Geoelectrical structure beneath the northwest Pacific - A review

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Electrical conductivity recently draws attention as one of the key factors to identify state and composition of the Earth's mantle. It is now well-known that electrical conductivity is very sensitive to the presence of partial melts and volatile elements such as carbon or water. It, therefore, is quite feasible to predict water content and/or melt fraction of a specific portion of the Earth's mantle by comparing the results of electromagnetic (EM) field work and those of laboratory experiments on electrical conductivity of mantle rocks. In the following, we include a brief review of recent results of both disciplines with a special attention to properties of the mantle beneath the old northwest Pacific.

A variety of electrical conductivity profiles with depth is now available from single site analyses (Schultz et al., 1993; Motobayashi and Toh, 2007) through semi-global scales (Utada et al., 2003; Kuvshinov et al., 2005) via regional scales (Lizarralde et al., 1995; Neal et al., 2000). These field results have been derived in various tectonic regimes such as the stable craton (Schultz et al., 1993), the continental lithosphere (Olsen, 1998; Tarits et al., 2004) and oceanic areas (Lizarralde et al., 1995; Motobayashi and Toh, 2007). If we focus on the north Pacific results, one key issue is whether or not the asthenosphere is electrically conductive. Utada et al. (2003) found a very resistive asthenosphere beneath the north Pacific in a semi-global scale, which was further confirmed by Kuvshinov et al. (2005) using a more elaborate bathymetry/topography modeling. However, a single site analysis (Motobayashi and Toh, 2007) and a regional scale modeling (Lizarralde et al., 1995) respectively in the northwest and northeast Pacific both showed a peak of electrical conductivity at a depth of ˜200 km. This discrepancy should be examined carefully in terms of the frequencies used in modeling and analysis as well as the sensitivity of each dataset to the respective model, for it is critically related to the potential of the oceanic mantle melting by perturbations such as plate flexure.

Even if we have one common electrical conductivity profile for the oceanic mantle, another issue that may arise is the actual water content in the upper mantle from asthenospheric depths through the mantle transition zone. Since Karato (1990) pointed out a possible strong effect of water on the upper mantle properties (especially on electrical conductivity), a series of laboratory measurements has been conducted so far. However, those experimental results seem to differ severely in a quantitative sense. For example, Huang et al. (2005) reported a huge effect of water on electrical conductivity of both wadsleyite and ringwoodite, partially based on the experimentally determined conductivity that was originally interpreted as dry spinel and modified spinel (Xu et al., 1998). On the contrary, Yoshino et al. (2008) claimed that there is no need to add water in the mantle transition zone in order to explain the electrical conductivity profile determined by EM field works. The same contradiction is applicable for the asthenosphere, viz., there exist contrasting experimental results of strong (Wang et al., 2006) and weak (Yoshino et al., 2006) water effects on olivine conductivity. The water issue still seems to be a matter of hot debates in the high pressure mineral physics.

We will illustrate these situations using a newly derived electrical conductivity profile beneath the northwest Pacific (Motobayashi and Toh, 2007) and referring to the latest results of laboratory experiments. Apart from the olivine conductivity, it is at least very important to determine the actual water storage in the mantle transition zone since wadsleyite and ringwoodite are known to have a good storage capacity for water as large as ˜3 wt% (Inoue et al., 1995).