Dyke-induced vs tectonic-controlled graben formation in a heterogeneous crust: Insights from field observations and numerical models

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Dyke propagation is the most common way of magma transfer towards the surface. Their emplacement generates stresses at their tips and the surrounded host rock initiating surficial deformation, seismic activity, and graben formation. Although active deformation and seismicity are studied in monitored volcanoes, the difference between dyke-induced and tectonic-controlled grabens is still less understood.

Here, we explore the difference between dyke-induced vs tectonic-controlled graben formation in stratovolcanoes with heterogeneous crustal properties like Mt. Etna (Italy) and Santorini (Greece). The field observations are related to Mt. Etna's 1928 AD fissure eruption, which partly generated dyke-induced grabens along its expression, and to the Santorini volcano, where tectonic-controlled grabens become pathways for later dyke injections. Field campaigns have revealed the stratigraphic sequence of the shallow host rock successions that became the basis of several suites of numerical models. The latter investigated the boundary conditions (overpressure or external stress field) and the geometrical and mechanical parameters that i) could produce temporary stress barriers and hence stall the propagation of a dyke towards the surface, and ii) shall form a graben at the surface. The detailed analysis, results and interpretations propose that soft materials in the stratigraphy, such as pyroclastic rocks, suppress the stresses at the vicinity of a propagating dyke and do not promote the generation of a graben above a propagating dyke. Also, the study explores the conditions where inclined ascending dykes produce semi-grabens and the generation of wide or narrow graben structures. Finally, the results give valuable insights on the field-related parameters that can encourage dyke deflection in pre-existing grabens in the shallow crust. All the latter can be theoretically applied in similar case studies worldwide.