# Upper mantle conductivity structure of the back-arc region beneath northeastern China

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**Abstract.** The upper mantle electrical conductivity structure of the Pacific back-arc region beneath northeastern China was investigated by the magnetotelluric (MT) and geomagnetic depth sounding (GDS). The MT and GDS responses were inverted to 1-D models to depth of about 1000 km. Conductance delta functions commonly appear at depths $100 \sim 200$ km, around 300 km and $500 \sim 600$ km. Some profiles have the delta functions at about 850 km. The conductivity enhancement observed at the depth of about 850 km is evidence for a local discontinuous, heterogeneous mantle.

## 1 Introduction

Seismic tomographic studies of whole mantle reveal that a high velocity zone lies depths of between 400 and 670 km beneath the Wadati-Benioff zone in the back-arc region of the East Asia (e.g. Fukao *et al.,* 1992). This high velocity zone is interpreted as a subducted stagnant slab in the mantle transition zone. On the other hand, the Neogene volcanic activities overlie coincidently the same stagnant slab in the NE China.

Several hypotheses are proposed for this back-arc volcanic activity from petrological arguments. One hypothesis interprets as that the mantle of this back-arc region is anomalously hot. The nature of this high thermal region is supposed to be quite different from that of the hot spot and called 'hot region' (Miyashiro, 1986). Another is that this volcanism is caused by upwelling of non-depleted mantle. Since this upwelling mantle accumulates volatile components, this region is called a 'wet region' (Iwamori, 1992). Tatsumi and Eggins (1995) interpret the upwelling mantle as an hartzbargite plume, which is separeted from the stagnant slab.

Electrical conductivity is a physical parameter highly sensitive to the presence of temperature, water and volatiles. An investigation of the conductivity structure would therefore elucidate the dynamics of the back-arc region in the East Asia. This study aims to present an electrical conductivity model of the upper mantle in the back-arc region of NE China.

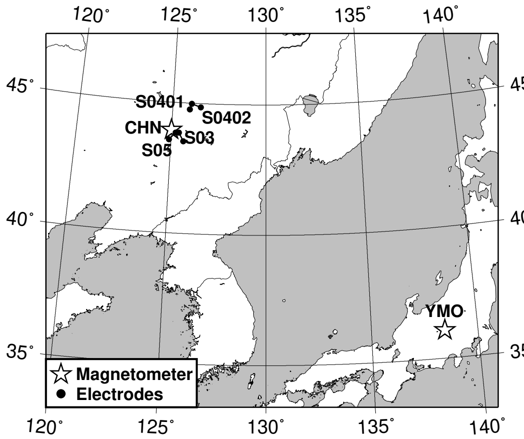


**Figure 1.** Observation sites. CHN and YMO represent Changchun and Yatsugatake geomagnetic observatories, respectively.

## 2 Observation and Data Processing

MT and GDS are electromagnetic induction methods to infer conductivity structure from the earth's transfer functions. MT transfer function, $Z_{ij}(i, j =$

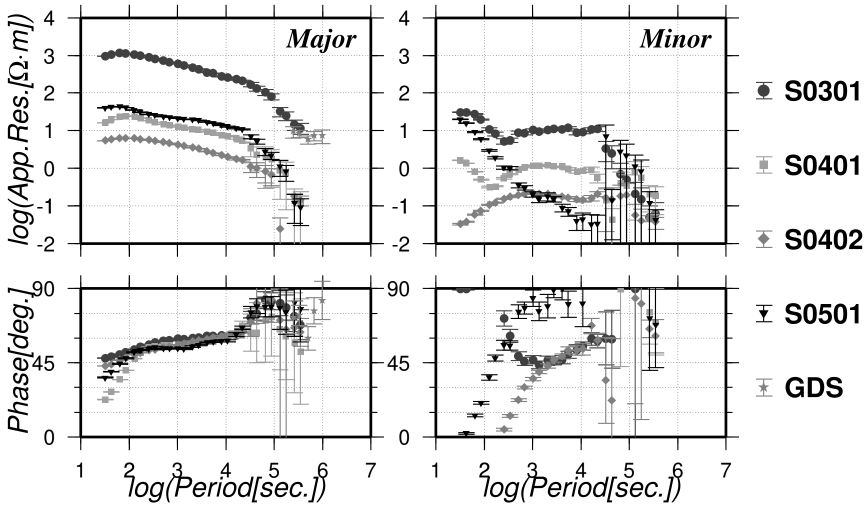


**Figure 2.** Sounding curves composed of MT and GDS responses.

$x, y$) and GDS transfer function, A and B are defined as follows.

$$\begin{bmatrix} E_x \\ E_y \end{bmatrix} = \begin{bmatrix} Z_{xx} & Z_{xy} \\ Z_{yx} & Z_{yy} \end{bmatrix} \begin{bmatrix} H_x \\ H_y \end{bmatrix}$$
$$H_z = A \cdot H_x + B \cdot H_y$$

where $E_i, H_i (i = x, y)$ are electric and magnetic field spectra, and $x, y$ represent N-S and E-W components, respectively. These transfer functions are transformed into apparent resistivity and phase responses, which are used in the interpretations.

Figure 1 represents the observation Sites. We employed the Network-MT method by using land telephone lines to measure the electric field variations with long electrode spacing, as it is most suited for deep and regional structure (Uyeshima *et al.*, 2000). Magnetic field variations are acquired at an Ocean Hemisphere network Project (OHP) geomagnetic site in Changchun.

MT and GDS transfer functions were calculated by using the robust processing technique (Chave *et al.*, 1987). We also applied the remote-reference processing by using geomagnetic record at Yatsugatake Geomagnetic Observatory (Figure 1) as the remote site. GDS transfer functions were calculated in the period range where the characteristic magnetic source field can be approximated by the $P_1^0$ spherical harmonic. Figure 2 represents the GDS and MT response curves. The major apparent resistivity responses are about one order of magnitude larger than the minor ones.

# 3 1-D Inversion

Since GDS response is less affected by static shift than MT response (Neal *et al.*, 2000), we matched the MT response curves to the GDS one. Such a treatment is possible only when the toroidal mode of electromagnetic field is absent (Utada and Munekane, 2000). We tried to invert the response functions into 1-D conductivity structure, in which condition is satisfied. The 1-D inversion procedures used here are the $\rho^+$ and Occam inversions. The former constructs 1-D depth versus conductance delta function model. The latter constructs smooth 1-D conductivity model by using penalty matrix.

Figure 3 shows the 1-D models constructed by $\rho^+$ and Occam inversions. Two models obtained by these inversions are consistent with each other. We can see delta function clearly at the depths of 100∼200 km, about 300 km and 500∼600 km. However, it appears at around 850 km for S03/S05 and at around 600 km for S0401/S0402. This possibly indicates a lateral variation of the conductivity almost monotonously increases with depth.

# 4 Concluding Remarks

Because of long period and of the presence of the Japan sea and the Pacific Ocean to the east of the studied area, we must to examine whether the effect of ocean induction influences the observed responses. However, the 3-D forward modeling (Mackie *et al.*, 1994) resulted that the oceanic effect does not influence considerably the responses at all observation sites.

The profiles and response functions of S03/S05

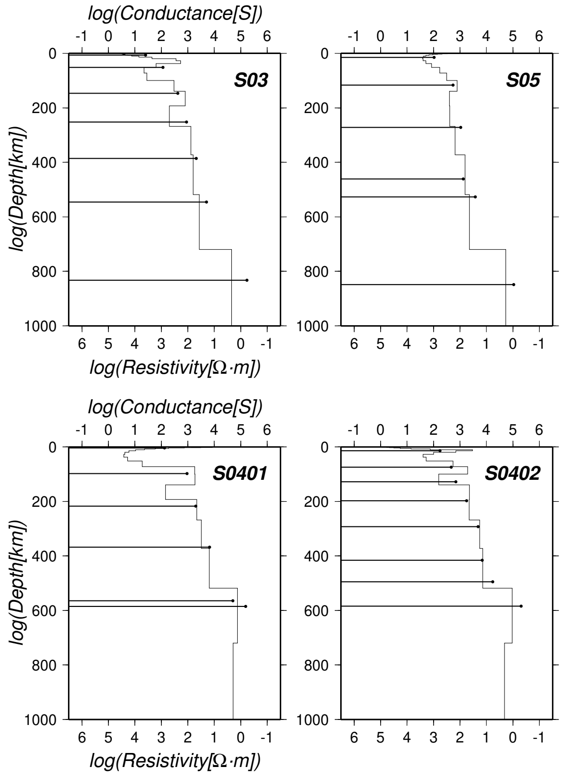


**Figure 3.** 1-D models inferred by Occam and $\rho^+$ inversion. The smooth models obtained by Occam inversion are represented in log(*resistivity* [Ω·m]) unit, and the delta function models by $\rho^+$ inversion are shown in log(*conductance*[S]).

are slightly different from those of S0401/S0402. The phase response functions of S03/S05 have a more obvious inflection point at 10000∼30000 second periods than those of S0401/S0402. This difference may be explained by the existence or absence of a conductance delta function at about 850 km. Our S03/S05 conductivity models are similar to the model of the stable craton at Carty Lake (Schultz *et al.*, 1993; Neal *et al.*, 2000). Neal *et al.*(2000) interpreted that the delta functions at 850 km is attributed to the discontinuity at the depth of 660 km. However both the delta functions at the depths of 500∼600 km and 850 km appear in our models. Some seismic studies reported the presence of the discontinuity at the depth about 850 km (e.g. Kawakatsu and Niu, 1994). Therefore the presence of the conductance delta function at the depth of 850 km may be related to the presence of seismic discontinuity.

The obvious correlation between the conductivity profile and the stagnant slab is not yet found in this study. The next step should examine the similar experiment to the surrounding area to delineate lateral variations of the electrical conductivity.

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# 5 Reference

Chave, A. D., D. J. Thomson and M. E. Ander, On the robust estimation of power spectra, coherences, and transfer functions, *J. Geophys. Res.*, **92,** 633–648, 1987.

Fukao, Y., M. Obayashi, H. Inoue and M. Nenbai, Subducting slabs stagnant in the mantle transition zone, *J. Geophys. Res.*, **97,** 4,809–4,822, 1992.

Iwamori, H., Degree of melting and source composition of Cenozoic basalts in southwestern Japan: evidence for mantle upwelling by flux melting, *J. Geophys. Res.*, **97,** 10,983–10,995, 1992.

Kawakatsu, H. and F. Niu, Seismic evidence for a 920km discontinuity in the mantle, *Nature*, **371**, 301–305, 1994.

Mackie, R. L., J. T. Smith and T. R. Madden, Three-dimensional electromagnetic modeling using finite difference equations: the magnetotelluric example, *Radio Sci.*, **29,** 923–935, 1994.

Miyashiro, A., Hot regions and the origin of marginal basins in the western pacific, *Tectonophysics*, **122**, 195–216, 1986.

Neal, S. L., R. L. Mackie, J. C. Larsen and A. Schultz, Variations in the electrical conductivity of the upper mantle beneath North America and the Pacific Ocean, *J. Geophys. Res.*, **105, 8**,229–8,242, 2000.

Schultz, A., R. D. Kurtz, A. D. Chave and A. G. Jones, Conductivity discontinuities in the upper mantle beneath a stable craton, *Geophys. Res. Lett.*, **20,** 2,941–2,944, 1993.

Tatsumi, Y. and S. Eggins, *Subduction zone magmatism,* 211 pp., Blackwell Science, London, 1995.

Utada, H. and H. Munekane, On galvanic distortion of regional three-dimensional magnetotelluric impedances, *Geophys. J. Int.*, **140**, 385–398, 2000.

Uyeshima, M, H. Utada and Y. Nishida, Network-MT method and its first results in central and eastern Hokkaido, NE Japan, *Geophys. J. Int., submitted*, 2000.