Geophysical Research Abstracts
Vol. 13, EGU2011-13677, 2011
EGU General Assembly 2011

Volume balance model for dispersal of particulate sediment in geological source-to-sink systems

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The treatment of the transfer of mass at the Earth's surface, from source to sink, as a bulk diffusive process over geological time scales permits the reconstruction of ancient sediment discharges from mountainous source areas and promotes an understanding of the tectonic and climatic driving mechanisms for long-term landscape dynamics. The slope-related sediment discharge from mountain catchments is estimated using a bulk diffusivity based on the length of fluvial concentrative flow. The sediment supply is delivered to depositional basins with spatial distributions of tectonically generated accommodation, which allows solutions of a 2-dimensional volumetric sediment budget for combinations of sediment discharge, depositional length and accommodation. The diffusion model is therefore dominated by parameters that can be constrained by geological datasets derived from sedimentary isopachs, thermochronology, and position of grain-size fronts in the depositional basin, as well as being informed by a range of provenance tools employed to make confident connections between source and sink.

The diffusion theory quantitatively links key properties of ancient sediment routing systems, and promotes an improved understanding of the teleconnections within sediment routing systems under changing tectonic and climatic forcing. It also provides vital input to models of the downstream fining of particulate sediment, thereby promoting the use of granulometric trends in basin analysis.

When applied to geological examples in the Pobla Basin of the south-central unit of the southern Pyrenees (deposited 42-27 millions of years ago), we recognize different types of sediment routing system ranging from small, middle Eocene fans with clasts derived primarily from local carbonate rock sources, filling small, tectonically active wedge-top basins, to an extensive, coalescing, gravel 'drape' of Oligocene age with clasts derived from catchments eroding back to the main drainage divide, built by transverse flow across the entire wedge-top zone. These different sediment routing systems in the Pobla Basin exhibit variations in their sediment budget over time that can be linked to the changing tectonic and topographic history through the mid Eocene to Oligocene interval, but climatic variations cannot be deciphered over the time scale investigated (15 Myr).