Rates and pathways of permafrost soil organic carbon degradation in Arctic tundra

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It has been estimated that almost half of the global soil organic carbon (SOC) is stored in Arctic permafrost ecosystems. During thaw, large quantities of greenhouse gases (GHG) such as CO_2 and CH_4 are released from biogeochemical transformations of SOC, which potentially provides a significant feedback to the global warming. To predict GHG production and to understand the pathways and mechanisms of SOC degradation in tundra soils, both field investigations at the Barrow Environmental Observatory (BEO) in Alaska and laboratory-scale incubation experiments were conducted. Field analyses of pore-water samples show both spatial and seasonal patterns of aqueous geochemistry in the active layer of low- and high-centered polygons. Dissolved Fe(II) and CH_4 in pore waters from saturated polygons increased with soil depth, and higher ratios of dissolved CH_4/CO_2 were observed in late August than in early July. These observations corroborate with the results showing the decreased concentrations of small organic anions (e.g., acetate, formate, propionate, and butyrate) from July to August, suggesting that methanogenesis proceeded along with Fe(III) reduction from Spring to late Summer. Laboratory microcosm incubations were performed at ecologically relevant temperatures of -2 and 8 °C, and a suite of geochemical parameters including organic acids, carbohydrates, alcohols, Fe(II)/(III), and CH_4 and CO_2 were determined to assess the rates and pathways of Arctic SOC degradation under anoxic conditions. Microcosms at 8 °C showed a higher accumulation of organic acids than those at -2 °C in the organic layer, and greater consumption of organic acids was detected in the mineral layer than in the organic layer. We also found that common sugars (e.g., glucose, cellubiose, xylose) degraded rapidly in the organic horizon, consistent with the high CO_2 production at early stage of the incubation. The biogeochemical processes we document here for anoxic tundra soils are thus pertinent to understanding organic matter decomposition as thaw depth and duration increase in permafrost, and the rates and pathways we identify will form the basis for a computational modeling framework in predicting feedbacks to warming climate.