Hydro-Chemo-Mechanically Coupled Computational Fluid and Solid Dynamics in Deformable Porous Media

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Method

We have developed a method through which to model coupled fluid and porous media mechanics such as clay swelling/contraction and fluid-induced clay transport within Digital Rock Physics. Direct numerical simulations (DNS) in these scenarios are implemented through a modified Darcy-Brinkman Equation, a formulation that approximates Navier-Stokes in a free fluid, and Darcy's Law in a microporous domain. Coupling with poromechanics is achieved by incorporating porous media conservation equations (with appropriate momentum sources) into this framework. This is an exciting development, since, to the best of our knowledge, this is the first CFD model to capture dynamic hydro-chemo-mechanical couplings in DNS without the need of dynamic remeshing. Due to formulation's generality, this method can be applied to pseudoplastic and/or poroelastic porous media.

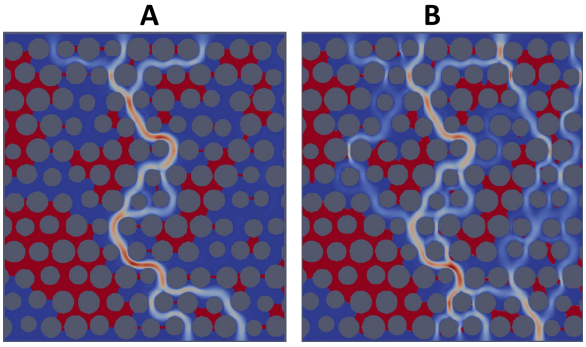

Figure 1: Steady state fluid velocity profiles through a simplified rock structure before (A) and after (B) fluid-driven displacement of porous media.

Verification and Application

We applied/verified our model by comparing it to several experiments, ranging from swelling-controlled systems to fluid-driven systems. Finally, we use this model to predict transient changes in the permeability of clayey sedimentary rocks as a function of pressure and chemical gradients.