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

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Dykes are mixed-mode magma-filled cracks which may grow and propagate through the earth crust if their internal pressure is high enough. They often show complex propagation paths which may be due to interaction with crustal heterogeneities or to heterogeneous crustal stress. In fact, dykes tend to open in the direction of the least compressive stress direction. However, it has been shown that dykes take some distance to adjust to the optimal orientation. Particularly, if the magma pressure is high enough with respect to the external stress, dyke paths may not be affected by the orientation of the external stress.
Previous experimental and numerical studies focusing on the trade-off between dyke overpressure and external stress did not consider the effect of other parameters which may affect dyke propagation paths. For instance, the effect of the dyke length has never been addressed before.
In the study at the hand, we address the issue of how the length of dykes may affect their propagation path in presence of an external, heterogeneous stress field. We provide a revised threshold for deflection, which accounts for the magnitude of the external stress, the dyke internal pressure, and length. We make use of numerical simulations of dyke propagation, carried out with a two-dimensional boundary element model, and of analogue experiments of air-filled crack propagation into a transparent gelatin block. We used a finite element model to compute the external stress field acting within the gelatin box, and we show that the effect of the rigid boundaries is not negligible. Finally, we perform a direct, quantitative comparison between analogue experiments and 2D numerical simulations. We find that, given the same ratio between external stress and dyke pressure, longer dykes are less sensitive to the external stress, and therefore tend to be less deflected.
Our results have important implications for volcanological studies which aim to address the problem of complex trajectories of magmatic dykes (i.e. to forecast scenarios of new vents opening at volcanoes), but it also has implications for studies that address the growth and propagation of natural and man-induced hydrofractures.