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Persistence of topography in ancient mountain belts: geomorphology's 'elephant in the room'?

Daniel Peifer Bezerra, Cristina Persano , Martin Hurst , Paul Bishop , and Àngel Rodes
School of Geographical & Earth Sciences, University of Glasgow, UK

The long-lasting persistence of mountainous topography in tectonically stable intraplate settings remains enigmatic. Conceptual and numerical models have indicated that the cessation of tectonic activity and thus, the absence of counteracting forces to the destructive surface processes, lead to a long-term decline of relief. However, there are several examples of post-orogenic mountain belts (e.g. the Appalachians, the Ural Mountains) that are marked by a current 'residual' topography with locally steep hillslopes and channel gradients that, according to the models, should have long flattened. The question of how these mountains have survived without any significant active tectonics remains unanswered. The key conundrum is that rates of denudation are known to vary primarily with topographic relief worldwide, yet post-orogenic landscapes characterised by high relief are often found to have low denudation rates. Here we present data that quantify both the erosion rates and the morphometric parameters of a classic post-orogenic landscape to investigate the relationship between topography, the exposed lithology and erosion rates in post-orogenic mountains. Our case study area is Brazil's Quadrilátero Ferrífero (QF), an unglaciated, high relief, ancient landscape that is thought to have been tectonically stable for the last 500 Myr; the area is remote (∼400 km) from the distant baselevel and consists of both resistant and weak lithologies. We performed a quantitative analysis of the topography of the QF and measured cosmogenic 10Be concentrations in alluvial sediments to estimate basin-wide erosion rates for 25 catchments, with variable size (1-100 km2), topographic context (e.g. catchment-average hillslope angles of 11-31°), and exposed bedrock resistance (from the resistant quartzites to the least resistant, under tropical conditions, gneisses and granitic rocks). 10Be-derived erosion rates are overall low (∼< 30 m/Myr), in agreement with determinations in other intraplate settings where the topography is pronounced (e.g. the Cape Mountains in Africa). Our quantification of the morphometric parameters permits us to explore the relationship between erosion and topography further. We found a counter-intuitive, negative allometric correlation (y=a*x̂b, with negative b) between all the catchment-averaged morphometric parameters, including local relief, hillslope mean angle and normalised steepness index, and erosion rates. There is, however, a positive relationship between topography and rock resistance, whereby, in general, the more resistant the exposed rock is to erosion, the steeper and more rugged is the topography of the catchment. There is also a relationship between rock resistance and erosion rates: the catchments with quartzite are eroded the slowest (∼0.8-5 m/Myr), whereas the catchments under non-resistant schists and phyllites, or mixed lithologies, erode a little faster (∼5-10 m/Myr), and the gentle basins under the least-resistant gneisses and granitic rocks erode at rates of up to ∼25 m/My. Our data suggest that lithology is a first-order control on erosion. The extremely low erosion rates of the high relief quartzite, irrespective of its steep topography, support the hypothesis that the topography of the QF has an ancient origin and is able to survive for many millions of years, possibly even increasing the original relief, as the conceptual models of Twidale and Crickmay first suggested.