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Deformation and exhumation of the Bhutan Himalaya derived from the inversion of thermochronologic and thermometric data

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The kinematics of late Tertiary crustal deformation across the Himalaya has seen passionate debate over the past decade. Data acquisition and modelling studies have focused primarily on the western and central Himalaya, where findings about crustal deformation and exhumation, and the resulting thermal structure, have been extrapolated to elsewhere in the orogen. Although the major lithotectonic units and their bounding structures are remarkably continuous along strike, significant differences in other features limit the applicability of individual study conclusions to the greater orogen. In particular, the Eastern Himalaya of Bhutan are difficult to link to existing kinematic models, due to unique documented features including: (1) Preservation of Tethyan metasediments atop the Greater Himalayan Sequence (GHS) indicating a lower exhumation magnitude, (2) apatite fission-track (FT) ages markedly older than further west (3) a steep, convex topographic front spatially restricting modern orographic precipitation to foothill elevations of <2000 m, (4) preservation of low-relief landscape remnants at 2000-3000 m elevation and (5) uplift of a foreland plateau producing tectono-climatic perturbations along the range front since the Late Miocene.

We quantify the kinematic history of the Bhutanese Himalaya using low-temperature thermochronology, thermometric data and thermokinematic numerical modelling. We complement published data with 75 apatite FT, 27 zircon FT, 60 apatite (U-Th-Sm)/He (AHe) and 40 zircon (U-Th-Sm)/He (ZHe) ages from bedrock samples along two North-South and one East-West transect across Bhutan. Thermochronometric analysis for up to five systems in selected GHS bedrock samples indicates dissimilar cooling patterns from temperatures of $\sim$375 °C to the near surface (i.e. muscovite 39Ar/40Ar to AHe). Specifically, all the samples from the landscape remnants in central and eastern Bhutan show a marked decrease in cooling rate from 50-100 °C/Ma between 5-8 Ma to 7-20 °C after 5 Ma. In contrast, samples from outside these geomorphic features, in northern and western Bhutan, show near steady cooling at $\sim$25 °C/Ma.

This disparity and the age data sets are further considered in new kinematic models for North-South transects across eastern and western Bhutan. These models honour existing geophysical, metamorphic and structural data, including balanced cross-sections, and are evaluated by inversion of observed age/temperature data to clarify key tectonic and thermal parameters using the 3D thermokinematic model Pecube. Models consider the last 12 Ma, with the geometry of the Main Himalayan Thrust (MHT), the India-southern Tibet convergence rate, its partitioning into over- and underthrusting of the Indian plate, radiogenic heat production and model basal temperature treated as free parameters. Preliminary model results suggest the MHT geometry varies from West to East and that the age distribution is particularly sensitive to the convergence rate partitioning; with respect to Nepal, we find slightly higher overthrusting values ($\sim$30% of the total convergence). Ongoing work will define the permissible range of other free parameters.