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Fault plane solutions of earthquakes from deep geothermal reservoirs

H. Asanuma (1), Y. Mkukuhira (1), S. Mitsumori (1), M. Haring (2), D. Wyborn (3), and M. Adachi (4)

(1) Graduate School of Environmental Studies, Tohoku University (asanuma@ni2.kankyo.tohoku.ac.jp), (2) Geothermal Exploration Co. Ltd. (haring@geothermal.ch), (3) Geodynamics Co. Ltd. (Doone.Wyborn@geodynamics.com.au), (4) Okuaizu Geothermal Co., Ltd. (oag-adachi@oac.mitsui-kinzoku.co.jp)

We have collected seismic data from EGS and hydrothermal geothermal reservoirs at Basel, Switzerland, Cooper Basin, Australia, and Yanaizu-Nishiyama, Japan. The depth of the reservoir is from 2km to 5km and type of possible slip from the stress state is different for each field. Felt earthquakes have been observed at all the fields with/without clear correlation to human operation to the reservoir. We have estimated fault pale solutions (FPS) of the events using polarization of the first break of P-wave and seismic structure of the hypocenters of the seismic multiplets, and investigated relationship to the other source parameters including magnitude, source radii, and stress drop.

The followings have been found throughout this study.

(a) Most of the FPSs showed consistency to the Coulomb's criterion for shear slip, suggesting that earthquakes occurred from "highly slip-able" fractures.

(b) The data from Cooper Basin showed that most of the felt earthquakes have origin in rupture of strong asperity, which behaved as a kind of hydraulic barrier, within the most permeable fractures.

(c) Unbalanced seismicity was clearly observed for the dataset from Basel and Yanaizu-Nishiyama. We identified sets of conjugate pair of fractures from the Coulomb's theorem. However, number of seismic evens and released seismic wave energy showed strong unbalance for each fractures. This suggests that one fracture released most of the strain energy by small number of events, although data shows that the slip is not peculiar from the viewpoint of the scaling law.

(d) The estimated source radii of the felt earthquakes are much larger than the expected size of fracture in the highly fractured reservoir in cases at Basel and Yanaizu-Nishiyama. We did not find higher stress drop, which may show local stress concentration, was not observed.

Although many of the mechanism behind the large earthquakes have not been clarified or fully interpreted, we conclude that the FPS dependent characteristics of the earthquakes would be a one of the keys to understand and model the earthquakes from the reservoirs.