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The Role of Local Instabilities in Fluid Invasion into Permeable Media Studied by in situ X-Ray Microtomography

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Considering the paradigmatic case of random piles of spheres, fluid front morphologies emerging during slow immiscible displacement with a global front velocity of 3 μm/s are investigated in real time by X-ray micro–tomography and quantitatively compared with model predictions. Controlled by the wettability of the bead matrix two distinct displacement patterns are found with a transition region of about ≈ 30° separating both regimes. Within each regime the displacement behavior is fairly insensitive to the exact contact angle [1].

A compact front morphology emerges if the invading fluid wets the beads while a fingered morphology is found for non–wetting invading fluids, causing the residual amount of defending fluid to differ by one order of magnitude. The corresponding crossover between these two regimes in terms of the advancing contact angle is governed by an interplay of wettability and pore geometry and can be predicted on the basis of a purely quasi–static consideration of local instabilities that control the local progression of the invading interface as similarly introduced by Cieplack and Robbins for 2D systems [2], [3]. In particular the absence or the appearance of 'Burst-Instabilities'where the local instability occurs when the pressure in a throat exceeds the required filling pressure can be used to distinguish the transition between both wetting regimes. For the non-wetting system where the local front progression occurs mainly by 'Burst-Instabilities'an interconnected and very extended network of invading and defending phase develops at later times. The interconnected network of the defending phase is slowly drained by gutter flow leading to an increased residual saturation which is reached only after a substantial flush of the invading phase. If time allows, also the situation of bead and grain packs consisting of heterogeneous bead sizes, grain shapes or heterogeneous wettability will be discussed in brief.

References

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