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Numerical simulation of two-phase flows in digital core samples with underresolved porosity

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Micro-CT scans are widely used for rock models in Digital Rock Physics applications. However, up to one-half of the connected porosity of carbonates and shales is underresolved with micro-CT due to the small pore size. This underresolved pore space may still support multiphase fluid flow. To simulate two-phase flows in models where both large-scale and underresolved pores are present, we developed a numerical algorithm based on the combination of the phase-field model with two-phase filtration, which supports continuous phase transport in a multi-scale pore space.

The fluid flow is simulated using the unified Navier-Stokes-Brinkman equation, which is well suited for the models where the absolute permeability is at the level of mcroDarcy, which is the case for the underresolved porosity of carbonates and shales. This equation is solved using the projection-based method. The phase transport in the resolved pores is governed by the Cahn-Hilliard equation of the phase field, which makes it simple to treat the complex geometry and topology of the pore space and the phase. Phase transport in the underresolved pores satisfies the two-phase filtration equation, accounting for the capillary pressure. The two models are coupled at the interface between the resolved and underresolved pores based on flux continuity. Additionally, the wetting-angle boundary condition is satisfied for the phase-field model.

The designed algorithm and its GPU-based implementation are used to estimate the relative permeability and capillary pressure of the samples with underresolved porosity.

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