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Fracturing in granular media: the role of capillarity, wetting, and disorder

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The advent of shale oil and shale gas into the energy landscape has relied on achieving vigorous stimulation of the rock by means of horizontal drilling and hydraulic fracturing. Traditionally, hydraulic fracturing is understood as a single-fluid-phase, pressure-driven process, in which the fluid (typically water with additives) is injected at a high-enough rate that the pressure builds up faster than it can dissipate by permeating into the rock, thereby fracturing it. However, the prevalent conditions for shale (ultra fine pore size, moderate overburden stress, and poor cementation) suggest that capillary forces could play an important role in the fracturing process. Here, we show the results of our recent experimental and theoretical studies on fracturing of granular media by means of injection of an immiscible fluid. We conduct carefully controlled injection experiments in a quasi-2D granular medium (a circular Hele-Shaw cell filled with glass beads), in an experimental set-up that allows us to systematically study the impact of capillarity (by varying injection rate, bead size, and fluid-fluid surface tension), wetting properties (by treating the beads and the cell plates by chemical vapor deposition of silane-based substances) and confinement (by varying the load on the cell). Our choice of defending and invading liquids and granular medium allows us to investigate a wide range of contact angles, from drainage to imbibition. We demonstrate that wettability exerts a powerful influence on the invasion/fracturing morphology of unfavorable mobility displacements. High time resolution imaging techniques and particle image velocimetry (PIV) allow us to quantify matrix displacement and fracture opening dynamics. Our results provide insights on fracture propagation, fracture length distribution and the fracture drainage area, parameters which are critically important to better understand long-term hydrocarbon production from shale.