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Multiscale network modeling of flow in carbonate rocks with microporosity

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Diagenetic events lead to substantial variation in pore size, shape, and connectivity in carbonate rocks and porosity at multiple scales (submicron to hundreds of millimeters). This diversity in carbonate porous systems has a significant effect on petrophysical properties leading to different flow characteristics in carbonates from that of siliciclastics. In this study, we focus on the role of microporosity (i.e., sub-resolution porosity) in multiphase flow through carbonate rocks with inherited structural and wettability heterogeneities. The study sample is a Ketton limestone (almost pure calcite) bearing a distinctly bimodal pore size distribution. The pore network of the Ketton sample is initially obtained using the generalized network extraction method, which allows three-dimensional (3D) pore space discretization of the underlying high-resolution X-ray computed microtomography (μCT) image (Raeini et al. 2017). In the generalized extraction workflow, all void space voxels in the μCT image are included in the network at different discretization levels. The resultant corners of the pore space extending from the throats at restriction points to the adjacent pore centers are identified as elements of the resolved network. In the network model created initially, only the resolvable macropores are considered (3.58 μm voxel size in our example). To characterize the sub-resolution porosity regions, differential imaging between μCT scan of the sample saturated with high-salinity brine as the contrast phase and dry scan is applied. This approach provides a porosity characterization based solely on interconnected porosity between macropores and sub-resolution micropores within grains, which contributes to flow and transport. The sub-resolution porosity regions are connected to the neighboring macro-porosity elements as equivalent effective links. In the flow simulations, the effective links representing microporosity networks do not undergo discrete pore-scale displacement events but are characterized by average pressure-saturation-conductance functions. The multiscale network model is calibrated with the Ketton carbonate macroscopic flow parameters measured by *in situ* μCT-monitored flow-through experiments under steady-state flow and altered wettability conditions (Zhang et al. 2022). The experimentally validated multiscale network model capturing sub-resolution pore space can be used for more quantitative future flow and transport studies in complex porous systems where the inclusion of microporosity yields more accurate predictions.

Participation

In-Person

References

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Zhang, G., Foroughi, S., Raeini, A.Q., Blunt, M.J. and Bijeljic, B., 2022. The impact of bimodal pore size distribution and wettability on relative permeability and capillary pressure in a microporous limestone with uncertainty quantification. Advances in Water Resources, 104352.

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