MAR16-2015-000592

Abstract for an Invited Paper
for the MAR16 Meeting of
the American Physical Society

Fingers, toes and tongues: the anatomy of interfacial instabilities in viscous fluids

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The invasion of one fluid into another of higher viscosity is unstable and produces complex patterns in a quasi-two dimensional geometry. This viscous-fingering instability, a bedrock of our understanding of pattern formation, has been characterized by a most-unstable wavelength that sets the characteristic *width* of the fingers. We have shown that a second, previously overlooked, parameter governs the *length* of the fingers and characterizes the dominant global features of the patterns. Because interfacial tension suppresses short-wavelength fluctuations, its elimination would suggest an instability producing highly ramified singular structures. Our experimental investigations using miscible fluids show the opposite behavior – the interface becomes more stable even as the stabilizing effect of interfacial tension is removed. This is accompanied by slender structures, tongues, that form in the narrow thickness of the fluid. Among the rich variety of global patterns that emerge is a regime of blunt structures, "toes", that exhibit the unusual features characteristic of proportionate growth. This type of pattern formation, while quite common in mammalian biology, was hitherto unknown in physical systems.