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## Seismicity induced during thermal and hydraulic stimulation of the well GRT1 at the Rittershoffen deep geothermal site, France

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In a geothermal reservoir, seismicity may be induced due to pressure changes in the underground as a result of drilling, stimulation or circulation operations. The induced seismic events are therefore strongly linked to the fluid flow and the geological structures that make this fluid flow possible. The development of the deep geothermal site at Rittershoffen (Alsace, France) was monitored continuously by different seismic networks covering various operational periods from September 2012 to October 2014, including the drilling of the well doublet GRT1/GRT2, the thermal, hydraulic and chemical stimulations of GRT1 and circulation tests between the two wells. The seismicity induced by these operations has the potential to give valuable insight into the geomechanical behaviour of the reservoir and the geometry of the underground fracture network. Here, we focus on the comparison of the seismicity induced during the thermal and hydraulic stimulation of the well GRT1 to highlight similarities and differences of the seismic response of a reservoir to different types of stimulation operations.

To obtain a robust database for this analysis, we first apply a template matching code to the continuous waveforms recorded by the seismic networks. This technique is based on the calculation of the correlation coefficient between continuous and template waveforms. It outperforms conventional STA/LTA detectors in terms of sensitivity to events with low signal-to-noise ratio and picking consistency for events with waveforms similar to the templates. As template database, we use a manually picked seismic catalogue covering the different stimulation periods of GRT1 and the drilling period of GRT2 described in Maurer et al. (sub.). This starting catalogue contains over 1300 events, 146 recorded during thermal stimulation of GRT1, 990 during hydraulic stimulation of GRT1 and 184 during the drilling of GRT2.

The application of the template matching algorithm to the continuous waveforms recorded during the stimulation periods resulted in the detection of about 300 events for the thermal stimulation and nearly 3000 events for the hydraulic stimulation. Hence, the event database was doubled for the thermal and tripled for the hydraulic stimulation compared to the original template database. All events are then relocated with HypoDD, using the travel time differences between the events to gain precise relative locations. This makes it possible to image the seismically active structures during the stimulation operations. The comparison of the spatial distribution of the seismicity can answer questions like whether the same structures in the same reservoir area were activated, how large the seismically active reservoir volumes during each stimulation were and if they can be approximated by the same fault plane. Additionally, the relative magnitudes for the newly detected events are calculated from the magnitudes of the templates to further characterize the seismicity during the two stimulation operations.

### References

Maurer, V., Gaucher, E., Grunberg, M., Koepke, R. and Pestourie, R.: Seismicity induced during the development of the Rittershoffen geothermal field, France. (submitted).

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