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Decoding downstream trends in stratigraphic grain-size as a function of tectonic subsidence and sediment supply

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Regional grain-size trends preserved in sedimentary deposits theoretically embed important information on the dynamics of sediment routing systems and their sensitivity to external forcing mechanisms. In simple terms, downstream sediment fining is driven primarily by selective deposition of sediment, and mediated by abrasion of the clasts during transport. However, the relative efficiency of this process is determined by (1) the physical characteristics of the input sediment supply; (2) the spatial distribution of subsidence rate, which generates the accommodation necessary for sediment preservation; (3) the detailed mechanics of sediment transport and deposition. A key challenge is therefore to determine how these first two factors control the calibre and spatial distribution of deposits over timescales of several hundred thousand years without incorporating the details of hydraulics and sediment transport which are largely unknowable for time-averaged stratigraphy in the geological past. One method to solve this problem is to assume self similarity between the long-term, longitudinal grain-size distribution of the substrate and the dimensionless relative mobility function for gravel, using only the local mean and standard deviation of grain-sizes in transport as scaling parameters. In principle, this approach offers a simple means to explore the controls on downstream fining in fluvial deposits, but until now there have been few attempts to test this methodology using fluvial sedimentary successions where we have clear and independently derived constraints on the rates and volumes of sediment deposition through time.

We address this challenge using detailed grain-size data from the Eocene Pobla Basin, Spanish Pyrenees, where the timing of sediment deposition is known from palaeomagnetic and palaeontological dating, the system is closed so mass is conserved, and where good exposure enables time-lines within stratigraphy to be picked out unambiguously. For successive stratigraphic horizons, we derive downstream trends in coarse-fraction grain-size for two basin-filling sediment routing systems with maximum length-scales of 5 and 40 km respectively, using Wolman and photographic point counts, and palaeocurrent data from pebble imbrications and groove casts. These data are compared to the Oligocene Antist Group, a laterally extensive transverse system that drained from the axis of the Pyrenees towards the Ebro basin. Our results show that the rate of grain-size fining varies over time and with depositional length in all three systems, and can only be explained by the changing balance of sediment supply to accommodation generation. We use this well-constrained detailed data set as an input to the selective deposition model, and we therefore assess the extent to which regional grain-size trends can now be decoded for sediment supply and subsidence variables over geological timescales