Palaeoenvironment and palaeoclimate of the Middle Miocene lake in the Steinheim basin, SW Germany: A reconstruction from C, O, and Sr isotopes of fossil remains

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Received 23 November 2005; received in revised form 30 March 2006; accepted 27 April 2006

Abstract

A differentiated reconstruction of palaeolimnologic, –environmental, and –climatic conditions is presented for the Middle Miocene long-term freshwater lake (14.3 to 13.5 Ma) of the Steinheim basin, on the basis of a combined C, O, and Sr isotope study of sympatric skeletal fossils of aquatic and terrestrial organisms from the lake sediments.

The oxygen isotope composition for lake water of the Steinheim basin (δ18O H2O = +2.0 ± 0.4‰ VSMOW, n = 6) was reconstructed from measurements of δ18O PO4 of aquatic turtle bones. The drinking water calculated from the enamel of large mammals (proboscideans, rhinocerotids, equids, cervids, suids) has δ18O H2O values (δ18O H2O = −5.9 ± 1.7‰ VSMOW, n = 31) typical for Middle Miocene meteoric water of the area. This δ18O H2O value corresponds to a mean annual air temperature (MAT) of 18.8 ± 3.8 °C, calculated using a modern-day δ18O H2O-MAT relation. Hence, large mammals did not use the lake water as principal drinking water. In contrast, small mammals, especially the then abundant pika Prolagus oeningensis drank from 18O-enriched water sources (δ18O H2O = +2.7 ± 2.3‰ VSMOW, n = 7), such as the lake water. Differences in Sr and O isotopic compositions between large and small mammal teeth indicate different home ranges and drinking behaviour and support migration of some large mammals between the Swabian Alb plateau and the nearby Molasse basin, while small mammals ingested their food and water locally.

Changes in the lake level, water chemistry, and temperature were inferred using isotopic compositions of ostracod and gastropod shells from a composite lake sediment profile. Calcitic ostracod valves (Ilyocypris binocularis; δ18O = +1.7 ± 1.2‰ VPDB, δ13C = −0.5 ± 0.9‰, VPDB, n = 68) and aragonitic gastropod shells (Gyrulus spp.; δ18O = +2.0 ± 1.3‰ VPDB, δ13C = −1.1 ± 1.3‰ VPDB, n = 89) have δ18O and δ13C values similar to or even higher than those of marine carbonates. δ13C values of the biogenic carbonates parallel lake level fluctuations while δ18O values scatter around +2 ± 2‰ and reflect the short term variability of meteoric water inflow vs. longer term evaporation. 87Sr/86Sr ratios of aragonitic Gyrulus spp. gastropod shells parallel the lake level fluctuations, reflecting variable inputs of groundwater and surface waters. Using a water δ18O H2O value of +2.0‰ VSMOW, water temperatures calculated from skeletal tissue δ18O values of ostracods are 16.7 ± 5.0 °C, gastropods 20.6 ± 5.6 °C, otoliths 21.8 ± 1.4 °C, and fish teeth 17.0 ± 2.7 °C.

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doi:10.1016/j.palaeo.2006.04.007