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Dirt, dates and DNA: Single-grain OSL and radiocarbon chronologies of perennially-frozen sediments, and their implications for sedimentary ancient DNA studies

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Recent studies using ‘sedimentary’ ancient DNA (*sed*aDNA) techniques have demonstrated that sequence-based taxonomic identifications can be reliably made from perennially-frozen bulk sediment samples that are up to several hundred thousand years old. Amongst other possible uses, this technique provides the opportunity to search for genetic traces of extinct fauna in contexts in which in situ macrofossils are exceedingly rare or absent. In well controlled circumstances, *sed*aDNA can provide a sensitive tool for investigating species evolution and extinction dynamics. The use of *sed*aDNA techniques for this purpose, however, is reliant on the provision of reliable numerical age control directly on the bulk sediments from which DNA is extracted for analysis.

An implicit assumption of the *sed*aDNA approach is that the extracted DNA is autochthonous with the host deposit and that it has not been physically transported from older source deposits or reworked within the sedimentary profile by post-depositional mixing. In this paper we investigate whether these fundamental conditions are upheld for (i) a range of perennially-frozen wetland sites across the Taimyr Peninsula and adjacent coastal lowlands of north-central Siberia, and (ii) locally-derived, perennially-frozen, loess sediments exposed along a 14.5 m thick river bluff sequence at the Stevens Village site, interior Alaska. Single-grain optically stimulated luminescence (OSL) and radiocarbon (^{14}C) dating are combined to constrain the ages of both the inorganic and organic fractions of perennially-frozen deposits from which *sed*aDNA of extinct and extant species have been recovered. In doing so, we aim to provide new insights into the physical processes that can affect perennially-frozen *sed*aDNA sequences in high-latitude regions. OSL and ^{14}C age/depth profiles, as well as single-grain equivalent dose (D_e) distribution characteristics, are used to assess the stratigraphic integrity of these *sed*aDNA sequences by (i) identifying the presence of primary or reworked organic and inorganic material, and (ii) examining the types of depositional and post-depositional processes that have affected specific sedimentary facies.

The results of this study demonstrate that even though DNA preservation and stratigraphic integrity are commonly superior in perennially-frozen settings, this does not, in itself, guarantee the suitability of the *sed*aDNA approach. The combined OSL and ^{14}C chronologies reveal that certain perennially-frozen sites may be poorly suited for *sed*aDNA analysis, and that careful site selection is paramount to ensuring the accuracy of any *sed*aDNA study. In particular, our findings indicate that high-energy fluvial contexts should be approached with caution or avoided altogether, since periodic erosion of older deposits from upstream can release ‘old’ genetic material that is not readily degraded during the limited duration of transport commonly experienced in these systems. Low-energy ponding environments, such as small thermokarst lakes, may offer more favourable settings for contemporaneous deposition of *sed*aDNA and dateable materials. However, even these types of settings must be treated with caution when the sedimentary infill is directly sourced from, or underlain by, much older, primary clastics and organic deposits that contain ancient DNA. Wind-blown deposits hold promise if the pre-existing DNA can be shown to have been erased during the last episode of sediment transport.