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Crustal fingering: solidification on a moving interface XIAOJING FU, Massachusetts Institute of Techonology, JOAQUIN JIMENEZ-MARTINEZ, MARK PORTER, Los Alamos National Laboratory, LUIS CUETO-FELGUEROSO, Technical University of Madrid, Madrid, Spain, RUBEN JUANES, Massachusetts Institute of Techonology — Viscous fingering–the hydrodynamic instability that takes place when a less viscous fluid displaces a more viscous fluid–is a well known phenomenon. Motivated by the formation of gas hydrates in seafloor sediments and during the ascent of gas bubbles through ocean water, here we study the interplay of immiscible viscous fingering with solidification of the evolving unstable interface. We present experimental observations of the dynamics of a bubble of Xenon in a water-filled and pressurized Hele-Shaw cell. The evolution is controlled by two processes: (1) the formation of a hydrate "crust" around the bubble, and (2) viscous fingering from bubble expansion. To reproduce the experimental observations, we propose a phase-field model that describes the nucleation and thickening of a porous solid shell on a moving gas-liquid interface. We design the free energy of the three-phase system (gas-liquid-hydrate) to rigorously account for interfacial effects, mutual solubility, and phase transformations (hydrate formation and disappearance). We introduce a pseudo-plasticity model with large variations in viscosity to describe the plate-like rheology of the hydrate shell. We present high-resolution numerical simulations of the model, which illustrate the emergence of complex "crustal fingering" patterns as a result of gas fingering dynamics modulated by hydrate growth at the interface.

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