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Challenges for Microfluidic Devices in Representing Flow in Geological Formations

Wednesday, 1 June 2022 09:20 (1h 10m)

Microfluidic devices offer unique opportunities to directly observe multiphase flow in porous media. However, as a direct representation of flow in the 3D pore networks of geological formations, conventional microfluidics face several challenges.
One is the ability of microfluidic networks to represent steady two-phase flow without fluctuating occupancy of locations in the network. The ability of two phases to form steady, intertwined flow pathways is a key property of 3D pore networks (King and Masihi, 2019). This is not possible a two-dimensional network (Fisher, 1961) unless the flow paths of the two phases can cross at some locations in the network. Crossings are possible in a microfluidic network if wetting phase can form a bridge across the top and bottom of a gap between grains at a pore throat while non-wetting phase flows through the throat.
We examine the conditions under which this is possible using the Surface Evolver software (Brakke, 1992) to determine fluid interface shapes in several different throat geometries. Specifically, we determine the capillary pressures Pc at which strongly nonwetting phase penetrates a throat, and then the lower values of Pc at which wetting phase forms a bridge between grains, and the yet-lower values of Pc at which wetting phase re-invades and blocks the throat ("snap-off").
For relatively long straight or curved throats, the capillary pressure for bridging is the same as that for snap-off. Microfluidic networks designed to represent flow in geological formations that feature throats of this geometry cannot support steady two-phase flow without fluctuating occupancy of the pore space. In other words, flow is forced into the high-capillary-number regime where phases displace each other in the network.
Concave throats, as between cylindrical pillars, can support bridges over a substantial range of capillary pressure. Steady two-phase flow would be possible in networks of pores with throats of this geometry. The range of capillary pressures at which bridging is stable increases as throats become more strongly concave (i.e., pillar radius decreases) and for narrower throats. Strongly concave throats can also prevent "Roof" snap-off as nonwetting phase penetrates a pore body through a narrow throat.

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References

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Time Block Preference

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

Participation

In person

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