Resistivity structure in the southern part of Boso peninsula, central Japan

Makoto Harada[1], Nobuhiro Isezaki[2], and Katsumi Hattori[2]

1. Institute of Oceanic Research and Development, Tokai University
2. Graduate School of Science, Chiba University

Abstract

Magnetotelluric surveys were carried out in the southern part of Boso Peninsula to image the deep structure of subducting oceanic plates and the shallow sediments. We obtained 2 north-south profiles across the Kamogawa-Hayama tectonic belt (hereafter, KHTB). The resistivity distribution of Philippine Sea plate and Pacific plate were revealed, furthermore, the three-dimensional geometry of Philippine Sea plate and subsurface structure were also demonstrated. The model indicates that conductive layer exists to the depth of 20 km, and clear vertical boundary exists at the northern boundary of KHTB. This heterogeneous structure may correspond to the conductive accretionary prism and the forearc basin, which were developed due to the subduction of Philippine Sea plate. The resistivity of uppermost Philippine Sea plate shows complex spatial variation. Historically, large earthquakes and slow slip events have occurred repeatedly in the vicinity of Boso Peninsula. The resistivity distribution possibly suggests a relationship with the occurrence of such tectonic events.

1. INTRODUCTION

Boso Peninsula is located near the triple-junction of the tectonic plates, where the Philippine Sea (PHS) plate subducts beneath the Eurasian (EUR) plate from the south, while the Pacific (PAC) plate subducts beneath the EUR and PHS plates from the east [1] (Fig.1). Therefore, tectonic activities which are associated with the subduction are remarkable. The last two large earthquakes in the Kanto district are 1703 Genroku earthquake (M8.4) and 1923 Kanto earthquake (M7.8), of which source zones have been considered as the upper boundary of the subducting PHS plate. In addition, recent geodetic studies have revealed that a few slow slip events occurred repeatedly in the vicinity of Boso Peninsula since the late 1980s.

The main purpose of this study is to infer the geological and tectonic structures beneath the southern Boso Peninsula by using the magnetotelluric (MT) exploration. Many seismological models have been suggested for the Kanto district. This MT study may provide some electrical constraints to the subducting plates and surface geological structure.

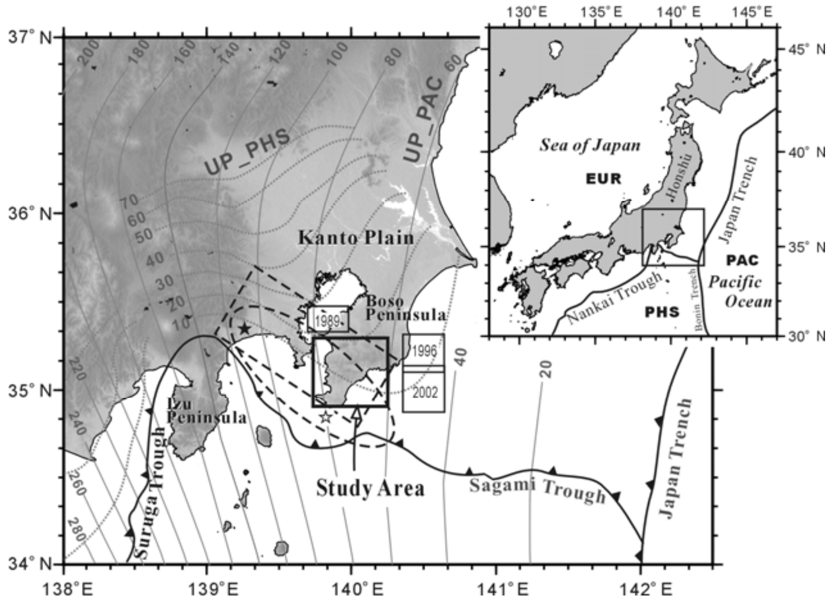

Fig.1. Map showing the plate configurations with the depth (km) contour of the upper boundaries of subducting slabs [1]. The focal zones of 1923 Kanto earthquake (rectangle with broken line) and 1703 Genroku earthquake (ellipse with broken line) are shown. Solid and open stars indicate the epicenter of 1923 and 1703 earthquakes, respectively. The source regions of the 1989, 1996, and 2002 silent earthquakes are also displayed with black rectangles [2]. EUR denotes Eurasian Plate; PAC, Pacific Plate; and PHS, Philippine Sea Plate. UP_PAC and UP_PHS denote upper surface of subducting Pacific and Philippine Sea plates, respectively.

2. OBSERVATIONS AND DATA ANALYSES

We carried out the magnetotelluric (MT) observations for twice in 2001 and 2005 to study the 2-dimensional resistivity structures in the southern part of Boso Peninsula. The observation points are located along the two North-south baselines (A-A’ and B-B’) which cross the East-west oriented KHTB (Fig. 2). The length of the baselines are about 35 km for A-A’, and 22 km for B-B’ baseline, respectively. The distance of two baselines is about 10 km. These locations are determined to study the 2- and 3-dimensional electromagnetic properties which are due to the complex tectonic structures and coastline effects.

We used 10 MT acquisition systems (U43; manufactured by Tierra Technica Inc.) to obtain the magnetic field and telluric data. All data were sampled with 1.0 Hz. Six U43’s were fixed at every 10 km and measured during the campaign (July to August, 2001) to obtain the longer period response. The other 4 systems were used to fill up fixed points at every 1 ~ 2 km. The measurements of 4 systems were generally conducted for 4 ~7 days, and then, moved to next stations. Unfortunately, we did not encounter to severe magnetic storm during the field campaign in 2001.

The calculation of impedance tensors from the observed magnetic and electric data was performed by using the robust processing algorithm [4]. To decrease the error due to a contamination of local artificial noise, the remote reference processing technique [5] was applied. We used the geomagnetic data obtained at Kakioka Magnetic Observatory, Japan Meteorological Agency as the reference data. At the stations, where the range of data quality is from fair to good, we could obtain the impedance tensors in the period range of 8 ~ 5,400 seconds. At several stations installed in the urban areas, impedance tensors could not be obtained in lower than 100 second and/or higher than 2,000 second due to the poor data quality.

The decomposition technique [6] was applied for impedance tensor to correct the galvanic distortion. Furthermore, the effects of regional geological strike and the dimensionality of the model were investigated.

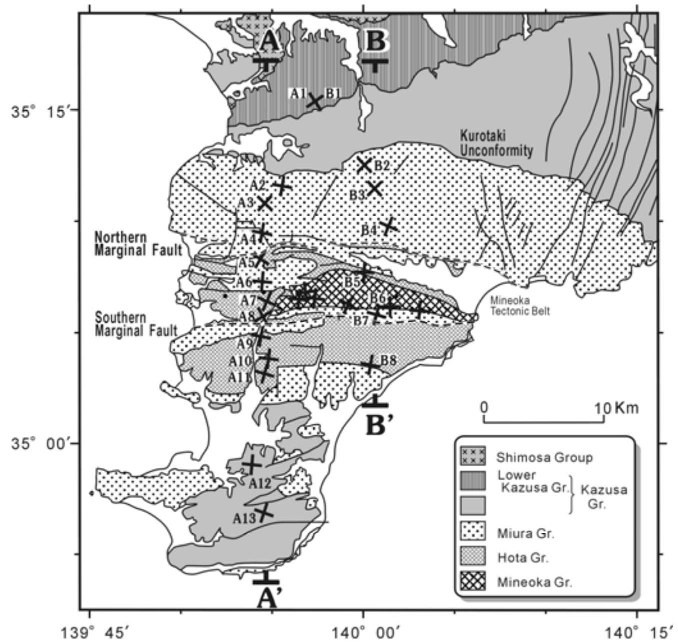

Fig.2. Site location for the magnetotelluric surveys which are illustrated on the geological map [3]. Cross indicates the regional geological strikes estimated by decomposition algorithm [6]. A-A' and B-B' are the baselines for the 2-dimensional resistivity modeling.

We used a 2-D modeling code [7] to find the optimum model fitting of the apparent resistivity and phase. The inversions were performed for 20 frequencies of TM and TE mode data. In the initial model, a half-space crust was given with uniform resistivity of 100 Ohm-m, and the resistivity of the oceanic region was constrained to 0.3 Ohm-m. The static shifts of apparent resistivity are corrected by the algorithm at every iterative calculation, however, the amount of correction was generally small in these profiles. After achieving 7 ~ 9 iterations, the root mean square (RMS) misfit decreased to 1.0.

3. 2-D RESISTIVITY MODEL

Fig. 3 shows the final resistivity models for (a) A-A' and (b) B-B' profiles, respectively. The seismic event which have occurred within a longitude range of ±0.05 degrees in each baseline, during the period of 1980 and 2004, whose magnitude is more than 2, are illustrated on the 2-D model. Fig.4 (a) and (b) display the depth of 0-30 km in Fig.3 (a) and (b), respectively. The following features can be derived from the resistivity models. (1) At depth from about 25 ~ 70 km, resistive block (R1 in Fig.3) stretches from south to north. The resistivity of the block is about 400 ~ 600 Ohm-m. (2) Conductive layer exists form the surface to 20 ~ 25 km. The thickness of conductive layer indicates remarkable lateral heterogeneities. Furthermore, a clear vertical boundary is suggested beneath the site A5 in Fig.4 (a). The depth of the lower boundary of conductive layer reaches to more than 20 km in the southern area (C1 in Fig.4 (a)), while the depth is thinner in the northern area (C2). These conductive layers are covered with extremely conductive layers (C3, C4, and C5).

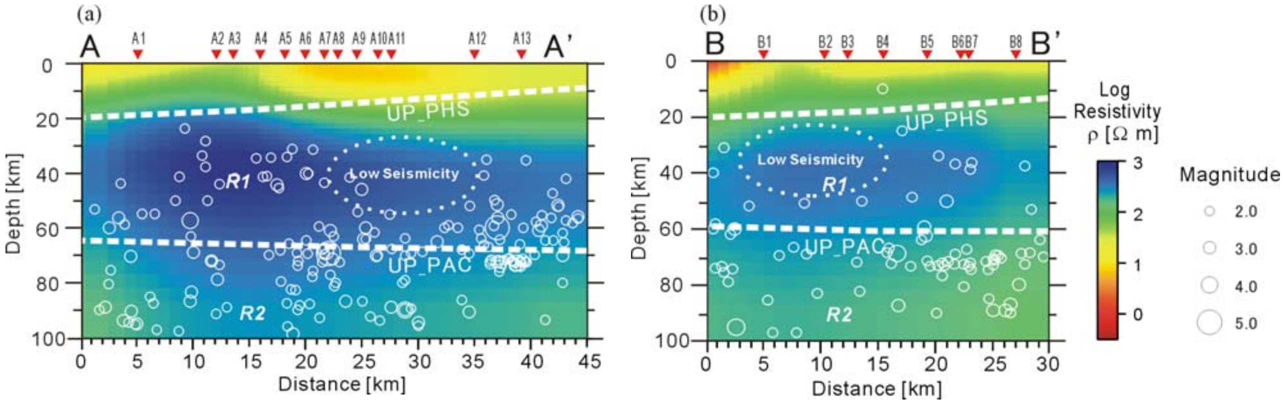

Fig.3. 2-D resistivity structure along the baselines A-A' and B-B'. The depth of 0-100km.

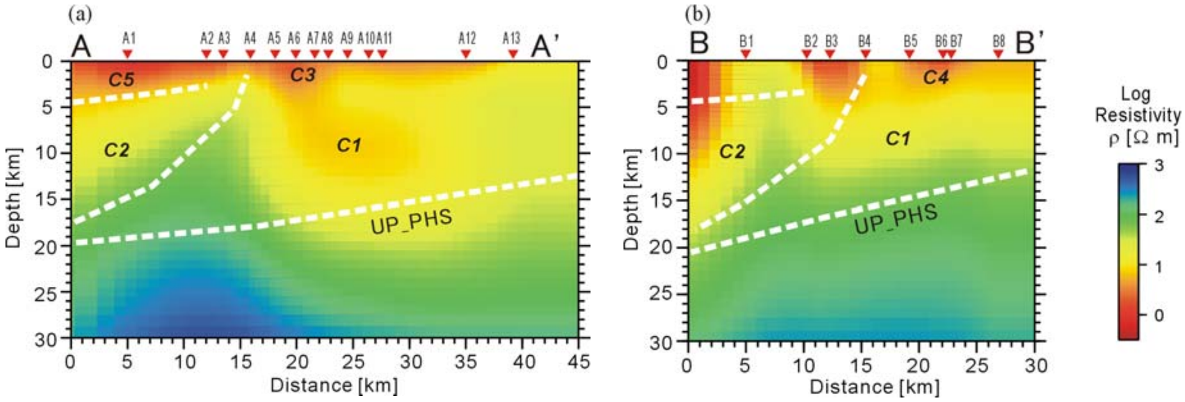

Fig.4. 2-D resistivity structure along the baselines A-A' and B-B'. The depth of 0-30 km.

4. INTERPRETATION

1) *Subducting Plates*

The resistive body (R1 in Fig.3) exists at a depth of 20 ~ 70 km, which is covered with thick conductive layers. Taking account of the configuration of subducting plates (Fig.1), R1 and R2 may coincident with subducting PHS and PAC plates, respectively. The resistivity of PHS plate is estimated as 300 ~ 1,000 Ohm-m. Distribution of R1 is quite similar with the high P wave velocity zone in the southern Boso Peninsula [8]. The upper boundary of R1 in A-A' profile (Fig.3) has a peak beneath the site A3 ~ A4, while the boundary is almost flat in B-B' profile; that is, the depth to the upper PHS plate indicate East-west heterogeneities.

Seismic reflection experiment [9] showed that large amplitude reflected waves were observed beneath A8 ~ A12 (accretionary prism), while weak-to-no-amplitude reflections were observed beneath A1 ~ A5 (forearc basin) [10]. The existence of seismic reflector and conductive uppermost layer of PHS plate may be interpreted as the presence of trapped fluid which is supplied from the dehydration of a subducting slab [11]. On the contrary, resistive uppermost layer and ineligible seismic reflector may be interpreted as the asperity [9], where the large earthquake will occur repeatedly [12]. Several studies suggested that the source fault of the 1923 Kanto earthquake occurred at the boundary between the PHS and EUR plates, and the eastern patch of two asperities spreads to western part of the Boso Peninsula [2][9][13], where is just beneath the northern part of A-A' baseline (sites A1 ~ A5). In addition, the source regions of slow slip event are in the middle part of Tokyo bay for 1989 event and in the east of the Boso Peninsula neighboring the eastern asperity of 1923 Kanto earthquake for 1996 and 2002 events [2]. Their source fault locates at the boundary of PHS and EUR plates [14]. B-B' baseline locates close to the 1996 and 2002 events. Beneath the sites of B2 ~ B4, resistivity at the depth of 10 ~ 20 km is conductive compare with that of A-A' profile. The spatial variation of large earthquakes and slow slip events may reflect the complex distribution of asperity and non-asperity zones [12]. Therefore, this resistivity distribution may be a result or cause of complex asperity distribution.

2) Shallow conductive layer

The conductive layer shallower than 30 km indicates the characteristic lateral heterogeneity (Fig.4). A clear boundary is obtained beneath the site A5 in A-A' profile (Fig. 4(a)). In the southern region, thickness of conductive zone, of which resistivity is less than 50 Ohm-m (C1 in Fig. 4 (a)), reaches 20 km, while the conductive layer (C2 in Fig. 4(a)) reaches 10 km at most in the northern region. This boundary is coincident with the northern marginal fault of KHTB, where the east-west oriented fractured massif and southwest-northeast oriented mountains are bounded (Fig.2). Since a fractured rock indicates high porosity in general, the conductive layer in the KHTB (A5 ~A8) may be caused by trapped conductive fluid [11].

The conductive layer (C5) in the northern side of the KHTB is interpreted as the former forearc basin of subducting PHS plate [10]. The thickness of sediment layer is from a few km to 4 km in this region [15]. The relatively resistive layer under the sediment is coincident with the basement which has been formed since middle Miocene.

The southern conductive zone (C1) can be interpreted as the accretionary prism of subducting PHS plate, which is covered with the Neogene sediment [10]. High conductivity zone (C3, 3 Ohm-m) exists at the depth of 10 km beneath the sites A8 ~ A11, where the thickness of conductive layer exceeds 20 km. The lowest part of this conductive layer (C1) may correspond to the low seismic wave velocity zone [8][9].

Fig. 4(a) and Fig. 4(b) show 3-dimensional distribution of sediment and basement above the PHS plate. The conductive layer of which resistivity less than several tens ohm-m in B-B' profile is thinner compared to one in A-A' profile as a whole. Same tendency has been also pointed out from the receiver function analyses in the Kanto district [16]. These differences may be caused by the heterogeneous distribution of conductive sedimentary layer and/or water-bearing oceanic basalt on the subducting slab on the PHS plate.

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