Climate controls on weathering fronts and implications for critical zone responses to global change

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The chemical weathering that leads to export of Ca to the oceans and sequestration of CO_2 over geological time, occurs in the critical zone (CZ), which is the terrestrial zone between the vegetation canopy and the bottom of actively cycling groundwater. Weathering in the CZ does not occur uniformly, as reflected in weathering profiles with depth, which vary dramatically with lithology, topography, climate and other parameters. As a result, the responses of weathering to global change may vary signifcantly from location to location.

To investigate the controls on weathering in the CZ, we analysed elemental and mineralogical weathering fronts with depth in profiles developed on several lithologies, across a range of climate zones, using datasets from the literature and some newly measured profiles. Here we focus on granitic sites, which show dramatic differences in weathering front morphologies across climate zones. We also built reactive transport models to simulate granitic weathering to test the sensitivity of weathering front morphologies to a range of controls, and then to global change scenarios.

Granitic weathering fronts in relatively wetter sites are deeper than in drier sites. Cool, humid sites produce fronts with weaker gradients than warm, humid sites, which exhibit sharp gradients reflecting rapid, intense weathering. We documented signficant correlations between the gradients of the granitic weathering fronts and mean annual precipitation, with mean annual temperature showing a weaker effect on fronts in humid sites, and a negligible effect in arid sites.

Weak granitic weathering occuring 10s to 100s of meters deep in temperate profiles may limit both weathering exports and the influence of surficial biogeochemical processes on weathering rates. Similarly, accumulation of intensively weathered regolith above sharp weathering fronts in the humid tropics can decouple shallow and deep biogeochemical cycles. However, these fronts also produce sharp permeability fronts, facilitating rapid export of solutes from the CZ and the high weathering fluxes that are well documented for such catchments. Thus, predicting the impacts of global change on weathering exports and CZ biogeochemical processes may not be achievable without depth-dependent CZ models.