Changing conditions for mineral-organic carbon interactions across the permafrost landscape: hot moments more than hot spots?

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The Earth's high latitude regions are warming twice as fast as the global average which enhances the thawing of permafrost. According to geological archives, abrupt thaw and thermokarst formation in the past have induced changes in redox conditions in ice-rich permafrost deposits, affecting iron distribution and interactions between organic carbon and iron (Monhonval et al. 2021), modifying thereby the protective role of minerals for organic matter. This example illustrates that the evolution of mineral-organic carbon interactions with permafrost thaw is a potentially important player in the modulation of permafrost carbon emissions. The stability of mineral surfaces and the availability of metal ions for binding organic carbon are likely to vary upon changing water saturation in response to permafrost thaw and deepening of the active layer. Using the distribution of mineral elements with direct (Fe) or indirect (Si) interactions with organic carbon, we investigate the changing conditions for mineral-organic carbon interactions on a variety of scales across the modern permafrost landscape. Our results show that at the pedon scale localized freeze-thaw events occurring during the winter period create hot moments for soil biogeochemical reactions in microenvironments (~10 to 20 cm thick soil layers) and that these reactions affect the solute transfer from soils to rivers. Our data also support that hot spots for biogeochemical reactions are created in the novel active layer resulting from thermokarst slump deposits upon abrupt thaw. The temporal and spatial heterogeneity in the distribution of unfrozen soil microenvironments in the permafrost landscape is more complex than previously thought. The role played by ice and frost at structuring and compartmentalizing microenvironments hosting mineral-organic carbon interactions in permafrost soils should be seen as more variable seasonally and spatially.

Monhonval et al. 2021. Iron redistribution upon thermokarst processes in the Yedoma domain. Front. Earth Sci. 9, doi.org/10.3389/feart.2021.703339.