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Comment on: 'One-dimensional magnetotelluric inversion using an adaptation of Zohdy's resistivity method' by B.A. Hobbs and C.C. Dumitrescu[1]

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The principle of Zohdy's (1989) algorithm has been applied by Hobbs and Dumitrescu (1997) to magnetotelluric (MT) data, yielding a layered resistivity model with the number of layers corresponding to the number of discretely measured frequencies. A similar approach was used earlier by Xu and Liu (1995). Both Hobbs and Dumitrescu (1997) and Xu and Liu (1995) expand the concept of Zohdy's (1989) algorithm into the MT inverse problem, and use the same resistivity refinement formulae to adjust the model parameters, namely equation (23) of Hobbs and Dumitrescu (1997) and equation (8) of Xu and Liu (1995). The advantages of their procedures are obvious, as mentioned by Hobbs and Dumitrescu (1997), i.e. that no extraneous information has to be provided and that this scheme produces a gradation of resistivity with depth, differing from the smooth model of Occam's inversion (Constable, Parker and Constable 1987). When applying Zohdy's (1989) method to magnetotelluric data, a transformation from the conventional frequency scale to a length scale is a prerequisite. Hobbs and Dumitrescu (1997), as well as Xu and Liu (1995), suggested using the Bostick (1977) or the Schmucker (1970) transformations to construct suitable initial model depths and resistivities in their procedures. After constructing an initial model, the depth scale is first changed by a multiplicative factor, through minimization of the χ^2 misfit. However, we do not believe that it is always true that these transformations produce the appropriate depths of the model. We present an example where these transformations provide a misleading estimation of model depths, and where a model with an unsatisfactory fit is produced by these procedures. Hence this scheme does not provide a high enough confidence in the inverse model parameters.

The COPROD data (Fig. 1) from an MT site in Scotland obtained by Jones and Hutton (1979) were widely distributed for the purpose of comparing one-dimensional inversions (e.g. Constable, Parker and Constable 1987; Parker and Booker 1996; Zhang and Paulson 1997). A significant feature of the COPROD MT data is the upward bias from 45° in the phase at the five early periods. Although the large error bars in the phase show a great uncertainty at 28.5 and 38.5 s, the extrapolated phase values of these two periods from the three later phase data, i.e. at the periods of 52.1,

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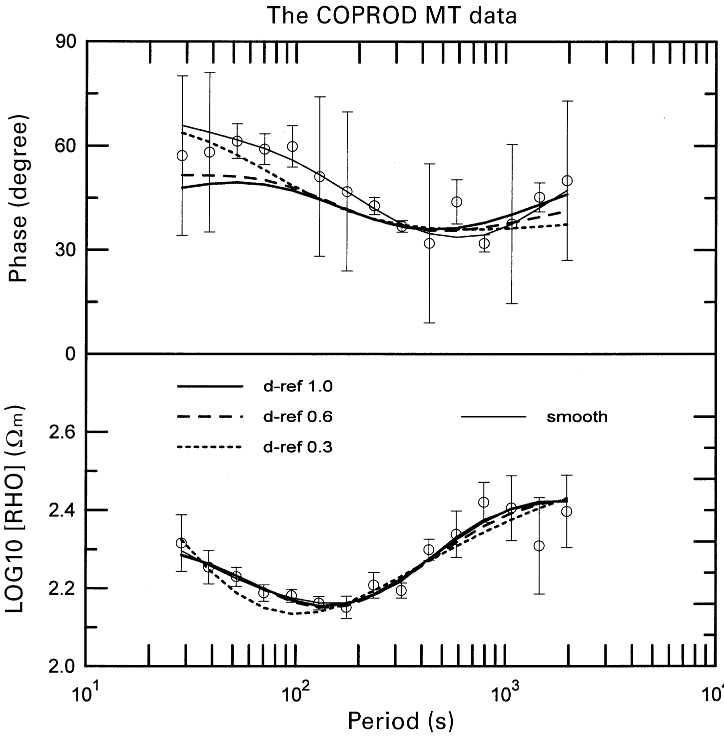

Figure 1. The COPROD MT data (open circles with error bars) together with three MT responses of the iterative results inverted by Xu and Liu's (1995) program. The thick solid, dashed and dotted lines represent the depth-refinement factors of 1.0, 0.6 and 0.3, respectively. Also shown is the smooth version of the real field data (thin solid lines). A detailed explanation can be found in the text.

70.5 and 95.5 s, remain above 45°. Thus, this feature indicates that a resistive thin layer, associated with the shortest measured period of 28.5 s, exists in the near-surface. Using several examples, Hobbs and Dumitrescu (1997) demonstrated that their proposed algorithm is quite capable of properly inverting the subsurface structure, starting from the 'complete' data. Here the so-called 'complete' data usually have a phase value of 45° at the shortest measured period. It is well known that the phase at the shortest measured period is 45° and the apparent resistivity is equal to the resistivity of the shallowest layer if the exploration depth for the first period is less than the thickness of the shallowest layer. On the other hand, a deviation from 45° at the first period indicates that the measured period is so long that the apparent resistivity is a combination of the apparent resistivities of the first layer and deeper layers. Thus the discretely measured data are 'incomplete' and observations in that period do not give the resistivity of the shallowest layer. Then, with 'incomplete' data such as the COPROD MT data, could Hobbs and Dumitrescu's (1997) or Xu and Liu's (1995) procedures provide a stable iterative process and a geologically plausible model?

To evaluate the ability of their procedures to process the 'incomplete' MT data, we have inverted the COPROD data using Xu and Liu's (1995) program. Figure 1 shows the MT responses, with the thick solid, dashed and dotted lines indicating three inverted models with different depth-refinement factors correcting the Bostick (1977) transformation. While the depth-refining multiplicative factor of 1.0 represents no corrections to the model depths of Bostick's (1977) transformation, a factor of 0.3 represents a large amount of depth refinement which reduces each layer thickness by 70% of the initial thickness given by the Bostick (1977) transformation. Figure 1 also shows the smooth version of the field data (the thin solid lines), which was used to construct a starting model. It can be seen that the high phase values at early periods were not usually fitted when a small amount of depth refinement, such as that obtained with the factors 0.6 or 1.0, was applied. As described above, it is easy to understand that a surficial resistive thin layer is required for fitting the early high phase data. However, the calculated thickness, obtained using the Bostick (1977) transformation which relies solely on the resistivity data, of the first layer would be too thick for this surficial 'thin' one. Could we fit the COPROD data by applying a small multiplicative factor for depth refinement? A factor of 0.3, corresponding to 11 scale changes in the depth-refining stage of Hobbs and Dumitrescu's (1997) procedure, might be appropriate for fitting the early high phase data. Unfortunately, owing to the reduction of the overall inverse depth, a misfit will affect the phase and resistivity data at the longer periods. Then, is it possible to improve the iterative results? It might be possible to achieve this by different transformations of apparent resistivity accompanied with phase data to depth, such as Schmucker's (1970) transformation or the recently frequency-normalized impedance function proposed by Basokur, Kaya and Ulugergerli (1997).

We conclude that, when applying Zohdy's (1989) method to MT data, the appropriate transformation of frequency scale to depth scale is an important step. Optimizing it will reduce the calculation time and will improve the iterative result to provide a more reliable model. In particular, the Bostick (1977) transformation might need to be replaced by other transformations in order to evaluate the model depths.

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