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Modelling the interplay between magmatic intrusions and strike-slip faults: application to Miyakejima (Japan) and Mt. Etna (Italy)

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Magma is often transported in the brittle crust by means of diking, which are magma-filled lenses propagating by fracturing rock at their tip and pinching themselves closed at their back. One of the main unanswered question revolving around diking is how dikes are arrested. Several mechanisms have been suggested that may concur in stopping a dike: magma freezing; magma volume loss in the dike tail; dikes reaching a level of buoyancy inversion; stress heterogeneities exerting compression around the propagating tip; structural discontinuities such as layering, or co-diking slip on pre-existing fractures or faults. The interaction of dikes with faults and fractures has been investigated through crustal deformation and seismic studies, theoretically, numerically and experimentally. Most of studies assume static dikes, that generate seismicity or react to the presence of fractures. In this work we use a boundary element approach to study the interplay between a propagating dike and pre-stressed fault. While the stresses induced by a propagating dike may favor slippage on a fault, also slip occurring on a large structure will change the stress state in the medium and influence the dynamics of the dike. We use a 2D boundary element plain strain model for fluid-filled fracture propagation based on the Displacement Discontinuity Method. For the present applications, we implemented the full coupling between a strike-slip lubricated fault (a friction free shear crack) and a mixed-mode dike (accounting for both tensile and shear displacement components). The dike is propagated by adding an element at the tip. By computing the energy released during dike propagation for a range of virtual elongations in different directions, our code indicates the energetically favored trajectory for the dike and whether the dike will accelerate, decelerate or stop in a given location. We apply our model to the 2000 dike intrusion at Miyakejima, Izu arc, Japan, and to the interaction between the Pernicana fault and flank intrusions at Mt. Etna, Sicily, Italy. We constrain the initial geometry and physical parameters in our model by using seismic and deformation measurements and inversions. Next, we describe the dike dynamics in interaction with the shear structures, and evaluate the contribution of slippage events on faults in arresting the dikes.