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Characterization of solid particles in East Siberian ice wedges: Implications on the paleoenvironment and provenance

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Ice wedges are subsurface ice mass structures that are considered to form by freezing precipitation mixed with airborne dust and soil particles. This mixture then flows through the active layer into the cracks and grows by repeated thermal contractions in the deeper permafrost layer over time. These ice masses characteristically contain high concentrations of dissolved solutes and solids, presumably derived from the surrounding soil. Because of their unique properties and distribution, ice wedges have been regarded as an alternative archive for reconstructing paleoclimate and paleoenvironment. This study examined the geochemical properties of the solid phase contained in the ice wedges and investigated the paleoenvironmental information based on the mineralogical and chemical composition of the solid particles.

In this study, ice wedge samples collected from three different locations in East Siberia were used. The solid particles in the ice wedge were recovered by filtration after thawing the samples, fractionated by their size, and analyzed using X-ray diffraction (XRD), X-ray fluorescence spectrometry (XRF), scanning electron microscopy (SEM), and X-ray absorption fine structure (XAFS) spectroscopy. The solid particles included minerals commonly found in soil, such as quartz, feldspar, and various clay minerals and had little differences in mineralogy and chemical composition among the samples, except those of clay fraction (< 2 μm). The particles in the clay fraction were consistently characterized by higher Fe and Mn concentrations with broad XRD peaks compared to those of the others (i.e., bulk and silt fractions). It is noteworthy that the Fe- and Mn-containing solids consisted of distinct phases based on the XAFS analysis, likely indicative of the differing environmental settings of their origin. In addition, the geochemical data of the solid particles can be harnessed to infer their provenance or parental rocks by employing various geochemical proxies. These results would provide the information on the origin of the solid particles and eventually the processes of ice wedge formation and their geological implications.