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Characterising river response to active normal faulting: from transient landscape to topographic steady state.

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Characterising the transient dynamics of fluvial systems to tectonic or climatic forcing remains an outstanding challenge in the field of geomorphology. In principle, it should give insight into long term fluvial erosion processes, and is vital in order to calibrate the sensitivity of landscape to changing boundary conditions. Unfortunately, recent numerical and field attempts to do this have generally met with limited success; firstly because many landscape models rely either explicitly or implicitly on the assumptions of topographic steady-state, and secondly because there are few data sets which clearly identify fluvially-mediated landscapes under transient conditions. Largely this is because there is little agreement on what constitutes diagnostic field criteria for identifying transience in landscape, and the timescale over which these perturbations last. We address this issue using detailed field data of channel morphology, valley width and grain size for bedrock rivers crossing well-constrained active normal faults in Central Italy which differ in their rate, history and spatial distribution of uplift. We identify channels in three distinct tectonic settings; **(i)** block uplift; constant slip rate for 3 Ma; **(ii)** back-tilted fault block; constant slip rate for 3 Ma and **(iii)** back-tilted fault block; increase in slip rate at 0.75 Ma, and for each of these cases evaluate the extent to which downstream changes in unit stream power correlate with footwall uplift.

We are able to identify unambiguously rivers undergoing a transient response to tectonics and we demonstrate that the diagnostic criteria of this signal include (a) significant long-profile convexities (over-steepened reaches) which scale with the magnitude of the slip-rate increase, (b) a loss of hydraulic scaling, (c) channel aspect ratios which are a strong non-linear function of slope, (d) elevated coarse-fraction grain-sizes and (e) reduced downstream variability in channel planform geometry. We are also able to distinguish between channels in hydraulic energy equilibrium and topographic steady state and show that the latter are characterised by good hydraulic scaling, but significant valley narrowing in the zone of maximum uplift. The results challenge the application of steady-state paradigms to transient settings and show that assumptions of power-law width scaling are inappropriate for rivers which have not reached topographic steady state, whatever exponent is used. Finally by comparing these cases, we evaluate the likely evolution of bedrock channels under-going a transient response to fault acceleration and determine how transient conditions decay to topographic steady state. In particular we demonstrate that detachment-limited channels are vulnerable to headwater beheading if the rate of over-steepened reach migration is low, and that this acts to limit response timescales. We estimate that the period to eliminate long-profile convexity for these channels is $\sim$1Ma, and that good hydraulic scaling is regained within 3Ma for channels approaching the detachment-limited end member.