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Challenges for geochronologies in permafrost environments: the case of Bol'shoy Lyakhovsky, Siberian Arctic

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Ice-bearing Quaternary deposits in permafrost environments comprise valuable archives of paleoenvironmental and palaeo-landscape dynamics over several glacial-interglacial cycles. Information on past conditions manifest in the mineralogical, organic and ice inventories. The characteristic ground ice abundance of permafrost evolves largely due to water supply by precipitation and surface run-off, while air, and consequently near-surface, temperatures control to which depth deposits freeze or thaw. This has several consequences on the continuity of permafrost sequences. Permafrost preservation or degradation depends basically on (1) climatic conditions during formation, (2) their decoupling from the active layer depth and (3) past relief conditions.

In this context, warmer interstadial and interglacial periods promote permafrost degradation by ground ice melt and subsequent surface subsidence. Such processes are commonly named as thermokarst that forms basins and valleys within older deposits and creates new accumulation areas. Shifts between periglacial accumulation and erosion frequently cause gaps in permafrost sequences. This complicates geochronological interpretations as representatives of consecutive Quaternary periods may be found at laterally different positions and altitudes. Additionally, they may comprise differing sediment properties as a consequence of paleo-relief and related process dynamic.

With this contribution, we discuss the challenges for establishing Quaternary geochronologies of arctic permafrost sequences using the example of Bol'shoy Lyakhovsky Island (New Siberian Archipelago). The island exposes sequences at its southern coast that are among the oldest dated Quaternary terrestrial permafrost deposits. Various proxies for paleo environmental reconstruction unravel at least three generations of cold- and warm-stage deposition ranging from the Holocene to the Eemian (MIS 5e) Interglacial, and potentially beyond that. However, the stratigraphic context is ambiguous due to the vertical discontinuity and potential hiatuses, especially for units older than the MIS 3 Interstadial.

For example, stadial conditions of the MIS 4 and the MIS 6(?) are recorded in sediment units locally named as Kuchchugui Suite. The floodplain sediments are dated by AMS radiocarbon to < 53 ka BP and to 57 - 79 ka by IRSL. The lithostratigraphic context of other sites suggests Kuchchugui-like floodplain deposits that pre-date the Eemian Interglacial but remain without numerical ages so far.

Despite the use of different dating methods to obtain permafrost formation ages there are still obvious discrepancies when comparing geochronological results from different physical methods. One main problem is that dating methods are generally not well established on frozen material and refer to differing permafrost components. Some of the challenges are related to unknown influences of freeze-thaw processes on chemical and physical parameters relevant for the chosen dating technique. Here, we cannot give the ultimate answer, but rather aim to highlight and discuss the advantages and drawbacks of the different dating techniques applied in our study area, including AMS radiocarbon, luminescence and radioisotope Th/U methods.