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Insight into earthquake generation from evolution of pore fluid pressures in a stimulated geothermal reservoir

TERAKAWA, Toshiko[1*] ; DEICHMANN, Nicholas[2]

[1]Graduate School of Environmental Studies, Nagoya University, [2]ETH Zurich

We developed an inversion method to estimate the evolution of pore fluid pressure fields from earthquake focal mechanism solutions. The basic assumption in this approach is that seismic slip occurs in the direction of the resolved shear traction acting on pre-existing faults, controlled by the Coulomb failure criterion with a constant friction coefficient. Application of the method to induced seismicity in the Basel enhanced geothermal system (EGS) in Switzerland shows the evolution of pore fluid pressure in response to fluid injection experiments. For a few days following the initiation of the fluid injection, overpressurized fluids were concentrated around the injection well and then anisotropically propagated within the reservoir until the well was shut in and bled off. At four representative locations the pore fluid pressure increased together with the wellhead pressure for the first 3?5 days, and reached a ceiling by the time of shutting in. The peak pressure in the reservoir was less than the minimum principal stress at each depth, indicating that hydraulic fracturing did not occur during the stimulation. This suggests that seismic events may play an important role in promoting the development of permeable channels, particularly southeast of the borehole where the largest seismic event (Mw 2.95) occurred. The induced events were primarily controlled by a decrease in fault strength due to an increase in pore fluid pressures. However, the largest event (the mainshock) was not directly related to a drastic decrease in fault strength at the hypocenter. The precise relative location of the hypocenters indicated that substantial stress loading by the preshocks on the same fault plane promoted the dynamic rupture of the mainshock.

Keywords: pore fluid pressure, stress, earthquake, focal mechanism, inversion theory, fluid injection