Assessing the influence of microporosity on imbibition in complex pore structures with multi-scale pore network models

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ABSTRACT

Understanding the relative permeability behavior of complex geological materials during imbibition is an important challenge in e.g. petroleum engineering, environmental engineering and CO2-sequestration. While image-based pore network models have helped to understand how the pore-scale properties influence this behavior, specially adapted multi-scale models are needed to perform such simulations on rocks with wide pore size distributions. In previous work, we have developed a multi-scale image-based pore network model, which takes unresolved microporosity into account by adding special links (micro-links) with upscaled microporosity properties to the classical network description (pores and throats) [1]. Here, we present rules to simulate imbibition in such networks under different wettability scenarios.
Compared to drainage, the filling sequence during imbibition is more complex, as snap-off and cooperative pore filling have to be taken into account. In our model, the saturation and fluid conductivities of the microporosity at each point in the simulation are encoded in capillary pressure and relative permeability curves which are provided as input. Thus, an adequate network description of the microporosity is required to assess these curves under the prevailing wettability conditions. This network description can for example be obtained by performing high-resolution imaging experiments on the microporosity.
To describe the filling sequence of the multi-scale network as a whole, the connectivity of both fluid phases (e.g. oil and water) in the microporous links is taken into account. Macropores can be filled with the invading fluid through neighbouring microporosity if it percolates through the microporosity. During waterflooding in the water-wet case, the invasion capillary pressure at which this happens is generally controlled by the geometry of the macropore. During waterflooding under oil-wet conditions, the invasion capillary pressure is instead controlled by the microporosity, and a percolation theory approach is used to determine through which micro-links water percolates first. Furthermore, microporosity can also provide an escape path for the defending phase if this phase percolates through it. We thus also take the defending phase’s connectivity into account at the prevailing capillary pressure, which can affect the network’s trapping behaviour.
In this work, we show how quasi-static, multi-scale pore network models can be used to incorporate information from multiple scales, and we illustrate how this approach can be used to investigate the influence of microporosity on relative permeability and resistivity index behavior during imbibition. The validity of the model is tested by comparing results to network models with individual micropores [2] and by treating networks extracted from micro-computed tomography scans of rocks with complex pore geometries (e.g. carbonates).

REFERENCES

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