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Stages of the Late Quaternary environment of NE Siberian lowlands during the last 200 ka – Permafrost records from northern Yakutia

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Permafrost sequences in Yakutian coastal lowlands preserved palaeoenvironmental records of the last 200 ka. Several stages could be separated using a multiproxy study approach. Because the study region is separated by the neotectonically active rift zone between the North American and Eurasian continental plates, the available stratigraphical records are different between the plate regions. Middle Pleistocene deposits are only exposed along the Dimitrii Laptev Strait, the eastern part of the study region and situated on the North American plate. The identified pre-Eemian cold period (>200 to 130 ka) was subdivided into a stadial-interstadial alternation and is characterized by ice-rich deposits with thick syngenetic ice wedges (older Ice Complex formation) as well as loess-like flood plain deposits. The following Eemian warming resulted in thawing of ice-rich deposits and the formation of ice wedge casts and thermokarst depressions filled with subaerial and lacustrine deposits. Pollen-based reconstructions show that summer temperatures during the Eemian climate optimum were at least 4-5˚C higher than today. However, plant macrofossils point to summer temperatures even 10˚C higher. The vegetation changed from open steppe-like associations at the beginning of the Eemian to shrub tundra during the optimum, and to tundra-like associations at the transition to the following glacial stage. During the Early Weichselian,

loess-like floodplain accumulation, shallow water bodies, and very sparse vegetation were characteristic features in the Laptev Strait region on the North American plate edge. In contrast, the records west of the plate boundary, in the central and western Laptev Sea regions, cover less than the last 100 ka. Here, the Early Weichselian palaeoenvironment was characterized by wide fluvial runoff plains in front of the low mountain ridges. The comparably rare bioindicators reflect the existence of a tundra-steppe environment during the time of deposition.

Strong changes in all environmental conditions are evident with the beginning of the Middle Weichselian interstadial in connection with the repeated continuous formation of Ice Complex sequences. Large syngenetic ice wedges, ice-supersaturated deposits, segregated ice veins, and thick cryoturbated peaty palaeosol horizons reflect accumulation conditions very different from the previous fluvial stage. In conclusion, landscape characteristics in many regions of northeast Siberian lowlands were apparently different. Subaerial accumulation within polygonal ice wedge nets, which were formed on poorly-drained plains in the foreland of the mountain ridges is assumed for this period. This stage of relatively moderate environmental conditions was characterized by strong seasonal differences, as indicated by summer (plant macro fossils) and winter (ground ice) air temperature proxies. Multiple palaeoenvironmental proxies indicate the continued existence of a mammoth steppe under very extremely cold-arid, continental conditions during the Late Weichselian cold stage (LGM). Large ice wedges developed continuously during this period too. At several sites LGM records are missing, which is possibly related to strong erosional events due to post-glacial and Holocene thermokarst and neotectonic processes.

Permafrost degradation due to climate warming at the end of the Late Pleistocene resulted in widespread thermo-erosion and lacustrine sedimentation in thermokarst basins. Bølling-Allerød interstadial records of a shrubby tundra point to a relatively warm climate with mean summer temperatures of about 10˚C, which was much warmer than in the previous period. Thermal degradation of the Ice Complex is also indicated by the presence wetland plants. Younger Dryas stadial records reflecting a short cooling period exist only in some places. For the Early Holocene Optimum, pollen-based climate reconstruction inferred a substantially warmer and more humid climate than at present. The tundra steppe disappeared completely due to increasing paludification and shelf submergence over the Holocene. During the early Holocene, a shrub-tundra formed with boreal elements, which later retreated in response to the late Holocene cooling.