Role of iron-carbon interactions in the release of greenhouse gases from permafrost soils

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Abstract

As permafrost thaws, vast stocks of organic carbon which accumulated over long time periods within these soils are vulnerable to microbial decomposition and carbon may be released as the greenhouse gases CO_2 and CH_4. The release of these greenhouse gases from permafrost systems is expected to lead to runaway positive feedbacks. The timescale and magnitude of the permafrost-climate feedback is highly uncertain as knowledge gaps remain regarding the rate of decomposition of permafrost organic carbon. These knowledge gaps stem, in part, from lacking understanding of the association between organic carbon (in the form of natural organic matter) and minerals, especially high surface area iron (oxyhydr)oxide minerals. This iron-carbon association has the potential to stabilize the organic matter, lower its bioavailability and therefore protect it from biodegradation – representing a "rusty carbon sink". In this work, we investigated the coupling of iron and carbon cycles in permafrost peatlands and its effect on greenhouse gas release. Our initial work showed that up to 20% of the organic carbon in intact permafrost sites may be associated with iron(III) (oxyhydr)oxides and thereby protected from microbial decomposition. We then found that at the onset of thaw, this association is broken down, likely due to the microbial reduction and dissolution of iron(III) minerals. As a consequence, the previously protected organic carbon is thus released and becomes bioavailable. Using microbiological and molecular biological tools as well as greenhouse gas measurements, we linked this breakdown to an increase in the abundance of methanogenic microorganisms and concentrations of methane. Additional work also suggests that part of the released organic carbon may re-associate with dissolved iron in thaw ponds to form flocs. Currently, we are investigating the molecular composition of organic matter with high-resolution mass spectrometry techniques (FT-ICR-MS) as it undergoes these redox processes with the goal of linking bioavailability to composition. We complement our studies with laboratory microbial enrichment and isolation approaches and microbial community analyses to determine the microbial key players controlling iron(III) reduction and the potential for subsequent microbial Fe(II) oxidation. Collectively, the results of this project suggest that upon

thawing, organic matter previously associated with minerals is mobilized and is likely susceptible to microbially mediated release as CO_2 and CH_4.

Keywords

Permafrost, carbon, iron

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Conflicts of interest

The authors have declared that no competing interests exist.