Investigating the hydrology and biogeochemistry of fractured bedrock underlying forest soils

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ABSTRACT:

In many environments, soils are shallow and underlain by fractured bedrock. Fluid flow through unsaturated fractured bedrock has direct consequences for spatiotemporal patterns of groundwater recharge, biogeochemical cycling, contaminant remediation, and water-rock interactions. However, unsaturated zone processes in fractured bedrock environments are largely inferred because limited tools for quantifying water fluxes, residence times, and storage volumes within fractured bedrock exist at the field scale. Here, I present approaches for investigating hydrologic and associated biogeochemical processes within unsaturated fractured bedrock that have been pursued as part of Critical Zone research associated with the Eel River Critical Zone Observatory in Northern California and the East River Watershed Function Scientific Focus Area near Crested Butte, Colorado. I focus on the challenge of partitioning water storage in the bedrock vadose zone between plant water uptake, groundwater drainage and storage, as well as identifying whether transpired water is sourced from unsaturated or saturated conditions. I compare inferences made via water budget analyses, stable water isotopes, and geochemical analyses to direct measurements of water composition and water content made within the fractured bedrock unsaturated zone. These direct measurements of water content include borehole nuclear magnetic resonance, neutron moderation, gamma ray logging, and electrical resistivity as well as in-situ sensing via time-domain reflectometry and transmission. Findings highlight both advances and challenges in monitoring water storage dynamics in fractured bedrock, and the research need to incorporate such measurements into conceptual hydrologic models.