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Migration of Crustal Fluids in Fracture System

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Accurate prediction of fluid migration within the Earth's crust is required for various engineering applications such as the geologic disposal of high-level nuclear wastes, and oil/gas exploration. Understanding crustal fluid migration is also essential in the prediction of important natural phenomena including earthquakes and volcanism. Fractures in subsurface rocks behave as major fluid pathways, and identifying fracture flow characteristics is essential to modeling fluid migration pathways.

Previously, we studied fluid flow through various single fractures in granite at a wide range of confining pressures of up to 100 MPa, demonstrating fluid flow along preferential flow paths (channeling flow) at every given condition due to natural heterogeneity of aperture distributions. The fracture plane was divided into three kinds of areas where flowing, stagnant, and no fluid (contacting asperity) exists. The area with flowing fluid was expected only 5-20% of the fracture plane depending on the aperture distributions. With respect to the fractures with shear displacement, the contacting asperities tended to align in the direction perpendicular to the shear displacement. Flow paths created in the aperture distributions seemed less tortuous in the perpendicular direction due to the distribution of the contacting asperities, which resulted in greater permeability for the perpendicular direction. The contact area increased and the anisotropic distribution was enhanced with increasing normal stress. Consequently, the anisotropic flow was enhanced with increasing normal stress to the fracture.

Currently, we have developed a new concept Discrete Fracture Network (DFN) model simulator, GeoFlow, in which fractures can have aperture distributions with natural heterogeneities. Lab-scale fluid flow simulations have been conducted for fracture networks by using both the conventional and the new DFN model simulators. In the conventional DFN model simulator, fractures have no aperture distribution, and fluid flow in the fracture plane is therefore quite uniform, which is conflict with numerous filed and laboratory observations. On the other hand, GeoFlow clearly shows preferential flow paths in each fracture plane depending on the heterogeneous aperture distribution, and 3-D channeling flow in the fracture network. We also have conducted analyses on aperture distributions for different fracture sizes in order to develop a methodology to predict field-scale fracture aperture distributions by laboratory investigations. The research on the size effect is approaching completion. 3-D channeling flow in a field-scale fracture system will be addressed in the near future.

Keywords: Crustal fluid, Fracture system, Channeling flow, Permeability, Anisotropy, Size effect