

Quantitative links between biota, mass-balance geochemistry and the soil atmosphere in the Piedmont uplands Critical Zone, USA

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The pO_2 and pCO_2 in regolith control pH and pe gradients with depth and therefore play an important role in weathering and evolution of the Critical Zone (CZ). Yet few studies have measured soil gas in the deeper portions of the CZ where the conversion of rock to soil begins. We explore the relationships between soil gas (O_2/CO_2) and bulk geochemistry along three weathering profiles developed on granite and diabase in eastern USA. Gas sampling campaigns show that the mean slope of O_2 with respect to corresponding CO_2 concentrations ranges from -0.86 to -1.07 for the three profiles. This relationship suggests root and microbial respiration primarily drive the consumption of O_2 and production of CO_2 within all profiles, which is supported by decreasing flux rates for both gases with depth. Time-series results at all sites show increases in CO_2 and decreases in O_2 during the late fall and winter below the clay-rich subsoil. These temporal changes in gas profiles appear related to perched water layers in the subsoil overlying the saprolite, which restricts CO_2 diffusive loss towards the surface. The sustained increase in saprolite CO_2 may cause a decrease in solution pH and a higher chemical weathering potential during the winter. The integrated consumption of O_2 to CO_2 determined from the regolith geochemistry, defined as R, is almost equal to 0.02 for all three profiles despite differences in regolith lithology and thickness. The similarities between R and the soil gas slopes for the three profiles is not a coincidence and the deeper portions of the CZ weather in an environment where soil respiration, partly controlled by climate, sets the boundary conditions for O_2 and CO_2 concentrations and flux. These gases initiate porosity development through oxidation and dissolution of minerals. A positive feedback results from increased porosity and surface area allowing for more oxidation and mineral dissolution as regolith moves towards the surface.