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Tool Belts: Latitudinal-Belt Predictions for the Persistence of Landscapes

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The ability of rivers to cut through rock and re-establish equilibrium sets the pace of landscape response to uplift. Because of associations between tectonics, erosion, and weathering, high rates of rock uplift may initiate a cascade of processes that are linked to high rates of weathering and eventually sequestration of CO_2 over geologic timescales. How long does it take to completely change the topographic form after uplift and where on Earth do relict landscapes persist despite uplift?

Large expanses of subdued landscapes are common at high elevation in mountain ranges. Preservation of subdued fragments amongst steeply dissected regions can therefore be a simple matter of chance, reflecting the time it takes for dissection to remove any remaining parcel of the pre-existing topography after a tectonic perturbation. Some of these relicts may, however, possess characteristics – often a product of the climate – that make them intrinsically resistant to dissection. One common mode of conversion of a subdued landscape into a deeply dissected one is the propagation of upstream-migrating erosion waves that transmit the signal of uplift and base level lowering across entire landscapes. Following a shift in tectonic forcing, the Earth's surface progressively adjusts its topographic form over millions of years, seeking to re-establish equilibrium with the new forcing.

Here, we show that a high degree of weathering leading to smaller average soil grains at the surface hinders the capacity of rivers to incise. We show that globally, rates of cosmogenic nuclide-derived denudation rates fall into latitudinal belts with (1) low rates of denudation in areas with high temperatures and high precipitation where rock fragments do not persist at the soil surface, (2) high rates of denudation at mid-latitudes where rock fragments exist and are carried efficiently by the river flow, and (3) low rates of denudation at high latitudes where large grains at the surface inhibit channelized flow. We hypothesize that climate sets the pace for landscape change through a balance between slope and grain size. This process acts as a governor on flux of weathering products to the oceans.