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Coupled flow and deformation in heterogeneous fractured media: A multirate mass transfer approach for double-porosity poroelasticity

Tuesday, 1 June 2021 20:00 (1 hour)

Anthropogenic and natural fractured aquifers are common examples of dual porosity matrix-fracture systems, where the fracture network provides highly-conductive flow pathways and the low-permeability matrix stores most of the fluid. Fluid production or extraction leads to land subsidence and potentially to induced seismicity. Mechanical deformations have recently been proposed as effective monitoring tools for reservoir characterization, complementing flow data.

Coupled flow and mechanical deformation in fractured media is often modeled using the classical theory of dual-porosity poroelasticity (DPP), based on Barenblatt's hypothesis of pressure equilibrium inside the rock matrix blocks. However, classical DPP cannot be expected to upscale flow and deformation in fractured rocks when non-equilibrium effects are relevant. Equilibrium can be expected to appear if the matrix blocks are small, so that the matrix diffusion time is comparable to the flow time scales along the fractures. In practice, matrix blocks may be large enough so that diffusion time scales are long, and the equilibrium hypothesis breaks down.

We study non-equilibrium effects in coupled flow and deformation in fractured media through a theoretical non-equilibrium, dual-porosity model. We use this theory to obtain the scalings for drainage and displacement to be expected for coupled flow and deformation in highly-heterogeneous, fractured porous media. The theoretical model allows to identify what behavior to expect in fractured aquifers and reservoirs, revealing the limitations of classical DPP formulations.

We compare analytical predictions and scalings with high-fidelity numerical simulations, where we describe the coupled flow and deformation for both the rock matrix and a network of discrete fractures, explicitly represented by lower-dimensional (1D) objects. The results show strong tailing in land subsidence and fluid fluxes that cannot be captured by classical DPP or single porosity effective medium approaches. Conversely, theoretical predictions from the multirate DPP model and the high-fidelity numerical simulations agree, even for highly heterogeneous matrix-fracture systems.

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Time Block Preference

Time Block B (14:00-17:00 CET)

References

Andrés, S., Dentz, M., and Cueto-Felgueroso, L. (2021). Multirate mass transfer approach for double-porosity poroelasticity in fractured media. Water Resources Research, Under review

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