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# Fault ruptures and geothermal effects of the second earthquake, 29 May 2008, South Iceland Seismic Zone

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ABSTRACT

The Reykjafjall N–S source fault ruptured during the $M_w$ 6.3 earthquake doublet on May 29, 2008, in the South Iceland Seismic Zone (SISZ). The northern part of the fault intersects the easternmost high-temperature geothermal field of Hengill in an extinct volcano that began shifting away from the Western Rift Zone 120,000 years ago. Geophysical data indicate that the N–S fault ruptured over 20 km length at depth. Our detailed field mapping along the fault length shows that the southern part of the fault did not rupture the surface mostly due to the greater depth of seismicity (down to 9 km) there. The surface ruptures were dominantly found along the northern half of the fault in the highland within the high-temperature field where aftershocks were shallower than 5 km. There, the surface ruptured on portions of six parallel N–S fault segments and not on a single fault plane. Hot springs are aligned on the two westernmost fault segments within the area of increased geothermal activity after the earthquake. Other Riedel shears (ENE, E–W, WNW and NNW) hosting geothermal activity also ruptured. On the N–S faults, surface ruptures and hot springs are organised in left-stepping arrays indicating dextral motion with offsets between 0.5 and 2 m. On other Riedel shear sets ruptures have a right-stepping arrangement indicating sinistral motion with a maximum horizontal offset of a metre. All fresh ruptures had centimetre-scale normal-slip and openings <1 m but up to 1.5 m along atypical N–S structures.

Our results fit with the lineations in the aftershocks and with fault plane solutions. They also show that the 2008 source fault ruptured within a 2-km wide deformation zone where previous earthquakes and changes to geothermal activity have occurred at least since 1706. This implies that major earthquakes in this area may have a common source fault at depth and a wider deformation zone at the surface. Our study demonstrates how transform faulting at the junction of a rift segment causes recurring medium–large earthquakes that control fault behavior and permeability in fractured geothermal fields.



## 1. Introduction

At an interval of three seconds on May 29, 2008 an earthquake doublet, $M_w$ 6.3 hit the eastern margin of Hengill geothermal area at its intersection with the SISZ (Fig. 1a and b) (Brandsdóttir et al., 2010; Decriem et al., 2010; Einarsson, 2010; Sigbjörnsson et al., 2009; SIL database Icelandic Meteorological Office, 2009). GPS, InSAR, and aftershocks reveal two parallel vertical N–S dextral faults 5 km apart.

The first and easternmost event originated near Ingólfsfjall. The aftershocks delineate a 10-km long N–S source fault mostly to the north of Ölfusá River (e.g., Brandsdóttir et al., 2010). Geodetic data suggest a horizontal offset up to 1.9 m at 2 to 4 km depth along this fault (Decriem et al., 2010).

The second event occurred to the west, near Reykjafjall. The aftershocks define a 20-km long N–S structure stretching from the ocean shoreline to the highland north of Ölfusá River (Fig. 1b). Geodetic data indicate maximum 1.4 m horizontal offset at 3–6 km depth (Decriem et al., 2010). Overall, the aftershocks seem to be shallower than 5.5 km in the highland on the northern halves of the two source faults but deeper, down to 9 km depth, in the lowland (Brandsdóttir et al., 2010). The aftershocks also show other weaknesses such as a conspicuous 20-km long ENE structure intersecting the N–S faults to the north of Ölfusá River (Fig. 1b).

We began a detailed mapping of the Reykjafjall source fault a day after the earthquakes in 2008 and completed our tectonic analysis in 2010 after three field campaigns (Khodayar and Björnsson, 2010; Khodayar et al., 2008). Parallel to our study, Þorbjörnsson et al. (2009) monitored the water level changes in the boreholes. For this they mapped the outline of the surface ruptures of both source faults and the geothermal activity associated with the Reykjafjall Fault. Einarsson (Personal communication) made thorough

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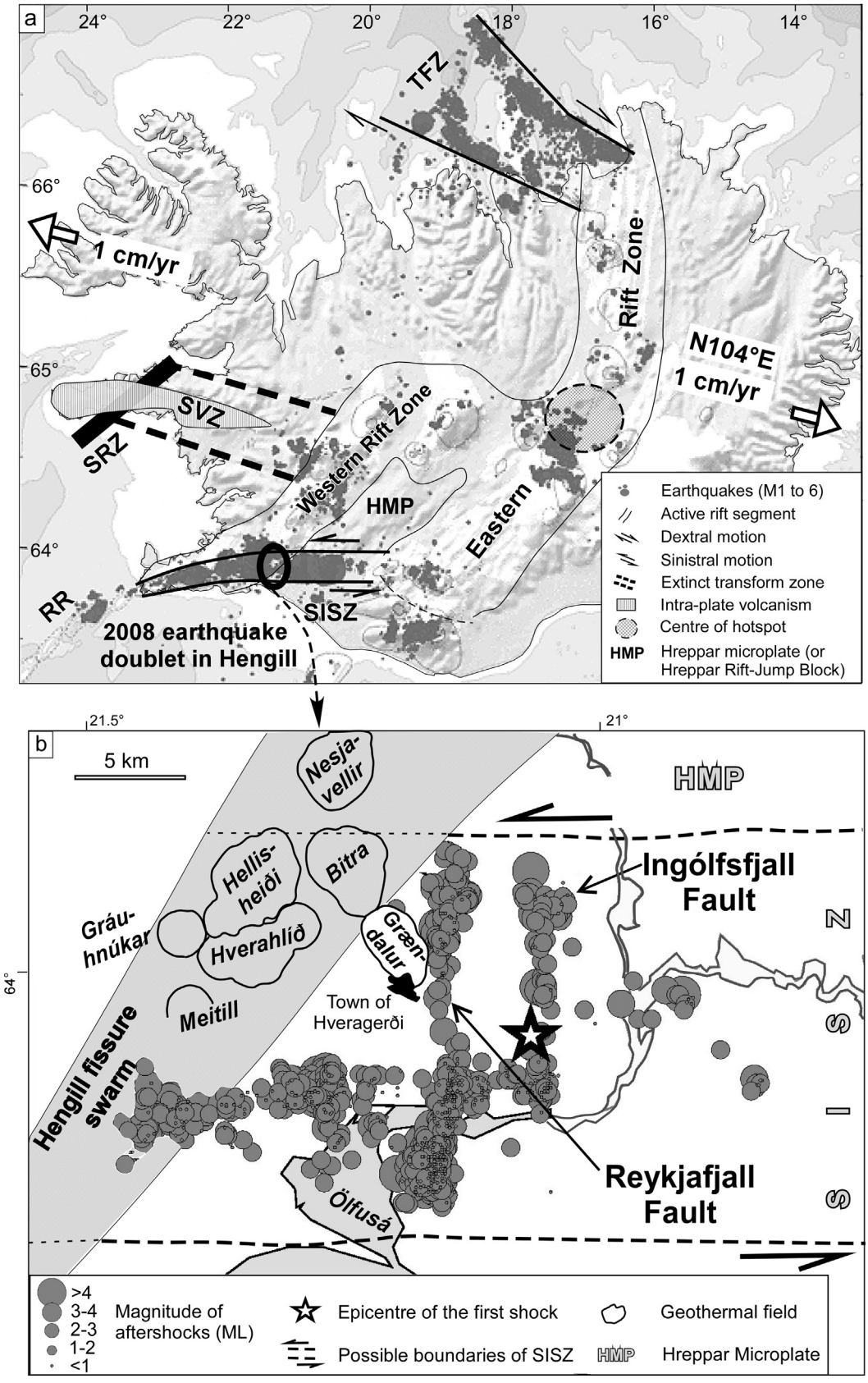


**Fig. 1.** Plate boundaries in Iceland, seismicity, Hengill geothermal fields, and aftershocks of the 2008 earthquakes. (a) Main tectonic elements (modified from Jóhannesson and Sæmundsson, 1998), present-day seismicity (Guðmundsson et al., 2001; Jakobsdóttir, 2008) and spreading direction (DeMets et al., 1990). TFZ: Tjörnes Fracture Zone; SISZ: South Iceland Seismic Zone; RR: Reykjanes Ridge; SRZ Snæfellsnes Rift Zone; SVZ: Snæfellsnes Volcanic Zone. (b) Compilation of aftershocks (modified from Decriem et al., 2010) and high-temperature geothermal fields (modified from Björnsson, 2007). Note that the epicentre of the mainshock in Reykjafjall has not been determined instrumentally as this event occurred only 3 seconds after the mainshock in Ingólfsfjall.