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Two-Dimensional Modelling by Using COPROD2 Magnetotelluric Data

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Two-dimensional modelling on COPROD2 MT data showed that the lateral extent of the NACP anomalous structure is about 100 km whereas for the TOBE it is about 16 km. The NACP anomalous structure consists of two vertical adjacent blocks with smaller resistivity (3.9 Ω·m) and bigger depth (14 km) to a top of the block for the western block than those for the eastern block (10 Ω·m resistivity and 9 km depth), overlaying a uniform half-space resistivity of 53 Ω·m at 60 km depth. The TOBE anomalous structure also consists of two vertical adjacent blocks. The depths to the top and the bottom of western block are about 5 km and 45 km respectively and they are about 2 km and 60 km for eastern block.

1. Introduction

Two-dimensional modelling was undertaken on the static shift corrected MT data along profile COPROD2 provided by JONES (1988). The procedure for data interpretation included the following steps.

(1) Observed apparent resistivity and phase at 35 sites along profile COPROD2 were qualitatively analysed and the characteristic sections appeared in the profile.

(2) One-dimensional inversion was undertaken on the data typical of every section, in which the electrical log data in boreholes located near the sites south of the profile illustrated by JONES (1988) were considered.

(3) The data from 35 locations were inverted by one-dimensional layer model.

With above two steps, the shallow structures were fixed and the initial models for 2-D modelling were constructed.

(4) Two-dimensional trial-and-error forward modelling of responses was carried out to finally determine the acceptable model reproducing observed data.

2. Preliminary Investigation

2.1 Qualitative analysis

As JONES and CRAVEN (1990) indicated, the apparent resistivity and the phase at the higher frequencies for almost all sites are 1-D, in that TM and TE polarizations give the same responses at each site.

The values of the apparent resistivities at the highest frequency asymptote for most sites are around 10 Ω·m; only at those sites from 155.2 km (pc5005) to 214.6 km (pc5001) over the TOBE the values are smaller (about 4 Ω·m). Furthermore, MT data for both modes of polarization overlap at all periods for sites between −174.3 km (pcs014) and −78.8 km (pcs405) indicating 1-D. At the other sites the apparent resistivities of both polarizations at longer periods separate from each other. The starting periods of separation are about 100 seconds for most sites, but at sites 169.4 km (pc5004) and 181.2 km (pc5003), corresponding to the TOBE anomaly, the starting separation periods are about 10 seconds. Therefore the data at sites located east of −78.8 km (pc5405) exhibit 2-D (or 3-D) effects and the TOBE anomaly occurs at shallower depth than the NACP.

Figure 1 illustrates pseudosections of apparent resistivity and phase of TM and TE polarizations. The TE pseudosections clearly indicate that two low resistivity anomalies corresponding to NACP and TOBE appear even though their accurate positions are not obtained because of false conducting layer effects off the flank of a 2-D body (BERDICHEVSKY and DIMITRIEV, 1976). Thus the whole profile can be geometrically and roughly divided into five sections as follows: (a) from −174.3 km (pcs014) to −55.7 km (pcs002); (b) from −45.8 km (pcs001) to 41.8 km (pc5012) over NACP; (c) from 54.5 km (pc5011) to 155.2 km (pc5005); (d) from 169.4 km (pc5004) to 181.2 km (pc5003) over the TOBE; (e) from 194.1 km (pc5002) to 232.8 km (pc5000).

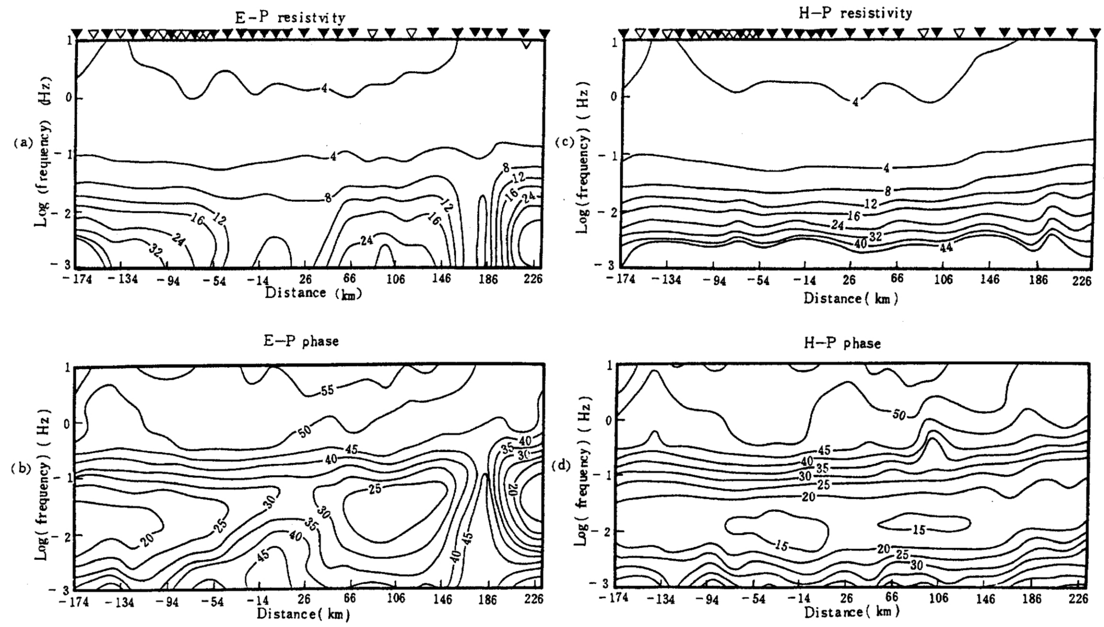

Fig. 1. Pseudosections of observed data at 35 sites along profile COPROD2. (a) (top left) The apparent resistivities observed in the E-polarization mode of induction plotted as contoured pseudosection. (b) (bottom left) The phases observed in the E-polarization mode of induction plotted as contoured pseudosection. (c) (top right) The apparent resistivities observed in B-polarization mode of induction plotted as contoured pseudosection. (d) (bottom right) The phases observed in B-polarization mode of induction plotted as contoured pseudosection. On the top of profile the sites with inverted solid triangles are representive of used sites, the sites with inverted open triangles are representive of unused sites (these symbols are used throughout similar figures in the paper).

The characteristic section of the profile is not displayed in TM pseudosections as clearly as in TE ones due to it being insensitive to the structure generating the anomalous responses.

2.2 One-dimensional inversion

Firstly, the apparent resistivity and the phase typical of each of five sections were used for 1-D inversion. Their positions are at −84.6 km (pcs005), 4.9 km (pc5014), 117.3 km (pc5007), 181.2 km (pc5003) and 232.8 km (pc5000). The electrical log data of the nearest borehole located south of the sites (JONES, 1988) were combined in the starting model.

Secondly, the apparent resistivity and the phase at each of 35 sites were inverted. The results showed us that there are not significantly varying resistivity and thickness laterally for the shallow layer. The surficial layer is about 3 Ω·m in resistivity and about 2.5 km in thickness for the greater part of the profile. The layer over TOBE and the vicinity is 2.8 Ω·m in resistivity and 1.3 km in thickness.

There are low resistivity layers at depths of 9.3 km for NACP (see site 4.9 km, pc5014) and of 2.7 km for TOBE (see site 181.2 km, pc5003). Their resistivities are 5.6 Ω·m and 1.2 Ω·m respectively. For site pc5003, a slightly higher resistivity layer is present at a depth of 6.5 km below the low resistivity layer. But there is no low resistivity layer for other three sections in the crust (Fig. 2).

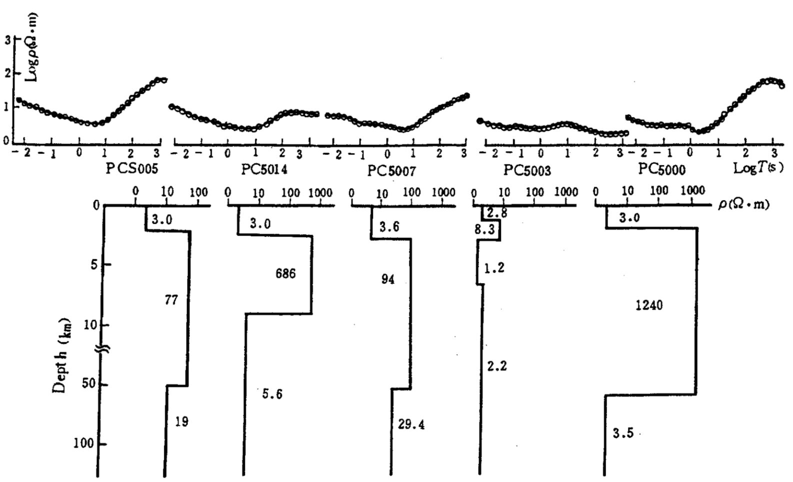

Fig. 2. One-dimensional inversion results for 5 sites typical of each of five sections. The layered model for every site (bottom diagram) and the comparison of model responses with observed apparent resistivities for TE mode (top diagram) are presented.

3. Two-Dimensional Model

A finite element method using triangular elements (after WANG and GAO, 1984 and UTADA, 1987) was used in trial-and-error forward modelling. TM and TE polarization responses were calculated at 14 periods over the four decades 0.03–1000.0 seconds (three points/decade) and then interpolated for contouring purposes. Two-dimensional (2-D) initial models for forward calculation were constructed on the basis of qualitatively analysed results and 1-D inversion results for every site. By comparing calculated responses with observed data along the profile, the older models were modified and the newer models were constructed step by step.

In order to reduce calculating time and storage, the observed data at 25 of 35 sites were utilized for comparison of responses with observed data. At the other 10 sites the apparent resistivity and the phase were quite similar to those at their neighbour sites and implied that structure was laterally homogeneous near these sites. Thus these data were ignored in 2-D modelling. Eight of these 10 sites are located in the first section and two of them in the third section. The data at all border sites of every section were used in the calculation and in data comparison to ensure that no information about resistivity structure was lost.

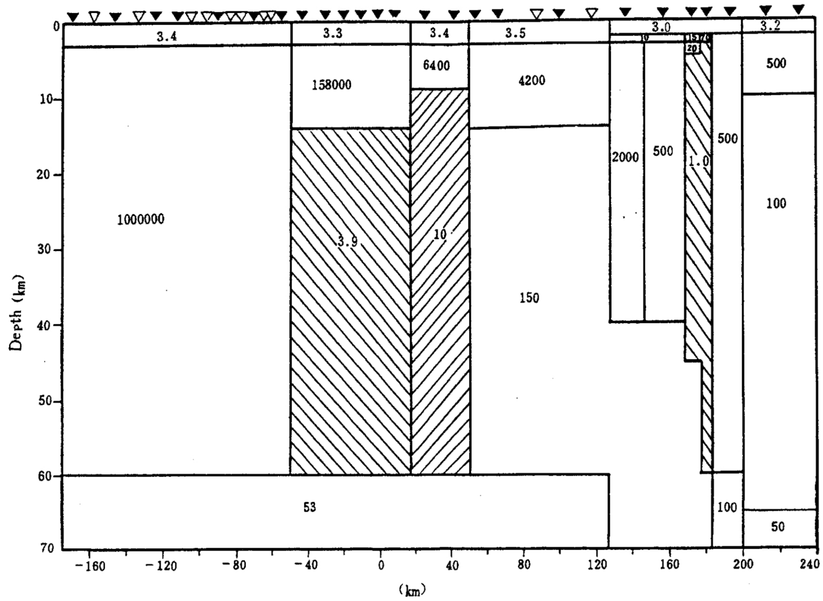

Fig. 3. Final 2-D model of profile COPROD2. There are two low resistivity blocks for NACP and TOBE respectively. The NACP anomaly is similar to the model by AGARWAL and WEAVER (1993). The responses at 25 of 35 sites were calculated and compared with real data.

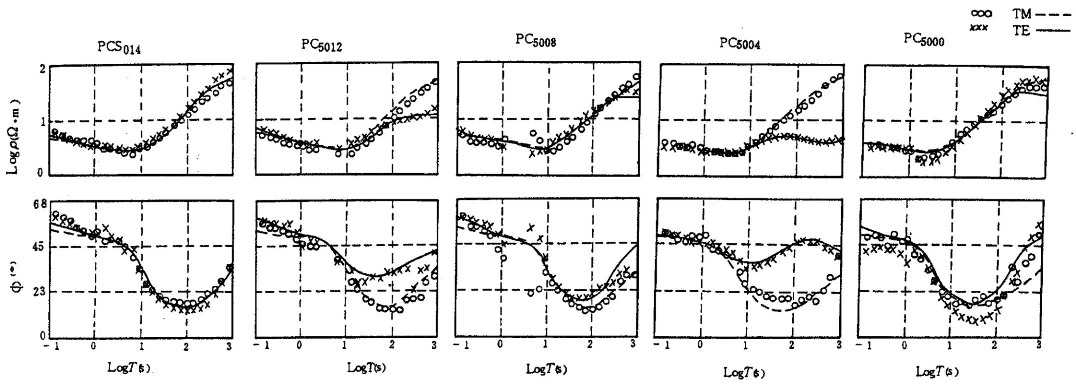

Fig. 4. The comparison of apparent resistivity and phase values of real data and model data at 5 sites typical of every section. The observed data are marked with cross (TE) and circle (TM). The model data are marked with solid line (TE) and dashed line (TM) respectively.

Figure 3 illustrates the final 2-D model obtained by forward calculation. Figure 4 presents the comparison of calculated responses with the observed data at 5 sites for TM and TE polarizations. These five sites (−174.3 km, pcs014; 41.8 km, pc5012; 96.2 km, pc5008; 169.4 km, pc5004; 232.8 km, pc5000) are located in five sections respectively. Figure 5 shows pseudosections of calculated apparent resistivity and phase responses of TM and TE polarizations at 25 sites, which can be compared with the pseudosections in Fig. 1.

Among the variety of 2-D models for forward calculation, two relatively simple models were

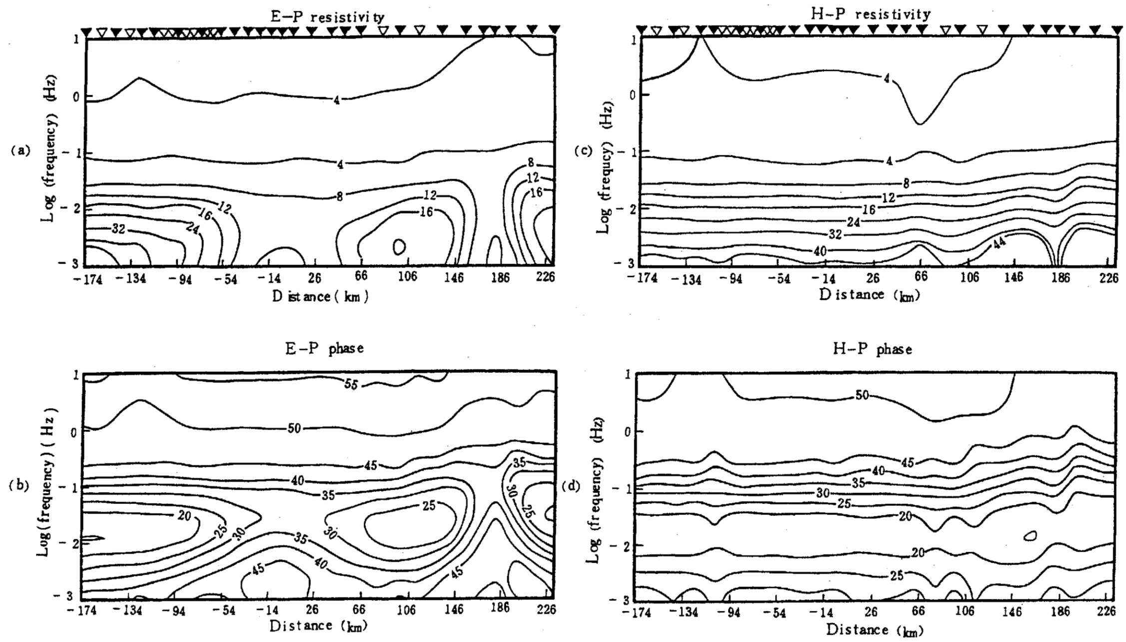

Fig. 5. The pseudosections of model responses constructed using model data at 25 sites. (a) (top left) Apparent resistivity in TE model. (b) (bottom left) Phase in TE model. (c) (top right) Apparent resistivity in TM model. (d) (bottom right) Phase in TM model.

included. One was produced using stitched 1-D inversion results at all sites along the profile. The calculated responses of this 2-D model failed to match the observed data for most sites. The another was a five-column 2-D model, i.e., as consisted of five lateral homogeneous layer models corresponding to five sections with each being the average of the layer models at all sites in every section. This model does not give a response matching the observed data either.

In order to evaluate non-uniqueness of 2-D modelling, a great deal of model responses have been calculated focussing on the anomalous structures. For example, when the anomalous structures moved up or down or moved westward or eastward, the data fitting of calculated responses to the observed data became worse. We have also tried to make the two blocks into one under the NACP and TOBE respectively, i.e., same resistivity and same thickness of the blocks were applied in NACP and TOBE anomalous structures respectively, but it is difficult to find a model fitting the observed data. When the lateral extent of anomalous structures changed, either smaller or larger, the model responses at the border sites of the anomalies (e.g., at sites pcs002 or pcs001; pc5012 or pc5011; pc5005 or pc5004; and pc5003 or pc5002) changed a lot and expressed serious misfit to the observed data. Thus the experiments strongly suggested that the final model (Fig. 3) is an acceptable model.

In the final model, the NACP anomaly (second section), of about 100 km width, is divided into two columns with a vertical boundary between sites pc5014 and pc5013. The western column has the smaller resistivity (3.9 Ω·m) and occurs at greater depth (14 km) than the eastern one, with 10 Ω·m at 9 km. This model for the NACP is similar to that obtained by AGARWAL and WEAVER (1993) in which only the NACP anomaly was calculated. The basement of the anomaly is at 60 km depth. Below is a uniform half-space resistivity of 53 Ω·m.

To the west of NACP (first section), the resistivity structure is 1-D. A surficial low resistivity layer overlays a very high resistivity zone.

The TOBE anomaly (fourth section) is about 16 km width (from 168 km to 184 km) and 1 Ω·m resistivity. It also consists of two adjacent vertical blocks whose depth to the top is 5 km and 2 km for the western and eastern blocks respectively. The depths to the bottom of the two blocks are around 45 km and 60 km for western block and eastern block respectively.

The inhomogeneity is revealed to the west of TOBE (third section). A moderate resistivity zone of about 150 Ω·m below the higher resistivity blocks occurs at 14 km for its western part and at 40 km for eastern part. To the east of TOBE (fifth section), a comparatively higher resistivity zone underlays the surficial low resistivity layer and surrounds a moderate resistivity body (100 Ω·m). The uniform half-space resistivity of 50 Ω·m occurs at a depth of 65 km.

4. Discussion

The agreement between model response and observed data for both TM and TE polarizations is very good at all sites along the profile COPROD2, the only exceptions being an overestimate of the long period TE phase at the sites pc5006, pc5005, pc5002 and pc5001 and an under-estimate of long period TE apparent resistivities at the site pc5001. The disagreement of model response and real data indicated that 3-D effects might exist.

The experiment also indicated that the model constructed simply by 1-D models of every site cannot reproduce responses matching the observed data well and thus 1-D inversion is limited in a 2-D situation.

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