Out of equilibrium sinuosity: The development of incised meandering channels in response to base-level fall

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Meandering rivers and valleys are dominant landscape features on Earth and Mars, and central to a geomorphological debate: do sinuous channels actively develop during steepening of regional slope or whether they inherited the sinuosity of an ancient meandering channel through vertical incision? This and related questions were studied by field-scale case studies of channel evolution, numerical simulations, and physical laboratory experiments. Here, we document and investigate decadal- and field-scale formation of meandering valleys in perennial channels. These channels have incised into a homogeneous erodible substrate in response to the progressive Dead Sea level fall in recent decades (>30 m over 40 years). This unique study area enabled analysis of three clusters of adjacent elongating and incising channels with stable confined discharge, that evolved through an active increase in regional and channel slopes. The emerged slopes greatly vary along the study area and channels, allowing the test of slope impact under three primary settings: (a) relatively long and low gradients on shelf-like margins, (b) sharp basinward gradient increase on a shelf-slope transition, and (c) steepening slopes. These clusters triggered different channel and valley response by means of stream incision depth, channel sinuosity, and valley width. The sinuosity of the channels was actively increased only following steepening in the valley slope. During stable valley slope, the channels were mainly incising vertically, inheriting previous sinuous pattern. The highest sinuosity was developed in the channel within the most steepening slope, that was also developed the deepest and widest valley. Together with the Jordan River response to the same Dead Sea level fall in recent decades, these insights promote the interpretations regarding the evolution of incised meandering channels under changes in regional slope. Abundant evidence for chute cutoffs along an incised channel can imply that frequent overbank floods prevailed in the channel during the incision, whereas the absence of or rare evidence for such cutoffs can be the result of infrequent, high-magnitude floods during the evolution.