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The Dynamic Topography of Madagascar: A Cenozoic History of Uplift and Erosion

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The physiography of Madagascar is characterised by flights of high-elevation but low-relief plains (i.e. peneplains); 42% of the landscape is above 500 m in elevation. Such laterite-capped low relief plains are thought to form due to widespread denudation during periods of tectonic quiescence. Cross-cutting relationships suggest these plains formed during the Cenozoic [1]. Peneplains are now found at up to 2 km in elevation, suggesting Madagascar has undergone significant and widespread uplift. In addition, Eocene nummulitic (i.e. marine) limestones at elevations of ~400 m above sea level and newly dated, emergent 125 ka coral reefs suggest that Madagascar has experienced differential vertical motions during Cenozoic and Recent times. Malagasy rivers are deeply incised and contain steepened-reaches and upward convexities, implying they have responded to rapid changes in uplift rate. This history of broad-scale vertical motion is framed by a tectonic history of quiescence and/or extension. In contrast, low temperature thermochronology and ^{10}Be derived erosion rates suggest that both Cenozoic and Recent average denudation rates have been low; whilst modern hillslope erosional gullies (i.e. lavaka) suggest erosion rates are currently high [2,3]. To bridge the gap between this disparate evidence we model spatio-temporal regional uplift and erosion patterns through analysis of drainage networks. We inverted 2566 longitudinal river profiles using a damped non-negative, least-squares linear inversion to determine the history of regional uplift. We used a simplified version of the stream power erosional law. River profiles were extracted from the 3 arc-second Shuttle Radar Topography Mission (SRTM) digital elevation model. The model is calibrated with field observations of the elevation of Cenozoic limestones and dated marine terraces. The residual misfit between observed and calculated river profiles is low (χ^2 = 1.1), suggesting rivers appear to contain coherent signals that record regional uplift. Results suggest that Malagasy topography grew diachronously by 1–2 km during the last 15–20 Ma. We use these results to predict sedimentary flux rates to the Mozambique Channel during the Neogene and close the loop between uplift, erosion and sediment supply. Results suggest that the Cenozoic history of uplift is a primary driver for modern day erosional processes, and hence the modern-day geomorphology of Madagascar. Admittance calculations, the history of basaltic volcanism and nearby oceanic residual age-depth measurements all suggest that as much as 0.8—1.1 km of Cenozoic uplift in Madagascar is supported by mantle processes.

References:

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