The isotopic composition of valves and organic tissue of diatoms grown in steady state cultures under varying conditions of temperature, light and nutrients

- Implications for the interpretation of oxygen isotopes from sedimentary biogenic opal as proxies of environmental variations

Abstract

The oxygen isotopes of diatomaceous silica from marine and freshwater sediments are frequently used as indicators of the palaeotemperature development, particularly in cases where calcareous microfossils are rare or absent. With regard to terrestrial waters it is unknown whether or not palaeotemperature scale can be used in a limnic ecosystem. Due to the fact that the seasonal variations in lakes are larger than in oceans, specific problems arise when working with freshwater sediments. Thus, an understanding of the contribution of the various factors (e.g. temperature, light, nutrients, competition) influencing the formation of isotope signals in biogenic opal is a prerequisite for the accurate interpretation of environmental processes. Since it is impossible to examine the influence of a single parameter under natural ecosystem conditions due to permanent changes of the environment, laboratory experiments with single diatom species are needed.

Therefore, the aim of this study was to investigate the correlation between the oxygen isotope variations in biogenic opal and different environmental parameters using steady state cultures with diatoms. It should be examined whether or not the different diatom species grown under identical conditions show equal oxygen isotope ratios (species relationship), if variations of the water temperature induce variations of the oxygen isotope ratio (relationship with temperature), variable parameters such as light intensity and nitrate concentration influence the isotope ratio, and if vital effects (e.g. growth rate) lead to variations of the oxygen isotope ratio.

The experiments with diatoms were carried out using two fermenter systems. An illumination unit, constructed especially for the experiments, produced the necessary natural light spectrum. For the study two diatom species were chosen, which were morphologically different. These were the pennate form *Fragilaria crotonensis* and the centric form *Cyclotella meneghiniana*. The diatoms were grown at temperatures of 9, 12, 15, 18, 21 and 24°C. Subsequently, the influence of various nitrate concentrations of the medium (10.5, 21, 52.5 and 105 mg/l) was examined. Moreover

experiments with various natural light intensities (200, 500, 1100 and 1700 µmol photons $m^{-2}s^{-1}$) were performed.

Based on the data obtained from the experiments, a negative linear correlation between the oxygen isotope ratio and the water temperature was found for both diatom species. The temperature coefficients obtained in this study were not species-specific. The temperature coefficient determined for *Fragilaria crotonensis* within the temperature range of 15 - 24°C was ≈ -0.28‰/°C. For *Cyclotella meneghiniana* grown at a growth rate of 0.34 d^{-1} employing temperatures in the range of 15 - 21°C, the temperature coefficient was ≈ -0.27‰/°C. The same species grown at a growth rate of 0.2 d^{-1} and operating in a temperature range of 9 - 18°C also resulted in a temperature coefficient of ≈ -0.27‰/°C.

Varying nitrate concentrations examined in this study did not influence the oxygen isotope fractionation between diatomaceous silica and water. This finding is very important for further applications of the oxygen isotope ratio of diatom valves for reconstruction of the water temperature, since varying nitrate concentrations in lakes will not mask the temperature effect.

It was also found, that variations in the light intensity influence the oxygen isotope fractionation during diatom valve morphogenesis. The light coefficient (φ) was ≈0.05‰/100 µmol photons $m^{-2}s^{-1}$. The effect of the light intensity is opposite to the effect of the temperature and leads to a partial suppression of the fractionation effect induced by temperature. Thus, the effect of the light intensity should be taken into consideration in reconstructions of the water temperature.

Species-specific effects found on the basis of this study are distinctly expressed in the amount of the oxygen isotope fractionation despite equal water temperature. On the one hand, different growth rates caused differences in the fractionation of a single diatom species. On the other hand, there were also differences in the fractionation between diatom species grown with the same growth rate. Thus, for reconstructions of the water temperature, it is important to separate the valves of single diatom species from e.g. a plankton sample.

The results of this study increase hitherto existing information about the relationship of the oxygen isotope fractionation between diatomaceous silica and water. The new findings from this study should help in the interpretation of the stable oxygen isotope ratios of diatom valves.