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Iron and carbon dynamics along a mineral-rich permafrost thaw gradient in Iceland

LAUREL THOMAS ARRIGO[1], LOUISA WOLPERT[1], ISABELLA ZELANO[2], YI-HO TSENG[1], STARRI HEIÐMARSSON[3] AND ÞORSTEINN SÆMUNDSSON[4]

[1]University of Neuchâtel
[2]University of Neuchatel
[3]Northwest Iceland Nature Research Centre
[4]Faculty of Life- and Environmental Sciences / Institute of Earth Sciences, University of Iceland

Permafrost regions store large amounts of organic carbon. While carbon in intact permafrost may be stabilized through association with mineral phases, as increasing global temperature leads to permafrost thaw, soils may become waterlogged, resulting in anoxic environments that promote microbial iron reduction, iron mineral dissolution, and the mobilization and mineralization of previously mineral-bound OC.

Coupled iron and carbon dynamics in thawing permafrost soils have been demonstrated in various Arctic environments including Stordalen mire (Sweden), Alaska, and the Qinghai-Tibet Plateau. However, little is known about coupled iron and carbon dynamics in Icelandic permafrost landscapes. Due to intense aeolian deposition of poorly-weathered volcanic material across the Icelandic highlands, permafrost soils of Iceland have uniquely high mineral contents. Yet recent modeling suggesting an increase in the thickness of the active layers due to seasonal warming.[1] These rapid landscape level changes make the study of mineral controls on carbon dynamics in Icelandic permafrost soils of critical importance, as these soils contain an estimated 30-50 kg/m^2 SOC.[2]

To better understand iron and carbon dynamics in the mineral-rich permafrost soils of Iceland, we explored the Orravatnsrústir palsa site in Iceland's Central Highlands, where lithalsas (permafrost mounds covered by mineral-rich organic soils), surrounded by permanently waterlogged fens, undergo seasonal freeze-thaw cycles. We measured oxidation-reduction potential and sampled soil cores of the active layer and collected depth-resolved porewater across two thaw gradients (intact lithalsa, recently collapsed lithalsa, fen). Using elemental analysis, selective chemical extractions, XRF, XRD, and XAS, we determined the elemental and mineral composition of the soils and measured porewater samples for aqueous carbon and iron concentrations.

Results showed higher carbon contents in fens than in lithalsas in both soil and porewater samples. While the composition of crystalline primary and clay minerals were similar across all samples, results from selective chemical extractions revealed differences in the type and abundance of iron minerals across the thaw gradient. Combined, these findings provide new insights into the coupled iron-carbon dynamics in the active layer of iron- and mineral-rich permafrost soils in a sub-arctic region.

[1] Sæmundsson, et al., Geomorphology (2012).
[2] Schuur et al., Nature (2015).