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Soil rare earth element (REE) distributions in permafrost-affected soils as indicators of geochemical processes

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Distinct thermal regimes in periglacial environments create unique geochemical cycling conditions that are being altered by permafrost degradation across the Arctic. As these cryosphere-watershed chemical dynamics continue to evolve, indicators of landscape-scale permafrost thaw and chemical cycling are needed to track and quantify the associated changes. In this study we investigated rare earth element (REE) concentrations in permafrost-affected soil profiles and adjacent surface waters to inform REE utility as geochemical tracers of permafrost-thaw sourcing and chemical cycling. We compare soil REE of permafrost and the seasonally thawed active layer to assess soil REE distributions as a product of chemical cycling for three sites in northern Alaska and three sites in western Greenland that are each subject to varied pedogenic conditions. We then use surface water REE to identify the potential for permafrost degradation signals in each region.

Within the soil profiles, reservoir REE transfer functions revealed differences in REE fractionation between the permafrost and active layer that varied in character across sampling sites. Enrichment in heavy REE of permafrost was apparent in Alaskan sites while species preference between these reservoirs were less pronounced in the Greenland sites. The discrepancy in the character of fractionation reflects the importance of localized soil weathering conditions and permafrost formation factors in impacting species preferred degradation, retention, and translocation within the soil environment. Soil profiles in all Alaska and Greenland sites exhibited enrichment of extractable REE near, or in, the top of the near-surface permafrost, likely due to accumulation and freezing, which can serve as an important zone for REE-watershed sourcing upon thawing. Surface water REE (<0.45 μm) generally mirrored species-abundance patterns for each soil, and in repeat measurements REE varied throughout the thaw season with the flux of transporting complexes modulated by seasonal top-down soil thaw. Enrichment in heavy REE of surface waters near active thermokarst degradation at an Alaskan site potentially presents a local thaw signal. Our results indicate the importance of soil thermal status for the distribution of REE in permafrost-affected soils and demonstrate the utility of REE as geochemical indicators of permafrost processes and catchment permafrost stability in a dynamic Arctic.