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Experiments on two-phase flow in a quasi-2D porous medium: investigation of boundary effects in the measurement of pressure-saturation relationships

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We have performed two-phase flow experiments to analyze the drainage from a quasi-2D random porous medium. The medium is transparent, which allows for the visualization of the invasion pattern during the flow and is initially fully saturated with a viscous fluid (a dyed glycerol-water mix). As the pressure in the fluid is gradually reduced, air penetrates from an open inlet, thus displacing the fluid which leaves the system from the outlet in the opposite side.

A feedback mechanism was devised to control the experiment: the capillary pressure (difference in pressure between the non-wetting and wetting phases) is continuously increased to be just above the threshold value necessary to drive the invasion process. This mechanism is intended to keep the invasion process slow, in the so-called capillary regime, where capillary forces dominate the dynamics. Pressure measurements and pictures of the flow are recorded and the pressure-saturation relationship is computed. The effects of the boundary conditions to this quantity are verified experimentally by repeatedly performing the analysis using porous media of different sizes. We show that some features of the pressure-saturation curve are strongly affected by boundary effects. The invasion close to the inlet and outlet of the model are particularly influenced by the boundaries and this is reflected in the phases of pressure building up in the pressure-saturation curves, in the beginning and end of the invasion process. Conversely, at the central part of the model (away from the boundaries), the invasion process happens at an essentially constant capillary pressure, which is reflected as a plateau in the pressure-saturation curve.

Additionally, the use of a high-resolution camera allows us to analyze the images down to the pore scale. We can directly obtain a distribution of pore-throat sizes in the model (and their associated capillary pressure thresholds) and divide it into distributions of invaded / non-invaded pores. By measuring these separate distributions dynamically, we can show how they evolve with the invasion process.