Some title about abrasion and landscape evolution

Vanessa Gabel1, 2 and Gregory E. Tucker1, 2

1Cooperative Institute for Research in Environmental Sciences

2Department of Geological Sciences, University of Colorado, Boulder

**Abstract**

**Introduction**

Sediment is a key component of eroding landscapes. Sediment generation and transport influence the geometry and erosional efficiency of the fluvial network, which in turn sets the timescales over which tectonic and climatic signals are propagated throughout the landscape (e.g., Sklar and Dietrich 1998). Coarse sediment, which is transported as bedload in rivers, influences the slope, concavity, and elevation of river channels (Duvall et al, 2004, Johnson et al., 2009, Lai et al., 2021, Gabel et al., 2023). Bedload also influences a river’s erosional efficiency through the “tools and cover” effect (Gilbert, 1877, Sklar and Dietrich, 2001), and transport of bedload material can consume a significant fraction of a river’s total energy budget, reducing the amount of stream power available to bedrock erosional processes (Sklar and Dietrich, 2006). A thorough understanding of the controls on bedload transport rate is therefore critical to landscape evolution modeling.

Bedload transport rates in rivers are controlled by both channel hydraulic geometry (width, depth, and slope) and physical properties of the sediment itself, such as density (Pfeiffer et al., 2022) and abradability (Dingle et al., 2017, Attal and Lavé, 2006, 2009). Sediment abrasion not only bears on the mass of bedload sediment moving through a river system, there is also emerging evidence that abrasion may be a key factor in producing channel concavity (Wickert and Schildgen, 2019, Gabel et al., 2023). Additionally, sediment abradability dictates the lengthscale over which sediment delivered to the channel persists as bedload during downstream transport. Coarse sediment that is highly resistant to abrasion is very persistent as bedload, meaning that its transport consumes energy in the river system (through the partitioning of bed shear stress) for longer distances when compared with softer, more abradable sediments. This directly bears on the efficiency with which the river in question is able to erode bedrock, and thus sediment abrasion is a key process to examine in landscape evolution studies that seek to understand the variables that set landscape relief and the factors that contribute to the longevity of high elevations in actively eroding landscapes.

**Background**

Landscape evolution models that are primarily concerned with the study of erosional landscapes may not include specific sediment fluxes at all; those that do often do so in terms of a time-averaged bulk flux, as opposed to an instantaneous flux that can dynamically influence system behavior. Moreover, sediment flux is typically calculated with a linear dependence on drainage area, which implies that sediment transport rate can grow indefinitely with basins of increasing size (e.g., Shobe et al., 2017, Wickert and Schildgen, 2019).

Despite this simple treatment, field observations, experiments, and numerical models that account for sediment abrasion point to something different: bedload does not increase indefinitely. Field studies from the Himalaya, while they do not explicitly measure bedload transport, bear out the reality that sediment abrasion drastically modifies bedload by tracking the fraction and composition of gravel load reaching the outlet of basins of different sizes; larger basins export a smaller fraction of their total sediment load as gravel (Attal and Lavé, 2006, Dingle et al., 2017). Laboratory experiments corroborate this observation and have demonstrated that bedload transport rate reaches an asymptote where bedload transport rate no longer increases with the distance traveled by grains in a flume (a proxy for drainage area) (Attal and Lavé, 2009). These experiments also offer insight into the length scales required to reach asymptotic bedload transport rates under conditions of heterogeneous sediment mixtures. Numerical models that treat abrasion as a fraction of bedload mass lost per kilometer are able to produce a plateau in bedload transport rate (Gabel et al., 2023). And field studies that have examined other aspects of the fluvial system, such as grain size measurements or calculations of bedload shear stress, may bear out a similar story of abrasion’s influence on bedload even when demonstrating as much was not the primary intention of the work (e.g., Pitlick and Cress, 2002, Langston and Temme, 2019).

While the importance of abrasion in modifying characteristics of bedload sediment has been demonstrated and acknowledged in previous studies, and possible influence on larger landscape features has been speculated upon (e.g., Attal and Lavé, 2009) we have yet to rigorously demonstrate how abrasion bears on river profile development, particularly in river systems that are both “transport-limited” and “bedrock-incising.” Here we will explore the consequences of diminishing bedload relative to drainage area in such a river system.

**Approach and Scope**

Here we apply a one-dimensional model that captures steady state fluvial forms to examine how features such as channel relief and concavity are impacted under different sediment abrasion regimes. We build upon a previously published model by incorporating multiple classes of sediment abradability. The model used in this study applies to gravel-bed rivers with channel geometries consistent with many alluvial rivers, but that also accomplish bedrock erosion; a full description of the model and its limitations can be found in Gabel et al., 2023. We aim to test the sensitivity of channel profiles to the effects of abrasion modifying bedload and describe the impacts of sediment abrasion on landscape evolution.