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Mechanical interaction between the fissure and graben of the 1783 Skaftareldar Eruption and the hyaloclastite Laki Mountain

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The Skaftareldar (Laki) Eruption of 1783 in South Iceland produced a 27-km-long, NE-trending fissure with some 140 crater cones. The fissure is associated with a narrow graben and a hyaloclastite mountain (Laki), both located close to the centre of the fissure. The main graben dissects and extends to the northeast and southwest of the hyaloclastite mountain. In the mountain, the graben which is mostly 200-300 m wide becomes wider and reaches a maximum width of about 500 m. The total visible length of the graben is 5-6 km, the vertical displacement on the boundary faults being variable but reaching a maximum of at least 6-7 m. Parts of the graben may be buried by the lava flows of the 1783 eruption. At the top of the Laki Mountain, the boundary faults are gaping by as much as 2-3 m; they are thus mixed-mode, that is, partly tension fractures and partly shear fractures. In addition, there is a set of NW-trending faults, of unknown age, dissecting the Laki Mountain.

The feeder-dyke to the Skaftareldar Eruption did not reach the top of the Laki Mountain. The associated volcanic fissure only extends for a short while up into the slope of the mountain, and there stops. In particular, within the mountain the feeder-dyke only reaches the surface in its northwestern slopes which constitute a part of a large normal fault (of an unknown age). Also, close to the mountain, the feeder dyke uses the boundary faults of the graben as channels to the surface, so that parts of the volcanic fissure coincide with segments of the normal faults of the graben.

To better understand the mechanical interaction between the volcanic fissure (feeder-dyke), the graben and the Laki Mountain, we made numerical models where the hyaloclastite mountain is modelled as a soft, elastic inclusion. The results show, first, that the inclusion tends to suppress the tensile and shear stresses associated with the propagating feeder-dyke and the normal faults of the graben, respectively, thereby making it difficult, but not impossible, for these fractures to propagate through the entire Laki Mountain. Second, the results indicate that the local stress field which develops within the mountain during the feeder-dyke emplacement encourages the dyke's path to curve towards, and reach the surface along, the large normal fault that forms the mountain's northwestern slope.

The relationship between the graben and the feeder dyke is complex. The fundamental question is if the graben existed, partly or wholly, before the eruption and thus captured the associated feeder-dyke, or if the feeder-dyke itself was entirely responsible for the graben formation. Because parts of the boundary faults are used as paths to the surface by the feeder-dyke, these fault segments clearly existed at the time of the 1783 eruption. However, the faults may still have been induced by stresses related to the feeder-dyke or at least generated during the rifting event that was associated with the Laki 1783 eruption.