Geologic Hazards Associated With a Proposed Dam on the Yarlung-Tsangpo River in SE Tibet

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#1 – Background

For over a decade anecdotes and media reports have been circulating about a proposed dam on the Yarlung-Tsangpo River in SE Tibet. The proposed site is in the deep canyon of the Yarlung-Tsangpo, where the river leaves the Tibetan Plateau, falling ~2000 meters across an immense knickzone developed along an irregular U-shaped reach ~100 km in length (Figures 1 to 3).

The fundamental purpose of the dam would be generation of potentially as much as ~40,000 MW of hydropower to be used in diverting a portion of the impounded river to water-starved regions of northern China (for comparison, the Three Gorges project is rated at slightly more than 20,000 MW). If pursued, the Tsangpo dam would be part of the broader "Western Route" of the *nan shui bei diao* water-diversion scheme ("transferring water from the south to the north"). We have no concrete knowledge that a Tsangpo project is in active planning, and officials have downplayed stories about such reports (Biron and Dodin, 2007). However, given the persistent media reports, the pressing water-resources issues in China as well as an equally pressing need to provide large amounts of cleaner energy, we feel it timely to assess the impact of a Tsangpo dam.

Offsetting benefits that a dam would offer in the form of improved water supply to northern China, significant water-flow and sediment-flux impacts would be felt downstream in the Brahmaputra system in northeastern India and Bangladesh, and hazards associated with a dam located in such a geologically active area would be substantial. Further, the dam and reservoir would likely ruin the pristine, ecologically and ethnographically diverse Pemako region around the Yarlung-Tsangpo canyon, an area of great significance to Tibetan Buddhists.

We have been examining the geodynamic evolution of eastern Tibet and now have considerable geophysical and geological data that bear on the siting of a dam at this location. Our conclusion is that despite the allure of its vast hydropower potential, the Big-Bend knickzone is a dangerously unsuitable place to site a dam.

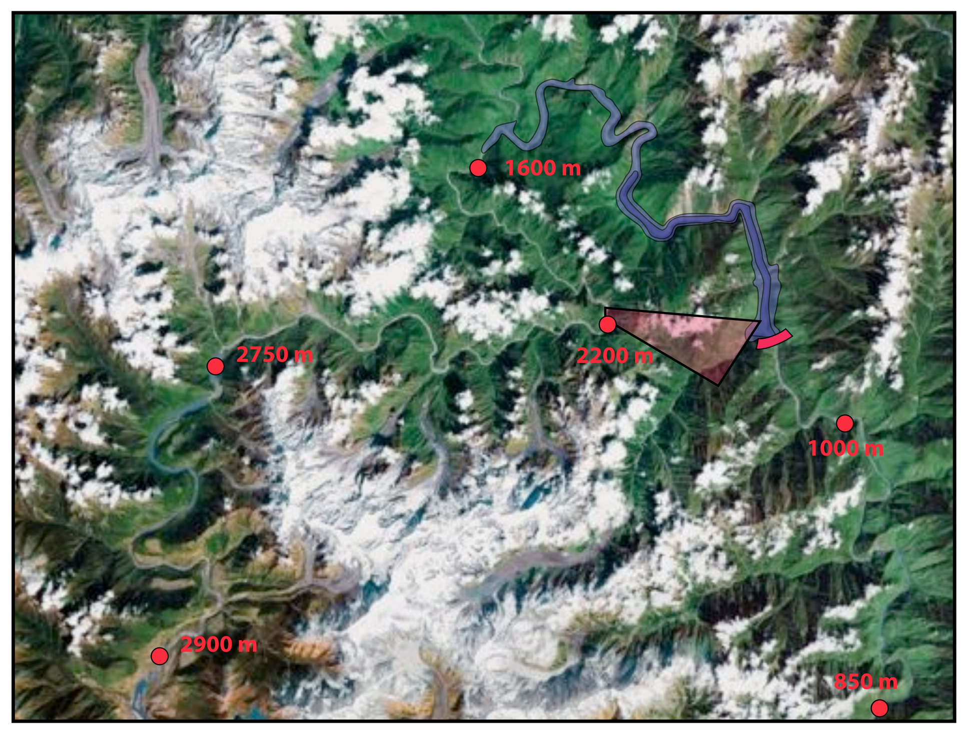


Figure 1 (above). Google Earth image showing location of proposed dam at Big-Bend knickzone. Wedge shows path for diversion tunnels into downstream dam. Approximate extent of 250 m and 500 m impoundments shown in blue.

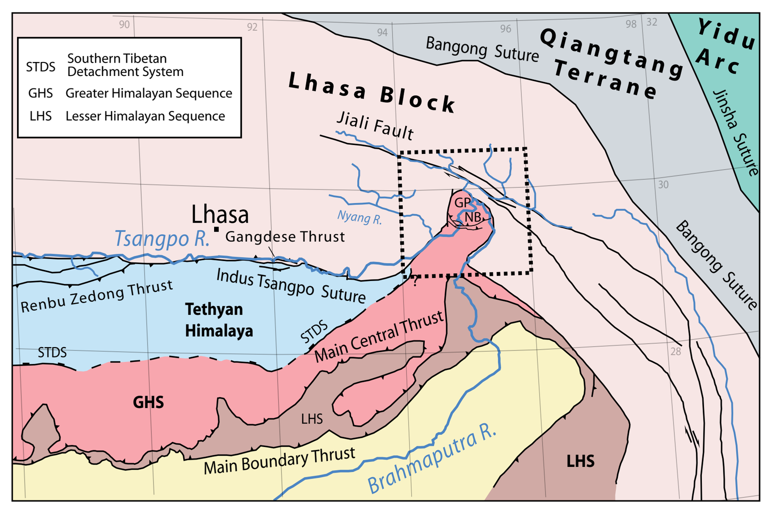


Figure 2 (above). Cartoon showing main geologic elements around the knickzone and Namche Barwa - Gyala Peri massif (dashed box).

#2 – Geodynamic Context

The proposed dam site at the great Tsangpo knickzone is located at the far easternmost end of the Himalayan arc, where it terminates in the active Namche Barwa - Gyala Peri massif. At a more regional scale, GPS results show that steep three-dimensional velocity gradients exist across the region, and in the easternmost Himalaya near Namche Barwa >50% of the Indian – Eurasian plate convergence is accommodated within the high-strain zone that reaches to the southern edge of the proposed site. The 1950 Assam earthquake (M8.6) was one expression of the high local strain rates, and caused considerable damage within the canyon area.

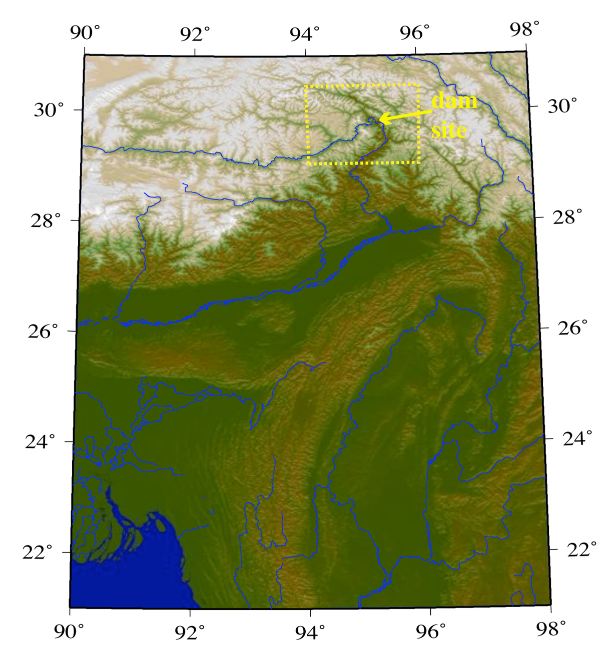


Figure 3 (above). DEM showing location of proposed dam and its context in SE Asia.

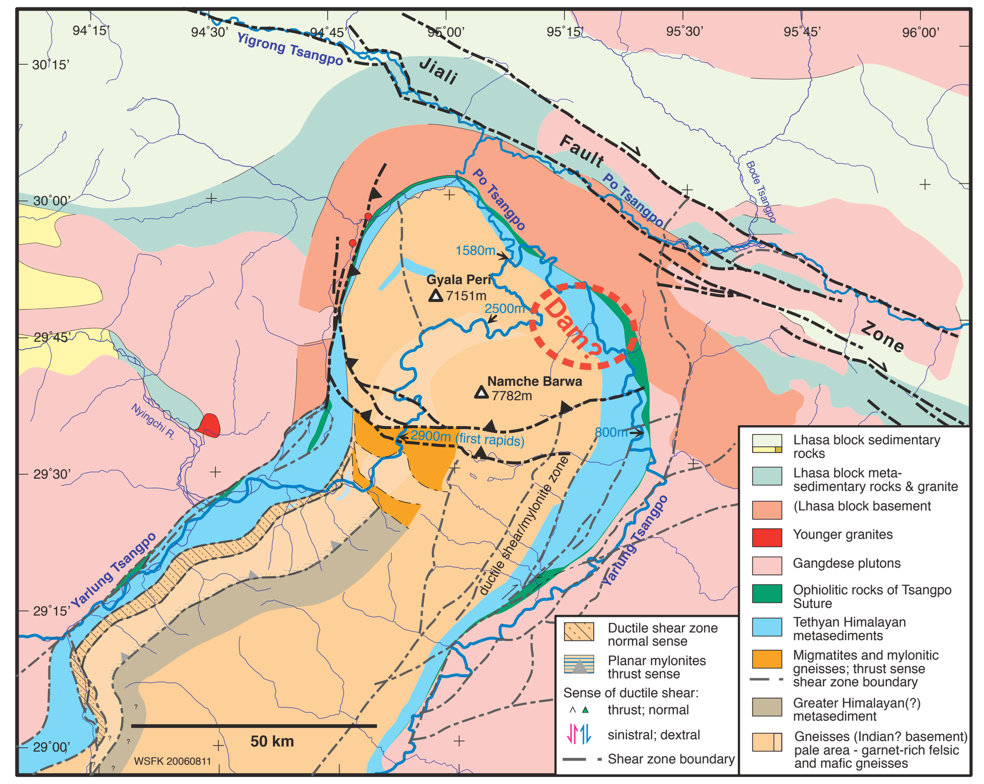


Figure 4. Geological map of SE Tibet near the Big-Bend knickzone, showing Namche Barwa-Gyala antiform. Active faults drawn in black. Approximate location of the dam and diversion tunnel proposed in some schemes shown by dashed red oval.

#3 – Active Tectonics: Structure and Antiform Evolution

The Big-Bend knickzone is developed across an active antiformal metamorphic massif that exposes Indian-plate basement (Figure 3) as a result of a recent and probably ongoing tectono-metamorphic episode. Granite dikes and migmatites give U-Pb zircon ages from 1 to 10 Ma, and metamorphic geochronology and *P-T* work shows that the massif has experienced ~6 mm/yr of exhumation during at least the past 3-4 m.y. Our studies suggest that the knickzone is likely pinned at the growing antiform and that in fact the two features are part of a coupled system in which erosion localizes and enhances deformation and local rock uplift. Biotite $^{40}Ar/^{39}Ar$ cooling ages break sharply across what appear to steep massif-bounding faults (Figure 5a), consistent with a continuum of activity that continues to the present.

Figure 5a. Biotite $^{40}Ar/^{39}Ar$ cooling ages. This dating system has a closure temperature of about 350˚C.

Figure 5b. Zircon U-Th/He cooling ages. This dating system has a closure temperature of about 200˚C.

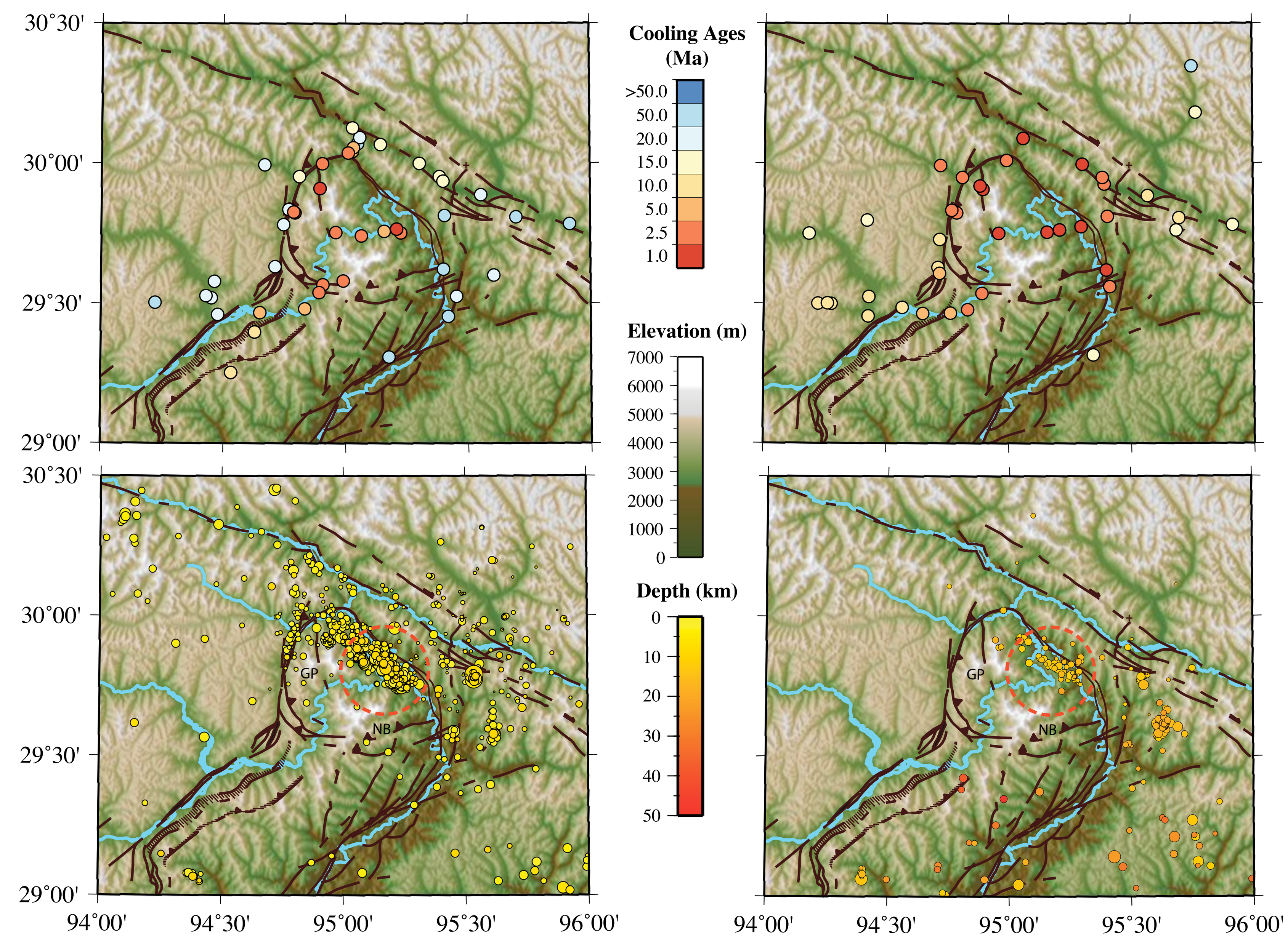


Figure 6a. Seismic events, depths less then 10 km.

Figure 6b. Seismic events, depths more then 10 km.

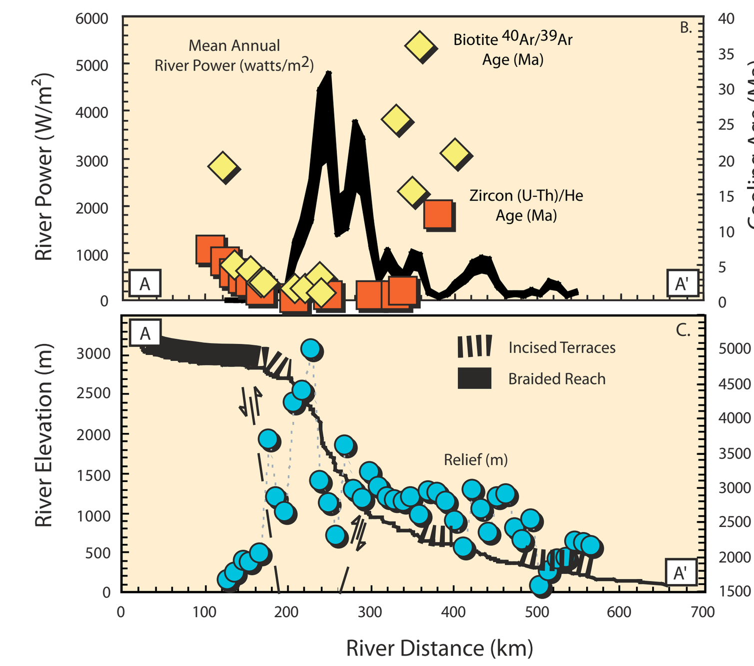
#4 – Seismicity

As part of a regional seismic array deployed for 15 months in 2003 - 2004, we installed a denser array of short-period instruments closer to the Namche Barwa massif. Our results show a spectacular clustering of events below its northernmost boundary (Figures 6a and 6b). These do not represent shallow topographic stresses related to the gorge, as a number of hypocenter locations extend to considerable depths of more than 10 km. These must be related to active deformation beneath the massif. Figures 6a and 6b show a total of 1477 events (mb 1.0 to 5.6, with a range of first motions). The possible dam site is located within the dashed red circle.

#5 – Sediment Fluxes and Geomorphology

Around the Yarlung-Tsangpo canyon, slopes are very steep, relief is extreme (Figure 7, bottom), and erosion is landslide-dominated. Erosion rates integrated over timescales ranging from millions of years to the present, using techniques including petrology, thermochronology, cosmogenic isotopes, and detrital dating all converge on sustained erosion rates of some 5 mm/yr or more, with the possibility that local bedrock incision rates are much higher. There is enormous stream power at the knickzone (Figure 7, top), and the sediment fluxes developed in this region are enormous (Figure 8).

Figure 7. Plots comparing cooling ages, stream power, relief, and the Tsangpo's long profile in and near the knickzone. From Finnegan et al. (in press).



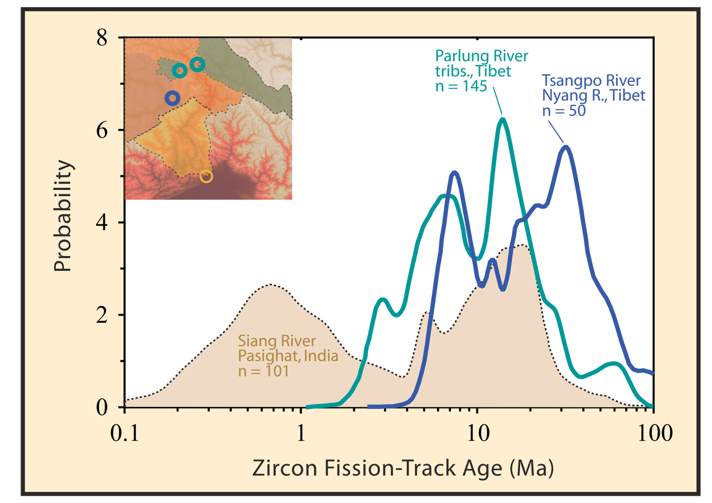


Figure 8. Fission-track data from detrital zircons obtained from sands sampled upstream and downstream of the Big-Bend knickzone. Compare the distribution of ages observed downstream at Pasighat, India with those obtained from the Tsangpo upstream of the knickzone: some 50% of the downstream zircons are very young (less than 2 Ma; mode at 0.6 Ma).

The only possible source is the Namche Barwa massif (see Figure 5b). Coupled with estimates of total sediment flux measured at Pasighat, these data suggest a modern mean erosion rate of 13 ± 6 mm/yr in the area surrounding the knickzone, supplying some 100 Mt/yr of sediment to the Tsangpo. From Stewart et al. (in review).

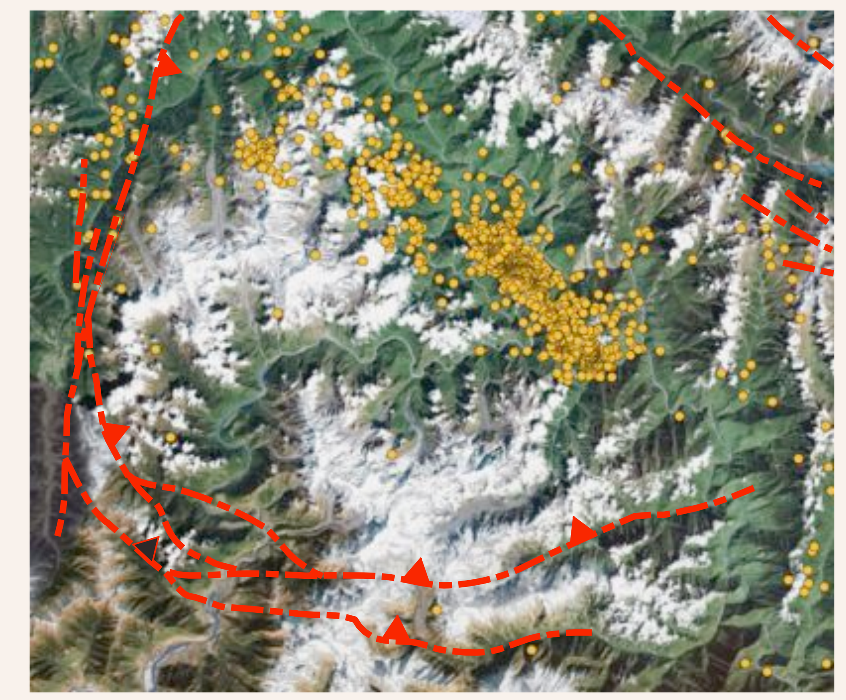


Figure 9. Summary of data relevant to dam siting.

#6 – Implications for Dam Siting and Hazards

Our data indicate that any dam placed within the Yarlung-Tsangpo canyon would be at high risk, with the dam and diversion being prone to failure due to pronounced seismic hazards and focused deformation. As it fills, water pressure behind the dam could help trigger shallow earthquakes and landslides, and the dam would be difficult to maintain given the high frequency of landsliding and extreme local bedrock exhumation rates that would lead to rapid siltation. Further, this impoundment of the Yarlung-Tsangpo would greatly starve the sediment flux downstream into the Brahmaputra and ultimately the Bay of Bengal systems. As such, the dam, which would be built at the cost of an ecologically precious region, would likely not succeed in its purpose while causing significant harm locallly and downstream.

Acknowledgements

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References

Biron, C.L., and Dodin, Th., 2007. Siphons to the north. Himal Southasian, v. 20(9). http://www.himalmag.com/2007/september/tibet_dam_mao_zedong.htm.

Finnegan, N. J., Hallet, B., Montgomery, D. R., Zeitler, P. K., Stone, J. O., Anders, A. M., and Liu, Y., in press. Coupling of rock uplift and river incision in the Namche Barwa-Gyala Peri massif, Tibet. Geological Society of America Bulletin.

Stewart, R. J., Hallet, B., Zeitler, P. K., Malloy, M.A., Allen, C. M., and Trippet, D., in review. Brahmaputra sediment flux dominated by highly localized rapid erosion from the easternmost Himalaya. Geology, in review.

Geodynamics of Indentor Corners

More Information: http://www.ees.lehigh.edu/groups/corners