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Transition from Vertical to Lateral Diking at the Neutral Buoyancy Line

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Buoyant hydraulic fractures (HF) are a viable approach to model propagating magmatic intrusions in the lithosphere. Solutions for fully planar three-dimensional (3D) HF suggest the existence of a family of solutions as a function of fluid and solid properties [1]. Theoretically, such buoyant fractures ascent in a self-sustained manner if no heterogeneities exist.

We investigate the presence of a neutral buoyancy line (NBL) as a possible arrest mechanism of such buoyant self-sustained fractures. The NBL stems from a change in solid density and leads to a reversed buoyancy. In other words, the rock density in the upper layer is smaller than the density of the fluid, whereas the inverse is true in the lower layer (see figure 1). When a vertically propagating dike encounters this kind of heterogeneity, three outcomes are possible: The fracture can laterally spread along the NBL, arrest without lateral propagation and possibly initiate an intermediate magma chamber, or “burst” through the upper layer and become a feeder dike.

We focus on the first two possible outcomes and exclude the emergence of feeder dikes. Using numerical simulations, we delimit the conditions distinguishing the arrest from lateral spreading and characterize the transition from vertical to lateral dike propagation under various conditions.

Our simulations emphasize the dependence of lateral diking on the ratio between the total volume release and a limiting, minimal volume required for the emergence of self-sustained vertical dikes [2, 3, 4]. If the release volume is sufficient, the dike spreads laterally along the NBL. In the resulting horizontal intrusion, two-dimensional (2D) solutions of horizontal cross-sections in the viscosity- [5] and the toughness-dominated regime emerge. The emergence of the respective limits strongly correlates with the depth of the source magma chamber, a problem parameter we vary to compare simulation results with observations from lateral dike rifting intrusions. In particular, we discuss if these rifting sequences require a shallow, proximal to the NBL magma chamber or can originate from a deeper source as vertical dikes and then transition to lateral propagation.

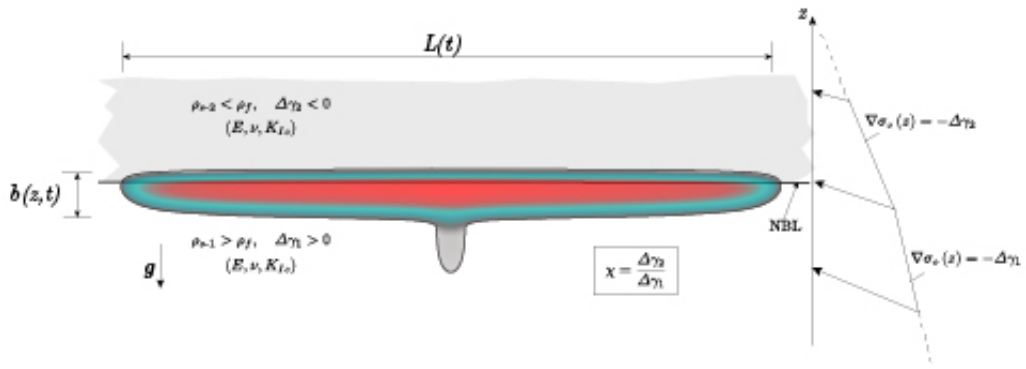

Figure 1: Buoyant hydraulic fracture encountering a neutral buoyancy line.

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