Assessment of combined spatiotemporal multiplet analysis and static stress drop mapping as a general method for identification and characterization of main seismogenic zones in Enhanced Geothermal Systems

Description for the General Public

Underground fluid injection is an activity commonly undertaken during shale gas exploitation, geothermal energy production or underground wastewater storage. In case of Enhanced Geothermal Systems (EGS), which are developing fast in Europe and USA, fluid is injected into the reservoir in order to create new fractures and enhance heat flow into the production wells. This leads to an occurrence of earthquakes which may be destructive, like M5.5 Pohang earthquake which occurred on November 15, 2017 in South Korea. Information about the shape of underground fracture network and its development during injection activities is very important for controlling induced seismicity.

One of known seismological methods for underground fracture network imaging is based on identification of so called multiplets, i. e. seismic events with high level of waveform similarity. Groups of very similar seismic waveforms are used as an input into high-accuracy relocation methods. As a result, an image of fracture network and local tectonic structures can be obtained. Recently, we have successfully used spatial multiplet analysis for identification of discontinuities at small seismicity cluster from The Geysers geothermal field in California. Additionally, our analysis revealed that combined temporal analysis of multiplets and estimation of seismic source parameters, such as static stress drop, can be used to distinguish structures activated by various physical processes. **In this project we plan to check whether combined spatiotemporal multiplet analysis and static stress drop estimation can be successfully used for identification and classification of underground structures in other EGS environments exhibiting different geological conditions. Moreover, we will check if the method can be used to designate structures posing the highest seismic risk for the area.**

For the purpose of proposed research we plan to use three EGS datasets representing various geological conditions and tectonic complexity: (1) dataset from deep geothermal stimulation near Helsinki (Finland) representing the most homogenous reservoir with no tectonically active discontinuities, (2) isolated cluster of seismicity from The Geysers geothermal field (Northern California) representing intermediate case of tectonic complexity, (3) dataset from Coso geothermal field (Southern California) located in tectonically active region and representing the most complex tectonic setting. The analysis will be conducted for each dataset separately in the following steps:

1. Visualization of fracture network and identification of main structures using multiplet analysis.
2. Classification and characterization of identified structures using differences in static stress drops of earthquakes.
3. Assessment of the location of the strongest seismic events in relation to mapped fracture network.
4. Estimation of Peak Ground Velocity during earthquakes and seismic moment release within identified structures.

The analysis of chosen datasets in steps 1 and 2 will give us an overview if proposed method can be treated as a general method for identification of main seismogenic zones in EGS. Steps 3 and 4 will answer the question if we can designate structures posing the highest seismic risk.

Proposed method for fracture network imaging does not require high costs and can be applied in almost real time. **Developing a general and effective method for tracking underground fracture network and identification of the main fault zones would provide a useful tool for real time control of fluid-induced seismicity and development of traffic light system. Additionally, identification of structures posing the highest seismic risk can significantly improve seismic hazard assessment in such areas.** In current situation of urgent need for clean energy sources this issue becomes of great importance, also in Poland which has a significant geothermal potential.