Bedrock to soil: Where rocks meet life in the Critical Zone

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Why can't we predict the rates of weathering or erosion of bedrock *a priori*? The rates of these processes affect such important phenomena as soil formation, nutrient release to ecosystems, C sequestration in soils, and toxin release or uptake into regolith. At present we cannot in general predict the depth or chemistry of regolith because we lack the observations and models that might allow such predictions. Furthermore, the processes that control weathering and erosion, even at the base of the Critical Zone (CZ), combine chemical, physical, and biological phenomena that are hard to decouple. In the United States and elsewhere around the world, natural observatories – Critical Zone Observatories – have been established to investigate how water and gas interact with bedrock, regolith, sediments, and biota to define the Earth's surface. For example, the Susquehanna Shale Hills Critical Zone Observatory (SSHCZO) is the focus of research by more than thirty scientists deriving from fields that include geochemistry, geomorphology, sedimentology, ecology, hydrology, environmental engineering, soil science, and microbiology. Five other such CZ observatories are now operating in the U.S., with more being established in Europe, Australia, and China. At the same time, these CZ Observatories can be compared to less well instrumented sites along environmental gradients to elucidate controls on important CZ processes. Many patterns can be observed by making comparisons across such gradients in environmental variables. Some of these patterns, quantified using intensively collected data from SSHCZO as well as smaller datasets collected across the wider Critical Zone data set (Critical Zone Exploration Network data), suggest answers to first-order questions about how the Earth's surface changes in response to climatic, tectonic, and anthropogenic drivers.

The movement of rock particles up and water pores down through weathering bedrock

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As bedrock is exposed at Earth's surface, it weathers to form regolith. One of the biggest challenges in predicting the depth and chemistry of regolith is relating the chemistry of weathering to changes in the size and distribution of the weathering particles. We have developed simple models that relate the fracture spacing of bedrock to the formation of weathering rock particles in the weathering zone. These models simulate the size diminution of such fragments of rock as they move up and out of the regolith. The models are being compared to models of chemical transformation versus depth using either soil grain chemistry or mineralogy for granitic, basaltic, and shale systems. Particle size versus depth patterns can thus be related to chemistry versus depth patterns. In fact, however, not only are particles moving up and out of the Critical Zone, but water 'particles' – i.e. pores – move down and through the underlying bedrock. We need to understand the chemistry, size, and distribution of these pores. To do this, we use neutron scattering, microscopy, and tomography to probe the distribution of pores. These efforts are painting a picture of the mineral-water interface during weathering that has both mass and surface fractal character. Such a model for this interface elucidates how to make more accurate projections of weathering and erosion.