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Pedon-scale controls on sulfur – driven carbon release from high latitude soils

DR. CATHERINE HIRST[1], DR. JOTIS BARONAS[1], MADELEINE BOHLIN[2,3], JULIA L.A. KNAPP[1], GERARD ROCHER-ROS[4] AND EMILY STEVENSON[5]

[1]Durham University
[2]Uppsala University
[3]Stockholm University
[4]Umeå University
[5]GFZ Helmholtz-Zentrum für Geoforschung

Pyrite (FeS_2) oxidation contributes to carbon (C) cycling in soils through i) the supply of protons (H+ ions) promoting carbonate mineral dissolution and inorganic C release and ii) the supply of sulfate (SO_4^{2-}) and iron (Fe) for bacteria to use as an alternative electron acceptor during organic C consumption which controls the type and amount of inorganic C release from soils to the atmosphere, i.e. carbon dioxide vs methane formation. In high latitudes, FeS_2 oxidation is increasing with permafrost thaw [1] resulting in C transfer to the atmosphere [2] and Fe transfer to rivers [3]. Yet, whether FeS_2 oxidation is a first-order control on high latitude soil C cycling remains unclear.

In this study we hypothesise that sediment composition and hydrology constrain sulfur (S)-driven C cycling. To test this hypothesis, we identified 6 plots with contrasting soil composition (marine sulfides, alluvial sediment and peat deposition) and soil water content (water table and topography) in a 0.1 km^2 area of Northern Sweden (near Hörnefors, Västerbotten County). At each plot, soil (1.5 m depth, 10 cm increments), groundwater (integration of 1 m of soil depth) and pore waters (30 cm, 60 cm, 90 cm depth) were sampled in June 2024, following snowmelt, and in August 2024, following summer rain. Water table depth was monitored continuously (every 30 minutes) between sampling in June and August. We observe contrasting soil water pH (3.8 to 5.2), Fe (1 to 22 mg/L), SO_4^{2-} (11 to 132 mg/L), dissolved inorganic C (15 to 52 mg/L C) and dissolved organic C concentrations (3 to 29 mg/L) between plots and soil depths. This concentration data is set-alongside S isotopes in sulfate ($\delta^{34}S_{SO42-}$, $\delta^{18}O_{SO42-}$), O isotopes in water ($\delta^{18}O_{H2O}$), the molecular size of dissolved organic C, and dissolved inorganic carbon speciation (CO_2, CH_4) to inform on S-driven C cycling processes in high latitude soils.

[1] Kemeny et al., (2023). *Global Biogeochemical Cycles*, *37*(11).

[2] Walsh et al., (2024). *Science Advances*, *10*(41).

[3] O'Donnell et al., (2024). *Communications Earth & Environment*, *5*(1), p.268.