Landscape Evolution of the Bhutan Himalaya – Insights from Tectonic Geomorphology and Low-Temperature Thermochronology

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In contrast to the steep, rugged terrain that characterizes the southern slopes of the Himalaya in most areas, discontinuous regions of low-relief and shallow-slope occur perched at high elevations (~3500 m) in the middle latitudes of Bhutan. These surfaces are marked by subdued landforms, thick soils and saprolites, massive alluvial and colluvial fills, and presumably slow erosion rates. It is likely that these landscapes were once more continuous east to west across Bhutan and possibly extended south toward the foreland. However, due to active river incision, only isolated patches remain. These enigmatic surfaces pose two problems: (1) how and why did low-relief surfaces develop? and (2) how and why did they become perched at high elevations above rugged mountains and deep river gorges? Although robust answers to these questions require the integration of many modes of investigation, the age of low-relief surface development and the age of its uplift to higher elevations are crucial to our understanding of how climate and tectonics have shaped the Bhutan Himalaya.

Several hypotheses can be proposed to explain the existence of these topographic benches or the escarpments that bound them to the north and south. Plausible hypotheses include either temporal or spatial controls on the evolution of the landforms.

Temporal: The physiographic benches are relict low-relief landscapes perched above rapidly incising canyons.

1)Large regions of subdued landscape were uplifted to their current elevation by decreasing precipitation and maintaining constant uplift. The change in regional precipitation rate was likely a consequence of the uplift of the Shillong Plateau to the south (<3.5 Ma, Worm and others, 1998; 3-4 Ma, Biswas and others, 2007), which produced a rain shadow effect. (Grujic and others, 2006)

2)Large regions of subdued landscape were uplifted to their current elevation by an increase in rock uplift rate.

Spatial: The physiographic benches reflect spatially-variable rock uplift.

3)Fault zones have created the escarpments to the north and south of the low-relief landscapes (Tobgay and Hurtado 2004), as has been proposed for other physiographic transitions in the Himalaya (e.g. Hodges and others, 2001; Wobus and others, 2005).

Our first approach to obtaining quantitative information regarding the timing of uplift of the low-relief surfaces involved sampling an elevation transect beneath the low-relief region in the Bumthang area of eastern Bhutan (Figure 1) for single-crystal apatite (U-Th)/He dating. The cooling ages for most samples decrease with distance below the low-relief surface from 5.94 +/- 0.38 to 4.41 +/- 0.04 Ma (2σ), down to a depth of ~1600 m below the surface (Figure 2). They define a linear array on an apparent-age versus elevation plot suggestive of steady, relatively rapid exhumation at a rate of ~2 mm/yr from around 6 to 5 Ma. However, the lowest sample in the transect is younger than predicted by this exhumation rate. Although more data are needed, this preliminary result implies a deceleration in exhumation rate after ~ 5 Ma, which may suggest establishment of the low-relief surface at about that time. If the surface was established by ~ 5 Ma at low elevations, then uplift of the surface to its current elevation of ~ 3500 m was a Pliocene-Quaternary process.

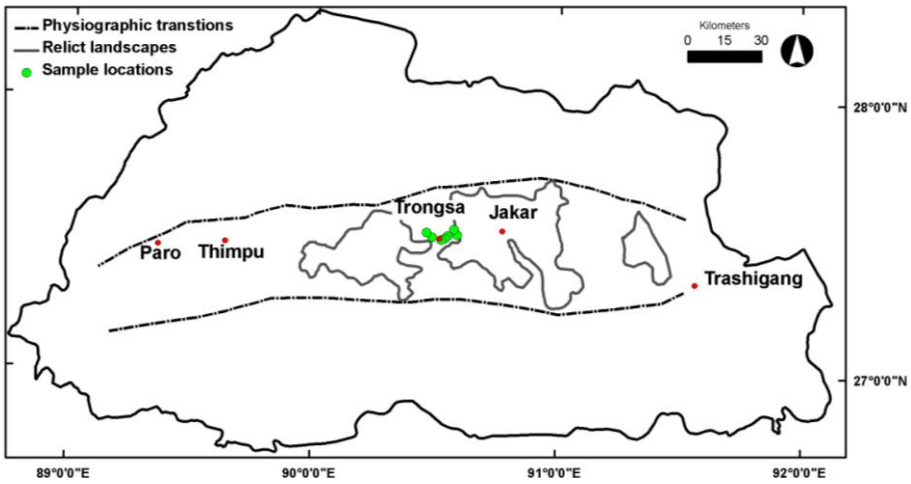

Figure 1. Simplified map of Bhutan showing the proposed relict landscapes of Grujic and others (2006) and physiographic transitions. Apatite (U-Th)/He vertical transect sample locations are denoted in large circles and located in eastern Bhutan near Trongsa. The Bumthang low-relief surface is demarcated with a solid line around Jakar.

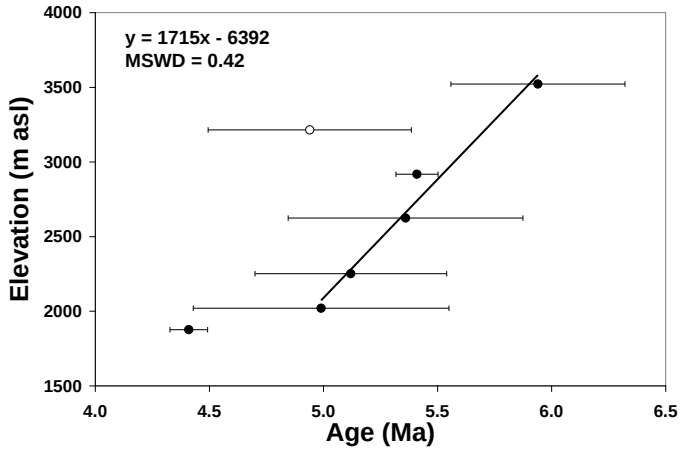

Figure 2. Age-elevation plot of single grain apatite (U-Th)/He samples beneath the Bumthang surface. The cooling ages for most samples decrease with distance below the low-relief surface from 5.94 +/- 0.38 to 4.41 +/- 0.04 Ma (2σ). The data define a linear trend suggestive of exhumation at a rate of ~2 mm/yr from around 6 to 5 Ma. The lowermost sample of the transect has a younger cooling age than predicted by the ~2 mm/yr trend of higher-elevation samples. The sample denoted with a white circle was omitted from the least-squares regression.

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