Permeability evolution in high-temperature fractured granite by water-rock reaction at elastic and plastic conditions

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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. Moreover, a recent study on permeability of fractured granite at temperatures exceeding the brittle-ductile transition (BDT) temperature of ca. 360˚C has suggested that potentially exploitable supercritical geothermal resources may form even in the ductile granitic crust. This is because high permeability may be created by tensile fracturing such as hydraulic fracturing in the ductile crust, in which shear fracturing may not be likely, and the created permeability may not be destroyed even though a transition from elastic to plastic deformation of fracture surfaces (elastic-plastic transition) leads to strongly stress-dependent and irreversible permeability. However, there is still concern about viability of permeability because previous studies have suggested that fracture permeability reduction occurs with time at high temperature and high effective confining stress conditions due to pressure solution at bridging asperities within the fracture, and an increase of permeability reduction rate by the elastic-plastic transition is also suggested. In the present study, hydrothermal flow-through experiments have been conducted on granite samples containing a single tensile fracture at 400°C, a pore pressure of 10 MPa, and effective confining stresses of 18, 30 and 50 MPa, with a flow rate of 0.1 g/min, where the elastic-plastic transition stress at 400°C is 40 MPa. Permeability reduction was observed at 30 and 50 MPa, where the permeability reduction was faster for the higher stress level. On the other hand, permeability increased at 18 MPa. Permeability reduction rate was positively correlated with effective confining stress, as expected from the theory of pressure solution. However, the increase of the reduction rate from 30 MPa to 50 MPa (elastic to plastic conditions) was larger than that from 18 MPa to 30 MPa (elastic to elastic conditions). These results imply that dissolution was dominant reaction in these experiments, and permeability increased and decreased respectively at the lowest and other stress levels depending on influence of the pressure solution. Moreover, these results imply an acceleration of permeability reduction rate (i.e, pressure solution) by the elastic-plastic transition. The permeability reduction rate at the plastic condition seemed to be several times larger than that at the elastic condition.

Keywords: permeabiliy, ductile crust, supercritical geothermal resource

