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Slip-able area: New index to evaluate the fault area under critical state based on microseismic data at stimulation

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Unexpected occurrence of felt earthquake has been big issue as critical environmental burden associated with geothermal development and other energy extraction. The magnitude of seismic events induced by fluid stimulation is generally small enough to be perceived on the ground. However, at the Basel, Switzerland, some of the events had large magnitude, resulting in the shutdown of engineered geothermal system (EGS) project. Our previous study has revealed the fundamental characteristics and the trigger mechanisms of the large event at Basel. However, we have not reached full understanding of physics of the large events, which enable us to control or manage the magnitude of induced events.

Concept of Slip-able area

Our previous study suggested that the dynamic behavior of pore pressure especially propagation of pressure at the shut-in correlate the event magnitude because many of large events occurred at the shut-in phase in Basel. The pore pressure gradient should exist from the well head to the pressure front during the stimulation. At the shut-in when pumping is stopped, the pressure source despairs and subsequently the pressure gradient may become small with time. Finally, the pore pressure in the reservoir will go back hydrostatic state uniformly. In the relaxation process of the pore pressure gradient, it can be expected that the pore pressure at the far field from the well might slightly increase to average pore pressure increase in whole reservoir. Pore pressure increase at the front of the stimulated zone may put large part of the fault plane into near critical state. In contrast, only some part of the fault plane may become critical state, when the pore pressure increases with the pressure gradient. This is the expected scenario for occurrence of the large event at the shut-in.

So, in this study, we originally defined new concept of Slip-able area, which describes the summation of fault areas in study area, under critical state during/after the stimulation. The informations used in estimating Slip-able are given by the detailed analysis of microseismic events and stress information. Slip-able area can provide the information of the potential fault area which can have shear slip at semi real time. Slip-able area can be directly converted into the event magnitude, suggesting it is also available to the risk assessment of the large event.

Methodology of estimation for Slip-able area

We propose the methodology to estimate Slip-able area as follows.

1.Determine the number of the potential fracture within a given rock volume from microseismic data at the first stage of the stimulation.

2.Characterize the size of the fractures from source parameter of microseismic events and their critical pore pressure for shear slip.

3.Divide the reservoir area into a number of the block with the same size of step1.

4.Determine the stimulated volume in three dimensions by the divided block and information on occurrence of microseismic events.

5.Infer the number of the fracture in a stimulated volume determined in step 4.

6.Estimate maximum increase in pore pressure at given time in each block of stimulated volume.

7.Identify the fault area of the fracture under critical state using the information assummed in step 2.

8.Integrate all fault area of the fractures identified in step 7.

We have to note that the methodology shown above includes some steps with much difficulty or impossible because determination of critical pore pressure is based on the information on orientation of fracture plane and stress information in study area. These informations are not available in many of the geothermal field. Estimation of fault area also required high quality data set of microseismic events. In these cases, it can be valid for simplification to use appropriate constant values like b value as a substitute for characterizing of fault size.

Keywords: Microseismicty, Felt earthquake, Magnitude, Fault area, Risk assessment, Basel