Progress in the morphodynamics of bedrock-alluvial rivers

Peter A. Nelson
Department of Civil and Environmental Engineering, University of Genoa, Italy

Bedrock rivers link climate, tectonics, and topography, and drive landscape evolution. Sediment in bedrock channels plays a major role in their dynamics, because bedrock abrasion due to impacts from saltating bedload particles is an important, and sometimes dominant, erosive mechanism. However, because bedrock channels are characterized by conditions where sediment supply is less than the channel's transport capacity, morphodynamic theory that has provided valuable insights on alluvial rivers cannot readily be applied to bedrock systems.

Here I present some recent work aimed at improving our ability to model and understand the morphodynamics of bedrock rivers, particularly the effects of sediment on channel evolution. First, I present a model in which the cross-sectional shape of a bedrock channel evolves in response to abrasion from saltating bedload particles. The model captures the so-called "tools" and "cover" effects, and it simulates the dynamics between sediment supply and channel shape previously observed in experiments. I then present a theoretical framework for the morphodynamics of bedrock-alluvial channels that overcomes the restrictive assumption of sufficient sediment supply by reformulating the sediment continuity equation to account for temporal changes in the areal concentration of sediment on nonalluviated surfaces. As a first example of the utility of this theoretical framework, I present a linear stability analysis that shows that an initially uniform distribution of sediment cover on a flat bedrock surface is unstable to small perturbations. This suggests that sediment cover in bedrock channels tends to concentrate into regions that may eventually be alluviated, in general agreement with experimental observations. Finally, I present some recent theoretical work aimed at understanding finite amplitude bars in mixed bedrock-alluvial channels, in which we predict flow and bed topography in a wide channel of constant curvature that is underlain by bedrock. Our results indicate that because the presence of bedrock limits the maximum scour depth, the average slope in the channel bend and the relative height of the alluvial bar are larger and smaller, respectively, than the analogous fully-alluvial case.