A DC RESISTIVITY SURVEY OF THE MIRANDA HOT SPRINGS AREA

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ABSTRACT

A small scale D.C. Resistivity survey of the Miranda Hot Springs area was conducted primarily to test the "Half Schlumberger method" of locating narrow feeder zones within geothermal fields.

The results of both standard Schlumberger and half Schlumberger techniques are given together with the results of 2D-resisvitity modelling.

No definite conclusions could be drawn about the geological structure of this area from the limited data measured during this survey.

INTRODUCTION

A small scale DC resistivity survey, designed primarily to test the "Half Schlumberger" or "combined head on profiling method" was conducted at the Miranda hot springs area.

This technique which has been described by Cheng (1980), has been shown to be able to detect the position and dip of conductive zones, i.e. fault zones acting as conduits for geothermal fluids, whereas the standard resistivity method using a colinear array does not readily detect such narrow feeder zones.

The hot springs occurring in the area are believed to be associated with the inferred Firth of Thames fault (Hochstein, 1978) which bounds the Western edge of the Hauraki Depression (Hochstein and Nixon, 1979), see Fig. 1.

Half Schlumberger measurements were made along four profiles oriented perpendicular to the inferred Firth of Thames fault. The half Schlumberger array is shown in Fig. 2.

Normal Schlumberger traversing measurements (AB/2 = 150 and 300 m) were made concurrently at twenty-three stations to localise the lateral extention of thermal waters. Also, five Schlumberger sounding of maximum AB/2 = 420 m were made to determine true resistivity and to find basement depths.

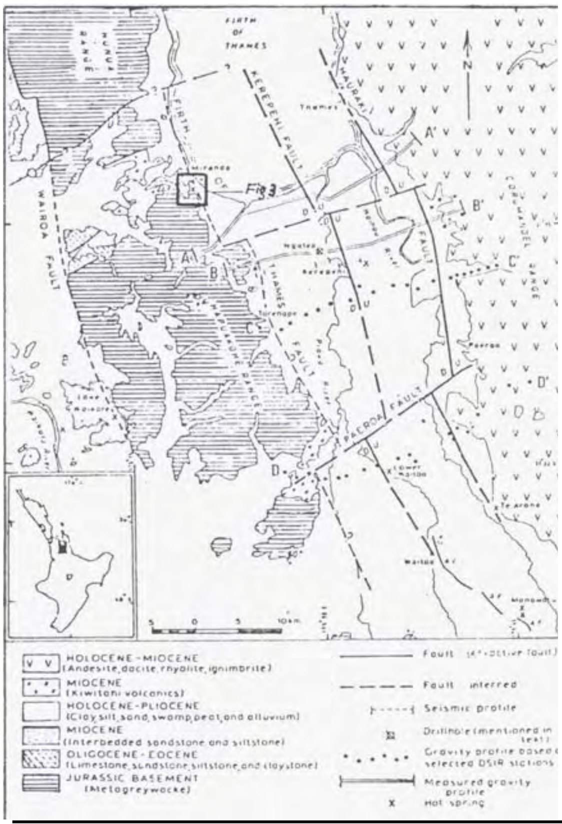


FIGURE 1: General oeology of the Hauraki Depression (after Healy et al 1964 and Schofield 1967) and the position of seismic and gravity profiles (from Hochstein and Nixon 1979).

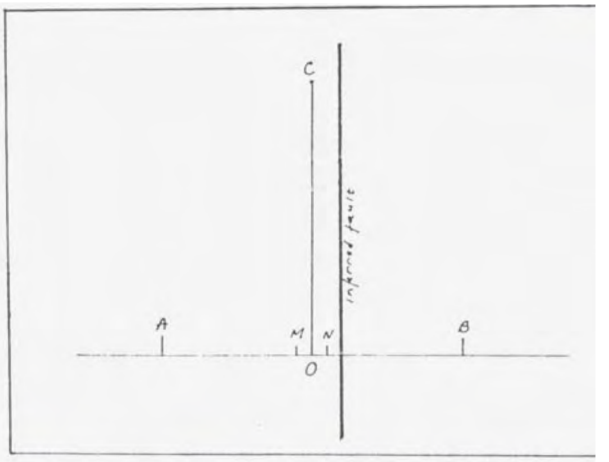


FIGURE 2: A schematic diagram of the half Schlumberger array: A, B and C are current electrodes, M and N are measured electrodes.

GEOLOGICAL SETTING

The Miranda thermal area lies at the Western edge of the Hauraki Depression on a flat area about one metre above sealevel and approximately 700m inland from the sea edge (Fig.3). The natural discharge features consist solely of a number of small warm and hot springs, localised in an area of 240m x 90m around the large swimming pool at Miranda. The temperature of the springs ranges from 33°C to 57°C (April 1981, air temperature 23°C).

No hydrothermally altered rocks have been found in the area, nor is there silica or sinter deposition.

The geology of the area consists of a basement of Mesozoic greywacke overlain by the impervious Waitemata Group of sedimentary rocks. Andesite volcanics, i.e. Kiwitahi volcanics, outcrop to the North and West of the area. A thick mass of pumice (or ignimbrite?) is exposed on low scarps (15-20m) about 150m West of the springs. (Fig.3).

Hochstein and Nixon (1979) concluded that the Hauraki Depression is an active rift feature giving rise to horst and graben structures controlled by three parallel major faults (Fig.1). These faults are believed to control the appearance of hot springs at the margins and centre of the depression.

RESULTS AND INTERPRETATIONS OF SCHLUMBERGER TRAVERSING AND SOUNDING

The apparent resistivity maps for the AB/2= 150m and 300m are shown in Figs.3 and 4, respectively, while the results and interpreted sounding curves are shown in Fig.5.

Interpretation of the VES curves was made by curve matching processes, automatic interpretation and trial and error calculation of theoretical sounding curves by Gosh's method all of which were used to reach a geologically and geo-electrically sensible result.

On the basis of the interpreted sections a map of true resistivity of the Waitemata Group sediments greywacke was made (Fig.6).

As can be seen in the apparent resistivity map for AB/2=300m, a small area of low resistivity (i.e. ≈ 0.3 km^2) to depths of about 85m (Figs.5 and 9) correlates with the occurrence of the hot springs. The low apparent resistivities present over the Eastern part of the area as can be seen in the AB/2=150m map, reflect the influence of both the thermal fluids and the seawater. The influence of the seawater is also visible in the true resistivity maps with both the resistivity of the greywacke and Waitemata Group decreasing gradually towards the sea.

The true resistivity of the greywacke may also show the influence of the thermal fluids by the lower resistivity lobe present in the region of the surface springs (Fig.6). This lobe is not present in the true resistivity map of the Waitemata Group and may reflect much greater permeability in the greywacke.

The relatively sharp transition in apparent resistivities (AB/2=300m, Fig.4) from approximately 40 Ohm-m to 30 Ohm-m seems to correspond to the lithological change from greywacke, which outcrops in the West, to the recent sedimentary rocks which cover most of the area.

TWO DIMENSIONAL MODELLING AND RESULTS OF HALF SCHLUMBERGER

Measurements from only two of the four profiles namely C and D, gave relatively undisturbed results. Probable current leakage and or the effect of electric fences disturbed the resistivities measured along profile A and B.

The resistivities from profiles C and D were modelled using the 2D finite element computer program of Dey and Morrison (1976). Twenty 2D models were constructed. The models were adjusted by trial and error in an attempt to fit both the half Schlumberger and traversing data to the theoretical values given by the models. Layer resistivities and thicknesses were taken from VES interpretations (Fig.5). A resistivity of 20-25 Ohm-m was taken as a representative value for the sedimentary cover, i.e. Waitemata Group; the resistivity of the 10m surface layer was taken as between 3 and 5 Ohm-m.

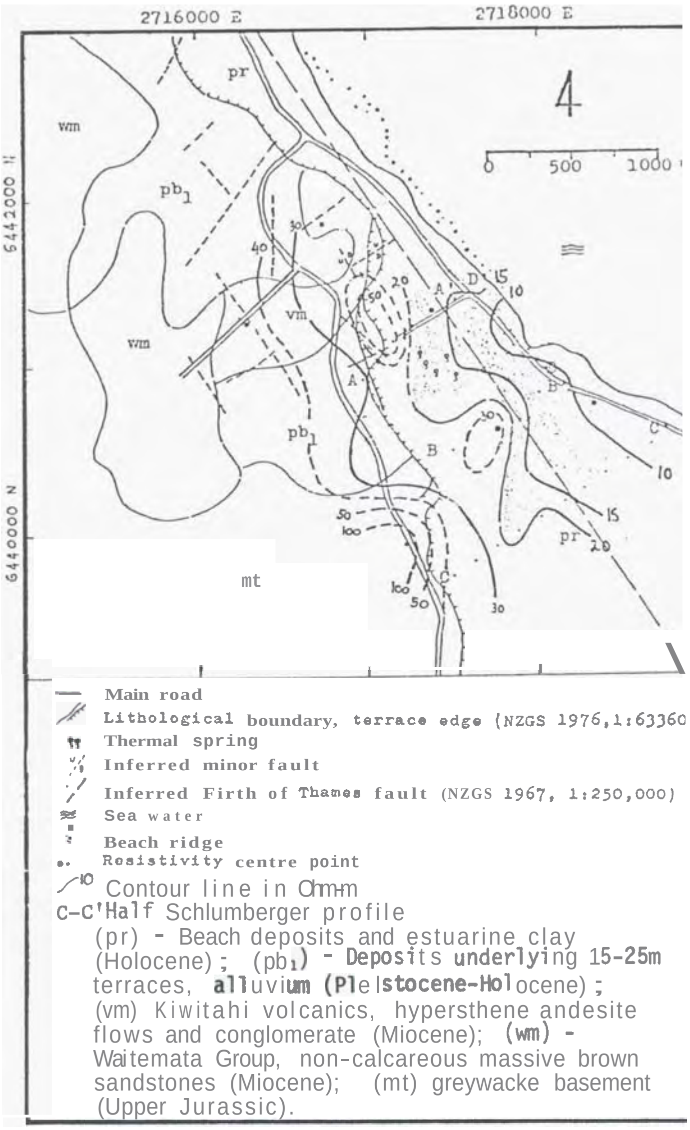


FIGURE 3: Geological sketch map of the Miranda thermal area after NZGS 1967, 1:63360 and map showing the lateral distribution of apparent resistivities of Schlumberger array for AB/2 = 150m.

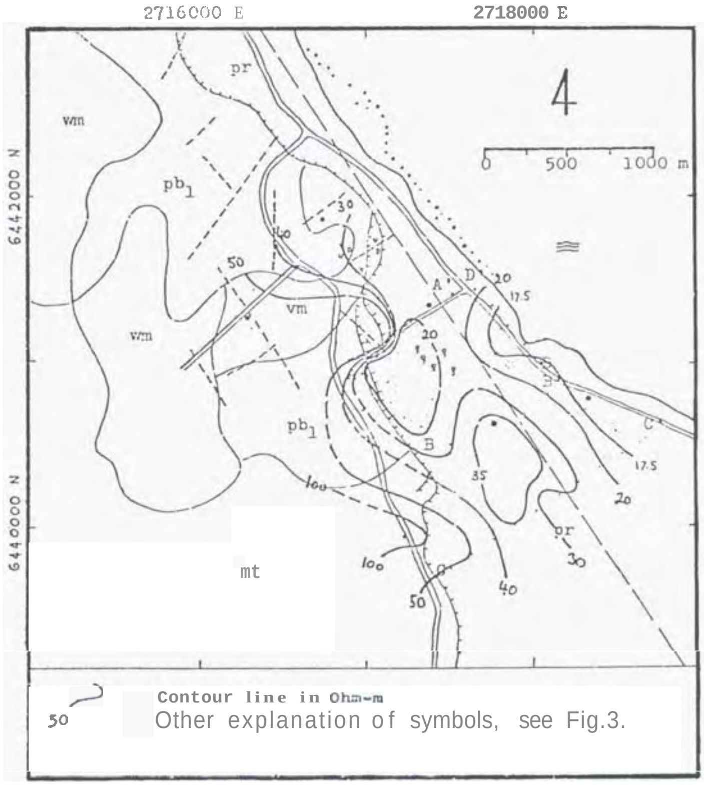


FIGURE 4: Map showing the lateral distribution of apparent resistivities from Schlumberger array (AB/2 = 300m) at the Miranda thermal area.

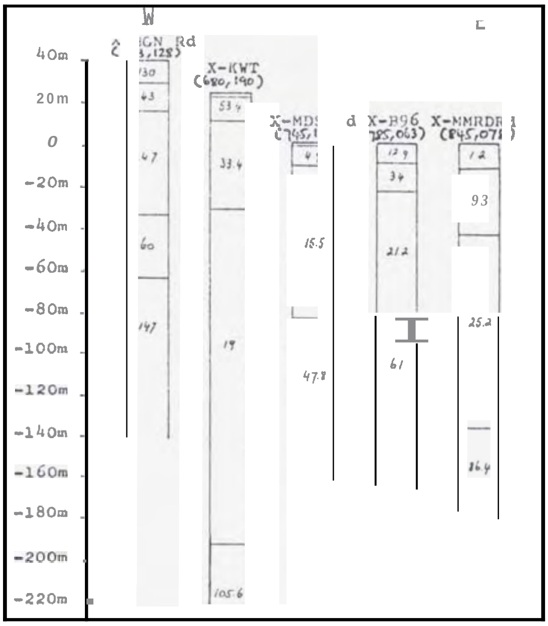
To simulate the changing true resistivity of greywacke basement, a resistivity of 75 Ohm-m was taken as representative of the seawater saturated greywacke, increasing to 125 Ohm-m to the West, reflecting the decreasing salinity (Fig.6).

Profile C

This profile shows high apparent resistivities in the West and low resistivity in the East and was the Southern most profile measured.

The resistivity and thickness of a small area of the conductive surface layer in the central of the profile was varied for different models between 2 to 3 Ohm-m resistivity and 30 to 10m thickness. Small changes of true resistivity and thickness of the surface layer produced large changes in calculated apparent resistivities. Changing the true resisvity and thickness of the Waitemata Group produced less change.

Varying the greywacke resistivity had negligible affect on calculated apparent resistivities. This reflects the sensitivity of the 2D-resistivity modelling technique to local near surface inhomogenities. This model gives a relatively good fit for this profile. Nevertheless, the resistivity of the basement in the West is probably higher than 125 Ohm-m, in order to produce the high apparent resistivity differences between the two halves of the Schlumberger array that occurs between stations C -100 and C -103.



Correlation between electro and lithologic units

Electro stratigraphic unit	Inferred lithologic unit
Upper resistive layer (43-130 Ω.m)	Kiwitahi volcanics and pyroclastic material
Conductive layer (1.2-12.9 Ω.m)	Waitemata Group, where the upper part is saturated with sea or/ and thermal water
Moderate resistive layer (15.5-33 Ω.m)	
Lower resistive substratum (50-150 Ω.m)	Greywacke

FIGURE 5: Electro stratigraphic units of the Miranda thermal area, from VES interpretations (model based on results of auxiliary curve matching and automatic interpretation then controlled by using Gosh's method).

Figure 7 shows the model and the calculated apparent resistivities for a basement of 125 Ohm-m.

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Profile D

This profile runs North to South, parallel to the uniform low apparent resistivities pattern (Figs. 3 and 8). A simple model of a uniform basement of resistivity 75 Ohm-m disected by a vertical narrow low resistivity zone was considered to model the profile. Variation in the depth of the vertical conductive zone had a small effect on the calculated apparent resistivity of the models.

It is interesting to note that the "cross over" intersection of calculated apparent resistivities shown in Fig.7 (which give a relatively good fit) occur not only at AB/2=150m but also at AB/2=300m whereas the observed apparent resistivities do not show any such cross over in the AB/2=300m result.

DISCUSSIONS AND CONCLUSIONS

A map showing the depth to the resistive substratum which is likely to correspond to the top of the greywacke, was contoured on the basis of the five VES interpretations and the nearby outcrop of greywacke in the area (Fig.9).

The depth to greywacke increases slowly from the South towards the region near the springs; the depth then increases rapidly to the North. The reasons for this rapid change in depth are not clear, since the depth in the northern part of the area is controlled by only one VES, X-KWT (680,190). This sharp change is interpreted as a probable concealed structural feature which could be a local normal fault; or the edge of a circular feature, i.e. an old depression. The interpretation of this feature as a fault scarp (?) is suggested by the inferred structural limitations seen in the air-photos, the E-W alignment of the main springs and also the cross-over in the half Schlumberger profile D (AB/2=150m). The model (Fig.8) which took account of this cross-over suggests the presence of a narrow conductive body striking approximately perpendicularly to the profile as does the small resistivity lobe present in true resistivity of the greywacke basement (Fig.6). This interpertation, however, must be regarded as tentative at best because of the lack of data in the Northern part of the area. Also the results of this survey do not allow any firm conclusions to be reached about the existence or otherwise, of the Firth of Thames fault.

A gravity survey, combined with further resistivity soundings would clarify the basement structure. For testing the half Schlumberger method, it is suggested that a survey be conducted in an area in which the subsurface features are well defined, such as at the Kerepehi hot springs area in the middle of the Hauraki Depression which has been surveyed with seismics and gravity (Fig.1).

The cross over present in the apparent resistivity curves ρa^{AC} and ρa^{BC} for the AB/2-150m array that does not occur for the AB/2=300m array (see explanation in profile D) probably means that the CO distance (see diagramatic in Fig.2) used in this survey was not great enough (i.e. AB/2=300m, CO=600m) and therefore the array was insensitive.

The result of the models show that near surface effects are far more important than the deeper effects for 2D resistivity modelling. Nevertheless, these models give an idea of the gross structure of the area.

The isolated low apparent resistivity anomaly. i.e. 20 Ohm-m for AB/2 = 300m suggests the area where the shallow hot water accumulates is about 0.3 sq. km at average depth of about 85m below ground surface. (Figs. 4 and 9).

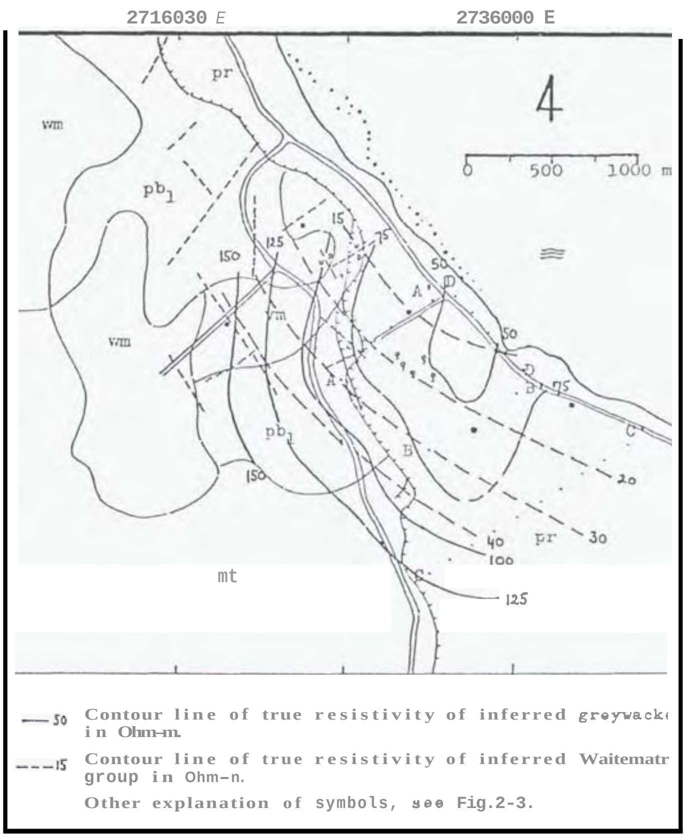

FIGURE 6: Map showing the gradual decrease from West to East of true resistivities of inferred greywacke and Waitemata Group.

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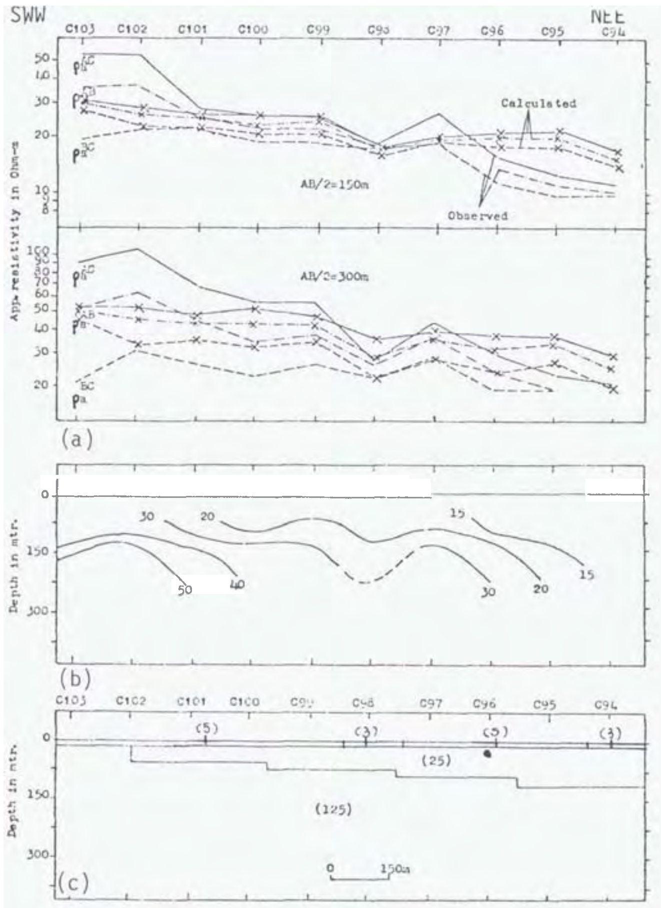

FIGURE 7: Geophysical profiles along line C: (a) - observed and calculated approximate resistivities from half Schlumberger and Schlumberger traversing; (b) - iso approximate resistivity profile (assumed: depth investigation was AM/4m) contour line in Ohm-m and (c) - a 2D resistivity model. (25) is a true resistivity value in Ohm-m.

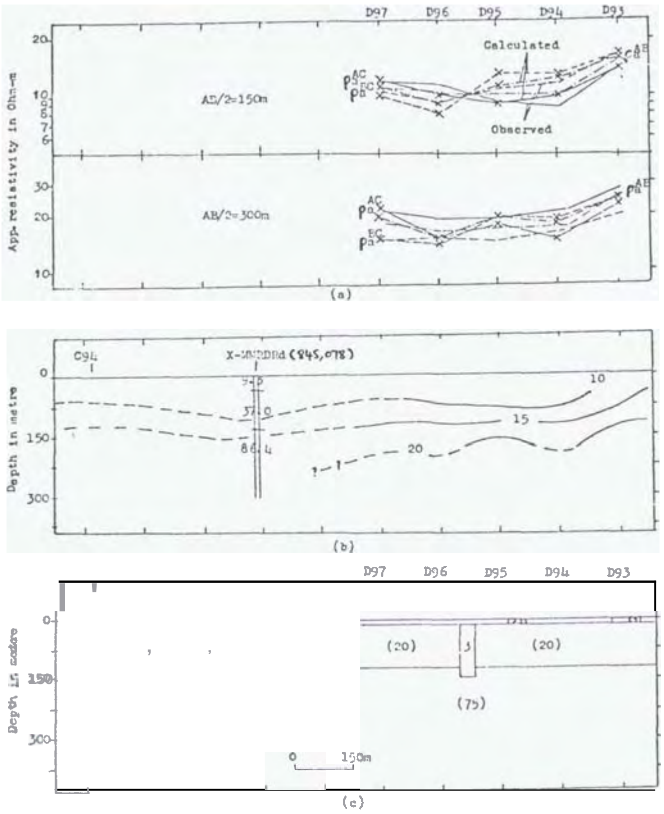

FIGURE 8: Resistivity Profile D. (a) -observed and computed apparent resistivities from half Schlumberger and Schlumber traversing; (b) -iso app. resistivity profile (assumed: depth investigation was AB/4m contour line in Ohm-m and (c) -2D resistivity model; (20) is true resistivity value in Ohm-m.

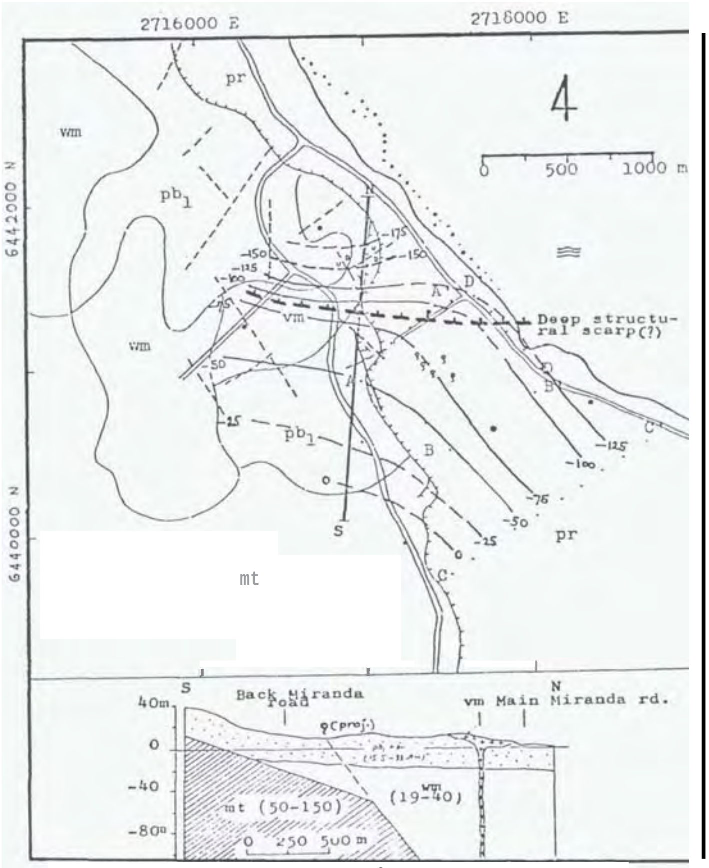

FIGURE 9: Map showing top of lower resistive sub stratum, presumably corresponding to the top of the inferred greywacke and N-S cross section of the area.
-50 Contour line in m with respect to the mean sea level; for explanation of other symbols, see Fig.3.

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