Seismic imaging of St Gallen (Switzerland) deep geothermal field medium properties

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Sub-surface operations for energy production may originate various environmental risks among which, of great relevance is the seismic risk due to the induced seismicity associated with field operations.

In the framework of the H2020 Science4CleanEnergy project, S4CE, a multi-disciplinary project aimed at understanding the underlying physical mechanisms underpinning sub-surface geoe-
energy operations and to measure, control and mitigate their environmental risks, we have investigated the role of fluids in the generation of the seismicity induced during the deep geothermal drilling project close to the city of St.Gallen, Switzerland. To this aim we applied the Focal Mechanism Tomography (FMT) technique and the velocity and attenuation tomography using data collected by the Swiss Seismological Service in 2013 while realizing well control measures after drilling and acidizing the GT-1 well. The dataset consists of 347 earthquakes with magnitude \( M_{L \text{corr}} \) between -1.2 and 3.5. P and S phases were initially hand-picked on three-component ground velocity recordings. As an additional enhancement, a refined re-picking algorithm based on the waveforms cross-correlation was applied providing accurate travel-times data set. The revised picks and P polarities were used both to re-locate the events, using probabilistic approach considering both the absolute both the differential arrival times, and to estimate fault mechanisms using the FPFIT code. Only those events having at least 6 clear P-wave polarities have been analysed. To better constrain the focal mechanisms, for the larger magnitude events the BISTROP code (Bayesian Inversion of Spectral-Level Ratios and P-Wave Polarities) has been also applied.

Using the FMT technique we estimated the 3D excess pore fluid pressure field at the events hypocentre. Basically, the technique assumes that fault strength is controlled by Coulomb failure criterion and, under the hypothesis of uniform stress field, it ascribes the focal mechanism variations to pore fluid pressure acting on faults.

The velocity model and the attenuation model have been estimated by using an iterative
tomographic inversion of P and S arrival times and t* quantities, which are defined as the ratio of the travel time and quality factor (Q). The t* measures for both P and S wave have been obtained from the analysis of the displacement spectra. We found that fault mechanisms do not fit a uniform stress-field. Based on the events depth, at least two different stress-fields are required. FMT results indicate that fluids contributed to the generation of the induced events. Taking into account for the uncertainties, the inferred excess pore fluid pressure is consistent with the wellhead pressure. Moreover, a correlation exists between the high excess pore fluid pressure and the high Vp/Vs values.

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