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Fluid fraction dependence of elastic wave velocity and electrical conductivity of a water-saturated rock

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Fluid-filled cracks must be dominant conduction paths at the mid-crustal depth. Electrical conductivity must strongly depend on the connectivity of cracks. What amount of crack is required to form an interconnected network? How does its connectivity change with its amount? In order to solve these problems, we are experimentally studying electrical conductivity of water-saturated rocks with various amounts of crack. The amount of crack is changed by confining pressure, and evaluated via elastic wave velocity.

A cylindrical sample (D=25 mm, L=30 mm) of Aji granite (Kagawa pref., Japan) was saturated with KCl aqueous solution (0.01mol/L). The porosity is 0.68%, and the density 2.656 g/cm^3. Electrical conductivity was measured with the two-electrode method (Ag-AgCl electrodes, f=1 Hz-100 kHz), and elastic wave velocity the pulse transmission technique (PZT transducers, f=2 MHz). Measurements have been made using a 200 MPa hydrostatic pressure vessel, in which confining and pore-fluid pressures can be separately controlled. The confining pressure was increased up to 125 MPa, keeping the pore-fluid pressure 0.1 MPa. It took one day or longer for the electrical conductivity to become stationary after increasing the confining pressure.

The electrical conductivity decreased by an order of magnitude as the confining pressure increased from 0.1 MPa to 25 MPa. It decreased by only 1% with the increase of confining pressure from 25 MPa to 125 MPa. Elastic wave velocity increased by 5% as the confining pressure increased from 0.1 MPa to 25 MPa. It showed 2% increase with increasing confining pressure from 25 MPa to 125 MPa.

These changes in electrical conductivity and elastic wave velocities must be caused by the closure of cracks. Based on elastic stiffness of Aji granite at 180 MPa, we can estimate the aspect ratio of a crack which closes at a given confining pressure. The aspect ratio is 3.6x10^{-4} for the closure pressure of 25 MPa, and 1.8x10^{-3} for 125 MPa. The large decrease in conductivity, which was observed below 25 MPa, is caused by the closure of cracks with the aspect ratio less than 3.6x10^{-4}. Cracks with the aspect ratio from 3.6x10^{-4} to 1.8x10^{-3} closed as the confining pressure increased from 25 MPa to 125 MPa, leading to only a slight decrease in conductivity. The connectivity of fluid is still maintained by cracks with the aspect ratio lager than 1.8x10^{-3}. Two groups of crack dominate the change in electrical conductivity up to 125 MPa.

Keywords: water-saturated rock, elastic wave velocity, electrical conductivity, fluid fraction, aspect ratio of crack