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On the propagation path of magma-filled dikes and hydrofractures: the competition between external stress, internal pressure, and crack length.

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Mixed-mode fluid-filled cracks represent a common means of fluid transport within the earth crust. They grow and propagate if their internal pressure is high enough. They often show complex propagation paths which may be due to interaction with crustal heterogeneities or heterogeneous crustal stress. However, it is not always trivial to explain those paths in the light of the stress field acting in the crust. In fact, it has been shown that if the fluid pressure is high enough with respect to the external stress, their paths may not be affected by the orientation of the external stress. Previous experimental and numerical studies focused on the trade-off between fluid overpressure and external stress, but they did not quantify the effect of crack length on the propagation path.

In this study, we address the role of crack length on the propagation paths in presence of an external heterogeneous stress field. We make use of numerical simulations of magmatic dikes and hydrofracture propagation, carried out using a two-dimensional boundary element model, and analogue experiments of air-filled crack propagation into a transparent gelatin block. We use a 3D finite element model to compute the stress field acting within the gelatin block and perform a quantitative comparison between 2D numerical simulations and experiments.

We confirm that, given the same ratio between external stress and fluid pressure, longer fluid-filled cracks are less sensitive to the background stress, and we quantify this effect on fluid-filled crack paths. Combining the magnitude of the external stress, the fluid pressure, and the crack length, we define a new parameter, which characterize two end-member scenarios for the propagation path of a fluid-filled fracture: i) the fluid-filled crack follows the direction perpendicular to the minimum compression due to the external stress; ii) the fluid-filled crack is not sensitive to the external stress (the stress change induced by the crack opening dominate the propagation). Our results have important implications for volcanological studies which aim to address the problem of complex trajectories of magmatic dikes (i.e. to forecast scenarios of new vents opening at volcanoes), but also have implications for studies that address the growth and propagation of natural and induced hydrofractures.