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Unstable invasion during imbibition in regular porous media

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The unstable fluid-fluid displacement patterns in porous media with rough invasion fronts and trapping of the defending phase are often observed in drainage, i.e., when the solid is non-wetting to the invading phase. Reversely, during imbibition, compact and faceted growth is expected in regular porous media with geometrically homogeneous pore structure due to the favoured overlap event at the pore scale. Here, we report the irregular growth of invading fluid during an imbibition process in two-dimensional regular porous media. The ramified invasion patterns associated with thin fingers and trapping of the defending fluids are reminiscent of capillary fingering, which are often observed only in drainage conditions. Through examining the capillary pressure signals and type of pore-scale invasion mechanisms during multiphase flow, the differences between compact and faceted displacement and unstable growth are revealed. We analyse the critical events at pore-scale that determines the pore-filling process, which leads to a phase diagram describing the dominance of event type across a wide range of porosity and wetting conditions. Through conducting systematic quasi-static radial injection simulations, excellent agreement is observed on the transition boundary from faceted and compact displacement patterns towards irregular and dendritic invasion morphologies. This is reflected by the overlap of the transition boundaries from analytical prediction, type of pore-scale invasion events, and macroscopic morphology quantified by the fractal dimension. This work provides new insights on the role of geometrical features of solid structures during fluid displacement processes with emphasis on the porosity and wettability of regular porous media. The findings would assist in guiding the design of microfluidic devices to deterministically control the multiphase flow, transport and reaction processes.

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Participation

Online

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