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Quantifying the slip-rates, spatial distribution and evolution of active normal faults from geomorphic analysis: Field examples from an oblique-extensional graben, Southern Turkey

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Quantifying the extent to which geomorphic features can be used to extract tectonic signals is a key challenge in the Earth Sciences. Here we analyse the drainage patterns, geomorphic impact and long profiles of bedrock rivers that drain across and around normal faults in a regionally significant oblique-extensional graben in Southern Turkey that has been mapped geologically, but for which there are poor constraints on the activity, slip-rates and Plio-Pleistocene evolution of basin-bounding faults. We show that drainage in the graben is strongly asymmetric, and by mapping the distribution of wind-gaps we are able to evaluate how the drainage network has evolved through time. By comparing the presence, size and distribution of long profile convexities, we demonstrate that the northern margin of the graben is tectonically quiescent, whereas the southern margin is bounded by active faults. Our analysis suggests that rivers crossing these latter faults are undergoing a transient response to on-going tectonic uplift, and this interpretation is supported by classic signals of transience such as gorge formation and hill-slope rejuvenation within the convex reach. Additionally, we show that the height of long profile convexities varies systematically along the strike of the southern margin faults, and we argue that this effect is best explained if fault linkage has led to an increase in throw rate on the faults through time. By measuring the average length of the original fault segments, we estimate the throw rate enhancement along the faults, and thus calculate the range of times for which fault acceleration could have occurred, given geological estimates of fault throw. These values are compared with the times and slip-rates required to grow the documented long-profile convexities enabling us to quantify both the present-day slip-rate on the fault and the timing of fault acceleration. Our results have substantial implications for predicting earthquake hazard in this densely populated area, enable us to constrain the tectonic evolution of the graben through time, and more widely, demonstrate that geomorphic analysis can be used as an effective tool for estimating fault slip rates over time periods $> 10^6$ years, even in the absence of direct geodetic constraints.