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Upscaling Fluid-Flow and Mechanical Properties in Coupled Matrix+Fractures+Fluids Systems*C*the HYDRO-DDA Approach

Geomechanical effects can be significant in many reservoirs, and can be represented in reservoir simulation by (loose or tight) coupling between the geomechanical and flow simulators. As always, there is a scale issue: cell sizes are controlled by the available computational power and the user's patience/budget. In this paper, we demonstrate the feasibility of calculating coupled upscaled flow and mechanical properties for geological systems composed of realistic configurations of fracture-bounded porous blocks of rock. We consider single-phase flow (simulated by HYDRO, based on the finite element method). Geomechanical processes are simulated by DDA (Discontinuous Deformation Analysis), which is a type of discrete element system. The integrated simulation environment, HYDRO-DDA, allows us to represent fluid flow through systems of matrix blocks and their bounding, open fractures. Mechanical loads are applied to that system of blocks, and hydraulic boundary conditions are applied to the fluid system. Fluid pressures influence the fracture apertures, and the geomechanical deformations alter the porosity and permeability distributions, which in turn alter the fluid pressures and the resulting flow. One of the systems studied is a "seal" layer that is flexed while subjected to a fluid pressure gradient (representing a top-seal above a reservoir layer below). The effective (bulk) permeability of the fractured seal layer is a function of the fluid pressure gradient, as expected, but the relationship is non-linear with multiple maxima and minima. Variations in mechanical loading also are important. The HYDRO-DDA approach can develop continuum-scale, coupled flow and mechanical representations that capture underlying discontinuum physics.