ferrite. The carbon content decreased towards one side of the specimen and exhibited lath-like ferrite and a Widmanstätten structure. The grain sizes of the ferrite and former austenite ranged between ASTM 6 and 7, indicating austenitization temperatures around 900 °C. The steel used for this artifact was impure and contained numerous inclusions in unspecific order and in swarms. Some of these inclusions were flattened while others were still blocky and angular in shape. They consisted of iron hydroxides, pieces of glassy slag with crowded wustite dendrites, small voids and unidentified dark single-phase inclusions. The whole artifact was heavily corroded and only one third of the sound steel survived. The former rectangular outline of the artifact was still visible in some parts of the layering of the corrosion.
Chemical composition: -
Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Late Ironworking Groups
Interpretation: This iron ring consisted of nearly eutectoid steel. It was hot-worked to some extent and successfully normalized. The numerous blocky impurities along with the lack of compositional and inclusion banding suggested that the starting material was a primary bloom. Also the comparably high carbon rate indicated that the material had not been repeatedly hot-worked or recycled.

Lab.-Number: DBM 4483b/06
Site catalogue number: 12
Site name: N69/01-2
Unit: Test 2
Quadrant: -
Level: 25-35 cm
Object: Rod with loop-like end, iron
Size: 5.4 x 1.0 x 0.48 cm, incomplete.
Weight: 2.8 g
Illustrations: Figures 123 and 213
Methods of analyses: MD, PCS
Magnetism: Strongly magnetic.
Macroscopic description: This was an iron rod with roundish cross section. The exterior was rusty brown and the interior was metallic silver and rusty brown. The undamaged end was curved like a loop. It was strongly corroded with rust scale that flaked off. Sand adhered to the artifact.
Microscopic description: The metal was hypoeutectoid steel with about 0.5wt% to 0.7wt% carbon and a zone of strong decarburization. The microstructure was inhomogeneous and showed compositional variation. It mainly consisted of a matrix of proeutectoid ferrite and Widmanstätten saw teeth penetrating the pearlite field. The grain size of the ferrite polygons and former austenite grains ranged between ASTM 5 and 7. This indicated austenitization temperatures above 900 °C. The section displayed decarburization towards the outer margins and the microstructure changed into lath-like ferrite with interstitial pearlite. Most inclusions were strongly elongated and strung out into banded structures. They mainly contained corrosion products and a few minute slag inclusions. Some globular voids existed as well. Corrosion entered the object along cracks and open bands of inclusions. The original surface was not preserved.
Chemical composition: -
Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Late Ironworking Groups
Interpretation: This artifact consisted of hypoeutectoid high carbon steel, which was extensively hot-worked (decarburization, banded structures of flattened inclusions). It was heated to the austenite field (normalized) and cooled down rapidly, probably in air. The Widmanstätten structure indicated that the metal was rather brittle.

Lab.-Number: DBM 4484b/06
Site catalogue number: 12
Site name: N69/01-2
Unit: Test 2
Quadrant: -
Level: 25-35 cm
Object: Point, iron
Size: 4.9 x 0.5 x 0.42 cm, incomplete.
Weight: 2.1 g
Illustrations: Figure 213
Methods of analyses: MD, PCS
Magnetism: Very strongly magnetic.
Macroscopic description: This was a heavily corroded iron needle or point. The exterior was rusty brown and the interior metallic silver and rusty brown. In cross section (transverse section) the artifact showed a rectangular core of metallic iron. Sand was trapped in the coat of corrosion.

Microscopic description: This sample was heavily corroded and exhibited a very inhomogeneous microstructure. The content of carbon ranged from less than 0.02wt% up to an almost eutectoid state. The transition from one microstructural zone to the other was sharp. In the low carbon areas, ferrite was largely equiaxed and polygonal. Grain sizes ranged between ASTM 7 and 8. With increasing carbon content, tertiary cementite precipitated along ferrite grain boundaries and pearlite islands developed in interstices. High carbon areas were dominated by lamellar pearlite and with decreasing carbon content some ferrite polygons appeared in between. The specimen showed traces of a mechanical treatment. In the high carbon zone, one found compressed grain boundary allotriomorphs and with decreasing carbon content, banded pearlite alternated with flattened ferrite grains. However, not all of the sections showed grain deformation. Recrystallization became evident in the low carbon area where flattened polygons were surrounded by a zone of recrystallized microstructure with heterogeneous grain sizes ranging between ASTM 5 to 9. The pearlite present in the sample was partially degenerated with signs of the beginnings of spheroidization. Some zones and bands of the sample hardly responded to etching. This might indicate phosphorous segregation.
The sample was highly porous and strongly permeated and decomposed by corrosion. Only one third of the sample persisted as sound steel and iron. The original outline of the artifact was rectangular. Inclusions occurred as zonal or banded corrosion products and as numerous small globular voids. Larger strongly angular and fissured voids were associated with strong corrosion. Most inclusions were aligned in parallel straight though sometimes wavy lines.
Chemical composition: -
Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Late Ironworking Groups
Interpretation: The source material of this object was strongly hot-worked (inclusion banding), and it consisted of a number of joined pieces of metal, ranging from soft wrought iron to high carbon steel. The welds were not always well performed (lines of corrosion). The object was normalized and air-cooled (traces of a Widmanstätten structure) and subsequently cold-worked (grain deformation). The degenerated pearlite indicates that it was subject to warm working and annealing at subcritical temperatures which caused some ferrite to recrystallize.

Lab.-Number: DBM 4485/06
Site catalogue number: 4
Site name: N99/21
Unit: 50/51
Quadrant: c
Level: 6
Object: Clip, iron
Size: 1.62 x 0.5 x 0.3 cm, incomplete.
Weight: 0.2 g
Illustrations: -
Methods of analyses: MD, PCS
Magnetism: Very strongly magnetic.
Macroscopic description: This clip was made from a thin uniform ribbon of sheet metal. The exterior was rusty brown and the interior was metallic silver. One end was curved inwards. The other end was bent open. The clip was probably oval in its original state. It was slightly corroded and sand grains adhered to the artifact.
Microscopic description: The metal consisted of pure iron and low carbon steel with carbon values reaching not much above 0.02wt%. In microstructure it consisted of equiaxed polygonal ferrite of varying grain sizes in the region of ASTM 5 to 9. Some grain boundary cementite became segregated in some sections and due to increasing carbon content small lamellar pearlite islands developed in interstices. The overall composition was very homogeneous.
The steel contained only a few inclusions and voids of non-flattened appearance. Along the edges, a number of islands of iron hydroxides were present.
Chemical composition: -
Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Late Ironworking Groups
Interpretation: This clip was made from a very soft and homogeneous material. The non-flattened nature of the inclusions without layering suggested that the starting material had not yet been extensively recycled. The microstructure indicated that it recrystallized after cold working.

Lab.-Number: DBM 4486/06
Site catalogue number: 3
Site name: N98/39-2
Unit: 52/55
Quadrant: -
Level: 998
Object: Clip/ribbon, iron
Size: 1.25 x 0.69 x 0.65 cm, incomplete.
Weight: 0.6 g
Illustrations: **Figure 214**
Methods of analyses: MD, PCS
Magnetism: Very strongly magnetic.
Macroscopic description: The artifact was a ribbon of sheet metal. The exterior was rusty brown and the interior was metallic silver and rusty brown. It was irregularly curved. It might have been an iron clip that had been bent open. It was strongly corroded and rust scale flaked off. Corrosion obliterated the original shape of the object. Sand adhered to it.

Microscopic description: In transverse section the sample revealed hypoeutectoid steel. The carbon content was difficult to estimate because the pearlite was highly degenerated. It could range between 0.4wt% and 0.6wt% C, locally around fuel inclusions it was probably be even higher. The carbon distribution showed compositional variation and decarburization of the outer margins. Ferrite was present in equiaxed and inhomogeneous polygons of variable grain sizes varying from ASTM 4 to 8. The pearlite was largely degenerated and spheroidized cementite was scattered throughout the matrix. Some cementite still reflected the original grain boundaries of the austenite. Small islands of neogenetic pearlite occurred throughout the sample.
The object contained numerous inclusions of corrosion products, slag (wustite in a glassy matrix) and larger blocky and fissured voids with the remnants of fuel. The latter caused minor carburization around them at elevated temperatures. Most of the smaller inclusions were flattened, although non-flattened ones and small globular voids did occur as well. Most inclusions were part of slightly waved banded laminas. A rind of corrosion enveloped the artifact and disrupted the original surface. Corrosion also penetrated the sound metal through cracks and fissures along the larger voids in the material.
Chemical composition: -
Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Early Ironworking Groups
Interpretation: This artifact consisted of hypoeutectoid steel, which had been extensively hot-worked (banding of flattened inclusions). The carburization around the fuel inclusions seemed to have been unintentional. It was extensively warm-worked at subcritical temperatures, yet small islands of neogenetic pearlite indicated that temperatures temporarily exceeded Ac_1.

Lab.-Number: DBM 4707/06
Site catalogue number: 12
Site name: N98/32
Unit: Quadrant: -
Level: -
Object: Ferruginous sandstone
Size: -
Weight: 131 g
Illustrations: -
Methods of analyses: MD, ICP-OES
Magnetism: None magnetic.
Macroscopic description: This sample originated from hard, fine grained, and banded ferruginous sandstone. The color was of light reddish brown (MCC 5YR6/4). The streak was of the same color and intensity.
Microscopic description: -
Identified mineral phases: -
Chemical composition:

Fe_2O_3	8.01
SiO_2	81.30
Al_2O_3	3.73
CaO	0.33
MnO	0.13
TiO_2	0.69
MgO	1.95
Na_2O	0.08
P_2O_5	0.04
Total	95.45
LOI 1050°C	2.70
	wt%

Ba	519
Cr	60
Sr	79
V	542
Y	n.d.
Zr	555
As	n.d.
Bi	n.d.
Cu	10
Ni	37
Pb	17
Zn	29
Sb	14
S	n.d.
	ppm

Mineralogical composition from XRD: -
Interpretation: Ferruginous sandstone, possibly the parent rock of the residual weathering profiles along the river.

Lab.-Number: DBM 4708/06
Site catalogue number: 30
Site name: N69/03
Unit: B1973
Quadrant: -
Level: -
Object: Slag
Size: 8.5 x 6.5 x 3.6 cm, complete.
Weight: 131 g
Illustrations: Figures 154, 155 and 174
Methods of analyses: MD, PCS
Magnetism: Strongly magnetic.
Macroscopic description: The exterior of the specimen was medium gray and rusty brown. In cross section it was medium gray and metallic silver. The shape of the slag was concave-convex. The upper side was of a granular structure and the underside was sponge-like with big charcoal imprints. The slag cooled down in a charcoal bed. The density was medium. The texture showed minute to medium-sized roundish to amorphous-angular pores up to 0.7 cm in diameter. A high amount of powdery fuel and some bits of charcoal were embedded in the sample. The slag was partially corroded.
Microscopic description: In cross section the sample consisted mainly of fayalite with metallic iron and partially reduced iron ore. Fayalite appeared as first phase and solidified in macro-crystalline big blocky crystals in a glassy matrix.

Crystals of the 2nd and 3rd generation developed in interstices. It was obvious that all wustite was effectively reduced to metallic iron. Within this slag mass, partially reduced bits of iron ore were of particular interest. They were of compact micro-granular texture and under reflecting light they showed the light-gray to eggshell-gray colors of goethite and wustite. Some of them were only partially reduced to metallic iron along the outer margin. The latter appeared either as an accumulation of individual grains or the beginnings of the formation of coral-like structures. After etching with 3% Nital, the metal consisted of ferrite polygons with some grain boundary cementite. The carbon content was less than 0.02wt%. The grain size varied between ASTM 6 and 8. Furthermore, zones of reduced iron in labyrinthine structures until incipient fusion also existed. The microstructure consisted of ferrite polygons with small pearlite islands in interstices. The carbon content was that of low carbon steel and ranged from 0.25wt% to 0.3wt%. The fused parts of the steel exhibited tiny roundish pores and slag inclusions. In some parts of the sample, small inclusions of eutectoid steel were present. A very high amount of powdery fuel or fuel ashes was associated with the ore and bloom.

Identified mineral phases: Fayalite, metallic iron (ferrite, pearlite), goethite, wustite, glass.
Chemical composition: -
Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Late Ironworking Groups
Interpretation: This was a smelting slag with bloom and partially reduced lumps of iron ore. The fully reacted fayalitic part of the slag indicated that iron ore and probably fuel had been replenished to the running furnace during the smelt. The rim of elemental iron around the ore lumps represented the stage of the α–iron formation at the beginning of the reduction process. The texture and shape of the partially reduced ore lumps implied that nodular plinthic segregations comparable to sample 4712/07 were used. The variation in the carbon content of the iron reflected the time that the elemental iron spent in the furnace and corresponded to the variations in the wustite buffer that normally prevented the iron from carburization. The small eutectoid steel inclusions were probably from the preceding smelting cycle.

Lab.-Number: DBM 4709/06
Site catalogue number: 30
Site name: N69/03
Unit: B1973
Quadrant: -
Level: -
Object: Slag
Size: 7.2 x 6.7 x 2.8 cm, complete.
Weight: 139 g
Illustrations: Figures 154 and 155
Methods of analyses: MD, PCS
Magnetism: Very strongly magnetic.
Macroscopic description: The exterior of the specimen was medium gray and rusty brown. In cross section it was medium gray and metallic silver. The shape of the slag was plano-convex. The exterior was of granular structure with big charcoal imprints on the underside. The slag cooled down in a charcoal bed. The density was medium and the texture had small to medium-sized roundish pores up to 0.9 cm in diameter. Some powdery fuel was embedded in the sample. The slag was partially corroded and some sand grains were trapped in the coat of rust.
Microscopic description: In cross section the sample consisted mainly of fayalite with comparably little wustite (less than 5area%) and metallic iron. Fayalite appeared as macrocrystalline blocky and sometimes lath-like crystals. Some small individual wustite crystals (granular to slightly dendritic) started to develop in interstices as second phase. Interstices were filled with either a fayalite/wustite eutectic or, in rare cases, with glass. Metallic iron appeared as insular zones of coral-like and labyrinthine structures, or in dense, completely fused condition. After etching with 3% Nital, the metallic iron revealed a strongly inhomogeneous content of carbon. The coral-like and labyrinthine structures consisted of roundish ferrite monocrystals or ferrite polycrystals with some grain boundary cementite in loose distribution. The carbon content was below 0.02wt%. With increasing compactness, the metal fragments became more and more carburized up to eutectoid high carbon steel with 0.8wt% of carbon. The medium carbon steel showed a Widmanstätten structure with proeutectoid ferrite allotriomorphs and side plates in the pearlitic matrix. The high carbon steel fragments consisted of pure pearlite. The bloom was in parts corroded to iron hydroxides. The part of the slag that yielded the carburized bloom fragments also contained a high amount of powdery fuel in its pores. A thin hematitic cooling skin developed in some zones of the sample.
Identified mineral phases: Fayalite, metallic iron (ferrite, pearlite, cementite), wustite, goethite, glass.
Chemical composition: -
Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Late Ironworking Groups
Interpretation: The regular microstructure of the slag suggested that this was a piece of smelting slag with iron bloom. The size of the crystal indicated that the slag cooled down slowly in a furnace but

was taken out while it was still in a hot state because the steel exhibited structures of air-cooling. The sample indicated that the smelters produced pure iron as well as high carbon steel in the same smelt. The strong carburization might be the result of direct contact of the sample with elemental carbon. However, it might also be the result of a prolonged exposure to reducing gases after the slag had been tapped from the furnace. Nevertheless, it illustrates the inhomogeneous carbon distribution in blooms. The sample was probably discarded during primary smelting because it was not sintered enough for further use.

Lab.-Number: DBM 4710/06
Site catalogue number: 29
Site name: N06/02
Unit: -
Quadrant: -
Level: -
Object: Iron ore
Size: -
Weight: 9 g
Illustrations: -
Methods of analyses: MD, ICP-OES
Magnetism: Very weakly magnetic.
Macroscopic description: This was a tubular aggregate of iron hydroxide from a weathered plinthic horizon. It was collected from the surface. It was vesicular and hard. Colors ranged from brown (MCC 7.5YR4/4), strong brown (MCC 7.5YR5/8) to dark yellowish brown (MCC 10YR4/6). The streak was yellowish brown. There were inclusions of preserved fiber of organic origin. It was non-effervescent when tested with 3% HCl.
Microscopic description: -
Identified mineral phases: -
Chemical composition:

Fe_2O_3	72.70
SiO_2	15.52
Al_2O_3	0.26
CaO	0.29
MnO	0.32
TiO_2	0.02
MgO	0.12
Na_2O	0.01
P_2O_5	0.04
Total	89.26
LOI 1050°C	11.20
	wt%

Ba	88
Cr	10
Sr	13
V	22
Y	10
Zr	628
As	n.d.
Bi	n.d.
Cu	55
Ni	35
Pb	n.d.
Zn	34
Sb	24
S	n.d.
	ppm

Mineralogical composition from XRD: -
Interpretation: Plinthic nodular aggregate of iron hydroxides, suitable for bloomery smelting. The LOI of 11.2wt% indicated a high portion of organic matter, which positively influenced the quality of the ore because it implied porosity and an impact of fuel ashes on the smelt.

Lab.-Number: DBM 4711/06
Site catalogue number: 29
Site name: N06/02
Unit: -
Quadrant: -
Level: -
Object: Iron ore
Size: -
Weight: 30 g
Illustrations: -
Methods of analyses: MD, ICP-OES, XRD
Magnetism: Moderately magnetic.
Macroscopic description: This was an irregular, roundish, nodular aggregate of iron hydroxide from a weathered plinthic horizon. It was collected from the surface. It was vesicular and hard. Colors ranged from dusky red (MCC 10R3/2) to dark red (MCC 2.5YR3/6). The streak was very strongly red. There were some inclusions of preserved fiber of organic origin. It was non-effervescent when tested with 3% HCl.
Microscopic description: -
Identified mineral phases: -
Chemical composition:

Fe_2O_3	80.09
SiO_2	9.49
Al_2O_3	0.07
CaO	0.25
MnO	0.39
TiO_2	0.01
MgO	0.13
Na_2O	n.d.
P_2O_5	0.05
Total	90.48
LOI 1050°C	7.84
	wt%

Ba	106
Cr	10
Sr	10
V	17
Y	n.d.
Zr	656
As	n.d.
Bi	n.d.
Cu	54
Ni	21
Pb	n.d.
Zn	37
Sb	25
S	n.d.
	ppm

Mineralogical composition from XRD: DBM 5191/07, quartz, hematite, goethite.
Interpretation: Plinthic nodular aggregate of iron hydroxides. The LOI of 7.84wt% indicated a high portion of organic matter and other volatile

elements, which positively influenced the quality of the ore because it promoted porosity and it implied an impact of fuel ashes on the smelt.

Lab.-Number: DBM 4712/06
Site catalogue number: 29
Site name: N06/02
Unit: -
Quadrant: -
Level: -
Object: Iron ore
Size: -
Weight: 143 g
Illustrations: Figure 171
Methods of analyses: MD, PTS, ICP-OES, XRD
Magnetism: Very weakly magnetic.
Macroscopic description: This was an irregular, roundish, nodular aggregate of iron hydroxides from a weathered plinthic horizon. It was collected from the surface. It was vesicular and hard. Colors ranged from brown (MCC 7.5YR4/4), strong brown (MCC 7.5YR5/8) to dark yellowish brown (MCC 10YR4/6). The streak was yellowish brown. There were inclusions of preserved fiber of organic origin. It was non-effervescent when tested with 3% HCl.
Microscopic description: DBM 4400/07: In thin section the sample consisted of an aggregate of microgranular iron hydroxides. The matrix varied in density and color. It showed depositional sequences of cloud-like structures of granular aggregates. Moreover, iron hydroxides precipitated in concentrically grown bands around cellular root channel structures, which were replaced by iron oxides. The sample was very porous and contained some unspecific organic material.
Identified mineral phases: -
Chemical composition:

Fe_2O_3	77.60
SiO_2	6.09
Al_2O_3	0.05
CaO	0.09
MnO	0.40
TiO_2	0.01
MgO	0.14
Na_2O	n.d.
P_2O_5	0.02
Total	84.39
LOI 1050°C	13.50
	wt%

Ba	60
Cr	n.d.
Sr	10
V	19
Y	n.d.
Zr	618
As	n.d.
Bi	n.d.
Cu	54
Ni	26
Pb	n.d.
Zn	31
Sb	22
S	n.d.
	ppm

Mineralogical composition from XRD: DBM 5192/07: Goethite, hematite.

Interpretation: Plinthic nodular aggregate of iron hydroxides. The LOI of 13.5wt% indicated a high portion of organic matter which positively influenced the quality of the ore because it implied an impact of fuel ashes on the smelt. Moreover, porosity in microstructure and the high loss of ignition suggested that ores of such kind could easily be reduced.

Lab.-Number: DBM 4713/06
Site catalogue number: 30
Site name: N06/04
Unit: -
Quadrant: -
Level: -
Object: Iron ore
Size: -
Weight: 11.1 g
Illustrations: -
Methods of analyses: MD, ICP-OES, XRD
Magnetism: Moderately magnetic.
Macroscopic description: This was a nodular aggregate of iron hydroxides from the ferruginous soft plinthic upper soil horizon immediately below the sod (see soil description Site Catalogue No. 30). The nodule was hard, friable and contained organic material. The soil color was of reddish brown (MCC 5YR4/4). It was slightly effervescent when tested with 3% HCl. Within this horizon many soft nodules of iron hydroxides occurred (see sample 4716/06). The soil and the nodules were moderately magnetic.
Microscopic description: -
Identified mineral phases: -
Chemical composition:

Fe_2O_3	76.10
SiO_2	8.16
Al_2O_3	0.05
CaO	5.94
MnO	0.54
TiO_2	0.01
MgO	0.80
Na_2O	0.01
P_2O_5	0.06
Total	91.67
LOI 1050°C	5.71
	wt%

Ba	232
Cr	n.d.
Sr	67
V	10
Y	n.d.
Zr	313
As	n.d.
Bi	n.d.
Cu	57
Ni	10
Pb	n.d.
Zn	46
Sb	22
S	n.d.
	ppm

Mineralogical composition from XRD: DBM 5193/07: Quartz, hematite, goethite.
Interpretation: Plinthic nodular aggregate of iron hydroxides, slightly calcareous, suitable for bloomery smelting.

Lab.-Number: DBM 4714/06
Site catalogue number: 30
Site name: N06/04
Unit: -
Quadrant: -
Level: 0 to 10 cm below surface
Object: Iron ore
Size: -
Weight: 15 g
Illustrations: -
Methods of analyses: MD, ICP-OES
Magnetism: Non-magnetic.
Macroscopic description: This was a nodular aggregate of iron hydroxides from the upper soil horizon. It was slightly hard, friable, roundish in shape, porous and penetrated by grass roots. It was strong brown (MCC 7.5YR5/6) in color. The streak was yellowish red. It was moderately effervescent when tested with 3% HCl. There were macroscopic calcite crystals in the sample. The nodule was about 5 cm in diameter.
Microscopic description: -
Identified mineral phases: -
Chemical composition:

Fe_2O_3	76.10
SiO_2	8.16
Al_2O_3	0.05
CaO	5.94
MnO	0.54
TiO_2	0.01
MgO	0.80
Na_2O	0.01
P_2O_5	0.06
Total	91.67
LOI 1050°C	5.71
	wt%

Ba	232
Cr	n.d.
Sr	67
V	10
Y	n.d.
Zr	313
As	n.d.
Bi	n.d.
Cu	57
Ni	10
Pb	n.d.
Zn	46
Sb	22
S	n.d.
	ppm

Mineralogical composition from XRD: -
Interpretation: This was a plinthic nodular aggregate of iron hydroxides, slightly calcareous, suitable for bloomery smelting.

Lab.-Number: DBM 4715/06
Site catalogue number: 30
Site name: N06/04
Unit: -
Quadrant: -
Level: -5 to -15 cm
Object: Iron ore
Size: -
Weight: 87 g
Illustrations: -
Methods of analyses: MD, ICP-OES, XRD
Magnetism: Non-magnetic.
Macroscopic description: This is a nodular aggregate of iron hydroxides from the upper soil horizon. It is slightly hard, friable, roundish in shape, porous and penetrated by grass roots. It is about 5 cm in diameter. Color ranges from very dusky red (MCC 2.5YR2.5/3) to dark red (MCC 2.5YR3/6). The streak is very strongly red. It was moderately effervescent when tested with 3% HCl.
Microscopic description: -
Identified mineral phases: -
Chemical composition:

Fe_2O_3	71.40
SiO_2	2.94
Al_2O_3	0.01
CaO	13.70
MnO	0.66
TiO_2	0.01
MgO	0.50
Na_2O	0.02
P_2O_5	n.d.
Total	89.24
LOI 1050°C	10.60
	wt%

Ba	226
Cr	n.d.
Sr	68
V	10
Y	n.d.
Zr	361
As	12
Bi	n.d.
Cu	49
Ni	10
Pb	n.d.
Zn	44
Sb	24
S	n.d.
	ppm

Mineralogical composition from XRD: DBM 5194/07: Hematite, calcite.
Interpretation: Plinthic aggregate of iron hydroxides, slightly calcareous, suitable ore for bloomery smelting.

Lab.-Number: DBM 4716/06
Site catalogue number: 30
Site name: N06/04
Unit: -
Quadrant: -
Level: -
Object: Iron ore
Size: -
Weight: 114.6 g
Illustrations: -
Methods of analyses: MD, ICP-OES
Magnetism: Moderately magnetic.
Macroscopic description: This was a sample of the highly ferruginous soft plinthic upper soil horizon, 5 to 15 cm below the surface. The soil was soft, sandy, silty clay, plastic and sticky. The color ranged from reddish brown (MCC 5YR4/4), yellowish red (MCC 5YR4/6) to strong brown (MCC 7.5YR4/6). The soil was non-effervescent when tested with 3% HCl.

Within this horizon many soft nodular aggregates of iron hydroxides occurred of 3 to 5 cm in diameter (see sample 4713/06). The soil and the nodules were moderately magnetic.
Microscopic description: -
Identified mineral phases: -
Chemical composition:

Fe_2O_3	27.10
SiO_2	64.20
Al_2O_3	2,82
CaO	0.40
MnO	0.18
TiO_2	0.17
MgO	0.40
Na_2O	0.02
P_2O_5	0.09
Total	95.39
LOI 1050°C	4.80
	wt%

Ba	467
Cr	52
Sr	31
V	157
Y	52
Zr	702
As	n.d.
Bi	n.d.
Cu	23
Ni	58
Pb	n.d.
Zn	21
Sb	20
S	649
	ppm

Mineralogical composition from XRD: -
Interpretation: Soil from a plinthic horizon, not suitable for bloomery smelting.

Lab.-Number: DBM 4717/06
Site catalogue number: 4
Site name: N99/21
Unit: 75/14
Quadrant: d
Level: 52
Object: Slag
Size: 3.0 x 2.2 x 1.8 cm, complete.
Weight: 10 g
Illustrations: -
Methods of analyses: MD, PTS, ICP-OES
Magnetism: Strongly magnetic.
Macroscopic description: The exterior of the specimen was brownish medium gray. In cross section it was dark gray. The shape of the slag was amorphous. A hematitic cooling skin formed on the exterior of the slag in some pores. It cooled down in a sand bed. The density was low and the pumice-like texture showed minute to small roundish and round pores. The sample was strongly corroded and many sand grains and small slag nodules were trapped in the coat of rust.
Microscopic description: In cross section the sample revealed an inhomogeneous layered and conglomerated structure of a fayalitic slag with high wustite concentrations and compositional variations. Wustite crystallized first within the sample and appeared as dense crowded agglomerations of granular crystals. The main slag mass consisted of a glassy fayalite/wustite eutectic. Towards the outer margin of the sample, some blocky fayalites became separated from the eutectic. Some areas of the sample consisted only of the solidified fayalite/wustite eutectic. In some sections, fine columnar fayalites developed in a glassy matrix, and they occurred together with new silica-rich mineral phases generated by a number of strongly altered quartz grains which were exposed to thermal stress and formed new phases.
In sections low of wustite, coral-like, labyrinthine and compacted structures of iron hydroxides suggested that the sample contained some metallic iron. These bloom structures were associated with the aforementioned small fayalites and altered quartz. Also, this part of the sample contained a high amount of powdery fuel or fuel ashes.
The slag was highly porous and pumice like. A cooling skin formed along one side of the sample and consisted of magnetite, which had been reduced to wustite. A rim of sand grains adhered to the sample in a matrix of iron hydroxides.
Identified mineral phases: Fayalite, wustite, goethite, metallic iron, magnetite, quartz
Chemical composition:

Fe_2O_3	27.10
SiO_2	64.20
Al_2O_3	2,82
CaO	0.40
MnO	0.18
TiO_2	0.17
MgO	0.40
Na_2O	0.02
P_2O_5	0.09
Total	95.39
LOI 1050°C	4.80
	wt%

Ba	467
Cr	52
Sr	31
V	157
Y	52
Zr	702
As	n.d.
Bi	n.d.
Cu	23
Ni	58
Pb	n.d.
Zn	21
Sb	20
S	649
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Early Ironworking Groups
Interpretation: This was a heterogeneous refining slag, which formed under reducing conditions and high temperatures. The compact patterns of the wustite together with the overall high content of FeO suggested that this slag formed during advanced refining activities. The corroded structures indicated bloom inclusions that corroded later. The quartz inclusions might have served as a flux.

Lab.-Number: DBM 4718/06
Site catalogue number: 4
Site name: N99/21
Unit: 75/14
Quadrant: c
Level: 12
Object: Slag
Size: 6.7 x 5.4 x 3.9 cm, complete.
Weight: 10 g
Illustrations: -
Methods of analyses: MD, PTS, ICP-OES
Magnetism: Weakly magnetic.
Macroscopic description: The exterior of the specimen was brownish medium gray. In cross section it was dark gray. The shape of the slag was plano-convex and it cooled down in a sand bed. The surface was coarse and irregular. The density was very low and the pumice-like texture showed minute to medium-sized roundish to amorphous angular pores. Small oblong pores solidified in divergent order along the underside of the slag. The sample was slightly corroded.
Microscopic description: Thin section examination revealed the highly inhomogeneous, layered and conglomerated nature of the sample. It mainly consisted of wustite and fayalite yet the portion of iron oxides strongly varied throughout the sample. In zones of high iron oxide content, wustite crystallized as first phase and took the form of crowded granular to slightly dendritic crystal agglomerations. Some highly compacted wustite showed structures of tabular and amorphous hammerscale. In large parts of the sample, wustite was followed by blocky fayalites of varying size. Interstitial space could be filled with a fayalite/wustite eutectic, a leucite/wustite eutectic and sometimes leucite as final phase. Some secondary fayalites were present as well. Other zones revealed that the fayalite/wustite eutectic was followed by a fayalite/leucite eutectic. However, it was not always clear whether the eutectic compositions solidified one after another or whether they coexisted in the slag mass. Some zones of the sample consisted of a fayalite/wustite eutectic only. In zones of low iron oxide content, blocky fayalite crystals were the first phase to grow. They could be followed by an interstitial fayalite/leucite eutectic, by a glassy matrix or by a leucite/spinel eutectic.
Numerous quartz grains were present within the slag, which exhibited reaction to thermal stress in varying degree. Some transformed into new silica-rich mineral phases. Within the whole slag, many small angular and subangular grains of metallic iron were present and some of them were corroded.
Identified mineral phases: Fayalite, wustite, leucite, goethite, quartz, metallic iron, silica-rich mineral phases.

Chemical composition:

Fe_2O_3	76.90
SiO_2	21.48
Al_2O_3	0.44
CaO	1.19
MnO	0.08
TiO_2	0.03
MgO	0.19
Na_2O	n.d.
P_2O_5	n.d.
Total	100.32
	wt%

Ba	144
Cr	12
Sr	20
V	n.d
Y	n.d.
Zr	788
As	n.d.
Bi	n.d.
Cu	n.d.
Ni	n.d.
Pb	230
Zn	n.d.
Sb	33
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Late Ironworking Groups
Interpretation: This was a smithing hearth bottom from a final step in bloom consolidation. The plano-convex appearance and its layered texture with oblong pores radiating along the underside of the sample were indicative of smithing hearth bottoms. The slag formed under hot reducing conditions. The shape of the hammerscale lost in the slag bath suggested that mainly consolidated metal was hammered which still contained some primary slag (thick hammerscale flakes, amorphous hammerscale). The angular appearance of the small metal fragments also implied that the slag formed at an advanced stage of bloom processing as did the fractured quartz in the sample that was probably used as a fluxing agent. The phase composition was highly heterogeneous on a microscopic scale and mirrored its mixed sources such as smelting slag remnants, fuel ashes, hammerscale and fluxes.

Lab.-Number: DBM 4719/06
Site catalogue number: 4
Site name: N99/21
Unit: 70/45
Quadrant: a
Level: 53
Object: Slag
Size: 4.9 x 2.4 x 2.2 cm, incomplete.
Weight: 42 g
Illustrations: -
Methods of analyses: MD, PTS, ICP-OES
Magnetism: Non-magnetic.
Macroscopic description: The exterior of the specimen was grayish medium brown. In cross section it was dark to medium gray. The shape of the slag was convex-convex. The upper side was irregular in

appearance. The slag cooled down in a sand bed and formed a sandy coat on the underside. The density was medium. The texture included small to medium-sized round pores up to 0.7 cm in diameter. Some powdery fuel was embedded in the sample. The slag was slightly corroded with some adhering sand.
Microscopic description: In thin section the sample revealed a layered structure and a changing iron oxide content. Wustite was the first phase to develop in the bottom layer and took the form of amorphous, sometimes crowded dendritic structures. Blocky fayalite crystals developed next in a poorly crystallized fayalite/wustite eutectic. When present, interstices were filled with glass. The middle layer of the sample consisted only of a fayalite/wustite eutectic with slightly columnar crystal growth. The upper layer mainly consisted of fayalite, which grew as large, sometimes skeletal, blocky crystals. In some sections, dendritic wustite developed after the fayalite. Interstitial space was filled with a fayalite/leucite eutectic.
Only a few fragments of metallic iron occurred. They were strongly corroded and eluded further examination. A coat of sand grains was trapped in the slag along the underside of the sample. These grains were only slightly altered from thermal stress.
Identified mineral phases: Fayalite, wustite, glass, goethite, quartz, metallic iron
Chemical composition:

Fe_2O_3	70.80
SiO_2	28.34
Al_2O_3	0.75
CaO	0.62
MnO	0.09
TiO_2	0.04
MgO	0.10
Na_2O	0.01
P_2O_5	0.11
Total	100.87
	wt%

Ba	189
Cr	n.d.
Sr	22
V	59
Y	n.d.
Zr	932
As	n.d.
Bi	n.d.
Cu	48
Ni	12
Pb	n.d.
Zn	n.d.
Sb	26
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Early Ironworking Groups
Interpretation: This was a layered slag with varying content of iron oxides. It formed under hot reducing conditions and cooled down slowly. The irregular appearance of the wustite in the lower part of the sample suggested that the slag formed during an initial step of bloom refinement. The convex bottom of the specimen and its rim of unaltered sand grains trapped in the slag implied that this slag was drained into a pit. Also, the lack of abundant gromps can hint to the fact that this slag formed from material drained away from a refining furnace before much hammering and consolidation was carried out. It cooled down slowly under reducing conditions in a protected environment. Nevertheless, the sample was difficult to interpret.

Lab.-Number: DBM 4720/06
Site catalogue number: 4
Site name: N99/21
Unit: 70/45
Quadrant: c
Level: 34
Object: Slag
Size: 4.4 x 3.1 x 1.9 cm, complete.
Weight: 34 g
Illustrations: -
Methods of analyses: MD, PCS, XRD
Magnetism: Strongly to very strongly magnetic.
Macroscopic description: The exterior of the specimen was rusty brown and medium gray. In cross section it was greenish medium gray and metallic silver. The shape of the slag was amorphous-flat. The exterior was of an irregular, slightly granular structure. The density was medium to high and the texture showed small to medium-sized amorphous-roundish pores. Some powdery fuel and bits of charcoal were embedded in the sample. The slag was strongly corroded inside and outside and sand grains were trapped in the coat of rust.
Microscopic description: In cross section the sample consisted mainly of metallic iron and fayalite. The sample was lost for some unknown reasons and was only partially analyzed. Leucite and an acicular silica-rich phase crystallized first. Both phases were followed by acicular fayalite and a leucite/fayalite/spinel eutectic. The slag contained many quartz grains, which were strongly altered due to thermal stress. However, some of them were not fractured at all. About 60area% of the sample consisted of metallic iron in sponge-like labyrinthine to incipient fused structures. Only little fuel was present in the sample. The section had not been etched.
Identified mineral phases: Metallic iron, fayalite, silica-rich mineral phases, quartz, goethite, spinel.
Chemical composition: -
Mineralogical composition from XRD: DBM 5195/07, fayalite, magnetite, quartz, cristobalite, tridymite.
Absolute age: -
Occupation horizon: Early Ironworking Groups
Interpretation: The sample was probably a smelting slag with bloom. The microcrystalline nature of the fayalite implied that it was air-cooled. Sand was probably added to alter the slag's melting point and fluidity. It was discarded during primary smithing for unknown reasons. The structural similarity to sample

4721/06 implied that it might also have been formed from a flow of redundant smelting slag that was drained away during initial bloom refining.

Lab.-Number: DBM 4721/06
Site catalogue number: 4
Site name: N99/21
Unit: 70/45
Quadrant: c
Level: 43
Object: Slag
Size: 3.4 x 2.4 x 1.8 cm, complete.
Weight: 31 g
Illustrations: -
Methods of analyses: MD, PCS
Magnetism: Strongly magnetic.
Macroscopic description: The exterior of the specimen was rusty brown and medium gray. The sample was lost for unknown reasons and was only partially analyzed. In cross section it was greenish medium gray and metallic silver. The shape of the slag was amorphous. The exterior was of irregular granular structure. The density was medium and the texture contained minute to small amorphous-roundish and angular pores. The slag was strongly corroded inside and outside and sand grains were trapped in the coat of rust.
Microscopic description: In cross section the sample consisted mainly of metallic iron, fayalite, a silica-rich dark phase and goethite. The silica-rich dark gray phase seemed to have been leucite and crystallized first before microcrystalline acicular to lath-like fayalite developed. A glassy matrix solidified in interstices. Only little wustite was present in the sample and took the form of strongly compacted tabular and amorphous hammerscale inclusions. Metallic iron appeared in sponge-like labyrinthine structures and in incipient fused condition. It was strongly corroded. The sample contained sand grains which strongly reacted under thermal stress and formed unidentified new dark-gray silica-rich mineral phases.
Identified mineral phases: Leucite (possibly), fayalite, metallic iron, goethite, wustite, glass, silica-rich mineral phases.
Chemical composition: -
Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Early Ironworking Groups
Interpretation: This was a slag from advanced bloom refining because it contained tabular hammerscale and bloom fragments. The slag composition indicated hot reducing conditions in a refining furnace and the acicular nature of the fayalite implied that the slag was air-cooled. The numerous reacted sand grains (quartz) can be seen as fluxing agent used for compacting and welding a semi-consolidated bloom.

Lab.-Number: DBM 4722/06
Site catalogue number: 16
Site name: N96/08-1
Unit: -
Quadrant:
Level: Surface
Object: Slag
Size: 16.7 x 12.6 x 4.7 cm, complete.
Weight: 1017 g
Illustrations: -
Methods of analyses: MD, PCS, ICP-OES
Magnetism: Variable, weakly magnetic, strongly magnetic around iron inclusions.
Macroscopic description: The exterior of the specimen was red-brown. In cross section it was dark gray and metallic silver. The shape of the slag was plano-convex. The slag solidified in a sand bed with some bits of charcoal and a coat of slagged sand trapped on its underside. The upper face was irregular with large voids and a partially developed cooling skin. The density was medium to high and varied from layer to layer. The texture showed minute to large roundish and oblong pores up to 2.6 cm in diameter. The large voids were more often present in the upper part of the slag cake. Within the bottom layers of the slag, voids were smaller and oblong pores solidified in divergent order. Powdery fuel or fuel ashes, and charcoal bits were trapped in the slag. The sample was partially corroded. However, the 'rusty' color of the slag originated probably from the iron-rich reddish soil in which the specimen was found.
Microscopic description: In cross section the sample revealed an inhomogeneous layered structure of a fayalitic slag with inclusions of metallic iron. Wustite crystallized first within the slag and took the form of small regular dendritic crystals and crowded medium-sized agglomerations of granular and dendritic crystals. The wustite concentrations varied within the sample, and the compacted wustite zones were concentrated in the lower parts of the sample. The bottom layer consisted of wustite followed by large blocky fayalites in a glassy mass of a fayalite/wustite eutectic, which developed the beginnings of lath-like crystals. Interstitial space was filled with a glassy matrix. Around the blocky fayalites, some secondary wustite began to crystallize.
The upper part of the sample was more heterogeneous. The bottom layer graded into a zone of increasingly better developed columnar to lath-like crystals of the fayalite/wustite eutectic and some large blocky fayalites occurred. More interstitial space developed in this section than in the lower parts of the sample and it was filled with leucite, which was in some parts idiomorphic. It was followed by a wustite/leucite and a fayalite/leucite eutectic. In other parts of the upper layer, the wustite-fayalite crystal succession was followed by a fayalite/wustite and a leucite/spinel eutectic. However, the dominant part of the sample consisted only of a fayalite/wustite eutectic.

The slag contained small angular fragments of compacted metallic iron. After etching with 3% Nital, the iron displayed a ferritic-pearlitic microstructure of strongly deformed grains with distorted grain boundaries. Much of the ferrite showed lines of deformation within the individual crystals. Some grains were in the process of recrystallization. The average carbon content was estimated at approximately 0.1 to 0.15wt% C and lower. Grain sizes of the ferrite polygons were estimated to range between ASTM 3 and 8 in zones of recrystallization. The pores of the compacted metallic parts were irregular and angular in shape and some were flattened. The whole sample contained numerous prills of eutectic and hypereutectic cast iron consisting of ledeburite and varying volume fractions of secondary and primary cementite. Their occurrence indicated working temperatures above 1153 °C, a strongly reducing atmosphere and enough time for the high carburization of the reduced iron. The pieces of metal sank down to the bottom of the refining furnace because they had a higher specific weight than the slag. Some of the metallic iron was corroded.

Identified mineral phases: Fayalite, wustite, leucite, metallic iron (ferrite, pearlite, ledeburite, cementite), goethite, spinel, quartz, glass.

Chemical composition:

Fe_2O_3	77.00
SiO_2	19.71
Al_2O_3	1.01
CaO	0.56
MnO	0.09
TiO_2	0.04
MgO	0.14
Na_2O	n.d.
P_2O_5	0.13
Total	98.68
	wt%

Ba	68
Cr	18
Sr	24
V	627
Y	42
Zr	1002
As	n.d.
Bi	n.d.
Cu	55
Ni	23
Pb	n.d.
Zn	n.d.
Sb	17
	ppm

Mineralogical composition from XRD: -

Absolute age: -

Occupation horizon: Undated, probably Late Ironworking Groups

Interpretation: This was a smithing hearth bottom from advanced primary smithing. The overall plano-convex morphology, together with its layered structure and oblong pores in divergent order along the underside were indicative of smithing slags. Moreover, the layered nature suggested several events of heating under which the slag cake formed and so too did the highly varying fayalite/wustite/leucite ratio throughout the sample. The ironworkers processed a low carbon bloom and the pore and grain deformation of the latter implied that the bloom had already been compacted and extensively hammered (cold-worked) before it was lost in the slag bath. The slag must have been liquid to allow the iron fragments to sink down to the bottom of the refining furnace. Liquidus temperatures were probably low due to the high leucite content in the slag. The prills of cast iron, which formed during primary smithing within the slag, provided evidence of high temperatures within the furnace and enough time for the iron to dissolve a high amount of carbon under strongly reducing conditions.

Lab.-Number: DBM 4723/06

Site catalogue number: 16

Site name: N06/08

Unit: -

Quadrant: -

Level: -

Object: Iron ore

Size: -

Weight: 125 g

Illustrations: -

Methods of analyses: MD, ICP-OES, XRD

Magnetism: Non-magnetic.

Macroscopic description: This was a sample of a pisolitic ferricrete. The crust consisted of small pisolites of 0.3 to 1 cm in diameter, mixed with some quartz grains of the same size. The pisolites were hard, sandy and a very dark grayish brown (MCC 10YR3/2). The streak was pale yellowish brown. The pisolites were cemented by a strong brown (MCC 7.5YR5/8) ferrous matrix.

Microscopic description: -

Identified mineral phases: -

Chemical composition:

Fe_2O_3	43.90
SiO_2	45.18
Al_2O_3	3.01
CaO	0.12
MnO	0.10
TiO_2	0.12
MgO	0.17
Na_2O	n.d.
P_2O_5	0.06
Total	92.65
LOI 1050°C	7.27
	wt%

Ba	159
Cr	62
Sr	n.d.
V	1648
Y	15
Zr	688
As	n.d.
Bi	n.d.
Cu	44
Ni	22
Pb	n.d.
Zn	16
Sb	15
S	n.d.
	ppm

Mineralogical composition from XRD: DBM 5196/07: Goethite, quartz.

Interpretation: Pisolitic ferricrete, suitable for bloomery smelting only with beneficiation.

Lab.-Number: DBM 4724/06
Site catalogue number: 17
Site name: N96/05-1
Unit: -
Quadrant: -
Level: -
Object: Iron ore
Size: -
Weight: 65.2 g
Illustrations: -
Methods of analyses: MD, ICP-OES, XRD
Magnetism: Non-magnetic.
Macroscopic description: This was a sample of pisolitic ferricrete which cropped out at the site (see soil description Site Catalogue No. 17). The crust consisted of small pisolites, 0.3 to 0.6 cm in diameter, mixed with some quartz grains of the same size. They were cemented by a strong brown (MCC 7.5YR5/8) ferrous matrix. The pisolites were sandy, hard and black (MCC 2.5Y2.5/1). The streak was pale grayish brown. Space between the pisolites was filled with sand grains.
Microscopic description: -
Identified mineral phases: -
Chemical composition: (see also sample 5205/07)

Fe_2O_3	29.30
SiO_2	50.33
Al_2O_3	4.40
CaO	0.11
MnO	8.95
TiO_2	0.15
MgO	0.19
Na_2O	n.d.
P_2O_5	0.05
Total	93.48
LOI 1050°C	7.11
	wt%

Ba	10380
Cr	199
Sr	38
V	1389
Y	29
Zr	676
As	n.d.
Bi	n.d.
Cu	30
Ni	18
Pb	n.d.
Zn	n.d.
Sb	19
S	n.d.
	ppm

Mineralogical composition from XRD: DBM 5199/07: Goethite, quartz.
Interpretation: Pisolitic ferricrete, suitable for bloomery smelting only with beneficiation.

Lab.-Number: DBM 4725/06
Site catalogue number: 17
Site name: N06/09
Unit: -
Quadrant: -
Level: -
Object: Iron ore
Size: -
Weight: 357.2 g
Illustrations: Figure 172
Methods of analyses: MD, PTS, ICP-OES
Magnetism: Non-magnetic
Macroscopic description: This sample originated from strongly weathered very hard ferruginous sandstone of varying grain size. It contained banded zones of iron hydroxides enrichments. The colors ranged from yellowish brown (MCC 10YR5/6) to dark gray (MCC 10YR4/1) in zones rich in iron hydroxides. The streak was pale yellow.
Microscopic description: In thin section the sample consisted of sand varying in grain fraction (mainly quartz), which was cemented by a goethitic matrix with colloform growth banding. Some subangular grains of hematite were embedded in the matrix together with some unspecific organic inclusions.
Identified mineral phases: -
Chemical composition:

Fe_2O_3	25.70
SiO_2	67.10
Al_2O_3	1.39
CaO	0.07
MnO	0.05
TiO_2	0.08
MgO	0.07
Na_2O	n.d.
P_2O_5	0.02
Total	94.48
LOI 1050°C	4.65
	wt%

Ba	60
Cr	204
Sr	n.d.
V	845
Y	13
Zr	554
As	n.d.
Bi	n.d.
Cu	36
Ni	24
Pb	n.d.
Zn	29
Sb	25
S	n.d.
	ppm

Mineralogical composition from XRD: -
Interpretation: Ferruginous sandstone, possible parent rock of the residual weathering profiles along the river.

Lab.-Number: DBM 4726/06
Site catalogue number: 17
Site name: N06/09
Unit: -
Quadrant: -
Level: -
Object: Iron ore
Size: -
Weight: 352.5 g
Illustrations: Figure 172
Methods of analyses: MD, PTS, ICP-OES, XRD
Magnetism: Non-magnetic.
Macroscopic description: This was a large hard single ferruginous pisolite of approximately 10 cm in diameter. It was blackish to dark red (MCC 10R3/4 to 10R3/6). The streak was a strong red.
Microscopic description: DBM 4401/07: In thin section

the sample consisted of sand grains (mainly quartz) which were cemented by depositional successions of alternating ferrous or siliceous matrices. The ferrous matrix consisted of granular aggregates of iron oxides of varying concentrations. In some areas the structure was in some form granular, in others the oxides segregated in a layered and sometimes concentric formation of growth bands. The ratio of the siliceous to the ferrous matrix varied within the sample. In some zones granular microaggregates of ferrous-siliceous composition were cemented by a matrix of iron oxides.

Identified mineral phases: -

Chemical composition:

Fe_2O_3	40.06
SiO_2	54.07
Al_2O_3	1.95
CaO	0.16
MnO	0.32
TiO_2	0.08
MgO	0.33
Na_2O	0.01
P_2O_5	0.08
Total	97.07
LOI 1050°C	-
	wt%

Ba	768
Cr	79
Sr	14
V	1764
Y	25
Zr	520
As	n.d.
Bi	n.d.
Cu	40
Ni	47
Pb	n.d.
Zn	34
Sb	11
S	n.d.
	ppm

Mineralogical composition from XRD: DBM 5197/07: Hematite, quartz.

Interpretation: Ferruginous pisolite, suitable for bloomery smelting only with beneficiation.

Lab.-Number: DBM 4727/06

Site catalogue number: 21

Site name: N98/44

Unit: -

Quadrant: -

Level: Surface

Object: Slag

Size: 11.1 x 8.7 x 3.6 cm, incomplete.

Weight: 315 g

Illustrations: -

Methods of analyses: MD, PCS, ICP-OES

Magnetism: Variable, magnetic surface skin, very strongly magnetic around inclusions of elemental iron, most of the slag was only very weakly magnetic. Macroscopic description: The exterior of the slag lump was of medium gray to reddish brown and the interior was blackish to blackish gray and metallic silver. The slag was plano-convex in shape and it solidified in a charcoal bed leaving many impressions of fuel lumps on the underside. Small flow structures also formed on the underside. A cooling skin was present on the upper side of the slag. The texture was of medium to high density and showed minute to medium-sized round and roundish pores up to a diameter of 0.8 cm. Minute oblong pores occurred in divergent order relative to the underside. Powdery fuel and some bits of charcoal were trapped in the specimen. The exterior of the slag was only minimally corroded and only a few quartz grains adhered to the sample due to corrosion.

Microscopic description: In cross section the sample revealed a layered and conglomerated structure. Wustite crystallized first within the sample and appeared as crowded and compacted agglomerations of granular to dendritic medium-sized crystals. Some wustite exhibited tabular and irregular structures of hammerscale. Large blocky fayalites developed in a mass of an amorphous to columnar and lath-like crystallized eutectic of fayalite and wustite. In some areas, interstices did not develop at all. In other areas, interstices were filled with leucite in a glassy groundmass, or, leucite was in eutectic intergrowth with fayalite and/or wustite. In those interstices that were filled only with a glassy groundmass, secondary fayalites and wustite occurred. Also, around the blocky fayalites, some secondary wustite began to crystallize. Large pieces of compacted metallic iron were present in the sample. These pieces were remarkably strongly interspersed with powdery fuel or fuel ashes. Furthermore, the whole sample contained small prills of metallic iron, which were obviously reduced from wustite within the slag itself. After etching with 3% Nital, the sample revealed pieces of metal ranging from low carbon to high carbon hypereutectoid steel. The low carbon steel took the form of irregular polygonal to lath-like ferrite grains with grain boundary cementite and the beginnings of pearlite formation in interstices. The carbon content ranged from 0.02 to 0.03wt%. The ferrite grains were in parts deformed and showed some slip bands, though in other sections the microstructure was recrystallized. The grain sizes ranged from ASTM 1 to 7. In some pieces of metal, the low carbon steel microstructure gradually changed into a eutectoid high carbon steel structure of pearlite. Additionally, lumps of hypereutectoid steel occurred showing a microstructure of pearlite with secondary cementite indicating carburization between 1.1 and 1.5wt% C. The metallic lumps contained round to oval pores and inclusions. The larger pieces of elemental iron collected at the bottom of the refining furnace because they descended through the liquid slag. Only a few sand grains were present in the material along the outer margin of the sample. They were only slightly exposed to thermal stress.

Identified mineral phases: Fayalite, wustite, leucite, ferrite, pearlite, goethite, glass, quartz.

Chemical composition:

Fe_2O_3	77.35
SiO_2	23.66
Al_2O_3	0.75
CaO	0.35
MnO	0.09
TiO_2	0.03
MgO	0.18
Na_2O	n.d.
P_2O_5	0.08
Total	102.48
	wt%

Ba	42
Cr	27
Sr	16
V	835
Y	30
Zr	970
As	n.d.
Bi	n.d.
Cu	58
Ni	n.d.
Pb	n.d.
Zn	11
Sb	32
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Undated, probably Late Ironworking Groups
Interpretation: This was a smithing hearth bottom from advanced and final refining activities. It displayed a plano-convex morphology and oblong pores in divergent order along the underside of the slag cake. The high amount of fuel alongside the metallic iron found in the slag suggested that the ironworkers possibly carburized the wrought iron to high carbon steel. However, the hypereutectoid steel was too hard to be forged. Grain deformation and slip bands implied cold working and hammering to consolidate the bloom. The composition of the whole sample evidenced strongly reducing conditions and temperatures comparable to ones found during smelting operations. The melting point of the slag was probably low due to the high content of leucite. The small metal lumps were probably lost in the slag bath during refining.

Lab.-Number: DBM 4728/06
Site catalogue number: 21
Site name: N98/44
Unit: -
Quadrant: -
Level: -
Object: Iron ore
Size: -
Weight: 69.4 g
Illustrations: -
Methods of analyses: MD, ICP-OES
Magnetism: Non magnetic.
Macroscopic description: This sample originated from a sandstone layer, which displayed varying degrees of chemical weathering. It consisted of a hard silicified part poor in iron oxides and a slightly hard, sandy ferruginous part. The latter was red in color (MCC 10R4/8). It was non-effervescent when tested with 3% HCI.
Microscopic description: -
Identified mineral phases: -
Chemical composition:

Fe_2O_3	4.07
SiO_2	92.60
Al_2O_3	1.19
CaO	0.06
MnO	0.24
TiO_2	0.09
MgO	0.25
Na_2O	0.02
P_2O_5	0.02
Total	98.25
LOI 1050°C	1.48
	wt%

Ba	1082
Cr	n.d.
Sr	15
V	173
Y	n.d.
Zr	6.19
As	n.d.
Bi	n.d.
Cu	n.d.
Ni	28
Pb	n.d.
Zn	24
Sb	19
S	643
	ppm

Mineralogical composition from XRD: -
Interpretation: Ferruginous sandstone, possible parent rock of the residual weathering profiles along the river.

Lab.-Number: DBM 4729/06
Site catalogue number: 22
Site name: N98/45
Unit: -
Quadrant: -
Level: -
Object: Iron ore
Size: -
Weight: 16.7 g
Illustrations: -
Methods of analyses: MD, ICP-OES
Magnetism: Non-magnetic.
Macroscopic description: This sample originated from soft ferruginous sandstone. The color of the sandstone ranged from dusky red (MCC 2.5YR4/4) to dark red (MCC 2.5YR4/6). The streak was pale red.
Microscopic description: -
Identified mineral phases: -
Chemical composition:

Fe_2O_3	12.00
SiO_2	88.80
Al_2O_3	1.17
CaO	0.11
MnO	0.03
TiO_2	0.08
MgO	0.34
	wt%

Ba	110
Cr	n.d.
Sr	14
V	206
Y	n.d.
Zr	342
As	**n.d.**
	ppm

Na_2O	n.d.
P_2O_5	n.d.
Total	98.52
LOI 1050°C	1.43
	wt%

Bi	n.d.
Cu	16
Ni	13
Pb	228
Zn	n.d.
Sb	14
S	222
	ppm

Mineralogical composition from XRD: -
Interpretation: Ferruginous sandstone, possible parent rock of the residual weathering profiles along the river.

Lab.-Number: DBM 4730/06
Site catalogue number: 25
Site name: N98/46
Unit: -
Quadrant: -
Level: -
Object: Iron ore
Size: -
Weight: 168 g
Illustrations: -
Methods of analyses: MD, ICP-OES
Magnetism: Non-magnetic.
Macroscopic description: This sample originated from a pisolitic ferricrete (see soil description Site Catalogue No. 25). The sample consisted of small pisolites of about 0.3 to 1 cm in diameter. They were cemented by a ferrous agent. The whole sample was hard and silicified. The color was of dark brown (MCC 10YR3/3) and black (MCC 10YR2/1).
Microscopic description: -
Identified mineral phases: -
Chemical composition:

Fe_2O_3	11.30
SiO_2	79.70
Al_2O_3	2.44
CaO	0.14
MnO	3.41
TiO_2	0.11
MgO	0.31
Na_2O	0.04
P_2O_5	n.d.
Total	97.45
LOI 1050°C	2.98
	wt%

Ba	3334
Cr	58
Sr	24
V	300
Y	n.d.
Zr	339
As	21
Bi	n.d.
Cu	10
Ni	37
Pb	n.d.
Zn	n.d.
Sb	22
S	294
	ppm

Mineralogical composition from XRD: -
Interpretation: Highly siliceous pisolitic ferricrete, not suitable for bloomery smelting.

Lab.-Number: DBM 4731/06
Site catalogue number: 6
Site name: N06/01
Unit: -
Quadrant: -
Level: -
Object: Iron ore
Size: -
Weight: 155 g
Illustrations: Figure 172
Methods of analyses: MD, PTS, ICP-OES, XRD
Magnetism: Non-magnetic
Macroscopic description: This sample originated from a pisolitic ferricrete (see soil description section 2.6). It consisted of hard pisolites of sizes in the region of 0.4 to 1.7 cm in diameter. They were porous to dense in texture and black (MCC 10YR2/1). The pisolites were cemented by a yellowish red (MCC 5YR4/6) ferrous matrix. The streak was pale yellow.
Microscopic description: DBM 4399/07: In thin section the sample consisted of sand grains which were cemented in a matrix of goethite. The latter consisted of an accumulation of very fine-grained oxides, which formed bands of varying density. Some of the oxides deposited sequentially in concentric structures. The sample contained some subangular hematite grains and unspecific organic material together with cellular root channel structures, which were replaced by iron hydroxides.
Identified mineral phases: -
Chemical composition:

Fe_2O_3	48.10
SiO_2	42.54
Al_2O_3	2.12
CaO	0.11
MnO	0.35
TiO_2	0.12
MgO	0.04
Na_2O	n.d.
P_2O_5	0.09
Total	91.62
LOI 1050°C	13.30
	wt%

Ba	157
Cr	59
Sr	20
V	1052
Y	29
Zr	818
As	n.d.
Bi	4.86
Cu	173
Ni	495
Pb	10
Zn	n.d.
Sb	n.d.
S	n.d.
	ppm

Mineralogical composition from XRD: DBM 5198/07, goethite, quartz.
Interpretation: Pisolitic ferricrete, suitable for bloomery smelting only with beneficiation or by using fluxes.

Lab.-Number: DBM 5188/07
Site catalogue number: 32
Site name: N07/03
Unit: -
Quadrant: -
Level: -
Object: Iron ore
Size: -
Weight: 231.7 g
Illustrations: -
Methods of analyses: MD, ICP-OES, XRD
Magnetism: Non-magnetic.
Macroscopic description: Sample 5188/07 was an upgraded version of Sample 5202/07 where only selected iron-rich particles became analyzed. This was a test to find out whether there would be a considerable increase in the iron oxide content by manual selection.
Microscopic description: -
Identified mineral phases: -
Chemical composition: (compare to DBM 5202/07)

Fe_2O_3	75.3
SiO_2	15.20
Al_2O_3	0.85
CaO	0.01
MnO	0.11
TiO_2	0.03
MgO	0.04
Na_2O	n.d.
P_2O_5	0.09
Total	91.62
LOI 1050°C	12.30
	wt%

Ba	270
Cr	139
Sr	n.d.
V	206
Y	n.d.
Zr	n.d.
As	n.d.
Bi	486
Cu	173
Ni	495
Pb	10
Zn	n.d.
Sb	n.d.
S	n.d.
	ppm

Mineralogical composition from XRD: (s. DBM 5202/07), goethite.
Interpretation: Plinthic hardpan, iron ore suitable for bloomery smelting.

Lab.-Number: DBM 5189/07
Site catalogue number: 32
Site name: N07/03
Unit: -
Quadrant: -
Level: Experimental smelt
Object: Slag
Size: -
Weight: -
Illustrations: -
Methods of analyses: MD, ICP-OES
Magnetism: Non-magnetic.
Macroscopic description:
Microscopic description: -
Identified mineral phases: -
Chemical composition:

Fe_2O_3	60.10
SiO_2	38.50
Al_2O_3	0.69
CaO	0.10
MnO	0.80
TiO_2	0.04
MgO	0.24
Na_2O	n.d.
P_2O_5	0.08
Total	100.50
	wt%

Ba	1815
Cr	n.d.
Sr	38
V	n.d.
Y	-
Zr	-
As	n.d.
Bi	464
Cu	163
Ni	90
Pb	140
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Modern
Interpretation: This was a sample of furnace slag from an experimental smelt at Kauti. It was taken for comparison with the archaeological material from Kauti.

Lab.-Number: DBM 5190/07
Site catalogue number: 32
Site name: N07/02-1
Unit: -
Quadrant: -
Level: Surface
Object: Slag
Size: 12.4 x 8.7 x 3.7 cm, incomplete.
Weight: 532.1 g
Illustrations: -
Methods of analyses: MD, ICP-OES
Magnetism: Variable, mostly non-magnetic, some parts were very strongly magnetic.
Macroscopic description: The exterior of the specimen was a rusty brown, and the interior was medium to dark gray. The shape of the slag was tabular. The structure was irregular and sponge-like with large open voids. Towards one zone on the underside of the slag, small granular unreduced bits of iron ore of about 2 to 3 mm in diameter occurred. The slag cooled down in a charcoal bed and the underside showed large imprints of fuel. The overall density was medium and the texture had large roundish pores up to 2.5 cm in diameter. In some places, macrocrystalline crystals were present at the surface. Some sand was trapped in the layer of corrosion.
Microscopic description: -
Identified mineral phases: -

Chemical composition: -

Fe_2O_3	76.60
SiO_2	22.10
Al_2O_3	0.36
CaO	0.05
MnO	0.08
TiO_2	0.01
MgO	0.11
Na_2O	n.d.
P_2O_5	0.10
Total	99.40
	wt%

Ba	129
Cr	10
Sr	n.d.
V	10
Y	-
Zr	-
As	n.d.
Bi	521
Cu	229
Ni	51
Pb	170
Zn	n.d.
Sb	n.d.
	ppm

Mineralogical composition from XRD: -
Absolute age: -
Occupation horizon: Late Ironworking Groups
Interpretation: This was a furnace slag with unreacted ore. Magnetism indicated that it contained some bloom.

Lab.-Number: DBM 5201/07
Site catalogue number: 48
Site name: N07/04
Unit: -
Quadrant: -
Level: -
Object: Iron ore
Size: -
Weight: 107.5 g
Illustrations: -
Methods of analyses: MD, ICP-OES, XRD
Magnetism: Non-magnetic.
Macroscopic description: This was a sample of pisolitic ferricrete. The crust consisted of ferrous pisolites of sizes varying between 0.3 to 3 cm together with gypsum and silcrete nodules. Colors ranged from pale yellow (MCC 2.5Y8/3), strong brown (MCC 7.5YR4/6) to black (MCC 10YR2/1). The crust was cemented by a ferrous matrix. The streak was pale yellow.
Microscopic description: -
Identified mineral phases: -
Chemical composition:

Fe_2O_3	36.70
SiO_2	51.10
Al_2O_3	6.08
CaO	0.01
MnO	0.39
TiO_2	0.29
MgO	0.18
Na_2O	0.01
P_2O_5	0.12
Total	94.87
LOI 1050°C	6.99
	wt%

Ba	748
Cr	86
Sr	n.d.
V	219
Y	n.d.
Zr	n.d.
As	25
Bi	328
Cu	107
Ni	81
Pb	n.d.
Zn	n.d.
Sb	n.d.
S	n.d.
	ppm

Mineralogical composition from XRD: Goethite, muscovite, quartz.
Interpretation: Pisolitic ferricrete, not suitable for bloomery smelting.

Lab.-Number: DBM 5202/07
Site catalogue number: 32
Site name: N07/03
Unit: -
Quadrant: -
Level: -
Object: Iron ore
Size: -
Weight: 231.7 g
Illustrations: s. DBM 5188/07
Methods of analyses: MD, ICP-OES, XRD
Magnetism: In parts slightly magnetic.
Macroscopic description: This was a sample of a plinthic hardpan. It was an extremely hard crust of iron hydroxides of approximately 40 to 50 cm in thickness (see soil description section 2.32). It consisted of accumulated layers of iron hydroxide segregations 0.2 to 1.5 cm in thickness, which witnessed the climatic activities during its formation. The interspace between the individual layers varied in thickness and it was filled with sand. In other parts, the crust showed a rather vesicular sponge-like structure. Colors ranged from black (MCC 5YR2.5/1) to strong brown (MCC 7.5YR5/8). The sample was non-calcareous when tested with 3% HCI. Some blackish parts were slightly magnetic.
Microscopic description: -
Identified mineral phases: -
Chemical composition: (Compare to 5188/07)

Fe_2O_3	73.40
SiO_2	18.16
Al_2O_3	0.66
CaO	0.01
MnO	0.32
TiO_2	0.02
MgO	0.04
	wt%

Ba	695
Cr	n.d.
Sr	n.d.
V	10
Y	n.d.
Zr	n.d.
As	n.d.
Bi	478
	ppm

Na_2O	n.d.
P_2O_5	0.07
Total	92.68
LOI 1050°C	11.80
	wt%

Cu	176
Ni	58
Pb	13
Zn	n.d.
Sb	n.d.
S	n.d.
	ppm

Mineralogical composition from XRD: Goethite.
Absolute age: -
Occupation horizon: -
Interpretation Plinthic hardpan, iron ore suitable for bloomery smelting.

Lab.-Number: DBM 5203/07
Site catalogue number: 33
Site name: N07/07
Unit: -
Quadrant: -
Level: -
Object: Iron ore
Size: -
Weight: 140 g
Illustrations: -
Methods of analyses: MD, ICP-OES, XRD
Magnetism: Non-magnetic.
Macroscopic description: This was a sample of plinthic nodular aggregates of iron hydroxides (iron stone), which occurred in the upper soil horizon of the site (see soil description section 2.33). They were dry, hard and vesicular. They were of strong brown (MCC 7.5YR5/8) color and non-effervescent when tested with 3% HCl.
Microscopic description: -
Identified mineral phases: See below
Chemical composition:

Fe_2O_3	66.70
SiO_2	21.32
Al_2O_3	0.06
CaO	0.22
MnO	0.86
TiO_2	0.01
MgO	0.22
Na_2O	n.d.
P_2O_5	0.04
Total	89.41
LOI 1050°C	13.90
	wt%

Ba	501
Cr	n.d.
Sr	38
V	10
Y	n.d.
Zr	n.d.
As	13
Bi	452
Cu	16
Ni	68
Pb	15
Zn	n.d.
Sb	n.d.
S	n.d.
	ppm

Mineralogical composition from XRD: Goethite, siderite, quartz.
Absolute age: -
Occupation horizon: -
Interpretation: Iron stone, suitable for smelting.

Lab.-Number: DBM 5205/07
Site catalogue number: 17
Site name: N96/05-1
Unit: -
Quadrant: -
Level: -
Object: Iron ore
Size: -
Weight: 65.2 g
Illustrations: -
Methods of analyses: MD, ICP-OES, XRD
Magnetism: s. DBM 4724/06
Macroscopic description: See sample 4724/06. Sample 5205/07 was an upgraded version of sample 4724/06 with selected particles rich in iron oxides. This was a test to find out whether there would be a considerable increase in the iron hydroxide content by manual selection.
Microscopic description: -
Identified mineral phases: -
Chemical composition: (Compare to 4724/06)

Fe_2O_3	73.40
SiO_2	18.16
Al_2O_3	0.66
CaO	0.01
MnO	0.32
TiO_2	0.02
MgO	0.04
Na_2O	n.d.
P_2O_5	0.07
Total	92.68
LOI 1050°C	11.80
	wt%

Ba	695
Cr	n.d.
Sr	n.d.
V	10
Y	n.d.
Zr	n.d.
As	n.d.
Bi	478
Cu	176
Ni	58
Pb	13
Zn	n.d.
Sb	n.d.
S	n.d.
	ppm

Mineralogical composition from XRD: s. 5199/07, goethite, quartz
Absolute age: -
Occupation horizon: -
Interpretation: Pisolitic ferricrete, suitable for bloomery smelting only with beneficiation.

Appendix 2: Oral History Interviews

Appendix 2.1 Iron production at Vungu-Vungu narrated by Petrus Kudumo Kampanzela (called Mukisi Koro)

This interview was held in four parts on August 14 and 23 in 2006, July 31 and October 4 in 2007 in Kayengona (Rundu Rural East Constituency) by Eileen Kose. Michael Hakusembe (Kapako) assisted and translated the interview. The entire interview is recorded on videotape. This interview comprises questioning and a record of four hours of forging. While watching him at the forge, I continued my interview and asked again questions on issues that I did not understand previously. In 2007, we visited him again in order to get more information on the songs that the people used to sing while they were operating the bellows.

P. K. Kampanzela lives among the Shambyu and his uncle practiced iron production in this area, yet many technological and cultural features differ from those that are found among the Shambyu iron-workers of the Vakwandjadi clan as described in the interviews with Modestus Kashera and Harupe Paulus Haididira Kaputungu.

Petrus Kudumo Kampanzela was born on February 22, 1927 in Tondoro. He is a Kwangali. He speaks Rugciriku, Rukwangali, Thimbukushu, and Oshiherero. He is a professional blacksmith,[380] potter, and healer. He grew up in Tondoro and settled in Vungu-Vungu when he was about 30 years old. He came under the rule of Maria Mwengere and lived there for about five years. He lived in Vungu-Vungu close to the archaeological site and had to move when people established the dairy farm there. At the time when he came to Vungu-Vungu there existed many homesteads at this location, perhaps about 10 of them. All of the inhabitants left because of the farm. He went to Kayengona, but he does not remember how old he was at this time. Later in his life, P. K. Kampanzela was the headman of Kayengona under the rule of Hompa Maria Mwengere. When he lived in Vungu-Vungu, he still saw people producing iron there. One of his uncles was a blacksmith and another uncle was a smelter in Kosawo and later in Vungu-Vungu. The latter moved to Vungu-Vungu earlier than he did and smelted at Vungu-Vungu. His father was a traditional healer. According to P. K. Kampanzela, the famous Vungu-Vungu tree was located behind (i.e. south of) the contemporary fence of the dairy farm (N06/06-1),[381] approximately 300 m east of the broad erosional slope where a lot of building rubble was recently dumped (Figure 106). According to his statement, the tuff bricks had been laying there forever. The old smelting site was located between the Vungu-Vungu tree and the erosional slope, approximately 10 m to 15 m east of the slope.[382] South of the tree, there was the former Hompa's palace. When he lived in Vungu-Vungu, there were about ten homesteads at this place. According to his statement, the smelting site was affected by flooding and there might have been some soil accumulating and now covering the old smelting site. P. K. Kampanzela remembers only two smelting sites. One was in Vungu-Vungu and one in M'pupo[383] in Angola. Chief Advisor Sikerere told him about another site at Ndonga in the Omatako Omuramba.[384]

2.1.1 Smelting site

People chose Vungu-Vungu to be a smelting site in honor of the Shambyu rulers. During that time, the Hompa still lived in Vungu-Vungu.[385] According to him, people manufactured iron in Vungu-Vungu since the time of Hompa Ndango.[386] People also

[380] Despite his age, he still manufactures tools. He told us that he still has to work in order to make a living. Otherwise his life would be hard. Usually, his son helps him out, but he was in Grootfontein at the time that we came for the interviews. During his main season of production (August to October), shortly before the rainy season starts in northern Namibia, he forges up to 4 axes or hoes per day. He produces about 28 to 30 axes and 23 to 24 hoes per year. The main season of production for axes is in August and September, the one for hoes in October. He also sells some knives, maybe 20 per year. His main income is from axes and hoes. In his society, there exist people who are skilled blacksmiths but only produce from time to time some tools for their own need.

[381] As far as we were able to relocate the place of the Vungu-Vungu tree, it must have been at about S17°58'05''/E19°51'15''.

[382] In this zone, we found big lumps of iron slag and charcoal concentrations.

[383] Here the interviewee referred to the Popa Falls of the Kwito River in southern Angola, approximately 40 km northeast of Vungu-Vungu.

[384] Here the interviewee referred to the smelting site of Kauti in the Ndonga Omuramba.

[385] Here he refers to Hompa Kapinga and Nyumba who lived in Vungu-Vungu in the late eighteenth and early nineteenth century (Fleisch & Möhlig, 2002, pp. 132-137).

[386] There is some contradiction in P. K. Kampanzela's statement with respect to when iron manufacturing started in this region. He was not sure if iron smelting started under the rule of Hompa Ndango or Mbambangandu. Mbambangandu I ruled from ~1874 until 1909 and lived in Mamono. Hompa Ndango was in power from 1915 until 1924 and lived in Kayengona (Fleisch & Möhlig, 2002, p. 163). Later, Hompa Mbambangandu II was in power from 1925 until 1948 and lived in Gove. His follower was Hompa Maria Mwengere between 1949 and 1987.

had been smelting at Gove under the rule of Hompa Mbambangandu II (Shimbangu). Hompa Mbambangandu still saw the smelting site of Vungu-Vungu. This was the time when his uncle was a smelter in Vungu-Vungu.
The smelters determined the place where the smelting site was laid out. If somebody owned a large homestead, he could lay out a smelting area there; however, the smelting zone was always outside of the homesteads. It comprised roughly 20 m² and was fenced with reed mats. People lived with their entire families in permanent habitation locations around the smelting site. P. K. Kampanzela does not remember the reason why the smelting zones were always outside of the homesteads. As long as people did not use this area, everybody was allowed to enter this location.

2.1.2 Ore and Mining

The ironworkers from Vungu-Vungu went collecting their ore at M'pupo in contemporary Angola, but they smelted in Vungu-Vungu. Some Nyemba who came to Namibia in order to trade their iron tools told them about the iron ore of M'pupo. M'pupo was a smelting site of the Nyemba people. It is located in an Omuramba (dry riverbed) about a one-day's walk [~ 40 km] from Vungu-Vungu. The Gciriku people never smelted at this location, they just collected ore in this region.
At the M'pupo sites people extracted stones [i.e. iron ore]. They did not collect red sands. These stones were found exposed at the surface; sometimes they were a bit below the surface. At this place, there are white stones, red stones and black stones. People collected the black stones of roundish or angular shape. The ironworkers collected stones of good quality only. Stones of good quality were very heavy.[387] People dug up the ore with digging sticks and removed the sand from the stones. Six to eight men from Vungu-Vungu went to collect iron ore at these sites. They transported pieces of ore as big as brick-sized in leather bags. All together, the men were on the trip for three days. One individual was able to carry one bag of ore. Depending on their need for iron, the ironworkers used four to ten bags of ore for one smelt. In case they needed more iron, the ironworkers went again collecting ore after the smelt, and smelted again. It was not allowed to take the stones to the village, but he did not remember the reason why. It was allowed for women to look at the stones and to touch these stones.

[387] We showed him the iron ore nodules and concretions from Dikundu, and he said that the iron ore that they preferred were heavier.

2.1.3 Charcoal

The charcoal for the smelt was made by the ironworkers or by some boys of the village. The charcoal was made in the bush, approximately a one-hour walk away from the smelting site, and was then brought to the pit. People used wood of the *mutundungu* (*Burkea Africana*, Wild Seringa) *mugoro* (*Terminalia sericea*, Silver Terminalia) and *mupako* (*Erythrophleum africanum*, Ambo Teak) trees because it lasted in the smelting process.

2.1.4 Smelting

Twelve to thirteen people were necessary to perform a smelt. People smelted in the winter season, sometimes two to three times a year. They smelted in circular pits with a flat bottom. These pits had an approximate diameter of one meter and were knee deep. The pits were dug with a digging stick and sometimes, the bottom of the pit was covered with a clay lining. People usually set up their smelting pits under a big tree where they found some shade. People used only one pit at the same time. The ironworkers put the charcoal and the ore in three or four alternating layers in the smelting pit. They started with a charcoal layer at the bottom, covered it with ore, and put again charcoal on top of the ore and so on. They added no other materials (such as a charm or medicine) to the batch. They did not close the pit for the smelt. The ironworkers smelted during the night, from sunset to dawn. Four people were in charge of one bellows during the smelt, which means that sixteen to seventeen people operated the four bellows throughout the night. If the stones became molten, the iron separated from the slag. The slag was at the bottom, the good quality iron was on top of it. The waste of the smelt was black; sometimes there were white ashes. People discarded the waste from the smelt in a short radius around the pit. The ironworkers used their smelting pit for one year or longer. Sometimes they protected it with a roof. If the smelting site was too polluted, they made a new pit. All together, the iron manufacturing process took two weeks starting from collecting the ore until the metal was melted.

2.1.5 Bellows

The ironworkers used four bellows and placed them around the pit. They needed four blowing pipes for one pit. The blowing pipes were made out of clay. The cups of the bellows were made out of wood of the *rupundu* (*Grewia flavescens*, Sandpaper Raisin) and *ukara* (*Pterocarpus angolensis*?) trees because it was easy to shape and resilient. The cups of the bellows were covered with hides of domestic animals or game; however, people never used elephant, rhino or hippopotamus hides because they were not flexible enough.[388] The sticks to operate the bellow were chest-high and allowed the ironworkers to work standing upright or sitting. Some of the bellows were decorated with a few carvings. The blacksmiths operate their bellows with different methods: Pumping both cups in the same rhythm produces a strong airflow, pumping the cups alternately produces a lighter airflow but is not as tiring for the ironworkers as the first method.

2.1.6 Iron

Two hours after the smelt, the ironworkers removed the iron with a stick. The iron was silvery in color. The iron was removed from the pit in several longish narrow pieces. There could have been thirty pieces or more of an approximate diameter of a reed stick and 10 cm to 15 cm in length. If the ironworkers recovered more than hundred pieces of bloom, it was considered a good smelt. If there were less than twenty or thirty pieces, it was considered a bad smelt. Raw iron of good quality was shiny, hard and heavy. Raw iron of poor quality was not shiny. It was brittle and light in weight. The raw iron was consolidated in a forge near the furnace, no more than 5 to 10 m away from it.

2.1.7 Rituals and taboos

During the time of the smelt, it was forbidden for [fertile] women to enter the smelting area. Men, small children of both sexes and elderly women were allowed to stay at the smelting site. Women were regarded as men after their menopause. The iron-workers stayed at the smelting site in traditional houses. They wore their habitual dress. The ironworkers were expected to stay at the smelting site until their work was done. Sometimes, they sent some boys for food; sometimes some elderly women came and brought them something to eat. Before the ironworkers started with the smelt, they slaughtered a goat or a cow in honor of their ancestors. They detached the heart of the animal and moved it around the smelting pit. They did so hoping that nobody would be injured during the smelt. The ironworkers were supposed to eat and to finish the meat of these animals at the smelting site. They were not allowed to take leftovers of this meat back home after the smelt. They threw the bones of these animals in the river in order not to become tired and sick during their work.

[388] Today, P. K. Kampanzela covers the cups of his bellows with fabric, which he keeps wet so that the air will be better compressed. It is difficult to get leather and hides these days. People cook and eat goatskins for instance. He too eats the skin of goats.

The ironworkers used to sing several songs while they were operating the bellows at the site[389]. These songs are called *kisi*.
First song:

NyaKasereke Ntungurume wazara kazara
komutwe, NyaKasekere

Second song:

Kumona maherekadi ayee (2x), kangere

Nimusumba kapi anitu ayee (2x), kangere

Nimwali kapi ani hompo aye (2x) kangere

When the ironworkers were done with their work, people brought a big barrel of beer. The ironworkers started drinking. They celebrated their successful smelt and that nobody was injured. If the smelt did not succeed, the ironworkers did not celebrate after work. An unsuccessful smelt was a sign that one of the ironworkers brought ill luck to the group because he probably had sexual intercourse with a woman during the preparation of the smelt. They tried to find out who was to blame for the failure through questioning among each other and because they knew who had been absent from the smelting site for a while. The punishment for the guilty ironworker was to pay a cow.

2.1.8 Forging and trading

The ironworkers refined blooms close to the smelting pit at a distance of 5 to 10 m. The workplaces of the blacksmiths are close to their homesteads at a specific place that they repeatedly used. They were afraid that women would cross the forge. If a woman crossed the forge, she would fall sick. If women are visiting the blacksmith's working place, they are not allowed to cross the forge and the bellow. If a woman crossed either of these things, she would get menstrual bleeding that would not stop, even if she were not at the time of her regular menstruation. People of the hospitals are not able to heal this sickness. Only traditional healers can. To heal an affected woman, the healer digs up a pit at sunset and puts some traditional medicine in the pit. The woman has to sit naked for two hours above the smoking medicine, and then she will be healed. The medicines that traditional healers use are special leaves of the Manketti tree (*Ricinodendron rautanenii*). Usually one may find small holes and depressions at such trees where some water collects. At these spots, the tree sprouts small twigs with leaves. These leaves are used for the treatment of women who had crossed the forge. Women are allowed to touch the bellows and the tools.

[389] The same songs are still sung by contemporary blacksmiths.

The actual problem is if they cross the bellows. Men were allowed to carry some fire from the forge to their homesteads in order to use it there.[390] If women used charcoal from the forge, they would get a headache. The smithy is always located at the same place. In this way, women may not become hurt involuntarily. A smithy is always located outside of the homestead because people did not want to put women in danger. In the past, the ironworkers used a big piece of raw iron as an anvil. The ironworkers manufactured their working hammers by digging a channel into the bottom of the smelting pit with the shape of a hammerhead in which the molten iron could flow. Blacksmiths used this piece of iron for forging. Sometimes, they simply used a big piece of raw iron as a hammer. Additionally, the blacksmiths equipment consists of a sharpening stone[391] and one or two bellows depending on the number of people who forge. In the past and sometimes still today, they use sticks in order to touch the hot iron items. They use the same type of wood for forging as they use for smelting. The waste of the forging process is black and thin like small leaves. The white pieces of the waste are ashes. The blacksmiths produce their charcoal in the bush where the tree species that they need are located. There the blacksmiths felt a tree cut it into smaller pieces and produce charcoal. They use three types of wood: mugoro (*Terminalia sericea*, Silver Terminalia), mutundungu (*Burkea Africana*, Wild Seringa), mupako (*Erythrophleum africanum*, Ambo Teak. They put soil on the burning wood if it burns red. They burn the wood for one day take the charcoal back home.

Blacksmiths forge(d) the following tools:[392]
Etemo: Hoe
Ekuwa:[393] Ax
Poko: Single-edged knife[394]
Rufuro: Double-edged knife
Egonga: Hunting spear
Ngumba: Arrowhead with a single wing
Ehewo: Double winged arrowhead
Nomoho: Fishing spear
Epowa: Fire strikers (flint and steel)
Blacksmiths never manufactured jewelry and cosmetic knives. The blacksmiths use varying types of wood for the handles of their axes and hoes: *mutumba* (*Combretum hereroense*, Kierieklapper), *mwege* (*Dichrostachys cinera*, Sicklebush), *mupupu* (*Combretum psidoides*, Bush Willow), *mugoro* (*Terminalia sericea*, Silver Terminalia, Yellow Wood, Vaalbush), *musu* (*Acacia erioloba*, Camel Thorn Tree). The shaft holes are burned into the handle with a heated fishing spear (*nomoho*). People cut the boughs in such a way that a crotch is part of the bough at one end. This is called *spara* 'face of the handle'. The head of the ax is made from this part of the tree. The best and strongest wood is mupupu (*Combretum psidoides*, Bush Willow) which is very hard. Other good quality woods are *mugoro* (*Terminalia sericea*, Silver Terminalia), and mwege (*Dichrostachys cinera*, Sicklebush). *Mwege*-wood is used to make bows.

The blacksmith sold their tools at their working places. There were no markets. They sold their tools to people of the neighboring villages but also to people from farther away including Nyemba, Kwangali, Shambyu and Hambukushu. Within their families and among close friends, tools and raw metal were given free. Friends and family members in turn provided the ironworkers with other things that they needed. In case iron items were sold to outsiders, they made sure that people from their neighborhood or region knew these outsiders. They never sold iron items to people whom nobody knew because the locals did not know what they would do with these items.
People exchanged their tools for the following items:
1 *Etemo* (hoe):[395]
2 chickens or 1 young goat, alternatively 12 kg mahangu.[396]
1 *Ekuwa* (ax):
2 chickens or one young goat, alternatively 12 kg mahangu.
1 knife: (either *poko* or *rufuro*):
2 chickens or 1 young goat alternatively 12 kg mahangu.
1 *Egonga* (Hunting spear):
1 cow, alternatively eight chickens, or three female goats together with one male goat, or 50 kg of mahangu. Spears were as valued as cows because people were able to kill wild animals with them.
1 *Nomoho* (Fishing spear): 2 chickens or 12 kg of mahangu.
P. K. Kampanzela does not remember the exchange rates for arrowheads anymore. The value of one cow would be three axes or hoes, five knifes or one spear. People gave iron tools free to San people because they were considered poor. Also, they got raw metal free

[390] It seems as if women could use charcoal or glow that was taken by a man to its homestead without getting harmed.
[391] These days P. K. Kampanzela sharpens his tools with a metal file.
[392] All names are given in Rukwangali.
[393] These days, blacksmiths use leaf springs (a flat piece of scrap metal measuring about 30 cm in length) from vehicle suspensions in order to forge an ax. They usually get their raw materials from car dealers and scrap metal merchants. They taper the metal piece at one edge first so that it may fit into a shaft hole later, then they taper the opposite site. Thereafter, they cut the piece in the middle and shape the cutting edges at the flat edges of the metal pieces.
[394] According to P. K. Kampanzela, *poko* is a Nyemba loanword.

[395] These days, a hoe without handle costs about 50 N$, with handle it costs about 70 N$.
[396] Pearl millet (*Pennisetum glaucum*).

so that they could forge some arrowheads. Sometimes the San people brought some berries and meat in return. Honey was given for corn, pottery was exchanged for meat.

2.1.9 Socio-cultural context

In the Shambyu society existed professional potters, carpenters, healers, smelter and blacksmiths. Smelters and blacksmiths were highly respected because they knew how to manufacture tools and where to find suitable ore. Both trades were respected in the same way. The ironworking trades could be learned from an outsider or from someone within the family. Ironworkers were not wealthier than other members of their society were. They kept livestock, they farmed and they hunted in order to make a living. Some blacksmiths were healers, but they were not able to do magic. The King was neither a smelter nor a blacksmith. There existed no specific marriage restrictions for smelters and blacksmiths. They were allowed to marry two or three women, as could any man within their society.

2.1.10 History

According to P. K. Kampanzela, in the past Kwangali, Mbunza, Gciriku, Shambyu and Nyemba knew how to produce iron. He does not know if there existed other groups who produced metal. According to his statement, San people were able to forge. They had developed this technology by themselves; however, they did not know how to smelt. P. K. Kampanzela does not remember who might have shown their ancestors how to produce iron and he does not know how long his people had been in the iron production. People stopped smelting when the white people came. When he was young, the mines of Tsumeb and Kombat were established. People stopped the traditional ironworking and preferred to perform easier jobs in the mines. It was easier to get iron from there. The white people did not see the traditional smelting anymore.

2.2 Smelting sites of the Tjaube people, narrated by Modestus Kashera Shimbiringua

This interview was held on October 9, 2007 in Kamboho, (Mashare Constituency) by Eileen Kose. Michael Hakusembe (Kapako) assisted and translated the interview. I met M. Kashera shortly before I left Namibia during my last field season in 2007 and had the opportunity for a short interview. As there was no time left for a detailed interview, I only roughly followed my questionnaire. There exist an audio recording of the interview.

Modestus Kashera Shimbiringua was born in 1924 in Hoha in the Gciriku territory. He was born in the year when Hompa Nyangana passed away. He grew up in Gove. His mother was a Tjaube and his father was a Gciriku. He is a descendant of Mankoto[397] and of the Vakwandjadi Clan. He was a professional blacksmith. He heard the history of the Tjaube people from his uncles Katanga Muyowa and Hausiku Muronga. These uncles heard the history about their clan from Mangundu Lishaka who was married to a daughter of Mankoto. M. Kashera speaks some German, which he had learned from the missionaries. His knowledge about the past comes from his grandparents and collateral relatives. At the time that he grew up, people did not know anymore how to produce iron. The elderly people had passed away with their knowledge. The knowledge about iron making became lost after the death of King Mankoto.

2.2.1 Smelting and mining sites

In the past, people dug for stones [i.e. iron ore] and brought them to the site where the bellows were placed [i.e. the smelting site]. There they lit a fire and operated the bellows. They dug a pit so that the stones could flow like water. After they had generated new iron, they cut it into pieces and forged tools. Modestus Kashera Shimbiringua remembered the following smelting sites of the Tjaube people:

Kauti: A big tree is at the location where King Mankoto used to live. At Kauti, the Kangomba Omuramba leads to the east. There, one may find small red stones at the surface. At this place, one must dig somewhat in the ground in order to find iron ore. In the past, people were not able to dig so deep because they had no spades. Mankoto was his ancestor. He had been smelting at Kauti. Modestus Kashera Shimbiringua did not know the exact location of the ancient smelting site. His ancestors sat and smelted west of the Livuyu tree.[398] Boys collected the stones [i.e. iron ore]. The elderly smelters only worked when the smelting fire was lit.

Vungu-Vungu: In Vungu-Vungu, there lived an elderly man called Lishara and his people. He smelted at Vungu-Vungu and brought his things [i.e. tools] to Mankoto at Kauti. However, M. K. Shimbiringua did

[397] Here the interviewee refers to the Tjaube King Mankoto (see Fleisch & Möhlig 2002, p. 29).

[398] *Livuyu* (*Adansonia digitata*, Baobab) trees were said to had been planted by the Tjaube protagonist Mankoto as a marker of their territory (Sandelowsky, 1968, ms.). In the same way, the Vungu-Vungu tree served as a landmark among the Shambyu and Gciriku people. Following Curtis' Tree Atlas of Namibia (Curtis & Mannheimer, 2005, p. 450), Baobab is uncommon to rare in the Kavango, if not absent.

not remember where the ironworkers from Vungu-Vungu mined their ore. The stones were of reddish brown color. Also, he does not remember where the ancient smelting site was located. The Tjaube people called this place Utu.
In **Fumbe**, the Tjaube ironworkers used to mine ore. He is not sure whether there was a smelting site too.
Gove: Lishara also lived in Gove together with Kapilika. Kapilika's homestead was north of the graveyard of the royal clan at Gove. 'Gove' is a place name of the Tjaube people. Kapilika's people smelted iron at Gove.[399] The ironworkers collected the iron ore at Fumbe, south of Mashare. From there they transported the ore on an ox-sleigh[400] to Gove. The stones [i.e. iron ore] were brownish. The ancient smelting site in Gove is situated on a shallow hill close to the grave of Hompa Mbambangandu. It is west of the graveyard and southeasterly of the tree where Hompa Mushinga's tombstone is placed. This is the place where the Tjaube ironworkers sat and worked. Until today, one can find slag scatters around the smelting site.[401] The people smelted on the surface. At the smelting site, there used to be big trees, but they were all cut. This is how one may recognize a smelting site. In former times, there was a big Acacia tree northwesterly of the smelting area, which is no longer there. North of the smelting site, there was a path, which is not recognizable anymore.
The smelting sites could be close to the settlements. This means that they smelted approximately 800 m away from the settlements with women and children. Sometimes they smelted in the bush because they did not want to carry the ore to the smelting site.

2.2.2 Smelt

The ironworkers stuck up a pile of charcoal and ore. They dug some channels in the ground in order to lead the liquid slag away from the pile. First, the ironworkers lit a fire. Then they piled up some ore knee-high. Then they covered it with charcoal. The ironworkers used three bellows to activate the fire, which were set up in a semicircle. They always used the same places to smelt. They started with the smelt in the afternoon hours and smelted until dawn. M. K. Shimbiringua did not remember the number of days the preparation of a smelt took, starting from collecting the ore and preparing the charcoal until the iron was finished. The bellows were made out of wood of the *uguwa* tree (*Pterocarpus angolensis*). The smelters used charcoal made out of wood of the *rupako* tree (*Erythrophleum africanum*) and *untu* tree (*muntu*, *musu*) (*Acacia erioloba*)

2.2.3 Rituals and Taboos

People used to sing the following songs at the smelting site:

Yenu kuno, tuyadukute ndenga,

Kutanta ashi, yenu kuno tuyadukute mawe
ghakare vikuhlo ngatu rughaniteko.

Women and small children were not allowed to be present at the smelting site. This was a rule. In the past, women did not approach the workplaces of men, and men did not approach the workplaces of women. Women were not allowed to touch the ore. This was a rule too. However, M. K. Shimbiringua did not remember if the smelting sites were fenced. The ironworkers were not allowed to carry the iron ore to the habitation locations. Also, they were not allowed to smelt inside of a settlement; however, M. K. Shimbiringua did not remember the reason of this prohibition. It was not allowed for the ironworkers to have sexual intercourse with their wives during the smelting work in progress. If one of them slept with a woman, the smelt would fail because either the ore would not melt or the pieces of raw iron would be so small that it would not be forgeable. It was forbidden to take charcoal or embers from the smelting site to the homesteads. The ironworkers had to sleep at the smelting site.

2.2.4 Forging and trading

The Tjaube blacksmiths produced the following tools:
Mbo: Ax
Litemo: Hoe
Mbere: Single-edged knife
Rufuro: Double-edged knife
Liwonga: Thrusting spear with leaf-shaped point and a wooden shaft
Kashindani: Throwing spear made completely out of metal. A cow tail was attached at the back point.
Mashewo: leaf-shaped arrowhead[402]
Ndamba: double-winged arrowhead[403]
Shinyombo: Y-shaped (forked) arrowhead[404]

[399] See Fleisch & Möhlig (2002, pp. 41-42f).
[400] These days, the ox-sleighs are pulled by cows and oxen. In former time, before cattle was introduced to the Kavango area in the 19th century, they were pulled by people.
[401] We found a lot of slag and some pottery scattering at the surface in a radius of approximately 1 km west and southwest of the Hompas' graveyard at Gove. M. K. Shimbiringua showed us the prehistoric smelting site that he referred to after the interview (N11/02-5, SI 17).
[402] All sorts of animals apart from elephants were hunted with this type of arrowhead.
[403] This type of arrowhead was used with poison for the hunting of large antelopes and giraffes.
[404] Used for hunting springboks.

Ngumba: single-winged, harpoon-like arrowhead [405]
Musho: Fishing spear
Linyamuna: Razor/cosmetic knife
Mbo (?): Chisel or wood carving tool
Shtoroha: Fire striker (fling and steel)
In former times, the ironworkers forged bracelets and feet bangles if the iron was too soft for making tools from it. Blacksmiths used water to harden their tools.

In former times, the ironworkers forged mainly tools for their own families. Other people could 'buy' some tools that they needed. However, in the past, people did not know business in the modern sense. The blacksmith gave tools free expecting a service in return later. This is why there existed no fixed rates for tools. Rates and prices came with the white people. Modestus Kashera Shimbiringua had never heard that the San people smelted in the past. In the beginnings, they only manufactured arrows out of the bones of giraffes. Later, they got raw iron and forged their own arrowheads.
Blacksmith have to work outside of their homesteads. That is what they learned from their ancestors, but he does not know the reason why. In former times, women were not allowed to be present at the blacksmiths' workplaces. These days in the course of gender equality, women are allowed to approach and to watch the work at the forge. Also they are now allowed to touch the tools.[406] However, it is still prohibited for women to cross a blacksmith's fire and his bellows. If women did, they would get menstrual bleeding which would not stop. Modestus Kashera Shimbiringua is not sure if this problem might be treated in modern hospitals; he thinks traditional healers can only heal it. Still today it is prohibited to take charcoal and embers from the forge to the homesteads. Only embers from the homestead fires can be taken to the smithy.

2.2.5 History

Modestus Kashera does not know from whom the Tjaube people might have learned the ironworking skills. The Tjaube people came from a place called Kahonda. This place was in the east. They came with their knowledge about ironworking to Kauti. The Tjaube came from contemporary Angola and went first to the country of the Hambukushu at a place called Shadihuoa. There, they only forged, but did not smelt. This place is about 15 km east of Dikundu. Later they moved to Dunsa. Dunsa is situated at the junction of the Dunsa and Kaudom Omiramba (dry riverbeds). Thereafter, they moved to Sancana. This place is located in the bush in Rugciriku. There they met San people from South Africa. They moved together with these San to Kauti. When King Mankoto passed away, the Tjaube and the San families separated [i.e. no longer lived in the same places]. There was a fight at Kauti between Mankoto and the Shambyu Hompa Mushinga Nkuru and Nasira. The Shambyu wished to settle in Kauti. However, Mankoto Nkuru was a Hompa himself and was not willing to allow them to settle there. Thereupon, the Shambyu asked for assistance from the Kwangali people at Nkurenkuru. Together they killed Mankoto in his residence. They took Mankoto's nephews and shared their hostages. The Tjaube became slaves. This is the history of the Tjaube people how it was passed on to him from his parents.

2.2.6 List of terms related to field of iron

Mushambuli: Ironworker (smelter and blacksmith)
Ndenga: Iron ore
Vikuwo: Metal/iron
Kera: Tuyere
Mareta (general term for waste): Slag and scale
Muduyi: Bellows
Lireva: Anvil
Muveto: Traditional (blacksmith's) hammer
Mpamo: Pliers
Likesho: Sharpening stone
Mulireva: Smithy, workplace of the blacksmith

2.3 Shambyu ironworkers of the Vakwandjadi clan, narrated by Harupe Paulus Haididira Kaputungu

This interview was held by Eileen Kose on October 14, 2007 in Mashare (Mashare Constituency). Stephen Nependa (Gove) assisted and translated the interview. During my interview with M. K. Shimbiringua, he recommended me to contact H. P. H. Kaputungu in order to get more information about the ancient mining area at Fumbe. Thereupon, we visited H. P. H. Kaputungu on the last day of my field trip. The information presented in the following are my notes taken during our conversation. There exist no audio recordings.
H. P. H. Kaputungu was born December 8, 1921 in Mashare. He is a professional blacksmith. He belongs to the Vakwandjadi clan. The meaning of Kwandjadi is 'the first master of the rain'. H. P. H. Kaputungu's father was a smelter.
The ancestors of the ironworkers of the Vakwandjadi clan chose specific smelting sites that they recurrently used. Only specific people were allowed to be at these sites, namely family members and relatives. He did not remember exactly each of the ancient

[405] Used for hunting birds and fishes.
[406] This means that in former times women were banished from the forge in the same way that they were excluded from the smelting sites. Also, in former times women were not allowed to touch guns.

sites because he was a small child when people stopped the traditional iron production in this region. The generation who had the knowledge about the iron production passed away. The knowledge and the apprenticeship of the iron trade was restricted to ironworking families and strongly regularized. If a man married into an ironworking family, he had to prove his integrity first for a period of two to three years, before his brothers-in-law introduced him to the iron trade.[407] In the early days, the knowledge about iron production was a secret of the royal clan. Later, the population grew and the royal clan had to share their knowledge in order to provide enough tools and weapons for the people.

In the time when the Tjaube used to live in the Fontein Omuramba, the river valley carried water.[408] There was the Livuyu tree at Kauti.[409] At this time, the Tjaube knew about iron production. The Tjaube already knew about iron production before they came to the Kavango region. When the first Shambyu came, they had no iron weapons. This is why they lost the first war against the Tjaube. In the following attack, the Shambyu were armed with iron weapons. This is the reason why they won the second fight. Some prisoners who went with the Kwangali continued smelting in their country in Ukuyu.[410] Today this place is called Makusu and is situated in contemporary Angola. The enslaved Tjaube brought the knowledge about iron production to the Kwangali.

The Tjaube also lived in Kapako. H. P. H. Kaputungu's father was from Kapako. It is said that they also smelted in Kapako in the past. H. P. H. Kaputungu remembered the ancient smelting site in Vungu-Vungu. It was located close to the Vungu-Vungu tree. In former times, people smelted at Gove because the Hompa lived there. After the first fight of the Tjaube against the Shambyu people, they started to communicate with each other. In Vungu-Vungu, both groups were united and smelted together. He also remembers that opposite to Nyangana in modern day Angola people used to smelt too. The ironworkers of the Vakwandjadi clan always smelted and forged close to the Hompa's residence. The iron tools and weapons were stored in the royal residence. This is why the workplace of the iron-workers was always close to the King's residence. People thought that in case of warfare all weapons were available in the palace. Some people in the community needed iron tools and weapons for their private use. The Hompa knew which member of his community did not own iron tools and weapons and lent them out, particularly for agricultural work. However, every iron tool and weapon belonged to the Hompa. The private users had to bring them back after work. Also hunting weapons had to be brought back to the King. After the war against the Kwanyama and Kwangali, people decided to dig a large pit in order to hide their most important and valuable items. Even if most people were killed during a war, the enemies would not be able to pillage the most valuable items of the community. One day, Queen Mushinga wished to see what was in the pit despite that she was blind. All the tools were stored in this pit. The Queen wanted to go into the pit in order to touch all these items. When she was in the pit, she passed away. She committed suicide in this pit. Thereupon the people were afraid to touch any of the items that had been stored there. They buried Queen Mushinga with all the items in this pit.[411]

There was an ancient mining site in the Fumbe Omuramba near Rujaja. People at Rujaja might know the exact location. The ironworkers who carried the ore to the river used to sing on their way, but H. P. H. Kaputungu did not remember these songs. The ironworkers transported the ore on sleighs that they had to pull. At this time, people had no oxen yet, they did not know how to domesticate animals although some of them had some cattle.

Later, the ironworkers started to produce guns.[412] They cast gun barrels out of iron and loaded the guns with a mixture of wool of a specific tree and hard particles. With these guns, they were able to kill an elephant. The white people prohibited the use of these guns and confiscated them. People were forced to hide their traditional guns. This took place after World War II under the rule of the South Africans. The Portuguese also prohibited the traditional guns. The South Africans prohibited the traditional blacksmiths from performing their craft.

[407] All of the Kavango peoples follow the matrilineal succession (cf. Gibson, Larson & McGurk, 1981). In the matrilineal system, the clan affiliation and the craft knowledge was passed on through the female line. Children learned the iron trade mainly from their uncles, e.g. the mother's brothers.

[408] For the detailed history of the migration of the Tjaube people see Fleisch and Möhlig (2002, pp. 29-36).

[409] Livuyu (*Adansonia digitata*, Baobab) trees were said to be planted by the Tjaube protagonist Mankoto as a territory marker (Sandelowsky, 1968). In the same way, the Vungu-Vungu tree serves as a landmark among the Shambyu and Gciriku people. Following Curtis' Tree Atlas of Namibia (Curtis & Mannheimer, 2005, p. 450), Baobab is uncommon to rare in the Kavango, if not absent.

[410] After the death of the Tjaube King Mankoto, the Tjaube people became enslaved. Some of them went with the Kwangali people, some of them stayed with the Shambyu and Gciriku (Fleisch & Möhlig, 2002, p. 50).

[411] This story of a pit with all valuable items of the country refers to Queen Mushinga's end. According to the Shambyu chronicle as F. J. Hausiku (Fleisch & Möhlig 2002, pp. 139-140) told it, the elderly Queen moved to a solid pit house after having lost sight in which she passed away.

[412] A kind of muzzleloader.

2.4 Gciriku iron production at Kashivi, Angola, narrated by Paulus Ndumba

This interview was held in three parts on August 24, and October 5 and 9, 2007 in Rucara by Eileen Kose, and assisted and translated by Michael Hakusembe. During the first part of the interview, Kandjimi Unengu, a nephew of P. Ndumba joined our conversation. He never witnessed iron smelting, but still possessed a very rich knowledge about iron production. The interview was recorded on videotape. Paulus Ndumba was born in 1914 in Mabushe, Namibia. His mother was a Nyemba and his father a Gciriku. Paulus Ndumba spent his entire life in the Gciriku region. He was a professional blacksmith. He speaks Gciriku, Nyemba, Rukwangali, Rumanyo, Oshivambo, Afrikaans and some German. Paulus Ndumba's grandfather was a smelter. Paulus Ndumba witnessed iron production at the age of fourteen or fifteen years. When he was young, Pater Bierfert was the bishop of the Nyangana Mission. Pater Bierfert observed iron production in Angola.

2.4.1 Smelting site

In the past, the Gciriku people smelted at a place named Kashivi in contemporary Angola. This site was approximately in a one-hour walk west of the Nyangana mission. Further smelting sites were deeper in the Angolan interior such as Simbaranda that was located in a three days walk north of Kashivi. Simbaranda was a smelting site of the Nyemba people. Several families used the smelting site of Kashivi. Each family had its own smelting pit. When Paulus Ndumba was a young boy, his grandfather Sikerete Urungi owned one of the smelting pits and used it over several years. Sikerete's sons, his cousins and his nephews assisted him in accomplishing the smelt. Four to five people formed one working team, and several people assisted in the smelt in order to be paid in tools for their service later.

The smelting sites were close to the villages in a distance of approximately 800 m. People lived there permanently all year around. The actual smelting site was not protected with a fence. The smelters chose a working zone under a tree and built a traditional house with open walls. The working zone as such measured approximately 10 m x 10 m. People used to smelt close to the source of ore. All the smelters of Kashivi used ore from the same mining area.

2.4.2 Ore and Mining

People collected iron ore at several locations in the bush in an approximate radius of 500 m from the smelting site and brought it to the furnace. Some ores could be found closer to the smelting site, and others were farther away. People used only iron ore from one source (i.e. one extraction pit) for one smelt. Iron ore was mined in Kashivi, in Rumono, which was used by the Nyemba people in modern day Angola in a one-day drive west of Kashivi; and in Okekete close to Katere.

The actual mining area in Kashivi had a dimension of approximately 10 x 10 m. The sand where they used to dig up the stones [i.e. iron ore] was red. The stones looked like those from Kauti.[413] Sometimes, animals such as aardvarks and warthogs brought some iron ore to the surface. P. Ndumba does not remember the difference between good and bad quality iron ore. The holes in which people dug up the ore measured approximately 1.5 m to 2 m in diameter and they were of knee to waist depth. Only men were allowed to collect ore. A team of three to four ironworkers collected the iron ore for a smelt. They used axes in order to dig up the ore. People used the ore as it was extracted from the ground. They did not chop the stones up before the smelt. The ironworkers carried the ore to the furnace site in cukuma-baskets. These containers were closed baskets of knee height measuring approximately 60 cm to 80 cm in diameter. Two individuals carried these baskets hanging from a bar. People needed two to three of such baskets for one smelt. The same men who collected the iron ore also carried these baskets to the smelt.

2.4.3 Charcoal

Charcoal for the smelting process was mainly made from the *mupako* tree (*Erythrophleum africanum*, Ambo Teak) and the *uuntu* tree (*Acacia erioloba*, Camel-Thorn Tree). The ironworking team produced the charcoal where they found suitable trees. Some of these trees were near the smelting site and others were farther away. People carried the charcoal from the place where they had burned the trees to the smelting site. For one smelt, they needed three to four *cukuma* baskets of charcoal. This would be a heap of charcoal of approximately 1.50 to 2 m in diameter and of knee height.[414]

2.4.4 Smelting

The ironworkers dug elongated box-shaped smelting pits with axes and hoes measuring approximately 2 m in length, 30 cm in wide and as deep as a thigh.

[413] At this point, the interviewee refers to the ore from Kauti because we showed him several ore samples that we collected from the Kavango area. The iron ore from Kauti is a black layered plinthic crust (Figure 14).

[414] At this point P. Ndumba referred to a volume of two to three modern 50 kg-flour bags.

The pit had no clay lining. The smelters operated the pit furnace with two bellows, which were located outside of the pits. The smelting pit was charged with one layer of charcoal at the bottom, one layer of iron ore on top of the charcoal layer, and again a charcoal layer covering the ore layer. The ironworkers put no other contents or materials into the smelting pit. The smelting pit was not closed or covered during the smelt. The smelters placed long blowing pipes below the deepest charcoal layer in the pit. They started with the smelt at one narrow end of the pit and placed the bellows in a 90° angle to each other, one at the narrow edge and one at the broad edge. As soon as the iron was melted at one end of the pit, they changed the position of the blowing pipes and the bellows and placed them at the opposite end of the pit furnace. People smelted during the night from the evening until the early morning. They smelted during the night because of the lower temperatures so that the people had more power for their work. The ironworkers observed how the stones melted. The stones were liquid like water. The master smelter decided when the smelt was over. After one day, the bloom was cooled down and the ironworkers took it out of the pit. The other slag remnants remained in the furnace pit. The ironworkers took these remnants out later and discarded them. Generally, the appearance of the slag is dark and a little shiny. The pieces of the slag are as small as pieces of charcoal or like a *mungongo*-nut. There were no larger pieces. The smelters discarded the slag and the failed iron always at the same place. This place was approximately 5 to 10 m away from the smelting pit. After the smelt, the ironworkers sometimes refilled the pit with soil. Sometimes they left the pit as it was or they protected their furnace with thorny boughs.

People smelted during the winter and the summer seasons as long as it did not rain. Sometimes they smelted up to ten times a year, depending on their need for iron.

The smelting activities, starting from collecting the ore until the final production of raw iron, took two to two and a half weeks.

2.4.5 Bellows

The bellows were made of *ughuwa*-wood (*Pterocarpus angolensis*) because this specific wood is lightweight and does not break easily. Each bellow consisted of two cups on a bottom board. The jars measured half the length of a lower leg in height, and each jar displayed an approximate diameter of 30 cm (both jars together approximately 60 cm on the bottom board). They were connected to the furnace by two air channels measuring approximately 30 cm in length. The blowing pipes were made out of clay and measured approximately 1 m in length. At the bellows' side (air supply) they measured approximately 10 cm in diameter, and at the furnace side (air outflow) approximately 3 cm in diameter. P. Ndumba does not know of tuyeres made of stone. The master smelter started operating the bellows and was replaced by other members of the ironworking team later. Even children assisted in operating the bellows. A pit furnace and the bellows could be decorated if the ironworker wished them to be ornamented. The bellows were either made by the ironworkers themselves or they were bought from somebody else.

2.4.6 Iron

The bloom (iron) and the slag remained in the pit until the ironworkers took them out. When the smelt was over, the result was a chunk of slag and metal, which was later separated by forging. They carried the bloom with their hands to their smithies. There the iron was separated from the slag and beaten out. The bloom was approximately 50 cm in length, as long as a lower leg, and followed the elongated contour of the smelting pit. The ironworkers knew the quality of the iron. Good quality iron was hard and heavy. Iron of poor quality looked like fish scales and was flaky. The ironworkers discarded the poor quality pieces. The amount of new iron that the smelters generated depended on the amount of ore that they used for the smelt. If the people had a good smelt, the ironworkers gained a piece as big as the size of a lower leg. If they had a bad smelt, the piece was of the size of a lower arm. Sometimes, they generated no iron from the smelt. If the smelt failed, people had only numerous small pieces of iron of approximately 1 cm in diameter. The smelter discarded these pieces.

2.4.7 Rituals and Taboos

The smelting site was a forbidden zone for women. Men were allowed to watch the ironworkers at work, but they were not allowed to touch things at the site. If a man would have had intercourse the night before, and if he would touch things at the smelting site, the smelt would fail. If somebody meant mischief to the smelters, he could touch something at the smelting site with a bad intention. Therefore, it was safer to keep people away from the smelting site. Small children were allowed to watch the work of the smelters because they are still innocent, even girls up to an age of around 12 years. In theory, it would be possible to smelt within the villages as long as no women entered the smelting zone. Also, people could store some iron ore within their settlements, but as soon as the people started preparing a smelt, nobody other than the ironworkers were allowed to touch the iron ore.

Before people started with a smelt, the ironworkers announced that nobody was allowed anymore to enter the working area. While the ironworkers collected the ore and while they were preparing the charcoal, they were staying at the smelting camp but even so, they were permitted to visit their families and homesteads in the morning. The ironworkers ate at their homesteads but also kept some food at the smelting site. If they did not have enough food, they could get it from their families or send somebody in order to get something to eat. It was not allowed to kill at the smelting site. The slaughtering of animals did not belong in their sphere of work. However, they were allowed to bring meat from outside to the smelting zone.

The ironworkers wore no specific clothing at the smelting site, but they decorated their heads with feathers of chickens during the smelt. They performed no special sacrificial ceremony at the smelting site, but the master smelter always put some secret medicine on the ore before they lit the furnace. Paulus Ndumba did not recall the moment during the iron production process in which the head of the group placed his medicine because it was kept as a secret of the master smelters.

The ironworkers drank alcoholic beverages in order to work faster and not to become tired. They sang a specific song during their smelting work:

Yeveyeni ndenga

Yakakutambura kamuye voyo ndenga.

Yeveyeni ndenga.

Tuvapekere Ndungurume wazala katjara kumtwe.

This song was meant to keep the ironworkers awake. It was sung in Nyemba by the Gciriku smelters even though they did not understand the meaning of the song.

When the smelt was successful, the smelters organized a party for the participating workers. If the group of smelters was wealthy, more people could join the party. When the smelt was not successful, they celebrated only for a short while because every member wished to leave the smelting site as fast as possible since they did not succeed. In such a case, the elderly smelters had to analyze the situation in order to find out what went wrong. Oftentimes, they were not able to blame an individual ironworker for having had intercourse during the period of iron manufacturing. Sometimes, the smelters held a meeting in order to question themselves who might be to blame for the failure of the smelt. If they found somebody guilty, the master smelter questioned this person separately in order to find out if he really is to blame on that.

The interviewee did not remember any case in which the culprit was earnestly punished. However, once found guilty, the individual was not permitted to approach the smelting site any more. For this reason, the smelting site was a forbidden zone for the people from the village and the master smelter was able to better control the activities at the site.

2.7.8 Forging and trading

The smithy was 500 to 800 m away from the smelting site. The smithy was supposed to be outside of the smelting site but he does not remember the reason why. Women were allowed to be present at the blacksmith's workplace; however, they were not allowed to cross the smithy or the bellows. If a woman crossed the smithy, she would get continuous menstrual bleeding. The interviewee did not know how to heal this sickness. People were not allowed to carry charcoal from the smithy to their homesteads. It was only allowed to use this charcoal outside of the homesteads. Women who used charcoal from a blacksmith's fire in their household became sick because the charcoal had been treated with the bellows. If women used such charcoal they would get menstrual bleeding. The interviewee did not know the reason why. Also, it was not allowed to take embers from the blacksmith's fire in order to light another fire. This would cause the same problems to women. There was no problem for men to use such charcoal.

The working tools of a blacksmith were an iron hammer (*tshindoma*), an anvil (*liyundo*) that consisted of a piece of iron that was set in a large chunk of wood, iron pliers (*tshimana*) and one bellow (*muduye*) with a blowing pipe (*likera*), and a sharpening stone (*liwe ya kurora*). People preferred flattened red stones form the river as sharpening stones. Furthermore, blacksmiths used fishing spears (*musho*) in order to burn the shaft hole into the ax handles. The blacksmiths used the same types of wood for the fire of their forge as they used for the smelt. People used these types of wood because the charcoal was considered to be strong', i.e. the fire of such wood would last and produce high temperatures of the embers. The waste from the forging activities looked like fish scales. It is whitish and black in color. The blacksmiths forged the following tools:

Litemo lya linene: Big hoe
Litemo lya lididi: Small hoe
Mbo lya inene: Big ax
Mbo lya lididi: Small ax
Mbere:[415] Single edged knife
Rufuro: Double edged knife,

[415] According to P. Ndumba, all knives (including the razors) were always sold with a wooden sheath.

Liwonga: [416] Spear with two-winged head,
Karumbi:[417] Spear with a leaf-shaped head,
Ngumba:[418] Single-winged, harpoon-like arrowhead
Ndamba:[419] Double-winged arrowhead
Lishewe:[420] Leaf-shaped arrowhead
Nteta:[421] Transverse arrowhead
Tshinyombo:[422] Y-shaped (forked) arrowhead
Musho: Fishing spear in varying sizes.
Tshithora: Fire or sparks striker,
Linyamuna:[423] Razor
Likoredo:[424] Chisel or wood carving tool,
Mtungo: Needle for basketry:
Tshindoma: Blacksmith's hammer,

People produced no iron jewelry.[425] Usually, the tools that the ironworkers produced were sold to the neighboring villages. Sometimes people came and bought items at the blacksmith's place. It was not allowed to sell raw metal; yet, the interviewee did not remember the reason why. Sometimes, the blacksmiths traveled from Nyangana to Nkurenkuru in order to sell their items there. It took them two weeks to walk to Nkurenkuru. Sometimes, their journey took longer because they had to rest and to recover. Some ironworkers took a wife in one of the villages along their route. People traveled not only for trading purposes, they were looking for good-looking women in order to get a place to sleep over on their journey. Usually, the ironworkers traveled with assistants. These could be two young men for example of a minimum age of around 20 years. Each assistant had to carry 10 hoes and 10 axes, or 5 hoes and 10 axes. In addition, they took many knives with them. At this time, the Kwangali produced no iron. According to P. Ndumba, they might have learned it later when the Nyemba people came because they know how to smelt. He did not hear about other people selling their tools among the Kwangali. Sometimes, Hambukushu came in order to buy iron items from the Gciriku blacksmiths. Sometimes, the Gciriku blacksmiths went to the Hambukushu and sold some tools there. However, he did not remember to which places they went. According to the interviewee, the Shambyu were not able to smelt. They are only blacksmiths and learned the ironworking when the Europeans came.

The tools that the Gciriku blacksmiths produced were exchanged for other goods for the following rates:

Mbo lya inene (big ax):
Big basket[426] full of mahangu or a medium sized goat.

Mbo lya lididi (small ax):
Were not sold, but given to the assistants of the iron-workers in return for their services

Litemo lya linene (big hoe):
Big basket[427] full of mahangu or a medium sized goat.[428]

Litemo lya lididi (small hoe):
Medium sized basket[429] full of mahangu or two chickens.

Mbere (knife): Both types (*mbere* & r*ufuro*): 20 ct.[430] or a small basket[431] of mahangu, alternatively one chicken. Generally, knifes varied in size and were sold for different quantities of mahangu, but always for one chicken only.

Liwonga (spear with a leaf-shaped head):
These spears were exchanged for small baskets of mahangu, corn, nuts or beans. Depending on their sizes, they could also be exchanged for one to two chickens.

Karumbi: This type of spear was not sold because it was considered to protect its owner from enemies. These spears were given to the people who assisted the ironworkers in return for their service. Other individuals could borrow these spears from the ironworkers and their helpers.

Arrowheads: Generally, arrowheads were inalienable. They were considered too small to be sold. Arrowheads were given to the assistants of the ironworkers in return for their service. Smelters received arrowheads from the blacksmiths, which were produced from their own raw material.

Musho (fishing spear): Fishing spears were not salable items. The interviewee never saw the elder generation selling or exchanging these tools. Fishing spears were given to those who assisted in the iron production or they were given to male family members.

Linyamuna (razor): Razors were only lent out by the blacksmiths to friends and family members.

Tshithora (fire striker): The blacksmiths lent firelighters out or they gave them free to friends and helpers.

Tshindoma: The blacksmith's hammer were not sold, only for the personal use of the blacksmiths.

[416] Stabbing spear. All kinds of animals could be hunted with this type of spear. The hunters stabbed the animals with this spear.
[417] Throwing spear. All kinds of animals could be hunted with this type of spear. The spear remained in the animal and the hunters followed the injured animals.
[418] Used for hunting small animals, caracals and fishes.
[419] Used for hunting large game with poisoned arrowheads.
[420] Used for hunting caracals.
[421] Used for hunting caracals and small antelopes.
[422] Used for hunting caracals and small antelopes.
[423] Used for shaving the head.
[424] Used for carving drums and mortars. A long pole with a broad Y-shaped sharp point.
[425] According to Paulus Ndumba, copper and copper jewelery was introduced to this area with the arrival of the Europeans. People bought copper jewelery from Umbundu traders. These traders bought their items from the Portuguese in central Angola.

[426] Approximately 50 cm in diameter and knee-high.
[427] See footnote 426.
[Z] Chicken were not accepted as payment for a hoe.
[429] Approximately 30 cm in diameter and half the length of a lower leg in height.
[430] It is not clear to which time the 20 ct. refer.
[431] Approximately 20 cm in diameter and one third of a lower leg in height.

The San people knew how to forge, but they did not know how to smelt. The interviewee assumed that they used scrap metal. He did not know how or from whom the San people could have learned the iron trade. In the past, the Gciriku people exchanged goods with San people such as bush meat for mahangu, honey for knifes, and fruits of the Sandveld for pottery.

2.4.9 Sociocultural context

In the Gciriku society, iron smelting and the blacksmiths' work were not perceived to be separate trades. An ironworker was able to do both, producing iron and forging. Everybody could learn the ironworkers trade. Ironworking was not restricted to certain families or clans. If an individual was trained in ironworking, he could build his own furnace.
Smelters were more respected than those who forged only because there would be no iron without their knowledge. Smelters knew how to choose and to collect the right ore, and how to smelt. Smelters were respected because of their work but they had no other influence within their community. Hompas were not smelters or blacksmiths. They did not want to perform such hard work. The blacksmiths gave the Hompas finished tools as gifts (they never gave them raw metal). The blacksmiths tried to put themselves on good terms with the Hompa because they feared the Hompa's judgment in a trial. Some ironworkers were healers. Many blacksmiths are healers [today], but not he himself. Some ironworkers could do magic, others not. Blacksmiths were rich people. They were rich in goats and cattle and rich in mahangu because they exchanged tools for mahangu. They had large fields and some of them went hunting, if they wished to hunt. There existed no marriage restrictions for ironworkers. They were permitted to marry the women they desired according to the ruling marriage customs.

2.4.10 History

P. Ndumba does not remember how long people had been smelting in Kashivi or how long the Gciriku people had been smelting in general. He does not know if there was a time when the people had not been smelting yet. According to his information, the Gciriku people learned the iron trade while they still settled along the Kwando River.[432] The Gciriku people stopped producing their own iron when he was a small boy. The elderly generation passed away with their knowledge and the white people brought their own iron. None of the local ironworkers wanted to continue with the demanding smelting work because they were now able to get iron in an easier way.
Paulus Ndumba remembered the story of the raid of the Tawana against the Gciriku[433] from his grandfather. During this war, many of the Gciriku men were killed. When the war was over, the widows took new husbands from the Kwangali and Ovambo region. Some of the new husbands who came to live with their wives were blacksmiths, but none of them was a smelter. In this time, the Gciriku still produced their own iron.
Paulus Ndumba remembered that only the Gciriku and the Nyemba produced iron in the past. According to him, the Shambyu, Kwangali, Mbunza, Hambukushu or Chokwe did not produce iron. Of other peoples such as the Kwanyama he did not know. In his memory, the people living east of the Gciriku were those who smelted. Probably, the Lozi people smelted.

2.4.11 List of terms related to field of iron

Muduguti ndenga (operator of the stones) (*Muwiki go mamanya* (Rkw.)): Smelter
Mushambuli (*Muhambuli* (Rkw.): Blacksmith
Ndenga: Iron ore
Makara: Charcoal
Likwina: Pit (general term)
Mareta: Slag, scale (general term for waste)
Tshikuwo: Metal
Pakudugutira ndenga: Smelting site
Palirewa: Forge
Tuyendeni tukarankede: Let's go and burn stones
Muduye: Bellows
Likera: Blowing pipe

2.5 Hambukushu iron production at Kapongo, narrated by Petrus Kashako Kaputura

This interview was held on August 26 and 27, 2006, in Havo, Mukwe Constituency, by Eileen Kose. Cosmas Kashongo assisted and translated the interview.
Petrus Kashako Kaputura was born the 1st February 1911 in Shadjunu (Shadikonsoro) and passed away in early 2007. He was resident in Havo. The interview comprises five hours of answering and questioning on videotapes. P. K. Kaputura was a farmer in Havo. He moved to this village in 1972 because it was easy here to make a living on agriculture. His mother tongue was Thimbukushu. Additionally, he spoke Fanagalo and Xhosa, which he had learned during his time in the South African mines. P. K. Kaputura never

[432] At this point, the interviewee referred to a time when the Gciriku people still lived in the Mashi region before they started to migrate to the Kavango River (Fleisch & Möhlig, 2002, pp. 65-69).

[433] This happened in the year 1894 (Fleisch & Möhlig, 2002, p. 58).

smelted himself. The information that he could provide about ironworking in the Mbukushu area originated from his brother in law named Lishasha. Lishasha was a smelter in Kapongo, which is approximately 7 km west of Havo.[434] P. K. Kaputura watched Lishasha conducting smelts at the age of eleven or twelve This might have been around 1920 to 1925. Furthermore, he provided some information about iron production of the Nyemba people.

2.5.1 Smelting site

P. K. Kaputura remembered only the smelting site of Kapongo. People used to smelt there because they found suitable ore on site. He did not know how long people had been smelting in Kapongo. Only one village had the right to smelt at this site. A group of fifteen or more men from Kapongo performed the smelting activities. Before they started preparing a new smelt, they would hold a meeting to determine the need for new iron. Some of the workers already knew how to smelt, others had to be trained on the jobsite. Usually only one furnace was in use at the time. The dimension of the smelting site comprised approximately 10 m². Typically, the smelting site was approximately 500 to 600 m from the villages; this was considered far away from the villages. The smelters were afraid to be seen by the women from the village.

2.5.2 Ore and mining

The smelters used red, brown,[435] and black nodules as iron ores, which were exposed on the surface.[436] They collected them by hand. These nodules were very hard. The ore had not been chopped up, sorted out, or improved before the smelt. Those who were responsible for the smelt collected the ore. They collected every nodule without exception because they needed the iron.[437] The men carried the ore in large funnel-shaped baskets called *thimbamba* to the furnace site. These baskets were of knee-height, with a diameter of approximately one meter. For one smelt, approximately 10 full baskets of ore nodules were necessary. The workers shared these baskets with each other, because not every member of the group was in possession of such transport baskets. One day, one group of the workers used them, the next day, they were used by the other part of the group. They collected a large amount of nodules and stacked up the iron ore in a pile chest-high of an adult man with an average diameter of 6 m to 7 m at its base.

2.5.3 Charcoal

Charcoal for the smelting process was made from four types of trees: *mupako* (*Erythrophleum africanum*, Ambo Teak), *mushosho* (*Terminalia sericea*, Silver Terminalia), *muthu* (*Acacia erioloba*, syn. *giraffae*, Camel Thorn Tree), *mukuthi* (*Baikiaea plurijuga*, Rhodesian Teak), *ghuhehe* (*Burkea Africana*, Red Syringa). These types of wood produced good heat. The same group of workers who collected the ore was also responsible for making the charcoal for the smelt. They produced the charcoal where they found suitable entire trees, which were already dry (dead). They did the charcoal burning right at the site were the dry trees were located. Then they collected the charcoal and carried it to the smelting site. For one smelt, they needed a heap of charcoal of approximately 2 to 3 m in diameter and a height of 1.80 to 2 m.

2.5.4 Smelting

People used furnaces made from termite hills because they needed a stable construction to protect the fire from the wind. The local soil was sandy and soft and not suitable to build a furnace from it. The smelters cut the tip of the termite hill at a height of 1.7 m to 1.8 m and hollowed it out. Below the bottom of the termite hill, the smelters installed a drain for the molten iron to flow out. Laterally and level with the ground, they carved out small holes through the furnace walls and installed four bellows around the furnace. P. K. Kaputura could no longer remember what type of tools the smelters used in order to construct the furnace.

It was possible to smelt at any time in the year apart from the rainy season. However, typically people smelted only once a year. Preparing a smelt took around one month. Two weeks of labor were necessary to produce sufficient charcoal and another two weeks to collect the ore. The furnace was charged with three layers of charcoal and two layers of ore (from the bottom to the top in the following succession: charcoal – ore – charcoal – ore – charcoal). Then the smelters lit the batch with a piece of wood from the top. Additionally, a medicine[438] was put into the furnace to protect those who did not belong to the group of smelters from getting burnt from the iron. The furnace was not closed during the smelt. The fire was lit in the evening hours at sunset. After one night

[434] The smelting site of Kapongo visited in 2007 is roughly 2.5 km northeast of Havo.

[435] The color concept for ‚brown' does not exist in Thimbukushu language. C. Kashongo added it to the translation.

[436] For the description of the ore see section 4.1.1, Sample No. 4710/06, 4711/06, 4712/06.

[437] Obviously they did not sort the ore for quality.

[438] Unfortunately P. K. Kaputura could not remember the ingredients of their medicine

of smelting [after having operated the furnace for approximately 7 hours], the molten iron flowed out. After the iron had poured out of the furnace and after the channel was full, they stopped operating the bellows and stopped the fire. First, the iron flowed out of the furnace and then the waste [slag]. The smelters waited until the iron was solidified after approximately one hour. Then they took it out of the drain with their hands. Before they could touch the iron, they dipped their hands in liquid medicine. The iron was viscous and of silvery color. Subsequently, they filled the furnace again whilst the furnace was still hot. To do so, they had to remove the waste from the furnace first. The waste from the smelt was black and red and looked like small chunks of charcoal or even smaller. They dumped the waste of the smelt in a distance of approximately 20 m from the actual smelting site. The workers repeated the smelting process depending on the amount of iron they needed. Sometimes they smelted repeatedly for the entire week until they had enough of the metal. They stopped the furnace when they decided that they had enough. The furnaces were used several times.[439] If a smelt was not successful, the ore had not been reduced to iron. In such cases the sound of the bellows was different as well, and known to the smelters as a potentially not successful smelting process. If the iron had not melted properly, they left the batch in the furnace and went home. At home in their villages they discussed who of the group might have to be blamed for the failure of the smelt and who made a mistake. Afterwards they continued with the smelt. They cleaned out the furnace and the waste looked like the batch that they had put into the furnace before. Then they lit a new fire.

2.5.5 Bellows

The bellows were made out of the wood of the *ghughuwa* tree (*Pterocarpus angolensis*). The dimension of the bellow cups was half the length of a lower leg (around 40 cm) in height, and of an average diameter of roughly 30 cm. Two wooden air channels measuring approximately 1 to 1.20 m in length completed the cups. The bellow cups were covered with animal skins, which originated mainly from game species such as springboks, dikdik antelopes or baboons. The skins of these animals were particularly suitable because they were soft and allowed for a good compression of air in the cups. They could use goat skins for the same purpose; however the skins of game species were considered superior. Leather from larger game species such as elephant, hippopotamus, buffalo, rhinoceros, giraffes, kudu antelopes, and domesticated animals such as cattle was too inflexible. The sticks with which the smelters operated the bellows were chest-high and the smelters operated with them standing upright. Everybody from the working group was supposed to operate the bellows during the smelt. Neither the furnaces nor the bellows were decorated. Tuyeres were made out of clay from the river. At the bellows' side (air inflow), the pipes were about 20 cm in diameter and at the furnace's side around 10 cm (air outflow). The dimension was the length of a lower leg.[440]

2.5.6 Iron

The raw iron in the channel had a dimension of 60 to 70 cm in length and of a forearm [of an adult man] in diameter. A piece of iron of such dimensions was considered to be a successful smelt. People carried the new piece of raw iron on their shoulders to the village in order to forge.

According to the description from P. K. Kashako, there was no difference in quality with respect to the iron produced. The iron from the first smelt was sharpened at one edge. They treated the iron in a hot state and cooled it subsequently in cold water. Then they could use it and shape one sharp (tapering) edge with a hammer. It was a chisel like tool. The iron pieces from subsequent smelts and the big chisel tool were carried to their homesteads. There they used the big chisel to divide the raw iron from the subsequent smelts into six smaller chunks.

2.5.7 Ritual and Taboos

The permanent villages were 500 to 600 m away from the smelting site.[441] It was not permitted to smelt in the villages because of the families living there. The actual smelting site was a restricted zone. Only men above a certain age, in particular married men who already had children or unmarried men of advanced age were allowed to enter the smelting zone. The ironworkers did not put up fences around the furnace site; however, the people from the villages were informed that it was not permitted to approach the zone of ironworking. It was not permitted to carry iron ore to the villages. Iron ore in the village would cause the next smelt to be unsuccessful. This was a law. Once the ore was collected by the smelters, women were not permitted to look at it or to touch it nor were women permitted to assist in collecting the ore. However, as long as the ore was not yet collected and still exposed on the local fields, women were allowed to see it. During the ironworking activities, the workers slept at the smelting site under a tree.

439 This means that people used it for several years.

440 Approximately 50 cm in length.

441 This distance was considered to be far away.

They worked in turns. They ate self-prepared porridge and meat. For instance, they slaughtered a goat or hunted some game (antelopes). The smelters were allowed to take meat left-overs back home to their families. Sometimes family members (men and women) brought them some food to the smelting site. They brought it only half the distance to the furnace site because they were not permitted to approach the smelting zone.
The smelters performed no specific ceremonies before they started with the smelting activities. But they needed to have a discussion before they started with the smelt. There were no sacrificial ceremonies. Only the leader of the group of smelters collected roots of the tree, which provided the medicine for smelting. He put these roots on a plate in some water. Every ironworker could dip his hands into the liquid so that he would not get burned during the smelting process.
The ironworkers wore no specific clothing during the smelt. They sang songs during the smelting process. He could not remember all these songs. Some songs were in Nyemba, some in Thimbukushu. Some were songs for dancing. The smelters sang because they liked it. He could not remember the name of these songs. [He sang a song in Nyemba]. For him this is just a song. He does not understand the meaning of this song. They smelters rejoiced in their work. The ironworkers only sang while they operated the bellows. When the smelt was successful, people organized a party for the whole community. When the smelt was not successful, there was no party. When the smelt was not successful, one of the smelters was considered to have had sexual intercourse with his wife (or any woman), or an unauthorized person had entered the smelting zone. There was no specific punishment for the person who was blamed for the failure of the smelt, but everybody hated and ostracized this person. However, the smelters were not always able to find a person to be blamed.

2.5.8 Forging and trading

The forges were always located inside the villages. Every homestead had its own forge under a tree outside the fenced in area of the homestead. A forge was considered dangerous inside the homestead because of playing children, the fire danger, and danger to the women living there. Blacksmiths used iron hammers, anvils (*dyundo*) [442] and pliers made out of two pieces of tree bark. Before touching the hot iron, they dipped the pliers into water. Blacksmiths used sharpening stones of fine-grained sandstone, which could be found along the river. They used tuyeres, bellows and water. The charcoal for forging tools was made out of the same tree species as for smelting. Wood from these tree species produces a hot glow. It is important to use the correct type of wood, otherwise the iron would have poor quality and become brittle. The waste from forging activities looks like leaves and is black and beige in color.
Women could approach the forge, but they were not allowed to cross the fire. If a woman crossed the smithy she would suffer from menstrual bleeding. According to P. K. Kaputura, people treated this disease with shoots of the *ghunyondo* tree (*Combretum imberbe*, Leadwood)[443] and the *ghushi* tree (*Guibourtia coleosperma*).[444] Traditional healers prepared the leaves of the tree and gave it to the women to drink until they recovered. It was not permitted to carry embers from the forge to the homesteads because these fires would cause sickness among the women.
People forged the following tools:
Kamo: ax,
Ditemo: hoe,
Dyayo: adz
Moko: single edged knife
Thimende: double edged knife,
Diyonga: hunting spear,
Disho: leaf-shaped arrowhead
Dindambwa: harpoon-shaped arrowhead
Muho: fishing spear also frequently used to burn holes into wood such as handles for hoes and axes.
Dirovo: hooks for caching crocodiles,
Dinyamuna: razors
Rubeko: cosmetic knives for women.
Dikuro: wood carving knives,
Mweto: 'traditional hammer'

The Hambukushu ironworkers only produced tools for their own use. They distributed these tools within their families. Sometimes, tools were exchanged for other goods.
The rates of exchange were as follows:
1 *kamo* (ax): 1 cow or bull or 5 goats or 1 big basket of mahangu
1 *ditemo* (hoe): 1 cow or bull, or 5 goats
1 *dyayo* (adz): 1 chicken (no mahangu)
1 knife (*moko* or *thimende*): 1 goat or 3 chickens, or a small basket of mahangu
1 *diyonga* (hunting spear): 1 goat (no mahangu accepted)
Arrowheads and fishing spears were free of charge. The hooks for hunting crocodiles as well as razors and cosmetic knifes were inalienable and were not given

442 A piece of iron in a larger chunk of wood.

443 According to Curtis & Mannheimer (2005, p. 481) Combretum imberbe is regarded as having mythical properties among the Herero and Ovambo groups and has also numerous medicinal properties.

444 According to Curtis and Mannheimer (2005, p. 205) Guibourtia coleosperma is used for many secular purposes and various parts are used medicinally.

to other people. Raw iron and iron ore was not sold. San people who maintained friendly relationships with the Mbukushu were given free arrowheads. Normally, San people made arrow heads out of bones. San people were dangerous hunters and traded meat for the items that they obtained from the Mbukushu. In addition to that, the San people were given free axes and clay pots but they always gave some other goods in return.

2.5.9 Sociocultural context

In the Hambukushu society, there are professional potters, carpenters, healers, fishers, basket and mat makers and hunters. Every family had its own blacksmith. Smelters and blacksmiths were skilled workers. People had a more or less elaborate knowledge on how to work metal. If a man desired to become a skilled blacksmith, he needed to learn these skills from an experienced blacksmith. Everyone could be a smelter, but there were only a few experienced smelters with good knowledge of their trade. The knowledge of ironworking and production had to be obtained from an expert in this field. Usually the trade knowledge was passed on within the family and was not taught by ironworking neighbors. Smelters and blacksmiths were respected within their society because they had the knowledge of smelting iron and how to manufacture iron tools. There was no difference with respect to status and prestige between the two trades.

Ironworkers had no specific powers such as magical power. Some were healers, but not because they were smelters. The King of the Mbukushu was not a smelter or blacksmith. Smelters and blacksmiths were wealthier than other members of their society. For instance, they owned more cattle and fields than others. Like everybody in the Hambukushu society, they were permitted to hunt, but not everyone had the necessary hunting skills. There were only a few hunters in the village. There were no marriage restrictions for ironworkers. They were permitted to marry the woman they desired according to the ruling marriage customs.

2.5.10 History

The Hambukushu were self-taught smelters and blacksmiths. The Hambukushu were in the iron production for a long time. The production of iron ceased when the white explorers arrived and provided the Hambukushu with European tools. When those European explorers arrived, P. K. Kashako was eleven or twelve years old.

He remembered that the Kwanyama, Kwangali, Mbunza, Gciriku, Shambyu, Nyemba and Chokwe were able to produce iron. The San people produced no iron. They obtained their tools from the Hambukushu. Sometimes people from Angola brought [sold] tools to the Kavango peoples. People from Angola did not come in order to get ore from the Kapongo area. They had their own iron ore.

2.6 Hambukushu iron production at Dikundu, narrated by Marembo Bernardo Tovero, Yimadhara Joseph Matende, Manyandero Filipus Mukura, Marcus Kandunda and Peter Kandjendje

This interview was held the on August 12, 2006 in Dikundu by Eileen Kose and translated by Cosmas Kashongo. Open questions from this interview and from the interview with Petrus Kashako Kaputura about the Kapongo smelting site were revised and complemented on September 3, 2006 in Dikundu. Marembo Bernardo Tovero was born in 1952 in Diyogha. He is the headman of Dikundu. Yimadhara Joseph Matende was born in 1951, Manyandero Filipus Mukura and Marcus Kandunda were born in 1958. They live in Dikundu and are farmers. Peter Kandjendje is a teacher in Muthinduku and fluent in English. Marembo Bernardo Tovero speaks Thimbukushu, Afrikaans, Rukwangali, Rugciriku, Xhosa and Fanagalo, which he learned during his time in South African mines. The information that the interviewees could provide about ironworking in the Hambukushu area originated from their grandfathers and uncles. They conducted smelts at Dikundu until they started to work as itinerant workers in the mines of Tsumeb and Johannesburg.

2.6.1 Smelting site

The historical smelting site of Dikundu is situated in one of the fields of Headman Tovero. The interviewees remembered two historical smelting sites in Dikundu. Further sites were in Havo, Shamaturu and Shividi. People used to smelt at these locations because they found suitable ore on site and good soil to make a living on agriculture. Usually people smelted close to the source of ore. All smelting sites in this region were of the same importance. Dikundu was a large smelting location exclusively for the people from Dikundu. Originally, the smelting site was far from the villages.[445] The historical smelting site of Dikundu was as remote from the village as it is today so that women could not see the site. Every village had its own smelting site and smelted for its

[445] The smelting site of Dikundu that Beatrice Sandelowsky excavated in the late 60s is located in a distance of approximately 1 km from the contemporary village.

own use. The smelting site was an open space of the dimension of a tree[446] without any fence. Nevertheless, it was forbidden to approach this location. People respected the ironworkers and their smelting site. If they did not smelt, women, children and even the ironworkers themselves were not allowed to approach the smelting location.

2.6.2 Ore and mining

In former times, the Hambukushu people still lived exclusively along the Kavango River. There they had no iron ore in this area and did not smelt along the river. People were supposed to go to the Omiramba in order to collect ore. There they smelted on site. At that time, the Dikundu village did not exist yet. People knew about these localities (iron ore occurrences) from hunters because they knew the region very well. In the past, the people from the river knew the smelting sites and named these localities. Later, everybody was allowed to smelt in the Dikundu area. Villages farther away came to collect iron ore in the Dikundu area and to take it back home to their own smelting sites. They exchanged mahangu and cattle for iron ore. The interviewees did not remember people from Angola coming to the Dikundu region in order to smelt. The Nyemba people did not know these sites. Sometimes people came from the south to the Dikundu smelting sites.

The iron ore looked like a stone but it was soft.[447] The color of the ore is red and brown. Some of the stones display only a red line. The latter were of poor quality. Some stones look like the red sand[448] but they are different from it. People also used the brownish stones but their quality was inferior to the red ore. They did not use the yellowish stones. Some of these stones were exposed on the surface. If they found a site where many of these stones were found, they started to collect this iron ore. If the surface ore was exhausted, they dug to a depth of approximately 1 to 1.20 m. Sometimes they found iron ore while they were plowing their fields. Only married men were allowed to dig up the ore. The ironworkers used axes, hoes and digging sticks. If the stones were too big they crushed them approximately to the size of a fist or tennis ball because the ore was easier to be smelted in this size. The ironworkers carried these stones in leather bags on their shoulders and on their head to the furnace site. The amount of stones that was transported in these bags depended on the physical strength of the individuals who had to carry them. The amount of the ore that they collected depended on the amount of iron that they wished to produce.

2.6.3 Charcoal

The eldest member of the group who was considered the most experienced was supposed to produce the charcoal for the smelt so that the charcoal was of good quality. People produced charcoal far distance the villages since a man who had sexual intercourse with his wife during the time of preparing a smelt would not be able to detect the right species of trees required for the iron production process. Moreover, he would burn himself on the burning trees. People used the following types of trees: *guthu* (*Acacia erioloba*, syn. *giraffae*, Camel Thorn Tree), *ghukuthi* (*Baikiaea plurijuga*, Rhodesian Teak), and *ghupako* (*Erythrophleum africanum*, Ambo Teak). Wood from these tree species produces high temperatures in the furnace and the embers in the furnace would last longer than from other types of wood.

2.6.4 Smelting

A varying number of people participated in a smelt, depending on the need of iron of the individuals who were involved in these activities. Sometimes there were ten, twelve, or more than twenty ironworkers. Those who were in need of iron were expected to work for it. If only five individuals were in need of new tools, only these five individuals carried out the iron production. A group of married men came together from each homestead that was in need of new iron. The headman of the village and the head of the families decided the time period when the smelting should take place and which members of the community were allowed to carry out these activities. People smelted at any season apart from the rainy season, depending on their need for iron. This could be one to three times a year. The entire smelting process from the beginning until the end took two months. It took a long time to collect all the materials necessary and finally to produce iron. Sometimes, the ironworkers had to collect their raw materials from remote localities and had to carry them to the smelting site first. During the smelting period, the ironworkers were busy with the preparation of the smelt all day long and did not pursue other activities.

People usually used only one furnace at a time even if twenty individuals wished to produce new iron. They took turns at the furnace and the furnace was

446 Here the interviewees referred to the diameter of a treetop of approximately 10 to 15 meters.

447 This refers to iron ore nodules as can be seen in Figure 13. See samples 4713/06, 4714/06, 4715/06, 4716/06 but also to larger concretions of around 30 cm in diameter.

448 Here the interviewees refer to the plinthic top soil as seen in Figure 12 .The ore concretions are found slightly below the surface within these red soils.

never turned off. People used furnaces made from termite hills. They hollowed a suitable termite hill out so that a person might crawl inside the furnace. The termite mound that the ironworkers selected to serve as a furnace was of such dimensions that a person could fit in. The interviewees did not remember the exact dimensions because people had no measuring instruments in the past. Below the bottom of the termite mound, the smelters installed a drain for the molten iron to flow out. In the past people used digging sticks called *munyondo* in order to hollow out the anthill. Later they used axes. The ironworkers used their furnaces for many years.

The smelters charged the furnace, alternating layers of charcoal with layers of ore until the furnace was filled up. They started with a layer of charcoal at the bottom of the furnace. One side of the furnace stayed open in order to supply further materials. The smelters added no other supplements to the batch. People carried out the smelt during the night. They started at night and sometimes continued during the day. Sometimes they operated the furnace for 24 hours until all the collected ore was used up. The ironworkers supplied the furnace with new ore while the molten iron poured out. In case that the smelt did not succeed, the batch looked like what they put in before. The ore had not melted. The ironworkers waited until the next morning. Then they knew that something was wrong although there had been fire in the furnace the whole night through. They removed the defective materials from the furnace and charged it again. The waste from the furnace was brownish and looked like rusty iron. The smelters dumped the waste of a smelt at a distance of approximately 10 m from the actual smelting site. They cleaned out the working area when the smelt was over.

Ironworkers had to apply magic in order to perform their trade, otherwise they would be burned and hurt. However, none of the ironworkers was a magician nor was he a healer due to his specific knowledge of ironworking and production.

2.6.5 Bellows

The ironworkers installed two to four bellows around the furnace, depending on the size of the furnace. The bellows were decorated. The blowing pipes of the bellows were made out of clay. They measured approximately 30 to 40 cm in length and the thicker side of the pipes showed a diameter of roughly 20 cm. They formed the blowing pipes with their hands while the clay was still wet and fired these blowing pipes later. The ironworkers laid out four places from where the bellows could be operated. Both cups of the bellows were made out of the wood of the *mushuwa* tree[449] and were covered with hides. The smelters operated the bellows while sitting or standing upright and they kept the place clean where the bellows were installed. The bellows were always stored outside of the homesteads. Also, the person who made a new bellow had to abstain from sexual intercourse during this time.

2.6.6 Iron

The iron poured out of the furnace into the drain. The smelters shaped the fresh iron while it was still liquid. The ironworkers were able to touch the hot iron without being burned because they dipped their hands in a medicine before they started the smelting activities. If only a little iron poured out of the furnace, the iron was liquid. If a larger amount of iron poured out of the furnace, it was viscous. The smelters waited less than one day before they took the iron out of the drain. They took it out with their hands as soon as the iron had been cooled down. It was real iron. It could not be smelted again. The ironworkers carried their piece of raw iron to the village. The color of the iron was grayish. Formerly, the iron was hard. The smelters again put this piece of raw iron into a fire until it became soft again and cut it into pieces. The quality of the new iron was always the same. Usually people obtained a piece of raw iron of the dimension of the length of an arm or shorter per smelt. Raw iron of poor quality was considered brittle and light in weight. They thought it burned easily like wood.

2.6.7 Rituals and Taboos

Only married men were allowed to conduct a smelt. However, they were expected to keep away from their wives. The smelting sites were set up far away from the villages so that women and children would not be present at such sites.

There were no sacrificial ceremonies before the smelt. During the night of the smelt, the ironworkers used to sing songs of the Nyemba people, although they did not understand the meaning of these songs. The Hambukushu and Nyemba people frequently intermarried in the past, thus the children grew up with songs in Nyemba and Thimbukushu. The tenor of these songs does not necessarily seem related to smelting. The ironworkers had been singing and dancing the whole night through in order not to fall asleep. A person who did not want to fall asleep started dancing.

[449] Probably *ghughuwa* (*Pterocarpus angolensis*, Dolfbaum, Kiaat).

The interviewees remembered the following two songs.
First song:

Kupi kutughunwa?

Kaghundongo-ndongo,

Mutjima toko mutjima kaghuru ngunda.

This song is part of tale of the ogre dikithi who swallowed homesteads and villages.[450] He also ate some ironworkers with their tools, a smelting furnace with its charcoal and the bellows. Inside of the stomach, the people lit a fire with the bellows the charcoal of the ironworkers so that the giant became thirsty. They started to forge tools and aggravated his pain. He tried to drink water from some lakes but the lakes dried up when he arrived. Finally, his stomach burst and set the people free. Only a fire ignited by bellows would be powerful enough to kill the ogre. The ironworker of Dikundu sung this song, which are the words of the giant, because they were proud to be powerful heroes like the ironworking hero of the tale. They were heroes because they had the power to produce iron.
Second song:

Tuyende kumeyu mahupa,

Ngwaranga.

This song refers to ironworkers who were thirsty because of their hard labor. They went fetching water from a well but the well was dry. So they returned with an empty calabash. This song is meant to encourage the ironworkers to continue with their work even if they are thirsty and there is no water to drink available. It was sung at any occasion in daily live where people were expected to hold out and continue with their work.
The ironworker's wives slaughtered chickens and goats for their husbands before they left so that they might have enough food at the smelting site. If the ironworkers run out of food, elderly postmenopausal women brought some food to the smelting site. They brought it only half the distance to the furnace site and needed to hide themselves behind shrubs and trees because they were not permitted to approach the smelting zone. From there they called the ironworkers so that somebody from the smelting site may come and get the food. Later, the ironworkers brought their plates back to this place in the bush. The people of the village brewed beer after a successful smelt.
If a smelt was unsuccessful, the ironworkers felt depressed. Iron of poor and brittle quality was produced if women had been around the smelting site or in case one of the ironworkers practiced sexual intercourse during the period of smelting activities. The head of the family summoned a meeting in order to identify the ironworker who had made a mistake. It was thought that a smelt would fail if one of the smelters absented himself from the smelting site and practiced sexual intercourse with his wife (or any woman) during the smelting activities. This was the only reason why a smelting procedure would fail. Even woman was questioned about their potential offence against the law.

[450] The complete tale is published in Seifert (2006, pp. 50-55).

2.6.8 Forging and trading

People were not allowed to smelt in the village but they were allowed to forge within settlements. The forges however were always located between the individual homesteads. Each homestead had its own forge and at least one person who knew how to forge. The fire of the forge was powerful. It was not allowed to place the forge inside of homesteads because the fire would be close to fertile women. In such a case, the tools of a blacksmith would be spoiled and he could become burned and injured by the fire in the forge. The workplaces of the blacksmiths are not fenced in, but women are not allowed to be present there. Whenever a women brings something to eat to the people at the forge, she is expected to keeps a certain distance. The fire of the forge was never lit with embers from a homestead's fire, which has been used by menstruating women. The embers taken from a homestead's fire would spoil the tools.
The blacksmiths used anvils that consisted of a conical piece of iron set in a large chunk of wood with a flattened end for hammering. Further, ironworkers used a sharpening stone, a heavy hammer made out of metal, water for cooling the items down and only one bellow. The blacksmiths used charcoal from the same species of trees that they used for the smelting process. The waste from the forging process is black in color and is of flat leaf-like appearance. People forged the following tools:
Kamo: Ax
Ditemo: Hoe
Moko: Knife with one cutting edge
Thimende: Knives with two cutting edges
Diyonga: Hunting spear
Dindambwa: Harpoon-shaped arrowhead
Dirovo djo thi: Fishing hook
Dirovo djo ngandu: hooks for catching crocodiles[451]
Dinyamuna: Razors
Rubeko: Cosmetic knives for women
Mweto: Traditional hammer

[451] Hooks for caching crocodiles are made for hunting crocodiles that killed a human individual or cattle. People put such a hook with a goat on it in the river and tied up the hook at a tree.

Each village smelted on its own. People produced iron tools only for their own use. They did not sell or exchange the iron ore. Occasionally, people sold tools to villages that were not in possession of a smelting location. These people had to exchange goods in order to get some iron or some tools. They never sold the raw metal. The rates of exchange were as follows:
1 *kamo* (ax): 1 cow or bull or 2 goats or 1 hide-bag of mahangu[452]
1 *ditemo* (hoe):[453] 1 cow or bull, or 2 goats or 5 chickens
1 knife (*moko* or *thimende*): 1 or 2 chickens depending on the size of the knife
Spears were personal weapons and were never exchanged for other goods. People did not exchange arrowheads, cosmetic knifes and razors. The hooks for hunting crocodiles were sometimes loaned to other people free of charge, but they were never sold. The San people were not able to smelt. They lived near the people who ate pap.[454] They lived on hunting in the bush. They did not smelt and they did not forge. Sometimes, if for instance a kudu antelope was caught, San people exchanged meat for iron items such as arrowheads. Sometimes, they exchanged meet for mahangu flour [455] or honey for tobacco.

2.6.9 Sociocultural context

In the Hambukushu society there existed professional potters, carpenters, healers, fishers and ironworkers. Every married individual was expected to farm in order to make a living. Usually the trade knowledge of ironworking was passed on within the family and sometimes, skilled neighbors taught it. Frequently, ironworkers were heads of their families because they possessed a broad knowledge.[456] Generally, blacksmiths and smelters were respected members of their communities. There was no difference with respect to status and prestige between the two trades. Ironworkers were wealthier than other individuals of their communities were because they owned metal. Additionally they owned fields and cattle and hunted for their own needs. Everybody was able to hunt if the individual had enough dogs. The number of ironworkers within a community depended on the size of each village. Every family and each homestead had at least one person who was trained in ironworking. Ironworkers were able to do both, the iron production and the forging. These skills were not perceived to be separate trades. The master smelter could be the headman of the village or an individual who was particularly skilled in ironworking. Since the ironworkers used to work together in teams, they knew who was a good smelter. Usually the Fumu was able to smelt. The rulers knew the techniques of iron production even if they never performed a smelt by themselves. There were no marriage restrictions for ironworkers. They were permitted to marry the woman they desired according to the ruling marriage customs.

2.6.10 History

According to the interviewees, probably God showed the Hambukushu people how to produce iron. However, they do not know how long their people had been in the iron production because people did not count the days in the past. In the past people started to smelt stones [iron ore] because they had no tools. The interviewees could not remember how long people had been smelting at these sites in Dikundu.
Every people or ethnic group, which lived along the Kavango River in the past, smelted their own iron. The interviewees remembered the Kwangali, Mbunza, Gciriku, Shambyu, Hambukushu, Nyemba, Tswana and Haruyi (Caprivi). The San people learned it from the Hambukushu.

2.6.11 List of terms related to field of iron

Mwandhe: Bellow
Dikera: Tuyere
Muhemunyuni: Smelter
Thitapo: Smelting furnace
Mupowa: Drain from the furnace
Yithuthunganyi: Slag
Katenda yikuvo: Producing iron
Makara: Charcoal
Kathira: Iron ore
Thituvo: Iron
Ukoporo/Roto: Copper
Muka kufura/Kafura nyondo: Blacksmith
Muka kutenda yikuve: To forge
Mwara/difurero: Forge, workplace of a blacksmith
Mweto: Hammer of a blacksmith
Dyundo: Anvil
Mayura: Pliers made out of tree bark
Meyu: Water used for quenching
Diwe: Sharpening stone

[452] According to the interviewees, such a bag contained approximately 60 kg of Mahangu.
[453] If a person practiced illegally sexual intercourse with his neighbor's wife, he had to pay a penalty of one hoe or 10 cows or bulls.
[454] Here the interviewees refer to horticulturalists and agriculturalists, which lived in the neighborhood of the Kavango River and further north.
[455] They frequently exchanged meat for a superfine, ground flour without husks.
[456] However, a family head or a village head did not necessarily know about the iron trade. For instance, it was also of importance to have reached an adequate age to reach such a position.

2.7 Interview with Headman Kavinja at Dikundu, conducted by Beatrice Sandelowsky July 8 and 11, 1969 (Manuscript)

Had an illuminating interview with an old Hambukushu man whom our two workers from yesterday brought with us out to the site. His name is Kavinja and he is '*vourman*' of Kaptein Alfons – the chief of the Hambukushu [...]. By question and answer technique the following information was elicited: Many years ago, when Kavinja was a still a young boy 5 men from Angola, Hagamashi, came here to work metal. They stayed two months. At sunrise, they would leave to fetch red sand and would return at midday with their leather bags filled.

They would make a hole in the ground 12'' – 18'' in diameter with two furrows leading off it. A fire would be made in the sand and heated from two bellows in the furrows. The bellows were made of wood and goatskin and the tuyere was made out of clay from an anthill. The bellows were worked one whole day and right through the night. Then the metal (iron ?) was left to cool - it would have collected in the center of the hole. Then they would tap it out and go to the shade of a big tree (the one where we are working now) and start beating the iron and making their hoes and spears and arrows. Here, under the big tree they had another fire with bellows and would heat the metal again for working it.

The slag, it was explained, was the '*vvilgoed*' (dirt stuff), which would float on top and be on the sides. The good metal (iron) would be in the center. When they bring it to the shade to work it's in a big chunk with all the dirt stuff sticking to it all around it. It would be beaten and all the slag would fall off and the pure metal would then be heated again and again in the fire just to get a little softer. Asking how high the pile of sand for smelting would be, Kavinja said: Only small because each man would smelt his sand alone. They did not put all their sand together on one big pile.

Then he took us a few yards down to the road fairly thickly overgrown there is a hill (ant- ??) with lots of slag on and around it. In sort of circular form around it there are small heaps – a few yards from one another with red sand – clay & slag – the red color forming a sharp contrast with the surrounding gray soil.

Questioning about an anvil we were told that they would first take a large piece of iron they had made and use that as an anvil. Then they would work the other tools on that.

According to our three Mbukushu informants the Mbukushu did not know how to work metal. [...]. Max asked: how did the people from Angola know that the red sand was there? Answer: Two men first came to the chief of the Mbukushu to ask whether there wasn't any real red sand somewhere. Then the chief sent of his men to show them. In return, before the Hagamashi left thirty implements – hoes, adzes, spears, arrows etc. The chief thanked them very much.

Drove to the place where they are said to have fetched the red sand for smelting. Kavinja showed us the way about 6 miles from the site of smelting by car – on foot there probably is a shorter route.

We first passed one Omuramba with very red sand in the bottom of it – but Kavinja said this was not good – it was only used to put on the outside of the heap. Then further on we came to another – or probably other part of the same Omuramba – and there was really extremely red sand in the bottom if it forming a sharp contrast to the white sand on the edges. I took a sample of this powders red sand – Kavinja said they dug deeper for the real good red sand. So we also dug down a little and [...] lenses of yellowish – lighter colored sand could be seen.

According to Kavinja the sand from this place has a special name kathira and the place's name is Kapongo.

Kavinja also said that in the old days people came from far away to fetch this sand – from as far as Nyangana. Furthermore Kavinja told us (and made one) tuyere by taking the tip off the top of an anthill and bring a hole through it. It need not be specially fired – it is hard enough as it is.

2.8 Nyemba Iron production at Kafuma, Angola, narrated by Alberto Munoma Makayi

This interview was held with Alberto Munoma Makayi on August 7 in 2006. The interview was revised and complemented on August 1 and 8, and October 6 in 2007. Michael Hakusembe and Hilda Ndumba assisted and translated the Interview. The interview was recorded on video tape.

A. M. Makayi was born in 1948 in Kafuma, Angola. He is a Nyemba; both parents were Nyemba. He speaks Runyemba and Rukwangali. He is a professional blacksmith and sells his tools at the Open Market in Rundu. A. M. Makayi came to Namibia in 1973 in order to work for the construction of the railway from Windhoek to Rehoboth. After he had broken his leg, he became unable to work at the railway construction anymore. In 1975, he settled in Rundu.

A. M. Makayi grew up in Kafuma. His father was a smelter. He learned the iron trade from his father. The interviewee participated in smelts and operated the bellows when he was 20 or 30 years old. Following A. M. Makayi, people used to smelt in Kafuma until 1973 because of the war. Access to scrap metal was very limited in this region during the war. This is the way traditional smelting had been practiced until the 1970es.[457]

2.8.1 Smelting site

Sitave[458] was the name of the site where the interviewee participated in the traditional smelting. It was about a two-days-walk north of Cantana.[459] In Kafuma, people smelted near the mines. Generally, the Nyemba people used to smelt near or at their mining sites. People laid out the smelting sites roughly 3 km away from the permanent settlements. If necessary, they could also be closer. They smelted in the same area where they found the iron ore. The name of the mining area of Sitave was Sindenga. It was about 2 km away from Sitave. There existed another very important smelting site of the Nyemba people called Mukundu in a one-day-walk north of the Kavango River. Only at these sites were the red sands of good quality that the Nyemba people used to smelt. At Kafuma, people usually used only one furnace at a time. The smelting zone as such was of a dimension of about 10 m by 10 m. The interviewees could not remember how long people had been smelting at these sites in Sitave.

2.8.2 Ore and Mining

The ironworkers used [secondary] ores, which they called red sands. The consistency was hard like clay from the river. It seems as if there were no differences regarding the quality of the raw material. Only adult men older than 20 years were allowed to dig for ore, because they had enough knowledge of iron making. The red sand was dug up with digging sticks, but sometimes the ironworkers also collected it from the surface. Sometimes, they dug pits of an approximate diameter of 5 m and of hip height in order to get good ore, depending on how many people were available for the mining. The pieces of ore that they extracted were about the size of a lower leg. The ironworkers put pieces of ore of such size in their smelting pits. The ironworkers carried four 'bricks' of ore at a time on elliptical wooden dishes to the smelting pit. Boys were allowed to assist this part of the preparation of the smelt. For one smelt, they needed about 50 to 100 of these ore bricks but he could not remember precisely the exact number of bricks that they needed for one smelt.

2.8.3 Charcoal

The charcoal for the smelt was made from the *mukosho* tree (*Erythrophleum africanum*, Ambo Teak) because the embers of this wood were known to last in the furnace. The ironworkers collected wood in order to produce the charcoal needed everywhere the specific trees grew. Also, people from the neighboring villages could produce charcoal for the smelters. They received raw iron in return for their service. For one smelt, 35 to 40 baskets of charcoal were needed. People used big baskets and small baskets. Most accidents happened during the preparation of the charcoal because people injured themselves with their axes. However, it was considered a normal accident and it was not thought to be caused by the violation of any taboo.

2.8.4 Smelting

About thirty ironworkers conducted one smelt. The oldest man was their leader. People smelted up to three times a year. They smelted only during winter times (i.e. the dry season), because they feared the heavy rains of the summer season. If it began to rain before people had finished with their smelts, the ironworkers build a roof over the pit. The ironworkers smelted in pits measuring approximately 10 m in length and between 1.50 m and 2 m in width. They dug box-shaped pits of knee depth with digging sticks in the sandy soil with two furrows leading away from the furnace at the long edges. The ironworkers placed two bellows at the narrow edges. The smelters charged the furnace with three layers. They started with a layer of ore at the bottom and continued with a layer of charcoal that was covered with ore again. A. M. Makayi could not remember the thickness of these layers. The ironworkers put no other contents or materials into the smelting pit. The filled up pit was not closed or covered. They lit the fire from both narrow edges. Thirty people or more who took turns at the bellows where needed to conduct one smelt. The ironworkers smelted from sunset to dawn. The melt was liquid and solidified later. The metal

[457] The Kafuma Omuramba runs north-south for a distance of approximately 100 km in southern Angola and opens to the Kavango River valley at Bengo and Kasivi at E 19°18', approx. 40 km west of Rundu. The smelting sites are situated roughly 80 km north of the Kavango in contemporary Angola. Following Kwangali Hompa Sitentu Mpasi, Kafuma was a very important smelting site for the Kwangali, Kwanyama, and Nyemba people.

[458] Sitave is also called Situwe.

[459] A. M. Makayi gave contradictory information with respect to the distance of Sitave from the Kavango River: In one of our earlier meetings he stated, that Sitave lays a two days walk north of Cantana. Cantana, however, lies 35 km air distance north of the river. In one of the following meetings he stated, that Sitave is in a walking distance of one and a quarter day away from the Kavango River. From the border-crossing Kandendere, one may reach Mpempa in one day. From there, one has to do again a walk of half a day in order to reach Sitave.

concentrated at the bottom, the slag was on top of it. Metal and slag separated on its own. The good quality metal was at the bottom of the pit and the slag partially flowed off into the furrows. After the pit had been cooled down for an hour, the smelters took out the bloom with their hands. People removed the remaining waste. They discarded the slag and all the other remains near the pits. The pits were used repeatedly, sometimes for one or two years, sometimes even longer. The entire working process, starting from the production of charcoal and the collection of ore until the raw iron was generated, took one month.

2.8.5 Bellows

The bellows were made out of *mukula* wood (*Pterocarpus angolensis*) and consisted of two cups with either having an air channel. The cups were covered with hides of cattle or goats. The sticks attached to the hides to operate the airflow were chest high and made out of *mdimbamdimba*(?) wood, because people considered it robust. The ironworkers operated the bellows standing upright. They used a specific pumping technique to avoid an aspiration of hot air that would burn the wooden bellows. The smelters placed a conical blowing pipe made out of clay in front of the wooden air channels. The blowing pipe measured approximately 1 m in length, 10 cm in diameter at the edge that was connected to the bellows, and about 3 to 5 cm in diameter at the edge that was put into the smelting pit. The interviewee does not know blowing pipes made out of stone. Together with the blowing pipes, the bellows measured between 1 m and 1½ m in length. Only the strongest of the ironworkers were allowed to operate the bellows. During one night of smelting, ten to twelve individuals took turns at the bellows.

2.8.6 Iron

The ironworkers differentiated three smelting products: raw iron of good quality, raw iron of bad quality and waste (i.e. slag). The good quality iron collected in the middle of the pit, the one of less quality at the edges of the pit. The smelters usually generated five or six pieces of raw iron, sometimes up to ten. They were of varying size, sometimes as big as half a loaf of bread, some were flat, and some were as small as a cigarette box or even smaller. The larger pieces were of better quality, the smaller ones were of poorer quality because the metal was brittle. Raw iron of good quality was heavy; pieces of poorer quality were light in weight. Out of six pieces of raw iron from one smelt, there could be three to four of good quality and two of poorer consistency. This was considered a successful smelt. Sometimes, the iron-workers generated only four pieces of raw iron. This was considered not successful; however, the amount of generated iron depended on the amount of iron ore that the smelters processed. The ironworkers called the iron of poor quality *manyana*.[460] It was given to the assistants so that they could forge something for their own needs. This iron was brittle compared to that of higher quality, but he does not know the reason why. The iron of good quality was called *tshitima sha utale* and kept by the smelters. Those assistants who participated repeatedly in the smelting work were rewarded with good quality iron. The ironworkers carried the raw iron away from the smelting site. They could store it in their own homesteads. They heated the blooms in the forge until they started to glow in a red color. The ironworker pounded the iron with a hammer. Being heated again, the iron was easy to divide into smaller pieces

2.8.7 Rituals and Taboos

At the smelting site, the ironworkers were dressed up like elderly women with game hides and blankets. This was a law. In the night of the smelt, they started drinking around midnight. They drunk *kashipembe*[461] and *wampuka* in order not to get tired. The women who stayed in the villages shouted and sang encouragement from there. If the smelt was successful, everybody celebrated the smelt. The ironworkers who operated the bellows during the night sang specific songs the whole night through. These songs were thought to provide them with power so that they would not become tiered.

Tumuyeveye Ndungulume wadhala kantjala kumutwe.

In other circumstances, people performed this song to welcome important men. The name Ndungulume stands for an important person who wore a headdress of honor or crown on his head. Usually, in an ordinary context, people sang this song while the women were dancing and trilling to welcome the person. Figuratively, the ironworkers of Kafuma praised their bellows like the important Ndungulume. Like an important man, it was thought that the bellows brought prosperity to the people. In their case, the bellows brought iron tools to the people. The bellows were the most important tools of the smelting process. The ironworkers who operated the bellows wore a headdress made of ostrich feathers. This headdress expressed their rejoicing in their work. At the same

[460] Manyana is a general term for waste and is also used for slag and scale.
[461] Hot liquor produced from the peel and flesh of Manketti fruits.

time, women were trilling from the villages in order to encourage their husbands at the smelting site.
Another song that was sung at the furnace while the ironworkers operated their bellows was the song of the Eland.

Lishefu lyange, lishefu lyange,

ya thiha Mukonda muna Ghumba wa Ndala – va nanee!

Ndina hono kukava Kangovo mukalu,

Kangovo wa mukalu kumushikula – lishefu lyange,

Kangovo wa mukala kumulandula – lishefu lyange,

Lishefu lyange,

Lya thiha Mukonda muna Ghumba wa Ndalee-ee!

Ndjina hono kukava Kangovo wamukalu.

Figuratively, the smelting process was considered as difficult as following an injured antelope in the bush during the hunt and the smelters identified themselves with the hero hunter.[462]

People lived close to the smelting site with their entire families. The smelting sites were set up where the iron ore was found. This could also be in the vicinity of a homestead. It was not strictly forbidden to visit the smelting site, but it was not welcomed either. Some people were invited to visit this location, others were not invited. It was prohibited for younger women [i.e. menstruating women] to enter the smelting zone during the smelt, but elderly women [i.e. post-menopausal women] were allowed to come. Also, it was prohibited for the ironworkers to practice sexual intercourse with a woman during the time of the smelting work. Moreover, the smelt was carried out during the night because no women were walking around. Small children (boys and girls) were allowed to be present at the smelting site under supervision, yet it was prohibited for children to play at the site. The smelting area was fenced with reed mats or shrubs at a safe distance from the fire in order to protect the site from animals or playing children.

[462] The song was not only sung at the smelting site of Kafuma where ironworkers applied spiritual hunting techniques in order to succeed in metal fabrication. The more common use of this praise song was within the initiation ceremonies of boys and girls in the Nyemba society. Another use was in healing rituals for a specific mental illness, which caused a person to run away from his or her community (H. Ndumba, personal communication).

During the smelting period, the ironworkers ate only game and fish since they rejoiced in the smelting activities so that they felt like not killing domestic animals. The ironworkers went hunting and fishing before they started with their work. However, the interviewee did not remember the amount of food that they collected before they started with their work. They drank alcoholic beverages and milk. Every morning, one of their team went hunting so that they had enough food.
Every individual ironworker asked his ancestors for assistance before they started with the smelt. In case someone broke the taboo and had sexual intercourse during the smelting work, the fire of the smelting pit would burn him and the iron would become brittle and would break easily. The whole community would condemn and abandon the guilty person.

2.8.9 Forging and trading

People forged close to or even within their homesteads depending on whether there were small children around who might be endangered by the forge. Every blacksmith had its individual work place that he habitually used. The blacksmiths took a piece of raw iron and shaped it into the desired form. For this, they used a metal hammer. It was not necessary to beat the raw iron out after the smelt. The blacksmiths used hammers out of iron, metal pliers rumana, an anvil that consisted of an iron hammer head that was set in a large chunk of wood, an iron chisel, two types of sharpening stones and one bellows with a blowing pipe measuring about 50 cm in length. The blacksmiths used water to harden their tools. They dipped a finished ax into cold water while the iron was still hot. The blacksmiths used the same type of charcoal made from the *mukosho* tree (*Erythrophleum africanum*, Ambo Teak) as they did for the smelting fire. They heated the raw iron in the forge until it became red. Then they divided it into smaller pieces with a hammer. Waste of the forging process is called manyana utale. It is of black color and of the shape of small coins. The Nyemba blacksmiths produced the following tools:
Kakandu: Simple ax
Mutaka: Ax with extended pointed corners
Matemo autale: Hoe
Mpoko mulanja: Single-edged knife
Mwele: Double-edged knife in a wooden sheath[463]
Likunga: Simple spear with leaf shaped head and a wooden handle
Likunga mupembe: Spear with leaf shaped head and a wooden handle. An additional iron point is attached at the back[464] covered by a cow tail.

[463] Used for the cutting of meat and reed.
[464] According to the interviewee, the back point is used to stick the spear into the ground.

Ndamba: Double-winged arrowhead
Ngumba: Single-winged harpoon-like arrowhead
Tshingombo: Y-shaped forked arrowhead
Mungamba: Leaf-shaped arrowhead
Mumba: Head of a harpoon
Tshiwe: Needle/knife for basketry[465]
Tshishongo: Needle/awl for basketry[466]
Muhotolo: Fire striker (flint and steel): It consists of a flint stone, a flat iron/steel ring and wool and seeds of the *muntja*(?) and *mukia*(?) trees serving as tinder.

Some Nyemba blacksmiths manufactured iron jewelery, but not at Kafuma. Ironworkers of Kafuma and Kakeni produced copper jewelery; however, A. M. Makayi could not remember from where the Nyemba ironworkers obtained their copper.

Women could approach the forge and watch the blacksmith's work, but they were not allowed to touch things or to cross the fire. A. M. Makayi does not know what would have happened, if a woman had crossed the fire. He stated that girls could operate the blacksmith's bellow without problems. Women were allowed to take embers from the blacksmiths' fires to their hearths; though it was prohibited to take charcoal from the smelting to the homesteads. The interviewee did not remember the reason for this ban.

The Nyemba traded axes, hoes, two types of knives, spears, and harpoons. The size of an item was not important in setting the exchange rates. Some exchange rates of tools and weapons were:[467]
1 ax (either *kakandu* or *mutaka*): 1 goat
1 *matemo autale* (hoe): 2 goats or 40 ct. (1945-1951)
1 knife (either *mpoko mulanja* or *mwele*): 1 chicken
1 spear (either *likunga* or *likunga mupembe*): 1 goat or 1 barrel of mahangu

The blacksmiths exchanged heads of harpoons (*mumba*) for charcoal for the forge. For one bag of charcoal of 20 to 50 kg, the blacksmith forged two harpoon points and gave one of them to his customer.[468] Customers could also pay with field labour. People could obtain arrowheads through providing the ironworkers with their work force for the smelting work or any work to do at the fields. For one day of work, the ironworkers gave 2 to 3 arrowheads to their assistants depending on how hard somebody had worked. The ironworkers also exchanged three arrowheads for one chicken. For one fire striker, a person had to work two days. Unrefined raw iron was given only to the smelting assistants. One cow was given for two hoes and one ax. If a person was in need of a new tool but had no resources to pay for it (i.e. small livestock or mahangu), he could provide the blacksmith with his work force for two or three days, dependently of the value of the tool and the efforts of the individual person at work. The blacksmiths also lent out tools free. A man who intended to get married was expected to pay one cow to his future in-laws. If he was not able to do so, alternatively he could offer four hoes and one ax. However, as soon as he was able to afford a cow, he had to give a cow anyway.

San people used to live in the bush in the Nyemba territory and maintained exchange relationships with the Nyemba people. San people were not involved in the smelting trade but they could obtain iron tools from the Nyemba people. The Nyemba exchanged axes for honey and meat. They also obtained salt, tobacco, and corn from the Nyemba. However, they did not live together.

2.8.10 Sociocultural context

Every man who was interested could learn the iron trade at Kafuma. Smelter and blacksmith were different trades and highly respected within the Nyemba society. Smelters had a higher reputation than blacksmiths. Ironworkers possessed power to produce tools. Some of them were healers. Some of them were able to do magic. The Nyemba king was a hunter, healer and a blacksmith. Ironworkers were under the control of the Headmen. However, they were free to decide the time of the next smelt. Ironworkers were rich members of their society because they exchanged metal tools for domestic animals. Ironworkers hunted and cultivated fields in order to make a living. They exchanged tools for cattle. In the Nyemba society, there were no specific marriage restrictions for ironworkers. They were permitted to marry the woman they desired according to the ruling marriage customs. In accord with their social status, they were permitted to have three wives. Farmers had two wives and a Hompa had two or three wives.

Smelting was a big event because everybody got the opportunity to get some iron. People came from far in order to help with the smelt. Some people came from Kuji, Ilonga, Tshithimba, Tshiwambi, Luntovu and Cahema. These places were about 30 to 50 km away (which means a one-day's walk) from the smelting sites of Kafuma.

465 Knife-like with a bent point and a wooden handle.
466 Like a thick needle with a wooden handle
467 In the course of our interview meetings, A. M. Makayi gave contradictory exchange rates for the iron tools. In 2007 he gave us the following rates: 1 hoe *matemo autale*: 1 goat; both types of axes: 1 chicken each; 1 spear of the *likunga* type: 3 chickens; 1 of the *likunga ya mpembe* type: 2 chickens; 3 arrowheads: 1 chicken; one tool for basketry either *tshive* or *tshishongo*: 1 chicken; one fire striker: 1 chicken or a big cup of mahangu.
468 At this point, the interviewee probably referred to the fact that two harpoon points were made from one single piece of raw iron as can be seen from hoes and axes.

2.8.11 History

The Nyemba people received their knowledge about iron production from their ancestors in order to end the suffering of the people. The country of origin of the Nyemba ancestors was in the north and was called Tshitauwe. Tshitauwe is a tributary of the Kwito River. The ancestors of the Nyemba people had been producing iron for many thousands of years. The ancestors showed the people how to create the smelting fire and the places where the iron ore is found. When he grew up, the knowledge about iron production was already there. One person must have shown their ancestors how to produce iron. The Nyemba founder kings in Tshitauwe already knew how to smelt.
According to the interviewee, only the Nyemba were able to produce iron and to manufacture tools. The Kwangali, Mbunza, Shambyu, and Hambukushu knew how to forge, but they did not know how to smelt. People with no metallurgical knowledge at all were the Ovambo, Kwanyama, Herero, Gciriku, Umbundu and San people. This is the reason why the Nyemba people traded their tools to their neighborhood and farther away to people living in contemporary Namibia, particularly to the Kwangali people.

2.8.12 List of terms related to field of iron

Muvandje: Bellow
Nkela ya muvandje: Tuyere
Kashondjo: Blacksmith/Smelter
Kamuvandje ndi vindenga: Smelting pit
Manungu: Charcoal
Vitima ya utale: Traditionally made iron
Theta vikugu: Scrap metal
Hamuyere ya yavindenga: Forge, workplace of a blacksmith
Hatji taho / tjina tja vindenga: Smelting place

Appendix 3: Tables

Site catalogue number	Site name	Excavation	Finds	Features and interpretation	Chronology	Pottery style
1	Bunya	-	Pottery	Midden of a settlement site.	LIG	Vungu-Vungu
2	Karangana	-	Pottery, lithics	EIG and LIG settlement sites.	EIG, LIG	Divuyu/Kapako Vungu-Vungu
3	Ruuga	N98/39-1 N98/39-2	Pottery, lithics, faunal remains, charcoal, slag, ore, tuyere fragments, metal artifacts, OES beads, burnt clay, modern material	EIG Bloom refining site, fine smithing site, smelting furnace(?), stone working places, midden of a settlement. LIG settlement, smelting and bloom refining site.	EIG, LIG	Divuyu/Kapako, Vungu-Vungu
4	Kapako	N68/01 N68/02 N99/21-1 to 7	Pottery, lithics, faunal remains, botanical remains, slag, metal artifacts, tuyere fragment, clay pipes, OES artifacts, glass beads, modern material	EIG stone working place, bloom refining and fine smithing site, midden of a settlement. Transition from a lithic EIG horizon to a non-lithic EIG horizon. LIG smelting site(?), bloom refining and fine smithing site, midden of a settlement.	EIG, LIG	Divuyu/Kapako Vungu-Vungu
5	Mupini	-	Pottery, lithics, clay pipe	LIG Settlement site, undated earlier occupation of the site.	LSA, undated, LIG	Vungu-Vungu, unspecific
6	Mupini Quarry	-	Iron ore	Geological site.	Omatako Formation	
7	Rundu Ngandu Lodge, Rundu Ushivi Road	-	Lithics	Geological site. ESA, MSA, LSA occupation site.	Eiseb and Omatako Formation, ESA, MSA, LSA	
8	Rundu Sarasungu Lodge	-	Pottery	Settlement site.	LIG	Vungu-Vungu
9	Rundu Sarasungu Road	N99/20	Pottery, metal artifacts, glass beads, industrial glass	Settlement site, blacksmith's workshop.	LIG	Vungu-Vungu
10	Rundu Immigration Office	N98/27	Pottery, lithics, glass beads, iron ore	Settlement site.	LIG	Gove, Vungu-Vungu

Table 1, continued on next page: Overview of site complexes.

Site catalogue number	Site name	Excavation	Finds	Features and interpretation	Chronology	Pottery style
11	Kaisosi	-	Pottery, lithics	Settlement site.	LIG	Gove, Vungu-Vungu
12	Vungu-Vungu	N69/01-1 & -2 N96/03-3 N98/32-2	Pottery, lithics, faunal remains, botanical remains, slag, ore, metal artifacts, tuyere fragment, OES artifacts, glass beads, modern material.	LSA occupation site. LIG settlement site, trade post(?), smelting site, bloom refining and fine smithing site, refining furnace(?), midden of a settlement. Historical royal residence and smelting site.	LSA, LIG	Gove, Vungu-Vungu
13	Mayana-N'Kwazi	-	Pottery	(Temporary?) settlement site.	LIG	Vungu-Vungu
14	Mayana	-	Pottery, faunal remains	Settlement site.	Undated	Unspecific
15	Muhopi	-	Pottery, tuyere fragments	Settlement and metal working site.	LIG	Vungu-Vungu
16	Utokota	-	Iron ore, slag	Geological site, bloom refining site.	Omatako Formation, undated	
17	Gove-Mbamban-gandu	N11/02-1	Pottery, slag, iron ore, tuyere, metal artifacts, lithics, OES artifacts, glass beads, faunal remains	Geological site. Middle Stone Age occupation site. Settlement and smelting site, midden of a settlement. Historical royal residence and smelting site.	Omatako Formation, MSA, LSA, LIG	Gove, Vungu-Vungu
18	Gove-East	-	Lithics, pottery	Settlement site.	Undated	Unspecific
19	Gove-North	-	Pottery	(Temporary?) settlement site.	LIG	Vungu-Vungu
20	Tjeye	-	Pottery, slag, tuyere frag-ments, lithics	Middle Stone Age occupation site. Settlement and metal working site.	MSA, LIG	Vungu-Vungu
21	Tjeye-East	-	Iron ore, slag, lithics	Geological site. Bloom refining site.	Omatako Formation, MSA, undated	
22	Mashare and Mashare-West	-	Iron ore, pottery	Geological site. Settlement site.	Eiseb and Omatako Formation, EIG	Divuyu/Kapako
23	Mashare-East		Pottery, lithics	Settlement/ occupation site.	Undated	Unspecific

Table 1, continued from previous page and continued on next page: Overview of site complexes.

Site catalogue number	Site name	Excavation	Finds	Features and interpretation	Chronology	Pottery style
24	Mashare Agricultural College	-		Geological site.	Omatako Formation	
25	Mupapama-North		Lithics, iron ore	Geological site. Middle Stone Age occupation site.	Omatako Formation, MSA	
27	Nyangana-Kangwenu	N98/43-1	Pottery, lithics, faunal remains, OES artifacts	Settlement site, midden of a settlement, bloom refining activities.	LIG	Vungu-Vungu
28	Shikoro		Pottery	Settlement site.	LIG	Vungu-Vungu
29	Kapongo		Iron ore	Geological site. Historical smelting and mining site, smelting and refining furnaces.	Omatako Formation, LIG	
30	Dikundu		Iron ore, slag	Geological site. Historical smelting and mining site, smelting and refining furnace.	Omatako Formation, LIG	
31	Mapuri			Geological site. Early Stone Age occupation site.	Eiseb Formation, ESA	
32	Kauti		Iron ore, slag	Geological site. Historical royal residence, historical smelting and mining site.	Omatako Formation, LIG	
33	Koro		Iron ore	Geological site.	Omatako Formation	
34	Hamoye		Iron ore	Geological site.	Omatako Formation	
35	Tamsu		Glass beads, faunal remains	(Temporary?) settlement site.	LIG	
36	Andara Island		Pottery, lithics, glass, glass beads, OES artifacts, burnt clay	LIG Settlement site. Undated occupation horizon of the EIG or early LIG.	LIG	Vungu-Vungu, unspecific
37	Andara South		Pottery	Settlement site.	Undated	Unspecific
38	Dryogha		Pottery	Settlement site.	LIG	Vungu-Vungu
39	Kake		Pottery, glass beads	Settlement site.	LIG	Vungu-Vungu
40	Kake-West		Pottery	Settlement site.	LIG	Vungu-Vungu
41	Divundu-North		Pottery	Settlement site.	LIG	Vungu-Vungu
42	Divundu-South		Pottery	Settlement site.	LIG	Vungu-Vungu

Table 1, continued from previous page and continued on next page: Overview of site complexes.

Site catalogue number	Site name	Excavation	Finds	Features and interpretation	Chronology	Pottery style
43	Ndongo-North		Pottery	Settlement site.	Undated	Unspecific
44	Ndongo-South		Pottery	Settlement site.	LIG, undated	Vungu-Vungu, unspecific
45	Popa-South		Pottery	Settlement site.	LIG	Vungu-Vungu
46	Popa-West		Pottery	Settlement site.	LIG	Vungu-Vungu
47	Popa-Southeast		Pottery	Settlement site.	LIG	Vungu-Vungu
48	Popa		Iron ore	Geological site.	Omatako Formation	
49	Popa-North		Pottery, lithics	Settlement site.	Undated	Unspecific
50	Bagani-West		Pottery, glass beads	Settlement site.	LIG, undated	Vungu-Vungu, unspecific
51	Bagani		Pottery	Settlement site.	LIG	Vungu-Vungu
52	Bagani-Northeast		Pottery	Settlement site.	LIG	Vungu-Vungu
53	Bagani-East		Pottery	Settlement site.	Undated	Unspecific
54	Kamutjonga		Pottery, faunal remains, metal artifacts, wooden implement	Midden of a settlement site.	LIG	Vungu-Vungu
55	Kamutjonga-South		Pottery, glass beads, metal artifacts, schist fragments	Midden of a settlement site.	LIG	Vungu-Vungu
56	Kamutjonga-Southeast		Pottery	Settlement site.	Undated	Unspecific
57	Mahango Central		Pottery	Settlement site.	Undated	Unspecific
58	Mahango South		Pottery	Settlement site.	EIG, LIG	Divuyu/Kapako, Vungu-Vungu
59	Thinderuvu Water Mouth		Pottery	Settlement site, undated occupation horizon of the EIG or early LIG.	Undated	Unspecific
60	Mohembo Border Control		Pottery, lithics, glass bead	LIG settlement site, undated occupation horizon of the EIG or early LIG.	LIG, undated	Vungu-Vungu, unspecific

Table 1, continued from previous page: Overview of site complexes.

Site catalogue number	Site number	Area	Unit	Quad-rant	Level	Lab. number	DBM Sample number	^{14}C-age BP	$\delta^{13}C$ (0/00)	Dated Material	References
12	N98/32	2				KN-5313		20±40		Bone	Richter, 2005
12	N98/32	2				KN-5329		40±60		Bone	Richter, 2005
54	N83/17					Pta-3745		40±40		Bone	Kinahan, 1986
12	N98/32					KN-5643		50±40		Charcoal collected from sediment	Kose, 2009
12	N98/32	2				KN-5191		85±30		Charcoal collected from sediment	Richter, 2005
12	N98/32	2				KN-5330		100±50		Charcoal collected from sediment	Richter, 2005
54	N83/17					Pta-3758		110±45		Charcoal	Kinahan, 1986
27	N98/43	1			Layer A	KN-5375		120±35		Charcoal from sediment, Layer A, 30 cm below the surface	Richter, 2005
30	N69/03					Pta-235		120±50		Charcoal from the bottom of a smelting furnace, 75 cm below the surface	Sandelowsky, 1974
4	N99/21	1				KN-5574		175±30		Charcoal collected from sediment, 20 cm below the surface	Richter, 2005
3	N98/39	2	56/52		27	KIA28852		175±40	-25.79±0.19	Charcoal extracted from slag, 10-30 cm below the surface	Kose, 2009
27	N98/43	1			Layer B	KN-5377		220±35		Charcoal from sediment, Layer B, 45 cm below the surface	Richter, 2005

Table 2, continued on next page: Radiocarbon dates of the Kavango region.

Table 2

Site catalogue number	Site number	Area	Unit	Quad-rant	Level	Lab. number	DBM Sample number	^{14}C-age BP	δ^{13}C (0/00)	Dated Material	References
27	N98/43	1			Layer C	KN-5376		235±35		Charcoal from sediment, Layer C, 55-65 cm below the surface	Richter, 2005
12	N98/32	Surf. 4c				Poz-20699	DBM 4433/06	270±30		Charcoal extracted from a SHB, eroding out north of excavation area N98/32	Kose, 2009
10	N98/27					KN-5190		280±30		Charcoal collected from sediment, 30-50 cm below the surface	Richter, 2005
30	N69/03					Poz-20703		320±30		Charcoal extracted from slag found in situ at the bottom of a smelting furnace, 75 cm below the surface	Kose, 2009
12	N69/01	2				Pta-236		320±45		Charcoal collected from sediment, 25-40 cm below the surface	Sandelowsky, 1979
12	N69/01	2				Poz-20671		355±30		Charcoal extracted from pottery, 25 cm below the surface	Kose, 2009
3	N98/39	2				Poz-20700	DBM 4410/06	355±30		Charcoal extracted from slag, surface collection	
17	N11/02	1	Unit 2	b	Level 10	COL #2330.1.1.		356±35		Charcoal extracted from pottery	

Table 2, continued from previous page and continued on next page: Radiocarbon dates of the Kavango region.

Site catalogue number	Site number	Area	Unit	Quad-rant	Level	Lab. number	DBM Sample number	^{14}C-age BP	δ^{13}C (0/00)	Dated Material	References
12	N69/01	1				Poz-20702	DBM 4415/06	400±30		Charcoal extracted from a block of smelting slag, surface collection around N69/01-1	Kose, 2009
3	N98/39	2				Poz-20698	DBM 4411/06	410±30		Charcoal extracted from slag, surface collection	Kose, 2009
4	N99/21	1				KN-5575		1050±35		Charcoal collected from sediment, 40 cm below the surface	Richter, 2005
3	N98/39	2	52/54		440	KIA28850		1090±35	-20.47±0.36	Charcoal extracted from slag, 45-55 cm below the surface	Kose, 2009
4	N68/02					Pta-234		1110±50		Charcoal collected from sediment, 60-70 cm below the surface	Sandelowsky, 1979
4	N99/21	B1533				Poz-20670		1305±30		Charcoal extracted from pottery collected by Reverend van Niekerk in 1967, 107 cm below the surface	
3	N98/39	2	52/50	c	437	Poz-20697		1360±30		Charcoal extracted from pottery, 65 cm below the surface	

Table 2, continued from previous page and continued on next page: Radiocarbon dates of the Kavango region.

Site catalogue number	Site number	Area	Unit	Quad-rant	Level	Lab. number	DBM Sample number	^{14}C-age BP	δ^{13}C (0/00)	Dated Material	References
3	N98/39	2	52/52	c	58	Poz-20695		1390±30		Charcoal extracted from pottery, 55 cm below the surface	
3	N98/39	1				KN-5577		1440±35		Charcoal collected from sediment, 45-65 cm below the surface	Richter, 2005
4	N99/21	1	50/51	c	6	Poz-20693	4558/07	1475±30		Charcoal extracted from pottery, 15-35 cm below the surface	
4	N99/21	3	70/45	c	47	Poz-20682		1480±30		Carburized *frusa*, collected from sediment, 60 cm below the surface	
4	N99/21	3	70/45	d	55	Poz-20680		1535±30		Charcoal extracted from pottery, 70 cm below the surface	
4	N99/21	3	70/45	d	55	Poz-20694		1545±30		Charcoal extracted from pottery, 70 cm below the surface	
4	N99/21	3	70/45	c	56	Poz-20679		1550±30		Charcoal extracted from pottery, 70 cm below the surface	Kose, 2009

Table 2, continued from previous page and continued on next page: Radiocarbon dates of the Kavango region.

Site catalogue number	Site number	Area	Unit	Quad-rant	Level	Lab. number	DBM Sample number	^{14}C-age BP	δ^{13}C (0/00)	Dated Material	References
4	N99/21	3	70/45	c	88	Poz-20668		1565±30		Charcoal collected from sediment associated with LSA lithics, 110 cm below the surface	
4	N99/21	1	51/51	d	6	Poz-20677	DBM 4539/07	1580±30		Charcoal extracted from pottery, 15-35 cm below the surface	
11	N98/45	1				Poz-20673		1555±30		Charcoal extracted from pottery, surface collection	Kose, 2009
17	N11/02	1	Unit 2	d	7	COL #2331.1.1.		1538±37		Charcoal extracted from pottery	
3	N98/39	2	51/55	c	615	KIA 28853		1565±20	-21.87±0.05	Charcoal extracted from pottery, 50 cm below the surface	Kose, 2009
3	N98/39	2	50/55	a	882	Poz-20696		1570±30		Charcoal extracted from pottery, 55-60 cm below the surface	
3	N98/39	2	51/54	c	948	COL #2332.1.1		1580±38	-29.9	Charcoal extracted from tuyere, 55 cm below the surface	
3	N98/39	2	51/55	a	701	KIA 28854		1602±23	-22.33±0.06	Charcoal extracted from pottery, 85 cm below the surface	Kose, 2009

Table 2, continued from previous page and continued on next page: Radiocarbon dates of the Kavango region.

Site catalogue number	Site number	Area	Unit	Quad-rant	Level	Lab. number	DBM Sample number	^{14}C-age BP	δ^{13}C (0/00)	Dated Material	References
3	N98/39		59/55	b	188	Poz-20676		1615±30		Charcoal extracted from pottery, 27 cm below the surface	
4	N98/39	1	50/51	d	6	Poz-20678		1620±30		Charcoal extracted from pottery, 15-35 cm below the surface	
3	N98/39	2	52/55	b	1015	Poz-20675		1670±30		Charcoal extracted from pottery, 60 cm below the surface	
3	N98/39	2	51/51	d	412	Poz-20674		1740±40		Charcoal extracted from pottery, 67 cm below the surface	
3	N98/39	2	52/54	a	601	KIA 28851		2182±46	-22.31±0.21	C extracted from slag, 65-70 cm below the surface	
3	N98/39	1				KN-5578		2670±40		Charcoal collected from sediment, 65-95 cm below the surface	Richter, 2005
3	N98/39	1				KN-5576		3222±58		Charcoal collected from sediment, 0-45 cm below the surface	Richter, 2005
3	N98/39	2	50/53	d	940	Poz-20669		3455±35		Charcoal collected from sediment, 40-50 cm below the surface	

Table 2, continued from previous page: Radiocarbon dates of the Kavango region.

Site	Area	Lab. number	^{14}C-age BP	Dated material	References
Divuyu	Fea3	Beta-13266	1190±70	Charcoal collected from sediment, 90-130 cm below the surface	Denbow, 2011
Divuyu	Baobab 2c	Beta-13267	1220±70	Charcoal collected from sediment, 30-40 cm below the surface	Denbow, 2011
Divuyu	Baobab 1x	Beta-13265	1330±60	Charcoal collected from sediment, 60-70 cm below the surface	Denbow, 2011
Divuyu	Acacia 100W.21N	Beta-13264	1330±60	Charcoal collected from sediment, 110-120 cm below the surface	Denbow, 2011
Divuyu	Baobab 2c	Beta-13269	1370±60	Charcoal collected from sediment, 70-80 cm below the surface	Denbow, 2011
Divuyu	Baobab 2c	Beta-13268	1400±70	Charcoal collected from sediment, 50-60 cm below the surface	Denbow, 2011
Nqoma	Periphery 233W.122N	Beta-13263	860±60	Charcoal collected from sediment, 30-50 cm below the surface	Denbow, 2011
Nqoma	Outpost OP 2	Wits-836	970±50	Charcoal collected from sediment, 40-50 cm below the surface	Denbow, 2011
Nqoma	Outpost 41W.26S	Beta-13261	970±50	Charcoal collected from sediment, 40-50 cm below the surface	Denbow, 2011
Nqoma	Test sq 40W.00	Beta-13262	980±60	Charcoal collected from sediment, 110-120 cm below the surface	Denbow, 2011
Nqoma	Central 00.31N	Beta-13255	970±70	Charcoal collected from sediment, 40-50 cm below the surface	Denbow, 2011
Nqoma	Blacksmith 182W.107N	Beta-13260	1000±60	Charcoal collected from sediment, 60-70 cm below the surface	Denbow, 2011
Nqoma	Society A12	Iso-11411	1000±80	Charcoal collected from sediment, 30-45 cm below the surface	Denbow, 2011
Nqoma	Central 00.31N	Beta-13256	1220±70	Charcoal collected from sediment, 60-70 cm below the surface	Denbow, 2011
Nqoma	Central 00.31N	Beta-13257	1290±60	Charcoal collected from sediment, 80-90 cm below the surface	Denbow, 2011
Cho/ana	Square G and H	Pta-6909	1030±50	Charcoal collected from sediment, 25 cm below the surface	Smith & Lee, 1997
Kapwirimbwe		Gx-1012	1495±95	Charcoal collected from the refill of a refuse pit	Phillipson, 1968
Kapwirimbwe		Gx-1013a	1575±110	Charcoal collected from the refill of a refuse pit	Phillipson, 1968
Kapwirimbwe		Gx-1013b	1590±85	Charcoal collected from the refill of a refuse pit	Phillipson, 1968
Dambwa	Trench XV	SR-106	1400±100	Sample taken from a single piece of charred wood, 46 cm below the surface	Fagan, Phillipson & Daniels, 1969
Dambwa	Trench II	SR-62	1380±110	Mix of charcoal sampled form sediment between 46-107 cm below the surface	Fagan, Phillipson & Daniels, 1969
Dambwa	?	SR-110	1340±120	?	Fagan, Phillipson & Daniels, 1969
Dambwa	Trench X	SR-97	1250±95	Charcoal collected from sediment, 46-61cm below the surface	Fagan, Phillipson & Daniels, 1969
Dambwa	Trench X	SR-98	1220±90	Charcoal collected from sediment, 46-61cm below the surface	Fagan, Phillipson & Daniels, 1969

Table 3, continued on next page: Radiocarbon dates from selected sites with pottery traditions related to the Early Ironworking Groups sites of the middle Kavango region.

Site	Area	Lab. number	^{14}C-age BP	Dated material	References
Dambwa	Trench X	SR-96	1140±95	Charcoal collected from sediment, 46-61cm below the surface	Fagan, Phillipson & Daniels, 1969
Chondwe,	Trench II, Level 5	GX-1330	845±85	Charcoal collected from sediment, 90-105 cm below the surface	Mills & Filmer, 1972
Chondwe,	Trench II, Level 6	GX-1331	890±85	Charcoal collected from sediment, 105-120 cm below the surface	Mills & Filmer, 1972
Chondwe,	Trench I, Level 5	GX-1010	1110±95	Charcoal collected from sediment, 90-105 cm below the surface	Mills & Filmer, 1972
Chondwe,	Trench I, Level 5	GX-1009	1185±130	Charcoal collected from sediment, 90-105 cm below the surface	Mills & Filmer, 1972
Chondwe,	Trench II, Level 12	N-997	1200±145	Charcoal collected from sediment, 195-202 cm below the surface	Mills & Filmer, 1972
Chondwe,	Trench II, Level 12	N-998	1490±160	Charcoal collected from sediment, 202-210 cm below the surface	Mills & Filmer, 1972
Benfica		Pta-?	1770±50	Carbon from shell	Valdeyron & Da Silva Domingos, 2009
Benfica		Pta-212	1810±50	Charcoal from shell midden	Valdeyron & Da Silva Domingos, 2009
Naviundu	IoHw2, Four II	Hv 11402	1555±55	Carbon collected from sediment from the bottom of a copper smelting furnace	Anciaux de Faveaux & De Maret, 1984
Naviundu	IoHw2, Fosse I	Hv 10591	1565±55	Carbon collected from sediment from the bottom of a pit, 70 cm below the surface	Anciaux de Faveaux & De Maret, 1984
Naviundu	IoHw2, Fosse III	Hv 11403	1605±75	Carbon collected from sediment in a clay pot from a pit, 1.25cm below the surface	Anciaux de Faveaux & De Maret, 1984
Lac Ndembo	Unit 20N19E	Beta-292441	1250±30	Oil palm nut collected from sediment, 40-50 cm below the surface	Denbow, 2013
Lac Ndembo	Unit 20N17E	Beta-292440	1340±30	Oil palm nut collected from sediment, 30-40 cm below the surface	Denbow, 2013
Kayes	Unit 9S,0	Tx-6692	1440±60	Charcoal and oil palm nut collected from sediment, 70-80 cm below the surface	Denbow, 2013
Kayes	Unit 10S,0	Tx-6682	1550±80	Charcoal collected from sediment, 80- 90 cm below the surface	Denbow, 2013
Kayes	Unit 19S,0	Tx-6691	1720±70	Charcoal collected from sediment, 30-40 cm below the surface	Denbow, 2013
Mandingo-Kayes	East unit I	Tx-5957	1720±80	Charcoal and oil palm nut collected from sediment, 22-40 cm below the surface	Denbow, 2013
Mandingo-Kayes	West unit I	Tx-5958	1810±60	Charcoal and oil palm nut collected from sediment, 30-40 cm below the surface	Denbow, 2013
BP 113	Unit 70-80e; 2-4s	Tx-7016	1810±60	Charcoal collected from sediment, 40-50 cm below the surface	Denbow, 2013

Table 3, continued from previous page and continued on next page: Radiocarbon dates from selected sites with pottery traditions related to the Early Ironworking Groups sites of the middle Kavango region.

Site	Area	Lab. number	^{14}C-age BP	Dated material	References
BP 113	Unit N5	Tx-7727	1820±60	Charcoal collected from Fea. 1	Denbow, 2013
BP 113	Unit 78-79e; 14s,	Tx-7729	1930±50	Charcoal collected from the refill of Pit 1	Denbow, 2013
BP 113	Unit 49-50e; 21n,	Tx-7728	1940±50	Charcoal collected from sediment, 50- 60 cm below the surface	Denbow, 2013
BP 113	Unit 49-50e; 19n,	Tx-7730	1930±50	Charcoal collected from the refill of Pit 6	Denbow, 2013

Table 3, continued from previous page: Radiocarbon dates from selected sites with pottery traditions related to the Early Ironworking Groups sites of the middle Kavango region.

Site catalogue Numbber	SC 1	SC 2	SC 5	SC 6	SC 8	SC 9	SC 10		
Site no.	**N97/09**	**N98/40**	**N07/01**	**N06/01**	**N98/23**	**N99/20**	**N98/25**	**N98/27**	**N98/29**
Pottery	4 pcs/ 35 g	20 pcs/ 186 g	6 pcs/ 58 g		2 pcs/ 118 g	44 pcs/ 694.5 g	17 pcs/ 149 g	64 pcs/ 253 g	4 pcs/ 18 g
Ceramic artifact									
Clay pipe			1 pc/ 8 g						
Lithics/ manuports		11 pcs/ 113.8 g	8 pcs/ 94.6 g				1 pc/ 10 g	9 pcs/ 78.02 g	
Slag & Ore fragments				n/ 167 g			1 pc/ 2.6 g		
Tuyere fragments									
Metal artifacts						5 pcs/ 30.1 g			
(Burnt) clay									
OES/shell beads/ artifacts									
Glass beads						2 pcs/ 0.02 g		1 pc/ 0.1 g	
Faunal remains									
Bone artifacts									
Charcoal									
Botanical remains									
Modern material						62 pcs/ 271.7 g			
Total	**4 pcs/ 35 g**	**31 pcs/ 299.8 g**	**15 pcs/ 160.6 g**	**n/ 167 g**	**2 pcs/ 118 g**	**113 pcs/ 996.32 g**	**19 pcs/ 161.6 g**	**74 pcs/ 331.12 g**	**4 pcs/ 18 g**

Table 4: Total finds of the site catalogue nos. 1, 2, 5, 6, 8, 9, and 10.

Ruuga, SC no. 3							
	N98/39				N05/01	N05/02	N05/10
	Surface	Area 1 & 2	Area 3	Area 4			
Pottery	345 pcs/ 2886 g	4442 pc /10.678 g	28 pcs/ 194 g	154 pcs/ 790 g	8 pcs/ 48 g	33 pcs/ 139 g	11 pcs/ 36 g
Clay pipe	1 pc/2 g				1 pc/ 14 g		
Lithics	1 pc/ 152 g	7657 pcs/ 12.009 g	115 pcs/ 344 g	5 pcs/ 203 g	9 pcs/ 39 g	9 pcs/ 95 g	5 pcs/ 41 g
Slag & Ore fragments	18 pcs/ 885 g	202 pcs/ 905 g		1pc/ 14 g	not collected		2 pcs/3 g
Tuyere fragments	4 pcs/ 145g	5 pcs/ 117 g	1 pc/ 26 g				
Metal artifacts		41 pcs/ 154 g					
Burnt clay	2 pcs/ 49 g	4 pcs/ 29 g					
OES beads and preforms		247 pcs/ 29 g					
Glass beads	1 pc/0.1 g						
Faunal remains	267 pcs/ 408 g	5203 pcs/ 1758 g					
Bone artifacts							
Charcoal		n/ 1599 g					
Botanical remains		57 pcs/ 27 g					
Modern material	18 pcs/ 111 g	695 pcs/ 989 g		1 pc/ 20 g			
Total	**656 pcs/ 4638 g**	**18.551 pcs/ 28294 g**	**144 pcs/ 564 g**	**161 pcs/ 1027 g**	**18 pcs/ 101 g**	**42 pcs/ 234 g**	**18 pcs/ 80 g**

Table 5: Total finds of site catalogue no. 3.

Kapako, SC no. 4								
N99/21								
	Surface	**Area 1**	**Area 2**	**Area 3**	**Area 4**	**Area 5**	**Area 6**	**Area 7**
Pottery	16 pcs/ 227 g	392 pcs/ 1052 g		919 pcs/ 2898 g	217 pcs/ 359 g	196 pcs/ 489 g	60 pcs/ 149 g	116 pcs/ 707 g
Ceramic artifact					2 pcs/3 g	2 pcs/4.8 g		
Clay pipe								
Lithics/ manuports	not counted	173 pcs/ 645 g	not counted	184 pcs/ 332.4 g	18 pcs/ 10.8 g	17 pcs/ 15.7 g	42 pcs/ 71 g	43 pcs/ 121.8 g
Slag & Ore fragments	22 pcs/ 2040 g	66 pcs/ 308.84 g	11 pcs/ 816.4 g	52 pcs/ 354.5 g	21 pcs/ 29.9 g	13 pcs/ 221 g		3 pcs/ 3.5 g
Tuyere fragments		1pc/ 8.3 g					1pc/ 2.5 g	
Metal artifacts		6 pcs/ 3.2 g		7 pcs/ 7.2 g	12 pcs/ 5.9 g	1 pcs/ 0.18 g	4 pcs/ 4.9 g	
(Burnt) clay		1 pc/ 15.1 g		2 pcs/ 1.5 g	1 pc/ 4.5 g	3 pcs/ 59.8 g		1 pc/ 9.7 g
OES beads/ artifacts		14 pcs/ 2.5 g		3 pcs/ 0.3 g	1 pc / 0.3 g	5 pcs/ 1 g	1 pc/ 0.1 g	4 pcs/ 1.2 g
Glass beads		8pcs/ 1.5g						
Faunal remains	not collected	not counted		1289 pcs/ 677.4 g	155 pcs/ 55 g	175 pcs/ 163 g	27 pcs/ 9 g	38 pcs/ 20 g
Bone artifacts								1 pc/3 g
Charcoal	not collected	not counted		not counted	not counted	not counted	not collected	not collected
Botanical remains	not collected			3 pcs/ 0.31 g	10 pcs/ 4.5 g			
Modern material	not collected	1 pc/ 27.5 g		1 pc/ 0.1 g	7 pcs/ 0.5 g		8 pcs/ 24.7 g	
Total	**38 pcs/ 2267 g**	**662 pcs/ 2063.9 g**	**11 pcs/ 816.4 g**	**2460 pcs/ 4271.3 g**	**444 pcs/ 473.4 g**	**412 pcs/ 954.5 g**	**143 pcs/ 257.2 g**	**206 pcs/ 866.2 g**

Table 6, continued on next page: Total finds of site catalogue no. 4.

Kapako, SC no. 4					
	N05/02	**N06/07**	**N98/38**	**N68/01**	**N68/02**
Pottery	33 pcs/ 139 g	10 pcs/ 206 g	2 pcs/ 17 g	195 pcs/ nn	776 pcs/ nn
Ceramic artifact					
Clay pipe					6 pcs/ nn
Lithics/ manuports				3 pcs/ nn	143 pcs/ nn
Slag & Ore fragments			2 pcs/ 58 g	6 pcs/ nn	14 pcs/ nn
Tuyere fragments					
Metal artifacts				1pc/ nn	3 pcs/ nn
(Burnt) clay		5 pcs/ 93.8 g		26 pcs/ nn	32 pcs/ nn
OES beads/ artifacts					4 pcs/ nn
Glass beads					
Faunal remains				14 pcs/ nn	375 pc/ nn
Bone artifacts					
Charcoal				not counted	not counted
Botanical remains					
Modern material			1 pc/ 4.8 g		
Total	**18 pcs/ 101 g**	**42 pcs/ 234 g**	**18 pcs/ 80 g**	**245 pcs/ nn**	**1353 pcs/ nn**

Table 6, continued from previous page: Total finds of site catalogue no. 4.

Site catalogue no.	SC 11		SC 13	SC 15	SC 16	SC 19	SC 20	SC 21	SC 22
Site no.	**N98/26**	**N98/33**	**N96/06**	**N96/07**	**N96/08(-1)**	N96/11	**N98/41**	**N98/44**	**N98/45**
Pottery	1pc/ 30 g	13 pcs/ 43 g	3 pcs/ 28 g	3 pcs/ 17 g		2 pcs/ 5 g	3 pcs/ 41 g		1 pc/ 15 g
Ceramic artifact									
Clay pipe									
Lithics/ manuports	2 pcs/ 67.6 g	4 pcs/ 54.4 g		2 pcs/ 43.7 g					
Slag & Ore fragments					6 pcs/ 1455 g		1 pc/ 16.2 g	3 pcs/ 389.3 g	4 pcs/ 250.7 g
Tuyere fragments							1 pc/ 16.1 g		
Metal artifacts									
(Burnt) clay									
OES/shell beads/ artifacts									
Glass beads									
Faunal remains									
Bone artifacts									
Charcoal									
Botanical remains									
Modern material									
Total	**3 pcs/ 97.6 g**	**17 pcs/ 97.4 g**	**3 pcs/ 28 g**	**5 pcs/ 60.7 g**	**6 pcs/ 1455 g**	**2 pcs/ 5 g**	**5 pcs/ 73.3 g**	**3 pcs/ 389.3 g**	**5 pcs/ 265.7 g**

Table 7: Total finds of site catalogue nos. 11, 13, 15, 16, 19, 20, 21, and 22.

Vungu-Vungu, SC no. 12									
N98/32									
	Surface	**Surf. 1**	**Surf. 2**	**Surf. 3**	**Surf. 4**	**Surf. 5**	**Surf. 6**	**Surf. 7**	**Area 1 & 2 (after Kose, 2004)**
Pottery	28 pcs/ 217 g	3 pcs/ 16 g	8 pcs/ 31 g	19 pcs/ 89 g	98 pcs/ 560 g	18 pcs/ 187 g	2 pcs/ 11 g	3 pcs/ 42 g	1275 pcs/ 4324 g
Ceramic artifact									
Clay pipe			2 pcs/ 4.8 g		6 pcs/ 27 g	1 pc/ 1.7 g	1 pc/ 8.3 g	1 pc/ 2.1 g	16 pcs/ 25 g
Lithics/ manuports	4 pcs/ 30 g		2 pcs/ 34 g		4 pcs/ 113 g	2 pcs/ 38 g	4 pcs/ 33 g	1 pc/ 7 g	174 pcs/ 409 g
Slag & Ore fragments	40 pcs/ 1277 g			1 pc/ 6.4 g	5 pcs/ 174.5 g		2 pcs/ 46 g	1 pcs/ 17.7 g	100 pcs/ 433.2 g
Tuyere fragments	6 pcs/ 172 g				1 pc/ 9 g		1 pc/ 39.6 g	2 pcs/ 37.4 g	15 pcs/ 34 g
Metal artifacts					3pc/ 4.4g	1pc/ 13.1g	1pc/ 6.4g		6pc/ 7.8g
(Burnt) clay	1 pc/ 31 g								11 pcs/ 96 g
OES/shell beads/ artifacts	5 pcs/ 2 g		1 pc/ 0.5 g		137 pcs/ 80 g				170 pcs/ 77.5 g
Glass beads	2 pcs/ 0.5 g	8 pcs/ 1.5 g			22 pcs/ nn				51 pcs/ nn
Faunal remains	7 pcs/ 41 g			not counted	not counted		not counted		2384 pcs/ 3400 g
Bone artifacts									
Charcoal									not counted
Botanical remains									4 pcs/ 4 g
Modern material									18 pcs/ 11.4 g
Total	**47 pcs/ 1770.5 g**	**11 pcs/ 17.5 g**	**13 pcs/ 70.3 g**	**20 pcs/ 95.4 g**	**276 pcs/ 968 g**	**22 pcs/ 239.8 g**	**11 pcs/ 144.3 g**	**8 pcs/ 106.2 g**	**4222 pcs/ 8816.4 g**

Table 8: Total finds of site catalogue no. 12, Areas N98/32.

Vungu-Vungu, SC no. 12										
	N96/03			N96/04	N98/30	N98/34	N98/35	N98/36	N98/37	N69/01-1 &-2 (after Sandelowsky, 1969, 1979)
	Area 1	Area 2	Area 3							
Pottery	not collected	3 pcs/ 45 g	65 pcs/ 262 g	5 pcs/ 44 g	5 pcs/ 55 g	8 pcs/ 44 g	1 pc/ 9 g	6 pcs/ 61 g	1 pc/ 10 g	5681 pcs/ nn
Ceramic artifact										
Clay pipe										55pc/ nn
Lithics/ manuports	not collected		8 pcs/ 48.8 g		3 pcs/ 8.3 g	2 pcs/ 35 g				20 pcs/ nn
Slag & Ore fragments	not collected		257 pcs/ 1693 g		4 pcs/ 207 g	4 pcs/ 90 g			4 pcs/ 376 g	15 pcs/ 1711.2 g
Tuyere fragments			2 pcs/ 34 g							1 pc/ 12 g
Metal artifacts										18 pcs/ nn
(Burnt) clay										
OES/shell beads/ artifacts		2 pcs/ 1 g	1 pc/ 0.5 g							136 pcs/ nn
Glass beads										182 pcs/ nn
Faunal remains			1 pc/ 0.5 g							2189 pcs/ nn
Bone artifacts										
Charcoal										not counted
Botanical remains										
Modern material										
Total	**-**	**5 pcs/ 46 g**	**334 pcs /2038.8 g**	**5 pcs/ 44 g**	**12 pcs/ 270.3 g**	**14 pcs/ 169 g**	**1 pc/ 9 g**	**6 pcs/ 61 g**	**5 pcs/ 386 g**	**8297 pcs/ nn**

Table 9: Total finds of site catalogue no. 12, areas N96/03, N96/04, N98/30, N98/34, N98/35, N98/36, N98/37, and N69/01.

Site catalogue number	SC 17					
Site no.	**N96/05**	**N96/12**	**N96/09**	**N97/02**	**N11/02-1**	**N11/02-5**
Pottery	65 pcs/ 816 g	1 pcs/ 14 g		7 pcs/ 77 g	not counted	30 pcs/ 401 g
Ceramic artifact						
Clay pipe						
Lithics/ manuports					not counted	
Slag & Ore fragments	2 pcs/ 88.7 g	3 pcs/ 103.1 g	2 pcs/ 709.7 g	1 pc/ 16 g	9 pcs/ 21.4 g	
Tuyere fragments	2 pcs/ 74.1 g			2 pcs/ 43 g	1 pc/ 14.1 g	
Metal artifacts					1 pc/6 g	
(Burnt) clay						
OES/shell beads/ artifacts					not counted	
Glass beads					not counted	
Faunal remains					not counted	
Bone artifacts						
Charcoal						
Botanical remains						
Modern material						
Total	**69 pcs/ 978.8 g**	**4 pcs/ 117.1 g**	**2 pcs/ 709.7 g**	**10 pcs/ 136 g**	**> 11 pcs/ 42.5 g**	**30 pcs/ 401 g**

Table 10: Total finds of site catalogue no. 17.

Site catralogue number	**SC 23**	**SC 25**	**SC 26**		**SC 27**		**SC 28**	**SC 29**
Site no.	**N96/15**	**N98/46**	**N96/13**	**N98/48**	**N98/43 Surf.**	**N98/43-1**	**N98/42**	**N906/02**
Pottery	1 pcs/ 9 g		9 pcs/ 71 g	4 pcs/ 39 g	52 pcs/ 464 g	38 pcs/ 1781.1 g	4 pcs/ 19 g	
Ceramic artifact								
Clay pipe								
Lithics/ manuports						1 pcs/ 0.1 g		
Slag & Ore fragments		1 pcs/ 168 g			3 pcs/ 116 g	10 pcs/ 76.72 g		n/ 986 g
Tuyere fragments								
Metal artifacts								
(Burnt) clay								
OES/shell beads/ artifacts						3 pcs/ 0.9 g		
Glass beads								
Faunal remains								
Bone artifacts								
Charcoal								
Botanical remains								
Modern material								
Total	**1 pcs/ 9 g**	**1 pcs/ 168 g**	**9 pcs/ 71 g**	**4 pcs/ 39 g**	**55 pcs/ 625 g**	**52 pcs/ 1858.82 g**	**4 pcs/ 19 g**	**n/ 986 g**

Table 11: Total finds of site catalogue nos. 23, 25, 26, 27, 28, and 29.

Site catalogue number	SC 30			SC 32			SC 33	SC 34	SC 35
Site no.	**N06/04**	**N69/03**	**N69/03-1**	**N07/02-1**	**N07/03**	**N07/06**	**N07/07**	**N99/15**	**N99/19**
Pottery									
Ceramic artifact									
Clay pipe									
Lithics/ manuports									
Slag & Ore fragments	13 pcs/ 2618.6g	24 pcs/ 947.9 g not complete	11 pcs/ 414.6 g not complete	8 pcs/ 1108.2 g	2 pcs/ 1174.1 g	n/ 310.9 g	n/ 955.3 g	n/ 720.6 g	
Tuyere fragments									
Metal artifacts									
(Burnt) clay									
OES/shell beads/ artifacts									
Glass beads									9 pcs/ 1.4 g
Faunal remains									
Bone artifacts									
Charcoal									
Botanical remains									
Modern material									
Total	**13 pcs/ 2618.6 g**	**> 24 pcs/ 947.9 g**	**> 11 pcs/ 414.6 g**	**8 pcs/ 1108.2 g**	**2 pcs/ 1174.1 g**	**n/ 310.9 g**	**n/ 955.3 g**	**n/ 720.6 g**	**9pcs/ 1.4 g**

Table 12: Total finds of site catalogue nos. 30, 32, 33, 34, and 35.

SC no.	Site no.	Pottery			Clay pipe	Lithics	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Deb-itage	Tool type	Core type	Length/ mm	Tool pre-form	Weight/ g
			Dec.	Un-dec.													
1	N97/09	4	4														35
2	N98/40	20	4	16													186
2	N98/40					3	2	2	1								18.5
2	N98/40					3	1	2			1						2.3
2	N98/40					1	1							1	41		58.5
2	N98/40					1	1						33		24		8
2	N98/40					1	1							1	38		21.4
2	N98/40					1	1							5	25		8.4
2	N98/40					1	1							4	38		17.5
5	N07/01	6	2	4													58
5	N07/01				1												8
5	N07/01					1	2						60		59	Flake	62.3
5	N07/01					2	2			1	1						23,9
5	N07/01					2	1				1	1					9.9
5	N07/01					1	1							4	28		9.8
5	N07/01					1	1					1	49		51	Blade	16.6
5	N07/01					1	1						49		46	Flake	5.9
8	N99/23	2	1	1													118

Table 13: Finds from site catalogue nos. 1, 2, 5, and 8, pottery, clay pipe, lithics.

SC no.	Site no.	Area	Qua-drant	Level	Pottery	Porce-lain			Glass beads	Glass	Plastics	Weight/g
							Dec.	Undec.				
9	N99/20	25/25	b	5						5		20.1
9	N99/20	25/25	d	5						8		26.80
9	N99/20	25/25		5	9			9				31
9	N99/20	25/25		5		1		1				3.8
9	N99/20	25/26	a	5	1			1				17.5
9	N99/20	25/26	b	5		1	1					3.2
9	N99/20	25/26	d	5	4			4				193
9	N99/20	25/26	d	Sed.						1		13.9
9	N99/20	25/26	d	Sed.	1			1				22
9	N99/20	25/26			1		1					2
9	N99/20	26/25	a	5						3		19.2
9	N99/20	26/25	b	4	1			1				21
9	N99/20	26/25	b	5						2		7
9	N99/20	26/25	c	4						1		6.1
9	N99/20	26/25	c	5	3			3				46
9	N99/20	26/25	d	5	1		1					9
9	N99/20	26/26	a	5						1		1
9	N99/20	26/26	a	5	1			1				2.5
9	N99/20	26/26	b	5							1	0.9

Table 14, continued on next page: Finds from site catalogue no. 9, pottery, porcelain, glass beads, industrial glass, plastics.

SC no.	Site no.	Area	Quad-rant	Level	Pottery	Porce-lain			Glass beads	Glass	Plastics	Weight/g
							Dec.	Undec.				
9	N99/20	26/26	b	5						1		1.4
9	N99/20	26/26	b	5						1		0.5
9	N99/20	26/26	b	5	1		1					6
9	N99/20	26/26	b	5	1			1				54
9	N99/20	26/26	b	5	2			2				20
9	N99/20	26/26	c	5						1		5.2
9	N99/20	26/26	c	5	4			4				34
9	N99/20	26/26	d	5	1		1					3
9	N99/20	26/26	d	5	1			1				5.5
9	N99/20	26/27	c	0						33		164.3
9	N99/20	vd			7		6	1				175
9	N99/20			4						3		4.8
9	N99/20			4	3			3				46
9	N99/20			4					2			0.02
9	N99/20										1	0.5

Table 14, continued from previous page: Finds from site catalogue no. 9, pottery, porcelain, glass beads, industrial glass, plastics.

SC no.	Site no.	Area	Quad-rant	Level	Pottery			Glass bead	Iron ore	Lithics	RM	Chip <10mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Tool type	Core type	Length/ mm	Weight/g
						Dec.	Un-dec.													
10	N98/25									1	2				1					10
10	N98/25				17	1	16													149
10	N98/27	25/25	a	50	1		1													3
10	N98/27	25/25	c	50	1		1													5
10	N98/27	25/25	d	20	1		1													9
10	N98/27	25/25	d	20/1	1		1													5
10	N98/27	25/25			3		3													33
10	N98/27	25/25	b	50	4		4													4
10	N98/27	25/25	d	50	4		4													11
10	N98/27	25/25		0	5		5													17
10	N98/27				44	3	41													166
10	N98/27	25/25	b	30						3	2		1			2				17.4
10	N98/27	25/25	b	50						1	2		1							3.6
10	N98/27	25/25	c	50						1	2	1								0.01
10	N98/27	25/25		0				1												0.01
10	N98/27			Surf.						2	2		2							35.8
10	N98/27			Surf.						1	1			1						4.8
10	N98/27			Surf.						1	4					1				16.4
10	N98/29				4		4													18
11	N98/26				1	1														30
11	N98/26									2	2			2						9.5

Table 15, continued on next page: Finds from site catalogue nos. 10 and 11, pottery, glass beads, iron ore, lithics.

SC no.	Site no.	Area	Quad-rant	Level	Pottery			Glass bead	Iron ore	Lithics	RM	Chip <10mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Tool type	Core type	Length/ mm	Weight/g
						Dec.	Un-dec.													
11	N98/26									1	1						60		72	58.1
11	N98/33				13	2	11													43
11	N98/33									1	2					1				39.1
11	N98/33									3	1			1		2				15.3

Table 15, continued from previous page: Finds from site catalogue nos. 10 and 11, pottery, glass beads, iron ore, lithics.

SC no.	Site no.	Area	Pottery			Lithics	RM	Chip < 10mm	Flake < 15 mm	Flake > 15 mm	Blade	Deb-itage	Tool type	Core type	Length/ mm	Weight/g
				Dec.	Undec.											
13	N96/06		3		3											28
15	N96/07		3													17
17	N11/02	5	30	15	15											401
17	N96/05		65	12	43											816
17	N97/02		7	7												77
17	N96/12		1	1												14
19	N96/11		2	2												5
20	N98/41		3		3											41
22	N98/45	1	1		1											15
23	N96/15		1	1												9
26	N96/13		9	9												71
26	N98/48		4													39

Table 16: Finds from site catalogue nos. 13, 15, 17, 19, 20, 22, 23, and 26, pottery.

SC no.	Site no.	Area	Unit	Qua-drant	Level	Pottery			Glass bead	OES bead	OES pre-form	Lithics	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Tool type	Core type	Length/ mm	Weight/g
							Dec.	Undec.														
27	N98/43	1	4/5	a	0-20	2	2	16														175
27	N98/43	1	4/5	a	20-40	1		1														8
27	N98/43	1	4/5	b	40-60	1		1														9
27	N98/43	1	5/5	a	20-40					1												0,2
27	N98/43	1	5/5	b	40-60	2		2														4
27	N98/43	1	5/5	b	40-60					1												0,1
27	N98/43	1	5/5	b	60-80	10		1														108
27	N98/43	1	5/5	b	80-100	8		8														15
27	N98/43	1	5/5	c	20-40	1		1														34
27	N98/43	1	5/5	c	20-40	1		1														34
27	N98/43	1	5/5	d	40-60	4		4														112
27	N98/43	1	5/5	d	40-60						1											0.6
27	N98/43	1	5/5	d	60/80	1		1														7

Table 17, continued on next page: Finds from site catalogue nos. 27, 28, and 35, pottery, glass beads, OES beads, lithics.

SC no.	Site no.	Area	Unit	Qua-drant	Level	Pottery			Glass bead	OES bead	OES pre-form	Lithics	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Tool type	Core type	Length/ mm	Weight/g
							Dec.	Undec.														
27	N98/43	1	5/5	d	60/80	3		3														83
27	N98/43	1	5/5	d	60/80 unten	1		1														5
27	N98/43	1	5/5	d	60-80							1	2	1								0.1
27	N98/43	1	5/5		0	2		2														152
27	N98/43	1	5/5		60-80	1	1															1035
27	N98/43					52	2	50														464
28	N98/42					4	1	3														19
35	N99/19								9													1.4

Table 17, continued from previous page: Finds from site catalogue nos. 27, 28, and 35, pottery, glass beads, OES beads, lithics.

SC no.	Site no.	Area	Unit	Quarant	Level	Pottery			Weight/g
							Dec.	Un-dec.	
3	N98/39	1	48/10	a	6	5	1	4	30
3	N98/39	1	48/10	a	9	2		2	23
3	N98/39	1	48/10	b	6	20		20	103
3	N98/39	1	48/10	b	9	4		4	9
3	N98/39	1	48/10	c	6	16		16	66
3	N98/39	1	48/10	d	6	8		8	50
3	N98/39	1	48/10	d	9	7	2	5	12
3	N98/39	1	49/10	a	6	3	3		5
3	N98/39	1	49/10	a	9	10	1	9	21
3	N98/39	1	49/10	b	6	11	2	9	45
3	N98/39	1	49/10	b	9	6		6	20
3	N98/39	1	49/10	c	6	11	2	9	19
3	N98/39	1	49/10	c	9	8	1	7	36
3	N98/39	1	49/10	d	6	22		22	66
3	N98/39	1	49/10	d	9	6		6	34
3	N98/39	2	50/50	a	315	5	1	4	23
3	N98/39	2	50/50	a	344	1		1	7
3	N98/39	2	50/50	a	362	2		2	7
3	N98/39	2	50/50	a	377	1		1	10
3	N98/39	2	50/50	a	387	2		2	1
3	N98/39	2	50/50	a	416	1		1	5
3	N98/39	2	50/50	b	257	4	1	3	3
3	N98/39	2	50/50	b	315	5		5	85
3	N98/39	2	50/50	b	344	1		1	10
3	N98/39	2	50/50	b	362	3		3	13
3	N98/39	2	50/50	b	377	1		1	5

SC no.	Site no.	Area	Unit	Quarant	Level	Pottery			Weight/g
							Dec.	Un-dec.	
3	N98/39	2	50/50	b	416	2	1	1	4
3	N98/39	2	50/50	c	257	4		4	5
3	N98/39	2	50/50	c	315	8		8	13
3	N98/39	2	50/50	c	331	2		2	1
3	N98/39	2	50/50	c	362	3		3	4
3	N98/39	2	50/50	c	434	2		2	3
3	N98/39	2	50/50	d	257	4		4	2
3	N98/39	2	50/50	d	315	14	1	13	40
3	N98/39	2	50/50	d	331	2		2	4
3	N98/39	2	50/50	d	344	4		4	18
3	N98/39	2	50/50	d	362	2		2	1
3	N98/39	2	50/50	d	377	1		1	4
3	N98/39	2	50/50	d	387	1		1	5
3	N98/39	2	50/50		204	7		7	5
3	N98/39	2	50/50		212	20	2	18	19
3	N98/39	2	50/50		228	19	4	15	44
3	N98/39	2	50/50		270	22		22	37
3	N98/39	2	50/50		290	14		14	41
3	N98/39	2	50/51	a	705	3	1	2	2
3	N98/39	2	50/51	a	718	7		7	9
3	N98/39	2	50/51	a	733	5		5	67
3	N98/39	2	50/51	a	736	2		2	18
3	N98/39	2	50/51	a	746	1		1	1
3	N98/39	2	50/51	a	755	1		1	1
3	N98/39	2	50/51	a	765	1		1	1
3	N98/39	2	50/51	a	771	1		1	9

Table 18, continued on next page: Finds from site catalogue no. 3, pottery.

SC no.	Site no.	Area	Unit	Quarant	Level	Pottery			Weight/g
							Dec.	Un-dec.	
3	N98/39	2	50/51	b	705	3		3	6
3	N98/39	2	50/51	b	718	14		14	20
3	N98/39	2	50/51	b	733	7		7	34
3	N98/39	2	50/51	b	736	1		1	1
3	N98/39	2	50/51	b	756	1		1	1
3	N98/39	2	50/51	b	765	9	1	8	43
3	N98/39	2	50/51	b	771	1		1	1
3	N98/39	2	50/51	c	705	1	1		1
3	N98/39	2	50/51	c	718	5	2		12
3	N98/39	2	50/51	c	733	4	1	3	38
3	N98/39	2	50/51	c	736	1		1	7
3	N98/39	2	50/51	c	755	4		4	14
3	N98/39	2	50/51	c	765	1		1	1
3	N98/39	2	50/51	d	705	12	2	10	44
3	N98/39	2	50/51	d	718	5		5	8
3	N98/39	2	50/51	d	736	2		2	7
3	N98/39	2	50/51	d	746	2		2	1
3	N98/39	2	50/51	d	755	3		3	1
3	N98/39	2	50/51	d	765	1		1	4
3	N98/39	2	50/51	d	771	1		1	3
3	N98/39	2	50/51		643	1		1	1
3	N98/39	2	50/51		638	6		6	3
3	N98/39	2	50/51		643	5		5	16
3	N98/39	2	50/51		664	21	4	17	78
3	N98/39	2	50/51		689	10	1	9	6
3	N98/39	2	50/52	a	73	4		4	3
3	N98/39	2	50/52	a	446	9		9	24
3	N98/39	2	50/52	b	73	1	1		9
3	N98/39	2	50/52	b	91	6		6	4
3	N98/39	2	50/52	c	73	2		2	8
3	N98/39	2	50/52	c	91	7		7	6
3	N98/39	2	50/52	c	446	1	1		1
3	N98/39	2	50/52	d	73	14	1	13	5
3	N98/39	2	50/52	d	91	2		2	1
3	N98/39	2	50/52	d	113	8		8	23
3	N98/39	2	50/52		16	2		2	8
3	N98/39	2	50/52		21	22	4	18	23
3	N98/39	2	50/52		34	10		10	16
3	N98/39	2	50/52		54	37	4	33	88
3	N98/39	2	50/53	a	879	13		13	10
3	N98/39	2	50/53	a	889	6		6	14
3	N98/39	2	50/53	a	901	1		1	1
3	N98/39	2	50/53	a	918	3		3	13
3	N98/39	2	50/53	a	930	3	1	2	3
3	N98/39	2	50/53	a	940	3		3	2
3	N98/39	2	50/53	a	959	2	1	1	2
3	N98/39	2	50/53	b	879	15	2	13	24
3	N98/39	2	50/53	b	889	5	1	4	29
3	N98/39	2	50/53	b	901	2	1	1	2
3	N98/39	2	50/53	b	918	3	1	2	2
3	N98/39	2	50/53	b	930	2		2	2
3	N98/39	2	50/53	b	940	4	2	3	4
3	N98/39	2	50/53	b	959	1		1	1
3	N98/39	2	50/53	c	879	11		11	57
3	N98/39	2	50/53	c	889	4		4	4
3	N98/39	2	50/53	c	918	1	1		5
3	N98/39	2	50/53	c	940	2		2	3
3	N98/39	2	50/53	d	879	31		30	92
3	N98/39	2	50/53	d	889	1	1		15
3	N98/39	2	50/53	d	918	4	1	3	3
3	N98/39	2	50/53	d	940	2		2	5
3	N98/39	2	50/53		812	14	1	13	22
3	N98/39	2	50/53		826	14	1	13	20
3	N98/39	2	50/53		839	22	3	19	39
3	N98/39	2	50/53		859	18	2	16	31
3	N98/39	2	50/54	a	353	7		7	22
3	N98/39	2	50/54	a	393	7		7	1
3	N98/39	2	50/54	a	408	5		5	3
3	N98/39	2	50/54	a	459	4		4	6
3	N98/39	2	50/54	a	554	4		4	1
3	N98/39	2	50/54	a	568	3		3	1
3	N98/39	2	50/54	a+b	417	1		1	99
3	N98/39	2	50/54	b	353	5		5	1
3	N98/39	2	50/54	b	431	4		4	1
3	N98/39	2	50/54	b	459	6		6	3
3	N98/39	2	50/54	b	554	3		3	1
3	N98/39	2	50/54	c	353	41		41	53
3	N98/39	2	50/54	c	393	5	1	4	11
3	N98/39	2	50/54	c	408	7	2	5	4
3	N98/39	2	50/54	c	431	4	1	3	26
3	N98/39	2	50/54	c	459	5	1	4	5
3	N98/39	2	50/54	c	554	1		1	1
3	N98/39	2	50/54	d	353	7	2	5	8
3	N98/39	2	50/54	d	381	1	1		46
3	N98/39	2	50/54	d	393	13		13	12
3	N98/39	2	50/54	d	408	1		1	5

Table 18, continued from previous page and continued on next page: Finds from site catalogue no. 3, pottery.

SC no.	Site no.	Area	Unit	Quarant	Level	Pottery			Weight/g
							Dec.	Un-dec.	
3	N98/39	2	50/54	d	431	2		2	11
3	N98/39	2	50/54	d	459	4		4	8
3	N98/39	2	50/54	d	554	2		2	4
3	N98/39	2	50/54		240	10	1	1	5
3	N98/39	2	50/54		267	24	4	20	24
3	N98/39	2	50/54		293	43	4	39	61
3	N98/39	2	50/54		334	13	1	12	83
3	N98/39	2	50/55	a	873	3		3	17
3	N98/39	2	50/55	a	882	1	1		43
3	N98/39	2	50/55	a	897	4		4	29
3	N98/39	2	50/55	a	906	2		2	7
3	N98/39	2	50/55	a	943	1		1	1
3	N98/39	2	50/55	a	963	1		1	8
3	N98/39	2	50/55	a	920a	4		4	21
3	N98/39	2	50/55	b	873	6	1	5	24
3	N98/39	2	50/55	b	897	2		2	1
3	N98/39	2	50/55	b	934	5		5	1
3	N98/39	2	50/55	b	943	3	1	2	2
3	N98/39	2	50/55	b	963	2		2	1
3	N98/39	2	50/55	b	970	1		1	0
3	N98/39	2	50/55	c	873	6	2	4	11
3	N98/39	2	50/55	c	897	2		2	1
3	N98/39	2	50/55	c	906	4		4	1
3	N98/39	2	50/55	c	920a	1		1	2
3	N98/39	2	50/55	c	943	3		3	4
3	N98/39	2	50/55	d	873	15	1	14	15
3	N98/39	2	50/55	d	897	6		6	10
3	N98/39	2	50/55	d	906	1	1		5
3	N98/39	2	50/55	d	934	3		3	1
3	N98/39	2	50/55	d	943	2		2	3
3	N98/39	2	50/55	d	963	3	1	2	2
3	N98/39	2	50/55	d	920a	4	1	3	66
3	N98/39	2	50/55		819	23	5	18	40
3	N98/39	2	50/55		842	25	2	23	34
3	N98/39	2	50/55		853	16	1	15	45
3	N98/39	2	51/50	a	730	10		10	4
3	N98/39	2	51/50	a	762	2		2	8
3	N98/39	2	51/50	b	730	6		6	5
3	N98/39	2	51/50	b	752	3	1	2	9
3	N98/39	2	51/50	b	762	2		2	1
3	N98/39	2	51/50	b	774	1		1	1
3	N98/39	2	51/50	b	781	4		4	9
3	N98/39	2	51/50	c	730	4	1	3	59
3	N98/39	2	51/50	c	752	2		2	17
3	N98/39	2	51/50	c	762	1	1		7
3	N98/39	2	51/50	c	774	2		2	10
3	N98/39	2	51/50	c	788	1	1		1
3	N98/39	2	51/50	d	730	11		11	7
3	N98/39	2	51/50	d	752	5		5	9
3	N98/39	2	51/50		640	3		3	1
3	N98/39	2	51/50		646	18	1	17	31
3	N98/39	2	51/50		670	16	2	14	19
3	N98/39	2	51/50		722	28	3	25	22
3	N98/39	2	51/50		801	21	2	19	41
3	N98/39	2	51/51	a	347	8	1	7	14
3	N98/39	2	51/51	a	402	3		3	4
3	N98/39	2	51/51	a	412	3		3	1
3	N98/39	2	51/51	a	425	1		1	1
3	N98/39	2	51/51	a	449	1		1	2
3	N98/39	2	51/51	a	560	2		2	4
3	N98/39	2	51/51	b	347	4	1	3	6
3	N98/39	2	51/51	b	402	4	1	3	31
3	N98/39	2	51/51	b	412	6		6	7
3	N98/39	2	51/51	b	425	1	1		4
3	N98/39	2	51/51	b	449	1		1	1
3	N98/39	2	51/51	b	466	2		2	32
3	N98/39	2	51/51	b	560	2		2	1
3	N98/39	2	51/51	c	347	3	1	2	6
3	N98/39	2	51/51	c	402	2	1	2	18
3	N98/39	2	51/51	c	425	2		2	1
3	N98/39	2	51/51	c	449	2		2	1
3	N98/39	2	51/51	c	466	1		1	1
3	N98/39	2	51/51	c	560	3		3	12
3	N98/39	2	51/51	d	347	8	2	6	19
3	N98/39	2	51/51	d	402	9	1	8	9
3	N98/39	2	51/51	d	412	5	1	4	13
3	N98/39	2	51/51	d	425	3		3	1
3	N98/39	2	51/51	d	449	1		1	1
3	N98/39	2	51/51	d	466	2		2	1
3	N98/39	2	51/51	d	582	1		1	1
3	N98/39	2	51/51		248	4		4	1
3	N98/39	2	51/51		260	12	2	10	7
3	N98/39	2	51/51		284	28	3	25	57
3	N98/39	2	51/51		317	1		1	1
3	N98/39	2	51/51		317	22	7	15	36
3	N98/39	2	51/51		400	6		6	7

Table 18, continued from previous page and continued on next page: Finds from site catalogue no. 3, pottery.

SC no.	Site no.	Area	Unit	Quarant	Level	Pottery			Weight/g
							Dec.	Un-dec.	
3	N98/39	2	51/52	a	863	8		8	13
3	N98/39	2	51/52	a	876	2		2	15
3	N98/39	2	51/52	a	893	2	1	1	3
3	N98/39	2	51/52	a	903	3		3	1
3	N98/39	2	51/52	a	916	3	1	2	13
3	N98/39	2	51/52	a	928	1		1	1
3	N98/39	2	51/52	b	863	7		7	4
3	N98/39	2	51/52	b	876	7		7	4
3	N98/39	2	51/52	b	893	5		5	15
3	N98/39	2	51/52	b	903	5	1	4	4
3	N98/39	2	51/52	b	936	2	1	1	4
3	N98/39	2	51/52	c	863	6		6	3
3	N98/39	2	51/52	c	876	5		5	13
3	N98/39	2	51/52	c	903	1		1	1
3	N98/39	2	51/52	c	916	3		3	10
3	N98/39	2	51/52	c	928	1		1	2
3	N98/39	2	51/52	c	951	3		3	2
3	N98/39	2	51/52	d	863	14	1	13	14
3	N98/39	2	51/52	d	876	4		4	34
3	N98/39	2	51/52	d	893	5		5	7
3	N98/39	2	51/52	d	916	1		1	1
3	N98/39	2	51/52		814	7		7	5
3	N98/39	2	51/52		823	10		10	15
3	N98/39	2	51/52		836	30	6	24	44
3	N98/39	2	51/52		848	22	2	20	56
3	N98/39	2	51/53	a	453	5		5	4
3	N98/39	2	51/53	a	571	3	1	2	2
3	N98/39	2	51/53	a	605	6		6	12
3	N98/39	2	51/53	a	631	2		2	1
3	N98/39	2	51/53	a	650	1		1	17
3	N98/39	2	51/53	b	453	7		7	109
3	N98/39	2	51/53	b	571	1		1	9
3	N98/39	2	51/53	b	605	5		5	11
3	N98/39	2	51/53	c	453	4		4	9
3	N98/39	2	51/53	c	605	1		1	6
3	N98/39	2	51/53	c	631	2		2	4
3	N98/39	2	51/53	c	650	2	1	1	2
3	N98/39	2	51/53	c	659	2		2	1
3	N98/39	2	51/53	c	667	3		3	4
3	N98/39	2	51/53	d	453	6	1	5	8
3	N98/39	2	51/53	d	605	1		1	2
3	N98/39	2	51/53	d	650	4	1	3	6
3	N98/39	2	51/53	d	667	2		2	4
3	N98/39	2	51/53		302	4		4	4
3	N98/39	2	51/53		329	9	1	8	13
3	N98/39	2	51/53		370	25	3	22	132
3	N98/39	2	51/53		691	1		1	3
3	N98/39	2	51/53		693	1		1	3
3	N98/39	2	51/54	a	948	4		4	15
3	N98/39	2	51/54	a	973	4		4	14
3	N98/39	2	51/54	a	990	2		2	1
3	N98/39	2	51/54	a	994	2		2	1
3	N98/39	2	51/54	a	1000	2		2	4
3	N98/39	2	51/54	a	1006	7	1	6	7
3	N98/39	2	51/54	b	948	15	1	14	17
3	N98/39	2	51/54	b	973	10	1	9	67
3	N98/39	2	51/54	b	1000	3		3	1
3	N98/39	2	51/54	b	1006	7		7	3
3	N98/39	2	51/54	c	948	6		6	59
3	N98/39	2	51/54	c	973	8		8	4
3	N98/39	2	51/54	c	990	2		2	2
3	N98/39	2	51/54	c	994	4		4	1
3	N98/39	2	51/54	c	1000	1		1	1
3	N98/39	2	51/54	c	1006	4		4	1
3	N98/39	2	51/54	c	1012	2		2	1
3	N98/39	2	51/54	d	948	5		5	10
3	N98/39	2	51/54	d	973	7	2	5	23
3	N98/39	2	51/54	d	990	1		1	1
3	N98/39	2	51/54	d	994	4		4	3
3	N98/39	2	51/54	d	1000	1		1	1
3	N98/39	2	51/54	d	1006	6		6	7
3	N98/39	2	51/54	d	1012	2		2	1
3	N98/39	2	51/54		832	6	1	5	11
3	N98/39	2	51/54		850	20		20	18
3	N98/39	2	51/54		870	18	4	14	94
3	N98/39	2	51/54		912	23	2	21	48
3	N98/39	2	51/55	a	596	9	1	8	25
3	N98/39	2	51/55	a	609	7		7	10
3	N98/39	2	51/55	a	619	6		6	7
3	N98/39	2	51/55	a	636	3		3	4
3	N98/39	2	51/55	a	655	4		4	17
3	N98/39	2	51/55	a	674	2		2	1
3	N98/39	2	51/55	a	701	5		5	9
3	N98/39	2	51/55	b	596	5		5	5
3	N98/39	2	51/55	b	609	6		6	26
3	N98/39	2	51/55	b	619	2		2	2

Table 18, continued from previous page and continued on next page: Finds from site catalogue no. 3, pottery.

SC no.	Site no.	Area	Unit	Quarant	Level	Pottery			Weight/g
							Dec.	Un-dec.	
3	N98/39	2	51/55	b	636	2		2	1
3	N98/39	2	51/55	b	655	2		2	2
3	N98/39	2	51/55	b	674	3		3	3
3	N98/39	2	51/55	c	596	1		1	6
3	N98/39	2	51/55	c	609	8		8	60
3	N98/39	2	51/55	c	615	6	1	5	125
3	N98/39	2	51/55	c	636	1		1	1
3	N98/39	2	51/55	c	655	1		1	7
3	N98/39	2	51/55	c	701	1		1	1
3	N98/39	2	51/55	d	596	4		4	2
3	N98/39	2	51/55	d	609	6		6	35
3	N98/39	2	51/55	d	619	6		6	11
3	N98/39	2	51/55	d	636	4		4	3
3	N98/39	2	51/55	d	609	1		1	1
3	N98/39	2	51/55	d	674	1		1	1
3	N98/39	2	51/55		336	5	1	4	10
3	N98/39	2	51/55		399	14	3	11	23
3	N98/39	2	51/55		428	23	4	19	80
3	N98/39	2	51/55		573	5		5	7
3	N98/39	2	52/50	a	396	6		6	10
3	N98/39	2	52/50	a	405	5		5	9
3	N98/39	2	52/50	a	437	4		4	3
3	N98/39	2	52/50	a	551	1		1	5
3	N98/39	2	52/50	b	396	7		7	11
3	N98/39	2	52/50	b	405	5		5	10
3	N98/39	2	52/50	b	437	3		3	3
3	N98/39	2	52/50	b	551	3	1	2	10
3	N98/39	2	52/50	c	396	6	2	4	22
3	N98/39	2	52/50	c	405	3	1	2	10
3	N98/39	2	52/50	c	434	1	1		25
3	N98/39	2	52/50	c	437	3	1	2	18
3	N98/39	2	52/50	c	456	5	2	3	4
3	N98/39	2	52/50	c	551	1		1	7
3	N98/39	2	52/50	d	396	5		5	11
3	N98/39	2	52/50	d	405	4		4	11
3	N98/39	2	52/50	d	437	5	1	4	4
3	N98/39	2	52/50	d	456	2		2	6
3	N98/39	2	52/50	d	551	1		1	1
3	N98/39	2	52/50		305	3	1	2	5
3	N98/39	2	52/50		324	11		11	11
3	N98/39	2	52/50		350	20	1	19	74
3	N98/39	2	52/50		384	13	2	11	22
3	N98/39	2	52/51	a	727	7		7	34

SC no.	Site no.	Area	Unit	Quarant	Level	Pottery			Weight/g
							Dec.	Un-dec.	
3	N98/39	2	52/51	a	777	3		3	3
3	N98/39	2	52/51	a	785	1	1		1
3	N98/39	2	52/51	b	727	11		11	51
3	N98/39	2	52/51	b	742	10		10	3
3	N98/39	2	52/51	b	758	1		1	1
3	N98/39	2	52/51	b	768	3		3	7
3	N98/39	2	52/51	b	777	2		2	1
3	N98/39	2	52/51	c	727	6		6	10
3	N98/39	2	52/51	c	742	5		5	8
3	N98/39	2	52/51	c	758	4		4	1
3	N98/39	2	52/51	c	768	1		1	4
3	N98/39	2	52/51	d	727	5	1	4	4
3	N98/39	2	52/51	d	742	6		6	7
3	N98/39	2	52/51	d	758	7		7	6
3	N98/39	2	52/51	d	768	6	1	5	2
3	N98/39	2	52/51	d	777	3		3	2
3	N98/39	2	52/51		682	24	1	22	38
3	N98/39	2	52/51		698	13	3	10	40
3	N98/39	2	52/51		710	11		11	24
3	N98/39	2	52/51		724	23	4	19	67
3	N98/39	2	52/52	a	56	7	1	6	12
3	N98/39	2	52/52	b	57	13	4	9	24
3	N98/39	2	52/52	b	79	5	1	4	9
3	N98/39	2	52/52	b	109	2		2	4
3	N98/39	2	52/52	c	58	10	3	7	43
3	N98/39	2	52/52	c	70	2		2	1
3	N98/39	2	52/52	c	79	3		3	15
3	N98/39	2	52/52	d	70	3	2	1	1
3	N98/39	2	52/52	d	79	1	1		5
3	N98/39	2	52/52	d	86	4	2	2	5
3	N98/39	2	52/52	d	109	3	1	2	10
3	N98/39	2	52/52		17	4	1	4	6
3	N98/39	2	52/52		23	12	1	11	28
3	N98/39	2	52/52		32	15	3	12	44
3	N98/39	2	52/52		46	22	3	19	40
3	N98/39	2	52/53	a	885	4	1	3	24
3	N98/39	2	52/53	a	909	2		2	6
3	N98/39	2	52/53	a	924	3		3	1
3	N98/39	2	52/53	a	946	1		1	2
3	N98/39	2	52/53	a	961	3	1	2	6
3	N98/39	2	52/53	a	976	4		4	3
3	N98/39	2	52/53	b	867	7		7	6
3	N98/39	2	52/53	b	885	5		5	2

Table 18, continued from previous page and continued on next page: Finds from site catalogue no. 3, pottery.

SC no.	Site no.	Area	Unit	Quarant	Level	Pottery			Weight/g
							Dec.	Un-dec.	
3	N98/39	2	52/53	b	909	5		5	2
3	N98/39	2	52/53	b	924	2		2	1
3	N98/39	2	52/53	b	946	7		7	24
3	N98/39	2	52/53	b	961	6		6	4
3	N98/39	2	52/53	c	867	6	1	5	6
3	N98/39	2	52/53	c	885	5		5	20
3	N98/39	2	52/53	c	961	3	1	2	4
3	N98/39	2	52/53	c	976	1		1	1
3	N98/39	2	52/53	d	867	3	1	2	9
3	N98/39	2	52/53	d	885	5	1	4	40
3	N98/39	2	52/53	d	909	1		1	1
3	N98/39	2	52/53	d	924	1		1	2
3	N98/39	2	52/53	d	961	1		1	3
3	N98/39	2	52/53		816	18	1	17	13
3	N98/39	2	52/53		829	21	3	18	71
3	N98/39	2	52/53		845	13		13	35
3	N98/39	2	52/54	a	464	10		10	37
3	N98/39	2	52/54	a	565	4		4	8
3	N98/39	2	52/54	a	601	4		4	1
3	N98/39	2	52/54	a	622	5	1	4	12
3	N98/39	2	52/54	a	634	4		4	10
3	N98/39	2	52/54	b	464	27	1	26	50
3	N98/39	2	52/54	b	565	3	1	2	17
3	N98/39	2	52/54	b	601	3		3	7
3	N98/39	2	52/54	b	622	3		3	5
3	N98/39	2	52/54	b	634	4		4	3
3	N98/39	2	52/54	c	464	1		1	6
3	N98/39	2	52/54	c	464	3		3	5
3	N98/39	2	52/54	c	565	17		17	26
3	N98/39	2	52/54	c	601	11		11	7
3	N98/39	2	52/54	c	622	4		4	2
3	N98/39	2	52/54	c	634	1		1	5
3	N98/39	2	52/54	d	464	2	1	1	10
3	N98/39	2	52/54	d	565	13	2	11	29
3	N98/39	2	52/54	d	601	3		3	8
3	N98/39	2	52/54		319	1		1	1
3	N98/39	2	52/54		338	15	1	14	35
3	N98/39	2	52/54		374	87	5	82	150
3	N98/39	2	52/54		420	52	1	51	35
3	N98/39	2	52/54		440	136	3	133	129
3	N98/39	2	52/55	a	1009	1		1	3
3	N98/39	2	52/55	a	1015	1		1	1
3	N98/39	2	52/55	a	1019	2		2	5
3	N98/39	2	52/55	a	1022	3		3	10
3	N98/39	2	52/55	a	1025	1		1	1
3	N98/39	2	52/55	a	1035	1		1	5
3	N98/39	2	52/55	b	1003	5	1	4	3
3	N98/39	2	52/55	b	1009	5		5	7
3	N98/39	2	52/55	b	1015	6	1	5	61
3	N98/39	2	52/55	b	1019	1		1	2
3	N98/39	2	52/55	b	1022	5		5	3
3	N98/39	2	52/55	b	1025	2		2	1
3	N98/39	2	52/55	b	1035	1		1	1
3	N98/39	2	52/55	b	1040	1	1		7
3	N98/39	2	52/55	c	1003	3		3	2
3	N98/39	2	52/55	c	1009	6		6	13
3	N98/39	2	52/55	c	1015	4	1	3	18
3	N98/39	2	52/55	c	1019	4		4	8
3	N98/39	2	52/55	c	1022	3	1	2	3
3	N98/39	2	52/55	c	1032	2		2	1
3	N98/39	2	52/55	c	1035	2		2	1
3	N98/39	2	52/55	d	1003	6		6	5
3	N98/39	2	52/55	d	1009	12	1	11	69
3	N98/39	2	52/55	d	1015	12	1	11	41
3	N98/39	2	52/55	d	1019	15		15	5
3	N98/39	2	52/55	d	1022	3		3	4
3	N98/39	2	52/55	d	1025	1		1	1
3	N98/39	2	52/55	d	1035	5	1	4	3
3	N98/39	2	52/55		965	7		7	2
3	N98/39	2	52/55		979	20	1	19	37
3	N98/39	2	52/55		988	40	2	38	97
3	N98/39	2	53/55		413a	13	3	10	35
3	N98/39	2	53/55		443	38	2	3	56
3	N98/39	2	53/55		468	15	3	12	60
3	N98/39	2	54/52	b	557	1	1		17
3	N98/39	2	54/52	c	88	1		1	2
3	N98/39	2	54/52	d	63	1		1	1
3	N98/39	2	54/52	d	76	6		6	8
3	N98/39	2	54/52		18	11	2	9	18
3	N98/39	2	54/52		25	24	3	21	52
3	N98/39	2	54/52		37	23	2	21	39
3	N98/39	2	54/52		50	33	4	29	130
3	N98/39	2	54/52		100	5		5	19
3	N98/39	2	56/52	a	68	7	1	6	17
3	N98/39	2	56/52	a	94	6		6	15
3	N98/39	2	56/52	c	68	10	1	9	37

Table 18, continued from previous page and continued on next page: Finds from site catalogue no. 3, pottery.

Table 18

SC no.	Site no.	Area	Unit	Quadrant	Level	Pottery	Dec.	Un-dec.	Weight/g
3	N98/39	2	56/52	d	68	11	4	7	37
3	N98/39	2	56/52	d	94	1		1	5
3	N98/39	2	56/52		19	9	2	7	24
3	N98/39	2	56/52		27	42	3	39	76
3	N98/39	2	56/52		40	51	5	46	160
3	N98/39	2	56/52		795	8		8	26
3	N98/39	2	56/52		40	1	1		26
3	N98/39	2	57/53	a	182	4		4	5
3	N98/39	2	57/53	a	199	19	5	14	82
3	N98/39	2	57/53	a	230	3		3	8
3	N98/39	2	57/53	b	182	1		1	4
3	N98/39	2	57/53	b	199	17	3	14	78
3	N98/39	2	57/53	b	230	6		6	8
3	N98/39	2	57/53	b	250	4	1	3	9
3	N98/39	2	57/53	c	182	3		3	1
3	N98/39	2	57/53	c	199	6		6	21
3	N98/39	2	57/53	c	230	5		5	6
3	N98/39	2	57/53	d	199	4		4	6
3	N98/39	2	57/53	d	230	6		6	24
3	N98/39	2	57/53	d	250	1		1	1
3	N98/39	2	57/53	d	281	3		3	12
3	N98/39	2	57/53		139	3		3	4
3	N98/39	2	57/53		144	13		13	10
3	N98/39	2	57/53		155	20		20	23
3	N98/39	2	57/53	a	182	2	2		4
3	N98/39	2	57/53	d	182	4		4	2
3	N98/39	2	57/53	d	199	1	1		3
3	N98/39	2	57/55	a	185	5	1	4	13
3	N98/39	2	57/55	a	201	6	1	5	4
3	N98/39	2	57/55	a	232	11	2	9	16
3	N98/39	2	57/55	a	254	7	1	6	33
3	N98/39	2	57/55	a	276	3	1	2	13
3	N98/39	2	57/55	a	309	3		3	1
3	N98/39	2	57/55	b	185	11	5	6	35
3	N98/39	2	57/55	b	201	5		5	4
3	N98/39	2	57/55	b	232	20		20	118
3	N98/39	2	57/55	b	254	3	2	1	4
3	N98/39	2	57/55	c	185	4		4	2
3	N98/39	2	57/55	c	201	8		8	25
3	N98/39	2	57/55	c	232	9		9	46
3	N98/39	2	57/55	c	254	9	1	8	11
3	N98/39	2	57/55	c	276	3		3	5
3	N98/39	2	57/55	d	185	7	2	5	4
3	N98/39	2	57/55	d	201	5		5	2
3	N98/39	2	57/55	d	232	20	3	17	65
3	N98/39	2	57/55	d	254	6		6	30
3	N98/39	2	57/55		146	6		6	8
3	N98/39	2	57/55		167	16		16	15
3	N98/39	2	58/50	a	152	10		10	10
3	N98/39	2	58/50	b	152	19	1	18	70
3	N98/39	2	58/50	b	170	3		3	1
3	N98/39	2	58/50	c	152	7	2	5	19
3	N98/39	2	58/50	c	170	2	1	1	3
3	N98/39	2	58/50	d	152	10	1	9	15
3	N98/39	2	58/50	d	170	4		4	9
3	N98/39	2	58/50		115	8	1	7	12
3	N98/39	2	58/50		126	26		26	52
3	N98/39	2	58/50	a	192	1	1		6
3	N98/39	2	59/51	c	358	3		3	25
3	N98/39	2	58/52	a	130	3		3	4
3	N98/39	2	58/52	a	149	3		3	4
3	N98/39	2	58/52	a	162	4		4	2
3	N98/39	2	58/52	a	178	17	1	16	30
3	N98/39	2	58/52	a	190	38		38	106
3	N98/39	2	58/52	a	223	6		6	7
3	N98/39	2	58/52	b	130	4	1	3	2
3	N98/39	2	58/52	b	149	7	1	6	5
3	N98/39	2	58/52	b	162	10		10	20
3	N98/39	2	58/52	b	178	5		5	2
3	N98/39	2	58/52	c	130	8	1	7	11
3	N98/39	2	58/52	c	149	3		3	2
3	N98/39	2	58/52	c	162	6	1	5	8
3	N98/39	2	58/52	c	223	19		19	113
3	N98/39	2	58/52	d	130	1		1	2
3	N98/39	2	58/52	d	149	4		4	6
3	N98/39	2	58/52	d	162	10		10	20
3	N98/39	2	58/52	d	178	8		8	26
3	N98/39	2	58/52	d	223	12	1	11	21
3	N98/39	2	58/52		96	5		5	7
3	N98/39	2	58/52		98	8	1	7	8
3	N98/39	2	58/52		118	18	3	15	38
3	N98/39	2	58/52	a	162	1	1		1
3	N98/39	2	58/52	c	178	13		13	86
3	N98/39	2	58/54	a	180	15	4	11	24
3	N98/39	2	58/54	a	219	5	1	4	12
3	N98/39	2	58/54	b	180	7	2	5	21

Table 18, continued from previous page and continued on next page: Finds from site catalogue no. 3, pottery.

SC no.	Site no.	Area	Unit	Qua-drant	Level	Pottery			Weight/g
							Dec.	Un-dec.	
3	N98/39	2	58/54	b	219	3	1	2	3
3	N98/39	2	58/54	c	180	9	2	7	125
3	N98/39	2	58/54	c	219	11	3	8	22
3	N98/39	2	58/54	d	180	12	1	11	25
3	N98/39	2	58/54	d	219	9		9	56
3	N98/39	2	58/54		142	15	1	14	27
3	N98/39	2	58/54		164	30	4	26	34
3	N98/39	2	59/51	a	322	5		5	3
3	N98/39	2	59/51	a	341	9		9	5
3	N98/39	2	59/51	a	358	7	1	6	15
3	N98/39	2	59/51	a	391	1		1	1
3	N98/39	2	59/51	b	322	5		5	4
3	N98/39	2	59/51	b	341	3		3	1
3	N98/39	2	59/51	b	358	6		6	6
3	N98/39	2	59/51	b	365	2		2	2
3	N98/39	2	59/51	b	391	1	1		1
3	N98/39	2	59/51	b	322	1	1		1
3	N98/39	2	59/51	c	322	5		5	2
3	N98/39	2	59/51	c	341	5		5	15
3	N98/39	2	59/51	c	358	1	1		1
3	N98/39	2	59/51	c	365	2		2	2
3	N98/39	2	59/51	c	391	2		2	16
3	N98/39	2	59/51	d	322	6		6	5
3	N98/39	2	59/51	d	341	3	1	2	2
3	N98/39	2	59/51	d	358	11	2	9	28
3	N98/39	2	59/51	d	365	2		2	2
3	N98/39	2	59/51	d	391	3	1	2	10
3	N98/39	2	59/51		273	5	1	4	7
3	N98/39	2	59/51		299	14	3	11	44
3	N98/39	2	59/53		134	24	6	18	39
3	N98/39	2	59/53		173	23	1	22	55
3	N98/39	2	59/53		215	1		1	9
3	N98/39	2	59/53		265	39	6	33	162
3	N98/39	2	59/53		287	3	1	2	5
3	N98/39	2	59/53		119a	4		4	9
3	N98/39	2	59/55	a	188	18	3	15	81
3	N98/39	2	59/55	b	188	12	3	9	18
3	N98/39	2	59/55	b	216	1	1		1
3	N98/39	2	59/55	c	188	8	1	7	65
3	N98/39	2	59/55	c	216	3	1	2	2
3	N98/39	2	59/55	d	188	14	3	11	22
3	N98/39	2	59/55	d	216	7	1	6	12
3	N98/39	2	59/55		160	1	1		1
3	N98/39	2	59/55		132	5	1	4	2
3	N98/39	2	59/55		140	15	1	14	18
3	N98/39	2	59/55		160	42	4	38	78
3	N98/39					73	37	36	903
3	N98/39	1			3	37	1	36	233
3	N98/39	2				64	2	52	287
3	N98/39	2			2	3	1	2	35
3	N98/39	2			14	26	13	13	312
3	N98/39	2			40	1		1	1
3	N98/39	2			42	30	24	6	215
3	N98/39	2			982	6		6	18
3	N98/39	2			1046	78	8	70	479
3	N98/39	2 east			42	2		2	68
3	N98/39	2 south			41	18	3	15	227
3	N98/39	2 south				1	1		6
3	N98/39	2 west			14	6	1	5	102
3	N98/39	3			5	28	6	22	194
3	N98/39	4				154	12	142	790
3	N05/01					8	7	1	48
3	N05/02					33	24	9	139
3	N05/10					11	10	1	42

Table 18, continued from previous page and continued on next page: Finds from site catalogue no. 3, pottery.

SC no.	Site no.	Area	Unit	Quadrant	Level	Burnt clay	Faunal remains	Weight/g	Botanical remains	Weight/g	Charcoal/g
3	N98/39	1	48/10	a	9						2
3	N98/39	1	48/10	a	6						5
3	N98/39	1	48/10	b	9						4
3	N98/39	1	48/10	c	4						5
3	N98/39	1	49/10	b	4						3
3	N98/39	1	49/10	d	6						1
3	N98/39	2	50/50	a	257		1	1			
3	N98/39	2	50/50	a	315		1	1			
3	N98/39	2	50/50	a	315						1
3	N98/39	2	50/50	a	331		1	2			
3	N98/39	2	50/50	a	331						1
3	N98/39	2	50/50	a	344		1	1			
3	N98/39	2	50/50	a	344		1	1			
3	N98/39	2	50/50	a	344						1
3	N98/39	2	50/50	a	362		3	1			
3	N98/39	2	50/50	a	362						1
3	N98/39	2	50/50	a	387		2	1			
3	N98/39	2	50/50	a	387						2
3	N98/39	2	50/50	a	434						1
3	N98/39	2	50/50	b	257		3	1			
3	N98/39	2	50/50	b	257		6	1			
3	N98/39	2	50/50	b	257						1
3	N98/39	2	50/50	b	331						1
3	N98/39	2	50/50	b	344						1
3	N98/39	2	50/50	b	362		1	1			
3	N98/39	2	50/50	b	362						1
3	N98/39	2	50/50	b	377		1	1			
3	N98/39	2	50/50	b	377		1	1			
3	N98/39	2	50/50	b	387						1
3	N98/39	2	50/50	c	257		6	1			
3	N98/39	2	50/50	c	257						1
3	N98/39	2	50/50	c	315		2	1			
3	N98/39	2	50/50	c	315		8	1			
3	N98/39	2	50/50	c	315						2
3	N98/39	2	50/50	c	331		1	1			
3	N98/39	2	50/50	c	377		2	1			
3	N98/39	2	50/50	c	387						1
3	N98/39	2	50/50	c	434		1	1			
3	N98/39	2	50/50	d	254		1	1			
3	N98/39	2	50/50	d	257		2	1			
3	N98/39	2	50/50	d	257		4	0			
3	N98/39	2	50/50	d	315						1
3	N98/39	2	50/50	d	331		1	1			

SC no.	Site no.	Area	Unit	Quadrant	Level	Burnt clay	Faunal remains	Weight/g	Botanical remains	Weight/g	Charcoal/g
3	N98/39	2	50/50	d	345		4	1			
3	N98/39	2	50/50	d	362		2	1			
3	N98/39	2	50/50	d	377		3	1			
3	N98/39	2	50/50	d	387		1	1			
3	N98/39	2	50/50	d	387						1
3	N98/39	2	50/50	d	416		1	1			
3	N98/39	2	50/50		212		5	12			
3	N98/39	2	50/50		212		9	1			
3	N98/39	2	50/50		212				1	1	
3	N98/39	2	50/50		228		4	1			
3	N98/39	2	50/50		228		7	4			
3	N98/39	2	50/50		246		1	1			
3	N98/39	2	50/50		246		1	1			
3	N98/39	2	50/50		270		2	1			
3	N98/39	2	50/50		270		6	1			
3	N98/39	2	50/50		290		3	1			
3	N98/39	2	50/50		290		10	4			
3	N98/39	2	50/50		290						4
3	N98/39	2	50/50		291		1	1			
3	N98/39	2	50/51	a	705		1	1			
3	N98/39	2	50/51	a	705		2	2			
3	N98/39	2	50/51	a	705						1
3	N98/39	2	50/51	a	718		2	1			
3	N98/39	2	50/51	a	718						1
3	N98/39	2	50/51	a	736		1	1			
3	N98/39	2	50/51	a	736		3	1			
3	N98/39	2	50/51	a	736						3
3	N98/39	2	50/51	a	746		1	1			
3	N98/39	2	50/51	a	746						14
3	N98/39	2	50/51	a	754		4	1			
3	N98/39	2	50/51	a	754						1
3	N98/39	2	50/51	a	765		1	1			
3	N98/39	2	50/51	a	765		5	1			
3	N98/39	2	50/51	a	765						1
3	N98/39	2	50/51	a	771		1	1			
3	N98/39	2	50/51	a	771		2	6			
3	N98/39	2	50/51	a	771						1
3	N98/39	2	50/51	b	705		1	1			
3	N98/39	2	50/51	b	705						2
3	N98/39	2	50/51	b	718		4	1			
3	N98/39	2	50/51	b	718		9	1			
3	N98/39	2	50/51	b	736		2	1			
3	N98/39	2	50/51	b	736		3	1			

Table 19, continude on next page: Finds from site catalogue no. 3, burnt clay, faunal remains, botanical remains and charcoal.

SC no.	Site no.	Area	Unit	Quadrant	Level	Burnt clay	Faunal remains	Weight/g	Botanical remains	Weight/g	Charcoal/g
3	N98/39	2	50/51	b	736						6
3	N98/39	2	50/51	b	746		4	1			
3	N98/39	2	50/51	b	746						1
3	N98/39	2	50/51	b	754						1
3	N98/39	2	50/51	b	765		1	1			
3	N98/39	2	50/51	b	765		5	1			
3	N98/39	2	50/51	b	765						1
3	N98/39	2	50/51	b	771		1	1			
3	N98/39	2	50/51	b	771						1
3	N98/39	2	50/51	c	705		4	1			
3	N98/39	2	50/51	c	705						1
3	N98/39	2	50/51	c	718						1
3	N98/39	2	50/51	c	736		3	1			
3	N98/39	2	50/51	c	736		7	1			
3	N98/39	2	50/51	c	736						3
3	N98/39	2	50/51	c	746		1	2			
3	N98/39	2	50/51	c	746		1	2			
3	N98/39	2	50/51	c	746						1
3	N98/39	2	50/51	c	754		1	1			
3	N98/39	2	50/51	c	754		1	1			
3	N98/39	2	50/51	c	754						1
3	N98/39	2	50/51	c	765		2	1			
3	N98/39	2	50/51	c	771		1	1			
3	N98/39	2	50/51	c	771		2	1			
3	N98/39	2	50/51	d	705		1	1			
3	N98/39	2	50/51	d	705		5	1			
3	N98/39	2	50/51	d	705						1
3	N98/39	2	50/51	d	718		1	1			
3	N98/39	2	50/51	d	718		5	1			
3	N98/39	2	50/51	d	736		3	1			
3	N98/39	2	50/51	d	736						1
3	N98/39	2	50/51	d	746		1	1			
3	N98/39	2	50/51	d	746		1	1			
3	N98/39	2	50/51	d	746						1
3	N98/39	2	50/51	d	754		1	1			
3	N98/39	2	50/51	d	754		6	1			
3	N98/39	2	50/51	d	754						1
3	N98/39	2	50/51	d	765		1	1			
3	N98/39	2	50/51	d	768						1
3	N98/39	2	50/51	d	774						1
3	N98/39	2	50/51		625		1	1			
3	N98/39	2	50/51		625						1
3	N98/39	2	50/51		639		3	1			
3	N98/39	2	50/51		639		8	1			
3	N98/39	2	50/51		639				1	1	
3	N98/39	2	50/51		639						3
3	N98/39	2	50/51		643		5	1			
3	N98/39	2	50/51		643				2	1	
3	N98/39	2	50/51		643						
3	N98/39	2	50/51		664		7	2			
3	N98/39	2	50/51		664		12	1			
3	N98/39	2	50/51		664						1
3	N98/39	2	50/51		689		2	1			
3	N98/39	2	50/51		689		3	1			
3	N98/39	2	50/51		689				2	1	
3	N98/39	2	50/51		689						1
3	N98/39	2	50/51		736				1	1	
3	N98/39	2	50/52	a	73		2	1			
3	N98/39	2	50/52	a	73		5	1			
3	N98/39	2	50/52	a	73						3
3	N98/39	2	50/52	a	91		1	1			
3	N98/39	2	50/52	a	91						1
3	N98/39	2	50/52	b	73		3	1			
3	N98/39	2	50/52	b	73		9	1			
3	N98/39	2	50/52	b	73						5
3	N98/39	2	50/52	b	91		1	1			
3	N98/39	2	50/52	b	91		2	1			
3	N98/39	2	50/52	b	91						3
3	N98/39	2	50/52	c	73		1	1			
3	N98/39	2	50/52	c	73		1	1			
3	N98/39	2	50/52	c	73				3	1	
3	N98/39	2	50/52	c	73						1
3	N98/39	2	50/52	c	91		1	1			
3	N98/39	2	50/52	c	91		4	1			
3	N98/39	2	50/52	c	91						3
3	N98/39	2	50/52	d	73		2	1			
3	N98/39	2	50/52	d	73		2	1			
3	N98/39	2	50/52	d	73						1
3	N98/39	2	50/52	d	91		2	1			
3	N98/39	2	50/52	d	91		3	1			
3	N98/39	2	50/52	d	91						5
3	N98/39	2	50/52		16						1
3	N98/39	2	50/52		21		6	4			
3	N98/39	2	50/52		21		8	1			
3	N98/39	2	50/52		21				10	1	
3	N98/39	2	50/52		21						5

Table 19, continued from previous page and continude on next page: Finds from site catalogue no. 3, burnt clay, faunal remains, botanical remains and charcoal.

SC no.	Site no.	Area	Unit	Quadrant	Level	Burnt clay	Faunal remains	Weight/g	Botanical remains	Weight/g	Charcoal/g
3	N98/39	2	50/52		34		3	1			
3	N98/39	2	50/52		34		6	1			
3	N98/39	2	50/52		34						3
3	N98/39	2	50/52		50						3
3	N98/39	2	50/52		54		10	1			
3	N98/39	2	50/52		54		15	2			
3	N98/39	2	50/52		54				7	1	
3	N98/39	2	50/52		54						
3	N98/39	2	50/52		54						6
3	N98/39	2	50/52		113		2	0			
3	N98/39	2	50/52		113		8	5			
3	N98/39	2	50/52		113						14
3	N98/39	2	50/52		446		3	1			
3	N98/39	2	50/52		446		19	1			
3	N98/39	2	50/52		446				5	1	
3	N98/39	2	50/52		446						9
3	N98/39	2	50/53	a	870						3
3	N98/39	2	50/53	a	879		3	1			
3	N98/39	2	50/53	a	879		9	17			
3	N98/39	2	50/53	a	889		4	1			
3	N98/39	2	50/53	a	889		6	1			
3	N98/39	2	50/53	a	889						2
3	N98/39	2	50/53	a	901		5	1			
3	N98/39	2	50/53	a	901						2
3	N98/39	2	50/53	a	918		1	1			
3	N98/39	2	50/53	a	918		9	1			
3	N98/39	2	50/53	a	918						3
3	N98/39	2	50/53	a	930		8	1			
3	N98/39	2	50/53	a	930						3
3	N98/39	2	50/53	a	940		1	1			
3	N98/39	2	50/53	a	940		11	1			
3	N98/39	2	50/53	a	940						3
3	N98/39	2	50/53	a	959		1	1			
3	N98/39	2	50/53	a	959		18	2			
3	N98/39	2	50/53	a	959						2
3	N98/39	2	50/53	a	967		16	1			
3	N98/39	2	50/53	b	879		3	6			
3	N98/39	2	50/53	b	879		5	1			
3	N98/39	2	50/53	b	879						2
3	N98/39	2	50/53	b	889		2	1			
3	N98/39	2	50/53	b	889		6	1			
3	N98/39	2	50/53	b	889						1
3	N98/39	2	50/53	b	901		1	1			
3	N98/39	2	50/53	b	901		3	1			
3	N98/39	2	50/53	b	901						1
3	N98/39	2	50/53	b	918		2	2			
3	N98/39	2	50/53	b	918		4	1			
3	N98/39	2	50/53	b	930		1	1			
3	N98/39	2	50/53	b	930		4	1			
3	N98/39	2	50/53	b	930						3
3	N98/39	2	50/53	b	940		10	1			
3	N98/39	2	50/53	b	959						1
3	N98/39	2	50/53	b	967		2	1			
3	N98/39	2	50/53	b	967		8	1			
3	N98/39	2	50/53	b	967						1
3	N98/39	2	50/53	b	989		4	1			
3	N98/39	2	50/53	c	879		1	1			
3	N98/39	2	50/53	c	879		2	1			
3	N98/39	2	50/53	c	879						2
3	N98/39	2	50/53	c	889		1	1			
3	N98/39	2	50/53	c	889		3	1			
3	N98/39	2	50/53	c	889						1
3	N98/39	2	50/53	c	901		1	1			
3	N98/39	2	50/53	c	901		3	1			
3	N98/39	2	50/53	c	901						1
3	N98/39	2	50/53	c	918		1	1			
3	N98/39	2	50/53	c	918		2	1			
3	N98/39	2	50/53	c	918						7
3	N98/39	2	50/53	c	930		3	1			
3	N98/39	2	50/53	c	930						27
3	N98/39	2	50/53	c	940		2	1			
3	N98/39	2	50/53	c	940		5	1			
3	N98/39	2	50/53	c	940						2
3	N98/39	2	50/53	c	959		1	1			
3	N98/39	2	50/53	c	959		4	1			
3	N98/39	2	50/53	c	959						1
3	N98/39	2	50/53	c	967		2	1			
3	N98/39	2	50/53	c	967						1
3	N98/39	2	50/53	d	856						65
3	N98/39	2	50/53	d	856						87
3	N98/39	2	50/53	d	879		2	1			
3	N98/39	2	50/53	d	879		5	1			
3	N98/39	2	50/53	d	889		4	1			
3	N98/39	2	50/53	d	889		11	1			
3	N98/39	2	50/53	d	901		3	1			
3	N98/39	2	50/53	d	918		9	1			

Table 19, continued from previous page and continude on next page: Finds from site catalogue no. 3, burnt clay, faunal remains, botanical remains and charcoal.

SC no.	Site no.	Area	Unit	Quadrant	Level	Burnt clay	Faunal remains	Weight/g	Botanical remains	Weight/g	Charcoal/g
3	N98/39	2	50/53	d	930		3	1			
3	N98/39	2	50/53	d	930		9	1			
3	N98/39	2	50/53	d	940		4	3			
3	N98/39	2	50/53	d	940		12	2			
3	N98/39	2	50/53	d	959		1	1			
3	N98/39	2	50/53	d	959		13	2			
3	N98/39	2	50/53	d	967		9	1			
3	N98/39	2	50/53		812		2	1			
3	N98/39	2	50/53		812		2	1			
3	N98/39	2	50/53		826		2	1			
3	N98/39	2	50/53		826		9	1			
3	N98/39	2	50/53		839		27	3			
3	N98/39	2	50/53		839		29	2			
3	N98/39	2	50/53		859		22	4			
3	N98/39	2	50/53		859		30	2			
3	N98/39	2	50/54	a	353		3	1			
3	N98/39	2	50/54	a	353		5	1			
3	N98/39	2	50/54	a	353						1
3	N98/39	2	50/54	a	393		6	1			
3	N98/39	2	50/54	a	393		20	1			
3	N98/39	2	50/54	a	393						3
3	N98/39	2	50/54	a	408		2	1			
3	N98/39	2	50/54	a	408		4	1			
3	N98/39	2	50/54	a	408						1
3	N98/39	2	50/54	a	431		3	1			
3	N98/39	2	50/54	a	431		5	1			
3	N98/39	2	50/54	a	431						2
3	N98/39	2	50/54	a	459		2	2			
3	N98/39	2	50/54	a	459		15	1			
3	N98/39	2	50/54	a	459						3
3	N98/39	2	50/54	a	554		1	1			
3	N98/39	2	50/54	a	554		14	1			
3	N98/39	2	50/54	a	554						2
3	N98/39	2	50/54	a	568		5	1			
3	N98/39	2	50/54	a	568						1
3	N98/39	2	50/54	a	967						1
3	N98/39	2	50/54	b	353		4	1			
3	N98/39	2	50/54	b	353		5	1			
3	N98/39	2	50/54	b	353						1
3	N98/39	2	50/54	b	408		2	1			
3	N98/39	2	50/54	b	408		8	1			
3	N98/39	2	50/54	b	408						1
3	N98/39	2	50/54	b	431		1	1			

SC no.	Site no.	Area	Unit	Quadrant	Level	Burnt clay	Faunal remains	Weight/g	Botanical remains	Weight/g	Charcoal/g
3	N98/39	2	50/54	b	431		5	1			
3	N98/39	2	50/54	b	431						1
3	N98/39	2	50/54	b	459		3	1			
3	N98/39	2	50/54	b	459		4	1			
3	N98/39	2	50/54	b	459						1
3	N98/39	2	50/54	b	554		3	1			
3	N98/39	2	50/54	b	554		6	1			
3	N98/39	2	50/54	b	554						1
3	N98/39	2	50/54	b	568		1	1			
3	N98/39	2	50/54	b	568		3	1			
3	N98/39	2	50/54	b	568						1
3	N98/39	2	50/54	c	353		5	1			
3	N98/39	2	50/54	c	353		16	3			
3	N98/39	2	50/54	c	353						2
3	N98/39	2	50/54	c	393		4	1			
3	N98/39	2	50/54	c	393		4	1			
3	N98/39	2	50/54	c	393						1
3	N98/39	2	50/54	c	408		6	1			
3	N98/39	2	50/54	c	408		7	1			
3	N98/39	2	50/54	c	408						1
3	N98/39	2	50/54	c	431		3	1			
3	N98/39	2	50/54	c	431						1
3	N98/39	2	50/54	c	459		10	1			
3	N98/39	2	50/54	c	459		12	1			
3	N98/39	2	50/54	c	459						2
3	N98/39	2	50/54	c	554		2	1			
3	N98/39	2	50/54	c	554		3	1			
3	N98/39	2	50/54	c	568		10	1			
3	N98/39	2	50/54	c	568						1
3	N98/39	2	50/54	d	353		6	1			
3	N98/39	2	50/54	d	353		20	4			
3	N98/39	2	50/54	d	353						3
3	N98/39	2	50/54	d	381		1	2			
3	N98/39	2	50/54	d	393		2	1			
3	N98/39	2	50/54	d	393		2	1			
3	N98/39	2	50/54	d	393		5	1			
3	N98/39	2	50/54	d	393		19	6			
3	N98/39	2	50/54	d	393						1
3	N98/39	2	50/54	d	393						1
3	N98/39	2	50/54	d	408		2	1			
3	N98/39	2	50/54	d	408		2	1			
3	N98/39	2	50/54	d	408						2
3	N98/39	2	50/54	d	431		3	1			

Table 19, continued from previous page and continude on next page: Finds from site catalogue no. 3, burnt clay, faunal remains, botanical remains and charcoal.

SC no.	Site no.	Area	Unit	Quadrant	Level	Burnt clay	Faunal remains	Weight/g	Botanical remains	Weight/g	Charcoal/g
3	N98/39	2	50/54	d	431						1
3	N98/39	2	50/54	d	459		2	1			
3	N98/39	2	50/54	d	459		2	1			
3	N98/39	2	50/54	d	459		14	1			
3	N98/39	2	50/54	d	459		14	1			
3	N98/39	2	50/54	d	459						4
3	N98/39	2	50/54	d	554		4	5			
3	N98/39	2	50/54	d	554		6	1			
3	N98/39	2	50/54	d	554						1
3	N98/39	2	50/54	d	568		1	1			
3	N98/39	2	50/54	d	568		9	1			
3	N98/39	2	50/54	d	568						1
3	N98/39	2	50/54		240		1	1			
3	N98/39	2	50/54		240		8	1			
3	N98/39	2	50/54		240						1
3	N98/39	2	50/54		267		6	1			
3	N98/39	2	50/54		267		7	1			
3	N98/39	2	50/54		267						1
3	N98/39	2	50/54		280				2	1	
3	N98/39	2	50/54		293		2	1			
3	N98/39	2	50/54		293		19	2			
3	N98/39	2	50/54		293		31	7			
3	N98/39	2	50/54		293						4
3	N98/39	2	50/54		334		4	1			
3	N98/39	2	50/54		334		22	7			
3	N98/39	2	50/54		334						7
3	N98/39	2	50/55	a	873		3	1			
3	N98/39	2	50/55	a	873						2
3	N98/39	2	50/55	a	897		1	1			
3	N98/39	2	50/55	a	897		3	1			
3	N98/39	2	50/55	a	897						2
3	N98/39	2	50/55	a	906		2	1			
3	N98/39	2	50/55	a	906		4	2			
3	N98/39	2	50/55	a	906						1
3	N98/39	2	50/55	a	934		6	1			
3	N98/39	2	50/55	a	934						3
3	N98/39	2	50/55	a	943		2	4			
3	N98/39	2	50/55	a	943		9	3			
3	N98/39	2	50/55	a	943						4
3	N98/39	2	50/55	a	963		2	1			
3	N98/39	2	50/55	a	963		17	2			
3	N98/39	2	50/55	a	963						1
3	N98/39	2	50/55	a	970		2	1			
3	N98/39	2	50/55	a	970						1
3	N98/39	2	50/55	a	920a		1	1			
3	N98/39	2	50/55	a	920a		5	1			
3	N98/39	2	50/55	a	920a						1
3	N98/39	2	50/55	b	873		8	1			
3	N98/39	2	50/55	b	873						1
3	N98/39	2	50/55	b	897		1	1			
3	N98/39	2	50/55	b	897		5	5			
3	N98/39	2	50/55	b	897						1
3	N98/39	2	50/55	b	906		4	1			
3	N98/39	2	50/55	b	906						1
3	N98/39	2	50/55	b	934		2	1			
3	N98/39	2	50/55	b	934						1
3	N98/39	2	50/55	b	943		3	19			
3	N98/39	2	50/55	b	943		24	6			
3	N98/39	2	50/55	b	943						1
3	N98/39	2	50/55	b	963		1	1			
3	N98/39	2	50/55	b	963		31	4			
3	N98/39	2	50/55	b	970		8	1			
3	N98/39	2	50/55	b	970						1
3	N98/39	2	50/55	b	920a		2	1			
3	N98/39	2	50/55	b	920a						1
3	N98/39	2	50/55	c	873		1	1			
3	N98/39	2	50/55	c	873		2	1			
3	N98/39	2	50/55	c	873		4	1			
3	N98/39	2	50/55	c	873						2
3	N98/39	2	50/55	c	897		1	1			
3	N98/39	2	50/55	c	897		3	1			
3	N98/39	2	50/55	c	897						1
3	N98/39	2	50/55	c	906		2	1			
3	N98/39	2	50/55	c	906		4	1			
3	N98/39	2	50/55	c	934		1	1			
3	N98/39	2	50/55	c	934		6	1			
3	N98/39	2	50/55	c	934						2
3	N98/39	2	50/55	c	943		4	1			
3	N98/39	2	50/55	c	943						1
3	N98/39	2	50/55	c	963		3	1			
3	N98/39	2	50/55	c	963		4	1			
3	N98/39	2	50/55	c	963						1
3	N98/39	2	50/55	c	970		1	1			
3	N98/39	2	50/55	c	920a						1

Table 19, continued from previous page and continude on next page: Finds from site catalogue no. 3, burnt clay, faunal remains, botanical remains and charcoal.

SC no.	Site no.	Area	Unit	Quadrant	Level	Burnt clay	Faunal remains	Weight/g	Botanical remains	Weight/g	Charcoal/g
3	N98/39	2	50/55	d	873		2	1			
3	N98/39	2	50/55	d	873		9	1			
3	N98/39	2	50/55	d	873						5
3	N98/39	2	50/55	d	897						1
3	N98/39	2	50/55	d	906		1	1			
3	N98/39	2	50/55	d	906						2
3	N98/39	2	50/55	d	934		1	1			
3	N98/39	2	50/55	d	934		1	1			
3	N98/39	2	50/55	d	934						1
3	N98/39	2	50/55	d	943		1	1			
3	N98/39	2	50/55	d	943		3	8			
3	N98/39	2	50/55	d	943						1
3	N98/39	2	50/55	d	963		9	1			
3	N98/39	2	50/55	d	963						1
3	N98/39	2	50/55	d	970		5	1			
3	N98/39	2	50/55	d	976						1
3	N98/39	2	50/55	d	920a		3	1			
3	N98/39	2	50/55	d	920a		9	1			
3	N98/39	2	50/55	d	920a						3
3	N98/39	2	50/55		811		1	1			
3	N98/39	2	50/55		811						1
3	N98/39	2	50/55		819		8	1			
3	N98/39	2	50/55		819				2	1	
3	N98/39	2	50/55		819						2
3	N98/39	2	50/55		842		1	3			
3	N98/39	2	50/55		842		14	2			
3	N98/39	2	50/55		842		27	3			
3	N98/39	2	50/55		842						5
3	N98/39	2	50/55		853		27	3			
3	N98/39	2	50/55		853		33	8			
3	N98/39	2	50/55		853						6
3	N98/39	2	51/50	a	730		5	1			
3	N98/39	2	51/50	a	730		8	1			
3	N98/39	2	51/50	a	730						1
3	N98/39	2	51/50	a	730						
3	N98/39	2	51/50	a	752		2	1			
3	N98/39	2	51/50	a	762		4	1			
3	N98/39	2	51/50	a	762						1
3	N98/39	2	51/50	a	774		4	1			
3	N98/39	2	51/50	a	774						1
3	N98/39	2	51/50	a	781		1	1			
3	N98/39	2	51/50	a	781		3	1			
3	N98/39	2	51/50	b	730		4	1			

SC no.	Site no.	Area	Unit	Quadrant	Level	Burnt clay	Faunal remains	Weight/g	Botanical remains	Weight/g	Charcoal/g
3	N98/39	2	51/50	b	730		12	1			
3	N98/39	2	51/50	b	752		2	1			
3	N98/39	2	51/50	b	752		28	1			
3	N98/39	2	51/50	b	752						3
3	N98/39	2	51/50	b	762		2	1			
3	N98/39	2	51/50	b	762		2	1			
3	N98/39	2	51/50	b	774		2	1			
3	N98/39	2	51/50	b	774		2	2			
3	N98/39	2	51/50	b	781		3	1			
3	N98/39	2	51/50	c	730						1
3	N98/39	2	51/50	c	752		8	2			
3	N98/39	2	51/50	c	752						1
3	N98/39	2	51/50	c	774		1	1			
3	N98/39	2	51/50	c	774						
3	N98/39	2	51/50	c	781						1
3	N98/39	2	51/50	c	788		4	1			
3	N98/39	2	51/50	c	788						1
3	N98/39	2	51/50	d	730		2	1			
3	N98/39	2	51/50	d	730		2	1			
3	N98/39	2	51/50	d	752		3	1			
3	N98/39	2	51/50	d	752		5	1			
3	N98/39	2	51/50	d	774		3	1			
3	N98/39	2	51/50	d	774						1
3	N98/39	2	51/50	d	781		2	1			
3	N98/39	2	51/50	d	781						1
3	N98/39	2	51/50		640						1
3	N98/39	2	51/50		646		9	1			
3	N98/39	2	51/50		670		2	1			
3	N98/39	2	51/50		670		9	1			
3	N98/39	2	51/50		670						1
3	N98/39	2	51/50		722		5	1			
3	N98/39	2	51/50		722		13	3			
3	N98/39	2	51/50		801						1
3	N98/39	2	51/51	a	347		12	2			
3	N98/39	2	51/51	a	347						1
3	N98/39	2	51/51	a	402		1	1			
3	N98/39	2	51/51	a	402		4	1			
3	N98/39	2	51/51	a	402						1
3	N98/39	2	51/51	a	412		1	1			
3	N98/39	2	51/51	a	412						5
3	N98/39	2	51/51	a	425						1
3	N98/39	2	51/51	a	429		1	1			
3	N98/39	2	51/51	a	429		3	1			

Table 19, continued from previous page and continude on next page: Finds from site catalogue no. 3, burnt clay, faunal remains, botanical remains and charcoal.

SC no.	Site no.	Area	Unit	Quadrant	Level	Burnt clay	Faunal remains	Weight/g	Botanical remains	Weight/g	Charcoal/g
3	N98/39	2	51/51	a	449		1	1			
3	N98/39	2	51/51	a	449		2	1			
3	N98/39	2	51/51	a	449						2
3	N98/39	2	51/51	a	449						6
3	N98/39	2	51/51	a	466		3	1			
3	N98/39	2	51/51	a	466						2
3	N98/39	2	51/51	a	560						1
3	N98/39	2	51/51	a	582						1
3	N98/39	2	51/51	b	317						3
3	N98/39	2	51/51	b	347		1	1			
3	N98/39	2	51/51	b	347						1
3	N98/39	2	51/51	b	402		3	1			
3	N98/39	2	51/51	b	402						1
3	N98/39	2	51/51	b	412		2	1			
3	N98/39	2	51/51	b	412						1
3	N98/39	2	51/51	b	425						2
3	N98/39	2	51/51	b	449		1	1			
3	N98/39	2	51/51	b	449		1	1			
3	N98/39	2	51/51	b	449						1
3	N98/39	2	51/51	b	486						5
3	N98/39	2	51/51	b	560		2	1			
3	N98/39	2	51/51	b	560						2
3	N98/39	2	51/51	b	582						1
3	N98/39	2	51/51	c	347		1	1			
3	N98/39	2	51/51	c	347						1
3	N98/39	2	51/51	c	402		1	1			
3	N98/39	2	51/51	c	402		4	1			
3	N98/39	2	51/51	c	402						1
3	N98/39	2	51/51	c	412		1	1			
3	N98/39	2	51/51	c	412						1
3	N98/39	2	51/51	c	425		5	1			
3	N98/39	2	51/51	c	425						1
3	N98/39	2	51/51	c	449		5	2			
3	N98/39	2	51/51	c	449						6
3	N98/39	2	51/51	c	466		1	1			
3	N98/39	2	51/51	c	466						4
3	N98/39	2	51/51	c	560						1
3	N98/39	2	51/51	c	568						1
3	N98/39	2	51/51	c	582		1	1			
3	N98/39	2	51/51	d	347		2	1			
3	N98/39	2	51/51	d	347						1
3	N98/39	2	51/51	d	371		1	30			
3	N98/39	2	51/51	d	402		1	1			

SC no.	Site no.	Area	Unit	Quadrant	Level	Burnt clay	Faunal remains	Weight/g	Botanical remains	Weight/g	Charcoal/g
3	N98/39	2	51/51	d	402						1
3	N98/39	2	51/51	d	412		2	1			
3	N98/39	2	51/51	d	412						3
3	N98/39	2	51/51	d	425		2	1			
3	N98/39	2	51/51	d	425						1
3	N98/39	2	51/51	d	449						1
3	N98/39	2	51/51	d	466		4	1			
3	N98/39	2	51/51	d	466						3
3	N98/39	2	51/51	d	560		1	1			
3	N98/39	2	51/51	d	560						2
3	N98/39	2	51/51	d	582		1	1			
3	N98/39	2	51/51	d	882						1
3	N98/39	2	51/51		248		1	1			
3	N98/39	2	51/51		260		1	1			
3	N98/39	2	51/51		260		1	1			
3	N98/39	2	51/51		260						1
3	N98/39	2	51/51		284		6	1			
3	N98/39	2	51/51		284						1
3	N98/39	2	51/51		317		1	1			
3	N98/39	2	51/51		317		4	1			
3	N98/39	2	51/51		400		2	1			
3	N98/39	2	51/51		400						1
3	N98/39	2	51/52	a	863		3	1			
3	N98/39	2	51/52	a	863		4	1			
3	N98/39	2	51/52	a	863						1
3	N98/39	2	51/52	a	874		17	4			
3	N98/39	2	51/52	a	876		1	1			
3	N98/39	2	51/52	a	876						1
3	N98/39	2	51/52	a	893		2	1			
3	N98/39	2	51/52	a	893		3	11			
3	N98/39	2	51/52	a	893						4
3	N98/39	2	51/52	a	903		1	1			
3	N98/39	2	51/52	a	903						2
3	N98/39	2	51/52	a	916		2	1			
3	N98/39	2	51/52	a	916						2
3	N98/39	2	51/52	a	928		1	1			
3	N98/39	2	51/52	a	928						1
3	N98/39	2	51/52	a	936		7	1			
3	N98/39	2	51/52	a	936						3
3	N98/39	2	51/52	a	951		5	1			
3	N98/39	2	51/52	a	951						1
3	N98/39	2	51/52	b	863		2	1			
3	N98/39	2	51/52	b	863		5	1			

Table 19, continued from previous page and continude on next page: Finds from site catalogue no. 3, burnt clay, faunal remains, botanical remains and charcoal.

SC no.	Site no.	Area	Unit	Quadrant	Level	Burnt clay	Faunal remains	Weight/g	Botanical remains	Weight/g	Charcoal/g
3	N98/39	2	51/52	b	863						1
3	N98/39	2	51/52	b	876		3	1			
3	N98/39	2	51/52	b	876		8	12			
3	N98/39	2	51/52	b	876						2
3	N98/39	2	51/52	b	893		1	1			
3	N98/39	2	51/52	b	893		4	1			
3	N98/39	2	51/52	b	893						2
3	N98/39	2	51/52	b	903						1
3	N98/39	2	51/52	b	916		1	1			
3	N98/39	2	51/52	b	916						1
3	N98/39	2	51/52	b	928		16	1			
3	N98/39	2	51/52	b	936		2	1			
3	N98/39	2	51/52	b	936		26	8			
3	N98/39	2	51/52	b	936						1
3	N98/39	2	51/52	b	951		1	1			
3	N98/39	2	51/52	b	951						1
3	N98/39	2	51/52	c	863		1	1			
3	N98/39	2	51/52	c	863		1	1			
3	N98/39	2	51/52	c	876		1	1			
3	N98/39	2	51/52	c	876		3	1			
3	N98/39	2	51/52	c	876						1
3	N98/39	2	51/52	c	893		1	1			
3	N98/39	2	51/52	c	893		2	1			
3	N98/39	2	51/52	c	893						1
3	N98/39	2	51/52	c	903		4	1			
3	N98/39	2	51/52	c	916		1	1			
3	N98/39	2	51/52	c	916						1
3	N98/39	2	51/52	c	928						1
3	N98/39	2	51/52	c	936		1	1			
3	N98/39	2	51/52	c	936		11	1			
3	N98/39	2	51/52	c	936						1
3	N98/39	2	51/52	c	951		6	2			
3	N98/39	2	51/52	c	951		10	1			
3	N98/39	2	51/52	c	951				1	1	
3	N98/39	2	51/52	c	951						6
3	N98/39	2	51/52	d	863		4	1			
3	N98/39	2	51/52	d	863						1
3	N98/39	2	51/52	d	876		5	1			
3	N98/39	2	51/52	d	876		7	1			
3	N98/39	2	51/52	d	876						1
3	N98/39	2	51/52	d	893		1	1			
3	N98/39	2	51/52	d	893						1
3	N98/39	2	51/52	d	903		2	1			
3	N98/39	2	51/52	d	903		3	1			
3	N98/39	2	51/52	d	903						2
3	N98/39	2	51/52	d	916		4	2			
3	N98/39	2	51/52	d	916						1
3	N98/39	2	51/52	d	928		4	1			
3	N98/39	2	51/52	d	928		13	2			
3	N98/39	2	51/52	d	928						1
3	N98/39	2	51/52	d	936		1	1			
3	N98/39	2	51/52	d	936		22	7			
3	N98/39	2	51/52	d	936						1
3	N98/39	2	51/52	d	951		4	1			
3	N98/39	2	51/52	d	951		60	14			
3	N98/39	2	51/52	d	951						1
3	N98/39	2	51/52		801		4	1			
3	N98/39	2	51/52		801		4	1			
3	N98/39	2	51/52		801				1	1	
3	N98/39	2	51/52		814		3	1			
3	N98/39	2	51/52		814						1
3	N98/39	2	51/52		823		1	1			
3	N98/39	2	51/52		823				1	1	
3	N98/39	2	51/52		823						2
3	N98/39	2	51/52		836		17	4	1	1	3
3	N98/39	2	51/52		848		16	3			3
3	N98/39	2	51/53	a	453		9	2			1
3	N98/39	2	51/53	a	571		9	2			1
3	N98/39	2	51/53	a	605		8	3			1
3	N98/39	2	51/53	a	631		11	2			1
3	N98/39	2	51/53	a	650						4
3	N98/39	2	51/53	a	659		4	2			2
3	N98/39	2	51/53	a	667		12	2			3
3	N98/39	2	51/53	b	453		12	2			4
3	N98/39	2	51/53	b	571		11	2			4
3	N98/39	2	51/53	b	605		1	1			15
3	N98/39	2	51/53	b	631						5
3	N98/39	2	51/53	b	650		2	1			3
3	N98/39	2	51/53	b	659		10	2			1
3	N98/39	2	51/53	b	667						1
3	N98/39	2	51/53	b	669		2	1			
3	N98/39	2	51/53	c	453		8	2			1
3	N98/39	2	51/53	c	571		4	1			1
3	N98/39	2	51/53	c	605		2	1			1
3	N98/39	2	51/53	c	631		2	2			15
3	N98/39	2	51/53	c	631						15

Table 19, continued from previous page and continude on next page: Finds from site catalogue no. 3, burnt clay, faunal remains, botanical remains and charcoal.

SC no.	Site no.	Area	Unit	Quadrant	Level	Burnt clay	Faunal remains	Weight/g	Botanical remains	Weight/g	Charcoal/g
3	N98/39	2	51/53	c	647						40
3	N98/39	2	51/53	c	650						11
3	N98/39	2	51/53	c	659		14	1			2
3	N98/39	2	51/53	c	667		21	3			1
3	N98/39	2	51/53	c-d	652						15
3	N98/39	2	51/53	d	453		11	6			4
3	N98/39	2	51/53	d	605		6	2			8
3	N98/39	2	51/53	d	631		1	1			2
3	N98/39	2	51/53	d	650		3	2			2
3	N98/39	2	51/53	d	659		1	2			1
3	N98/39	2	51/53	d	667		6	2			1
3	N98/39	2	51/53		50		16	4			
3	N98/39	2	51/53		302						1
3	N98/39	2	51/53		329		6	2			5
3	N98/39	2	51/53		370		24	4			11
3	N98/39	2	51/53		691		6	1			1
3	N98/39	2	51/53		693		4	2			1
3	N98/39	2	51/54	a	948		12	2			1
3	N98/39	2	51/54	a	972						1
3	N98/39	2	51/54	a	973		7	2			
3	N98/39	2	51/54	a	990		7	2			4
3	N98/39	2	51/54	a	994		1	1			6
3	N98/39	2	51/54	a	1000		10	2			1
3	N98/39	2	51/54	a	1006		10	2			1
3	N98/39	2	51/54	a	1012		9	2			2
3	N98/39	2	51/54	b	948		9	2			1
3	N98/39	2	51/54	b	973		9	2			1
3	N98/39	2	51/54	b	990		4	2			1
3	N98/39	2	51/54	b	994		5	2			5
3	N98/39	2	51/54	b	1000		7	2			1
3	N98/39	2	51/54	b	1006		11	2			1
3	N98/39	2	51/54	b	1012		18	1			1
3	N98/39	2	51/54	c	948		9	2			1
3	N98/39	2	51/54	c	973		15	2			1
3	N98/39	2	51/54	c	990		3	2			1
3	N98/39	2	51/54	c	994		2	2			1
3	N98/39	2	51/54	c	1000		1	5			1
3	N98/39	2	51/54	c	1006		6	2			1
3	N98/39	2	51/54	c	1012		3	1			1
3	N98/39	2	51/54	d	948		10	4			1
3	N98/39	2	51/54	d	973		3	2			1
3	N98/39	2	51/54	d	990		3	1			1
3	N98/39	2	51/54	d	994		3	2			2
3	N98/39	2	51/54	d	1000						2
3	N98/39	2	51/54	d	1006		5	2			1
3	N98/39	2	51/54	d	1012		8	1			1
3	N98/39	2	51/54		832		7	2			1
3	N98/39	2	51/54		850		14	2			1
3	N98/39	2	51/54		870		82	8			4
3	N98/39	2	51/54		912		36	6			3
3	N98/39	2	51/55	a	596		6	4			2
3	N98/39	2	51/55	a	609		5	1			4
3	N98/39	2	51/55	a	619		12	1			2
3	N98/39	2	51/55	a	636		19	3			2
3	N98/39	2	51/55	a	655		19	3			4
3	N98/39	2	51/55	a	674		7	2			3
3	N98/39	2	51/55	a	701		10	3			2
3	N98/39	2	51/55	b	596		11	2			1
3	N98/39	2	51/55	b	609		13	12			
3	N98/39	2	51/55	b	619		8	5			2
3	N98/39	2	51/55	b	636		5	1			1
3	N98/39	2	51/55	b	655		8	2			15
3	N98/39	2	51/55	b	674		6	2			
3	N98/39	2	51/55	b	701		15	1	2	1	1
3	N98/39	2	51/55	c	596		2	2			1
3	N98/39	2	51/55	c	609		9	4			3
3	N98/39	2	51/55	c	614						1
3	N98/39	2	51/55	c	619						1
3	N98/39	2	51/55	c	636		13	5			1
3	N98/39	2	51/55	c	655		12	2			3
3	N98/39	2	51/55	c	674		4	1			4
3	N98/39	2	51/55	c	701		18	3			1
3	N98/39	2	51/55	d	596		7	2			1
3	N98/39	2	51/55	d	609		11	2			1
3	N98/39	2	51/55	d	619		2	1			1
3	N98/39	2	51/55	d	636		9	2			2
3	N98/39	2	51/55	d	655		2	2			1
3	N98/39	2	51/55	d	674		14	2			1
3	N98/39	2	51/55	d	701		17	3			1
3	N98/39	2	51/55		336		3	1			
3	N98/39	2	51/55		336		5	2			
3	N98/39	2	51/55		399		13	12			1
3	N98/39	2	51/55		428		31	4			4
3	N98/39	2	51/55		573		14	3			4
3	N98/39	2	51/55		678		8	2			3

Table 19, continued from previous page and continude on next page: Finds from site catalogue no. 3, burnt clay, faunal remains, botanical remains and charcoal.

SC no.	Site no.	Area	Unit	Quadrant	Level	Burnt clay	Faunal remains	Weight/g	Botanical remains	Weight/g	Charcoal/g
3	N98/39	2	51/55		712		3	1			1
3	N98/39	2	52/50	a	405						1
3	N98/39	2	52/50	a	437		1	1			4
3	N98/39	2	52/50	a	456		7	2			3
3	N98/39	2	52/50	a	551		19	1			1
3	N98/39	2	52/50	b	396		5	2			1
3	N98/39	2	52/50	b	405						1
3	N98/39	2	52/50	b	437		2	1			3
3	N98/39	2	52/50	b	456		11	1			1
3	N98/39	2	52/50	b	551		34	5			3
3	N98/39	2	52/50	c	396		1	2			1
3	N98/39	2	52/50	c	405						1
3	N98/39	2	52/50	c	437		10	2			2
3	N98/39	2	52/50	c	456		15	3			3
3	N98/39	2	52/50	c	551		2	1			
3	N98/39	2	52/50	c	551		34	4			1
3	N98/39	2	52/50	d	396		1	1			1
3	N98/39	2	52/50	d	405		2	1			2
3	N98/39	2	52/50	d	437		8	1			3
3	N98/39	2	52/50	d	456		4	1			3
3	N98/39	2	52/50	d	551						1
3	N98/39	2	52/50		305				1	3	
3	N98/39	2	52/50		324		1	1	7	3	
3	N98/39	2	52/50		350		11	2			5
3	N98/39	2	52/50		384		1	1			1
3	N98/39	2	52/51	a	727		3	1			1
3	N98/39	2	52/51	a	742		2	1			1
3	N98/39	2	52/51	a	758		2	1			2
3	N98/39	2	52/51	a	768						7
3	N98/39	2	52/51	a	777		4	1			1
3	N98/39	2	52/51	a	785						1
3	N98/39	2	52/51	b	727		2	2			1
3	N98/39	2	52/51	b	742		6	1			1
3	N98/39	2	52/51	b	758						3
3	N98/39	2	52/51	b	768		1	1			5
3	N98/39	2	52/51	b	777						1
3	N98/39	2	52/51	b	785						2
3	N98/39	2	52/51	c	727		9	13			2
3	N98/39	2	52/51	c	742		3	2			1
3	N98/39	2	52/51	c	758		2	2			1
3	N98/39	2	52/51	c	768		8	1			4
3	N98/39	2	52/51	c	777						2
3	N98/39	2	52/51	c	785		2	1			1
3	N98/39	2	52/51	d	727		6	1			2
3	N98/39	2	52/51	d	742						2
3	N98/39	2	52/51	d	758		1	1			4
3	N98/39	2	52/51	d	768		6	2			1
3	N98/39	2	52/51	d	777		6	2			1
3	N98/39	2	52/51	d	785		1	1			
3	N98/39	2	52/51		682		12	2			1
3	N98/39	2	52/51		698		8	1			1
3	N98/39	2	52/51		710		4	1			1
3	N98/39	2	52/51		723		10	2			5
3	N98/39	2	52/52	a	56		4	2			2
3	N98/39	2	52/52	a	70						1
3	N98/39	2	52/52	a	79		3	2			2
3	N98/39	2	52/52	a	86		12	2			
3	N98/39	2	52/52	a	109		18	2			1
3	N98/39	2	52/52	b	57						1
3	N98/39	2	52/52	b	70		2	1			1
3	N98/39	2	52/52	b	79		3	1			3
3	N98/39	2	52/52	b	86		4	3			1
3	N98/39	2	52/52	b	109		23	3			1
3	N98/39	2	52/52	c	58		8	2			
3	N98/39	2	52/52	c	70						1
3	N98/39	2	52/52	c	79		5	2			7
3	N98/39	2	52/52	c	86		10	2			2
3	N98/39	2	52/52	c	109		11	2			1
3	N98/39	2	52/52	d	59		4	2			1
3	N98/39	2	52/52	d	70		3	2			3
3	N98/39	2	52/52	d	79		9	2			2
3	N98/39	2	52/52	d	86		3	2			2
3	N98/39	2	52/52	d	109		15	2			1
3	N98/39	2	52/52		23		3	1			1
3	N98/39	2	52/52		32		12	2			1
3	N98/39	2	52/52		46		10	5	1	1	
3	N98/39	2	52/53	a	867		1	1			7
3	N98/39	2	52/53	a	885		13	6			4
3	N98/39	2	52/53	a	909		2	2			1
3	N98/39	2	52/53	a	924		4	1			1
3	N98/39	2	52/53	a	946		7	11			1
3	N98/39	2	52/53	a	961		4	1			
3	N98/39	2	52/53	a	976		20	4			1
3	N98/39	2	52/53	b	867		1	1			
3	N98/39	2	52/53	b	885		1	1			
3	N98/39	2	52/53	b	885						1

Table 19, continued from previous page and continude on next page: Finds from site catalogue no. 3, burnt clay, faunal remains, botanical remains and charcoal.

SC no.	Site no.	Area	Unit	Quadrant	Level	Burnt clay	Faunal remains	Weight/g	Botanical remains	Weight/g	Charcoal/g
3	N98/39	2	52/53	b	909		1	1			1
3	N98/39	2	52/53	b	924		7	10			2
3	N98/39	2	52/53	b	946		7	1			
3	N98/39	2	52/53	b	946						1
3	N98/39	2	52/53	b	961		7	2			1
3	N98/39	2	52/53	b	961						1
3	N98/39	2	52/53	b	976		9	2			1
3	N98/39	2	52/53	c	867		5	2			1
3	N98/39	2	52/53	c	885		8	2			4
3	N98/39	2	52/53	c	909		5	2			1
3	N98/39	2	52/53	c	924		7	1			1
3	N98/39	2	52/53	c	946		3	1			1
3	N98/39	2	52/53	c	961		8	1			1
3	N98/39	2	52/53	c	976		19	4			1
3	N98/39	2	52/53	d	867		4	2			2
3	N98/39	2	52/53	d	885		3	2			2
3	N98/39	2	52/53	d	924		7	1			5
3	N98/39	2	52/53	d	946		8	3			1
3	N98/39	2	52/53	d	961		11	2			1
3	N98/39	2	52/53	d	976		21	3			1
3	N98/39	2	52/53	d	989						1
3	N98/39	2	52/53		816		2	1			1
3	N98/39	2	52/53		829		52	4			1
3	N98/39	2	52/53		845		16	2			2
3	N98/39	2	52/54	a	464		7	3			1
3	N98/39	2	52/54	a	564						3
3	N98/39	2	52/54	a	565		6				
3	N98/39	2	52/54	a	601		9	2			8
3	N98/39	2	52/54	a	622		5				2
3	N98/39	2	52/54	a	634		19	3			4
3	N98/39	2	52/54	b	464		5	2			3
3	N98/39	2	52/54	b	565		9	2			1
3	N98/39	2	52/54	b	601		11	1			5
3	N98/39	2	52/54	b	622		5	2			4
3	N98/39	2	52/54	b	634		23	4			
3	N98/39	2	52/54	c	464		11	1			2
3	N98/39	2	52/54	c	565		6	2			10
3	N98/39	2	52/54	c	601		9	1			3
3	N98/39	2	52/54	c	622		3	1			1
3	N98/39	2	52/54	c	634		5	1			2
3	N98/39	2	52/54	d	464		2	2			1
3	N98/39	2	52/54	d	565						7
3	N98/39	2	52/54	d	601		11	2			5

SC no.	Site no.	Area	Unit	Quadrant	Level	Burnt clay	Faunal remains	Weight/g	Botanical remains	Weight/g	Charcoal/g
3	N98/39	2	52/54	d	622						2
3	N98/39	2	52/54	d	634		22	20			1
3	N98/39	2	52/54		319		1	1			
3	N98/39	2	52/54		338						7
3	N98/39	2	52/54		374		46	5			3
3	N98/39	2	52/54		420		12	2			3
3	N98/39	2	52/54		440		62	8			12
3	N98/39	2	52/55	a	1003						1
3	N98/39	2	52/55	a	1009		7	3			3
3	N98/39	2	52/55	a	1015		8	2			2
3	N98/39	2	52/55	a	1019		5	2			3
3	N98/39	2	52/55	a	1022		19	3			4
3	N98/39	2	52/55	a	1025		11	2			3
3	N98/39	2	52/55	a	1035		14	7			5
3	N98/39	2	52/55	b	1003						1
3	N98/39	2	52/55	b	1009		16	32			
3	N98/39	2	52/55	b	1015		7	3			1
3	N98/39	2	52/55	b	1019		7	2			2
3	N98/39	2	52/55	b	1022		9	2			4
3	N98/39	2	52/55	b	1025		9	1			6
3	N98/39	2	52/55	b	1032		2	1			
3	N98/39	2	52/55	b	1032		16	1			4
3	N98/39	2	52/55	b	1035		3	1			3
3	N98/39	2	52/55	b	1040		1	1			1
3	N98/39	2	52/55	c	1003		3	2			1
3	N98/39	2	52/55	c	1009		8	4			
3	N98/39	2	52/55	c	1015		3	2			2
3	N98/39	2	52/55	c	1019		11	2			2
3	N98/39	2	52/55	c	1022		2	1			4
3	N98/39	2	52/55	c	1025		14	1			3
3	N98/39	2	52/55	c	1032		2	1			4
3	N98/39	2	52/55	c	1035						2
3	N98/39	2	52/55	d	979		1	1			
3	N98/39	2	52/55	d	988		75	11			
3	N98/39	2	52/55	d	1003		2	2	1	1	3
3	N98/39	2	52/55	d	1009		3	2			
3	N98/39	2	52/55	d	1015		36	14			3
3	N98/39	2	52/55	d	1019		10	2			8
3	N98/39	2	52/55	d	1022		6	2			11
3	N98/39	2	52/55	d	1025		11	2			4
3	N98/39	2	52/55	d	1032		15	5			3
3	N98/39	2	52/55	d	1035		11	2			2
3	N98/39	2	52/55	d	1040		3	2			1

Table 19, continued from previous page and continude on next page: Finds from site catalogue no. 3, burnt clay, faunal remains, botanical remains and charcoal.

SC no.	Site no.	Area	Unit	Quadrant	Level	Burnt clay	Faunal remains	Weight/g	Botanical remains	Weight/g	Charcoal/g
3	N98/39	2	52/55		965						1
3	N98/39	2	52/55		979						1
3	N98/39	2	52/55		988						1
3	N98/39	2	52/55		1026		1	11			
3	N98/39	2	52/55		d	1		3			
3	N98/39	2	53/55		443		19	6			1
3	N98/39	2	53/55		468		6	1			1
3	N98/39	2	53/55		413a		6	5			1
3	N98/39	2	54/52	a	63		5	2			2
3	N98/39	2	54/52	a	76		2	1			1
3	N98/39	2	54/52	a	88						1
3	N98/39	2	54/52	b	63		1	1			3
3	N98/39	2	54/52	b	76		2	2			1
3	N98/39	2	54/52	b	88		9	2			1
3	N98/39	2	54/52	c	63		3	1			2
3	N98/39	2	54/52	c	76						1
3	N98/39	2	54/52	c	88						1
3	N98/39	2	54/52	d	63		2	2			3
3	N98/39	2	54/52	d	76		2	1			3
3	N98/39	2	54/52	d	88		5	1			1
3	N98/39	2	54/52		25		2	1			1
3	N98/39	2	54/52		37		10	5			4
3	N98/39	2	54/52		50		26	5			24
3	N98/39	2	54/52		100		1	1			2
3	N98/39	2	56/52	a	68		12	7			4
3	N98/39	2	56/52	a	94		10	1			2
3	N98/39	2	56/52	b	68						1
3	N98/39	2	56/52	b	94		5	1			
3	N98/39	2	56/52	c	68		23	12			4
3	N98/39	2	56/52	c	94		24	1			2
3	N98/39	2	56/52	d	68		38	6			5
3	N98/39	2	56/52	d	94		3	1			1
3	N98/39	2	56/52		27		9	2			11
3	N98/39	2	56/52		40		19	5			9
3	N98/39	2	56/52		795		16	2			6
3	N98/39	2	57/53	a	182						2
3	N98/39	2	57/53	a	199		7	2			4
3	N98/39	2	57/53	a	230		1	1			4
3	N98/39	2	57/53	a	250		1	1			
3	N98/39	2	57/53	a	250		7	1			1
3	N98/39	2	57/53	b	182						1
3	N98/39	2	57/53	b	199						1
3	N98/39	2	57/53	b	230		6	2			3
3	N98/39	2	57/53	b	250						1
3	N98/39	2	57/53	c	182		1	1			2
3	N98/39	2	57/53	c	199		5	2			2
3	N98/39	2	57/53	c	230		2	1			3
3	N98/39	2	57/53	c	250		4	2			2
3	N98/39	2	57/53	c	281		4	2			5
3	N98/39	2	57/53	d	199		1	1			2
3	N98/39	2	57/53	d	230						1
3	N98/39	2	57/53	d	250		6	2			1
3	N98/39	2	57/53	d	281		4	2			1
3	N98/39	2	57/53		144		7	2			
3	N98/39	2	57/53		155		7	2			1
3	N98/39	2	57/53		182						1
3	N98/39	2	57/55	a	185						1
3	N98/39	2	57/55	a	201						2
3	N98/39	2	57/55	a	232		5	2			5
3	N98/39	2	57/55	a	254		7	2			4
3	N98/39	2	57/55	a	276		3	1			
3	N98/39	2	57/55	a	276		6	1			1
3	N98/39	2	57/55	a	309		6	3			
3	N98/39	2	57/55	a	309						
3	N98/39	2	57/55	b	185						2
3	N98/39	2	57/55	b	201		5	2			1
3	N98/39	2	57/55	b	232		3	1			3
3	N98/39	2	57/55	b	254		6	1			1
3	N98/39	2	57/55	b	276						1
3	N98/39	2	57/55	c	185		4	1			1
3	N98/39	2	57/55	c	201		1	1			
3	N98/39	2	57/55	c	232						2
3	N98/39	2	57/55	c	254		1	1			2
3	N98/39	2	57/55	c	276		7	2			1
3	N98/39	2	57/55	d	185		5	2			
3	N98/39	2	57/55	d	201						2
3	N98/39	2	57/55	d	232		13	3			2
3	N98/39	2	57/55	d	254		1	1			
3	N98/39	2	57/55	d	254		4	2			2
3	N98/39	2	57/55	d	276		2	1			
3	N98/39	2	57/55	d	309		3	1			
3	N98/39	2	57/55		146		9	1			
3	N98/39	2	57/55		167		7	4			
3	N98/39	2	57/55		167						2
3	N98/39	2	58/50	a	152		1	1			1
3	N98/39	2	58/50	a	152						1

Table 19, continued from previous page and continude on next page: Finds from site catalogue no. 3, burnt clay, faunal remains, botanical remains and charcoal.

SC no.	Site no.	Area	Unit	Quadrant	Level	Burnt clay	Faunal remains	Weight/g	Botanical remains	Weight/g	Charcoal/g
3	N98/39	2	58/50	b	152		6	1			
3	N98/39	2	58/50	b	152						1
3	N98/39	2	58/50	c	152		4	2			
3	N98/39	2	58/50	c	170						1
3	N98/39	2	58/50	c	192		11	2			
3	N98/39	2	58/50	d	152		2	1			1
3	N98/39	2	58/50	d	170						1
3	N98/39	2	58/50	d	192						1
3	N98/39	2	58/50	d	276		2	1			
3	N98/39	2	58/50		26		1	1			
3	N98/39	2	58/50		115		2	1			
3	N98/39	2	58/52	a	130		1	1			1
3	N98/39	2	58/52	a	149		2	1			
3	N98/39	2	58/52	a	162		2	1			4
3	N98/39	2	58/52	a	178		5	2			
3	N98/39	2	58/52	a	223						3
3	N98/39	2	58/52	b	30						1
3	N98/39	2	58/52	b	149		1	1			1
3	N98/39	2	58/52	b	162		1	1			1
3	N98/39	2	58/52	b	172		3	1			
3	N98/39	2	58/52	b	178						1
3	N98/39	2	58/52	b	223		1	1			
3	N98/39	2	58/52	c	130		1	1			
3	N98/39	2	58/52	c	149						1
3	N98/39	2	58/52	c	162		6	1			1
3	N98/39	2	58/52	c	178		10	4			4
3	N98/39	2	58/52	c	223		3	3			7
3	N98/39	2	58/52	d	130		1	1			1
3	N98/39	2	58/52	d	149	1		4			1
3	N98/39	2	58/52	d	162		3	1			2
3	N98/39	2	58/52	d	178		5	3			6
3	N98/39	2	58/52		98		4	2			3
3	N98/39	2	58/52		118		3	2			1
3	N98/39	2	58/54	a	180		2	2			2
3	N98/39	2	58/54	a	219		1	1			
3	N98/39	2	58/54	a	219		3	1			2
3	N98/39	2	58/54	a	237		1	1			
3	N98/39	2	58/54	b	180		1	1	1	1	1
3	N98/39	2	58/54	b	219		7	1			2
3	N98/39	2	58/54	b	237		6	1			2
3	N98/39	2	58/54	c	180						1
3	N98/39	2	58/54	c	219		3	1			3
3	N98/39	2	58/54	d	180		4	2			3

SC no.	Site no.	Area	Unit	Quadrant	Level	Burnt clay	Faunal remains	Weight/g	Botanical remains	Weight/g	Charcoal/g
3	N98/39	2	58/54	d	219		8	2			4
3	N98/39	2	58/54		142		11	2	1	1	
3	N98/39	2	58/54		164		7	2			1
3	N98/39	2	59/51	a	322		1	1			1
3	N98/39	2	59/51	a	341		1	1			1
3	N98/39	2	59/51	a	358		3	1			2
3	N98/39	2	59/51	a	365		15	2			
3	N98/39	2	59/51	a	369						1
3	N98/39	2	59/51	a	391		14				1
3	N98/39	2	59/51	b	322						1
3	N98/39	2	59/51	b	341		3	1			1
3	N98/39	2	59/51	b	358		16	2			1
3	N98/39	2	59/51	b	365						1
3	N98/39	2	59/51	b	391		7	1			1
3	N98/39	2	59/51	c	322		3	1			1
3	N98/39	2	59/51	c	341		3	1			1
3	N98/39	2	59/51	c	358		4	1			1
3	N98/39	2	59/51	c	365		24	3			1
3	N98/39	2	59/51	c	391		2	1			1
3	N98/39	2	59/51	d	322		4	1			2
3	N98/39	2	59/51	d	341		2	1			1
3	N98/39	2	59/51	d	358		4	1			1
3	N98/39	2	59/51	d	365		4	2			1
3	N98/39	2	59/51	d	391		25	4			1
3	N98/39	2	59/51		273						1
3	N98/39	2	59/51		299		4	2			4
3	N98/39	2	59/53		134		7	1			
3	N98/39	2	59/53		173		10	1			
3	N98/39	2	59/53		265		30	4			3
3	N98/39	2	59/53		287		7	1			4
3	N98/39	2	59/55	a	188		5	2			2
3	N98/39	2	59/55	b	188	1		6			
3	N98/39	2	59/55	b	188		1	1			3
3	N98/39	2	59/55	b	216		10	2			2
3	N98/39	2	59/55	c	188		4	2			1
3	N98/39	2	59/55	c	216		13	4			1
3	N98/39	2	59/55	d	188		7	2			1
3	N98/39	2	59/55	d	216		20	2			1
3	N98/39	2	59/55		132		3	1	3	1	
3	N98/39	2	59/55		140		6	1			1
3	N98/39	2	59/55		160	1		14			
3	N98/39	2	59/55		160		17	18			1
3	N98/39	2	west		14		2	2			

Table 19, continued from previous page and continude on next page: Finds from site catalogue no. 3, burnt clay, faunal remains, botanical remains and charcoal.

SC no.	Site no.	Area	Unit	Quadrant	Level	Burnt clay	Faunal remains	Weight/g	Botanical remains	Weight/g	Charcoal/g
3	N98/39	2			2		29	108			
3	N98/39	2			13	1		41			
3	N98/39	2			42	1		8			
3	N98/39	2			982		4	7			
3	N98/39	2			1046		218	136			
3	N98/39	2					14	107			

Table 19, continude on next page: Finds from site catalogue no. 3, burnt clay, faunal remains, botanical remains and charcoal.

SC no.	Site no.	Area	Unit	Quadrant	Level	Glas	Textiles	Plastics	Other	Weight/g
3	N98/39	2	50/50		204	2				1
3	N98/39	2	50/50		204		1			1
3	N98/39	2	50/50		212	3				1
3	N98/39	2	50/50		228	1				1
3	N98/39	2	50/51	a	746			2		1
3	N98/39	2	50/51	b	718			1		1
3	N98/39	2	50/51	c	718			2		1
3	N98/39	2	50/51	c	736	1				1
3	N98/39	2	50/51	c	736			1		1
3	N98/39	2	50/51	c	746			1		1
3	N98/39	2	50/51	c	771			1		1
3	N98/39	2	50/51	d	705	2				1
3	N98/39	2	50/51	d	718			1		1
3	N98/39	2	50/51	d	736	2				2
3	N98/39	2	50/51	d	736			3		1
3	N98/39	2	50/51	d	746			10		1
3	N98/39	2	50/51	d	755			1		1
3	N98/39	2	50/51		625	5				2
3	N98/39	2	50/51		638	1				1
3	N98/39	2	50/51		638		1	4		1
3	N98/39	2	50/51		643	3				3
3	N98/39	2	50/51		643			7		1
3	N98/39	2	50/51		664	3				3
3	N98/39	2	50/51		664			1		1
3	N98/39	2	50/51		689			3		1
3	N98/39	2	50/51	d	755	1				1
3	N98/39	2	50/51	d	765			3		1
3	N98/39	2	50/52	c	73	1				1
3	N98/39	2	50/52	c	91	1				1
3	N98/39	2	50/52	c	91		1			1
3	N98/39	2	50/52	d	73	1				1
3	N98/39	2	50/52		21	3				1
3	N98/39	2	50/52		21			10		1
3	N98/39	2	50/52		34		1	1		1
3	N98/39	2	50/52		54	1				3
3	N98/39	2	50/52		54	2				1
3	N98/39	2	50/52		54		1			1
3	N98/39	2	50/52		54			15		1
3	N98/39	2	50/52	d	113			1		1
3	N98/39	2	50/52	c	446		1			1
3	N98/39	2	50/53	c	930	1				1
3	N98/39	2	50/52		16	7				7
3	N98/39	2	50/53		812	15				9
3	N98/39	2	50/53		812		1			1
3	N98/39	2	50/53		812			2		1
3	N98/39	2	50/53		839	1				1
3	N98/39	2	50/53		839			2		1
3	N98/39	2	50/54	c	554			1		1
3	N98/39	2	50/54	d	459		1			1
3	N98/39	2	50/54		240	7				9
3	N98/39	2	50/54		240		1			1
3	N98/39	2	50/54		240			1		1
3	N98/39	2	50/54		267			4		1
3	N98/39	2	50/55		811	8				7
3	N98/39	2	50/55		819	1				207
3	N98/39	2	50/55		819	1				34
3	N98/39	2	50/55		819	13				9
3	N98/39	2	50/55		819		4			7
3	N98/39	2	50/55		841		3			1
3	N98/39	2	50/55		841	1				1
3	N98/39	2	50/55		853	1				1
3	N98/39	2	50/55	d	920a			1		1
3	N98/39	2	51/50		646			1		1
3	N98/39	2	51/51		260	1				1
3	N98/39	2	51/51		260		2			1
3	N98/39	2	51/51		284		2			1
3	N98/39	2	51/52		814	4				3
3	N98/39	2	51/52		814			1		1
3	N98/39	2	51/52		823	1				1
3	N98/39	2	51/52		823			1		1
3	N98/39	2	51/52		836	4				5

Table 20, continued on next page: Finds from site catalogue no. 3: glass, textiles, plastics and other modern material.

SC no.	Site no.	Area	Unit	Quadrant	Level	Glas	Textiles	Plastics	Other	Weight/g
3	N98/39	2	51/52		836			1		3
3	N98/39	2	51/53		302	8				25
3	N98/39	2	51/53		302				1	1
3	N98/39	2	51/53		329	1				1
3	N98/39	2	51/54		832	4				3
3	N98/39	2	51/54		832			5		1
3	N98/39	2	51/54		850	4				11
3	N98/39	2	51/54		870			1		1
3	N98/39	2	51/55	a	609	2				1
3	N98/39	2	51/55		336	68				37
3	N98/39	2	51/55		399	1				1
3	N98/39	2	51/55		399		1			1
3	N98/39	2	52/50		305	2				1
3	N98/39	2	52/50		305			4		1
3	N98/39	2	52/50		350	2				1
3	N98/39	2	52/50		350			1		1
3	N98/39	2	52/51		682	5				1
3	N98/39	2	52/51		682		1			1
3	N98/39	2	52/51		682			4		1
3	N98/39	2	52/52	d	109			1		1
3	N98/39	2	52/52	d	574 (59)	1				25
3	N98/39	2	52/52		17	1				1
3	N98/39	2	52/53		816	4				1
3	N98/39	2	52/53		816		1	1		1
3	N98/39	2	52/53		816			12		12
3	N98/39	2	52/53		829	1				1
3	N98/39	2	52/53		829			1		29
3	N98/39	2	52/54		319	5				1
3	N98/39	2	52/54		338	93				94
3	N98/39	2	52/54		338		1			1
3	N98/39	2	52/54		338			1		1
3	N98/39	2	52/55		965	20				15
3	N98/39	2	52/55		965		3			1
3	N98/39	2	52/55		965			2		1
3	N98/39	2	52/55		979	3				8
3	N98/39	2	52/55		988	2				1
3	N98/39	2	53/55		413a	56				61
3	N98/39	2	53/55		413a		1			2
3	N98/39	2	53/55		413a			1		1
3	N98/39	2	54/52		18	1				1
3	N98/39	2	54/52		18			3		1
3	N98/39	2	54/52		18				3	18
3	N98/39	2	56/52		19	11				14
3	N98/39	2	56/52		19			1		1
3	N98/39	2	56/52		27	2				1
3	N98/39	2	57/53		139	3				2
3	N98/39	2	57/53		144	9				6
3	N98/39	2	57/53		144		1			1
3	N98/39	2	57/53		144			2		1
3	N98/39	2	57/53		155	2				1
3	N98/39	2	57/53	a	199			20		3
3	N98/39	2	57/53		139			3		1
3	N98/39	2	57/55		146	1				2
3	N98/39	2	57/55		146				1	20
3	N98/39	2	58/50	c	115		1			1
3	N98/39	2	58/50	c	126			4		1
3	N98/39	2	58/50	c	152			3		1
3	N98/39	2	58/50	c	192			10		1
3	N98/39	2	58/50		115	4				4
3	N98/39	2	58/52	b	130	2				1
3	N98/39	2	58/52		98	9				11
3	N98/39	2	58/52		98		1			3
3	N98/39	2	58/52		118	4				3
3	N98/39	2	58/52		118		1			1
3	N98/39	2	58/52		118			1		1
3	N98/39	2	58/54		142	6				1
3	N98/39	2	58/54		142				1	35
3	N98/39	2	58/54		164	2				1
3	N98/39	2	59/51	c	341	1				1
3	N98/39	2	59/51		229	1				2
3	N98/39	2	59/51		273	9				28
3	N98/39	2	59/51	d	358		1			19
3	N98/39	2	59/53		134	5				5
3	N98/39	2	59/53		134		1	1		36
3	N98/39	2	59/53		134		1	1		1
3	N98/39	2	59/53		173		1			1
3	N98/39	2	59/53		265		1			1
3	N98/39	2	59/55		132	6				4
3	N98/39	2	59/55		132			6		1
3	N98/39	2	59/55		140	12				33
3	N98/39	2	59/55		140			6		1
3	N98/39	2			2	16				103
3	N98/39	2			14	1				6
3	N98/39	2							1	2
3	N98/39	4			7		1			20

Table 20, continued from previous page: Finds from site catalogue no. 3, glass, textiles, plastics and other modern material.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	1	48/10	a	6	1								5		13	99		1	0.01
3	N98/39	1	48/10	a	6	1	1				3								4	0.6
3	N98/39	1	48/10	a	6	2	3		3	1			1						7	1.6
3	N98/39	1	48/10	a	9	1	3		3	1	4		1						11	9.5
3	N98/39	1	48/10	a	9	2			1										1	0.8
3	N98/39	1	48/10	b	6	1	2	2	1				3						5	4.7
3	N98/39	1	48/10	b	6	2		2			1		1						3	5.4
3	N98/39	1	48/10	b	9	1								18		19	99		1	0.5
3	N98/39	1	48/10	b	9	1								43		16	99		1	0.4
3	N98/39	1	48/10	b	9	1	3	1	3		3		4						10	5.6
3	N98/39	1	48/10	b	9	2	1				1								2	0.6
3	N98/39	1	48/10	c	9	1	1	6	2	2	4		4						15	14.4
3	N98/39	1	48/10	c	9	2	1				2		1						3	0.9
3	N98/39	1	48/10	d	6	1								30		18	Flake		1	0.8
3	N98/39	1	48/10	d	6	1	1												1	0.1
3	N98/39	1	48/10	d	6	2		1			2		1						3	5.4
3	N98/39	1	48/10	d	9	1	5	4	2	2	2		1						15	8.9
3	N98/39	1	48/10	d	9	2	1	2		1			1						4	3.7
3	N98/39	1	49/10	a	6	1	6	2	1		1		3						10	14.5
3	N98/39	1	49/10	a	6	2		1			1								2	111.2
3	N98/39	1	49/10	a	9	1								43		13	99		1	0.3
3	N98/39	1	49/10	a	9	1								99		14	Flake	x	1	0.8
3	N98/39	1	49/10	a	9	1								99		16	Flake		1	0.8
3	N98/39	1	49/10	a	9	1	4		3		1								8	3.3
3	N98/39	1	49/10	a	9	2		1	1		1		3						3	4.2
3	N98/39	1	49/10	b	6	1	6	2	3	4	3		8						18	18.5
3	N98/39	1	49/10	b	6	2	2	1	1		1		2						5	4.5
3	N98/39	1	49/10	b	9	1	1	1	4		2		3						8	6.2
3	N98/39	1	49/10	b	9	2		1	3		2		1						6	3.1
3	N98/39	1	49/10	c	6	1	2	1			3		3						6	4.8
3	N98/39	1	49/10	c	6	2	1												1	0.01
3	N98/39	1	49/10	c	9	1								29		18	99		1	0.8
3	N98/39	1	49/10	c	9	1	1		2		4		3						7	9.1
3	N98/39	1	49/10	c	9	2	1												1	0.1
3	N98/39	1	49/10	d	6	1								30		20	99		1	0.5
3	N98/39	1	49/10	d	6	1	4	3	1	1			3						9	7.1
3	N98/39	1	49/10	d	6	2	3	1	1				1						5	2
3	N98/39	1	49/10	d	9	1								43		14	99		1	0.2
3	N98/39	1	49/10	d	9	1	4	2	1		3		3						10	18.9
3	N98/39	1	49/10	d	9	2		1	1		1		2						3	9.1
3	N98/39	2	50/50	a	315	1	2	2					1						4	9.1
3	N98/39	2	50/50	a	331	1		1											1	1.1

Table 21, continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	50/50	a	344	1	1												1	0.1
3	N98/39	2	50/50	a	344	2					2								2	0.46
3	N98/39	2	50/50	a	362	1		1			1								2	1.1
3	N98/39	2	50/50	a	387	1								29		11	Flake		1	0.9
3	N98/39	2	50/50	a	387	1					1								1	0.7
3	N98/39	2	50/50	a	416	1	2												2	0.3
3	N98/39	2	50/50	b	257	1	2												2	0.1
3	N98/39	2	50/50	b	315	1				1	4								5	8
3	N98/39	2	50/50	b	331	1	1	1			1		2						3	6.1
3	N98/39	2	50/50	b	362	1								40		11	Flake		1	0.6
3	N98/39	2	50/50	b	362	2					1		1						1	0.3
3	N98/39	2	50/50	b	387	1					1		1						1	2.4
3	N98/39	2	50/50	c	257	1	1												1	0.04
3	N98/39	2	50/50	c	315	1								22		22	Flake		1	0.6
3	N98/39	2	50/50	c	315	1								60		14	Flake		1	1.3
3	N98/39	2	50/50	c	315	1	2		1		2		1						5	3.4
3	N98/39	2	50/50	c	315	2		1					1						1	0.8
3	N98/39	2	50/50	c	331	1		2											2	3.4
3	N98/39	2	50/50	c	362	1					1								1	1.8
3	N98/39	2	50/50	c	377	2		1											1	2.2
3	N98/39	2	50/50	c	387	1	1												1	0.1
3	N98/39	2	50/50	c	416	2			2										2	0.5
3	N98/39	2	50/50	d	315	1	2		1		3		2						6	4.8
3	N98/39	2	50/50	d	344	1	1				1								2	1.1
3	N98/39	2	50/50	d	344	2				1			1						1	0.76
3	N98/39	2	50/50	d	362	1								11		17	Flake		1	0.2
3	N98/39	2	50/50	d	362	1			1		1		1						2	5
3	N98/39	2	50/50	d	377	1			1										1	0.9
3	N98/39	2	50/50	d	387	1		1		1			2						2	7.8
3	N98/39	2	50/50		204	1	1		1										2	0.9
3	N98/39	2	50/50		212	2								51		36	Blade		1	3.7
3	N98/39	2	50/50		212	1									1	10			1	17.6
3	N98/39	2	50/50		212	1	2		3	1	4		3						10	6.8
3	N98/39	2	50/50		212	2	1		2	1	1		1						5	2.2
3	N98/39	2	50/50		228	1								12		16	Blade		1	0.5
3	N98/39	2	50/50		228	1								12		15	Flake		1	0.3
3	N98/39	2	50/50		228	1								29		14	Flake		1	0.3
3	N98/39	2	50/50		228	1								38		12	Flake		1	0.9
3	N98/39	2	50/50		228	1								39		16	Micro-blade		1	0.3
3	N98/39	2	50/50		228	1	11	3	4		5		8						23	18.23
3	N98/39	2	50/50		228	2	4	3			1		3						8	13.4
3	N98/39	2	50/50		270	1								12		13	Flake		1	0.4
3	N98/39	2	50/50		270	1	4	2	2		2		5						10	8

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	50/50		270	2	4		1										5	0.7
3	N98/39	2	50/50		290	1	1	1	1				1						3	2
3	N98/39	2	50/51	a	705	1		1	2		5		3						8	20.7
3	N98/39	2	50/51	a	718	2					1								1	2.3
3	N98/39	2	50/51	a	733	1		1											1	0.7
3	N98/39	2	50/51	a	733	2					1								1	1.4
3	N98/39	2	50/51	a	736	1			2										2	0.7
3	N98/39	2	50/51	a	746	1								43		13	Blade		1	0.3
3	N98/39	2	50/51	a	746	2	1	1											2	1.4
3	N98/39	2	50/51	a	755	2			1				1						1	0.9
3	N98/39	2	50/51	a	765	1	1	1											2	3.2
3	N98/39	2	50/51	a	771	1			1				1						1	0.2
3	N98/39	2	50/51	b	705	1		1											1	1
3	N98/39	2	50/51	b	718	1	3	3			5		2						11	18.8
3	N98/39	2	50/51	b	718	2	1												1	0.2
3	N98/39	2	50/51	b	733	1		1											1	0.5
3	N98/39	2	50/51	b	736	1	1				1								2	3.2
3	N98/39	2	50/51	b	746	1	1	1					1						2	7.2
3	N98/39	2	50/51	b	765	1	3		1				1						4	1
3	N98/39	2	50/51	c	705	1			1		1		1						2	2.2
3	N98/39	2	50/51	c	718	2					1								1	0.5
3	N98/39	2	50/51	c	736	1	2				1								3	1.5
3	N98/39	2	50/51	c	746	1	1												1	0.1
3	N98/39	2	50/51	c	746	2		1											1	0.5
3	N98/39	2	50/51	c	754	1			1				1						1	0.9
3	N98/39	2	50/51	c	765	1	1			1	1		1						3	12
3	N98/39	2	50/51	c	771	1			1				1						1	0.9
3	N98/39	2	50/51	c	771	2					1								1	0.2
3	N98/39	2	50/51	d	705	1	1				1		1						2	3.2
3	N98/39	2	50/51	d	705	2					2								2	1.6
3	N98/39	2	50/51	d	718	1								1		19	Flake		1	1
3	N98/39	2	50/51	d	718	1		2			3		2						5	5.7
3	N98/39	2	50/51	d	718	2	1	1											2	1.4
3	N98/39	2	50/51	d	746	1	1		1		1		2						3	2.6
3	N98/39	2	50/51	d	746	2		1											1	7.3
3	N98/39	2	50/51	d	765	1			1										1	0.4
3	N98/39	2	50/51	d	765	2					1		1						1	3.3
3	N98/39	2	50/51		625	1	1				1		1						2	0.55
3	N98/39	2	50/51		625	2		1											1	0.84
3	N98/39	2	50/51		639	1	2	1	4		3		1						10	3.9
3	N98/39	2	50/51		639	2		1					1						1	1.5
3	N98/39	2	50/51		643	1	2	2	1	1	2		3						8	14.1
3	N98/39	2	50/51		643	2					1								1	0.6
3	N98/39	2	50/51		664	1	9	5	1		8		7						23	38.5

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	50/51		664	1					1								1	6
3	N98/39	2	50/51		664	2	2	1	1										4	6.1
3	N98/39	2	50/51		689	1	6	1	3	1	3		5						14	14.9
3	N98/39	2	50/51		689	2		1			1								2	7.5
3	N98/39	2	50/52	a	73	1	1		1	2			2						4	9.1
3	N98/39	2	50/52	a	91	1			2										2	0.24
3	N98/39	2	50/52	a	91	2	1				1								2	0.7
3	N98/39	2	50/52	a	405	1							1	10		18	Micro-blade		1	0.3
3	N98/39	2	50/52	b	73	1							1		7	42			1	25.9
3	N98/39	2	50/52	b	73	1	3	2			2		2						7	7.7
3	N98/39	2	50/52	b	73	2	1				1		1						2	1.5
3	N98/39	2	50/52	b	91	1	2				4		3						6	0.3
3	N98/39	2	50/52	c	73	1	3		3				2						6	1.6
3	N98/39	2	50/52	c	91	1		1					1						1	2.2
3	N98/39	2	50/52	d	73	1	2	1					1						3	1.7
3	N98/39	2	50/52	d	73	2					1		1						1	0.2
3	N98/39	2	50/52	d	91	1	1	1	1				3						3	6.8
3	N98/39	2	50/52		21	1								40		20	Flake		1	1.6
3	N98/39	2	50/52		21	1								40		8	Flake		1	0.1
3	N98/39	2	50/52		21	1	14	1	3	2	8		8						28	7.7
3	N98/39	2	50/52		21	2	5	2	3		4		4						14	16.9
3	N98/39	2	50/52		34	1	6	2			6		2						14	5.4
3	N98/39	2	50/52		54	1	15	4	4		6		3						29	20.7
3	N98/39	2	50/52		54	2	2	1	2		5		2						10	11.8
3	N98/39	2	50/52		113	2		1			3		1						4	2.2
3	N98/39	2	50/52		446	1								12		18	Micro-blade		1	0.4
3	N98/39	2	50/52		446	1	2	3	2		8		5						15	9.8
3	N98/39	2	50/52		446	2		1											1	1
3	N98/39	2	50/52		446	3	1												1	0.1
3	N98/39	2	50/53	a	879	1	3				1		1						4	9.9
3	N98/39	2	50/53	a	879	2					2								2	1.6
3	N98/39	2	50/53	a	889	1	8	3	3		11		8						25	37.7
3	N98/39	2	50/53	a	901	1	6	1	3		5		8						15	14.2
3	N98/39	2	50/53	a	901	2					1								1	2.2
3	N98/39	2	50/53	a	918	1	2	2	2	1	1		4						8	33.2
3	N98/39	2	50/53	a	918	2					1								1	0.3
3	N98/39	2	50/53	a	930	1		1	5	1	1		5						8	6.3
3	N98/39	2	50/53	a	940	1			1		2		1						3	4.1
3	N98/39	2	50/53	a	940	2			1				1						1	0.2
3	N98/39	2	50/53	a	959	1	2	2	1		1		1						6	5.9
3	N98/39	2	50/53	b	879	1	3			1	4		1						8	2.3
3	N98/39	2	50/53	b	879	2			1				1						1	0.3

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	50/53	b	889	1	10	5	8		18		15						41	61
3	N98/39	2	50/53	b	889	2	1		1		3		1						5	2.7
3	N98/39	2	50/53	b	901	1	6	7	4		6		7						23	43.7
3	N98/39	2	50/53	b	901	2		3			1		1						4	11.3
3	N98/39	2	50/53	b	918	1	3	2	1	1	2		3						9	16.3
3	N98/39	2	50/53	b	918	2					1		1						1	1.4
3	N98/39	2	50/53	b	930	1								48		29	Flake		1	1.8
3	N98/39	2	50/53	b	930	1									7	35			1	19.1
3	N98/39	2	50/53	b	930	1		4		1	3								8	3
3	N98/39	2	50/53	b	930	2	2	7	2	1	1		2						13	11.9
3	N98/39	2	50/53	b	940	1		2					1						2	10.7
3	N98/39	2	50/53	b	959	1		1			1		1						2	3.7
3	N98/39	2	50/53	b	967	1	2												2	0.2
3	N98/39	2	50/53	c	879	1	4	1	1				2						6	5.7
3	N98/39	2	50/53	c	879	2					2								2	50.2
3	N98/39	2	50/53	c	889	1	9	5	2		10		10						26	28.3
3	N98/39	2	50/53	c	889	2		1	4		1		3						6	2.7
3	N98/39	2	50/53	c	901	1	2	1		1	3		1						7	6.2
3	N98/39	2	50/53	c	901	2		1											1	4.7
3	N98/39	2	50/53	c	918	1	2												2	0.15
3	N98/39	2	50/53	c	918	2	1												1	0.15
3	N98/39	2	50/53	c	930	2		1											1	2.1
3	N98/39	2	50/53	c	940	2	1	2											3	0.6
3	N98/39	2	50/53	d	879	1	2	1			1		1						4	1.9
3	N98/39	2	50/53	d	889	1	8	1	4	1	4		3						18	6.9
3	N98/39	2	50/53	d	889	2	1				2		2						3	19.5
3	N98/39	2	50/53	d	901	1	12	4	5		3		8						24	31.5
3	N98/39	2	50/53	d	901	2		1			4		3						5	8.9
3	N98/39	2	50/53	d	918	1	4				2		2						6	21.6
3	N98/39	2	50/53	d	918	2	2												2	0.2
3	N98/39	2	50/53	d	930	1	7			1			1						8	1
3	N98/39	2	50/53	d	940	1								12		15	Flake		1	0.5
3	N98/39	2	50/53	d	940	1	3	1			4		1						8	2.6
3	N98/39	2	50/53	d	940	2	1												1	0.1
3	N98/39	2	50/53		812	1								1		15	Flake		1	0.2
3	N98/39	2	50/53		812	1	3	1			2		2						6	8.9
3	N98/39	2	50/53		812	2					1								1	0.4
3	N98/39	2	50/53		812	23					2								2	1.2
3	N98/39	2	50/53		826	1	3	2	1		5		7						11	12
3	N98/39	2	50/53		826	2	3				2		2						5	1.3
3	N98/39	2	50/53		839	1								23		21	Blade		1	0.8
3	N98/39	2	50/53		839	1								38		12	Blade		1	0.3
3	N98/39	2	50/53		839	1	20	3	3	1	13		7						40	27
3	N98/39	2	50/53		839	2	2	2	2	1	3		1						10	6

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	50/53		859	1	8	2	6	1	3		5						20	15.4
3	N98/39	2	50/53		859	2	1												1	0.1
3	N98/39	2	50/54	a	353	2	1			1									2	1.2
3	N98/39	2	50/54	a	393	1	7	2			4		6						13	14.6
3	N98/39	2	50/54	a	393	2					1								1	1.1
3	N98/39	2	50/54	a	408	1	4	1			2		2						7	6.9
3	N98/39	2	50/54	a	408	2		1											1	0.87
3	N98/39	2	50/54	a	431	1	2	1			2		2						5	5.8
3	N98/39	2	50/54	a	431	2	1				1								2	0.3
3	N98/39	2	50/54	a	459	1	5												5	0.3
3	N98/39	2	50/54	a	459	2			2										2	1.5
3	N98/39	2	50/54	a	554	1	2		1		2								5	1.3
3	N98/39	2	50/54	a	554	2					1								1	0.6
3	N98/39	2	50/54	a	568	1	1												1	0.02
3	N98/39	2	50/54	ab	417	1		1	1										2	4.6
3	N98/39	2	50/54	b	353	1	3	1	3		2		1						9	6
3	N98/39	2	50/54	b	408	1							1		1	50			1	50
3	N98/39	2	50/54	b	408	1	3		3				2						6	1
3	N98/39	2	50/54	b	408	2			1										1	0.2
3	N98/39	2	50/54	b	431	1	4				1								5	0.5
3	N98/39	2	50/54	b	459	1	3		1		1		1						5	0.8
3	N98/39	2	50/54	b	554	1	4	1	1				1						6	2.3
3	N98/39	2	50/54	b	554	2			1										1	0.2
3	N98/39	2	50/54	b	568	1	2	1	2										5	2.3
3	N98/39	2	50/54	b	568	2	1												1	0.01
3	N98/39	2	50/54	c	353	1	3	1	1		1		1						6	2.1
3	N98/39	2	50/54	c	353	2					1								1	0.17
3	N98/39	2	50/54	c	393	1	1	1	2		3		4						7	15
3	N98/39	2	50/54	c	393	2	4	1	1		1		3						7	3.4
3	N98/39	2	50/54	c	408	1	4	3	2				3						9	5.1
3	N98/39	2	50/54	c	431	1								43		13	99		1	0.3
3	N98/39	2	50/54	c	431	1	4		1	1	3		4						9	2.5
3	N98/39	2	50/54	c	459	1							1		5	45			1	36
3	N98/39	2	50/54	c	459	1	6		1		2		2						9	6.3
3	N98/39	2	50/54	c	459	2	1				1								2	0.4
3	N98/39	2	50/54	c	554	1	1		1		1								3	0.4
3	N98/39	2	50/54	c	554	2	1												1	0.1
3	N98/39	2	50/54	c	568	1	2						1						2	0.2
3	N98/39	2	50/54	d	353	1	4		2		1								7	1
3	N98/39	2	50/54	d	353	2	2												2	0.5
3	N98/39	2	50/54	d	393	1								43		16	Flake		1	0.5
3	N98/39	2	50/54	d	393	1							1		5	46			1	28.9
3	N98/39	2	50/54	d	393	1	9	7	6		4		7						26	43
3	N98/39	2	50/54	d	393	2	4	3			2		7						9	11

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

Table 21

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	50/54	d	408	1							1		1	54			1	58.9
3	N98/39	2	50/54	d	408	1	12	6	4	1	7		2						30	48
3	N98/39	2	50/54	d	408	2	2	2	1		1		1						6	11.6
3	N98/39	2	50/54	d	431	1								60		41	Flake		1	10.3
3	N98/39	2	50/54	d	431	1	2				1								3	0.4
3	N98/39	2	50/54	d	431	2	1	1											2	2.2
3	N98/39	2	50/54	d	459	1	3	2	1				4						6	8
3	N98/39	2	50/54	d	459	2	1	1			1		1						3	2
3	N98/39	2	50/54	d	554	1								12		11	99		1	0.2
3	N98/39	2	50/54	d	554	1	3		1				1						4	0.5
3	N98/39	2	50/54	d	554	2		1					1						1	0.5
3	N98/39	2	50/54	d	568	1	1			2	1		1						4	0.5
3	N98/39	2	50/54		240	1	5	2		1			1						8	10.3
3	N98/39	2	50/54		240	2			1	1									2	0.8
3	N98/39	2	50/54		267	1								59		33	Flake		1	4.2
3	N98/39	2	50/54		267	1	18	2	5	1	3		4						29	13.4
3	N98/39	2	50/54		267	2	5		4		4		3						13	10.2
3	N98/39	2	50/54		267	99						1							1	0.1
3	N98/39	2	50/54		293	1	16	1	7	1	4		10						29	18.2
3	N98/39	2	50/54		293	2	4	2	4		2		4						12	15.6
3	N98/39	2	50/54		293	99			1										1	1.1
3	N98/39	2	50/54		293	99						2							2	0.7
3	N98/39	2	50/54		334	1	10	1	4	2	2		3						19	22.8
3	N98/39	2	50/54		334	2	3		2		2		2						7	2.3
3	N98/39	2	50/55	a	873	1	2	1	1		1		2						5	3.2
3	N98/39	2	50/55	a	897	1	2												2	0.3
3	N98/39	2	50/55	a	897	2	1	1											2	3
3	N98/39	2	50/55	a	906	1	1		1		1		2						3	52.7
3	N98/39	2	50/55	a	906	2				1									1	2.1
3	N98/39	2	50/55	a	934	1		2											2	2.2
3	N98/39	2	50/55	a	943	1	1	1	2				1						4	4
3	N98/39	2	50/55	a	943	2					1								1	1.4
3	N98/39	2	50/55	a	963	1	2		1		2		1						5	1.1
3	N98/39	2	50/55	a	970	1	1				1		1						2	0.7
3	N98/39	2	50/55	a	920a	1	2				1		1						3	0.6
3	N98/39	2	50/55	a	920a	2		1					1						1	4.7
3	N98/39	2	50/55	b	873	1	1												1	0.01
3	N98/39	2	50/55	b	873	2	1	1			1		1						3	5.9
3	N98/39	2	50/55	b	906	1	6				1								7	0.5
3	N98/39	2	50/55	b	906	2					2								2	1.6
3	N98/39	2	50/55	b	934	2								40		9	99		1	0.01
3	N98/39	2	50/55	b	934	1	1												1	0.01
3	N98/39	2	50/55	b	943	1								1		16	Flake		1	0.2
3	N98/39	2	50/55	b	943	1		1	2		1		1						4	5.4

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	50/55	b	943	2		1											1	5.2
3	N98/39	2	50/55	b	963	1								12		19	Flake		1	0.7
3	N98/39	2	50/55	b	963	1	1	3			2		3						6	8.4
3	N98/39	2	50/55	b	970	1	1						1						1	0.2
3	N98/39	2	50/55	b	920a	1		1											1	0.4
3	N98/39	2	50/55	b	920a	2				1									1	0.01
3	N98/39	2	50/55	c	873	1		1				1	1						2	0.5
3	N98/39	2	50/55	c	897	1	1	1			3		3						5	23
3	N98/39	2	50/55	c	897	2		1				1	1						2	4
3	N98/39	2	50/55	c	906	1	2	1	2		1		2						6	21.6
3	N98/39	2	50/55	c	934	1	1	1			1								3	13.6
3	N98/39	2	50/55	c	943	1	1		2										3	0.5
3	N98/39	2	50/55	c	943	2		2					1						2	3.2
3	N98/39	2	50/55	c	963	1	1	2											3	3.4
3	N98/39	2	50/55	c	970	2			1				1						1	1
3	N98/39	2	50/55	c	920a	1	2		1										3	0.7
3	N98/39	2	50/55	c	920a	2	1		1										2	0.6
3	N98/39	2	50/55	d	873	1								99		11	Flake	x	1	0.4
3	N98/39	2	50/55	d	873	1	2	1			1		2						4	3.3
3	N98/39	2	50/55	d	897	1	2												2	0.2
3	N98/39	2	50/55	d	897	2		2			1		2						3	3.3
3	N98/39	2	50/55	d	906	2								12		20	Flake		1	1.9
3	N98/39	2	50/55	d	906	1	1	2					1						3	19.1
3	N98/39	2	50/55	d	934	1	1		2										3	0.5
3	N98/39	2	50/55	d	934	2	1												1	0.01
3	N98/39	2	50/55	d	943	1							1		1	52			1	46.2
3	N98/39	2	50/55	d	943	1	1												1	0.01
3	N98/39	2	50/55	d	954	1								12		19	Flake		1	0.5
3	N98/39	2	50/55	d	954	1								30		20	Flake		1	0.8
3	N98/39	2	50/55	d	954	23								Abrad-er		98			1	175.4
3	N98/39	2	50/55	d	963	1									7	56			1	45.3
3	N98/39	2	50/55	d	963	1	1	1			2		3						4	12.6
3	N98/39	2	50/55	d	963	2	2		1										3	0.3
3	N98/39	2	50/55	d	970	1			1										1	1
3	N98/39	2	50/55	d	920a	1	3						1						3	0.2
3	N98/39	2	50/55		811	1	1												1	0.1
3	N98/39	2	50/55		819	1	4	1		1	6		5						12	14.7
3	N98/39	2	50/55		819	2	1		2		3		2						6	1.8
3	N98/39	2	50/55		842	1								1		25	Flake		1	0.8
3	N98/39	2	50/55		842	1								12		24	Flake		1	0.8
3	N98/39	2	50/55		842	2								60		32	Blade		1	2.3
3	N98/39	2	50/55		842	1	3		2		3								8	2.1
3	N98/39	2	50/55		842	2	14	5	8	1			8						28	41.9

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	50/55		853	1								11		18	Flake		1	0.2
3	N98/39	2	50/55		853	1	12	3	1		6		3						22	6.7
3	N98/39	2	50/55		853	2	4		1		4		5						9	3.5
3	N98/39	2	51/50	a	730	1	1												1	0.01
3	N98/39	2	51/50	a	730	2	2	2	1		2		4						7	8.3
3	N98/39	2	51/50	a	752	1		1	1										2	1.5
3	N98/39	2	51/50	a	762	1	2		2		1		2						5	11.9
3	N98/39	2	51/50	a	774	2	1					1							2	10.2
3	N98/39	2	51/50	b	730	1								1		9	99	x	1	0.01
3	N98/39	2	51/50	b	730	1	2		1										3	0.4
3	N98/39	2	51/50	b	730	2					1								1	0.5
3	N98/39	2	51/50	b	752	2		2											2	7.6
3	N98/39	2	51/50	b	774	1				1	1								2	0.4
3	N98/39	2	51/50	b	774	2	1	1			1		1						3	3.3
3	N98/39	2	51/50	c	730	2		1											1	17.8
3	N98/39	2	51/50	c	752	1	1												1	0.2
3	N98/39	2	51/50	c	774	1					1	1	1						2	3.2
3	N98/39	2	51/50	d	730	1							1		4	29			1	15.6
3	N98/39	2	51/50	d	730	1	4												4	0.4
3	N98/39	2	51/50	d	752	2	3				1								4	3.5
3	N98/39	2	51/50	d	774	1	2				1								3	1
3	N98/39	2	51/50	d	781	1	1				2								3	1.1
3	N98/39	2	51/50	d	781	1			1										1	0.7
3	N98/39	2	51/50	d	781	2	3												3	0.2
3	N98/39	2	51/50		640	1								55		41	Flake		1	3.9
3	N98/39	2	51/50		640	1						1							1	0.4
3	N98/39	2	51/50		640	2					1								1	0.7
3	N98/39	2	51/50		646	1	1			1			1						2	5.6
3	N98/39	2	51/50		646	2		2			1								3	7.1
3	N98/39	2	51/50		670	1								1		19	Flake		1	0.6
3	N98/39	2	51/50		670	2	13	5	2	1	2		7						23	4.1
	N98/39	2	51/50		722	1								1		20	Flake		1	0.8
3	N98/39	2	51/50		722	1	8	3	2	1	3	1	6						18	2.3
3	N98/39	2	51/50		801	1								1		13	99		1	0.01
3	N98/39	2	51/50		801	1	5	3	2		4		5						14	9
3	N98/39	2	51/50		801	2	1												1	0.2
3	N98/39	2	51/51	a	347	1	1					1							2	0.01
3	N98/39	2	51/51	a	347	2					2								2	2.7
3	N98/39	2	51/51	a	412	1									7	34			1	12
3	N98/39	2	51/51	a	412	1	3				1		1						4	0.9
3	N98/39	2	51/51	a	412	2			1				1						1	0.9
3	N98/39	2	51/51	a	425	1			1		1		2						2	2.7
3	N98/39	2	51/51	a	449	1		1			1		1						2	1
3	N98/39	2	51/51	a	466	2					2		1						2	1.8

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	51/51	a	560	2		1											1	0.4
3	N98/39	2	51/51	b	347	2	2	1			1		1						4	32.3
3	N98/39	2	51/51	b	347	99					1								1	1.1
3	N98/39	2	51/51	b	402	1				1									1	0.3
3	N98/39	2	51/51	b	402	2	1				3		2						4	3.6
3	N98/39	2	51/51	b	412	1							1		1	38			1	33.7
3	N98/39	2	51/51	b	412	2	4	1	1				2						6	1.1
3	N98/39	2	51/51	b	425	1	3			1			1						4	1.9
3	N98/39	2	51/51	b	425	2	2												2	0.01
3	N98/39	2	51/51	b	449	2		1		1	1		1						3	1.3
3	N98/39	2	51/51	b	466	1		3					1						3	5.1
3	N98/39	2	51/51	b	466	2					1								1	0.2
3	N98/39	2	51/51	b	560	1	1				1								2	1.9
3	N98/39	2	51/51	b	560	2	1	2					1						3	3.5
3	N98/39	2	51/51	b	582	1								1		17	Flake		1	0.4
3	N98/39	2	51/51	b	582	1						1	1						1	0.4
3	N98/39	2	51/51	c	347	1	1				1								2	0.5
3	N98/39	2	51/51	c	347	2	1			1									2	0.2
3	N98/39	2	51/51	c	402	1	1												1	0.01
3	N98/39	2	51/51	c	402	2	1												1	0.01
3	N98/39	2	51/51	c	425	1		1					1						1	1.6
3	N98/39	2	51/51	c	425	2	1	1											2	6.8
3	N98/39	2	51/51	c	449	2	2	1					1						3	2.3
3	N98/39	2	51/51	c	560	2							1		7	80			1	153
3	N98/39	2	51/51	c	582	2	1												1	0.1
3	N98/39	2	51/51	d	347	1	4		1										5	0.5
3	N98/39	2	51/51	d	347	2	2	2	1				3						5	4.2
3	N98/39	2	51/51	d	412	1	4	1	1				2						6	2
3	N98/39	2	51/51	d	425	1	2	1					1						3	0.8
3	N98/39	2	51/51	d	425	2		1	1	1									3	2
3	N98/39	2	51/51	d	449	2	2	1	1				1						4	4.8
3	N98/39	2	51/51	d	466	1		1					1						1	1.8
3	N98/39	2	51/51	d	466	2	1		1										2	0.4
3	N98/39	2	51/51	d	560	1	2				1		2						3	8.6
3	N98/39	2	51/51	d	560	2	1		1										2	0.5
3	N98/39	2	51/51		248	2	1						1						1	0.1
3	N98/39	2	51/51		260	1								12		11	Flake		1	0.01
3	N98/39	2	51/51		260	1	2		2				2						4	1.4
3	N98/39	2	51/51		284	1	6	3	4		3		3						16	5.1
3	N98/39	2	51/51		284	2	3	4	2		3		3						12	6.3
3	N98/39	2	51/51		317	1								1		25	Flake		1	1
3	N98/39	2	51/51		317	2								29		21	Flake		1	1.1
3	N98/39	2	51/51		317	1	6	1	2		6		2						15	12
3	N98/39	2	51/51		317	2	4	2			1		2						7	5.2

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	51/52	a	863	1	3		1	1	1		3						6	7.1
3	N98/39	2	51/52	a	863	2	2		1										3	0.4
3	N98/39	2	51/52	a	876	1		3	1				2						4	12.2
3	N98/39	2	51/52	a	876	2	1		2				1						3	4.9
3	N98/39	2	51/52	a	893	1	1	1	1				1						3	2.1
3	N98/39	2	51/52	a	893	2						1	1						1	48.5
3	N98/39	2	51/52	a	903	1	2												2	0.1
3	N98/39	2	51/52	a	903	2					1								1	146.7
3	N98/39	2	51/52	a	916	1	2	1	3	1	1		1						8	5
3	N98/39	2	51/52	a	916	2	1												1	0.1
3	N98/39	2	51/52	a	928	1	1		3										4	1.4
3	N98/39	2	51/52	a	936	1					1								1	0.5
3	N98/39	2	51/52	b	863	1	3	2	1				2						6	5.8
3	N98/39	2	51/52	b	863	2	1				1								2	0.3
3	N98/39	2	51/52	b	876	1								1		20	Blade		1	0.6
3	N98/39	2	51/52	b	876	1		4					3						4	13.6
3	N98/39	2	51/52	b	903	1	1		1		1		2						3	1.6
3	N98/39	2	51/52	b	903	2					1		1						1	291.4
3	N98/39	2	51/52	b	916	1	2				1								3	1
3	N98/39	2	51/52	b	916	2					1		1						1	0.4
3	N98/39	2	51/52	b	928	1								1		22	Flake		1	0.8
3	N98/39	2	51/52	b	928	1			2				1						2	0.8
3	N98/39	2	51/52	b	936	1			2				1						2	0.8
3	N98/39	2	51/52	b	951	1		1					1						1	15.5
3	N98/39	2	51/52	c	863	1	1	1	1				1						3	8.6
3	N98/39	2	51/52	c	876	1	2												2	0.3
3	N98/39	2	51/52	c	893	1	2				1		1						3	0.7
3	N98/39	2	51/52	c	893	2	1		2										3	0.5
3	N98/39	2	51/52	c	903	1				1			1						1	0.1
3	N98/39	2	51/52	c	916	1		2					2						2	6.6
3	N98/39	2	51/52	c	916	2		1											1	4.2
3	N98/39	2	51/52	c	928	1					1		1						1	1.7
3	N98/39	2	51/52	c	928	2		1					1						1	156.3
3	N98/39	2	51/52	c	936	1	2	2	4	1			3						9	4.9
3	N98/39	2	51/52	c	936	2	1												1	0.1
3	N98/39	2	51/52	c	951	1								43		9	99		1	0.2
3	N98/39	2	51/52	c	951	1	1	2	2				4						5	15.9
3	N98/39	2	51/52	d	863	1			1		1		1						2	0.9
3	N98/39	2	51/52	d	863	2			1										1	0.3
3	N98/39	2	51/52	d	876	1								3		14	Flake		1	0.1
3	N98/39	2	51/52	d	876	1	3			2			2						5	1.5
3	N98/39	2	51/52	d	893	1	4	1		1	1		3						7	10.8
3	N98/39	2	51/52	d	903	1	1												1	0.1
3	N98/39	2	51/52	d	916	1	3												3	0.4

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	51/52	d	916	2		1											1	1.8
3	N98/39	2	51/52	d	936	1	1	1											2	4.6
3	N98/39	2	51/52	d	951	1	1												1	0.2
3	N98/39	2	51/52		814	1	3	2	3				3						8	4.4
3	N98/39	2	51/52		814	2			2		1								3	1.1
3	N98/39	2	51/52		823	1								12		24	Blade		1	0.6
3	N98/39	2	51/52		823	1								12		13	Flake		1	0.4
3	N98/39	2	51/52		823	1	5		4		2		2						11	3.3
3	N98/39	2	51/52		823	2	1	1	1	1	1		2						5	9.9
3	N98/39	2	51/52		836	1								46		37	Blade		1	2
3	N98/39	2	51/52		836	1	13	2	4	3	6		8						28	19.5
3	N98/39	2	51/52		836	2	2	2		1	4		2						9	6.4
3	N98/39	2	51/52		848	1	7	3	2	2	4		6						18	15.5
3	N98/39	2	51/52		848	2		1	1				1						2	6
3	N98/39	2	51/53	a	453	1	1												1	0.2
3	N98/39	2	51/53	a	453	2	1				1								2	0.7
3	N98/39	2	51/53	a	571	1	3		1	1									5	1.1
3	N98/39	2	51/53	a	571	2		2	1				2						3	24.4
3	N98/39	2	51/53	a	605	1								12		21	Flake		1	0.5
3	N98/39	2	51/53	a	605	1	1												1	0.1
3	N98/39	2	51/53	a	631	1	5												5	0.5
3	N98/39	2	51/53	a	631	2			1										1	0.3
3	N98/39	2	51/53	a	650	1	3	1	2				1						6	2
3	N98/39	2	51/53	a	650	2		1					1						1	7.5
3	N98/39	2	51/53	a	659	1	2	1	1				1						4	1.7
3	N98/39	2	51/53	a	659	2	1		1				1						2	0.7
3	N98/39	2	51/53	a	667	1	2	1					2						3	4.3
3	N98/39	2	51/53	b	453	1	4		3		2								9	2.8
3	N98/39	2	51/53	b	453	2			3		2		1						5	2.2
3	N98/39	2	51/53	b	571	1	3	1	2		3		4						9	6
3	N98/39	2	51/53	b	571	2		1		1									2	1.6
3	N98/39	2	51/53	b	605	1	4	2	1		1		3						8	72.8
3	N98/39	2	51/53	b	605	2	2												2	0.1
3	N98/39	2	51/53	b	631	2								29		19	Flake		1	0.6
3	N98/39	2	51/53	b	631	1	2	1	2				1						5	4.8
3	N98/39	2	51/53	b	631	2	3	1											4	1.2
3	N98/39	2	51/53	b	650	2	1			1									2	0.4
3	N98/39	2	51/53	b	659	1	2		1				1						3	1.1
3	N98/39	2	51/53	b	659	2									1	67			1	119.7
3	N98/39	2	51/53	b	659	2		1											1	0.9
3	N98/39	2	51/53	b	667	1	1		2										3	0.7
3	N98/39	2	51/53	c	453	1	5		2		1		2						8	3.4
3	N98/39	2	51/53	c	453	2							1		1	46			1	15.8
3	N98/39	2	51/53	c	571	1	2		1	1			1						4	0.8

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	51/53	c	571	2	2				1		1						3	0.6
3	N98/39	2	51/53	c	605	1	1	1	1				1						3	15.2
3	N98/39	2	51/53	c	605	2		2					1						2	6.8
3	N98/39	2	51/53	c	631	1	1		1										2	0.5
3	N98/39	2	51/53	c	631	2		1											1	1.3
3	N98/39	2	51/53	c	650	1							1		5	39			1	14.4
3	N98/39	2	51/53	c	650	1	4		1										5	0.5
3	N98/39	2	51/53	c	659	1								1		15	Flake		1	0.01
3	N98/39	2	51/53	c	659	1	1	1	1			1	2						4	6.1
3	N98/39	2	51/53	c	667	1			2		1		2						3	2.4
3	N98/39	2	51/53	c	667	2			2										2	0.8
3	N98/39	2	51/53	d	453	1							1		1	45			1	30.1
3	N98/39	2	51/53	d	453	1	6		1		1		1						8	1.1
3	N98/39	2	51/53	d	453	2	1	1			1		2						3	2.3
3	N98/39	2	51/53	d	605	1							1		1	21			1	79
3	N98/39	2	51/53	d	605	1	4			1	9		3						14	11.4
3	N98/39	2	51/53	d	605	2		2			2		3						4	3.2
3	N98/39	2	51/53	d	631	1	2		1				1						3	1.4
3	N98/39	2	51/53	d	650	1	2												2	0.2
3	N98/39	2	51/53	d	650	2			1										1	0.3
3	N98/39	2	51/53	d	659	1	1				1		1						2	3.6
3	N98/39	2	51/53	d	659	2	1												1	0.1
3	N98/39	2	51/53	d	667	1	1				1		1						2	0.4
3	N98/39	2	51/53	d	667	2		1			1		1						2	3.3
3	N98/39	2	51/53		302	1								1		12	Blade		1	0.2
3	N98/39	2	51/53		302	1	1		1		1								3	0.6
3	N98/39	2	51/53		329	1								1		9	99		1	0.03
3	N98/39	2	51/53		329	1								43		17	Blade		1	0.8
3	N98/39	2	51/53		329	1	7	2	2				3						11	4.5
3	N98/39	2	51/53		329	2	3	1	2		1		2						7	7
3	N98/39	2	51/53		370	1							1		1	27			1	12.8
3	N98/39	2	51/53		370	1							1		4	30			1	23.7
3	N98/39	2	51/53		370	1	31	2	8	2	20		11						63	22.6
3	N98/39	2	51/53		370	2	8	4	2		4		6						18	12.4
3	N98/39	2	51/53		691	1							1		7	36			1	17
3	N98/39	2	51/53		691	1	2			1			1						3	2.2
3	N98/39	2	51/53		691	2	1												1	0.1
3	N98/39	2	51/54	a	948	1	2												2	0.1
3	N98/39	2	51/54	a	948	2	1		1		1	1							4	24.2
3	N98/39	2	51/54	a	973	1								40		20	Flake		1	1
3	N98/39	2	51/54	a	973	1	1		2		2	1	4						6	2.4
3	N98/39	2	51/54	a	973	2	1	1	2				2						4	4.1
3	N98/39	2	51/54	a	990	1	5	1	1		2		2						9	6.2
3	N98/39	2	51/54	a	990	2	2	1	3		1		2						7	3.5

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	51/54	a	994	1		1			2								3	0.8
3	N98/39	2	51/54	a	994	2	1												1	0.1
3	N98/39	2	51/54	a	1000	1	2	1	1		2		3						6	4.4
3	N98/39	2	51/54	a	1000	2	1												1	0.1
3	N98/39	2	51/54	a	1006	1		1											1	6.7
3	N98/39	2	51/54	a	1012	1								99		9	99	x	1	0.01
3	N98/39	2	51/54	a	1012	1	1				1		1						2	0.4
3	N98/39	2	51/54	b	948	1	3	1		1			1						5	11.6
3	N98/39	2	51/54	b	948	2			2										2	0.3
3	N98/39	2	51/54	b	973	2								12		18	Blade		1	0.5
3	N98/39	2	51/54	b	973	1								40		19	Blade		1	0.8
3	N98/39	2	51/54	b	973	1								48		26	Flake		1	1.2
3	N98/39	2	51/54	b	973	1							1		7	34			1	21.7
3	N98/39	2	51/54	b	973	1	2	1	2		3		3						8	13.9
3	N98/39	2	51/54	b	973	2	1	5	3		3		6						12	48.1
3	N98/39	2	51/54	b	990	1							1		5	54			1	77.1
3	N98/39	2	51/54	b	990	1	3		4		4		7						11	18.2
3	N98/39	2	51/54	b	990	2	1		2		2								5	1.7
3	N98/39	2	51/54	b	994	1	5	1	1	1	1		2						9	3.3
3	N98/39	2	51/54	b	994	2	1	1	1		1		3						4	27.7
3	N98/39	2	51/54	b	1000	1	1	1			2		3						4	5
3	N98/39	2	51/54	b	1000	2					1								1	0.3
3	N98/39	2	51/54	b	1006	1	1	2					3						3	5.9
3	N98/39	2	51/54	b	1006	2		1											1	3.8
3	N98/39	2	51/54	b	1012	1	3				1		2						4	1.2
3	N98/39	2	51/54	b	1012	2					1								1	3.7
3	N98/39	2	51/54	c	948	1	1	1			1								3	1
3	N98/39	2	51/54	c	948	2		1	1				2						2	10
3	N98/39	2	51/54	c	973	1	2				1								3	0.3
3	N98/39	2	51/54	c	973	2	1	1					1						2	11.4
3	N98/39	2	51/54	c	990	1								1		53	Flake		1	3.6
3	N98/39	2	51/54	c	990	1	5	1	1		3		6						10	10.3
3	N98/39	2	51/54	c	990	2		4	3	1			5						8	22.3
3	N98/39	2	51/54	c	994	1	4				1		1						5	0.7
3	N98/39	2	51/54	c	994	2			1										1	0.3
3	N98/39	2	51/54	c	1000	1	3												3	0.3
3	N98/39	2	51/54	c	1000	2				1			1						1	0.8
3	N98/39	2	51/54	c	1006	1	2	3	2		2		4						9	17.4
3	N98/39	2	51/54	c	1006	2	1		1	1	2		5						5	3.8
3	N98/39	2	51/54	c	1012	1	1												1	0.3
3	N98/39	2	51/54	c	1012	2		1	1		1								3	2.5
3	N98/39	2	51/54	d	948	1	1	3	1		1		4						6	11.8
3	N98/39	2	51/54	d	973	1							1		1	47			1	67.3
3	N98/39	2	51/54	d	973	1		1	2				2						3	14.4

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	51/54	d	973	2	1	3	1										5	31
3	N98/39	2	51/54	d	990	1							1		1	45			1	42.6
3	N98/39	2	51/54	d	990	1							1		1	43			1	42.6
3	N98/39	2	51/54	d	990	1					2								2	0.5
3	N98/39	2	51/54	d	990	2	3	1	1				1						5	2.8
3	N98/39	2	51/54	d	994	1	1	2			2		3						5	14.6
3	N98/39	2	51/54	d	994	2	1	1		1	1		2						4	8.2
3	N98/39	2	51/54	d	1000	1	5	1	2				5						8	16.7
3	N98/39	2	51/54	d	1000	2	1	1			1		1						3	3.8
3	N98/39	2	51/54	d	1006	1	2												2	0.4
3	N98/39	2	51/54	d	1006	2		3					2						3	5.3
3	N98/39	2	51/54	d	1012	1								99		14	Flake	x	1	0.4
3	N98/39	2	51/54	d	1012	1	1	1	1										3	2.1
3	N98/39	2	51/54		832	2								43		15	99		1	0.5
3	N98/39	2	51/54		832	1	5				1		1						6	0.7
3	N98/39	2	51/54		832	2			1	1	2		3						4	1.4
3	N98/39	2	51/54		850	1								11		11	Flake		1	0.01
3	N98/39	2	51/54		850	1	7	3	3		2		5						15	6.3
3	N98/39	2	51/54		850	2	4	1			2		2						7	1.6
3	N98/39	2	51/54		870	1								1		11	99	x	1	0.01
3	N98/39	2	51/54		870	1	32	7	3	1	2		9						45	23.8
3	N98/39	2	51/54		870	2	5	6	2		7		10						20	45.8
3	N98/39	2	51/54		912	1	5	2	4		3		4						14	9.2
3	N98/39	2	51/54		912	2	1		2		1		2						4	1.1
3	N98/39	2	51/55	a	596	1								1		18	Flake		1	0.5
3	N98/39	2	51/55	a	596	1	6												6	0.5
3	N98/39	2	51/55	a	596	2		2					1						2	2.8
3	N98/39	2	51/55	a	609	1	1	1			1		3						3	6.9
3	N98/39	2	51/55	a	619	1								1		16	Flake		1	0.4
3	N98/39	2	51/55	a	619	1	3	2	1		4		4						10	33.7
3	N98/39	2	51/55	a	619	2		3					3						3	51.1
3	N98/39	2	51/55	a	636	1								48		30	Flake		1	1.4
3	N98/39	2	51/55	a	636	1	3	3	3				4						9	32.4
3	N98/39	2	51/55	a	655	1		1	1		1		3						3	10.7
3	N98/39	2	51/55	a	655	2	2	2	2	1	1		1						8	5.7
3	N98/39	2	51/55	a	674	1			3		1		2						4	4.7
3	N98/39	2	51/55	a	674	2	1												1	0.3
3	N98/39	2	51/55	a	701	1		1					1						1	137.1
3	N98/39	2	51/55	b	609	1					1		1						1	4.3
3	N98/39	2	51/55	b	609	2	1				1								2	0.8
3	N98/39	2	51/55	b	619	1				1	1		2						2	4.3
3	N98/39	2	51/55	b	619	2		1					1						1	2.7
3	N98/39	2	51/55	b	636	1		1					1						1	0.9
3	N98/39	2	51/55	b	636	2		1			1								2	15

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	51/55	b	655	1	3		3				1						6	2
3	N98/39	2	51/55	b	655	2		1					1						1	10.7
3	N98/39	2	51/55	b	674	1								1		20	Flake		1	0.5
3	N98/39	2	51/55	b	674	1	1	1											2	1.7
3	N98/39	2	51/55	b	701	1								1		18	Flake		1	0.4
3	N98/39	2	51/55	b	701	1			2				1						2	1.4
3	N98/39	2	51/55	c	596	1			1		1		1						2	0.8
3	N98/39	2	51/55	c	596	2			1										1	0.2
3	N98/39	2	51/55	c	609	1	1			1	1		2						3	3.2
3	N98/39	2	51/55	c	609	2	1						1						1	0.2
3	N98/39	2	51/55	c	619	1		1					1						1	2.3
3	N98/39	2	51/55	c	619	1			2	1	1		2						4	3.4
3	N98/39	2	51/55	c	619	2		2	2				3						4	6.8
3	N98/39	2	51/55	c	636	1			1		1		2						2	15.1
3	N98/39	2	51/55	c	636	2			3				2						3	10.3
3	N98/39	2	51/55	c	655	2								12		23	Flake		1	1.3
3	N98/39	2	51/55	c	655	1	3	2	4				5						9	8.5
3	N98/39	2	51/55	c	655	2			2										2	0.8
3	N98/39	2	51/55	c	674	1					2								2	2.4
3	N98/39	2	51/55	c	674	2		1											1	3.4
3	N98/39	2	51/55	c	701	1	2												2	0.3
3	N98/39	2	51/55	d	596	1	1												1	0.1
3	N98/39	2	51/55	d	609	1		1	1	2									4	0.9
3	N98/39	2	51/55	d	619	1		3	1		1		2						5	10.2
3	N98/39	2	51/55	d	619	2		1					1						1	1.7
3	N98/39	2	51/55	d	636	1	1	1	2										4	1.4
3	N98/39	2	51/55	d	655	1								99		20	99	x	1	0.9
3	N98/39	2	51/55	d	655	1			2		1								3	1
3	N98/39	2	51/55	d	655	2	1	1	1				1						3	34.2
3	N98/39	2	51/55	d	674	1	3		1										4	0.8
3	N98/39	2	51/55	d	674	2		1			1		2						2	4.8
3	N98/39	2	51/55	d	701	1		1					1						1	0.9
3	N98/39	2	51/55	d	701	2	1	1					1						2	2.3
3	N98/39	2	51/55		336	1	5	3	1				1						9	8.3
3	N98/39	2	51/55		336	2	3			1									4	1.4
3	N98/39	2	51/55		399	1	3	1					2						4	0.7
3	N98/39	2	51/55		399	2		1			3		3						4	8.2
3	N98/39	2	51/55		400	1	1	1	1	1	1		2						5	2.4
3	N98/39	2	51/55		400	2	1				1								2	0.1
3	N98/39	2	51/55		428	1								1		25	Flake		1	1.2
3	N98/39	2	51/55		428	1								1		20	Blade		1	0.4
3	N98/39	2	51/55		428	1								38		11	99		1	0.2
3	N98/39	2	51/55		428	1								99		9	99	x	1	0.01
3	N98/39	2	51/55		428	1	20	1	3		7		4						31	15.6

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	51/55		428	2	8	2	2		4		6						16	40
3	N98/39	2	51/55		573	1	5	2	1				2						8	3.4
3	N98/39	2	51/55		573	2		1		2			2						3	7.8
3	N98/39	2	51/55		678	1	1			1									2	0.4
3	N98/39	2	51/55		678	2	1	1					1						2	1.6
3	N98/39	2	51/55		712	1					1								1	0.5
3	N98/39	2	52/50	a	437	1	2		3		1		1						6	3.1
3	N98/39	2	52/50	a	456	1		2	1										3	6.4
3	N98/39	2	52/50	b	396	1	1				2								3	5
3	N98/39	2	52/50	b	396	1					1								1	4
3	N98/39	2	52/50	b	396	2	2	2					1						4	2.4
3	N98/39	2	52/50	b	405	1					2		2						2	21.5
3	N98/39	2	52/50	b	437	1	2	2		1									5	9.1
3	N98/39	2	52/50	b	437	2	1												1	0.01
3	N98/39	2	52/50	b	456	1		1											1	0.9
3	N98/39	2	52/50	b	456	2	1												1	0.01
3	N98/39	2	52/50	b	551	1								10		17	Micro-blade		1	0.2
3	N98/39	2	52/50	b	551	1								43		17	Flake		1	0.9
3	N98/39	2	52/50	b	551	1		1				1	1						2	2.9
3	N98/39	2	52/50	b	551	2	1	1					1						2	2.8
3	N98/39	2	52/50	c	396	2								40		18	Micro-blade		1	0.6
3	N98/39	2	52/50	c	405	1			1										1	0.2
3	N98/39	2	52/50	c	437	1								5		11	Flake		1	0.5
3	N98/39	2	52/50	c	437	1	1				1		1						2	7.6
3	N98/39	2	52/50	c	437	2	2												2	0.5
3	N98/39	2	52/50	c	456	1	2	1	1										4	1.6
3	N98/39	2	52/50	c	456	2	2	1	1										4	1.3
3	N98/39	2	52/50	c	551	1	1		1				1						2	0.4
3	N98/39	2	52/50	d	396	2		1	1				1						2	1.6
3	N98/39	2	52/50	d	405	1			1				1						1	0.5
3	N98/39	2	52/50	d	405	2		1			1		1						2	2
3	N98/39	2	52/50	d	437	1								29		19	Flake		1	0.8
3	N98/39	2	52/50	d	437	1		1	1		1								3	1.5
3	N98/39	2	52/50	d	437	2	1												1	0.1
3	N98/39	2	52/50	d	456	1		1	1										2	0.9
3	N98/39	2	52/50	d	456	2					1								1	2
3	N98/39	2	52/50	d	551	1									5	43			1	37.4
3	N98/39	2	52/50	d	551	1	1	1											2	1.2
3	N98/39	2	52/50	d	551	2			1				1						1	0.2
3	N98/39	2	52/50		305	1								48		29	Flake		1	1.2
3	N98/39	2	52/50		305	1					2								2	0.5
3	N98/39	2	52/50		305	2						4							4	2.6

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	52/50		324	1	4	4	2		4		3						14	8.9
3	N98/39	2	52/50		324	2	1	3	1		1	2	4						8	15.5
3	N98/39	2	52/50		350	1								34		20	Blade		1	1.1
3	N98/39	2	52/50		350	1								43		12	Flake		1	0.2
3	N98/39	2	52/50		350	1	13	4	4	1			7						22	8.3
3	N98/39	2	52/50		350	2	9	4	2	1	1		2						17	6.5
3	N98/39	2	52/50		384	1								48		30	Flake		1	3.3
3	N98/39	2	52/50		384	1	2	1					1						3	18.9
3	N98/39	2	52/50		384	2	1	1			1								3	9.1
3	N98/39	2	52/51	a	727	2			1				1						1	1.4
3	N98/39	2	52/51	a	742	1			2										2	2
3	N98/39	2	52/51	a	742	2		3			1		1						4	35.3
3	N98/39	2	52/51	a	768	1	2												2	0.3
3	N98/39	2	52/51	a	768	2						1							1	2.5
3	N98/39	2	52/51	a	777	1							1		7	31			1	14.5
3	N98/39	2	52/51	a	777	1	2		1				1						3	0.9
3	N98/39	2	52/51	a	777	2		1				1							2	3.1
3	N98/39	2	52/51	a	785	1			1										1	0.4
3	N98/39	2	52/51	a	785	2	1					1	1						2	1.7
3	N98/39	2	52/51	b	727	1	1				1								2	0.3
3	N98/39	2	52/51	b	727	2	1			1	3		2						5	1.7
3	N98/39	2	52/51	b	742	2	2	1	1		1								5	3.4
3	N98/39	2	52/51	b	758	1	1												1	0.01
3	N98/39	2	52/51	b	758	2		1											1	1
3	N98/39	2	52/51	b	768	1							1		1	26			1	11.4
3	N98/39	2	52/51	b	768	1	4				1		2						5	0.8
3	N98/39	2	52/51	b	768	2		1		1			1						2	3
3	N98/39	2	52/51	b	777	1	2												2	0.2
3	N98/39	2	52/51	b	777	2		1	1		1								3	2.9
3	N98/39	2	52/51	c	727	1		2	1	1	1		2						5	3.9
3	N98/39	2	52/51	c	727	2	2												2	0.1
3	N98/39	2	52/51	c	742	1	1												1	0.01
3	N98/39	2	52/51	c	742	2	1	1			1	1	3						4	11.3
3	N98/39	2	52/51	c	758	1	1												1	0.001
3	N98/39	2	52/51	c	768	1	1	1			2		1						4	5.3
3	N98/39	2	52/51	c	768	2	1												1	0.1
3	N98/39	2	52/51	c	777	1			1										1	0.4
3	N98/39	2	52/51	c	777	2			1										1	0.3
3	N98/39	2	52/51	c	785	1	1	1	1		1								4	4.2
3	N98/39	2	52/51	d	727	1								1		7	99	x	1	0.01
3	N98/39	2	52/51	d	727	1								43		13	99		1	0.3
3	N98/39	2	52/51	d	727	1					1								1	0.2
3	N98/39	2	52/51	d	727	2	1	2				1	2						4	6.1
3	N98/39	2	52/51	d	742	1	2	1	1		1								5	1.7

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	52/51	d	742	2	1												1	0.01
3	N98/39	2	52/51	d	758	1	1												1	0.01
3	N98/39	2	52/51	d	758	2		1											1	0.2
3	N98/39	2	52/51	d	768	1	3		1		2		2						6	2.2
3	N98/39	2	52/51	d	768	2					1								1	0.3
3	N98/39	2	52/51	d	777	1								12		20	Flake		1	0.7
3	N98/39	2	52/51	d	777	1								12		14	99		1	0.3
3	N98/39	2	52/51	d	777	1	2												2	0.2
3	N98/39	2	52/51	d	777	2	2		1		2		1						5	0.7
3	N98/39	2	52/51	d	785	2				1									1	0.5
3	N98/39	2	52/51		682	1								28		19	Flake		1	0.6
3	N98/39	2	52/51		682	1	6	1			2		3						9	5.8
3	N98/39	2	52/51		682	2	7	3	1		4		4						15	4.8
3	N98/39	2	52/51		698	1								27		12	Flake		1	1.1
3	N98/39	2	52/51		698	1	20	1	2		5	1	3						29	7.1
3	N98/39	2	52/51		698	2	9	4	4		3	4	3						24	15.6
3	N98/39	2	52/51		710	1	7	1			2		2						10	1.6
3	N98/39	2	52/51		710	2	1	2			1		2						4	4.2
3	N98/39	2	52/51		723	1							1	39		13	Blade		1	1
3	N98/39	2	52/51		723	1							1		1	33			1	18.6
3	N98/39	2	52/51		723	1	6	1	3		2		2						12	6.1
3	N98/39	2	52/51		723	2	3	6	4		7		7						20	29.5
3	N98/39	2	52/52	a	56	1	1	1	1		1		1						4	1.1
3	N98/39	2	52/52	a	56	2					1								1	0.2
3	N98/39	2	52/52	a	70	1					1		1						1	9.4
3	N98/39	2	52/52	a	70	2		3			1		4						4	9.2
3	N98/39	2	52/52	a	79	1				1									1	0.2
3	N98/39	2	52/52	a	86	1	1	3	2		1		3						7	12.4
3	N98/39	2	52/52	a	86	2		1											1	1.5
3	N98/39	2	52/52	a	109	1	2				1								3	0.5
3	N98/39	2	52/52	a	109	2	2				1								3	0.4
3	N98/39	2	52/52	b	57	1								1		23	Flake		1	0.7
3	N98/39	2	52/52	b	57	1								48		26	Flake		1	0.9
3	N98/39	2	52/52	b	57	1	2	2	2		4		4						10	22.5
3	N98/39	2	52/52	b	57	2		2					1						2	71.6
3	N98/39	2	52/52	b	70	1								1		15	99		1	0.6
3	N98/39	2	52/52	b	70	1			1	1	2		1						4	2.4
3	N98/39	2	52/52	b	70	2	1												1	0.01
3	N98/39	2	52/52	b	79	1	1				2								3	1.4
3	N98/39	2	52/52	b	79	2		1	1		1		2						3	20.3
3	N98/39	2	52/52	b	86	1					1								1	2.6
3	N98/39	2	52/52	b	86	2	1												1	0.1
3	N98/39	2	52/52	b	109	1								26		18	Flake		1	0.8
3	N98/39	2	52/52	b	109	1				1									1	1.1

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	52/52	c	58	1	2		2										4	1.7
3	N98/39	2	52/52	c	58	2					1								1	0.7
3	N98/39	2	52/52	c	70	1	2				4		1						6	4
3	N98/39	2	52/52	c	70	2		1	1		1		1						3	1.1
3	N98/39	2	52/52	c	79	1								38		12	99		1	0.3
3	N98/39	2	52/52	c	79	1									4	28			1	9.8
3	N98/39	2	52/52	c	79	1	2	1	1		2								6	3.7
3	N98/39	2	52/52	c	86	1	1		1		1		1						3	1.2
3	N98/39	2	52/52	c	109	1		1			1								2	0.9
3	N98/39	2	52/52	c	109	2		1											1	0.1
3	N98/39	2	52/52	d	59	2								1		20	Flake		1	0.7
3	N98/39	2	52/52	d	59	2								60		40	Flake		1	9.7
3	N98/39	2	52/52	d	59	1	2	2	3				3						7	19.1
3	N98/39	2	52/52	d	59	2		2			1								3	6.3
3	N98/39	2	52/52	d	70	1							1	60		40			1	9.2
3	N98/39	2	52/52	d	70	1	5	1			3		4						9	9.1
3	N98/39	2	52/52	d	70	2	1				1		1						2	39.9
3	N98/39	2	52/52	d	79	1	2	2	1				3						5	10.4
3	N98/39	2	52/52	d	79	2	1	2	1		1		1						5	5.4
3	N98/39	2	52/52	d	86	1	2		1										3	0.8
3	N98/39	2	52/52	d	86	2	1		2										3	0.8
3	N98/39	2	52/52		17	1								1		22	Flake		1	0.7
3	N98/39	2	52/52		17	1			1										1	0.3
3	N98/39	2	52/52		23	1	7	2	3	1	6		7						19	21
3	N98/39	2	52/52		23	2	1	2	2	1	6		4						12	18.5
3	N98/39	2	52/52		32	1								30		19	99		1	0.7
3	N98/39	2	52/52		32	1	6	2	3	1	6		4						18	27.2
3	N98/39	2	52/52		32	2	5	3	1										9	10.5
3	N98/39	2	52/52		46	1								55		33	Flake		1	2.3
3	N98/39	2	52/52		46	1	7	3	2	2	5		4						19	15.7
3	N98/39	2	52/52		46	2	4	4	2	1	4		4						15	24
3	N98/39	2	52/53	a	867	1								47		29	99		1	1
3	N98/39	2	52/53	a	867	1		3	1		3		4						7	49.1
3	N98/39	2	52/53	a	885	1	5	2			2		4						9	13.3
3	N98/39	2	52/53	a	885	2	1	1			1		1						3	1.8
3	N98/39	2	52/53	a	909	1								60		28	Flake		1	2.4
3	N98/39	2	52/53	a	909	1	1	3			1		3						5	8.6
3	N98/39	2	52/53	a	909	2					1								1	0.2
3	N98/39	2	52/53	a	924	1	1				1		1						2	1.3
3	N98/39	2	52/53	a	946	1							1	43		24	Flake		1	0.3
3	N98/39	2	52/53	a	946	1	1				2		1						3	5.8
3	N98/39	2	52/53	a	961	1					1		1						1	0.5
3	N98/39	2	52/53	a	976	1									2	35			1	16.7

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	52/53	a	976	1			2		1								3	1.9
3	N98/39	2	52/53	b	885	1	2												2	0.1
3	N98/39	2	52/53	b	924	1	2												2	0.4
3	N98/39	2	52/53	b	946	1								30		18	Flake		1	0.5
3	N98/39	2	52/53	b	946	1					3		2						3	2.5
3	N98/39	2	52/53	b	946	2		1					1						1	2.8
3	N98/39	2	52/53	b	961	1		3	2	2			3						7	9.9
3	N98/39	2	52/53	b	961	2			2										2	0.8
3	N98/39	2	52/53	b	976	1	2		1		1		1						4	1.1
3	N98/39	2	52/53	b	976	2		1					1						1	7.2
3	N98/39	2	52/53	c	867	1	4		2	2	3		6						11	6.6
3	N98/39	2	52/53	c	867	2		1	1										2	1.4
3	N98/39	2	52/53	c	885	1	5	2			1		4						8	6.8
3	N98/39	2	52/53	c	885	2	2	3	1	1	3		8						10	10.3
3	N98/39	2	52/53	c	909	1	3	2	2		2		3						9	3.8
3	N98/39	2	52/53	c	909	2		1					1						1	1.7
3	N98/39	2	52/53	c	924	2					1								1	0.6
3	N98/39	2	52/53	c	946	1			2		1		1						3	0.5
3	N98/39	2	52/53	c	946	2			1										1	0.8
3	N98/39	2	52/53	c	961	1	1	2	1		1		2						5	1.6
3	N98/39	2	52/53	c	961	2					1								1	0.2
3	N98/39	2	52/53	c	976	1			1										1	0.7
3	N98/39	2	52/53	c	976	2		1					1						1	7
3	N98/39	2	52/53	d	867	1	2		1				1						3	1.3
3	N98/39	2	52/53	d	867	2		1			2								3	4.2
3	N98/39	2	52/53	d	885	2		1	3				2						4	3.9
3	N98/39	2	52/53	d	909	1								12		20	Flake		1	0.5
3	N98/39	2	52/53	d	909	1		1	1	1	1		2						4	8.5
3	N98/39	2	52/53	d	909	2		3	1	1	1		2						6	27
3	N98/39	2	52/53	d	924	1								40		15	Flake		1	0.5
3	N98/39	2	52/53	d	924	1									4	22			1	10.1
3	N98/39	2	52/53	d	924	1	2		1		2								5	7
3	N98/39	2	52/53	d	924	2			1				1						1	2.7
3	N98/39	2	52/53	d	946	1	3				1		1						4	1.6
3	N98/39	2	52/53	d	946	2	1												1	0.1
3	N98/39	2	52/53	d	961	1	1	1					1						2	2.7
3	N98/39	2	52/53	d	961	2					1		1						1	0.3
3	N98/39	2	52/53	d	976	1	2	1					2						3	2.2
3	N98/39	2	52/53		816	1	6		1		2		1						9	1
3	N98/39	2	52/53		816	2	2		1										3	0.8
3	N98/39	2	52/53		816	23					1								1	79
3	N98/39	2	52/53		829	1							1		4	38			1	33.8
3	N98/39	2	52/53		829	1	3	6	1		5		11						15	11.1

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	52/53		829	2	1	2	1	1	3		5						8	8.1
3	N98/39	2	52/53		845	1								1		17	Flake		1	0.4
3	N98/39	2	52/53		845	1	1				2		3						3	1.3
3	N98/39	2	52/53		845	2	1	3	1		3		3						8	20.4
3	N98/39	2	52/54	a	464	1	6		1		1		2						8	1
3	N98/39	2	52/54	a	464	2	1	1					1						2	0.5
3	N98/39	2	52/54	a	565	2								12		23	Blade		1	0.6
3	N98/39	2	52/54	a	565	1	6		2		1		3						9	3.1
3	N98/39	2	52/54	a	565	2	1				5		3						6	1.1
3	N98/39	2	52/54	a	601	1	8	1	1										10	2.7
3	N98/39	2	52/54	a	601	2		2											2	2.2
3	N98/39	2	52/54	a	622	1								1		16	99	x	1	0.3
3	N98/39	2	52/54	a	622	1								43		17	Flake		1	0.2
3	N98/39	2	52/54	a	622	1			1				1						1	1.3
3	N98/39	2	52/54	a	622	2	1				1								2	0.5
3	N98/39	2	52/54	a	634	1								12		21	Flake		1	0.6
3	N98/39	2	52/54	a	634	1								13		18	Flake		1	0.5
3	N98/39	2	52/54	a	634	1	2	1	1		1		1						5	4.6
3	N98/39	2	52/54	a	634	2	5		1		1		2						7	75.8
3	N98/39	2	52/54	b	464	1	2				1		1						3	0.2
3	N98/39	2	52/54	b	464	2		1			1		1						2	3.1
3	N98/39	2	52/54	b	565	1							1	1		24	Blade		1	1
3	N98/39	2	52/54	b	565	1								1		18	Flake		1	0.7
3	N98/39	2	52/54	b	565	2								1		17	Flake		1	0.5
3	N98/39	2	52/54	b	565	2								12		16	99		1	0.6
3	N98/39	2	52/54	b	565	1	1	1	1				1						3	2.1
3	N98/39	2	52/54	b	565	1	6	2			3		4						11	3.9
3	N98/39	2	52/54	b	565	2		2	1				2						3	15
3	N98/39	2	52/54	b	565	2			1										1	0.4
3	N98/39	2	52/54	b	601	2								12		21	Flake		1	1.2
3	N98/39	2	52/54	b	601	1	5	1	1		3		2						10	5.8
3	N98/39	2	52/54	b	601	2	1	2			1		1						4	0.9
3	N98/39	2	52/54	b	622	1	1												1	0.01
3	N98/39	2	52/54	b	622	2				1									1	0.03
3	N98/39	2	52/54	b	634	1	1	1		1			2						3	2.2
3	N98/39	2	52/54	b	634	2		1			2		2						3	1.8
3	N98/39	2	52/54	c	464	1		2	1				1						3	1
3	N98/39	2	52/54	c	464	2					1		1						1	1.6
3	N98/39	2	52/54	c	601	1	4		2		3		2						9	1.4
3	N98/39	2	52/54	c	601	2	1		1				2						2	0.4
3	N98/39	2	52/54	c	622	1	3	2			2		2						7	9.6
3	N98/39	2	52/54	c	622	2	3	1	3		1		2						8	4.3
3	N98/39	2	52/54	c	634	1	4	1		1			1						6	1.3

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	52/54	c	634	2				1	1		2						2	1.3
3	N98/39	2	52/54	d	464	1	18	5	5	2	4		9						34	38.1
3	N98/39	2	52/54	d	464	2	4	5			3		4						12	17
3	N98/39	2	52/54	d	565	1	4	3	1		4		5						12	13.3
3	N98/39	2	52/54	d	565	2	3	2	2	1	3		6						11	10.5
3	N98/39	2	52/54	d	565	23		1					1						1	17.5
3	N98/39	2	52/54	d	601	1	2				1		1						3	0.4
3	N98/39	2	52/54	d	601	2	2	3			1		3						6	3.4
3	N98/39	2	52/54	d	622	1								1		16	Flake		1	0.6
3	N98/39	2	52/54	d	622	1	1												1	0.2
3	N98/39	2	52/54	d	622	2		1											1	1.5
3	N98/39	2	52/54	d	634	1								40		20	Flake		1	1
3	N98/39	2	52/54	d	634	1	2	2		1			1						5	9.8
3	N98/39	2	52/54	d	634	2	1												1	0.2
3	N98/39	2	52/54		338	1	7		1	4									12	1.2
3	N98/39	2	52/54		374	1								3		13	Flake		1	0.1
3	N98/39	2	52/54		374	2								12		23	Flake		1	0.5
3	N98/39	2	52/54		374	1	24	10	6	1	11		7						52	25.4
3	N98/39	2	52/54		374	2	10	2	3	1	8		7						24	19.5
3	N98/39	2	52/54		420	1	11	1		1	3		5						16	4.6
3	N98/39	2	52/54		420	2	1	1	1		2		2						5	2.8
3	N98/39	2	52/54		440	1								12		15	Flake		1	0.5
3	N98/39	2	52/54		440	2								12		22	Flake		1	0.5
3	N98/39	2	52/54		440	1	18	6	4	2	11		8						41	39.8
3	N98/39	2	52/54		440	2	3	2	2		1		1						8	4.9
3	N98/39	2	52/55	a	1009	1					1		1						1	0.6
3	N98/39	2	52/55	a	1009	2		1					1						1	4.5
3	N98/39	2	52/55	a	1015	1							1		7	46			1	31.2
3	N98/39	2	52/55	a	1015	1	1	2					2						3	12.2
3	N98/39	2	52/55	a	1019	1							1		1	37			1	22.2
3	N98/39	2	52/55	a	1019	1	1	1	1		1								4	1.6
3	N98/39	2	52/55	a	1019	2		1											1	3.4
3	N98/39	2	52/55	a	1022	1					1		1						1	4.1
3	N98/39	2	52/55	a	1022	2	2		1										3	1.1
3	N98/39	2	52/55	a	1025	1							1		5	26			1	13.1
3	N98/39	2	52/55	a	1025	1	1	1	1				3						3	3.4
3	N98/39	2	52/55	b	1003	1	1	1	1		1								4	2.4
3	N98/39	2	52/55	b	1003	2	1				1								2	0.4
3	N98/39	2	52/55	b	1009	1			1										1	3.8
3	N98/39	2	52/55	b	1009	2					2		1						2	8.4
3	N98/39	2	52/55	b	1015	1		1	1		2		3						4	6.5
3	N98/39	2	52/55	b	1019	1	3												3	0.2
3	N98/39	2	52/55	b	1022	1	3												3	0.5

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	52/55	b	1022	2				1			1						1	1.7
3	N98/39	2	52/55	b	1025	2					1		1						1	0.4
3	N98/39	2	52/55	b	1032	1	3			1									4	0.9
3	N98/39	2	52/55	b	1032	2	1			1	2		2						4	6.7
3	N98/39	2	52/55	b	1040	1					1		1						1	1
3	N98/39	2	52/55	c	1003	1			1		1		1						2	0.9
3	N98/39	2	52/55	c	1009	1		1	1		1		2						3	1.8
3	N98/39	2	52/55	c	1009	2		2					2						2	2.6
3	N98/39	2	52/55	c	1015	1								1		19	Flake		1	0.4
3	N98/39	2	52/55	c	1015	1			1		1		1						2	0.7
3	N98/39	2	52/55	c	1015	2	1				1								2	0.4
3	N98/39	2	52/55	c	1019	1	1	1					1						2	3.1
3	N98/39	2	52/55	c	1019	2	1						1						1	1.8
3	N98/39	2	52/55	c	1022	1	2	3	1		2		2						8	32.7
3	N98/39	2	52/55	c	1022	2	1	1			1		1						3	1.6
3	N98/39	2	52/55	c	1025	1	1		2										3	0.6
3	N98/39	2	52/55	c	1025	2	1												1	0.01
3	N98/39	2	52/55	c	1032	1	2	1	1				1						4	5.9
3	N98/39	2	52/55	c	1035	1	1	3			2								6	8.4
3	N98/39	2	52/55	c	1035	2		1	1				1						2	1.6
3	N98/39	2	52/55	d	1003	1			1				1						1	0.3
3	N98/39	2	52/55	d	1003	2	1	1					1						2	1.5
3	N98/39	2	52/55	d	1009	1	1				1								2	0.6
3	N98/39	2	52/55	d	1015	1	7	4	4		3		4						18	17
3	N98/39	2	52/55	d	1015	2	2	6			2		4						10	16.3
3	N98/39	2	52/55	d	1019	1	7	2	2	1	3		3						15	7.4
3	N98/39	2	52/55	d	1019	2	3	5	1	1	2		5						12	23.2
3	N98/39	2	52/55	d	1022	1								43		15	Flake		1	0.5
3	N98/39	2	52/55	d	1022	1	4		2	1	3		2						10	2.1
3	N98/39	2	52/55	d	1022	2	1				1								2	0.4
3	N98/39	2	52/55	d	1025	1							1		7	31			1	20.3
3	N98/39	2	52/55	d	1025	1			2				1						2	0.8
3	N98/39	2	52/55	d	1025	2		2		1									3	6.6
3	N98/39	2	52/55	d	1032	1					1								1	0.2
3	N98/39	2	52/55	d	1032	2	1												1	0.01
3	N98/39	2	52/55	d	1035	1					1		1						1	0.9
3	N98/39	2	52/55		965	1		1	3				2						4	5.1
3	N98/39	2	52/55		979	1	1	1	2	2	3		3						9	14.6
3	N98/39	2	52/55		979	2	2	2			1								5	2.2
3	N98/39	2	52/55		988	1								3		10	Flake		1	0.1
3	N98/39	2	52/55		988	1								6		19	Flake		1	0.5
3	N98/39	2	52/55		988	1								12		10	Flake		1	0.1
3	N98/39	2	52/55		988	1								30		18	Flake		1	0.5

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	52/55		988	1								60		33	Flake		1	3.9
3	N98/39	2	52/55		988	1	10	2	3		4		4						19	13.1
3	N98/39	2	52/55		988	2	7				2								9	2.8
3	N98/39	2	52/55		998	1		6	4		9		8						19	19.2
3	N98/39	2	52/55		998	2	3	1					1						4	9.9
3	N98/39	2	53/55		443	1								1		19	Flake		1	0.8
3	N98/39	2	53/55		443	2								1		19	Flake		1	0.9
3	N98/39	2	53/55		443	2								12		14	Flake		1	0.7
3	N98/39	2	53/55		443	1							1		1	26			1	12
3	N98/39	2	53/55		443	1	23	2	4	1	8		9						38	9.5
3	N98/39	2	53/55		443	2	3	5	2	1	8		4						19	19.6
3	N98/39	2	53/55		468	1	2		1		1		2						4	3.9
3	N98/39	2	53/55		468	2		1			1								2	1.4
3	N98/39	2	53/55		413a	2								1		16	Flake		1	0.6
3	N98/39	2	53/55		413a	1							1		7	27			1	5.9
3	N98/39	2	53/55		413a	1	3		1	2			2						6	1.3
3	N98/39	2	53/55		413a	2	1	1			1		1						3	9.1
3	N98/39	2	54/52	a	63	2								1		24	Flake		1	1.2
3	N98/39	2	54/52	a	63	1		1	1		1		1						3	1.4
3	N98/39	2	54/52	a	63	2	3												3	0.4
3	N98/39	2	54/52	a	76	1							1	12		17	Flake		1	0.9
3	N98/39	2	54/52	a	76	1							1		1	22			1	7.4
3	N98/39	2	54/52	a	76	1	1				4		1						5	3.3
3	N98/39	2	54/52	a	76	2	2	1	1				1						4	5.7
3	N98/39	2	54/52	a	88	1	2												2	0.1
3	N98/39	2	54/52	b	63	1	4	2	1				1						7	6.2
3	N98/39	2	54/52	b	63	2	2	1											3	25.4
3	N98/39	2	54/52	b	76	1	5		3		3		2						11	2.5
3	N98/39	2	54/52	b	76	2	2	1											3	2.2
3	N98/39	2	54/52	b	88	2								1		21	Flake		1	0.8
3	N98/39	2	54/52	b	88	1	1	1											2	2.1
3	N98/39	2	54/52	c	63	1	1	2			2		2						5	4.4
3	N98/39	2	54/52	c	63	2	1		1		1		2						3	0.5
3	N98/39	2	54/52	c	76	1	2		1		2								5	3.3
3	N98/39	2	54/52	c	76	2		1	1	1			2						3	9.3
3	N98/39	2	54/52	c	88	1							1		7	36			1	17
3	N98/39	2	54/52	c	88	2		1			1								2	1.2
3	N98/39	2	54/52	d	63	1	1				2		1						3	0.7
3	N98/39	2	54/52	d	63	2	1	1		1	1								4	4
3	N98/39	2	54/52	d	76	1								38		16	Blade		1	0.3
3	N98/39	2	54/52	d	76	1							1		4	16			1	4.6
3	N98/39	2	54/52	d	76	1				1	2		1						3	3.1
3	N98/39	2	54/52	d	76	2	6				2								8	1.6

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	54/52	d	88	1			2										2	1.6
3	N98/39	2	54/52	d	88	2		1					1						1	1.4
3	N98/39	2	54/52		18	1								30		17	Flake		1	0.6
3	N98/39	2	54/52		18	1	6	1	3		5		1						15	9.6
3	N98/39	2	54/52		18	2	1	1					1						2	0.8
3	N98/39	2	54/52		25	1								12		10	Blade		1	0.01
3	N98/39	2	54/52		25	1							1	29		15	99		1	0.4
3	N98/39	2	54/52		25	1								30		18	Flake		1	0.6
3	N98/39	2	54/52		25	1								39		15	Blade		1	0.3
3	N98/39	2	54/52		25	1								56		26	Flake		1	1.4
3	N98/39	2	54/52		25	1								99		21	Flake		1	1.3
3	N98/39	2	54/52		25	1	17	5	6	1	12		12						41	21.4
3	N98/39	2	54/52		25	2	5	2			1		1						8	5.2
3	N98/39	2	54/52		37	1								1		19	Flake		1	0.8
3	N98/39	2	54/52		37	2								1		23	Flake		1	0.8
3	N98/39	2	54/52		37	1	15	4	4	3	8		8						34	35.2
3	N98/39	2	54/52		37	2	11	3	3		2		4						19	10.2
3	N98/39	2	54/52		50	1								1		25	Flake		1	0.5
3	N98/39	2	54/52		50	1								1		14	Flake		1	0.3
3	N98/39	2	54/52		50	2								1		17	Flake		1	0.4
3	N98/39	2	54/52		50	1								17		14	99		1	0.4
3	N98/39	2	54/52		50	1								18		20	Flake		1	0.8
3	N98/39	2	54/52		50	1							1	43		13	Flake		1	1
3	N98/39	2	54/52		50	1								43		24	Flake		1	0.7
3	N98/39	2	54/52		50	1							1		1	40			1	32
3	N98/39	2	54/52		50	1							1		1	40			1	16.7
3	N98/39	2	54/52		50	1									5	27			1	10.5
3	N98/39	2	54/52		50	1									7	41			1	37.2
3	N98/39	2	54/52		50	1							1		7	39			1	14.7
3	N98/39	2	54/52		50	1							1		7				1	11.3
3	N98/39	2	54/52		50	1	56	24	19	7	34		50						140	138.8
3	N98/39	2	54/52		50	2	19	24	14	7	13		20						77	148.9
3	N98/39	2	54/52		100	1	1	2					1						3	5.2
3	N98/39	2	54/52		100	2					2		2						2	2.7
3	N98/39	2	56/52	a	68	1								1		19	Flake		1	0.7
3	N98/39	2	56/52	a	68	1	13	1	8	1	3		6						26	7.8
3	N98/39	2	56/52	a	68	2	3	1	4		2		2						10	9.4
3	N98/39	2	56/52	a	94	1							1	54		40	Flake		1	4.1
3	N98/39	2	56/52	a	94	1	2	1	2				2						5	1.6
3	N98/39	2	56/52	a	94	2		1		1			1						2	4.6
3	N98/39	2	56/52	b	68	1	9	2	7		2		7						20	13.5
3	N98/39	2	56/52	b	68	2	2	1	2				2						5	7.3
3	N98/39	2	56/52	b	94	1	2	2	3	1	7		7						15	12.9

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	56/52	b	94	2	2	4	2		2		2						10	6.8
3	N98/39	2	56/52	c	68	1								3		8	99		1	0.01
3	N98/39	2	56/52	c	68	2								3		12	99		1	0.01
3	N98/39	2	56/52	c	68	1								11		17	Flake		1	0.1
3	N98/39	2	56/52	c	68	1								43		13	Flake		1	0.4
3	N98/39	2	56/52	c	68	1							1	43		14	99		1	0.3
3	N98/39	2	56/52	c	68	1							1		1	33			1	34
3	N98/39	2	56/52	c	68	1	17	6	4		6		8						33	14
3	N98/39	2	56/52	c	68	2	7	1	1		1		1						10	10.1
3	N98/39	2	56/52	c	94	1	3	1		1	2	1	4						8	8.3
3	N98/39	2	56/52	c	94	2	2	1					2						3	6.7
3	N98/39	2	56/52	d	68	1								1		17	Flake		1	0.4
3	N98/39	2	56/52	d	68	2								43		18	Blade		1	0.6
3	N98/39	2	56/52	d	68	1	4	2	4	1	3		1						14	7.2
3	N98/39	2	56/52	d	68	2	6		2	2			4						10	5
3	N98/39	2	56/52	d	94	1	1	1					1						2	16.3
3	N98/39	2	56/52	d	94	2	1												1	0.1
3	N98/39	2	56/52		19	1								40		12	Blade		1	0.01
3	N98/39	2	56/52		19	1	8	1	4	3	3		6						19	9.8
3	N98/39	2	56/52		19	2	1	2	4				2						7	13.4
3	N98/39	2	56/52		27	1								18		18	99		1	0.5
3	N98/39	2	56/52		27	1	14	8	10		5		11						37	22.6
3	N98/39	2	56/52		27	2	8	4	1	2	4		4						19	18.4
3	N98/39	2	56/52		40	1								3		13	Flake		1	0.1
3	N98/39	2	56/52		40	1							1	38		12	Flake		1	0.7
3	N98/39	2	56/52		40	1								40		15	Flake		1	0.5
3	N98/39	2	56/52		40	1								48		29	Blade		1	1.1
3	N98/39	2	56/52		40	1	22	19	9	4	14		27						68	57.5
3	N98/39	2	56/52		40	2	26	5	9	2	10		7						52	46.5
3	N98/39	2	56/52		795	1								1		20	Flake		1	0.5
3	N98/39	2	57/53	a	182	1			1				1						1	0.5
3	N98/39	2	57/53	a	182	2	1												1	0.1
3	N98/39	2	57/53	a	199	1								48		26	Flake		1	2
3	N98/39	2	57/53	a	199	1	1	1	1	1	2		2						6	8.6
3	N98/39	2	57/53	a	199	2	1	1	3		3		2						8	43.4
3	N98/39	2	57/53	a	230	1								42		15	99		1	0.5
3	N98/39	2	57/53	a	230	1	1	11	2		5		11						19	29.9
3	N98/39	2	57/53	a	230	2	5	2	3		2		2						12	10.4
3	N98/39	2	57/53	a	250	1	7	1	1	4			2						13	9.2
3	N98/39	2	57/53	a	250	2	1		1	3			3						5	6.3
3	N98/39	2	57/53	a	281	1	3												3	0.2
3	N98/39	2	57/53	b	182	1							1		33				1	20.7
3	N98/39	2	57/53	b	182	1	5	2	1		2		2						10	25.1

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	57/53	b	182	2		1											1	29.2
3	N98/39	2	57/53	b	199	1	4		1		5		1						10	2.8
3	N98/39	2	57/53	b	199	2	5	1			1		1						7	4
3	N98/39	2	57/53	b	230	1								1		18	Flake		1	0.8
3	N98/39	2	57/53	b	230	1								1		19	Flake		1	0.7
3	N98/39	2	57/53	b	230	1							1		4	40			1	15
3	N98/39	2	57/53	b	230	1	7	3	5	1	9								25	16.7
3	N98/39	2	57/53	b	230	2	3	3	2		1		2						9	8.2
3	N98/39	2	57/53	b	250	1								1		15	Flake		1	0.5
3	N98/39	2	57/53	b	250	1	2	1	3		1		3						7	30.2
3	N98/39	2	57/53	b	250	2		1	2		1		2						4	1.8
3	N98/39	2	57/53	b	281	2					1								1	0.2
3	N98/39	2	57/53	b	182	1								11		17	Flake		1	0.2
3	N98/39	2	57/53	c	182	1									1	30			1	14.3
3	N98/39	2	57/53	c	182	1	2		1		2		1						5	0.9
3	N98/39	2	57/53	c	182	2					1								1	0.5
3	N98/39	2	57/53	c	199	1	2	2	1				2						5	3.4
3	N98/39	2	57/53	c	199	2	1				2								3	1.2
3	N98/39	2	57/53	c	230	1							1		1	32			1	19.2
3	N98/39	2	57/53	c	230	1	8	3	4		7		7						22	8.8
3	N98/39	2	57/53	c	230	2	1	1	3		1		2						6	2.7
3	N98/39	2	57/53	c	250	1	2	2	3				2						7	4.5
3	N98/39	2	57/53	c	250	2	2				1		2						3	12.3
3	N98/39	2	57/53	c	279	2							1		1	78			1	267.4
3	N98/39	2	57/53	d	182	2								1		19	Flake		1	0.7
3	N98/39	2	57/53	d	182	1	3				1		1						4	0.01
3	N98/39	2	57/53	d	199	1	1	1	3		1								6	2.8
3	N98/39	2	57/53	d	199	2	1		2				1						3	0.7
3	N98/39	2	57/53	d	230	1	2	2	2		1								7	4.9
3	N98/39	2	57/53	d	230	2	5	2	2	1			2						10	5.1
3	N98/39	2	57/53	d	250	1	2	3		1	1		2						7	12.1
3	N98/39	2	57/53	d	250	2			1		3								4	8.4
3	N98/39	2	57/53	d	281	1							1	43		11	99		1	0.2
3	N98/39	2	57/53	d	281	1	1		3	1	1		3						6	7.8
3	N98/39	2	57/53	d	281	2	2												2	0.2
3	N98/39	2	57/53		139	1	1												1	0.01
3	N98/39	2	57/53		144	1								39		13	Blade		1	0.3
3	N98/39	2	57/53		144	1	11	2	3	2	5		8						23	10.8
3	N98/39	2	57/53		144	2		1			2		2						3	1.1
3	N98/39	2	57/53		155	1								6		17	Flake		1	0.3
3	N98/39	2	57/53		155	1	14	6	4		6		12						30	20.90
3	N98/39	2	57/53		155	2	6		1		2		1						9	3.6
3	N98/39	2	57/55	a	185	1	2	1	1		1		1						5	1.4

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	57/55	a	201	1								47		36	Flake		1	3.2
3	N98/39	2	57/55	a	201	1	2		2										4	0.7
3	N98/39	2	57/55	a	201	2	4												4	0.3
3	N98/39	2	57/55	a	232	1	3	2	2		6		6						13	18.2
3	N98/39	2	57/55	a	232	2		2					1						2	5.9
3	N98/39	2	57/55	a	254	1	12	3	2	1	4		8						22	1.7
3	N98/39	2	57/55	a	254	2			4		4		1						8	36.6
3	N98/39	2	57/55	a	276	1	3		2	1	1		4						7	26.6
3	N98/39	2	57/55	a	276	2	2	2	1		1		4						6	7
3	N98/39	2	57/55	b	185	1	5	1	2				4						8	8.3
3	N98/39	2	57/55	b	185	2	1				1		1						2	0.9
3	N98/39	2	57/55	b	201	1	2		2		2		4						6	2.1
3	N98/39	2	57/55	b	201	2	1												1	0.01
3	N98/39	2	57/55	b	232	1	3		3		1								7	2
3	N98/39	2	57/55	b	232	2	2			1	1		1						4	2.5
3	N98/39	2	57/55	b	254	1								1		18	Flake		1	0.6
3	N98/39	2	57/55	b	254	1	4		3				1						7	1.8
3	N98/39	2	57/55	b	254	2	2	1	1				1						4	6.5
3	N98/39	2	57/55	b	276	2		1											1	0.4
3	N98/39	2	57/55	c	185	1	3	1			1		2						5	3.3
3	N98/39	2	57/55	c	185	2	2				2		2						4	1
3	N98/39	2	57/55	c	201	1	3						2						3	0.5
3	N98/39	2	57/55	c	201	2	2				1		2						3	1
3	N98/39	2	57/55	c	232	1	3	3			1		4						7	14.2
3	N98/39	2	57/55	c	232	2	5				2		1						7	2.3
3	N98/39	2	57/55	c	254	1	7	1	6	2	8		9						24	51.5
3	N98/39	2	57/55	c	254	2		3	1		1		1						5	6
3	N98/39	2	57/55	c	276	1	6		5		1		3						12	3.1
3	N98/39	2	57/55	c	276	2	3		1	1	1		3						6	1
3	N98/39	2	57/55	d	185	1		1					1						1	1.3
3	N98/39	2	57/55	d	185	2	1		1				2						2	1.4
3	N98/39	2	57/55	d	201	1	3	2	2		1		2						8	8.3
3	N98/39	2	57/55	d	201	2	1	1											2	18.4
3	N98/39	2	57/55	d	232	1	10	5	4	1	4		9						24	17
3	N98/39	2	57/55	d	232	2	4	1	1		1		3						7	5
3	N98/39	2	57/55	d	254	1								29		16	Flake		1	0.5
3	N98/39	2	57/55	d	254	1	5	4	3		4		5						16	9.4
3	N98/39	2	57/55	d	254	2	1	1	2		1		2						5	41.4
3	N98/39	2	57/55	d	276	2								47		27	Blade		1	1.2
3	N98/39	2	57/55	d	276	1	2	3			1		1						6	4.9
3	N98/39	2	57/55		146	1								1		10	99		1	0.01
3	N98/39	2	57/55		146	1	18	1	4	2	4		10						29	8.7
3	N98/39	2	57/55		146	2	5	4	1		3		4						13	15.8

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	57/55		167	1								30		17	Flake		1	0.5
3	N98/39	2	57/55		167	1	17	1	1		3		6						22	3.5
3	N98/39	2	57/55		167	2	6	2	2		2		4						12	12.5
3	N98/39	2	58/50	a	152	1								1		19	Flake		1	0.7
3	N98/39	2	58/50	a	152	1		1			1		1						2	16.3
3	N98/39	2	58/50	a	152	2	2	5			2		1						9	11.6
3	N98/39	2	58/50	a	170	1								12		22	Flake		1	0.7
3	N98/39	2	58/50	a	170	1	2	1	1										4	9.6
3	N98/39	2	58/50	a	192	1								12		21	Flake		1	0.5
3	N98/39	2	58/50	b	152	1	4	1	1		4								10	5.4
3	N98/39	2	58/50	b	152	2	6	5	3		17	1	11						32	41.8
3	N98/39	2	58/50	b	170	1								47		26	Flake		1	1.1
3	N98/39	2	58/50	b	170	2			2		1		2						3	1.6
3	N98/39	2	58/50	c	152	1	7		1		1								9	2.9
3	N98/39	2	58/50	c	152	2	4				1	2							7	1.7
3	N98/39	2	58/50	c	170	1							1		1	26			1	11.3
3	N98/39	2	58/50	c	170	1	1												1	0.01
3	N98/39	2	58/50	c	170	2	2	1				2							5	15.4
3	N98/39	2	58/50	c	192	1								48		35	Flake		1	3.6
3	N98/39	2	58/50	c	192	1							1		5	1			1	27.7
3	N98/39	2	58/50	c	192	2	1				3								4	6.2
3	N98/39	2	58/50	d	152	1							1		1	28			1	13.8
3	N98/39	2	58/50	d	152	1	1		2		1								4	0.5
3	N98/39	2	58/50	d	152	2					3		1						3	0.9
3	N98/39	2	58/50	d	170	2		4			9	1	2						14	19
3	N98/39	2	58/50	d	192	2	1	4		1	3		3						9	29.8
3	N98/39	2	58/50		115	1							1		4	28			1	18.7
3	N98/39	2	58/50		115	1	1	2											3	2.2
3	N98/39	2	58/50		115	2	4	3	2		1		3						10	7.8
3	N98/39	2	58/50		126	1								40		21	Blade		1	0.8
3	N98/39	2	58/50		126	1	8	1	2		7		4						18	7.1
3	N98/39	2	58/50		126	2	4	2			3	1	4						10	17.7
3	N98/39	2	58/52	a	130	1			1		1		1						2	0.5
3	N98/39	2	58/52	a	130	2	2				3		2						5	1.3
3	N98/39	2	58/52	a	149	1	1												1	0.01
3	N98/39	2	58/52	a	149	2	4	3			4	2	4						13	12.8
3	N98/39	2	58/52	a	162	1	2		5		2								9	5
3	N98/39	2	58/52	a	162	2	7	5	7		10		12						28	71.1
3	N98/39	2	58/52	a	178	1	4		1		2		2						7	1.5
3	N98/39	2	58/52	a	178	2	2	1	1		3		1						7	3.7
3	N98/39	2	58/52	a	223	1							1		1	20			1	5.1
3	N98/39	2	58/52	a	223	1	1	2	1		1		2						5	2.4
3	N98/39	2	58/52	a	223	2	1		1										2	1.3

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	58/52	b	130	1	6	1			2		1						9	2.3
3	N98/39	2	58/52	b	149	1	1												1	0.01
3	N98/39	2	58/52	b	149	2	5	3			5		3						13	31.6
3	N98/39	2	58/52	b	162	1							1		1	36			1	22.1
3	N98/39	2	58/52	b	162	1	8	3			2		4						13	11.5
3	N98/39	2	58/52	b	162	2							1		7	39			1	38
3	N98/39	2	58/52	b	162	2	1	3	3		1		3						8	14.8
3	N98/39	2	58/52	b	178	1								47		25	Flake		1	1
3	N98/39	2	58/52	b	178	1		5	2				4						7	11.9
3	N98/39	2	58/52	b	178	2	1	5	1		1	1	4						9	114.1
3	N98/39	2	58/52	b	223	1		1	2		1	1	2						5	14.8
3	N98/39	2	58/52	b	223	2	4			1	3								8	1.4
3	N98/39	2	58/52	c	130	2	2	1	1										4	1.4
3	N98/39	2	58/52	c	149	1	6						1						6	0.6
3	N98/39	2	58/52	c	149	2	1		1		2		1						4	4.7
3	N98/39	2	58/52	c	162	1	2												2	0.1
3	N98/39	2	58/52	c	162	2	5	2			1		2						8	4.7
3	N98/39	2	58/52	c	178	1								1		19	Flake		1	0.9
3	N98/39	2	58/52	c	178	1								47		28	Blade		1	1
3	N98/39	2	58/52	c	178	1	6	1	3		6		4						16	6.3
3	N98/39	2	58/52	c	178	2	6	3	3		7		10						19	28.3
3	N98/39	2	58/52	c	223	1		1	1		2		1						4	7.6
3	N98/39	2	58/52	c	223	2	2	1			2		1						5	13.4
3	N98/39	2	58/52	d	130	2	3												3	0.3
3	N98/39	2	58/52	d	149	1					1								1	0.4
3	N98/39	2	58/52	d	149	2	1			1									2	4
3	N98/39	2	58/52	d	162	1	1				2		2						3	1.4
3	N98/39	2	58/52	d	162	2	1			1	3		1						5	8.2
3	N98/39	2	58/52	d	178	1							1		7	22			1	22.5
3	N98/39	2	58/52	d	178	2	6	5	6		7	1	8						25	23.4
3	N98/39	2	58/52	d	223	2								30		20	Flake		1	0.7
3	N98/39	2	58/52	d	223	1	3				1								4	0.6
3	N98/39	2	58/52	d	223	2		1	3		3		3						7	8.7
3	N98/39	2	58/52		96	1			2										2	0.7
3	N98/39	2	58/52		96	2			2		1		1						3	1.2
3	N98/39	2	58/52		98	1	2	1	1			1							5	6.3
3	N98/39	2	58/52		98	2	3	1			2		4						6	5.4
3	N98/39	2	58/52		118	1	8	2	4		5		1						19	9.9
3	N98/39	2	58/52		118	2	8	2	3		10								23	10.8
3	N98/39	2	58/54	a	180	1								1		25	Flake		1	0.5
3	N98/39	2	58/54	a	180	1								18		20	99		1	0.5
3	N98/39	2	58/54	a	180	1	6	3	1		2	1	4						13	6.1
3	N98/39	2	58/54	a	180	2	3		1		2		2						6	10.7

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	58/54	a	219	1							1		1	47			1	35.8
3	N98/39	2	58/54	a	219	1	3	2	3	1	3		8						12	30.6
3	N98/39	2	58/54	a	219	2									1	25			1	6.1
3	N98/39	2	58/54	a	219	2	5	1	5			2	3						13	14.1
3	N98/39	2	58/54	a	237	1	5				1		2						6	5.4
3	N98/39	2	58/54	a	237	2	3	1	1		1								6	2
3	N98/39	2	58/54	b	180	1								99		9	99		1	0.01
3	N98/39	2	58/54	b	180	1	3	5	1		3		6						12	13.9
3	N98/39	2	58/54	b	180	2	4	3	1		1		2						9	9
3	N98/39	2	58/54	b	219	1								60		29	Flake		1	2.8
3	N98/39	2	58/54	b	219	1	3	5	2		1		5						11	18.9
3	N98/39	2	58/54	b	219	2	3	2	1	1	2		2						9	9.3
3	N98/39	2	58/54	b	237	1	2	1											3	2.6
3	N98/39	2	58/54	b	237	2	2		1			1	1						4	4.4
3	N98/39	2	58/54	c	180	2								1		20	99		1	0.4
3	N98/39	2	58/54	c	180	1							1		1	41			1	38.9
3	N98/39	2	58/54	c	180	1	2		1				1						3	0.3
3	N98/39	2	58/54	c	180	2	5	1	2		1		5						9	6.8
3	N98/39	2	58/54	c	219	1							1		4	43			1	49
3	N98/39	2	58/54	c	219	1	2	3	2	1	3		4						11	5.9
3	N98/39	2	58/54	c	219	2	6	10	4	2	6		3						28	30
3	N98/39	2	58/54	c	219	23		1											1	4
3	N98/39	2	58/54	d	180	1								1		18	Flake		1	0.5
3	N98/39	2	58/54	d	180	1								3		13	Flake		1	0.1
3	N98/39	2	58/54	d	180	1	6	4			4		5						14	14.3
3	N98/39	2	58/54	d	180	2	3				3		4						6	6.1
3	N98/39	2	58/54	d	219	2								12		18	99		1	0.4
3	N98/39	2	58/54	d	219	1	6		7		1		4						14	4.9
3	N98/39	2	58/54	d	219	2		5	1		5	1	6						12	26.4
3	N98/39	2	58/54		137	1								1		17	Flake		1	0.6
3	N98/39	2	58/54		137	1	2												2	0.01
3	N98/39	2	58/54		137	2	1	2			2		2						5	5.5
3	N98/39	2	58/54		142	2								1		18	Flake		1	0.6
3	N98/39	2	58/54		142	1								43		12	99		1	0.4
3	N98/39	2	58/54		142	1								99		14	99	x	1	0.01
3	N98/39	2	58/54		142	1							1		7	54			1	73.6
3	N98/39	2	58/54		142	1	6		2		6		3						14	3.1
3	N98/39	2	58/54		142	2	14	5	8	2	3		10						32	27.4
3	N98/39	2	58/54		164	1								40		10	99		1	0.4
3	N98/39	2	58/54		164	1								43		17	99		1	0.5
3	N98/39	2	58/54		164	1	13	3	7		5		9						28	17
3	N98/39	2	58/54		164	2	19	6	6	1	6	2	12						40	25
3	N98/39	2	59/51	a	322	1	1		1										2	0.2

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	59/51	a	322	2	1				3								4	0.9
3	N98/39	2	59/51	a	341	1	2	1			1		2						4	1
3	N98/39	2	59/51	a	341	2					1								1	0.6
3	N98/39	2	59/51	a	358	1								43		17	99		1	1.1
3	N98/39	2	59/51	a	358	1	5	4	1				4						10	6
3	N98/39	2	59/51	a	358	2	4			1	2		2						7	2.5
3	N98/39	2	59/51	a	365	1	4	6	2	1	4		6						17	22.7
3	N98/39	2	59/51	a	365	2	4	1	1	1	3								10	35.8
3	N98/39	2	59/51	a	391	1							1		7	48			1	23.6
3	N98/39	2	59/51	a	391	1							1		7	31			1	16.5
3	N98/39	2	59/51	a	391	1	2	2			1		1						5	5.2
3	N98/39	2	59/51	a	391	2	2												2	0.4
3	N98/39	2	59/51	b	322	2								12		15	99		1	0.4
3	N98/39	2	59/51	b	322	1			1										1	0.3
3	N98/39	2	59/51	b	322	2							1		5	32			1	14.4
3	N98/39	2	59/51	b	341	1	1	1											2	1.6
3	N98/39	2	59/51	b	341	2	2	1	1		2		1						6	6.8
3	N98/39	2	59/51	b	358	1	4	1			1								6	2.2
3	N98/39	2	59/51	b	358	2	2	2	1				1						5	4.5
3	N98/39	2	59/51	b	365	1									1	28			1	8.1
3	N98/39	2	59/51	b	365	1		7	4		1		5						12	23.4
3	N98/39	2	59/51	b	365	2	1	2	2		1		3						6	5.4
3	N98/39	2	59/51	b	391	1		1	1				1						2	1.1
3	N98/39	2	59/51	c	322	1	1				1		1						2	0.5
3	N98/39	2	59/51	c	341	2								1		16	Flake		1	0.6
3	N98/39	2	59/51	c	341	1	2		2				1						4	0.8
3	N98/39	2	59/51	c	341	2					2								2	0.6
3	N98/39	2	59/51	c	358	1									3	28			1	11.1
3	N98/39	2	59/51	c	358	1	1		1										2	0.5
3	N98/39	2	59/51	c	358	2		2	1		1		1						4	22.9
3	N98/39	2	59/51	c	365	1								99		3	99		1	0.3
3	N98/39	2	59/51	c	365	1									7	28			1	14.6
3	N98/39	2	59/51	c	365	1	3	1			2		2						6	4.3
3	N98/39	2	59/51	c	365	2									1	28			1	8.1
3	N98/39	2	59/51	c	365	2					3								3	1.4
3	N98/39	2	59/51	c	391	1		1			1		1						2	2.1
3	N98/39	2	59/51	d	322	1	7												7	0.8
3	N98/39	2	59/51	d	341	1								6		17	99		1	0.6
3	N98/39	2	59/51	d	341	1	3	1	2		2								8	3.3
3	N98/39	2	59/51	d	341	2		1			1		1						2	0.5
3	N98/39	2	59/51	d	358	2								30		17	99		1	0.5
3	N98/39	2	59/51	d	358	1	1	4	1		2		3						8	6.1
3	N98/39	2	59/51	d	358	2	3	7	2				3						12	16.8

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

Table 21

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	59/51	d	365	1								1		20	Flake		1	0.5
3	N98/39	2	59/51	d	365	1							1	33		12	Flake		1	0.2
3	N98/39	2	59/51	d	365	1	2	1	3		1								7	4.9
3	N98/39	2	59/51	d	365	2		3					2						3	9.1
3	N98/39	2	59/51	d	391	1	4	2	4		1								11	4.9
3	N98/39	2	59/51		273	1		1			2		2						3	2.4
3	N98/39	2	59/51		273	2	2		1										3	0.7
3	N98/39	2	59/51		299	2								12		10	99		1	0.01
3	N98/39	2	59/51		299	1									1	49			1	10.1
3	N98/39	2	59/51		299	1	6	2	5		4		4						17	8.8
3	N98/39	2	59/51		299	2	3	1	3	1	1		6						9	4.4
3	N98/39	2	59/53		134	1								11		18	Flake		1	0.2
3	N98/39	2	59/53		134	1								30		20	Flake		1	0.6
3	N98/39	2	59/53		134	2								40		7	Flake		1	0.2
3	N98/39	2	59/53		134	2								42		15	Flake		1	0.9
3	N98/39	2	59/53		134	1	26	6	10		9		14						51	20.7
3	N98/39	2	59/53		134	2	15	2	5		1		4						23	8.7
3	N98/39	2	59/53		173	2								40		18	Flake		1	0.5
3	N98/39	2	59/53		173	1	9	4	4	2	4		12						23	8.2
3	N98/39	2	59/53		173	2	3	3		1	4		4						11	10.7
3	N98/39	2	59/53		265	2								1		16	Flake		1	0.4
3	N98/39	2	59/53		265	1								20		16	Flake		1	0.4
3	N98/39	2	59/53		265	2								30		19	Flake		1	0.7
3	N98/39	2	59/53		265	1								33		15	Flake		1	1
3	N98/39	2	59/53		265	1								43		18	Flake		1	1.1
3	N98/39	2	59/53		265	1								48		26	Flake		1	0.8
3	N98/39	2	59/53		265	1							1		1	30			1	7.8
3	N98/39	2	59/53		265	1							1		3	42			1	38.7
3	N98/39	2	59/53		265	1	26	15	20	7	14		25						82	109.3
3	N98/39	2	59/53		265	2							1		7	37			1	22.7
3	N98/39	2	59/53		265	2	11	15	6	1	8		10						41	98.3
3	N98/39	2	59/53		287	1								12		19	Flake		1	0.9
3	N98/39	2	59/53		287	1		3	6	1	3		4						13	13.3
3	N98/39	2	59/53		287	2		2	1		3		1						6	4.9
3	N98/39	2	59/53		119a	2			1										1	0.2
3	N98/39	2	59/55	a	188	2								3		11	Flake		1	0.1
3	N98/39	2	59/55	a	188	1								12		23	Flake		1	0.6
3	N98/39	2	59/55	a	188	1									7	27			1	8.3
3	N98/39	2	59/55	a	188	1	5	2	3		3		5						13	24.1
3	N98/39	2	59/55	a	188	2	5	2	3	1	2		3						13	9.8
3	N98/39	2	59/55	b	188	2								48		30	Flake		1	1
3	N98/39	2	59/55	b	188	1	4	2			4		4						10	8.4
3	N98/39	2	59/55	b	188	2			3				2						3	1.1

Table 21, continued from previous page and continued on next page: Finds from site catalogue no. 3, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10 mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Tool incomplete	Total number	Weight/g
3	N98/39	2	59/55	b	216	1								25		12	99		1	0.4
3	N98/39	2	59/55	b	216	1								99		10	99	x	1	0.3
3	N98/39	2	59/55	b	216	1							1		7	41			1	29
3	N98/39	2	59/55	b	216	1	6	3	3		4		4						16	13.1
3	N98/39	2	59/55	b	216	2	9	1	4		2		2						16	12.5
3	N98/39	2	59/55	c	188	1	2	4	1		1		4						8	16.7
3	N98/39	2	59/55	c	188	2	3	1					1						4	6.4
3	N98/39	2	59/55	c	216	1	2	3	1		2								8	32.5
3	N98/39	2	59/55	c	216	2	3	1	2	3	1		1						10	8.3
3	N98/39	2	59/55	d	188	1	4	3	2	1	3		7						13	63.1
3	N98/39	2	59/55	d	188	2	2	1		1	2		1						6	1.9
3	N98/39	2	59/55	d	216	2								12		15	99		1	0.01
3	N98/39	2	59/55	d	216	1	1	5	2	1	4		7						13	19.8
3	N98/39	2	59/55	d	216	2	2		1										3	0.5
3	N98/39	2	59/55		132	1							1		7	38			1	16.1
3	N98/39	2	59/55		132	1	1												1	0.01
3	N98/39	2	59/55		132	2			1										1	0.4
3	N98/39	2	59/55		140	1								12		19	Flake		1	0.5
3	N98/39	2	59/55		140	1	21	3	2	1	3		3						30	10
3	N98/39	2	59/55		140	2	4	2	1	1	2		2						10	28.5
3	N98/39	2	59/55		160	1								3		12	99		1	0.3
3	N98/39	2	59/55		160	1								23		12	99		1	0.5
3	N98/39	2	59/55		160	1							1		7	36			1	20.7
3	N98/39	2	59/55		160	1	32	7	10	2	3		5						54	48.6
3	N98/39	2	59/55		160	2	7	2	6	3	7		4						25	12
3	N98/39	2			1046	1							1		4	52			1	151.6
3	N98/39	4			7	2		1			4		2						5	203.2
3	N05/02					1								43		21	Blade		1	1.3
3	N05/02					1								48		29	99		1	2.4
3	N05/02					1								48		27	99		1	1.3
3	N05/02					1								60		29	99		1	1.7
3	N05/02					1								99		14	99		1	0.6
3	N05/02					1							1		1	32			1	17
3	N05/02					1		1					1						1	11.2
3	N05/02					1										17			1	6.2
3	N05/02					2		1					1						1	52.8
3	N05/10					1		2		3			2						5	41.3

Table 21, continued from previous page: Finds from site catalogue no. 3, lithics.

Tool type (total n = 259)								
1	**3**	**5**	**6**	**10**	**11**	**12**	**13**	
Micro-segment < 25 mm	Micro-segment < 14 mm	Isosceles triangle	Scalene triangle	Long micro-point, unilaterally retouched	Long micro-double-point, unilaterally retouched	Short micro-point, unilaterally retouched	Long micro-point, symmetrically bilaterally retouched	
64	9	2	3	2	6	39	1	**Number**
24.7	3.5	0.7	1.15	0.7	2.3	15	0.3	**Percentage**
Tool type								
17	**18**	**20**	**22**	**23**	**25**	**26**	**27**	
Short micro-point, symmetrically bilaterally retouched	Short micro-point, asymmetrically bilaterally retouched	Short micro-double-point, asymmetrically retouched	Alternately retouched micro-double-point	Terminally retouched micro-point, oblique	Backed bladelet	Micro-side-scraper	Thick double micro-side-scraper	
1	4	1	1	2	1	1	1	**Number**
0.3	1.5	0.3	0.3	0.7	0.3	0.3	0.3	**Percentage**
Tool type								
28	**29**	**30**	**33**	**34**	**38**	**39**	**40**	
Flat double micro-scraper	High-backed micro-side-scraper	Low-backed micro-side-scraper	Micro-end-scraper	Terminally retouched straight microlith	Laterally fine retouched microlith	Laterally retouched microlith	Backed microlith	
1	8	13	2	1	6	4	15	**Number**
0.3	3.1	5	0.7	0.3	2.3	1.5	5.8	**Percentage**
Tool type								
42	**43**	**46**	**47**	**48**	**51**	**54**	**55**	
Denticulated microlith	Miscellaneous microliths	Angled backed point	Convex backed point	Large segment > 25 mm	Endscraper on a blade >25 mm	Notched flake > 25 mm	Denticulate > 25 mm	
2	25	1	6	11	1	1	2	**Number**
0.7	9.6	0.3	2.3	4.2	0.3	0.3	0.7	**Percentage**
Tool type								
56	**59**	**60**	**Undetermined**					
Borer > 25 mm	Oblique truncated flake > 25 mm	Miscellaneous retouched artifacts > 25 mm						
1	1	8	12					Number
0.3	0.3	3.1	4.6					Percentage

Table 22: Finds from site catalogue no. 3, lithic tool types.

Core type	Description	Number (total n = 83)	Percentage
1	Single-platform core, conical or cylindirical	35	42.16%
2	Discoidal core	1	1.20%
3	Bipolar core	3	3.61%
4	Polyhedral core	9	10.84%
5	Bilateral discoid core	9	10.84%
6	Irregular core	26	31.30%

Table 23: Finds from site catalogue no. 3: lithic core types.

SC no.	Site no.	Level	Shards	Clay pipe frags.	Faunal remains	Quartzite/ Chalcedony	Lime-stone	Slag	Iron artifact	Copper artifact	Clay/ Burnt clay	OES beads or frags.
4	N68/01	0′′-3′′	70	1	42	2	6	2			10	
4	N68/01	3′′-9′′	157		69	3	7	3	1		3	2
4	N68/02	9′′-12′′	44	5	55	2	12	3			6	1
4	N68/01	12′′-15′′	18		40		12				8	1
4	N68/01	15′′-18′′	6		62	4	4				4	
4	N68/01	18′′-21′′	34		20	8	3	2				
4	N68/01	21′′-24′′	92		26	25	3	3				
4	N68/02	24′′-27′′	307		27	22	9	1	1			
4	N68/01	27′′-30′′	12		27		8				1	
4	N68/01	30′′-36′′	36		7	5	4			1		
4	N68/01	36′′42′′				4						
4	N68/02	0′′-3′′										
4	N68/02	3′′-9′′	2									
4	N68/02	9′′-12′′	1									
4	N68/02	12′′-15′′										
4	N68/02	15′′-18′′						1				
4	N68/02	18′′-21′′						2				
4	N68/02	21′′-24′′										
4	N68/02	24′′-27′′	169		11	2		2			25	
4	N68/02	27′′-30′′										
4	N68/02	30′′-36′′	23		3	1		1	1		1	
4	N68/02	36′′-42′′										

Table 24: Finds from site catalogue no. 4, area N68/01 and N68/02, after Sandelowsky (1979) corrected.

SC no.	Site no.	Area	Unit	Quadrant	Level	Pottery			Weight/g
							Dec.	Undec.	
4	N99/21	1	46/92	d	Surf.	4		4	19
4	N99/21	1	49/51	a	1	6		6	29
4	N99/21	1	50/50	a	4	1		1	0.4
4	N99/21	1	50/50	a	6	8	8		9
4	N99/21	1	50/50	a	9	8		8	43
4	N99/21	1	50/50	b	4	1		1	10
4	N99/21	1	50/50	b	6	27	5	22	51
4	N99/21	1	50/50	b	9	1		1	1
4	N99/21	1	50/50	c	4	6		6	37
4	N99/21	1	50/50	c	6	48	6	42	155
4	N99/21	1	50/50	c	9	26		26	33
4	N99/21	1	50/50	c	10	1		1	0.5
4	N99/21	1	50/50	d	6	84	3	81	168
4	N99/21	1	50/50	d	9	2		2	2.5
4	N99/21	1	50/51	a	6	17	3	14	42
4	N99/21	1	50/51	b	4	2		2	2
4	N99/21	1	50/51	b	6	9		9	49
4	N99/21	1	50/51	c	4	5		5	6.3
4	N99/21	1	50/51	c	6	33	7	26	60
4	N99/21	1	50/51	d	4	1		1	8.5
4	N99/21	1	50/51	d	6	17	2	15	48.5
4	N99/21	1	51/50	a	4	2		2	10
4	N99/21	1	51/50	a	6	8		8	61
4	N99/21	1	51/50	a	9	4	1	3	5
4	N99/21	1	51/50	b	9	3		3	1
4	N99/21	1	51/50	c	4	6		6	6.5
4	N99/21	1	51/50	c	10	1		1	16
4	N99/21	1	51/50	d	4	2		2	4
4	N99/21	1	51/51	a	4	1		1	5
4	N99/21	1	51/51	a	6	18	1	17	66
4	N99/21	1	51/51	b	4	2		2	3
4	N99/21	1	51/51	b	6	2	2		4
4	N99/21	1	51/51	c	4	3		3	15
4	N99/21	1	51/51	c	6	18	4	14	45
4	N99/21	1	51/51	d	4	5		5	15
4	N99/21	1	51/51	d	6	3	3		7
4	N99/21	1	53/48	a	1	7	1	6	14
4	N99/21	3	70/45	a	1	26	1	25	35
4	N99/21	3	70/45	a	12	13	1	12	84
4	N99/21	3	70/45	a	16	8	1	7	23
4	N99/21	3	70/45	a	20	3		3	7
4	N99/21	3	70/45	a	28	11	4	7	12

SC no.	Site no.	Area	Unit	Quadrant	Level	Pottery			Weight/g
							Dec.	Undec.	
4	N99/21	3	70/45	a	29	4	1	3	4
4	N99/21	3	70/45	a	32	6		6	8
4	N99/21	3	70/45	a	36	13		13	30
4	N99/21	3	70/45	a	40	43	9	34	144
4	N99/21	3	70/45	a	45	70	4	66	388
4	N99/21	3	70/45	a	49	37		37	82
4	N99/21	3	70/45	a	53	17	1	15	91
4	N99/21	3	70/45	a	57	4		4	1
4	N99/21	3	70/45	a	61	4		4	2
4	N99/21	3	70/45	a	65	4		4	2
4	N99/21	3	70/45	a	74	1		1	1
4	N99/21	3	70/45	a	82	5		5	1
4	N99/21	3	70/45	a	104	1		1	1
4	N99/21	3	70/45	b	2	4		4	2
4	N99/21	3	70/45	b	6	12		12	11
4	N99/21	3	70/45	b	9	11		11	13
4	N99/21	3	70/45	b	13	6	1	6	8
4	N99/21	3	70/45	b	17	13		13	40
4	N99/21	3	70/45	b	21	9		9	14
4	N99/21	3	70/45	b	24	4		4	5
4	N99/21	3	70/45	b	25	4		4	6
4	N99/21	3	70/45	b	33	7		7	11
4	N99/21	3	70/45	b	37	8		8	5
4	N99/21	3	70/45	b	41	8	2	6	29
4	N99/21	3	70/45	b	46	35	9	26	114
4	N99/21	3	70/45	b	50	35	3	32	109
4	N99/21	3	70/45	b	54	12	2	10	33
4	N99/21	3	70/45	b	66	1		1	1
4	N99/21	3	70/45	b	71	2	1	1	2
4	N99/21	3	70/45	b	75	3		3	4
4	N99/21	3	70/45	b	83	2	1	1	2
4	N99/21	3	70/45	b	87	2		2	1
4	N99/21	3	70/45	b	91	4		4	1
4	N99/21	3	70/45	c	4	2		2	1
4	N99/21	3	70/45	c	7	12	2	10	22
4	N99/21	3	70/45	c	10	8		8	10
4	N99/21	3	70/45	c	14	14		14	51
4	N99/21	3	70/45	c	18	9		9	16
4	N99/21	3	70/45	c	22	5	1	4	5
4	N99/21	3	70/45	c	30	4		4	3
4	N99/21	3	70/45	c	31	6	2	4	11
4	N99/21	3	70/45	c	34	14	1	13	36

Table 25, continued on next page: Finds from site catalogue no. 4, pottery.

SC no.	Site no.	Area	Unit	Quadrant	Level	Pottery			Weight/g
							Dec.	Undec.	
4	N99/21	3	70/45	c	39	10		10	18
4	N99/21	3	70/45	c	39	1	1		1
4	N99/21	3	70/45	c	43	38	2	36	243
4	N99/21	3	70/45	c	47	54		54	191
4	N99/21	3	70/45	c	52	51	4	47	81
4	N99/21	3	70/45	c	56	9	1	8	89
4	N99/21	3	70/45	c	63	3		3	15
4	N99/21	3	70/45	c	67	4		4	1
4	N99/21	3	70/45	c	72	1		1	1
4	N99/21	3	70/45	c	76	1		1	1
4	N99/21	3	70/45	c	88	2		2	2
4	N99/21	3	70/45	c	92	4		4	1
4	N99/21	3	70/45	c	96	1		1	1
4	N99/21	3	70/45	c	102	2	1	1	2
4	N99/21	3	70/45	d	5	3		3	5
4	N99/21	3	70/45	d	8	9	1	8	27
4	N99/21	3	70/45	d	11	21	1	20	27
4	N99/21	3	70/45	d	15	10	1	9	41
4	N99/21	3	70/45	d	19	6	1	5	10
4	N99/21	3	70/45	d	23	1		1	5
4	N99/21	3	70/45	d	27	8	1	7	166
4	N99/21	3	70/45	d	35	12	1	12	35
4	N99/21	3	70/45	d	38	17	1	16	42
4	N99/21	3	70/45	d	42	11		11	38
4	N99/21	3	70/45	d	48	41	8	33	142
4	N99/21	3	70/45	d	51	46	1	45	126
4	N99/21	3	70/45	d	55	13		10	76
4	N99/21	3	70/45	d	60	6		6	7
4	N99/21	3	70/45	d	89	1		1	1
4	N99/21	3	70/45	d	93	1		1	1
4	N99/21	3	70/45	d	107	1		1	15
4	N99/21	3	70/45		69	5		5	5
4	N99/21	4	73/29	a	4	2		2	8
4	N99/21	4	73/29	a	8	17		17	7
4	N99/21	4	73/29	a	12	2		2	4
4	N99/21	4	73/29	a	16	8		8	32
4	N99/21	4	73/29	a	20	1		1	3
4	N99/21	4	73/29	a	28	2		2	1
4	N99/21	4	73/29	a	32	1		1	1
4	N99/21	4	73/29	a	44	15		15	21
4	N99/21	4	73/29	b	5	4		4	2
4	N99/21	4	73/29	b	9	5	1	4	5
4	N99/21	4	73/29	b	13	6		6	3
4	N99/21	4	73/29	b	17	11		11	27
4	N99/21	4	73/29	b	21	9	1	8	16
4	N99/21	4	73/29	b	25	3		3	3
4	N99/21	4	73/29	b	37	1		1	1
4	N99/21	4	73/29	b	41	3		3	1
4	N99/21	4	73/29	b	45	6		6	6
4	N99/21	4	73/29	c	6	11	1	10	10
4	N99/21	4	73/29	c	10	2		2	8
4	N99/21	4	73/29	c	14	2		2	18
4	N99/21	4	73/29	c	18	5		5	8
4	N99/21	4	73/29	c	22	5	1	4	18
4	N99/21	4	73/29	c	27	1		1	1
4	N99/21	4	73/29	c	30	1		1	1
4	N99/21	4	73/29	c	34	2		2	2
4	N99/21	4	73/29	c	42	3		3	5
4	N99/21	4	73/29	c	46	24	3	21	33
4	N99/21	4	73/29	d	7	7		7	2
4	N99/21	4	73/29	d	11	7		7	10
4	N99/21	4	73/29	d	15	4		4	9
4	N99/21	4	73/29	d	19	6		6	5
4	N99/21	4	73/29	d	23	5		5	32
4	N99/21	4	73/29	d	26	2		2	3
4	N99/21	4	73/29	d	31	2		2	8
4	N99/21	4	73/29	d	35	4		4	1
4	N99/21	4	73/29	d	39	7	1	6	6
4	N99/21	4	73/29	d	43	8		8	8
4	N99/21	4	73/29	d	48	13	1	12	30
4	N99/21	5	74/14	a	49	1	1		1
4	N99/21	5	75/14	a	9	3		3	5
4	N99/21	5	75/14	a	13	1		1	2
4	N99/21	5	75/14	a	17	1		1	1
4	N99/21	5	75/14	a	25	3		3	18
4	N99/21	5	75/14	a	33	1		1	2
4	N99/21	5	75/14	a	45	7		7	12
4	N99/21	5	75/14	a	49	29	3	26	115
4	N99/21	5	75/14	a	58	5	1	4	3
4	N99/21	5	75/14	a	74	1		1	1
4	N99/21	5	75/14	b	6	1		1	3
4	N99/21	5	75/14	b	10	4		4	6
4	N99/21	5	75/14	b	14	3		3	4
4	N99/21	5	75/14	b	38	3	1	2	4

Table 25, continued from previous page and continued on next page: Finds from site catalogue no. 4, pottery.

SC no.	Site no.	Area	Unit	Quadrant	Level	Pottery			Weight/g
							Dec.	Undec.	
4	N99/21	5	75/14	b	42	1		1	2
4	N99/21	5	75/14	b	50	33	2	31	63
4	N99/21	5	75/14	b	54	2	1	1	4
4	N99/21	5	75/14	b	59	1		1	1
4	N99/21	5	75/14	c	8	3		3	4
4	N99/21	5	75/14	c	12	5		5	9
4	N99/21	5	75/14	c	16	4		4	29
4	N99/21	5	75/14	c	20	1		1	2
4	N99/21	5	75/14	c	28	1		1	3
4	N99/21	5	75/14	c	32	3		3	6
4	N99/21	5	75/14	c	48	2		2	5
4	N99/21	5	75/14	c	51	5		5	23
4	N99/21	5	75/14	c	55	3		3	2
4	N99/21	5	75/14	c	60	1		1	1
4	N99/21	5	75/14	c	64	1		1	1
4	N99/21	5	75/14	d	7	4		4	7
4	N99/21	5	75/14	d	15	2		2	3
4	N99/21	5	75/14	d	19	3		3	11
4	N99/21	5	75/14	d	23	7		7	10
4	N99/21	5	75/14	d	28	2		2	6
4	N99/21	5	75/14	d	31	2		2	4
4	N99/21	5	75/14	d	39	2		2	4
4	N99/21	5	75/14	d	43	4	1	3	7
4	N99/21	5	75/14	d	47	4		4	9
4	N99/21	5	75/14	d	52	32	2	30	67
4	N99/21	5	75/14	d	56	3		3	6
4	N99/21	5	75/14	d	73	1		1	1
4	N99/21	5	75/14		92	1		1	22
4	N99/21	6	48/94	a	5	17	1	16	16
4	N99/21	6	48/94	a	6	14		14	74
4	N99/21	6	48/94	b	2	6	1	5	15
4	N99/21	6	48/94	c	3	1		1	1
4	N99/21	6	48/94	c	7	10		10	23
4	N99/21	6	48/94	c	8	9		9	16
4	N99/21	6	48/94	d	4	3		3	4
4	N99/21	7	45/89	b	4	12	1	11	49
4	N99/21	7	45/89	b	5	14	1	13	46
4	N99/21	7	45/89	b	6	13	1	12	192
4	N99/21	7	45/89	b	7	40	5	35	246
4	N99/21	7	45/89	d	4	5		5	19
4	N99/21	7	45/90	d	9	5	1	4	16
4	N99/21	7	45/90	d	10	6		6	26
4	N99/21	7	45/90	d	11	18		18	63
4	N99/21	7	45/90	d	12	3		3	16
4	N68/01	B1575	A			2	2		34
4	N68/01	B1575	B		15-22''	36	18	18	348
4	N68/01	B1575	B		15-24''	1	1		3
4	N68/01	B1575	B		28-34''	7	2	4	50
4	N68/01	B1575	B + C			8		8	11
4	N68/01	B1575	C			18	10	8	126
4	N68/01	B1575	D			14		14	240
4	N68/01	B1575				26	17	9	1212.1
4	N68/02	B1592			0-3''	2	2		4
4	N68/02	B1592			18-24''	19	12	7	91
4	N68/02	B1592			20-30''	6	3	3	45
4	N68/02	B1592			24-30''	42	35	7	223
4	N68/02	B1592			30-36''	2	1	1	4
4	N68/02	B1592			9-12''	1	1		7
4	N99/21		47.38/ 96.72		Surf.	1		1	4
4	N99/21		47.5/ 96.8		Surf.	1		1	3
4	N99/21				Surf.	14		14	220
4	B1533				107 cm below surface	3	1	2	124
4	B4217				Surf.	1	1		14
4	N05/02				Surf.	33	24	9	139
4	N06/07				Surf.	10		10	206
4	N98/38				Surf.	2		2	17

Table 25, continued from previous page: Finds from site catalogue no. 4, pottery.

SC no.	Site no.	Area	Unit	Quadrant	Level	Ceramic artifacts	Burnt clay	Faunal remains	Botanical remains	Glass	Plastics	Others	Glass beads	OES beads	OES preform	Weight/g
4	N99/21	1	50/50	a	9										1	0.3
4	N99/21	1	50/50	b	6									1		0.2
4	N99/21	1	50/50	b	6								1			0.2
4	N99/21	1	50/50	c	6						1					27.5
4	N99/21	1	50/50	c	6									1		0.2
4	N99/21	1	50/50	c	9								1			0.1
4	N99/21	1	50/50	d	9									1		0.1
4	N99/21	1	50/51	a	4									1		0.2
4	N99/21	1	50/51	a	6									1		0.1
4	N99/21	1	50/51	b	6									1		0.3
4	N99/21	1	50/51	b	6								1			0.2
4	N99/21	1	51/50	a	6									1		0.2
4	N99/21	1	51/50	a	6									1		0.1
4	N99/21	1	51/50	a	9									1		0.1
4	N99/21	1	51/50	b	6									1		0.1
4	N99/21	1	51/50	c	6								1			0.1
4	N99/21	1	51/51	b	6		1									15.1
4	N99/21	1	51/51	b	6								1			0.3
4	N99/21	1	51/51	d	6									1		0.1
4	N99/21	1	51/51	d	6									1		0.1
4	N99/21	1	51/51	d	6								1			0.3
4	N99/21	1	51/51	d	6								1			0.1
4	N99/21	1	51/51	d	6								1			0.2
4	N99/21	3	70/45	a	1			4								1
4	N99/21	3	70/45	a	12		1									0.5
4	N99/21	3	70/45	a	12			6								1
4	N99/21	3	70/45	a	16			32								10
4	N99/21	3	70/45	a	28			14								4
4	N99/21	3	70/45	a	29			8								2
4	N99/21	3	70/45	a	32			7								1
4	N99/21	3	70/45	a	36		1									1
4	N99/21	3	70/45	a	36			4								3
4	N99/21	3	70/45	a	40			10								4
4	N99/21	3	70/45	a	45			42								41
4	N99/21	3	70/45	a	49			39								8
4	N99/21	3	70/45	a	53			19								14
4	N99/21	3	70/45	a	57			22								4
4	N99/21	3	70/45	a	65			5								1
4	N99/21	3	70/45	a	78			6								1
4	N99/21	3	70/45	a	82			3								1
4	N99/21	3	70/45	a	86			3								1
4	N99/21	3	70/45	a	94			1								1
4	N99/21	3	70/45	a & b	20 & 21			57								29
4	N99/21	3	70/45	b	2			2								1

Table 26, continued on next page: Finds from site catalogue no. 4, ceramic artifacts, burnt clay, faunal remains, botanical remains, glass, plastics, glass beads, OES beads and preforms, others.

SC no.	Site no.	Area	Unit	Quadrant	Level	Ceramic artifacts	Burnt clay	Faunal remains	Botanical remains	Glass	Plastics	Others	Glass beads	OES beads	OES preform	Weight/g
4	N99/21	3	70/45	b	6			18								5
4	N99/21	3	70/45	b	6					1						0.1
4	N99/21	3	70/45	b	9			4								1
4	N99/21	3	70/45	b	13			41								18
4	N99/21	3	70/45	b	17			36								22
4	N99/21	3	70/45	b	24			8								2
4	N99/21	3	70/45	b	24									1		0.1
4	N99/21	3	70/45	b	25			6								1
4	N99/21	3	70/45	b	33			16								5
4	N99/21	3	70/45	b	37			7								2
4	N99/21	3	70/45	b	41			18								5
4	N99/21	3	70/45	b	46			26								6
4	N99/21	3	70/45	b	50			45								13
4	N99/21	3	70/45	b	54			50								53
4	N99/21	3	70/45	b	58			23								4
4	N99/21	3	70/45	b	71			9								1
4	N99/21	3	70/45	b	75			3								1
4	N99/21	3	70/45	b	79			14								2
4	N99/21	3	70/45	b	83			2								1
4	N99/21	3	70/45	b	87			9								1
4	N99/21	3	70/45	b	91			14								1
4	N99/21	3	70/45	b	95			2								1
4	N99/21	3	70/45	b	105			2								14
4	N99/21	3	70/45	c	4			3								1
4	N99/21	3	70/45	c	7			2								1
4	N99/21	3	70/45	c	10			9								2
4	N99/21	3	70/45	c	14			16								12
4	N99/21	3	70/45	c	18			53								17
4	N99/21	3	70/45	c	22			13								2
4	N99/21	3	70/45	c	22				1							0.01
4	N99/21	3	70/45	c	30			5								2
4	N99/21	3	70/45	c	31			6								2
4	N99/21	3	70/45	c	34			7								3
4	N99/21	3	70/45	c	39			5								3
4	N99/21	3	70/45	c	43			3								2
4	N99/21	3	70/45	c	47			6								103
4	N99/21	3	70/45	c	47			75								74
4	N99/21	3	70/45	c	52			3								4
4	N99/21	3	70/45	c	52			92								40
4	N99/21	3	70/45	c	52				2							0.3
4	N99/21	3	70/45	c	56			25								17
4	N99/21	3	70/45	c	67			1								1
4	N99/21	3	70/45	c	72			10								1
4	N99/21	3	70/45	c	76			2								1

Table 26, continued from previous page and continued on next page: Finds from site catalogue no. 4, ceramic artifacts, burnt clay, faunal remains, botanical remains, glass, plastics, glass beads, OES beads and preforms, others.

SC no.	Site no.	Area	Unit	Quadrant	Level	Ceramic artifacts	Burnt clay	Faunal remains	Botanical remains	Glass	Plastics	Others	Glass beads	OES beads	OES preform	Weight/g
4	N99/21	3	70/45	c	76									1		0.1
4	N99/21	3	70/45	c	80			5								1
4	N99/21	3	70/45	c	84			3								1
4	N99/21	3	70/45	c	88			5								1
4	N99/21	3	70/45	c	92			8								1
4	N99/21	3	70/45	c	96			4								1
4	N99/21	3	70/45	d	5			3								1
4	N99/21	3	70/45	d	8			7								2
4	N99/21	3	70/45	d	11			10								1
4	N99/21	3	70/45	d	15			49								17
4	N99/21	3	70/45	d	15									1		0.1
4	N99/21	3	70/45	d	19			19								3
4	N99/21	3	70/45	d	23			8								1
4	N99/21	3	70/45	d	26			4								1
4	N99/21	3	70/45	d	27			4								1
4	N99/21	3	70/45	d	35			4								1
4	N99/21	3	70/45	d	42			5								6
4	N99/21	3	70/45	d	48			72								27
4	N99/21	3	70/45	d	55			40								16
4	N99/21	3	70/45	d	60			15								1
4	N99/21	3	70/45	d	68			7								1
4	N99/21	3	70/45	d	73			1								1
4	N99/21	3	70/45	d	77			5								1
4	N99/21	3	70/45	d	81			3								2
4	N99/21	3	70/45	d	85			4								1
4	N99/21	3	70/45	d	89			9								1
4	N99/21	3	70/45	d	93			6								3
4	N99/21	3	70/45	d	107			8								3
4	N99/21	3	70/45		69			8								6.4
4	N99/21	4	73/29	a	8	2										3
4	N99/21	4	73/29	a	16			12								4
4	N99/21	4	73/29	a	20		1									4.5
4	N99/21	4	73/29	a	32			9								1
4	N99/21	4	73/29	a	40			6								1
4	N99/21	4	73/29	a	44			12								1
4	N99/21	4	73/29	b	9			1								1
4	N99/21	4	73/29	b	13			1								1
4	N99/21	4	73/29	b	17			5								1
4	N99/21	4	73/29	b	21			3								1
4	N99/21	4	73/29	b	21				10							4.3
4	N99/21	4	73/29	b	33			14								1
4	N99/21	4	73/29	c	6			3								1
4	N99/21	4	73/29	c	10			5								2
4	N99/21	4	73/29	c	14			1								1

Table 26, continued from previous page and continued on next page: Finds from site catalogue no. 4, ceramic artifacts, burnt clay, faunal remains, botanical remains, glass, plastics, glass beads, OES beads and preforms, others.

SC no.	Site no.	Area	Unit	Quadrant	Level	Ceramic artifacts	Burnt clay	Faunal remains	Botanical remains	Glass	Plastics	Others	Glass beads	OES beads	OES preform	Weight/g
4	N99/21	4	73/29	c	18			3								3
4	N99/21	4	73/29	c	22			4								6
4	N99/21	4	73/29	c	28			6								2
4	N99/21	4	73/29	c	30			1								1
4	N99/21	4	73/29	c	42			20								12
4	N99/21	4	73/29	c	46			7								2
4	N99/21	4	73/29	d	7			2								1
4	N99/21	4	73/29	d	7							Gagate				4.5
4	N99/21	4	73/29	d	11						3					0.2
4	N99/21	4	73/29	d	15			13								1
4	N99/21	4	73/29	d	15						4					0.3
4	N99/21	4	73/29	d	15										1	0.3
4	N99/21	4	73/29	d	19			1								1
4	N99/21	4	73/29	d	23			5								1
4	N99/21	4	73/29	d	26			2								1
4	N99/21	4	73/29	d	35			1								2
4	N99/21	4	73/29	d	43			8								1
4	N99/21	4	73/29	d	48			7								3
4	N99/21	4	73/29		37			3								2
4	N99/21	5	75/14	a	17			2								1
4	N99/21	5	75/14	a	21		1									21.8
4	N99/21	5	75/14	a	25	1										3.3
4	N99/21	5	75/14	a	29			2								1
4	N99/21	5	75/14	a	33			22								61
4	N99/21	5	75/14	a	45			3								2
4	N99/21	5	75/14	a	49			6								2
4	N99/21	5	75/14	a	53			9								7
4	N99/21	5	75/14	a	58			3								1
4	N99/21	5	75/14	a	62			2								1
4	N99/21	5	75/14	a	70			25								18
4	N99/21	5	75/14	a	74			2								1
4	N99/21	5	75/14	b	6			2								1
4	N99/21	5	75/14	b	10										1	0.1
4	N99/21	5	75/14	b	22			1								1
4	N99/21	5	75/14	b	26			4								1
4	N99/21	5	75/14	b	26	1										1.5
4	N99/21	5	75/14	b	36			14								20
4	N99/21	5	75/14	b	38			5								5
4	N99/21	5	75/14	b	50		2									38
4	N99/21	5	75/14	b	50			5								4
4	N99/21	5	75/14	b	54			1								2
4	N99/21	5	75/14	b	67			5								1
4	N99/21	5	75/14	b	75			3								2
4	N99/21	5	75/14	b	79			7								1
4	N99/21	5	75/14	b	160			10								5

Table 26, continued from previous page and continued on next page: Finds from site catalogue no. 4, ceramic artifacts, burnt clay, faunal remains, botanical remains, glass, plastics, glass beads, OES beads and preforms, others.

SC no.	Site no.	Area	Unit	Quadrant	Level	Ceramic artifacts	Burnt clay	Faunal remains	Botanical remains	Glass	Plastics	Others	Glass beads	OES beads	OES preform	Weight/g
4	N99/21	5	75/14	c	12			1								1
4	N99/21	5	75/14	c	16			3								1
4	N99/21	5	75/14	c	20										1	0.1
4	N99/21	5	75/14	c	36			7								1
4	N99/21	5	75/14	c	44			3								1
4	N99/21	5	75/14	c	60			10								6
4	N99/21	5	75/14	c	64			2								1
4	N99/21	5	75/14	c	72			1								3
4	N99/21	5	75/14	d	7			1								1
4	N99/21	5	75/14	d	7										1	0.2
4	N99/21	5	75/14	d	15			1								1
4	N99/21	5	75/14	d	19										1	0.3
4	N99/21	5	75/14	d	47			6								4
4	N99/21	5	75/14	d	52			7								5
4	N99/21	6	48/94	a	1			5								2
4	N99/21	6	48/94	a	5			1								1
4	N99/21	6	48/94	a	5			11								3
4	N99/21	6	48/94	a	5					2						20.9
4	N99/21	6	48/94	a	5									1		0.1
4	N99/21	6	48/94	a	6			6								1
4	N99/21	6	48/94	a	6					2						1.1
4	N99/21	6	48/94	c	7			2								1
4	N99/21	6	48/94	c	7						1					0.1
4	N99/21	6	48/94	c	7					3						2.6
4	N99/21	6	48/94	c	8			2								1
4	N99/21	7	45/89	a	4										1	0.9
4	N99/21	7	45/89	b	4		1									9.7
4	N99/21	7	45/89	b	4			5								5
4	N99/21	7	45/89	b	5			1								1
4	N99/21	7	45/89	b	5									1		0.1
4	N99/21	7	45/89	b	6			1								1
4	N99/21	7	45/89	b	7			19								5
4	N99/21	7	45/89	d	2			1								1
4	N99/21	7	45/90	d	9			1								1
4	N99/21	7	45/90	d	9									1		0.1
4	N99/21	7	45/90	d	10									1		0.1
4	N99/21	7	45/90	d	11			7								4
4	N99/21	7	45/90	d	12			3								2
4	N99/21				Surf.									2		0.4
4	N68/01	B1575	B		15''-22''		1									30.1
4	N68/01	B1575	B		28''-34''		1									14.2
4	N68/01	B1575					6									339
4	N06/07						5									93.8
4	N98/38									1						4.1

Table 26, continued from previous page: Finds from site catalogue no. 4, ceramic artifacts, burnt clay, faunal remains, botanical remains, glass, plastics, glass beads, OES beads and preforms, others.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Total number	Weight/g
4	N99/21	1	50/50	a	4	1					1							1	0.9
4	N99/21	1	50/50	a	6	1	6				7		4					13	4
4	N99/21	1	50/50	a	6	2					2							2	0.6
4	N99/21	1	50/50	a	9	1	2		1	2	1							6	3
4	N99/21	1	50/50	a	9	2		3	2		1							6	6.4
4	N99/21	1	50/50	b	6	1	2		1		1		1					4	1.1
4	N99/21	1	50/50	b	6	1				1	1							2	1.1
4	N99/21	1	50/50	b	6	1									1	24		1	8.1
4	N99/21	1	50/50	b	6	2		1										1	2
4	N99/21	1	50/50	b	6	2	1	1										2	2.1
4	N99/21	1	50/50	b	6	23					3							3	47.3
4	N99/21	1	50/50	b	9	1	3	1	2		2		4					8	5.3
4	N99/21	1	50/50	b	9	2					6							6	3.6
4	N99/21	1	50/50	b	10	1	2	2	1		1		1					6	12.1
4	N99/21	1	50/50	b	10	2		3	2		3							8	8.5
4	N99/21	1	50/50	c	10	1								56		50	Flake	1	10.5
4	N99/21	1	50/50	c	10	1								60		26	Flake	1	6
4	N99/21	1	50/50	d	6	1	2		1	1	2		2					6	3.1
4	N99/21	1	50/50	d	6	1								1		20	Flake	1	1.2
4	N99/21	1	50/50	d	6	2	1											1	0.01
4	N99/21	1	50/50	d	9	1								12		16	99	1	0.5
4	N99/21	1	50/50	d	9	2		2	1		3							6	8.5
4	N99/21	1	50/50	d	9	2								23		23	99	1	1.5
4	N99/21	1	50/51	a	4	2		1	1				1					2	1.1
4	N99/21	1	50/51	a	6	1		1	1		1		2					3	3.7
4	N99/21	1	50/51	b	4	1			1				1					1	2.5
4	N99/21	1	50/51	b	6	1			1		1							2	2.9
4	N99/21	1	50/51	b	6	2		1										1	1.5
4	N99/21	1	50/51	c	6	1					2		1					2	0.8
4	N99/21	1	50/51	d	4	1								3		8	99	1	0.01
4	N99/21	1	50/51	d	6	1		1			3		1					4	20
4	N99/21	1	50/51	d	6	2			1									1	0.8
4	N99/21	1	51/50	a	4	1					1							1	0.2
4	N99/21	1	51/50	a	6	1	1		1		2		1					4	8.5
4	N99/21	1	51/50	a	6	2					3		1					3	143.1
4	N99/21	1	51/50	a	9	1	6	1	1		2		2					10	4.4
4	N99/21	1	51/50	a	9	2	1				4							5	10.8
4	N99/21	1	51/50	b	4	2					1							1	1.1
4	N99/21	1	51/50	b	9	1								3		7	99	1	0.01
4	N99/21	1	51/50	b	9	1	2			1	2		1					5	5.3
4	N99/21	1	51/50	c	4	1								39		15	99	1	0.4
4	N99/21	1	51/50	d	4	1					1		1					1	1.1
4	N99/21	1	51/50	d	4	2					1							1	1.9

Table 27, continued on next page: Finds from site catalogue no. 4, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Total number	Weight/g
4	N99/21	1	51/51	a	4	1	1											1	0.01
4	N99/21	1	51/51	a	6	1	1		2		2		2					5	14
4	N99/21	1	51/51	a	6	2					5							5	16.2
4	N99/21	1	51/51	a	6	2					1							1	210.5
4	N99/21	1	51/51	b	4	1								38		16	99	1	0.4
4	N99/21	1	51/51	b	6	1					1							1	0.8
4	N99/21	1	51/51	c	4	1					1							1	2.2
4	N99/21	1	51/51	c	4	1								60		28	Flake	1	7.5
4	N99/21	1	51/51	c	6	1	2		2		4		3					8	17.4
4	N99/21	1	51/51	c	6	1	2		2		4		3					8	17.4
4	N99/21	1	51/51	c	6	2			1		1							2	11.8
4	N99/21	1	51/51	d	6	1								43		14	99	1	0.4
4	N99/21	1	51/51	d	16	2								18		21	Flake	1	0.8
4	N99/21	3	70/45	a	12	1		1					1					2	1
4	N99/21	3	70/45	a	16	1	3											3	0.2
4	N99/21	3	70/45	a	20	1	1											1	0.2
4	N99/21	3	70/45	a	32	1	1	1					1					2	0.3
4	N99/21	3	70/45	a	36	2			1		1		1					2	1.5
4	N99/21	3	70/45	a	40	2					2							2	3
4	N99/21	3	70/45	a	49	1					1							1	0.3
4	N99/21	3	70/45	a	62	2		1										1	0.8
4	N99/21	3	70/45	a	65	2					1							1	11.2
4	N99/21	3	70/45	a	70	1	1											1	0.01
4	N99/21	3	70/45	a	74	1	5	1					2					6	0.9
4	N99/21	3	70/45	a	78	1	1				1		1					2	1
4	N99/21	3	70/45	a	82	1	2		2				2					4	1.1
4	N99/21	3	70/45	a	86	1	3						2					3	0.2
4	N99/21	3	70/45	a	86	2	1											1	0.01
4	N99/21	3	70/45	a	90	1							1	40		16	Flake	1	0.5
4	N99/21	3	70/45	a	90	1	2	1			1		3					4	1.9
4	N99/21	3	70/45	a	94	1	4				1		1					5	0.5
4	N99/21	3	70/45	a	98	1	2				1							3	0.6
4	N99/21	3	70/45	a	98	2									1	80		1	145
4	N99/21	3	70/45	a	104	1					1		1					1	1.5
4	N99/21	3	70/45	b	6	2					3		1					3	14
4	N99/21	3	70/45	b	6	23					1							1	2.7
4	N99/21	3	70/45	b	13	2					2							2	0.8
4	N99/21	3	70/45	b	37	1	1											1	0.1
4	N99/21	3	70/45	b	37	23	1											1	0.2
4	N99/21	3	70/45	b	50	2					1							1	1.8
4	N99/21	3	70/45	b	62	1	2											2	0.2
4	N99/21	3	70/45	b	62	2			1		1							2	12.4
4	N99/21	3	70/45	b	66	1			1				1					1	0.4

Table 27, continued from previous page and continued on next page: Finds from site catalogue no. 4, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Total number	Weight/g
4	N99/21	3	70/45	b	71	1	1											1	0.01
4	N99/21	3	70/45	b	75	1	2											2	0.01
4	N99/21	3	70/45	b	75	2	2											2	0.1
4	N99/21	3	70/45	b	79	2		1			1		1					2	2.6
4	N99/21	3	70/45	b	83	1			1									1	0.1
4	N99/21	3	70/45	b	87	1	4	1	1				1					6	7.6
4	N99/21	3	70/45	b	91	1	3		1		3							7	1.9
4	N99/21	3	70/45	b	91	2	3				1							4	0.6
4	N99/21	3	70/45	b	95	1	1											1	0.01
4	N99/21	3	70/45	b	95	2	1				1		1					2	0.5
4	N99/21	3	70/45	b	101	1	3		1									4	0.9
4	N99/21	3	70/45	c	7	1					1							1	1.1
4	N99/21	3	70/45	c	7	2			1									1	5.9
4	N99/21	3	70/45	c	22	1					1		1					1	8.7
4	N99/21	3	70/45	c	34	2					2							2	16.5
4	N99/21	3	70/45	c	39	1					1							1	0.4
4	N99/21	3	70/45	c	39	2					2							2	7.1
4	N99/21	3	70/45	c	52	2					1							1	6.7
4	N99/21	3	70/45	c	72	1	1											1	0.01
4	N99/21	3	70/45	c	76	1	3											3	0.1
4	N99/21	3	70/45	c	76	1	1											1	0.01
4	N99/21	3	70/45	c	80	1	1				1							2	1.1
4	N99/21	3	70/45	c	84	1	4	2			3		1					9	3.2
4	N99/21	3	70/45	c	84	2	3											3	0.2
4	N99/21	3	70/45	c	88	1	5				1							6	0.7
4	N99/21	3	70/45	c	88	2	1											1	0.1
4	N99/21	3	70/45	c	92	1	3											3	0.1
4	N99/21	3	70/45	c	92	2	2				2							4	1
4	N99/21	3	70/45	c	96	1	1											1	0.01
4	N99/21	3	70/45	c	102	1		1					1					1	1.6
4	N99/21	3	70/45	c	106	2		1					1					1	15.7
4	N99/21	3	70/45	d	5	1					1		1					1	0.4
4	N99/21	3	70/45	d	8	1	1		1									2	0.3
4	N99/21	3	70/45	d	8	2					1							1	0.7
4	N99/21	3	70/45	d	15	1	3				1		1					4	28.2
4	N99/21	3	70/45	d	19	1	2						1					2	0.1
4	N99/21	3	70/45	d	23	1	1											1	0.1
4	N99/21	3	70/45	d	27	1	1											1	0.01
4	N99/21	3	70/45	d	27	2	1											1	0.2
4	N99/21	3	70/45	d	35	1					1		1					1	0.5
4	N99/21	3	70/45	d	35	2			1									1	0.2
4	N99/21	3	70/45	d	38	2					2		1					2	1.2
4	N99/21	3	70/45	d	68	1	2											2	0.1

Table 27, continued from previous page and continued on next page: Finds from site catalogue no. 4, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Total number	Weight/g
4	N99/21	3	70/45	d	68	2								18		13	Flake	1	0.4
4	N99/21	3	70/45	d	73	1	2											2	0.1
4	N99/21	3	70/45	d	77	1	1											1	0.1
4	N99/21	3	70/45	d	81	1	2											2	0.2
4	N99/21	3	70/45	d	85	1	3	1	1		1		2					3	5.3
4	N99/21	3	70/45	d	85	2	2											2	0.1
4	N99/21	3	70/45	d	89	1	5		1		1		2					7	1.1
4	N99/21	3	70/45	d	93	1	2		2				1					4	1.2
4	N99/21	3	70/45	d	97	2	1		2									3	2
4	N99/21	4	73/29	a	8	1					1							1	0.3
4	N99/21	4	73/29	a	32	1	1											1	0.01
4	N99/21	4	73/29	a	44	1	2											2	0.2
4	N99/21	4	73/29	b	5	1	1											1	0.01
4	N99/21	4	73/29	b	9	1	1											1	0.01
4	N99/21	4	73/29	c	6	2	1				1							2	0.5
4	N99/21	4	73/29	c	14	1	1				1							2	0.6
4	N99/21	4	73/29	c	26	1					1							1	0.5
4	N99/21	4	73/29	c	28	1					1							1	1.1
4	N99/21	4	73/29	d	11	1			1		1							2	0.8
4	N99/21	4	73/29	d	19	1					1							1	0.5
4	N99/21	4	73/29		2	1			1				1					1	0.5
4	N99/21	4	73/29		2	2					1							1	1.3
4	N99/21	5	75/14	a	53	1	1											1	0.2
4	N99/21	5	75/14	a	53	23					3							3	1.2
4	N99/21	5	75/14	b	50	1		1										1	1
4	N99/21	5	75/14	b	63	2							1	39		18	Flake	1	1.7
4	N99/21	5	75/14	c	60	1	1		1									2	0.6
4	N99/21	5	75/14	c	60	23					1							1	3.7
4	N99/21	5	75/14	d	52	23	3				4							7	6.2
4	N99/21	5	75/14	d	73	23					1							1	1.1
4	N99/21	6	48/94	a	5	1	5		3		4		1					12	3.1
4	N99/21	6	48/94	a	5	2		1			2							3	15.4
4	N99/21	6	48/94	a	6	1		2	4	1	4		2					11	14.9
4	N99/21	6	48/94	a	6	1							1	55		55	Flake	1	13
4	N99/21	6	48/94	a	6	1								43		9	99	1	0.3
4	N99/21	6	48/94	a	6	2			1									1	0.6
4	N99/21	6	48/94	c	7	1		1										1	0.4
4	N99/21	6	48/94	c	7	2					1							1	0.6
4	N99/21	6	48/94	c	8	1		2	1	1	2		5					6	17.1
4	N99/21	6	48/94	c	8	2					1							1	0.8
4	N99/21	6	48/94	d	3	1	1	1					1					2	0.9
4	N99/21	6	48/94	d	3	2			1									1	0.5
4	N99/21	6	48/94	d	4	1		1										1	3.4

Table 27, continued from previous page and continued on next page: Finds from site catalogue no. 4, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Natural stones	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Total number	Weight/g
4	N99/21	7	45/89	a	4	1			1		1		1					2	4
4	N99/21	7	45/89	a	4	2				1								1	3.6
4	N99/21	7	45/89	b	1	1								17		24	99	1	1.1
4	N99/21	7	45/89	b	4	1		1			1		1					1	1.3
4	N99/21	7	45/89	b	4	1								39		15	99	1	0.2
4	N99/21	7	45/89	b	4	2		1	1		1							3	6.9
4	N99/21	7	45/89	b	5	1		2					2					2	1.9
4	N99/21	7	45/89	b	5	2					1							1	0.9
4	N99/21	7	45/89	b	6	1		1	2				2					3	3.2
4	N99/21	7	45/89	b	7	1		1	1		2		2					4	7.1
4	N99/21	7	45/89	b	7	1								38		14	Blade	1	0.4
4	N99/21	7	45/89	b	7	2					2		2					2	10.2
4	N99/21	7	45/89	c	4	1	1											1	0.05
4	N99/21	7	45/89	d	4	1	1	1										2	0.9
4	N99/21	7	45/89	d	4	2			1									1	0.3
4	N99/21	7	45/90	d	9	1				1								1	0.3
4	N99/21	7	45/90	d	9	2		1					1					1	7.1
4	N99/21	7	45/90	d	10	2		1				1	1					2	4.7
4	N99/21	7	45/90	d	11	1		1		1	1							3	1.6
4	N99/21	7	45/90	d	11	1							1		12.2	30		1	12.2
4	N99/21	7	45/90	d	11	1					1		1					1	13.2
4	N99/21	7	45/90	d	11	2		1			1							2	1.1
4	N99/21	7	45/90	d	12	1	1		1									1	0.6
4	N99/21	7	45/90	d	12	2		2			2							4	29.8
4	N99/21	7	45/90	d	12	23		1										1	9.1
4	N68/02	B1592			0-3“	1				1			1					1	1.9
4	N68/02	B1592			0-3“	2					1		1					1	19
4	N68/02	B1592			3-9“	2					2							2	3.8
4	N68/02	B1592			9-12“	1			1		1		2					2	0.9
4	N68/02	B1592			12-15“	1			1		1		2					2	0.9
4	N68/02	B1592			12-15“	2					1							1	1.8
4	N68/02	B1592			15-18“	2					1							1	3.4
4	N68/02	B1592			18-24“	1		1	1		1		1					3	10.7
4	N68/02	B1592			18-24“	2		3			17		5					20	159.1
4	N68/02	B1592			24-30“	1		1			2		1					3	10.9
4	N68/02	B1592			24-30“	2		2			20							22	87.6
4	N68/02	B1592			30-36“	1		1					1					1	13.5
4	N68/02	B1592			30-36“	2		1			2		1					3	21
4	N68/02	B1592			36-42“	1		2			1		3					3	44.3
4	N98/38					1									7	29		1	15.1

Table 27, continued from previous page: Finds from site catalogue no. 4, lithics.

	Tool type						
Area	**1**	**3**	**12**	**17**	**18**	**23**	**38**
	Micro-segment < 25 mm	Micro-segment < 14 mm	Short micro-point, unilaterally retouched	Short micro-point, symmetrically bilaterally retouched	Short micro-point, asymmetrically bilaterally retouched	Terminally retouched micro-point, oblique	Laterally fine retouched microlith
N99/21-1	1	2	1		1	1	1
N99/21-3					1		
N99/21-6							
N99/21-7				1			1

	Tool type					
	39	**40**	**43**	**55**	**56**	**60**
	Laterally retouched microlith	Backed microlith	Miscellaneous microliths < 25 mm	Denticulate > 25 mm	Borer > 25 mm	Mischellaneous artifacts > 25 mm
N99/21-1	1		1		1	2
N99/21-3		1				
N99/21-6			1	1		
N99/21-7	1					

Table 28: Finds from site catalogue no. 4, lithic tool types in number.

SC no.	Site no.	Area	Unit	Quadrant	Level	Pottery			Burnt clay	OES beads	OES preforms	OES debris	Faunal remains	Botanical remains	Glass	Plastics	Weight/g
							Dec.	**Undec.**									
12	N96/03	2			0-2	1	1										23
12	N96/03	2			0-3					1							0.5
12	N96/03	2			0-3	1	1										4
12	N96/03	2			0-4					1							0.5
12	N96/03	2			0-5	1	1										18
12	N96/03	3	88/25	b	5	1		1									4.8
12	N96/03	3	88/26	b	7	4		4									25.2
12	N96/03	3	88/26	b	18	4		4									13.5
12	N96/03	3	88/26	b	19	21	1	20									117.3
12	N96/03	3	88/26	b	19						1						0.5
12	N96/03	3	88/26	b	21	20	20	18									48.7
12	N96/03	3	88/28	b	11	1		1									0.5
12	N96/03	3	88/28	d	20	4		4									16,.7
12	N96/03	3	88/29	b	13	5		5									35.4
12	N96/03	3	88/29	b	13								1				0.5
12	N96/03	3	88/29	d	14	5		5									16.2

Table 29, continued on next page: Finds from site catalogue no. 12, pottery, burnt clay, OES artifacts, faunal remains, botanical remains, glass, and plastics.

SC no.	**Site no.**	**Area**	**Unit**	**Quadrant**	**Level**	**Pottery**			**Burnt clay**	**OES beads**	**OES preforms**	**OES debris**	**Faunal remains**	**Botanical remains**	**Glass**	**Plastics**	**Weight/g**
							Dec.	**Undec.**									
12	N96/04	Surface				2		2									31
12	N96/04	Surface			0-2	3	3										13
12	N98/30					5	5										55
12	N98/32	2	30/29		13	33		33									84
12	N98/32	2	30/29	a	13								3				58
12	N98/32	2	30/29	b	13								4				22
12	N98/32	2	30/29	c	13								4				22
12	N98/32	2	30/29	d	13								5				80
12	N98/32	2	31/21	d	26					1							0.1
12	N98/32	2	31/29	a	23	19	1	18									89.1
12	N98/32	2	31/29	a	23						2						0.7
12	N98/32	2	31/29	a	23								13				11
12	N98/32	2	31/29	b	15	7	1	6									8.6
12	N98/32	2	31/29	b	15								2				1
12	N98/32	2	31/29	b	16	10	1	9									20.1
12	N98/32	2	31/29	b	16					1							0.01
12	N98/32	2	31/29	b	16								19				7
12	N98/32	2	31/29	b	18	26		26									91.5
12	N98/32	2	31/29	b	18				1								3
12	N98/32	2	31/29	b	18								9				79
12	N98/32	2	31/29	b	24	17	3	14									137.5
12	N98/32	2	31/29	b	24					3							0.8
12	N98/32	2	31/29	b	24								16				96
12	N98/32	2	31/29	b	33					1							0.1
12	N98/32	2	31/29	b	33								6				192
12	N98/32	2	31/29	b	33	20	2	18									99.7
12	N98/32	2	31/29	b	36								28				76
12	N98/32	2	31/29	b	36	32		32									91.2
12	N98/32	2	31/29	b	42								63				52
12	N98/32	2	31/29	b	42	6		6									7.2
12	N98/32	2	31/29	d	22	10		10									30.8
12	N98/32	2	31/29	d	22								8				19
12	N98/32	2	31/29	d	26						1						0.4
12	N98/32	2	31/29	d	26								10				82
12	N98/32	2	31/29	d	26	39	1	38									171.3
12	N98/32	2	31/29	d	34						3						3.1
12	N98/32	2	31/29	d	34								34				104
12	N98/32	2	31/29	d	34	21		21									181.3
12	N98/32	2	31/29	d	37								88				146
12	N98/32	2	31/29	d	37	10	3	7									68.7
12	N98/32	2	31/29	d	43						1						0.3
12	N98/32	2	31/29	d	43								12				74

Table 29, continued from previous page and continued on next page: Finds from site catalogue no. 12, pottery, burnt clay, OES artifacts, faunal remains, botanical remains, glass, and plastics.

SC no.	**Site no.**	**Area**	**Unit**	**Quadrant**	**Level**	**Pottery**			**Burnt clay**	**OES beads**	**OES preforms**	**OES debris**	**Faunal remains**	**Botanical remains**	**Glass**	**Plastics**	**Weight/g**
							Dec.	**Undec.**									
12	N98/32	2	31/29	d	43	11		11									35.6
12	N98/32	2	31/29		14	5		5									15
12	N98/32	2	33/19	a	5	3		3									9
12	N98/32	2	33/19	b	5	9		9									25.8
12	N98/32	2	33/20	a	5	14	2	12									27.3
12	N98/32	2	33/20	b	5	14		14									29
12	N98/32	2	33/20	c	5	20	2	18									47.2
12	N98/32	2	33/20	d	5	7	1	6									14.1
12	N98/32	2	33/20	d	5									1			1
12	N98/32	2	33/20	d	49	6		6									15.6
12	N98/32	2	33/20	d	49								11				18
12	N98/32	2	33/21	a	5	7	1	6									23.6
12	N98/32	2	33/21	a	5						2						0.4
12	N98/32	2	33/21	a	5								3				1
12	N98/32	2	33/21	b	5	8		8									29.1
12	N98/32	2	33/21	b	5						1						0.6
12	N98/32	2	33/21	b	5								3				16
12	N98/32	2	33/21	c	5					1							0.1
12	N98/32	2	33/21	c	5								2				1
12	N98/32	2	33/21	c	5	11	4	7									19.9
12	N98/32	2	33/21	d	5					1							0.1
12	N98/32	2	33/21	d	5	10		10									23.4
12	N98/32	2	33/22	a	5	3		3									10.2
12	N98/32	2	33/22	a	5								1				1
12	N98/32	2	33/22	c	5	7	1	6									25.2
12	N98/32	2	33/22	c	5					2							0.5
12	N98/32	2	33/22	d	5						2						1.8
12	N98/32	2	33/22	d	5								6				5
12	N98/32	2	33/22	d	5	17	1	16									36.7
12	N98/32	2	33/23	a	5	15		15									54
12	N98/32	2	33/23	a	58	1		1									2
12	N98/32	2	33/23	a	5						1						0.3
12	N98/32	2	33/23	b	5	4	2	2									10.7
12	N98/32	2	33/23	b	5						1						0.3
12	N98/32	2	33/23	c	5	4		4									17.9
12	N98/32	2	33/23	c	5						2						0.4
12	N98/32	2	33/23	d	5	10		10									30.3
12	N98/32	2	33/24	a	5	5		5									15.3
12	N98/32	2	33/24	a	5						1						0.3
12	N98/32	2	33/24	a	5								2				2
12	N98/32	2	33/24	b	5					1							0.7
12	N98/32	2	33/24	b	5								1				1

Table 29, continued from previous page and continued on next page: Finds from site catalogue no. 12, pottery, burnt clay, OES artifacts, faunal remains, botanical remains, glass, and plastics.

SC no.	Site no.	Area	Unit	Quadrant	Level	Pottery			Burnt clay	OES beads	OES preforms	OES debris	Faunal remains	Botanical remains	Glass	Plastics	Weight/g
							Dec.	Undec.									
12	N98/32	2	33/24	b	5	12		12									29.1
12	N98/32	2	33/24	c	5	15	1	14									36.1
12	N98/32	2	33/24	c	5								2				4
12	N98/32	2	33/24	d	5	16		16									54.9
12	N98/32	2	33/24		61	14	2	12									57.6
12	N98/32	2	33/24		61								1				1
12	N98/32	2	34/19	a	5	3		3									15.6
12	N98/32	2	34/19	b	5	10	2	8									33.6
12	N98/32	2	34/19	c	5								3				3
12	N98/32	2	34/20	a	5	12	1	11									33.2
12	N98/32	2	34/20	a	5								2				14
12	N98/32	2	34/20	b	5	13	1	12									32.9
12	N98/32	2	34/20	b	5					1							0.1
12	N98/32	2	34/20	b	5						1						0.4
12	N98/32	2	34/20	b	5								3				19
12	N98/32	2	34/20	c	5	16		16									33.1
12	N98/32	2	34/20	c	5					1							0.1
12	N98/32	2	34/20	d	5					1							0.1
12	N98/32	2	34/20	d	5	11	1	10									39
12	N98/32	2	34/20		50	8		8									19.1
12	N98/32	2	34/21		53					1							0.2
12	N98/32	2	34/21	a	5	16	1	15									27
12	N98/32	2	34/21	a	5					1							0.1
12	N98/32	2	34/21	b	5	19		19									52.4
12	N98/32	2	34/21	c	5	11		11									60.2
12	N98/32	2	34/21	c	5								2				6
12	N98/32	2	34/21	d	5	32	1	31									108.1
12	N98/32	2	34/21		53	9		9									25.8
12	N98/32	2	34/22	a	5						1						0.4
12	N98/32	2	34/22	b	5	19	2	17									39.4
12	N98/32	2	34/22	c	5	17	2	15									38.5
12	N98/32	2	34/22	c	5					2							0.2
12	N98/32	2	34/22	c	5						3						1.4
12	N98/32	2	34/22	d	5	20		20									59.5
12	N98/32	2	34/22	d	5						2						1.2
12	N98/32	2	34/22	d	5								2				3
12	N98/32	2	34/23	a	17	36	4	32									119.3
12	N98/32	2	34/23	a	17					1							0.3
12	N98/32	2	34/23	a	17						1						0.3
12	N98/32	2	34/23	a	17								8				7
12	N98/32	2	34/23	a	20	20	2	18									68.5
12	N98/32	2	34/23	a	20					1							0.1

Table 29, continued from previous page and continued on next page: Finds from site catalogue no. 12, pottery, burnt clay, OES artifacts, faunal remains, botanical remains, glass, and plastics.

SC no.	Site no.	Area	Unit	Quadrant	Level	Pottery			Burnt clay	OES beads	OES preforms	OES debris	Faunal remains	Botanical remains	Glass	Plastics	Weight/g
							Dec.	Undec.									
12	N98/32	2	34/23	a	20						2						1.2
12	N98/32	2	34/23	a	20								8				6
12	N98/32	2	34/23	a	29	19		19									175.4
12	N98/32	2	34/23	a	29						4						2.3
12	N98/32	2	34/23	a	29								18				32
12	N98/32	2	34/23	a	32	19	4	15									63.9
12	N98/32	2	34/23	a	32						2						1
12	N98/32	2	34/23	a	32								15				36
12	N98/32	2	34/23	a	63								1				215
12	N98/32	2	34/23	b	5	6		6									13.6
12	N98/32	2	34/23	b	8	1	1										15
12	N98/32	2	34/23	b	10	1		1									0.5
12	N98/32	2	34/23	b	10								1				1
12	N98/32	2	34/23	b	11	17	1	16									136.9
12	N98/32	2	34/23	b	11						2						0.4
12	N98/32	2	34/23	b	11							1					0.1
12	N98/32	2	34/23	b	11								27				48
12	N98/32	2	34/23	b	12								13				46
12	N98/32	2	34/23	b	21								14				6
12	N98/32	2	34/23	b	38	38		38									134.4
12	N98/32	2	34/23	b	38					2							0.2
12	N98/32	2	34/23	b	38						1						0.1
12	N98/32	2	34/23	b	38								45				126
12	N98/32	2	34/23	b	40	20		20									55.2
12	N98/32	2	34/23	b	40						5						3.2
12	N98/32	2	34/23	b	40								31				81
12	N98/32	2	34/23	b	41	16		16									69.6
12	N98/32	2	34/23	b	41								16				36
12	N98/32	2	34/23	c	5	6		6									17.2
12	N98/32	2	34/23	c	21								1				5
12	N98/32	2	34/23	c	25								5				3
12	N98/32	2	34/23	c	27	12		12									44.9
12	N98/32	2	34/23	c	27					1							0.5
12	N98/32	2	34/23	c	27						2						0.6
12	N98/32	2	34/23	c	27								5				6
12	N98/32	2	34/23	c	28	23	2	21									67.5
12	N98/32	2	34/23	c	28								18				36
12	N98/32	2	34/23	d	5	7		7									14.8
12	N98/32	2	34/23	d	19	4		4									13.4
12	N98/32	2	34/23	d	21	45	5	40									151.9
12	N98/32	2	34/23	d	21					1							0.5
12	N98/32	2	34/23	d	21						1						0.5

Table 29, continued from previous page and continued on next page: Finds from site catalogue no. 12, pottery, burnt clay, OES artifacts, faunal remains, botanical remains, glass, and plastics.

SC no.	Site no.	Area	Unit	Quadrant	Level	Pottery			Burnt clay	OES beads	OES preforms	OES debris	Faunal remains	Botanical remains	Glass	Plastics	Weight/g
							Dec.	Undec.									
12	N98/32	2	34/23	d	21								14				17
12	N98/32	2	34/23	d	35					1							0.5
12	N98/32	2	34/23	d	35								9				96
12	N98/32	2	34/23	d	35	29	2	27									138.4
12	N98/32	2	34/23	d	39	22	1	21									107
12	N98/32	2	34/23		59	15	2	13									64
12	N98/32	2	34/23		59								1				1
12	N98/32	2	34/23 oder 31/29								1						0.5
12	N98/32	2	34/23 oder 31/29										62				64
12	N98/32	2	34/32	b	24								4				2
12	N98/32	2	35/19	a	5	7	1	6									15.9
12	N98/32	2	35/19	a	5								2				9
12	N98/32	2	35/19	b	5	12		12									32.2
12	N98/32	2	35/19	b	5								1				13
12	N98/32	2	35/19	d	5								1				1
12	N98/32	2	35/20	a	5	12	1	11									17.3
12	N98/32	2	35/20	b	5	10		10									16.2
12	N98/32	2	35/20	b	5					1							0.5
12	N98/32	2	35/21	a	5	17	1	16									39.4
12	N98/32	2	35/21	a	5					2							1
12	N98/32	2	35/21	a	5								3				2
12	N98/32	2	35/21	b	5	5	1	4									9
12	N98/32	2	35/21	c	5	16	2	14									77
12	N98/32	2	35/21	c	5					1							0.5
12	N98/32	2	35/21	d	5						1						0.5
12	N98/32	2	35/21	d	5								1				1
12	N98/32	2	35/21	d	5	12	1	11									32.4
12	N98/32	2	35/21		54	25	4	21									102.8
12	N98/32	2	35/21		54								2				3
12	N98/32	2	35/22	a	5	29	1	28									56.9
12	N98/32	2	35/22	b	5	2		2									4.9
12	N98/32	2	35/22	c	5	12	1	11									57.2
12	N98/32	2	35/23	a	5	3		3									3.4
12	N98/32	2	35/23	b	5	2		2									6
12	N98/32	2	35/23	c	5	5		5									6.2
12	N98/32	2	35/23	c	5					1							0.5
12	N98/32	2	35/23	d		2	1	1									7.5
12	N98/32	2	35/23		60	2		2									11.6
12	N98/32	2	35/24	b	5	1	1										1

Table 29, continued from previous page and continued on next page: Finds from site catalogue no. 12, pottery, burnt clay, OES artifacts, faunal remains, botanical remains, glass, and plastics.

SC no.	Site no.	Area	Unit	Quadrant	Level	Pottery			Burnt clay	OES beads	OES preforms	OES debris	Faunal remains	Botanical remains	Glass	Plastics	Weight/g
							Dec.	Undec.									
12	N98/32	2	35/24	d	5	3		3									4.9
12	N98/32	2	50/50	a	6	4		4									5.8
12	N98/32	2	50/50	a	6										1		0.01
12	N98/32	2	50/50	a	6										2		2.3
12	N98/32	2	50/50	a	6								1				12.5
12	N98/32	2	50/50	a	9	20		20									60
12	N98/32	2	50/50	a	9					1							0.5
12	N98/32	2	50/50	a	9						1						0.5
12	N98/32	2	50/50	a	9								93				37.5
12	N98/32	2	50/50	b	6	3		3									2.8
12	N98/32	2	50/50	b	6					5							2.5
12	N98/32	2	50/50	b	6						1						0.5
12	N98/32	2	50/50	b	6										1		0.3
12	N98/32	2	50/50	b	6								23				7
12	N98/32	2	50/50	b	9	28		28									92
12	N98/32	2	50/50	b	9					2							1
12	N98/32	2	50/50	b	9						2						1
12	N98/32	2	50/50	b	9								38				28
12	N98/32	2	50/50	b	9//1	1		1									7
12	N98/32	2	50/50	b	9//2								2				3
12	N98/32	2	50/50	b	9//4								10				22
12	N98/32	2	50/50	c	6						1						0.5
12	N98/32	2	50/50	c	6								6				11
12	N98/32	2	50/50	d	6	7	1	6									7.9
12	N98/32	2	50/50	d	6					2							1
12	N98/32	2	50/50	d	6						3						1.5
12	N98/32	2	50/50	d	6								8				2
12	N98/32	2	50/51	a	6	2	2										6
12	N98/32	2	50/51	a	6					1							0.5
12	N98/32	2	50/51	a	6								6				3
12	N98/32	2	50/51	a	9	21	2	19									43
12	N98/32	2	50/51	a	9							1					0.5
12	N98/32	2	50/51	a	9								60				38.5
12	N98/32	2	50/51	b	6	9		9									26
12	N98/32	2	50/51	b	6					2							1
12	N98/32	2	50/51	b	6						1						0.5
12	N98/32	2	50/51	b	6							1					0.5
12	N98/32	2	50/51	b	6											1	0.1
12	N98/32	2	50/51	b	6								28				7
12	N98/32	2	50/51	b	9	42	3	39									110.6
12	N98/32	2	50/51	b	9						1						0.5
12	N98/32	2	50/51	b	9				6								30.8

Table 29, continued from previous page and continued on next page: Finds from site catalogue no. 12, pottery, burnt clay, OES artifacts, faunal remains, botanical remains, glass, and plastics.

SC no.	**Site no.**	**Area**	**Unit**	**Quadrant**	**Level**	**Pottery**			**Burnt clay**	**OES beads**	**OES preforms**	**OES debris**	**Faunal remains**	**Botanical remains**	**Glass**	**Plastics**	**Weight/g**
							Dec.	**Undec.**									
12	N98/32	2	50/51	b	9								40				34
12	N98/32	2	50/51	c	6	28		28									76.3
12	N98/32	2	50/51	c	6						1						0.5
12	N98/32	2	50/51	c	6							2					1
12	N98/32	2	50/51	c	6										1		0.01
12	N98/32	2	50/51	c	6										1		3.1
12	N98/32	2	50/51	c	6								16				4
12	N98/32	2	50/51	c	9	18		18									64
12	N98/32	2	50/51	c	9								39				31
12	N98/32	2	50/51	d	6	12		12									20.2
12	N98/32	2	50/51	d	6					1							0.5
12	N98/32	2	50/51	d	6						2						1
12	N98/32	2	50/51	d	6									1			1
12	N98/32	2	50/51	d	6								29				46
12	N98/32	2	50/51	d	9	47	5	42									207.5
12	N98/32	2	50/51	d	9				1								4.5
12	N98/32	2	50/51	d	9									1			1
12	N98/32	2	50/51	d	9								59				24
12	N98/32	2	50/51		9//2								3				11
12	N98/32	2	51/50	a	6	15		15									23
12	N98/32	2	51/50	a	6					1							0.5
12	N98/32	2	51/50	a	6							1					0.5
12	N98/32	2	51/50	a	6								61				45.5
12	N98/32	2	51/50	a	9	57	1	56									139.3
12	N98/32	2	51/50	a	9					2							1
12	N98/32	2	51/50	a	9						6						3
12	N98/32	2	51/50	a	9								263				53
12	N98/32	2	51/50	a	9//1								2				43
12	N98/32	2	51/50	a	9//2	1		1									1
12	N98/32	2	51/50	b	6	10		10									19.4
12	N98/32	2	51/50	b	6					4							2
12	N98/32	2	51/50	b	6						3						1.5
12	N98/32	2	51/50	b	6								37				9
12	N98/32	2	51/50	b	9	44	5	39									102.5
12	N98/32	2	51/50	b	9					4							2
12	N98/32	2	51/50	b	9						4						2
12	N98/32	2	51/50	b	9						2						1
12	N98/32	2	51/50	b	9								144				56
12	N98/32	2	51/50	b	9//1								7				8
12	N98/32	2	51/50	b	9//2	1		1									3.3
12	N98/32	2	51/50	b	9//3	1		1									3.6
12	N98/32	2	51/50	b	9//4								3				23

Table 29, continued from previous page and continued on next page: Finds from site catalogue no. 12, pottery, burnt clay, OES artifacts, faunal remains, botanical remains, glass, and plastics.

SC no.	**Site no.**	**Area**	**Unit**	**Quadrant**	**Level**	**Pottery**			**Burnt clay**	**OES beads**	**OES preforms**	**OES debris**	**Faunal remains**	**Botanical remains**	**Glass**	**Plastics**	**Weight/g**
							Dec.	**Undec.**									
12	N98/32	2	51/50	c	6	5		5									5
12	N98/32	2	51/50	c	6					1							0.5
12	N98/32	2	51/50	c	6								9				2
12	N98/32	2	51/50	c	9	37	4	33									90
12	N98/32	2	51/50	c	9					1							0.5
12	N98/32	2	51/50	c	9						1						0.5
12	N98/32	2	51/50	c	9							2					1
12	N98/32	2	51/50	c	9								169				43
12	N98/32	2	51/50	c	9//1								7				59
12	N98/32	2	51/50	c	9//2	1		1									1
12	N98/32	2	51/50	c	9//2								4				1
12	N98/32	2	51/50	d	6	4		4									17
12	N98/32	2	51/50	d	6					3							1.5
12	N98/32	2	51/50	d	6							2					1
12	N98/32	2	51/50	d	6								24				5
12	N98/32	2	51/50	d	9						6						3
12	N98/32	2	51/50	d	9								72				27
12	N98/32	2	51/50	d	9	18	1	17									67.5
12	N98/32	2	51/50	d	9//2								1				22
12	N98/32	2	51/50	d	9//3	1		1									15
12	N98/32	2	51/51	a	6	17	1	16									33.2
12	N98/32	2	51/51	a	6					1							0.5
12	N98/32	2	51/51	a	6									1			1
12	N98/32	2	51/51	a	6										3		4.8
12	N98/32	2	51/51	a	6								3				7
12	N98/32	2	51/51	a	9	15	4	11									39
12	N98/32	2	51/51	a	9								2				30
12	N98/32	2	51/51	a	9//1	3		3									1.8
12	N98/32	2	51/51	a	9//1								3				3
12	N98/32	2	51/51	b	6	17	2	15									43.3
12	N98/32	2	51/51	b	6					1							0.5
12	N98/32	2	51/51	b	6						3						1.5
12	N98/32	2	51/51	b	6							2					1
12	N98/32	2	51/51	b	6											6	0.01
12	N98/32	2	51/51	b	6								87				42
12	N98/32	2	51/51	b	9	1		1									1
12	N98/32	2	51/51	b	9								12				1
12	N98/32	2	51/51	c	6	9		9									12
12	N98/32	2	51/51	c	6					1							0.5
12	N98/32	2	51/51	c	6										1		0.5
12	N98/32	2	51/51	c	6								26				16
12	N98/32	2	51/51	c	9	48	6	43									223.2

Table 29, continued from previous page and continued on next page: Finds from site catalogue no. 12, pottery, burnt clay, OES artifacts, faunal remains, botanical remains, glass, and plastics.

SC no.	Site no.	Area	Unit	Quadrant	Level	Pottery			Burnt clay	OES beads	OES preforms	OES debris	Faunal re-mains	Botanical remains	Glass	Plastics	Weight/g
							Dec.	Undec.									
12	N98/32	2	51/51	c	9					1							0.5
12	N98/32	2	51/51	c	9								159				171.5
12	N98/32	2	51/51	c	14								7				5
12	N98/32	2	51/51	c	9//1								5				16
12	N98/32	2	51/51	c	9//3								1				110
12	N98/32	2	51/51	c	9//4								1				120
12	N98/32	2	51/51	d	6	27		27									66.1
12	N98/32	2	51/51	d	6					2							1
12	N98/32	2	51/51	d	6						5						2.5
12	N98/32	2	51/51	d	6										1		0.3
12	N98/32	2	51/51	d	6								118				44.5
12	N98/32	2	51/51	d	9	15	2	13									29.5
12	N98/32	2	51/51	d	9					3							1.5
12	N98/32	2	51/51	d	9						1						0.5
12	N98/32	2	51/51	d	9				3								57.5
12	N98/32	2	51/51	d	9//1								1				1
12	N98/32	Suf. 1				3	1										16
12	N98/32	Suf. 2									1						0.5
12	N98/32	Suf. 2				8	6	2									31
12	N98/32	Surf. 3				19		1									89.4
12	N98/32	Surf. 4a				40	38	2									286
12	N98/32	Surf. 4a								13							19.5
12	N98/32	Surf. 4b								56							28
12	N98/32	Surf. 4b									56						28
12	N98/32	Surf. 4b										4					0.5
12	N98/32	Surf. 4b				52	50	2									265
12	N98/32	Surf. 4b									2						1
12	N98/32	Surf. 4b										3					1.5
12	N98/32	Surf. 4c								2							1
12	N98/32	Surf. 4c									1						0.5
12	N98/32	Surf. 4c				6	6										9
12	N98/32	Surf. 5				18	16	2									187
12	N98/32	Surf. 6				2	2										11
12	N98/32	Surf. 7				3	2	1									41.7
12	N98/32	Surface								5							1.9
12	N98/32	Surface				23	18	5									217
12	N98/32	Surface							1								31
12	N98/32	Surface											7				41
12	N98/34					8		8									44
12	N98/35					1	1										9
12	N98/36					6	2	4									61
12	N98/37					1	1										10

Table 29, continued from previous page: Finds from site catalogue no. 12, pottery, burnt clay, OES artifacts, faunal remains, botanical remains, glass, and plastics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Total number	Weight/g
12	N96/03	3	88/26	b	18	2		1									1	11.8
12	N96/03	3	88/26	b	19	2		1									1	23.2
12	N96/03	3	88/26	b	19	1					1						1	1.4
12	N96/03	3	88/26	b	7	1					1						1	0.5
12	N96/03	3	88/29	b	13	1	1		1		1						3	0.7
12	N96/03	3	88/29	b	13	2		2				1					1	11.2
12	N98/32	2	31/29	d	37	1			1			1					1	0.4
12	N98/32	2	31/29	d	37	1						1	39		13	Flake	1	0.4
12	N98/32	2	31/29	a	23	2		1			1						2	1.6
12	N98/32	2	31/29	b	14	2		1									1	1.4
12	N98/32	2	31/29	b	14	1					1						1	0.4
12	N98/32	2	31/29	b	16	2	2										2	0.2
12	N98/32	2	31/29	b	18	1			1								1	0.4
12	N98/32	2	31/29	b	24	2					1						1	1.8
12	N98/32	2	31/29	b	24	1					1	1					1	3.4
12	N98/32	2	31/29	b	33	2		1	1								2	4.7
12	N98/32	2	31/29	b	33	1							99		11	99	1	0.5
12	N98/32	2	31/29	b	36	2			1								1	0.4
12	N98/32	2	31/29	b	42	1			1			1					1	1.1
12	N98/32	2	31/29	d	26	2					1						1	2.2
12	N98/32	2	31/29	d	34	1	1	1				1					2	5.9
12	N98/32	2	31/29	d	37	1		1	1								2	4.7
12	N98/32	2	33/20	a	5	1		1				1					1	3.4
12	N98/32	2	33/20		49	1		1	1			2					2	1.7
12	N98/32	2	33/20		49	2					1						1	0.7
12	N98/32	2	33/23		58	1		1				1					1	1.6
12	N98/32	2	33/24	a	5	1					1	1					2	3.2
12	N98/32	2	33/24	a	5	1						1	43		17	Flake	1	2.4
12	N98/32	2	34/19	a	5	2					1						1	2.8
12	N98/32	2	34/20		50	1			1								1	1.2
12	N98/32	2	34/21	a	2						1						1	1
12	N98/32	2	34/21	a	5	1		1									1	1.9
12	N98/32	2	34/21	c	5	1		1				1					1	9.9
12	N98/32	2	34/21	c	5	1						1	63		51	Flake	1	9.9
12	N98/32	2	34/21	d	5	1			1			1					1	0.3
12	N98/32	2	34/21	d	5	2					1						1	1.4
12	N98/32	2	34/22	b	5	1					1						1	2.4
12	N98/32	2	34/22	b	5	2					1						1	2.5
12	N98/32	2	34/22	c	5	1		1									1	12.1
12	N98/32	2	34/22	d	5	2		1			1	1					2	3.2
12	N98/32	2	34/23	a	17	1					1	1					1	0.7
12	N98/32	2	34/23	a	20	1		1				1					1	2.5
12	N98/32	2	34/23	a	29	1		1									1	0.9

Table 30, continued on next page: Finds from site catalogue no. 12, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Total number	Weight/g
12	N98/32	2	34/23	a	29	1							38		16	Flake	1	0.9
12	N98/32	2	34/23	a	29	1					1						1	0.8
12	N98/32	2	34/23	a	32	1		2				1					2	6.4
12	N98/32	2	34/23	b	5	1			1								1	0.3
12	N98/32	2	34/23	b	11	1				1							1	2.3
12	N98/32	2	34/23	b	11	2		1									1	2
12	N98/32	2	34/23	b	11	2							43		22	Flake	1	2.2
12	N98/32	2	34/23	b	11	1					1						1	1.6
12	N98/32	2	34/23	b	38	2		1									1	8.1
12	N98/32	2	34/23	c	5	1	1					1					1	0.3
12	N98/32	2	34/23	c	27	1						1	56		53	Flake	1	21.3
12	N98/32	2	34/23	c	27	2		1									1	3
12	N98/32	2	34/23	c	27	1					2	1					2	3.1
12	N98/32	2	34/23	c	28	1					1						1	0.2
12	N98/32	2	34/23	d	21	1		1			1	2					2	7.8
12	N98/32	2	34/23	d	21	2					1						1	1.4
12	N98/32	2	34/23		59	2		1									1	1.4
12	N98/32	2	35/22	a	5	1		1				1					1	2.5
12	N98/32	2	35/22	a	5	2					1						1	0.7
12	N98/32	2	35/22	b	5	2		1									1	2.5
12	N98/32	2	35/22	c	5	1					1						1	1.4
12	N98/32	2	50/50	a	6	9			1								1	0.5
12	N98/32	2	50/50	a	6	1		1			1	1					2	2.8
12	N98/32	2	50/50	a	9	2			1								1	0.6
12	N98/32	2	50/50	b	6	23					1						1	0.4
12	N98/32	2	50/50	b	6	2					1						1	0.2
12	N98/32	2	50/50	b	9	2			1								1	0.3
12	N98/32	2	50/50	c	6	2					2						2	1.2
12	N98/32	2	50/50	c	6	1					1						1	0.4
12	N98/32	2	50/50	d	6	1	1			1							2	0.3
12	N98/32	2	50/50	d	6	2		1				1					1	18.1
12	N98/32	2	50/50	d	6	23					1						1	2.2
12	N98/32	2	50/50	d	6	4					1						1	4.9
12	N98/32	2	50/51	a	6	2		1			1						2	2
12	N98/32	2	50/51	a	6	1					1	1					1	0.4
12	N98/32	2	50/51	a	9	1					2	2					2	3.8
12	N98/32	2	50/51	b	9	1					1						1	0.3
12	N98/32	2	50/51	b	9	2	1										1	0.1
12	N98/32	2	50/51	c	6	2	1				2						3	1.5
12	N98/32	2	50/51	c	6	1											1	0.01
12	N98/32	2	50/51	c	9	2		1		1							1	1.7
12	N98/32	2	50/51	c	9	2						1		6	55		1	85.2
12	N98/32	2	50/51	d	6	9					1						1	0.7

Table 30, continued from previous page and continued on next page: Finds from site catalogue no. 12, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Total number	Weight/g
12	N98/32	2	50/51	d	6	2		1									1	1.5
12	N98/32	2	50/51	d	6	1			1			1					3	2.2
12	N98/32	2	50/51	d	9	2		1									1	0.9
12	N98/32	2	50/51	d	9	99					1						1	0.7
12	N98/32	2	51/50	a	6	1					2						2	0.4
12	N98/32	2	51/50	a	9	1	4				5	5					9	7.1
12	N98/32	2	51/50	a	9	2		1			2						3	7.8
12	N98/32	2	51/50	a	9	4					1						1	0.3
12	N98/32	2	51/50	a	9	99					1						1	0.2
12	N98/32	2	51/50	b	6	2					2						2	0.4
12	N98/32	2	51/50	b	6	4					1						1	0.3
12	N98/32	2	51/50	b	9	2	1		1		1						3	1.1
12	N98/32	2	51/50	b	9	1	1	1	1		6	7					9	23.3
12	N98/32	2	51/50	c	6	2					1						1	0.9
12	N98/32	2	51/50	c	6	1	1										1	0.01
12	N98/32	2	51/50	c	9	2		1									1	44.8
12	N98/32	2	51/50	c	9	1	2		1								3	1
12	N98/32	2	51/50	d	6	2					2						2	1.3
12	N98/32	2	51/50	d	9	1			1		2	1					3	1.6
12	N98/32	2	51/51	a	6	1	1				4	3					5	3.9
12	N98/32	2	51/51	a	6	2					1						1	0.8
12	N98/32	2	51/51	a	6	4					1						1	0.5
12	N98/32	2	51/51	a	9	1			1								1	3.3
12	N98/32	2	51/51	a	9//1	1	1				1						2	0.4
12	N98/32	2	51/51	b	6	1					4	3					4	7.1
12	N98/32	2	51/51	b	6	2	2		1								3	1
12	N98/32	2	51/51	b	6	4					1						1	0.2
12	N98/32	2	51/51	c	6	1	1				1	1					2	0.5
12	N98/32	2	51/51	c	6	2											2	0.1
12	N98/32	2	51/51	d	6	1	1		1		3						5	1.9
12	N98/32	2	51/51	d	9	2			1								1	0.5
12	N98/32	Surf. 2				2							55		28	Flake	1	3.3
12	N98/32	Surf. 2				1						1		5	41		1	30.8
12	N98/32	Surf. 4-5				1						1	46		28	99	1	1.8
12	N98/32	Surf. 4-5				1							18		15	99	1	0.4
12	N98/32	Surf. 4-5				1							23		20	99	1	2
12	N98/32	Surf. 4a				1						1		1	37		1	47.6
12	N98/32	Surf. 4a				2								5	48		1	38.4
12	N98/32	Surf. 4a				1						1	60		28	Flake	1	3.1
12	N98/32	Surf. 4a				Glass							60		63	Flake	1	24
12	N98/32	Surf. 5				1							12		16	99	1	0.3
12	N98/32	Surf. 5				1						1		4	42		1	39.4
12	N98/32	Surf. 6				2							60		59	Flake	1	25.4

Table 30, continued from previous page and continued on next page: Finds from site catalogue no. 12, lithics.

SC no.	Site no.	Area	Unit	Quadrant	Level	RM	Chip < 10mm	Flake < 15 mm	Flake > 15 mm	Blade	Debitage	Artifact with cortex	Tool type	Core type	Length/mm	Tool preform	Total number	Weight/g
12	N98/32	Surf. 6				1							25		20	Blade	1	0.6
12	N98/32	Surf. 6				1							43		23	Blade	1	1.8
12	N98/32	Surf. 6				2							60		43	Flake	1	4.9
12	N98/32	Surf. 7				2							60		40	99	1	7
12	N98/32					1							10		24	99	1	0.5
12	N98/32					1						1		6	39		1	19.4
12	N98/32					1							63		55	Flake	1	5.6
12	N98/32					1							33		23	Flake	1	4.9
12	N98/30					1		1		2		1					3	8.3
12	N98/34					1		3				3					1	20.1
12	N98/34					2		1									1	4.8
12	N96/04					2					2						2	40.4

Table 30, continued from previous page: Finds from site catalogue no. 12, lithics.

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpretation
416	3	N98/39	1	48/10	a	6	0.3		Unspecific slag
417	3	N98/39	1	49/10	a	6	41	DBM 4388/06	Furnace slag
419	3	N98/39	1	49/10	b	6	2		Unspecific slag
425	3	N98/39	2	50/51		638	2.9		Processing slag with gromps
427	3	N98/39	2	50/51		638	1.1		Gromp
426	3	N98/39	2	50/51		638	0.9		Processing slag
429	3	N98/39	2	50/51		689	0.8		Processing slag with gromps
431	3	N98/39	2	50/51		689	4.6		Processing slag
430	3	N98/39	2	50/51		689	2		Unspecific slag
421	3	N98/39	2	50/51	b	733	5		Processing slag with gromps and adhering amorphous hammerscale
422	3	N98/39	2	50/51	d	705	59	DBM 4389/06	Iron bloom fragment in smelting slag
441	3	N98/39	2	50/52		54	1.1		Unspecific slag
440	3	N98/39	2	50/52		54	1.8		Unspecific slag
434	3	N98/39	2	50/52	d	73	0		Hammerscale flake from secondary smithing
435	3	N98/39	2	50/52	d	73	0		Hammerscale flake from secondary smithing
436	3	N98/39	2	50/52	d	73	0		Hammerscale flake from secondary smithing
443	3	N98/39	2	50/53		839	0.2		Amorphous hammerscale
444	3	N98/39	2	50/53		859	30.6		Small SHB with small adhering gromps and slag fragments. Coarse quartz particles adhere to the underside.
442	3	N98/39	2	50/53	d	918	39	DBM 4390/06	Flow slag from smelting
459	3	N98/39	2	50/54		267	0.2		Amorphous hammerscale

Table 31, continued on next page: Finds from site catalogue no. 3, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
416			USL															
417	SSL			FSL			FL											
419			USL															
425		PSL							GR		PS							
427									GR		PS							
426		PSL									PS							
429		PSL							GR		PS							
431		PSL																
430			USL															
421		PSL							GR	HS	PS							
422	SSL							BL			PS							
441			USL															
440			USL															
434		PSL								HS		SS						
435		PSL								HS		SS						
436		PSL								HS		SS						
443		PSL								HS	PS							
444		PSL			SHB				GR			SS		QZ				
442	SSL			FSL														
459		PSL								HS								

Table 31, continued from previous page and continued on next page: Finds from site catalogue no. 3, slag, metal artifacts, iron ore, and tuyere fragments (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpretation
460	3	N98/39	2	50/54		267	0		Hammerscale flake
456	3	N98/39	2	50/54		267	0.1		Hammerscale flake
454	3	N98/39	2	50/54		293	35	DBM 4391/06	Processing slag, SHB from final refining
461	3	N98/39	2	50/54		293	0.2		Amorphous hammerscale with adhering gromps
463	3	N98/39	2	50/54		334	1.2		Furnace slag
464	3	N98/39	2	50/54		334	0.3		Unspecific slag
462	3	N98/39	2	50/54		334	2.1		Unspecific slag
465	3	N98/39	2	50/54		334	35		Unspecific slag
446	3	N98/39	2	50/54	b	353	1.1		Processing slag with gromps
447	3	N98/39	2	50/54	b	356	1.2		Unspecific slag
474	3	N98/39	2	50/55		819	1		Processing slag
468	3	N98/39	2	50/55	b	873	0.8		Thick hammerscale flake
428	3	N98/39	2	51/50		640	1.2		Unspecific slag
479	3	N98/39	2	51/50		722	3.4		Flow slag from smelting
478	3	N98/39	2	51/50		801	0.7	DBM 4395/06	Bloom fragment in smelting slag
475	3	N98/39	2	51/50	a	730	1.6		Amorphous hammerscale with adhering gromps
476	3	N98/39	2	51/50	c	774	2	DBM 4394/06	Bloom fragment in smelting slag
477	3	N98/39	2	51/50	d	730	24	DBM 4393/06	Processing slag from initial refining
489	3	N98/39	2	51/51		284	16	DBM 4396/06	SHB from initial refining with gromps
491	3	N98/39	2	51/51		284	3		Unspecific slag
492	3	N98/39	2	51/51		284	0.9		Unspecific slag
490	3	N98/39	2	51/51		317	15	DBM 4397/06	SHB from secondary smithing
493	3	N98/39	2	51/51		317	0.7		Unspecific slag
494	3	N98/39	2	51/51		317	2.5		Unspecific slag
481	3	N98/39	2	51/51	a	402	6		Unspecific slag
484	3	N98/39	2	51/51	b	402	2.6		Gromp
482	3	N98/39	2	51/51	b	402	18	DBM 4398/06	Unspecific slag
485	3	N98/39	2	51/51	b	412	1		Unspecific slag
486	3	N98/39	2	51/51	c	347	1		Unspecific slag
488	3	N98/39	2	51/51	d	560	1		Gromp
487	3	N98/39	2	51/51	d	560	3		Unspecific slag
498	3	N98/39	2	51/52		836	23.7	DBM 4400/06	SHB from secondary smithing
499	3	N98/39	2	51/52		836	3.9	DBM 4401/06	Flow slag from smelting
502	3	N98/39	2	51/52		836	0.2		Unspecific slag
501	3	N98/39	2	51/52		836	1.9		Unspecific slag
500	3	N98/39	2	51/52		836	5.7		Unspecific slag
503	3	N98/39	2	51/52		848	1.4		Unspecific slag
496	3	N98/39	2	51/52	d	876	0		Hammerscale flake
495	3	N98/39	2	51/52	d	876	24	DBM 4402/06	Processing slag from final refining with fractured quartz
510	3	N98/39	2	51/53		370	0.9		Processing slag with gromps
512	3	N98/39	2	51/53		370	0.8		Thick hammerscale flake
513	3	N98/39	2	51/53		370	3		Unspecific slag

Table 31, continued from previous page and continued on next page: Finds from site catalogue no. 3, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
460		PSL								HS								
456		PSL								HS								
454		PSL			SHB													
461		PSL								HS	PS							
463	SSL																	
464			USL															
462			USL															
465			USL															
446		PSL																
447			USL															
474		PSL																
468		PSL								HS	PS							
428			USL															
479	SSL																	
478	SSL							BL	GR		PS							
475		PSL							GR	HS	PS							
476	SSL							BL	GR		PS							
477		PSL		FSL					GR		PS							
489		PSL			SHB		FL		GR		PS							LIG
491			USL															LIG
492			USL															LIG
490		PSL			SHB							SS						EIG
493			USL															EIG
494			USL															EIG
481			USL															EIG
484									GR		PS							EIG
482			USL															EIG
485			USL															EIG
486			USL															EIG
488									GR		PS							EIG
487			USL															EIG
498		PSL			SHB							SS						
499	SSL																	
502			USL															
501			USL															
500			USL															
503			USL															EIG
496		PSL								HS								EIG
495		PSL					FL				PS			QZ				EIG
510									GR		PS							EIG
512		PSL								HS	PS							EIG
513			USL															EIG

Table 31, continued from previous page and continued on next page: Finds from site catalogue no. 3, slag, metal artifacts, iron ore, and tuyere fragments (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpretation
511	3	N98/39	2	51/53		370	1.3		Unspecific slag
504	3	N98/39	2	51/53	a	605	0.9		Unspecific slag with gromps
505	3	N98/39	2	51/53	c	571	15	DBM 4403/06	Flow slag from smelting
506	3	N98/39	2	51/53	d	453	0.1		Processing slag
1	3	N98/39	2	51/54		870	0.2		Microsphere
2	3	N98/39	2	51/54		870	0		Hammerscale flake
518	3	N98/39	2	51/54		870	0.1		Amorphous hammerscale
1070	3	N98/39	2	51/54		870	0.3		Amorphous hammerscale
515	3	N98/39	2	51/54	d	1000	0.4		Unspecific slag
516	3	N98/39	2	51/54	d	1006	2.4		Amorphous hammerscale with adhering gromps
10	3	N98/39	2	51/55		428	1		Unspecific slag
3	3	N98/39	2	51/55	a	619	2	DBM 4404/06	Bloom fragment in smelting slag
4	3	N98/39	2	51/55	a	655	0.4		Amorphous hammerscale
5	3	N98/39	2	51/55	a	674	0.4		Tick hammerscale flake
6	3	N98/39	2	51/55	d	596	2.4		Unspecific slag
14	3	N98/39	2	52/50		350	0.1		Hammerscale flake with adhering minute gromps
13	3	N98/39	2	52/50		350	4.3		Processing slag
12	3	N98/39	2	52/50		350	0.1		Amorphous hammerscale
26	3	N98/39	2	52/51		682	0.5		Hammerscale flake
27	3	N98/39	2	52/51		682	0.3		Unspecific slag
18	3	N98/39	2	52/51		698	0.4		Microsphere
19	3	N98/39	2	52/51		710	2.5		Processing slag
15	3	N98/39	2	52/51	c	727	6.3		Processing slag
16	3	N98/39	2	52/51	d	742	0.8		Unspecific slag
23	3	N98/39	2	52/52		32	1.3		Unspecific slag
25	3	N98/39	2	52/52		46	1.1		Unspecific slag with gromps
22	3	N98/39	2	52/52		46	56	DBM 4405/06	SHB from final refining with gromps
24	3	N98/39	2	52/52		46	2.4		Unspecific slag
20	3	N98/39	2	52/52	c	58	0.8		Gromp
31	3	N98/39	2	52/53		829	1.7		Processing slag with quartz fragments
30	3	N98/39	2	52/53		829	34	DBM 4406/06	Tap slag
32	3	N98/39	2	52/53		845	0.4		Thick hammerscale flake with adhering gromps
28	3	N98/39	2	52/53	a	976	3.5		Unspecific slag
35	3	N98/39	2	52/54		374	1.7		Processing slag
37	3	N98/39	2	52/54		374	0.7		Processing slag
36	3	N98/39	2	52/54		374	3.2		Amorphous hammerscale
38	3	N98/39	2	52/54		420	0.6		Unspecific slag
39	3	N98/39	2	52/54		440	27	KIA 28850	Unspecific slag
33	3	N98/39	2	52/54	a	601	21	KIA 28851	Unspecific slag
1102	3	N98/39	2	52/54	a	634	4.5		Unspecific slag
34	3	N98/39	2	52/54	b	634	0.6		Unspecific slag
51	3	N98/39	2	52/55		988	3	DBM 4407/06	Bloom fragment in smelting slag

Table 31, continued from previous page and continued on next page: Finds from site catalogue no. 3, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
511			USL															EIG
504			USL						GR									EIG
505	SSL																	EIG
506		PSL																EIG
1		PSL								HS								EIG
2		PSL								HS								EIG
518		PSL								HS	PS							EIG
1070		PSL								HS	PS							
515			USL															EIG
516		PSL							GR	HS	PS							EIG
10			USL															EIG
3	SSL							BL	GR		PS							EIG
4		PSL								HS	PS							EIG
5		PSL								HS	PS							EIG
6			USL															EIG
14		PSL							GR	HS	PS							
13		PSL									PS							
12		PSL								HS	PS							
26		PSL								HS								EIG
27			USL															EIG
18		PSL								HS								EIG
19		PSL																EIG
15		PSL									PS							EIG
16			USL															EIG
23			USL															EIG
25			USL						GR		PS							EIG
22		PSL			SHB		FL				PS							EIG
24			USL															EIG
20									GR		PS							EIG
31		PSL												QZ				
30	SSL			FSL														
32		PSL							GR	HS	PS							EIG
28			USL															EIG
35		PSL																EIG
37		PSL																EIG
36		PSL								HS	PS							EIG
38			USL															EIG
39			USL															EIG
33			USL															EIG
1102			USL															EIG
34			USL															EIG
51	SSL							BL	GR		PS							EIG

Table 31, continued from previous page and continued on next page: Finds from site catalogue no. 3, slag, metal artifacts, iron ore, and tuyere fragments (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpretation
52	3	N98/39	2	52/55		988	0.5		Amorphous hammerscale
53	3	N98/39	2	52/55		988	0.3		Unspecific slag
55	3	N98/39	2	52/55		998	0.2		Thick hammerscale flake with adhering gromps
54	3	N98/39	2	52/55		998	0.3		Unspecific slag
40	3	N98/39	2	52/55	a	1015	0.5		Unspecific slag
41	3	N98/39	2	52/55	a	1032	0.3		Unspecific slag
42	3	N98/39	2	52/55	c	1009	0.9		Processing slag
44	3	N98/39	2	52/55	c	1035	0.4		Gromps
43	3	N98/39	2	52/55	c	1035	1		Unspecific slag
47	3	N98/39	2	52/55	d	1009	0.2		Thick hammerscale flake with adhering gromps
46	3	N98/39	2	52/55	d	1009	0.7		Thick hammerscale flake
48	3	N98/39	2	52/55	d	1025	2		Amorphous hammerscale with adhering gromps
56	3	N98/39	2	53/55		468	1.6		Thick hammerscale flake with adhering gromps and some charcoal
	3	N98/39	2	54/52		18	3.6		Gromp
61	3	N98/39	2	54/52		25	0.7		Amorphous hammerscale
60	3	N98/39	2	54/52		25	3.2		Processing slag with microspheres. Furnace slag inclusions
58	3	N98/39	2	54/52		37	0.9	DBM 4408/06	Furnace slag
62	3	N98/39	2	54/52		37	0.01		Unspecific slag
64	3	N98/39	2	54/52		50	0.9		Amorphous hammerscale with adhering gromps
63	3	N98/39	2	54/52		50	0.2		Processing slag
57	3	N98/39	2	54/52	b	63	0.2		Thick hammerscale flake with adhering gromps
67	3	N98/39	2	56/52		27	78	DBM 4409/06	Processing slag from advanced refining slag with gromps
68	3	N98/39	2	56/52		27	0.8		Unspecific slag
1068	3	N98/39	2	56/52		27	35	KIA 28852	Unspecific slag
65	3	N98/39	2	56/52	a	68	7		Furnace slag with bloom inclusions
1079	3	N98/39	2	57/33		144	0.1		Hammerscale flake
77	3	N98/39	2	57/53		155	0.9		Unspecific slag
69	3	N98/39	2	57/53	b	199	1.8		Unspecific slag
78	3	N98/39	2	57/53	c	182	1.1		Unspecific slag
72	3	N98/39	2	57/53	c	230	0.2		Unspecific slag
71	3	N98/39	2	57/53	c	230	0.3		Unspecific slag
75	3	N98/39	2	57/53	d	199	0.9		Processing slag with gromps
73	3	N98/39	2	57/53	d	199	9.5		Unspecific slag
74	3	N98/39	2	57/53	d	199	2.7		Processing slag
80	3	N98/39	2	57/55	a	232	1.2		Amorphous hammerscale with adhering gromps
79	3	N98/39	2	57/55	a	232	2.3		Gromp
83	3	N98/39	2	57/55	b	232	8.8		Processing slag with gromps

Table 31, continued from previous page and continued on next page: Finds from site catalogue no. 3, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
52		PSL								HS	PS							EIG
53			USL															EIG
55		PSL							GR	HS	PS							EIG
54			USL															EIG
40			USL															EIG
41			USL															EIG
42		PSL									PS							EIG
44		PSL							GR	HS	PS							EIG
43			USL															EIG
47		PSL							GR	HS	PS							EIG
46		PSL								HS	PS							EIG
48		PSL							GR	HS	PS							EIG
56		PSL							GR	HS	PS							EIG
									GR		PS							
61		PSL								HS	PS							
60		PSL								HS	PS							
58	SSL																	EIG
62			USL															EIG
64		PSL							GR	HS	PS							EIG
63		PSL																EIG
57		PSL							GR	HS	PS							EIG
67		PSL							GR		PS							
68			USL															
1068			USL															LIG
65	SSL							BL										EIG
1079		PSL								HS		SS						
77			USL															
69			USL															EIG
78			USL															
72			USL															EIG
71			USL															EIG
75		PSL							GR		PS							EIG
73			USL															EIG
74		PSL																EIG
80		PSL							GR	HS	PS							EIG
79									GR		PS							EIG
83		PSL							GR		PS							EIG

Table 31, continued from previous page and continued on next page: Finds from site catalogue no. 3, slag, metal artifacts, iron ore, and tuyere fragments (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpretation
84	3	N98/39	2	57/55	c	254	1.1		Unspecific slag
85	3	N98/39	2	57/55	d	185	0.5		Thick hammerscale flake with adhering gromps
86	3	N98/39	2	57/55	d	201	0.3		Amorphous hammerscale
88	3	N98/39	2	58/50	a	152	0.7		Amorphous hammerscale
89	3	N98/39	2	58/50	b	152	13.3		Silica-rich processing slag
91	3	N98/39	2	58/52	a	130	0.4		Amorphous hammerscale
93	3	N98/39	2	58/52	a	162	12.5		Processing slag: Small SHB with small adhering gromps and slag fragments. Coarse quartz particles adhere to the underside.
92	3	N98/39	2	58/52	a	162	18.2		Unspecific slag
94	3	N98/39	2	58/52	b	149	0.2		Thick hammerscale flake with adhering gromps
100	3	N98/39	2	58/54		142	0.2		Thick hammerscale flake with adhering gromps
99	3	N98/39	2	58/54		142	1.2		Unspecific slag with gromps
103	3	N98/39	2	58/54		164	0.8		Gromp
101	3	N98/39	2	58/54		164	0.3		Thick hammerscale flake
102	3	N98/39	2	58/54		164	0.9		Hammerscale flake
97	3	N98/39	2	58/54	b	180	0.4		Processing slag with adhering quartz fragments
96	3	N98/39	2	58/54	b	180	6		Processing slag
98	3	N98/39	2	58/54	c	180	1		Gromp with adhering quartz fragments
104	3	N98/39	2	59/51	a	358	1.5		Unspecific slag
105	3	N98/39	2	59/51	a	365	0.7		Thick hammerscale flake
106	3	N98/39	2	59/51	a	365	0.1		Unspecific slag
108	3	N98/39	2	59/51	b	322	0.3		Thick hammerscale flake with adhering gromps
107	3	N98/39	2	59/51	b	322	0.1		Hammerscale flake
109	3	N98/39	2	59/51	b	341	0.1		Amorphous hammerscale
110	3	N98/39	2	59/51	c	365	0.4		Unspecific slag
111	3	N98/39	2	59/51	d	322	0.4		Unspecific slag
112	3	N98/39	2	59/51	d	341	0.2		Amorphous hammerscale
113	3	N98/39	2	59/51	d	358	0.4		Unspecific slag with iron ore fragments
115	3	N98/39	2	59/53		265	3.1		Gromp
116	3	N98/39	2	59/53		265	1.1		Processing slag
121	3	N98/39	2	59/53		265	0		Hammerscale flake
120	3	N98/39	2	59/53		265	0.4		Amorphous hammerscale
119	3	N98/39	2	59/53		265	0.9		Unspecific slag
296	3	N98/39	2	59/53		265	0.7		Unspecific slag
117	3	N98/39	2	59/53		265	0.4		Unspecific slag
122	3	N98/39	2	59/53		287	0.7		Hammerscale flake
130	3	N98/39	2	59/55		140	0.8		Unspecific slag
134	3	N98/39	2	59/55		160	3.7		Amorphous hammerscale with adhering gromps
131	3	N98/39	2	59/55		160	0.5		Processing slag

Table 31, continued from previous page and continued on next page: Finds from site catalogue no. 3, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
84			USL															EIG
85		PSL							GR	HS	PS							EIG
86		PSL								HS	PS							EIG
88		PSL								HS	PS							
89		PSL									PS							
91		PSL								HS	PS							
93		PSL			SHB													
92			USL															
94		PSL							GR	HS	PS							
100		PSL							GR	HS	PS							
99			USL						GR		PS							
103									GR		PS							
101		PSL								HS	PS							
102		PSL								HS								
97		PSL								EIG				QZ				
96		PSL								EIG								
98									GR	EIG	PS			QZ				
104			USL															
105		PSL								HS	PS							
106			USL															
108		PSL							GR	HS	PS							
107		PSL								HS								
109		PSL								HS	PS							
110			USL															
111			USL															
112		PSL								HS	PS							
113			USL										OR					
115									GR		PS							
116		PSL																
121		PSL								HS								
120		PSL								HS	PS							
119			USL															
296			USL															
117			USL															
122		PSL								HS								
130			USL															
134		PSL							GR	HS	PS							
131		PSL									PS							

Table 31, continued from previous page and continued on next page: Finds from site catalogue no. 3, slag, metal artifacts, iron ore, and tuyere fragments (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpretation
1067	3	N98/39	2	59/55		160	0.2		Thick flat hammerscale
133	3	N98/39	2	59/55		160	0.2		Unspecific slag
132	3	N98/39	2	59/55		160	0.4		Unspecific slag
124	3	N98/39	2	59/55	d	188	2.2		Processing slag with gromps
126	3	N98/39	2	59/55	d	188	1.3		Unspecific slag
125	3	N98/39	2	59/55	d	188	1.3		Unspecific slag
141	3	N98/39	2			2	42.6		Processing slag, small SHB
144	3	N98/39	2			2	5.4		Processing slag, small SHB
139	3	N98/39	2			2	85.7		Processing slag, SHB
145	3	N98/39	2			2	70.6		Gromp
140	3	N98/39	2			2	45.8		Furnace slag
146	3	N98/39	2			2	4.2		Unspecific slag
143	3	N98/39	2			2	13.6		Unspecific slag
142	3	N98/39	2			2	28		Unspecific slag
1113	3	N98/39	2			2	14.8		Modern sheet metal fragment
136	3	N98/39	2			42	51	DBM 4410/06; Poz-20700	Processing slag, SHB advanced refining with gromps
150	3	N98/39	2			42	12.7		Furnace slag with flow structures, slag tap-ping into a slag pit?
149	3	N98/39	2			42	6.1		Unspecific slag
148	3	N98/39	2			42	5		Unspecific slag
137	3	N98/39	2			1046	190	DBM 4411/06; Poz-20698	Processing slag from initial refining with gromps
155	3	N98/39	2				106		Processing slag
157	3	N98/39	2				50		Unspecific slag
158	3	N98/39	2				70		Unspecific slag
156	3	N98/39	2				84		Unspecific slag
152	3	N98/39	4			7	14.1		Processing slag with gromps
Iron artifacts									
415	3	N98/39	1	48/10	a	6	0.3		Iron clip
418	3	N98/39	1	49/10	b	6	1.5		Iron plate
420	3	N98/39	2	50/50		212	0.3		Iron metal sheet
1078		N98/39	2	50/51	c	736	3.7		Iron bar
437	3	N98/39	2	50/52		21	0.01		Iron sheet metal
439	3	N98/39	2	50/52		34	0.01		Iron sheet metal
438	3	N98/39	2	50/52		34	0.4		Iron can fragment
432	3	N98/39	2	50/52	d	73	0.01		Fragment of an iron sheet metal
433	3	N98/39	2	50/52	d	73	2		Industrial wire
455	3	N98/39	2	50/54		240	0.01		Fragment of an iron metal sheet
450	3	N98/39	2	50/54		267	0.3		Bent iron wire, probably unfinished link of a chain
451	3	N98/39	2	50/54		267	0.6		Tin can tap
457	3	N98/39	2	50/54		267	0.01		Sheet metal fragment, probably from can
458	3	N98/39	2	50/54		267	0.01		Iron sheet metal

Table 31, continued from previous page and continued on next page: Finds from site catalogue no. 3, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
1067		PSL								HS	PS							
133			USL															
132			USL															
124		PSL							GR		PS							
126			USL															
125			USL															
141		PSL			SHB							SS						
144		PSL			SHB													
139		PSL			SHB													
145		PSL							GR		PS							
140	SSL																	
146			USL															
143			USL															
142			USL															
1113																		
136		PSL			SHB				GR		PS			QZ				LIG
150	SSL			FSL		SP												
149			USL															
148			USL															
137		PSL							GR		PS							LIG
155		PSL			SHB													
157			USL															
158			USL															
156			USL															
152		PSL							GR		PS							
Iron artifacts																		
415																IA		EIG
418																IA		EIG
420																IA		MOD
1078																IA		EIG
437																IA		MOD
439																IA		MOD
438																IA		MOD
432																IA		MOD
433																IA		MOD
455																IA		MOD
450																IA		LIG
451																IA		MOD
457																IA		UDT
458																IA		UDT

Table 31, continued from previous page and continued on next page: Finds from site catalogue no. 3, slag, metal artifacts, iron ore, and tuyere fragments (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpretation
449	3	N98/39	2	50/54	c	459	0.02	DBM 4439/06	Iron clip
472	3	N98/39	2	50/55		811	0.01		Iron sheet metal fragment, probably from can
471	3	N98/39	2	50/55		819	0.7		Industrial iron wire
470	3	N98/39	2	50/55		842	2.5	DBM 4474/06	Iron bar
7	3	N98/39	2	51/50		640	20.3		Elastic industrial spring used in a trap
497	3	N98/39	2	51/52		848	0.2		Iron bead
507	3	N98/39	2	51/53		302	2.3		Iron wire
517	3	N98/39	2	51/54		850	0.01		Can fragment
8	3	N98/39	2	51/55		336	0.3		Iron sheet metal
29	3	N98/39	2	52/53		816	22.5		Industrial screw with screw-nut
49	3	N98/39	2	52/55		998	1.1	DBM 4437/06	Single iron hook
50	3	N98/39	2	52/55		998	0.6	DBM 4486/06	Ribbon of sheet metal, clip
45	3	N98/39	2	52/55	d	1015	0.4	DBM 4475/06	Iron chain fragment
66	3	N98/39	2	56/52		19	0.01		Iron sheet metal
76	3	N98/39	2	57/53		139	0.01		Fragment of iron sheet metal
1077	3	N98/39	2	57/53		144	0.2		Thin sheet metal, probably from can
70	3	N98/39	2	57/53	c	230	0.01		Iron ribbon fragment
87	3	N98/39	2	57/55		146	43.6		Soda or beer can
1119	3	N98/39	2	57/55	a	185	0.01		Small fragment of a thin sheet metal
90	3	N98/39	2	58/50		126	0.01		Iron sheet metal
95	3	N98/39	2	58/52		98	20.8		Soda or beer can
114	3	N98/39	2	59/53		265	0.3		Blade of a hacksaw
128	3	N98/39	2	59/55		140	0.3		Iron sheet from a tin can
135	3	N98/39	2			2	16		Iron artifact
1115	3	N98/39	2			2	14.8		Industrial sheet metal fragment with enamel
Copper artifacts									
11	3	N98/39	2	52/50		384	0.8	DBM 4432/06	Copper bead
81	3	N98/39	2	57/55	b	185	1.1	DBM 4392/06	Copper bead
Iron ore									
423	3	N98/39	2	50/51		643	0.1		Sandy iron ore
424	3	N98/39	2	50/51		664	0.2		Sandy iron ore
452	3	N98/39	2	50/54		334	0.5		Sandy iron ore
448	3	N98/39	2	50/54		353	0.2		Sandy iron ore
453	3	N98/39	2	50/54		353	0		Sandy iron ore
445	3	N98/39	2	50/54	b	408	0		Sandy iron ore
473	3	N98/39	2	50/55		853	0.1		Sandy iron ore
466	3	N98/39	2	50/55	b	873	0.4		Sandy iron ore
467	3	N98/39	2	50/55	b	943	0.3		Sandy iron ore
480	3	N98/39	2	51/51	a	402	7	DBM 4419/06	Iron ore (specularite)
9	3	N98/39	2	51/55		399	0.3		Sandy iron ore
17	3	N98/39	2	52/51		682	0		Sandy iron ore

Table 31, continued from previous page and continued on next page: Finds from site catalogue no. 3, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
449																IA		EIG
472																IA		MOD
471																IA		MOD
470																IA		EIG
7																IA		MOD
497																IA		EIG
507																IA		MOD
517																IA		MOD
8																IA		MOD
29																IA		MOD
49																IA		EIG
50																IA		EIG
45																IA		EIG
66																IA		MOD
76																IA		MOD
1077																IA		MOD
70																IA		EIG
87																IA		MOD
1119																IA		UDT
90																		UDT
95																IA		MOD
114																IA		MOD
128																IA		MOD
135																IA		UDT
1115																IA		MOD
Copper artifacts																		
11																	CO	EIG
81																	CO	EIG
Iron ore																		
423													OR					
424													OR					
452													OR					
448													OR					
453													OR					
445													OR					
473													OR					
466													OR					
467													OR					
480													OR					
9													OR					
17													OR					

Table 31, continued from previous page and continued on next page: Finds from site catalogue no. 3, slag, metal artifacts, iron ore, and tuyere fragments (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpretation
1111	3	N98/39	2	52/54	a	634	0.01		Iron ore, hematite
82	3	N98/39	2	57/55	b	201	0		Sandy iron ore
129	3	N98/39	2	59/55		160	0.3		Sandy iron ore
123	3	N98/39	2	59/55	d	216	0		Sandy iron ore
Tuyerefragments									
138	3	N98/39	2			2	61.4		Tuyere fragment, organic temper
154	3	N98/39	2			2	17.9		Tuyere fragment, organic temper
147	3	N98/39	2			42	36.5		Tuyere fragment, organic temper
1085	3	N98/39	2				28.7		Tip of a tuyere, grog temper
469	3	N98/39	2	50/55	c	873	16.1		Tuyere fragment, organic temper
483	3	N98/39	2	51/51	b	402	26.4	DBM 4399/06; COL#2332.1.1	Tip of a tuyere, organic temper
509	3	N98/39	2	51/53		370	11.4		Tuyere fragment (organic temper) used in iron processing
514	3	N98/39	2	51/54	c	948	59		Tuyere fragment, organic temper
21	3	N98/39	2	52/52	d	70	4.3		Tuyere fragment, organic temper
151	3	N98/39	3			5	25.9		Tip of a tuyere, organic temper

Table 31, continued from previous page and continued on next page: Finds from site catalogue no. 3, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SC no.	Site no.	Area	Unit	Qua-drant	Level	W/g	Sample no.	Interpretation
181	4	N99/21	1	49/51	a	1	2.7		Processing slag
180	4	N99/21	1	49/51	a	1	5.6		Processing slag
182	4	N99/21	1	50/50	a	4	1.2		Conglomerated and slagged hammerscales
185	4	N99/21	1	50/50	a	6	8.6		Tuyere fragment adhering to unspecific slag
192	4	N99/21	1	50/50	a	6	0.5		Gromp
193	4	N99/21	1	50/50	a	6	0.5		Gromp
194	4	N99/21	1	50/50	a	6	1.3		Gromp
195	4	N99/21	1	50/50	a	6	1.2		Gromp
184	4	N99/21	1	50/50	a	6	4.8		Unspecific slag
183	4	N99/21	1	50/50	a	6	20.2		Small SHB from secondary smithing
190	4	N99/21	1	50/50	a	6	0.6		Gromp
191	4	N99/21	1	50/50	a	6	0.2		Amorphous hammerscale
189	4	N99/21	1	50/50	a	6	0.9		Amorphous hammerscale
188	4	N99/21	1	50/50	a	6	0		Hammerscale flake
187	4	N99/21	1	50/50	a	6	0.3		Hammerscale flake
186	4	N99/21	1	50/50	a	6	0.2		Hammerscale flake with small gromps
202	4	N99/21	1	50/50	b	6	0.1		Unspecific slag
197	4	N99/21	1	50/50	b	6	16.7		Unspecific slag

Table 32, continued on next page: Finds from site catalogue nos. 4 and 6, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
1111													OR					
82													OR					
129													OR					
123													OR					
Tuyerefragments																		
138															TY			EIG
154															TY			EIG
147															TY			EIG
1085															TY			LIG
469															TY			EIG
483															TY			EIG
509															TY			EIG
514															TY			EIG
21															TY			EIG
151															TY			EIG

Table 31, continued from previous page: Finds from site catalogue no. 3, slag, metal artifacts, iron ore, and tuyere fragments (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	RM	SS	OR	QZ	TY	IA	CO	PE
181		PSL									PS								
180		PSL									PS								
182		PSL								HS									
185			USL													TY			LIG
192									GR		PS								
193									GR		PS								
194									GR		PS								
195									GR		PS								
184			USL																
183		PSL			SHB								SS						
190		PSL							GR		PS								
191		PSL								HS	PS								
189		PSL								HS	PS								
188		PSL								HS									
187		PSL								HS									
186		PSL								HS	PS								
202			USL																
197			USL																

Table 32, continued from previous page and continued on next page: Finds from site catalogue nos. 4 and 6, slag, metal artifacts, iron ore, and tuyere fragments. (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, RM: Raw material, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Qua-drant	Level	W/g	Sample no.	Interpretation
198	4	N99/21	1	50/50	b	6	3.7		Unspecific slag
201	4	N99/21	1	50/50	b	6	1.3		Unspecific slag
200	4	N99/21	1	50/50	b	6	0.3		Unspecific slag
196	4	N99/21	1	50/50	b	6	0		Copper clip, link
199	4	N99/21	1	50/50	b	6	1.5		Processing slag
205	4	N99/21	1	50/50	b	6	0.4		Conglomerated and slagged hammerscales
204	4	N99/21	1	50/50	b	6	0.1		Hammerscale flake
203	4	N99/21	1	50/50	b	6	0		Hammerscale flake
207	4	N99/21	1	50/50	c	6	3.9		Unspecific slag with gromp
206	4	N99/21	1	50/50	c	6	3		Unspecific slag
214	4	N99/21	1	50/50	d	6	0.6		Gromp
212	4	N99/21	1	50/50	d	6	0.2		Unspecific slag
209	4	N99/21	1	50/50	d	6	1.8		Unspecific slag
208	4	N99/21	1	50/50	d	6	3.2		Unspecific slag
210	4	N99/21	1	50/50	d	6	2.8		Unspecific slag
213	4	N99/21	1	50/50	d	6	0.2		Hammerscale flake
211	4	N99/21	1	50/50	d	6	0.2		Hammerscale flake
216	4	N99/21	1	50/51	a	6	117		Unspecific slag
218	4	N99/21	1	50/51	a	6	0.5		Unspecific slag
217	4	N99/21	1	50/51	a	6	6.6		Unspecific slag
215	4	N99/21	1	50/51	a	6	4.8		Processing slag
219	4	N99/21	1	50/51	b	6	2.8		Crown cap
220	4	N99/21	1	50/51	c	6	0.2	DBM 4485/06	Iron clip
222	4	N99/21	1	50/51	c	6	< 1		Curved sheet metal fragment, probably from tin can
221	4	N99/21	1	50/51	c	6	< 1		Iron sheet metal fragment
223	4	N99/21	1	50/51	c	6	4.8		Processing slag
225	4	N99/21	1	50/51	c	6	1.6		Conglomerated hammerscale flakes and spheres
224	4	N99/21	1	50/51	c	6	12.1		Processing slag
228	4	N99/21	1	50/51	d	4	0.8		Thick hammerscale flake
234	4	N99/21	1	50/51	d	6	3		Unspecific slag
233	4	N99/21	1	50/51	d	6	4		Unspecific slag
232	4	N99/21	1	50/51	d	6	1.4		Unspecific slag
229	4	N99/21	1	50/51	d	6	0.4		Unspecific slag
230	4	N99/21	1	50/51	d	6	0.2		Unspecific slag
226	4	N99/21	1	50/51	d	6	0		Industrial sheet metal
227	4	N99/21	1	50/51	d	6	17	DBM 4435/06	Initial refining slag with gromps
231	4	N99/21	1	50/51	d	6	1.3		Amorphous hammerscale
237	4	N99/21	1	51/50	a	6	2.3		Unspecific slag
235	4	N99/21	1	51/50	a	6	16	DBM 4436/06	Initial refining slag with gromps
236	4	N99/21	1	51/50	a	6	0.8		Flow slag from smelting
238	4	N99/21	1	51/50	a	9	1.8		Gromp
239	4	N99/21	1	51/50	a	9	2		Processing slag with gromps

Table 32, continued from previous page and continued on next page: Finds from site catalogue nos. 4 and 6, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	RM	SS	OR	QZ	TY	IA	CO	PE
198			USL																
201			USL																
200			USL																
196																		CO	
199		PSL																	
205		PSL								HS			SS						
204		PSL								HS			SS						
203		PSL								HS			SS						
207			USL						GR		PS								
206			USL																
214									GR		PS								
212			USL																
209			USL																
208			USL																
210			USL																
213		PSL								HS									
211		PSL								HS									
216			USL																
218			USL																
217			USL																
215		PSL																	
219																	IA		MOD
220																	IA		LIG
222																	IA		MOD
221																	IA		MOD
223		PSL																	
225		PSL								HS			SS						
224		PSL																	
228		PSL								HS	PS								
234			USL																
233			USL																
232			USL																
229			USL																
230			USL																
226																	IA		MOD
227		PSL							GR		PS								
231		PSL								HS	PS								
237			USL																
235		PSL							GR		PS								
236	SSL			FSL															
238									GR		PS								
239		PSL							GR		PS								

Table 32, continued from previous page and continued on next page: Finds from site catalogue nos. 4 and 6, slag, metal artifacts, iron ore, and tuyere fragments. (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, RM: Raw material,SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Qua-drant	Level	W/g	Sample no.	Interpretation
240	4	N99/21	1	51/50	b	9	2		Unspecific slag
241	4	N99/21	1	51/50	b	9	2		Unspecific slag
242	4	N99/21	1	51/50	d	4	9.1		Furnace slag with bloom inclusion
243	4	N99/21	1	51/51	a	4	0.6		Conglomerated and slagged hammerscales with gromps
244	4	N99/21	1	51/51	a	6	0.8		Unspecific slag
245	4	N99/21	1	51/51	a	6	1.4		Thick hammerscale flake
246	4	N99/21	1	51/51	c	4	0.2		Hammerscale flake
247	4	N99/21	1	51/51	c	6	0.6		Small gromp
248	4	N99/21	1	51/51	c	6	2		Smelting slag with bloom remains
249	4	N99/21	1	51/51	c	6	0.6		Small gromp
250	4	N99/21	1	51/51	d	4	6.7		Unspecific slag with gromp
251	4	N99/21	1	51/51	d	4	0.2		Microsphere
252	4	N99/21	1	53/48	a	1	3.7		Gromp
349	4	N99/21	2			Surf.	7.2		Gromp
355	4	N99/21	2			Surf.	35		Unspecific slag
352	4	N99/21	2			Surf.	27.4		Unspecific slag
354	4	N99/21	2			Surf.	35		Unspecific slag
356	4	N99/21	2			Surf.	44		Unspecific slag
351	4	N99/21	2			Surf.	24		Unspecific slag
357	4	N99/21	2			Surf.	370		Processing slag, SHB
353	4	N99/21	2			Surf.	36.4		Processing slag, SHB with gromps
358	4	N99/21	2			Surf.	10.1		Processing slag
350	4	N99/21	2			Surf.	70.6		Processing slag
348	4	N99/21	2			Surf.	157		Tap slag with bloom inclusions, cooled down in slag pit
308	4	N99/21	3	70/45		69	0		Iron ore
255	4	N99/21	3	70/45	a	1	0.7		Amorphous hammerscale with gromp
254	4	N99/21	3	70/45	a	1	0.4		Thick hammerscale flake
257	4	N99/21	3	70/45	a	12	0.5		Unspecific slag with gromp
256	4	N99/21	3	70/45	a	12	0.7		Gromp
258	4	N99/21	3	70/45	a	12	3		Unspecific slag
259	4	N99/21	3	70/45	a	12	1		Processing slag
260	4	N99/21	3	70/45	a	12	0.3		Hammerscale flake
261	4	N99/21	3	70/45	a	16	0.4		Hammerscale flake
262	4	N99/21	3	70/45	a	20	0.9		Conglomerated hammerscale flakes and microspheres
263	4	N99/21	3	70/45	a	36	2		Unspecific slag
1056	4	N99/21	3	70/45	a	36	1.1		Burnt clay
253	4	N99/21	3	70/45	a	53	42	DBM 4719/06	Tap slag from refining/ processing which cooled down in slag pit
269	4	N99/21	3	70/45	b	2	0.6		Unspecific slag
264	4	N99/21	3	70/45	b	2	0.2		Fragment of iron sheet metal
1088	4	N99/21	3	70/45	b	2	4.1		Bullet casing

Table 32, continued from previous page and continued on next page: Finds from site catalogue nos. 4 and 6, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	RM	SS	OR	QZ	TY	IA	CO	PE
240			USL																
241			USL																
242	SSL								GR										
243		PSL							GR	HS	PS								
244			USL																
245		PSL								HS	PS								
246		PSL								HS									
247									GR		PS								
248	SSL							BL			PS								
249									GR		PS								
250			USL						GR		PS								
251		PSL								HS									
252									GR		PS								
349									GR		PS								LIG
355			USL																LIG
352			USL																LIG
354			USL																LIG
356			USL																LIG
351			USL																LIG
357		PSL			SHB														LIG
353		PSL			SHB				GR										LIG
358		PSL																	LIG
350		PSL																	LIG
348	SSL					SP		BL											LIG
308														OR					UDT
255		PSL							GR	HS	PS								LIG
254		PSL								HS	PS								LIG
257			USL						GR		PS								LIG
256									GR		PS								LIG
258			USL																LIG
259		PSL											SS						LIG
260		PSL								HS									LIG
261		PSL								HS			SS						LIG
262		PSL								HS									LIG
263			USL																EIG
1056																			EIG
253		PSL		FSL		SP					PS								EIG
269			USL																LIG
264																	IA		MOD
1088																	IA		MOD

Table 32, continued from previous page and continued on next page: Finds from site catalogue nos. 4 and 6, slag, metal artifacts, iron ore, and tuyere fragments. (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, RM: Raw material,SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Qua-drant	Level	W/g	Sample no.	Interpretation
277	4	N99/21	3	70/45	b	9	1.7		Unspecific slag with gromps
266	4	N99/21	3	70/45	b	13	2.9		Slagged sand and clay
265	4	N99/21	3	70/45	b	13	1.7		Sandy iron ore
268	4	N99/21	3	70/45	b	17	1.6		Unspecific slag with gromp
267	4	N99/21	3	70/45	b	17	1		Processing slag
270	4	N99/21	3	70/45	b	21	1.5		Unspecific slag
272	4	N99/21	3	70/45	b	24	0.3		Unspecific slag
271	4	N99/21	3	70/45	b	24	1.8		Processing slag with gromps
273	4	N99/21	3	70/45	b	25	0.2		Hammerscale flake
274	4	N99/21	3	70/45	b	33	0.2		Amorphous hammerscale
1083	4	N99/21	3	70/45	b	50	0.7		Iron bar
275	4	N99/21	3	70/45	b	75	0.8		Conglomerated hammerscale flakes and microspheres with gromps
276	4	N99/21	3	70/45	b	79	2.1		Processing slag
1091	4	N99/21	3	70/45	c	10	2		Lead seal
283	4	N99/21	3	70/45	c	10	4.9		Processing slag with adhering hammerscales and gromps
284	4	N99/21	3	70/45	c	10	0.8		Processing slag
285	4	N99/21	3	70/45	c	10	0.4		Amorphous hammerscale
286	4	N99/21	3	70/45	c	14	0.4		Gromp
278	4	N99/21	3	70/45	c	14	3.5		Sandy iron ore
287	4	N99/21	3	70/45	c	18	0.3		Amorphous hammerscale
288	4	N99/21	3	70/45	c	22	0.9		Unspecific slag
282	4	N99/21	3	70/45	c	34	31		Unspecific slag
280	4	N99/21	3	70/45	c	34	34	DBM 4720/06; 5195/07	Furnace slag with bloom and quartz inclusion
289	4	N99/21	3	70/45	c	39	45.4		Processing slag, SHB
281	4	N99/21	3	70/45	c	43	31	DBM 4721/06	Advanced refining slag with gromps
279	4	N99/21	3	70/45	c	52	58.4		Ferruginous sandstone
290	4	N99/21	3	70/45	c	52	0.1		Hammerscale flake
295	4	N99/21	3	70/45	d	5	0.9		Unspecific slag with gromp
291	4	N99/21	3	70/45	d	8	0.2		Fragment of iron sheet metal
118	4	N99/21	3	70/45	d	15	0.7		Unspecific slag
297	4	N99/21	3	70/45	d	19	1.9		Gromp
298	4	N99/21	3	70/45	d	19	1		Unspecific slag
1057	4	N99/21	3	70/45	d	19	1		Slagged sand
299	4	N99/21	3	70/45	d	23	3.1		Unspecific slag with gromp
300	4	N99/21	3	70/45	d	27	5.2		Processing slag
301	4	N99/21	3	70/45	d	38	3.2		Gromp
304	4	N99/21	3	70/45	d	38	0.6		Unspecific slag
302	4	N99/21	3	70/45	d	38	0.4		Unspecific slag
303	4	N99/21	3	70/45	d	38	0.1		Hammerscale flake
292	4	N99/21	3	70/45	d	42	50.2		Ferruginous sandstone
293	4	N99/21	3	70/45	d	42	4.1		Ferruginous sandstone
294	4	N99/21	3	70/45	d	42	0		Iron ore

Table 32, continued from previous page and continued on next page: Finds from site catalogue nos. 4 and 6, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	RM	SS	OR	QZ	TY	IA	CO	PE
277			USL						GR		PS								LIG
266			USL																LIG
265														OR					LIG
268			USL						GR		PS								LIG
267		PSL																	LIG
270			USL																LIG
272			USL																LIG
271		PSL							GR		PS								UDT
273		PSL								HS									EIG
274		PSL								HS	PS								EIG
1083																	IA		EIG
275		PSL								HS	PS								EIG
276		PSL									PS								EIG
1091																	A		MOD
283		PSL							GR	HS	PS								LIG
284		PSL																	LIG
285		PSL								HS	PS								LIG
286									GR		PS								LIG
278														OR					LIG
287		PSL								HS	PS								LIG
288			USL																LIG
282			USL																EIG
280	SSL							BL	GR		PS				QZ				EIG
289		PSL			SHB														EIG
281		PSL							GR		PS				QZ				EIG
279														OR					EIG
290		PSL								HS			SS						EIG
295			USL						GR		PS								LIG
291																	IA		MOD
118			USL																LIG
297									GR		PS								LIG
298			USL																LIG
1057			USL																LIG
299			USL						GR		PS								LIG
300		PSL																	UDT
301									GR		PS								EIG
304			USL																EIG
302			USL																EIG
303		PSL								HS									EIG
292														OR					EIG
293														OR					EIG
294														OR					EIG

Table 32, continued from previous page and continued on next page: Finds from site catalogue nos. 4 and 6, slag, metal artifacts, iron ore, and tuyere fragments. (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, RM: Raw material,SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Qua-drant	Level	W/g	Sample no.	Interpretation
305	4	N99/21	3	70/45	d	42	4.8		Processing slag with gromp
306	4	N99/21	3	70/45	d	48	0.7		Unspecific slag
307	4	N99/21	3	70/45	d	77	0.1		Hammerscale flake
309	4	N99/21	4	73/29	a	12	0.4		Rim of a tin can
310	4	N99/21	4	73/29	a	12	0.1		Fragment of iron sheet metal
321	4	N99/21	4	73/29	a	28	0.9		Sandy iron ore
312	4	N99/21	4	73/29	b	5	0		Iron ore
311	4	N99/21	4	73/29	b	5	0		Hammerscale flake
1093	4	N99/21	4	73/29	b	9	0		Iron sheet metal
1095	4	N99/21	4	73/29	b	9	0		Iron sheet metal
1094	4	N99/21	4	73/29	b	9	0		Iron sheet metal
1092	4	N99/21	4	73/29	b	9	1.8		Bottle top
313	4	N99/21	4	73/29	b	13	0.5		Unspecific slag with gromp
314	4	N99/21	4	73/29	b	13	0.1		Unspecific slag
315	4	N99/21	4	73/29	b	45	5.4		Processing slag with gromps
1054	4	N99/21	4	73/29	c	6	0.9		Unspecific slag
317	4	N99/21	4	73/29	c	6	0.2		Fragment of iron sheet metal
318	4	N99/21	4	73/29	c	6	0.1		Fragment of iron sheet metal
323	4	N99/21	4	73/29	c	6	2.1		Sandy iron ore
316	4	N99/21	4	73/29	c	6	2.6		Rim fragment of a tin can
322	4	N99/21	4	73/29	c	6	0.2		Sandy iron ore
319	4	N99/21	4	73/29	c	10	0.5		Iron ore
324	4	N99/21	4	73/29	c	14	0.8		Processing slag with gromps
320	4	N99/21	4	73/29	c	18	1.6		Sandy iron ore
325	4	N99/21	4	73/29	c	22	0.5		Conglomerated hammerscales
326	4	N99/21	4	73/29	c	46	0.6		Conglomerated microspheres
328	4	N99/21	4	73/29	d	7	0.1		Iron sheet metal
332	4	N99/21	4	73/29	d	11	0.4		Unspecific slag with gromps
330	4	N99/21	4	73/29	d	11	3.3		Unspecific slag
329	4	N99/21	4	73/29	d	11	0.1		Fragment of sheet metal
327	4	N99/21	4	73/29	d	11	3.2		Processing slag
331	4	N99/21	4	73/29	d	11	0.8		Amorphous hammerscale
1089	4	N99/21	4	73/29	d	15	0.5		Pellet from an air gun
333	4	N99/21	4	73/29	d	19	3.7		Flow slag from smelting
334	4	N99/21	4	73/29	d	43	1		Unspecific slag
335	4	N99/21	4	73/29	d	48	3.4		Unspecific slag
1096	4	N99/21	5	75/14	a	58	1.9		Processing slag
336	4	N99/21	5	75/14	b	26	2.3		Unspecific slag
338	4	N99/21	5	75/14	b	50	1.6		Amorphous hammerscale
337	4	N99/21	5	75/14	b	50	29		Silica-rich processing slag
340	4	N99/21	5	75/14	b	54	1.1		Gromp
341	4	N99/21	5	75/14	c	12	125	DBM 4718/06	SHB from final refining
342	4	N99/21	5	75/14	c	24	36.1		Furnace slag with bloom inclusions
346	4	N99/21	5	75/14	d	11	2.8		Unspecific slag

Table 32, continued from previous page and continued on next page: Finds from site catalogue nos. 4 and 6, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	RM	SS	OR	QZ	TY	IA	CO	PE
305		PSL							GR		PS								EIG
306			USL																EIG
307		PSL								HS			SS						EIG
309																	IA		MOD
310																	IA		MOD
321														OR					LIG
312														OR					LIG
311		PSL								HS			SS						LIG
1093																	IA		MOD
1095																	IA		MOD
1094																	IA		MOD
1092																	IA		MOD
313			USL						GR		PS								LIG
314			USL																LIG
315		PSL							GR		PS								EIG
1054			USL																LIG
317																	IA		MOD
318																	IA		MOD
323														OR					LIG
316																	IA		MOD
322														OR					LIG
319														OR					LIG
324		PSL							GR		PS								LIG
320														OR					LIG
325		PSL								HS			SS						LIG
326		PSL								HS			SS						EIG
328																	IA		MOD
332			USL						GR		PS								LIG
330			USL																LIG
329																	IA		MOD
327		PSL																	LIG
331		PSL								HS	PS								LIG
1089																	A		MOD
333	SSL			FSL															LIG
334			USL																EIG
335			USL																EIG
1096		PSL																	EIG
336			USL																LIG
338		PSL								HS	PS								EIG
337		PSL																	EIG
340									GR		PS								EIG
341		PSL			SHB						PS								LIG
342	SSL							BL											LIG
346			USL																LIG

Table 32, continued from previous page and continued on next page: Finds from site catalogue nos. 4 and 6, slag, metal artifacts, iron ore, and tuyere fragments. (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, RM: Raw material, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Qua-drant	Level	W/g	Sample no.	Interpretation
345	4	N99/21	5	75/14	d	11	2.5		Processing slag
1097	4	N99/21	5	75/14	d	52	2.4		Unspecific slag
343	4	N99/21	5	75/14	d	52	0.18		Iron clip
339	4	N99/21	5	75/14	d	52	5.5		Processing slag with gromps
344	4	N99/21	5	75/14	d	52	10	DBM 4717/06	Advanced refining slag with gromps
347	4	N99/21	5	75/14	d	52	0.8		Processing slag
178	4	N99/21	6	48/94	a	5	0.5		Bullet casing
179	4	N99/21	6	48/94	a	5	2.5		Tuyere fragment, unspecific slag
1082	4	N99/21	6	48/94	a	5	2.1		Copper bead
1090	4	N99/21	6	48/94	a	5	0.5		Pellet from an air gun
1084	4	N99/21	6	48/94	a	6	1.8		Iron point
177	4	N99/21	7	45/90	d	9	0.4		Amorphous hammerscale
175	4	N99/21	7	45/90	d	10	0.6		Processing slag with adhering hammerscales
176	4	N99/21	7	45/90	d	11	2.5		Processing slag
161	4	N68/01	B1575B			15′′-22′′	12		Gromp
162	4	N68/01	B1575B			15′′-22′′	8.1		Unspecific slag
160	4	N68/01	B1575B			15′′-22′′	27	DBM 4412/06	Processing slag with gromps
159	4	N68/01	B1575B			20′′-34′′	2	DBM 4476/06	Iron point fragment
172	4	N68/02	B1592				2.4		Gromp
167	4	N68/02	B1592				38.2		SHB
169	4	N68/02	B1592				22.1		Processing slag with gromps
171	4	N68/02	B1592				11.6		Processing slag with gromps
170	4	N68/02	B1592				16.3		Processing slag with gromps
168	4	N68/02	B1592				31.6		Processing slag
166	4	N68/02	B1592			24′′-30′′	19	DBM 4414/06	Processing slag with gromps
165	4	N68/02	B1592			24′′-30′′	13	DBM 4413/06	Furnace slag with bloom inclusion
164	4	N68/02	B1592			30′′-36′′	1.1	DBM 4484/06a	Copper ring fragment
163	4	N68/02	B1592			3′′-9′′	5.3	DBM 4477/06	Piece of raw metal (iron) lost during secondary smithing
359	4	N99/21	nördl. Mission Surf.				58.5		Furnace slag with bloom inclusions
360	4	N99/21	nördl. Mission Surf.				35		Tuyere fragment
1059	4	N99/21	Surf.				24.2		Unspecific slag
1081	4	N99/21	Surf.				1.8		Copper bead
363	4	N99/21	Surf.				13.1		Unspecific slag with gromps
364	4	N99/21	Surf.				167		SHB
365	4	N99/21	Surf.				500		SHB
362	4	N99/21	Surf.				154		SHB with gromps
361	4	N99/21	Surf.				212		Unspecific slag
174	4	N98/38					16.8		Processing slag, SHB
173	4	N98/38					41.1		Tap slag, cooled down in slag pit
366	6	N06/01					167	DBM 4399/07; 4731/06; 5198/07	Pisolitic ferricrete

Table 32, continued from previous page: Finds from site catalogue nos. 4 and 6, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	RM	SS	OR	QZ	TY	IA	CO	PE
345		PSL																	LIG
1097			USL																EIG
343																	IA		EIG
339		PSL									PS								EIG
344		PSL									PS				QZ				EIG
347		PSL							GR										EIG
178																	A		MOD
179																TY			LIG
1082																		CO	LIG
1090																	A		MOD
1084																	IA		LIG
177		PSL								HS	PS								
175		PSL								HS									
176		PSL																	
161									GR		PS								EIG
162			USL																EIG
160		PSL							GR		PS								EIG
159																	IA		EIG
172									GR		PS								UDT
167		PSL			SHB														UDT
169		PSL							GR		PS								UDT
171		PSL							GR		PS								UDT
170		PSL							GR		PS								UDT
168		PSL																	UDT
166		PSL							GR		PS								EIA
165	SSL							BL	GR		PS								EIA
164																		CO	EIA
163												RM	SS				IA		LIG
359	SSL							BL											LIG
360																TY			LIG
1059			USL																LIG
1081																		CO	LIG
363			USL						GR		PS								LIG
364		PSL			SHB														LIG
365		PSL			SHB														LIG
362		PSL			SHB														LIG
361			USL																LIG
174		PSL			SHB														
173	SSL			FSL		SP													
366														OR					

Table 32, continued from previous page: Finds from site catalogue nos. 4 and 6, slag, metal artifacts, iron ore, and tuyere fragments. (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, RM: Raw material, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpretation
399	12	N69/01	1				0.01		Microsphere
397	12	N69/01	1				1002	DBM 4415/06; Poz-20702	Furnace slag, cooled down in a slag pit
372	12	N69/01	1	F7/F8			11.9		Tuyere fragment
373	12	N69/01	1	F7/F8			8.5		Processing slag
376	12	N69/01	2	Surf. scrape 5 sg. m.			1.5		Copper bead
375	12	N69/01	2	Surf. scrape 5 sg. m.			0.01		Ore nodule
378	12	N69/01	2	Surf. scrape 5 sg. m.			0.01		Microsphere
377	12	N69/01	2	Surf. scrape 5 sg. m.			7.8		Flow slag from smelting
379	12	N69/01	2	Surf. scrape 5 sg. m.			7.2		Flow slag from smelting
374	12	N69/01	2	Test 10		0-20 cm	0.6		Copper bead
391	12	N69/01	2	Test 10		0-25 cm	189	DBM 4416/06	Processing slag, SHB from secondary smithing
393	12	N69/01	2	Test 10		0-25 cm	27.5		Processing slag with gromps
392	12	N69/01	2	Test 10		0-25 cm	26.2		Processing slag with gromps
387	12	N69/01	2	Test 4		0-20 cm	0.01		Copper bead
380	12	N69/01	2	Test 4		0-20 cm	0.01		Ore nodule
382	12	N69/01	2	Test 4		0-20 cm	0.4		Ore nodule
383	12	N69/01	2	Test 4		0-20 cm	1.2		Ore nodule
384	12	N69/01	2	Test 4		0-20 cm	0.01		Copper bead
386	12	N69/01	2	Test 4		0-20 cm	0.8		Copper bead
388	12	N69/01	2	Test 4		0-20 cm	1.1		Copper bead
390	12	N69/01	2	Test 4		0-20 cm	0.4		Copper bead
385	12	N69/01	2	Test 4		0-20 cm	0.8		Copper bead
389	12	N69/01	2	Test 4		0-20 cm	0.4		Copper bead
381	12	N69/01	2	Test 4		0-20 cm	0.4		Ore nodule
394	12	N69/01	2	Test 4-10		25-35 cm	3.4	DBM 4483/06a	Open ring of iron
395	12	N69/01	2	Test 4-10		25-35 cm	2.1	DBM 4484/06b	Iron point
396	12	N69/01	2	Test 4-10		25-35 cm	2.8	DBM 4483/06b	Iron rod with loop-like end
398	12	N69/01					441		Furnace slag
400	12	N96/03	3	88/25	b	5	5		Pisolite, iron ore
404	12	N96/03	3	88/25	b	5	2.7		Unspecific slag with gromps
402	12	N96/03	3	88/25	b	5	0.5		Unspecific slag with gromps
405	12	N96/03	3	88/25	b	5	0.9		Unspecific slag
407	12	N96/03	3	88/25	b	5	4		Unspecific slag
406	12	N96/03	3	88/25	b	5	6.5		Processing slag
403	12	N96/03	3	88/25	b	5	1		Microsphere

Table 33, continued on next page: Finds from site catalogue no. 12, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
399		PSL								HS								LIG
397	SSL					SP												LIG
372															TY			LIG
373		PSL																LIG
376																	CO	LIG
375													OR					LIG
378		PSL								HS								LIG
377	SSL			FSL														LIG
379	SSL			FSL														LIG
374																	CO	LIG
391		PSL			SHB							SS						LIG
393		PSL							GR		PS							LIG
392		PSL							GR		PS							LIG
387																	CO	LIG
380													OR					LIG
382													OR					LIG
383													OR					LIG
384																	CO	LIG
386																	CO	LIG
388																	CO	LIG
390																	CO	LIG
385																	CO	LIG
389																	CO	LIG
381													OR					LIG
394																IA		LIG
395																IA		LIG
396																IA		LIG
398	SSL																	LIG
400													OR					LIG
404			USL						GR		PS							LIG
402			USL						GR		PS							LIG
405			USL															LIG
407			USL															LIG
406		PSL																LIG
403		PSL								HS								LIG

Table 33, continued from previous page and continued on next page: Finds from site catalogue no. 12, slag, metal artifacts, iron ore, and tuyere fragments. (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpretation
401	12	N96/03	3	88/25	b	5	0.7		Amorphous hammerscale
526	12	N96/03	3	88/26	b	7	2		Unspecific slag
524	12	N96/03	3	88/26	b	7	4.7		Unspecific slag
523	12	N96/03	3	88/26	b	7	5.4		Unspecific slag
1064	12	N96/03	3	88/26	b	7	0.1		Unspecific slag
534	12	N96/03	3	88/26	b	7	0.5		Unspecific slag
529	12	N96/03	3	88/26	b	7	0.5		Unspecific slag
530	12	N96/03	3	88/26	b	7	0.4		Unspecific slag
519	12	N96/03	3	88/26	b	7	19.1		Processing slag with gromps
533	12	N96/03	3	88/26	b	7	0.7		Thick hammerscale flake with corroded gromps and adhering bone fragment
531	12	N96/03	3	88/26	b	7	0.2		Amorphous hammerscale
522	12	N96/03	3	88/26	b	7	10.9		Processing slag
532	12	N96/03	3	88/26	b	7	0.5		Microsphere
520	12	N96/03	3	88/26	b	7	3.6		Processing slag
521	12	N96/03	3	88/26	b	7	10.7		Processing slag with gromps
528	12	N96/03	3	88/26	b	7	1.9		Flow slag from smelting
527	12	N96/03	3	88/26	b	7	1.2		Flow slag from smelting
525	12	N96/03	3	88/26	b	7	3.6		Furnace slag with adhering hammerscale flakes
565	12	N96/03	3	88/26	b	18	2.9		Bloom fragment, gromp
571	12	N96/03	3	88/26	b	18	1.9		Bloom fragment, gromp
567	12	N96/03	3	88/26	b	18	4.2		Bloom fragment, gromp
568	12	N96/03	3	88/26	b	18	4.3		Piece of raw metal (iron)
680	12	N96/03	3	88/26	b	18	21.7		Tip of a tuyere
538	12	N96/03	3	88/26	b	18	1.5		Unspecific slag with gromps
542	12	N96/03	3	88/26	b	18	13.7		Unspecific slag with gromps
412	12	N96/03	3	88/26	b	18	11	DBM 4421/06	Unspecific slag
545	12	N96/03	3	88/26	b	18	5.9		Silica-rich slag droplet, unspecific
536	12	N96/03	3	88/26	b	18	3.4		Unspecific slag
537	12	N96/03	3	88/26	b	18	3.1		Unspecific slag
539	12	N96/03	3	88/26	b	18	1.9		Unspecific slag
541	12	N96/03	3	88/26	b	18	0.7		Unspecific slag with gromps
544	12	N96/03	3	88/26	b	18	13.7		Unspecific slag
549	12	N96/03	3	88/26	b	18	2.5		Unspecific slag
550	12	N96/03	3	88/26	b	18	2.4		Unspecific slag
552	12	N96/03	3	88/26	b	18	0.4		Unspecific slag
554	12	N96/03	3	88/26	b	18	0.8		Unspecific slag
556	12	N96/03	3	88/26	b	18	1		Unspecific slag
557	12	N96/03	3	88/26	b	18	0.5		Unspecific slag
551	12	N96/03	3	88/26	b	18	0.5		Unspecific slag
548	12	N96/03	3	88/26	b	18	3.8		Processing slag with gromps
546	12	N96/03	3	88/26	b	18	6.1		Processing slag with gromps
411	12	N96/03	3	88/26	b	18	44	DBM 4422/06	Initial refining slag

Table 33, continued from previous page and continued on next page: Finds from site catalogue no. 12, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
401		PSL								HS	PS							LIG
526			USL															LIG
524			USL															LIG
523			USL															LIG
1064			USL															LIG
534			USL															LIG
529			USL															LIG
530			USL															LIG
519		PSL							GR		PS							LIG
533		PSL							GR	HS	PS							LIG
531		PSL								HS	PS							LIG
522		PSL																LIG
532		PSL								HS								LIG
520		PSL									PS							LIG
521		PSL									PS							LIG
528	SSL			FSL														LIG
527	SSL			FSL														LIG
525	SSL									HS	PS							LIG
565									GR		PS							LIG
571									GR		PS							LIG
567									GR		PS							LIG
568																IA		LIG
680															TY			LIG
538			USL						GR		PS							LIG
542			USL						GR		PS							LIG
412			USL															LIG
545			USL															LIG
536			USL															LIG
537			USL															LIG
539			USL															LIG
541			USL															LIG
544			USL															LIG
549			USL															LIG
550			USL															LIG
552			USL															LIG
554			USL															LIG
556			USL															LIG
557			USL															LIG
551			USL															LIG
548		PSL							GR		PS							LIG
546		PSL							GR		PS							LIG
411		PSL							GR		PS							LIG

Table 33, continued from previous page and continued on next page: Finds from site catalogue no. 12, slag, metal artifacts, iron ore, and tuyere fragments. (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpretation
543	12	N96/03	3	88/26	b	18	7.2		Processing slag with gromps and ham-merscale flakes
561	12	N96/03	3	88/26	b	18	1.1		Processing slag with slagged hammersca-le flakes and microspheres
560	12	N96/03	3	88/26	b	18	0.5		Processing slag with adhering hammerscale flakes, slag fragments and microspheres
555	12	N96/03	3	88/26	b	18	0.9		Small amorphous hammerscale, se-condary smithing?
558	12	N96/03	3	88/26	b	18	1.1		Slag droplet in sand, processing slag
553	12	N96/03	3	88/26	b	18	1.1		Processing slag formed from conglomera-ted hammerscales
562	12	N96/03	3	88/26	b	18	0.4		Hammerscale flake
563	12	N96/03	3	88/26	b	18	0.2		Hammerscale flake
564	12	N96/03	3	88/26	b	18	1.6		Microsphere
566	12	N96/03	3	88/26	b	18	0.7		Microsphere
569	12	N96/03	3	88/26	b	18	0.2		Amorphous hammerscale
570	12	N96/03	3	88/26	b	18	1.3		Microsphere
559	12	N96/03	3	88/26	b	18	0.6		Conglomerated hammerscales with slag droplets
547	12	N96/03	3	88/26	b	18	5.3		Unspecific slag with gromps
540	12	N96/03	3	88/26	b	18	1.6		Flow slag droplet from smelting
535	12	N96/03	3	88/26	b	18	120.9		Furnace slag with unreacted ore inclusions
587	12	N96/03	3	88/26	b	19	4.3		Unspecific slag with gromps
585	12	N96/03	3	88/26	b	19	2.5		Unspecific slag
590	12	N96/03	3	88/26	b	19	121		Unspecific slag
572	12	N96/03	3	88/26	b	19	11.8		Unspecific slag
582	12	N96/03	3	88/26	b	19	3.1		Unspecific slag
584	12	N96/03	3	88/26	b	19	2		Amorphous hammerscales with gromps
589	12	N96/03	3	88/26	b	19	3.2		Processing slag, initial refining
578	12	N96/03	3	88/26	b	19	9		Processing slag
579	12	N96/03	3	88/26	b	19	10.9		Processing slag
580	12	N96/03	3	88/26	b	19	1.4		Amorphous hammerscale
581	12	N96/03	3	88/26	b	19	4.2		Small iron spheres
576	12	N96/03	3	88/26	b	19	9.5		Silica-rich processing slag with layers of iron rich slag, adhering hammerscales and gromps
577	12	N96/03	3	88/26	b	19	7.6		Processing slag
588	12	N96/03	3	88/26	b	19	2.4		Processing slag with microspheres
583	12	N96/03	3	88/26	b	19	7.4		Processing slag
575	12	N96/03	3	88/26	b	19	4.3		Processing slag
574	12	N96/03	3	88/26	b	19	3.5		Silica-rich processing slag with gromps
573	12	N96/03	3	88/26	b	19	2.5		Flow slag from smelting
586	12	N96/03	3	88/26	b	19	10.5		Flow slag from smelting
612	12	N96/03	3	88/26	b	21	1.4		Unspecific slag with gromps and small quartz fragments

Table 33, continued from previous page and continued on next page: Finds from site catalogue no. 12, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
543		PSL							GR	HS	PS							LIG
561		PSL								HS								LIG
560		PSL								HS		SS						LIG
555		PSL								HS		SS						LIG
558		PSL																LIG
553		PSL								HS		SS						LIG
562		PSL								HS								LIG
563		PSL								HS								LIG
564		PSL								HS								LIG
566		PSL								HS								LIG
569		PSL								HS	PS							LIG
570		PSL								HS								LIG
559		PSL								HS		SS						LIG
547			USL						GR		PS							LIG
540	SSL																	LIG
535	SSL												OR					LIG
587			USL						GR		PS							LIG
585			USL															LIG
590			USL															LIG
572			USL															LIG
582			USL															LIG
584		PSL							GR	HS	PS							LIG
589		PSL									PS							LIG
578		PSL																LIG
579		PSL									PS							LIG
580		PSL								HS	PS							LIG
581		PSL							GR		PS							LIG
576		PSL							GR	HS	PS							LIG
577		PSL									PS							LIG
588		PSL								HS								LIG
583		PSL																LIG
575		PSL																LIG
574		PSL																LIG
573	SSL			FSL														LIG
586	SSL			FSL														LIG
612			USL						GR		PS			QZ				LIG

Table 33, continued from previous page and continued on next page: Finds from site catalogue no. 12, slag, metal artifacts, iron ore, and tuyere fragments. (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpretation
626	12	N96/03	3	88/26	b	21	1.1		Unspecific slag with gromps
625	12	N96/03	3	88/26	b	21	0.9		Unspecific slag
609	12	N96/03	3	88/26	b	21	6.4		Unspecific slag with gromps
600	12	N96/03	3	88/26	b	21	2.1		Unspecific slag with gromps
605	12	N96/03	3	88/26	b	21	3.5		Unspecific slag with gromps
628	12	N96/03	3	88/26	b	21	0.9		Unspecific slag with gromps
608	12	N96/03	3	88/26	b	21	2.4		Unspecific slag with gromps
613	12	N96/03	3	88/26	b	21	6.9		Unspecific slag with gromps
646	12	N96/03	3	88/26	b	21	0.1		Unspecific slag with gromps
602	12	N96/03	3	88/26	b	21	3.2		Unspecific slag with gromps
607	12	N96/03	3	88/26	b	21	2.9		Unspecific slag with gromps
635	12	N96/03	3	88/26	b	21	0.8		Unspecific slag
639	12	N96/03	3	88/26	b	21	0.4		Unspecific slag
640	12	N96/03	3	88/26	b	21	0.2		Unspecific slag
624	12	N96/03	3	88/26	b	21	1.2		Unspecific slag
622	12	N96/03	3	88/26	b	21	1.4		Unspecific slag
645	12	N96/03	3	88/26	b	21	0.6		Unspecific slag
650	12	N96/03	3	88/26	b	21	0.2		Unspecific slag
653	12	N96/03	3	88/26	b	21	2.2		Processing slag ?
618	12	N96/03	3	88/26	b	21	1.1		Unspecific slag
617	12	N96/03	3	88/26	b	21	0.6		Unspecific slag
660	12	N96/03	3	88/26	b	21	0.9		Unspecific slag
603	12	N96/03	3	88/26	b	21	4.4		Unspecific slag with gromps
598	12	N96/03	3	88/26	b	21	4.1		Unspecific slag
597	12	N96/03	3	88/26	b	21	3.8		Unspecific slag
591	12	N96/03	3	88/26	b	21	26.5		Unspecific slag
611	12	N96/03	3	88/26	b	21	8.1		Unspecific slag
595	12	N96/03	3	88/26	b	21	2.1		Slagged sand
627	12	N96/03	3	88/26	b	21	1.1		Processing slag with gromps
413	12	N96/03	3	88/26	b	21	35	DBM 4423/06	Initial refining slag with gromps
658	12	N96/03	3	88/26	b	21	0.1		Hammerscale flake
659	12	N96/03	3	88/26	b	21	0.1		Flat amorphous hammerscale
644	12	N96/03	3	88/26	b	21	0.2		Droplet-like hammerscale
661	12	N96/03	3	88/26	b	21	0.2		Hammerscale flake
642	12	N96/03	3	88/26	b	21	1		Processing slag with adhering hammerscale
662	12	N96/03	3	88/26	b	21	2.7		Amorphous hammerscale with adhering hammerscale flakes
657	12	N96/03	3	88/26	b	21	0.2		Flat amorphous hammerscale
652	12	N96/03	3	88/26	b	21	0.2		Processing slag with adhering hammerscale
663	12	N96/03	3	88/26	b	21	0.6		Amorphous hammerscale with adhering hammerscale flakes
664	12	N96/03	3	88/26	b	21	0.6		Flat amorphous hammerscale
592	12	N96/03	3	88/26	b	21	24.6		Reheated unspecific slag fragment with gromps

Table 33, continued from previous page and continued on next page: Finds from site catalogue no. 12, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
626			USL						GR		PS							LIG
625			USL															LIG
609			USL						GR		PS							LIG
600			USL						GR		PS							LIG
605			USL						GR		PS							LIG
628			USL						GR		PS							LIG
608			USL						GR		PS							LIG
613			USL						GR		PS							LIG
646			USL						GR		PS							LIG
602			USL						GR		PS							LIG
607			USL						GR		PS							LIG
635			USL															LIG
639			USL															LIG
640			USL															LIG
624			USL											QZ				LIG
622			USL															LIG
645			USL															LIG
650			USL															LIG
653			USL															LIG
618			USL															LIG
617			USL															LIG
660			USL															LIG
603			USL															LIG
598			USL															LIG
597			USL															LIG
591			USL															LIG
611			USL															LIG
595			USL															LIG
627		PSL							GR		PS							LIG
413		PSL							GR		PS							LIG
658		PSL								HS								LIG
659		PSL								HS	PS							LIG
644		PSL								HS								LIG
661		PSL								HS								LIG
642		PSL								HS	PS							LIG
662		PSL								HS	PS							LIG
657		PSL								HS	PS							LIG
652		PSL								HS								LIG
663		PSL								HS	PS							LIG
664		PSL								HS	PS							LIG
592		PSL									PS							LIG

Table 33, continued from previous page and continued on next page: Finds from site catalogue no. 12, slag, metal artifacts, iron ore, and tuyere fragments. (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpretation
599	12	N96/03	3	88/26	b	21	3.8		Processing slag
656	12	N96/03	3	88/26	b	21	0.3		Hammerscale flake
601	12	N96/03	3	88/26	b	21	2.4		Conglomerated microspheres with adhering sand
655	12	N96/03	3	88/26	b	21	0.3		Conglomerated amorphous and flake hammerscales
665	12	N96/03	3	88/26	b	21	0.3		Microsphere
647	12	N96/03	3	88/26	b	21	0.2		Microsphere
673	12	N96/03	3	88/26	b	21	0.4		Microsphere
606	12	N96/03	3	88/26	b	21	3.6		Processing slag
651	12	N96/03	3	88/26	b	21	0.3		Conglomerated hammerscale flakes
648	12	N96/03	3	88/26	b	21	0.6		Processing slag with adhering hammerscale
649	12	N96/03	3	88/26	b	21	0.6		Processing slag with adhering hammerscale flakes
629	12	N96/03	3	88/26	b	21	0.4		Processing slag with microspheres
654	12	N96/03	3	88/26	b	21	0.3		Flat amorphous hammerscale
678	12	N96/03	3	88/26	b	21	0.01		Conglomerated microspheres and hammerscale flakes
1065	12	N96/03	3	88/26	b	21	0.9		Conglomerated microspheres
1066	12	N96/03	3	88/26	b	21	0.2		Microsphere
638	12	N96/03	3	88/26	b	21	0.2		Processing slag with adhering hammercale
414	12	N96/03	3	88/26	b	21	33	DBM 4424/06	SHB secondary smithing
641	12	N96/03	3	88/26	b	21	0.2		Processing slag with adhering hammerscale
593	12	N96/03	3	88/26	b	21	12.1		SHB, slagged sand with adhering hammerscale flakes from secondary smithing
636	12	N96/03	3	88/26	b	21	0.3		Processing slag, fractured quartz
620	12	N96/03	3	88/26	b	21	0.2		Processing slag with adhering hammerscale flakes and slagged sand
621	12	N96/03	3	88/26	b	21	1.4		Processing slag with adhering hammerscale
671	12	N96/03	3	88/26	b	21	0.8		Microsphere
679	12	N96/03	3	88/26	b	21	0.2		Microsphere
666	12	N96/03	3	88/26	b	21	0.3		Microsphere
677	12	N96/03	3	88/26	b	21	0.1		Microsphere
676	12	N96/03	3	88/26	b	21	0.4		Microsphere
634	12	N96/03	3	88/26	b	21	1		Silica-rich processing slag and adhering hammerscale flakes
675	12	N96/03	3	88/26	b	21	0.5		Microsphere
674	12	N96/03	3	88/26	b	21	0.2		Microsphere
672	12	N96/03	3	88/26	b	21	0.9		Microsphere
670	12	N96/03	3	88/26	b	21	0.1		Microsphere
669	12	N96/03	3	88/26	b	21	0.1		Microsphere
668	12	N96/03	3	88/26	b	21	0.2		Microsphere and adhering hammerscale flake
667	12	N96/03	3	88/26	b	21	0.2		Microsphere
610	12	N96/03	3	88/26	b	21	6.6		Small SHB

Table 33, continued from previous page and continued on next page: Finds from site catalogue no. 12, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
599		PSL																LIG
656		PSL								HS								LIG
601		PSL								HS								LIG
655		PSL								HS	PS							LIG
665		PSL								HS								LIG
647		PSL								HS								LIG
673		PSL								HS	PS							LIG
606		PSL																LIG
651		PSL								HS								LIG
648		PSL								HS	PS							LIG
649		PSL								HS	PS							LIG
629		PSL																LIG
654		PSL								HS	PS							LIG
678		PSL								HS								LIG
1065		PSL								HS								LIG
1066		PSL								HS	PS							LIG
638		PSL								HS								LIG
414		PSL			SHB							SS						LIG
641		PSL								HS		SS						LIG
593		PSL			SHB					HS		SS						LIG
636		PSL										SS		QZ				LIG
620		PSL								HS								LIG
621		PSL								HS								LIG
671		PSL								HS	PS							LIG
679		PSL								HS								LIG
666		PSL								HS								LIG
677		PSL								HS								LIG
676		PSL								HS								LIG
634		PSL								HS	PS							LIG
675		PSL								HS								LIG
674		PSL								HS								LIG
672		PSL								HS	PS							LIG
670		PSL								HS	PS							LIG
669		PSL								HS								LIG
668		PSL								HS								LIG
667		PSL								HS								LIG
610		PSL			SHB							SS						LIG

Table 33, continued from previous page and continued on next page: Finds from site catalogue no. 12, slag, metal artifacts, iron ore, and tuyere fragments. (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpretation
604	12	N96/03	3	88/26	b	21	4.9		Processing slag
594	12	N96/03	3	88/26	b	21	1.9		Flow slag from smelting
615	12	N96/03	3	88/26	b	21	15.2		Furnace slag
614	12	N96/03	3	88/26	b	21	11.6		Flow slag with bloom inclusions from smelting
632	12	N96/03	3	88/26	b	21	0.3		Flow slag from smelting
616	12	N96/03	3	88/26	b	21	12.7		Flow slag from smelting
596	12	N96/03	3	88/26	b	21	3.6		Furnace slag?
619	12	N96/03	3	88/26	b	21	0.3		Flow slag from smelting
623	12	N96/03	3	88/26	b	21	1.2		Flow slag from smelting
631	12	N96/03	3	88/26	b	21	1		Flow slag from smelting
633	12	N96/03	3	88/26	b	21	0.4		Flow slag from smelting
637	12	N96/03	3	88/26	b	21	0.3		Flow slag from smelting
643	12	N96/03	3	88/26	b	21	0.1		Flow slag from smelting
630	12	N96/03	3	88/26	b	21	2		Flow slag from smelting
1063	12	N96/03	3	88/26	b	21	0.3		Processing slag with quartz inclusions
681	12	N96/03	3	88/26	d	8	36		Iron rich sandstone
409	12	N96/03	3	88/26	d	8	3		Unspecific slag
408	12	N96/03	3	88/26	d	8	4		Unspecific slag
410	12	N96/03	3	88/26	d	8	3		Unspecific slag
689	12	N96/03	3	88/26	d	8	1.8		Microsphere
688	12	N96/03	3	88/26	d	8	0.2		Unspecific slag
687	12	N96/03	3	88/26	d	8	0.4		Unspecific slag
692	12	N96/03	3	88/26	d	8	2.9		Unspecific slag
683	12	N96/03	3	88/28	d	8	127	DBM 4418/06	SHB, final refining slag with gromps
690	12	N96/03	3	88/26	d	8	31		Processing slag with gromps
684	12	N96/03	3	88/28	d	8	31	DBM 4420/06	SHB, advanced refining slag with gromps
691	12	N96/03	3	88/26	d	8	3.8		Processing slag with gromps
685	12	N96/03	3	88/26	d	8	17.7		Silica-rich SHB
686	12	N96/03	3	88/26	d	8	20		Processing slag
682	12	N96/03	3	88/28	d	8	383	DBM 4417/06	Tap slag that cooled down in a slag pit
693	12	N96/03	3	88/26	d	8	4.3		Flow slag with bloom inclusions from smelting
694	12	N96/03	3	88/27	b	9	3.3		Silica-rich slag with gromps
695	12	N96/03	3	88/27	d	10	3.7		Processing slag with gromps and hammerscale flakes
696	12	N96/03	3	88/27	d	10	6		Unspecific slag with gromps
702	12	N96/03	3	88/27	d	10	0.1		Unspecific slag
697	12	N96/03	3	88/27	d	10	2.1		Unspecific slag
698	12	N96/03	3	88/27	d	10	1.3		Unspecific slag
703	12	N96/03	3	88/27	d	10	1.3		Processing slag with gromps
701	12	N96/03	3	88/27	d	10	0.2		Microsphere
705	12	N96/03	3	88/27	d	10	0.5		Amorphous hammerscale
704	12	N96/03	3	88/27	d	10	0.6		Hammerscale flakes

Table 33, continued from previous page and continued on next page: Finds from site catalogue no. 12, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
604		PSL							GR		PS							LIG
594	SSL			FSL				BL										LIG
615	SSL							BL										LIG
614	SSL			FSL				BL										LIG
632	SSL			FSL														LIG
616	SSL			FSL														LIG
596	SSL																	LIG
619	SSL			FSL														LIG
623	SSL			FSL														LIG
631	SSL			FSL														LIG
633	SSL			FSL														LIG
637	SSL			FSL														LIG
643	SSL			FSL														LIG
630	SSL			FSL														LIG
1063		PSL										SS		QZ				LIG
681													OR					LIG
409			USL															LIG
408			USL															LIG
410			USL															LIG
689			USL															LIG
688			USL															LIG
687			USL															LIG
692			USL															LIG
683		PSL			SHB				GR		PS							LIG
690		PSL							GR		PS							LIG
684		PSL			SHB				GR		PS							LIG
691		PSL							GR		PS							LIG
685		PSL			SHB							SS						LIG
686		PSL			SHB													LIG
682	SSL					SP		BL										LIG
693	SSL							BL										LIG
694		PSL							GR		PS							LIG
695		PSL							GR	HS	PS							LIG
696			USL						GR		PS							LIG
702			USL															LIG
697			USL															LIG
698			USL															LIG
703		PSL							GR		PS							LIG
701		PSL								HS								LIG
705		PSL								HS	PS							LIG
704		PSL								HS	PS							LIG

Table 33, continued from previous page and continued on next page: Finds from site catalogue no. 12, slag, metal artifacts, iron ore, and tuyere fragments. (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpretation
700	12	N96/03	3	88/27	d	10	1		Amorphous hammerscale
699	12	N96/03	3	88/27	d	10	1.4		Flow slag from smelting
707	12	N96/03	3	88/28	b	11	0.01		Unspecific slag
710	12	N96/03	3	88/28	b	11	2.1		Processing slag with gromps
706	12	N96/03	3	88/28	b	11	10.9		Processing slag with gromps and adhe-ring hammerscales
709	12	N96/03	3	88/28	b	11	0.001		Microsphere
708	12	N96/03	3	88/28	b	11	0.1		Microsphere
711	12	N96/03	3	88/28	d	12	5.3		Processing slag
712	12	N96/03	3	88/28	d	12	0.5		Thick amorphous hammerscale
713	12	N96/03	3	88/28	d	12	0.001		Droplet-like hammerscale
716	12	N96/03	3	88/28	d	12	0.1		Hammerscale flakes
715	12	N96/03	3	88/28	d	12	0.01		Hammerscale flakes
714	12	N96/03	3	88/28	d	12	0.2		Microsphere
720	12	N96/03	3	88/28	d	20	5.3		Slagged tuyere fragment with adhering slag and gromps
719	12	N96/03	3	88/28	d	20	3.7		Bloom fragment, gromp
717	12	N96/03	3	88/28	d	20	8.6		Unspecific slag with gromps
724	12	N96/03	3	88/28	d	20	0.4		Unspecific slag
723	12	N96/03	3	88/28	d	20	0.1		Unspecific slag
718	12	N96/03	3	88/28	d	20	5		Processing slag
722	12	N96/03	3	88/28	d	20	0.2		Amorphous hammerscale
721	12	N96/03	3	88/28	d	20	0.01		Hammerscale flake
736	12	N96/03	3	88/29	b	13	12.1		Tuyere fragment
728	12	N96/03	3	88/29	b	13	1		Unspecific slag
735	12	N96/03	3	88/29	b	13	3		Unspecific slag
730	12	N96/03	3	88/29	b	13	11.6		Processing slag with gromps and ham-merscale inclusions
732	12	N96/03	3	88/29	b	13	26	DBM 4427/06	Amorphous refining slag
1058	12	N96/03	3	88/29	b	13	2.5		Amorphous hammerscale with adhering gromps
734	12	N96/03	3	88/29	b	13	3.1		Microsphere
727	12	N96/03	3	88/29	b	13	0.7		Conglomerated large hammerscale flakes with adhering small flakes
729	12	N96/03	3	88/29	b	13	0.7		Amorphous hammerscale
726	12	N96/03	3	88/29	b	13	0.9		Amorphous processing slag with adhering very small microspheres, secondary smithing
733	12	N96/03	3	88/29	b	13	1.4		Microsphere
731	12	N96/03	3	88/29	b	13	12	DBM 4426/06	Bloom fragment in smelting slag
725	12	N96/03	3	88/29	b	13	1.9		Furnace slag
740	12	N96/03	3	88/29	d	14	1.6		Slagged sand with tiny gromps
744	12	N96/03	3	88/29	d	14	0.3		Unspecific slag droplets
737	12	N96/03	3	88/29	d	14	0.5		Unspecific slag
739	12	N96/03	3	88/29	d	14	0.4		Processing slag with gromps

Table 33, continued from previous page and continued on next page: Finds from site catalogue no. 12, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
700		PSL								HS	PS							LIG
699	SSL																	LIG
707			USL															LIG
710		PSL							GR		PS							LIG
706		PSL								HS	PS							LIG
709		PSL								HS								LIG
708		PSL								HS								LIG
711		PSL									PS							LIG
712		PSL								HS	PS							LIG
713		PSL								HS								LIG
716		PSL								HS								LIG
715		PSL								HS								LIG
714		PSL								HS								LIG
720				FSL					GR						TY			LIG
719									GR		PS							LIG
717			USL						GR		PS							LIG
724			USL															LIG
723			USL															LIG
718		PSL							GR	HS	PS							LIG
722		PSL								HS	PS							LIG
721		PSL								HS								LIG
736															TY			LIG
728			USL															LIG
735			USL															LIG
730		PSL							GR	HS	PS							LIG
732		PSL							GR		PS							LIG
1058		PSL							GR	HS	PS							LIG
734		PSL								HS								LIG
727		PSL								HS	PS							LIG
729		PSL								HS	PS							LIG
726		PSL								HS		SS						LIG
733		PSL								HS								LIG
731	SSL							BL	GR		PS							LIG
725	SSL																	LIG
740		PSL							GR			SS						LIG
744			USL															LIG
737			USL															LIG
739		PSL							GR		PS							LIG

Table 33, continued from previous page and continued on next page: Finds from site catalogue no. 12, slag, metal artifacts, iron ore, and tuyere fragments. (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpretation
741	12	N96/03	3	88/29	d	14	0.4		Amorphous hammerscale with adhering hammerscale flakes
742	12	N96/03	3	88/29	d	14	0.1		Hammerscale flakes
743	12	N96/03	3	88/29	d	14	0.1		Amorphous hammerscale
746	12	N96/03	3	88/29	d	14	0.3		Microsphere with adhering gromp
745	12	N96/03	3	88/29	d	14	0.3		Microsphere
738	12	N96/03	3	88/29	d	14	0.8		Flow slag from smelting
747	12	N96/03	3	88/30	b	15	3.1		Bloom fragment, gromp
754	12	N96/03	3	88/30	d	16	0.7		Unspecific slag with gromps
758	12	N96/03	3	88/30	d	16	0.2		Unspecific slag
751	12	N96/03	3	88/30	d	16	2.6		Unspecific slag
749	12	N96/03	3	88/30	d	16	4.1		Bloom fragment, gromp
755	12	N96/03	3	88/30	d	16	0.4		Microsphere
761	12	N96/03	3	88/30	d	16	0.001		Amorphous hammerscale
760	12	N96/03	3	88/30	d	16	0.7		Amorphous hammerscale with adhering microspheres and flakes
759	12	N96/03	3	88/30	d	16	1.3		Amorphous hammerscale with adhering hammerscale flakes
756	12	N96/03	3	88/30	d	16	0.9		Microsphere
757	12	N96/03	3	88/30	d	16	1.4		Amorphous hammerscale with adhering hammerscale flakes and small gromps
748	12	N96/03	3	88/30	d	16	9.5		Furnace slag with bloom inclusions
753	12	N96/03	3	88/30	d	16	1.3		Flow slag from smelting
752	12	N96/03	3	88/30	d	16	2.8		Flow slag with bloom inclusion from smelting
750	12	N96/03	3	88/30	d	16	4.5		Furnace slag
762	12	N98/30					31		Unspecific slag
763	12	N98/30					81		Unspecific slag
764	12	N98/30					69		Processing slag
765	12	N98/30					26		Processing slag
771	12	N98/32	2	31/29		14	5.4		Tuyere fragment
770	12	N98/32	2	31/29		14	5.3		Tip of a tuyere
766	12	N98/32	2	31/29	d	22	27.7		Bloom fragment, gromp
767	12	N98/32	2	31/29	d	22	3.9		Bloom fragment, gromp
768	12	N98/32	2	31/29	d	26	2.5		Tuyere fragment
769	12	N98/32	2	31/29	d	26	8		Processing slag with gromp
772	12	N98/32	2	33/22		55	2		Unspecific slag
773	12	N98/32	2	34/20		50	0.7		Copper bead
774	12	N98/32	2	34/23	a	32	4.1		Unspecific slag with gromp
780	12	N98/32	2	34/23	b	11	10		Tuyere fragment
776	12	N98/32	2	34/23	b	11	1.9		Unspecific slag with gromp
777	12	N98/32	2	34/23	b	11	10		Unspecific slag
778	12	N98/32	2	34/23	b	40	1.7		Processing slag
779	12	N98/32	2	34/23	b	41	1.7		Unspecific slag with gromp

Table 33, continued from previous page and continued on next page: Finds from site catalogue no. 12, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
741		PSL								HS	PS							LIG
742		PSL								HS								LIG
743		PSL								HS	PS							LIG
746		PSL							GR	HS								LIG
745		PSL								HS								LIG
738	SSL																	LIG
747									GR		PS							LIG
754			USL						GR		PS							LIG
758			USL															LIG
751			USL															LIG
749									GR		PS							LIG
755		PSL								HS	PS							LIG
761		PSL								HS	PS							LIG
760		PSL								HS	PS							LIG
759		PSL								HS	PS							LIG
756		PSL								HS	PS							LIG
757		PSL								HS	PS							LIG
748	SSL							BL	GR		PS							LIG
753	SSL																	LIG
752	SSL																	LIG
750	SSL																	LIG
762			USL															LIG
763			USL															LIG
764		PSL																LIG
765		PSL																LIG
771															TY			LIG
770															TY			LIG
766									GR		PS							LIG
767		PSL							GR		PS							LIG
768															TY			LIG
769		PSL							GR		PS							LIG
772			USL															LIG
773																	CO	LIG
774			USL						GR		PS							LIG
780															TY			LIG
776			USL						GR		PS							LIG
777			USL															LIG
778		PSL																LIG
779			USL						GR		PS							LIG

Table 33, continued from previous page and continued on next page: Finds from site catalogue no. 12, slag, metal artifacts, iron ore, and tuyere fragments. (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpretation
775	12	N98/32	2	34/23	b	41	19	DBM 4428/06	Furnace slag with unreacted ore inclusi-ons and bloom
781	12	N98/32	2	34/23	d	21	8		Unspecific slag
782	12	N98/32	2	34/23	d	21	1.2		Processing slag
783	12	N98/32	2	34/24	d	5	4.9		Double hook
784	12	N98/32	2	50/50	a	9	0.5		Unspecific slag
785	12	N98/32	2	50/50	b	9	0.01		Copper bead
787	12	N98/32	2	50/50	b	9	3		Unspecific slag
791	12	N98/32	2	50/50	b	9	0.4		Unspecific slag
786	12	N98/32	2	50/50	b	9	5		Unspecific slag
790	12	N98/32	2	50/50	b	9	0.1		Unspecific slag
788	12	N98/32	2	50/50	b	9	2.1		Conglomerated amorphous hammerscales with gromps
789	12	N98/32	2	50/50	b	9	3.9		Processing slag
792	12	N98/32	2	50/50	d	6	0.7		Iron-rich sandstone
793	12	N98/32	2	50/50	d	9	0.6		Unspecific slag with slagged tuyere remain
795	12	N98/32	2	50/51	a	6	2		Iron-rich sandstone
794	12	N98/32	2	50/51	a	6	3		Iron-rich sandstone
796	12	N98/32	2	50/51	a	9	0.5		Unspecific slag
798	12	N98/32	2	50/51	b	6	4		Iron-rich sandstone
797	12	N98/32	2	50/51	b	6	0.4		Iron-rich sandstone
799	12	N98/32	2	50/51	b	6	1.9		Processing slag with adhering ham-merscales and gromps
1106	12	N98/32	2	50/51	b	6	1		Processing slag with gromps
1107	12	N98/32	2	50/51	b	6	1		Processing slag with gromps
1105	12	N98/32	2	50/51	b	6	1.9		Processing slag with gromps
1101	12	N98/32	2	50/51	b	6	0.2		Small processing slag
803	12	N98/32	2	50/51	b	9	1.6		Bloom fragment, gromp
808	12	N98/32	2	50/51	b	9	11.4		Tuyere fragment
809	12	N98/32	2	50/51	b	9	5.4		Tuyere fragment
807	12	N98/32	2	50/51	b	9	0.2		Slagged sand
800	12	N98/32	2	50/51	b	9	14		Unspecific slag
801	12	N98/32	2	50/51	b	9	5		Unspecific slag
802	12	N98/32	2	50/51	b	9	4.2		Unspecific slag
804	12	N98/32	2	50/51	b	9	11		Unspecific slag
806	12	N98/32	2	50/51	b	9	0.3		Slagged sand
805	12	N98/32	2	50/51	b	9	3.1		Unspecific slag
1061	12	N98/32	2	50/51	b	9	3.1		Processing slag with gromps
810	12	N98/32	2	50/51	b	9//3	32.7		Tuyere fragment
1116	12	N98/32	2	50/51	c	6	1		Piece of worked iron
1118	12	N98/32	2	50/51	c	6	0.5		Iron ring
1120	12	N98/32	2	50/51	c	6	0.5		Iron ore
812	12	N98/32	2	50/51	c	9	0.5		Unspecific slag
811	12	N98/32	2	50/51	c	9	0.5		Unspecific slag

Table 33, continued from previous page and continued on next page: Finds from site catalogue no. 12, slag, metal artifacts, iron ore, and tuyere fragments.

Table 33

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
775	SSL							BL			PS		OR					LIG
781			USL															LIG
782		PSL												QZ				LIG
783																IA		LIG
784			USL															LIG
785																	CO	LIG
787			USL															LIG
791			USL															LIG
786			USL															LIG
790			USL															LIG
788		PSL							GR	HS	PS							LIG
789		PSL																LIG
792													OR					LIG
793															TY			LIG
795													OR					LIG
794													OR					LIG
796			USL															LIG
798													OR					LIG
797													OR					LIG
799		PSL							GR	HS		SS						LIG
1106		PSL							GR		PS							LIG
1107		PSL							GR		PS							LIG
1105		PSL							GR		PS							LIG
1101		PSL																LIG
803									GR		PS							LIG
808															TY			LIG
809															TY			LIG
807			USL											QZ				LIG
800			USL															LIG
801			USL															LIG
802			USL	FSL							PS							LIG
804			USL															LIG
806			USL											QZ				LIG
805			USL															LIG
1061		PSL							GR					QZ				LIG
810															TY			LIG
1116																IA		LIG
1118																IA		LIG
1120													OR					LIG
812			USL															LIG
811			USL															LIG

Table 33, continued from previous page and continued on next page: Finds from site catalogue no. 12, slag, metal artifacts, iron ore, and tuyere fragments. (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpretation
814	12	N98/32	2	50/51	d	9	7.1		Slagged tuyere fragment with adhering slag
815	12	N98/32	2	50/51	d	9	2.4		Slagged tuyere fragment with adhering slag
817	12	N98/32	2	50/51	d	9	3.7		Unspecific slag
813	12	N98/32	2	50/51	d	9	10		Unspecific slag
816	12	N98/32	2	50/51	d	9	2		Processing slag
825	12	N98/32	2	51/50	a	6	1.5		Unspecific slag with gromps
827	12	N98/32	2	51/50	a	6	0.6		Unspecific slag with gromps
822	12	N98/32	2	51/50	a	6	0.3		Unspecific slag with gromps
824	12	N98/32	2	51/50	a	6	0.3		Unspecific slag
823	12	N98/32	2	51/50	a	6	2		Slagged sand with gromps
826	12	N98/32	2	51/50	a	6	2.6		Furnace slag with bloom inclusions
819	12	N98/32	2	51/50	a	9	9.1		Tuyere fragment
820	12	N98/32	2	51/50	a	9	8.4		Tip of a tuyere
821	12	N98/32	2	51/50	a	9	18		Unspecific slag
818	12	N98/32	2	51/50	a	9	22	DBM 4429/06	Initial refining slag with gromps and partially reduced ore
828	12	N98/32	2	51/50	b	6	1.7		Unspecific slag with gromps
830	12	N98/32	2	51/50	b	6	0.5		Unspecific slag
829	12	N98/32	2	51/50	b	6	3		Unspecific slag
834	12	N98/32	2	51/50	b	9	2.1		Tuyere fragment
833	12	N98/32	2	51/50	b	9	0.5		Unspecific slag
832	12	N98/32	2	51/50	b	9	3		Unspecific slag
831	12	N98/32	2	51/50	b	9	3		Unspecific slag
836	12	N98/32	2	51/50	c	6	0.2		Slagged sand
835	12	N98/32	2	51/50	c	6	1.9		Processing slag with gromps
840	12	N98/32	2	51/50	c	9	8.8		Tip of a tuyere
839	12	N98/32	2	51/50	c	9	14		Unspecific slag
838	12	N98/32	2	51/50	c	9	0.3		Conglomerated small hammerscales with gromps
837	12	N98/32	2	51/50	c	9	1.1		Processing slag
841	12	N98/32	2	51/50	c	9//2	7.8		Tip of a tuyere with adhering small microspheres, secondary smithing
842	12	N98/32	2	51/50	c	9//2	10		Unspecific slag
843	12	N98/32	2	51/50	d	6	7		Unspecific slag
845	12	N98/32	2	51/50	d	6	1		Unspecific slag
844	12	N98/32	2	51/50	d	6	5		Unspecific slag
848	12	N98/32	2	51/50	d	9	1.1		Bloom fragment, gromp
847	12	N98/32	2	51/50	d	9	6		Unspecific slag
846	12	N98/32	2	51/50	d	9	4.5		Unspecific slag
849	12	N98/32	2	51/50	d	9	0.7		Furnace slag
1110	12	N98/32	2	51/51	a	6	0.8		Iron ore
850	12	N98/32	2	51/51	a	6	0.9		Processing slag
1099	12	N98/32	2	51/51	a	6	1.7		Processing slag
852	12	N98/32	2	51/51	a	9	0.5		Processing slag with gromps

Table 33, continued from previous page and continued on next page: Finds from site catalogue no. 12, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
814			USL												TY			LIG
815			USL												TY			LIG
817			USL															LIG
813			USL															LIG
816		PSL																LIG
825			USL						GR		PS							LIG
827			USL						GR		PS							LIG
822			USL						GR		PS							LIG
824			USL															LIG
823		PSL							GR		PS			QZ				LIG
826	SSL							BL			PS							LIG
819															TY			LIG
820															TY			LIG
821			USL															LIG
818		PSL						BL	GR		PS		OR					LIG
828			USL						GR		PS							LIG
830			USL															LIG
829			USL															LIG
834															TY			LIG
833			USL															LIG
832			USL															LIG
831			USL															LIG
836			USL											QZ				LIG
835		PSL							GR		PS							LIG
840															TY			LIG
839			USL															LIG
838		PSL							GR	HS		SS						LIG
837		PSL												QZ				LIG
841												SS			TY			LIG
842			USL															LIG
843			USL															LIG
845			USL															LIG
844			USL															LIG
848									GR		PS							LIG
847			USL															LIG
846			USL															LIG
849	SSL																	LIG
1110													OR					LIG
850		PSL																LIG
1099		PSL																LIG
852		PSL							GR		PS							LIG

Table 33, continued from previous page and continued on next page: Finds from site catalogue no. 12, slag, metal artifacts, iron ore, and tuyere fragments. (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpretation
851	12	N98/32	2	51/51	a	9	0.2		Processing slag
1098	12	N98/32	2	51/51	a		1.5		Unspecific slag
858	12	N98/32	2	51/51	b	6	11.2		Conglomerated hammerscale flakes from secondary smithing
854	12	N98/32	2	51/51	b	6	14		Unspecific slag
856	12	N98/32	2	51/51	b	9	0.5		Burnt clay
853	12	N98/32	2	51/51	b	9	0.6		A fragmented piece of a folder's prong fastener
857	12	N98/32	2	51/51	b	9	1		Unspecific slag
855	12	N98/32	2	51/51	b	9	0.1		Unspecific slag
859	12	N98/32	2	51/51	c	6	3		Iron rich sandstone
862	12	N98/32	2	51/51	c	9	4.9		Processing slag
861	12	N98/32	2	51/51	c	9	49.2		Furnace slag with bloom remains
860	12	N98/32	2	51/51	c	9	49.6		Furnace slag
1117	12	N98/32	2	51/51	c		0.8		Fragment of iron sheet metal
1108	12	N98/32	2	51/51	c		3.6		Pisolite, iron ore
863	12	N98/32	2	51/51	d	6	0.8		Bloom fragment, gromp
865	12	N98/32	2	51/51	d	6	0.7		Bloom fragment, gromp
864	12	N98/32	2	51/51	d	6	2		Bloom fragment, gromp
1109	12	N98/32	2	51/51	d	6	0.1		Pisolite, iron ore
866	12	N98/32	2	51/51	d	6	0.8		Unspecific slag
867	12	N98/32	2	51/51	d	6	0.7		Processing slag with gromps
1104	12	N98/32	2	51/51	d	6	1.8		Processing slag
1100	12	N98/32	2	51/51	d	6	0.4		Microsphere
1103	12	N98/32	2	51/51	d		0.6		Processing slag
907	12	N98/32	Surf.				43.6		Tuyere fragment
905	12	N98/32	Surf.				22.8		Tip of a tuyere
904	12	N98/32	Surf.				26.8		Tip of a tuyere
906	12	N98/32	Surf.				24		Tuyere fragment
877	12	N98/32	Surf.				35.1		Tuyere fragment
903	12	N98/32	Surf.				19.8		Tip of a tuyere
892	12	N98/32	Surf.				33		Unspecific slag
908	12	N98/32	Surf.				21.5		Unspecific slag
912	12	N98/32	Surf.				3.3		Unspecific slag
921	12	N98/32	Surf.				4.2		Unspecific slag
923	12	N98/32	Surf.				1.9		Unspecific slag
925	12	N98/32	Surf.				1.6		Unspecific slag
924	12	N98/32	Surf.				4.1		Unspecific slag
895	12	N98/32	Surf.				42.8		SHB with gromps
896	12	N98/32	Surf.				14.2		Smithing hearth bottom
898	12	N98/32	Surf.				116.8		Hammerscale flakes adhering to gromp
894	12	N98/32	Surf.				24		Processing slag with gromps and pseudo-morph of pit
901	12	N98/32	Surf.				0.7		Processing slag

Table 33, continued from previous page and continued on next page: Finds from site catalogue no. 12, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
851		PSL																LIG
1098			USL															LIG
858										HS		SS						LIG
854			USL															LIG
856																		LIG
853																	CO	MOD
857			USL															LIG
855			USL															LIG
859													OR					LIG
862		PSL																LIG
861	SSL							BL										LIG
860	SSL																	LIG
1117																IA		LIG
1108													OR					LIG
863									GR		PS							LIG
865									GR		PS							LIG
864									GR		PS							LIG
1109													OR					LIG
866			USL															LIG
867		PSL							GR		PS							LIG
1104		PSL																LIG
1100		PSL								HS								LIG
1103		PSL																LIG
907															TY			LIG
905															TY			LIG
904															TY			LIG
906															TY			LIG
877															TY			LIG
903															TY			LIG
892			USL															LIG
908			USL															LIG
912			USL															LIG
921			USL															LIG
923			USL															LIG
925			USL															LIG
924			USL															LIG
895		PSL			SHB				GR									LIG
896		PSL			SHB													LIG
898		PSL			SHB						PS							LIG
894		PSL					FL		GR									LIG
901		PSL																LIG

Table 33, continued from previous page and continued on next page: Finds from site catalogue no. 12, slag, metal artifacts, iron ore, and tuyere fragments. (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpretation
902	12	N98/32	Surf.				0.9		Processing slag with gromps
897	12	N98/32	Surf.				1.8		Processing slag with gromps
893	12	N98/32	Surf.				26		Processing slag
927	12	N98/32	Surf.				76.1		SHB
911	12	N98/32	Surf.				35.1		SHB
918	12	N98/32	Surf.				2.4		Processing slag with gromps
916	12	N98/32	Surf.				2		Processing slag with gromps
917	12	N98/32	Surf.				1.8		Processing slag with gromps
909	12	N98/32	Surf.				63.4		Processing slag with gromps
926	12	N98/32	Surf.				12.9		Processing slag with gromps
910	12	N98/32	Surf.				8.8		Processing slag with gromps
930	12	N98/32	Surf.				12		Processing slag
913	12	N98/32	Surf.				78.9		Processing slag
929	12	N98/32	Surf.				15		Amorphous processing slag from bottom of a pit
922	12	N98/32	Surf.				3.4		Processing slag with gromps
919	12	N98/32	Surf.				121.2		Processing slag
915	12	N98/32	Surf.				2.8		Processing slag
914	12	N98/32	Surf.				5.2		Processing slag
928	12	N98/32	Surf.				22.7		Processing slag
899	12	N98/32	Surf.				63		Flow slag from smelting
900	12	N98/32	Surf.				10.5		Flow slag from smelting
920	12	N98/32	Surf.				206		SHB, cooled down at the bottom of a pit of 30 cm in diameter.
880	12	N98/32	Surf.				3		Unspecific slag
931	12	N98/32	Surf.				31.9		Processing slag
879	12	N98/32	Surf.				5		Small SHB
878	12	N98/32	Surf.				8.3		Processing slag with gromps
875	12	N98/32	Surf.				58	DBM 4431/06	Processing slag with gromps
1071	3	N98/32	Surf.				131	DBM 4707/06	Ferruginous sandstone
881	12	N98/32	Surf. 3				6.4		Unspecific slag
882	12	N98/32	Surf. 4-5				42.2		Tuyere fragment
870	12	N98/32	Surf. 4a				3.3		Iron, tweezers-like tool, reshaped from industrial wire
869	12	N98/32	Surf. 4a				0.7		Press button
1060	12	N98/32	Surf. 4a				4.5		Unspecific slag with gromps
874	12	N98/32	Surf. 4a				34	DBM 4430/06	SHB, final refining slag
872	12	N98/32	Surf. 4c				0.4		Copper bead
883	12	N98/32	Surf. 4c				9		Tip of a tuyere with adhering ham-merscale flakes
885	12	N98/32	Surf. 4c				9		Unspecific slag
876	12	N98/32	Surf. 4c				122	DBM 4433/06; Poz-20699	SHB, Initial refining slag with partially reduced ore
884	12	N98/32	Surf. 4c				5		Silica-rich SHB with adhering minute microspheres, secondary smithing

Table 33, continued from previous page and continued on next page: Finds from site catalogue no. 12, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
902		PSL																LIG
897		PSL																LIG
893		PSL																LIG
927		PSL			SHB													LIG
911		PSL			SHB													LIG
918		PSL							GR		PS							LIG
916		PSL							GR		PS							LIG
917		PSL							GR		PS							LIG
909		PSL							GR		PS							LIG
926		PSL							GR		PS							LIG
910		PSL							GR		PS							LIG
930		PSL																LIG
913		PSL																LIG
929		PSL																LIG
922		PSL																LIG
919		PSL																LIG
915		PSL																LIG
914		PSL																LIG
928		PSL																LIG
899	SSL																	LIG
900	SSL																	LIG
920		PSL			SHB		FL				PS							LIG
880			USL															LIG
931		PSL																LIG
879		PSL			SHB							SS						LIG
878		PSL							GR		PS							LIG
875		PSL							GR		PS							LIG
1071													OR					
881			USL	FSL														LIG
882															TY			LIG
870																IA		MOD
869																IA		MOD
1060			USL						GR		PS							LIG
874		PSL			SHB													LIG
872																	CO	LIG
883												SS			TY			LIG
885			USL															LIG
876		PSL			SHB			BL			PS		OR					LIG
884		PSL										SS						LIG

Table 33, continued from previous page and continued on next page: Finds from site catalogue no. 12, slag, metal artifacts, iron ore, and tuyere fragments. (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpretation
871	12	N98/32	Surf. 5				13.1		Unidentified iron artifact, probably a hook
886	12	N98/32	Surf. 6				39.6		Tuyere fragment
868	12	N98/32	Surf. 6				6.4		Fragment of a copper bangle
887	12	N98/32	Surf. 6				29		SHB
888	12	N98/32	Surf. 6				16.9		Processing slag
890	12	N98/32	Surf. 7				25.9		Tuyere fragment
889	12	N98/32	Surf. 7				11.5		Tuyere fragment
891	12	N98/32	Surf. 7				16.7		Processing slag
932	12	N98/34					20		Unspecific slag
934	12	N98/34					17		Unspecific slag
933	12	N98/34					29		Unspecific slag
935	12	N98/34					24.1		Processing slag
938	12	N98/37					83		Unspecific slag
939	12	N98/37					120		Unspecific slag
936	12	N98/37					70	DBM 4434/06	SHB secondary smithing
937	12	N98/37					102.6		SHB

Table 33, continued from previous page and continued on next page: Finds from site catalogue no. 12, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpret.
1080	9	N99/20		26/26	b	5	0.4		Iron ribbon
367	9	N99/20		26/26	b	5	0.2		Iron plate
368	9	N99/20		26/26	d	5	1.9		Copper chain fragment
369	9	N99/20		26/26	d	5	1.1		Iron plate fragment
370	9	N99/20					26.5		Iron plate
371	10	N98/25					2.6		Iron ore fragment
941	15	N96/07					21.2		Tuyere fragment, grog tempered
940	15	N96/07					22.5		Tip of a tuyere, grog tempered
946	16	N96/08	1				1017	DBM 4722/06	SHB from advanced refining with gromps
947	16	N96/08					150		Unspecific slag
945	16	N96/08					163.2		Pisolitic ferricrete
943	16	N96/08					163		Pisolitic ferricrete
942	16	N96/08					125	DBM 4723/06; 5196/07	Pisolitic ferricrete
944	16	N96/08					125.6		Pisolitic ferricrete
948	17	N06/09					357.2	DBM 4725/06	Iron-rich sandstone

Table 34, continued on next page: Finds from site catalogue nos. 9, 10, 15, 16, and 17, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
871																IA		LIG
886															TY			LIG
868																	CO	LIG
887		PSL			SHB													LIG
888		PSL																LIG
890															TY			LIG
889														QZ	TY			LIG
891		PSL																LIG
932			USL															LIG
934			USL															LIG
933			USL															LIG
935		PSL																LIG
938			USL															LIG
939			USL															LIG
936		PSL			SHB							SS						LIG
937		PSL			SHB													LIG

Table 33, continued from previous page: Finds from site catalogue no. 12, slag, metal artifacts, iron ore, and tuyere fragments. (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
1080																IA		MOD
367																IA		MOD
368																	CO	LIG
369																IA		MOD
370																IA		MOD
371													OR					
941															TY			
940															TY			
946		PSL			SHB				GR		PS							
947			USL															
945													OR					
943													OR					
942													OR					
944													OR					
948													OR					

Table 34, continued from previous page and continued on next page: Finds from site catalogue nos. 9, 10, 15, 16, and 17, slag, metal artifacts, iron ore, and tuyere fragments. (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpret.
949	17	N06/09					352.5	DBM 4726/06; 4401/07; 5197/07	Pisolitic ferricrete
951	17	N11/02	1	Unit 1	c	11	6		Iron bar
950	17	N11/02	1	Unit 1	c	9	14.1		Tip of a tuyere, grog tempered
952	17	N11/02	1	Unit 3			21.4		9 small fragments of iron ore
953	17	N96/05					39		Tuyere fragment, grog tempered
970	17	N96/05					65.2	DBM 4724; 5199/07; 5205/07	Pisolitic ferricrete
954	17	N96/05					35.1		Tuyere fragment, grog tempered
955	17	N96/05					22.5		Unspecific slag
956	17	N96/12					40.4		Pisolitic ferricrete
958	17	N96/12					32.8		Unspecific slag
957	17	N96/12					28.1		Unspecific slag
961	17	N97/02					16		Unspecific slag
960	17	N97/02					17.7		Tuyere fragment, grog tempered
959	17	N97/02					25.3		Tip of a tuyere, grog tempered

Table 34, continued from previous page and continued on next page: Finds from site catalogue nos. 9, 10, 15, 16, and 17, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpretation
963	20	N98/41					16.2		Flow Slag
962	20	N98/41					16.1		Tuyere fragment with adhering slag
964	21	N98/44					69.4	DBM 4728/06	Ferruginous sandstone
1112	21	N98/44					13.9		Pisolitic ferricrete
965	21	N98/44	Surf.				315	DBM 4727/06	Advanced/final refining slag, SHB with gromps
966	22	N97/08					28.1		Pisolitic ferricrete
967	22	N97/08					66		Pisolitic ferricrete
969	22	N98/45					139.9		Pisolitic ferricrete
968	22	N98/45					16.7	DBM 4729/06	Ferruginous sandstone
971	25	N98/46					168	DBM 4730/06	Pisolitic ferricrete
974	27	N98/43	1	4/5	a	0-20 cm	3.2		Refining slag with gromps
973	27	N98/43	1	4/5	a	0-20 cm	2.1		Amorphous hammerscale
972	27	N98/43	1	4/5	a	0-20 cm	5		Slagged sand
975	27	N98/43	1	5/5	b	40-60 cm	53.6		Processing slag with gromps
976	27	N98/43	1	5/5	c	0-20 cm	8		Gromp

Table 35, continued on next page: Finds from site catalogue nos. 20, 21, 22, 25, and 27, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
949													OR					
951																IA		LIG
950															TY			
952													OR					
953															TY			
970													OR					
954															TY			
955			USL															
956													OR					
958			USL															
957			USL															
961			USL															
960															TY			
959															TY			

Table 34, continued from previous page: Finds from site catalogue nos. 9, 10, 15, 16, and 17, slag, metal artifacts, iron ore, and tuyere fragments. (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
963	SSL			FSL														
962															TY			
964													OR					
1112													OR					
965		PSL			SHB				GR									
966													OR					
967													OR					
969													OR					
968													OR					
971													OR					
974		PSL							GR		PS							
973		PSL								HS	PS							
972		PSL?																
975		PSL							GR		PS							
976									GR		PS							

Table 35, continued from previous page and continued on next page: Finds from site catalogue nos. 20, 21, 22, 25, and 27, slag, metal artifacts, iron ore, and tuyere fragments. (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpretation
978	27	N98/43	1	5/5	c	0-20 cm	0.01		Hammerscale flake
977	27	N98/43	1	5/5	c	0-20 cm	0.01		Hammerscale flake
980	27	N98/43	1	5/5	d	40-60 cm	1.8		Processing slag with gromps
979	27	N98/43	1	5/5	d	60-80 cm vessel contents	1.5	DBM 4440/06	Overcarburized bloom fragment
981	27	N98/43	1	5/5	d	60-80 cm unten	1.5		Flow Slag
984	27	N98/43	Surf.				26		Unspecific slag
983	27	N98/43	Surf.				55		Unspecific slag
982	27	N98/43	Surf.				35		Unspecific slag

Table 35, continued from previous page and continued on next page: Finds from site catalogue nos. 20, 21, 22, 25, and 27, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpret.
1074	29	N06/02					9	DBM 4710/06	Plinthic nodular concretion of iron oxides
1087	29	N06/02					608		Plinthic nodular concretion of iron oxides
985	29	N06/02					30	DBM 4711/06; 5191/07	Plinthic nodular concretion of iron oxides
1075	29	N06/02					13	DBM 4712/06; 4400/07; 5192/07	Plinthic nodular concretion of iron oxides
988	30	N06/04		1			0.5		Unspecific slag
987	30	N06/04		1			0.8		Unspecific slag
986	30	N06/04		1			0.9		Unspecific slag
993	30	N06/04		1			76.9		Unspecific slag
992	30	N06/04	Spade hole 1				114.6	DBM 4716/06	Plinthic soil sample
989	30	N06/04	Spade hole 1				11.1	DBM 4713/06; 5193/07	Plinthic nodular concretion of iron oxides
990	30	N06/04	Spade hole 1			0 to 10 cm below the surface	15	DBM 4714/06	Plinthic nodular iron oxide concretion
991	30	N06/04	Spade hole 1			5 to 15 cm below the surface	63	DBM 4715/06; 5194/07	Plinthic nodular iron oxide concretions
994	30	N06/04	Spade hole 1			5 to 15 cm below the surface	433.2		Plinthic nodular iron oxide concretions
995	30	N06/04	Spade hole 1			5 to 15 cm below the surface	85.6		Plinthic nodular iron oxide concretions
996	30	N06/04	Spade hole 2				1390		Unspecific slag

Table 36, continued on next page: Finds from site catalogue nos. 29 and 30, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
978		PSL								HS								
977		PSL								HS								
980		PSL							GR									
979								BL			PS							
981				FSL														
984			USL															
983			USL															
982			USL															

Table 35, continued from previous page: Finds from site catalogue nos. 20, 21, 22, 25, and 27, slag, metal artifacts, iron ore, and tuyere fragments. (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
1074													OR					
1087													OR					
985													OR					
1075													OR					
988			USL															LIG
987			USL															LIG
986			USL															LIG
993			USL															LIG
992													OR					
989													OR					
990													OR					
991													OR					
994													OR					
995													OR					
996			USL															

Table 36, continued from previous page and continued on next page: Finds from site catalogue nos. 29 and 30, slag, metal artifacts, iron ore, and tuyere fragments. (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpret.
997	30	N06/04	Spade hole 2			10 cm below the surface	313.7		Plinthic hardpan
998	30	N06/04	Surf.				113.4		Plinthic nodular iron oxide concretion
1011	30	N69/03	1				18.3		Unspecific slag
1001	30	N69/03	1	G 10			62		Unspecific slag
1002	30	N69/03	1	G 10			14		Unspecific slag
1003	30	N69/03	1	G 10			20.7		Tip of a tuyere
1004	30	N69/03	1	G 10			13.8		Tuyere fragment
1006	30	N69/03	1	G10			59.8		Smithing hearth bottom from refining with adhering tuyere fragment
1005	30	N69/03	1	G10			1.6		Slagged tuyere fragment
1007	30	N69/03	1	Under fallen tree			152.7		Smithing hearth bottom from refining
1010	30	N69/03	1	Under fallen tree			33.2		Smithing hearth bottom from refining
1008	30	N69/03	1	Under fallen tree			18.3		Furnace slag
1009	30	N69/03	1	Under fallen tree			20.2		Processing slag with adhering amorphous hammerscale
1021	30	N69/03					46		Furnace slag
1027	30	N69/03					15.2		Flow slag with adhering bloom particles
1015	30	N69/03					1.8		Flow slag with tiny bloom inclusions
1026	30	N69/03					3.6		Flow slag with adhering bloom particles
1023	30	N69/03					12.8		Bloom fragment
1014	30	N69/03					19.5		Furnace slag
1016	30	N69/03					5		Flow slag with bloom inclusions
1018	30	N69/03					23.8		Furnace slag with bloom inclusion
1020	30	N69/03					45.2		Furnace slag with bloom inclusion
1024	30	N69/03					9.2		Furnace slag with small bloom inclusion
1025	30	N69/03					13.7		Furnace slag with small bloom inclusion
1012	30	N69/03					139	DBM 4709/06	Furnace slag with bloom inclusion
1013	30	N69/03					131	DBM 4708/06	Furnace slag with bloom and ore inclusion
1030	30	N69/03					6.2		Flow slag
1017	30	N69/03					1.7		Flow slag
1019	30	N69/03					38		Smelting slag
1028	30	N69/03					12.6		Flow slag
1033	30	N69/03					11.4		Flow slag
1029	30	N69/03					3.9		Flow slag
1031	30	N69/03					8.3		Flow slag
1032	30	N69/03					18.4		Flow slag
1022	30	N69/03					4.8		Unspecific slag
999	30	N69/03		Furnace hole			350	DBM 4438/06; Poz-20703	Refining slag with gromps
1000	30	N69/03		Furnace hole			26.8		Unspecific slag with gromps

Table 36, continued on next page: Finds from site catalogue nos. 29 and 30, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
997													OR					
998													OR					
1011			USL															LIG
1001			USL															LIG
1002			USL															LIG
1003											PS				TY			LIG
1004											PS				TY			LIG
1006		PSL			SHB						PS				TY			LIG
1005		PSL									PS				TY			LIG
1007		PSL			SHB						PS							LIG
1010		PSL			SHB						PS							LIG
1008	SSL						FL											LIG
1009		PSL								HS	PS							LIG
1021	SSL																	LIG
1027	SSL			FSL					GR		PS							LIG
1015	SSL								GR									LIG
1026	SSL			FSL					GR									LIG
1023									GR		PS							LIG
1014	SSL							BL			PS							LIG
1016	SSL							BL										LIG
1018	SSL							BL			PS							LIG
1020	SSL							BL			PS							LIG
1024	SSL							BL			PS							LIG
1025	SSL							BL			PS							LIG
1012	SSL							BL			PS							LIG
1013	SSL							BL			PS		OR					LIG
1030	SSL			FSL														LIG
1017	SSL			FSL														LIG
1019	SSL																	LIG
1028	SSL			FSL														LIG
1033	SSL			FSL														LIG
1029	SSL			FSL														LIG
1031	SSL			FSL														LIG
1032	SSL			FSL														LIG
1022			USL															LIG
999		PSL			SHB				GR		PS							LIG
1000			USL						GR		PS							LIG

Table 36, continued from previous page: Finds from site catalogue nos. 29 and 30, slag, metal artifacts, iron ore, and tuyere fragments. (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab. ID	SC no.	Site no.	Area	Unit	Quad-rant	Level	W/g	Sample no.	Interpretation
1035	32	N07/02	1				3.7		Flow slag from smelting
1038	32	N07/02	1				505.6		A mix of slag and crushed pieces of ore. The sample contains metallic iron.
1039	32	N07/02	1				530.9	DBM 5190/07	A mix of slag and crushed pieces of ore. The sample contains metallic iron.
1034	32	N07/02	1				20.6		Glassy processing slag
1037	32	N07/02	1				4.3		Processing slag with gromps
1036	32	N07/02	1				5.2		Unspecific slag with gromps
1040	32	N07/02	1				23.4		Unspecific glassy slag
1044	32	N07/02	1				14.5		Unspecific slag that shows the shape of a furnace bottom. It might have been drained into a slag pit.
1041	32	N07/03					231.7	DBM 5202/07; 5188/07	Plinthic hardpan
1042	32	N07/03					942.4		Plinthic hardpan
1043	32	N07/06					310.9		Plinthic nodular concretions of iron oxides
1086	33	N07/07					120		Plinthic nodular concretions of iron oxides
1045	33	N07/07					20	DBM 5203/07	Plinthic nodular aggregates of iron oxide, iron stone
1046	33	N07/07				10 cm below the surface	267.5		Ferruginous soft plinthic soil deposit
1047	33	N07/07	1				372.5		Plinthic nodular concretions of iron oxides
1048	33	N07/07	1				175.3		Plinthic nodular concretions of iron oxides
1049	34	N99/15					245.2		Ferruginous silcrete
1050	34	N99/15					309.7		Ferruginous sandstone
1051	34	N99/15					104.6		Plinthic nodular concretions of iron oxides
1052	34	N99/15					61.1		Plinthic nodular concretions of iron oxides
1053	48	N07/04					107.05	DBM 5201/07	Pisolitic ferricrete

Table 37, continued on next page: Finds from site catalogue nos. 32, 33, 34, and 48, slag, metal artifacts, iron ore, and tuyere fragments.

Lab. ID	SSL	PSL	USL	FSL	SHB	SP	FL	BL	GR	HS	PS	SS	OR	QZ	TY	IA	CO	PE
1035	SSL			FSL														LIG
1038	SSL							BL					OR					LIG
1039	SSL							BL					OR					LIG
1034		PSL																LIG
1037		PSL							GR		PS							LIG
1036			USL						GR		PS							LIG
1040			USL															LIG
1044			USL			SP												LIG
1041													OR					
1042													OR					
1043													OR					
1086													OR					
1045													OR					
1046													OR					
1047													OR					
1048													OR					
1049													OR					
1050													OR					
1051													OR					
1052													OR					
1053													OR					

Table 37, continued from previous page: Finds from site catalogue nos. 32, 33, 34, and 48, slag, metal artifacts, iron ore, and tuyere fragments. (SSL: Smelting slag, PSL: Processing slag, USL: Unspecific slag, FSL: Flow slag, SHB: Smithing hearth bottom, SP: Slag pit, FL: Furnace lining, BL: Bloom, GR: Gromp, HS: Hammerscale, PS: Primary smithing, SS: Secondary smithing, OR: Ore, QZ: Quartz, TY: Tuyere, IA: Iron artifact, CO: Copper artifact, PE: Archaeological occupation period)

Lab.-no.	Location	Site-no.	SC-no.	Material	Lab. –Method
4419/06	Ruuga	N98/39-2	3	Specular hematite	ICP-OES
4707/06	Vungu-Vungu	N98/32	12	Ferruginous sandstone	ICP-OES
4710/06	Kapongo	N06/02	29	Plinthic soil: hardened nodule	ICP-OES
4711/06 (5191/07)	Kapongo	N06/02	29	Plinthic soil: hardened nodule	ICP-OES, XRD
4712/06 (4400/07, 5192/07)	Kapongo	N06/02	29	Plinthic soil: hardened nodule	ICP-OES, XRD, PTS
4713/06 (5193/07)	Dikundu	N06/04	30	Plinthic soil: soft nodule	ICP-OES, XRD
4714/06	Dikundu	N06/04	30	Plinthic soil: soft nodule	ICP-OES
4715/06 (5194/07)	Dikundu	N06/04	30	Plinthic soil: soft nodule	ICP-OES, XRD
4716/06	Dikundu	N06/04	30	Plinthic soil	ICP-OES
4723/06 (5196/07)	Utokota	N96/08-1	16	Pisolitic duricrust	ICP-OES, XRD
4724/06 (5199/07)	Gove-Mbambangandu	N96/05	17	Pisolitic duricrust	ICP-OES, XRD
4725/06	Gove-Mbambangandu	N96/05	17	Ferruginous sandstone	ICP-OES, PTS
4726/06 (4401/07, 5197/07)	Gove-Mbambangandu	N96/05	17	Pisolitic duricrust	ICP-OES, XRD, PTS
4728/06	Mashare	N98/45-1	22	Ferruginous sandstone	ICP-OES
4729/06	Mashare	N98/45	22	Ferruginous sandstone	ICP-OES
4730/06	Mashare Agricultural College	N06/05	24	Pisolitic duricrust	ICP-OES
4731/06 (4399/07, 5198/07)	Mupini Quarry	N06/01	6	Pisolitic duricrust	ICP-OES, XRD, PTS
5188/07	Kauti III (beneficiated)	N07/03	32	Petroplithite: hardpan	ICP-OES
5201/07	Popa	N07/04	48	Pisolitic duricrust	ICP-OES, XRD
5202/07	Kauti III	N07/03	32	Petroplithite: hardpan	ICP-OES, XRD
5203/07	Koro	N07/07	33	Plinthic soil	ICP-OES, XRD
5205/07	Gove-Mbambangandu (beneficiated)	N96/05	17	Pisolitic duricrust	ICP-OES

Table 38: Iron ore and sandstone samples from the Kavango region.

DBM Lab. no.	Ore group	Minerals
4710/06	I	
4711/06 (5191/07)	I	Hematite, quartz, goethite
4712/06 (4400/07, 5192/07)	I	Goethite, hematite
4713/06 (5193/07)	I	
4714/06	I	
4715/06 (5194/07)	I	
4716/06	I	
5203/07	I	Quartz, goethite, siderite
5188/07	II	
5202/07	II	Goethite
4723/06 (5196/07)	III	Quartz, goethite
4724/06 (5199/07)	III	
4726/06 (4401/07, 5197/07)	III	
4730/06	III	
4731/06 (4399/07, 5198/07)	III	
5201/07	III	Quartz, goethite, muscovite
5205/07	III	Quartz, goethite
4419/06	IV	

Table 39: Ore groups and main minerals of selected ore samples detected by XRD analyses.

DBM Lab. no.	Ore group	Fe_2O_3	SiO_2	Al_2O_3	CaO	MnO	MgO	TiO_2	Na_2O	P_2O_5	Total	LOI 1050°C	
4716/06	I	27.1	64.2	2.82	0.4	0.18	0.4	0.17	0.02	0.09	95.39	4.8	wt%
4714/06	I	61.8	6.2	0.01	12.8	0.67	1.11	0.01	n.d.	0.02	82.44	13.4	wt%
5203/07	I	66.7	21.32	0.06	0.22	0.86	0.22	0.01	n.d.	0.04	89.41	13.9	wt%
4715/06 (5194/07)	I	71.4	2.94	0.01	13.7	0.66	0.5	0.01	0.02	n.d.	89.24	10.6	wt%
4710/06	I	72.7	15.52	0.26	0.29	0.32	0.12	0.02	0.01	0.04	89.26	11.2	wt%
4713/06 (5193/07)	I	76.1	8.16	0.05	5.94	0.54	0.8	0.01	0.01	0.06	91.67	5.71	wt%
4712/06 (4400/07, 5192/07)	I	77.6	6.9	0.05	0.09	0.4	0.14	0.01	n.d.	0.02	84.39	13.5	wt%
4711/06 (5191/07)	I	80.09	9.49	0.07	0.25	0.39	0.13	0.01	n.d.	0.05	90.48	7.84	wt%
5202/07	II	73.4	18.16	0.66	0.01	0.32	0.04	0.02	n.d.	0.07	92.68	11.8	wt%
5188/07	II	75.3	15.2	0.85	0.01	0.11	0.04	0.03	n.d.	0.09	91.62	12.3	wt%
4730/06	III	11.3	79.7	2.44	0.14	3.41	0.31	0.11	0.04	n.d.	97.45	2.98	wt%
4724/06 (5199/07)	III	29.3	50.33	4.4	0.11	8.95	0.19	0.15	n.d.	0.05	93.48	7.11	wt%
5205/07	III	33.7	44.1	4.23	0.02	8.75	0.27	1	0.01	0.13	92.2	7.95	wt%
5201/07	III	36.7	51.1	6.8	0.01	0.39	0.18	0.29	0.01	0.12	94.87	6.99	wt%
4726/06 (4401/07, 5197/07)	III	40.06	54.07	1.95	0.16	0.32	0.33	0.08	0.01	0.08	97.07	-	wt%

Table 40 continued on next page: Major and minor elements detected in ore and sandstone samples from the Kavango region.

DBM Lab. no.	Ore group	Fe_2O_3	SiO_2	Al_2O_3	CaO	MnO	MgO	TiO_2	Na_2O	P_2O_5	Total	LOI 1050°C	
4723/06 (5196/07)	III	43.9	45.18	3.1	0.12	0.1	0.17	0.12	n.d.	0.06	92.65	7.27	wt%
4731/06 (4399/07, 5198/07)	III	48.1	42.54	2.12	0.11	0.35	0.2	0.12	n.d.	0.14	93.69	7.27	wt%
4419/06	IV	88.2	8.99	1.1	0.04	0.03	0.02	0.48	n.d.	0.01	98.88	-	wt%
4728/06		4.7	92.6	1.19	0.06	0.24	0.25	0.09	0.02	n.d.	98.52	1.48	wt%
4707/06		8.1	81.3	3.73	0.33	0.13	1.95	0.69	0.08	0.04	95.45	2.7	wt%
4729/06		12	84.8	1.17	0.11	0.03	0.34	0.08	n.d.	n.d.	98.52	1.43	wt%
4725/06		25.7	67.1	1.39	0.07	0.05	0.07	0.08	n.d.	0.02	94.48	4.65	wt%

Table 40 continued from previous page: Major and minor elements detected in ore and sandstone samples from the Kavango region.

DBM Lab. no	Ore group	Ba	Cr	Sr	V	Y	Zr	As	Bi	Cu	Ni	Pb	Zn	Sb	S	
4716/06	I	467	52	31	157	52	702	n.d.	n.d.	23	58	n.d.	21	20	649	ppm
4714/06	I	253	n.d.	87	14	n.d.	138	12	n.d.	44	18	n.d.	46	14	2658	ppm
5203/07	I	501	n.d.	38	10	n.d.	n.d.	13	452	16	68	15	n.d.	n.d.	n.d.	ppm
4715/06 (5194/07)	I	226	n.d.	68	10	n.d.	361	12	n.d.	49	10	n.d.	44	24	n.d.	ppm
4710/06	I	88	10	13	22	10	628	n.d.	n.d.	55	35	n.d.	34	24	n.d.	ppm
4713/06 (5193/07)	I	232	n.d.	67	10	n.d.	313	n.d.	n.d.	57	10	n.d.	46	22	n.d.	ppm
4712/06 (4400/07, 5192/07)	I	60	n.d.	10	19	n.d.	618	n.d.	n.d.	54	26	n.d.	31	22	n.d.	ppm
4711/06 (5191/07)	I	106	10	10	17	n.d.	656	n.d.	n.d.	54	21	n.d.	37	25	n.d.	ppm
5202/07	II	695	n.d.	n.d.	10	n.d.	n.d.	n.d.	478	176	58	13	n.d.	n.d.	n.d.	ppm
5188/07	II	270	139	n.d.	10	n.d.	n.d.	n.d.	486	173	495	10	n.d.	n.d.	n.d.	ppm
4730/06	III	3334	58	24	300	n.d.	339	21	n.d.	10	37	n.d.	n.d.	22	294	ppm
4724/06 (5199/07)	III	10380	199	38	1389	29	676	n.d.	n.d.	30	18	n.d.	n.d.	19	n.d.	ppm
5205/07	III	25480	60	60	762	n.d.	n.d.	60	285	97	109	76	16	n.d.	n.d.	ppm
5201/07	III	748	86	n.d.	219	n.d.	n.d.	25	328	107	81	n.d.	n.d.	n.d.	n.d.	ppm
4726/06 (4401/07, 5197/07)	III	768	79	14	1764	25	520	n.d.	n.d.	40	47	n.d.	34	11	n.d.	ppm
4723/06 (5196/07)	III	159	62	n.d.	1648	15	688	n.d.	n.d.	44	22	n.d.	16	15	n.d.	ppm
4731/06 (4399/07, 5198/07)	III	157	59	10	1052	29	818	n.d.	n.d.	40	30	n.d.	46	21	n.d.	ppm
4419/06	IV	13	n.d.	3	2379	n.d.	58	n.d.	n.d.	n.d.	13	n.d.	n.d.	n.d.	n.d.	ppm
4728/06		1082	n.d.	15	173	n.d.	619	n.d.	n.d.	n.d.	28	n.d.	24	19	643	ppm
4707/06		519	60	79	542	n.d.	555	n.d.	n.d.	10	37	17	29	14	n.d.	ppm
4729/06		110	n.d.	14	206	n.d.	342	n.d.	n.d.	16	13	228	n.d.	14	222	ppm
4725/06		60	204	n.d.	845	13	554	n.d.	n.d.	36	24	n.d.	29	25	n.d.	ppm

Table 41: Trace elements detected in ore and sandstone samples from the Kavango region.

DBM Lab. no.	Method	SC no.	Location	Site no.	Slag Material	Slag Group
4388/06	ICP-OES	3	Ruuga	N98/39-1	Flow slag, smelting	II
4389/06	PCS	3	Ruuga	N98/39-2	Bloom	III
4390/06	PTS/ICP-OES	3	Ruuga	N98/39-2	Flow slag, smelting	II
4391/06	PTS/ICP-OES	3	Ruuga	N98/39-2	SHB final refining	VI
4393/06	PTS/ICP-OES	3	Ruuga	N98/39-2	Initial bloom refining slag	IV
4394/06	PCS	3	Ruuga	N98/39-2	Bloom	III
4395/06	PCS	3	Ruuga	N98/39-2	Bloom	III
4396/06	PCS/ICP-OES	3	Ruuga	N98/39-2	SHB Initial bloom refining	IV
4397/06	ICP-OES	3	Ruuga	N98/39-2	SHB secondary smithing	VII
4398/06	ICP-OES	3	Ruuga	N98/39-2	unspeific	VIII
4400/06	PTS/ICP-OES	3	Ruuga	N98/39-2	SHB secondary smithing	VII
4401/06	ICP-OES	3	Ruuga	N98/39-2	Flow slag, smelting	II
4402/06	PTS/ICP-OES	3	Ruuga	N98/39-2	Final refining slag	VI
4403/06	ICP-OES	3	Ruuga	N98/39-2	Furnace slag	I
4404/06	PCS	3	Ruuga	N98/39-2	Bloom	III
4405/06	PTS/ICP-OES	3	Ruuga	N98/39-2	SHB Final refining	VI
4406/06	ICP-OES	3	Ruuga	N98/39-2	Flow slag, unspecific	II
4407/06	PCS	3	Ruuga	N98/39-2	Bloom	III
4408/06	ICP-OES	3	Ruuga	N98/39-2	Furnace slag	I
4409/06	PCS	3	Ruuga	N98/39-2	Advanced refining slag	V
4410/06	PCS/^{14}C	3	Ruuga	N98/39-2	SHB Advanced refining	V
4411/06	PCS/^{14}C	3	Ruuga	N98/39-2	Initial bloom refining slag	IV
4412/06	ICP-OES	4	Kapako	N68/01	Advanced refining slag	V
4413/06	PCS	4	Kapako	N68/02	Bloom	III
4414/06	ICP-OES	4	Kapako	N68/02	Advanced refining slag	V
4415/06	PTS/ICP-OES/^{14}C	12	Vungu-Vungu	N69/01	Furnace slag	I
4416/06	PTS/ICP-OES	12	Vungu-Vungu	N69/01	SHB Secondary smithing slag	VII
4417/06	PCS/ICP-OES	12	Vungu-Vungu	N96/03-3	Furnace slag	I
4418/06	PCS/ICP-OES	12	Vungu-Vungu	N96/03-3	SHB Final refining	VI
4420/07	PCS	12	Vungu-Vungu	N96/03-3	SHB advanced refining	V
4421/06	ICP-OES	12	Vungu-Vungu	N96/03-3	unspecific	VIII
4422/06	PTS/ICP-OES	12	Vungu-Vungu	N96/03-3	Initial bloom refining slag	IV
4423/06	PCS	12	Vungu-Vungu	N96/03-3	Initial bloom refining slag	IV
4424/06	PTS	12	Vungu-Vungu	N96/03-3	SHB secondary smithing	VII
4426/06	PCS	12	Vungu-Vungu	N96/03-3	Bloom	III
4427/07	ICP-OES	12	Vungu-Vungu	N96/03-3	SHB advanced refining	V
4428/06	PTS	12	Vungu-Vungu	N98/32-2	Furnace slag	I
4429/06	PTS/ICP-OES	12	Vungu-Vungu	N98/32-2	SHB Initial bloom refining	IV

Table 42, continued on next page: Slag and bloom samples from the Kavango region.

DBM Lab. no.	Method	SC no.	Location	Site no.	Slag Material	Slag Group
4430/06	PTS/ICP-OES	12	Vungu-Vungu	N98/32-Surf. 4a	SHB final refining	VI
4431/06	ICP-OES	12	Vungu-Vungu	N98/32-Surf. 1	Advanced refining slag	V
4433/06	PTS/ICP-OES/^{14}C	12	Vungu-Vungu	N98/32-Surf. 4c	SHB initial bloom refining	IV
4434/06	ICP-OES	12	Vungu-Vungu	N98/37	SHB secondary smithing	VII
4435/06	PCS/ICP-OES	4	Kapako	N99/21	Initial bloom refining slag	IV
4436/06	PCS	4	Kapako	N99/21	Initial bloom refining slag	IV
4438/06	PCS/ICP-OES/^{14}C	30	Dikundu	N69/02	SHB advanced refining	V
4440/06	PCS	27	Nyangana-Kangwenu	N98/43	Bloom	III
4708/06	PCS	30	Dikundu	N69/02	Bloom	III
4709/06	PCS	30	Dikundu	N69/02	Bloom	III
4717/06	PTS/ICP-OES	4	Kapako	N99/21-5	Advanced refining slag	V
4718/06	PTS/ICP-OES	4	Kapako	N99/21-5	SHB final refining	VI
4719/06	PTS/ICP-OES	4	Kapako	N99/21-3	Initial bloom refining slag	IV
4720/06	PCS	4	Kapako	N99/21-3	Bloom	III
4721/06	PCS	4	Kapako	N99/21-3	Advanced refining slag	V
4722/06	PCS/ICP-OES	16	Utokota	N96/08-1	SHB advanced refining	V
4727/06	PCS/ICP-OES	21	Tjeye-East	N98/44	SHB final refining	VI
5189/07	ICP-OES	32	Kauit III	N07/03	Furnace slag	I
5190/07	ICP-OES	32	Kauit II	N07/02-1	Furnace slag	I

Table 42, continued from previous page: Slag and bloom samples from the Kavango region.

DBM Lab. no.	Slag material	Slag Group	Main mineral phase successions
4403/06	Furnace slag	I	
4408/06	Furnace slag	I	
4415/06	Furnace slag	I	Upper layer: Wu<Fa<[FaWu]<Gl, lower layer: [FaWu]
4417/06	Furnace slag	I	Fa<Wu<[FaWu] + Fa<Wu<Gl
4428/06	Furnace slag	I	Fa<[FaLc] +Fa<Gl
5189/07	Furnace slag	I	
5190/07	Furnace slag	I	
4388/06	Flow slag, smelting	II	
4390/06	Flow slag, smelting	II	Sp(Mg)<Fa<Gl
4401/06	Flow slag, smelting	II	
4406/06	Flow slag, unspecific	II	

Table 43, continued on next page: Main mineral phase successions found in slag samples from the Kavango region (X>Y: phase Y followed phase X, X + Y: Phases X and Y solidified at the same time, [XY]: eutectic of X and Y).

DBM Lab. no.	Slag material	Slag Group	Main mineral phase successions
4389/06	Bloom	III	Fa<[FaLc]
4394/06	Bloom	III	Fa<[FaLc]<Gl
4395/06	Bloom	III	Fa<[FaLc]<Gl
4404/06	Bloom	III	Fa<Gl
4407/06	Bloom	III	Fa<Gl
4413/06	Bloom	III	Fa<Gl
4426/06	Bloom	III	Fa<Gl
4440/06	Bloom	III	
4708/06	Bloom	III	Fa<Gl
4709/06	Bloom	III	Fa<Wu<[FaWu]<Gl
4720/06	Bloom	III	?<?<Fa<[FaLcSp]
4393/06	Initial bloom refining slag	IV	Sp(Mg)+Wu<Fa<[FaWu]<Gl
4396/06	Initial bloom refining slag	IV	Wu<Fa<[FaWu]<Gl
4411/06	Initial bloom refining slag	IV	Wu<Fa<[FaWu]
4422/06	Initial bloom refining slag	IV	Wu<Fa<[FaWu] + Fa<Gl
4423/06	Initial bloom refining slag	IV	Wu<Fa+[FaWu]<Gl
4429/06	Initial bloom refining slag	IV	Wu<[FaWu] + Fa<Gl + Fa<[FaLc]
4433/06	SHB initial bloom refining	IV	Wu<Fa<[FaWu] + Wu<Fa<Gl + [FaWu]
4435/06	Initial bloom refining slag	IV	Bottom layer: Fa<[FaWu]<Wu + Fa<[FaWu]<[FaLc], top layer: Wu<[Fa-Wu]<Gl
4436/06	Initial bloom refining slag	IV	Wu<FaWu<[FaLc] + Wu<[FaWu]<Gl
4719/06	Initial bloom refining slag	IV	bottom layer: Wu<Fa<[FaWu]<Gl, middle layer: [FaWu], top layer: Fa<Wu<[FaLc]
4409/06	Advanced refining slag	V	Wu<[FaWu]<Gl + Wu<Fa+[FaWu]<Gl + Fa<Wu<Gl
4410/06	Advanced refining slag	V	Wu<[FaWu]<Gl + Wu<[WuLc] + Wu<Fa<Gl + Fa<[WuLc]
4412/06	Advanced refining slag	V	
4414/06	Advanced refining slag	V	
4420/07	SHB advanced refining	V	Bottom layer: Wu<Fa<Gl, top layer: Wu<[FaWu]<Gl
4427/07	SHB advanced refining	V	

Table 43, continued from previous page and continued on next page: Main mineral phase successions found in slag samples from the Kavango region (X>Y: phase Y followed phase X, X + Y: Phases X and Y solidified at the same time, [XY]: eutectic of X and Y).

DBM Lab. no.	Slag material	Slag Group	Main mineral phase successions
4431/06	Advanced bloom refining slag	V	
4438/06	SHB advanced refining	V	Fa<[FaWu]<[FaLc] + Fa<[FaLc] + Fa<[FaLcSp] + Wu<[FaWu]<Gl
4717/06	Advanced refining slag	V	Wu<[FaWu] + Wu<Fa<[FaWu] + Fa<Gl + Fa<Si-rich phase
4721/06	Advanced refining slag	V	Lc<Fa<Gl
4722/06	SHB advanced refining	V	Bottom layer: Wu<Fa<[FaWu]<Gl, upper layer: Wu<Fa<[Fa-Wu]<[WuLc]<[FaLc] + Wu<Fa<[FaWu]<Lc<[WuLc]<[FaLc] + Wu<Fa<[FaWu]<[LcSp]
4391/06	SHB final refining	VI	Wu<Fa<[FaWu]<Gl + Wu<[FaWu]<Gl
4402/06	Final refining slag	VI	Wu<[FaWu]<Gl + Fa<Sp(Mg)<[FaLc]<[FaLcSp] + Fa<[FaLc]<[FaLcSp]
4405/06	SHB final refining	VI	Bottom layer: Wu<Fa<[FaWu]<Lc, middle layer: Wu<Fa<[FaWu]<[FaLcSp], upper middle layer: Wu<Fa<[FaWu]<[FaLc], top layer: Fa<Wu<[FaLc]
4418/06	Final refining slag	VI	Wu<[FaWu]<Gl
4430/06	SHB final refining	VI	Bottom layer: Wu<[FaWu]<Gl + Fa<Wu<[FaLc], middle layer: Wu + Sp(Mg)<Fa, top layer: Sp(Mg)<Isc<Fa<Gl
4718/06	SHB final refining	VI	Wu<Fa<[FaWu] + Wu<Fa<[LcWu] + Wu<Fa<[FaWu]<Lc + Wu<Fa<[Fa-Wu]<[FaLc] + [FaWu] + Fa<[FaLc] + Fa<Gl + Fa<[LcSp]
4727/06	SHB final refining	VI	Layere 1: Wu<Fa<[FaWu], layer 2: Wu<Fa<[FaWu]<Lc<Gl + Fa<Wu<[FaWu] + Fa<Wu<[FaWu]<Gl, Fa<Wu<Gl
4397/06	SHB secondary smithing	VII	
4400/06	SHB secondary smithing	VII	Sp(Mg)<Fa<Sp(Hc)<[Sp(Hc+Mg)Lc] + Sp(Mg)<Fa<Gl
4416/06	Secondary smithing slag	VII	Wu<[FaWu]<Gl + Wu<[FaWu]<[FaLc]
4424/06	SHB secondary smithing	VII	Bottom layer: Fa<Gl +Fa<Wu<[FaWu], middle layer: Wu<[FaWu]<Gl + Wu<Fa<[FaWu]<Gl + Wu<Fa<Gl, top layer: Sp(Mg)<Isc<Fa<Gl
4434/06	SHB secondary smithing	VII	
4398/06	unspecific	VIII	
4421/06	unspecific	VIII	

Table 43, continued from previous page: Main mineral phase successions found in slag samples from the Kavango region (X>Y: phase Y followed phase X, X + Y: Phases X and Y solidified at the same time, [XY]: eutectic of X and Y).

DBM Lab. ID	SC no.	Slag group	Fe_2O_3	SiO_2	Al_2O_3	CaO	MnO	TiO_2	MgO	Na_2O	P_2O_5	Total	
4388/06	3	II	52.60	36.90	3.33	7.16	0.72	0.19	0.62	0.05	0.05	101.62	wt%
4390/06	3	II	66.50	31.20	2.22	0.66	0.17	0.15	0.19	0.06	0.06	101.22	wt%
4391/06	3	VI	73.70	26.12	1.13	0.63	0.15	0.04	0.16	0.01	0.07	102.01	wt%
4393/06	3	IV	65.30	26.20	1.78	6.45	0.65	0.08	0.48	0.02	0.04	101.01	wt%
4396/06	3	IV	78.00	20.96	1.14	0.31	0.05	0.05	0.12	0.01	0.06	100.70	wt%
4397/06	3	VII	82.00	17.23	1.17	0.24	0.01	0.05	0.13	< 0.01	0.11	100.92	wt%
4398/06	3	VIII	61.10	37.03	1.77	1.30	0.02	0.08	0.32	0.04	0.15	101.80	wt%
4400/06	3	VII	59.50	33.28	3.21	3.30	0.27	0.23	0.41	0.10	0.11	100.42	wt%
4401/06	3	II	76.40	23.21	1.27	0.26	0.19	0.07	0.14	0.01	0.07	101.63	wt%
4402/06	3	VI	66.70	31.20	1.36	1.10	0.14	0.05	0.26	0.03	0.14	100.98	wt%
4403/06	3	I	71.30	28.17	1.54	0.49	0.01	0.07	0.11	0.02	0.08	101.80	wt%
4405/06	3	VI	77.80	20.20	0.99	1.15	0.01	0.05	0.45	0.02	0.10	100.77	wt%
4406/06	3	II	77.30	21.50	1.43	0.27	0.02	0.07	0.07	< 0.01	0.09	100.75	wt%
4408/06	3	I	55.30	41.15	1.84	2.80	0.03	0.09	0.52	0.06	0.16	101.25	wt%
4412/06	4	V	78.60	18.89	1.50	0.35	0.43	0.06	0.11	< 0.01	0.07	99.57	wt%
4414/06	4	V	63.70	35.29	1.34	0.31	0.01	0.05	0.09	0.01	0.13	100.94	wt%
4415/06	12	I	72.50	25.90	1.95	0.64	0.01	0.09	0.28	< 0.01	0.07	101.45	wt%
4416/06	12	VII	81.90	15.9	1.47	0.25	0.02	0.07	0.08	< 0.01	0.13	99.01	wt%
4417/06	12	I	68.90	30.40	1.36	0.70	0.02	0.14	0.25	0.03	0.07	101.87	wt%
4418/06	12	VI	75.50	22.16	1.80	0.82	0.01	0.10	0.15	0.02	0.08	100.64	wt%
4421/06	12	VIII	77.00	19.97	2.16	0.51	0.02	0.10	0.16	< 0.01	0.10	100.02	wt%
4422/06	12	IV	71.59	24.96	1.66	0.37	0.01	0.08	0.17	< 0.01	0.10	98.94	wt%
4427/06	12	V	74.12	22.99	1.94	0.31	0.02	0.10	0.16	0.00	0.09	99.74	wt%
4429/06	12	IV	68.18	26.57	2.14	1.10	0.04	0.09	0.21	0.08	0.24	98.75	wt%
4430/06	12	VI	76.30	23.21	1.53	0.38	0.03	0.07	0.18	0.01	0.10	101.80	wt%
4431/06	12	V	79.90	18.10	1.80	0.68	0.01	0.08	0.12	0.07	0.13	100.89	wt%
4433/06	12	IV	67.60	28.47	2.31	0.49	0.03	0.12	0.16	0.11	0.19	99.49	wt%
4434/06	12	VII	65.30	32.80	1.78	0.49	0.02	0.07	0.14	0.01	0.14	100.74	wt%
4435/06	4	IV	80.20	18.29	1.37	1.16	0.02	0.06	0.08	0.01	0.18	101.37	wt%
4438/06	30	V	72.70	27.20	0.64	0.50	0.37	0.03	0.14	< 0.01	0.04	101.61	wt%
4717/06	4	V	74.90	21.80	0.84	0.25	0.11	0.05	0.12	< 0.01	< 0.01	98.07	wt%
4718/06	4	VI	76.90	21.48	0.44	1.19	0.08	0.03	0.19	< 0.01	< 0.01	100.32	wt%
4719/06	4	IV	70.80	28.34	0.75	0.62	0.09	0.04	0.10	0.01	0.11	100.87	wt%
4722/06	16	V	77.00	19.71	1.10	0.56	0.09	0.04	0.14	< 0.01	0.13	98.68	wt%
4727/06	21	VI	77.35	23.66	0.75	0.35	0.09	0.03	0.18	< 0.01	0.08	102.48	wt%
5189/07	32	I	60.10	38.50	0.69	0.10	0.80	0.04	0.24	< 0.01	0.08	100.50	wt%
5190/07	32	I	76.60	22.10	0.36	0.05	0.08	0.01	0.11	< 0.01	0.10	99.40	wt%

Table 44: Major and minor elements detected in slag samples from the Kavango region.

DBM Lab. no.	SC no.	Slag group	Ba	Cr	Sr	V	Y	Zr	As	Bi	Cu	Ni	Pb	Zn	Sb	
4388/06	3	II	492	n.d.	74	49	n.d.	54	n.d.	n.d.	n.d.	16	n.d.	n.d.	n.d.	ppm
4390/06	3	II	890	n.d.	45	18	n.d.	68	n.d.	n.d.	941	19	n.d.	n.d.	n.d.	ppm
4391/06	3	VI	746	n.d.	32	n.d.	n.d.	48	n.d.	n.d.	n.d.	19	n.d.	n.d.	n.d.	ppm
4393/06	3	IV	427	n.d.	60	36	n.d.	48	n.d.	n.d.	1154	15	n.d.	n.d.	n.d.	ppm
4396/06	3	IV	72	n.d.	14	26	n.d.	55	n.d.	n.d.	5	13	n.d.	n.d.	n.d.	ppm
4397/06	3	VII	57	n.d.	8	29	n.d.	53	n.d.	n.d.	26	8	n.d.	n.d.	n.d.	ppm
4398/06	3	VIII	141	n.d.	48	26	n.d.	54	n.d.	n.d.	12	17	n.d.	n.d.	n.d.	ppm
4400/06	3	VII	264	n.d.	62	n.d.	n.d.	57	n.d.	n.d.	n.d.	22	n.d.	n.d.	n.d.	ppm
4401/06	3	II	87	n.d.	15	25	n.d.	59	n.d.	n.d.	n.d.	13	n.d.	n.d.	n.d.	ppm
4402/06	3	VI	562	n.d.	52	16	n.d.	47	n.d.	n.d.	n.d.	18	n.d.	n.d.	n.d.	ppm
4403/06	3	I	114	n.d.	23	19	n.d.	58	n.d.	n.d.	n.d.	14	n.d.	670	n.d.	ppm
4405/06	3	VI	92	n.d.	31	24	n.d.	57	n.d.	n.d.	n.d.	32	n.d.	n.d.	n.d.	ppm
4406/06	3	II	47	n.d.	11	54	n.d.	59	n.d.	n.d.	n.d.	12	n.d.	n.d.	n.d.	ppm
4408/06	3	I	166	n.d.	71	28	n.d.	63	n.d.	n.d.	18	22	n.d.	n.d.	n.d.	ppm
4412/06	4	V	133	n.d.	11	27	n.d.	53	n.d.	n.d.	n.d.	12	n.d.	n.d.	n.d.	ppm
4414/06	4	V	89	n.d.	13	29	n.d.	53	n.d.	n.d.	3	14	n.d.	n.d.	n.d.	ppm
4415/06	12	I	90	n.d.	41	59	n.d.	57	n.d.	n.d.	20	16	n.d.	n.d.	n.d.	ppm
4416/06	12	VII	773	n.d.	26	86	n.d.	57	n.d.	n.d.	21	12	n.d.	n.d.	n.d.	ppm
4417/06	12	I	130	n.d.	77	30	n.d.	71	n.d.	n.d.	n.d.	36	n.d.	103	n.d.	ppm
4418/06	12	VI	83	n.d.	63	30	n.d.	69	n.d.	n.d.	14	14	n.d.	n.d.	n.d.	ppm
4421/06	12	VIII	487	n.d.	28	52	n.d.	67	n.d.	n.d.	11	13	n.d.	n.d.	n.d.	ppm
4422/06	12	IV	0	n.d.	24	1004	n.d.	53	n.d.	n.d.	n.d.	14	n.d.	n.d.	n.d.	ppm
4427/06	12	V	82	n.d.	29	71	n.d.	59	n.d.	n.d.	17	13	n.d.	n.d.	n.d.	ppm
4429/06	12	IV	263	n.d.	104	170	n.d.	54	n.d.	n.d.	18	12	n.d.	114	n.d.	ppm
4430/06	12	VI	74	n.d.	23	74	n.d.	53	n.d.	n.d.	n.d.	13	n.d.	n.d.	n.d.	ppm
4431/06	12	V	110	n.d.	65	89	n.d.	62	n.d.	n.d.	11	19	n.d.	n.d.	n.d.	ppm
4433/06	12	IV	143	n.d.	40	178	n.d.	60	n.d.	n.d.	n.d.	14	n.d.	n.d.	n.d.	ppm
4434/06	12	VII	147	n.d.	37	235	n.d.	53	n.d.	n.d.	515	14	n.d.	n.d.	n.d.	ppm
4435/06	4	IV	109	n.d.	26	32	n.d.	63	n.d.	n.d.	n.d.	9	n.d.	79	n.d.	ppm
4438/06	30	V	127	n.d.	9	12	n.d.	48	n.d.	n.d.	n.d.	16	n.d.	n.d.	n.d.	ppm
4717/06	4	V	148	n.d.	n.d.	105	n.d.	905	n.d.	n.d.	n.d.	20	n.d.	12	25	ppm
4718/06	4	VI	144	12	20	n.d.	n.d.	788	n.d.	n.d.	n.d.	n.d.	230	n.d.	33	ppm
4719/06	4	IV	189	n.d.	22	59	n.d.	932	n.d.	n.d.	48	12	n.d.	n.d.	26	ppm
4722/06	16	V	68	18	24	627	42	1002	n.d.	n.d.	55	23	n.d.	n.d.	17	ppm
4727/06	21	VI	42	27	16	835	30	970	n.d.	n.d.	58	n.d.	n.d.	11	32	ppm
5189/07	32	I	1815	n.d.	38	n.d.	-	-	n.d.	464	163	90	140	n.d.	n.d.	ppm
5190/07	32	I	129	10	n.d.	10	-	-	n.d.	521	229	51	170	n.d.	n.d.	ppm

Table 45: Trace elements detected in slag samples from the Kavango region.

DBM Lab. no.	Slag type	Slag group
4408/06	Furnace slag	I
4403/06	Furnace slag	I
4388/06	Flow slag, smelting	II
4390/06	Flow slag, smelting	II
4401/06	Flow slag, smelting	II
4406/06	Flow slag, unspecific	II
4393/06	Initial bloom refining slag	IV
4396/06	Initial bloom refining slag	IV
4402/06	Final refining slag	VI
4391/06	SHB final refining	VI
4405/06	Final refining slag	VI
4400/06	SHB secondary smithing	VII
4397/06	SHB secondary smithing	VII
4398/06	Unspecific	VIII

Table 46: Slag samples from SC 3 (Ruuga).

DBM Lab. no.	Slag type	Slag group
4719/06	Initial bloom refining slag	IV
4435/06	Initial bloom refining slag	IV
4414/06	Advanced refining slag	V
4717/06	Advanced refining slag	V
4412/06	Advanced refining slag	V
4718/06	SHB final refining	VI

Table 47: Slag samples from SC 4 (Kapako).

Sample no.	Slag type	Slag group
4417/06	Furnace slag	I
4415/06	Furnace slag	I
4433/06	SHB initial bloom refining	IV
4429/06	Iinitial bloom refining slag	IV
4422/06	Initial bloom refining slag	IV
4427/06	SHB advancedrefining	V
4431/06	Advanced bloom refining slag	V
4418/06	Final refining slag	VI
4430/06	SHB final refining	VI
4434/06	SHB secondary smithing	VII
4416/06	Secondary smithing slag	VII
4421/06	unspecific	VIII

Table 48: Slag samples from SC 12 (Vungu-Vungu).

DBM Lab. no.	Location	Site no.	SC no.	Period	Blooms	Refining slag	Carbon content in wt%
4389/06	Ruuga	N98/39-2	3	EIG	x		< 0.02 pure ferrite
4394/06	Ruuga	N98/39-2	3	EIG	x		< 0.02 - 0.7
4395/06	Ruuga	N98/39-2	3	EIG	x		0.2
4404/06	Ruuga	N98/39-2	3	EIG	x		0.02
4407/06	Ruuga	N98/39-2	3	EIG	x		0.02
4413/06	Kapako	N68/02	4	EIG	x		<0.02
4440/06	Nyangana-Kangwenu	N98/43	27	LIG	x		0.8 - 4.3
4708/06	Dikundu	N69/03	30	LIG	x		< 0.02, in parts 0.25 - 0.3, sometimes 0.8
4709/06	Dikundu	N69/03	30	LIG	x		< 0.02 - 0.8
4417/06	Vungu-Vungu	N96/03-3	12	LIG	x		< 0.02; 0.3 - 0.6
4426/06	Vungu-Vungu	N96/03-3	12	LIG	x		2 - 2.06
4396/06	Ruuga	N98/39-2	3	?		x	0.2; 0.8 - 0.85
4409/06	Ruuga	N98/39-2	3	?		x	< 0.02; 0.5
4410/06	Ruuga	N98/39-2	3	LIG		x	< 0.02; 0.2
4411/06	Ruuga	N98/39-2	3	LIG		x	< 0.02
4435/06	Kapako	N99/21	4	LIG		x	0.3 - 0.8
4436/06	Kapako	N99/21	4	LIG		x	< 0.02; 0.02 - 0.025; 1.6
4418/06	Vungu-Vungu	N96/03-3	12	LIG		x	0.03
4420/06	Vungu-Vungu	N96/03-3	12	LIG		x	0.1; 0.8
4423/06	Vungu-Vungu	N96/03-3	12	LIG		x	0.02 - 0.1
4722/06	Utokota	N96/08-1	16	LIG		x	0.1 - 0.15
4727/06	Tjeye-East	N98/44	21	LIG		x	0.02 - 0.03; 1.1 - 1.5

Table 49: Metallographic samples of selected blooms and crown material in refining slag.

DBM Lab.-no.	Location	Site no.	SC no.	Period	Artifact	Carbon content in wt%
4437/06	Ruuga	N98/39-2	3	EIG	Single hook	0.02 - 0.05
4439/06	Ruuga	N98/39-2	3	EIG	Clip	0.7 - 0.8
4474/06	Ruuga	N98/39-2	3	EIG	Bar	0.3 - 0.6
4475/06	Ruuga	N98/39-2	3	EIG	Chain fragment	0.4
4486/06	Ruuga	N98/39-2	3	EIG	Ribbon of sheet metal, clip	0.4 - 0.6
4476/06	Kapako	N68/01	4	EIG	Point fragment	0.3 - 0.7
4477/06	Kapako	N68/02	4	LIG	Piece of recycled raw material	0.1; 0.3
4485/06	Kapako	N99/21	4	LIG	Clip	> 0.02
4483a/06	Vungu-Vungu	N69/01	12	LIG	Open ring	0.7 - 0.8
4483b/06	Vungu-Vungu	N69/01	12	LIG	Rod with loop-like end	0.5 - 0.7
4484b/06	Vungu-Vungu	N69/01	12	LIG	Point	0.02 - 0.8

Table 50: Metallographic samples of selected iron artifacts.

DBM Lab. no.	Location	Site no.	SC no.	Period	Refining slag	Carbon content gromps in wt%	Carbon content prills in wt%
4396/06	Ruuga	N98/39-2	3	?	x	0.2; 0.8 - 0.85	~ 3
4409/06	Ruuga	N98/39-2	3	?	x	< 0.02	0.5
4410/06	Ruuga	N98/39-2	3	LIG	x	< 0.02; 0.2	~ 0.02
4411/06	Ruuga	N98/39-2	3	LIG	x	< 0.02	< 0.02
4436/06	Kapako	N99/21	4	LIG	x	< 0.02; 0.02 - 0.025; 1.6	> 0.8; > 2.06
4420/06	Vungu-Vungu	N96/03-3	12	LIG	x	0.1; 0.8	0.5 - 0.8
4722/06	Utokota	N96/08-1	16	LIG	x	0.1 - 0.15	> 4.3

Table 51: Comparison of C contents of crown material and iron prills in refining slags.

	Site catalogue no.					
	3	**4**	**9**	**12**	**17**	**Total**
Iron artifacts						
Undated	5					**5**
Modern	23	18	4	2		**47**
EIG	10	3				**13**
LIG	1	3		9	1	**14**
Total	**39**	**24**	**4**	**11**	**1**	**79**

Table 52: Total number of iron artifacts.

	Site catalogue no.	SC 3	SC 4	SC 9	SC 12	SC 17	Total
Artifact type							
Bangle (copper)					*1*		**1**
Clip/Bead (copper)		2	***3***		*13*		**18**
Ring (copper)			1				**1**
Chain (copper)				*1*			**1**
Clip/bead (iron)		*3* + ***1***	1 & *1*				**6**
Bar/rod (iron)		2	1		*1*	*1*	**4**
Point (iron)			1 & *1*		*1*		**3**
Ring (iron)					*2*		**2**
Hook (iron)		1			*1*		**2**
Sheet metal (iron)					*1*		**1**
Plate (iron)		1					**1**
Ribbon (iron)		2					**2**
Chain (iron)		1					**1**
Tweezers-like (iron)					*1*		**1**
Raw material (iron)			*1*				**1**
Unspecific (iron)					*2*		**2**
	Total	**13**	**4 & *6***	***1***	***23***	***1***	**48**

Table 53: Metal artifacts (iron and copper) from EIG (regular) and LIG (italic) sites.

	Fuel (Charcoal)			
	Smelting		Smithing	
Mbukushu	*guthu,*[469] *ghukuthi*	*Acacia erioloba,*	*guthu*	*Acacia erioloba,*
	ghupako	*Baikiaea plurijuga*	*ghukuthi*	*Baikiaea plurijuga*
	ghushosho	*Erythrophleum africanum*	*ghupako*	*Erythrophleum africanum*
	ghuhehe	*Burkea Africana*	*ghushosho*	*Burkea Africana*
		Terminalia sericea	*ghuhehe*	*Terminalia sericea*
Gciriku	*uuntu (muntu)*	*Acacia erioloba*	*uuntu (muntu)*	*Acacia erioloba*
	mupako		*mupako*	
		Erythrophleum africanum		*Erythrophleum africanum*
Shambyu	*untu* (*muntu, musu*)	*Acacia erioloba*	*untu* (*muntu, musu*)	*Acacia erioloba*
	rupako (mupako)		*rupako (mupako)*	
	mugoro	*Erythrophleum africanum*	*mugoro*	*Erythrophleum africanum*
	mutundungu		*mutundungu*	
		Terminalia sericea		*Terminalia sericea*
		Burkea Africana		*Burkea Africana*
Nyemba	*mukosho*	*Erythrophleum africanum*	*mukosho*	*Erythrophleum africanum*
Kwangali	*mupako*	*Erythrophleum africanum*	?	
	mutundungu	*Burkea Africana*		

Table 54: Tree species used in historical smelting and smithing.

	Wood			
	Cups of the bellows		Sticks of the bellows	
Mbukushu	*ghughuwa*	*Pterocarpus angolensis*	*mungovo*	*Grewia falcistipula*
Gciriku	*ughuwa*	*Pterocarpus angolensis*		
Shambyu	*ukara*	?	*rupundu*	*Grewia flavescens*
	ughuwa	*Pterocarpus angolensis*		
Nyemba	*mukula*	*Pterocarpus angolensis*	*mdimbamdimba*	?
			untu (*muntu, musu*)	*Acacia erioloba*
Kwangali	*ughuwa*	*Pterocarpus angolensis*	?	

Table 55: Tree species used for the bellows.

[469] There is contradictory information with respect ot the identification of *ghuthu*. Following Kathage (2003, p. 271) and Fisch (1977, p. 37) *ghuthu* denominates the tree species *Acacia erioloba*. Curtis Mannheimer (2005, p. 536) conisered it to be *Baikiaea plurijuga* but the Thimbukushu name of *Acacia erioloba* is not mentioned. In Rumanyo the same tree is called *muntu* (ibid. p. 136) and Bedell (1994) translated Rukwangali *musu* correspondingly.

Table 56

	Kwangali	Nyemba	Shambyu	Gciriku	Gciriku from Fisch (2008)	Mbukuhsu	Mbukushu from Fisch (2008)	Mbukushu from Van Tonder (1966)
Tools								
Axe: large	*Ekuva*	*Kakundu*	*Mbo*	*Mbo lya linene*		*Kamo*	*Kamo*	*Kamo*
Axe: small				*Mbo lya lididi*				
Axe: with extended corners		*Mutaka*						
Hoe: large	*Etemo*	*Matemo*	*Litemo*	*Litemo lya linene*		*Ditemo*		*Ditemo*
Hoe: small				*Litemo lya lididi*				
Adze: wood carving tool, hunting tool					*Mboghana*	*Dyayo*	*Dyayo*	*Diajo*
Chisel: wood carving tool			*Mbo*	*Likoredo*		*Dikuro*		
Knife: single-edged	*Mbere*	*Mpoko mulanja*	*Poko/Mbere*	*Mbere*		*Moko*		
Knife: double-edged	*Rufuro*	*Mwele*	*Rufuro*	*Rufuro*		*Thimende*		*Simende*
Knife: double-edged, large			*Shikuruedo (after Bosch, 1964)*					
Machete	*Ekatana*							
Leaf-shaped thrusting spear	*Egonga*	*Likunga*	*Liwonga*	*Liwonga*	*Lighonga*	*Diyonga*	*Dighonga*	
Arrow-shaped throwing spear		*Likunga mupembe*	*Kashindani*	*Karumbi*	*Karumbi*		*Mukwathi*	
Leaf-shaped spear, retroser-rated, used for hunting hippo					*Mponda*		*Mungungu*	*Muana*
Large leaf-shaped spear used for hun-ting elephants					*Lirunda*		*Dinodhi*	*Sipanda*
Ceremonial spear					*Rufumbwe*		*Matjaro*	
Arrowhead: single-winged		*Ngumba*	*Ngumba*	*Ngumba*	*Ngumba*			
Arrowhead: double-winged	*Ehewo?*	*Ndamba*	*Ndamba*	*Ndamba*	*Ndumba*	*Dindambwa*		
Arrowhead: forked/Y-shaped		*Tshingombo*	*Shinyombo*	*Tshinyombo*				
Arrowhead: leaf-shaped		*Mungamba*	*Mashewo*	*Lishewe*	*Lishevo*	*Disho*	*Dighongana*	

Table 56 continued on next page: Iron implements produced by the historical ironworkers of the middle Kavango region.

	Kwangali	Nyemba	Shambyu	Gciriku	Gciriku from Fisch (2008)	Mbukuhsu	Mbukushu from Fisch (2008)	Mbukushu from Van Tonder (1966)
Tools								
Arrowhead: transverse				*Nteta*				
Arrowhead: round								
Arrowhead: leaf-shaped, elongated					*Likangu*		*Dikangu*	
Fishing spear	*Nomoho*		*Musho*	*Musho*	*Musho*	*Muho*		
Fishing hook						*Dirovo djo thi*		
Head of Harpoon		*Mumba*						
Iron spit for large game traps					*Shitero*		*Thitjero/ Katjero*	
Crocodile hook						*Dirovo djo ngandu*		
Razor	*Sikuriso*		*Linyamuna*	*Linyamuna*		*Dinyamuna*		
Cosmetic knife						*Rubeko*		
Basketry tool	*Ntungo*	*Tshiwe and tshishongo*		*Mtungo*				
Fire striker	*Sitorowa/ Epowa*	*Muhotolo*	*Shtoroha*	*Tshithora*				
Pliers		*Rumana*						
Hammer: traditional/ blacksmith			*Muveto*	*Tshindoma*		*Mweto*		

Table 56 continued from previous page: Iron implements produced by the historical ironworkers of the middle Kavango region.

	Exchange rates			
	Nyemba	**Shambyu**	**Gciriku**	**Mbukuhsu**
Tools				
Axe: large	1 goat	2 chickens, 1 young goat, 12 kg millet	1 medium sized goat, 1 big basket of millet	1 cow/bull, 2-5 goats, 1 big basket or hide-bag of millet
Axe: small			Inalienable, were given to the smelting assistants in return for their services	
Axe: with extended corners	1 goat			
Hoe: large	2 goats, 40 ct. (1945-1951)	2 chickens, 1 young goat, 12 kg millet	1medium sized goat, 1 big basket of millet	1 cow/bull, 2-5 goats, 5 chickens
Hoe: small			2 chicken, 1 medium sized basket of millet	
Adze: wood carving tool, hunting tool				1 chicken
Chisel: wood carving tool			?	?
Knife: single-edged	1 chicken	2 chickens, 1 young goat, 12 kg millet	1 chicken, 1 basket of mahangu, the size of the basket depends on the size of the knife	1 goat, 1-3 chickens, 1 small basket of millet
Knife: double-edged	1 chicken	2 chickens, 1 young goat, 12 kg millet	1 chicken, 1 basket of mahangu, the size of the basket depends on the size of the knife	1 goat, 1-3 chickens, 1 small basket of millet
Knife: double-edged, large				
Leaf-shaped thrusting spear	1 goat, 1 barrel of millet	1 cow, 8 chickens, 3 female goats together with one male goat, 50 kg millet	1 to 2 chickens, 1 small basket of millet, corn, nuts or beans	1 goat, other consider it inalienable because it was a personal weapon
Arrow-shaped throwing spear	1 goat, 1 barrel of millet	?	Inalienable because it was a personal weapon given to the smelting assistants in return for their services	
Leaf-shaped spear, retroserrated, used for hunting hippo				
Large leaf-shaped spear used for hunting elephants				
Arrowhead: single-winged	2 to 3 arrowheads for one day of work, 3 arrowheads for 1 chicken	?	Inalienable, was given to the smelting assistants in return for their services	

Table 57, continued on next page: Exchange rates of iron implements in historical times in the middle Kavango region.

	Exchange rates			
	Nyemba	**Shambyu**	**Gciriku**	**Mbukuhsu**
Tools				
Arrowhead: double-winged	2 to 3 arrowheads for one day of work, 3 arrowheads for 1 chicken	?	Inalienable, was given to the smelting assistants in return for their services	Free of charge, inalienable
Arrowhead: forked/Y-shaped	2 to 3 arrowheads for one day of work, 3 arrowheads for 1 chicken	?	Inalienable, was given to the smelting assistants in return for their services	
Arrowhead: leaf-shaped	2 to 3 arrowheads for one day of work, 3 arrowheads for 1 chicken	?	Inalienable, was given to the smelting assistants in return for their services	Free of charge, inalienable
Arrowhead: transverse			Inalienable, was given to the smelting assistants in return for their services	
Arrowhead: round				
Arrowhead: leaf-shaped, elongated				
Fishing spear		2 chickens, 12 kg millet	Given free to male family members, given to the smelting assistants in return for their services	Free of charge
Fishing hook				?
Head of Harpoon	1 bag of charcoal for the forge			
Iron spit for large game traps				
Crocodile hook				Inalienable
Razor		?	Razors were lent out to friends and family members	Inalienable
Cosmetic knife				Inalienable
Basketry tool	1 chicken		?	
Fire striker	2 days of work, 1 chicken, a big cup of millet	?	Given free to friends and assistants	
Pliers	?			
Hammer: traditional/ blacksmith	?	?	Inalienable	?

Table 57, continued from previous page: Exchange rates of iron implements in historical times in the middle Kavango region.