Characterization of hydraulic fracturing phenomena in supercritical geothermal environments revealed by elastic wave measurements

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Supercritical geothermal resources above the critical temperature of water (374℃) are expected as potential novel geothermal resources [Watanabe et al., 2017, Nat. Geosci.]. Although granitic rocks under temperature and depth conditions where supercritical geothermal resources are present are considered ductile against compression, they may be brittle against tensile, so that it is suggested that the reservoir layer may be formed. In fact, we carried out hydraulic fracturing experiments on cylindrical granite with a borehole in σ_1 direction placed under 450℃ and confining pressure triaxial stress (greatest principal stress σ_1:90MPa, intermediate principal stress σ_2 / least principal stress σ_3:40 MPa), and then three-dimensional isotropic reticulated fractures are formed with a smaller water pressure than hydraulic fracturing at low temperature, and it is found that the permeability increases by about 1000 times [Watanabe et al., 2017, Geophys. Res. Lett.]. Based on this previous study, we are currently working on clarifying the phenomenon of hydraulic fracturing under supercritical geothermal environments using a hydraulic fracturing experiment system under high stress and true triaxial stress conditions.

We have carried out hydraulic fracturing experiments on cubic granite with vertically downward borehole at 400℃ or 450℃ and true triaxial stress (σ_1:40 MPa, σ_2:15 MPa, σ_3:5 MPa), and AE (Acoustic Emission) measurement during the experiment and P-wave velocity measurement before and after the experiment have been conducted. As a result, irrespective of temperature and stress field, the P wave velocity of the rock after the experiment decreased isotropically, and it was suggested that the formation of reticulated fractures found in the previous study is mainly due to pressurization of existing microcracks which are isotropically distributed in rocks by low viscosity water. Furthermore, as a result of AE measurement during the experiment, the peak of AE occurrence was present not only at the time when the borehole pressure reached the maximum value (breakdown pressure) but also after the breakdown. Considering the deformation behavior of the rock during the experiment and the observation result of the thin sections after the experiment, it is suggested that the first peak is due to the occurrence of hydraulic fracturing but the second peak is due to the occurrence of small scale shear deformation and fracture depending on the stress field of the rock where strength has decreased by hydraulic fracturing. As a result, the possibility that the rock behavior after the breakdown also affects the ultimate fracture pattern and the change of permeability was newly found.

・Watanabe, N. et al. Potentially exploitable supercritical geothermal resources in the ductile crust. Nat. Geosci. 10(2), 140–144 (2017).

・Watanabe, N., Egawa, M., Sakaguchi, K., Ishibashi, T. & Tsuchiya, N. Hydrofracturing and permeability enhancement in granite from subcritical/brittle to supercritical/ductile conditions. Geophys. Res. Lett. 44,

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