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Evaluation of the response of the Reykjanes high-temperature geothermal reservoir (Iceland) under production using Interferometric Synthetic Aperture Radar (InSAR) studies of ground surface deformation

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The Reykjanes geothermal system is a high-temperature seawater system situated at the southwestern tip of the Reykjanes Peninsula, SW Iceland. New Sentinel-1 satellite data have been used to evaluate the ground surface deformation induced by geothermal utilization between 2015 and 2017, using Interferometric Synthetic Aperture Radar (InSAR) methods. The total vertical and horizontal displacements have been estimated by stacking and combining two-year interval interferograms formed from two sets of images displaying different viewing geometries. The time series analysis of deformation reveal a steady and linear subsidence within a sub-circular bowl centered on the well field, at a maximum rate of about 20 mm/yr in the line-of-sight (LOS) of the satellite. The characteristics of the source of the observed deformation were then inverted using simple analytical models, considering the geothermal reservoir as a sphere, an ellipsoid or a penny shaped sill-like pressure source embedded in an elastic half space. The best fit was obtained for a spherical source at about 1 km depth contracting at a rate of -0.9e5 m3/yr over the two years.

These results are in accordance with previous deformation analysis for the period 2009-2016 and confirm the decline in the subsidence rate since the end of 2008. A maximum rate of more than 30 mm/yr was observed during the two first years of production (2006-2008) along a NE-SW elongated subsidence bowl. This was best modelled by an ellipsoid source situated at 2.2 km depth and contracting at an average rate of -7.6e5 m3/yr. In October 2017, the inferred total subsidence since the start of the production is close to 300 mm.

Such geodetic results can be compared to various information such as the reservoir structure, rock properties, production or monitoring data (e.g., pressure and temperature from well logging), for an integrated investigation of the geothermal system. Following the commissioning of the 100MWe power plant in 2006, production dramatically increased, resulting in a sudden pressure drop in the deep part of the reservoir and the development of a steam cap above 1.1 km depth. Subsequent to a decrease in the rate of pressure decline in 2008, well monitoring since 2015 indicates a slight increase in pressure at 1.6 km depth, without significant signs of cooling within the reservoir.

A preliminary interpretation suggests that the deformation at Reykjanes mainly depends on poro-elastic processes. During the two first years of production, an NE-SW elongated elliptical subsidence bowl formed in response to the large pressure drop along the NE-SW striking Reykjanes Fissure Swarm. From 2009 we suggest pressure decline in a steam cap near the top of the geothermal reservoir, in accordance with the migration of the modelled source of deflation from 2.2 km to 1 km depth and the change in the deformation pattern. This could have caused increases in vertical stresses and the compression of unconsolidated sediments (i.e marine sediments) from the upper volcano-sedimentary sequence.