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Molecular biogeochemistry of iron and manganese in wildfire ash and wood ash

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The western United States is facing unprecedented challenges due to increasing fire severity and the occurrence of large fires at the wildland-urban interface. One key feature of post-fire landscapes is the transformation of above-ground biomass and litter into a surface layer of ash. The composition of this ash depends on the type of fuel, burn severity, and the burn temperature. Wildfire ash, which has alkaline properties, abundant pyrogenic carbon, and elevated metal concentrations, is known to alter soil properties, including pH, water repellency and nutrient availability. However, the molecular-scale biogeochemistry of minerals within wildfire ash has been scarcely investigated.

In this talk, I will present our analyses of trace metal speciation in ash samples that span differences in vegetation-type, parent material and fire burn severity. Samples were characterized in terms of elemental composition using X-ray fluorescence mapping and chemical speciation using bulk and spatially resolved X-ray absorption near edge structure (XANES) spectroscopy and scanning transmission X-ray microscopy. A subset of samples was used in dissolution experiments to examine the mobilization of Fe, Mn and carbon.

Synchrotron-based analyses show that that wildfire generated stable Fe oxides like maghemite (γ-Fe_2O_3) and hematite (α-Fe_2O_3) that likely derived from surface soil or mineral dust rather than the vegetation, and Mn oxides such as hausmannite (Mn_3O_4) and bixbyite (Mn_2O_3) that derived primarily from the aboveground biomass. While these phases are typically considered to be more stable than the poorly crystalline Fe and Mn oxides common in unburned surface soil (e.g., ferrihydrite, birnessite), we observed greater mobilization of Fe and Mn in ash than soil in the presence of a model organic ligand. We attribute this enhanced reactivity to the absence of organo-mineral associations in the ash samples. This result has significant implications for postfire ecosystem recovery, where plants and microbes can access poorly accessible micronutrients through ligand exudation. Using similar geochemical methods, we characterized the wood ashes from specific tree species important in the Pacific Northwest. The integration of these ashes into high-fire ceramic glazes creates unique surfaces from which the public can explore ecosystem resilience and element transformation post wildfire.