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Tracing: A Graphical-Digital Method for Restoring Damaged Manuscripts

Dariya Rafiyenko

Abstract

Different kinds of graphical properties of manuscripts such as layout, marginalia, handwriting or text decorations are crucial for the palaeographic and philological analysis thereof. These properties help to locate the manuscript in time and space, as well as enhance the philological analysis of the text. However, in the case of ancient historical documents, this can be considerably impeded by various kinds of damages such as deterioration, erasure, moulds, fading, staining or overwriting, just to name a few. The aim of this paper is to provide a new and handy method for digital reconstruction referred to as *Tracing* that allows quite accurate reconstructing of the original graphical appearance of a damaged manuscript without requiring considerable technical expertise. *Tracing* is a non-invasive method that crucially relies on high-resolution digital images of the manuscript. Its application is illustrated here on the basis of the palimpsested manuscript *Vaticanus graecus* 73. *Tracing* was employed in order to restore the earlier, underlying text layer (*scriptio inferior*) on 12 folios or 24 pages. The results are quality images of the reconstructed manuscript pages that faithfully render the graphical properties of the original. These images may immediately be used for palaeographical and philological analyses.

Zusammenfassung

Für die paläographische und philologische Analyse von Handschriften sind mit dem Layout, den Marginalien, der Form der Handschrift oder der Textausschmückung ganz verschiedene Arten graphischer Merkmale von großer Bedeutung. Das Verständnis dieser Eigenschaften unterstützt nicht nur die Verortung von Handschriften in Zeit und Raum, sondern kommt auch der philologischen Analyse zugute. Bei manchen, besonders bei älteren Handschriften kann dies durch verschiedene Arten von Beschädigungen behindert werden: Verfall, Verblassung, Verfärbung, Ausradierung, Flecken oder Überschreibung – um nur einige zu nennen. Dieser Beitrag stellt mit der Nachzeichnung eine praktische Methode für die digitale Rekonstruktion vor, die eine getreue Nachbildung des ursprünglichen graphischen Erscheinungsbildes erlaubt ohne besondere technische Kenntnisse zu erfordern. Nachzeichnung ist ein nicht-invasives Verfahren, das entscheidend von hoch aufgelösten digitalen

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Abbildungen der Handschriften abhängt. Die Anwendung wird hier am Beispiel der Palimpsest-Handschrift *Vaticanus graecus* 73 vorgeführt. Die Nachzeichnung wurde hier angewandt, um den früheren, zuunterst liegenden Text (*scriptio inferior*) auf 12 folios oder 24 Seiten wiederherzustellen. Das Ergebnis sind gute Bilder der rekonstruierten Handschriftenseiten, die die graphischen Eigenschaften des Originals getreu wiedergeben. Diese Bilder können unmittelbar für die paläographische und philologische Analyse genutzt werden.

1 Introduction

Examination of historical documents is often impeded by various damages of the manuscript, for instance, by fading, staining, bleed-through, moulding, palimpsesting, and other forms of mutilation. In this paper, I primarily focus on palimpsested manuscripts that are frequently found in the Greek, Armenian, Georgian or Syriac traditions (Maniaci 2015, 73) and present a particularly complex case of damage: in the process of palimpsesting, the text is intentionally scraped or washed off so as to reuse the pages for copying new texts (Thomson 1912, 64–66). Needless to say, damages resulting from palimpsesting considerably decrease the legibility of the original text and make the graphical appearance of the manuscript pages no longer readily available for any kind of study.

Palimpsests have been paid much attention in modern paleographic research since many of them contain texts from earlier time periods that are otherwise unknown (a list of such manuscripts can be found in, *inter alia,* Wattenbach 1896, 299–317 and Thompson 1912, 65–66). An increasingly strong interest in palimpsests started to arise in the eighteenth century. This is also the time when a number of methods to uncover the underlying layers of writing in palimpsests were invented and adopted (Dillon 2007, 16–22). First of all, invasive methods were applied. These methods aimed at improving the legibility of the faded text by the use of chemical reagents such as oak-gall tincture, liver or sulphur tinctures, or Giobert tincture, a weak acid solution of potassium hexacyanoferrate (II) (Albrecht 2015, 31). As this often caused serious damaging effects, invasive methods were largely abandoned at the beginning of the twentieth century whereas various sparing optical techniques started to be primarily used for decipherment purposes. The documents were examined or imaged by means of light at different – also invisible to the human eye-wavelengths. Ultraviolet light was commonly used during the twentieth century. Nowadays, a number of more advanced digital imaging techniques are successfully applied to decipher the underwritings of palimpsests. As it is not possible to give a thorough overview of all such techniques here, I refer to the recent short description thereof in Albrecht (2015,

26–27, 31–33) with further references therein; below I mention some recent projects implementing such kind of techniques.

When it comes to the study of palimpsests, the main concern has always been to retrieve as much information of the *scriptio inferior* as possible, whereas little or no attempt has been made to restore the original look of the underlying document and make it available for research. This might be due to a number of reasons. First, it was technically challenging to produce and publish such images in the predigital era. Secondly, the restoration of the original appearance of the document was not on the agenda of traditional philology, whose main focus was always to decipher the text and make it legible for interpretative research. As a consequence, a transcript of the deciphered text was considered as sufficient.

One may wonder why it would be so important to re-create the original look of the underlying document at all. The idea that medieval texts have to be studied along with their material representation as a single phenomenon came up with the rise of the so-called 'new' or 'material' philology in the last quarter of the twentieth century (for an overview of this editorial school, see Baker 2010, especially 440–444, and Driscoll 2010, 90–95) and emphasized once again recently in, for example, Agapitos (2008), Pierazzo and Stokes (2011), and Pierazzo (2014). One of the premises of the material philology is formulated in Driscoll as follows: "[l]iterary works do not exist independently of their material embodiments and the physical form of the text is an integral part of its meaning" (2010, 90). The text of a historical document along with its graphical appearance returns into its original context and material reality that surrounded it; and thus it can be analyzed as an intellectual and cultural artefact of its time. Consequently, the restoration of the graphical appearance of historical documents was called for. Below I will show how the analysis of the graphical appearance of the manuscript can enhance our understanding of the ways the text could have been used by the reader on the basis of the example of codex *Vat. gr.* 73. The method to be envisaged below allowed me to determine a system of marginalia and pictograms in the margins of this manuscript. These are intended to help the reader to navigate through the content – a phenomenon that was ignored by the previous editions altogether.

Furthermore, graphical properties of the manuscript are crucial for the paleographic research, decipherment or dating. Properties of the original text composition such as punctuation may help to uncover the syntactic structure of the sentences as well as the functions of particular expressions within the sentences. Last but not least, the graphical appearance of the text may have impact on the philological interpretation of the text. For example, the layout of the text can provide clues as to its segmentation into chapters, sections, passages or similar. I conclude that the analysis of the graphical appearance of the manuscript is an indispensable part of the investigation of the manuscript.

When it comes to the facsimile edition of a historical document, there are three main options as to how it may be produced: (1) *reproduction*, (2) *restoration*, and (3) *reconstruction*. Reproduction (1) is a type of facsimile edition in which the photographical images are published as they are with no image processing. This approach is suitable in cases where the text – perhaps despite some minor damages – is immediately visible and legible. One of the earliest examples of this approach is, for instance, the edition of *Wulfila's Gothic Bible* by Hans Henning, published as early as 1913.

Both restoration (2) and reconstruction (3) presuppose that the images of the manuscript are published after some image processing to increase the legibility of the damaged text. During the process of restoration (2) particular characteristics of the original images of the manuscript are adjusted so as to enhance the legibility of the respective textual layer. Restoration (2) is a widely used technique. It was applied, for instance, within the *Digital Image Archive of Medieval Music* (DIAMM) project. The image processing techniques of this project, such as the global and single-area level adjustment, are described by Craig-McFeely and Lock (2006) in their *Digital Restoration Workbook*. Another restoration approach was adopted by Sparavigna (2009) while restoring Da Vinci's sketches. This approach heavily relies on manipulating colour-channels. Yet another technique similar to the former one was put forward by Stokes (2011) and adapted by Voth (2014). It is primarily designed for palimpsested manuscripts and was used to examine the oldest extant Old English manuscript on medical remedies. Technically sophisticated restoration methods relying on the combination of imaging under special conditions and image processing were applied in the projects supported by the *Early Manuscripts Electronic Library* (EMEL). The list of relevant projects can be found on the website of the EMEL project. The restored palimpsested text of Archimedes published in Easton et al. (2003), Easton and Knox (2004), Netz and Noel (2007) provides an illustration of the application of this method. Still another approach to restoration is the digital 3-D modeling of physical objects; the advantages of this approach are discussed in Brown and Seales (2001).

In the process of reconstruction (3) – as opposed to the restoration – a new graphical object is created, which should be as close to the original as possible. For example, reconstruction of the fragment of page 46 from *Vat. gr.* 73 is found in the edition of Mai (1827, 1). Its goal was to illustrate the layout and its function in the structure of the manuscript (*fig. 1* below). Another example is Gurtmann (2012). Here, an extensive digital reconstruction allowed to reveal the complete underlying text of parchment manuscript of Qur'an from Sanaa from ca. 650 CE.[1] Finally, another technique of reconstruction similar to the method of *Tracing* illustrated in Section 2 below is found

[1] This graphical reconstruction is to be published in the Brill series *Documenta Coranica* (ed. by F. Déroche, M. Marx, A. Neuwirth and Ch. Robin).

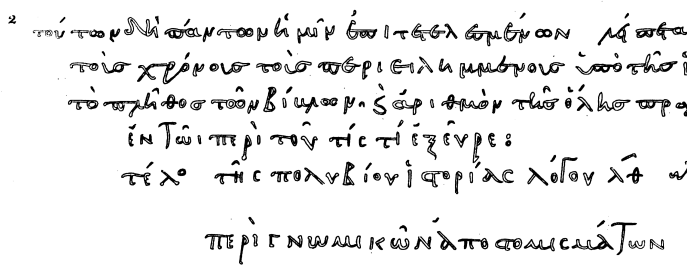

Figure 1: Reconstruction of the fragment of page 46 from *Vat. gr.* 73 published in the edition of Mai (1827, 1).

in Butcher and Hrynick (2012). Here, within the scope of the O*xford Outremer Map* project, a map from thirteenth century was digitally reconstructed, making once barely legible writings and images clearly visible.

Under both approaches, the restoration (2) and reconstruction (3), the critical question is as to how many amendments – if at all – may be made on images. Ideally, it is the duty of the researcher to ensure that facts are not manipulated and only most plausible emendations are made. Discussion of the ethical side of image manipulation may be found in Craig-McFeely and Lock (2006, 35–36, 53–54), Craig-McFeely (2008, §62), and Stokes (2011, 20). One possible solution to this is to supply the publication with the original images and the full list of all manipulations made.

2 The manuscript

In the next section, the technique of *Tracing* is outlined on the basis of *Vat. gr.* 73, a palimpsested parchment manuscript preserved in *Biblioteca Apostolica Vaticana*, Vatican City. Its upper textual layer, or *scirptio superior*, is dated back to the fourteenth century and contains the speeches of Aelius Aristides and the dialog *Gorgias* of Plato (Mercati and de'Cavalieri 1923, 67). It was only in the first quarter of the nineteenth century that an earlier textual layer, or *scriptio inferior*, was discovered by Angelo Mai (1782–1854), a celebrated philologist of the nineteenth century famous for finding a great number of hitherto unknown palimpsested texts of ancient authors (Dillon 2007, 10–22). He identified the *scriptio inferior* as one of the volumes of the Constantinian excerpt collection, or *Excerpta historica Constantiniana*, a tenth century historic encyclopaedia written in Constantinople in Ancient Greek language (Németh 2010). On the basis of palaeographical and codicological characteristics Jean Irigoin (1959) dated the manuscript into the first half of the tenth century, assuming that the *Vat. gr.* 73 is the original volume of the *Excerpta Constantiniana* assembled on behalf of

the emperor Constantine VII (913–959) for the imperial library. Only a subset of the original leaves of the *Excerpta Constantiniana* were palimpsested in the fourteenth century. It is assumed that the 177 folios, or 354 pages, preserved until today constitute around two third of the original manuscript.

Physical dimensions of the manuscript are 350/355 × 270/275 mm; writing surface covers approximately 255/260 × 185/200 mm. Written in 32 lines per page with approximaly 45–55 characters per line, the letters of both layers are about 5 mm high. The *scriptio superior* is written immediately above the *scriptio inferior*, fully covering it and extremely reducing its legibility (see fig. 2).

Rafiyenko (forthcoming) represents the reconstruction of the following 24 pages of *scriptio inferior*: 301, 302, 349, 350, 203, 204, 205, 206, 343, 344, 299, 300, 261, 262, 337, 338, 309, 310, 323, 324, 327, 328, 275 and 276.[2] These pages contain excerpts from an anonymous historiographer, the so-called *Anonymous post Dionem*, oftentimes identified as Peter the Patricius, an official and ambassador from the time of Justinian I (527–565)(Antonopoulos 1990). The text of the *Anonymous* is an account of Rome's history from the reign of Augustus (27 BCE–14 CE) to Constantine the Great (306–337 CE).

The text of the *scriptio inferior* of the *Vat. gr.* 73 has been edited twice: parts of it were edited by Mai in 1827; the full text was edited by Boissevain in 1906. Both editors studied the manuscript in autopsy and both of them used chemicals in order to enhance the legibility of the lower text (Mai 1827, XXXI–XXXIII; Boissevain 1884, 25). However, chemical treatments can considerably deteriorate the preservation condition of a palimpsest with the lapse of time (Wattenbach 1896, 311–312). In the case of the *Vat. gr.* 73, it remains unclear to what extent the manuscript was treated by Mai and Boissevain and how the treatment affected its condition. According to my own assessment, the legibility of the lower text did not considerably change since then. Previous editors were able to decipher most parts of the text (the editions of Mai 1827 and Boissevain 1906 contain almost no gaps in the text). Currently, the amount of the lower text which can be discerned with the naked eye amounts up to 90–95%.[3] The ink is for the most part discernible with the naked eye. However, the degree of preservation varies significantly from page to page, from line to line, and even from mark to mark. A number of images from *Vat. gr.* 73 are contained in Németh (2015).

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[2] The pagination in the *Vat. gr.* 73 has two peculiarities. First, page numbers instead of folio numbers are traditionally used for reference in *Vat. gr.* 73. Secondly, the pagination reflects the sequence of the pages in the palimpsested manuscript and therefore becomes re-ordered when the page sequence of the original manuscript is reconstructed.

[3] According to my own experience from the study of the manuscript both in the autopsy and by means of high-resolution digital images.

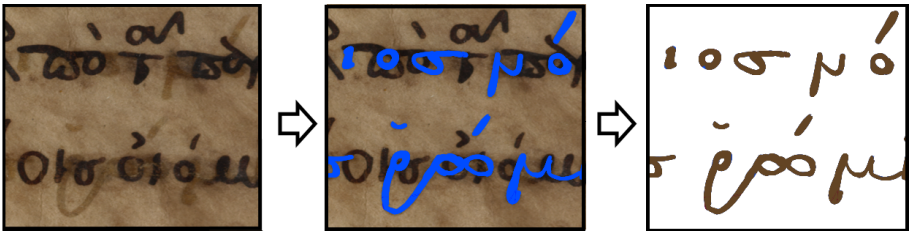

Figure 2: The process of the graphical reconstruction of the *Vat. gr.* 73 (fragment of p. 301)

3 The method

The impetus to develop the method of reconstruction of the *Vat. gr.* 73 came from the wish to facilitate the process of the autopsy of the manuscript for a new edition (Rafiyenko, forthcoming). Deciphering such a damaged text revealed itself as labour-intensive and, hence, time-consuming work. Collating took sometimes up to twenty hours per page. Nonetheless, irrespective of the time invested, previous collation brought little when a passage from the manuscript had to be consulted repeatedly; and subsequent revisions were almost as time-consuming. This called for a different method of decipherment that would allow fixing the deciphered characters in a digital form. The resulting images revealed themselves as a clear copy of the lower text and its original graphic appearance (cf. fig. 2 and fig. 3 below). The essence of the technique lies in manual re-tracing and re-drawing the contours with the stylus on the touch screen on significantly enlarged images. This allows rendering the scriber's handwriting very close to the original (cf. fig. 2).

3.1 Technical requirements

An image processing software with the Brush Function such as Paint.NET, GIMP, Photoshop, ImageJ or other is sufficient. Furthermore, one needs a digital drawing pad or drawing tablet and, finally, high resolution photos of a manuscript for the reconstruction. It is advisable to have a monitor with high quality resolution.

3.2 Tracing

The images are drawn with digital painting technique in an image-processing application. In order to be able to separate the original images from the reconstruction, the latter are drawn on a separate layer positioned above the layer containing the original image of the manuscript. Magnification ensures high accuracy of imitation of the ductus and of the characteristic shapes of the ink marks.

In my case, a magnification of eight to ten times has proved itself as optimal. For this purpose, I used a Hewlett Packard notebook with resistive touchscreen. The images were created with the Brush Function in the Paint.NET image-processing application. In a non-digital environment, one could potentially achieve comparable results by putting a transparent slide upon the image and, subsequently, re-drawing the ink marks on the slide manually. However, the crucial advantage of the digital method here is the possibility of modifying the characteristics of the original image, which allows to discern and to trace the original ink marks with a higher level of fidelity.

3.3 Results

The resulting images can be characterized as a two-dimensional, exact and truthful representation of the manuscript's underwritings. They represent the surface of the lower text in terms of a *topographical* edition[4] (the term coined by P. Sahle in personal communication).

In Rafiyenko (forthcoming), the exact appearance of the original manuscript pages – not readily discernible behind the ink marks from the fourteenth century layer – is restored (see fig. 3). The high level of granularity allows determining the ductus and the characteristic shapes of ink marks in all parts of the lower text. Thus, maximum fidelity to the features of the handwriting is achieved and such properties as the colour of the ink or spatial positioning are straightforwardly reproduced.

As the image of page 302 from the *Vat. gr.* 73 shows (fig. 3), graphical reconstruction of the manuscript page gives a clear picture of its overall appearance before it was palimpsested. It offers a number of advantages. First, it allows a better understanding of the layout of the *Vat. gr.* 73. It is clearly visible that the initial letter ὅ (see lines 1, 5, 9, 12, 16, 27, 29 and 30 of page 302 on fig. 3) is used as a visual marker of the starting point of each new excerpt in the *Excerpta Constantiniana,* being set off by the space left blank before it and by the use of the reddish ink. The visual appearance of initials is important here as it highlights the logical structure of the text and shows that borders of each excerpt were clearly marked as well as that the excerpt itself was construed as the smallest single unit of the text structure.

Furthermore, marginalia and pictograms in *Vat. gr.* 73 can now be studied since their exact positioning and design are clearly visible in the graphical reconstruction. On page 302, there are two marginalia (placed opposite the lines 1 und 5, see fig. 3) and seven pictograms in different state of preservation (placed on the left margin opposite the lines 7, 9, 14, 18, 26, 30 and 32, see fig. 3). The palaeographical characteristics thereof unequivocally indicate that both marginalia and pictograms belong to the hand

[4] *Topographical edition* refers to any edition which is a two-dimensional representation of the surface of the original document that was created by means of reconstruction.

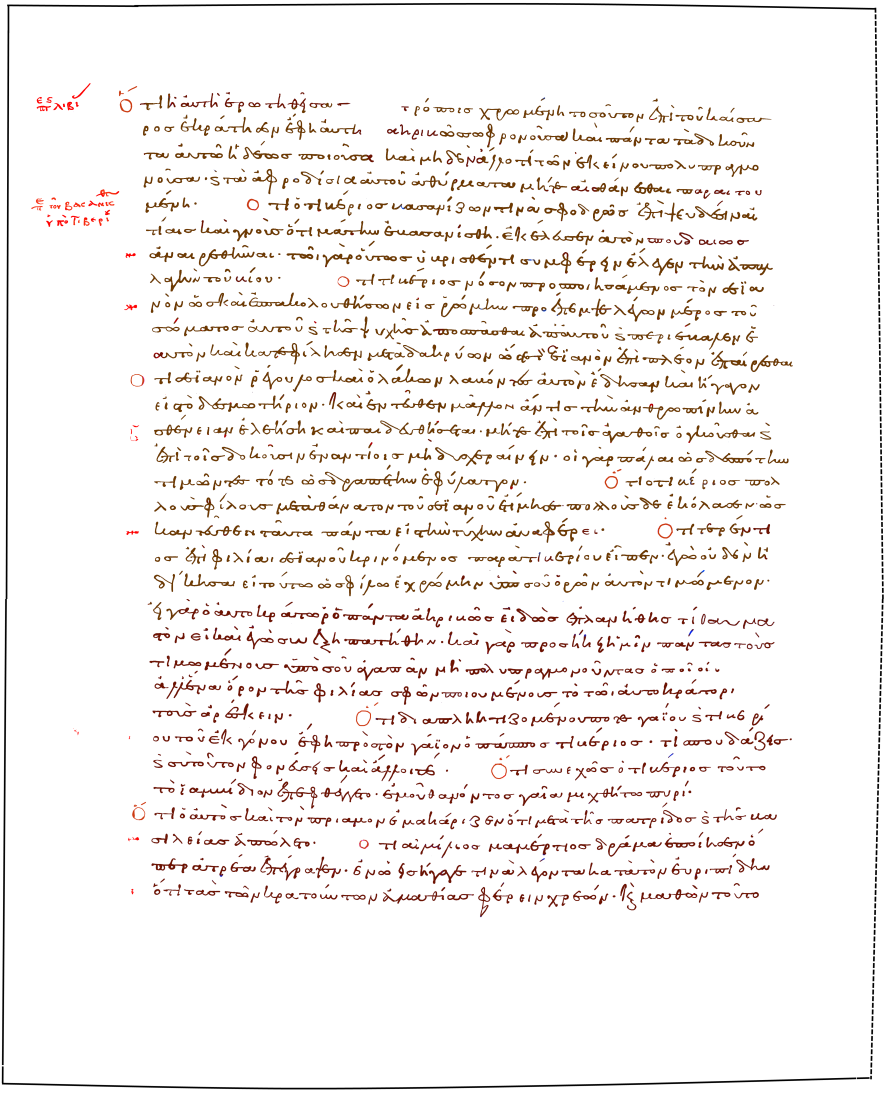

Figure 3: Graphical reconstruction of page 302 from the *Vat. gr.* 73

	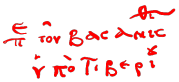	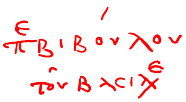
p. 302,1	p. 302,5–6	p. 328,9–10

Table 1: Samples of marginalia from the *Vat. gr.* 73.

of the main scribe and thus were designed in the tenth century by the compilers of the manuscript. Marginalia, 32 examples of which can be found on the 24 investigated pages of the manuscript (in Rafiyenko, forthcoming), were written in red ink and placed on the outer margins of the manuscript. They are positioned consistently at the beginning of each excerpt and indicate an acting person. As many of them are pointing to Roman emperors, it may be the case that they were also used as the chronological labels in the text. Pictograms, 147 samples of which are found on the 24 pages of the manuscript, were drawn with the same red ink as the marginalia and placed coherently on the left side of the main text. They are positioned in the middle or at the end of an excerpt and indicate the most important phrase of a given excerpt, its essence.

The reconstruction allows to establish different forms of pictograms (see *table 2*). The function of most of them could be discerned. For example, form (2) refers to passages with explicitely ironical intent, form (4) to citations of ancient authors in the text. The most numerous form (1) was presumably used without special function because it refers to a great number of passages which cannot be easily categorized (pictograms with similar function are found in papyri from Egypt of the period from 2 BCE to 7 CE, see McNamee 1992, 8).

It may be concluded that both marginalia and pictograms represent a system of content-related references that were designed to facilitate the navigation through the text of the *Excerpta Constantiniana*. The graphical reconstruction of the manuscript by means of *Tracing* makes it possible to compare the marginalia and pictograms and palaeographically analyse them (cf. *table 1*, *table 2*). The exact positioning of the marginalia and pictograms in the manuscript enhance the philological analysis of the text.

Another example of how reconstructed images can be used for the palaeographic research is presented in *table 3* below. Here, samples of the variants of the letter *epsilon* and its combinations with other letters are given. Such collations of scribal variants are important for further work with the manuscript. Notably, without the reconstruction, it is nearly impossible to acquire clear sample images of scribal variants in *Vat. gr.* 73.

As regards the truthfullness of the reconstructed images by means of *Tracing*, the major principle here may be formulated as follows: the reconstruction is based either

Nr.	Form	Number of samples in the manuscript	Indication of location in the manuscript (page, line)
(1)		86	*Passim*
(2)		13	302,26; 302,32; 206,23 etc.
(3)		2	310,25; 310,29
(4)		5	204,11; 206,2; 276,21; 276,22; 276,23

Table 2: Samples of pictograms from the *Vat. gr.* 73.

ε	-εί-	-εῖν	-σχεῖν	ἐπὶ
				
ἐτρ-	δὲ	ὥστε	ἐγὼ	ἐκ
				

Table 3: Variants of *epsilon* and its combinations with other letters in the *Vat. gr.* 73.

on the documental evidence for a character or on the unambigiously attested rests thereof. In turn, in case of ambiguity, when the form of the letter is almost entirely obscured the process of reconstruction is subject to the scholar's interpretation. In certain cases, a particular interpretation is strongly favourable because of the palaeographic norms and good acquaintance with the scriber's handwriting in this manuscript. Importantly, all amendments of this type should be marked in the critical apparatus. In other cases, where no reliable restoration can be made the space should remain blank in the reconstructed version and marked as such (cf. the marked spaces in figure 4). This also should be documented in the critical apparatus.

Certainly, these principles do not entirely exclude the possibility of over-interpretation on the part of the editor. However, the advocated method provides a much safer reconstruction tool than the traditional editorial one. Thus, in the edition of the *Excerpta Constantiniana* of Boissevain (1906), apart from tacitly made corrections of the text, the most prominent evidence of misrepresentation of the text is probably the fact that the marginalia and pictograms are neither mentioned nor represented, even though they are crucial for the understanding of the text as has been layed out above. In turn, the reconstruction of the *Vat. gr.* 73 by means of *Tracing* allows the researcher to see their exact positions, forms and the ductus and presents a more reliable source for the study of the text.

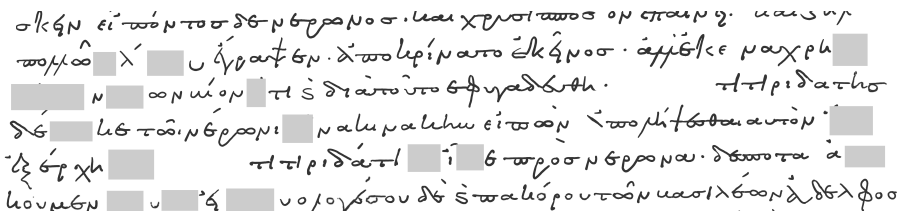

Figure 4: Illegible passages in the *Vat. gr.* 73 (p. 343, 8–13).

The method of *Tracing* has its limitations. It is time-consuming and requires a lot of effort on the part of the editor. It is, furthermore, applicable only to those manuscripts in which the lower or the damaged text may be perceived with naked eye – unless the photos have been additionally processed to enhance the legibility. Thus, *Tracing* can be considered as supplementary to more technically advanced methods such as methods relying on *multispectral imaging* (a list of projects using this technique can be found on the website of the EMEL project), *hyperspectral transformation imaging* (see Shiel, Rehbein and Keating 2009), and various techniques of image processing. Moreover, *Tracing* can also be applied in those cases in which more than one image is used as the basis for the reconstruction.

Crucially, the method has a number of advantages. Being fairly simple, it is immediately accessible to any researcher as it requires neither special software nor any technical expertise beyond the basics. At the same time, it ensures the results that cannot be achieved by simple, non-digital re-drawing. Furthermore, in contrast to automated reconstruction, the editor has the full control over the process of reconstruction here, thereby avoiding misinterpretations or mistakes made by software.

It is also advantageous concerning the philological accuracy and falsifiability of the reconstruction. This method allows the documentation of what exactly the editor sees in the lower text and what has been amended by the editor on the basis of contextual plausibility. It ensures more transparency in the process of text transcription and critical editing. Subjective decisions of the editor can be better controlled for and the requirement of falsifiability of research is more strongly obeyed than in the traditional approach.

4 Conclusion

In this paper I presented the method for reconstructing damaged manuscripts referred to as *Tracing*. It crucially relies on the re-drawing of poorly discernable contours of the original image under multiple magnification of the original size. The application

of the method was demonstrated on the basis of the palimpsested manuscript *Vat. gr.* 73. The method has a number of advantages in contrast to the traditional method. In particular, *Tracing* may be especially helpful in palaeographical and philological research because it yields qualitive pictures of the original graphical appearance of damaged manuscripts. It thus provides good empirical basis for further research on the manuscript. *Tracing* is both feasible and advantageous for the scholars of different philological subdisciplines because it does not require any advanced technical expertise nor does it require any specific technical equipment or software. Last but not least, the images produced via *Tracing* represent the editor's own artwork and, hence, should not require a copyright permission from the owning library.

Any kind of reconstruction can be considered as a step away from the real, imperfect characters of the manuscript towards their original form (as written by the scriber). While *Tracing* is about light and manual reconstruction of each and every single symbol (signs, letters, etc.) there are other, more powerful methods available that may supplement the result achieved by *Tracing.* Thus, the next step towards reconstructing transcriptions may rely on regularization of the text with the help of a font that imitates the form and the positioning of the original handwritten characters (see such an attempt in Vorbach 2012), a font where each glyph ideally would be an average of all real representations of a given character. Even though this type of reconstructing transcription diminishes the individuality of the handwritten text, it retains the topografical dimension and makes the text searchable by the computer.

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