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Impact of Wettability on Multiphase Flow and Granular Mechanics: Experiments, Modeling and Theory

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Many natural subsurface processes involve the interaction between multiphase flow and deformation of porous media like rocks and soils. Examples include hydraulic fracturing, induced seismicity from fluid injection, and subsidence from groundwater extraction, just to name a few. In some cases, such as soil desiccation cracks or methane venting from organic sediments, surface tension plays a fundamental role in the fluid-solid interaction. Here, we report some recent observations on how, in these cases, the flow and deformation are strongly modulated by wettability, that is, the relative affinity of each fluid to the solid making up the porous medium. These observations are surprising and intriguing, but a mechanistic explanation has heretofore remained elusive. Here, we present a fully-coupled dynamic model of granular mechanics and multiphase flow at the pore scale, which explicitly incorporates the impact of wettability. This mechanistic model allows us to explore the rich emerging behavior as a function of different parameters, such as capillary number, contact angle, initial packing density, and grain rigidity. Beyond the suggestive predictions of pattern formation, the model also hints at the origin of the transitions between patterns. We reconcile the rich behavior we observe in terms of a jamming transition, which opens a promising way to understand novel aspects of wet granular systems.