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Incision of the Colorado River in southern Utah – insights from channel profiles, local incision rates, and modeling of lithologic controls

K. Cook (1,2), K. Whipple (3), and A Heimsath (3)

(1) Department of Geosciences, National Taiwan University, Taipei Taiwan (klcook@ntu.edu.tw), (2) Department of Earth, Atmospheric, and Planetary Sciences, MIT, Cambridge, MA USA, (3) School of Earth and Space Exploration, Arizona State University, Tempe, AZ USA

The Colorado River and its tributaries in southern Utah and northern Arizona provide an opportunity to study the propagation of bedrock incision through a large heterogeneous fluvial network, as the system is continuing to adjust to the baselevel fall responsible for the Grand Canyon. Although the carving of the Grand Canyon was largely complete by ~1 Ma, the canyon ends at Lee's Ferry and the incision history of Colorado River system upstream of the associated large knickpoint has been the subject of debate. In conjunction with existing incision rate estimates based on the dating of strath terraces, we use longitudinal profiles of the Colorado and tributaries between Marble Canyon and Cataract Canyon to investigate the incision history of the Colorado in this region. We find that all but two of the tributaries in this region steepen as they enter the Colorado River. The consistent presence of oversteepened reaches with similar elevation drops in the lower section of these channels, and their coincidence within a corridor of high local relief along the Colorado, suggest that the tributaries are steepening in response to an episode of increased incision rate on the Colorado River. This analysis is supported by available incision rate data, as the spatial distribution of incision rates predicted by the channel profiles is consistent with existing rate estimates.

The two analyzed tributaries that show no evidence for this incision pulse, Trachyte Creek and Bullfrog Creek, have smoothly concave profiles and do not contain knickpoints. In order to evaluate the significance of these anomalous channel profiles, we measure in situ 10Be concentrations on four gravel-covered strath surfaces elevated from 1 m to 110 m above Trachyte Creek. The surfaces yield exposure ages that range from approximately 2.5 ka to 267 ka and suggest incision rates that vary between 350 and 600 m/my. These incision rates are similar to other rates determined within the high-relief corridor, and suggest that despite the lack of knickpoints in their long profiles, Trachyte and Bullfrog Creeks are also responding to the increase in incision rate on the Colorado. Sustained high incision rates combined with a smoothly concave profile suggest that these channels are responding in a continuous, transport-limited manner, perhaps driven by the combination of extremely durable diorite sediment and weak, easily abraded bedrock found in the channels of the Henry Mountains.

Finally, we use a simple numerical model of detachment-limited bedrock incision to investigate the relationship between the large convexity in the Colorado River at Lee's Ferry and the incision we observe farther upstream. Model results suggest that the pulse of incision we observe may be related to the interaction between the propagation of headward incision through the Grand Canyon and the presence of an upstream-dipping lithologic boundary at Lee's Ferry. This suggests that the large knickpoint at Lee's Ferry is neither the upstream extent of Grand Canyon incision nor solely related to lithology, but instead results from a combination of lithologic and transient effects.