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Correlating permeability with fracture property and hydrothermal alteration intensity of Toki granite samples

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Information on spatial distribution of permeability is essential to estimate groundwater flow in rock mass with a high degree of accuracy. Permeability of Toki granite samples was measured using permeameter in this study and space distribution and anisotropy of the permeability in rock core scale was shown. Correlation of permeability with fracture property and alteration intensity was discussed.

Samples are boring cores of Toki granite. Vertical sample is a core collected at borehole MIZ-1, excavated by Japan Atomic Energy Agency (hereafter JAEA) at Mizunami, Gifu prefecture, Japan. Horizontal sample consists of 30 cores collected at borehole 10MI22 and 10MI23, excavated in drift of Mizunami Underground Research Laboratory of JAEA.

Macroscopic fracture separates the vertical sample from contiguous part. To reveal relationship between permeability and distance from the macroscopic fracture, and to reveal relationship between permeability and azimuth direction (anisotropy), air permeability of 16 directions was measured in plane perpendicular to core axis. For the horizontal samples, permeability was measured at three points of 2.0cm from both ends and midpoint along core axis. Nitrogen gas injection type permeameter (TEMCO Inc., MP-401) was used for the measurement.

Image analysis was carried our to characterize fracture property of microcracks and mesocracks. Fracture image was prepared by tracing microcracks observed in thin section. Fracture image for mesocrack was traced from core surface image taken with fluorescent method. Fracture number, length and angle of each fracture, number of crossed point, were collected by image analysis.

The horizontal samples show various degrees of alteration and are classified as intact, fractured part, faulting part, and altered part based on criteria by JAEA. Powder X-ray diffraction analysis (XRD) and fluorescent X-ray analysis were employed to consider relationship between permeability and alteration intensity.

In permeability measurement of the vertical sample, permeability was larger at points near the macroscopic fracture and decreased with increase in the distance from the fracture. Additionally, permeability was larger in NE-SW direction and NW-SE direction.

Image analysis of microcrack showed that longer crack exists near the macroscopic fracture and that the fractures make network considering the number of crossing point. Dominant orientation of microcrack was NE-SW and NW-SE. Similar results were obtained in the mesocrack analysis, and fracture number and number of crossing point increased near the macroscopic fracture plane. Dominant orientations of mesocrack were NE-SW and NW-SE.

Dominant direction of fracture was similar between microcrack and mesocrack, and fractures observed in different scale have similar orientation. This direction is consistent with one where permeability is large, and it means that fracture orientation rules anisotropy of permeability.

Maximum compressive direction in deeper part than 250m beneath the surface around MIZ-1 is known to be NW-SE[1]. Anisotropy in permeability and fracture orientation shown in this study was consistent with the compressive direction in this area. This stress field may cause the fracture orientation and anisotropy of permeability.

Results of XRF analysis showed that Ca concentration varied depending on alteration intensity. Therefore, Ca concentration was used as index of hydrothermal alteration, and correlation with permeability was considered. Intact sample, whose Ca concentration is low, was relatively impermeable, and fractured part sample, whose Ca concentration was high, was relatively permeable. These results indicate that relatively strong hydrothermal alteration proceeded in more permeable part because hydrothermal solution can circulate easily in such permeable part.

[1] Sato et al., Rock stress measurement in 1000m -deep boreholes around Tono area-, JNC technical review, No.5, 1999.

Keywords: Permeability, Permeameter, Toki granite, Fracture property, Hydrothermal alteration, Anisotropy