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Formulation and validation of a mass-balance framework for fluvial successions

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Experimental work suggests the rate of loss of sediment from the earth's surface to permanent storage exerts a fundamental control on fluvial style, and so on fluvial stratigraphy. Since the rate of sediment loss and sediment calibre is principally controlled by three key parameters over geological timescales (spatial distribution of tectonic subsidence, sediment supply characteristics, rate of sediment supply), we can conclude that grain size characteristics and proportions of sedimentary facies at a given down-system location are independent of the length of the fluvial depositional system, and hence the system is fractal, or self-organised. This fractal behaviour provides an important link between modern processes and ancient sediments. Thus, with careful examination, fluvial successions present us with a time-integrated picture of the pattern of upstream-to-downstream sediment loss, and so of the interplay of tectonic subsidence and sediment supply. This concept could be a powerful and practical tool for field scientists and its validation will allow regional-scale predictions of outcrop and subsurface fluvial architecture, and the decoding of past forcing mechanisms from fluvial architecture. Preliminary results of detailed grain size data show that there is no downstream fining of any particular facies within the Castlegate, but that the proportion of facies changes systematically from upstream to downstream to accommodate the overall fining trend. Therefore, in the first instance, it is reasonable to use facies proportions to characterise downstream changes in grain size, and so as a potential measure of sediment loss downstream. We develop a theoretical and empirical framework to describe this behaviour.

Our current work is focussed on testing and validating this laboratory-derived concept via analysis of several fluvial successions for which independent estimates of the spatial distribution of tectonic subsidence and sediment supply are well constrained. We present work in progress on three stratigraphic units: the Organ Rock Formation (Permian Paradox Basin, Utah, USA), Blackhawk Formation & Castlegate Sandstone (Upper Cretaceous Western Interior Basin, Utah, USA) and Escanilla Formation (Eocene, Tremp-Ainsa Basins, Spain). The reasons for choosing these units as ancient test cases is: (1) their excellent exposure over upstream-to-downstream distances of up to 200 km, (2) they are the product of sandy braided fluvial systems, analogous to the laboratory experiments where this behaviour was first recognised; (3) they are well dated, so providing time-averaged estimates of the spatial distribution of deposition; and (4) sediment supply characteristics for each of the units can be constrained to a reasonable level. Each unit is adjusted to the prevailing tectonic and climatic boundary conditions at the time of deposition, and thus in combination they provide a sound real-world test of theory and experiments. The Blackhawk Formation, Castlegate Sandstone and Escanilla Formation pass down-dip into coeval shallow-marine deposits, such that sediment transfer between coupled fluvial and shallow marine systems can potentially be assessed.