

How stress transfer between volcanic and seismic zones affects volcanic and earthquake activity

Poster

Agust Gudmundsson¹

Sonja L. Philipp¹

Oceanic transform faults and ridge segments form a network where mechanical interaction is to be expected (Fig. 1). In particular, dike emplacement in ridge segments is likely to affect earthquake activity in the adjacent transform faults through processes such as stress transfer. Similarly, strike-slip displacement across transform faults may trigger dike injections and, eventually, eruptions in the adjacent ridge segments. For obvious reasons, direct observations of the possible mechanical interaction between submarine transform zones and ridge segments at mid-ocean ridges are difficult.

The subaerial seismic zones of Iceland, however, are in clear spatial connections with the adjacent volcanic zones (Fig. 2). These zones, therefore, provide excellent opportunities to study stress transfer between volcanic and seismic zones (Gudmundsson 2000). At the junctions with the Kolbeinsey Ridge in the north and the Reykjanes Ridge in the south, there are ocean-ridge discontinuities that host one or more seismic zones (Fig. 2). The northern discontinuity is referred to as the Tjörnes Fracture Zone (TFZ), a transform fault that is partly exposed on land as the Husavik-Flatey Fault (HFF). The southern discontinuity is referred to as the South Iceland Seismic Zone (SISZ). It is a

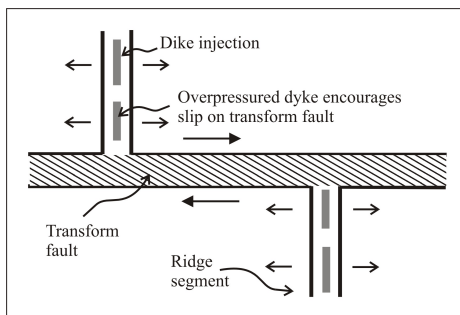


Figure 1: Ocean-ridge segments and transform fault forms an interconnected fracture system, where stress changes in one fracture (say, due to dike injection in a ridge segment) may be expected to be partly transferred to the adjacent fractures (here, transform faults).

zone where most of the seismogenic faulting occurs on conjugate strike-slip faults. The largest earthquakes in Iceland, reaching M7.1–7.3, occur on strike-slip faults in the TFZ and the SISZ.

In the SISZ, major destructive earthquakes occur at intervals of 80–100 years, the largest events reaching M7.1–7.3 (Gudmundsson and Brenner 2003). Although the zone is E–W trending, with an overall sinistral movement, most of the earthquakes are associated with NNE and ENE-trending strike-slip faults. We present numerical models indicating that when the SISZ is loaded to failure, stresses are transferred to, and concentrate at, its ends: tensile in the northeast and southwest quadrants and compressive in the northwest and southeast quadrants. These model results agree with observations made when the SISZ was loaded to failure in June 2000, resulting in two M6.6 earthquakes. For several years prior to the June 2000 earthquakes, compression, uplift and in-

¹ Department of Structural Geology and Geodynamics, Geoscience Centre, University of Göttingen, Goldschmidtstraße 3, D-37077 Göttingen

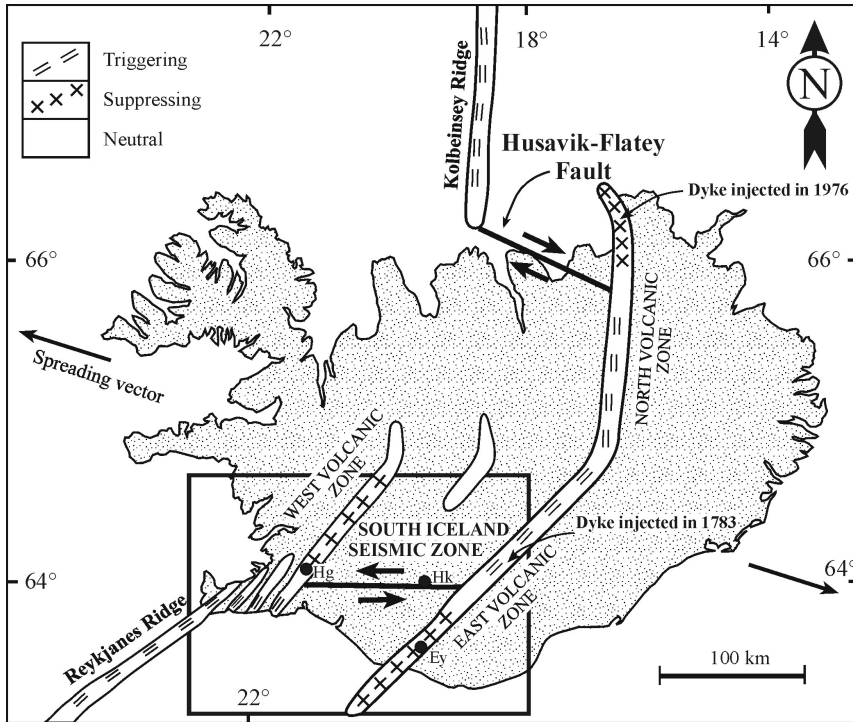


Figure 2: The Husavik-Flatey Fault (HFF) is the main structure of the Tjornes Fracture Zone which connects the North Volcanic Zone to the Kolbeinsey Ridge. HFF is an oceanic transform fault. By contrast, the South Iceland Seismic Zone (SISZ) is a zone of high shear stress concentration between the overlapping West and East Volcanic Zones (modified from Gudmundsson and Brenner 2003).

tense earthquake swarms (some events exceeding M4) occurred in two active composite volcanoes, Hengill and Eyjafjallajökull, located in the quadrants of compressive stresses (Fig. 3). Most of this earthquake activity came to an end following the June 2000 earthquakes.

Also, in the decades prior to the June 2000 earthquakes, the Hekla Volcano (Fig. 3), located in one of the quadrants of tensile stress, erupted unusually frequently. These composite volcanoes (with shallow magma chambers) act as ‘soft inclusions’ at which stresses transferred from the SISZ become con-

centrated. Deformation and seismicity in Eyjafjallajökull and Hengill and the unusually high eruption frequency in Hekla may thus be used as precursors to large earthquakes in the SISZ.

In South Iceland, stress is also transferred from the volcanic zones to the seismic zone. For example, stress transfer from the overpressured 27 km-long feeder dike of the 1783 Laki eruption to the nearby SISZ triggered the 1784 earthquake sequence, the largest historical one (that is, for the past 1100 years) in the SISZ. Thus, the largest historical eruption in Iceland, Laki 1783, trig-

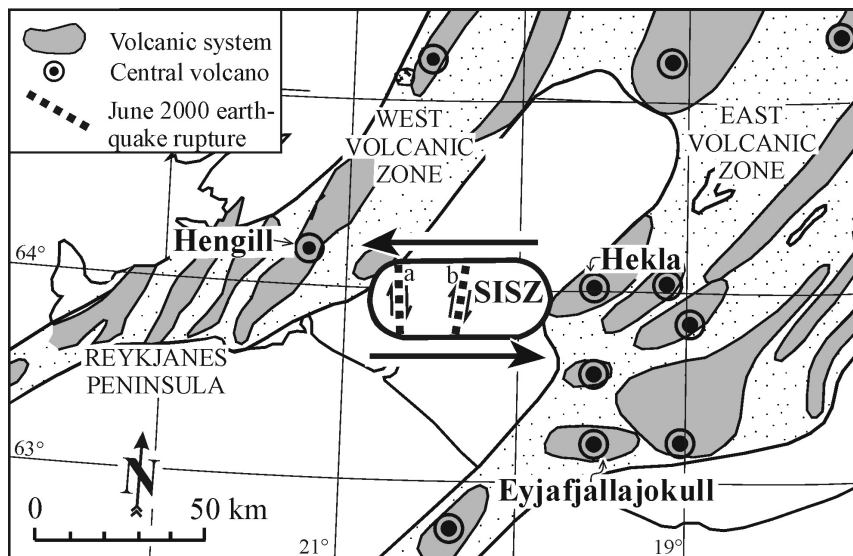


Figure 3: Location of the central volcanoes of Hengill, Hekla, and Eyjafjallajökull in relation to the South Iceland Seismic Zone (SISZ). Also indicated is the overall sinistral movement across the zone, as well as the two faults (a, b) associated with the June 2000 earthquakes (modified from Gudmundsson and Brenner 2003).

gered its largest historical earthquake sequence.

In contrast to the SISZ, the TFZ is a well-developed oceanic transform fault (Fig. 2). Its main structure is the HFF, an active dextral fault, partly exposed on land in North Iceland. Dike injection in 1976 in the North Volcanic Zone during the Krafla Fires (1975–1984) resulted in a nearly two-decade suppression of earthquake activity in the HFF (Fig. 2).

For regional dikes, such as those injected during the Laki 1783 and the Krafla 1976 eruptions, the magmatic overpressure may reach tens of megapascals. Part of the overpressure associated with the dikes is transferred as compressive stress to the nearby seismic zones, the SISZ and the HFF. The models presented here indicate that when

the dike-generated horizontal displacement is opposite to the normal displacement across the adjacent seismic zone, earthquakes are suppressed. By contrast, when the dike-generated displacement is consistent with the normal displacement across the adjacent seismic zone, earthquakes are triggered (Fig. 2).

References

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