Exhumation and Landscape Evolution along the Colorado River: A Proposed Means of Differentiating the Roles of Baselevel Fall and Lithologic Heterogeneity

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Abstract

Exhumation and Landscape Evolution along the Colorado River: A Proposed Means of Differentiating the Roles of Baselevel Fall and Lithologic Heterogeneity Varied lithology and complex base-level history are important factors controlling the evolution of the Colorado Plateau landscape. Steep-walled, high-relief canyons inset into low relief surfaces attest to relief production, with volcanic deposits and cosmogenic nuclides in sediments suggesting rates are higher within canyons than on plateau surfaces. Neogene acceleration in the rate of baselevel fall in response to integration of the Colorado River across the Grand Wash Cliffs and recent rock uplift may be responsible for the landscape non-equilibrium. Alternatively, a longer history of baselevel fall and long-lived relief is possible. A reconstructed 30 Ma paleosurface implies uniform incision of ~1.5 km on the Colorado River across the plateau since that time (others have suggested much of this is post 10 Ma). Thermochronologic data suggest substantial relief in the vicinity of Grand Canyon into the Miocene. A steady baselevel fall in the presence of pronounced lithologic heterogeneity (weak rocks over stronger rocks) provides a plausible explanation for non-equilibrium erosion and more recent relief production. As such, it is possible the transition from weaker to harder sedimentary rocks is the cause of the nonequilibrium erosion along tributaries. However, the lithologic heterogeneity will be expressed in the landscape whether or not baselevel fall rate accelerated. Topographically, this transition is indistinguishable from continuous baselevel fall through variable rock strength, because increase in baselevel drop is transmitted via discrete upstream-migrating knickpoints that can have the same form as knickpoints caused by the rock-type transition. Fortunately, there is a diagnostic difference expected in the patterns of erosion rates across the landscape. Naturally, in the case of accelerated baselevel fall, erosion rates everywhere upstream of the canyon rims should be slower than within the canyons. Although this suggests a trivial test looking for a change in erosion rates across knickpoints, the problem is not so easy because both scenarios describe transient landscapes in a state of relief production - erosion rates are expected to differ across knickpoints in either case. However, in the case of steady mainstem baselevel fall, slower erosion rates upstream of knickpoints result from the stable local baselevel formed by the lithologicaly-controlled canyon rim and are limited to the bench cut on the resistant caprock immediately surrounding the canyon. Farther upstream in headwater catchments where the caprock has not been exposed, erosion rates should match inner canyon rates. Thus the diagnostic test is the contrast between canyon and headwater erosion rates, which can be determined from cosmogenic 10-Be concentrations in strategically sampled fluvial sediments. If corrected for variability in quartz distribution and nuclide production rate, these data can be used to test between these alternative hypotheses for the history of baselevel fall.

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