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Japan Beyond-Brittle Project: a proposal of engineered geothermal power generation in ductile zones

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Current geothermal power generation from engineered geothermal system (EGS) technologies has two bottle-necks in practical use: one is losses of injected water and the other is risk of induced seismicity. The losses of injected water reach 50-70 % in such active tectonic regions as Japan. The risk of induced seismicity gives serious impacts in particularly less seismic regions such as Basel, Switzerland. To resolve these two bottle-necks, we propose a new power generation method which is EGS technologies in ductile zones. If we could create a confined brittle zone in ductile zones by hydraulic cooling, the envelopment of ductile zones would significantly mitigate the losses of injected water and risk of induced seismicity. This method could dramatically expand exploitable thermal-conduction resources beyond brittle zones. This method does not use any natural hydrothermal convection systems and would be ultimately compatible with numerous hot springs in Japan. Ductile zones have already been confirmed at an economically accessible depth in the Kakkonda geothermal field. Drilling targets of this method are a broad high-temperature thermal structure so that risk of failure of drilling could be far reduced. The ICDP-JBBP Workshop was planned to delineate possible methods creating a confined brittle zone in ductile zones in Sendai during 12-16 March 2013. We shall brief the results of the Workshop at the time of presentation.

Keywords: engineered geothermal system, losses of injected water, risk of induced seismicity, brittle zone, ductile zone

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In-situ measurement of porosity-permeability of granite during triaxial deformation experiments

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Hot Dry Rock (HDR) geothermal power generation is characterized by making artificial geothermal reservoir, which is different from conventional geothermal power generation. This system does not require natural hot water and steam. In this system, artificial reservoir is made by hydraulic fracturing in the basement due to high-pressure water injection, and water circulates in the system. To assess this type of geothermal system, we measured change of porosity and permeability during triaxial deformation experiment, and mechanical behavior of granite, which was used to discuss how water is circulated in the geothermal reservoir.

Aji granite was used as experimental sample, which is dense and fine, consists of mainly plagioclase, quartz, and biotite. Porosity and permeability were measured during triaxial deformation by intra-vessel deformation and fluid-flow apparatus (IVA) at Hiroshima University. Confining pressure was ranged from 10 MPa to 60 MPa at room temperature. The recovered samples after deformation experiments are observed by X-ray CT images at Tohoku University. The mechanical data during deformation experiments were used to analyze stress-strain curve and Mohr circle.

In original sample, porosity is 0.6-0.8% and permeability is 3.0x10-19 m2 at confining pressure Pc = 10 MPa. Porosity and permeability decrease with increase of confining pressure, 0.5-0.7% and 1.0x10-19 m2 at Pc = 60 MPa. During change of triaxial deformation, porosity and permeability were divided into four regions, (1) porosity and permeability slightly decrease, (2) porosity and permeability are nearly constant, (3) porosity and permeability gradually increase, (4) porosity and permeability suddenly increase after fracture. At the first process, decreasing porosity and permeability is due to close of original micro-crack and pore. At the second process, porosity and permeability tend to be constant during elastic deformation. At the third process, elastic deformation shift to brittle fracture, and therefore creation and propagation of crack increase porosity and permeability. At final process, porosity and permeability rapidly increase when rapture was started, and differential stresses suddenly drop. This change can be explained by disk sharped crack model, in which porosity and permeability are controlled by crack open width. However, our results show that possibility of other parameters such as crack radius and distance to explain change in porosity and permeability. X-ray CT images and Mohr circle analyses show that fracture angle is 24 degree at Pc = 20 MPa and 40 degree at Pc = 50 MPa. This increase in fracture angle indicates that Griffith crack controls fracturing at low pressure and Coulomb failure become more dominant at high pressure.

Using these fluid flow properties, we estimated residence time in actual HDR test site (Ogachi test site). The results indicate that residence time is about 3200 hours, which is much longer than in-situ tracer tests. This difference is probably due to experimental conditions, for instance, experiments were conducted at room temperature and dry condition. Therefore, we planned to carry further experiments under wet and high temperatures.

Keywords: porosity, permeability, granite, triaxial compression