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Permeability variation in Toki granite and its relationships with crack structure and alteration processes

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Understanding of physical and chemical properties of rock mass is essential to implement the geological disposal of the high level nuclear waste. Especially, extraction of highly permeable zone that acts as channel of fluid flow is required. In this study, permeability measurements of Toki granite were carried out to reveal the permeability variation in rock mass and to understand factors causing that. Image analysis was applied to disc-like specimens and thin sections of the granite, for quantitative characterization of crack structure. Additionally, fluorescent X-ray analysis (XRF) was carried out to obtain elemental compositions of granite cores showing various degrees of alteration and to consider the relationship of the permeability with the alteration degree.

Permeability was measured using the gas permeameter. The samples are cores collected from about 1 kilometer depth range boreholes in Tono area (Mizunami, Gifu, Japan) drilling by Japan Atomic Energy Agency (JAEA). Over 40 granite cores were sampled at 25-meter intervals ranging from 100 to 1000 meters depth to measure the permeability. Permeability was larger in the altered and fault zones. In addition, the anisotropy was appeared around the fault part and the permeability was enhanced along E-W direction. This direction is consistent with the fault strike, and thus the anisotropy of the permeability was presumably caused by the cracks developed in the fault movement.

Next, the crack structures were quantitatively characterized using an image analysis and compared with the permeability data to clarify their relationship. The specimens were impregnated with fluorescent resin and images were acquired to characterize the mesocrack structure using a fluorescent scanner equipped with ultraviolet ray source. Additionally, thin sections were made from the specimens and microphotographs for characterizing microcracks were taken with a stereomicroscope. Cracks were extracted from these images and length and direction of each crack were determined by the image analysis, following segmentation of crossing cracks. Positive correlation was observed between the permeability and cumulative crack length. These results suggest that cracks cause the permeability anisotropy and microcrack can be a factor controlling the permeability.

XRF was carried out to examine relationships between the permeability and the alteration processes of Toki granite. Positive correlations were recognized between the permeability and Ca concentration in the cores. Hydrothermal alteration of Toki granite is considered to follow three steps, 1) chloritization of biotite, 2) illitization of plagioclase, and 3) precipitation of calcite (Nishimoto and Yoshida, 2010). Considering that precipitation containing Ca is formed in the illitization of plagioclase, strong hydrothermal alteration presumably occurred in the altered and fractured zones that show relatively high Ca concentration. It implies that these zones were highly permeable as forming flow paths of hot water in the past. Although the fault-zone core had high permeability, its Ca concentration was relatively low. Fault movement caused development of fault gouge in addition to fracturing of granite. Permeability was enhanced by the fracturing, but the impermeable fault gouge occurred in the fault interfered circulation of hot water and addition of Ca precipitation.

These results suggest that fractured zone accompanying densely distributed microcracks and altered zone can be groundwater flow paths. Distribution of the highly permeable zones is essential to understand the hydrogeological structure.

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References

Nishimoto, S., Yoshida, H. (2010): Hydrothermal alteration of deep fractured granite: Effects of dissolution and precipitation, Lithos, vol. 115, pp. 153-162.

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