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INTERPRETATION OF HEAD-ON RESISTIVITY DATA FROM OLKARIA, KENYA

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Abstract

Head-on (half-Schlumberger) resistivity measurements along ten profiles (Cheng, 1980), together with sixty-seven Schlumberger soundings, have been carried out at Olkaria in 1981 and 1982. Analysis of this data has been by two-dimensional modelling with initial models derived from one-dimensional interpretation of the soundings (Kenya Power Co. Ltd, 1984). It has been found that "cross-overs" in the head-on data, usually interpreted qualitatively as the location of fault zones, are better modelled by simple lateral resistivity changes in the, vicinity. Strong near-surface variations in resistivity, indicated by rapid fluctuations in the head-on data for small AB/2 (250m), means that the precise location and dip of conductive zones cannot be well-determined.

Introduction

Head-on resistivity measurements have been carried out on ten profiles in the Olkaria Geothermal Area to study fault zones which have been proposed as exploration drilling targets. The results of the modelling studies on four of these profiles (Figure 1) will be presented in this paper. Measurements were initially made for AB/2 of 250 and 500m, but, as near-surface resistivity variations were found to strongly influence the 250m data, the survey was completed using 500m and 800m arrays. The lengths of the profiles were generally between 1000m and 2000m, with measurements every 100m.

Schlumberger soundings were made at intervals of 200 to 300m along each profile, with maximum array sizes of AB/2 = 350m to 1000m. The larger soundings were generally made at the centres and towards each end of the profiles.

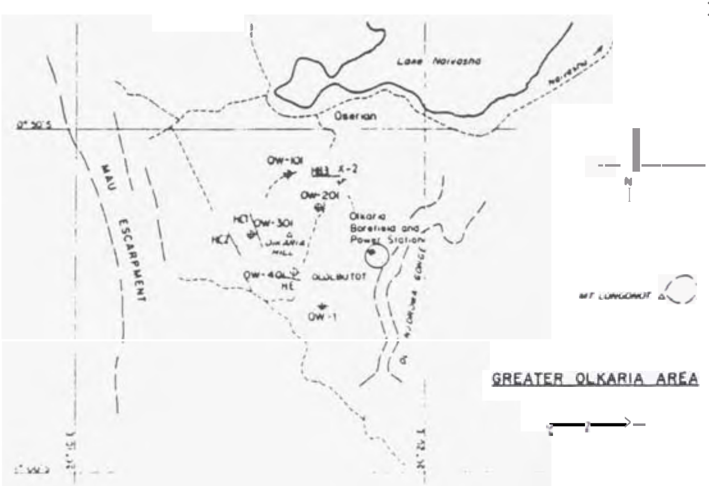


Figure 1. Location Map. Greater Olkaria Area.

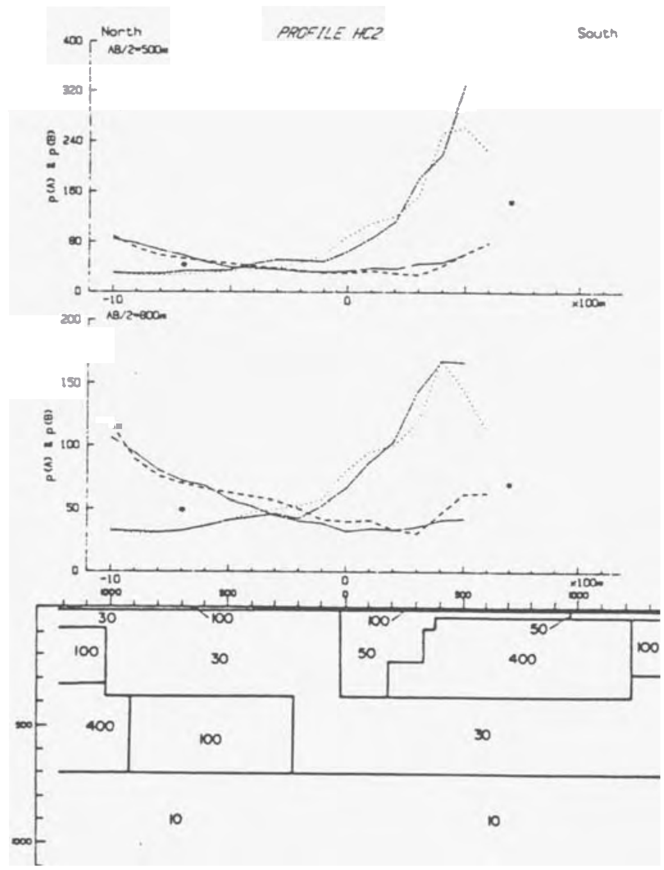


Figure 2. Find Model and Fit for Profile HC2.
Continuous line - ρ(A) measured
Broken line - ρ(B) measured
Dotted line - ρ(A) calculated
Dashed line - ρ(B) calculated
Asterisks - ρ(AB) from VES

Analysis

The Schlumberger soundings on each profile were interpreted in terms of one-dimensional models, which were then modified, if necessary, to provide consistency along the profiles, especially if the head-on data indicated layered conditions. Basement resistivities were from earlier large soundings in the vicinity of the profiles (Furgerson, 1972, Bhogal, 1980). The initial two-dimensional model was created using the VES interpretations, together with available structural and alteration information. Also, any indications of lateral resistivity boundaries in the Schlumberger soundings were used to locate these boundaries in the 2-D model. Wherever possible, the surface layer of the model has uniform resistivity to avoid erroneous results caused by potential electrodes straddling resistivity boundaries.

Following the calculation of predicted head-on and Schlumberger apparent resistivities, using a computer program developed by Dey and Morrison (1976), the models were adjusted to improve the €it to both the Schlumberger and the head-on data. Up to 30 model changes were required in some cases to obtain a satisfactory result.

Results

The head-on resistivity profiles range in complexity from those with smoothly-varying values and only one cross-over, to those with rapid resistivity fluctuations and up to three cross-overs. The goodness of fit of the latter profiles is generally poorer, even though the model chosen is usually more complex.

The results for profile HC2, to the west of Olkaria Hill, are shown in Figure 2. This simple cross-over is modelled by a broad zone of moderate resistivity, flanked by more resistive blocks. The northern block correlates with a regional feature indicated by recent deep soundings whereas the southern block is an expression of the hill in this area. The central low resistivities are probably pyroclastic sediments, but may be a weak expression of the Olkaria Fault. The precise depth or resistivity of the basement cannot be well-defined from the head-on data.

Figure 3 gives examples of the fit between the VES on the profile and the Schlumberger apparent resistivities calculated from the model. The deeper soundings were invaluable for controlling the model but those to AB/2 = 350m, carried out to investigate surface resistivities, were of lesser use.

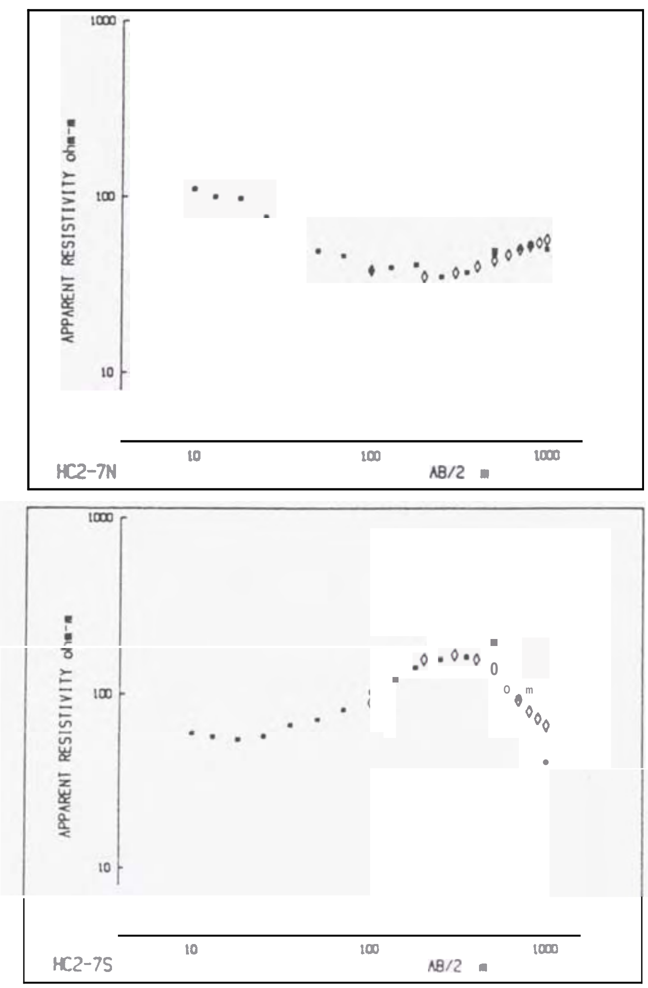


Figure 3. Fit to VES on Profile HC2.
Infilled squares - measured data
Diamonds - calculated points

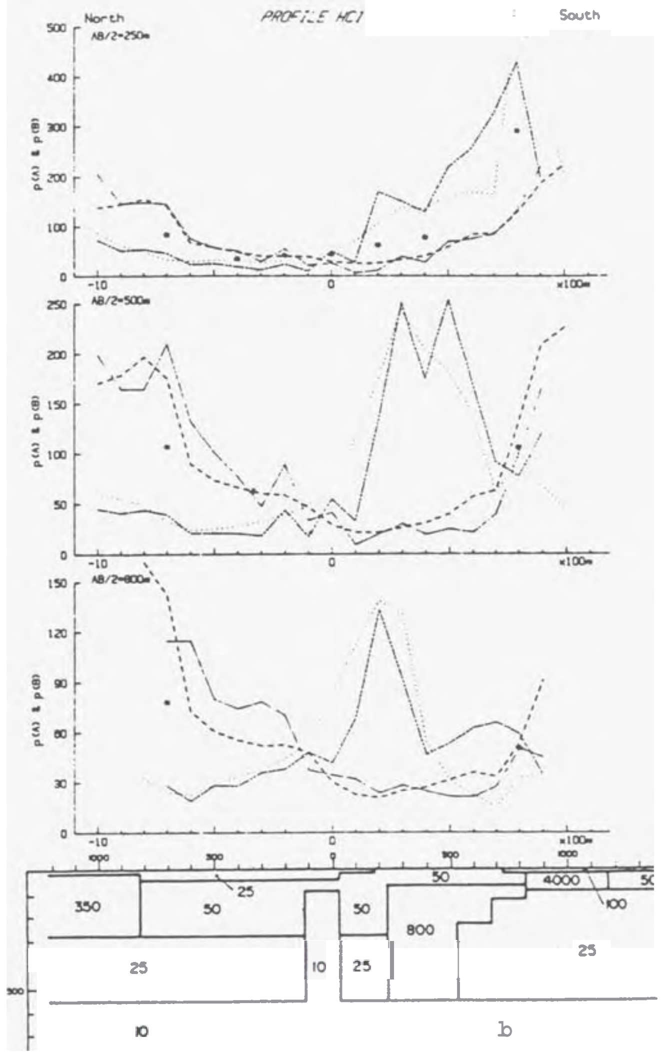
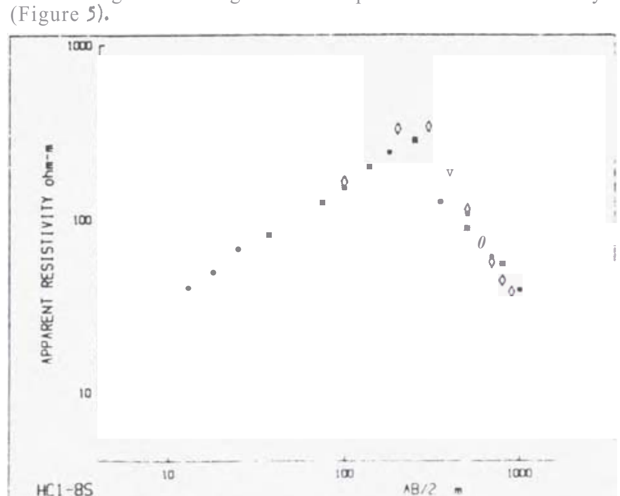


Figure 4. Final Model and Fit for Profile HCI.
Symbols as Figure 2.

Profile HC1 1200m east of HC2, was over rougher terrain, passing very near to explosion craters and areas of altered ground. Consequently, the head-on resistivities are much more variable although a broad pattern with two cross-overs is observed for all three AB/2 values (Figure 4). The final model contains a conductive dike corresponding to the inferred western extension of the Olkaria Fault, which produces an adequate fit to the first cross-over, but the second cross-over could not be well-modelled. Changes in surface resistivity were required on this profile to fit the sharp changes in head-on resistivity. The fit to Schlumberger soundings on this profile was satisfactory (Figure 5).



Profile HE, to the south of Olkaria Hill, shows a regular pattern for all AB/2 values, and is modelled very simply (Figure 6). The western block of high resistivity corresponds with elevated ground in this area. The low resistivity is interpreted as a sedimentary deposit of lacustrine or volcanic origin, with possible geothermal alteration of the upper 200m.

Profile HB3, NW of Olkaria Hill, has considerable similarities to HE, and it too is modelled with decreasing resistivities across the profile (Figure 7). In this case, however, the block of high resistivity has little correlation with any ground relief. Because the surface low resistivity to the east of this profile masks the influence of deeper layers, the basement resistivity and depth are poorly-defined in this region; even at moderate depths. For this reason, the elevated basement cannot be considered significant.

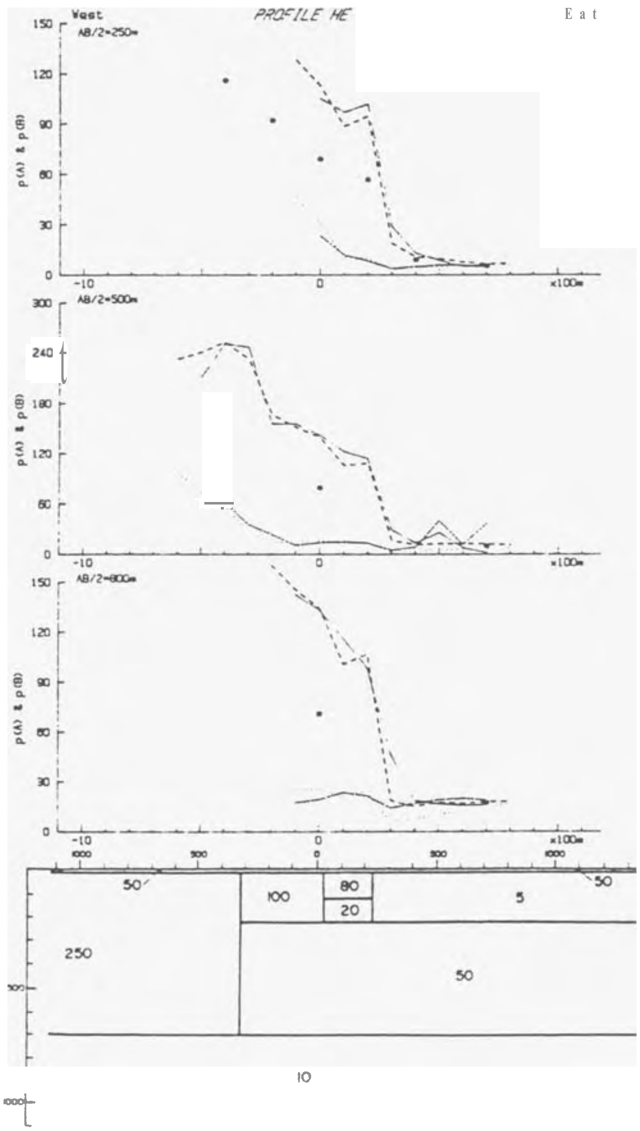


Figure 6. Final Model and Fit for Profile HE.
Symbols as Figure 2.

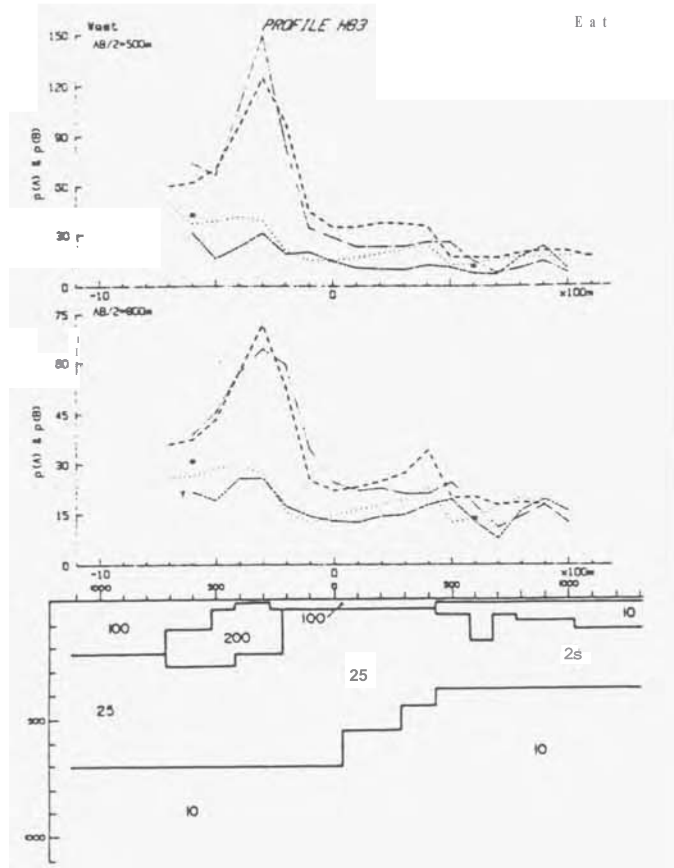


Figure 7. Final Model and Fit for Profile HB3.
Symbols as Figure 2.

Discussion and Conclusion

At Olkaria, the program of head-on resistivity measurements has not been successful in locating deep reaching conductive fracture zones which could provide exploration drilling targets. The failure of the method can be ascribed to a number of causes. Firstly, there is a basic ambiguity in the technique, with a number of differing models producing similar fits to the measured apparent resistivities. A degree of control is provided by the Schlumberger soundings, which must be considered an essential part of the method in a non-uniform volcanic environment such as Olkaria. The modelling difficulties are compounded by the sensitivity of the measured apparent resistivities to lateral near-surface variations in resistivity, which are often of a three-dimensional nature and cannot be satisfactorily modelled. Also, the dominance of the apparent resistivity fine structure by this near-surface "noise" obscures deeper effects.

The depth of penetration of the survey was somewhat limited, with calculated apparent resistivities insensitive to gross model changes below 600 to 700m in areas of high resistivity and considerably shallower where surface conductive layers exerted a masking influence. Suspected deep conductive zones were often situated beneath low-resistivity surface layers, resulting in very poor definition of their location and size. An indication of basement resistivities and depths was often afforded by the deeper Schlumberger soundings on the profile.

In general, the 2-D models have incorporated broad resistivity zones within 500m of the surface, to obtain a satisfactory fit to the data. Comparison of these models with those developed for interpretation of a dipole-dipole survey (Ross et al, 1979) shows a surprising degree of correlation over this depth range (Figure 8).

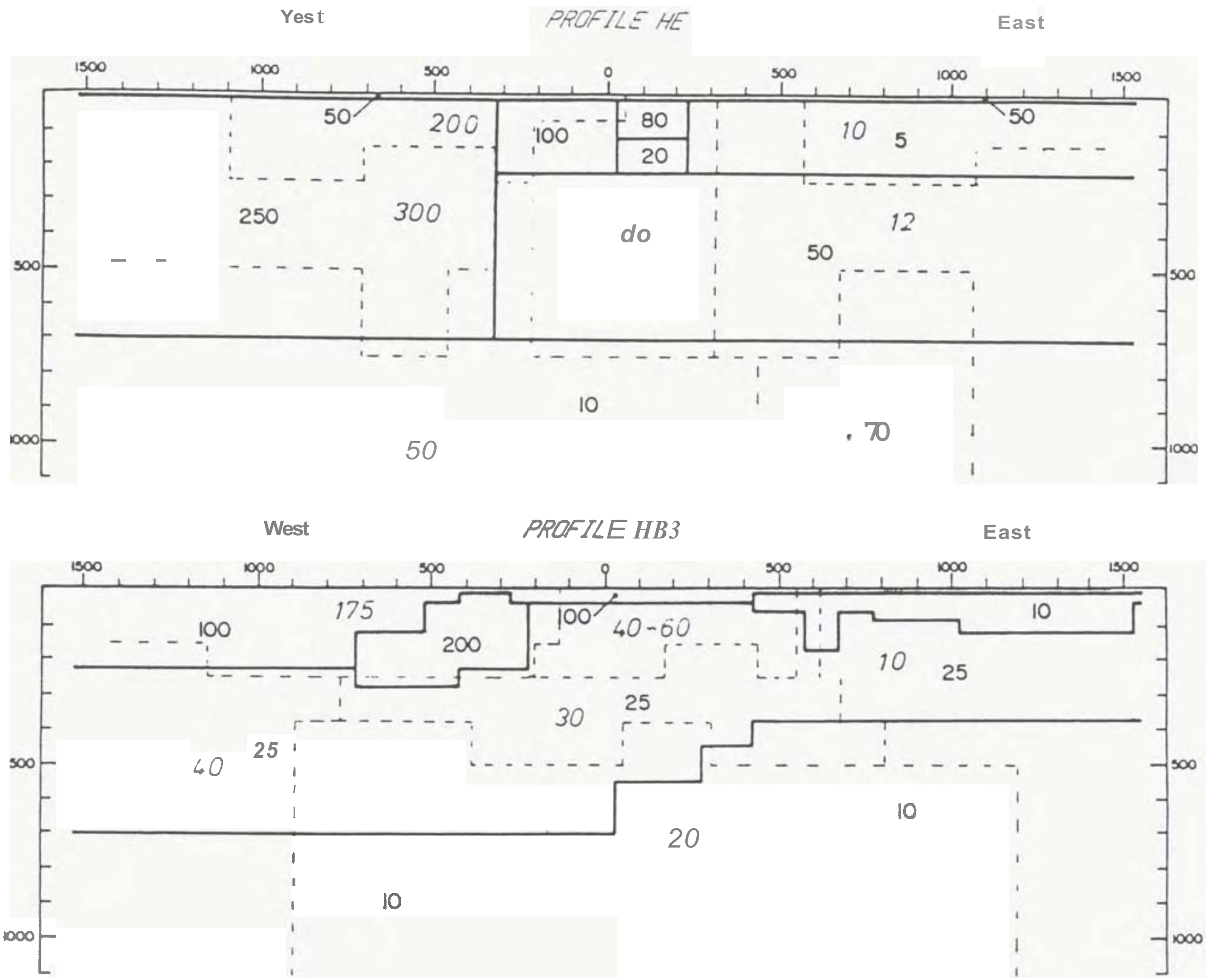


Figure 8. Comparison of models from head-on and dipole-dipole measurements.
Bold lines, values = head-on model
Dashed lines, italic values = dipole-dipole model.

The modelling studies presented here have shown that the method is very sensitive to lateral changes in resistivity to intermediate depths. In an area of complex near-surface resistivities, this makes any reliable identification of narrow conductive features almost impossible.

Acknowledgements

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