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Paleoclimatological Signals in the Oxygen Isotope Composition of Mammoth Skeletal Remains from Finland and Western Russia

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The stable isotopes of carbon and oxygen have been widely used for paleoenvironmental reconstructions. Compared to marine environments, isotopic investigations of past environmental conditions on land are complicated by many factors, including the lack of suitable study material.

The oxygen isotope composition (δ^{18}O) of the mineral component of vertebrate skeletons, carbonate-hydroxyapatite $Ca_9[(PO_4)_{4.5}(CO_3)_{1.5}]$ $(OH)_{1.5}$ (Driessens & Verbeeck, 1990), has been successfully used as a tool for paleoclimatological reconstructions of continental climates (e.g. Ayliffe et al., 1992; Bryant et al., 1994, 1996; Fricke et al., 1995; Genoni et al., 1998; Iacumin et al., 2004). The skeletal parts of mammals form at a constant temperature of ∼37 ˚C. Therefore, the oxygen isotope composition of the precipitating bone apatite is determined solely by the isotopic composition of the animal's body water (Longinelli, 1984; Luz et al., 1984). The δ^{18}O value of body water, in turn, tracks that of ingested environmental waters, which usually correspond to the mean δ^{18}O-value in the regional precipitation. The oxygen isotope composition of meteoric waters correlates with regional mean annual temperatures (Dansgaard, 1964), and, therefore, the isotopic composition of oxygen in fossil skeletal material can be used to reconstruct past atmospheric temperatures in terrestrial environments (Longinelli 1984).

Nine samples of bone and tooth enamel from woolly mammoth (*Mammuthus primigenius*) remains found from Finland, Russian Karelia and Western Russia were analysed for the oxygen isotope composition of the phosphate fraction and the carbon and oxygen isotope composition of the carbonate fraction in skeletal material. All samples have been radiocarbon dated in previous studies (Ukkonen et al., 1999; Lõugas et al., 2002; Saarnisto & Lunkka, unpub.;M. Saarnisto, pers.comm. 2003; I. Demidov, pers.comm. 2003), and are of late Middle Weichselian to Late Weichselian age, ranging from $>$ 45 800 to 18 700 cal yr BP. All samples were analysed for their chemical composition, and the isotopic fractionation between the phosphate and carbonate components of bioapatite was checked in order to evaluate the extent of post depositional alteration. On the basis of these tests, five out of the nine samples were interpreted to have retained their original, isotopic composition. The δ^{18}O values in these well preserved samples were used to estimate late Pleistocene climatic conditions in Finland and adjacent areas.

All analysed samples yielded $\delta^{13}C_C$ ($_C$=carbonate) values typical for C3-feeders, ranging from -13.4 to -9.1 ‰. Based on $\delta^{18}O_P$ ($_P$=phosphate) of the well preserved enamel samples, the isotopic composition of oxygen in late Pleistocene precipitation was 1-3 ‰ lower than the mean value of $\delta^{18}O_W$ in the present day precipitation in central and southern Finland. Applying the T- $\delta^{18}O_W$ –relationship of Kortelainen & Karhu (2004), 2-6 ˚C lower mean annual temperatures are implied for the Middle Weichselian ice-free period between 26 000 and 32 000 cal yr BP.

A humerus sample from Herttoniemi, Helsinki has yielded an age of 18 700 $\pm$ 180 cal yr BP (15 910 $\pm$ 155 yr BP; Ukkonen et al., 1999), which is problematic in relation to the accepted glacial history. As the bone was discovered in Holocene littoral clay/sand, it might have been transported to the find locality from elsewhere, possibly by icebergs (Ukkonen et al., 1999). The oxygen isotope data are consistent with this hypothesis. The sample yielded a much higher $\delta^{18}O_P$-value compared to other well preserved Pleistocene samples. Warmer climatic conditions compared to those prevailing in Finland today are implied for the original natural environment of this specimen.

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