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Effect of coast on magnetotelluric measurements in India

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Abstract
Magnetotelluric soundings were carried out at 45 stations along a north-south profile near western coast of India. The magnetotelluric results in the *E*- and *H*-polarizations showed a significant difference in behaviour. Detailed two-dimensional modelling was carried out to study the effect of the western and eastern coasts of India on magnetotelluric measurements. The effect of the coast on magnetotelluric measurements was seen near the coast in both the polarizations. This effect was maximum in the vicinity of the coast in broad frequency range. It is suggested that magnetotelluric measurements in the coastal region of India should be carried out in the *E*-polarization for a reliable vertical resistivity profile.

Key words *magnetotelluric method – resistivity structure – modelling – India*

1. Introduction

Magnetotelluric soundings at 45 stations were carried out along the profile Navsari-Dhanera near the western coast in the area covered by Deccan trap (fig. 1). Some of the recording stations were very close to the coast, at a distance of about 20 km. While the role of the coast on magnetotelluric fields has been known for a long time, the coast effect on magnetotelluric measurements in India has not been studied. The anomalous behaviour in the vertical component of the geomagnetic field along the Pacific coast of Japan was observed by Rikitake (1959) due to the origin of vertical force to currents flowing within the mantle. Similar anomalies have been observed at many geomagnetic stations located near the ocean coast (Parkinson, 1962). The coast effect has been understood as an anomalous geomagnetic field variation due to the concentration of currents induced in the ocean where conductive material is present at shallower depths. These effects are sometime significant depending upon the subsurface geology and contrast between the sea-water and subsurface layers. The coastal effects on geomagnetic fields have been widely studied (Ashour, 1973, Bailey, 1977, Fischer *et al.*, 1978, 1980; Fischer and Weaver, 1986; McKirdy and Weaver, 1984; McKirdy *et al.*, 1985).

In the present paper, we investigated the effect of the coast on magnetotelluric measurements along the west coast of India. The results show a significant effect of the coast on magnetotelluric measurements in *H*-polarization.

2. Description of two-dimensional model

We considered a 100 km stretch of ocean adjacent to both sides of the southern part of the Indian land region which is represented by a five layered resistive model (fig. 2). These layered models are based on the one-dimensional inversion result of magnetotelluric data recorded along a north-south profile (fig. 1) in

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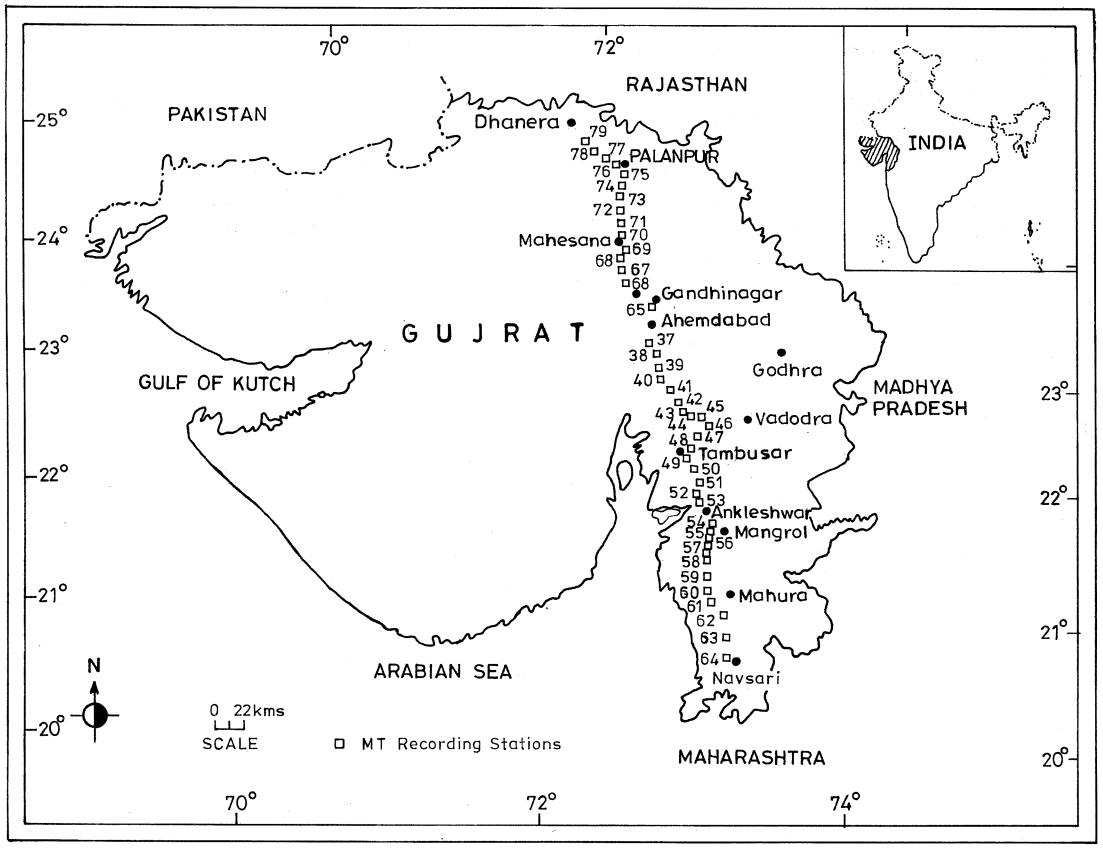

Fig. 1. Map showing magnetotelluric profile in the western coast of India.

the western coast of India. The model is restricted up to the continental slope, an extension of land under the ocean. Only in model 2, ocean depth was taken as 1.0 km, whereas in all other models ocean depth was taken to be 0.5 km forming angles with the continental shelf of 0.57° and 0.28° respectively. The five layered resistive structure was considered to be extended beneath the thin ocean layer. We took other models as shown in fig. 2 by changing the ocean depth and layered parameters (thickness and resistivity) of the model as found from the inversion of magnetotelluric data. The conductivity of thin ocean layer was taken as 4.0 S/m. The magnetotelluric responses (apparent resistivity and phase) were computed for all the models using Brewitt-Taylor and Weaver's (1976) finite difference algorithm for the period range 1.0-10000 s for *E*- and *H*-polarizations.

3. Results and discussion

Our detailed two-dimensional modelling results for all the models shown in fig. 2 show the effect of the coast on magnetotelluric measurements in *H*- polarization, in general. Here, we show the results for model 1 which is representative of the magnetotelluric sites where the recording station is about 20 km from the coast. We have illustrated the coast effect

through polar diagrams and pseudo-resistivity and pseudo-phase plots. In fig. 3, we have plotted the rotated impedance elements for different periods and for different distances from the coast. The rotated impedance elements Z_{xy} appear as two lobed and Z_{xx} appear as four lobed figures near the coast showing two- and three-dimensional effects. As the distance from the coast increases, two-lobed Z_{xy} and four lobed Z_{xx} figures change into one lobe as a perfect circle at period 100 s showing no effect of the coast away from the coast. For longer periods, the figures of rotated impedance elements Z_{xy} and Z_{xx} remain the same up to 125 km away from the coast showing a significant effect of the coast on the longer periods.

In fig. 4, we have shown the pseudo-sections for resistivity and phase for both *E*- and *H*-polarizations. In *E*-polarization, the resistivity contours are almost linear in pseudo-resistivity plots. For *E*-polarization, the middle portion of the resistivity section on *x*-axis shows a land region over which contours are almost linear. Near the coast point, the con-

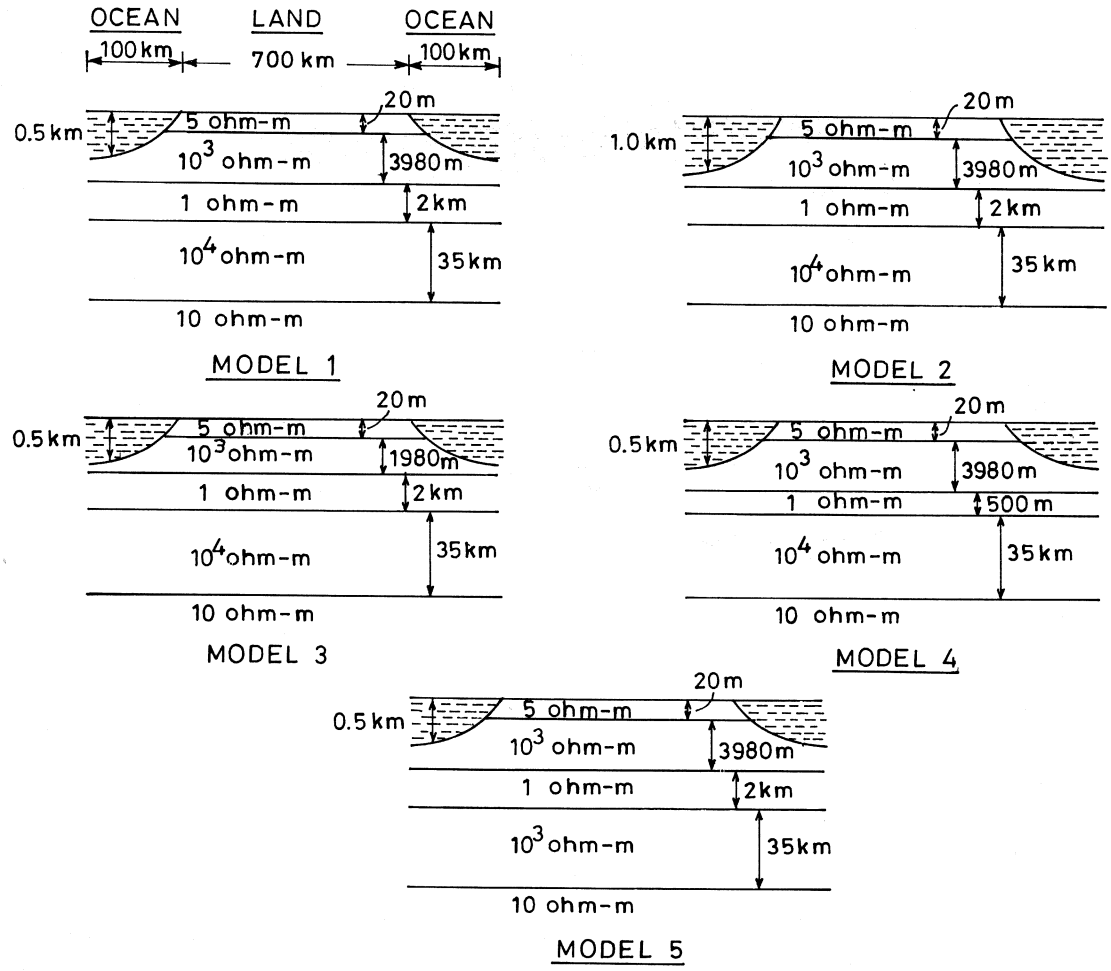

Fig. 2. Two-dimensional coastal models (scale shown in figures are not to scale).

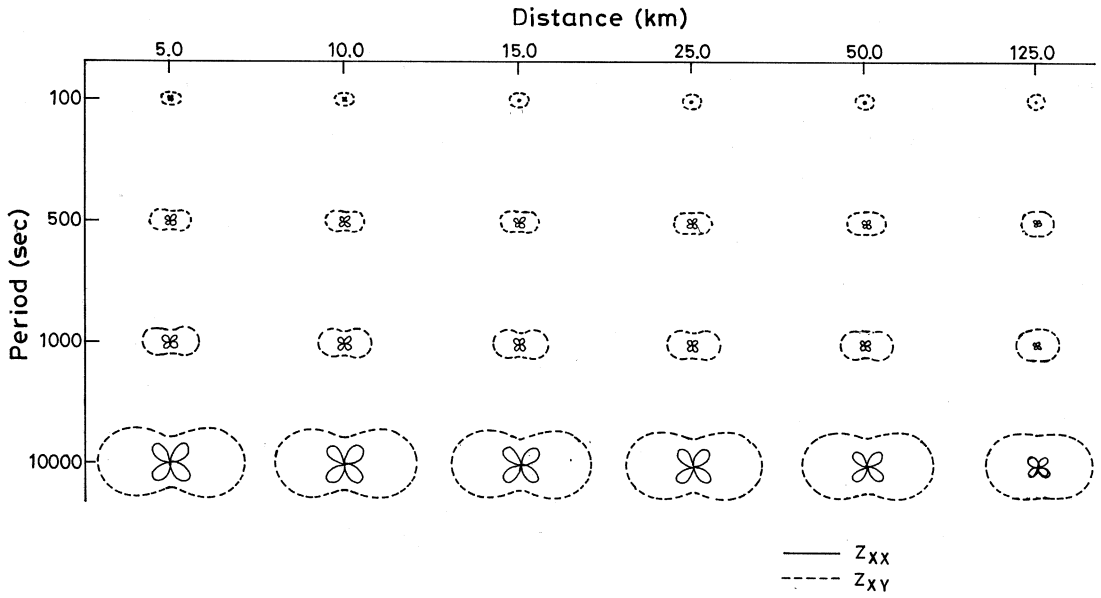

Fig. 3. Polar diagrams at different distances from the coast point.

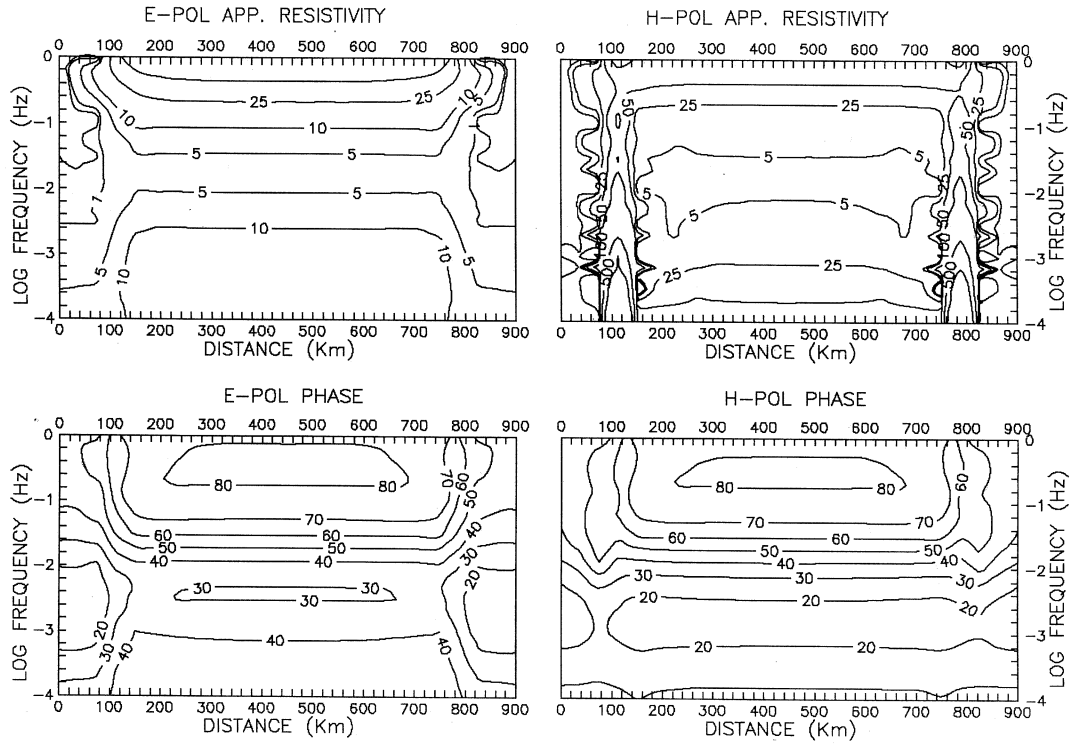

Fig. 4. Pseudo-resistivity and phase sections for coastal model.

tours are distorted, showing a significant coast effect on all five models shown in fig. 2. For phase contours, behaviour is similar to resistivity contours, but the distortion in contours is more pronounced for phase. The phase value decreases over the land region because it is less conductive than the ocean.

In the case of *H*-polarization, the pseudo-resistivity plots clearly show the coast effect. At shorter periods, the contours are almost linear over the land region but with the increase in period the resistivity behaviour changes. This shows that at longer periods, the effect of ocean is clearly seen. The sudden increase in resistivity at the ocean-land boundary is clearly seen in fig. 4. From the pseudo-resistivity plots, it is very clear that the coast effect is more pronounced in the resistivity section for *H*-polarization than those of *E*-polarization. The reason is that in *H*-polarization the electric field accumulates at the coast and results in a strong increase of the same on land near the coast. The streaming of currents along the poorly conductive continents and concentration of currents in the ocean is indicated in phase contours. This concentration of currents is because of the conductivity contrast between land and ocean. We further carried out detailed modelling to see the effect on much longer periods. Our results show that the response is greatly influenced by the coasts at longer periods even when the measurements are carried out far away from the coast. From the detailed modeling results over five types of models, we found that the ocean effect on magnetotelluric measurements is almost identical irrespective of the ocean depth in both the polarizations.

4. Conclusions

The present results show a significant effect of coast on magnetotelluric measurements in the southern part of India in the *H*-polarization. It was found that about 100 km away from the coast, the coast effect diminishes. It is suggested that for a reliable and better interpretation of magnetotelluric data from the coastal parts of India, the *E*-polarization magnetotelluric data should be considered.

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