Comment on “Tectonic control of Yarlung Tsangpo Gorge revealed by a buried canyon in Southern Tibet”

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Wang et al. (Reports, 21 November, 2014, p. 978) describe a buried canyon upstream of the Yarlung Tsangpo Gorge and argue that rapid erosion of the gorge was merely a passive response to rapid uplift at ~2.5 million years ago (Ma). We view these data as an expected consequence emerging from feedbacks between erosion and crustal rheology active well before 2.5 Ma.

W ang et al. (1) address the debate over the roles of tectonic versus surface forcing in orogenesis (2), concluding that “our results suggest that rapid incision within the Tsango Gorge is the result rather than the cause of rock uplift.” We offer an alternate viewpoint in which the important data reported by Wang et al. (1) match predictions (3) made using the aneurysm model and provide support for the idea that feedbacks between tectonic, rheological, thermal, and surface phenomena will inevitably and spontaneously develop in regions where sufficiently rapid tectonic uplift and focused erosion are superimposed.

As Wang et al. note, the reported 2 to 2.5 million years ago (Ma) age for the initiation of sediment accumulation upstream of the Namche Barwa knickpoint is a minimum, due to the complex infilling patterns in time and space expected after tectonic impoundment of a large sediment-laden river having major tributaries. Moreover, given the location of the dated core (well 3; 567 m in a basin of ~1000 m total depth) and assuming a constant sedimentation rate, sediment at the base of the projected ~1000 m of deepest fill could be 3 to 4 Ma in age.

In interpreting their data, Wang et al. assume that a singular impoundment occurred behind a sharply defined structure that became abruptly active at 2 to 2.5 Ma, but neither of these conditions applies to the Namche Barwa antiform and the Namche Barwa–Gyala Peri metamorphic massif. The current massif is terminated along its western, northern, and northeastern margins by active structures marked by sharp cooling-age discontinuities and abundant seismicity (Fig. 1A) (4). In contrast, to the southwest where sediments have accumulated, the cooling-age transition from the massif to the Namche Barwa antiform is gradual across the Nam La thrust zone that defines the southern boundary of the massif (Fig. 1B). The extreme rates and magnitude of rock uplift and exhumation are focused within the massif and decline progressively toward the antiform without any discontinuities across structural boundaries.

Available evidence also argues strongly against abrupt initiation of activity at 2.5 Ma. Thermochronologic and other data document a longer history of systematic focusing of exhumation and strain in southeastern Tibet, as predicted by the aneurysm model (3, 5–7). In the southeastern Lhasa block and Namche Barwa antiform, rapid exhumational cooling occurred from ~10 Ma to ~5 Ma, and within the massif itself, petrologic and age data suggest 10s of km of exhumation over the same interval (3, 4), a conclusion also supported by detrital dating (8). Rapid exhumation ceased in the Lhasa Block by 6 to 7 Ma and then in the antiform by ~4 Ma, but within the metamorphic massif, rapid cooling has continued and possibly accelerated (4). This progressive cessation of rapid cooling everywhere but the massif can be explained by focusing of deformation first into the antiform and then further localization into the massif, where acceleration of rock uplift could have slowed upstream exhumation rates by establishing a new local base level for the Yarlung Tsangpo at the stabilized knickpoint. Evolution of this coupled system would have taken place over an interval of time, starting as early as 10 Ma, with a focused zone of rapid uplift and erosion becoming a distinct emergent phenomenon by 5 Ma.

The observed distribution of structures and their evolution over several million years are consistent with upstream sediment accumulation beginning at 2.5 Ma or earlier. As regional rock uplift focused into the massif, uplift and erosion rates became locally sufficient to permit feedbacks to develop between coupled tectonic
and surface processes. These feedbacks led to development of a stabilized knickpoint with an upstream reduction in river gradient sufficient to permit sediment aggradation and, ultimately, accumulation. Patterns of sedimentation and sediment preservation behind such a developing bedrock uplift are likely to be complicated and dynamic. Given high rates of rock uplift, sediment supply by the Yarlung Tsangpo and its tributaries, and incision downstream of the knickpoint, such factors as perturbations to the sediment supply (e.g., a Quaternary increase), temporary glacial or landslide damming (9), and localized changes in the tectonic strain field would affect sediment distribution, accumulation, and preservation upstream of the knickpoint. Repeated episodes of sediment accumulation and evacuation could occur, as is suggested by the coarse basal sediments in well 5. In contrast to the 2.5 Ma age of basal sediments at well 3, at well 5 these sediments must be considerably younger than nearby bedrock having a U-Th/He zircon cooling age of 1.2 Ma (4).

We conclude with a comment about misunderstanding of the tectonic aneurysm model that emerges in Wang et al. (1) and elsewhere [e.g., (2)]. As we proposed (3, 5–7), this model operates at local scales and is foremost about tectonic processes. It is not about surface processes “triggering” rock uplift, at any rate. The tectonic aneurysm develops in response to exhumation-driven thermal thinning of the upper, high-strength portion of the crust in actively deforming regions that have the potential for rapid erosional flushing. The model produces characteristic observable signatures that include an elevated viscous-frictional transition as seen in hypocentral locations (10), active high-temperature hydrothermal systems (11, 12), and decompression anatexis and metamorphic PT paths (13, 14). In the context of the aneurysm model, when we have used the word “triggering,” it has referred to the emergence of feedbacks among several sets of coupled phenomenon, and not, as Wang et al., as well as others suggest (1, 2), instigation of rock uplift by erosion. Several elements are needed for these feedbacks to emerge: strong erosive power coupled to a vigorous transport system sufficient to remove enough material to perturb the thermal field; a nonlinear temperature-dependent rheology; and, above all, a crust, near failure, that is undergoing active deformation collocated with the strong erosion. Once feedbacks come into play, chicken-versus-egg arguments about tectonic versus erosional “control,” and cause-and-effect become irrelevant. Rather than challenging the concept of feedbacks between tectonics and erosion, we think that the results of Wang et al. provide striking confirmation.

REFERENCES
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