Induced seismicity in a geothermal reservoir: a case study in the Reykjanes peninsula in Iceland

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ABSTRACT

Induced seismicity related to subsurface processes at geothermal power plants is an active field of research where we contribute with a case study from the Reykjanes peninsula. We present our first results from the analyses of microseismic events that in one case are induced by fluid injections and in the other case occur due to natural, tectonic stress build up.

In this study, we try to relate microseismic event clouds to a fracture network by detailed characterization and clustering of individual microseismic events. These results will guide us in further testing and improving methods for:

a) numerical modelling of fluid flow in fractured media
b) interaction of fluid flow with fracture initiation/propagation and heat transfer
c) risk and hazard mitigation estimates related to induced seismicity

The Reykjanes geothermal field is located on the South-West of Iceland, on the Reykjanes Peninsula. A dense sensor network, composed of 38 three-component geophones, short period and broadband, has recorded both natural and induced seismicity from April 2014 until August 2015. Parts of this deployment is related to a previous study (EU project IMAGE), which had a different focus. Our study, however, is interested in microseismic events and fracture network modeling. We selected three different weeks of seismicity occurring in 2015 for further, more detailed analysis.

During these three weeks, 876 earthquakes were detected using an STA/LTA triggering method. Most of these events were characterized by a low frequency content of about 2 to 20 Hz. The locations of about 500 events have an uncertainty of less than 1.5 km, which allow us to separate earthquakes occurring on the Reykjanes Ridge from those located on the Reykjanes Peninsula. The first events are assumed to be natural seismicity, whereas the later ones are suspected to be induced earthquakes due to the geothermal activity known at these locations. Hence, we consider the 344 possibly induced events for further detailed analysis.

As some seismic events show waveform similarities, they have been cross-correlated. Clusters of similar events with a minimum cross-correlation coefficient greater than 0.5 (for both P- and S-waves) have been created. They were used to perform a relative location, using the double-difference method. 210 events are relocated, which is 61 % of the total catalogue. We hereafter focused on the analysis of only one week.

Most of these relocated microseismic events, which are closer to each other and shallower than their absolute locations indicate, seems to occur in the geothermal field. On the other hand, non-relocated seismic events appear to be outside of it and should present alignment along known geological fractures. A comparison with the occurrence times shows a general trend that seismic events migrated towards the surface over time. This observation is also made in other geothermal fields and could be linked to the rise of fluids.

A spectral analysis, based on the Brune (1970) model, leads to a magnitude range spanning from -0.4 to 1.6. Because of the chosen sampling rate and the corresponding cut-off frequency of the sensors, the corner frequency is not well constrained even if the plateau, which is directly linked to the moment magnitude, is well estimated. Most of the biggest events are not included in cluster families and are also the deepest events. Consequently, it seems that seismic events present two different behaviors, which is dependent on whether they are or are not part of a cluster.

REFERENCES

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