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The interaction between deepwater channel systems and growing thrusts and folds, toe-thrust region of the deepwater Niger Delta

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Gravity-driven seaward-verging thrusts, landward-verging back-thrusts and associated folds often characterize the slope and deepwater settings of passive margins. These structures, found in the "toe-thrust" region of the system, exert a significant control on sediment gravity flows because they create and determine the location and configuration of sediment depocentres and transport systems. Consequently, a quantitative understanding of the interaction between sediment gravity flows and seabed topography is required to understand these systems effectively. Here we make quantitative measurements of the geomorphic response of submarine channels to growing tectonic structures with the aim of providing new constraints on the long-term erosional dynamics of submarine channel systems.

This study exploits 3D seismic data in the outer toe-thrust region of the deepwater Niger Delta to analyze the interaction between Plio-Pleistocene channel systems and actively growing folds and thrusts. We mapped folds and thrusts from the seismic data and we used this data to reconstruct the history of fold growth. We then used the sea-bed seismic horizon to build a 50 m resolution Digital Elevation Model (DEM) of the sea floor in Arc-GIS. We extracted channel long- profiles across growing structures from the DEM, and made measurements of channel geometries at regular intervals along the channel length. This information was used to infer morphodyanamic processes that sculpted the channel systems through time, and to estimate the bed shear stresses and fluid velocities of typical flow events.

The bathymetric long profiles of these channels are relatively linear with concavity that range from -0.08 to -0.34, and an average gradient of $\sim 1^o$. Actively growing thrusts are typically associated with a local steepening in channel gradient by a factor of up to 3, and this effect extends 0.5 – 2 km upstream of the thrust. Within these knickzones, channel incision increases by approximately by a factor of > 2, with a corresponding width decrease of approximately 25%. Channel incision across growing structures is achieved through enhanced bed-shear stress driven incision (up to 200 Pa) and flow velocity (up to 5 ms^{-1}), assuming typical bulk sediment concentrations of 0.6%.

Comparison of structural uplift since 1.7 Ma, and channel incision over an equivalent period, shows that some of these channels are able to keep pace with the time-integrated uplift since 1.7 Ma, and may have reached a topographic (bathymetric) steady-state with respect to on-going thrusting. However, some of the sea-bed channels are yet to reach topographic steady-state because of factors which include recent change in gradient caused by structural uplift, and the impact of active channel diversion by growing structures. Generally, bed-shear stresses of $\sim$150 Pa are sufficient to keep pace with structural strain rates of 10^{-15} s^{-1}. More widely, our data demonstrates that submarine channel systems dynamically adjust their geometry and basal gradient in order to keep pace with growth of tectonic structures and our results suggest that these factors must be incorporated into models to fully predict the downslope pathways of sea-bed channels in structurally complex areas.