Hydro-Mechanical Modelling of Mudstone Compaction in a Salt Bounded Mini-Basin Subjected to Lateral Deformation

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Abstract

Most of the methods currently used for pore pressure prediction in mudrocks and compaction models implemented in basin modeling software assume 1D compaction based on vertical effective stress and porosity relationships. The method is insufficient in complex tectonic regimes in which stress tensors are variable. In this work, a coupled geomechanical-fluid flow modeling strategy is adopted, together with an advanced version of Cam clay constitutive model, to describe mudstone compaction accounting for the full 3D stress tensor. The aim is to demonstrate the suitability of coupled geomechanical models for capturing the true compaction phenomena in regions subjected to tectonic deformation. The modeling scenario consists of the evolution of a salt-bounded mini-basin. The Titan mini-basin was selected as a benchmark and the present-day geometry was based on the published data of Kane et al. (2012). Subsequent models were defined by introducing 20% lateral shortening synchronous with sediment deposition, by means of prescribed displacements in the salt-sediment interface and assuming interface length preservation. In order to assess the role of lateral transfer all models were simulated using two different lithology columns: a single, clay-rich lithology and a mixed lithology, which includes two sand-rich high permeability layers. The results of the ratio of horizontal to vertical effective stresses for the mixed lithology model with lateral shortening show the complex deformation regime. This consists of two main horizontally compressive regions located at two depocentres and a horizontal extensional region above the central salt diapir where layers form an anticline. Imposed lateral shortening caused an increase in overpressure up to 10 MPa for the single lithology model compared to the solution obtained from a 1D compaction model with no substantial changes in porosity. The application of the EDM in porosity distributions predicted by the model result in an overpressure underestimation of up to 6 MPa at a depth of 3400 m due to the deviation from the 1D compaction assumptions caused by the tectonic compaction. It is concluded that coupled geomechanical models are an excellent tool for pore pressure prediction in geological situations where the simpler approaches relaying on 1D compaction assumptions might result in overpressure underestimation.