3-D electrical resistivity models in the Erimo area, southern central Hokkaido

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SUMMARY

Erimo area, southern central Hokkaido, northern Japan is a geologically attractive area where the lower crustal rocks and mantle rocks are outcropped due to the arc-arc collision between the Northeastern Japan arc and Kurle arc. Because of seawater surrounding the Erimo area, MT impedances and tippers show strong three-dimensionality of resistivity structure. Thus we applied 3-D resistivity inversion method (WSINV3D program). We obtained several models varying rotation azimuth of the impedances, frequency band and a hyper-parameter of the inversion. All the models explain MT impedances including anomalous off-diagonal phases over 90 degrees. Although significantly different resistivity distributions are obtained outside of MT array, they show similar trends of resistivity distribution in the area shallower than 50 km depth. The similarity of resistivity distribution among the inversions with different conditions indicates robustness of the 3-D inversion results. Common features of these resistivity models are as follows: 1) Highly inclined resistive body (>1000 ohm-m) at the east of Hidaka Main Thrust (HMT), 2) Dike-like conductor (<30 ohm-m) beneath the HMT, and 3) An obvious conductive zone beneath the Horoman peridotite area. They will constrain the geological and aqueous fluid distribution beneath the arc-arc collision zone.

Keywords: arc-arc collision, out-of-quadrant phase, Hidaka Collision zone, 3-D inversion

INTRODUCTION

Recent progression of 3-D inversion method for magnetotelluric data enabled us to model resistivity distribution in geo-electrically complex areas. Erimo area, southern central Hokkaido, is located on the south part of Hidaka collision zone (HCZ) where the Kurile fore-arc and the northeastern (NE) Japan arc are collided (Figure 1). The Erimo area is a geologically interesting area where lower crustal and mantle rock body (Horoman Peridotite) are exposed in a large area. Because of strong three dimensionality of resistivity structure owing to seawater surrounding the Erimo cape and geological complexity, 1-D and 2-D modelling method failed to clarify the resistivity istribution. In this study, we used a 3-D inversion code and estimated 3-D resistivity distribution. In order to discuss robustness of the 3-D inversion, several models obtained from different conditions were compared. Then we interpreted geological and fluid distribution in the Erimo area.

OBSERVATION AND MT IMPEDANCES

Wide-band and long period MT surveys were carried out at 27 stations in 2004. Time-series MT data were recorded using an MTU2000 system (Phoenix Geophysics Ltd.) and U43 (Tierra Tecnica Ltd.) for wide-band data and long-period data, respectively. The time-series data were converted into impedance tensors in a frequency domain using the cascade decimation technique of Wight and Bostick (1980) and BIRRP program (Chave and Thomson, 2004). To avoid biases caused by local, artificial noise, a remote reference technique (Gamble et al., 1979) was applied using the

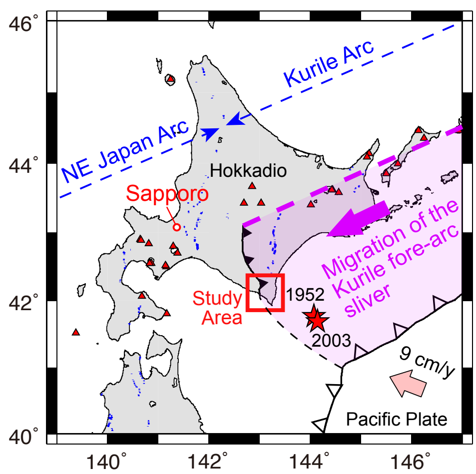

Figure 1. Location map. Red stars and triangles denote large earthquake over M8.0 and active volcanoes, respectively.

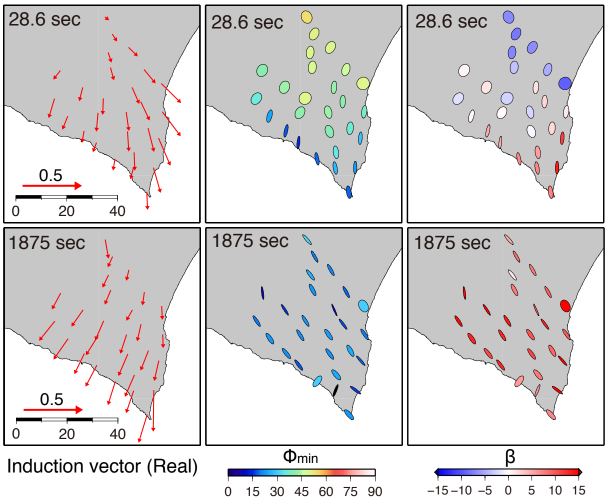

Figure 2. Induction vector and phase tensor ellipses.

horizontal magnetic field data from the Esashi station (operated by GSI) and Memanbetsu station (operated by JMA). As a result, high quality MT impedances were estimated between 0.003 ~ 12000 second.

The large skew angles of phase tensor (Caldwell et al., 2004) and induction vectors indicate strong three-dimensionality of resistivity structure (Figure 2). The off-diagonal components of MT impedance in the several sites show anomalous large phases over 90 degrees at any rotated azimuth (Figure 3). The phases increase from 1 Hz toward lower frequencies and exceed 90° and 180° around 0.01 and 0.001 Hz, respectively. The out-of-quadrant phases showing these features were commonly observed in the northeastern Japan (e.g. Ichihara et al., 2009) and were explained by 3-D resistivity heterogeneity inducing current channelling (Ichihara and Mogi, 2009).

3-D INVERSION

We modeled resistivity distribution based on the 3-D inversion program WSINV3D (Siripunvaraporn et al., 2004). The 3-D inversions were performed in various conditions changing rotation azimuth of impedance tensor (x-axes are settled in 0 degrees and 325 degrees), frequency-band of the impedances (16 periods between 0.00667 and 1800 seconds; 8 periods between 14.3 and 1800 seconds) and hyper parameter in the inversion code (time steps: 5 and 10). The 3-D resistivity models were discretized into 45 (x-axis) × 35 (y-axis) × 38 layers (including 7 air layers) (for the model 1). The size of blocks in the horizontal direction was 3 × 3 km within the survey area. Seawater is fixed to 0.3 ohm-m. The 300 ohm-m homogeneous resistivity model (excluding seawater area) was adapted as initial model for all inversions. Error floors were assigned to 10% and 20% for the off-diagonal and diagonal impedance components, respectively.

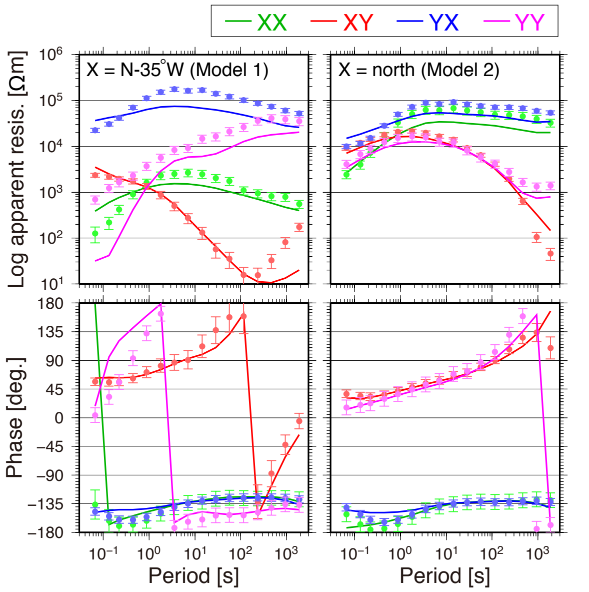

Figure 3. Observed (dots) and calculated (lines) sounding curves at the site D04 in the two rotation azimuths. See figure 4 for the explanations of model 1 and 2.

RESULTS AND INTERPRETAIONS

All the inverted models mostly explain MT impedances including anomalous phases in off-diagonal components (RMS misfit: 1.0~1.8, Figure 3). In the area of MT array, trends of resistivity distribution are similar among the models in shallow area (< 50 km depth) (Figure 4). The similarity of resistivity distribution among the different settings indicates robustness of the 3-D inversion results. On the other hand, resistivity features in the deeper area and outside of the MT array are significantly varied. Based on the skin depth, 50 km depth is adequately sensitive for the MT impedances used for the inversions (~1800 seconds). Thus the difference of resistivity distributions at the deep area may be caused by the narrow width of MT array (60×40 km).

Common features of resistivity models are as follows. 1) Highly inclined resistive body (>1000 ohm-m) is distributed at the east of Hidaka Main Thrust (HMT). 2) Dike-like conductor (<30 ohm-m), which a sensitivity test supports, is recognized beneath the HMT. 3) An obvious conductive zone is distributed beneath the Horoman peridotite area although the near surface (<500 m depth) of it shows high resistivity. The features 1) and 2) are also recognized in the cross section crossing north of the HMT (Ogawa et al., 1994). They imply collided upper-middle crust of Kurile arc to the NE Japan arc and will constrain the mineralogy and fluid distribution in the footwall side of HMT. According to the feature 3), shallower resistive body probably reflects peridotite. However, the conductor beneath it is not interpreted at this moment.

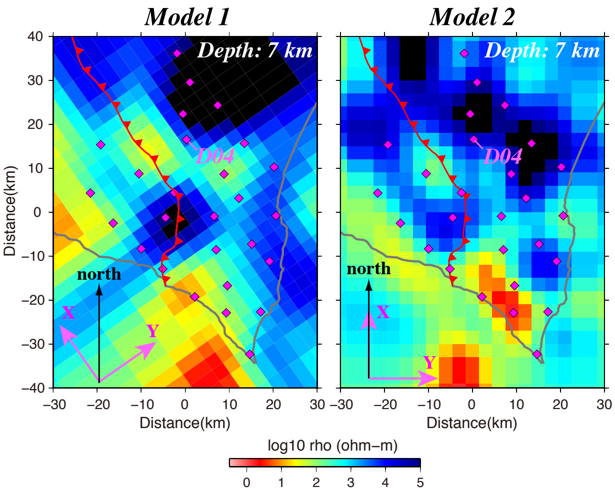

Figure 4. Horizontal resistivity distribution of the model 1 and 2 at depth 7.0 km. The x-axes of impedance tensor were settled to 0 and 325 degrees for model 1 and 2, respectively. Other inversion conditions were same for the both models (periods: 16 periods between 0.00667 and 1800 seconds, time steps: 5). Diamonds denote MT sites. The grey and red lines denote coastline, Hidaka Main Thrust, respectively. The RMS misfits are 1.07 and 1.27 for the model 1 and 2, respectively.

CONCLUSIONS

Based on the 3-D inversion code, we obtained several resistivity models in the Erimo area where seawaters significantly distort the MT impedances. We varied the following parameters in the inversion: rotation azimuth of the impedances, frequency band and a hyper-parameter of the inversion All the models explain MT impedances including anomalous phases in off-diagonal components (RMS misfit: 1.0~1.8). Although different resistivity distributions are obtained outside of the MT array, they show similar trend of resistivity distribution in the MT array shallower than 50 km depth. The similarity of resistivity distribution among the different settings indicates robustness of the inversion results. The obtained resistivity models will constrain the geological and aqueous fluid distribution beneath the arc-arc collision zone.

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