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Where does sediment come from? Characterising the links between catchment erosion and sediment export in tectonically perturbed landscapes

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Sediment routing systems represent the entire integrated erosion–transport-depositional system from source to sink. The depositional characteristics of any basin fill (the sink) are fundamentally a product of the coupled system of sediment release from hinterland catchments (the source) and its evolution during transport downstream. Changes to the tectonic (and climatic) boundary conditions governing the dynamics of both erosion and sediment transport should therefore determine the locus, nature and magnitude of sediment supply to neighbouring basins.While recent advances in tectonic geomorphology demonstrate the clear coupling between tectonic uplift and landscape denudation, there has been relatively little work characterising when and how sediment is released from tectonically-forced upland catchments and the way in which this supply is subsequently ‘sampled’ downstream by the fluvial system. This is unfortunate because a full understanding of the temporal and spatial behaviour of sediment routing systems raises the prospect of developing predictive models of basin stratigraphy in terms of differing conditions of hinterland tectonics and transport variables.

We address this challenge by exploring the extent to which sediment release in upland catchments can be expressed as a probability density function (pdf) of grain-size and volume characteristics, and we explore how such pdfs vary as a function of tectonic forcing. We demonstrate that catchments undergoing a transient response to active normal faulting show a significant increase in the capacity of the fluvial system to

both incise bedrock and transport sediment, and that this effect is associated with large volumetric export of material to the neighbouring basin over time periods of 10^6 years. Moreover, as the tectonically-induced wave of incision propagates upstream, we show that this transient effect determines the calibre of sediment in transport, producing bi-modal grain-size distributions with elevated D_{84} values within the transient reach. This is in direct contrast to the headwaters of these catchments, where the fluvial capacity to transport sediment is low, and the grain-size distribution of material in transit is mono-modal, with D_{50} typically < 4 cm. We also evaluate the length-scale over which this transient grain-size signal propagates downstream into the basin, and we show that the coarse-fraction sediment released is likely to be retained in the proximal hanging-wall if rates of tectonic subsidence are high, and if the axial river system is small, or far from the fault-bounded mountain front. Our results challenge the idea that basin sediment is sourced uniformly from upstream catchments in either space or time, demonstrate that sediment release is highly sensitive to tectonic and transport variables, and show that recent advances in our understanding of landscape dynamics ought to be incorporated more readily within the fields of sedimentology and stratigraphy.