Effects of faulting and cracking on directional anisotropy of electrical resistivity and permeability

K. Sawayama[1]
[1] Institute for Geothermal Sciences, Kyoto University, Japan, sawayama@bep.vgs.kyoto-u.ac.jp

SUMMARY

Recent electromagnetic surveys have imaged the directional anisotropy of the resistivity structures. The observed resistivity anisotropy in the crust has been interpreted as a sequence of faulting and cracking; however, their actual contributions to resistivity anisotropy are poorly understood owing to the paucity of data. Inspired by recent findings from the field, this study quantitatively investigated the changes in directional anisotropies of electrical resistivity using numerical and experimental approaches.

The fracture was created synthetically using fractional Brownian motion based on the measured profiles of granitic and gabbroic fracture surfaces. Each digital fracture model was subjected to normal loading of up to 100 MPa using a half-space-based dry contact model. The resistivity was calculated from deformed rough surfaces using the resistor network model, which allowed us to simulate larger-scale faults while maintaining both low computational cost and high accuracy. Similarly, fracture flow was estimated by the modified local cubic law.

The numerical results show that the directional anisotropy in fracture permeability and electrical resistivity at elevated normal stress is influenced by the matrix crack porosity, aspect ratio and thickness of the matrix body. Resistivity anisotropy (up to ~10) becomes insignificant under higher stress conditions, whereas permeability anisotropy is almost invariant with stress. These differences arise from the sensitivity of matrix porosity to each property: the contribution of matrix porosity is small for permeability but not negligible for resistivity. This also alters the permeability-resistivity relationship, changing the sensitivity of electrical observation to permeability estimation.

Keywords: Resistivity anisotropy, Permeability, Fractures, Tortuosity, Digital rock physics