Exploring subsurface geochemical landscapes in the critical zone

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Water, gas, and biota interact with bedrock to create and maintain the mantle of altered material known as regolith. This mantle in turn feeds human and non-human ecosystems. At the same time, our understanding of how regolith forms from bedrock is poor at best. Two features of regolith combine to make exploration difficult: the extreme heterogeneity of soil materials and the coupled nature of chemical, physical, and biological (including anthropogenic) factors affecting soil formation and dynamics. A new term has been coined to denote the single entity that incorporates all these aspects of the surface earth from vegetation canopy to groundwater: the critical zone (CZ). By exploring the CZ as a unit from depth to the surface, new insights are emerging. For example, we have observed linkages between the deep microbial community and lithology that document that the microbial communities are distinctly different on granite, basalt, shale, and sandstone. Using geochemical and geophysical tools, we are also learning how the deep architecture of the critical zone – including the distribution of subsurface reaction fronts -- controls water availability to plants and microbial communities. When geochemical observations of the CZ are made in locations carefully chosen based on geomorphological considerations and are paired with geophysical measurements across hillslopes, ridges, and watersheds, they inform more successful hydrologic and soil formation models. In the future we may be able to stop treating the subsurface as a black box but rather as a self-organizing system that we can understand and protect.