PROJECT TITLE: How do redox and temperature fluctuations influence mineral protection of organic matter during permafrost thaw?

DTP Research Theme(s): Living World, Changing Planet
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Project keywords: permafrost, Arctic, climate, redox cycling, iron, carbon, geomicrobiology

(A) Stordalen mire (Abisko, Sweden) showing the collapse of raised permafrost-supported palsas (left) into water-logged bogs (right).

(B) Iron-rich microbial mats forming at the edge of a water-logged peatland in Abisko.

Project Background

High latitude permafrost peatlands lock up vast amounts of Earth's soil carbon. There is much concern that this will be released as CO_2 and CH_4 following permafrost thaw, further exacerbating the climate crisis on a global scale (*1*). There is therefore urgent need to understand the factors which dictate whether carbon is stored or released in these regions as the Arctic rapidly warms (2). Previous work has demonstrated that carbon can be, in part, protected from degradation by reactive minerals such as poorly crystalline Fe(III) (oxyhydr)oxides (*3–5*). However, these minerals are very sensitive to microbial dissolution under anoxic conditions (*6*), suggesting the stability of this carbon sink will be highly dependent on redox conditions and microbial communities in the soils. Since permafrost peatlands are dynamic environments with redox conditions varying on a range of timescales, it is not yet clear whether with these reactive minerals provide a stable sink for old carbon over for long periods, or if observed Fe-C associations consist of "young" carbon which is periodically trapped at redox interfaces under dynamic conditions. This project will identify how temporal variation in redox conditions in permafrost peatlands impacts the stability of Fe(III) (oxyhydr)oxide minerals and how this, in turn, influences the mobility, bioavailability and turnover of organic matter during permafrost thaw.

Project Aims and Methods

The successful candidate will join a multi-disciplinary team of scientists to investigate the formation and destruction of reactive iron minerals under changing redox and temperature conditions using the following approaches:

1) High spatial and temporal resolution monitoring of porewater geochemistry (redox conditions, Fe(II)/Fe(III) ratios, dissolved organic carbon quantification and characterization, nutrient concentrations) along a permafrost thaw gradient in Abisko, Sweden throughout the period of seasonal melt (June to September).

2) Collection of sediment cores throughout the same period to characterize iron mineral reactivity and identity using selective dissolution and spectroscopic methods in different soil horizons. Age and composition of the iron-associated organic matter will be determined using a range of mass spectrometry techniques and radiocarbon dating of selected samples. Geochemical observations will be linked to microbial community shifts using 16S rRNA gene sequencing and microbial cultivation.

3) Laboratory-based microcosm and column experiments will be conducted using soils from the field site to simulate fluctuating redox and temperature conditions. Changes in porewater geochemistry, iron mineralogy, particulate/dissolved organic matter, microbial community composition and greenhouse gas emissions will be compared under different redox and temperature regimes.

Together these observations will contribute towards a multi-disciplinary, international effort to determine whether reactive iron minerals can protect carbon from degradation in vulnerable permafrost peatlands under a warming climate. Within this multi-disciplinary project there is ample room to adapt the focus of the work according to the student's experience and interests.

Candidate Requirements

The ideal candidate will have a strong background (preferably MSc-level) in a related discipline e.g. Earth Science, Physical Geography, Microbiology, Molecular Biology or Environmental Chemistry as well as a strong interest in Environmental Microbiology and Geochemistry. A desire to conduct field work is essential. Experience with wet chemical laboratory methods, microbial cultivation or molecular ecology would be highly beneficial. Good written and oral communication skills are required, as is the ability to work independently and in a team.

Collaborative Partner

This project has been designed together with the Center for Ecology and Hydrology, where the student will have access to next generation sequencing facilities and bespoke bioinformatic platforms, and receive training in the tools required for studying the response of soil microbes to environmental change.

Training

This project will provide training in cutting-edge laboratory methods required for geochemical monitoring, microbial cultivation and community analysis, and characterization of minerals and organic matter. The student will also be provided with extensive training in field skills with the opportunity to conduct field work in sub-Arctic Sweden at the Abisko Scientific Research Center. The student will be encouraged to participate in NERC GW4+ DTP training courses to develop both technical and personal skills essential for a successful scientific career. Funding is also provided for the student to present their research at a major international conference such as Goldschmidt, and the student will be supported in applying for travel grants to support further travel opportunities.

References / Background reading list

1. E. Schuur *et al.*, Climate change and the permafrost carbon feedback. *Nature*. **250**, 171–179 (2015).
2. United Nations Environment Programme, *Permafrost Peatlands: Losing ground in a warming world* (2019).
3. I. Kögel-Knabner *et al.*, Organo-mineral associations in temperate soils: Integrating biology, mineralogy, and organic matter chemistry. *J. Plant Nutr. Soil Sci.* **171**, 61–82 (2008).
4. M. W. I. Schmidt *et al.*, Persistence of soil organic matter as an ecosystem property. *Nature*. **478**, 49–56 (2011).
5. T. Riedel, D. Zak, H. Biester, T. Dittmar, Iron traps terrestrially derived dissolved organic matter at redox interfaces. *Proc. Natl. Acad. Sci.* **110**, 10101–10105 (2013).
6. E. D. Melton, E. D. Swanner, S. Behrens, C. Schmidt, A. Kappler, The interplay of microbially mediated and abiotic reactions in the biogeochemical Fe cycle. *Nat. Rev. Microbiol.* **12**, 797–809 (2014).

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The application deadline is 1600 hours GMT Monday 6 January 2020 and interviews will take place between 10 and 21 February 2020

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