Geochemical drivers of organic matter degradation in Arctic tundra

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Releases of carbon dioxide (CO_2) and methane (CH_4) from tundra soils are likely to change as Arctic environments adapt to changing climate. Understanding geochemical controls on these shifts in microbial CO_2 and CH_4 production is important for modeling land-atmosphere climate feedbacks. In this study, seasonal patterns of aqueous geochemistry were evaluated by sampling surface and pore waters from the Barrow Environmental Observatory (BEO) in northern Alaska. Water samples collected in early and late summers were analyzed for concentrations of solutes and dissolved gases. Dissolved organic carbon (DOC) was investigated with a suite of analytical techniques including X-ray absorption spectroscopy.

Soil pore waters were characterized by sharp vertical gradients with solute concentrations increasing with depth. In both surface and soil pore waters, DOC and ferrous Fe(2+) were dominant ionic species. Fe-DOC complexes were highest in saturated organic horizons, suggesting that microbial reduction of DOC-complexed ferric species may serve as a primary electron acceptors driving organic respiration in oxygen-limited areas. Pore waters also contained abundant carboxyl-containing organic molecules, including acetate and formate which can serve as substrates for methanogenesis and anaerobic Fe(3+) reduction. Indeed, both methanogenesis and Fe(3+) reduction were observed in complementary incubation studies of these tundra soils.

Dissolved CO_2 concentrations decreased during the summer and increased only slightly with depth; however, CH_4 concentrations increased significantly with depth and were highest near maximum thaw depth in late August. Additionally, CH_4 increased with increasing Fe across nearly all pore waters, indicating that hot spots of Fe reduction and methanogenesis were collocated. Results of this work will help elucidate sources, rates, and geochemical controls of C fluxes from tundra soils and can be integrated with modeling efforts to predict feedbacks to warming climate.