Permeability and possibility of formation of supercritical geothermal resources in the ductile crust

*Noriaki Watanabe[1], Tatsuya Numakura[1], Kiyotoshi Sakaguchi[1], Hanae Saishu[2], Atsushi Okamoto[1], Steven E. Ingebritsen[3], Noriyoshi Tsuchiya[1]

1. Graduate School of Environmental Studies, Tohoku University, 2. Renewable Energy Research Center, National Institute of Advanced Industrial Science and Technology (AIST), 3. US Geological Survey

A new and economically attractive type of geothermal resource was recently discovered in the Krafla volcanic system, Iceland, consisting of supercritical water at 450˚C. However, the hypothesis that the brittle–ductile transition (BDT) drastically reduces permeability implies that potentially exploitable geothermal resources (permeability $>10^{-16}$ m^2) could occur only in rocks with unusually high transition temperatures of >450˚C such as basalt. On the other hand, in contradition to this hypothesis, tensile fracturing is possible even in ductile rocks, and some permeability–depth relations proposed for the continental crust show no drastic permeability reduction at the BDT. Here we present experimental results suggesting that the BDT is not the first-order control on rock permeability, and that potentially exploitable resources may occur in rocks with much lower BDT temperatures, such as the granitic rocks with a transition temperature of ca. 360˚C that comprise the bulk of the continental crust. We find that permeability behavior for fractured granite samples at 350–500˚C under effective confining stress is characterized by a transition from a weakly stress-dependent and reversible behavior to a strongly stress-dependent and irreversible behavior at a specific, temperature-dependent effective confining stress level. This transition is induced by onset of plastic normal deformation of the fracture surface (elastic–plastic transition) and, importantly, causes no ‘jump’ in the permeability. Empirical equations for this permeability behavior suggest that potentially exploitable resources exceeding 450˚C may form at depths of 2–6 km even in the nominally ductile crust.

Keywords: permeabiliy, ductile crust, supercritical geothermal resource

