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Quantifying the transient response of bedrock channels to active normal faulting: new field observations

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Understanding the morphological response of the fluvial system to transient tectonic forcing is one of the major challenges facing quantitative geomorphology. In theory, insight gained from studying channel adjustment to changing tectonic rates should provide clear diagnostic tests of the many competing 'erosion laws' which aim to quantify stream incision. However, fluvial algorithms in current landscape models tend to be parameterised in terms of hydraulic scaling relationships, which only describe channel width and depth as power-law functions of river discharge or upstream drainage area. Unfortunately, these scaling relationships, which have been derived from channels in tectonically quiescent areas, are not appropriate for bedrock rivers in active settings. This problem is serious for understanding non-equilibrium systems because hydraulic adjustments are an important aspect of the morphodynamic response to tectonic and climatic forcing. Recent theoretical attempts to resolve this issue still rely fundamentally on assumptions of steady-state channel form. To devise an alternative approach we need to collect geometrical data for channels incising in areas where the boundary conditions are well-constrained independently.

We address this challenge by providing new and detailed field measurements of valley and bankfull channel width, depth, slope and grain-size data for an out-of-equilibrium channel with a drainage area of 65km^2 crossing an active extensional fault near Fiamignano, Italy, where there are excellent constraints on current rates of fault movement, and good evidence for an increase in throw-rate approximately 700 Kyr ago. We

show that in this situation channel width becomes strongly decoupled from drainage area immediately upstream of the fault and that channel aspect ratio and median grain-size are correlated with channel slope. The ratio of total stream power to coarse-fraction grain size peaks in precisely the areas where channel width-discharge scaling breaks down, implying that this is not merely a function of high substrate resistance. Moreover, values of unit stream power near the fault, calculated using measured bank-full widths, are four to five times higher than estimates using widths predicted from discharge scaling alone, and imply incision rates that are comparable to the known footwall uplift rate. Finally we compare the above results with channel geometry data for rivers crossing faults in the same area, which have been moving at a constant slip rate for up to 3 million years and display typical concave-up equilibrium profiles. We demonstrate that these channels do not show the same systematic variations in hydraulic geometry that we observe in the Fiamignano basin.