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How multiple dikes facilitate volcanic eruptions, with application to recent events on the Reykjanes Peninsula, Iceland

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Dikes supply magma to most volcanic eruptions. Understanding under what conditions propagating dikes reach the surface to erupt or, alternatively, become arrested (stop their propagation) or deflected so as to propagate primarily laterally or change into sills, is thus one of the fundamental tasks of volcanology. Many dike segments injected from magma sources do not reach the surface to feed volcanic eruptions. Instead, the dike segments become arrested, commonly at or close to contacts between mechanically dissimilar layers/units, at various crustal depths. This means that many and perhaps most volcanic unrest periods with dike injections do not result in eruptions. There are several conditions in the crust that make dike arrest likely, but the main one is layering where the layers have contrasting mechanical properties. Such layering means that local stresses are heterogeneous and anisotropic and thus in some layers unfavourable (e.g., because the layers act as stress barriers) for vertical dike propagation, resulting in dike arrest, lateral dike propagation beneath the stress barrier, or dike deflection into a sill. Here I show that once a dike has formed, its very existence tends to make the local stress field along the dike homogeneous (with invariable orientation of principal stresses) and favourable (with dike-parallel orientation of the maximum compressive principal stress) for later dike injections. This means that a later-injected dike may use an earlier-injected dike as a path, either along the margin or the centre of the earlier dike, thereby generating a multiple dike. Because earlier feeder-dikes form potential paths for later-injected dikes to the surface, many volcanic eruptions are fed by multiple dikes. Multiple dikes thus tend to favour dike propagation to the surface, thereby facilitating dike-fed eruptions. Examples of multiple-dike-fed eruptions include recent ones in Etna (Italy) and Kilauea (Hawaii), as well as in the Icelandic volcanoes Krafla and Hekla. Here, however, the focus is on several eruptions in the past few years on the Reykjanes Peninsula, Iceland. In particular, I discuss the eruptions of 2021, 2022, and 2023 in the volcano Fagradalsfjall as well as the 2023 eruption along the volcanic fissure Sundhnukar (close to the town of Grindavik), all the eruptions occurring on the Reykjanes Peninsula.