Supporting Information: Measurement of the Pore-Scale Velocity Distributions in a Two-Dimensional Porous Medium

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Experimental Setup. Our experimental apparatus includes 2D etched micromodels connected to a syringe pump that are placed under an optical microscope for flow visualization (Figure 1). A schematic of the micromodels is depicted in Figure 1 (right). The porous medium pattern is etched into silicon using standard photolithography techniques with an etching depth of 12µm. Holes are then drilled into the silicon wafer at each corner of the micromodel providing ports for fluid exit and entry into the fractures. The etched silicon wafer is thoroughly cleaned and then bonded to a glass plate. The silicon is oxidized during bonding, resulting in a thin silicon dioxide layer that is water wet. Details of the fabrication process are in Hornbrook et al. [2] and Buchgraber et al. [1].

The completed micromodel is mounted in an aluminum holder that provides fluid delivery and production from the micromodel. A Harvard syringe pump connected to a liquid vessel containing water or oil provides a constant injection rate ($5 \times 10^{-4}$ to $1.1 \times 10^{-2}$mL/min) into the micromodel. The micromodel is then placed under a Nikon ME600 microscope for flow visualization. Usually, we use ×40 magnification to track the motion of the fluids in the micromodel at a macroscopic scale. Once a region of dynamic interest is identified, greater magnifications, ×100, ×200, ×400 are used to focus on the pore scale.

Single-phase experiment: validation in the homogeneous micromodel. In Figure 2, we present the results obtained in the homogenous pattern when looking at the interface between the porous matrix and the fracture. The fluid is water seeded with micro-particles flowing through the micromodel with a flow imposed at 45º (arrow). The velocity magnitude, the displacement along $x$ direction and the displacement along $y$ are represented for both
Figure 2. Single-phase flow at the interface porous matrix/fracture (homogeneous micromodel, ×200 magnification), comparison between the experimental data obtained by micro-PIV (left column) and the numerical simulation (right column). The yellow arrow indicates the flow direction.

experiments (Figure 2, first column) and simulation (Figure 2, second column). The flow patterns of PIV results and numerical data are in good agreement.

Micro-PIV measurements of unstable flows. The micro-PIV technique has been validated for steady single-phase flows, usually 500 image pairs are considered to compute the averaged velocity distribution. For unstable flows we cannot average over long time periods. To obtain a velocity value for each time step, we performed convergence analysis of the micro-PIV measurements. For single-phase flow, we have a reference velocity distribution from the direct numerical simulation. In that case, we performed micro-PIV measurements for 1 to 500 image pairs and the results are then averaged for the number of image pairs under consideration. Our results indicate that an average over at least 20 image pairs is necessary to represent the actual velocity distribution. When the flow is unstable, as in the
two-phase drainage case, we compute the velocity for each time step by taking the 10 image pairs before and the 10 image pairs after the time step. The final velocity at a time step is the averaged velocity over the 20 image pairs.

Drainage two-phase experiment: movie.
