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Measurement of bedrock erosion by debris flows

L. Hsu and W.E. Dietrich

Department of Earth & Planetary Science, University of California, Berkeley, CA 94720 (Lhsu@eps.berkeley.edu)

Field and laboratory observations suggest that in debris flows, energetic collisions of large grains can cause erosion of the bed. On steep slopes, where debris flows are dominant, this wear may be the primary means of incising the channels. No process-based theory for bedrock incision by such flows exists, and the infrequency of such events makes them impractical to study in the field. We explore the relationship between wear rate of synthetic bedrock and collisional stresses in granular flows with laboratory experiments in a 60 cm diameter, 15 cm wide vertically rotating (horizontal axis) drum. The composition of the flow consists of varying amounts of gravel, water, and fines, from dry granular flows to muddy slurries. For no-slip conditions, the wear appears to occur at the front of the flow, when the faster-moving surface particles overtake the flow front and impact the bed. Erosion is obtained by differencing the initial and final mass of the imbedded erodible rock sample. The collisional stresses are approximated by a function of the mean grain diameter and the shear rate of the flow. The shear rate is estimated from the difference between the surface and bottom velocities of the flow divided by the flow depth.

We observe that erosion rate increases with higher shear rates and larger grain diameters. Small grain diameters with high shear rates and large grain diameters with low shear rates produce similar amounts of erosion, implying that neither factor overwhelms the other. Water-saturated flows produced greater erosion than dry granular flows, which may be a consequence of slight sliding at the bed. The strength of the erodible "bedrock" material is controlled by the cement to silica sand ratio, and erosion rate appears to be inversely related to this ratio. Experiments with observable slip at the bed have a lower shear rate, but high erosion rates. To explore this further, we vary boundary roughness which affects the amount of sliding that occurs at the bed of the flow. Our results suggest that for no-slip conditions at the base, inertial stresses,

which scale with shear rate and grain diameter, are correlated with erosion. However, sliding at the base of the flow will increase the amount of wear. Consequently, bed roughness and its effect on bottom slip significantly affects bedrock wear. Bedrock and concrete check dams show fractures and missing blocks when repeatedly inundated by debris flows. Thus, field observations reinforce the theory that impact forces at the base of the flow cause significant wear. Results from these experiments could be used to guide a modeling approach to stresses at the base of debris flows.