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Electrical conductivity of fluid-bearing rocks

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The electrical conductivity of dry crustal rocks is considerably lower than that of middle to lower crust determined by electromagnetic studies. On the other hand, the electrical conductivity structure of the crust determined by the MT method demonstrates that the regions showing high conductivity anomaly correspond to the root of a fault and hypocenter of an inland earthquake. Although it has been thought that these conductivity anomalies are originated from existence of fluid and melt, the conductivity of a fluid (especially water) under high pressure has not been measured because of its experimental difficulty. Therefore, in order to estimate the amount of fluid from electromagnetic observations, we need many assumptions such as the mixing model of fluid-rock system and given salt concentration. Since the supercritical fluid under high temperature and high pressure can contain high ion concentration, knowledge of fluid composition for typical crustal rocks is required to estimate fluid content from the observed conductivity values. However, electrical conductivity measurement of the fluid-bearing rock has not performed.

This study reports experimental results on electrical conductivity measurement of fluid-bearing rock. In our group, electric conductivity measurement of Quartz-H2O, Quartz-H2O-NaCl, and Albite-H2O systems has been performed as simple analog materials of the crust. We have measured as a function of temperature and the amount of fluid by the pressure of 1GPa. The aqueous fluid phase in samples was sealed using single crystal quartz capsule sandwiched by metal electrodes. First, Quartz-H2O system showed that electrical conductivity rises as the water content increases, and electrical conductivity also tends to increase with increasing temperature (Shimojuku et al. 2012). However, the electrical conductivity values were much lower than the observed ones. Because dominant solute in aqueous fluid in this system is electrically neutral Si(OH)4, the conductivity of fluid phase cannot increase largely. Therefore, to explain the observed high conductivity value, high concentration of ion as an electric charge carrier in aqueous fluid is required. For the system adding NaCl to Quartz+H2O, electrical conductivity showed almost no temperature dependency, but electrical conductivity increases with increasing salt concentration. Next we consider the case that the system contains alkali ion in fluid (Albite-H2O system). Unlike the Quartz+H2O system, temperature dependency was small but electrical conductivity once slightly decreases with increasing temperature then increases again at high temperatures. This trend agrees with the concentration change of a solute with the electric charge in the fluid via temperature. Thus, these observations suggest that even if temperature was low enough, fluid with certain ion concentration can produce the conductivity anomalies in the crust. If crust rock has dissolved into fluid as ionic charge, high NaCl concentration in fluid is not necessary to produce conductivity anomalies in the crust.

Keywords: electrical conductivity, fluid, crust