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Velocity variations of a propagating dyke in presence of an external stress field: insights from analogue models

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Magma transport through the upper part of the crust mainly occurs by planar intrusions, either dikes or sills. Recent fissure eruptions, like eruptive activity at Fernandina Island, Galapagos or the well-monitored 2014 Bárðarbunga-Holuhraun rifting event, revealed complex propagation paths and velocity variations which may have been caused by the external stress associated with the local topography. Forecasting where and when magma might reach the surface requires to fully understand parameters controlling magma trajectory and timing.
Due to the limitations of numerical simulations for fluid-filled fractures propagation, analogue experiments are currently the only way to gain information on both the intrusion path and velocity in 3D. In this study, we perform a series of experiments, injecting into a transparent block of solidified gelatin, various volumes of fluids characterized by different viscosities (air and three different silicon oils with viscosities ranging between $1{,}8.10^{-5}$ and $9{,}7.10^{-1}$ Pa.s). An heterogeneous stress field produced by a load at the surface is applied to the gelatin in order to explore the relative control of internal overpressure (buoyancy) and external stress field on fluid-filled crack paths and velocities. We compute the stress field acting in the gelatin using a 3D finite element model. When the fluid buoyancy is small enough with respect to the external stress field, the dyke path is deflected toward the loading, the intrusion tending to align with the direction of the maximum compressive stress. Whereas all intrusions show an acceleration when approaching the free surface, the deflected ones are strongly affected by a significant velocity decrease due to the external compressive stress gradient beneath the load, and by the buoyancy reduction due to the intrusion dip.