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Extracting Uplift Rate Histories From Longitudinal River Profiles: Examples From North America and Africa

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The physiography of the Earth's surface is a manifestation of vertical motions, erosion, and deposition of sediment. We show that a history of uplift rate of the continents during the last ~ 100 million years can be determined by jointly inverting the longitudinal profiles of rivers. We assume that the shape of a river profile is controlled by the history of uplift rate and moderated by the erosional process. We have parameterized fluvial erosion using a nonlinear advective-diffusive formulation. A river profile *per se* contains no information about the erosional timescale; values of erosional parameters must be calibrated. If either vertical incision rate or knickzone retreat rate is known independently, for example when palaeo-river profiles are preserved, we can calibrate the erosional model directly. Independent spot measurements of uplift offer another way to calibrate a regional model. In our inverse model, uplift rate is allowed to vary smoothly as a function of space and time, and upstream drainage area is invariant. Using this inverse methodology, we show that there exist time-correlative commonalities in the shapes of river profiles draining uplifted regions. We find that the rate at which knickzones propagate upstream is linearly dependent on slope in nearly all cases (i.e. $n = 1$ in the detachment-limited erosional model for ~ 600 North American and African rivers). The exponent on upstream drainage, m, which controls knickzone retreat rate, is typically < 0.5. Calculated retreat rates are therefore insensitive to large changes in upstream drainage area. Simultaneous inversion of profiles from the Colorado, Columbia, Mississippi and Rio Grande catchments shows that western North America experienced three regional phases of uplift during the last 100 Ma. The first phase of uplift occurred between 80–50 Ma, which generated ~ 1 km of topography at a rate of ~ 0.03 mm/yr. A second phase of uplift generated ~ 1.5 km of topography between 35–15 Ma at a rate of ~ 0.06 mm/yr. A final and smaller phase of uplift commenced ~ 5 Ma. These distinct phases of uplift are corroborated by spot estimates of palaeoaltimetry, timed growth of relief, thermochronometric data and by stratigraphic evidence of pulsed clastic efflux delivered to the Gulf of Mexico. An episodic uplift history is consistent with punctuated dynamic support of a large region, which is currently centred on Yellowstone. Inversion of the Congo, Nile, Niger, Ogooue, Orange, Zambezi rivers and their major tributaries indicates that domal swells in Africa have experienced a staged uplift history. The West African margin has experienced at least two phases of uplift during the last 30 Ma. Uplift in Afar began ~ 35 Ma. The Hoggar and Tibesti swells, in central North Africa, have an older history of uplift. These results are consistent with a staged magmatic history, delivery of sediment to the continental margins and stratigraphic observations, which suggest that the African landscape is responding to convection in the mantle.