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Gravity driven deformation on passive margins

Is analogue modeling the ultimate tool?

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Gravity driven deformation affecting a sedimentary cover above a décollement of weak rocks, leads, on passive margins and in deltas, to a large variety of growth structures. Oil industry exploration has provided spectacular seismic images of them. The typical structural zonation consists of (i) an extensional upslope domain in which the most common structures are tilted blocks, turtle-back anticlines and growth faults with associated rollovers, (ii) a downslope compressional domain, in which the most common structures are squeezed diapirs, inverted graben, reverse faults growth synclines and polyharmonic folds,and (iii) an abyssal undeformed domain.

Ductile flow of the basal décollement layer is accommodated by a combination of pure shear and simple shear. This affects the thickness of the weak layers through time. Meanwhile, sedimentation/erosion on the margin changes the thickness of the brittle cover. The resulting mechanical coupling between brittle and ductile layers therefore varies through time and produce complex and heterogeneous strain patterns.

We present here series of laboratory experiments on small-scale models used to study this coupling between brittle overburden and the decollement layer directly related to (i) the basal slope angle and (ii) the sedimentation rate.

Models are composed of two layer slabs, with Newtonian silicone putty at the base to represent the basal décollement -salt or shales- and dry sand on top to represent the sedimentary overburden. Synkinematic sedimentation layers are deposited during the experiment.

Brittle deformation in the extensional domain of the models always starts with grabens which evolve either symmetrically or asymmetrically or, into tilted blocks bounded by growth faults. Synthetic growth normal faults characterize the downslope part of this domain, while both synthetic and antithetic growth normal faults can occur in the upslope part. We demonstrate how the basal slope angle and the coupling between brittle overburden and ductile decollement control (i) the width of the deformation domains, (ii) the location of faulting in the overburden, (iii) the amount of rotation in the Growth fault/rollovers systems.

The initial zone of compression which first appears at some distance from the toe of the downslope ductile wedge propagates principally upslope in the formerly extensional domain. This compressional domain evolves into a domain of strong shortening characterized by folds, thrusts and squeezed diapirs. Where the folds are pinched-out, synclines can become detached pod-like structures encapsulated within the underlying ductile layer, and anticlines can isolate blobs of ductile material forming compressional diapirs that can extrude up to the surface. Unfolded layers develop into pop-up-type anticlines flanked by growth synclines.

Analogue models reproduce every structure encountered in gravity driven deformation, in the upslope extensional domain as well as in the downslope compressional domain. They are the ultimate tool to understand the mechanical relationship existing between (i) the decollement layer and the overburden, (ii) the basal slope and the sedimentation supply, the time and space relationship between compressionnal and extensional deformations.