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JAPAN BEYOND BRITTLE PROJECT (JBBP): SUPERCRITICAL GEOTHERMAL RESOURCES

Following the Great East Japan Earthquake and the accident at the Fukushima Daiichi Nuclear Power Plant that occurred 11 March 2011, geothermal energy came to be considered one of the most promising sources of renewable energy for the Japan's future. The temperatures of geothermal fields operating in Japan range from 200 °C to 300 °C (average ~250 °C), and the depths range from 1,000 m to 2,000 m (average ~1,500 m). In conventional geothermal reservoirs, the mechanical behavior of the rocks is presumed to be brittle, and convection of the hydrothermal fluid through existing network is the main method of circulation in the reservoir. One possible option for minimizing induced seismicity associated with geothermal development is to target a rock mass that is "beyond brittle," because the rock mechanics of a "beyond brittle" material is one of plastic deformation rather than brittle failure.

Our research group at Tohoku University (Japan) is conducting fundamental and engineering studies of "supercritical geothermal development" by which to potentially access deep, supercritical, hydrothermal fluids. The fundamental research shows that a "geothermal frontier" exists for supercritical conditions beyond the brittle–ductile transition, and the progress of our engineered and enhanced geothermal system research has opened up the possibility of accessing this supercritical geothermal resource (Watanabe et al. 2017). The general program under which all this research is being conducted is the "Japan Beyond Brittle Project".

Granite–porphyry systems associated with hydrothermal activity and mineralization provide suitable natural analogs for studying deep-seated geothermal reservoirs, where stockwork fracture systems are created in the presence of supercritical geothermal fluids (Batkhishig et al. 2012). Fracture networks and their formation mechanisms may be explored using petrology and fluid-inclusion studies in order to understand the characteristics of a "beyond brittle" supercritical geothermal reservoir. These geological studies also reveal a geological model for "beyond brittle" and "supercritical" geothermal reservoirs in subduction zones (Tsuchiya et al. 2016).

The new experimental system we developed was used for permeability measurements. The novelty of this system is the use of a special tri-axial cell, which uses a high-viscosity plastic melt as a confining fluid and a thin plastic film as a sleeve. The plastic melt is composed of polyether ether ketone (PEEK), which has a melting point of 343 °C and a decomposition temperature greater than 538 °C. It is now possible to perform hydraulic fracturing and then take measurements of permeability at supercritical conditions and under differential pressure conditions. Experimental results were reported in Watanabe et al. (2017a, b). Figure 1 shows a granite specimen after hydraulic fracturing under supercritical conditions. Hydraulic fracturing usually creates a sheared fracture in brittle materials. However, in the figure you can see "sweating rock" behavior, which indicates that the fractures are cloud-like and that permeability is strongly enhanced. The fracture style is completely different between subcritical and supercritical conditions: single and sheared fracturing occurs under subcritical conditions, whereas a fracture cloud occurs under supercritical conditions.

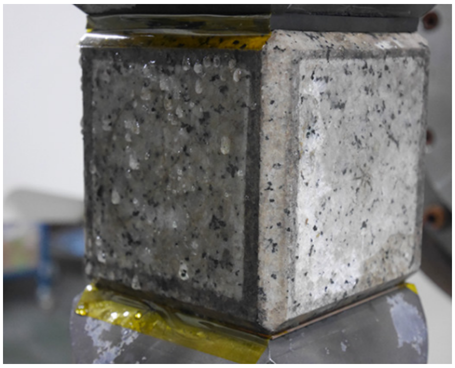

Figure 1 "Sweating Granite" after hydraulic fracturing under supercritical condition

The mechanical and hydrological behaviors are different between subcritical and supercritical states. Water–rock interactions also display unique characteristics, for example, under supercritical conditions (Okamoto et al. 2017; Saishu et al. 2014).

The Japan Beyond Brittle Project is challenging and at the cutting-edge of a real "geothermal frontier" with a subduction zone as an energy system.

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Noriyoshi TSUCHIYA
Graduate School of Environmental Studies, Tohoku University

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