Pressure dependence of elastic wave velocity and electrical conductivity in a brine-saturated granitic rock

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Geophysical mapping of fluids is critical for understanding crustal dynamics. A unified model of a fluid-bearing rock for velocity and conductivity is essential for quantitative inference on the fluid distribution. We have measured elastic wave velocities and electrical conductivity in a brine-saturated granitic rock under hydrostatic pressures and observed pore structures by X-ray CT and BIB-SEM. Based on observation of pores, we have constructed a phenomenological model to explain the observed pressure dependence of velocity and conductivity.
Measurements were made on a fine grained biotite granite saturated with 0.1 mol/L KCl solution. Both compressional and shear wave velocities increased with increasing confining pressure and electrical conductivity decreased. The velocities approached to those of solid phase at high pressure, while the conductivity was still much higher than that of the solid phase. These changes must reflect the closure of pores under pressure.
X-ray CT examinations showed that a lot of grain boundaries were open and that they formed connected conduction paths. Few intragrain cracks were observed. BIB-SEM observations on open grain boundaries showed that the aperture varied along a grain boundary. Grain boundary segments with large apertures must be connected to form connected conduction paths under high pressure.
“Bed of nails” model (Gangi, 1978) was employed to model an open grain boundary with varying aperture. The model assumed a power law distribution of aperture. Compressional wave velocity was calculated following the formulation of Carlson and Gangi (1985). “Bed of nails” model was combined with the effective medium theory (Kirkpatrick, 1973) to calculate electrical conductivity. The observed pressure dependence of compressional wave velocity was well reproduced, while that of conductivity poorly reproduced. The calculated conductivity tends to be lower than the measured value at high pressures. The model should take into account the connectivity of pores. The spatial distribution of aperture should be investigated.

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