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River morphology evolution driven by mass movements in tectonic active regions – A negative feedback response of transient landscape

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Incised valleys or steep slopes in tectonic active mountain areas are normally in a critical equilibrium state which is highly fragile and prone to deviate under exotic disturbances (e.g., earthquake, heavy precipitation, or even human activities), inducing mass movements (e.g., landslides, avalanche, and/or debris flows). Mass movements have great impacts on fluvial processes and may even reshape valley morphology, hence are powerful drivers to river evolution in those environments. Unfortunately, compared to the mass movements themselves (e.g., occurrence time, volume, dynamics and underlying mechanisms), less attention has been paid to the fluvial processes (in a short/intermediate-term) and the long-term evolution of river morphology corresponding to (and after) those mass movements (especially catastrophic ones). This motivates the current work.

The southeast Tibet, located on the east Qinghai-Tibet Plateau, is one of the most active regions globally in terms of tectonic motion and rates of uplift. Rivers in the lower Yalung Tsangpo basin in this area are investigated to understand the morphodynamics influenced by modern and historical mass movements and examine the feedbacks of fluvial processes to mass movements. River reaches influenced by typical mass movements were chosen for detailed field surveys, including: (1) the upper part of the Yalung Tsangpo Grand Canyon which has been seriously impacted by avalanches and debris flows from tributary gullies originating at glacial mountains of Namcha Barwa and Gyala Peri; (2) the lower reach of the Yigong River covering the Yigong Landslide from the Zhamunong Gully; (3) the lower reach of the Palong River influenced by debris flows from Guxiang and Tianmo gullies; and (4) the upper and middle reaches of the Palong River (extending roughly from Ranwu Lake to the upstream of Guxiang Lake) influenced by glacial processes and other induced mass movements since the last glacial maximum. Remote sensing images before and after the large-scale mass movements in recent decades were also used to track the corresponding river morphology variation.

Due to very high transport rate and volume of sediment incoming, mass movements have caused dramatic channel processes in east Tibet. Some even dammed the river, forming knickpoints and reshaping valley morphology. The morphology of the valleys in this area normally show alternating

sections of gorges and wide valleys, with a staircase-like longitudinal profile. The gorge sections exhibit single and deeply incised channels with a high-gradient channel bed and terraces. In contrast, the wide valley sections consist of lakes, braided or anabranching channels, gentle bed gradients, and thick alluvial deposits. In recent decades, mass movements (mostly debris flows), occurred more frequently through gullies in the reaches of gorge sections than through gullies along the wide valley sections. Mass movements deviate river morphology and slope from (quasi-)equilibrium to non-equilibrium state, however, with attendant rapid sediment incoming, valley bottom siltation and erosion benchmark rising, it triggers a negative feedback which drives the river morphology to a new round of development towards equilibrium.