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Estimation of anisotropic permeability of granite by using transient pulse method

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Physical properties of granites, such as strength, elastic wave velocity and permeability, show characteristics of anisotropy. These properties of intact granites depend largely on microcrack geometry. In particular, anisotropy is intimately related to the distribution of microcrack orientations.

Anisotropy of permeability of granite is emphasized in this paper. Hydraulic properties of Inada granite were measured in the laboratory. The specimens were prepared in the shape of cylinder perpendicular to three mutually orthogonal cutting planes: rift-, grain- and hardway-planes. Since granites are low-permeability rocks, we used the transient-pulse technique as the permeability test. This technique can be conducted under the condition of high confining pressure, high pore pressure and low hydraulic gradient during relatively short time. The procedure of the data analysis with nonlinear least squares method for obtaining both hydraulic conductivity and specific storage simultaneously were developed and successfully applied in the study. In the data analysis, the exact solution for the transient-pulse method was used and then the results were compared to those obtained by using the approximate solution. As a result of the laboratory measurement, the permeability perpendicular to the rift-plane is smaller than those perpendicular to the other planes. The anisotropy of permeability in the granite agreed well with that of P-wave velocity.

The 3-D distribution of microcrack orientation in the granite was estimated and its relation to the anisotropy of permeability was discussed in this study. Microscopic observation of thin sections is useful for knowing physical properties of rocks. Based on 2-D digital images from microscopic observation of thin sections of the granite, which have been made from three mutually orthogonal surfaces, 2-D orientations, lengths, apertures and surface densities of microcrack traces were extracted. The stereological technique was successively applied to the 2-D data for reconstructing 3-D microcrack geometry, such as 3-D orientations, diameters, apertures and volume densities of microcracks. A strong preferred orientation of the microcracks in the granite exists approximately almost parallel to the rift-plane. Finally, the permeability tensor of the granite was estimated from 3-D microcrack geometry. The tensor shows the orthogonal anisotropy. This result is suitable for the anisotropy of the permeability obtained from laboratory measurement. It is shown that the anisotropy of permeability and also in P-wave velocity agree well with 3-D distribution of microcracks in the granite.