Monitoring of Background Seismicity and Induced Earthquakes Associated with Enhanced Geothermal Systems in Ilan, Taiwan

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Hydro-fracturing stimulation is one of the key steps in the development of EGS. It aims to create a subsurface system full of cracks and fractures, thus providing an efficient water channel network to enhance the thermal energy extraction. Since small earthquakes are triggered by the occurrence of rock fracture, the distribution of hydro-fractures can be delineated by locations of these induced earthquakes. In this project, we have deployed 6 bore-hole seismometers to accurately capture the weak signals from these micro events. The influence on local seismicity from water-pumping is another important issue in this project. Preliminary analysis of data from our own borehole network indicates that many recorded local micro events are not reported in the CWB catalogue, thus, we need to rely on the borehole data to better evaluate the local background seismicity. We have also analyzed data during the stimulation experiments conducted in 11/09, 11/13 and 11/14, 2014. After various examinations, we noticed two major signals during the stimulations, the tremors, which are likely induced by water-pumping, and the free-oscillations of the water-filled cracks, which are obviously enhanced during the pumping period. However, probably because the energy from the induced rock failure is too weak, these signals were only recorded by the nearest borehole station, and there is no clear arrival time in the tremor signals. During the period from October 2014 to November 2015, 1313 local earthquakes were recorded by the bore-hole seismic network. We first determined the seismic velocity of the shallowest layer (depth < 500 m) with applying ambient noise technique on seismic records of local earthquakes, and inverted a minimum velocity model and preliminary locations of earthquakes by using the package VELEST developed by Kissling. We then relocated local earthquakes using “HYPODD” technique, and calculated local magnitude (ML) of these events. Most of these events are located at depth less than 5 km with rather small magnitudes (ML<1.0). Our results have well demonstrated that we are able to improve local micro-earthquake monitoring by using the bore-hole seismic network. During the stimulation experiments, no apparent variations of seismicity were noticed. Interestingly, the seismicity right beneath the injection well (2 –5 km) was clearly increased 3 days after the pumping, and such phenomena lasted for about 10 days. Besides the seismic swarm related to the stimulation experiments, we also identified several seismic swarms at shallow depth which imply relatively active geological structures in the study area.

Keywords: borehole seismometer, induced earthquakes, focal mechanism of micro-earthquake

