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Basin-Scale Geomechanics of Poroelastoplasticity and its Influence on Predicting Stress-Strain Behaviors and Flow Dynamics, a Case Study from Anadarko Basin, Oklahoma

Laainam Chaipornkaew[1], Noelle Schoellkopf[2], Allegra Hosford Scheirer[1], and Tapan Makerji[1]

[1]Stanford University
[2]Schlumberger

ABSTRACT

Basin and petroleum system modeling (BPSM) simulates the stress history in sedimentary basins. In tectonic-driven regimes, the stress state is controlled by the overburden load and tectonic forces. Thus, at least a poroelastic model is needed to derive 3D stress tensors in porous media using a fully-coupled deformation and fluid flow formulation. However, poroelasticity alone is not enough. The elastic constitutive equations allow the modeled material to sustain high levels of shear with minimum deformation; simply implementing the poroelastic model yields unrealistic high shear stress values on materials that have gone beyond yield strength. It is necessary to go beyond poroelasticity to poroelastoplasticity. This study investigates the effects of plastic deformation for shear failure and compaction at geological timescale for the Anadarko Basin. We started with a 3D BPSM project supplied by the USGS Digital Data Series 69-EE. Because that model did not incorporate pressure effects, we integrated pressure and paleo-pressure data and utilized a poroelastoplastic workflow in BPSM to realistically capture the effects of plastic deformation in predicting stress and overpressure in the context of sedimentary basin. The effects of variable lithological facies and rock strength anisotropies arising from sub-grid heterogeneity will be incorporated. Additionally, we plan to include available production data, emerging from the new petroleum plays of this rejuvenated basin, to track the response of migrating fluids to plastic deformation. Plastic constitutive equations predict shear stresses that facilitate porosity loss and permanent deformation, this workflow should allow for a more realistic estimation of stress and flow dynamics in this ultra-deep basin. Beyond the Anadarko basin, this study will serve as a case study to test the most appropriate poroelastoplastic constitutive relations for modeling basin-scale deformation.