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Geothermal, tectonic, and magmatic deformation processes in the Hengill area, Iceland

Halldór Geirsson (1), Cécile Ducrocq (1), Hanna Blanck (1,2,3), Thóra Árnadóttir (1), Kristín S. Vogfjörd (2), Bjarni Reyr Kristjánsson (4), Gunnar Gunnarsson (4), Vala Hjörleifsdóttir (4), Daniel Juncu (1,5), Freysteinn Sigmundsson (1), Benedikt G. Ófeigsson (2), Vincent Drouin (1,6)

(1) Nordvulk, Institute of Earth Sciences, University of Iceland, Reykjavík, Iceland (hgeirs@hi.is), (2) Icelandic Meteorological Office, Reykjavík, Iceland , (3) ISOR - Iceland Geosurvey, Reykjavík, Iceland, (4) Reykjavík Energy, Reykjavík, Iceland, (5) Leeds University, Leeds, UK, (6) National Land Survey of Iceland, Akranes, Iceland

Geothermal production, including fluid extraction and re-injection, causes permanent changes in crustal stresses and fluid pressure, which affects nearby seismicity and fault movements. Stress changes can in general also affect magmatic movements, such as dike propagation, dike arrest, and formation and growth of magma chambers. Here, we use the Hengill area in SW-Iceland as a natural laboratory to study study stress and fluid interactions of geothermal, tectonic, and magmatic processes.

Hengill has been subject to various geological events in the past decades. In addition to the ∼1.9 cm/yr of plate motion across the Hengill area, during 1994 to 1998 an intrusion caused uplift of about 8 cm in the Eastern part of the Hengill area and triggered nearly one hundred thousand of earthquakes with the largest one of magnitude 5.5. Relative relocations of those earthquakes are used to identify the strike, dip and rake of fault movements triggered by the intrusion. From the end of 1999 until 2006 the area was relatively quiet. In 2006 the Hellisheiði geothermal powerplant commenced and the Nesjavellir powerplant was enlarged, leading to a combined 420 MW electricity and 430 MW hot water produced in the Western part of the Hengill area. Localized subsidence of up to ∼2.5 cm/yr is observed in the main production areas, however, temporary inflation was observed in the main injection area. In 2006 widespread subsidence started in the Eastern part of the area, inferred to originate from about 7 km depth, similar to the intrusion in the nineties. This subsidence now amounts to at least 12 cm total, far exceeding the inflation in the nineties. In late 2017, the Eastern-Hengill subsidence temporarily changed to inflation, but subsidence resumed in the spring of 2018 (Ducrocq et al., this meeting). These deep inflation-deflation episodes link to the energy recharge processes of the geothermal systems, whether magma or hydrothermal fluids cause the deformation. In 2016 geothermal production started from a part of the Hengill area called Hverahlíð, a few km SE of the main production area. We observe small deformation in this region, in rough agreement with the relative geothermal fluid mass outtake in the area.

The deformation data provides a comprehensive description of ongoing processes and we have, for example, used it to generate time-dependent strain maps and constrain key reservoir parameters such as depth of pressure change, reservoir recharge, steam ratio and reservoir bulk modulus.