Title: **Root Influences on Mobilization and Export of Mineral-bound Soil Organic Matter**

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Project Abstract: Biogeochemical cycles within mountainous watersheds are key regulators of ecosystem carbon storage and downstream nutrient loadings, and they have shown to be particularly vulnerable to climate change impacts. Increasing temperature and persistent droughts have already dramatically changed vegetation cover across the mountainous western US, with unknown consequences for carbon and nutrient cycles in soils belowground. What remains elusive is to what extent associated changes in root-soil interactions may mobilize the vast pool of organic matter (OM) that has been stabilized by associations with minerals for centuries or millennia. Although plant root-driven OM mobilization from minerals may be a central control on carbon loss and nutrient export, such mechanisms are currently missing from conceptual and numerical models. The <u>*overall objective*</u> of this project is to identify the biogeochemical mechanisms by which roots destabilize mineral-OM associations and the cumulative impact on carbon and nutrient fate. To accomplish this goal, we integrated model system and greenhouse experiments with a scalable modeling approach. We conducted ***model system experiments*** to assess the vulnerability mineral-associated organic matter (MAOM) to exudate-mediated mechanisms. Our results show that common root exudates effectively destabilize MAOM not only through direct, ligand-driven mobilization mechanisms, but also indirect, microbially-mediated mechanisms relying on secondary metabolites and enzymes. We further found that OM bound to poorly crystalline Fe and Al (hydr)oxides is more vulnerable to exudate-induced destabilization than OM bound to more crystalline phases, particularly in response to direct, ligand-promoted mechanisms. These findings demonstrate that the stability of MAOM is not just a function of their inherent properties, but also will depend in large parts on the ability of plant roots and microbes to produce exudates capable of triggering suitable mobilization mechanisms. We further employed a well-controlled ***rhizobox approach***, combined with advanced microsensor and mass spectrometry techniques, to resolve spatiotemporal variations in the composition and availability of exudates along single growing roots of grasses. We show that the composition of functionally relevant exudate compounds varies at extremely short time scale, seemingly shifting from ligands such as aromatic acids around root tips to less reactive metabolites such as amino acids around mature root segments. These results suggest a prevalence of direct MAOM mobilization mechanisms around the root tip, while indirect MAOM mobilization strategies may dominate around more mature root segments. Finally, employing parallel microsensor measurements of moisture, redox, oxygen, and pH dynamics in the rhizosphere, we ***parameterized a rhizosphere (hydro)biogeochemistry reactive transport model***. The resulting model was used to assess how transient changes in (hydro)biogeochemical properties of the rhizosphere affect that stability of MAOM. Simulations suggest that diel pulses in root exudation are strong enough to significantly destabilize MAOM. We will further