Heat, Fluid and Fracture of Supercritical Geothermal Resources Renvealed by Field Survey and Hydrothermal Experiments

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Our research group is conducting fundamental and engineering studies of Supercritical Geothermal Development. Essential aspects to understand supercritical geothermal resources are HEAT, FLUID and FRACTURE. HEAT is a source of resources and FLUID is carrier of heat energy, and FRACTURE is pathway of fluid. Three components are valuable and important points for realizing super-hot and supercritical geothermal reservoirs.

HEAT & FLUID: We used an analysis of melt inclusions to estimate the amount of water input to the upper crust and quantify the properties of a deep-seated geothermal reservoir within a fossil caldera, the late Miocene Fukano Caldera (formation age 8–6 Ma), Sendai, NE Japan. The fossil magma chamber underlying the caldera is estimated to have a depth of ca. 2–10 km and a water content of 3.3–7.0 wt.%, and when the chamber was active it had an estimated temperature of 750C–795C. The water input into the fossil magma chamber is estimated at 2.3–7.6 t/yr/m arc length based on the magma chamber size the water content in the magma chamber and the length of volcanism periods of Fukano Caldera, NE Japan arc. The total amount of water that is stored in the chamber is ca. 1014 kg. The chamber is saturated in water and has potential as a deep-seated geothermal reservoir (Amanda et al., 2019).

FRACTURE: To understand the geological properties of a supercritical geothermal reservoir, we investigated granite–porphyry system as a natural analog. Quartz veins, hydrothermal breccia veins, and glassy veins are present in Neogene granitoids in NE Japan. The glassy veins formed at 500–550C under lithostatic pressures, and

FRACTURE: To understand the geological properties of a supercritical geothermal reservoir, we investigated granite–porphyry system as a natural analog. Quartz veins, hydrothermal breccia veins, and glassy veins are present in Neogene granitoids in NE Japan. The glassy veins formed at 500-550C under lithostatic pressures, and then pressures dropped drastically. The solubility of silica also dropped, resulting in formation of quartz veins under a hydrostatic pressure regime. Connections between the lithostatic and hydrostatic pressure regimes were key to t he formation of the hydrothermal breccia veins, and the granite porphyry system provides useful information of fracture in supercritical geothermal reservoirs (Tsuchiya et al., 2016, Nohara et al., 2019).

Our team are conducting several kinds of hydrothermal experiment. Watanabe et al. (2017) promoted potentiality and possibility of access to supercritical geothermal resources in terms of hydrothermal experiments. We reported the first experimental results for well stimulation involving the application of low-viscosity water to granite at temperatures >400C under true triaxial stress. This work demonstrates the formation of a network of permeable microfractures densely distributed throughout the entire rock body, representing a so-called cloud-fracture network (Watanabe et al., 2019).

Pore fluid pressures fluctuate between lithostatic and hydrostatic, depending on seismic activity, and some models suggest the possibility of flash vaporization, given that fluid pressures can drop to the level of vapor at fault jogs during seismic slip. We describe flash experiments conducted with silica-saturated solutions under conditions ranging from subcritical to supercritical. We found that amorphous silica is produced instantaneously as spherical nano- to micron-scale particles via nucleation and aggregation during the evaporation of water droplets. The nanoparticles are transformed to microcrystalline quartz very rapidly by dissolution and precipitation in hydrothermal solutions, with this process requiring less than one day under supercritical conditions because of the huge surface areas involved (Amagai et al., 2019).

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