Title

Dike-segment propagation, arrest, and eruption at Fagradalsfjall, Iceland

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Abstract

The volcanic eruption that began on 19 March 2021 at Fagradalsfjall is the first one to occur on the Reykjanes Peninsular for nearly 800 years and in Fagradalsfjall for about 6000 years. The feeder-dike was injected from a magma reservoir whose top is at about 10 km depth below the surface (but the reservoir itself reaches much greater depths). The dike formation involved at least two roof ruptures and resulting dike segments. The first occurred on 24 February and the second on 14 March 2021. The first rupture, marked by earthquakes of M2-3 close to the contact between the roof and the magma, occurred in the eastern half of the top-part of the reservoir. An injected dike segment propagated towards the surface but became arrested at the depths of 0.5-2 km. As its vertical propagation became arrested, while continuing to receive magma, the segment spread laterally, reaching an overall maximum dike strike-dimension (length) of about 10 km. The second rupture, also marked by earthquakes of M2-3, occurred about 1 km to the west of the first rupture. The injected dike segment following the second rupture eventually resulted in the dike propagating to the surface to feed the eruption which started on 19 March. We estimate the average vertical rate of the feeder-dike propagation at about 0.02 m s^{-1}. This is an order of magnitude lower than common rates of lateral dike propagation in rift zones, yet similar to the average rate during the Bardarbunga (Iceland) 2014 dike propagation (around 0.04 m s^{-1}). The initial volcanic fissure fed by the second dike segment had a length of less than 200 m and an opening of a fraction of a metre. Subsequently, several more 'dike-fingers' reached the surface and generated volcanic fissure segments. The total length of the discontinuous, segmented fissure is many hundred metres – but only one crater is presently active. Using the aspect ratio of the fissure and basic fracture mechanics, we estimate the magmatic overpressure (driving pressure) at the beginning of the eruption as about 3 MPa. The low driving pressure and small fissure opening displacement and length are in harmony with the very low volumetric flow (effusion) rate of about 10 m^3 s^{-1}.