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Crustal fingering: solidification on a viscously unstable interface XIAOJING FU, Massachusetts Institute of Technology, JOAQUIN JIMENEZ-MARTINEZ, Los Alamos National Laboratory, LUIS CUETO-FELGUEROSO, Technical University of Madrid, MARK PORTER, Los Alamos National Laboratory, RUBEN JUANES, Massachusetts Institute of Technology — Motivated by the formation of gas hydrates in seafloor sediments, here we study the volumetric expansion of a less viscous gas pocket into a more viscous liquid when the gas-liquid interfaces readily solidify due to hydrate formation. We first present a high-pressure microfluidic experiment to study the depressurization-controlled expansion of a Xenon gas pocket in a water-filled Hele-Shaw cell. The evolution of the pocket is controlled by three processes: (1) volumetric expansion of the gas; (2) rupturing of existing hydrate films on the gas-liquid interface; and (3) formation of new hydrate films. These result in gas fingering leading to a complex labyrinth pattern. To reproduce these observations, we propose a phase-field model that describes the formation of hydrate shell on viscously unstable interfaces. We design the free energy of the three-phase system to rigorously account for interfacial effects, gas compressibility and phase transitions. We model the hydrate shell as a highly viscous fluid with shear-thinning rheology to reproduce shell-rupturing behavior. We present high-resolution numerical simulations of the model, which illustrate the emergence of complex crustal fingering patterns as a result of gas expansion dynamics modulated by hydrate growth at the interface.

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