Poster #21-67

Metabolic Constraints of Organic Matter Mineralization and Metal Cycling During Flood Plain Evolution

Hannah Naughton[1], Carolyn Anderson[2], Christian Dewey[1.3], Peter Nico[3], Markus Kleber[4], Scott Fendorf[1*], and Marco Keiluweit[2]

[1]Stanford University, Stanford, CA
[2]University of Massachusetts-Amherst, Amherst, MA
[3]Lawrence Berkeley National Laboratory, Berkeley, CA
[4]Oregon State University, Corvallis, OR

Contact: fendorf@stanford.edu

BER Program: SBR
Project: University Award

Floodplains are poorly understood and dynamic components of the global carbon cycle that not are well represented in Earth system models. Further, they have a dominant influence on the cycling of important metals, such as uranium, within critical transport conduits between surface waters and groundwater. The physical characteristics of floodplains make the hydrology and associated coupled biology and geochemistry particularly responsive to ongoing and impending changes in climate, river management, and land development.

Important controls on carbon cycling within soils and sediments are imparted by mineral/metal associations and microbial metabolic constraints imposed by the respiratory pathway, both of which further serve to control metal fate and transport. Within floodplain soils and sediments, variations in hydrologic state (water saturation) coupled with structured porous media lead to extensive heterogeneity in redox environments and thus metabolic trajectories controlling organic carbon oxidation.

Using a combination of field-scale measurement with micro-scale laboratory experiments, we find that oxygen diffusion limitations lead to heterogeneous redox profiles, shifting microbial metabolism to less efficient anaerobic SOC oxidation pathways. Across the floodplain transect in the East River watershed we are examining, organic carbon bound to Fe(III) (hydr)oxides constitute the most appreciable C (and N and P) phase, particularly in deeper sediments. Additional laboratory incubations demonstrated that, because organic N and P are preferentially bound to easily reducible Fe(III) (hydr)oxides, these nutrients were mobilized under reducing (water saturated) conditions during flooding. Further, within saturated soils of the floodplain, thermodynamic constraints on microbial metabolism result in preferential utilize of organic carbon compounds. In model soils and sediments, we determined the distribution of operative microbial metabolisms and their cumulative impact on SOM transformations and overall oxidation rates within anaerobic microsites. Metabolic profiling shows anaerobic microsites reduced carbon oxidation rates by an order of magnitude relative to aerobic rates, with Fe reduction contributing more than 75% of the overall metabolism. Dissolved oxygen and nitrate alleviate the metabolic constraint and result in rapid utilization of metabolically protected reduced carbon compounds.

Collectively, our results illustrate the combined, and dynamic, impacts of mineral-associations and metabolic controls on carbon and metal fate. The highly variable hydrology of floodplains leads to concomitant changes in biogeochemical processes within soils that ultimate control organic carbon, nutrients, and metal cycles.