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Weathering as the limiting factor of denudation in the Western escarpment of the Andes

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A crucial issue in process geomorphology is the search for the scale and the extent to which precipitation, and climate in general, influences the nature and the rates of sediment transfer (weathering, erosion, sediment transport and deposition).

We present an analysis of the possible interplay between precipitation, weathering and denudation rates for the western Andean slope between the Cordillera and the Pacific coast. It is based on morphometric studies and quantitative 10Be denudation rate estimates of three transverse river systems (Piura at 5°S, Pisco at 13°S, and Lluta at 18°S) draining the Western escarpment of the Peruvian and North Chilean Andes. The systems originate at elevations >3000 m above sea level, cover an area between 3000 and 10'000 km2 and discharge into the Pacific Ocean. The precipitation rate pattern implies a hyperarid climate at the coast, and semi-arid to semi-humid conditions in the Cordillera where the streams rise. There, climatic conditions are generally controlled by the easterlies that deliver moisture from the Atlantic Ocean via the low level Andean jet.
The precipitation rate pattern of the Cordillera shows a North-South decreasing trend, from ca. 1000 mm/yr in Northern Peru to 150 mm/yr in Northern Chile. In these higher regions of the drainage basins, hillslopes are convex with nearly constant curvatures and are mantled by a >1 m thick regolith cover. In addition, hillslope erosion is limited to the regolith-bedrock interface. We interpret these geomorphic features to indicate weathering-controlled sediment discharge.
In the lower river segments, beyond tectonic knickzones, regular precipitation is almost absent. For the case of the Piura river in Northern Peru, precipitation in this segment occurs in relation to highly episodic El Niño events related to the westerlies. This results in a supply-limited sediment discharge, leading to predominance of channelized processes on the hillslopes, a spare regolith cover and an additional river profile knickzone in the transition zone between the easterlies and the westerlies.

Analysis of 10Be in quartz of river-born sand and of bedrock reveals that denudation correlates positively with the present-day rainfall pattern related to the easterlies. Denudation rates in the headwaters range from 0.14 mm/year in Northern Peru down to 0.05 mm/yr in Northern Chile (Kober et al., 2007). In addition, 10Be-based denudation rates reveal a decreasing trend from the Cordillera to the Pacific coast that positively correlates with the decreasing precipitation rate, irrespective of the nature of the bedrock. Interestingly, the 10Be analysis conducted in the Piura system reveals no influence of the episodic precipitation in relation to El Niño on the sediment production rates.

In summary, the pattern of denudation rates together with morphometric observations and quantitative denudation rate estimates strongly hints at weathering being the driving but also limiting factor of denudation. Accordingly, in the western Peruvian Andes, sediment production and export are most probably controlled by the pattern and rate of precipitation.

Kober, F., Ivy-Ochs, S., Schlunegger, F., Baur, H., Kubik, P. W., and Wieler, R. (2007). Denudation rates and a topography-driven rainfall threshold in northern Chile: Multiple cosmogenic nuclide data and sediment yield budgets. Geomorphology 83, 97-120.