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Electrical conductivity in the mantle transition zone beneath the northwestern Pacific: Implication for the presence of water

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The electrical conductivity of the Earth increases about three orders of magnitude in radial direction from the surface to the top of lower mantle, which is much larger than its possible lateral variation. Proper separation of radial and lateral variations is crucial to estimate three-dimensional (3-D) conductivity distribution from observations. We estimated a model of radial conductivity profile in the north Pacific from observations of cable voltage and geomagnetic field variations (Utada et al., 2003). This model can work as a reference model for the North Pacific, as it accounts for period dependence of observed responses at various locations in a least squares sense. Huang et al. (2005) compared the conductivity values of this model and those obtained by laboratory experiment on the Transition Zone (TZ) minerals under a wet condition, and inferred mean water content in the Pacific TZ to be 1-2 wt%. Further we obtained a model of 3-D conductivity distribution in TZ beneath the north Pacific region by minimizing the deviation between observed and calculated induction responses with a conductivity model consisting of the 1-D reference and perturbation, and compared with P-wave tomography (Fukao et al., 2004). Most of the anomalous features in electrical and seismic parameters are found to be consistently explained simply by temperature anomalies of up to a few hundred degrees, except a part of the TZ beneath the Philippine Sea. Next we considered the effect of water to account for this inconsistency (Koyama et al., 2005), and concluded this anomaly is ascribed to the excess water content of about 0.3 wt% or so.

We also estimated geomagnetic induction responses at periods longer than 1 day for 11 geomagnetic observatories in Europe and inverted them to 3-D electrical conductivity distribution in TZ below. Then the result was compared with the result of P- and S-wave tomography in the same region, which showed a good correlation with much less inconsistency than in the Philippine Sea case. This good correlation can be ascribed to the relatively young (hot) plate age subducting below Europe so that slab material had been completely dehydrated at shallower depths.

Though the electromagnetic tomography has potential to give geophysical constraints on mantle dynamics, it needs a lot of improvement in accuracy and resolution, as it is still at a premature stage. We are accumulating datasets for this purpose, and this paper presents some results from analyses of new datasets.

From May 2004 to May 2005, we deployed a new instrument with a 10 km long cable in the Philippine Sea to measure electric field variations. By using the obtained data, we estimated the inductive responses at periods longer than a day and compared them with those expected from the reference model. We found a systematic discrepancy between observed and calculated responses: observed ones tend to be at more conductive side at shorter periods and at more resistive side at longer periods. Considering the depth of field penetration at these periods, this tendency can be interpreted by the presence of conductive anomaly at shallower part and resistive anomaly at deeper part of TZ. This result is in a qualitative agreement with the feature of our 3-D model.

Both our reference and 3-D models were obtained in 2001 by inverting induction responses from geo-electromagnetic observations in the north Pacific, most of which are still in operation. Therefore there is an accumulation of time series data for nearly 5 years. We re-analyze the datasets to have more accurate induction responses. For example, some of the OHP geomagnetic and cable observations had been operated only for a few years by the time we analyzed in 2001. In this presentation, newly obtained inductive responses will be compared with those calculated from the reference and 3-D models to more rigorously examine lateral variations of the electrical conductivity in the north Pacific mantle TZ.