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A mechanistic model for bedrock undercut from saltating bedload particle impacts

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Bedrock walls can be undercut by saltating bedload particle impacts that are deflected by alluvial cover. Continued undercutting of the lower wall creates an imbalance on the wall and may cause the upper part to collapse and to widen the whole channel. Compared with vertical erosion rates, less is known about lateral erosion (undercutting) rates that are thought to dominate when river beds are alluviated. Here, we derive an analytical model for lateral erosion by saltating bedload particle impacts. The analytical model is a simplification of the Li et al. (2020) numerical model of the same process. The analytical model predicts a nonlinear dependence of lateral erosion rate on sediment supply, shear stress and grain size, revealing the same behaviour observed in the numerical model, but without tracking particle movements through time and space. The analytical model considers both uniformly distributed cover and patchy partial cover that is implemented with a fully alluviated patch along one bank and a bare bedrock along the other. The model predicts that lateral erosion rate peaks when the bed is ~70% covered for uniformly distributed alluvium and when the bed is fully covered for patchy alluvium. Vertical erosion dominates over lateral erosion for ~75% and >90% of sediment supply and transport conditions for uniformly distributed cover and patchy cover, respectively. We use the model to derive a phase diagram of channel responses (steepening, flattening, narrowing, widening) for various combinations of transport stage and relative sediment supply. Application of our model to Boulder Creek, CA captures the observed channel widening in response to increased sediment supply and steepening in response to larger grain size.