

Climate, Erosion, and Silicate Weathering: Comparing Reactive Surface Area and Chemical Weathering Indices Across Endmember Climates

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Silicate weathering can be an important driver of carbon cycling, releasing solutes that effectively sequester CO₂ through secondary mineral precipitation. However, the rate of silicate weathering, and thus the rate of solute release and eventual CO₂ sequestration is dependent upon the mineralogy, temperature, pH, and surface area available for weathering. By systematically analyzing the mineralogy, bulk geochemistry, grain size, and surface area of naturally occurring, fine-grained (mud-rich) sediments collected from slackwater bars in fluvial systems across six climate endmember watersheds with similar drainage area, granitoid bedrock lithology, and relief, we aim to better understand how climate influences chemical weathering processes and signatures in silicate sediments, including the potential impact on CO₂ cycling.

Through this decade-long project, we found that, despite comparing sediments derived from similar bedrock lithology and widely varying climate conditions (average annual temperature and precipitation ranged from 253-293K, 0-5000 mm, respectively), subtle differences in mineralogy and geochemistry of the source rock combined with transport processes that concentrate fine-grained mafic phases overwhelm any bulk chemistry signals produced by chemical weathering. Principal component analyses could not disentangle the effects of climate from provenance and transport on the sediment bulk chemistry, except in the hot, wet tropical system; this finding renders application of traditional chemical weathering indices largely ineffectual for climatic inferences. However, laboratory experiments designed to compare the reactive surface area of the natural sediments produced significant differences in solute fluxes released from the sediments collected in wet-based glacial systems compared to other environments, with the maximum potential CO₂ sequestration/m² predicted in the equatorial alpine glacial sediments. This suggests that equatorial glaciation may play an outsized role in affecting global CO₂ cycling as abundant, glacially produced fines possessing high reactive surface area accumulate in lower-elevation warm environments where chemical weathering and biomineralization are both more likely to occur.