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Theoretical Prediction and Field Examination of Bedrock Channel Morphology in Boulder-dominated Fluvial Reaches along the Liwu Catchment, Taiwan

Ron Nativ (1), Jens Turowski (2), Liran Goren (1), Johnathan Laronne (3), Niels Hovius (2,4)

(1) Geological and Environmental Sciences, Ben-Gurion University of the Negev, Beer Sheva, 84105, Israel (ronnat@post.bgu.ac.il), (2) GeoForschungsZentrum, Helmholtz Centre Potsdam, Potsdam, Germany, (3) Department of Geography and Environmental Development, Ben-Gurion University of the Negev, Israel, (4) University of Potsdam, Institute of Earth and Environmental Science, Am Neuen Palais 10, 14469 Potsdam, Germany

Bedrock channel morphology controls the rates and efficiency of fluvial incision and sediment routing within a river. However, the processes and parameters that govern channel morphology at the reach scale are poorly constrained. Particularly, width and slope are commonly parameterized using empirical basin-scale relations that neglect the potentially important role of sediment particles. This role has been postulated in a recent publication that combined the effect of sediment flux on fluvial incision with adjustments of channel morphology. Transportable sediments are considered to have a dual effect on incision: they can act as erosive tools, while they can also protect the bed from erosion. This approach does not include the presence of very large boulders within the channel. To develop quantitative understanding of channel morphology when large boulders cover the channel bed, we revise a sediment-flux dependent incision model to capture the dependency of channel width, slope, and sinuosity on boulder-concentration (ratio of boulder aerial cover and the total fluvial reach area). Two main assumptions are incorporated into the model: (i) boulders are immobile, and are constantly shielding the bed from erosion by impacting sediment grains, and (ii) boulders can route the sediments around them, such that the tools act on a smaller effective area. Our model predicts that the steady state channel width (W) scales with boulder concentration (Γ) according to: $W \propto (1\text{-}\Gamma)^{-\gamma}$, where γ is a positive constant. When $\Gamma \rightarrow 1$, a larger channel bed area is covered by boulders, and the width increases. In contrast, when $\Gamma \rightarrow 0$, the width dependency on boulder concentration vanishes. To test the predictive power of the model, we apply it to the Liwu catchment (620 km^2), a steep terrain that drains the eastern flanks of the central mountain range in Taiwan. This basin is characterized by channel reaches with high boulder concentrations, and boulder sizes of up to 20 meters in diameter. Drone surveys and available aerial photographs are used to map and digitize the reach morphology, boulder size and boulder concentration. A preliminary analysis reveals an increase of channel width with higher boulder concentration. Our modeling framework could be consequential for the evolution of bedrock channel morphology in response to intense environmental events, such as landslides and rockfalls.