How can we quantify the hydraulic permeability of fault based on geophysical survey?

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For understanding impacts of faults/fractures to the Earth's environment, evaluation of hydraulic permeability along fault and fractures are required because they hydrogeologically play a role of pathway of deep groundwater and gas. Previous studies have obtained the hydraulic characteristics using boreholes and rock samples. However, such information is only valid in a local scale, and it is basically considered to be difficult to estimate the hydraulic permeability at several-hundred meter scales or more. In this study, we try to estimate the permeability in and around fractures in typical bedrocks (e.g., granitic rocks) based on the geophysical explorations: resistivity, seismic velocity and so on. The geophysical logging experiment (e.g., cross-hole tomography) can indicate both local and larger scale geophysical information. More large-scaled information can be obtained by land-surface geophysical surveys. For evaluation of permeability of large-scale fault, a rock physical modeling will be helpful since it can connect geophysical property to the hydraulic property theoretically or numerically.
Prior to the challenge of large-scale permeability estimation, we applied the rock physical modeling to the small-scale geophysical measurements. We measured DC resistivity and elastic properties (Young modulus) on the exposed fresh granite at the Mizunami Underground Research Laboratory, Japan Atomic Energy Agency. Based on the simple rock physical model, we estimated the permeability of granite with less fracturing. The in-situ permeability measurements confirmed that the estimated values are enough close to the measured ones (within the difference of half of order). The technique is also valid to the permeability measurements by pumping test at wells. We succeeded that the observed permeability obtained at Mizunami can be reproduced by only using geophysical logging data such as resistivity and seismic P-wave velocity.
Then, we applied this rock physical model to the large-scale geophysical images based on the magnetotellurics and seismic tomography. Although it is a preliminary result, the estimated permeability structure by our method is not realistic one unfortunately. In this study, we discuss on the additional information and technique how the accuracy of estimated permeability is improved.

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