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Stable isotope compositions of mammoth teeth from Niederweningen, Switzerland: Implications for the Late Pleistocene climate, environment, and diet

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Abstract

Oxygen and carbon isotope compositions of well-preserved mammoth teeth from the Middle Würmian (40–70 ka) peat layer of Niederweningen, the most important mammoth site in Switzerland, were analysed to reconstruct Late Pleistocene palaeoclimatic and palaeoenvironmental conditions. Drinking water $\delta^{18}O$ values of approximately $-12.3 \pm 0.9‰$ were calculated from oxygen isotope compositions of mammoth tooth enamel apatite using a species-specific calibration for modern elephants. These $\delta^{18}O_{H_2O}$ values reflect the mean oxygen isotope composition of the palaeo-precipitation and are similar to those directly measured for Late Pleistocene groundwater from aquifers in northern Switzerland and southern Germany. Using a present-day $\delta^{18}O_{H_2O}$-precipitation–air temperature relation for Switzerland, a mean annual air temperature (MAT) of around 4.3 ± 2.1 °C can be calculated for the Middle Würmian at this site. This MAT is in good agreement with palaeotemperature estimates on the basis of Middle Würmian groundwater recharge temperatures and beetle assemblages. Hence, the climatic conditions in this region were around 4 °C cooler during the Middle Würmian interstadial phase, around 45–50 ka BP, than they are today.

During this period the mammoths from Niederweningen lived in an open tundra-like, C_3 plant-dominated environment as indicated by enamel $\delta^{13}C$ values of $-11.5 \pm 0.3‰$ and pollen and macroplant fossils found in the embedding peat. The low variability of enamel $\delta^{13}C$ and $\delta^{18}O$ values from different mammoth teeth reflects similar environmental conditions and supports a relatively small time frame for the fossil assemblage.

1. Introduction

1.1. The mammoths

The mammoth lineage developed in Africa and appeared in Europe about 3 Ma ago, evolving over several stages from *Mammuthus meridionalis*, *Mammuthus trogontherii* to the woolly mammoth *Mammuthus primigenius* (Lister and Sher, 2001). *M. primigenius* appeared in central Europe during the Early Pleistocene glaciation after 200 ka but originated in NE Siberia considerably earlier, probably around 800 ka (Lister and Sher, 2001). *M. primigenius* was present over most of Europe during much of the Last Cold stage from ca. 115–10 ka BP while around 9.6 ka BP the last mammoths disappeared from the Eurasian mainland (MacPhee et al., 2002; Stuart et al., 2002). Isolated dwarf forms of mammoths survived into the Holocene on St. Paul Island, Alaska until 7.9 ka BP (Guthrie, 2004) and even until 3.7 ka BP on the Wrangel Islands in the eastern Arctic Ocean (Vartanyan et al., 1993, 1995; Kuzmin and Orlova, 2004). The mammoth with its thick fur, isolating fat layer and small ears was essentially an elephant species adapted to the cold climate and open habitat of the tundra-like Mammoth Steppe environment (Guthrie, 1982; Kubiak, 1982). They were large herbivores capable of digesting large quantities (~150–300 kg/day) of nutrient-poor plants with low-protein and high-fibre content (Guthrie, 1982). Mammoths fed dominantly on grasses and sedges but

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