Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.34900

Fate of organic carbon associated with iron in thawing permafrost peat soils

PRACHI JOSHI[1], ANKITA CHAUHAN[2], EVA VOGGENREITER[3] AND ANDREAS KAPPLER[4]

[1]Swiss Federal Institute for Forest, Snow and Landscape Research WSL
[2]The University of Texas at Arlington
[3]University of Tuebingen
[4]Cluster of Excellence (EXC 3121): TERRA – Terrestrial Geo-Biosphere Interactions in a Changing World, University of Tübingen

Permafrost soils, estimated to contain 1330-1580 Pg carbon, are highly vulnerable to increasing temperatures that promote microbial activity and thereby the rapid release of the greenhouse gases carbon dioxide (CO_2) and methane (CH_4). The magnitude of this release is dependent upon microbial decomposition of organic carbon. One crucial factor in this process is the association between organic carbon and minerals, particularly iron(III) (Fe(III)) (oxyhydr)oxide minerals. In soils and sediments, these minerals are expected to bind large quantities of organic carbon, thus protecting it from decomposition. Although well studied in common soil systems, the role of iron (oxyhydr)oxide mineral interactions in carbon cycling is only recently being understood in permafrost systems, hampering accurate predictions of future greenhouse gas release.

In this project, we investigated the coupling between the carbon and iron cycles in thawing permafrost systems within two scenarios: (i) oxic soils underlain by ice collapse upon thaw, slowly getting waterlogged and transitioning to (seasonally) anoxic systems, and (ii) meltwater accumulates in pools (thaw ponds) within partially thawed soils, which may undergo temperature and redox changes. In scenario (i), we tested the effect of thaw on greenhouse gas release based on field and laboratory experiments with ^{57}Fe-labelled Fe(III)-OC phases. Depending on the thaw stage, we observed that the Fe(III) within these phases was completely reduced, with an increase in the CO_2 release. In contrast, CH_4 release was suppressed. In scenario (ii), we observed substantial complexation of iron by organic carbon in thaw ponds, contributing to the partial stabilization of Fe(II) and the distribution of organic carbon between different size fractions. Under fluctuating redox conditions, iron within these phases cycled rapidly between reduced and oxidized states. However, CO_2 release was similar to that under static oxic conditions, indicating limited protection of organic carbon by iron.

Collectively, the results of this work indicate that association with iron (oxyhydr)oxide minerals does not guarantee protection of organic carbon from microbial decomposition in thawing permafrost complexes; on the contrary, it may contribute to pulses of increased CO_2 upon thaw while suppressing CH_4 release.