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Bubbles breaking the walls: morphogenesis during gas migration in grain-filled conduits

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In numerous natural systems, including volcanic ones, overpressured gas finds a way through a mixture of solid grains and liquids.

Experiments on confined two-phase flow systems, involving air and a dense suspension, have revealed highly non -trivial flow morphologies. As the air displaces the suspension, the grains that make up the suspension tend to accumulate along the interface, and can build up force chains that jam the accumulated region. This dynamics will generate "frictional fingers" of air coated by a region of densely packed grains. The fingers have a characteristic width that balances surface tension and frictional forces of the densely packed grains. When these fingers grow under the influence of gravity, they can align either horizontally or vertically, or grow in a random isotropic fashion. The transition between the different modes offinger growth depends on the density of grains, and the gravitational force component. We present an analytic model to account for the transitions between the modes. We further present a numerical scheme that enables us to simulate the dynamics of the process. The numerical and analytic results are in good agreements with the experimental findings.
Finally we show how this process could explain patterns that emerge naturally in early stages of dyke formation. These patterns are formed when hot fluid displaces partly molten rocks and packs the hard mineral grains composing it together, thereby forming finger structures that remain frozen in the dyke walls.

We also show how bubbles of gas stabilized by frictional fingers in negligible gravity lead during the rise of overpressure to hoop stresses in the bubble frictional environment, that eventually buckles and destabilizes, and allows the bubbles to break their confining walls, giving rise to channelling and new bubble expansion.

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