Uplift and Exhumation along the Arun River (Eastern Nepal): Implications for the Mechanism of Uplift of the High Himalaya and the Coupling between Erosion and Tectonics

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The Arun River is one of the largest rivers across the Himalayan arch. Its deep valley is flanked by the >8 km peak of Mt. Everest and its ridge-to-valley relief exceeds 6 km. We combine (U-Th)/He and $^{40}Ar/^{39}Ar$ thermochronology, geomorphic analysis and thermo-kinematic modelling to decipher the mechanism of uplift across the High Himalaya of eastern Nepal and to examine possible tectonic, climatic and erosional interactions along the Arun deep gorge and the parallel Arun-Ama Drime antiformal structure.

Three different thermochronometers depict a pattern of decreasing valley-bottom cooling ages to the north. $^{40}Ar/^{39}Ar$ muscovite ages decrease from 16 Ma near the Main Boundary Thrust to 6 Ma north of the Himalaya topographic front. Zircon (U-Th)/He ages decrease from 6 Ma south of the topographic front to 2 Ma and apatite (U-Th)/He ages decrease from 3 to 0.8 Ma. The decrease in cooling ages across the topographic front is gradual, rather than abrupt. Farther to the north, across the transition to the Tibetan plateau, the increase in the ages is also gradual. At both of these transitions, the increase in exhumation rates towards the core of the range is apparently not a reflection of significant active faulting and more likely reflects mechanisms such as transport over a ramp and uplift due to duplex growth. The observed pattern limits the permissible duration and magnitude of out-of-sequence thrusting as well the possibility for significant, recent, normal faulting parallel to the south Tibetan detachment.

A 3D thermo-kinematic model which includes overthrusting over a flat-ramp-flat geometry and underplating, matches well the observed trends in the cooling ages while respecting geophysical constraints. The inferred spatial pattern of exhumation rates is in agreement with erosion rate proxies including relief, hillslope gradients, tributaries steepness, and specific stream power.

Exhumation rates along the Arun valley are higher than along the Everest (Rongbuk) valley and the Dudh Kosi upper reach, ~ 50 km to the west. This pattern seems to require some differential uplift with higher uplift rates along the Arun valley. Utilizing two thermochronologic transects perpendicular to the axis of the Arun antiform we discuss the possible activity of this structure and place constraints on accommodation of differential uplift.

To examine possible tectonic-climatic interactions, we characterize the north-to-south orographic rainfall gradient along the Arun valley using the Topical Rainfall Measuring Mission data (TRMM), rainfall measurement stations, and discharge gauges. Specific stream power (SSP), calculated using field-measured river width and the TRMM precipitation data, increases considerably across the topographic front of the Himalaya and delineates a ~50 km strip of rapid incision rate. The SSP remains high along this stretch despite more than a 3-fold decrease in precipitation. In addition, the (U-Th)/He cooling ages for apatite and zircon and $^{40}Ar/^{39}Ar$ muscovite ages keep decreasing at least 25 km north of the precipitation maximum. Considered in conjunction with previously published studies along the Marsyandi River this data suggests that the belt of rapid uplift within central and eastern Nepal is not a simple reflection of the spatial pattern of monsoon precipitation. We use the data to discuss the coupling between climate and tectonic deformation in the Himalaya and highlight other mechanisms which could localize strain.

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