Geophysics is geochemistry: Reading the effects of pyrite oxidation and clay weathering in the critical zone

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Water, gas, and biota interact with bedrock to create the complexity of regolith across the critical zone. Exploring regolith is difficult because it lies beneath our feet. To investigate it, either we dig pits (and destroy regolith structure and function) or we sample it in limited locations such as by pounding pieces off outcrops or by augering, push-sampling, drilling, etc. Regardless of the method, geochemists generally are confined to analysis of samples at point locations. New work in the critical zone observatories, however, has led to the realization that models can be used to extract geochemical and mineralogical information from geophysical surveys that are 1D (with depth), 2D (across transects), or 3D (across depth profiles across regions). When completed in concert with cored regolith or rock geochemistry, geophysical measurements can yield information about weathering reactions, mineralogy, porosity, water saturation, water chemistry, and fracture density and can thus allow geochemical models to be tested beyond point samples to hillslopes or watersheds. We present an example where we use sonic logs in concert with analyses of borehole samples (geochemistry, mineralogy, porosity, fracture density) to train a rock physics model. The model is then used to interpret seismic refraction data across transects of the shale-underlain watershed. We use the data to map the reaction fronts for clays and pyrite oxidation, and relate porosity and fracturing and water saturation to the geochemistry of weathering and the 3D structure of the watershed (the Susquehanna Shale Hills Critical Zone Observatory).