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Controls on the behaviour of sediment routing systems using a mass balance approach

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Sediment routing systems link source regions undergoing erosion with depositional sinks and involve a volumetric or mass budget. Understanding how these source-to-sink systems function is key to stratigraphic prediction, but estimation of their surface sediment discharges and depositional fluxes on geological time scales is a challenging problem. Moreover, resolving the extent to which tectono-climatic boundary conditions determine the temporal and spatial distribution of sediment characteristics remains contentious. In particular the rate of down-system fining of grain size, percentages of grain size fractions in preserved stratigraphy, position of moving boundaries, and evolution of gross depositional environments can all be related to variations in the volume of sediment supplied, the grain-size mix of the supply, and the spatial distribution of tectonic subsidence generating the accommodation. Deciphering how these factors interact to produce stratigraphy is a key challenge in the Earth Sciences.

Here we compare detailed reconstructions of palaeo-sediment routing systems from the mid-late Eocene Escanilla Formation and its time-equivalents, Spanish Pyrenees, with Mio-Pliocene sediment routing systems draining the Great Plains, Central USA. Rates of grain size fining along time-lines in stratigraphy are reconstructed as a function of down-system distance and cumulative sediment volume in time and space, and are contrasted within a dimensionless mass balance framework that accounts for sediment extraction as a function of sediment volume. Use of a mass-balance framework allows for consistent, quantitative comparison across sediment routing systems of varying scales and shapes. Our results demonstrate that the position of key stratigraphic observables, such as the gravel front and rate of grain size fining, are similarly controlled by mass extraction across systems that differ in size and extent, but that selective extraction of particular size classes (e.g. gravel, sand or fines) is more clearly related to the cumulative volume of that fraction available, rather than the total quantify of sediment supplied.