Quantitative evaluation of fracture distribution in granite and the relationship between fracture distribution and physical properties

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Recently, geothermal uses in the depth below the brittle-ductile boundary have been considered for collecting geothermal energy more efficiently than conventional geothermal uses [1]. One of them is supercritical geothermal power generation, which uses supercritical fluid of higher temperature and pressure than conventional type, and therefore output per power plant is expected to be increased [2]. In this geothermal development, there is a plan to artificially create geothermal reservoirs when the geothermal fluid enough for the power generation capacity does not exist in the rock. These artificial reservoirs are planned to be created through processes such as cooling rocks by water injection, emergence of brittle region, causing hydraulic fracturing, and then emergence of high permeability region. Here, crack generation and propagation by injecting water and cooling rock have some possibility of inducing earthquakes. Therefore, it is important to elucidate properties of crack generation and propagation in the rock in this situation. However, these properties have not been understood enough. In addition, clarifying the relationship between properties of crack distributions and elastic wave velocities, which is not established so far, may be of useful for investigating the crack distributions at actual geothermal development sites by elastic wave explorations.
In this study, we generate cracks in granite specimens by heating them up to 550℃ then cooling, and we clarified the relationship between the cooling rate and the conditions of crack distributions in the specimens. We also tried to clarify the relation between the crack conditions and physical properties such as (elastic wave velocity, porosity and elastic properties derived from the elastic wave velocities) .
Cylindrical specimens (20 mm in the diameter and 40 mm in the length) of granite from Oshima, Ehime Prefecture (initial porosity: <0.38 %, P and S wave velocity (V_P), (V_S) under water saturated condition: 5.96±0.14, 3.10±0.10 km/s, respectively) were used for the experiments. After being heated the specimens, were cooled in three ways with different cooling rates for the surface temperature (approximately 3.3 ℃/min, 17.7℃/min, and 516 ℃/sec). Observations of X-ray CT images revealed that microscopic cracks were generated in the specimens after the heating-cooling processes. Cracks were extracted from this CT images and the number of cracks was measured. The number of cracks per image (20 mm×40 mm) N was $600 < N < 2600$, and the faster the cooling rate was, the larger N per unit area was. This is probably because faster cooling rate causes the greater temperature difference between the center and surface of specimens, which causes larger difference in the degree of shrinkage of the minerals constituting the specimens, and then the minerals are easier to be separated from each other. When N is lager, the porosity is larger (0.60 - 0.82%), and V_P and V_S are smaller (4.63 - 4.86 and 1.69 - 2.15 km/s, respectively). Bulk modulus and shear modulus were decreased from 61 - 65 to 45 - 48 GPa and 24 - 26 to 7 - 13 GPa, respectively, through the heating-cooling processes. In the presentation, we will investigate the relationship between p, a parameter representing the distribution propability of cracks defined by Hestir & Long [3], and physical properties.

References
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