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Electrical conductivity of fluid-bearing rocks

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The middle to lower crust remains one of the most enigmatic parts of the Earth. Electromagnetic observations are sensitive to the current state and composition of these regions, rather than its state at formation obtained from petrological studies on exhumed samples. It has been well-known that high electrical conductivity values observed in the lower crust are not consistent with those of the dry rocks. There are two popular proposed causes of the observed enhanced electrical conductivity in the lower crust: saline fluids and grain-boundary films of carbon. Recent magnetotelluric studies have illustrated a presence of significant local conductivity anomalies in the middle to lower crust. Such conductivity anomalies are closely related to the active faults, epicenter of earthquake and the region where shear wave scattering was monitored at the mid-crustal depth. They have pointed out a possibility that the presence of fluid in the crust induce the earthquake and tectonic activity.
Firstly I introduce recent our results on electrical conductivity of graphite-coated quartz and anorthite grains in order to clarify the role of the grain boundary-films of carbon in crustal rocks on the high conductivity anomaly in the lower crust. When the samples held at high temperature (> 1000 K), the electrical conductivity of the carbon-coated samples deceased with time. After annealing, the conductivity-temperature relation was similar to the behavior of the dry samples. It suggests that the graphite film on the grain boundary is not stable form because of the high interfacial energy between silicate minerals and graphite. Therefore, it is concluded that the main cause of the conductive anomaly would not be the grain-boundary graphite film.
The fluid is likely to be the most plausible candidate to explain the high conductivity anomaly in the middle to lower crust. Although pure water cannot largely enhance the electrical conductivity, if the fluid phase contains ionic species and establishes the interconnection in the solid matrices, the bulk conductivity of the fluid-bearing rocks significantly increases. The conductivity measurements of water-rock system at atmospheric pressure have shown lower conductivity than the value observed in the lower crust. Therefore, many workers proposed a presence of saline fluid (e.g., NaCl). However, with increasing pressures and temperatures, the silicate minerals become soluble to the fluid. An increase of ionic species in the fluid reduces on the wetting angle between the fluid and silicate minerals and increases electric charge carriers in the rocks. These effects can contribute significantly to enhancement of the conductivity.
Because of experimental difficulty, there have been no conductivity data of the fluid-bearing rocks under high pressure. Thus, electrical conductivity of the fluid-bearing rocks under lower crustal condition has been estimated by extrapolation of atmospheric data. Thus it is dangerous to use the extrapolation value to estimate fluid fraction of the lower crust. The conductivity measurements of the fluid-bearing rocks are required to perform at high pressures and temperatures, corresponding to the conditions of the middle-to lower crust. Our research group has just started to try the electrical conductivity measurement of fluid-bearing rocks under high pressure. Although at this moment there is no data, I will be able to present the preliminary report on it at the conference.

Keywords: fluid, electrical conductivity, lower crust