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The 2000 Miyakejima dike injection: insight on the mechanisms governing the dike arrest

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Magma stored beneath volcanoes is often transported out of the magma chambers by means of laterally propagating dikes, which are magma-filled lenses that grow by fracturing rock at their tips. Lateral dike injections can lead to fissure eruptions if they intersect the flank of the volcano or the Earth's surface. This sometimes occurs tens of kilometers away from the volcanic edifice. The driving force for lateral dike propagation can be a lateral tectonic stress gradient, the stress gradient due to the topography, or simply the overpressure of the magma chamber. Those forces can act together and interact with the magma buoyancy and with structural discontinuities of the crust, such as pre-existing faults. The 2000 dike intrusion at Miyakejima volcano, Izu arc, Japan, propagated laterally for about 40 km and stopped in correspondence of a strike-slip fault system, sub-perpendicular to the dike plane. After stopping, the dike continued to inflate, without further propagation. During this inflation phase several earthquakes with M>6 occurred on that fault system. It has been proposed that the main cause for the dike arrest was the fault-induced stress. Here we use a boundary element approach to study the interplay between a propagating dike and a pre-stressed fault, accounting also for the stress gradient due to the topography overlying the dike. We use a 2D boundary element plain strain model based on the Displacement Discontinuity Method. For the present application, we focus on the coupling between a strike-slip fault and the dike. The dike is propagated by adding an element at the tip. Influx of magma during propagation is provided in order to maintain the dike overpressure large enough to fracture the rocks at the dike tip. By computing the energy released during the dike propagation, our code indicates whether the dike will accelerate, decelerate or stop at a given location. We find that the stress gradient induced by the topography alone is not able to explain the arrest of the 2000 Miyakejima dike at the prescribed location. However the joint effect of the topography and the stress induced by the strike-slip fault is consistent with the observed dike arrest and inflation phase, and with previous findings based on inversion of GPS measurements and seismic data.