Transient landscape evolution following uplift in the Southern Ecuadorian Andes

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Fluvial systems are driving landscape evolution in active tectonic settings. Examining differential denudation rates associated with specific channel and hillslope morphology contributes to understand the transient response of a landscape following uplift. Here, we explore the relationship between landscape morphology and erosion by quantifying basin-wide denudation rates of various morphological zones in the Southern Ecuadorian Andes. Cosmogenic radionuclides (^{10}Be) in quartz of river sediment were employed to constrain basin-wide denudation rates (10^4-10^5 yr). Along an east-west transect across the Cordillera Real, we carefully selected small basins (< 250 km²) to cover a wide range of morphological settings, and to be representative of specific areas of transient adjustment. Channel and slope morphology vary systematically from east to west, reflecting the transition from high-relief, strongly dissected topography in the eastern side of the Cordillera Real into relatively low-relief topography in the Inter-Andean valley. Basin-wide denudation rates range by nearly two orders of magnitude, from ~ 4 mm/kyr to ~ 400 mm/kyr, and show good correlation with channel and hillslope steepness indices.

The spatial pattern of differential denudation rates across the Cordillera Real reflects the transient adjustment of the landscape to rapid river incision following tectonic uplift. Relative high denudation rates (> ~200 mm/kyr) are measured in the eastern part of the Cordillera Real, where slopes and channels are steep and actively adjusting to rapid incision of the trunk stream. Basin-wide denudation rates are about ten times lower in the central part of the Inter-Andean valley. The presence of smooth concave river profiles indicates that the incision signal has not yet propagated into the Inter-Andean valley.

The consequence of Quaternary changes in chemical weathering rate for ocean chemistry

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Modern riverine chemistry and discharge is commonly used to estimate the long-term flux to the oceans of the many chemical species that have their primary source in the continental crust. Here we suggest that measurements of many modern rivers, only a few thousand years after a glacial period, are not representative of the long-term flux and we quantitatively assess the implications of such a suggestion for key marine geochemical budgets.

Blum and co-workers [e.g. 1] first developed the idea that physical grinding during glacial periods of the Quaternary was followed by rapid chemical weathering of fresh soils during the warm, wet conditions of interglacials. Recently [2], Pb isotopic records of the oceans were shown to be consistent with pulses of rapid weathering during the early stages of interglacials. The consequences for long-term Quaternary chemical weathering rates and the Sr isotopic record of seawater have been explored previously [1]. Here we focus on another important implication: that the instantaneous weathering rates implied by modern riverine cation flux are higher than the long term average. In our estimation, for regions that were glaciated 20 kyr ago but that are now ice-free, present day chemical weathering rates are a factor of 3 to 4 higher than the average rate for the past 2 to 3 Myr.

This finding has major implications for long-standing problems in ocean chemistry. For example, it remains a puzzle that the hydrothermal flux of Sr required to balance the modern riverine flux is much greater than is suggested by the extent of alteration of the oceanic crust [3]. Indeed, while there is growing convergence between ocean floor hydrothermal fluid flux estimates based on independent tracer exchanges [e.g. 4] and simple thermal calculations, estimates based upon the oceanic ^{87}Sr or Mg balances that rely on the quantification of the modern riverine flux are more than an order of magnitude greater. For elements such as Sr and Mg, with long oceanic residence times, modern riverine measured fluxes do not provide approriate estimates of the long-term inputs. The changes in weathering rates also imply dramatic variation in the supply of alkalinity and nutrients to the ocean, with consequences for atmospheric CO_2.

References

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