Iron biogeochemistry in Arctic tundra soils

ELIZABETH HERNDON[1], TANIYA ROY CHOWDHURY[2], ZIMING YANG[3], DAVID GRAHAM[2], BAOHUA GU[3] AND LIYUAN LIANG[3]

1Department of Geology, Kent State University, Kent OH 44242 (eherndo1@kent.edu)
2Biosciences Division, Oak Ridge National Laboratory, Oak Ridge TN 37831
3Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge TN 37831

Climate change is warming tundra ecosystems in the Arctic, resulting in the accelerated decomposition of soil organic matter (SOM) and release of carbon to the atmosphere. In the water-saturated soils that dominate Arctic landscapes, Fe redox cycling influences anaerobic decomposition of SOM and production of carbon dioxide (CO_2) and methane (CH_4). In this study, we combined geochemical analyses with synchrotron-source microprobe techniques (X-ray absorption near edge structure spectroscopy, X-ray fluorescence spectroscopy, and X-ray diffraction) to examine Fe speciation and mineralogy across redox gradients in seasonally-thawed soils at the Barrow Environmental Observatory (BEO) in northern Alaska. Our objective was to identify coupled Fe and microbial processes that affect decomposition of organic matter.

Tundra soils contained abundant iron oxyhydroxide minerals in the solid-phase and suspended in the soil solution. Iron was enriched relative to other metals in organic horizons, indicating that Fe was input to the organic horizon via upward diffusion and precipitation rather than cryoturbation and mixing with the mineral horizon. Dissolved Fe(III) was highest at the organic/mineral interface in the active layer, and organic-complexed ferric species likely serve as electron acceptors driving microbial respiration of SOM in oxygen-limited areas. Pore waters also contained abundant carboxyl-containing organic molecules which can serve as substrates for methanogenesis and anaerobic Fe-reduction. Both Fe-reduction and methanogenesis were measured in complementary soil incubation experiments. Our results indicate that Fe redox cycling and vertical transport impact SOM degradation in anoxic tundra soils. Fe-reduction near the permafrost boundary produces Fe(II) that diffuses upwards in the soil profile and is oxidized to Fe-oxyhydroxide minerals and organic-complexed Fe(III). Ferric iron influences organic matter decomposition by providing an abundant electron acceptor for microbial decomposition reactions, and Fe-bearing minerals provide reactive surfaces that sorb organic compounds and the limiting-nutrient P. These biogeochemical processes will become increasingly important to C fluxes as warming temperatures thaw mineral horizons that underlie surface peat layers.