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Ice-wedge based permafrost chronologies and stable-water isotope records from Arctic Siberia

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Late Quaternary permafrost of northern latitudes contains large proportions of ground ice, including pore ice, segregation ice, massive ice, buried glacier ice and in particular ice wedges. Fossil ice-wedges are remnants of polygonal patterned ground in former tundra areas, which evolved over several tens of thousands of years in non-glaciated Beringia. Ice wedges originate from repeated frost cracking of the ground in winter and subsequent crack filling by snowmelt and re-freezing in the ground in spring. Hence, the stable water isotope composition (δ18O, δD, d excess) of wedge ice derives from winter precipitation and is commonly interpreted as wintertime climate proxy.

Paleoclimate studies based on ice-wedge isotope data cover different timescales and periods of the late Quaternary. (MIS 6 to MIS 1). In the long-term scale the temporal resolution is rather low and corresponds to mid- and late Pleistocene and Holocene stratigraphic units. Recent progress has been made in developing centennial Late Glacial and Holocene time series of ice-wedge stable isotopes by applying radiocarbon dating of organic remains in ice samples.

Ice wedges exposed at both coasts of the Dmitry Laptev Strait (East Siberian Sea) were studied to deduce winter climate conditions since about 200 kyr. Ice wedges aligned to distinct late Quaternary permafrost strata were studied for their isotopic composition and dated by radiocarbon ages of organic matter within the wedge ice or by cosmogenic nuclide ratios (36Cl/Cl-) of the ice. The paleoclimate interpretation is furthermore based on geocryological and paleoecological proxy data and geochronological information (radiocarbon, luminescence, radioisotope disequilibria 230Th/U) from ice-wedge embedding frozen deposits.

Coldest winter conditions are mirrored by most negative δ18O mean values of -37 ‰ and δD mean values of -290 ‰ from ice wedges of the Last Glacial Maximum (26 to 22 kyr BP) while late Holocene (since about 4 kyr BP) and in particular modern ice wedges (last about 20 years) capture warmest winter conditions by δ18O mean values of -25 and -21 ‰ and δD mean values of -192 ‰ and -158 ‰ respectively. Further winter-climate variability on stadial-interstadial Quaternary scale is mirrored by the isotopic composition of related ice wedges.