Electrical Conductivity Anomalies beneath the Japan Arc

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As a result of intensive observations of geomagnetic variations over many years, the overall distribution of anomalous $Z$ fields has become clear in Japan. One of the anomalies, the central Japan anomaly, has been accounted for by a depression of a highly conducting layer in the mantle beneath Japan, although the effect of the sea on the anomaly has not been brought out quite clearly. The period dependence of the anomalies along lines across central and northeastern Japan is examined by making use of the transfer function technique. Anomalous $Z$ fields can be traced on a few islands in the Pacific Ocean south of central Japan, although they are strongly contaminated by island effects there. It is found out that the central Japan anomaly has a strong period dependence. The anomaly along the line across northeastern Japan also has a strong period dependence which is slightly different in its characteristics from that for the central Japan anomaly. Numerical calculations of electromagnetic induction based on the method given by Jones and Pascoe (1971), have been made for two-dimensional models, and the calculated transfer functions are compared with the observed ones. As a result, it is found out that the sea surrounding the Japan Islands plays an important role on both the anomalies. The anomaly in the central part of Japan, however, cannot be accounted for by the sea only. On the basis of these calculations, possible electrical conductivity models beneath the central and northeastern parts of Japan are put forward. It is concluded that a highly conducting layer seems likely to lie at a depth of 30 km beneath the Philippine Sea and the Japan Sea. Anomalous $Z$ fields associated with ssc's, geomagnetic bays and similar changes have been found on Oshima, Miyake-jima and Hachijo-jima Islands. Such an island effect is certainly caused by the induced electric currents which are distorted by the low conductivity of the island. However, the calculated effect does not agree with the observed one when electromagnetic coupling between the sea and the conducting layer in the mantle is ignored. A detailed study of electromagnetic coupling suggests that a highly conducting layer lies close to the earth's surface beneath the northern part of the Izu-Bonin arc.

1. Introduction

Geomagnetic variation anomalies have been found in many regions all over the world. Some of them have been interpreted in terms of the effect of the sea on geomagnetic variations. This type of anomaly has been observed at coastal
areas (coast effect, e.g., Schmucker, 1964; Everett and Hyndman, 1967; Hyndman and Cochrane, 1971; Lilley and Bennett, 1972: peninsula effect, e.g., Sasai, 1969; strait effect, e.g., Giorgi and Yokoyama, 1967) and on islands (island effect, e.g., Sasai, 1967, 1968; Honkura, 1971). Electrically conductive sedimentary layers also have strong effects on geomagnetic variations especially when they are connected with the open sea (e.g., Untiedt, 1970; Porath and Dziewonski, 1971). In addition to such effects, more stress has been put on the effects of anomalous structures of electrical conductivity in the crust and upper mantle in connection with tectonic processes within the earth (e.g., Schmucker, 1969, 1970; Uyeda and Rikitake, 1970; Porath et al., 1970; Camfield et al., 1970; Porath and Gough, 1971; Banks, 1973).

In Japan, observations of geomagnetic variations have been intensively carried out since the early 1950's and two major anomalies have been found along with a number of local ones, i.e., the central Japan anomaly (Rikitake, 1959, 1966) and the northeastern Japan anomaly (Kato et al., 1971). As for the central Japan anomaly, no physically plausible model had been put forward because of unusually large amplitude of vertical intensity variation along the Pacific coast in the central part of Japan, until it was found out that some portions of anomalous vertical field were due to the effects of the sea, i.e., the peninsula effect (Sasai, 1969) and the island effect (Sasai, 1967, 1968). Taking such effects into account, Rikitake (1969) put forward a model which approximately accounts for the central Japan anomaly. Kato et al. (1971) put forward a model for the northeastern Japan anomaly on the basis of $\Delta Z/\Delta H$ value distribution. According to their models, the geomagnetic variation anomalies in Japan seem to be accounted for by the undulation of a highly conducting layer in the upper mantle.

On the other hand, it has sometimes been pointed out that the geomagnetic variation anomalies in Japan might be due to the effects of the sea surrounding Japan (e.g., Roden, 1964). According to Rikitake (1961) and Rikitake and Sasai (1969), it seems unlikely, however, that the anomalies in Japan are accounted for by the effects of the sea only. In the case of the anomalies which have been observed in the British Isles (Edwards et al., 1971), they have been interpreted in terms of electric currents in the sea surrounding the British Isles. These two cases seem to be contradictory, because the circumstances are very similar in the point that both the Japan Islands and the British Isles are surrounded by the sea although tectonic activities are different from one another.

The writer has been speculating that the period dependence of the anomaly would be the key for solving the question whether or not the anomalies in Japan are due to the effects of the sea only. As the electromagnetic response strongly depends on periods of the inducing field, the period dependence of the anomaly due to the effects of the sea might be different from that due to the effects of a conducting layer in the mantle. In view of this, the writer has examined the
A theory of estimating perturbation of alternating electric currents by a lateral change of electrical conductivity in a two-dimensional structure has been put forward by Jones and Price (1970), although the calculation is entirely based on a numerical method. The theory has been applied to various models of electrical conductivity structure (e.g., Jones and Price, 1971). Honkura has examined the period dependence of Rikitake's model for the central Japan anomaly by making use of the theory (Rikitake and Honkura, 1973). Jones and Pascoe (1971) put forward a general computer program of the calculation of electric and magnetic fields due to perturbation by conductivity anomalies on the basis of the theory by Jones and Price (1970). Their method is certainly a powerful means for examining the electromagnetic response of various conductivity structures including both the sea and the upper mantle (Lines et al., 1973).

Very local anomalies have been observed on islands such as Christmas Island (Mason, 1963), Oshima Island (Sasai, 1967, 1968), Oahu Island (Klein, 1972), Hawaii Island (Klein, 1971), Miyake-jima Island (Honkura, 1971), Hachijo-jima Island (Honkura et al., 1973) and other islands. They have been called the island effect. Sasai (1968) examined the distortion of electric currents by Oshima Island and calculated magnetic fields due to the distortion on the basis of the theory of electromagnetic induction in a non-uniform thin sheet (Price, 1949; Rikitake, 1966). Honkura (1971) calculated magnetic fields due to the distortion of electric currents on Miyake-jima Island by making use of Sasai's method and showed that the calculated transfer functions are about twice as large as the observed ones. In view of the fact that the intensity of electric currents in the sea is reduced to some extent by electromagnetic coupling between the sea and a conducting layer in the mantle, Honkura (1973) examined such an electromagnetic coupling on the assumption that the electrical conductivity structure in the mantle is laterally uniform, and put forward a model of the electrical conductivity structure beneath Miyake-jima Island.

This paper aims at investigating the electrical conductivity structures beneath the northern part of the Izu-Bonin arc, the central part of Japan and the northeastern part of Japan, and also at examining the relation between the electrical conductivity structures and other geophysical structures as revealed by heat flow distribution, seismic wave velocity and attenuation anomalies.

2. Overall Geomagnetic Variation Anomaly in Japan

Overall features of geomagnetic variations in Japan have been brought out by intensive observations. Figure 1 shows ΔZ/ΔH value contours all over Japan (Rikitake, 1969). Two anomalies are clearly seen along the Pacific coast in
the central part of Japan and in the northeastern part of Japan. These have been called the central Japan anomaly and the northeastern Japan anomaly, respectively. Figure 2 shows a model of electrical conductivity structure beneath Japan which has been put forward by Rikitake (1969) on the basis of the $\Delta Z/\Delta H$ value distribution. In this figure, contours indicate a depth to a highly conducting layer in the upper mantle in units of km.

The period dependence of the anomaly has been examined along lines across the central and northeastern parts of Japan by making use of the transfer function technique. These two lines are shown in Fig. 1. The $Z$ (downward) variations are strongly correlated with the $H$ (geomagnetic northward) variations along the line A-A' across the central part of Japan, while a good correlation between the $Z$ and the $D$ (geomagnetic declination) variations is seen along the line B-B' across the northeastern part of Japan. Electrical conductivity structures beneath the areas along these lines will be investigated in Sections 4 and 5 respectively, taking the period dependence into account. Determination of the electrical conductivity structure beneath the area shown by a rectangle in Fig. 1 will be given in Section 3.
Fig. 2. Rikitake's model of electrical conductivity structure beneath the Japan arc as deduced from the overall $\Delta Z/\Delta H$ value distribution in Japan. Contours indicate the depth of the highly conducting layer in the mantle in units of km (After Rikitake, 1969).

Fig. 3. A bay-like variation observed at the stations on Miyake-jima Island. The arrows indicate a scale length for 20 gammas. The $H$ and $D$ components are almost the same at all the stations (After Honkura, 1971).

* 1 gamma = 1 nT
3. Electrical Conductivity Structure beneath the Northern Part of the Izu-Bonin Arc

Geomagnetic variations observed on an island are strongly influenced by perturbation of electric currents around the island. Such perturbation is best shown by a reversal of sign of the vertical component between the northern and southern observation points on an island when the inducing field varies in the north-south direction. Such local geomagnetic variation anomalies have been called the island effect.

Fig. 4. Parkinson vectors on Miyake-jima Island for periods of (a) 120, (b) 60, (c) 30, (d) 15, and (e) 5 min, respectively (After Honkura, 1971).
Figure 3 shows a bay-like variation observed at the observation points on Miyake-jima Island. Although a reversal of sign of the $Z$ component between the northern-most station (Ka) and the southern-most station (Tu) is not seen, the difference in amplitude of the $Z$ component is clearly observed. As a result of data analysis, it has been found out that the geomagnetic variation anomaly on Miyake-jima Island consists of two parts, i.e., the island effect and the central Japan anomaly. These two parts can be separated (see Honkura, 1971) and the island effect is clearly observed when the effect of the central Japan anomaly is removed. The central Japan anomaly thus separated from the island effect is strongly period-dependent. This result for the central Japan anomaly on Miyake-jima Island will be used in Section 4.

Figure 4 shows Parkinson vectors (Parkinson, 1959) at the observation points on Miyake-jima Island for periods of (a) 120, (b) 60, (c) 30, (d) 15 and (e) 5 min. Parkinson vectors for long periods are dominated by the central Japan anomaly and they point to almost the same direction at all the stations as shown in Fig. 4(a). On the other hand, those for short periods are dominated by the island effect and they tend to point to the nearest deep sea as shown in Fig. 4(e).

Figure 5 shows the distorted electric currents around Miyake-jima Island when the inducing field varies in the north-south direction. Magnetic fields on the island can be calculated from the current function which is numerically calculated on the basis of the theory of electromagnetic induction in a non-uniform thin sheet of conductor (Price, 1949; Rikitake, 1966). Then transfer functions can be determined, too. In the case of Miyake-jima Island, the calculated transfer functions are about twice as large as transfer functions determined from the observed data for the period range from 5 to 120 min. In this numerical calculation, however, the electromagnetic coupling between the sea and a conducting layer in the mantle has not been taken into account. It

![Fig. 5. The flow pattern of electric currents around Miyake-jima Island for the northward inducing field (After Honkura, 1971).]
seems likely, therefore, that the discrepancy in magnitude is caused by the electromagnetic coupling. Estimating the electromagnetic coupling in detail, it is concluded that a highly conducting layer lies very close to the earth’s surface beneath Miyake-jima Island as shown by a model in Fig. 6.

Fig. 6. A model of electrical conductivity structure beneath Miyake-jima Island. A broken line indicates Rikitake’s model for the global electrical conductivity structure within the earth (After Honkura, 1973).

Fig. 7. A bay-like variation observed at the stations on Hachijo-jima Island. The arrow indicates a scale length for 20 gammas. The $H$ and $D$ components are almost the same at all the stations (After Honkura et al., 1974).
Intensive observations of geomagnetic variations were also carried out on Hachijo-jima Island which is located about 100 km south of Miyake-jima Island. Figure 7 shows a bay-like variation observed at the observation points on Hachijo-jima Island. In this case, a beautiful reversal of sign of the Z component between the northern station (EL) and the southern station (NA) is clearly seen. According to the result of data analysis, the central Japan anomaly is superposed on the island effect for periods longer than 30 min or so. This result for the central Japan anomaly on Hachijo-jima Island will also be used in Section 4. Figure 8 shows Parkinson vectors at the stations on Hachijo-jima Island for a period of 30 min. They seem to reflect the island effect only and tend to point to the nearest deep sea.

Figure 9 shows the distorted electric currents around Hachijo-jima Island when the inducing field varies in the north-south direction. In the case of
Hachijo-jima Island, the calculated transfer functions are about twice as large as transfer functions determined from the observed data, as is the case for Miyake-jima Island. It is concluded, therefore, that the electrical conductivity structure beneath the northern part of the Izu-Bonin arc is likely to be represented by a model as shown in Fig. 6.

4. Electrical Conductivity Structure beneath the Central Part of Japan

Geomagnetic variation anomaly represented by unusually large amplitude of vertical intensity variation in the central part of Japan has been called the central Japan anomaly. According to the observations of geomagnetic variations on islands in the Pacific Ocean such as Oshima Island (SASAI, 1967, 1968), Miyake-jima Island (HONKURA, 1971) and Hachijo-jima Island (HONKURA et al., 1973), the effect of the central Japan anomaly seems likely to be extended over the Pacific Ocean, the southern limit of the anomaly being distant from the coast line by some 150 km. The period dependence of the central Japan anomaly has been examined by making use of the transfer function technique.

Figure 10 shows a bay-like variation at the stations in the central part of Japan. Variations of the \( H \) and \( D \) components are almost the same at all the stations over this region. Therefore, only \( H \) and \( D \) traces at YA are shown in this figure. On the other hand, variations of the \( Z \) component are different from station to station and its amplitude tends to become small toward the interior of Honshu. The coherence between variations of the \( Z \) component and

![Diagram](image-url)

Fig. 10. A bay-like variation observed at the stations along the line A–A' in the central part of Japan. The arrow indicates a scale length for 20 gammas. The \( H \) and \( D \) components are almost the same at all the stations.
those of the $H$ component is pretty good as seen in the figure. Figure 11 shows Parkinson vectors for a period of 60 min at the stations along the line across the central part of Japan. Parkinson vectors on the islands are determined for the central Japan anomaly which is separated from the island effect on each island. Taking into account the tendency that Parkinson vectors point to almost the same direction at all the stations, a two-dimensional treatment in the following may be justified.

The writer carried out numerical calculations for various two-dimensional models of electrical conductivity structure by making use of the method given by Jones and Pascoe (1971). Figure 12(a) shows the in-phase and out-of-phase parts of transfer functions determined for a conductivity model shown in the figure. The conductivity of sea water is assumed to be $4 \times 10^{-11}$ emu* and the period is taken as 120 min. The in-phase and out-of-phase parts of transfer functions determined from the observed data for the same period are also shown in the figure. The observed transfer functions seem to be approximately accounted for by this model of electrical conductivity structure, i.e., the sea and

\* 1 emu = $10^{11}$ S/m
Fig. 12. Transfer functions calculated for a two-dimensional model of electrical conductivity structure as shown below, together with the observed ones. The solid and broken lines indicate the in-phase and out-of-phase parts of the calculated transfer functions, while the closed and open circles indicate the in-phase and out-of-phase parts of the observed ones. The conductivity of sea water is taken as $4 \times 10^{-12}$ emu. The period is taken as (a) 120, (b) 60, (c) 30, and (d) 10 min, respectively.
Fig. 13. Transfer functions calculated for a two-dimensional model of electrical conductivity structure as shown below, together with the observed ones. The period is taken as (a) 10, (b) 30, (c) 60, and (d) 120 min, respectively.
Fig. 14. Transfer functions calculated for a two-dimensional model of electrical conductivity structure as shown below, together with the observed ones. The period is taken as (a) 10, (b) 30, (c) 60, and (d) 120 min, respectively.
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a uniform low conductor having a conductivity of $10^{-14}\text{emu}$. The writer also calculated transfer functions for the same conductivity model taking periods of 60, 30, and 10 min.

Figure 12(b) shows the in-phase and out-of-phase parts of transfer functions calculated for a period of 60 min along with the in-phase and out-of-phase parts of observed transfer functions for that period. In this case, the observed transfer functions are well accounted for by the model for both in-phase and out-of-phase parts. Figure 12(c) shows the result for 30 min. In this case, however, the calculated transfer functions become so large around the land-sea boundary that they do not fit in the observed transfer functions. The misfitting tendency becomes more remarkable for 10 min as shown in Fig. 12(d). After all, the model cannot be regarded as a likely model of the electrical conductivity structure beneath the central part of Japan. The observed transfer functions at a few stations do not fit in the general trend as seen in these figures. This certainly is due to perturbation of electric currents by the irregular land-sea distribution.

It is concluded from the above results that the central Japan anomaly cannot be accounted for by the sea only, although it is demonstrated that the sea has an important bearing on the central Japan anomaly. In the next place, an idea that the central Japan anomaly might be accounted for by the sea and a laterally uniform conducting layer in the upper mantle will be tested.

In order to investigate such a possibility, the writer calculated transfer functions for a model shown in Fig. 13. A highly conducting layer having a conductivity of $10^{-12}\text{emu}$ is assumed to lie uniformly below a depth of 30 km. Figure 13(a) shows the in-phase and out-of-phase parts of transfer functions calculated for a period of 10 min. In this case, the calculated transfer functions become very small especially around the coastal area compared with transfer functions calculated for a model shown in Fig. 12(d). This is interpreted in terms of reduction of electric current intensity in the sea due to the electromagnetic coupling between the sea and a highly conducting layer lying below a depth of 30 km. It turns out, however, that the electromagnetic coupling is so strong for longer periods that the calculated transfer functions become much smaller than the observed ones as shown in Fig. 13(b), (c), and (d) for 30, 60, and 120 min, respectively. It is not likely, therefore, that the central Japan anomaly is accounted for by laterally uniform conductivity structures in the upper mantle.

It is suggested from the results for the two cases in the above that a laterally non-uniform conductivity structure must exist beneath the central part of Japan. In looking for a conductivity model of that nature, two points should be taken into account. One is that the electromagnetic coupling between the sea and the conducting layer in the mantle must be strong for shorter periods. The other is that the effect due to a laterally non-uniform structure in the mantle
must be strong for longer periods.

Bearing such points in mind, the writer calculated transfer functions for several models. Among them, one of the best models is shown in Fig. 14. The in-phase and out-of-phase parts of transfer functions calculated for periods of 10, 30, 60, and 120 min are shown in Fig. 14(a), (b), (c), and (d) respectively, along with those determined from the observed data. In the model, the structure beneath the Japan Sea cannot be clearly determined because of the shortage of data on the side of the Japan Sea. But the model seems to account for the geomagnetic variation anomaly in the vicinity of Tottori facing the Japan Sea (Sumitomo, 1972), although the location does not quite agree with the line A–A'. It is concluded, therefore, that the geomagnetic variation anomaly in the central part of Japan is accounted for by the model.

5. Electrical Conductivity Structure beneath the Northeastern Part of Japan

Intensive observations of geomagnetic variations have been carried out by
Kato et al. (1971) in Tohoku district, the northeastern part of Japan. An unusually large amplitude of vertical intensity variation has been found in the northern-most area of Tohoku district when the inducing field varies in the north-south direction. Variations of the Z component in this area are completely opposite to those in the central part of Japan; that is, an upward field is observed when the inducing field points to the north. This anomaly has been called the northeastern Japan anomaly.

The CA (Conductivity Anomaly) groups at the Earthquake Research Institute and the Geographical Survey Institute carried out observations of geomagnetic variations with an array of magnetometers along a line across the middle part of Tohoku district. According to the $\Delta Z/\Delta H$ value distribution in Tohoku district, $\Delta Z/\Delta H$ value amounts to almost 0.0 along the line B–B’ as shown in Fig. 1. Instead, anomalous vertical fields have been observed especially near the Pacific coast when the inducing field varies in the east-west direction.

Figure 15 shows an example of the records obtained at the stations along the line B–B’. As variations of the $H$ and $D$ components are almost the same at all the stations along the line, only $H$ and $D$ traces at MI are shown in this figure. Amplitude of the $Z$ component tends to become small gradually from the side of the Pacific Ocean to the side of the Japan Sea. The coherence

![Fig. 16. Parkinson vectors at the stations along the line B–B’ in the northeastern part of Japan for a period of 60 min. Contours indicate the sea depth in meters.](image-url)
Fig. 17. Transfer functions calculated for a two-dimensional model of electrical conductivity structure as shown below, together with the observed ones. The solid and broken lines indicate the in-phase and out-of-phase parts of the calculated transfer functions, while the closed and open circles indicate the in-phase and out-of-phase parts of the observed ones. The conductivity of sea water is taken as $4 \times 10^{-11}$ emu. The period is taken as (a) 10, (b) 30, (c) 60, and (d) 120 min, respectively.
between the $Z$ and the $D$ components is high as seen in the figure. Figure 16 shows Parkinson vectors determined for a period of 60 min at the stations along the line. Parkinson vectors point to almost the same direction in parallel with the line $B-B'$ at all the stations. It would not be unreasonable, therefore, to assume a two-dimensional structure perpendicular to the line $B-B'$ or parallel to the coast line. In addition to these, it should be noticed that the amplitude of variations of the $Z$ component at IS is a little larger than that at MI deviating from the averaged trend as seen in Fig. 15 and Fig. 16. According to the geological map, a sedimentary layer spreads along the Kitakami River. Therefore such small perturbation is likely to be due to the sedimentary layer.

A model of electrical conductivity structure beneath the northeastern part of Japan is shown in Fig. 17. The conductivity of the sedimentary layer in the middle part of the land is assumed to amount to $5 \times 10^{-12}$ emu and the conductivity of the sea is taken as $4 \times 10^{-11}$ emu as usual. Figures 17(a), (b), (c), and (d) show the in-phase and out-of-phase parts of transfer functions calculated for periods of 10, 30, 60, and 120 min respectively, along with the in-phase and out-of-phase parts of the observed transfer functions for each period. The calculated transfer functions seem to agree approximately with the observed ones, although the calculated ones for long periods are a little smaller than the observed ones as seen in Fig. 17(d). Such a discrepancy between the observed and calculated transfer functions for long periods is also the case for the central Japan anomaly. This could be given rise to by the fact that the effect of the Japan Sea on both the anomalies may be overestimated. Being surrounded by the Asian Continent and the Japan Islands, the effect of the Japan Sea may well be smaller.

In view of the fact that a highly conducting layer seems to lie at a depth of 30 km beneath the Japan Sea as revealed in the case of the central Japan anomaly, another conductivity model as shown in Fig. 18 is also examined reaching a conclusion that transfer functions calculated for this model are almost the same as those calculated for the model as shown in Fig. 17. Figure

![Fig. 18. A two-dimensional model of electrical conductivity structure beneath the northeastern part of Japan.](image-url)
18 may well represent a likely conductivity structure beneath the northeastern part of Japan, although the anomaly along the line B-B' is primarily due to the effect of the sea.

6. Discussion and Concluding Remarks

A plausible model of electrical conductivity structure beneath the central part of Japan has been put forward in Section 4. According to the model, a highly conducting layer having a conductivity of $5 \times 10^{-12}$ emu lies at a depth range from 30 to 80 km beneath the Philippine Sea. The electrical conductivity structure beneath the northern part of the Izu-Bonin arc has been determined in Section 3 on the basis of the electromagnetic coupling between the sea and the ocean.

Fig. 19. The shear velocity model, ARC-1, together with the standard oceanic mantle models, 8099 and CITIIA (After Kanamori and Abe, 1968).

Fig. 20. A schematic model of the upper mantle structure beneath the northern part of Japan (After Utsu and Okada, 1968).
a conducting layer in the mantle. In this case, a highly conducting layer having a conductivity of $10^{-12}$ emu or thereabout lies at a depth range from 10 to 30 km.

According to the plate tectonics, the Pacific Ocean plate begins to sink beneath the Philippine Sea plate at the Izu-Bonin trench (KANAMORI, 1971), and a laterally non-uniform conductive structure is expected beneath the Izu-

Fig. 21. Smoothed contours of heat flow values in HFU (After WATANABE, 1972).
Bonin arc. Therefore, a highly conducting layer at a depth range 30–80 km beneath the northern part of the Philippine Sea seems to come up closer to the earth's surface beneath the Izu-Bonin arc.

According to a model of electrical conductivity structure beneath the northeastern part of Japan, no highly conducting layer lies beneath the Pacific Ocean although nothing can be said about the structure beneath the Japan trench from the present observations on land. It has been stressed throughout this study that the sea surrounding the Japan Islands plays an important role on geomagnetic variation anomalies. A number of local anomalies of minor extent found in all parts of Japan seem to be accounted for primarily by the effect of the sea. A model for the northeastern Japan anomaly which has been put forward by Kato et al. (1971) should be reexamined, because the sea is not taken into account in their calculations.

Studies on group velocities of long-period surface waves for various paths have revealed that the upper mantle structure beneath the Philippine Sea and the Japan Sea is different from the standard oceanic mantle structure. Kanamori and Abe have shown that the ARC-1 model represents the upper mantle structure beneath the Philippine Sea (Kanamori and Abe, 1968) and the Japan Sea (Abe and Kanamori, 1970). The ARC-1 model differs from the standard 8099 model in the point that the S-wave velocity is reduced by 0.3 to 0.4 km/sec over a depth range from 30 to 80 km as shown in Fig. 19. It has been suggested that partial melting is a likely cause of the S-wave velocity reduction. The electrical conductivity is expected to become high when partial melting occurs, according to the experiment by Presnall et al. (1972). Therefore, a highly conducting layer which is likely to lie at a depth range 30–80 km beneath the Philippine Sea and the Japan Sea seems to be interpreted in terms of partial melting. This interpretation is in good harmony with the results based on the surface wave data.

According to studies by Utsu (1967) and Utsu and Okada (1968), the P-wave velocity and Q in the mantle on the continental side of the deep seismic zone are lower than those in the mantle on the ocean side as shown in Fig. 20. As the conductivity seems to amount to $10^{-18}$ emu or thereabout in the mantle on the continental side and $10^{-14}$ emu or thereabout in the mantle on the Pacific Ocean side, the overall electrical conductivity structure beneath the Japan arc seems to be in good harmony with the results from the P-wave velocity and attenuation.

Intensive observations of heat flow have been carried out in Japan. According to the heat flow distribution in Japan (Watanabe, 1972; Uyeda, 1972), which is shown in Fig. 21, heat flow is much higher on the side of the Japan Sea than on the side of the Pacific Ocean, in the northeastern part of Japan. Heat flow in the northern-most part of the Philippine Sea is also very high, while it is not so high in the central part of Japan. The electrical conductivity
structure beneath the Japan arc seems to be in good harmony with the heat flow distribution.

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