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Electrical conductivity of fluid-bearing crustal rock under high pressure

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It has been reported that the electrical conductivities determined by magnetotelluric methods in the lower crust are much higher than those determined by dry laboratory samples of crustal rocks. The aqueous fluid is the most likely reason for the high-conductivity anomaly regions (e.g., Shankland and Ander, 1982). Since the solubility of silicate component in the aqueous fluid should increase with increasing pressure (Manning, 1994), the electrical conductivity of fluid-bearing rocks can be higher at pressure of the lower crust. To examine the effect of the soluble ionic species in aqueous fluid on the bulk rock conductivity, we measured the electrical conductivity of fluid-bearing quartzite as functions of temperature and fluid content under high pressure.

High-pressure experiments were carried out using a DIA-type high-pressure apparatus. Pyrophyllite was used as a pressure medium, and cylindrical graphite was used as a furnace. We used two kinds of the starting materials. One is the sintered quartz aggregate, which was synthesized from the mixture of quartz reagent and silicic acid using a piston-cylinder high-pressure apparatus. The other is chert generated from Tanba district, Japan. These staring materials initially contain 200-5560 wt. ppm H_2O as a fluid inclusion and OH species. To prevent a loss of water during the electrical conductivity measurements, we used a diamond single crystal capsule. Electrical conductivity was measured using the impedance spectroscopy method. Experiments were conducted at 1 GPa. Temperature range was from 700 to 1450K. The texture of the recovered samples was observed using field-emission scanning electron microscope, and the fluid content was measured using Fourier transformed infrared spectroscopy and calibration proposed by Paterson (1982).

The electrical conductivity increases proportional to (fluid fraction)$^{0.86}$. Our result suggests that the observational electrical conductivity at Tohoku, Japan (Ogawa et al. 2001) and New Zealand (Wannamaker et al. 2009) in the middle crust is unable to account for quartz plus H_2O. Therefore, plausible explanations of high-conductivity anomaly are presence of saline fluid and/or the other ionic species.

Keywords: electrical conductivity, fluid, crust