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Stochastic transport of pebbles in a Chilean canyon over millennia revealed by 10Be and a simple transport model

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The transport of coarse sediment (gravel to boulders) determines the morphology of alluvial rivers, the incision of bedrock rivers, the rate of propagation of tectonic and climatic sedimentary pulses from the mountains to the foreland basins. The transport of individual grains has been studied in experimental devices or by tracing tagged pebbles in rivers over several years. Over millennia, an advection-diffusion equation is usually used to predict the dynamics of coarse sediment in basins. Yet, there is no data describing the pebble dynamics over such long periods. Here we use 10Be in distinct grains [1-60 cm] along a 60 km canyon coming from a localised gneissic source within a catchment in Atacama, Chile. About 30 pebbles were sampled at 9 stations (distances of 15 km). The mean and variance of 10Be concentrations increase downstream. Using a simple model of stochastic transport of pebbles and 10Be acquisition during transport, we show that 1) the downstream 10Be concentration distribution implies that the transport rate of pebbles is weakly but clearly dependent on grain size in average, 2) for a given grain size, the mean transport rates are distributed with a long tail (1 km/yr – 1E-5 km/yr). Using a Monte Carlo approach, we show that the best-fit model of 10Be concentrations implies that an initial population of grains between 1 and 60 cm spread over time following a downstream distribution with a long tail. Consequently, the transport does not follows an advection-diffusion equation and the predicted residence times in this 60 km canyon are distributed as a power-law between several years and more than 50 thousand years These results have broad impacts on the modelling of coarse sediment transport in response to climatic or tectonic changes in fluvial systems.