Lithologically mediated feedbacks between subsurface weathering and ecosystem productivity

CLIFFORD S. RIEBE[1] AND RUSSELL P. CALLAHAN[1]

[1]University of Wyoming, Laramie, Wyoming, USA
criebe@uwyo.edu and rcallaha@uwyo.edu

Subsurface weathering creates porosity in bedrock, enabling storage and throughflow of ecosystem-sustaining water. But weathering is also influenced in part by plants, raising the possibility of feedbacks between vegetation density, rooting depth, and the thickness of the critical zone. However, connections between subsurface weathering and ecosystem productivity remain poorly understood, because the extent of weathering beneath the top 1-2 m of soil has rarely been quantified in studies of ecosystem productivity. Here we present a new approach to quantifying deep weathering over landscape scales and show how we applied it across sites spanning a gradient in forest cover in the Sierra Nevada Batholith, USA. Our approach quantifies subsurface distributions of porosity that reflect the net effect of mass loss and volumetric strain accumulated by chemical and physical weathering in saprolite. Because our analyses at each site condense data from multiple, 200 meter-long, crossing geophysical surveys of subsurface porosity, they should be representative of deep weathering over a roughly 40,000 m^2 area at each site.

Our analysis reveals sharp contrasts in weathering that correspond to differences in vegetation across the sites. Mean saprolite thickness varies from 1.9 to 9.6 m, and depth-integrated porosity varies from 0.8 to 4.5 m^3/m^2, increasing with remotely sensed estimates of evapotranspiration, a measure of ecosystem productivity that spans a three-fold range across the sites. In addition, porosity distributions vary strongly with bedrock composition, even though the granitic bedrock of our sites is similar enough that it is conventionally considered uniform in weathering studies. A multivariate analysis of our results is consistent with a lithologically mediated feedback between subsurface weathering and ecosystem productivity. Small differences in bedrock concentrations of quartz, mafic minerals, and plant-essential nutrients influence plant growth both directly, via nutrient supply, and indirectly, via creation of vital water-holding porosity. Plant growth may in turn influence the depth and degree of weathering both physically, via root wedging, and chemically, via corrosive root exudates. We suggest that this lithologically mediated feedback helps explain site-to-site variations in mortality that resulted from the epic 2012-2016 drought in the region.