Geophysical Research Abstracts
Vol. 18, EGU2016-11106, 2016
EGU General Assembly 2016

Causality between expansion of seismic cloud and maximum magnitude of induced seismicity in geothermal field

Yusuke Mukuhira (1), Hiroshi Asanuma (2), Takatoshi Ito (1), and Markus Häring (3)

(1) Institute of Fluid Science, Tohoku University, Sendai, Japan, (2) Fukushima Renewable Energy Institute (FREA), National Institute of Advanced Industrial Science and Technology (AIST), Koriyama, Japan, (3) (Former) Geo Explorers Ltd., Liestal, Switzerland

Occurrence of induced seismicity with large magnitude is critical environmental issues associated with fluid injection for shale gas/oil extraction, waste water disposal, carbon capture and storage, and engineered geothermal systems (EGS). Studies for prediction of the hazardous seismicity and risk assessment of induced seismicity has been activated recently. Many of these studies are based on the seismological statistics and these models use the information of the occurrence time and event magnitude. We have originally developed physics based model named "possible seismic moment model" to evaluate seismic activity and assess seismic moment which can be ready to release. This model is totally based on microseismic information of occurrence time, hypocenter location and magnitude (seismic moment). This model assumes existence of representative parameter having physical meaning that release-able seismic moment per rock volume (seismic moment density) at given field. Seismic moment density is to be estimated from microseismic distribution and their seismic moment. In addition to this, stimulated rock volume is also inferred by progress of microseismic cloud at given time and this quantity can be interpreted as the rock volume which can release seismic energy due to weakening effect of normal stress by injected fluid. Product of these two parameters (equation (1)) provide possible seismic moment which can be released from current stimulated zone as a model output. Difference between output of this model and observed cumulative seismic moment corresponds the seismic moment which will be released in future, based on current stimulation conditions. This value can be translated into possible maximum magnitude of induced seismicity in future. As this way, possible seismic moment can be used to have feedback to hydraulic stimulation operation in real time as an index which can be interpreted easily and intuitively.

Possible seismic moment is defined as equation (1), where D is seismic moment density (Mo/m^3) and V_{stim} is stimulated rock volume (m^3).

$$Mo_{possible} = D * V_{stim} (1)$$

We applied this conceptual model to real microseismic data set from Basel EGS project where several induced seismicity with large magnitude occurred and brought constructive damage. Using the hypocenter location determined by the researcher of Tohoku Univ., Japan and moment magnitude estimated from Geothermal Explorers Ltd., operating company, we were able to estimate reasonable seismic moment density meaning that one representative parameter exists and can characterize seismic activity at Basel at each time step. With stimulated rock volume which was also inferred from microseismic information, we estimated possible seismic moment and assess the difference with observed value. Possible seismic moment significantly increased after shut-in when the seismic cloud (stimulated zone) mostly progressed, resulting that the difference with the observed cumulative seismic moment automatically became larger. This suggests that there is moderate seismic moment which will be released in near future. In next few hours, the largest event actually occurred. Therefore, our proposed model was successfully able to forecast occurrence of the large events. Furthermore, best forecast of maximum magnitude was Mw 3 level and the largest event was Mw 3.41, showing reasonable performance in terms of quantitative forecast in magnitude. Our attempt to assess the seismic activity from microseismic information was successful and it also suggested magnitude release can be correlate with the expansion of seismic cloud as the definition of possible seismic moment model indicates. This relationship has been observed in microseismic observational study and several previous study also suggested their correlation with stress released rock volume. Our model showed harmonic results with these studies and provide practical method having clear physical meaning to assess the seismic activity in real time, based on microseismic data.