61. Pathways to Carbon Liberation: a Systems Approach to Understanding Carbon Transformations and Losses from Thawing Permafrost

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Project Goals: Our objective is to discover how microbial communities mediate the fate of carbon in thawing permafrost under climate change. We are engaged in a systems approach integrating (a) molecular microbial and viral ecology, (b) molecular organic chemistry and stable and radiocarbon isotopes, and (c) state-of-the-art modeling, along a chronosequence of permafrost thaw in subarctic Sweden.

Abstract: The fate of carbon (C) in thawing permafrost is an outstanding challenge of modern biogeochemistry and climate change. Permafrost C pools are large (~1700 PgC), and C dynamics of thawing permafrost complex: old C decomposes as it is liberated from thawing permafrost as CO_2 or CH_4, with a significant fraction cycling through lake sediments, even as new C accumulates due to thaw-initiated ecological succession.

Microbes mediate C dynamics in thawing permafrost, but a mechanistic understanding of how to scale microbial population dynamics, genomic potential, and expression to ecosystem-scale processes is missing. A key question is: What is the interplay of microbial communities and organic matter chemical structure in the decomposition/preservation of organic C across a thaw gradient? And intriguingly, what (if any) is the role of phage (viruses that infect prokaryotic cells) in mediating these processes? Viruses appear to play a large role in driving oceanic microbial functions, but these phenomena are virtually unstudied in terrestrial systems. This endeavor linking microbial and viral dynamics, organic geochemistry and trace gas production will improve models of C cycling in permafrost systems, and clarify the fate of C under future climates.

This builds upon existing work by our team on methane cycling in Stordalen Mire, Sweden, along a permafrost thaw chronosequence encompassing permafrost palsas and their initial collapse stage, thawing bog sites (dominated by Sphagnum spp.), fully- thawed and inundated fen sites (dominated by Eriophorum spp or Carex spp.), and lakes. Our newly begun work will use cutting edge technologies in both biogeochemistry and molecular microbial ecology to advance systems biology research on microbial carbon cycling through: (a) systems-level mapping of chemical states and ages of organic matter along thaw gradients (via FT-ICR-MS and ^{14}C analysis) to associated microbial communities, biochemical potentials, and activities (via meta-genomics, -transcriptomics, –proteomics, and viral genomics), and to CO_2 and CH_4 fluxes; (b) bioinformatics designed to simultaneously enhance the DOE Knowledgebase, and (c) integrated ecosystem C-cycle modeling testable by soil organic chemical and microbial data.

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