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Fluid front displacement dynamics affecting pressure fluctuations and phase entrapment in porous media

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Many natural and engineering processes involve motion of fluid fronts in porous media, from infiltration and drainage in hydrology to reservoir management in petroleum engineering. Macroscopically smooth and continuous motion of displacement fronts involves numerous rapid interfacial jumps and local reconfigurations. Detailed observations of displacement processes in micromodels illustrate the wide array of fluid interfacial dynamics ranging from irregular jumping-pinning motions to gradual pore scale invasions. The pressure fluctuations associated with interfacial motions reflect not only pore geometry (as traditionally hypothesized) but there is a strong influence of boundary conditions (e.g., mean drainage rate). The time scales associated with waiting time distribution of individual invasion events and decay time of inertial oscillations (following a rapid interfacial jump) provide a means for distinguishing between displacement regimes. Direct observations using high-speed camera combined with concurrent pressure signal measurements were instrumental in clarifying influences of flow rates, pore size, and gravity on burst size distribution and waiting times. We compared our results with the early experimental and theoretical study on burst size and waiting time distribution during slow drainage processes of Måløy et al. [Måløy et al., 1992]. Results provide insights on critical invasion events that exert strong influence on macroscopic phenomena such as front morphology and residual phase entrapment behind leading to hysteresis.

Måløy, K. J., L. Furuberg, J. Feder, and T. Jossang (1992), Dynamics of Slow Drainage in Porous-Media, Phys Rev Lett, 68(14), 2161-2164.