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Lithologic, tectonic, and climatic controls on chemical weathering, soil production, and erosion in New Zealand

Claire E Lukens (1), Kevin P Norton (1), Dennis E Dahms (2), and Eron R Raines (1)

(1) Victoria University of Wellington , Geography , New Zealand (claire.lukens@vuw.ac.nz), (2) University of Northern Iowa, Geography, United States

Over geologic timescales, chemical weathering in mountain landscapes may play an important role in regulating atmospheric CO_2. Understanding the feedbacks between climate, tectonics, erosion rates, biota, and weathering has been a recent focus of research, but disentangling these complex relationships remains a challenge. One area of particular interest has been the potential for a kinetic limit to weathering and soil production. Studies in New Zealand's Southern Alps were among the first to clearly exceed proposed kinetic limits on soil production and demonstrate thresholds in the influence of precipitation on chemical weathering. Here we present a new dataset that addresses chemical weathering, soil production rates, and surface erosion rates, measured across an altitudinal transect in the Tararua Range on New Zealand's North Island. The transect spans a kilometer in relief, and receives 3.5-5.5 m of annual precipitation. Underlying bedrock comprises silty and sandy members of the same Cretaceous Greywacke, but subtle lithologic changes correspond to abrupt shifts in soil production rates and total weathering. Total weathering across the transect is roughly invariant for each lithology and reflects near-complete depletion of weatherable species, consistent with a previously proposed threshold in the influence of precipitation. However, spatial patterns in weathering differ markedly in saprolite and in soils. Deep weathering in saprolite decreases with elevation and makes up a large fraction of the total weathering. This pattern suggests that climate may influence saprolite weathering, even where the total weathering is supply-limited. Spatial patterns in saprolite and total weathering do not correlate with an abrupt vegetation transition from dense forest to alpine tussock, which may suggest that biota are more strongly affected by a temperature threshold or more complex biogeochemical cycling. We contrast these results with new and previously published data from the Southern Alps, which have a similar climate but experience rapid tectonic uplift. There, the fresh supply of minerals to soils provided by uplift and erosion may enable much faster weathering and soil production rates. Taken together, these observations suggest a strong lithologic and tectonic control on soil production and weathering rates in humid climates.