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1-D crustal resistivity structure revealed by sea effect corrected magnetotelluric (MT) data obtained at Jeju Island, Korea

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ABSTRACT

Jeju Island, a volcanic island in South Korea, has been one of the main targets of geophysical and/or geological studies because of its tectonic importance associated with the volcanism and tectonic link to the southern Korean Peninsula. In this study, we reinterpret deep structures of Jeju Island based on the 1-D inversion results for the sea effect corrected MT data. Among 108 MT sites, we select 11 MT sites, which are uniformly spread out across the island and have good quality data for frequencies ranging from 10^3 to 10^{-3} Hz to examine the 1-D deep structures. The sea effect correction makes remarkable changes in the observed MT data at frequencies below about 1 Hz, playing an important role in revealing the deep structure. The 1-D resistivity models obtained from sea effect corrected MT data are greatly similar to one another, commonly showing the discontinuity at a depth of 18 km on average. This discontinuity can be interpreted as the transition zone separating resistive upper crust and conductive lower crust. This interpretation is consistent with the geophysical interpretations made for the southern part of the Peninsula which seems to be tectonically linked to Jeju Island. Reversely, this agreement can be the evidence supporting that Jeju Island is the extension of the Korean Peninsula.

Considering the tectonic environment and formation process of Jeju Island, it is noted that the low resistivity of the continental lower crust (CLC) beneath the island can be explained by the interconnected saline fluids which are associated with metamorphic and/or magmatic activity forming the island. All the results convince us that the newly built 1-D model for Jeju Island matches other geophysical and geological evidences.

1. Introduction

Jeju Island is a Quaternary volcanic island located on the continental margin in the southern end of the Korean Peninsula. It has an elliptical shape with the major axis in the direction of ENE: the major and minor axes are 73 km and 32 km long, respectively. Mt. Halla (1950 m high), a shield volcano, is located in its central part and dominates the landscape of the island. A number of parasitic scoria cones (more than 360) including several tuff rings and tuff cones are distributed over the entire island. The volcanism at this island was initiated 1.2 Ma ago and had continued on historic time with eruptions recorded until 1007 AD (Lee, 1982; Won et al., 1986). Although there is no common agreement on the origin of the volcanism of the island yet, mantle plume has been thought of as the most plausible cause for its origin (Choi et al., 2001; Lee, 1982; Park and Kwon, 1993).

A variety of geological and geophysical surveys have been carried out in Jeju Island to delineate the subsurface structures of the island. Most of those, however, have focused on shallow subsurface structures (< several kilometers in depth), which are mainly related to the development of groundwater (Jung et al., 1992; Koh, 1997; Lee, 1994). For the deeper part of the island, there has been a long-standing question about whether remnant geothermal regimes and/or deep-seated fractures associated with the former volcanic vents exist beneath the island or not. According to the most current geothermal gradient and heat flow map (Kim et al., 2004; Song et al., 2006), neither geothermally anomalous region nor anomalous heat flow has been detected in Jeju Island, although we expect that some geothermally anomalous regions might exist in the island. Since the results are against our expectation, there are needs to investigate geophysical and/or geochemical properties of the deeper structures reaching the lower crust or the upper mantle beneath the island. To study geophysical and/or geochemical properties for the deep earth, the natural-source magnetotelluric (MT) method has been widely used because of the following reasons: 1) its investigation depth is so deep reaching the upper mantle and 2) the electrical conductivity dealt with in the MT method is much more sensitive to geochemical changes than other physical properties such as acoustic impedance, density, and seismic velocity.

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In recent years, Lee et al. (2006) and Lee et al. (2009) tried to image the possible geothermal regime and/or deep-seated fractures within the shallow upper crust of the island using broad-band MT survey data. For the deeper structures such as the lower crust and the upper mantle, however, it is not easy to properly describe geoelectrical structures, because the observed low-frequency MT data seem to be strongly affected by the sea surrounding the island (Lee et al., 2009; Nam et al., 2009). This is in general called "sea effect", which is mainly attributed to electrically sharp contrast between the sea and the land (Nolasco et al., 1998; Santos et al., 2001; Yang et al., 2010). Recently, Yang et al. (2010) introduced an effective sea effect correction method for island MT data, and applied the method to MT data acquired in Jeju Island. However, since they only focused on showing the effectiveness of the sea effect correction method, they did not provide detailed geophysical interpretation for the subsurface structure of Jeju Island.

In this study, we interpret the deep part of Jeju Island based on the representative 1-D resistivity model estimated from the inversion for the sea effect corrected MT data. Since there are some limitations in determining the directionality of the structure using the sea effect uncorrected MT responses in the insular setting (Santos et al., 2001), we assume that the resistivity structures of the island can be approximated by 1-D structure. The 1-D treatment for the subsurface of Jeju Island seems to be reasonable, based on the facts that the skew values of the selected MT sites are fairly low and off-diagonal components of the impedance tensor are also very similar to each other. Although real subsurface structures of Jeju Island might be deviated from the 1-D earth, the representative 1-D resistivity model can contribute to further understanding of tectonic relationship between Jeju Island and its adjacent regions and provide a clue to the origin of volcanism of the island.

In the following sections, we begin by introducing the geological setting for Jeju Island, and then briefly explain the features of the MT data gathered in Jeju Island and the data correction methods such as the static shift and the sea effect correction. Next, we present 1-D resistivity models for the deep structures in Jeju Island through inversion and compare them with other geophysical results obtained in the southern part of the Korean Peninsula which has been known to be tectonically linked with the island. Finally, we discuss the origin of the deep structure of the island with geophysical, geological, and geochemical evidences.

2. Geological setting for Jeju Island

Jeju Island is a typical shield volcano located on the continental margin in the southern end of the Korean Peninsula, and has mainly formed since the late Pliocene (Khim et al., 2001; Yoon, 1997). The main geological characteristic of the island is that it is covered with Quaternary basaltic lava with high permeability, which allows meteoric water to infiltrate into the ground very quickly. Quaternary sedimentary formations underlying the basaltic lava reach a few hundreds of meters in depth, and consist of Pleistocene consolidated sedimentary rocks (Seogwipo Formation) in the upper part and Plio-Pleistocene unconsolidated sediments (U-formation) in the lower part. Both of the formations are marine-based and electrically conductive with the resistivity less than several tens of ohm-m (Lee et al., 2006), which makes it difficult to distinguish them from each other. Basement rocks, Jurassic–Cretaceous granites and Cretaceous–Tertiary rhyolitic tuff overlying the granites, lie at depths of about 250–300 m below the sea level (Koh, 1997). Fragments of the basements are found as xenoliths in tuffs and basaltic lavas or several drill holes, which show very similar rock faces and petrographic characteristics to those in the southern and south-western area of the Korean Peninsula (An et al., 1995; Yoon, 1997; Yun et al., 1999). Although this petrographic similarity between the basements indicates that Jeju Island is located in the extension of the southern part of the peninsula, but any geophysical evidences showing the tectonic extension were not presented so far.

3. Jeju MT data and corrections

MT surveys were performed with Phoenix MTU-5A systems by Korea Institute of Geoscience and Mineral resources (KIGAM) from 2004 to 2006. A total of 108 measurements were made along five survey lines in areas surrounding Mt. Halla (Fig. 1), which roughly cover the whole area of Jeju Island except for the coastal area where most of populations are concentrated. The site spacing was about 2–5 km along the survey

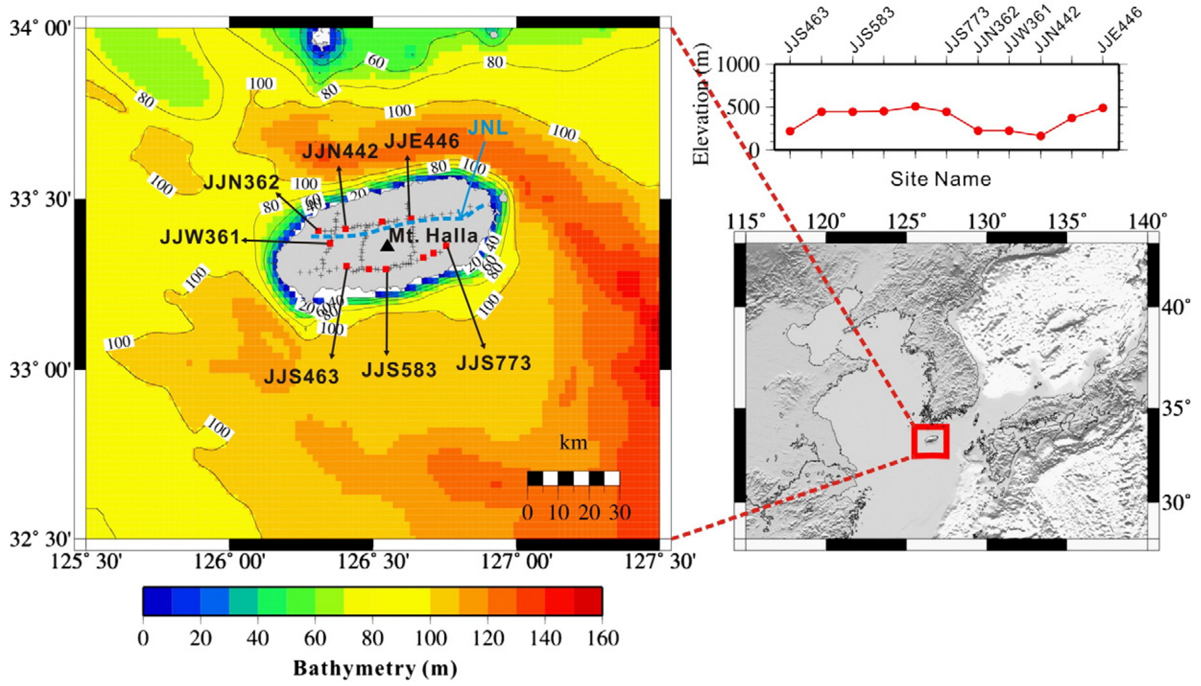

Fig. 1. A bathymetry map around the Jeju Island. A total of 11 MT sites (rectangular symbols) are selected for examining deep structure of the island, among 108 MT measurements (cross-hair symbols). The right-upper panel shows the elevation variation along the selected 11 sites. The survey line JNL (dotted line) is used for showing the example of static shift correction results.

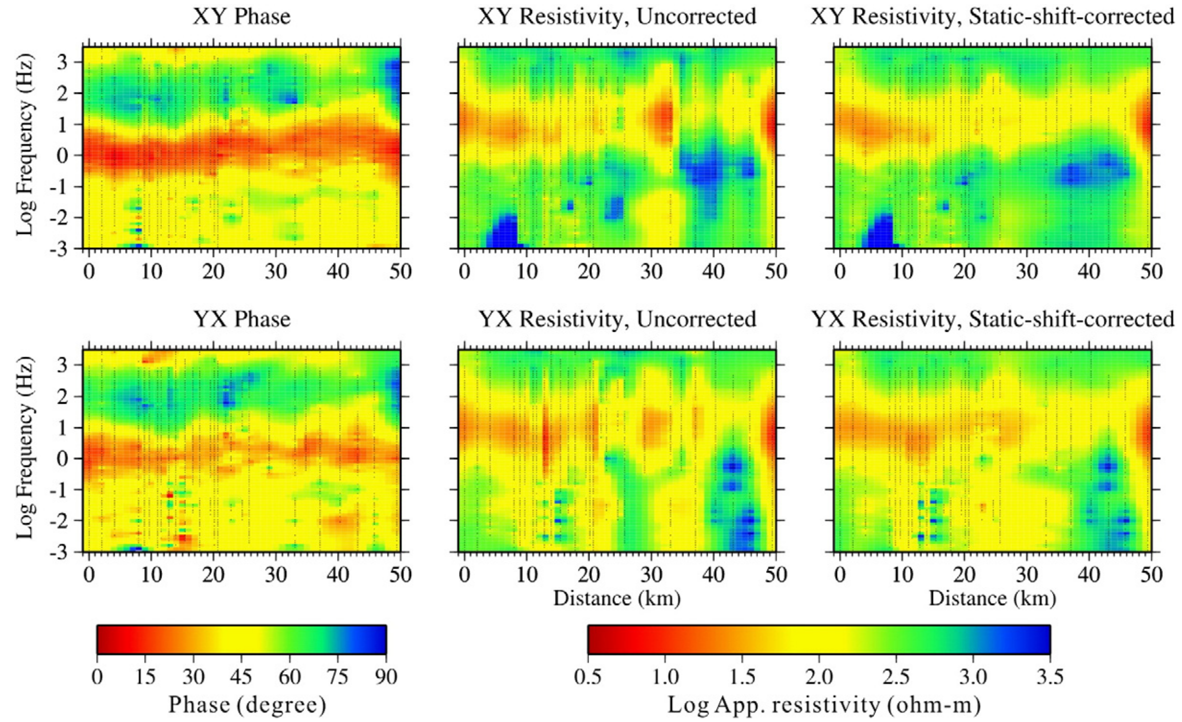

Fig. 2. Phase pseudosections (left) and apparent resistivity pseudosections before (middle) and after (right) static shift correction along the survey line JNL. The XY and YX denote the responses with the electric field directed to the north and the east, respectively.

lines, and MT data with broadband frequencies ranging from 10^3 to 3×10^{-4} Hz were acquired. All impedance tensors were estimated by robust remote reference processing with SSMT2000 software (Phoenix Co.). The details of data acquisition and processing method were described by Lee et al. (2006) and Nam et al. (2009). Now that we focus on the deep geoelectric structure of the island, we select only 11 sounding data with good quality even for low frequencies to 10^{-3} Hz among the processed MT data, which are uniformly distributed across the island (see Fig. 1).

According to Lee et al. (2009), Jeju MT data have some problems to be resolved for reliable interpretation: static shift effect, topographic effect and sea effect. Fig. 2 shows an example of static shift correction results for the survey line JNL. In Fig. 2, we see that the phases are consistent with each other, whereas the observed apparent resistivity shows abrupt changes. Considering that the conductive Quaternary sedimentary formations underlying the basaltic lava are ubiquitous over the island and their resistivity values do not show any significant changes (Lee et al., 2006), we may expect that the low apparent resistivity values due to the formation appear all over the sites with fairly continuous variation. Based on this geophysical expectation, a simple static shift correction is applied to observed impedance tensors so that XY and YX apparent resistivity values at frequencies ranging from 10 Hz to 30 Hz smoothly vary along each survey line. As shown in Fig. 2, we can observe that the continuity of the resistivity data is noticeably enhanced by the static-shift correction. The same static shift correction method was applied to the other survey lines, which yields the similar results.

We proceed to examine distortions due to topographic variations and the surrounding sea. Nam et al. (2009) reported the topographic effect appears at frequencies higher than 2 Hz and it can be explained by the elevation changes of the MT sites. Note that topographic changes of the selected MT sites are not severe as shown in Fig. 1. In addition, we are interested in revealing deep structures extracted from frequencies lower than 1 Hz. As a result, we do not consider the topographic effect. On the other hand, Yang et al. (2010) demonstrated that the sea effect hinders us from correctly interpreting the deep structure because the MT data at low frequencies below about 1 Hz are distorted by the surrounding sea. Therefore, the sea effect correction is an indispensable procedure to properly interpret the deep structure of the island.

Prior to correcting sea effects, we need to investigate the dimensionality of the selected MT data because the sea effect correction requires information on the dimension of the subsurface. Fig. 3 shows

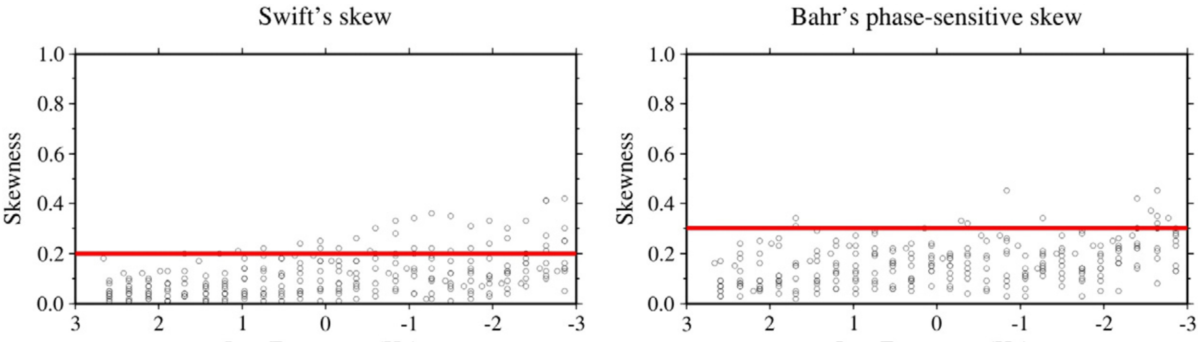

Fig. 3. Skewness of observed impedance tensor according to Swift's and Bahr's parameterization for the selected 11 sites. Solid lines in the panels indicate the empirically determined thresholds of 0.2 (Swift) and 0.3 (Bahr), respectively.

two kinds of skew values of observed MT impedances. In Fig. 3, most of the skew values are below the thresholds of 0.2 (Swift) and 0.3 (Bahr), which indicates that the subsurface structures can be assumed to be 1-D or 2-D. According to former studies (Lee, 1994; Nam et al., 2009), the geoelectrical structure of Jeju Island can be regarded as a 1-D earth consisting of four layers in a regional scale although there might exist local 2-D or 3-D structures. Based on these results, we assume a 1-D subsurface structure, which will also be supported by the sea effect corrected data.

Now we apply the iterative sea effect correction method (Yang et al., 2010) to the static shift corrected data, assuming that the subsurface structure is 1-D earth. In 1-D treatment, to alleviate the unwanted galvanic and inductive distortions, the effective impedances rather than the TE and TM modes are commonly employed (Berdichevsky et al., 1989; Likelybrooks, 1986). We select the determinant average (DET, Z_{det}) of MT impedance tensor described by $Z_{\text{det}} = \sqrt{Z_{xx}Z_{yy} - Z_{xy}Z_{yx}}$. The 3-D modeling algorithm and 1-D inversion method, which are required to correct the sea effect, are identical

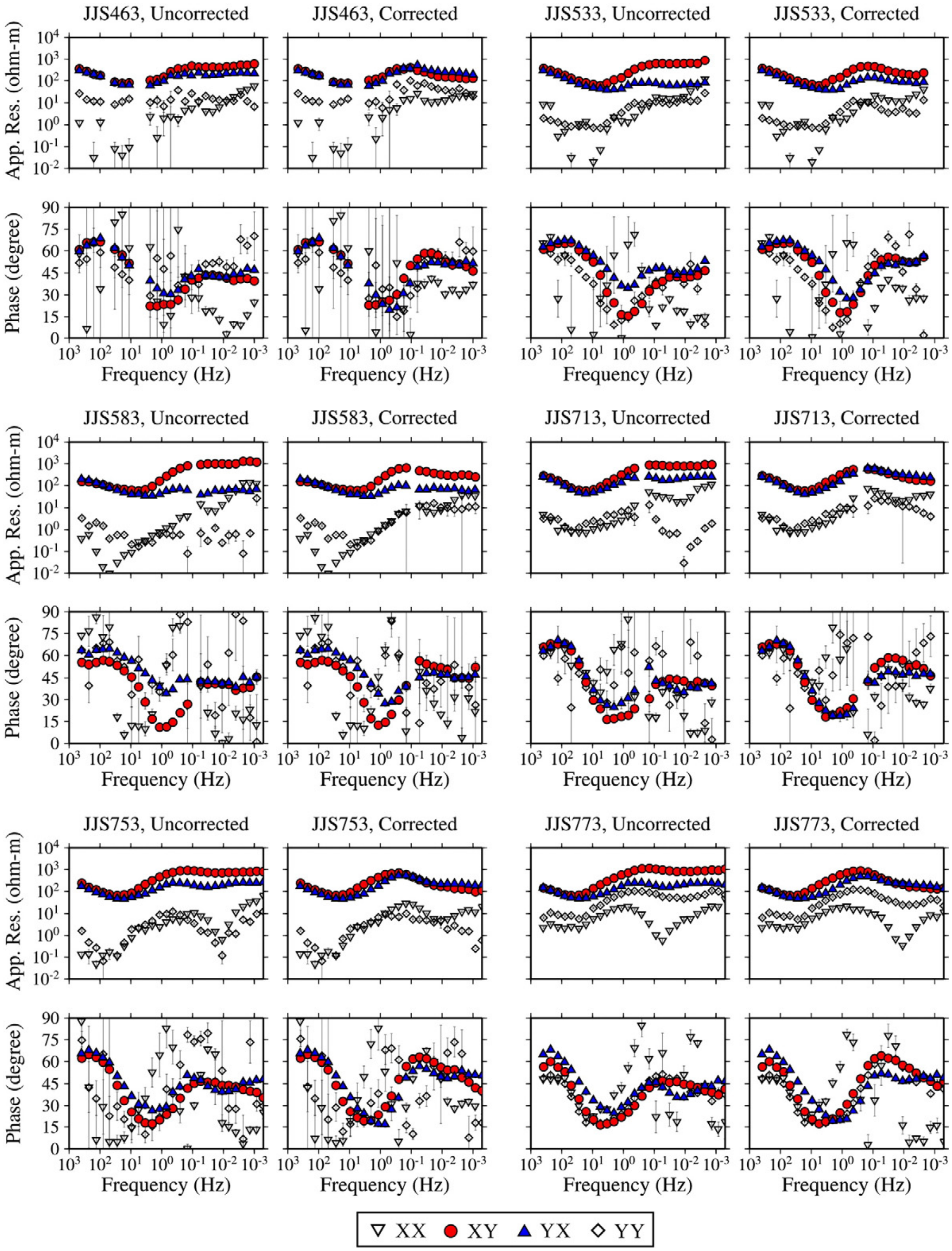

Fig. 4. Apparent resistivity and phase curves with error bars for the observed (sea effect uncorrected) and sea effect corrected data at all the sites.

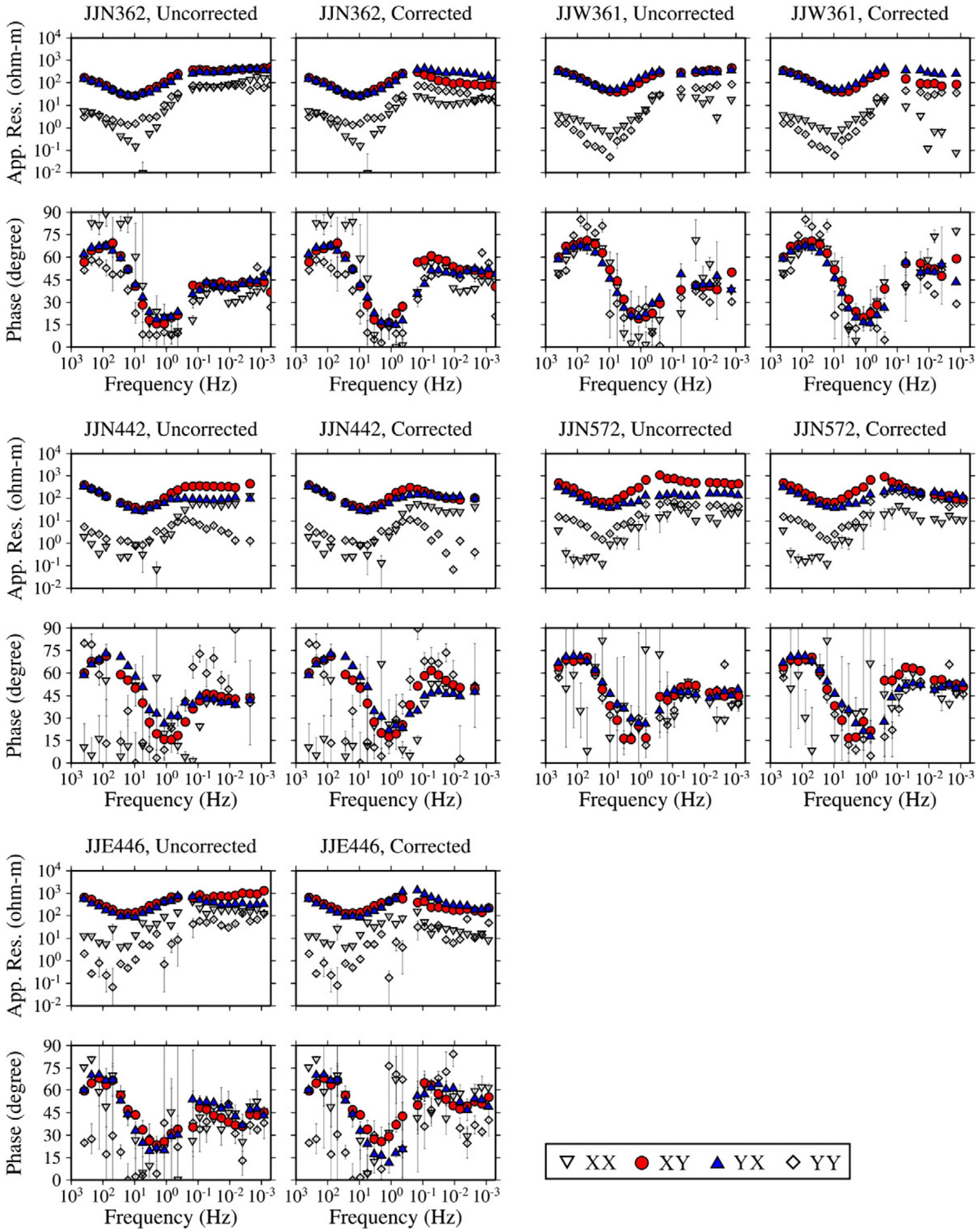

Fig. 4 (*continued*).

to those of Yang et al. (2010). That is, we use the staggered finite-difference algorithm (Mackie et al., 1993) for the 3-D modeling and Occam's method (Constable et al., 1987) for the 1-D inversion. The more detailed descriptions for the sea effect correction were presented by Yang et al. (2010).

Fig. 4 compares the MT responses at all sites before and after the sea-effect correction. The sounding curves of two modes of uncorrected MT data begin to split around 1 Hz at most sites, showing typical responses to three layers (resistive top, conductive middle, and resistive bottom layers). The sea effect correction makes two remarkable changes: first, all the sounding curves of corrected data clearly exhibit a 4-layered structure, indicating the existence of conductive bottom layer. Second, both sounding curves of the XY and YX modes of the corrected data are compatible with each other, which is the general feature that appears in the MT sounding curves for nearly 1-D earth. These results convince us that our 1-D approach is valid enough to provide reliable information on the deep structure beneath the island.

In Fig. 5, we present the apparent resistivity and phase data of Z_{det} before and after the sea effect correction at all the 11 sites. In terms of 1-D earth, all the sounding curves of corrected responses clearly show a 4-layered structure (resistive–conductive–resistive–conductive

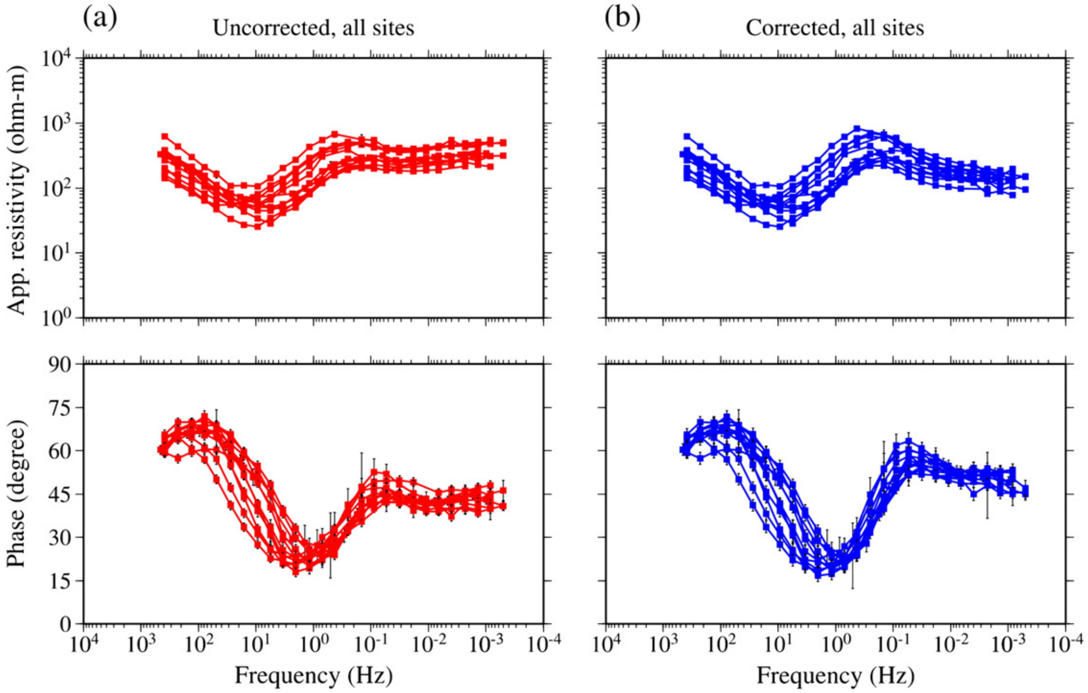

Fig. 5. Apparent resistivity (upper panel) and phase (lower panel) curves of the DET for (a) the observed (sea effect uncorrected) and (b) sea effect corrected data of all the sites with error bars.

pattern with increasing depth), while the uncorrected responses roughly show a 3-layered structure (resistive–conductive–resistive pattern with increasing depth). We can also confirm that the sea effect appears at frequencies lower than about 1 Hz, which are responsible for screening the responses of the deeper structures. In addition, the sea effect correction significantly enhances the decreasing gradient at frequencies lower than about 0.1 Hz in the apparent resistive curves and makes the local maximum around 0.05 Hz in the phase curves. These retrieved features are clear evidences demonstrating the large resistivity contrast between the 3rd and 4th layer. Accordingly, we expect that the sea effect correction increases the reliability of the deep electrical structure of the island.

4. Geophysical interpretations

4.1. 1-D layered-earth inversion

From the sea effect corrected MT data of Jeju Island, we could note that the subsurface model beneath the island is electrically divided into at least 4 layers in terms of 1-D earth. To clearly examine the boundary of each layer, we employ the 1-D layered-earth inversion (LI) method (Meju, 1992) for both the apparent resistivity and phase data of effective impedance Z_{det}. For observation errors, we assume minimum errors to be 7% for the apparent resistivity and 2° for the phase of Z_{det}. Data points with large scatter and large error bars (e.g., outliers) were removed through careful inspection.

The initial model for the 1-D LI method is assumed to consist of four layers, which are built based on the Occam's inversion results that were acquired in the sea effect correction (Yang et al., 2010). Fig. 6 shows 1-D models inverted from sea effect uncorrected and corrected responses for all the sites. Averaging LI results at all the sites yields a representative 1-D resistivity model for Jeju Island, which is also displayed in Fig. 6. We may also obtain a representative 1-D resistivity model by performing LI for the averaged MT data. However, because the model parameters of the 1-D models are dependent on data quality of each site (i.e., noise level), we favor the 1-D model which is statistically derived by averaging the 1-D models obtained at all the sites. Table 1 shows physical properties of the averaged 1-D model obtained by using the uncorrected and corrected responses, respectively.

In Fig. 6 and Table 1, we can observe the remarkable changes particularly in the thickness of the third layer and the resistivity of the fourth layer after the sea effect correction. The boundary between the third and fourth layers becomes deeper moving from a depth of 10 km to 18 km, and the resistivity value of the fourth layer changes from about 330 ohm-m to about 110 ohm-m, resulting in sharper resistivity contrast between the third and fourth layers. Clearly, these changes are attributed to the sea effect correction, and the root-mean-square (RMS) misfit values have also decreased after the correction at most sites (Fig. 6c).

On the other hand, we can observe slight changes of resistivity values underneath the interface between the third and fourth layers in the Occam's inversion results shown in Fig. 7, which may indicate the existence of a 5th layer. As a result, we also carry out the LI inversion assuming that the subsurface structures are composed of 5 layers. In Fig. 7c, we compare RMS misfits of the LI results for 5 layers with those of 4 layers. Although the 5-layered model yields RMS errors slightly lower than those of the 4-layered model at several sites, the 1-D models obtained by the LI with 5 layers show little significant changes compared to those generated by the LI with 4 layers. Adopting Occam's razor, we prefer the simplest model accounting for our data, and the 1-D model with 4 layers is thus selected to interpret the resistivity structure beneath the island.

4.2. Deep electrical structure beneath Jeju Island

The averaged 1-D model obtained from sea effect corrected responses exhibits a pattern of resistive–conductive–resistive–conductive layers as the depth increases. The uppermost layer (370 ohm-m) corresponds to the surface basaltic cover underlain by very conductive Quaternary sedimentary formation (30 ohm-m) down to 0.95 km. Below this is a region of moderately resistive layer (1750 ohm-m) reaching 18 km, overlying a conductive homogeneous bottom layer (110 ohm-m). Since the first and second layers are well known by the

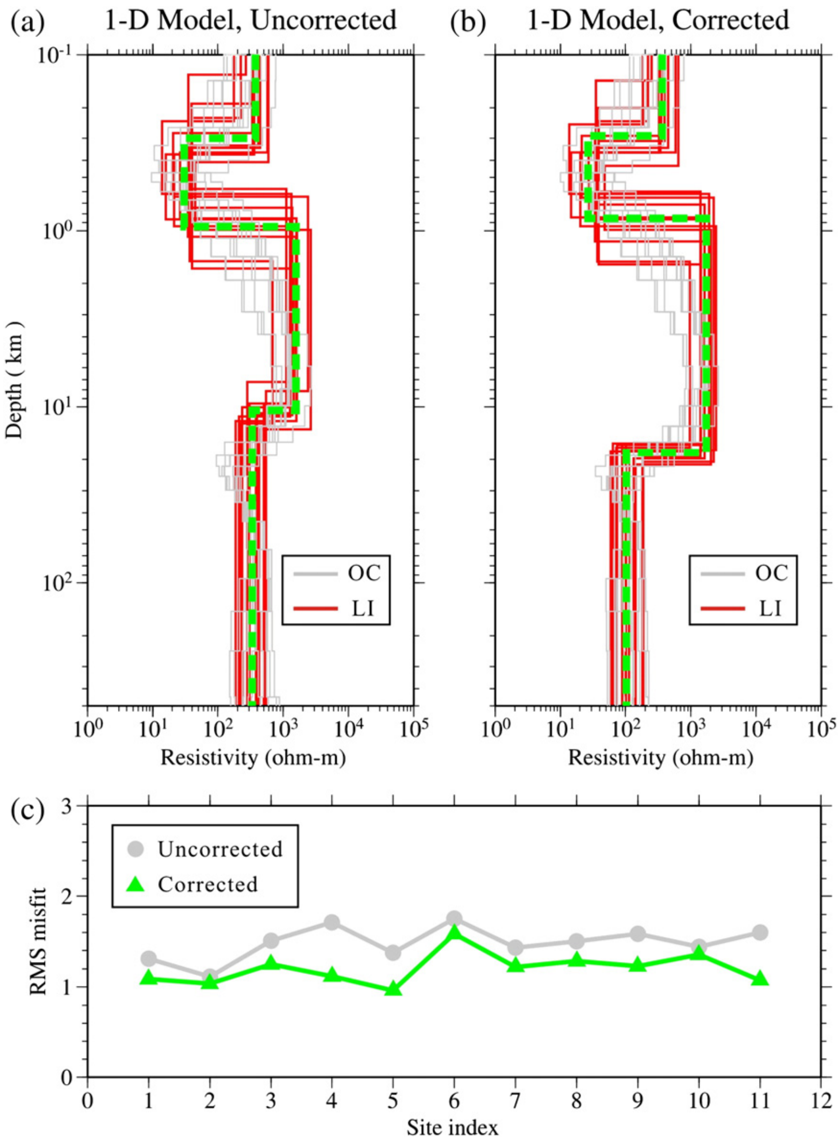

Fig. 6. 1-D resistivity models obtained by the Occam's inversion (OC) and the layered-earth inversion (LI) with 4 layers for (a) the sea effect uncorrected and (b) corrected DET at all the sites. Note that long-dashed lines denote the averaged 1-D models derived from all LI models. (c) Root-mean-square (RMS) errors between the observed and calculated responses along the sites.

former studies (Lee et al., 2006; Nam et al., 2009) and are not changed after the correction, we focus on the interpretation of the deeper parts (i.e., the third and fourth layers).

In general, the MT method is not sensitive to detect the Moho except for some regions where the conductive lower crust is absent and the upper crust (or just crust) is highly resistive (> several ten thousands of ohm-m) such as the Slave Craton and the East Indian Craton (Bhattacharya and Shalivahan, 2002; Jones, 1999; Jones and Ferguson, 2001; Spratt et al., 2009). In the case of Jeju Island, the upper crust, whose resistivity value is approximately 2000 ohm-m, is not highly resistive, and regional gravity and seismological studies (Choi et al., 1993; Yoo et al., 2007) demonstrated that the depth of Moho beneath the island is approximately 33–35 km. Based on these facts, the boundary located at a depth of 18 km beneath the island is not the Moho but likely to be the transition zone (i.e., brittle–ductile transition zone or Conrad discontinuity) separating the resistive upper crust and the conductive, continental lower crust (CLC). The conductive CLC has been globally observed in the continental setting (Gough,

Table 1
Physical properties of the arithmetically averaged 1-D resistivity models inferred from the observed (sea effect uncorrected) and the sea effect corrected responses at all the sites. The values in parenthesis indicate the standard deviations.

Layer	Sea-effect uncorrected		Sea-effect corrected	
	Resistivity, ohm-m	Depth, km	Resistivity, ohm-m	Depth, km
1st	378.9 (±131.5)	0.30 (±0.09)	372.7 (±142.7)	0.30 (±0.08)
2nd	30.1 (±10.9)	0.95 (±0.35)	29.7 (±11.0)	0.95 (±0.33)
3rd	1559.8 (±548.9)	10.52 (±1.93)	1751.86 (±432.6)	18.13 (±1.84)
4th	336.8 (±123.56)		110.4 (±45.4)	

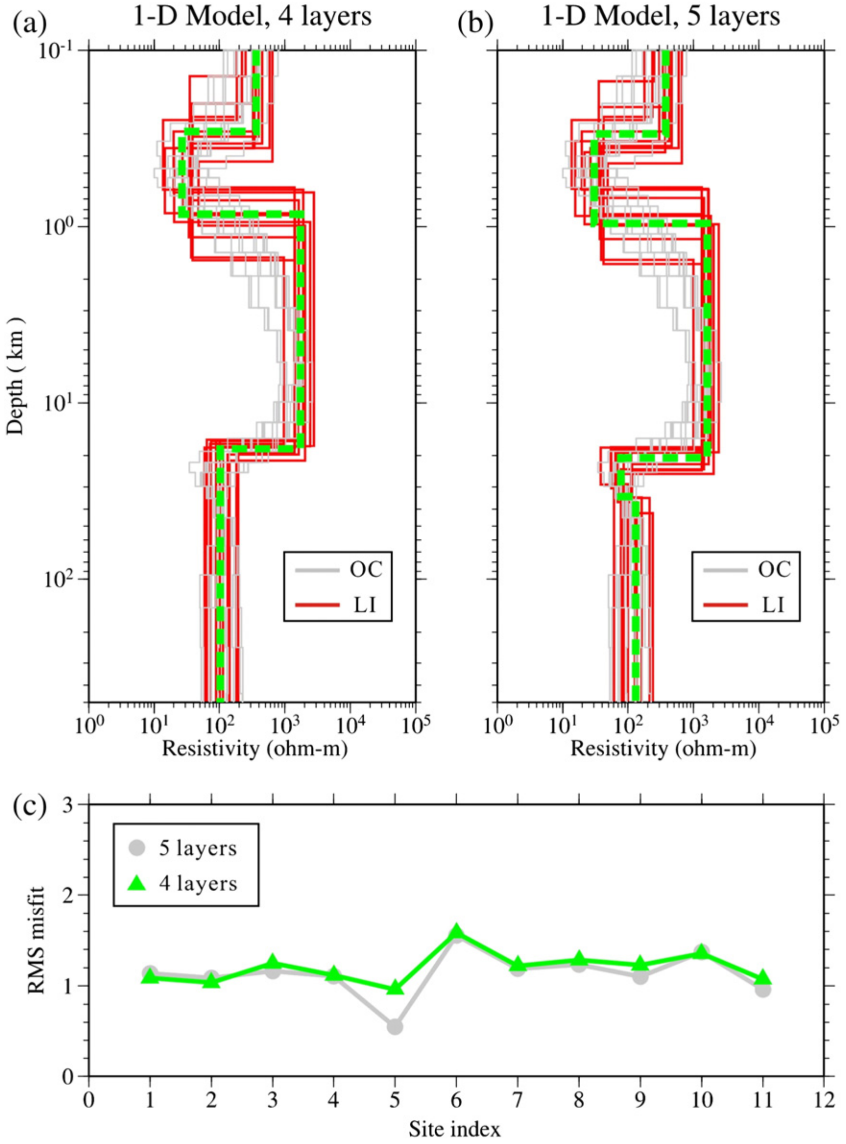

Fig. 7. The same as Fig. 6 but by inversion with (a) 4 layers and (b) 5 layers for the sea effect corrected data.

1986; Haak and Hutton, 1986; Jones, 1992), but the cause of the conductive CLC is still being disputed. The cause for the conductive CLC beneath the island will be discussed in the next section.

Since there is little geophysical study on the deep part of Jeju Island, it can be helpful to compare our results with other geophysical studies carried out in the southern part of the Korean Peninsula, grounded that Jeju Island can be considered as a tectonical extension of it. According to the previous MT study performed across the southern part of the Korean Peninsula (Lee, 2006), it was reported that the transition boundary between the resistive upper crust and conductive lower crust exists at a depth of approximately 18 km on average in the southeastern part (Fig. 8). In addition, recent seismological study (He and Hong, 2010) also reported that Conrad discontinuity exists at a depth of about 20 km in that region. This similarity indicates that 1-D resistivity model inferred from the MT data is fairly compatible with other geophysical data, supporting the previous studies that Jeju Island is a tectonical extension of the southeastern part of the Korean Peninsula. However, the resistivity values of the lower crust in Jeju Island differs from those of the southeastern part of the Korean Peninsula (the lower crust of Jeju Island has lower resistivity values than those of the Korean Peninsula by one order of magnitude), from which we can tell that they might have experienced different tectonic activities for some periods.

5. Discussions on the conductive CLC beneath Jeju Island

Since the silicate rocks, one of the main constituents of the lower crust, are highly resistive, the presence of the conductive CLC can be explained by the interconnected network of either saline fluid (Brace, 1971; Gough, 1986; Jones, 1992), mineral conducting phase (Duba et al., 1988; Frost et al., 1989), or partial melting (Sato and Ida, 1984; Waff, 1974). For the electrical property of the CLC, Haak and Hutton (1986) showed that the standard lower crust has a resistivity value ranging 100–300 ohm-m. In Precambrian regions, the lower crust typically has the conductance (conductivity × thickness) of around 20 S, whereas for Phanerozoic regions, the conductance of the lower crust is higher than that of Precambrian regions by an order of magnitude, e.g., about 400 S (Jones, 1999).

On the basis of 1-D resistivity model derived from the sea effect corrected Jeju MT data, the resistivity of the CLC beneath the island is estimated at 110 ohm-m and the conductance of the CLC reaches

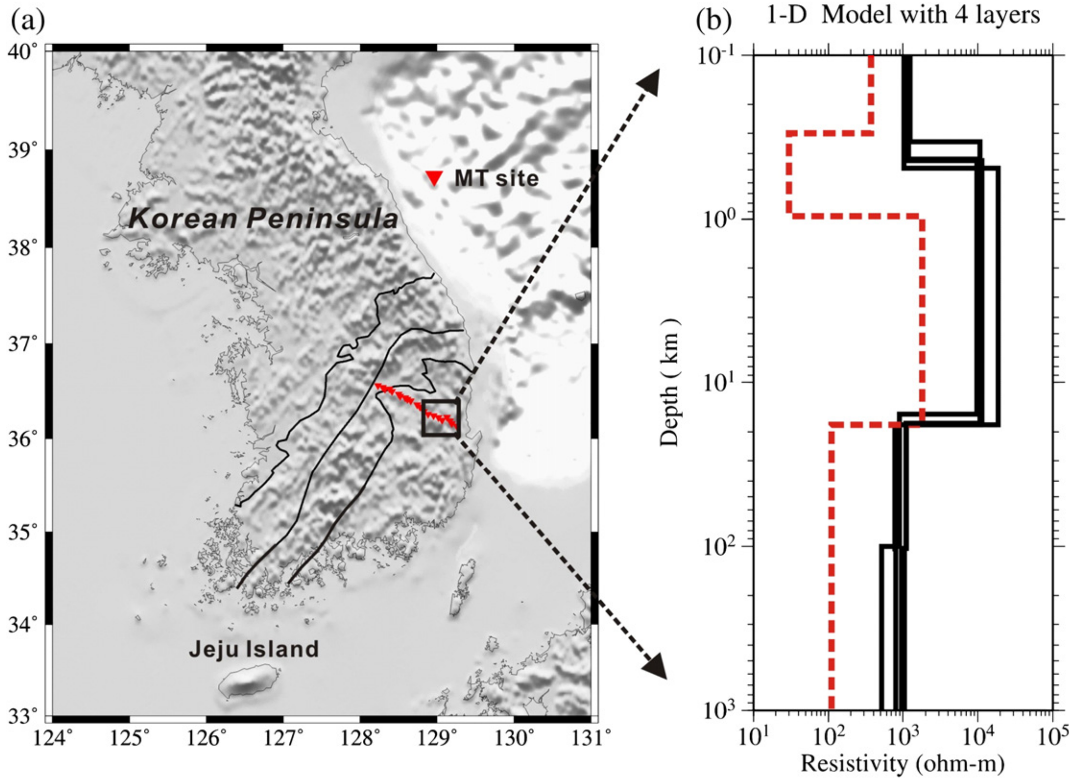

Fig. 8. (a) The map showing the simplified major tectonic boundaries in the Korean Peninsula and the MT sites of the previous study (Lee, 2006). (b) 1-D resistivity models obtained by the layered-earth inversion (LI) with 4 layers at the four sites (modified from Lee, 2006). Note that long-dashed line in Fig. 8b denotes the averaged 1-D model obtained from Jeju Island.

about 155 S, provided that the Moho of the island is located at a depth of 35 km (Yoo et al., 2007). These values for the resistivity and the conductance of the CLC in the island seem to be normal, compared to those of other regions. However, we cannot rely on these values completely, because the MT method only allows us to describe the depth to the top, and conductance (or thickness–resistivity ratio) of the layer. In this study, however, we used the averaged 1-D model to interpret the subsurface structures, which may play a role in reducing the uncertainty in the interpretation.

As candidates explaining the low resistivity of CLC beneath the island, conductive mineral phase or conducting fluids such as partial melting and saline water can be taken into account. For conductive mineral phase, graphite film has been thought of as the most plausible cause in many regions because a small fraction of graphite can greatly reduce the resistivity of the CLC (Duba et al., 1988; Frost et al., 1989). However, a small fraction of graphite will not significantly affect elastic properties and seismic velocity (Marquis and Hyndman, 1992), which indicates that graphite cannot explain increased seismic reflectivity at the interface between the upper and lower crust. Note that Conrad discontinuity exists at a depth of 20 km in the southern part of the peninsula, which is tectonically linked to Jeju Island. Therefore, the possible cause of the conductive CLC is likely to be partial melting and/or saline fluid rather than mineral conducting phase. The partial melting, however, is unlikely to be a candidate for explaining the low resistivity of CLC of the island, because the partial melting is generally linked to a geothermal anomaly but we could not detect any geothermal anomalies in Jeju Island. The heat flow of the island is approximately 50 mW/m^2, which is lower than that of the Korean Peninsula (60 mW/m^2) as well as global average of heat flow (65 mW/m^2) (Song et al., 2006). Accordingly, the interconnected saline fluid is the most plausible cause of the low resistivity of the CLC beneath the island at present, because it can be linked to metamorphic and/or magmatic process, which stems from hot spot or mantle plume describing the origin of Jeju Island.

Assuming that the low resistivity of the CLC results from the interconnected saline fluid, we can roughly infer the fluid fraction required to account for the resistivity of 110 ohm-m in the CLC beneath the island. For the crustal fluids, we may expect to find aqueous brines associated with metamorphic and/or magmatic processes, below the brittle–ductile transition zone. Hydration reaction related to heating the crustal rocks can result in brines with as much as 10 wt.% NaCl, but fluid volumes will likely be much less than 1% (Walther, 1994). The resistivity of rocks (ρ_{rock}) is related to both the resistivity of fluid (ρ_{fluid}) and the fluid fraction (f): $\rho_{rock} = \rho_{fluid}/f^n$ where $n \approx 1$ for partial melts and interconnected networks (Park and Mackie, 2000). Nesbitt (1993) showed that the resistivity of a 3.5 wt.% salt solution is estimated to be 0.04 ohm-m under the pressure of 3 kbar and the temperature of 300–500°C. If we assume that this is a reasonable estimate for fluid resistivity, the maximum interconnected fluid fraction in the CLC beneath the island is around 0.04%. The practical fluid fraction value, however, can be a little bit higher than 0.04% in Jeju Island, if the resistive CO$_2$-rich fluids are included (Yang (2004) reported the presence of CO$_2$-rich fluid in the xenoliths found in Jeju Island). Although we cannot estimate the accurate fluid fraction of the CLC under the circumstances, this fluid fraction value might give a clue for physical and/or chemical state of the CLC of the island.

6. Conclusions

We revealed the deep structures of Jeju Island including the lower crust based on the sea effect corrected MT data. The sea effect correction has made remarkable changes in the observed MT responses at frequencies below about 1 Hz, clearly indicating the existence of conductive bottom layer. From the sea effect corrected MT data of the 11 sites across the island, we built the new representative 1-D resistivity model for Jeju Island. This new 1-D resistivity model revealed the discontinuity at a depth of about 18 km beneath the island, which is interpreted as transition zone separating resistive upper crust and conductive lower crust. Furthermore, in the southern part of the Korean Peninsula which seems to be tectonically linked to Jeju Island, the transition zone separating the upper and lower crusts has been also estimated to be approximately 18 km from the previous MT survey and 20 km from recent seismological study. These results demonstrate that 1-D resistivity model inferred from the sea effect corrected MT responses is fairly reliable, and also support the previous studies that Jeju Island is a tectonical extension of the southern part of the Korean Peninsula.

For the cause of the conductive CLC beneath the island, the interconnected saline fluid rather than partial melting is thought of as the most plausible candidate, because the Jeju Island is not geothermally anomalous when compared to other regions. The interconnected network of saline fluid might be linked to metamorphic and/or magmatic process forming the Jeju Island. The theoretically computed fluid fraction value was 0.04% under the pressure of 3 kbar and the temperature of 300–500°C. This fluid fraction value can be higher in case of the resistive CO_2-rich fluid being included, and in practice, the existence of such CO_2-rich fluids has been reported in Jeju Island. Although we provide several evidences for our interpretation on deep structures of Jeju Island, we still feel that additional geophysical and geochemical data are needed to verify our interpretation.

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