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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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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 ($\delta^{18}O_{H2O}$=+2.0±0.4‰ VSMOW, n=6) was reconstructed from measurements of $\delta^{18}O_{PO4}$ of aquatic turtle bones. The drinking water calculated from the enamel of large mammals (proboscideans, rhinocerotids, equids, cervids, suids) has $\delta^{18}O_{H2O}$ values ($\delta^{18}O_{H2O}$=−5.9±1.7‰ VSMOW, n=31) typical for Middle Miocene meteoric water of the area. This $\delta^{18}O_{H2O}$ value corresponds to a mean annual air temperature (MAT) of 18.8±3.8 °C, calculated using a modern-day $\delta^{18}O_{H2O}$-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 ^{18}O-enriched water sources ($\delta^{18}O_{H2O}$=+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*; $\delta^{18}O$=+1.7±1.2‰ VPDB, $\delta^{13}C$=−0.5±0.9‰, VPDB, n=68) and aragonitic gastropod shells (*Gyraulus* spp.; $\delta^{18}O$=+2.0±1.3‰ VPDB, $\delta^{13}C$=−1.1±1.3‰ VPDB, n=89) have $\delta^{18}O$ and $\delta^{13}C$ values similar to or even higher than those of marine carbonates. $\delta^{13}C$ values of the biogenic carbonates parallel lake level fluctuations while $\delta^{18}O$ values scatter around +2±2‰ and reflect the short term variability of meteoric water inflow vs. longer term evaporation. $^{87}Sr/^{86}Sr$ ratios of aragonitic *Gyraulus* spp. gastropod shells parallel the lake level fluctuations, reflecting variable inputs of groundwater and surface waters. Using a water $\delta^{18}O_{H2O}$ value of +2.0‰ VSMOW, water temperatures calculated from skeletal tissue $\delta^{18}O$ 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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