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Microbial iron cycling in warming permafrost peatlands

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Northern hemisphere peatlands store vast amounts of carbon, particularly in permafrost regions where low temperatures inhibit organic carbon (OC) decomposition. With high latitudes warming faster than anywhere else on the planet, there is urgent concern about the impact of permafrost thaw on the stability of this carbon store. It has been previously observed that Fe(III) (oxyhydr)oxides help trap organic carbon in permafrost peatlands, which may limit carbon mobilization and degradation. However, thaw-induced collapse and waterlogging creates anoxic conditions which promote microbial Fe(III) reduction, Fe(III) mineral dissolution and mobilization of previously bound OC.

Despite previous work, it is unclear how variable Fe-associated OC is across the wider permafrost landscape and how its fate will change during future warming. We investigated thaw gradients at eight palsa mires in northern Scandinavia and observed that Fe content in intact palsas is highly variable (0.2 to 16 mg/g). This is typically present as Fe(III)(oxyhydroxides) and/or Fe(II)/Fe(III)-OC complexes. Upon thaw, all of the shallow peatlands (n=4), but not the deep (n=3) or sulfidic (n=1) peatlands, showed co-mobilisation of Fe and OC. The amount of Fe and OC released was independent of the pH of the collapsed wetland that forms, but pH strongly impacted microbial community composition. ASVs related to known Fe(II)-oxidizing and Fe(III)-reducing bacteria were present in all collapsed regions but were more abundant and more taxonomically diverse when pH was >5.

To further determine the impact of future warming on iron cycling in these collapse wetlands, we conducted a laboratory-based warming simulation by incubating columns of native or iron-amended peat at either 10°C or 30°C. Temperature increase broadly enhanced all microbial processes including Fe(III) reduction rates and extent, but iron amendment alone had little impact on porewater CO_2 and CH_4 concentration. Temperature also showed the largest impact on microbial community composition.

Together these results demonstrate that shallow, thawing peatlands are particularly susceptible to co-mobilisation of iron and organic carbon during thaw and that warming will likely enhance the existing microbial iron cycling in these growing collapse wetlands, with associated consequences for carbon decomposition and greenhouse gas emissions.