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Dissolution Patterns and Mixing Dynamics in Unstable Reactive Flow

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We study the fundamental problem of mixing and chemical reactions under a Rayleigh-Bénard-type hydrodynamic instability in a two miscible fluids system. The dense fluid mixture, which is generated at the fluids interface, leads to the onset of a convective instability. At the same time, a fast chemical dissolution reaction produces a characteristic porosity pattern that follows the regions of maximum mixing. Contrary to intuition, the dissolution pattern does not map out the finger geometry of the unstable flow. Instead, it displays a dome-like, hierarchical structure that reflects the positions of the ascending fluid interface. We find that this behavior is caused by stagnation points along the deformed interface, which act as mixing and reaction hotspots due to a strong compression of the interfacial boundary layer. We develop a model for mixing and reaction around the stagnation points of the deformed fluids interface that captures the evolution of the global scalar dissipation and reaction rates and predicts their independence of the Rayleigh number.