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Diffusive tendencies in continental slope bathymetry

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Many simulations of continental margin stratigraphy employ the diffusion transport model to represent the dispersal and deposition of sediments, but it is unclear the extent to which sediment transport occurs in the way required by the model, nor are there independent constraints on how the model mobility parameter K might vary. We have therefore carried out a study of continental slope multibeam echo-sounder and seismic reflection data to see whether slope deposits do in fact show the kinds of morphologies expected from a diffusion equation and then to develop ideas for how deposition could occur as required by the model where they do.

SLOPE MORPHOLOGY Many continental slopes incised by gullies and canyons have rounded, smooth inter-canyon divides (interfluves) between channels. For example, the southern Monterey Bay slope, from the shelf break down to below 1000 m depth, has rounded upper canyon walls. The central Atlantic USA slope between Norfolk and Washington canyons has rounded interfluves to 400 m depth, below which interfluves are sharp. These characteristics are interpreted to result from two classes of surface modification processes that oppose each other, leading to rough or smooth topography depending on their relative importance. One set involves sediment movements or varied deposition which smoothes the sediment surface. Another set incises the sediment surface, such as erosion by channelized sedimentary gravity flows and landsliding. The transition with depth from smooth to sharp interfluves for the Atlantic slope then reflects a decline in the importance of smoothing relative to incision. In another area, the northern Californian slope near the Eel River, the along-slope shapes of interfluves between closely spaced gullies are almost exactly parabolic, which is a steady state solution to the diffusion transport. The gully channels converge downslope, forming a dendritic system, so that channels are likely to have experienced sedimentary flows with increasing frequency and/or flow power progressively downslope. Seismic reflection data show that interfluves gain vertical relief and steeper along-slope gradients farther down the continental slope. These changes can be explained simply if the frequency of sedimentary flows and the flux of material they remove from channels increases in proportion to the channel spacing, leaving the interfluves to react to the incision according to a diffusion equation. Our survey of data from the literature suggests that diffusive-like morphology is common. Explanations for its occurrence are developed including effects of gravity on sand-grade bedload oscillated by cyclical bottom currents and larger bed shear stress over topographic highs relative to depressions leading to preferential deposition of fines in the latter.

SHELF EDGE MORPHOLOGY The shelf edge commonly (though not always) separates distinct geological and oceanographic environments: whereas the shelf is commonly sandy and influenced by strong currents, the continental slope is typically hemipelagic mud and influenced by weak currents. Echo-sounding profiles and seismic data of clinoform "rollovers" representing the ancient shelf edge show that it commonly has a simple rounded shape. Here we use multibeam echo-sounder, current meter and sediment trap data from the USA central Atlantic margin to explore some possible oceanographic origins of shelf edge curvature, which we interpret as significantly a result of intensified currents at the shelf edge and of the typical oceanward decline in current speeds away from there. The bathymetry shows that, whereas the slope is deeply incised by canyons, the shelf edge region is remarkably smooth, a morphology that we interpret as indicating the result of a diffusive-like evolution of bathymetry. Simple analytical expressions are developed to relate shelf edge curvature to the variation of current speeds with depth, based on formulae for suspended sediment deposition and bed load transport flux of sand. The expressions suggest that the central Atlantic USA shelf edge curvature could potentially be explained with the present-day current regime if the core of the shelf edge were formed of fine-grade sediment deposited from suspension, but that somewhat extreme parameter values are required. The current speed variation appears to be too gradual with depth to allow an explanation by bedload transport of sand-grade sediment, but such an explanation could be viable if the shelf edge were largely a relic of conditions during the Last Glacial Maximum and earlier low-stands. Both deposition of fines in the upper continental slope and intensification of bottom currents around the shelf edge affecting sand transport could then be consistent with the present curvature. If correct, these results suggest the possibility of interpreting the shape of the modern continental shelf edge and ancient morphology in seismic reflection data (“roll-overs”) in terms of current intensification.