Electrical conductivity profiles of oceanic and continental upper mantle: Laboratory and field experiments

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We estimated electrical conductivity profiles predicted from the chemical compositional models of the Earth's upper mantle with calculating phase diagrams in the CFMAS (CaO-FeO-MgO-Al2O3-SiO2) system, and compared them with observed ones. The pyrolite (McDonough & Sun, 1995) and piclogite compositional models were used for oceanic upper mantle, while on-craton and off-craton models (Rudnick, 1998) were adopted to sub-continents or tectosphere. Since the different two piclogite models (Anderson & Bass, 1986; Ita & Stixrude, 1992) have been proposed, we took account of the two models for piclogite. The Perple_X (e.g. Connoly & Kerrick, 1987) program was utilized for obtaining mineral proportions and mineral compositions along depth with minimizing the total Gibbs free energy. The used thermodynamic data base was SFO05 (Stixrude & Lithgow-Bertelloni, 2005; Fabrichnaya, 1999; Oganov, 2005). The appropriate adiabats were selected supposed that olivine-wadsleyite and ringwoodite-perovskite phase transitions be responsible to the seismic discontinuities of top and bottom of mantle transition zone (Katsura et al., 2004; Ito & Takahashi, 1989). The appropriate adiabat was regarded as the thermal structure of oceanic upper mantle, whereas the thermal structure of sub-continents was obtained by incorporating the effect of the mechanical boundary layer and of the crustal double heat production layers into the appropriate adiabat (McKenzie et al., 2005). Newly compiled laboratory data for electrical conductivity of minerals were as follows: olivine (Constable, 2006), garnet-majorite (Romano et al., 2006), wadsleyte (Yoshino et al., 2008), ringwoodite (op. cit.), and illmenite (Katsura et al., 2007). We referred to Xu et al.(2000) for other minerals' data.

The appropriate adiabats obtained from the piclogite model by Anderson & Bass (1986) and ringwoodite-perovskite phase transition were under 1600 K in potential temperature. On the other hand, those obtained from olivine-wadsleyite phase transition were over 1750 K potential temperature. The piclogite model by Anderson and Bass (1986) shows that wadsleite-ringwoodite phase transition begins at about 13.6 GPa on the condition of 1600K potential tenperature, which is not consistent with the seismic discontinuity data. Hence we excluded the piclogite model by Anderson and Bass (1986). The pyrolite and piclogite by Ita and Stixrude (1992) give consistent appropriate adiabats of 1550-1650K in potential temperature. The conductivity models obtained from the pyrolite or piclogite models show under one order of magnitude of the conductivity jump at the depth of olivine-wadsleyte transition. The calculated profiles agree well with the observed one in the mantle transition zone, while the property of the upper mantle except the mantle transition zone obviously higher than the observed. The observed standard conductivity model does not probably indicate the appropriate conductivity of the upper mantle shallower than mantle transition zone.

With regard to sub-continents, allowing for mechanical boundary and the crustal layers in the thermal structure does not give rise to any change of mineral proportion. The result indicates that the conductivity change by allowing for the mechanical boundary layer in the thermal structure is yielded by only thermal effect for conductivity of minerals. The calculated conductivity profiles with on- and off-craton models show significantly lower magnitude than the observed. A standard conductivity model of continent by observations has not yet been established. An electromagnetic field observation at middle geomagnetic latitudes is required to obtain a reliable conductivity profile. We started the electromagnetic field observation at the center of Australia aiming to investigate the standard conductivity profile.