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Regional-Scale Salt Tectonics Modelling: Bench-Scale Validation and Extension to Field-Scale

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The role of salt in the evolution of the West African continental margin, and in particular its impact on hydrocarbon migration and trap formation, is an important research topic. It has attracted many researchers who have based their research on bench-scale experiments, numerical models and seismic observations. This research has shown that the evolution is very complex. For example, regional analogue bench-scale models of the Angolan margin (Fort et al., 2004) indicate a complex system with an upslope extensional domain with sealed tilted blocks, growth fault and rollover systems and extensional diapers, and a downslope contractional domain with squeezed diapirs, polyharmonic folds and thrust faults, and late-stage folding and thrusting.

Numerical models have the potential to provide additional insight into the evolution of these salt driven passive margins. The longer-term aim is to calibrate regional-scale evolution models, and then to evaluate the effect of the depositional history on the current day geomechanical and hydrogeologic state in potential target hydrocarbon reservoir formations adjacent to individual salt bodies. To achieve this goal the burial and deformational history of the sediment must be modelled from initial deposition to the current-day state, while also accounting for the reaction and transport processes occurring in the margin. Accurate forward modeling is, however complex, and necessitates advanced procedures for the prediction of fault formation and evolution, representation of the extreme deformations in the salt, and for coupling the geomechanical, fluid flow and temperature fields. The evolution of the sediment due to a combination of mechanical compaction, chemical compaction and creep relaxation must also be represented.

In this paper ongoing research on a computational approach for forward modelling complex structural evolution, with particular reference to passive margins driven by salt tectonics is presented. The approach is an extension of a previously published approach (Crook et al., 2006a, 2006b) that focused on predictive modelling of structure evolution in 2-D sandbox experiments, and in particular two extensional sand box experiments that exhibit complex fault development including a series of superimposed crestal collapse graben systems (McClay, 1990) . The formulation adopts a finite strain Lagrangian method, complemented by advanced localization prediction algorithms and robust and efficient automated adaptive meshing techniques. The sediment is represented by an elasto-viscoplastic constitutive model based on extended critical state concepts, which enables representation of the combined effect of mechanical and chemical compaction. This is achieved by directly coupling the evolution of the material state boundary surface with both the mechanically and chemically driven porosity change. Using these procedures the evolution of the geological structures arises naturally from the imposed boundary conditions without the requirement of seeding using initial imperfections.

Simulations are presented for regional bench-scale models based on the analogue experiments presented by Fort et al. (2004), together with additional insights provided by the numerical models. It is shown that the behaviour observed in both the extensional and compressional zones of these analogue models arises naturally in the finite element simulations. Extension of these models to the field-scale is then discussed and several simulations are presented to highlight important issues related to practical field-scale numerical modelling.