River canyon evolution governed by autogenic channel-hillslope feedbacks

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Abstract
Geologists frequently debate the origin of iconic river canyons, as well as the extent to which river canyons record climatic and tectonic signals. Fluvid and hillslope processes work in concert to control canyon evolution; rivers both set the boundary conditions for adjoining hillslopes and respond to delivery of hillslope-derived sediment. But what happens when canyon walls deliver boulders that are too large for a river to carry? Large blocks of rock derived from resistant hillslope strata have recently been shown to control the evolution of canyons by inhibiting sediment transport and bedrock erosion. Here we present Blocklab, a 2-D model within the Landlab modeling toolkit that uses a hybrid discrete-continuum framework to track block transport throughout a river-canyon landscape in horizontally layered rock. Our model reveals that internal negative channel-hillslope feedbacks control erosion dynamics and result in characteristic planview and cross-sectional river-canyon forms. Surprisingly, while the presence of blocks in the channel initially slows incision rates, the subsequent removal of blocks from the oversteepened channel substantially increases incision rates. This interplay between channel and hillslope dynamics results in highly variable long-term erosion rates. These autogenic feedbacks can mask external signals, such as changes in rock uplift rate, complicating the interpretation of landscape morphology and erosion histories.

For more info

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