Biogeochemical Redox Interactions Modulate Soil Organic Matter Mineralization in Wet Arctic Tundra

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Wet Arctic tundra stores organic matter under conditions that limit oxidation, protecting soil C from mineralization. Prediction of greenhouse gas emissions from these sites will require modeling interactions among biotic and abiotic redox processes. The NGEE Arctic study site northwest of Nome, Alaska includes a small watershed with varying terrain and plant types. Near the top, a degraded peat plateau is underlain by mineral- and ice-rich permafrost. At the toe of the hillslope, tussock tundra intermixes with standing water and sedge-rich pools over degraded permafrost. Soil O horizons in both areas contain substantial stocks of soil organic matter.
Mineral soils generally have a sandy clay loam texture, and soil water content correlates with soil C and N as well as P, S and K. Diverse microbial communities catalyze a cascade of decomposition and redox reactions in the soils. Anoxic incubations of toe slope soils produced more CO_2 and CH_4 than plateau soils, fueled by higher concentrations of water-extractable organic C and mineral composition. These incubations showed rapid reduction of sulfate and Fe(III), followed by increased methanogenesis. Addition of molybdate inhibited the already low rate of sulfate reduction in the toe slope soil. Microbial community analysis identified members of two major types of methanogens: the acetoclastic family Methanosaetaceae and the hydrogenotrophic Rice Cluster II. Methanogen activity was inhibited by bromoethanesulfonate. Summer field campaigns measured redox-active species in soil pore waters. CH_4 and CO_2 concentrations were low in pore waters from the peat plateau and higher in the toe slope, consistent with incubation results and nutrient transport. Methane increased with depth and pH, while dissolved organic carbon and phosphate decreased with depth. CH_4, CO_2, and Fe(II) concentrations were correlated in pore waters, indicating contiguous anaerobic respiration processes. Concentrations of oxidized anions NO_3^- and SO_4^{2-} correlated with dissolved organic carbon and organic acids. These were more abundant in toe slope soils possibly due to nutrient transport from the hillslope. Although most soil water samples were undersaturated in dissolved oxygen, even deep pore waters that contained substantial amounts of dissolved Fe(II) had more than 2 mg/L dissolved oxygen. These results characterize the wet tundra of the Teller Road site as suboxic, where a complex mix of dissolved O_2 and redox-active ions can interact and influence soil organic matter decomposition and greenhouse gas emissions.