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Cerium anomaly as a redox tracer in soil pore waters from permafrost regions during the late shoulder season: implications for organo-mineral interactions

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Cerium anomaly is a redox tracer commonly related to the mechanism of oxidative scavenging of tetravalent cerium by iron and/or manganese oxides, or by organic carbon. This tool can therefore be used to trace the redox processes that take place during seasonal changes resulting from different hydrological conditions upon freezing in permafrost regions. These redox changes have a direct impact on the mobility of iron and carbon, and thereby on the organo-mineral interactions involved in organic carbon stability. Despite being a well-established geochemical tool, the cerium anomaly remains poorly explored in permafrost regions and is a valuable way to better capture redox changes in a warming Arctic context. Here, we investigate different redox sensitive parameters (cerium anomaly, redox potential, Fe^{2+}/Fe^{3+} ratio) coupled to physico-chemical parameters (pH, conductivity, and soil moisture) in soil pore waters from two different arctic study sites subject to permafrost thaw represented by a degradation gradient: a sporadic permafrost area in Stordalen (Abisko, Sweden) and a discontinuous permafrost area at Eight Mile Lake (Alaska, USA). Soil pore water samples were collected during the late shoulder season between September and November (2021 for Sweden and 2023 for Alaska), *i.e.,* the transition season between the growing season and winter. That season, understudied in the Arctic, is characterized by hydrological changes, and thereby by variations in redox conditions. By comparing the different redox sensitive parameters, the results show that the cerium anomaly allows to detect changes in redox conditions, providing an independent tracer for processes controlling soil pore water chemistry, such as the precipitation and dissolution of iron oxides, directly influencing iron-organic carbon interactions. Beyond traditional redox-sensitive tools, the cerium anomaly provides valuable insight to track the evolution of redox conditions occurring during late shoulder seasons in the Arctic.