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From river long profiles to fault slip rates; case studies from Central Greece

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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 and river long profiles of bedrock rivers that drain across and around normal faults in central Greece to determine fault throw rates and the timing of fault interaction and linkage in the area. We demonstrate that rivers draining the Sperchios fault zone and northern gulf of Evia often have two sets of knickpoints upstream of the active fault segments. The upper set of knickpoints have vertical elevations (measured upstream of the fault) that vary systematically along strike and that match the footwall relief. The lower set of knickpoints also have vertical elevations that follow the pattern of footwall relief, being lowest at the fault tips and greatest in the centre of the active faults. Because the knickpoints do not correlate with lithological boundaries, we interpret them as the transient response of the fluvial system to on-going faulting. The upper set of knickpoints we interpret to reflect fault initiation, and the lower set of knickpoints we interpret to reflect a younger slip rate increase as the basin-bounding faults interacted and linked. The ratio of normalised steepness index upstream and downstream of the lower knickpoints for each of the fault systems suggest a throw rate enhancement factor of at least a factor of 4, assuming that uplift rates are linearly proportional to normalised steepness index. These values are also in agreement with throw rate enhancement factors estimated independently by considering the length of original mapped fault segments compared to the present length of through-going faults in the area. Using these enhancement factor estimates, we calculate the range of times for which fault acceleration could have occurred, given geological estimates of footwall relief and fault throw. The derived values are then compared with the times and throw rates required to grow knickpoints with the documented vertical elevations upstream of the fault, enabling us to estimate both present day slip-rates and the timing of fault interaction and linkage. Additionally, our results suggest that landscape response times to active faulting in this area are substantially greater than 1 My. More widely, these findings have substantial implications for predicting earthquake hazard in this densely populated area, and demonstrate that geomorphic analysis can be used as an effective tool for estimating tectonic rates over million year time periods, even in the absence of direct geodetic constraints.