Geophysical Research Abstracts, Vol. 7, 03848, 2005
SRef-ID: 1607-7962/gra/EGU05-A-03848

Sediment cover and lithologic feedbacks in bedrock channels and canyons

J. Johnson (1), J. Farrow (2), K. Whipple (1), L. Sklar (2)

(1) Massachusetts Institute of Technology, MA, USA, (2) San Francisco State University, CA, USA

We present field and laboratory data that constrain how sediment cover and bedrock properties mediate channel incision into landscapes. In the Henry Mountains, Utah, USA, spatial variations in coarse sediment in different channels lead to different slope-area scaling for channel reaches incised through the same rock units, with boulder-rich bedrock channels cut to slopes steeper than channels with less coarse sediment and more exposed bedrock. When coarse sediment is locally sourced from valley side-walls, the coupling between channels and valleys can lead to counterintuitive relations between bedrock lithology and channel morphology. Collectively, these results suggest that, to capture the dynamics of channel erosion in this landscape, bedrock incision models require a sediment cover term.

Mixed bedrock-alluvial channels and canyons draining the Henry Mountains are ideal for unraveling the interconnected controls of sediment flux and bedrock properties on fluvial incision into bedrock because (1) sediment types vary systematically in different channels, with extreme differences in the durability and size distribution of sediment, and (2) channels incise through a range of bedrock lithologies with widely varying physical properties. Durable intrusive rock (diorite) forms the cores of the Henry Mountains. Sedimentary units surround the central peaks, primarily alternating between sandstones and mudstones. The spatial distribution of diorite bedrock (as well as diorite boulders stored in some pediment covers and fill terraces) results in varying amounts of coarse (large boulder to gravel), resistant diorite sediment in different channels. In contrast, the sedimentary bedrock lithologies of the landscape weather to form a wide range of sediment sizes, especially sand. Laboratory measurements of tensile strength and clast abrasion rates due to transport show that the sedimentary units (e.g. Navajo sandstone, tensile strength ~0.25 MPa) are measureably weaker and much more erodible than the diorite (tensile strength ˜13 MPa). Specific erosional forms (e.g. inner channels, scoops, potholes) observed in the field are similar in morphology, and sometimes in scale, to those we have formed experimentally in laboratory flumes.

Continuous field surveys quantify how sediment type, abundance, size distribution and bedrock exposure vary with local channel slope and morphology; we exploit these differences to constrain the importance of sediment cover on bedrock channel incision. Bedrock channels that contain abundant coarse diorite sediment tend to have significantly steeper slopes than adjacent channels with less diorite sediment. Downcutting is probably limited in these diorite-rich channels because the channels need to maintain a steep slope in order to transport the size distribution and flux of coarse sediment down the channel–i.e., we interpret the bedrock channel slope to be the transport slope required to move the diorite clasts. In contrast, adjacent channels with less diorite sediment are usually further incised (into identical bedrock lithologies) and have lower reach-averaged slopes, but also have more local slope variability which may reflect variations in bedrock properties.

Large boulders can also be locally derived from valley sidewalls, resulting sometimes in interesting feedbacks between channel slope, bedrock lithology and canyon width. Lithologically controlled valley widening amplifies the importance of local hillslope sedimentation and bed cover, while narrow canyons tend to decouple channels from hillslopes and local sediment supply. For example, at a particular lithologic contact (Wingate sandstone above, Chinle mudstone below) channel slopes usually increase through the weaker mudstone unit, in contrast to the conventional (stream power) wisdom that channel slope should decrease over a weaker lithology. However, valley (canyon) width increases once the lower mudstone is exposed because the stronger upper unit is undermined by some combination of hillslope erosion and lateral channel migration in the weaker mudstone. This in turn dumps resistant colluvial boulders directly into the channel and armors the bed. The consistency of oversteepening at this contact in many channels suggests that it is a lithologic feedback on channel downcutting rather than being a simple migrating wave of incision. Our data suggest that, in this landscape, the abundance and distribution of coarse sediment has significantly mediated the incision of individual bedrock channel reaches.