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Modelling of dyke-fault interactions in composite volcanoes

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Studies of composite volcanoes indicate three primary mechanisms that control dyke propagation, namely, stress barriers, elastic mismatch, and Cook-Gordon debonding or delamination. The mechanisms are supported by field observations, analogue, analytical and numerical models and represent major controls on the movement of magma from the source to the surface or, alternatively, the capture of magma in the crust. The deflection of a dyke into a contact often results in the formation of a sill. Sills, in turn, may eventually evolve into shallow magma chambers. While dyke deflection into contacts is well studied, dyke deflection into existing faults has received much less attention. To address this, we have made observations of dyke-fault interactions at a well-exposed dyke swarm at the Santorini volcano in Greece.

Here we combine field observations with FEM numerical models using COMSOL Multiphysics. The deflected dykes belong to a local dyke swarm (∼91 dykes) that were emplaced in a highly heterogeneous and anisotropic host rock. The swarm is dissected by a series of historic caldera collapse events and normal faults and is thus well exposed. Our models simulated a fault zone with parallel layers of progressively more compliant rocks, and the dykes, which meet the fault at different angles, are modelled as cavities with prescribed magmatic overpressures. We also simulated the effect of tectonic loading (i.e. regional extension or compression), and multiple dyke injections. Our models explore the mechanical conditions for, and potential outcomes of, dyke-fault interactions. For example, changing the thickness of the dyke has a large effect on the local stress field, partly because stiffer fault zones concentrate more stress than the compliant (soft) ones. Also, the stiffness of the fault core and the dyke-fault geometry to a degree control dyke deflection in the crust.