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# Two-Dimensional Forward Modeling of the NACP Anomaly (COPROD2R Data)

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A two-dimensional resistivity model was obtained for the COPROD2R data set by trial-and-error forward model fitting of the apparent resistivities and phases. Two major conductivity zones were found to explain the data in the zone where the NACP anomaly is located. The first one coincides with previous interpretations of the NACP anomaly, which results in four separate conductive bodies. The second is another deeper conductor, whose top is located at 26 km depth with its base deeper than 40 km. A test removing this deeper conductor was made in order to ensure its detectability.

## 1. Introduction

The COPROD2 data set has been exhaustively worked, being the main subject in the First Magnetotelluric Data Interpretation Workshop (MT-DIW1) in 1992. It was also treated during the second MT-DIW2 held in Cambridge in 1994.

The data consist of observations at thirty-five sites in southern Saskatchewan and Manitoba (Canada) aligned along an E-W 400 km profile crossing the Williston basin. Apparent resistivities corrected for static shift, phases, and geomagnetic transfer functions were provided in a period range from 0.0026 s to 1820 s. The electrical structure was predominantly two-dimensional (Jones, 1993), the measurement axes being NS and EW, so that the $E$-polarization direction is the northward-directed electric field. A major conductive anomaly, the North American Central Plains (NACP) conductivity anomaly (Jones and Savage, 1986), was detected within the basement, and another one on the eastern part of the profile called the TOBE conductive anomaly. A subset of these data, the COPROD2R dataset consisting of 20 MT sites located in the western and central parts of the profile, was studied with the aim of focusing on the NACP conductive anomaly. Previous interpretations of these data concur on the presence of an anomalous region of high conductivity within the mid-crust. In this paper we present the results of a two-dimensional forward modeling exercise for this subset, which is summarized in a model containing, additionally, another deeper conductor in order to explain the long period behaviour. Among the previous models also derived by forward two-dimensional model fitting there are those of Jones and Craven (1990), Takasugi *et al.* (1993) and Zhao *et al.* (1993).

## 2. Two-Dimensional Modeling

Once it was known that the electrical structure was two-dimensional and distortions due to static shift had been corrected, the two-dimensional forward modeling started with an inspection of the apparent resistivities and phases in order to determine features in the shape of the data curves. At periods lower than 10 s, the data show a reasonably one-dimensional resistivity structure. The major two-dimensional effect on the apparent resistivities and phases appears in the central part of the profile over the NACP conductivity anomaly. The separation between the responses in both polarizations occurs for periods beyond 20 s where the $E$-polarization apparent resistivities are lower than the $B$-polarization ones, with the opposite holding true for the phases.

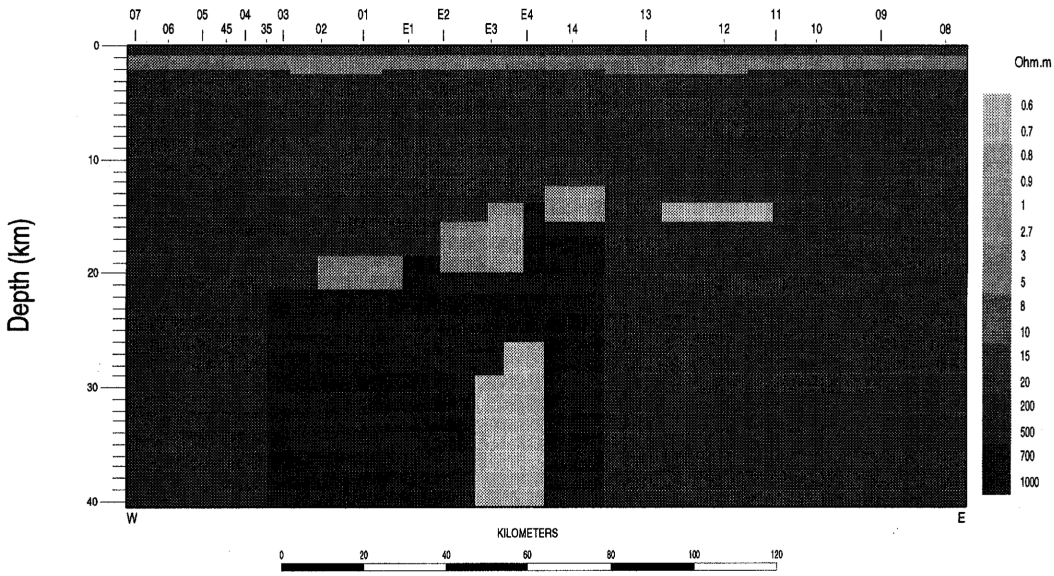


Fig. 1. Two-dimensional electrical resistivity model.

This behaviour indicates the presence of anomalous high conductive zones at depth. This effect is most marked mainly between sites PCS002 and PC5013, decreasing progressively with the distance from this area. Additionally, the horizontal location of some of these conductors has been constrained by using induction arrows (Schmucker, 1970).

Our two-dimensional model was obtained by forward trial-and-error model fitting of the apparent resistivities and phases using the finite element algorithm of Wannamaker *et al.* (1987). As two-dimensional lateral conductors mainly affect the $E$-polarization responses, we employed a one-dimensional inversion of the $B$-polarization data using Fischer and Le Quang's (1981) code to obtain a start model. The two-dimensional structure was built after successive attempts, taking into account the aforementioned two-dimensional effects on the data. Figure 1 shows the final two-dimensional model, with 450 nodes horizontally and 100 nodes vertically in the finite-element mesh. Figure 2 shows the data and model responses (solid lines) for 8 representative sites in the NACP zone. The RMS misfit, including all sites, all periods, and both polarizations, is 0.061 for apparent resistivity, and 3.8° for phase.

The surficial structures correspond to sediments of the Williston Basin. The thickness and resistivity of these uppermost electrical units were fixed, in accordance with the static shift correction (Jones, 1988). Deeper down, the model shows a uniform resistivity structure of more than 200 Ω·m, in which the anomalous conductive bodies are located.

At about 15 km depth, there are four bodies of around 1 Ω·m. These constitute a structure which is similar to the "multi body" (*JONES 2*) model of the NACP anomaly (Jones, 1993). Although these conductors explain the divergence between both polarizations around 20 s, they are not the only two-dimensional structures, since the divergence remains at longer periods. Accordingly, deeper conductors need to be taken into account to explain the data fully. The model we have obtained contains another deeper conductor, which leads to a better fitting of the data at longer periods. This conductor is located under sites PCSE03 and PCSE04, its top being at a depth of 26 km and its base at 60 km.

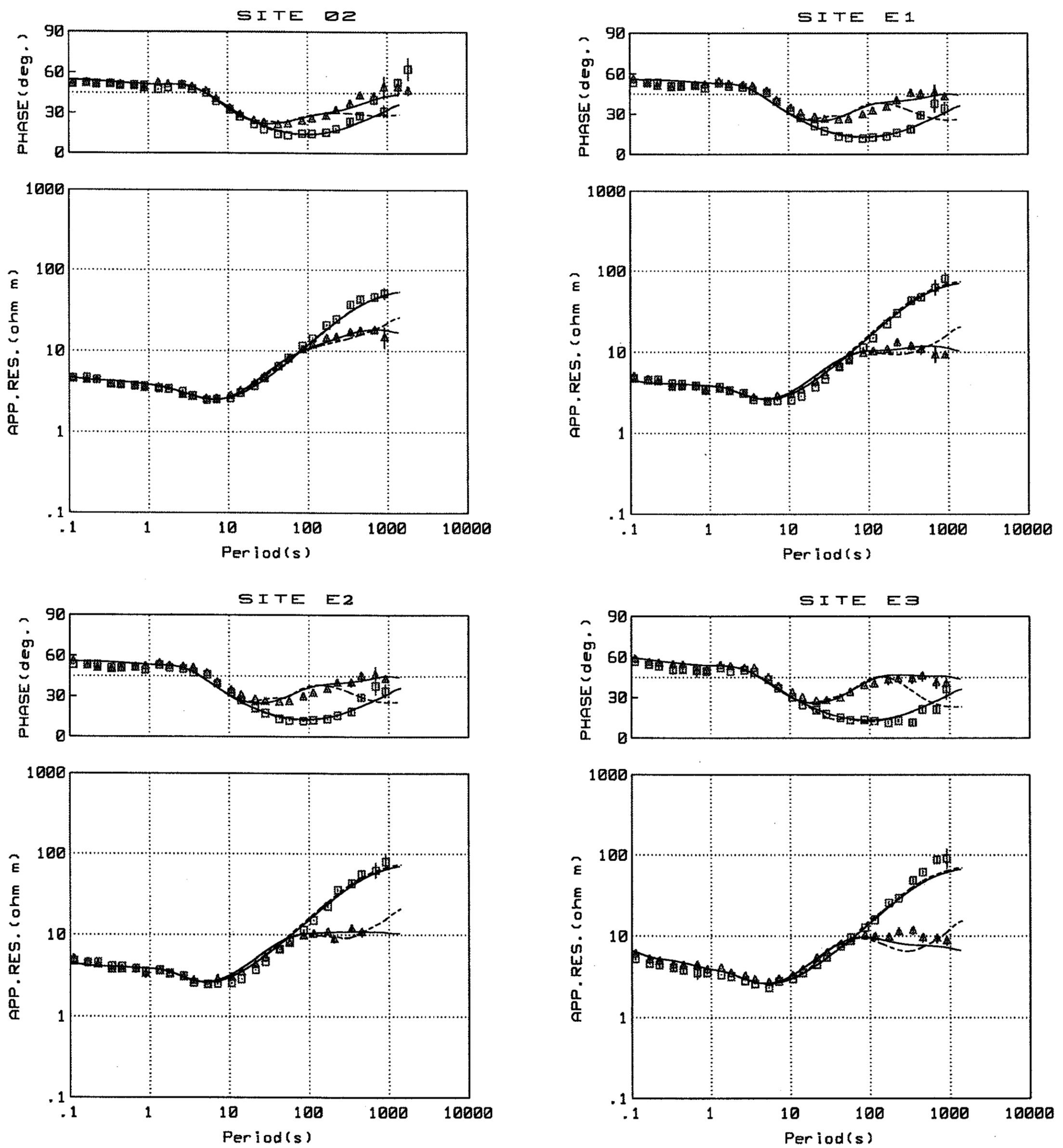


Fig. 2. Comparison between data and model responses. Triangles: $E$-polarization, squares: $B$-polarization. Solid lines: responses of model of Fig. 1. Dashed lines: responses for the alternative model without the deepest conductor (see text for explanations).

## 3. On the Resolution of the Deeper Conductor

The main difference with respect to previous models of the COPROD2 data set (see Jones, 1993) is the presence of the deepest conductor. To ensure that it is detected by the MT data, a test of sensitivity to its removal from the model was performed. Figure 2 shows the responses of the model without the deeper conductor (dashed lines). As can be seen, without this conductor

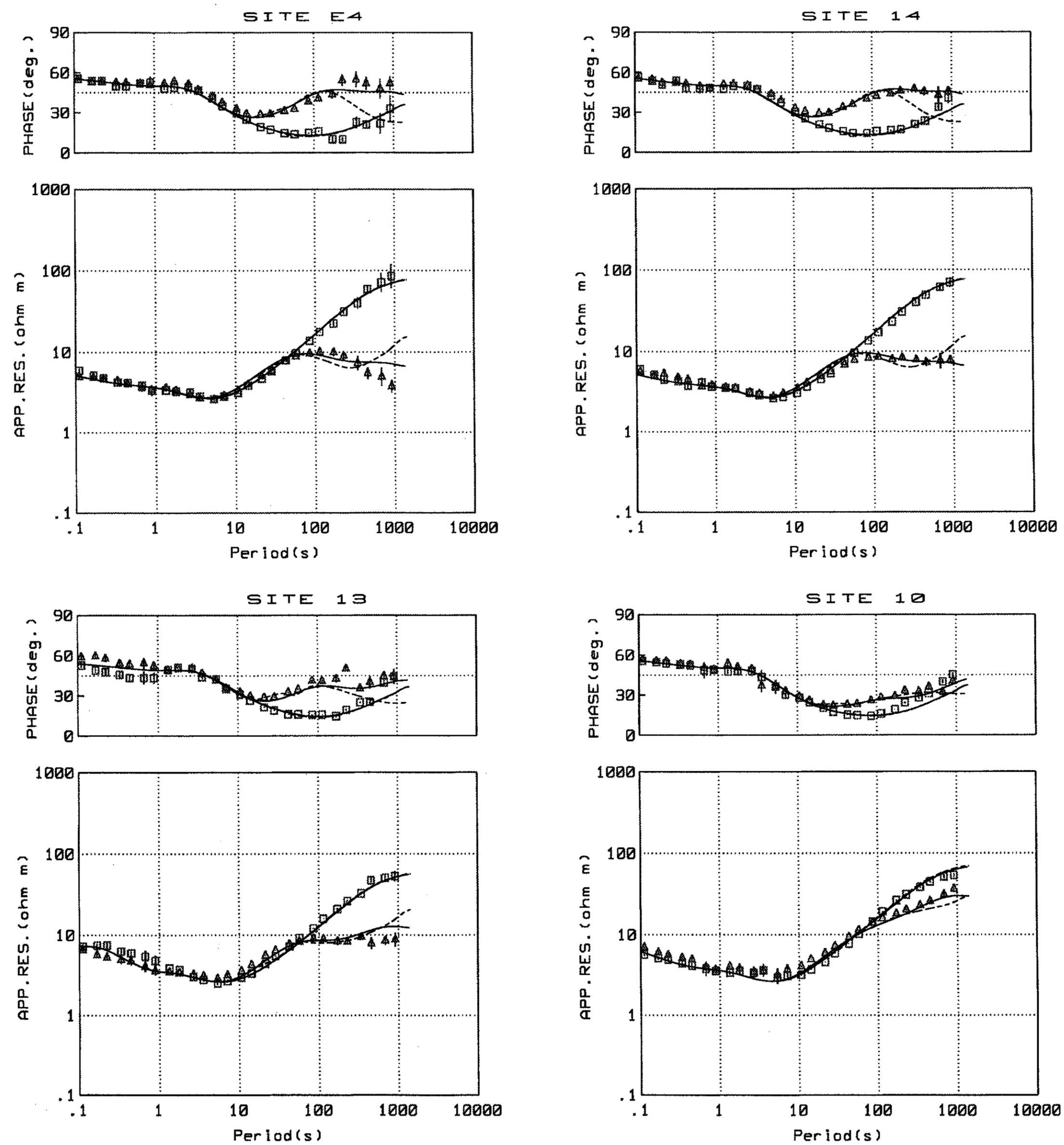


Fig. 2. (continued).

it is not possible to adjust the $E$-polarization for periods exceeding 100 s at sites located in the NACP zone. The divergence appearing beyond 20 s is caused by the NACP anomaly zone, but beyond 200 s (approximately) the apparent resistivities tend to become parallel, and the phases coalesce, unless a second deeper conductor is included in the model. On the other hand, it should be pointed out that the $B$-polarization is scarcely sensitive to this two-dimensional effect.

In order to have a more objective comparison between the two models, the RMS misfit of each one has been calculated in the region where the responses show the main divergences, i.e., the $E$-polarization ten longest periods (between 100 s and 910 s). The RMS misfit of the

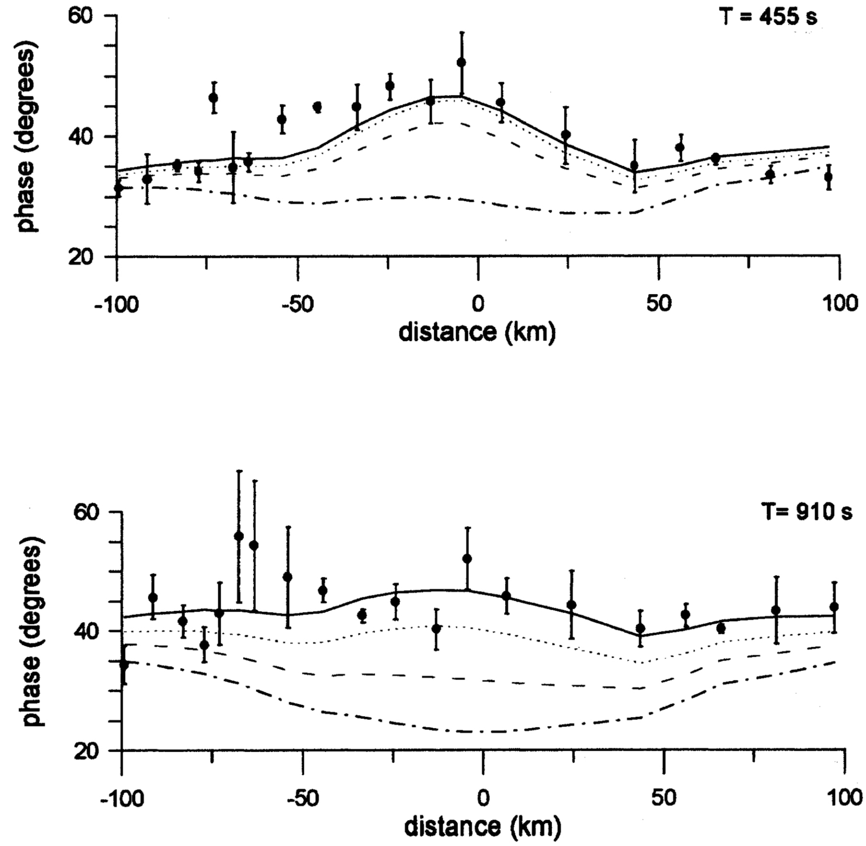


Fig. 3. $E$-polarization phases, and their errors, at periods of 455 s (upper graph) and 910 s (lower graph) and the model responses for different depths of the base of the deeper conductor: solid line, 60 km; dotted line, 40 km; dashed line, 33 km; dashed dotted line, without deeper conductor.

current model (Fig. 1) is 0.062 for apparent resistivity and 3.39° for phase. The RMS misfit of the alternative model without the deeper conductor is 0.083 for apparent resistivity and 8.4° for phase. Although the alternative model has the highest RMS, it is attenuated by the well fitted sites located far away from the anomalous conductors. This is seen in Fig. 3 which displays the different misfit of each model at two periods (455 s and 910 s). The alternative model (dashed dotted line) gives errors higher than 30° in the region of the NACP anomaly.

Different tests were carried varying the depth of the top of this deeper conductor out in order to find bounds for this parameter (its base was fixed at 60 km). The conclusion was that there are no important changes in the responses (same RMS misfit) when the top is located between 20 km and 30 km. Consequently, there is no resolution to separate both conductive zones (upper multibodies and deeper conductor). A test checking the resolution of the base of the deeper conductor was also performed. Figure 3 shows the responses for the bottom at 60 km (the current model, solid line), 40 km (dotted line) and 33 km (dashed line), the top being fixed at 26 km. At the period of 455 s, the depth must be higher than 33 km and at 910 s it must be at least at 40 km. Finally, the top of the deeper conductor was varied when the bottom was fixed at 40 km. In this case, the maximum depth of the top must be 26 km. Deeper depths resulted in significant errors (e.g., 30 km depth gives an error of 14° in $E$-polarization).

## 4. Conclusions

A two-dimensional model for the COPROD2R data set has been presented which shows two conductive zones. One of these is similar to earlier models which correspond to the NACP anomaly. The second conductive zone, whose detection is the subject of this paper, is located below the first anomaly. It is of great magnitude and located at a considerable depth since it is needed to fit the $E$-polarization data at periods exceeding 100 s. A test was performed to confirm the presence of this second conductor. The lower bounds (maximum depth of the top and minimum depth of the base) which fit the data are 26 km and 40 km respectively.

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