Investigating shale weathering rates across a latitudinal climosequence

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Weathering is an important process for landscape evolution in the Critical Zone but the role of climate in controlling weathering rates is poorly quantified. A transect of sites with varying mean annual temperature and precipitation rate has been established in the northern hemisphere as part of the Susquehanna Shale Hills Critical Zone Observatory to investigate the influence of climate on shale weathering. The transect consists of end members in Wales and Puerto Rico as well as sites in the Appalachian Mountains in New York, Pennsylvania, Virginia, Tennessee and Alabama. All sites are underlain by shale, the dominant lithology amongst sedimentary rocks on Earth and an important soil parent material. Weathering rates across these sites were determined using several different approaches. Shale weathering rates were calculated for ridgetop and slope topographic positions at all transect sites using soil geochemical profiles. On ridgetops, where water flow is largely vertical through the soil profile, the depth of soils and the extent of chemical depletion at the soil surface increases from north to south. At these ridgetop sites we observe a temperature dependence for Na loss, a proxy for feldspar weathering, with an apparent activation energy of 117 ± 30 kJ mol^{-1}, after correction for erosion rate variation along the transect (measured with ^{10}Be). Weathering on ridgetops progresses from kinetically limited at northern sites to transport limited in Puerto Rico. Similarly, we observe a temperature dependence for Mg loss, a proxy for chlorite weathering, with an apparent activation energy of about 60 kJ mol^{-1}. On slopes, soils show chemical depletion similar to that of the ridgetop profiles but are shallower (~70 cm) and thickness does not vary much between sites. In contrast, the depth of ridgetop soils increases from shallow (~ 30 cm) in Wales and Pennsylvania to increasingly deep toward the south (632 cm in Puerto Rico). If we assume that the sites included in this climosequence are in steady state, where the erosion rate is in balance with the weathering advance rate, these observations would suggest that the thickness of regolith is controlled by the kinetics (and therefore climate) of the weathering system across these tectonically inactive sites. Results from this study can be compared to geochemical models of regolith weathering to project the impact of climate change on soil formation and landscape evolution.