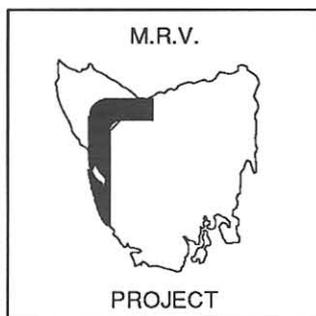


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## Mt Read Volcanics Project Geophysical Report 9

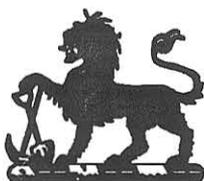
1988

# Geophysical signatures of Western Tasmanian mineralisation

Volume 1

## Signatures of mineral deposits

J. R. BISHOP and R. J. G. LEWIS



TASMANIA DEPARTMENT OF MINES

MT READ VOLCANICS PROJECT

GEOPHYSICAL SIGNATURES OF WESTERN TASMANIAN MINERALIZATION

VOLUME I

SIGNATURES of MINERAL DEPOSITS

by

J.R. Bishop & R.J.G. Lewis

MD/MG87/06  
LT/SIG/1-4  
December, 1988

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### SUMMARY

The geophysical responses recorded over the main mineral deposits in western Tasmania have been described and signature responses for 'type' bodies summarised. The effectiveness of the geophysical techniques being used for metalliferous exploration have been evaluated, as has the contribution geophysics can make in exploration over areas of thick glacial or basaltic cover. A data bank of the intrinsic electrical properties of most of the western Tasmanian rock types has been obtained from a program of in situ IP surveys and this is presented as an appendix to Volume II. This data has also been processed to produce the Cole-Cole spectral IP parameters, which have been analysed in an attempt to provide criteria for discriminating between different rock types: in particular, between economic sulphides, graphitic shales and barren pyrites. In terms of spectral IP parameters, useful discrimination is possible. It remains to be determined whether practical surveys can accurately measure the required parameters.

### INTRODUCTION

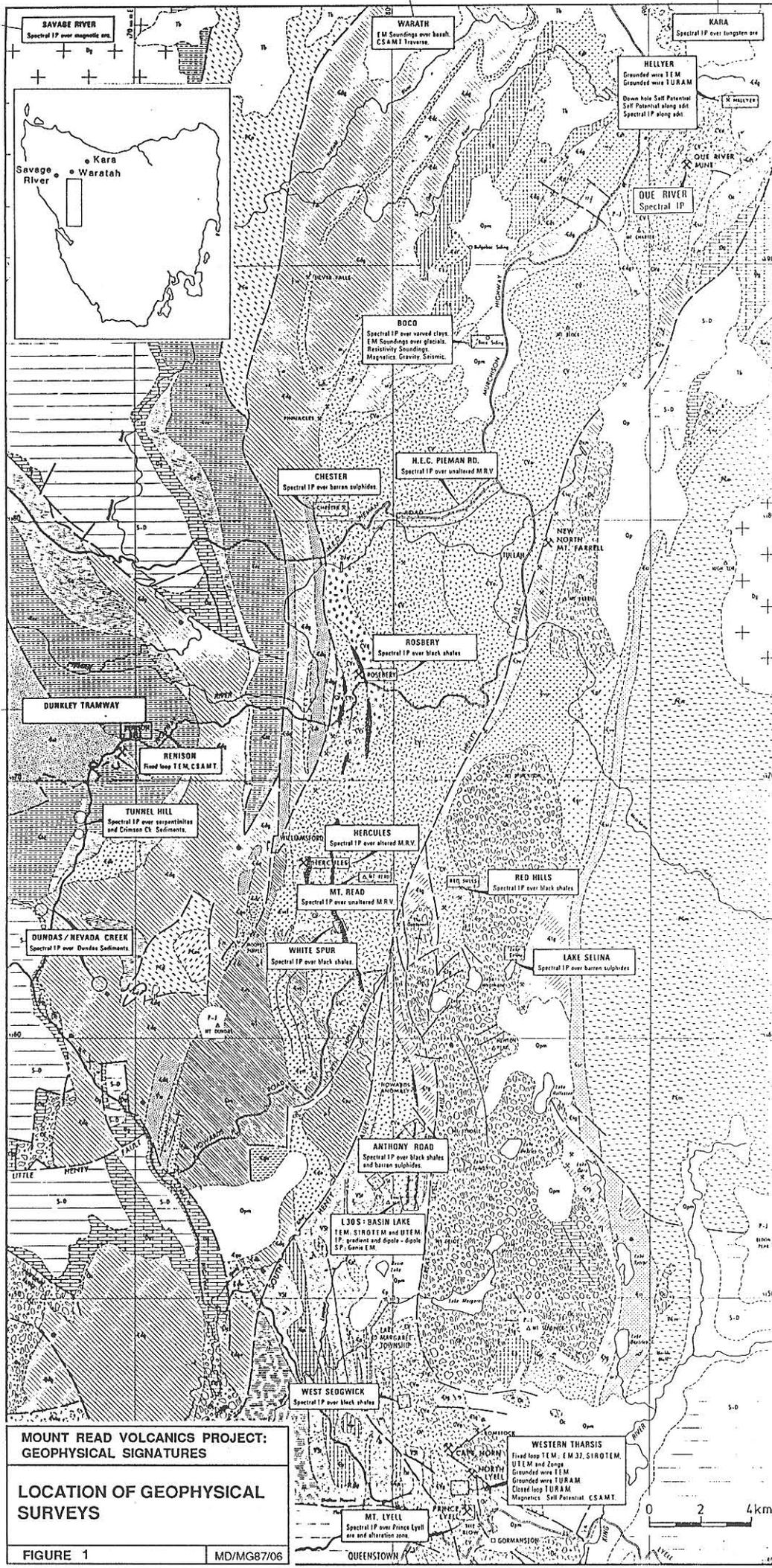
Geophysics was probably first used in Tasmania in 1928-29, when the Imperial Geophysical Experimental Survey (IGES) successfully carried out magnetic and electric surveys at Zeehan and Renison Bell (Edge and Laby, 1931) and it has continued to play an important role in exploration for metalliferous deposits in western Tasmania since that time. Three ore-bodies on the Mount Lyell Field have been attributed solely to geophysical surveys (Bishop, 1983a) and electromagnetic surveys had a major role in the finding of Que River (Webster and Skey, 1979) and they were instrumental in the discovery of Hellyer (Eadie and Silic, 1984). As the surface and near-surface become more thoroughly explored, the role of geophysics can be expected to increase as we attempt to investigate the earth to greater and greater depths.

This report, which was commissioned by the Tasmanian Mines Department as part of its Mount Read Volcanics Project, concentrates on deposits within the volcanics. However, comments have been made on all of the major metalliferous deposits in western Tasmania. Some geophysical surveys were commissioned specifically for this project and several techniques were tried at a number of different locations (see Figure 1). As well as using the results from these surveys, this report has been compiled from records on open file at the Mines Department and from data kindly provided by mining companies and companies exploring in Tasmania.

The aims of the project were to:--

- (1) Determine the geophysical responses of the economic deposits, their alteration zones and host rocks, as well as characteristics of the unwanted responses from black shales and barren sulphides.
- (2) Evaluate the effectiveness of the geophysical techniques now being used in western Tasmania.
- (3) Determine the application of geophysics in areas with a thick cover of alluvium or Tertiary basalt.
- (4) Experiment with new or modified methods to see if avenues could be found for improving the usefulness of geophysics in Tasmania.

This report covers only part of the geophysical component of the Mount Read Project. The responses of west coast deposits to gravity and aeromagnetic surveys have been discussed by Leaman (1987), thus this report concentrates on the electrical and electromagnetic techniques. Some physical property values are given here and in Volume II, but a large body of other data and different properties is being prepared by Richardson and Hudspeth (1988).



**MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES**

**LOCATION OF GEOPHYSICAL  
SURVEYS**

**FIGURE 1** MD/MG87/06

### GEOPHYSICAL RESPONSES FROM ECONOMIC DEPOSITS

Brief summaries of the geophysical surveys, both exploratory and experimental, which have been carried out over the major west coast mines are given below. Some surveys were carried out many years ago and since there was then no obligation to report such investigations to the Mines Department, the descriptions may not be complete. However all companies have cooperated with this project and it is believed that all important surveys are mentioned. The results of these surveys are used at the end of this report to summarise the geophysical characteristics of west coast 'type' deposits.

#### **HELLYER**

The Hellyer ore-body is a large (15 million tonne plus) base-metal volcanogenic massive sulphide deposit hosted by a suite of basic to intermediate lavas within the Mount Read Volcanics. It is a concealed, roughly elongate cone shaped body with its apex at the shallow end, about 90m below the surface. It plunges to the north to a depth of about 500m over its 750m strike length and averages 0.4% Cu, 7% Pb, 13% Zn, 160g/t Ag, 2.3g/t Au, 3% Ba and 1% As. A description of the geology and mineralogy is given by McArthur (1986). Hellyer was discovered by Aberfoyle Resources in 1983 and was the result of an intensive exploration program following that company's discovery of the Que River deposit, some 3km to the south.

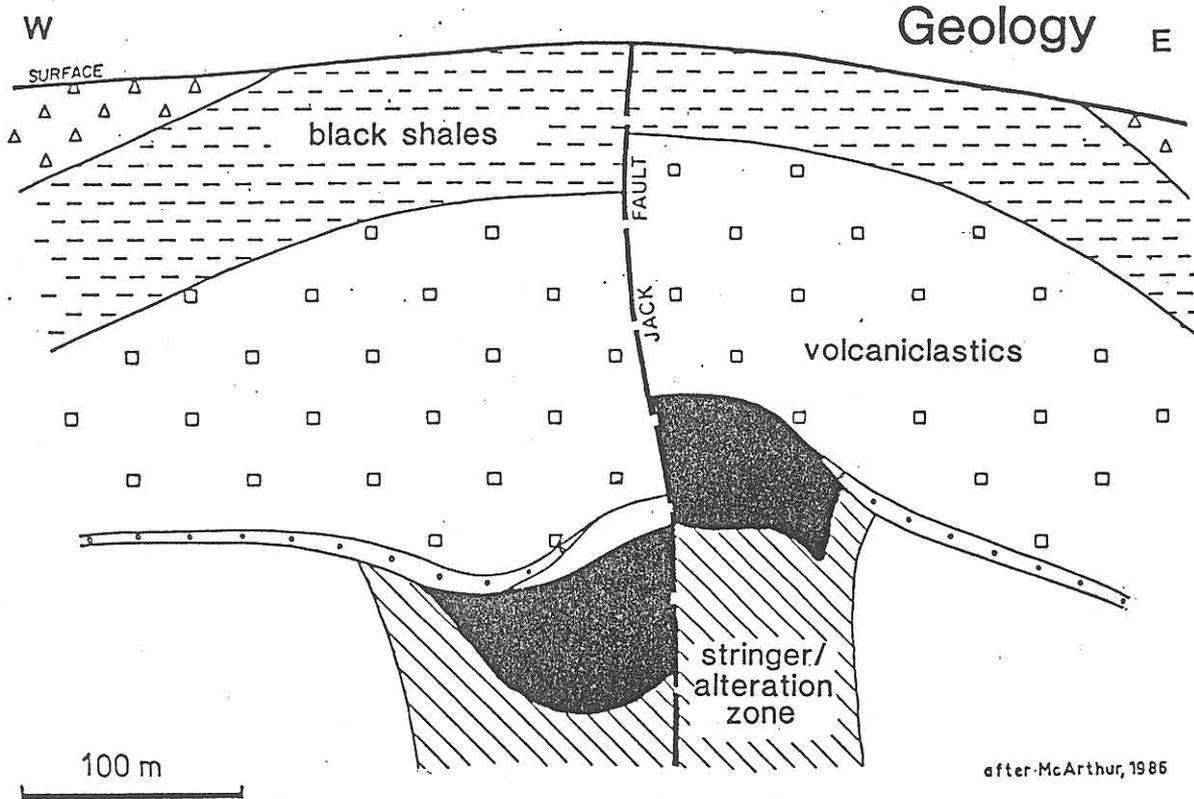
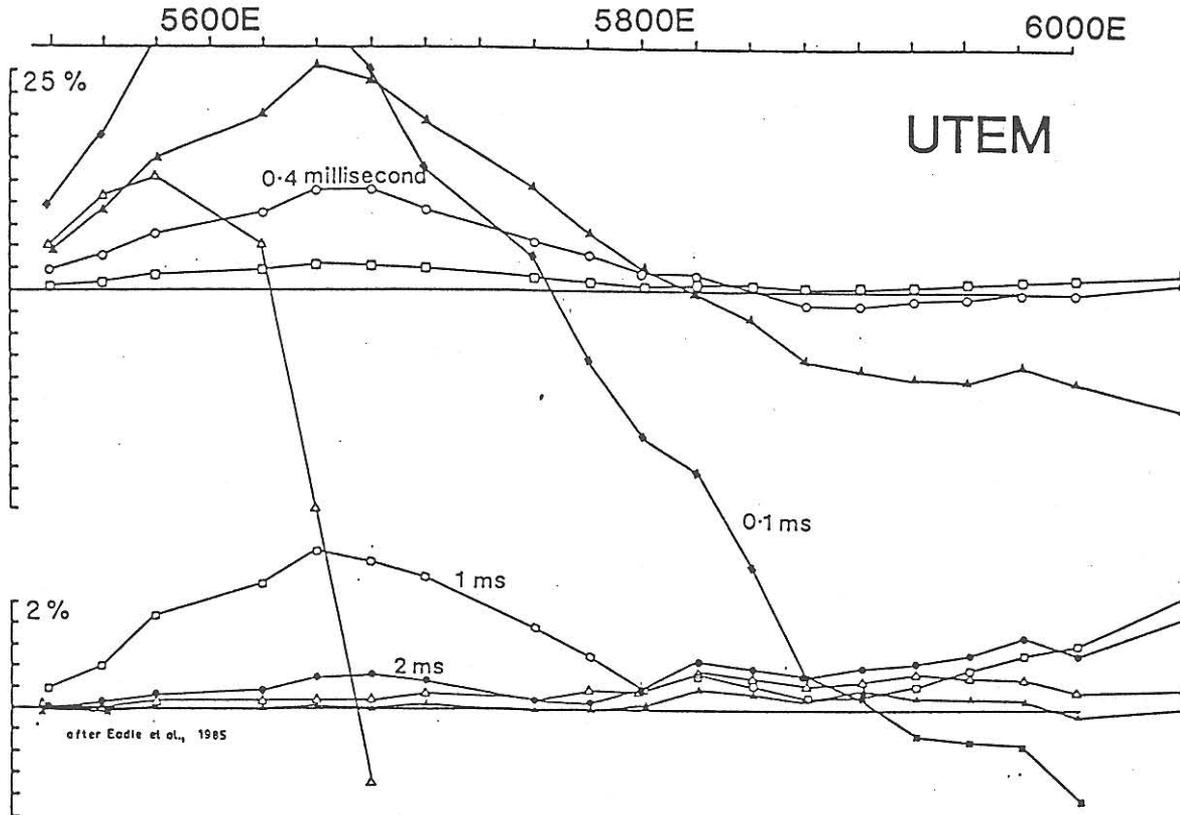
The first drill-hole to intersect Hellyer was targeted on a subtle (at late-time) UTEM anomaly (Eadie et al, 1985; see Figure 2). Down-hole EM (DHEM) surveys were carried out down most of the subsequent drill-holes and the strong responses have confirmed the high conductance of the sulphides. Figure 3 (Eadie, 1987) shows a well developed DHEM Sirotem anomaly at a distance of about 50m from the ore-body (DDH HL31), plus another profile (from DDH HL19) which demonstrates that good responses may be obtained at distances of more than 100m from the bulk of the body.

Eadie and Silic (1984) have shown that the poor UTEM response is due to the narrow width and limited depth extent of the deposit, rather than its depth of burial. Their computer modelling suggested a conductance of more than 50S. This compares with the lower limit from measurement of hand samples (4S/m; Table 1) which, with widths in excess of 20 to 30m, gives a conductance of the order of 100S\*. Our attempts to measure electrical properties in situ failed at Hellyer because the mineralization is so conductive. Parts are clearly much more conductive than the Que River mineralization.

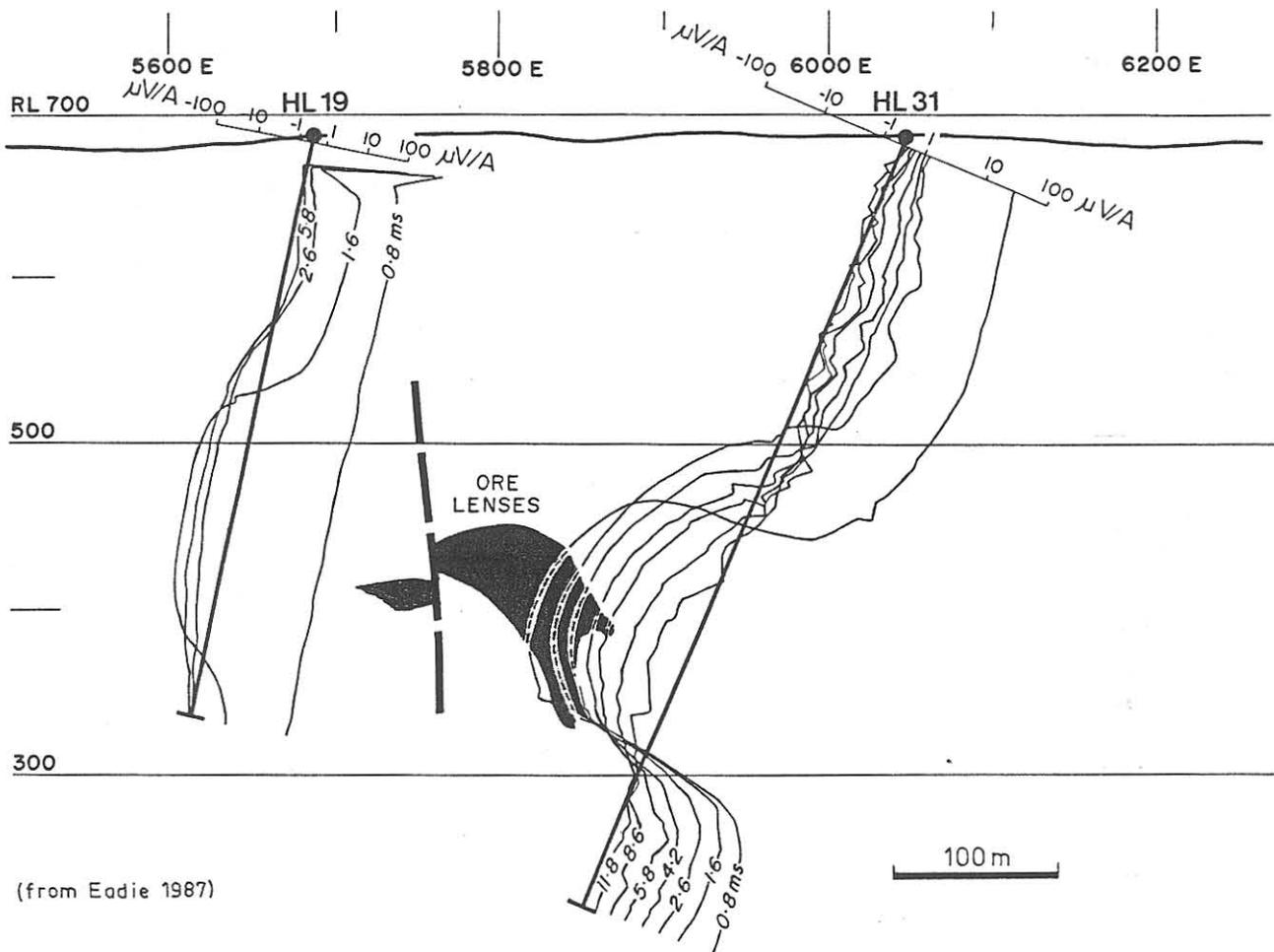
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\* One or two measurements of a few pieces of core do not give a representative value of a body's bulk conductivity, however the results did confirm the conclusions derived from the modelling.

# Hellyer



MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
HELLYER UTEM PROFILE: 10400N	
FIGURE 2	MD/MG87/06



MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
HELLYER DHEM PROFILES	
FIGURE 3	MD/MG87/06

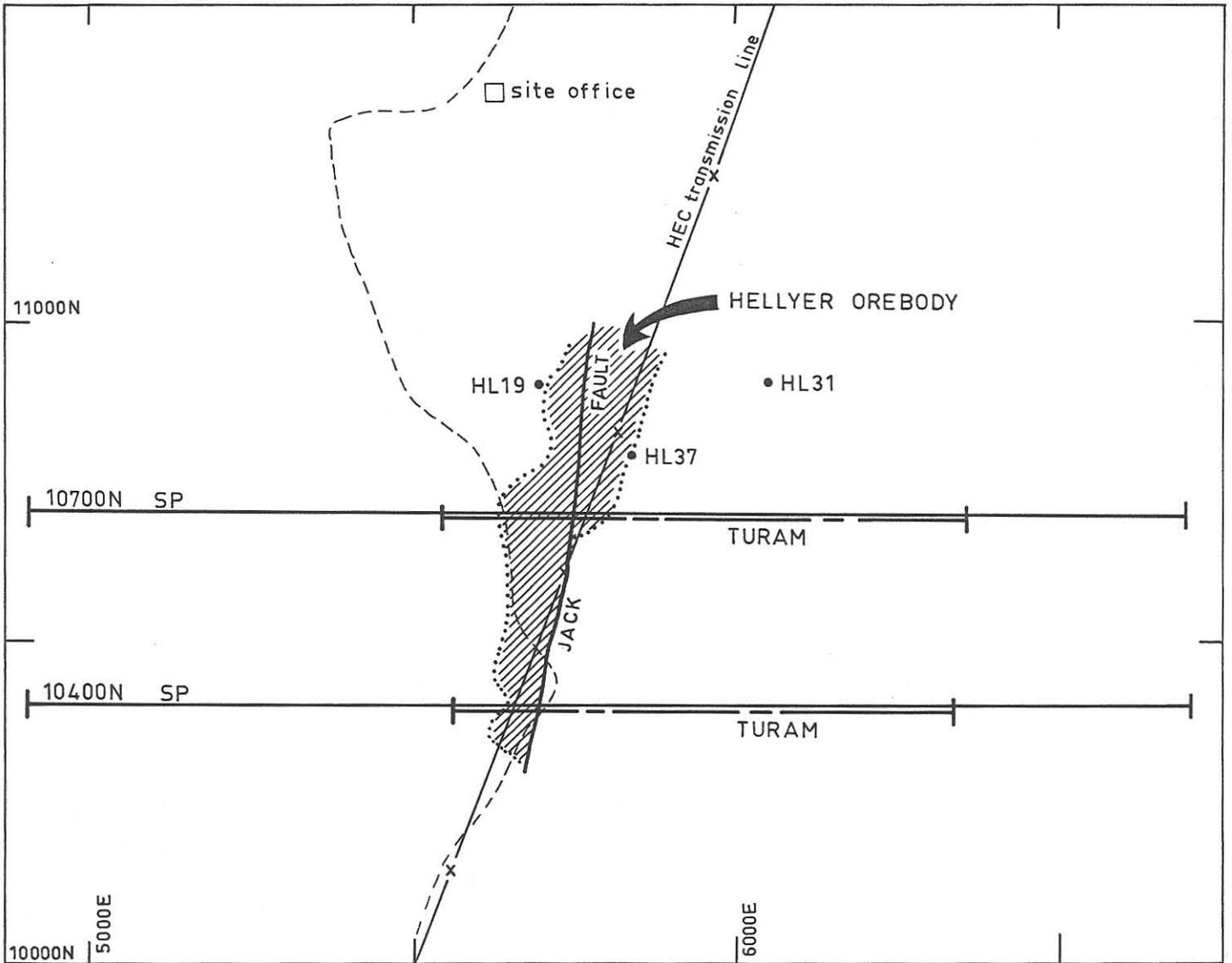
Although the deposit is highly chargeable (Table 1), the IP method was not applicable, due to interference from adjacent black shales at the large dipole spacings needed to 'see' the deposit. A carefully executed and corrected gravity survey has defined a low amplitude anomaly over the deposit (Hudspeth and Richardson, 1985). Eadie and Silic (1984) have stated that there is no consistent magnetic susceptibility contrast between the host rocks and the sulphides (see also Table 1 and Richardson and Hudspeth, 1988), however, Leaman (1987) has suggested that there is a subtle signature in the regional airborne data.

Regionally, the Hellyer deposit lies at the northern end of a broad area of altered volcanics. Following the successful definition of the Que River deposit by IP (see below), this area was 'blanket' covered by IP. Numerous chargeable zones of disseminated pyrite were defined and subsequently drill tested. The UTEM survey, which followed the IP coverage, was able to give a better resolution at greater depth. It was also able to provide much more discriminating and quantitative data. The weak response, recorded on the last (northernmost) line of the grid, was the only anomaly worthy of further attention in the whole survey (Eadie and Silic, 1984). The Que River black shales also form part of the regional geophysical picture. These are chargeable, but generally less conductive than the ore. They are further discussed later in this report.

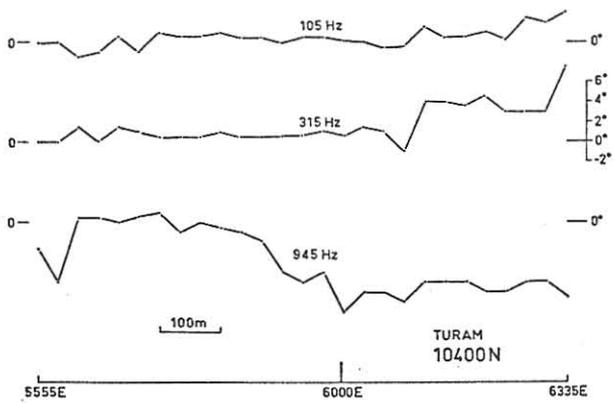
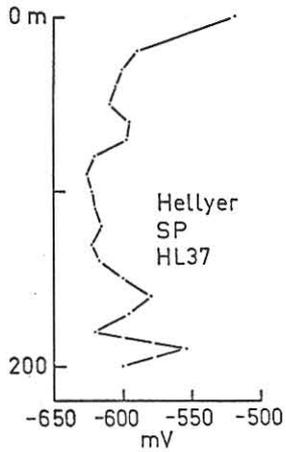
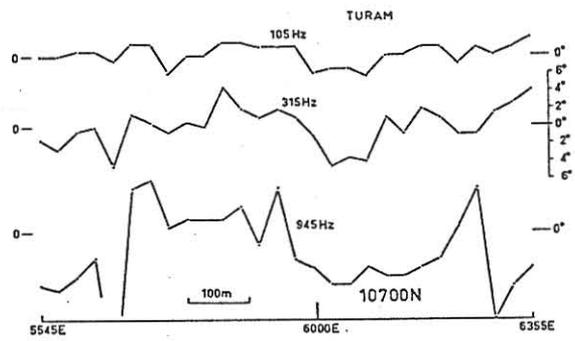
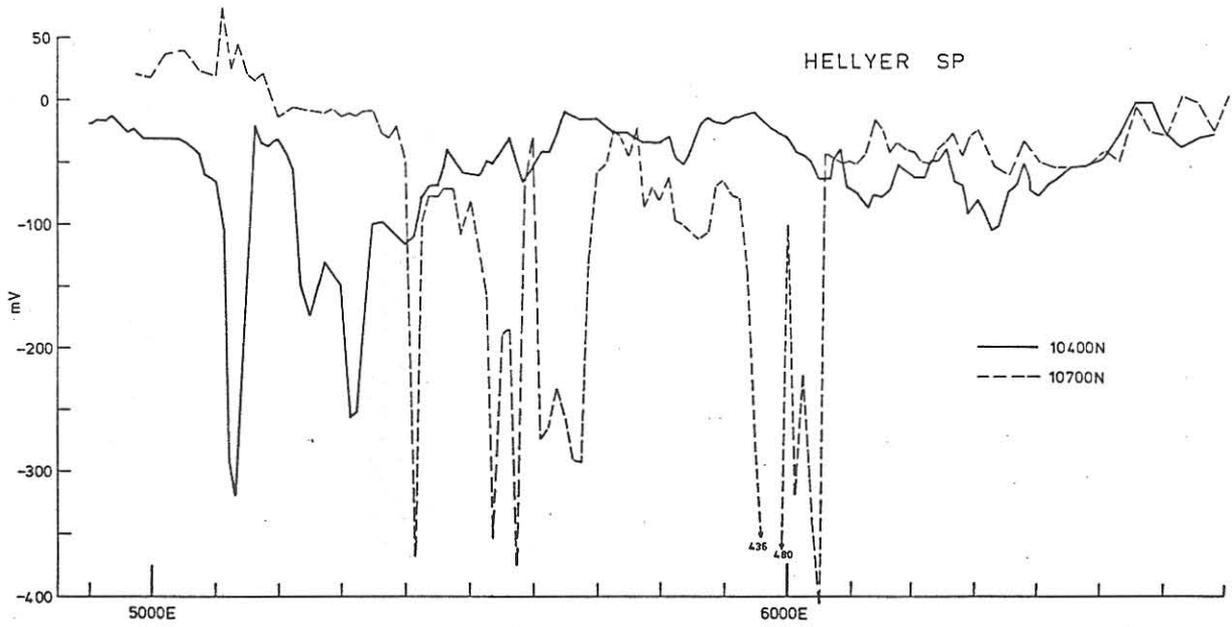
A number of surveys were planned over Hellyer for this project, but only some were carried out. Electrical noise from the overhead power lines (commissioned almost immediately after the discovery UTEM survey) and from equipment associated with the mine, precluded the collection of much meaningful data. EM techniques using a grounded wire, rather than the usual closed loop were attempted (location on Figure 4). It was hoped that such a source would better energise the orebody. The Zonge time domain EM (TEM) and the frequency domain EM (FEM) Turam methods were tried. For the latter, it was hoped that the narrow-band filters used in FEM would receive usable signal above the power line noise. The technique 'worked' in as much as the phase difference parameter apparently recorded real signal. (The other parameter, the field ratio, was very noisy.) However, the results show no indication of the buried body (Figure 5a). The black shales, centred at 5800E on line 10700N are the only recognisable geological response. The TEM survey was not successful (Figure 5b), but this may have been due as much to instrumental difficulties as the noisy environment.

Self potential surveys were also run across the two surface lines and down drill hole HL37 which intersected massive sulphides from 137m to 196m. The surface surveys responded only to the shales (Figure 5a), as did the down hole survey, which reached to only 200m of the 335m long hole. A survey was attempted along the adit: the data suggests that there is an SP anomaly associated with the deposit, however there are some large discrepancies in the data and the results have not been presented here.

Hellyer has been the subject of two unpublished geophysical Honours theses from the University of Tasmania. Mather (1985)



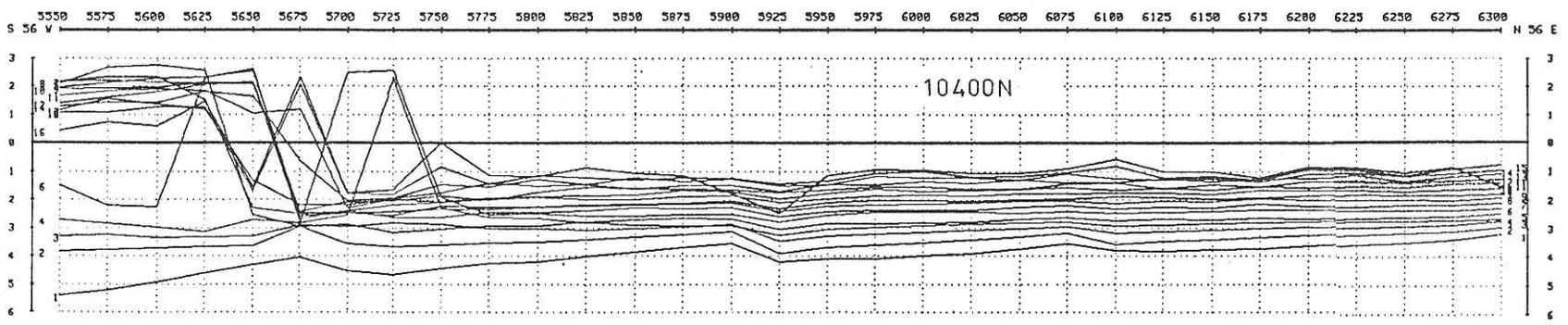
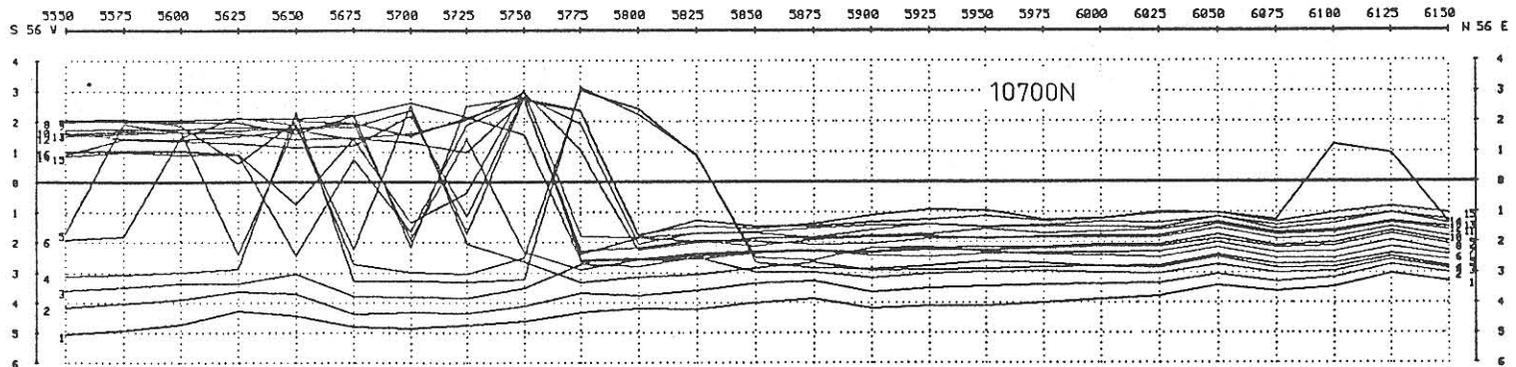
MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
HELLYER GEOPHYSICAL SURVEYS: LOCATION PLAN	
FIGURE 4	MD/MG87/06



MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES

HELLYER SP AND TURAM  
RESULTS

FIGURE 5A MD/MG87/06



Window MAGNITUDE  
 values in microV/ampere  
 Component: "CH1 Z, Rxna= 10000.0"

Survey by Zonge  
 Receiver: GDP 12 with Sirotem roving receiver

MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
HELLYER GROUNDED WIRE TEM RESULTS	
FIGURE 5B	MD/MG87/06

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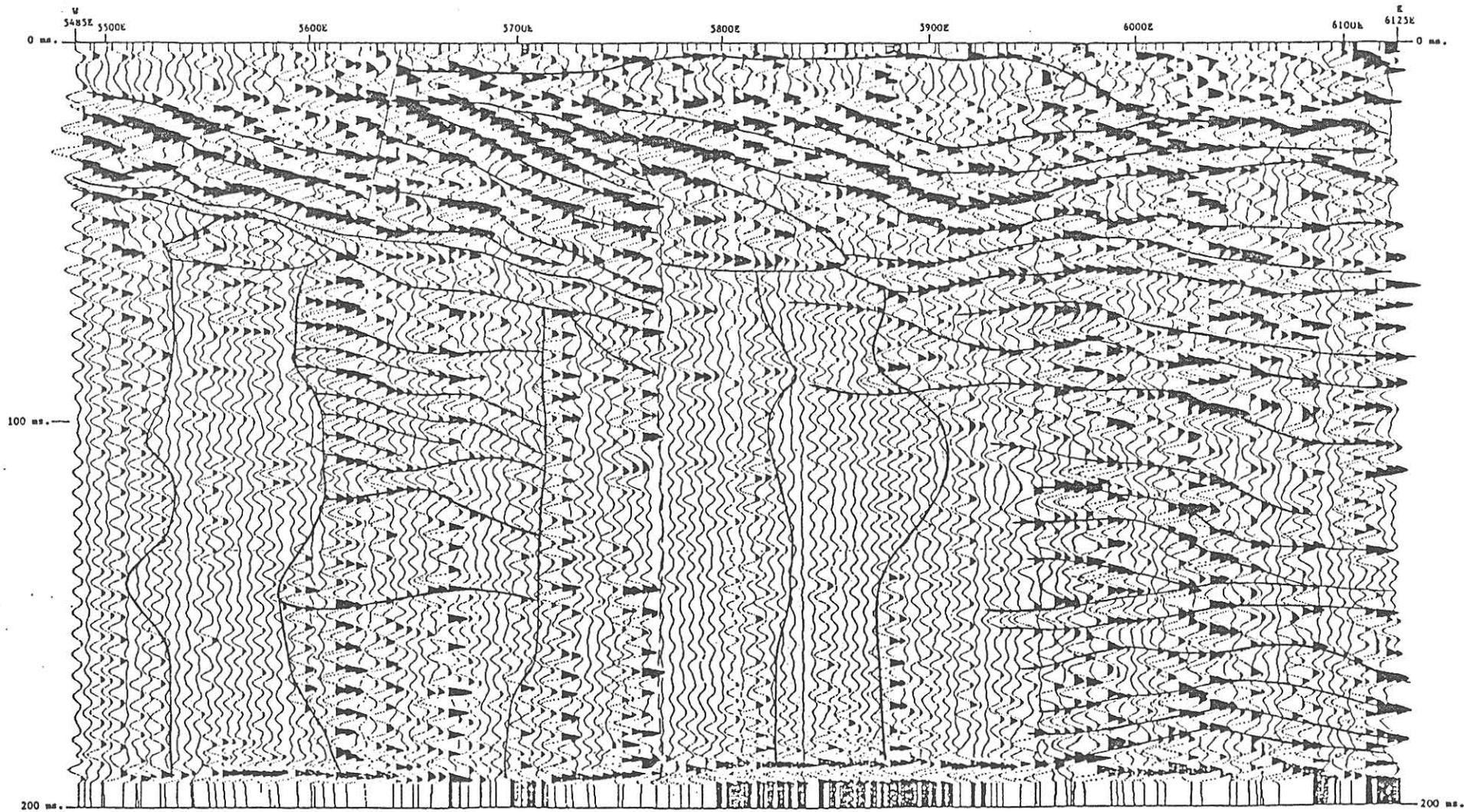
investigated the spectral IP properties of the Que River shales overlying Hellyer and his data have been used in Volume II on electrical properties. Tom Eadie first proposed an experiment using seismic reflection across Hellyer and subsequently Read (1986) carried out a seismic reflection survey on one traverse across the ore body. His results show that by meticulous attention to detail, particularly of static corrections, and the use of F/K (or velocity) filtering together with 12 fold CDP techniques it is possible to obtain interesting results about the general structure and mineralization of the deposit (Figures 6a & 6b). Read also measured rock properties and evaluated synthetic seismograms of reasonable models of Hellyer.

#### QUE RIVER

The geophysical (and geochemical) responses of the Que River deposit have been well summarised by Webster and Skey (1979). Their paper has had a considerable influence on exploration in Tasmania so the history of the deposit's discovery and subsequent developments are worth summarising here.

Like Hellyer and Rosebery, Que River is a 'type' base metal deposit for the Mount Read Volcanics. It is hosted by steeply dipping dacites and pyroclastics which are intercalated with andesitic agglomerates and lavas. These rocks are overlain by the graphitic Que River Slates. The deposit consists of a number of steeply dipping thin lenses of massive sulphides. The largest of these, the PQ lens, is 600m long, 150m deep, 9m wide and is about 75m below the surface. It contains 0.4% Cu, 7.7% Pb, 13.3% Zn, 205g/t Ag and 3.5g/t Au (Wallace and Green, 1982). The discovery was made on the 'S' lens, a zone of subcropping and subeconomic (relatively) copper rich mineralisation. This was found in 1974 by Aberfoyle Resources drilling combined soil geochemical and ground EM responses which were obtained from follow up of an airborne EM anomaly located close to anomalous stream geochemistry. The adjacent, but more deeply buried, economic lead-zinc rich PQ lens was discovered during drilling and later defined by IP. Since this lens gave no EM or SP response, nothing from an applied potential (mise-a-la masse) survey and only a weak resistivity anomaly from the IP (all in contrast to the S lens), Webster and Skey (1979) concluded that the economically important lead-zinc mineralisation was effectively non-conductive and that a necessary criteria for a drill target for volcanogenic massive sulphides in western Tasmania was "a soil geochemical anomaly and an induced polarisation anomaly in close proximity". This conclusion led to a general reluctance to use EM methods and to a continuing dependence on IP. However, as may be surmised from the above section on Hellyer, this reluctance did not persist with Aberfoyle themselves.

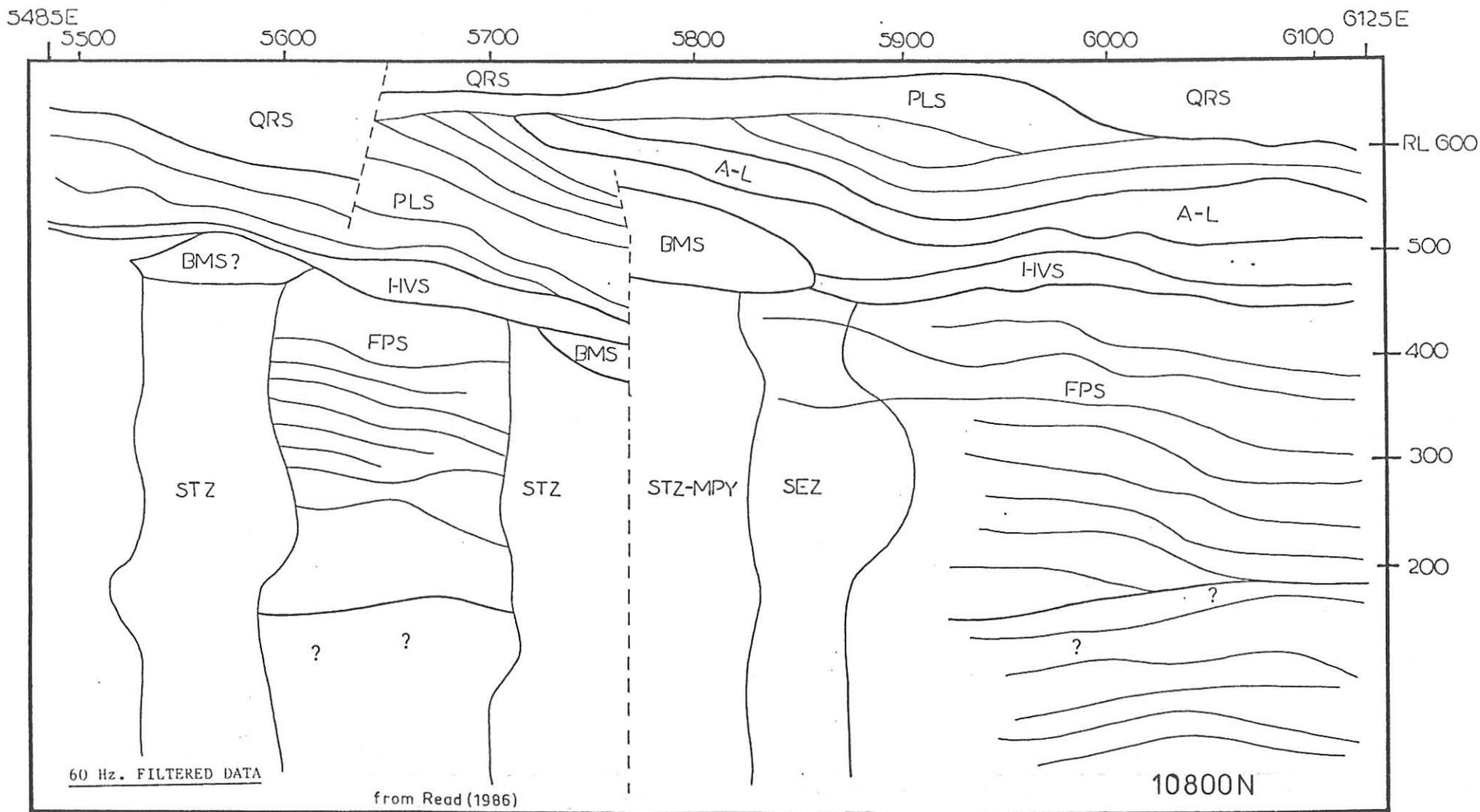
In 1978 an experimental Sirotem survey was carried out by BHP over the Que River deposit. This employed the then usual moving



from Read (1986)

MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
HELLYER SEISMIC REFLECTION SECTION	
FIGURE 6a	MD/MG87/06

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QRS	Que River Shale	BMS	Base Metal Sulfides	STZ-MPY	Stringer Zone - massive pyrite
PLS	Pillow Lava Sequence	FPS	Feldspar Pyritic Sequence		Unknown Rock Type
A-L	Basalt Lava		Stringer Envelope Zone		
HVS	Volcaniclastics		Stringer Zone		

**MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES**

**HELLYER SEISMIC REFLECTION  
INTERPRETATION**

FIGURE 6b

MD/MG87/06

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coincident loop technique and it also failed to define the Pb-Zn lens. In the same year Aberfoyle tried the UTEM method over Que River, using the now widely adopted large fixed transmitter loop technique. Whilst giving a large amplitude response to the copper lens at early times, a more persistent response was recorded over the lead-zinc lens (Staltari, 1986)\*. This led to the conclusion that the mineralisation was conductive in situ and that the UTEM method was an appropriate technique for exploration of Que River style mineralisation. This led to the Hellyer discovery in 1983.

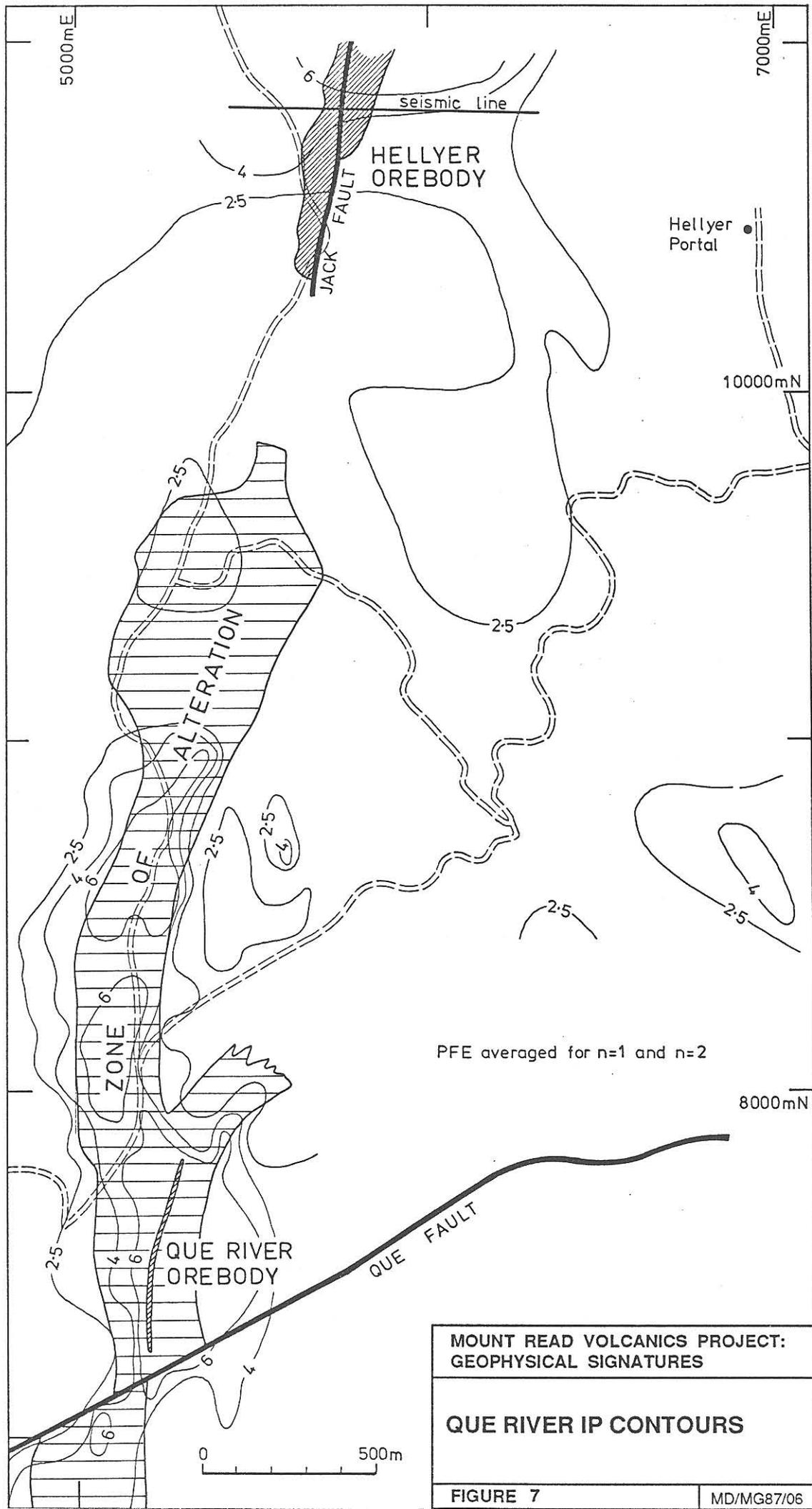
The Que River sulphides lie within a broad region of disseminated sulphides which has a strike length of at least 3.7km. The IP method does not distinguish the ore zones but the highest values occur around the mine (Figure 7 from Odgers, 1985). It is shown in the second volume of this report that the ore can be distinguished from the alteration zones and a wide variety of black shales by spectral analysis of IP measurements.

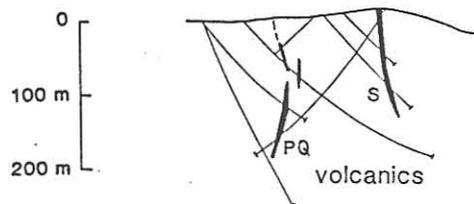
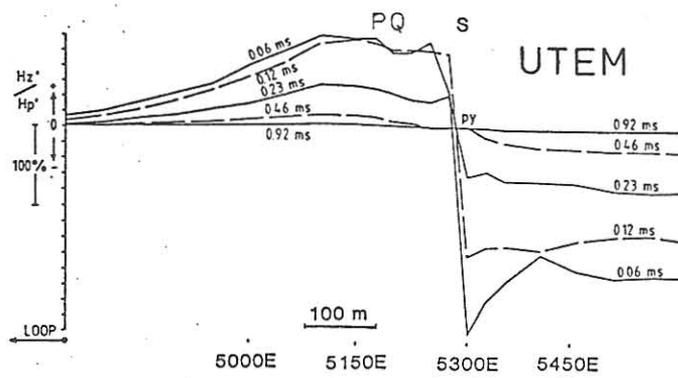
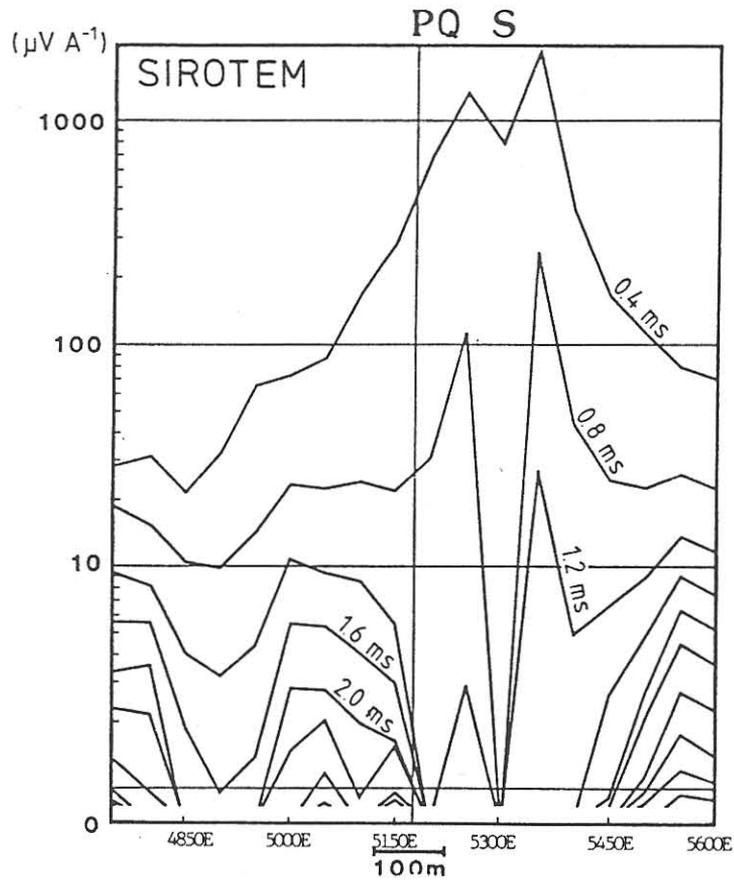
Staltari (1986) estimated a conductance of about 8S for the S lens from the Sirotem and about 15S for the PQ lens from the UTEM data (Figure 8). The results of petrophysical measurements on a very limited number of Que River ore specimens (Table 1) reinforced this interpretation and actually show a higher conductivity for the latter.# The measurements also indicate comparable (and high) chargeabilities. However, very numerous in situ measurements of PQ and S Lens properties by Mather (1985) (see Volume II) which give good average property values, clearly show that this is not the case and that the S lens is more conductive: the measurements produce an average resistivity of 2.5 $\Omega$ m for S compared with 18 $\Omega$ m for the high grade ores of the PQ Lens. (These results were measured using standard time domain IP waveforms with 2s current pulses. Because of the high chargeabilities the values will vary considerably with frequency).

Other EM results of interest over Que River include a trial Input line, which gave a very similar response over the black shales (Webster and Skey, 1979). Comparable responses for the shales and sulphides were also obtained by a Dighem survey flown for BHP as a part of a Dighem evaluation study. Although Dighem rejected the shales in their automated processing, comparable resistivities were calculated for the two conductors (see Figure 9 which shows a profile of the best Dighem response over Que River). Although more sensitive than the McPhar HEM-400 which 'discovered' Que River, the Dighem system also only located the subcropping S lens. A plan of the EM anomalies is given in Figure 10 showing the low conductance (less than 9S) grade '1' and '2' type conductors over a strike length of ~500m. The anomalies immediately

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\* The difference between the Sirotem and UTEM results can be attributed largely, if not solely, to the differences in the two survey techniques and not to any intrinsic differences in the equipment.

# The conductance (= conductivity x thickness) of a body largely determines its EM response.





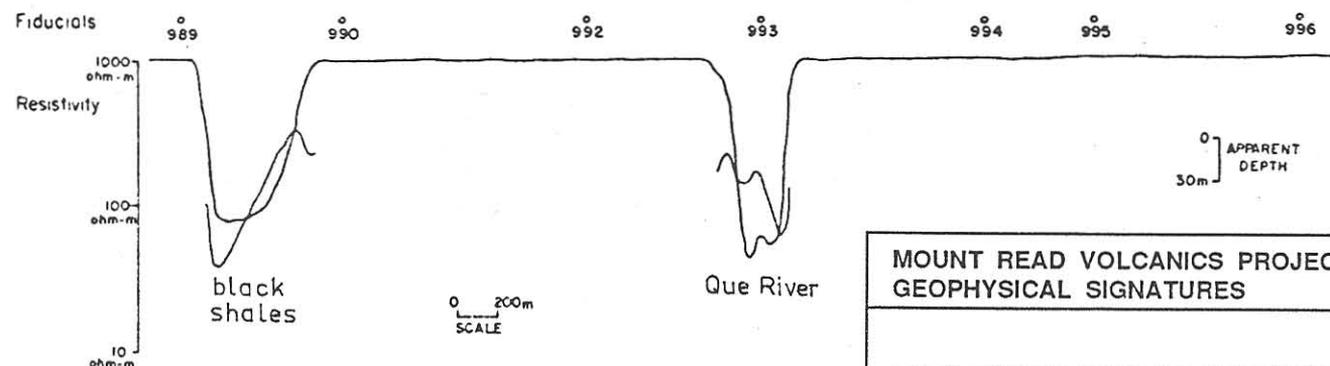
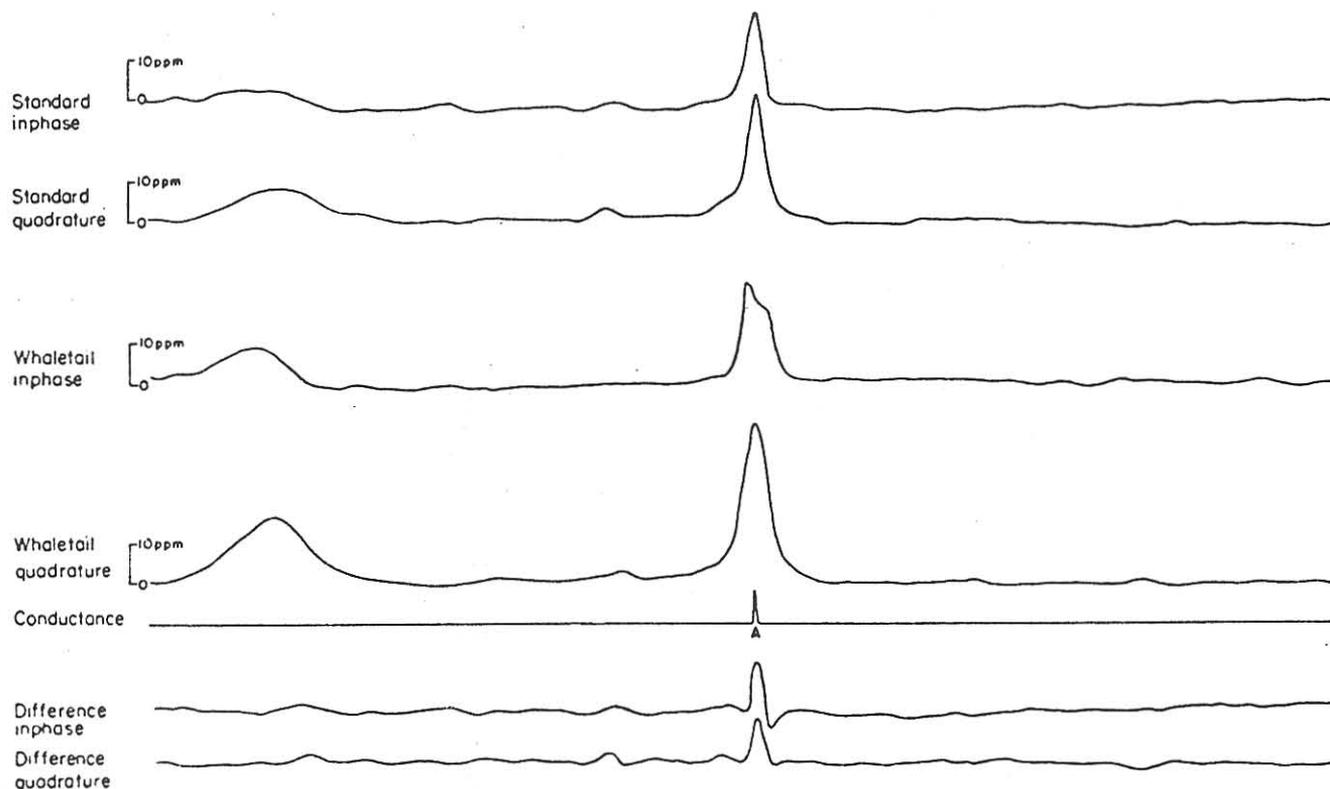
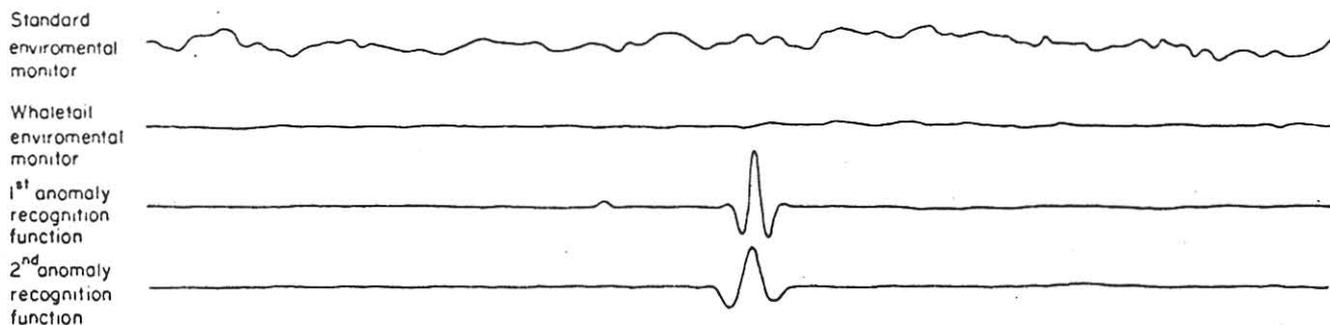
(from Staltari 1986)

MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES

QUE RIVER SIROTEM AND  
UTEM PROFILES 7400N

FIGURE 8

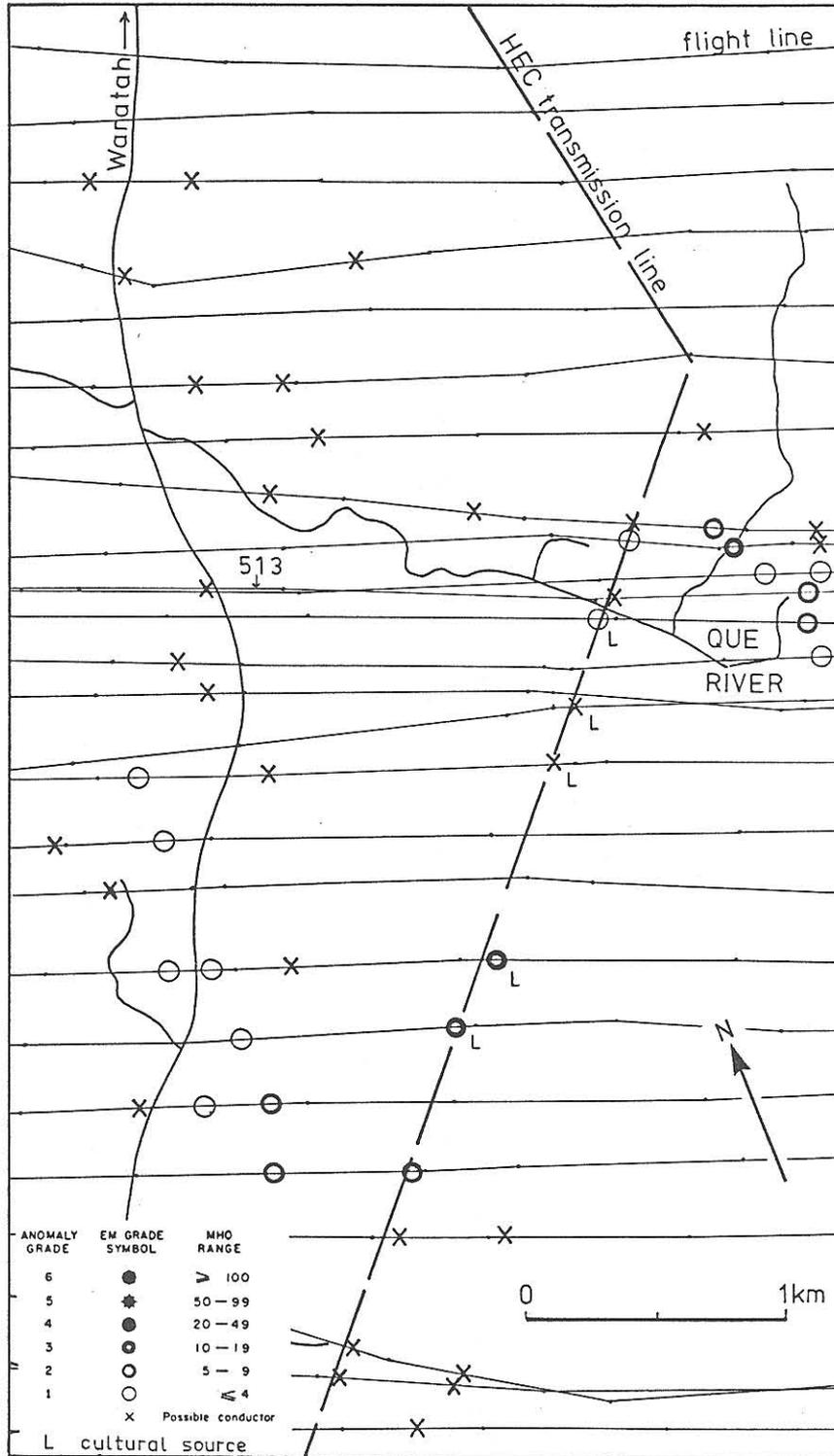
MD/MG87/06



MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES

QUE RIVER DIGHEM PROFILE

FIGURE 9 MD/MG87/06



**MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES**

**QUE RIVER DIGHEM EM  
ANOMALIES PLAN**

FIGURE 10

MD/MG87/06

to the west are cultural responses as of course are those over the power line. (It is interesting to note the variation in conductance grade given to the power line, which was not operating at the time of the survey.) The anomalies straddling the Murchison highway on the western edge of the survey are over the Que River graphitic shales. Horizontal and vertical loop ground EM surveys were used to locate the HEM-400 anomaly and the results are given in Webster and Skey (1979).

To summarise the results of all of the EM surveys over Que River, the systems available at the time of discovery were generally not good enough to detect the deeper, economic mineralisation. Later tests with a later generation, deeper penetrating time domain system (i.e. Sirotem) failed due to the poor resolution of the survey geometry\*. The UTEM succeeded with the even better penetration provided by a large transmitter loop and with the better resolution achievable from a single cross-over response.

With regard to the other physical properties, Webster and Skey (1979) stated that since there was "a lack of magnetic minerals in the ore and related rock units...the magnetic data proved to be of no value in this environment". However Leaman (1987) has noted a subtle low in the regional aeromagnetic data, which he suggests is probably due to local alteration. Leaman (1987) also comments on the gravity response over Que River. Small spiky responses were obtained which reflect the small tonnage of the deposit split up into a number of lenses. However with some processing Leaman and Richardson (1981) were able to obtain a good estimate of the size of the deposit, which was about 5 million tonnes.

## ROSEBERY

The Rosebery deposit has many similarities with the Hellyer and Que River deposits, being a volcanogenic polymetallic massive sulphide deposit hosted by the Mount Read Volcanics. It is an outcropping tabular deposit dipping at  $45^{\circ}$  to the east, with a strike length of 1700m and an average thickness of 6m. Prior to mining, it contained about 22 million tonnes averaging 0.7% Cu, 4.9% Pb, 15.9% Zn, 149g/t Ag and 2.8g/t Au (Iloff, pers. comm.). The ore horizons occur in an altered, pyritised sequence of siltstones and shales which are overlain by pyritic black shales. These sedimentary horizons are underlain by altered footwall schists and overlain by massive pyroclastics (Green et al., 1981) It is owned and operated by the Electrolytic Zinc Company (EZ).

The deposit was discovered in the late 19th century and geophysics has played little if any role in the development of the mine. And since the township of Rosebery is now sited over the deposit, it is difficult to carry out any electrical or magnetic surveys. Also, much of

-----  
\* The large fixed transmitter loop, also called the roving receiver (or RVR) mode, was not then available for Sirotem.

the ore has now been removed, especially at the upper levels, thus preventing any determination of its original gravitational response (although the company does have some old gravity data in its archives).

Despite this lack of data\*, the deposit is especially interesting geophysically, since it occurs in close proximity to black shales which have similar electrical properties to the ore. There are also the pyritised host rocks and altered footwall volcanics with disseminated pyrite, both of which produce strong IP responses. Figure 11, a contour plan of IP# suggests that, like the Que River deposit, Rosebery lies within a large halo of alteration. Bishop and Lewis (1985) made some underground spectral IP measurements at Rosebery and attempted to differentiate the various rock types, which were often indistinguishable from each other using the normal parameters of chargeability and resistivity, by determining the Cole-Cole parameters. The results suggest that all of the Rosebery material form a single group of materials outlining a distinct trend (the 'Rosebery Trend') in  $\tau$ -m space but separating into two groups in m-c space (Figures 9 & 10 Volume II). It appears that a large group of uninteresting materials can be eliminated by requiring that targets have  $\tau > 3s$ ,  $m > 0.5$ . The properties of Rosebery materials are given in Volume II together with a discussion. Initially it was thought that the black shales, tested in an open cut to the north of the mine, were not a representative sample: despite visible disseminated pyrite in the rock and a graphitic 'feel', there was little IP response. This is consistent with the spectral IP classification which would group these shales with the low grade mineralisation. Further sampling in the open cut and the township suggests that in fact these results are typical. This is further discussed in Volume II.

Apart from the recent work by Richardson and Hudspeth (1988), there have been few other petrophysical measurements of the Rosebery sulphides and associated rocks and some of these are given in Table 1. The conductivity measurements are variable but comparable with the Hellyer and Que River results. However, it is shown in Volume II that the in situ electrical properties of the Rosebery and Que River sulphides are remarkably similar but differ from Hellyer in that the latter is more conductive. Figure 12 shows some frequency domain IP results for sulphides and black shales at Rosebery. (It can be seen that the black shale responses are highly variable. Those showing little response are from the open cut; the others are from drill core.) The in situ similarities between Rosebery and Que River suggests that these deposits may be a more appropriate model for exploration than Hellyer

-----  
\* EZ were not unaware of geophysics. Their employment of a geophysicist at Rosebery in 1950 was almost certainly the first such appointment in Tasmania. In 1959 they carried out a downhole EM survey on the mine lease; probably another first.

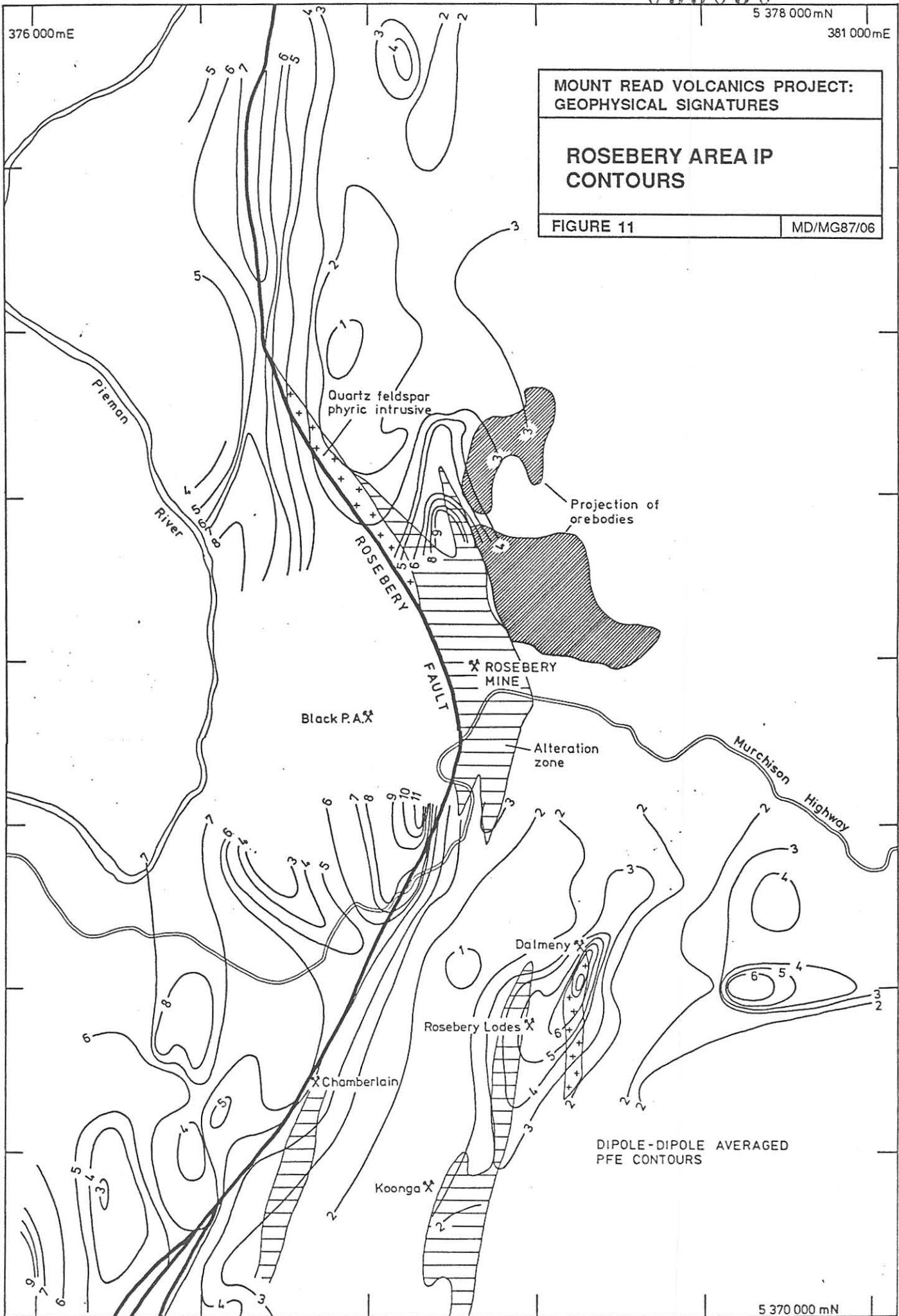
# Some of this IP data, collected in 1960-62, is amongst the earliest IP data obtained in Australia. EZ in conjunction with Rio Tinto (now CRA) were responsible for bringing McPhar Geophysics to Australia. Various follow-up and repeat surveys have confirmed the quality of the data.

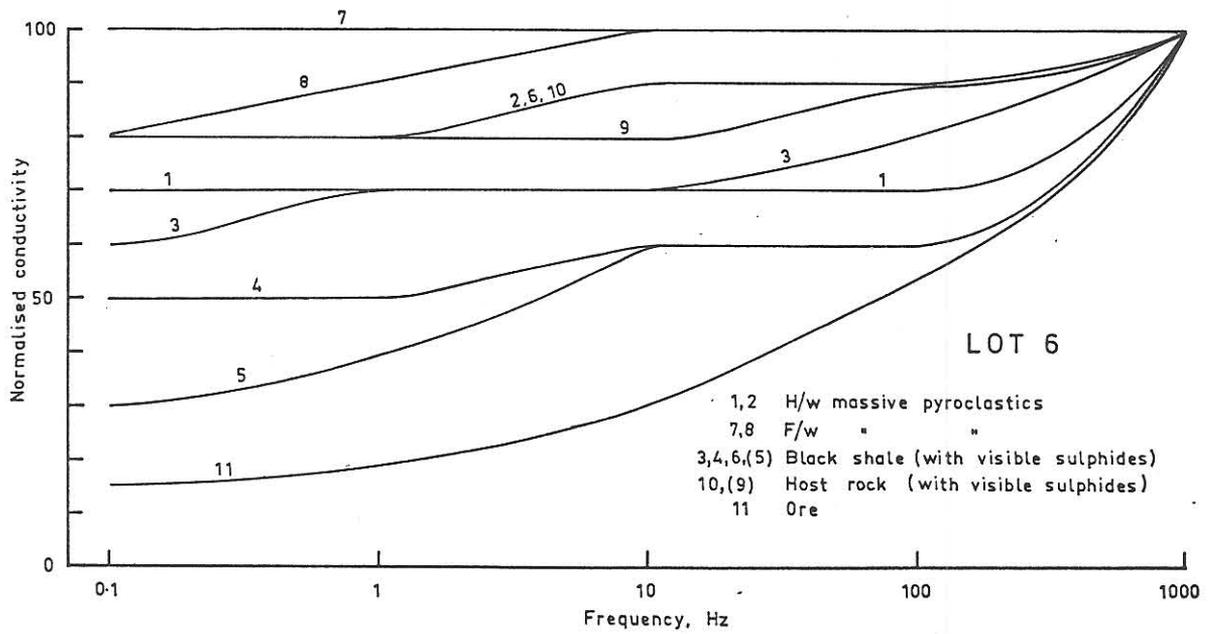
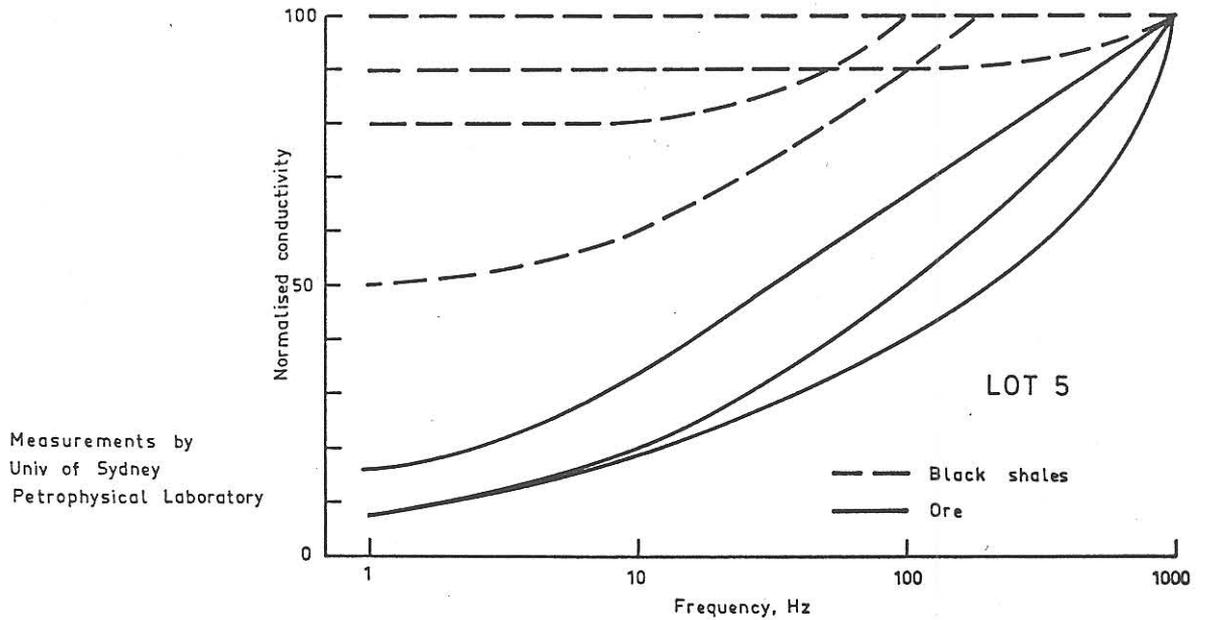
MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES

ROSEBERY AREA IP  
CONTOURS

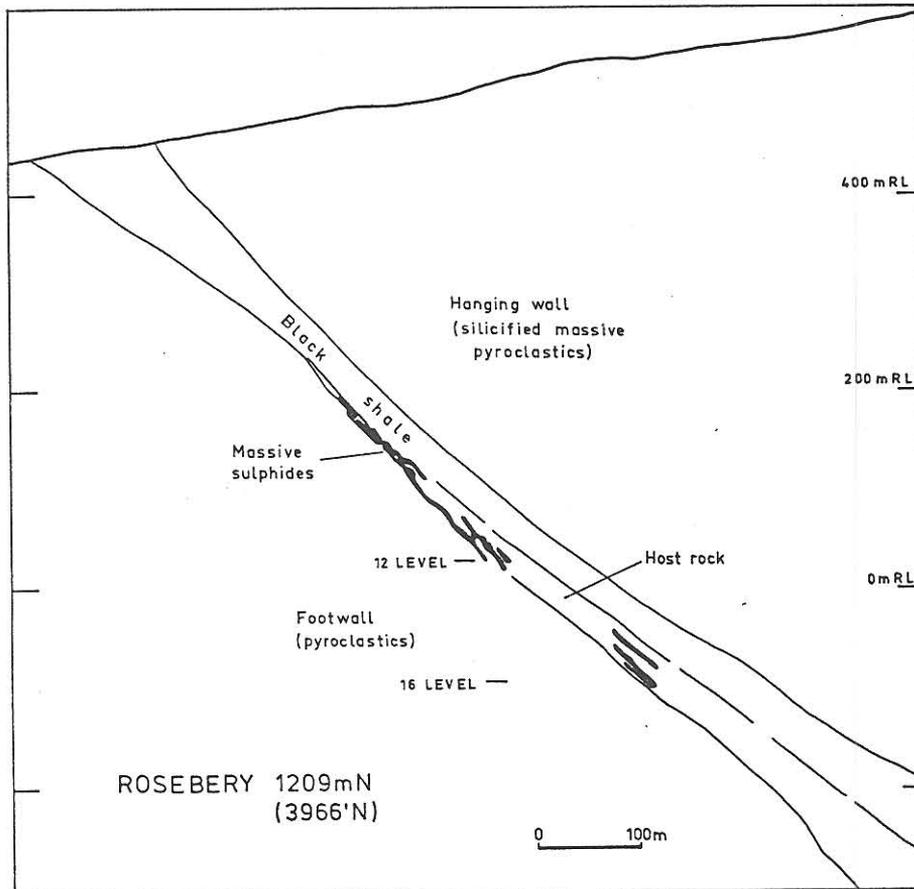
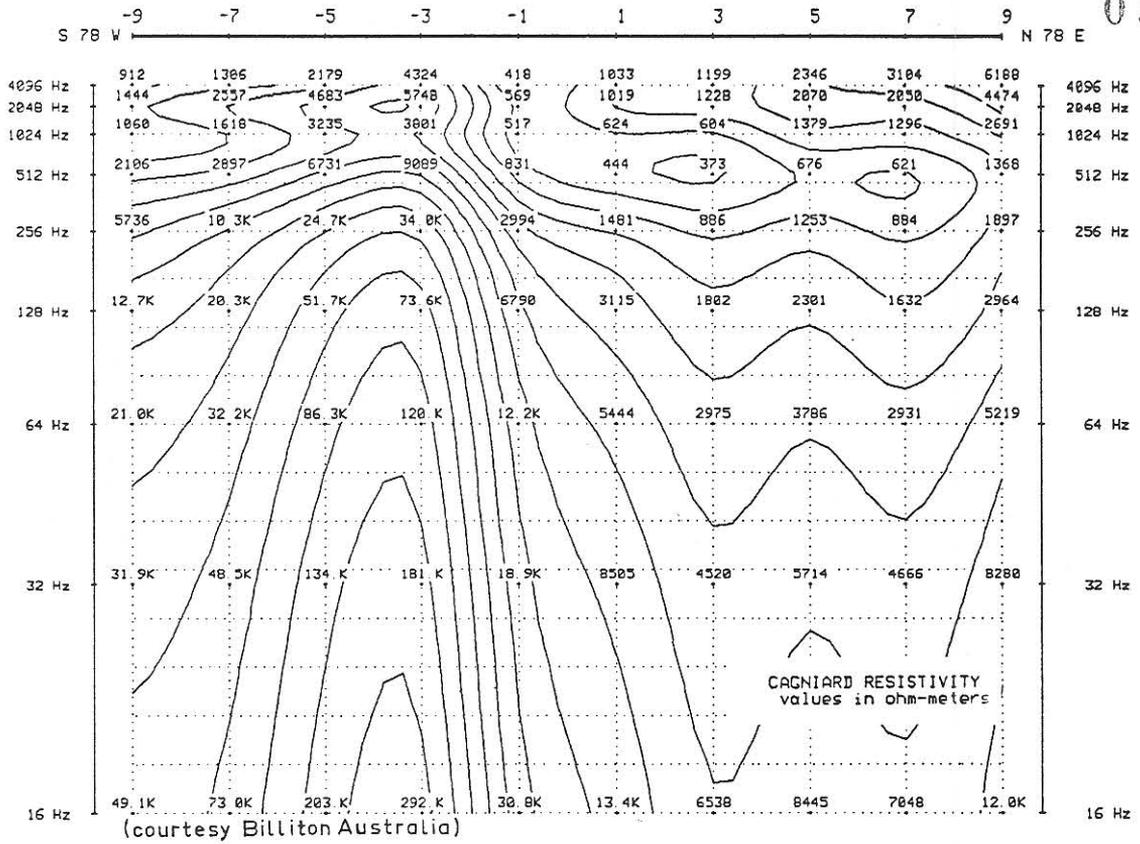
FIGURE 11

MD/MG87/06





MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
ROSEBERY PETROPHYSICAL MEASUREMENTS	
FIGURE 12	MD/MG87/06



MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES

ROSEBERY CSAMT SECTION

FIGURE 13

MD/MG87/06

which is possibly atypically conductive. That is, a good EM response to the sulphide deposit would be expected. However, it might not be resolved from the black shales, but could be interpreted only as a wider and more conductive section in the long anomalous zone over the black shales. If, at Rosebery, there had been a total, rather than partial, coverage of glacial material, such an interpretation would not have been easily checked by surface mapping or geochemistry. A gravity survey would be affected by the uneven basement topography beneath the glacials, but would certainly have located the subcropping Rosebery lode.

Figure 13 shows the results of a CSAMT profile across the Rosebery deposit. The general structure is well defined but at this stage\* it is not altogether certain how much of the response is due to black shales.

The limited petrophysical measurements listed in Table 1 indicate that the sulphides are not magnetic. Burton (1975) states that magnetite, with pyrrhotite and gold are "sporadically distributed rare minerals". However the black shales can be magnetic (Iiliff, pers. comm.)

#### MOUNT LYELL

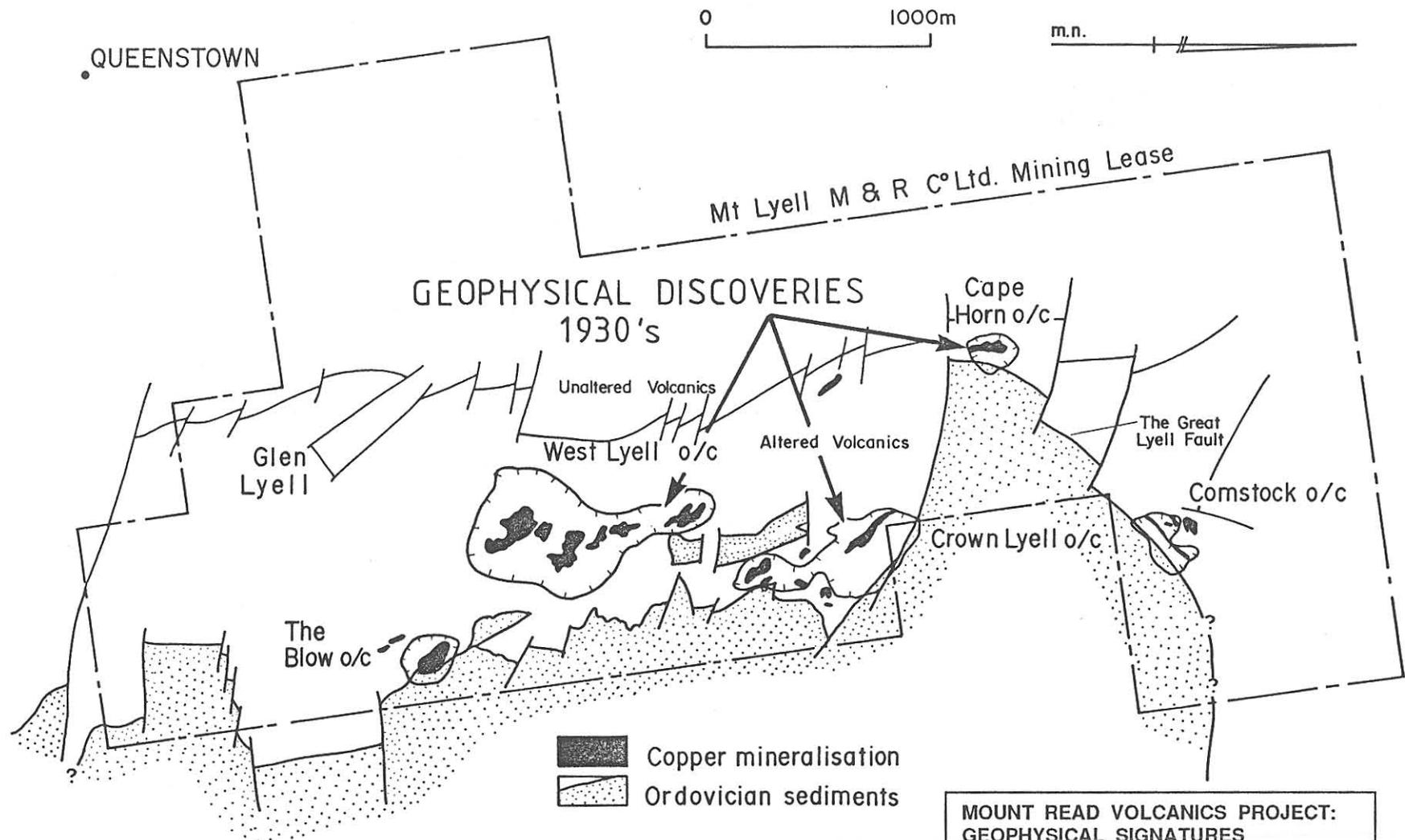
The Mount Lyell field is another long-established mining centre, dating back to the discovery of 'The Blow' in 1883. However unlike Rosebery, geophysics has played an important part in the area's development.

Although sharing the same host rocks, the Mount Read Volcanics, the Mount Lyell deposits are quite different from the massive polymetallic ores of Hellyer, Que River or Rosebery. At Mount Lyell, a number of separate copper-only deposits (with some gold credits) have been mined over an area of approximately 5 sq km (Figure 14). The bulk of the ore has been low-grade, disseminated sulphide. The field is bounded on the western side by relatively unaltered volcanics and on the eastern side by a steeply dipping faulted contact with Ordovician sediments and has yielded more than 100 million tonnes of ore averaging about 1.2% Cu. The various styles of mineralisation on the field have been summarised by Walshe and Solomon (1981). They are:-

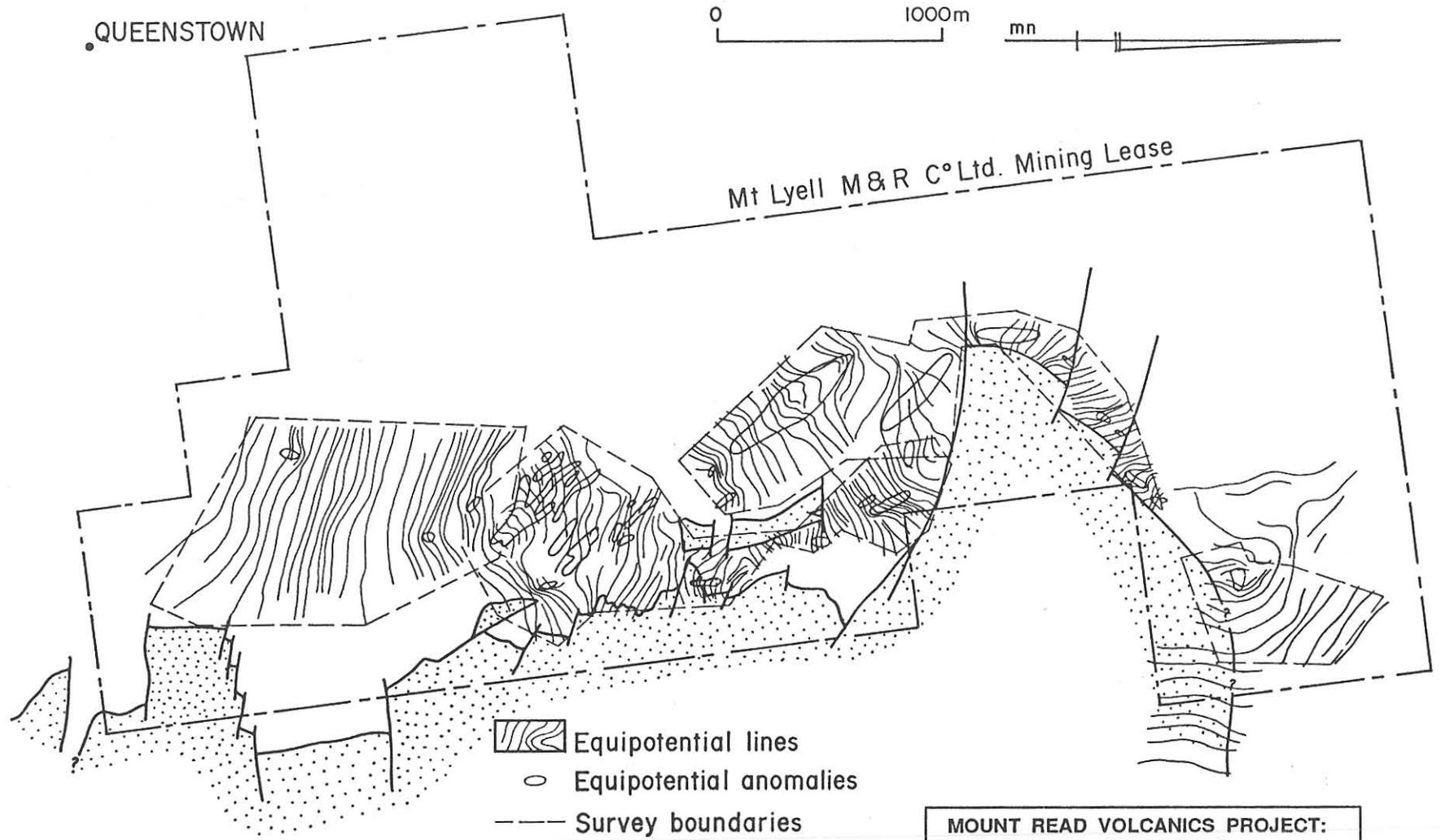
- (1) disseminated pyrite-chalcopyrite; e.g. Prince Lyell.
- (2) bornite-chalcopyrite; e.g. North Lyell.
- (3) massive pyrite-chalcopyrite; e.g. The Blow.
- (4) massive stratiform pyrite-galena-sphalerite-chalcopyrite; e.g. Tasman Lyell.

Walsh and Solomon (1981) cite some 15 separate ore bodies. Geophysically, these may be broadly classified into two types: massive

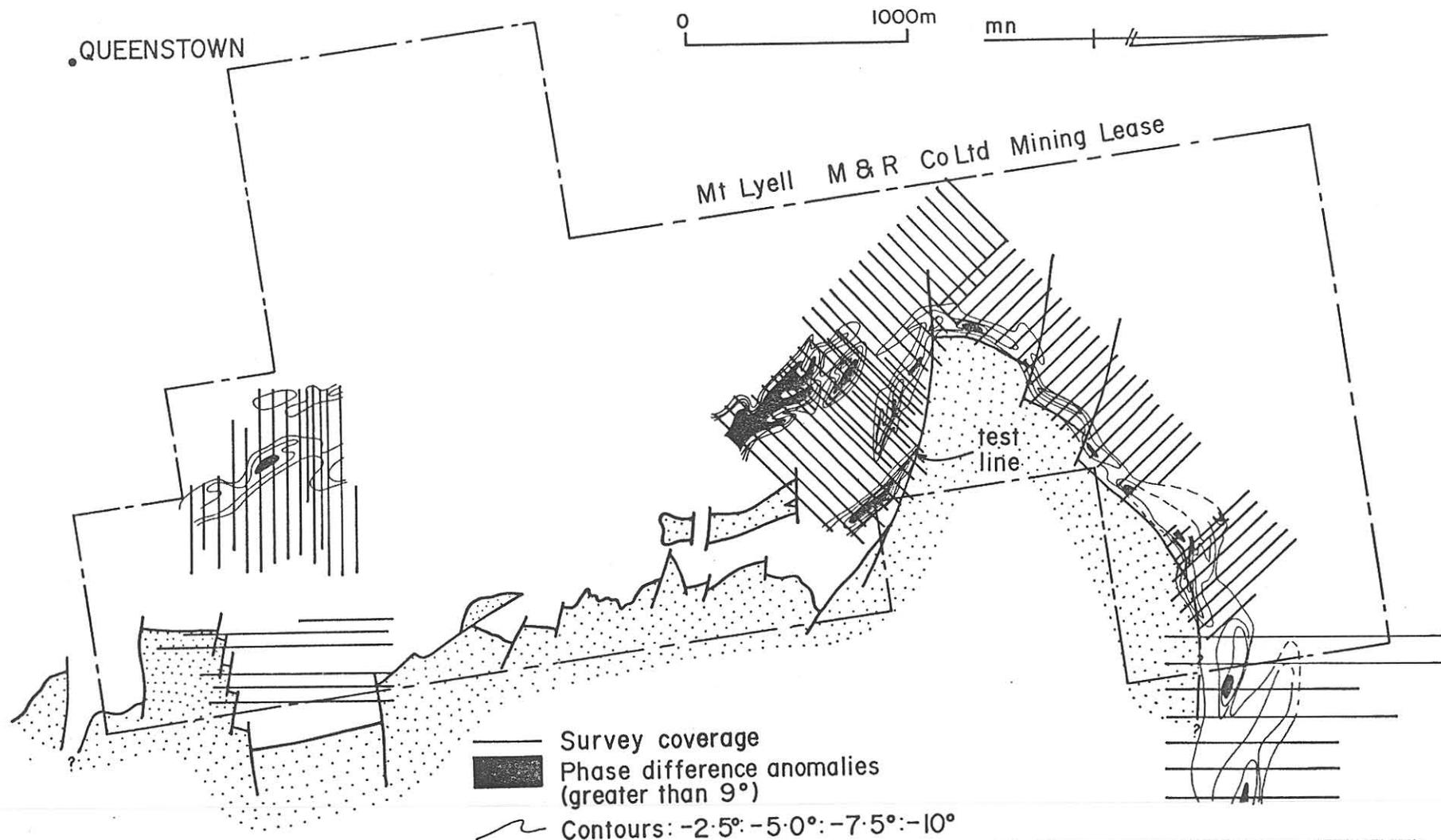
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\* This data was taken in the 'near field'. Further processing to remove this effect should improve the interpretation.



MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
MT LYELL MINERALISATION	
FIGURE 14	MD/MG87/06



MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
MT LYELL EQUIPOTENTIAL CONTOURS	
FIGURE 15	MD/MG87/06

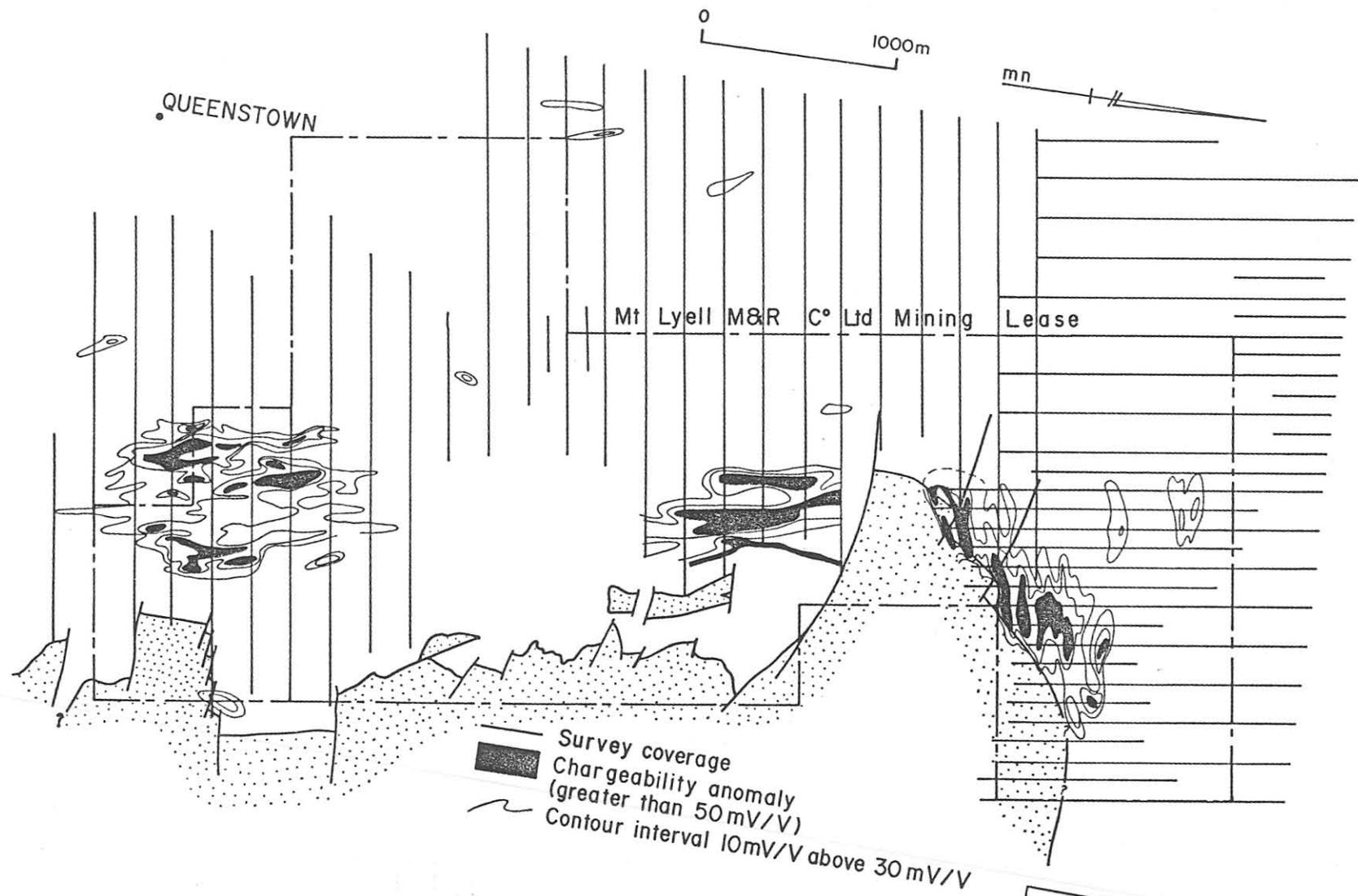


MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES

MT LYELL TURAM PHASE  
DIFFERENCE CONTOURS

FIGURE 16 MD/MG87/06

033037



MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES

MT LYELL GRADIENT ARRAY  
CHARGEABILITY

FIGURE 17

or disseminated sulphides. The massive ores may occur as small, sometimes deep deposits (such as Twelve West which was a 100,000 tonne orebody averaging about 6% copper at a depth of nearly 300m), while the disseminated bodies have generally been near-outcropping, often with a pyritic halo. (The largest of this type, the Prince Lyell, is 360m long (at the 0.8% Cu cut off), 10 to 90m wide and more than 800m down dip.) Originally worked by several separate companies, since 1933 the field has been worked by one concern, the Mount Lyell Mining and Railway Company.

With some gaps, geophysical surveys have been carried out at Mount Lyell since the mid 1930's up to the present day. Some of the earliest surveys were the most successful and a brief history is given here. Between 1934 and 1938 a considerable area was covered by the Equipotential (EP) method (Figure 15)\*. This electrical technique, which injects current directly into the ground (see Edge and Laby (1931)), outlined all of the known ore bodies and discovered three new ones. However, only one of these, The Blazey, was recognised at the time: the other two, Crown 3 and Cape Horn, were intersected by drill holes targeted on anomalies from later Turam and IP surveys. The Turam, which used a grounded wire source, was carried out in the 1950's and 1960's by the BMR (e.g., Rowston, 1957 and 1959; Williams, 1965, 1966 and 1967) and was designed to quantify and better locate the EP responses, and in this it was largely successful. The coverage and the phase difference contours are shown in Figure 16. Several IP surveys were carried out by the BMR and contractors in the 1960's and 1970's. These culminated in a gradient array IP survey in 1981 which covered most of the mine lease. The coverage and stronger anomalies (above 30mv/v) from this survey are shown in Figure 17. None of the IP surveys added much to the earlier work and all responded to the disseminated pyrite which is distributed throughout the field. To obtain spectral IP (Cole-Cole) parameters, underground in situ surveys were carried out within the Prince Lyell orebody and its alteration halo. The results are presented in Volume II of this report and show that the distribution of values is quite different from the massive volcanogenic sulphides typified by Que River and Rosebery.

The above descriptions of Mount Lyell have dealt solely with the electrical properties. Whilst the bulk of the surveys have been electrical or electromagnetic, the BMR and other investigators have tested the application of potential field methods. Reid (1975) noted that magnetite occurs as an accessory mineral, however it appears to be sporadic: the magnetic susceptibilities listed in Table 1 show only a few magnetic samples. The BMR found that the magnetic method was not diagnostic for ore (Bishop, 1982). However, Leaman (1987) has recognised responses to mineralisation in the regional aeromagnetic data and a

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\* E.L. Blazey and G.A. Douglas carried out these surveys. Their original maps are held by Mount Lyell and some of what is presumed to be their work is included in Bishop (1982).

trial Dighem survey recorded a 200nt magnetic anomaly over the West Lyell open cut\* (Bishop, 1981). Some early gravity work was carried out by Rio Tinto and this showed a strong negative gradient towards the Ordovician sediments. By graphical removal of the regional, Boniwell and McKenzie (1961) obtained a positive residual on the western side of the fault indicating "excess mass ... inherent to the sulphide incidence and its down dip distribution". The gravity data base has been recently upgraded as part of the Mount Read Volcanics Project and an interpretation using this data is given by Leaman (1987). Some dry bulk densities representative of the Mount Lyell ores are also listed in Table 1.

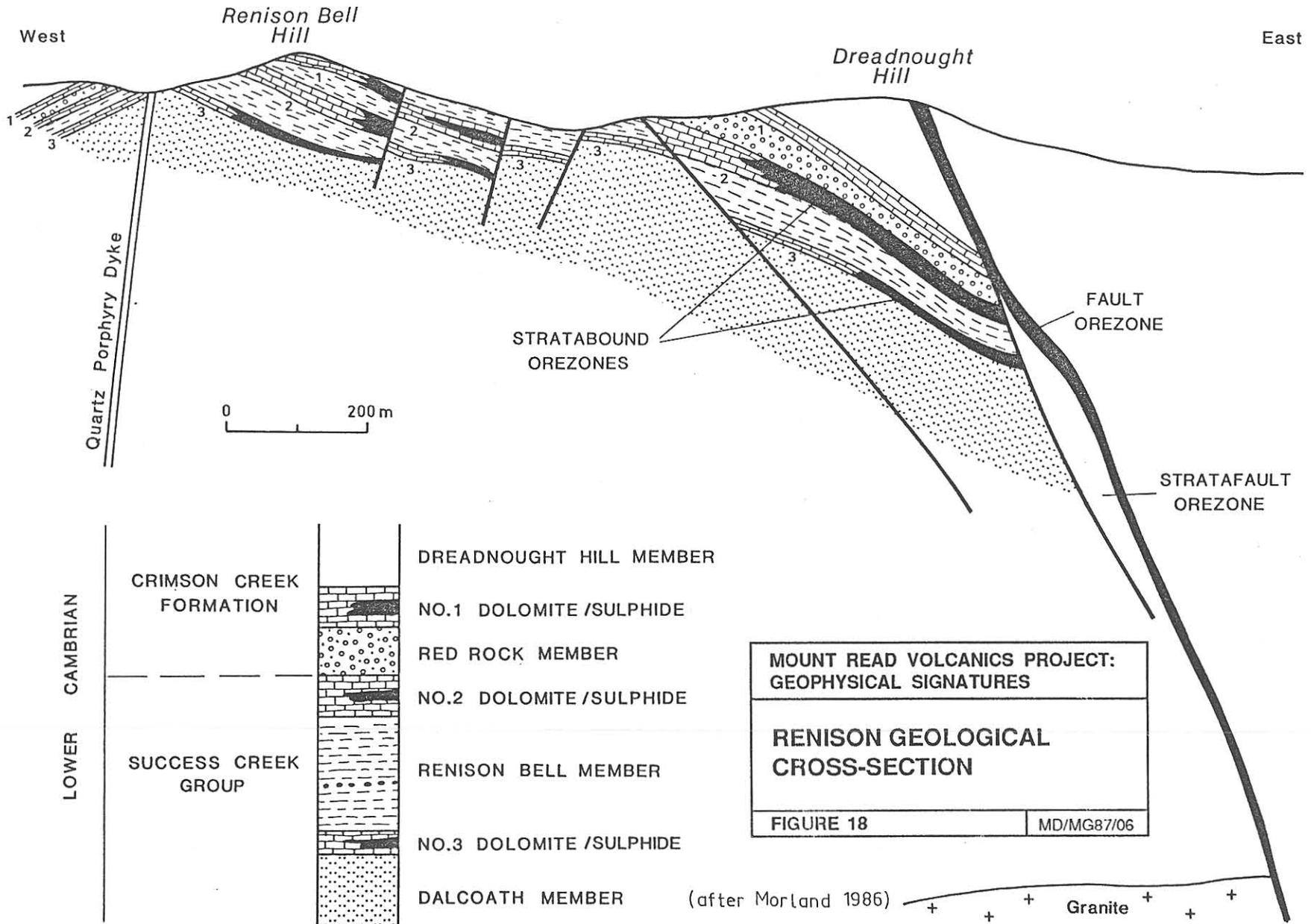
#### RENISON BELL

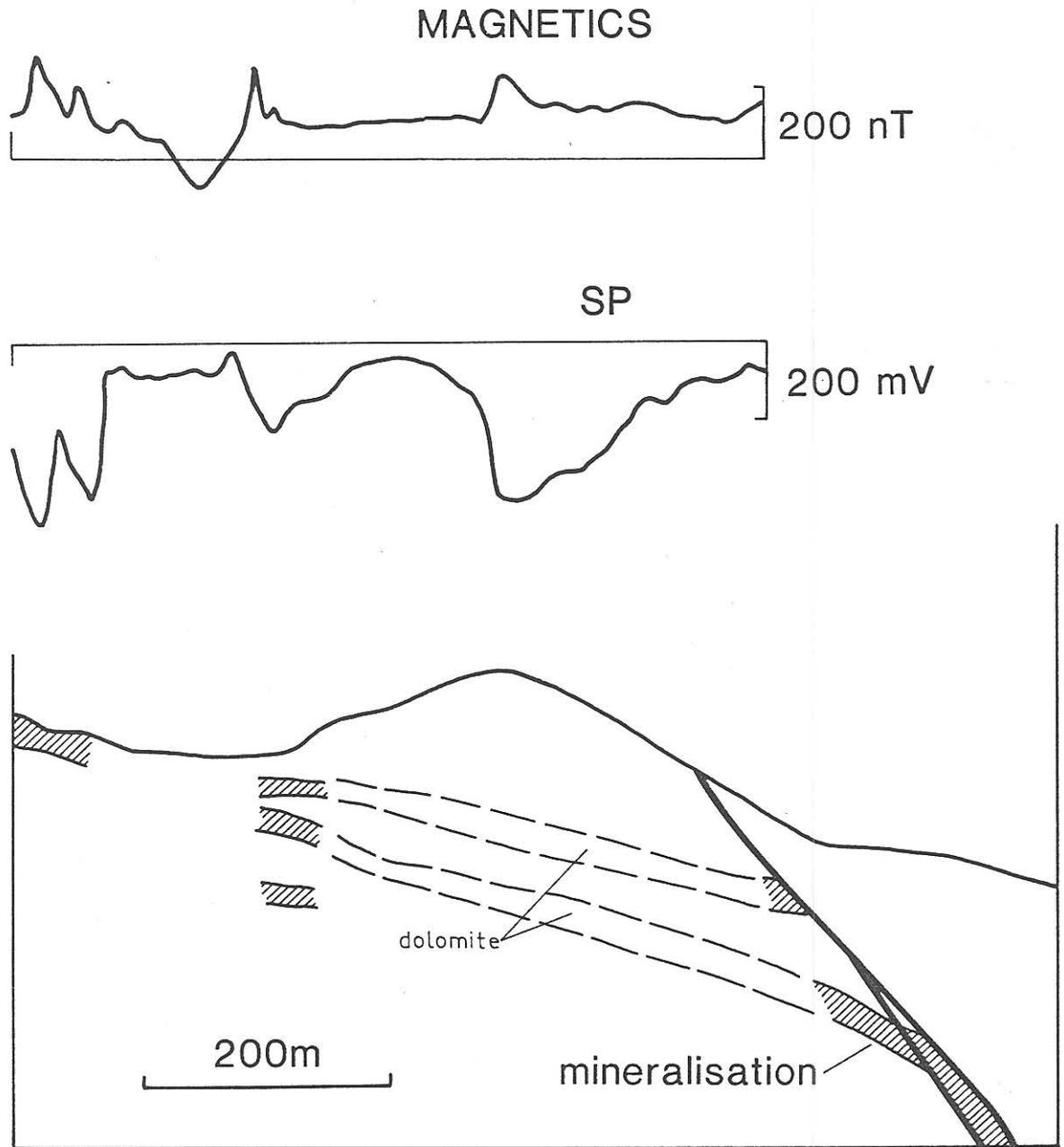
The Renison Bell tin field was discovered in the 1890's and is one of the world's largest sources of primary tin. Initially only alluvial tin and oxidised ore were mined, but with the successful separation of sulphides in the 1930's, the main tin deposits became economic. These are broadly of two types: (1) flat-lying stratabound ore replacing calcareous beds in Cambrian sediments and (2) steeply-dipping fault-bound ore (see Figure 18). The ore is cassiterite in association with massive pyrrhotite. It is strongly magnetic, highly conductive and provides an excellent geophysical target. Despite this, geophysics has been used here with only varying success and the history of its application is instructive.

The first geophysical surveys were carried out by the IGES in the late 1920's to determine the boundaries of the sulphide bodies. They carried out EP, Potential Ratio (a fore-runner of Turam), EM, SP and magnetic surveys. The EP method did not function in the most conductive areas (its success at Lyell was perhaps due to that field's resistive ground), but the EM was effective: Edge and Laby (1931) noting that at Renison, the minimum readings were higher than the normal upper limit of their equipment. The IGES also tried to conduct what must have been one of the first applications of a mise-a-la masse survey; however, the injected DC current into an exposed face was swamped by natural potentials. Measurements of these self potentials revealed strong anomalies to -500mv. Following the location of a number of conductors by EM and SP, the IGES surveyed the area with a magnetometer, recording vertical field anomalies between -3000 and +6000nt. The IGES judged magnetics the most useful method, particularly when used in conjunction with other (electrical) methods. Most of the IGES' drill hole recommendations were successful, either at the time or by later (deeper) re-drilling (e.g., Loftus-Hills, 1957 and Gilfillan, 1961).

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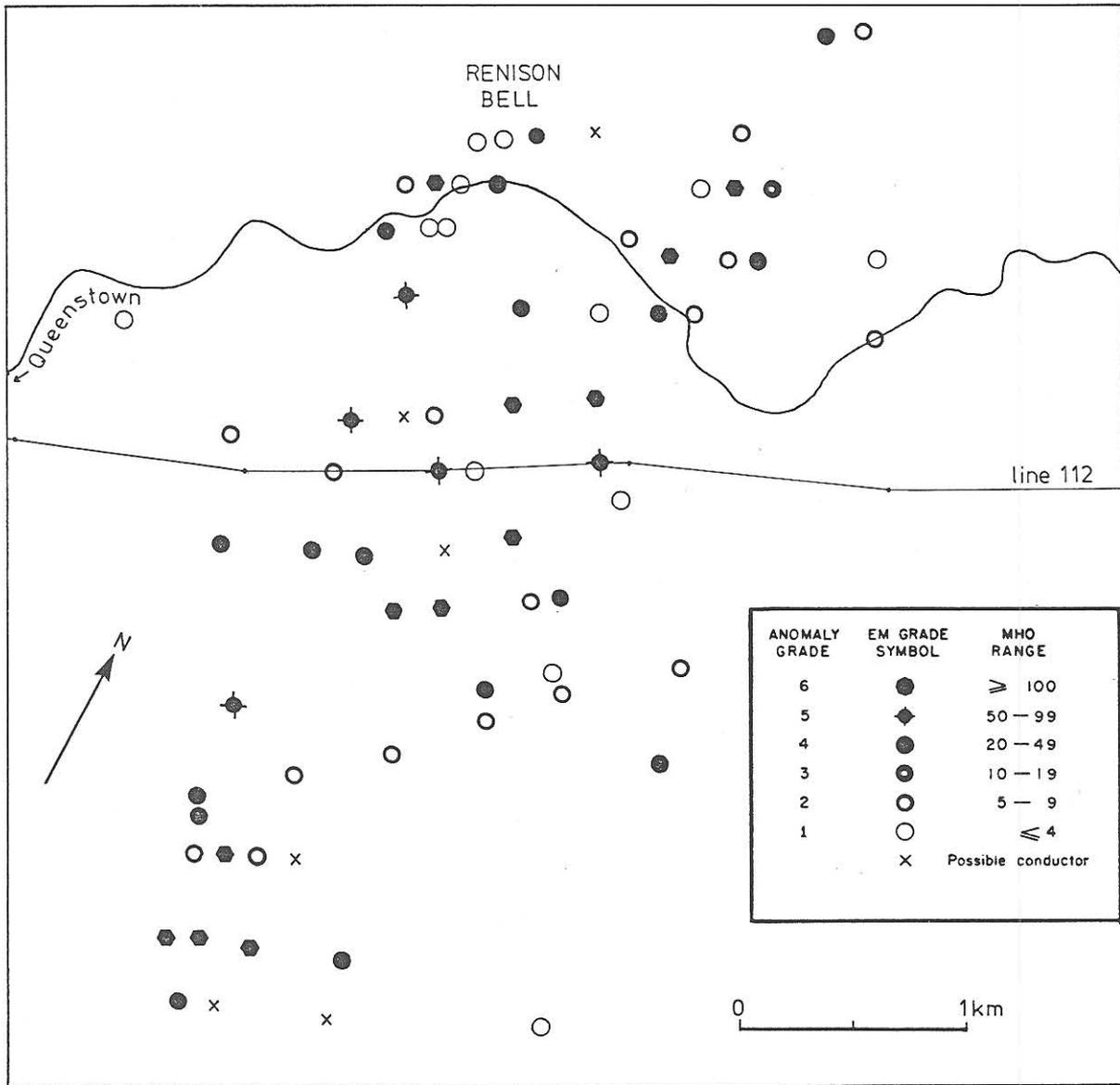
\* The Dighem EM data over the mine was considerably degraded by the noisy electrical environment and the results have not been presented here.





MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
RENISON MAGNETIC AND SP ANOMALIES	
FIGURE 19	MD/MG87/06



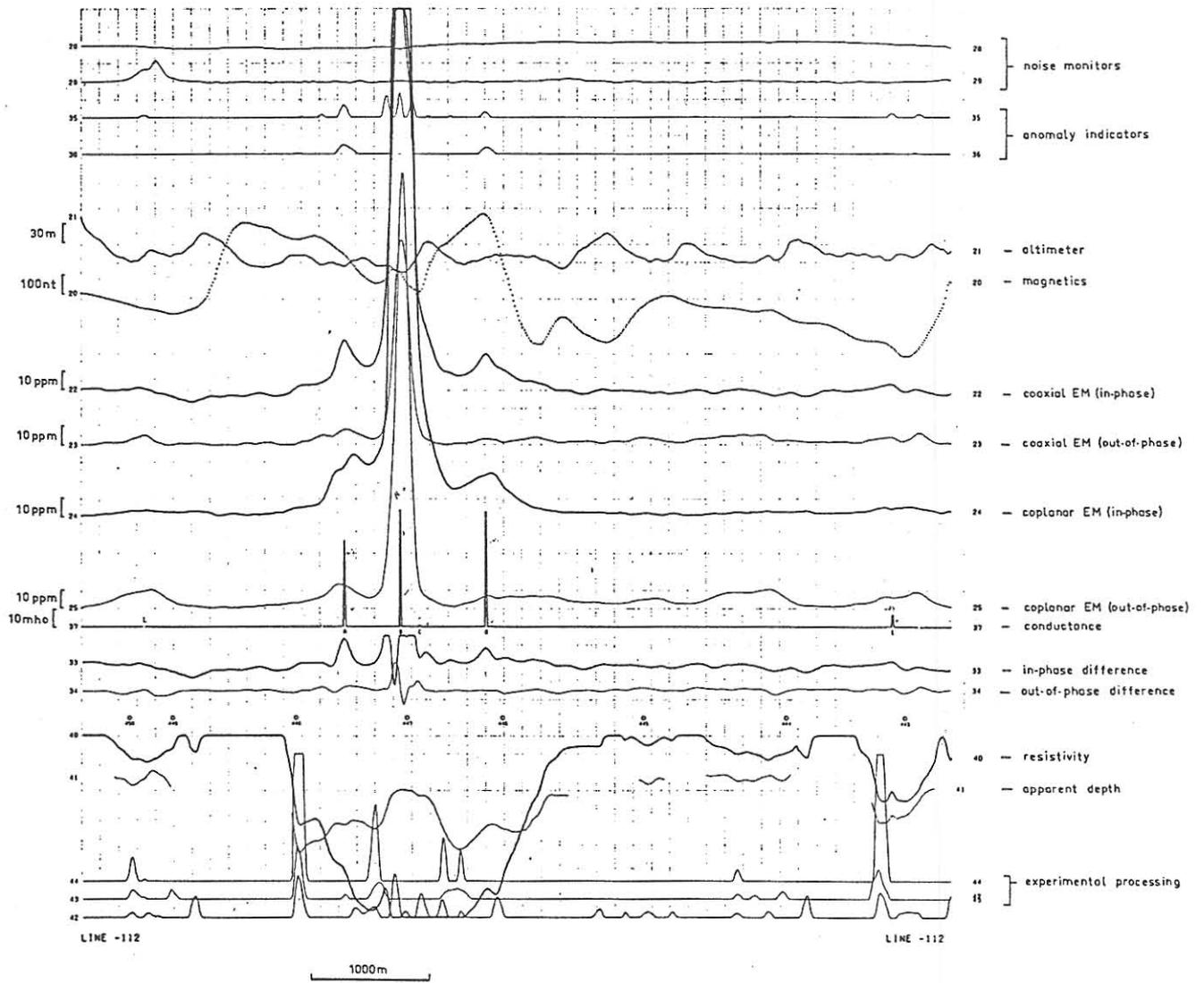


**MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES**

**RENISON DIGHEM EM  
ANOMALIES PLAN**

FIGURE 21

MD/MG87/06

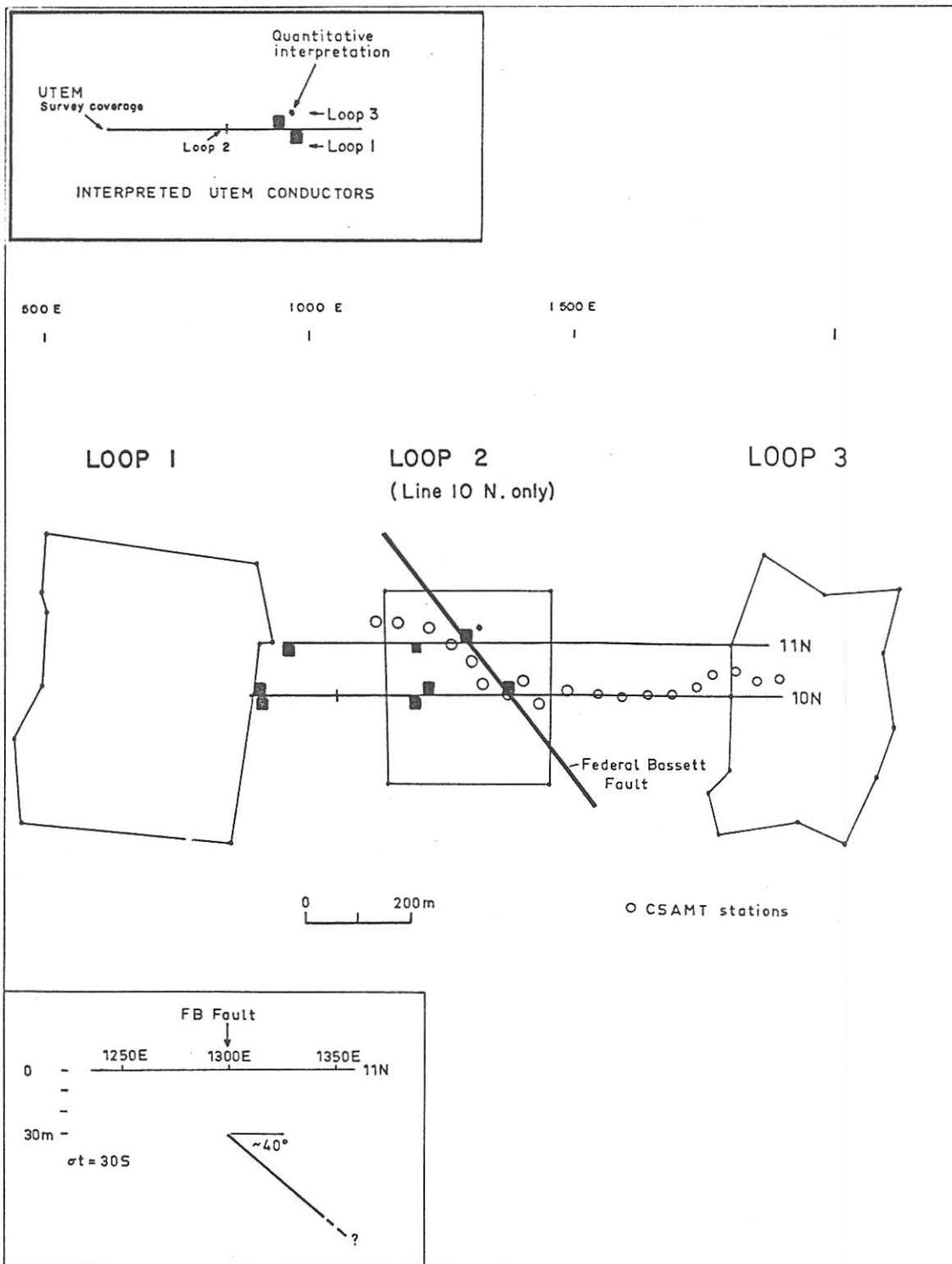


MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
RENISON DIGHEM PROFILE	
FIGURE 22	MD/MG87/06

The full potential of the Renison deposits was not appreciated until the early 1960's following a systematic exploration program. Geophysics was used in this program, but the interpretations were apparently of little assistance. The BMR conducted magnetic and SP surveys between 1950 and 1953 and the results have been compiled by Davidson et al (1957). A total of 27 anomalies were defined; most had magnetic and SP responses, but some were confined to one method. The magnetic anomalies had magnitudes of several thousands of gammas and the SP, several hundreds of millivolts (e.g. Figure 19). These were apparently interpreted as being due to steeply dipping tabular bodies, whereas the mineralisation mostly occurred as a series of faulted flat-lying sills (McGhie et al, 1960). It has since been established that remanence is important at Renison (Clark, 1984) and clearly the responses from a number of faulted, overlapping bodies would be complex. Whilst the advent of computers has made the problem more tractable, it is unlikely that 3 or even 2 overlapping sills could be effectively interpreted without a considerable geological input. Since the 1960's, exploration around the immediate mine area has been diamond drilling and geophysics played no further role until deep penetrating DHEM systems became available.

In 1985-86, a program of DHEM surveys was carried out which showed that the technique could effectively investigate the ground around the drill holes at depths approaching 1000m below the surface. Figure 20 shows the results from one loop of a five loop Sirotem survey of DDH S1182. The feature of most interest is the broad negative response at late times (channels 23-28), centred at 540m. Such a large response at such late times reflects the extremely conductive mineralisation at Renison. This anomaly has been interpreted as being due to an off-hole conductor with its centre about 100m away from the hole (Bishop et al, 1987).

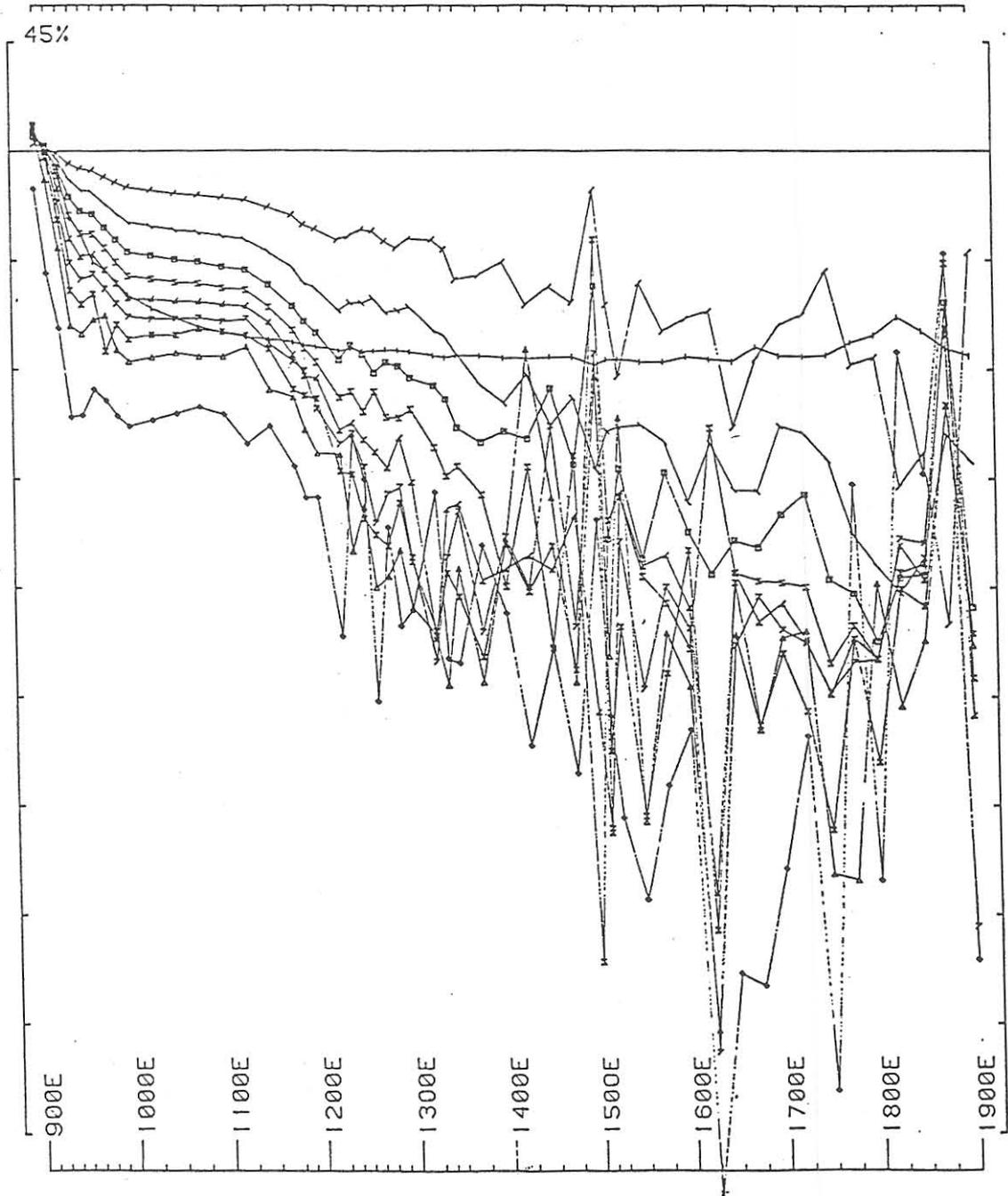
Because of its high conductivity, Renison has been tested by most, if not all, of the airborne EM systems which have been used in Australia. All surveys gave strong anomalies. Figure 21 shows the numerous high-conductance EM responses recorded over the mine area by a test Dighem survey and an example of the large amplitudes obtained is shown in Figure 22. Because of its high conductance and buried deposits, Renison was also included in the areas to be surveyed for the Mount Read Volcanics Project. A UTEM survey, using 3 loops for two traverses, was carried out over some deep mineralisation (Figure 23). Both lines were read from the two end loops (1 & 3) and the southern line, 10N, was also read using the middle loop to produce a three-fold overlap, thus giving enough data to try Lamontagne Geophysics' image processing (Macnae and Lamontagne, 1987). The results for line 10N are given in Figures 24a to g and for line 11N in Figures 25a to f. Figures 24a, 24e, 25a & 25d show the data as it is usually presented: 'continuous channel 1 normalisation' where channel 1 (the last time channel) is assumed to be the background primary field level. However at Renison, conditions are so conductive, that channel 1 is still responding and this type of normalisation is not applicable. Figures 24b, 24f, 25b & 25e show a modified plot where the data has been normalised by the calculated primary field, with much more meaningful results. The point normalised



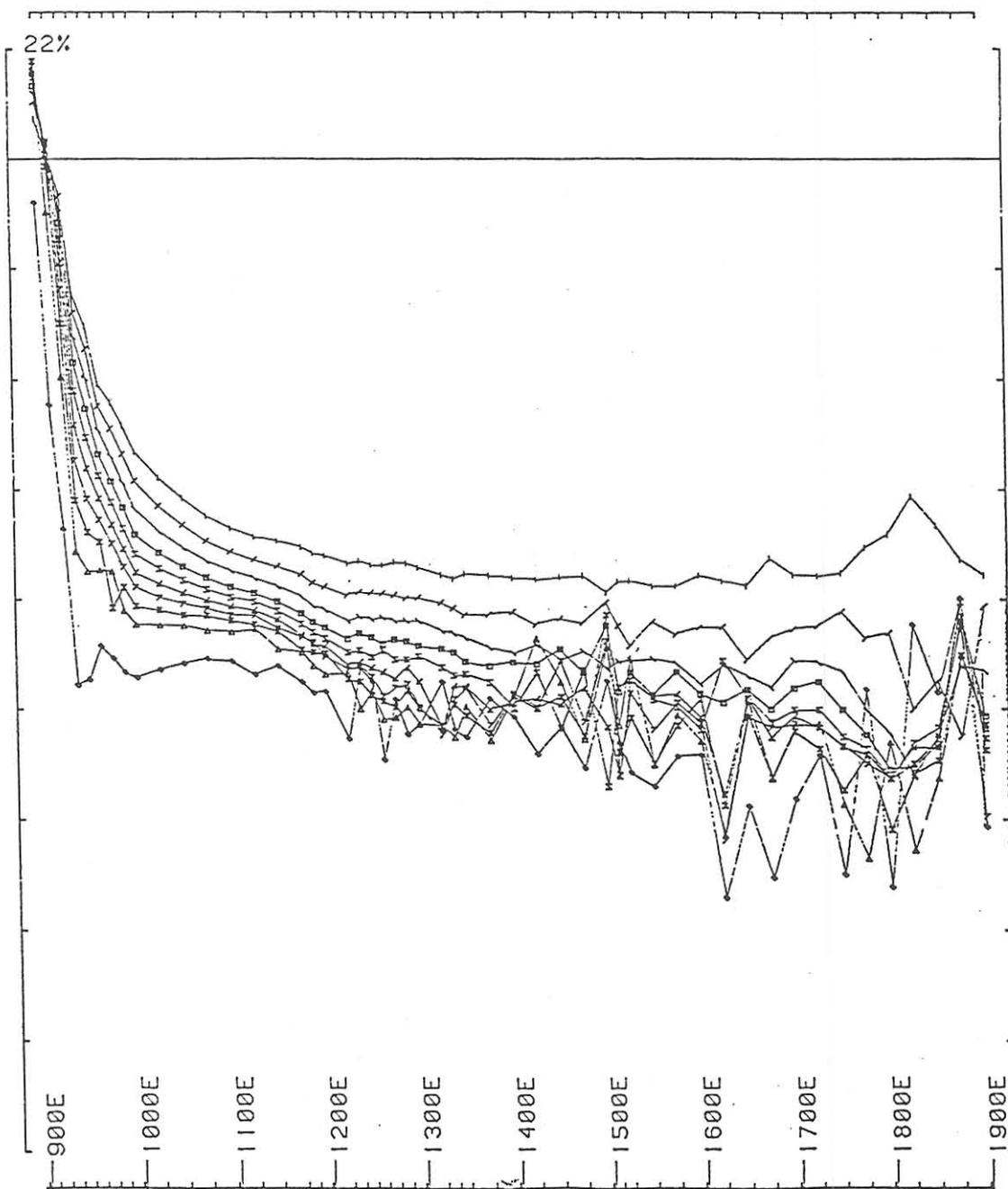
MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES

**UTEM AND CSAMT SURVEY  
LOCATION PLAN**

FIGURE 23 | MD/MG87/06



MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
RENISON UTEM SURVEY: Line 10N, Loop 1, continuous channel 1 normalisation	
FIGURE 24a	MD/MG87/06

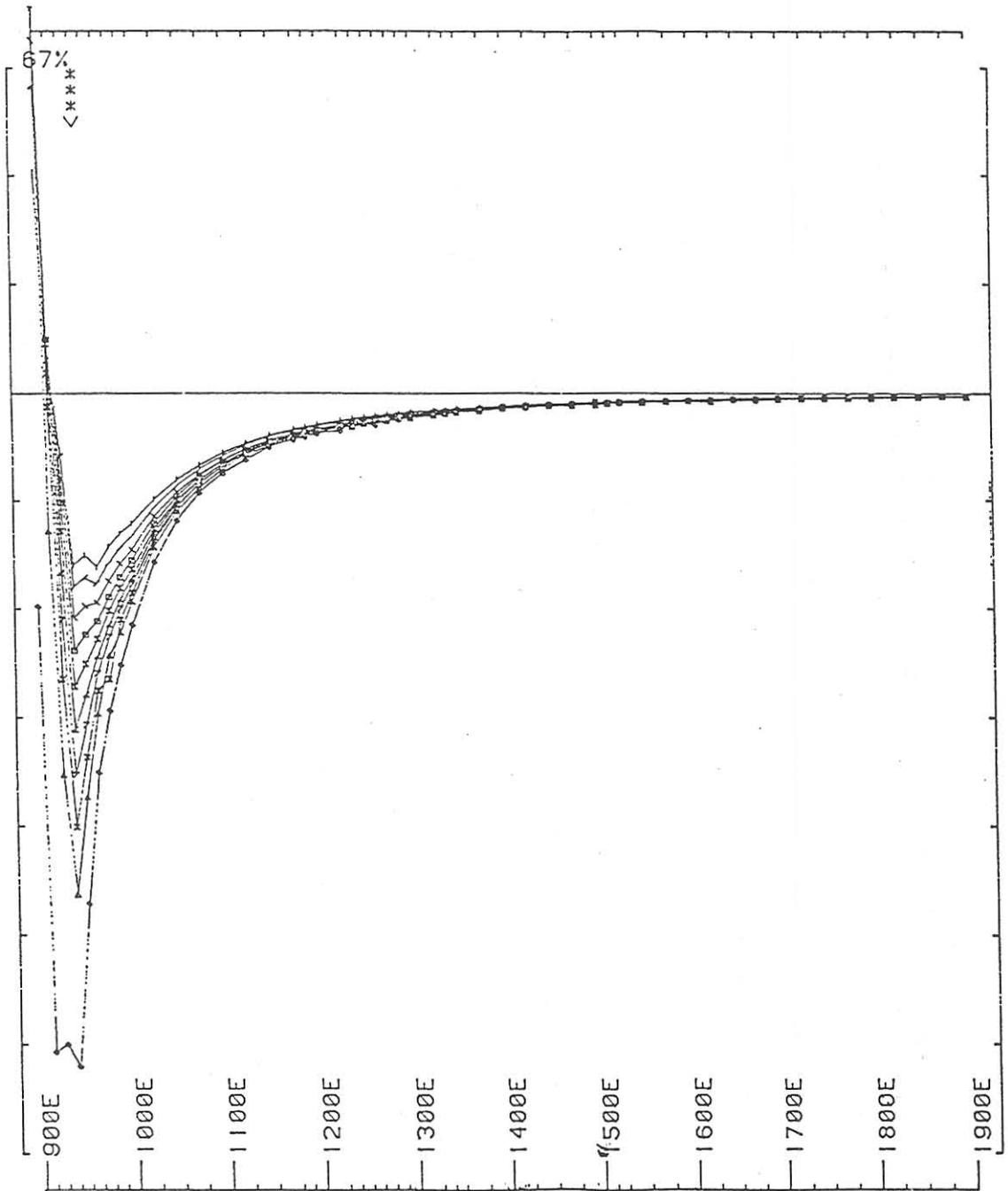


MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES

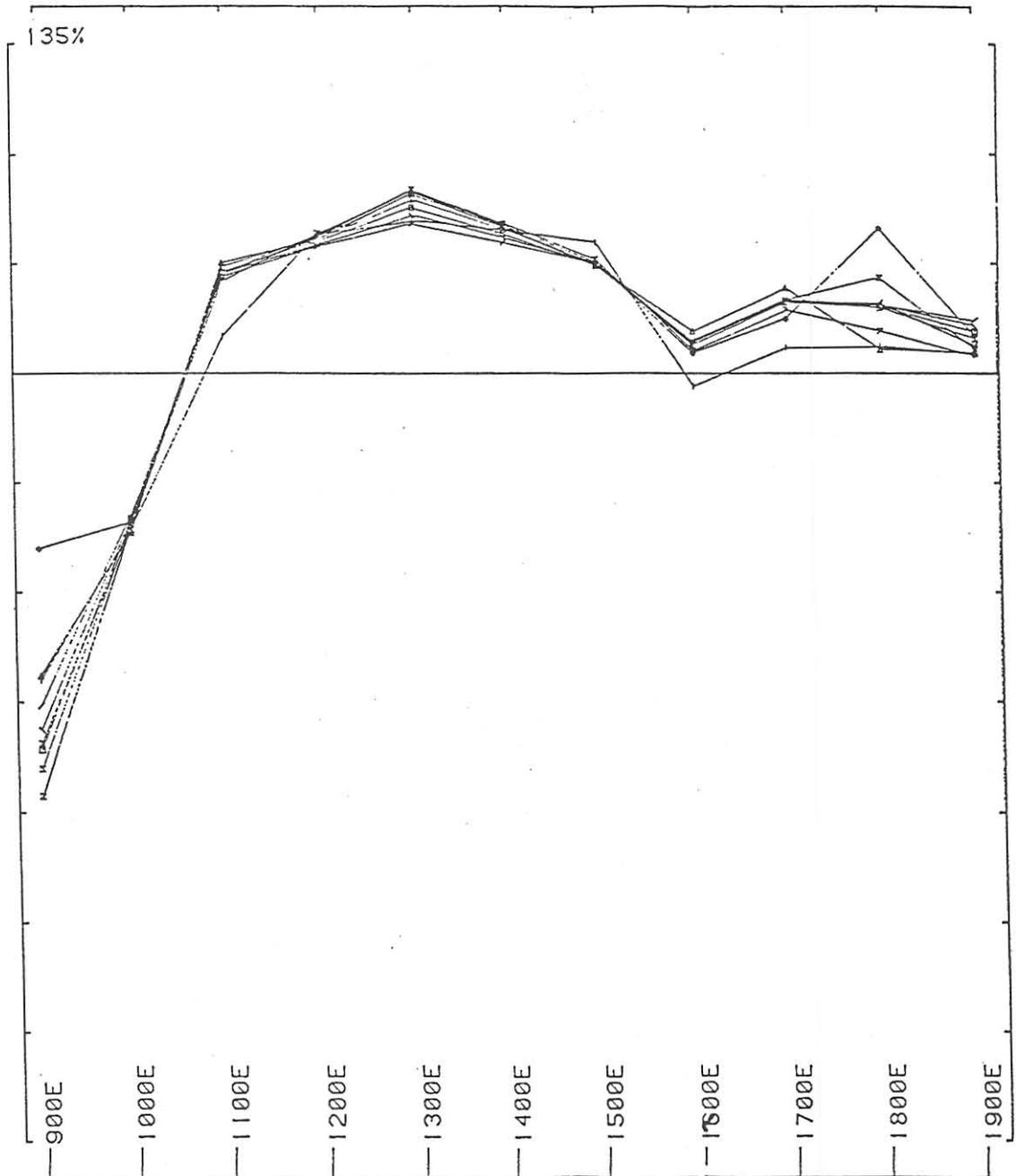
RENISON UTEM SURVEY:  
Line 10N, Loop 1, continuous  
normalisation with theoretical  
primary field)

FIGURE 24b

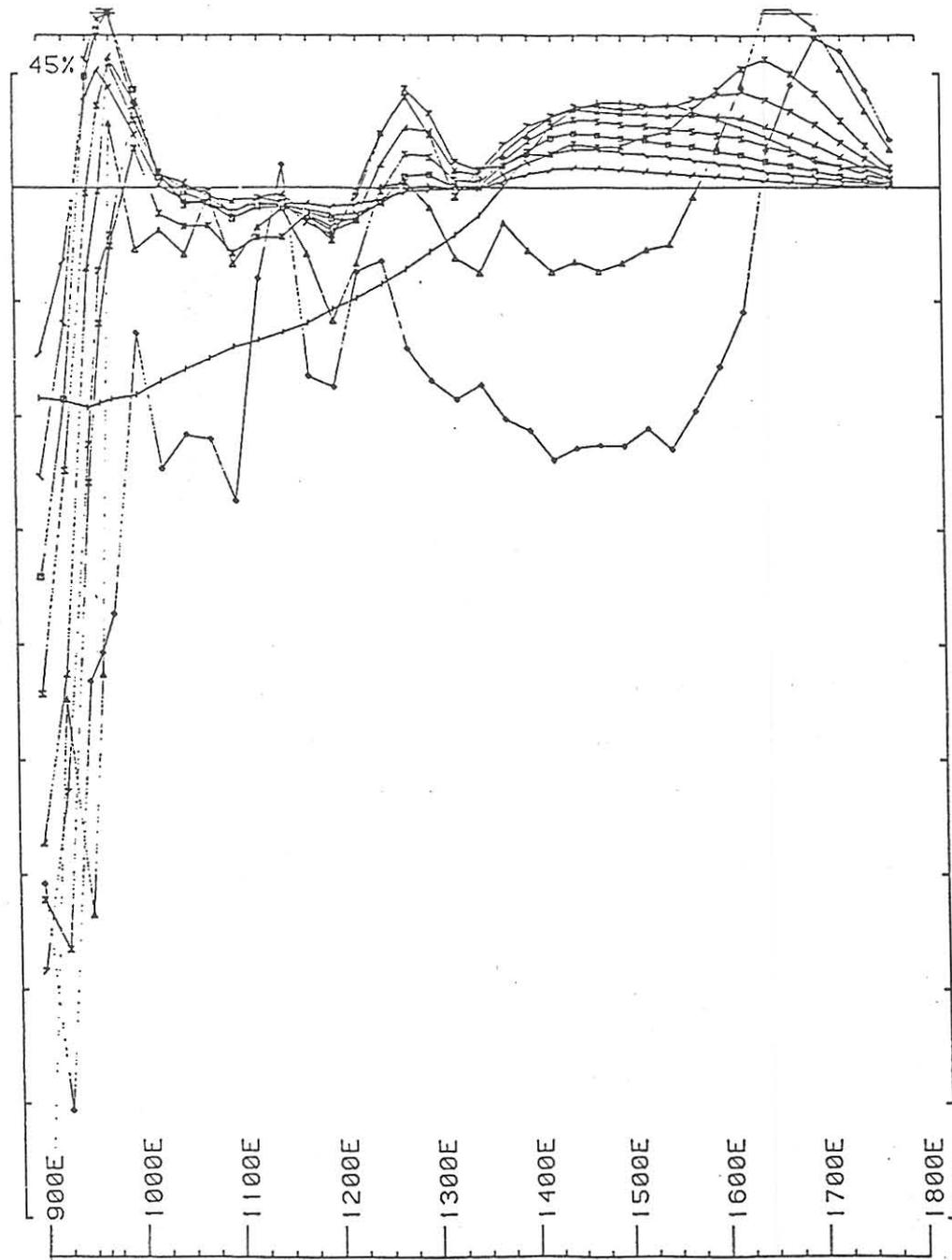
MD/MG87/06



MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
RENISON UTEM SURVEY: Line 10N, Loop 1, point normalisation	
FIGURE 24c	MD/MG87/06



MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
RENISON UTEM SURVEY: Line 10N, Loop 2, continuous normalisation (with theoretical primary field)	
FIGURE 24d	MD/MG87/06

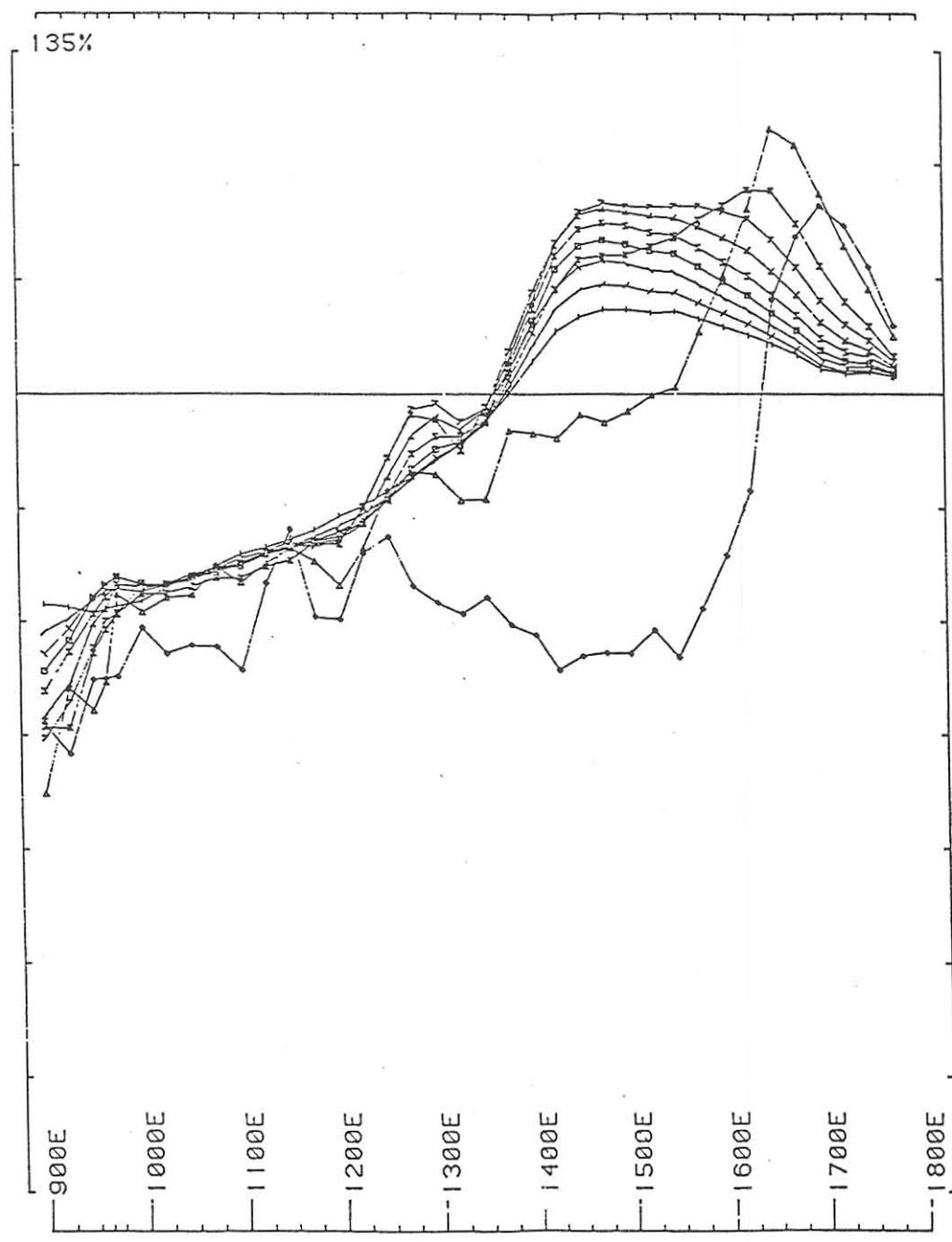


MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES

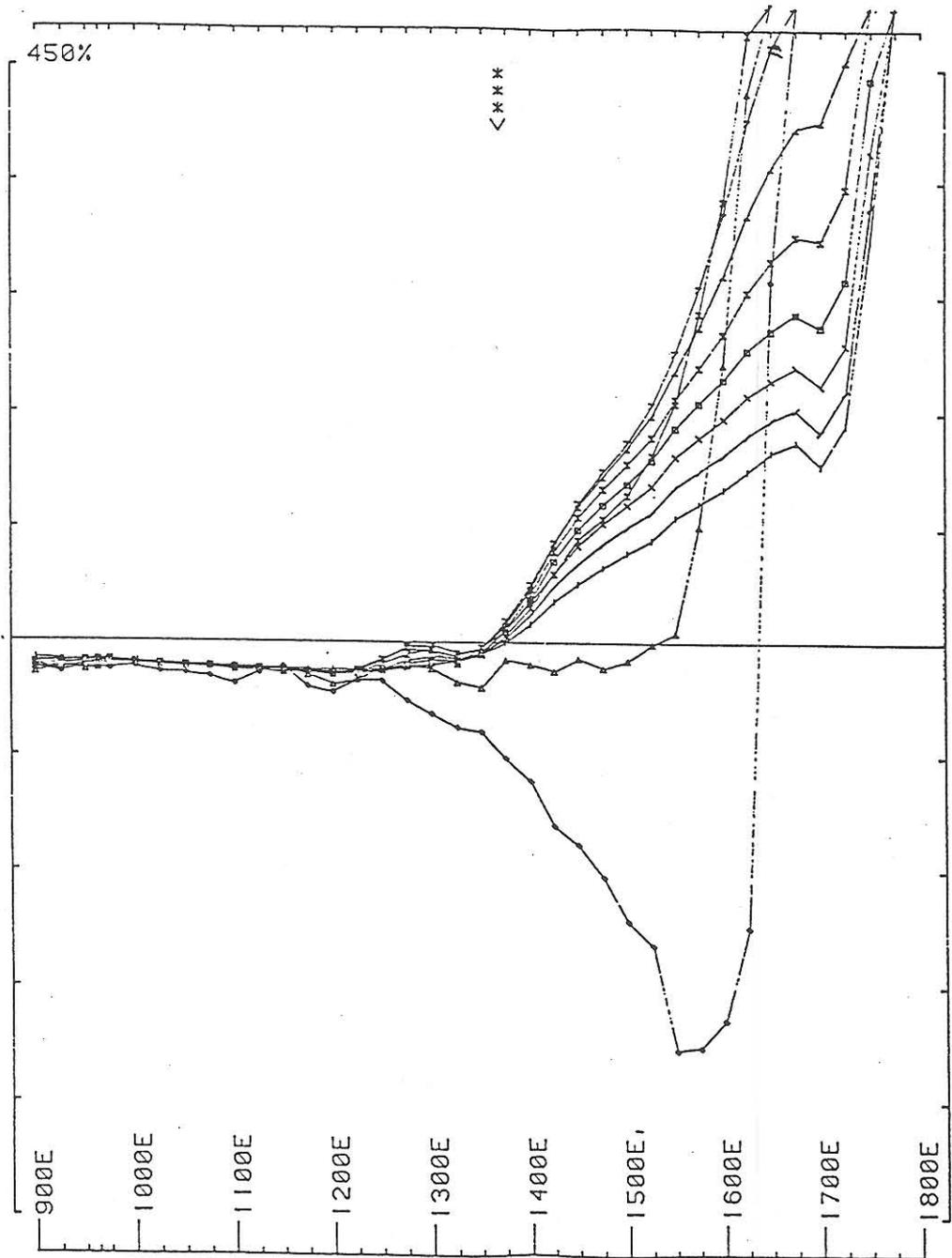
RENISON UTEM SURVEY:  
Line 10N, Loop 3, continuous  
channel 1 normalisation

FIGURE 24e

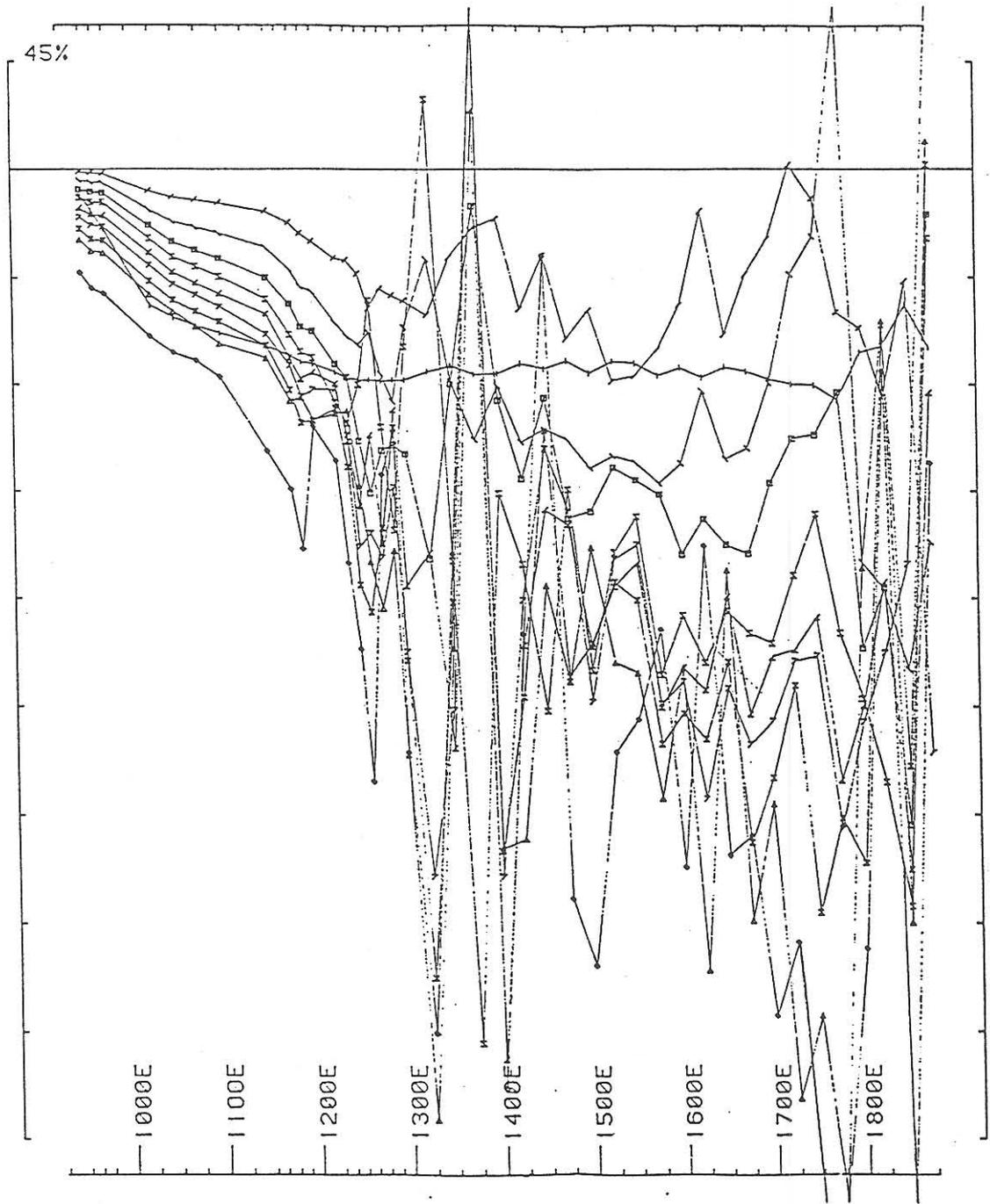
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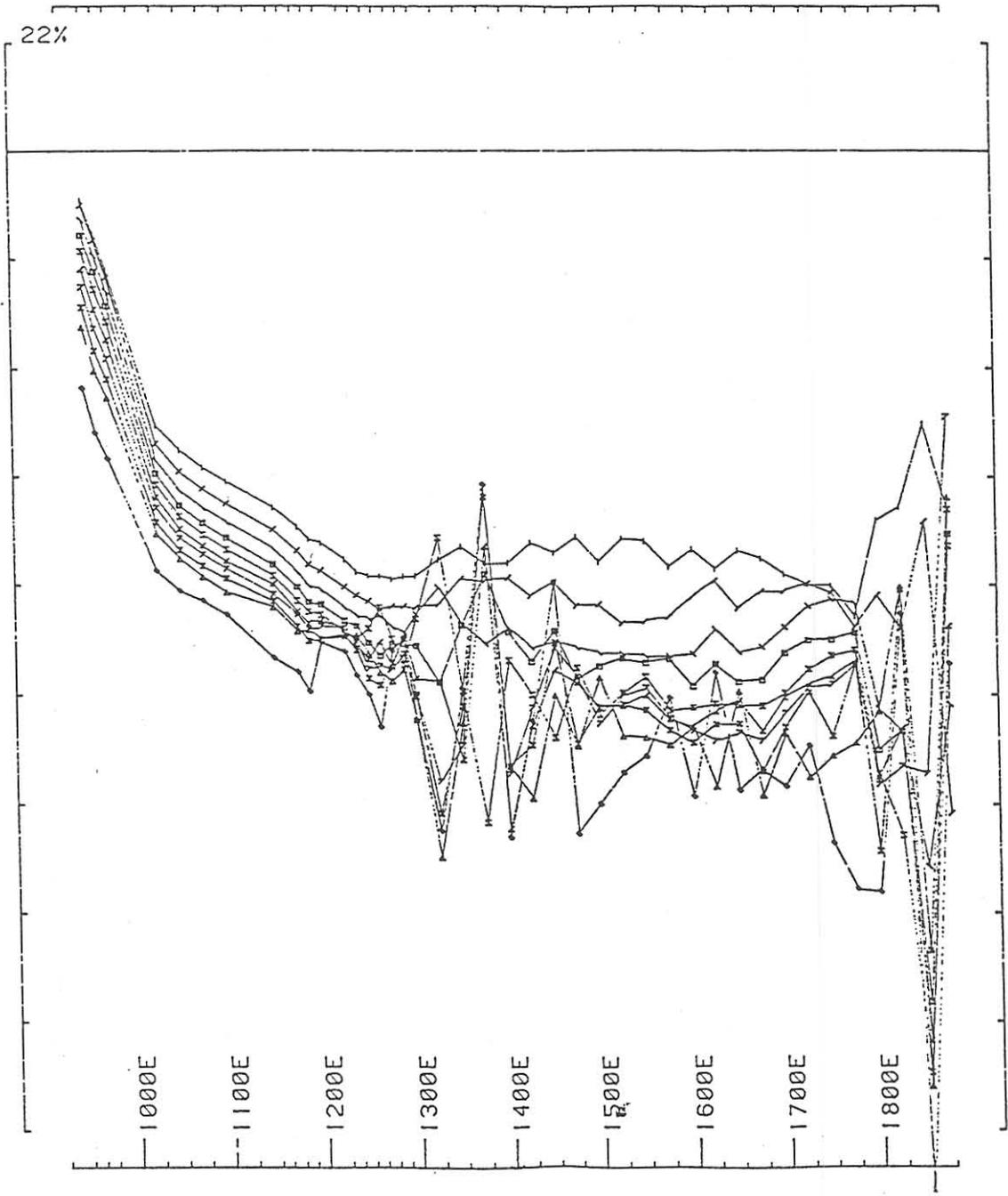
<b>MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES</b>	
<b>RENISON UTEM SURVEY: Line 10N, Loop 3, continuous normalisation (with theoretical primary field)</b>	
<b>FIGURE 24f</b>	<b>MD/MG87/06</b>



MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
RENISON UTEM SURVEY: Line 10N, Loop 3, point normalisation	
FIGURE 24g	MD/MG87/06



<b>MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES</b>	
<b>RENISON UTEM SURVEY: Line 11N, Loop 1, continuous channel 1 normalisation</b>	
<b>FIGURE 25a</b>	<b>MD/MG87/06</b>

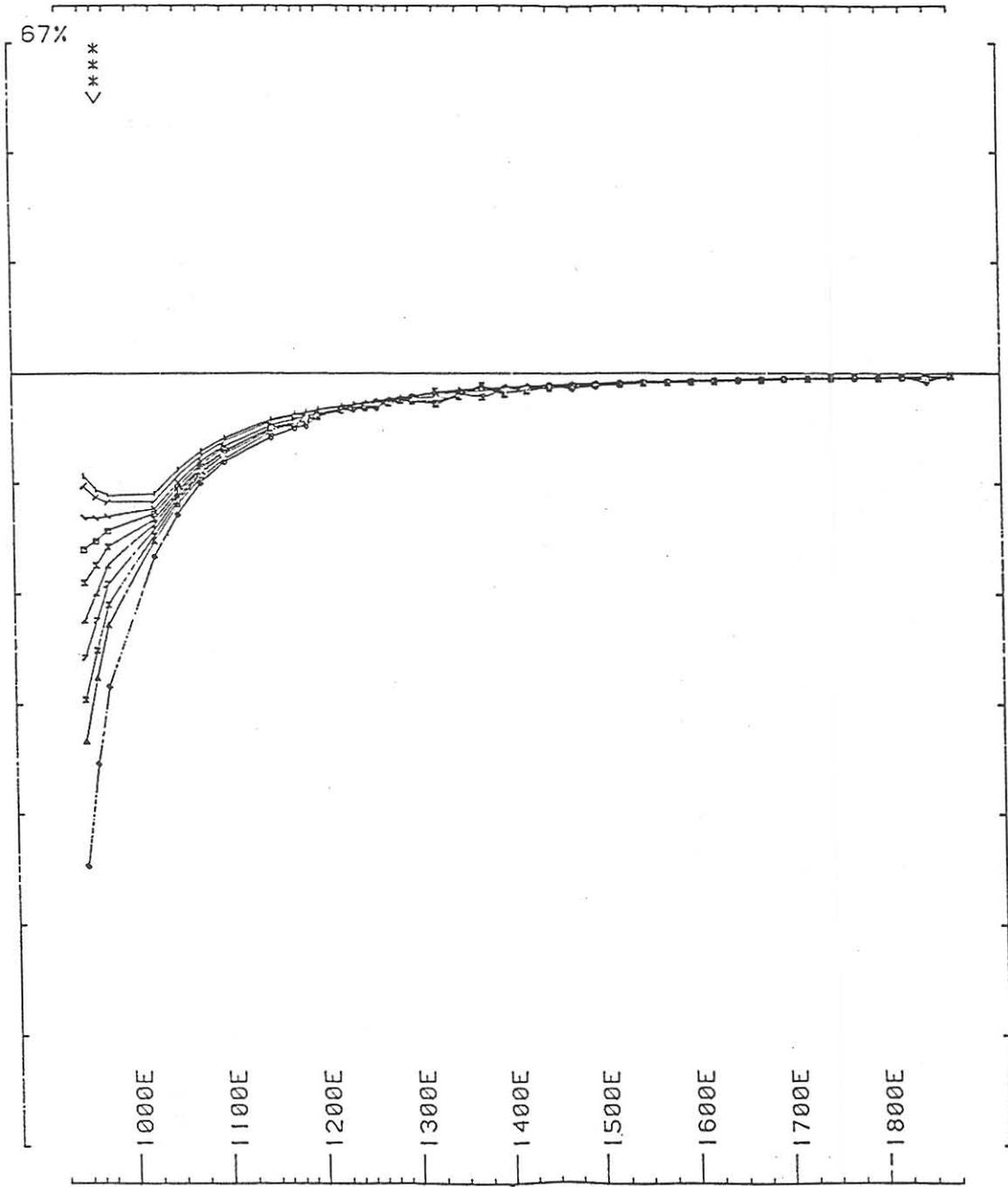


MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES

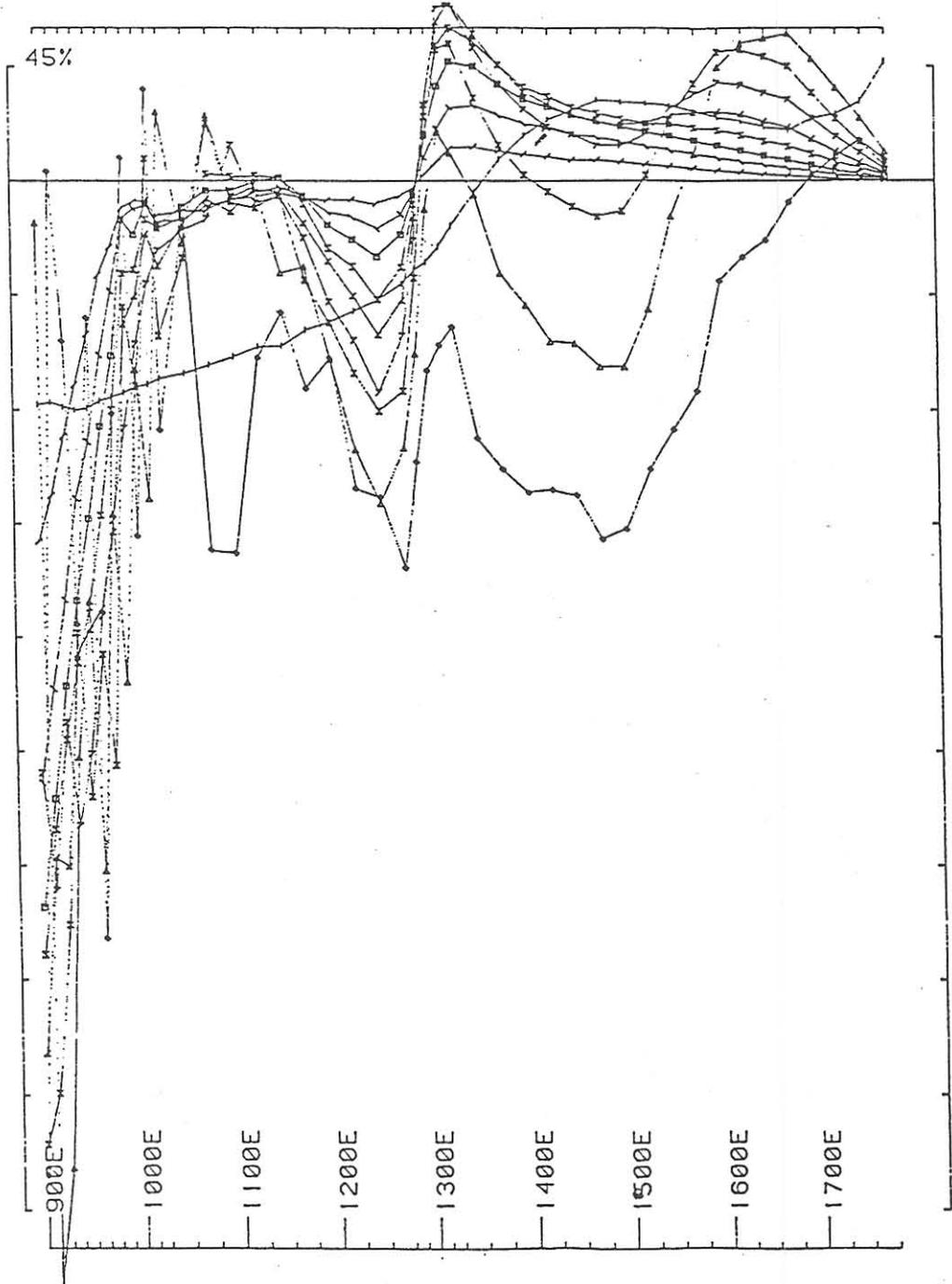
RENISON UTEM SURVEY:  
Line 11N, Loop 1, continuous  
normalisation (with theoretical  
primary field)

FIGURE 25b

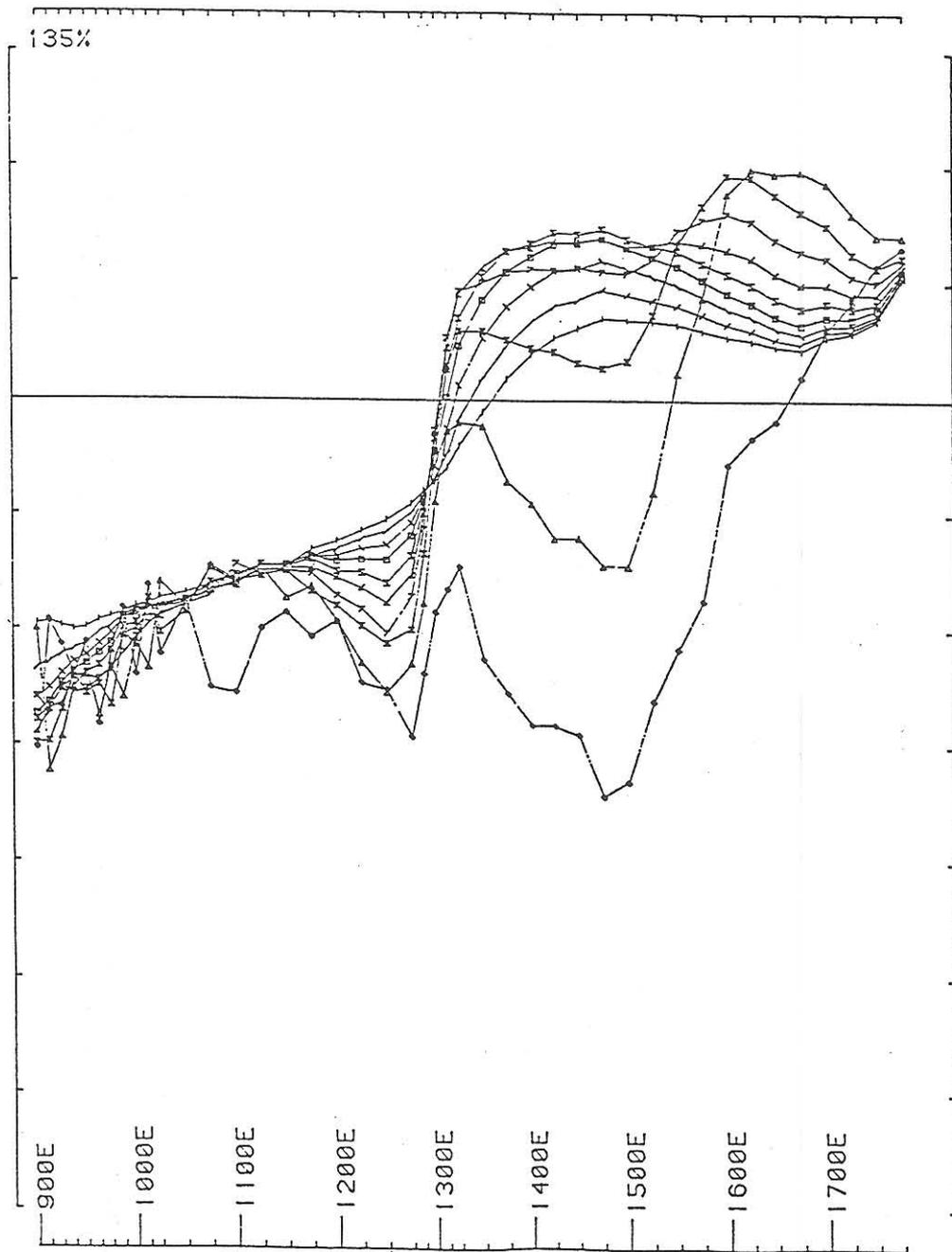
MD/MG87/06



MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
RENISON UTEM SURVEY: Line 11N, Loop 1, point normalisation	
FIGURE 25c	MD/MG87/06



MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
RENISON UTEM SURVEY: Line 11N, Loop 3, continuous channel 1 normalisation	
FIGURE 25d	MD/MG87/06

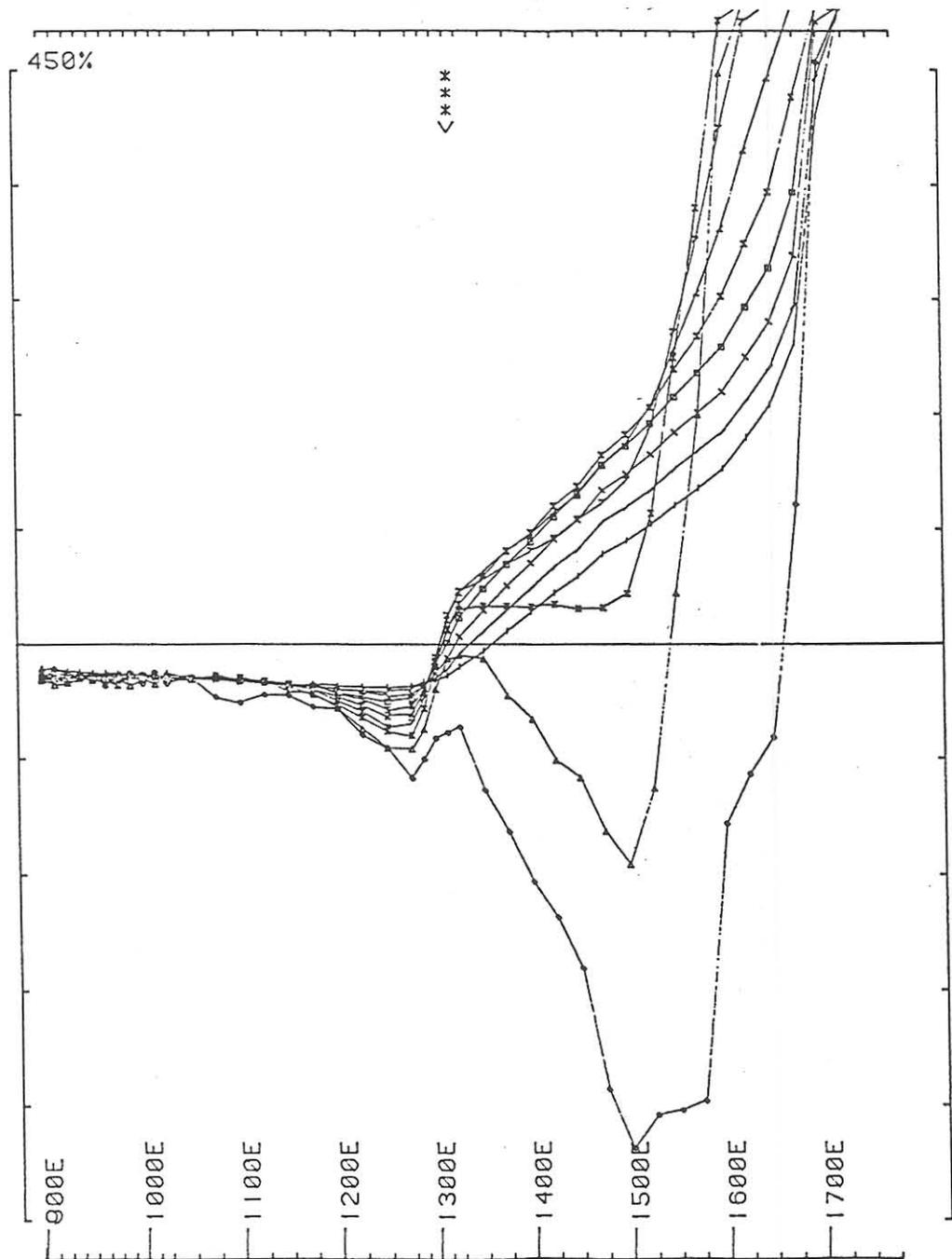


MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES

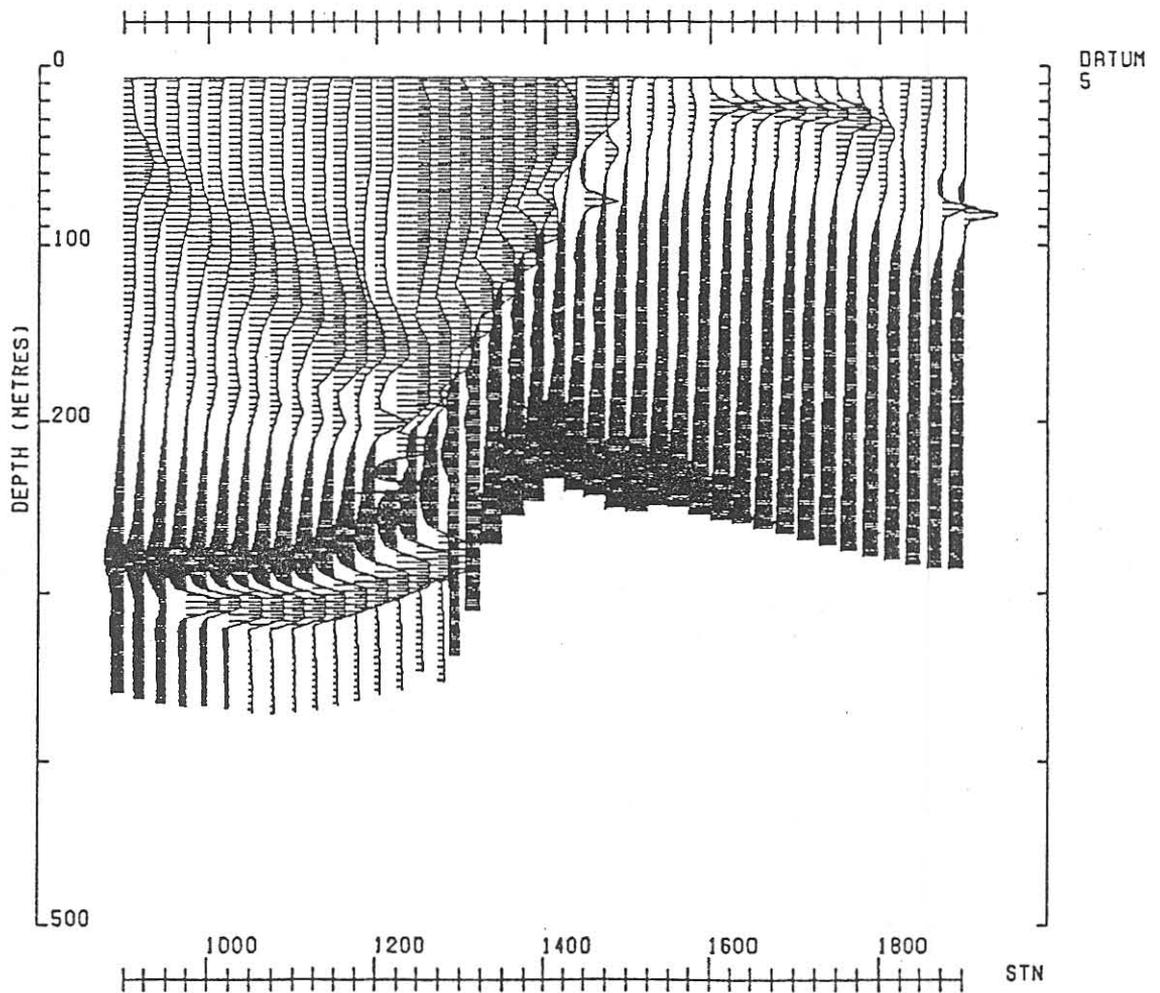
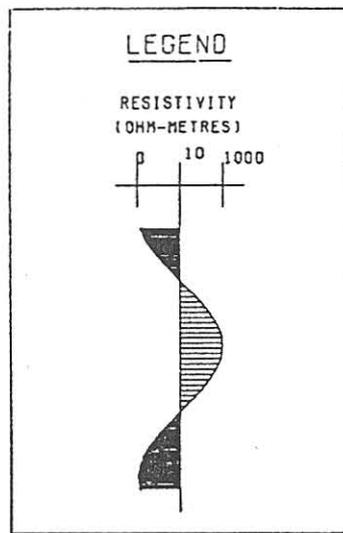
RENISON UTEM SURVEY:  
Line 11N, Loop 3, continuous  
normalisation (with theoretical  
primary field)

FIGURE 25e

MD/MG87/06

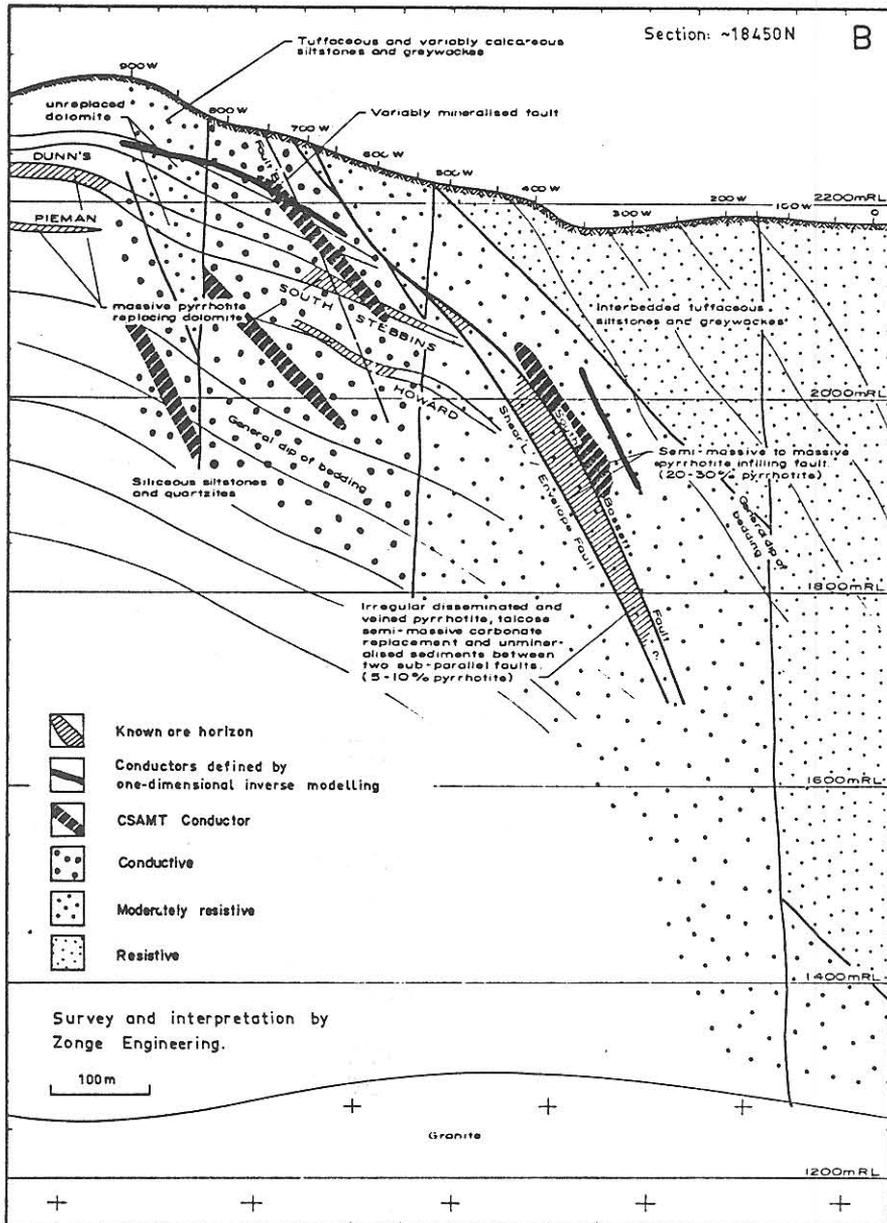
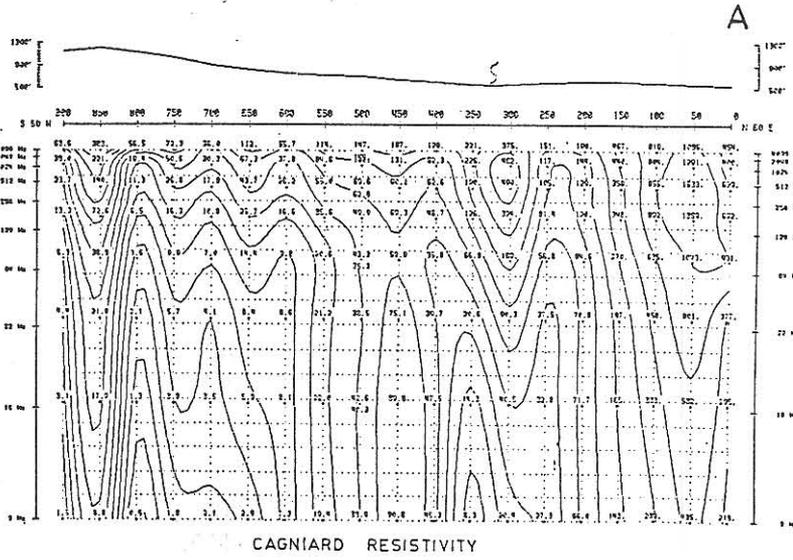


MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
RENISON UTEM SURVEY: Line 11N, Loop 3, point normalisation	
FIGURE 25f	MD/MG87/06



Processed by Lamontagne Geophysics

MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
RENISON UTEM SURVEYS: DEPTH-CONDUCTIVITY IMAGE PROCESSING	
FIGURE 26	MD/MG87/06



**MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES**

**RENISON CSAMT RESULTS**

FIGURE 27

MD/MG87/06

results (Figures 24c, 24g, 25c & 25f) give the true shape of the responses and are used for quantitative interpretation.

A plan of the interpreted positions of the conductors is given in Figure 23. The conductor immediately to the east of loop 1 is too close to the loop edge to be completely defined, but it is a strong conductor, effectively shielding all other conductors to the east. For example, note that the strong response at 1375E/10N - 1300E/11N defined by loop 3 was not seen at all by loop 1, thus illustrating the importance of transmitter loop position for this type of survey. Figure 23 also gives a cross-section of an interpreted thin conductor as the source for this response which coincides with the surface trace of the mineralised Federal Fault.

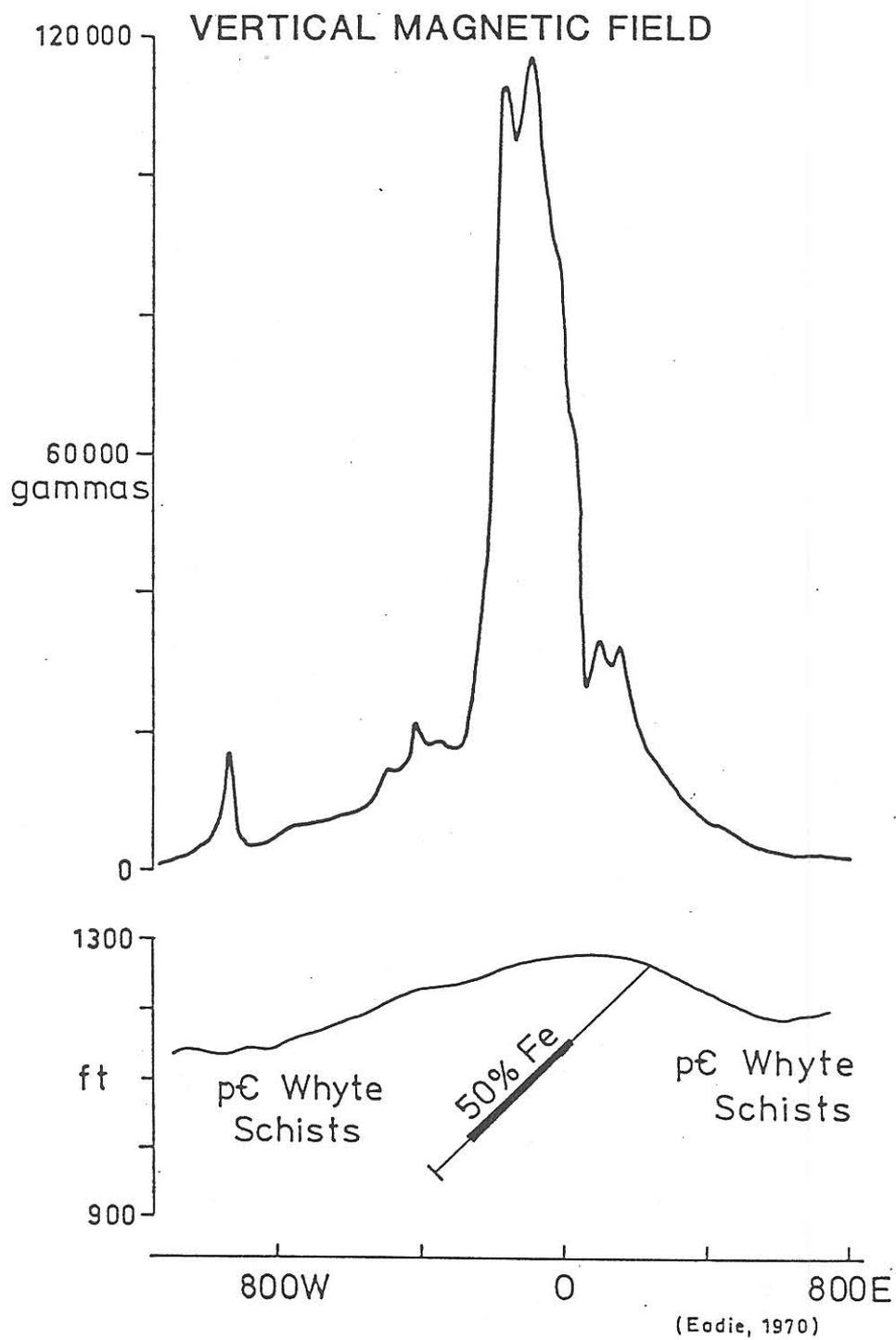
The UTEM data has also been processed to produce a 'depth-image' conductive section (Macnae & Lamontagne, 1987) of the ground (Figure 26). At the time of this interpretation their process was not able to cope with extreme conductivities and the apparent step in the section is not considered to be an accurate picture of the geology. This presentation appears to be an improvement on the conventional TEM interpretation, but still not as useful as a CSAMT traverse over the same mineralisation. Interpretation of the CSAMT gives, at least in this case, a much closer agreement with the known geology than the fixed loop TEM survey (Figure 27).

There have been a number of petrophysical measurements of the Renison ore and host rocks. A compilation by Newnham (1972) showed that the massive sulphides averaged a magnetic susceptibility of nearly 0.01 cgs units and a conductivity of about 5000 S/m. A few values have been included in Table 1. Clark (1984) stated that the effective remanent magnetisation of the massive ores was in "the same general sense as the induced magnetisation and about twice as strong". The density of Renison ore varies between 3.2 and 4 t/c.m. (Morland, 1986). There have been few sample IP measurements, but strong effects have been observed in the field. Results of recent testing are given in Richardson and Hudspeth (1988).

The above discussion has ignored the geophysical properties of the surrounding geological environment. A detailed presentation is beyond the scope of this report, but in places it is complex and includes: magnetic and/or conductive skarns, magnetic intrusives, chargeable and/or magnetic sediments (from black shales and disseminated pyrite, pyrrhotite and/or magnetite) and magnetic and conductive ultramafics (Bishop, 1983b). Thus despite the excellent geophysical properties of Renison ore, anomaly recognition and interpretation is not necessarily straightforward.

#### **SAVAGE RIVER**

The Savage River iron ore mine consists of a number of magnetite - pyrite deposits within PreCambrian basaltic volcanics and intrusives of the Arthur Lineament. The deposits had been known since the 1870's,



MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
SAVAGE RIVER GROUND MAGNETIC PROFILE	
FIGURE 28	MD/MG87/06

but it was not until an aeromagnetic survey of the area in 1956, that their full extent was appreciated. Detailed ground magnetic surveys by the BMR in the 1960's (see Figure 28 and Eadie, 1970) followed by drilling, indicated an economic resource and mining commenced in 1967 (Coleman, 1975).

Obviously, the deposit's magnetic susceptibility is its most useful geophysical parameter. Barnes (1982) gives a value of about 1.0 cgs units. A spectral IP survey was carried out to help determine the IP characteristics of magnetite and the results are discussed later in Volume II of this report. Eadie (1970) also noted that SP responses of the order of -200mv were recorded over the deposit.

#### KARA

The ore bodies at Kara consist of a number of scheelite-bearing magnetite skarns occurring within Ordovician carbonate sediments in close proximity to Devonian granitoid intrusions. A limited amount of petrophysical testing by Tasmania Mines, the owners of the mine, and by Shell Minerals (Oakes, 1981) indicates that the ore has a high magnetic susceptibility (e.g., typically 0.06cgs and sometimes greater than 1.0cgs). Remanence is significant with Koenigsberger ratios to 6 and not parallel to the induced field. Oakes (1983) also suggested a significant density contrast for the skarn (see Table 1).

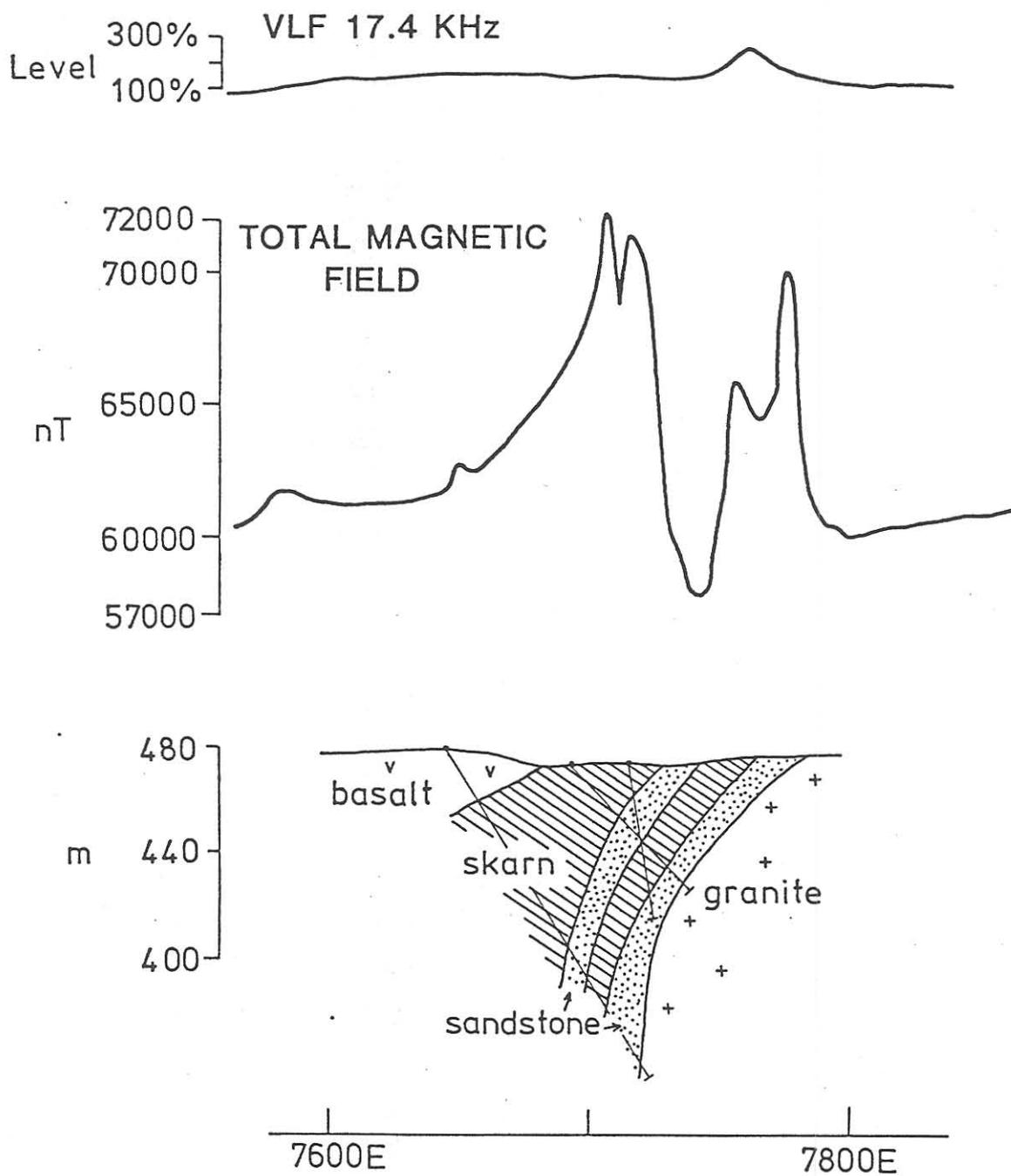
The sulphide content of the Kara ore is low (generally less than 1%) and the ore is unlikely to be very conductive. However it is probably sufficiently magnetic to respond to an EM survey\*. Oakes (1981) reported a VLF response over one of two outcropping skarns which were surveyed at Kara (Figure 29). An in situ spectral IP survey was carried out to see if this ore possessed any distinctive IP properties. The results are discussed in Volume II of this report but it is worth noting here that magnetite is chargeable, and at least in high concentrations may well produce a greater IP effect than a comparable concentration of sulphides.

#### OCEANA

Unlike the above deposits, Oceana is no longer an operating mine, however it represents an important and quite different style of mineralisation in western Tasmania. It is a limestone-hosted lead-silver deposit which is considered to have several similarities with the Silvermines sedimentary-exhalative deposits in Ireland (Legge et al, 1984). Other similar but smaller deposits (e.g., Mariposa) occur in the region. A number of electrical and electromagnetic surveys have been carried out over Oceana; none have unequivocally detected the mineralisation. Bishop (1985) suggests that the sulphides are probably electrically discontinuous, probably due to a coating of sphalerite

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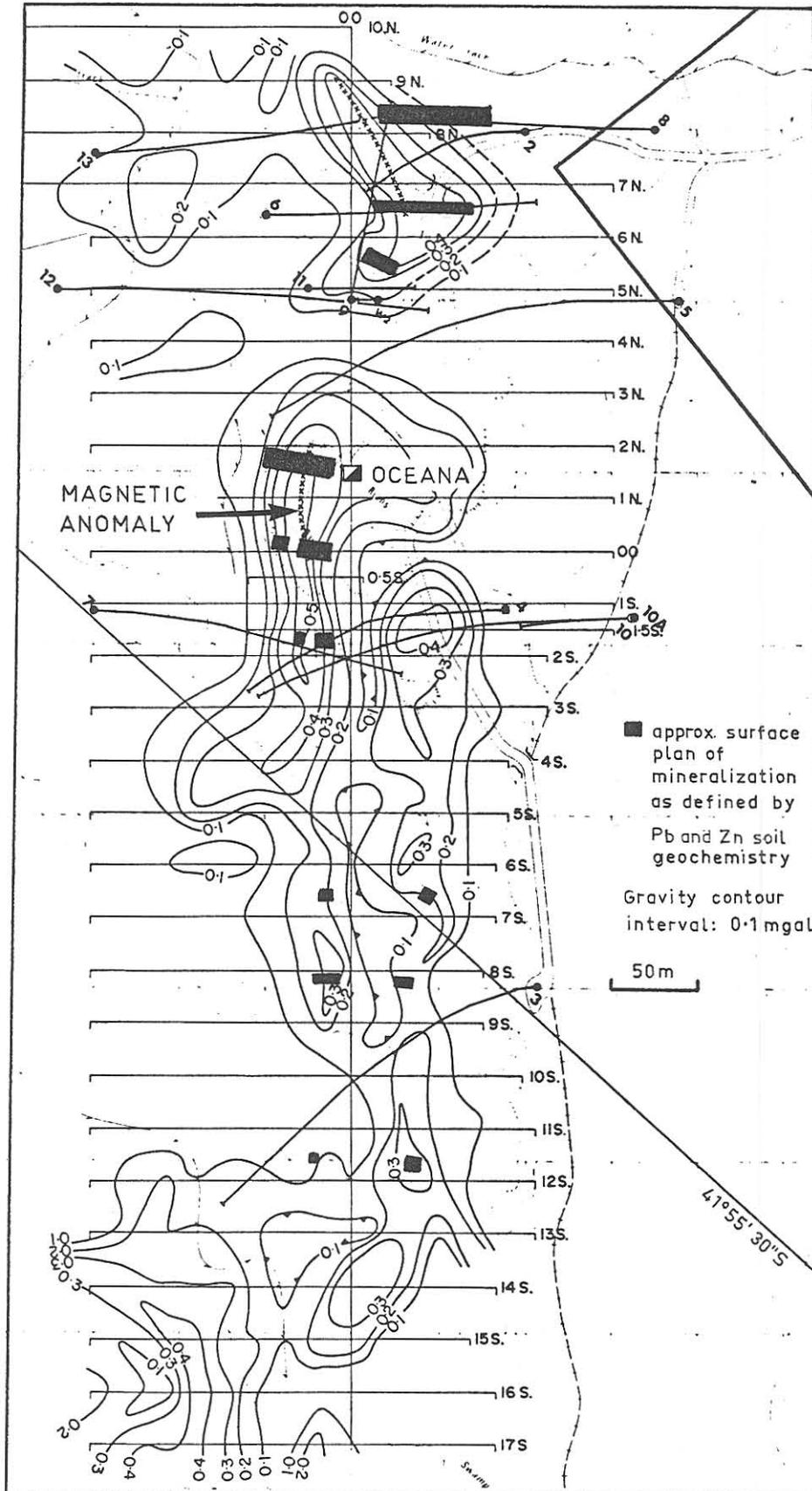
\* Logistical difficulties precluded a TEM sounding at Kara.



(from Oakes, 1981)

MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
KARA GROUND MAGNETIC AND VLF PROFILE	
FIGURE 29	MD/MG87/06

around the grains of galena. Gravity surveys have been more successful. Figure 30 shows gravity contours from a BMR survey (Langron, 1966) which defines the extent of the Oceana deposit. Some petrophysical measurements of Oceana core are given in Table 1.



MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES

OCEANA GRAVITY CONTOURS

FIGURE 30 MD/MG87/06

### GEOPHYSICAL RESPONSES FROM OTHER ROCK TYPES

Some petrophysical characteristics of rock types which commonly give rise to 'geological noise' are described below, together with some data on host rocks and alteration zones. The measurements over the former group were made to see if they might be more readily distinguished from economic mineralisation. Host rocks were surveyed so that more definite statements can be made about 'background' values and alteration zones were examined to see if the more subtle responses from this spatially larger target, which commonly exists around a massive sulphide deposit, can be used as an aid to exploration. The surveys conducted specifically for this report were spectral IP measurements and these are discussed in more detail in Volume II.

#### **ALTERATION ZONES**

Two areas around the recently closed Hercules mine and the Hellyer Mine decline were chosen as representative sites for spectral IP measurements. These may be contrasted with relatively unaltered volcanics from Mount Read and the Bastyan Dam Road at Tullah. As shown in Volume II it is not possible to distinguish these materials using IP properties. Clearly alteration zones may also include low grade mineralization but we group these cases with barren sulphides below. Also discussed below, under Evaluation of Methods, are results of geophysical surveys over the Western Tharsis sulphide zone at Mount Lyell. This subeconomic copper deposit might be classified as an alteration zone and the geophysical results, as responses over alteration. Clearly, 'alteration zone' encompasses a wide range of sulphide and other mineral concentrations and a wide range of electrical responses may be expected. More consistent results may be obtained with potential field methods. A magnetic low can often be observed over an area of alteration within the Mount Read Volcanics (Leaman, 1987) and (negatively) a good gravity anomaly is unlikely to be recorded over disseminated sulphides.

#### **BARREN SULPHIDES**

Barren sulphides could perhaps be included with the above group, however there are, within the Mount Read Volcanics, a number of discrete bodies of disseminated pyrite upon which a considerable amount of effort and money have been expended. There are now several geochemical approaches to help determine whether such bodies may be associated with massive base metal sulphides and our study hoped to add some geophysical techniques. The results, presented in Volume II show barren sulphides as having a quite different trend from the Mount Read base metal sulphides in spectral IP parameter space and are readily distinguished from targets of interest. However these measurements were made with small in situ surveys, and it remains to be seen whether these results can be immediately used for interpretation of every-day surveys.

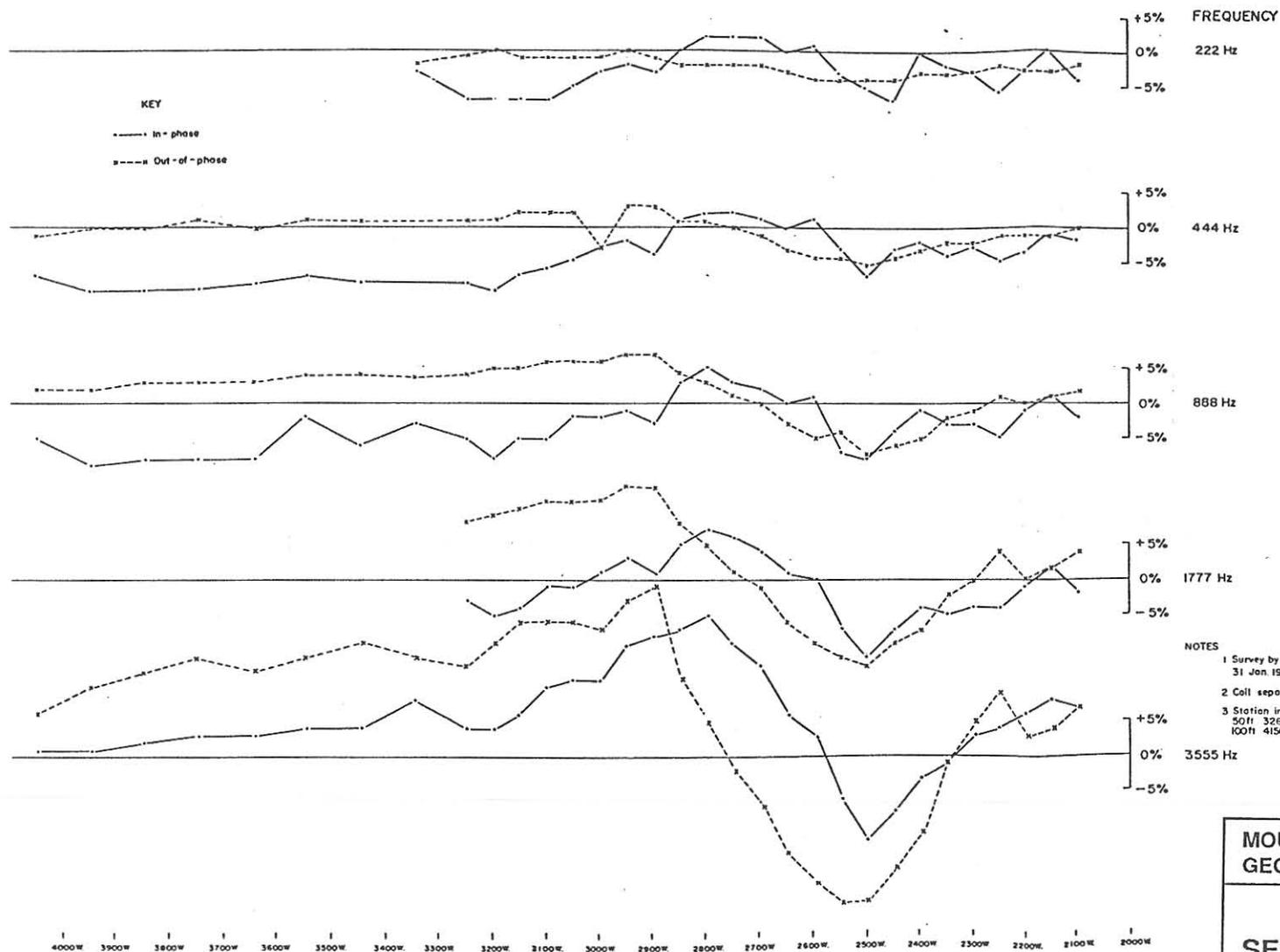
Some of these barren sulphide - mostly pyrite - bodies have had numerous geophysical surveys conducted over them. For example, the (main) Selina pyrite body has responded to airborne EM, ground EM, IP and magnetics. The results for a horizontal loop EM (Maxmin) survey are given in Figure 31. Interpretation of these results indicates a shallow (effectively outcropping) poor conductor. The calculated conductivity - thickness product of 1-2S gives an intrinsic resistivity of 50 to 100 $\Omega$ m for mineralisation about 100m wide. This may be compared with values of 100 to 200 $\Omega$ m recorded by a dipole-dipole IP survey. The higher positive peaks on the western side of the anomaly incorrectly suggest a western dip: they are probably caused by conductive glacial cover on the western section of the traverse.

The Chester Mine worked a massive barren pyrite body in the Mount Read Volcanics (as a flux for the Mount Lyell copper smelter). Spectral IP measurements also show that this need not be confused with targets of economic interest (see Volume II).

### BLACK SHALES

In western Tasmania there are numerous lenses of black (graphitic and pyritic) shales. They occur within the volcanics and sediments, from the PreCambrian through to (at least) the Ordovician. Black shales represent the ideal type of environment for a 'distal' massive sulphide deposit and there are a number of cases of massive sulphides in close association; e.g., Rosebery, Farrell and Red Hills. Many lodes on the Zeehan field are also in close proximity to black shales. The black shales have a wide range of electrical properties and they may be indistinguishable from sulphides. Thus from electrical surveys, black shales by themselves may be mistaken for sulphides or, alternatively, they may obscure a sulphide deposit. (There is also the Canadian case of Kidd Creek, where, it is alleged, a zone of EM conductors had such a long strike length, it was assumed to be due to black shales. It was some years before a drill hole showed that it was caused by more than 150 million tonnes of massive sulphide ore.) Figure 32 shows the variable EM responses recorded by a Dighem survey over black shales near Selina. This figure also gives the conductances and interpreted depths to assumed tabular sources. Later, in Evaluation of Geophysical Methods, results from TEM and IP surveys over a sulphide pod in close proximity to a large lens of black shale near Basin Lake are compared (Figures 61 - 64).

Confident discrimination of black shales from sulphide responses would be a milestone in geophysical applications. We have investigated how useful spectral IP measurements would be in achieving this goal. Black shales over Hellyer, at Rosebery, Red Hills, West Sedgwick, White Spur and on the Anthony Road (see Figure 1) were all surveyed with small dipole - dipole in situ surveys. As the target to be discriminated we take the PQ Lens at Que River. The results, given later in Volume II, indicate that the target can be discriminated from all of these black shales on the basis of DC resistivity and the 'spectral chargeability' m. This is, however, only part of the solution to the problem: it

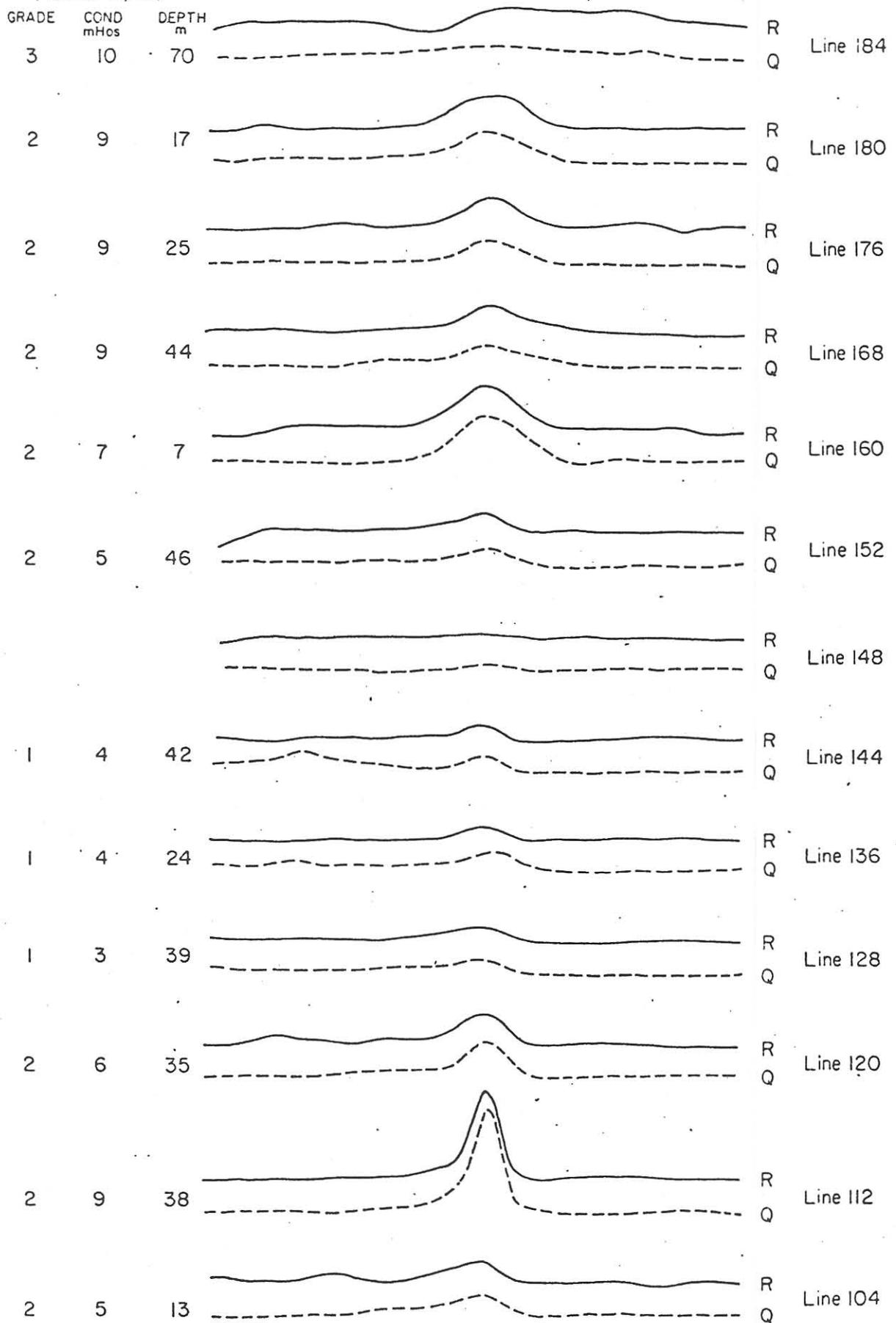


**MOUNT READ VOLCANICS PROJECT:  
 GEOPHYSICAL SIGNATURES**

**SELINA MAXMIN PROFILE**

FIGURE 31 MD/MG87/06

DIGHEM INTERP  
(Vertical dyke)



Dighem survey over  
Selina, March 1980



MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
SELINA BLACK SHALES: DIGHEM RESPONSES	
FIGURE 32	MD/MG87/06

remains to be shown that survey techniques, either IP or EM, can accurately measure these parameters in a typical field situation.

#### HOST ROCKS

Typical 'unaltered' Volcanics were surveyed with spectral IP on Mount Read and the HEC Pieman Rd. The chargeabilities and resistivities obtained from these rocks provide 'true' background values for IP exploration in the Mount Read Volcanics (see Volume II) and the spectral data provides a data set to compare with that obtained from the alteration zones. Observations included fresh sediments from the Dundas Group measured on the Dundas Rd and at Nevada Creek; Crimson Creek Formation sediments from Tunnel Hill, and serpentinite from Tunnel Hill. It proved impossible to distinguish alteration zones from background volcanics but unexplained phenomena are present: further work might provide a discrimination tool.

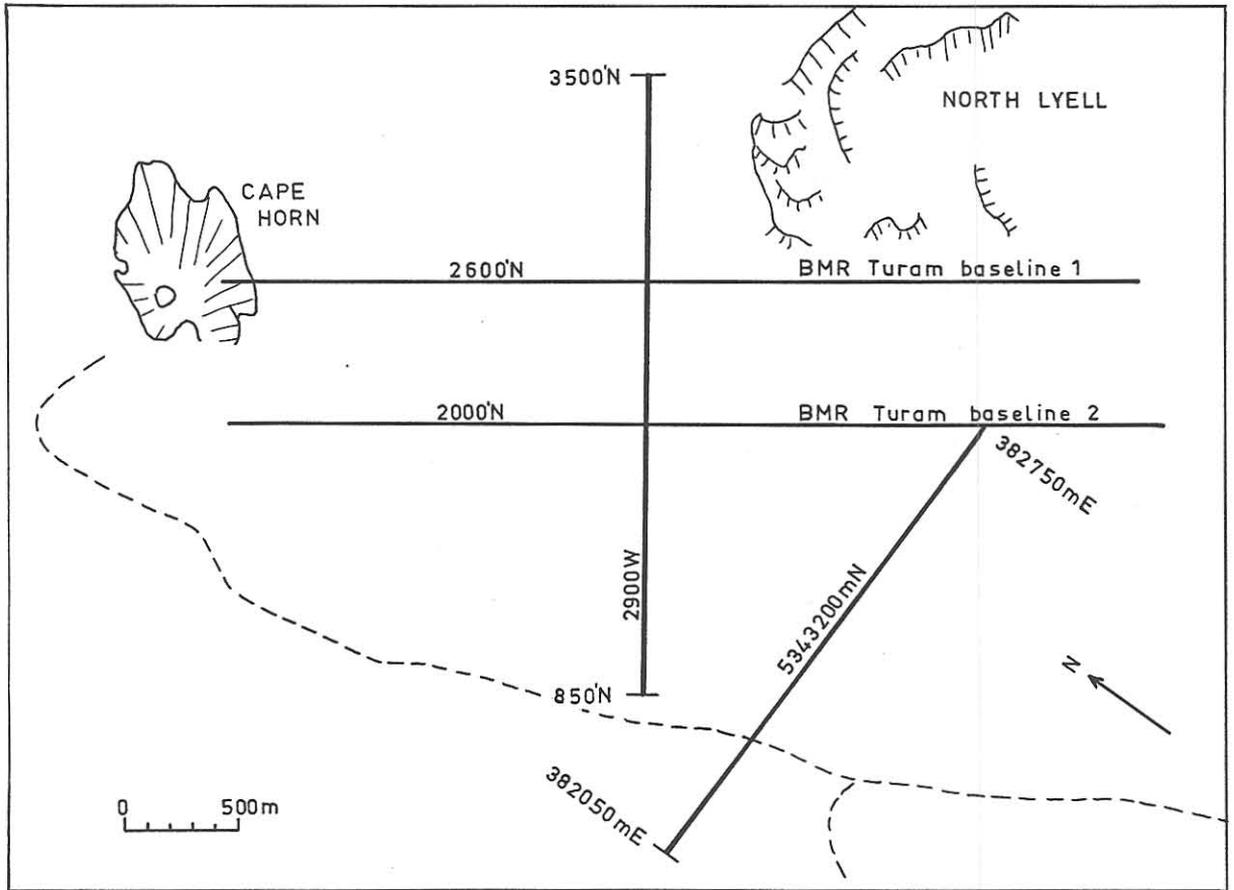
## EVALUATION OF GEOPHYSICAL TECHNIQUES IN USE IN WESTERN TASMANIA

Geophysics was probably first used in western Tasmania on a routine basis in the late 1950's to early 1960's, when Rio Tinto used Turam, gravity and magnetics over most of their prospects. Magnetics, of increasingly better quality, has remained, but EM gave way to IP in the 1970's when large areas were covered. In the 1980's fixed, large-loop TEM has been more popular, with DHEM being almost routinely carried out after drilling.

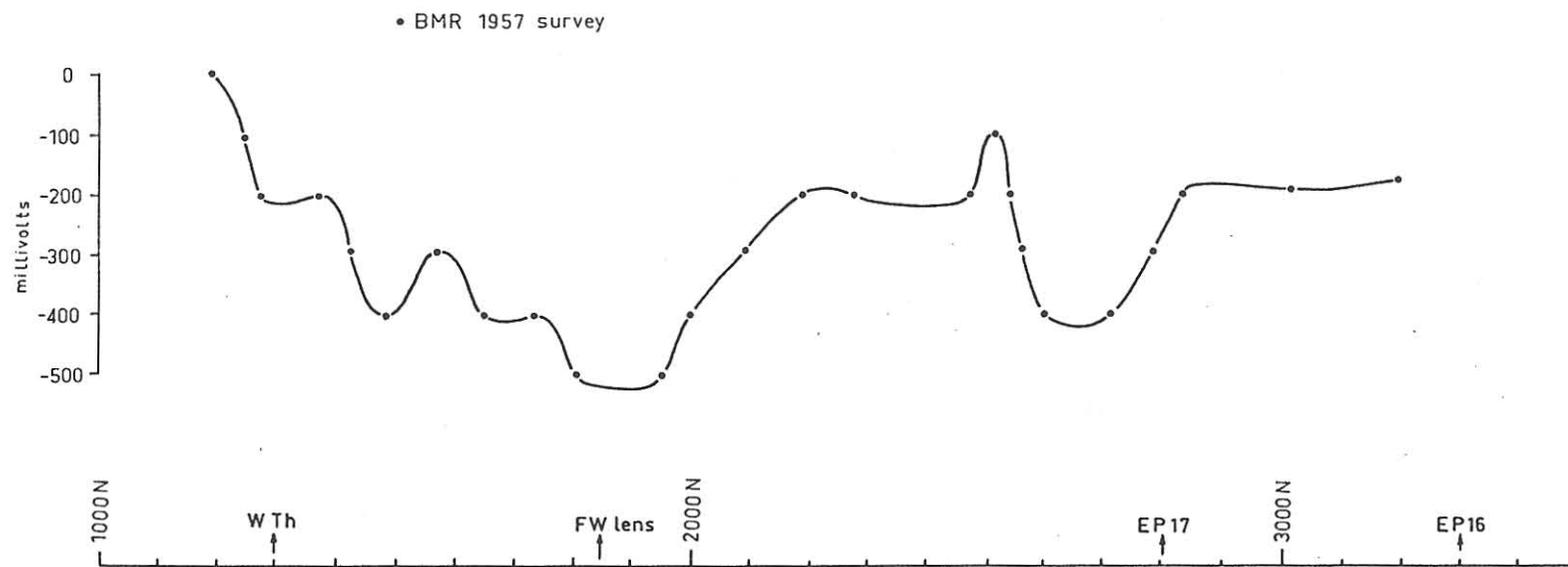
This section is not a user's manual on geophysical methods, rather it aims to inform about the types of techniques that can be found in the open file reports and to comment on some of the attributes and/or shortcomings of some of these techniques. Leaman (1987) has dealt with potential methods and this section will concentrate on electrical techniques. Many of the examples have been taken from the Western Tharsis area on the Mount Lyell mining field, since this has been a test site for many of the geophysical techniques tried in Tasmania. The location plan for these surveys is given in Figure 33.

### **ELECTRICAL TECHNIQUES**

Self potential is perhaps the simplest of all geophysical techniques, but one of the least understood. There is still no generally accepted theory to explain the observed magnitudes, which can be in excess of 1 volt. It is also one of the oldest exploration techniques (preceded only by magnetics) and was used successfully in Tasmania by the IGES in the late 1920's (Edge and Laby, 1931) and by the BMR in the 1950's and 60's (e.g., Rowston, 1957). It has been little used in Tasmania since that period; probably partly due to the lack of a sound theoretical basis, but mainly to a belief that it has no depth penetration. The method had something of a revival in the USA in the late 1970's, particularly for porphyry copper bodies, where effective search depths of up to 1km have been claimed for it (Corry, 1985)! For the Mount Read project, SP surveys were made above and through the Hellyer orebody. As was stated in an earlier section, the former was successfully completed, but the only recognisable responses were over the black shales (Figure 5a). An attempt was made to read self potentials along the Hellyer adit through the ore body, but large differences were found at repeated stations and the data is not presented here. The results of an SP survey over four subeconomic deposits on the Mount Lyell mining field are shown on Figure 34: strong responses were obtained, but with a much poorer resolution than a contemporary Turam survey (Figure 35). This has been partially ascribed to the steep topography (Rowston, 1957). All of the bodies traversed by this SP survey are either effectively outcropping or only shallowly buried. A better example is given by Webster and Skey (1979) who show a good (-300mv) response over the outcropping S Lens at Que River and a barely recognisable anomaly (to -40mv, with no strike



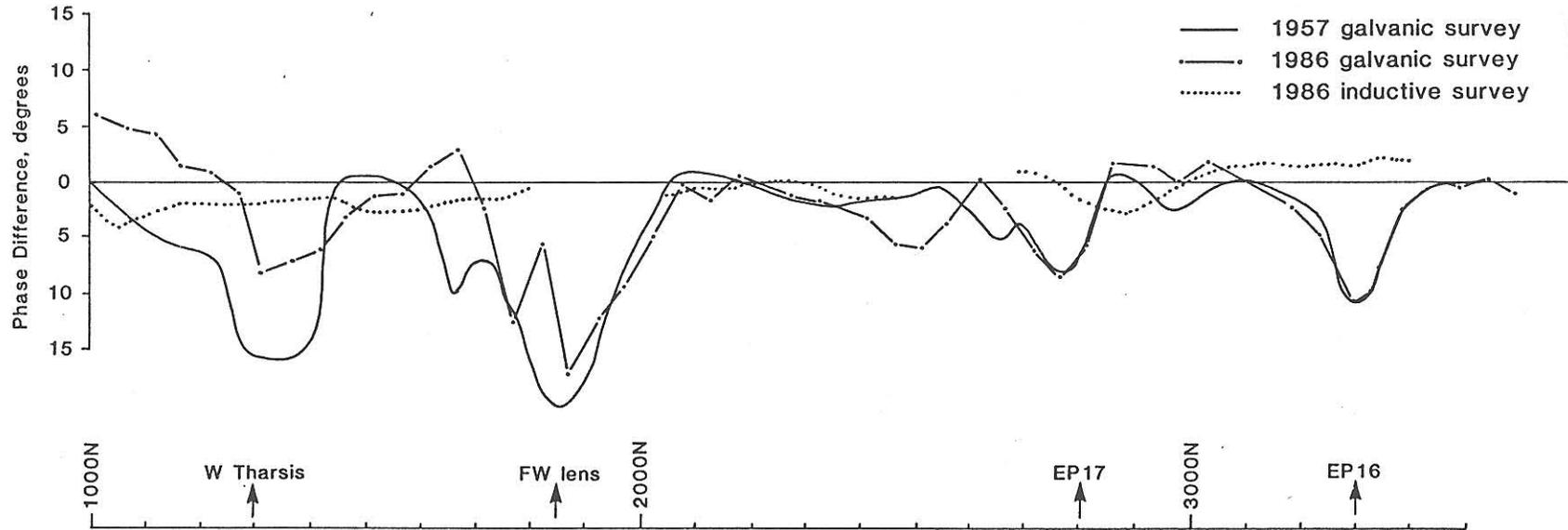
MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
MT LYELL GEOPHYSICAL SURVEYS: LOCATION PLAN	
FIGURE 33	MD/MG87/06



**MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES**

**MT LYELL LINE 29W:  
SELF POTENTIAL**

FIGURE 34 MD/MG87/06



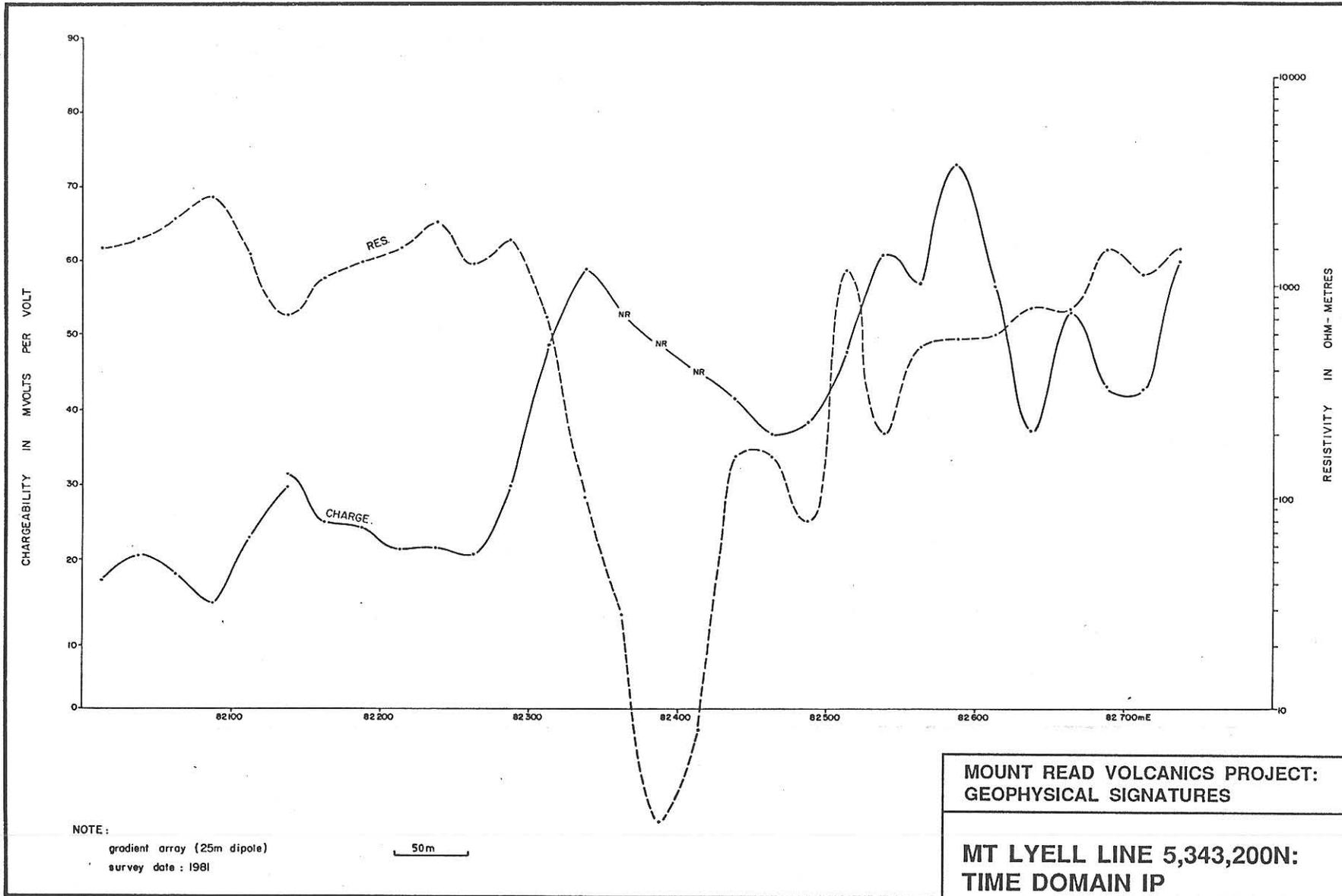
<b>MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES</b>	
<b>MT LYELL LINE 29W: TURAM PHASE DIFFERENCES</b>	
FIGURE 35	MD/MG87/06

extent) over the buried (to ~70m) 'PQ' lens. Thus from this example at least, the lack of interest in SP in the search for deeply buried massive sulphide deposits is well founded.

IP was possibly the most used geophysical method in the 1970's. Large areas were covered using the gradient array with detailing done with pole-dipole or dipole-dipole surveys. These surveys were generally very effective, accurately locating pyritised horizons, often through a glacial overburden. The majority of the work appears to have been conventional (i.e. electrical IP as distinct from magnetic IP (MIP)) time domain surveying, but frequency, frequency-phase and magnetic IP has been carried out. Some IP systems have been tested over a pyrite-chalcopyrite conductor at Mount Lyell (line 5,343,200N; location shown on Figure 33) and the results are presented here to illustrate some of the different parameters and, in this case, some of their shortcomings. While this example shows IP comparing poorly against some EM results, a later example shows IP performing better than the latest TEM systems.

A profile showing the chargeability (in mv/v) and apparent resistivity (in  $\Omega\text{m}$ ) from a gradient array survey at Mount Lyell is given in Figure 36. This shows a pronounced resistivity low with a corresponding rise in chargeability, but with conditions too conductive to obtain chargeability readings directly over the conductor. Figure 37 shows the frequency domain data, with the comment that the noise levels were too high at the western end to make valid readings. (The superiority of time domain in naturally noisy environments has been previously reported by Tschalkowsky and LeBrocq, 1980.) Apart from the resistivity low at 82400E, this data shows little correlation with the time domain data. The parameters measured are the percent frequency effect (PFE) and relative phase shift (RPS) between the fundamental (not stated, but one of 0.1, 0.3, 1 or 3 Hz) and the third harmonic. Magnetic IP was also carried out, with the magnetic coil plugged into the frequency domain IP receiver. These results show no response over the massive sulphides at 82400E, but do indicate a sharp contact at 82240mE, with the more chargeable material to the east (Figure 38).

These IP results may be compared with three horizontal loop EM surveys; Maxmin and Genie being frequency domain and Crone's PEM being time domain. All of these systems employed a moving source with a fixed transmitter-receiver separation. They were (and are) commonly used for follow up of airborne EM surveys. The Maxmin results for a 100m coil separation are shown in Figure 39. These results have a much larger amplitude than those over the Selina deposit, indicating a much larger tonnage of sulphides. A quantitative interpretation of the results also indicates a much more conductive body than the Selina pyrite zone. The order of magnitude increase in conductivity is attributed to a higher concentration of chalcopyrite in the Mount Lyell mineralisation. The Maxmin system requires careful levelling of the survey line (with a clinometer) and careful attention to survey procedure and data reduction to minimise topographic effects. To overcome these difficulties, the Genie system was developed. The Genie results (Figure 40) show a response comparable to the Maxmin. The first commercial horizontal loop time domain system developed was the Crone PEM system which used a small (10m diameter) transmitting loop and a separate receiver. The system

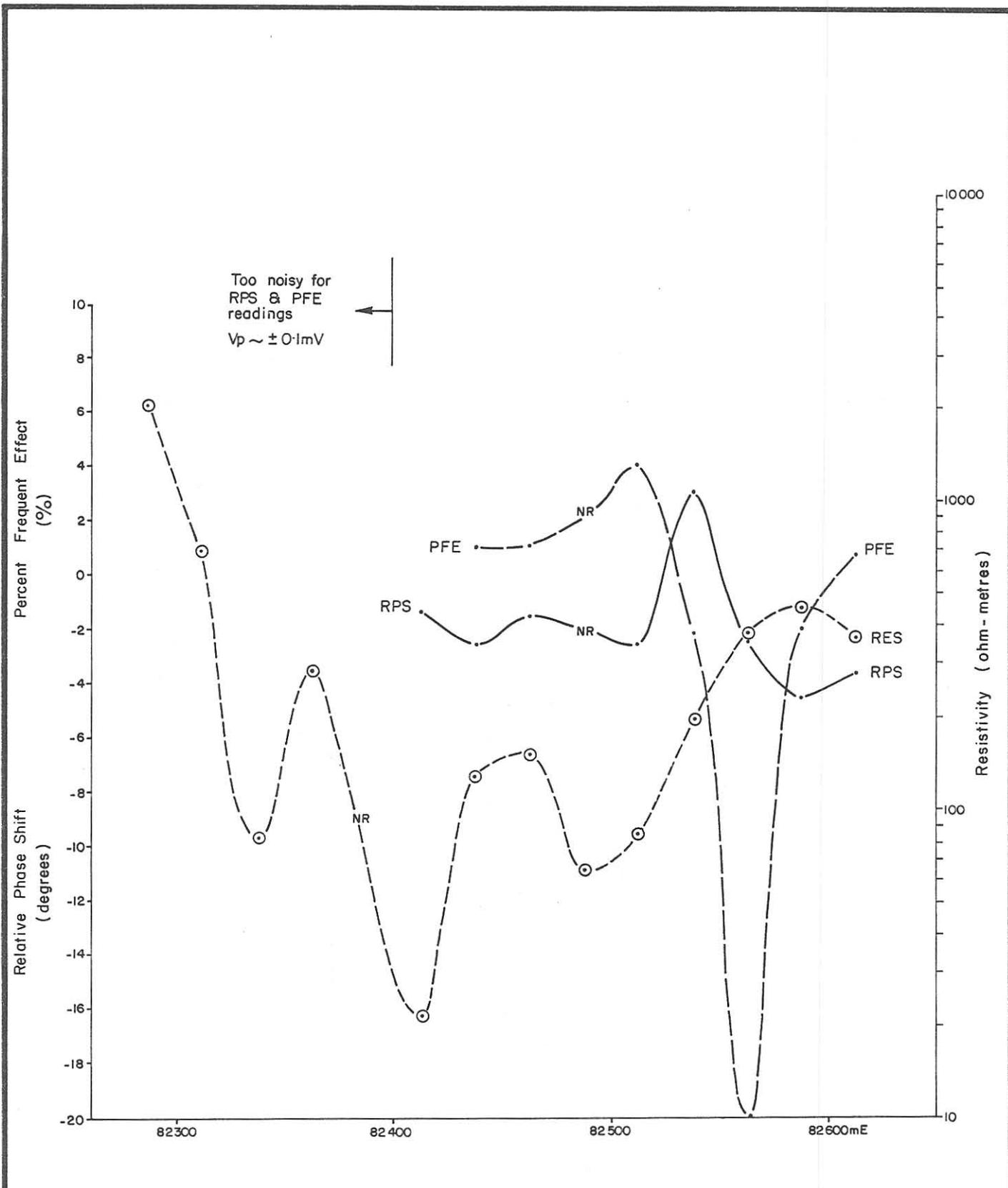


**MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES**

**MT LYELL LINE 5,343,200N:  
TIME DOMAIN IP**

FIGURE 36

MD/MG87/06



NOTE:

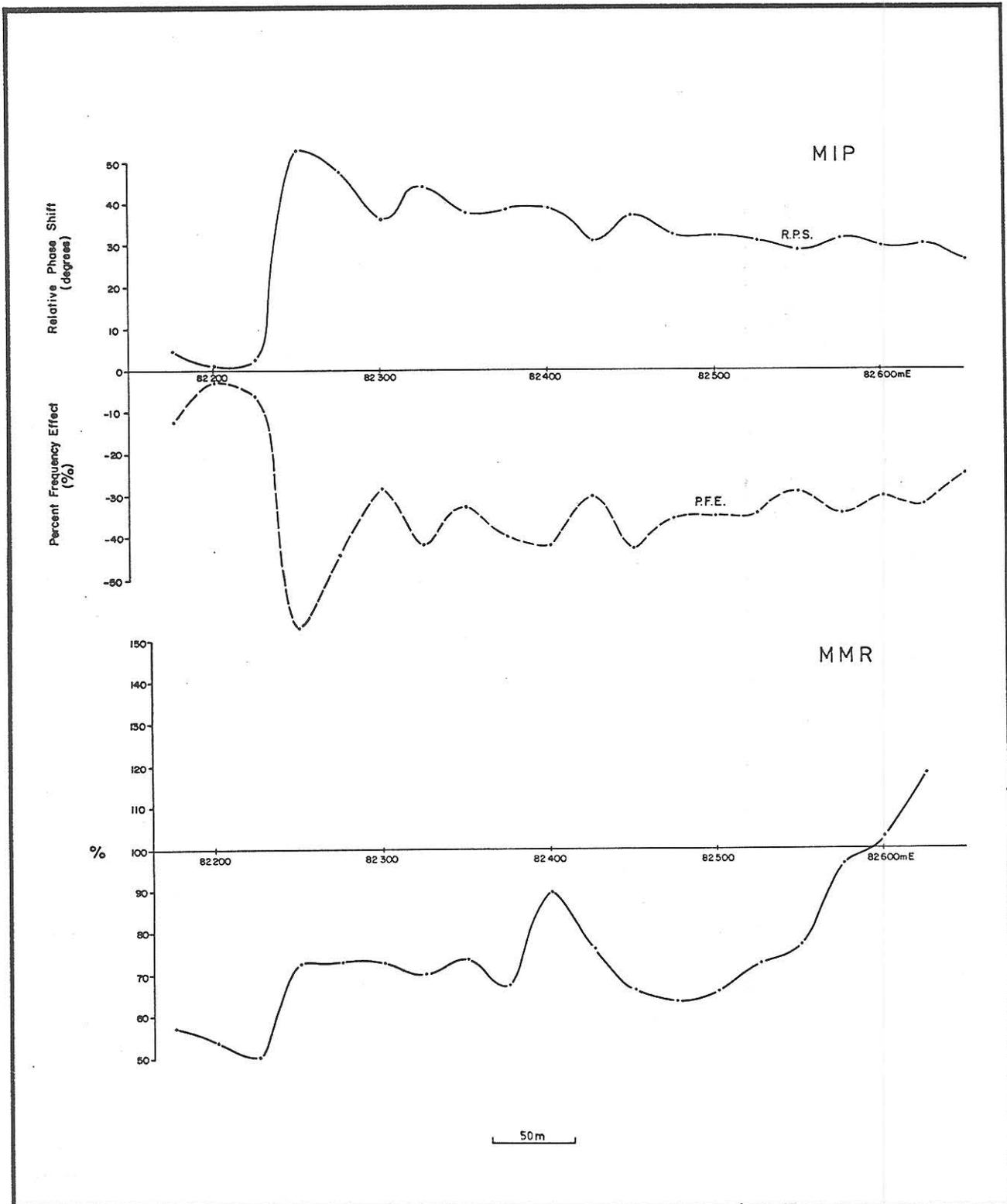
gradient array (25m dipole)

survey date : 1981

50 m

MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES

MT LYELL LINE 5,343,200N:  
FREQUENCY DOMAIN IP

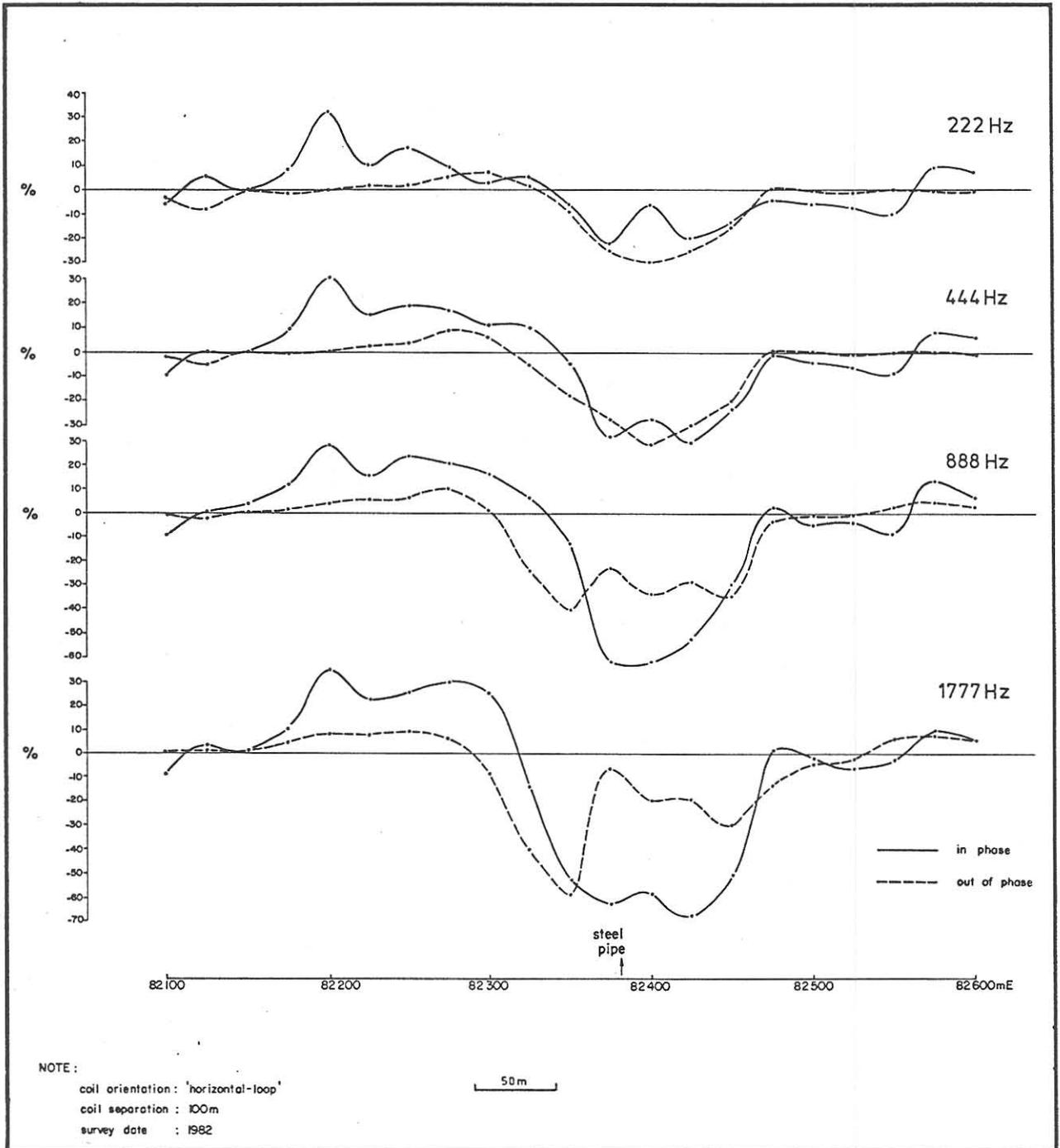


MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES

MT LYELL LINE 5,343,200N:  
MIP AND MMR

FIGURE 38

MD/MG87/06

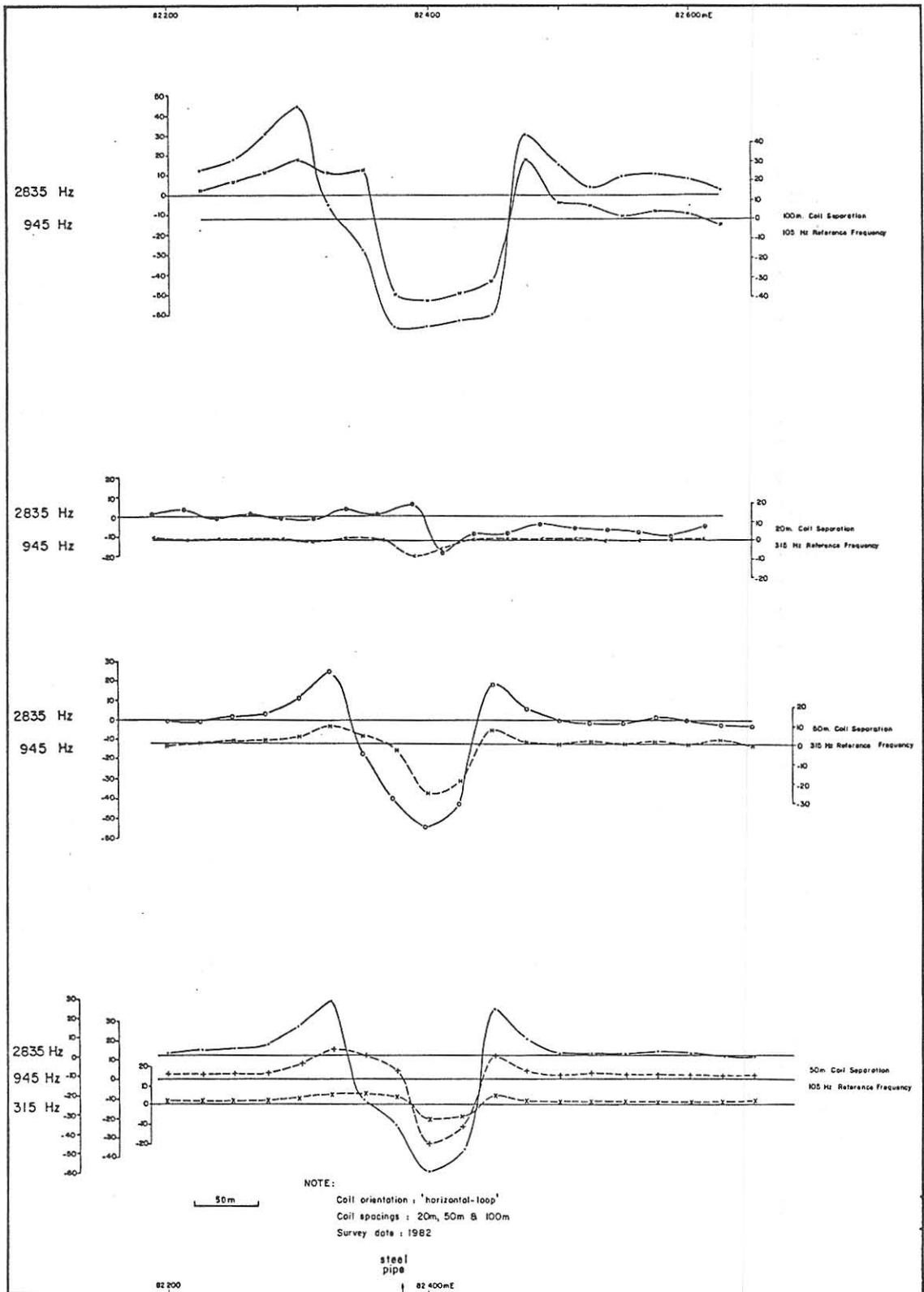


**MOUNT READ VOLCANICS PROJECT:  
 GEOPHYSICAL SIGNATURES**

**MT LYELL LINE 5,343,200N:  
 MAXMIN**

FIGURE 39

MD/MG87/06



MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES

MT LYELL LINE 5,343,200N:  
GENIE

FIGURE 40

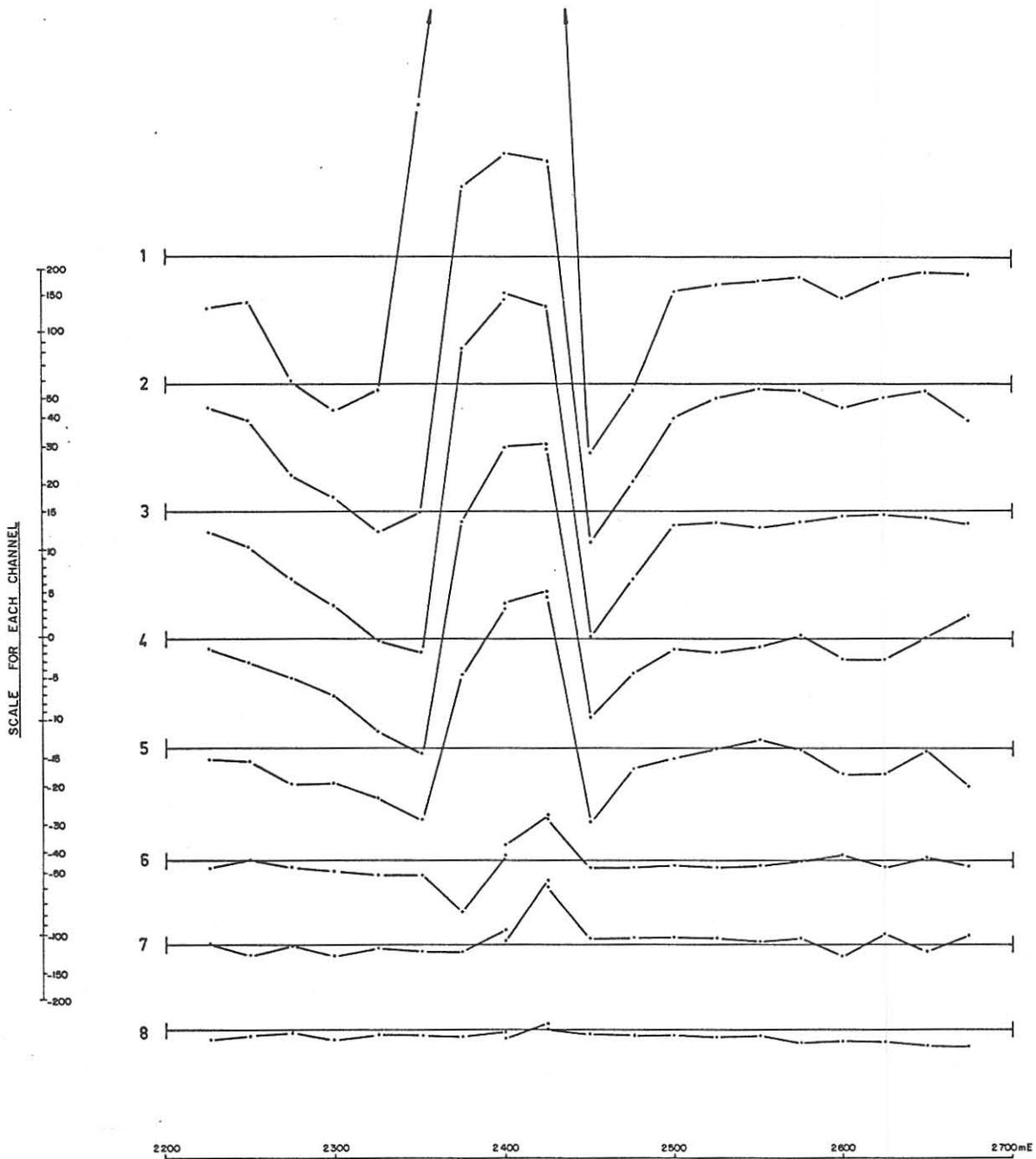
MD/MG87/06

worked well and Figure 41 shows the strong response obtained over the Mount Lyell mineralisation. The Crone PEM system uses the opposite sign convention to the frequency EM systems and therefore shows a positive anomaly where the Maxmin and Genie results show large minima.

A comparison of most EM methods has been obtained along strike from the above surveys, but over much less conductive mineralisation. The line was chosen by Mount Lyell to carry out a series of test surveys to help determine which would be the best approach for locating further zones of high grade copper. Ideally such a test would have been carried out over a small deeply buried massive sulphide body, since this was the expected target, but since all such known bodies had been mined, or nearly mined out, a line was chosen over four zones of subeconomic mineralisation; namely Western Tharsis, Footwall lens, EP17 and EP16\* (The latter two are named after Equipotential anomalies which covered the Anaconda and Crown 3 deposits respectively.) In the results, the zones have been labelled as W.Th. (at 1300'N), F/W lens (at 1850'N), EP17 (at 2800'N) and EP16 (at 3300'N) and the original BMR Turam survey (Rowston, 1957) shows a distinct response over each one (Figure 35). This Figure also shows the good agreement obtained by the 1986 survey for the Mines Department. In the intervening years between the BMR and Mount Lyell test surveys, a 200mm iron pipe was laid across the grid and pyritic boulders and waste from the Crown 3 open cut dumped across part of line 29W. To the south, there is now a road with more pipes and a minor power line. Further south there is a large 'noisy' power line. The positions of these 'cultural' features are also shown on the profiles. The 200mm pipe was removed before 1986, the year of the Mines Department's surveys. The results of test Maxmin and Genie surveys are shown in Figures 42 and 43. The former used a 100m coil separation and the latter 50m. Neither has responded to the mineralisation. The in-phase Maxmin responses are mostly topographical effects and the Genie with its smaller coil spacing, has responded to the iron pipe. There is however an unexpected and unexplained Maxmin response at 2150N indicating a weak conductor. The PEM system also failed to detect the deposits (Figure 44). Sirotem surveys using a large fixed loop (300m x 150m) and roving receiver (with a cable link to the transmitter) were also tried. The results, which are not given here (see Bishop, 1983a or 1984), were most disappointing. The data was noisy and showed large spikes at the loop edges. These surveys are in strong contrast to those carried out some years later for this report.

Large, fixed loop Sirotem, EM37, UTEM and Zonge (GDP-12) TEM surveys were carried out for the MRV project along 29W. The surveys were commissioned for comparison with each other and with the earlier EM surveys. The same loop position was used for all surveys and this coincided with the two positions of the BMR's grounded wire source (at 2000'N and 2600'N) for the Turam survey. The results (Figures 45 to 48)

-----  
\* This is the same line, 29W, as that described above for the Mount Lyell SP and Turam surveys.



NOTE:  
 coil separation : 50m  
 survey date : 1982

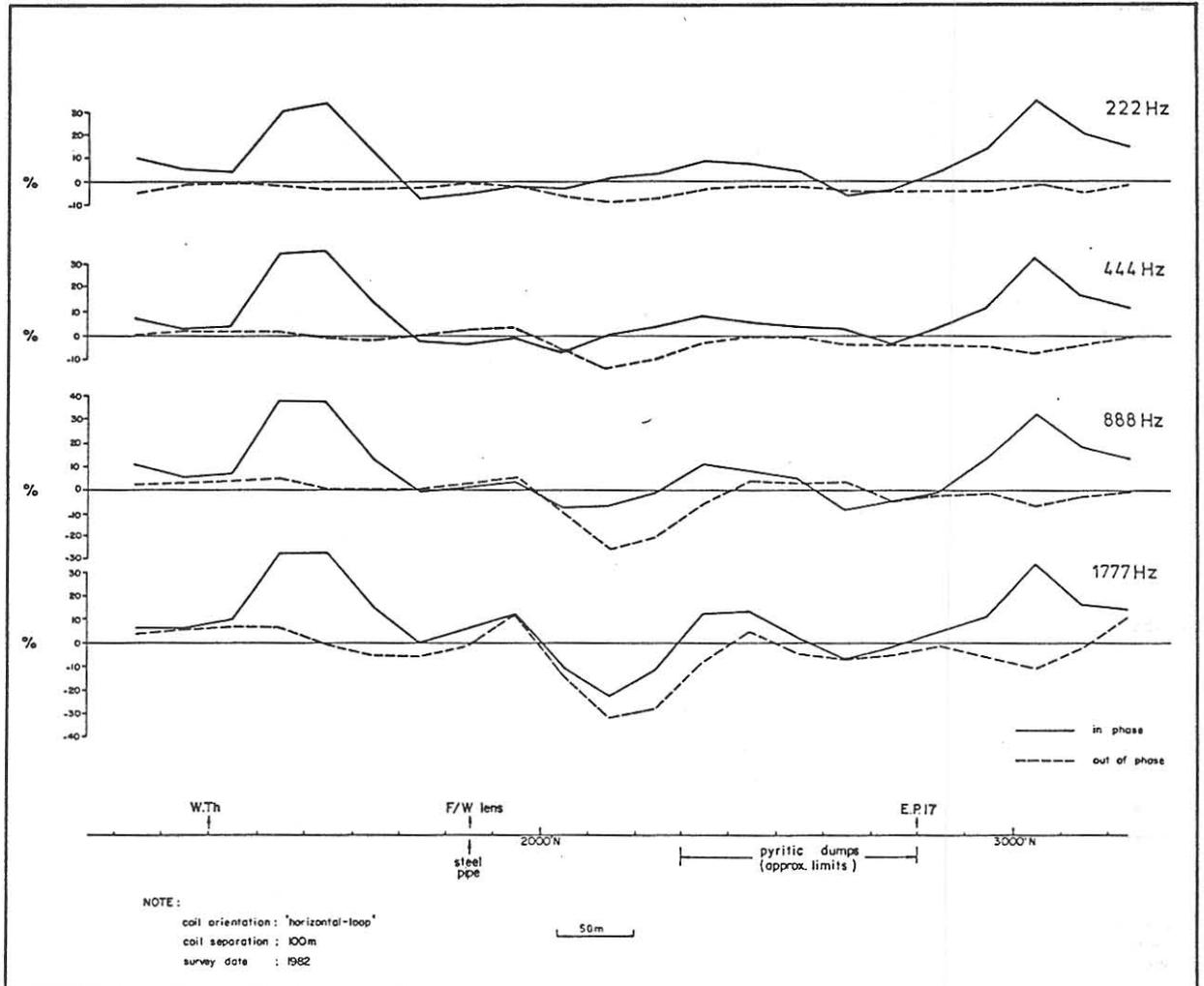
50m

MOUNT READ VOLCANICS PROJECT:  
 GEOPHYSICAL SIGNATURES

MT LYELL LINE 5,343,200N:  
 PEM

FIGURE 41

MD/MG87/06

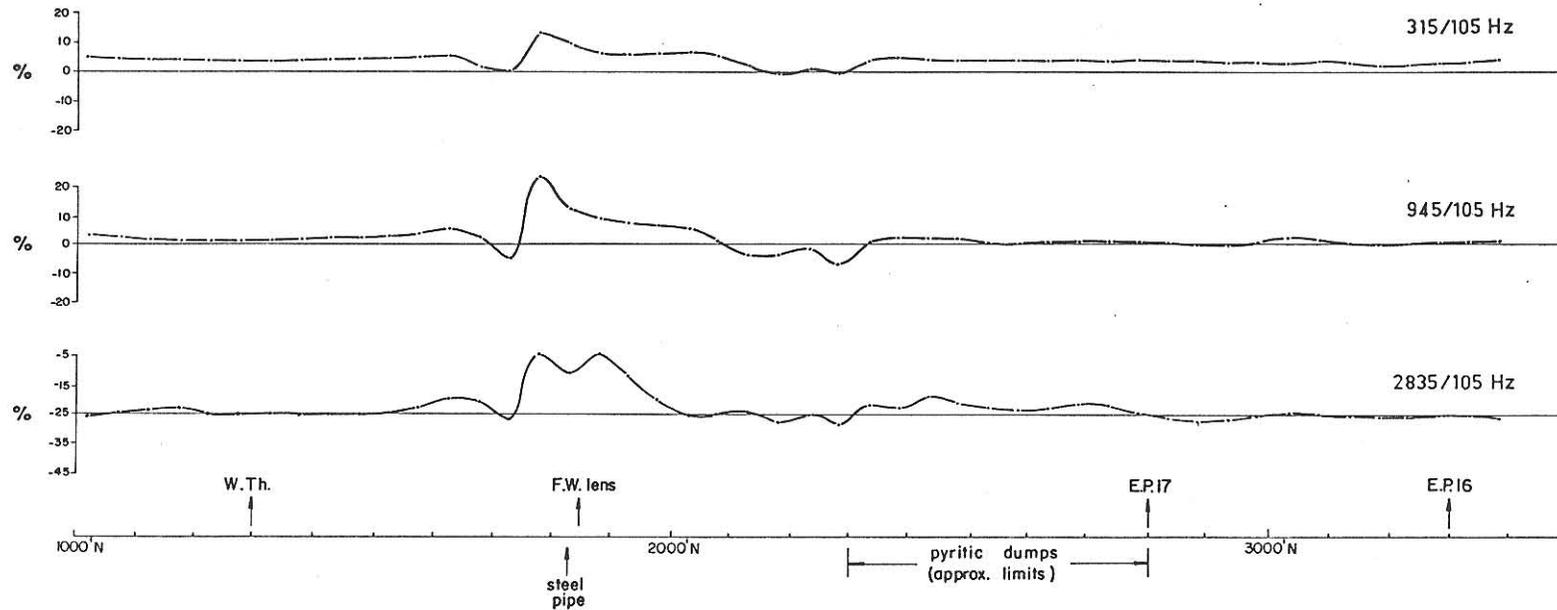


**MOUNT READ VOLCANICS PROJECT:  
 GEOPHYSICAL SIGNATURES**

**MT LYELL LINE 29W: MAXMIN**

FIGURE 42

MD/MG87/06



NOTE:  
 coil orientation : 'horizontal-loop'  
 coil separation : 50m  
 survey date : 1982

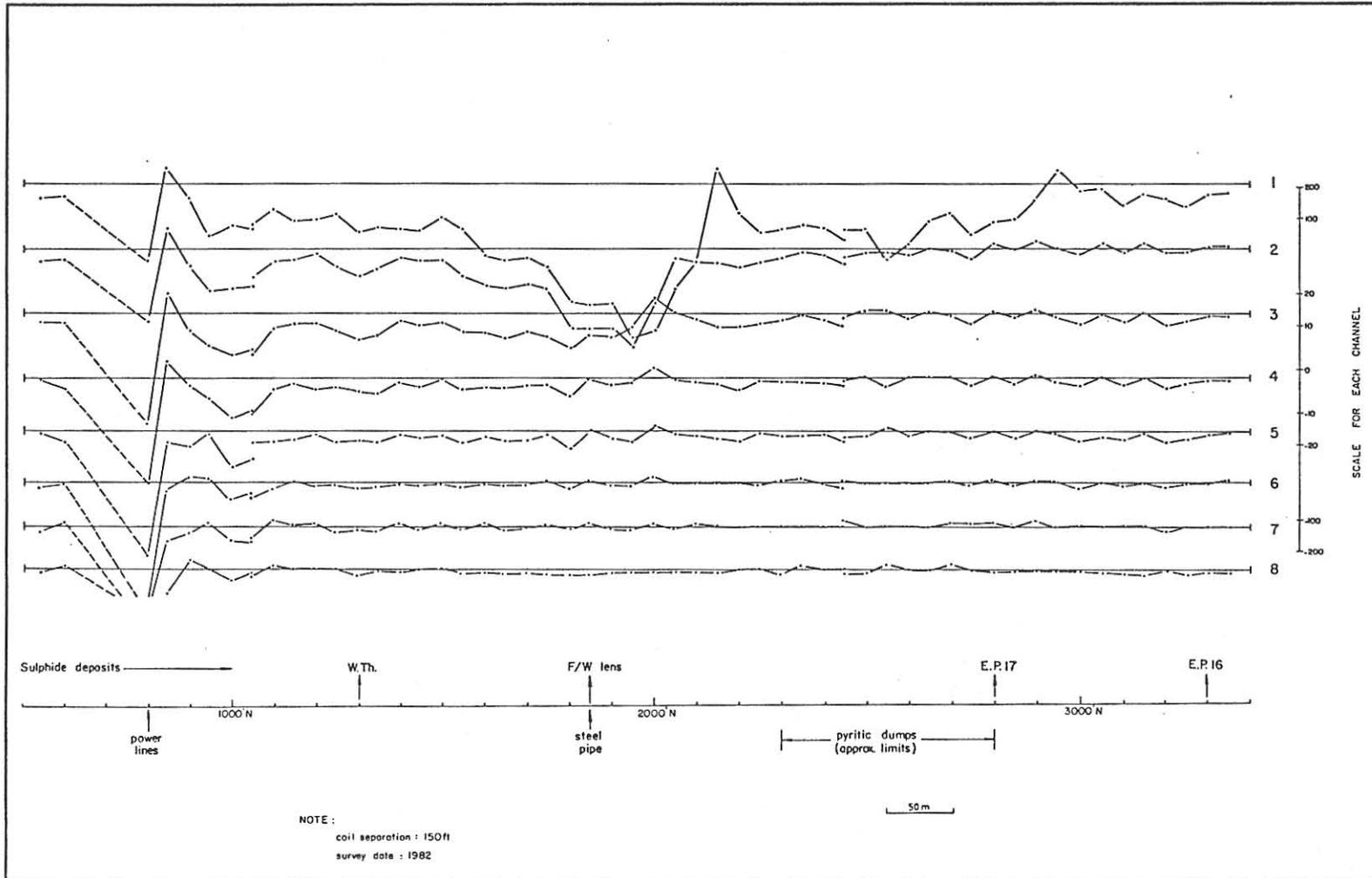
50m

MOUNT READ VOLCANICS PROJECT:  
 GEOPHYSICAL SIGNATURES

MT LYELL LINE 29W: GENIE

FIGURE 43

MD/MG87/06

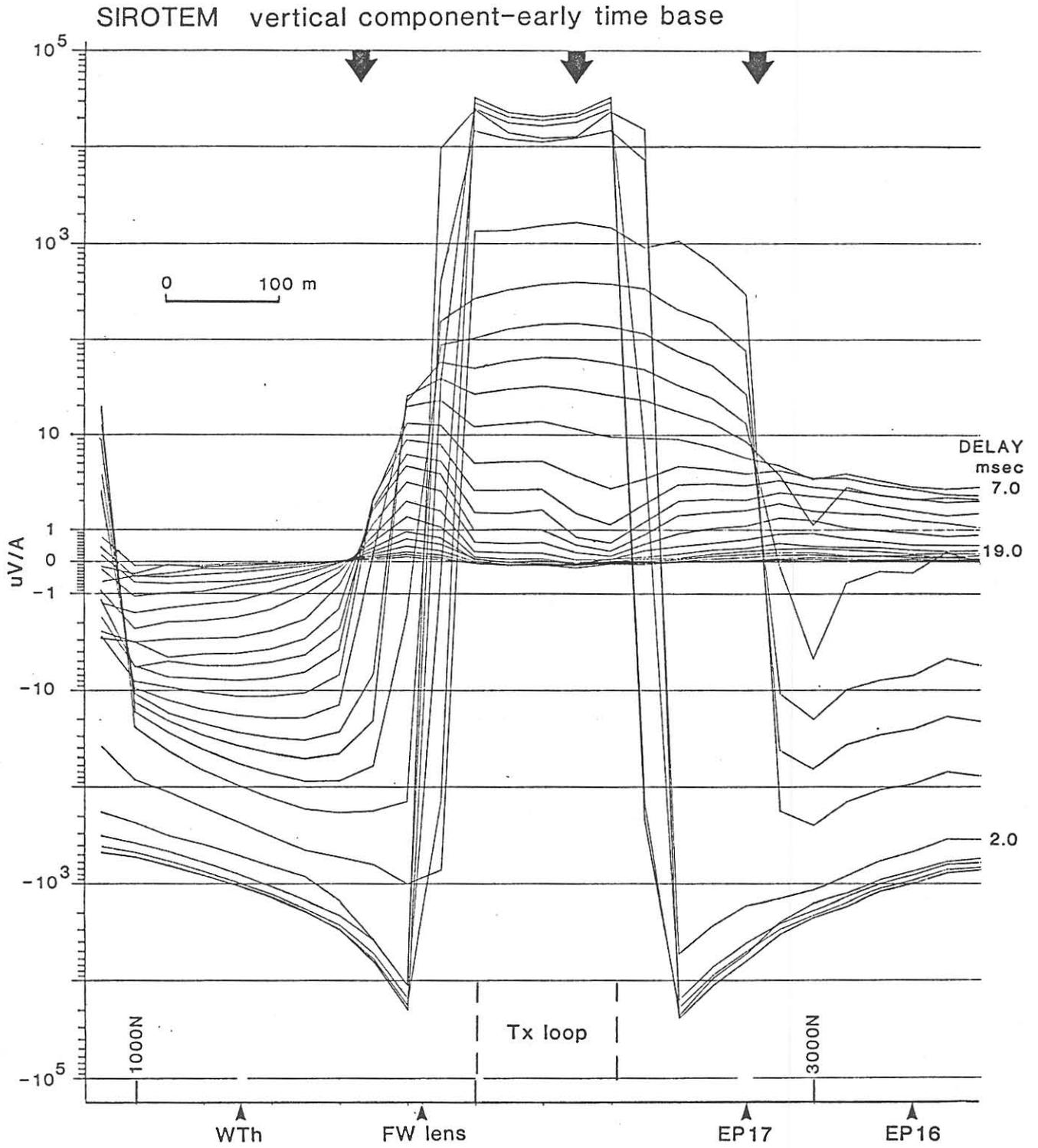


**MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES**

**MT LYELL LINE 29W: PEM**

**FIGURE 44**

**MD/MG87/06**

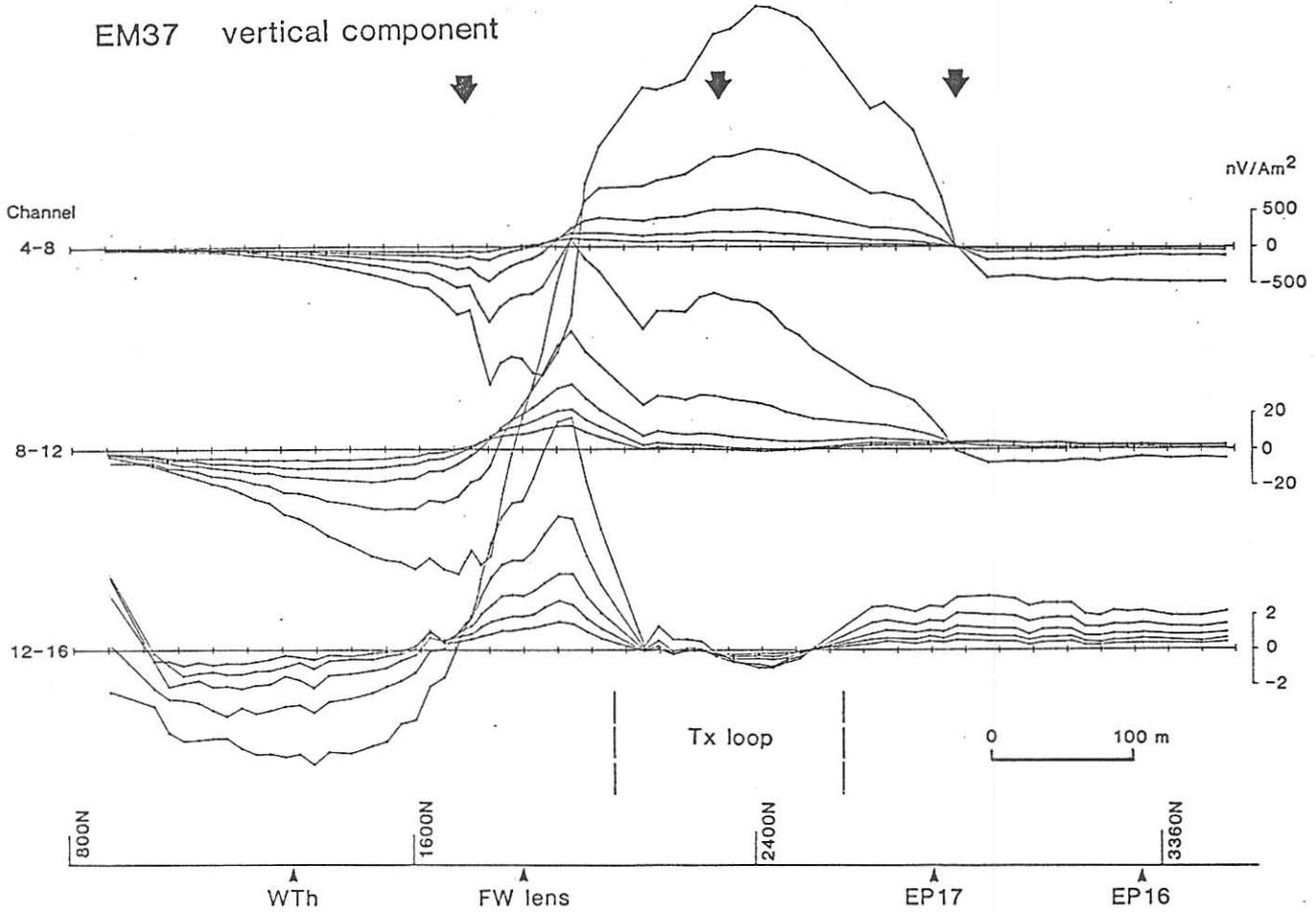


MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES

MT LYELL LINE 29W: SIROTEM

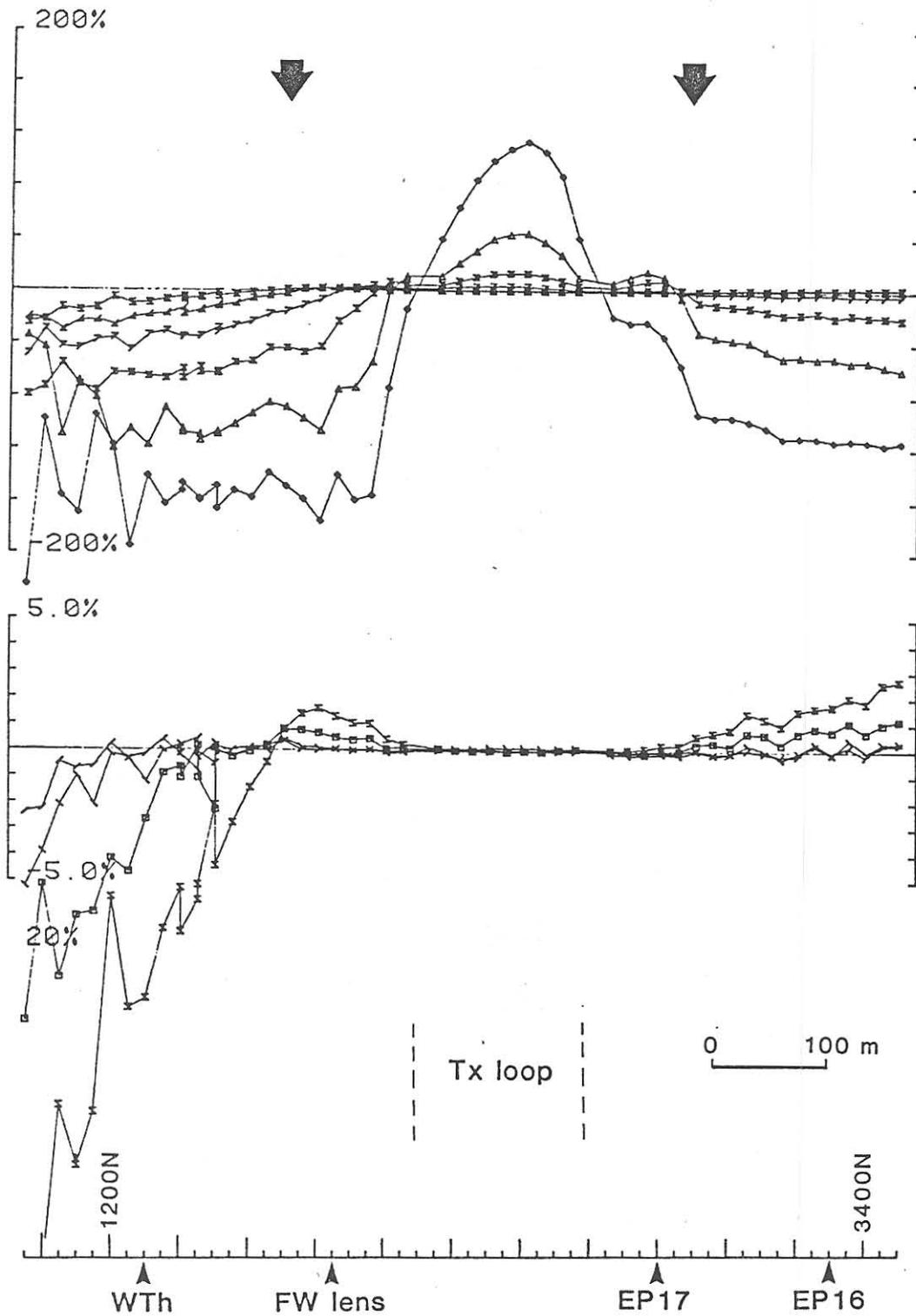
FIGURE 45

MD/MG87/06

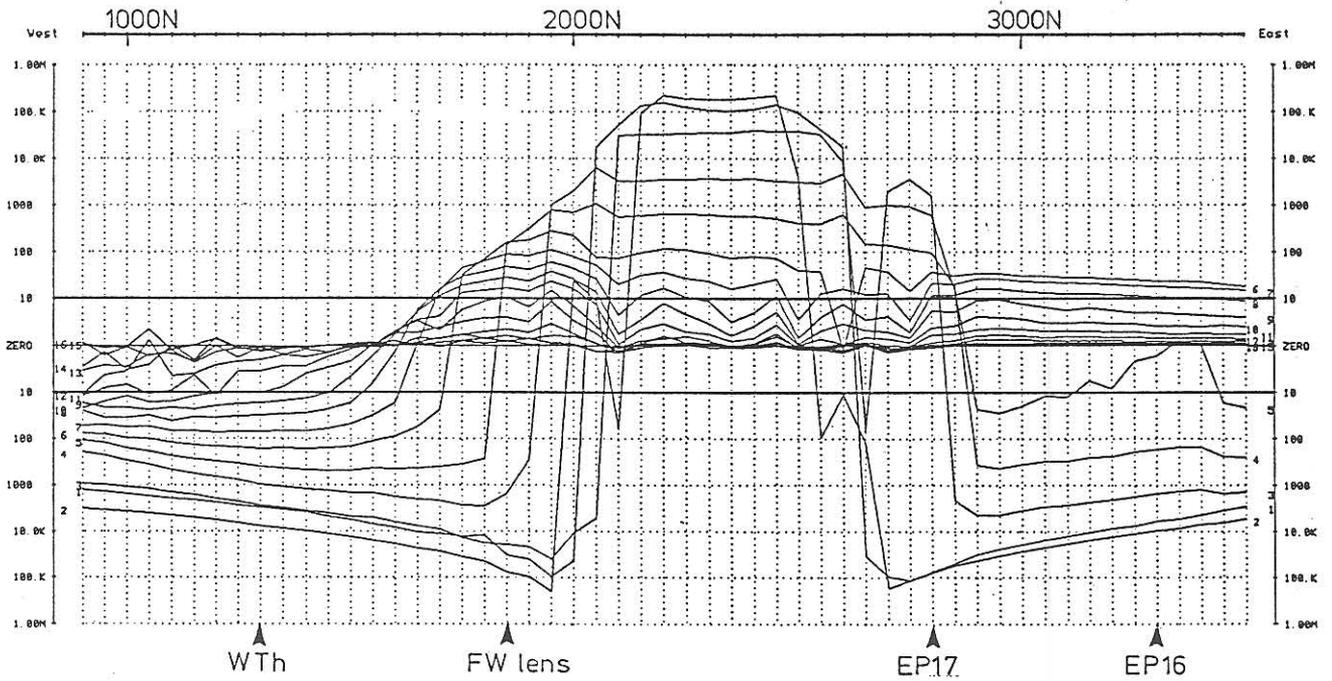


MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
MT LYELL LINE 29W: EM37	
FIGURE 46	MD/MG87/06

### UTEM vertical component



MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
MT LYELL LINE 29W: UTEM	
FIGURE 47	MD/MG87/06

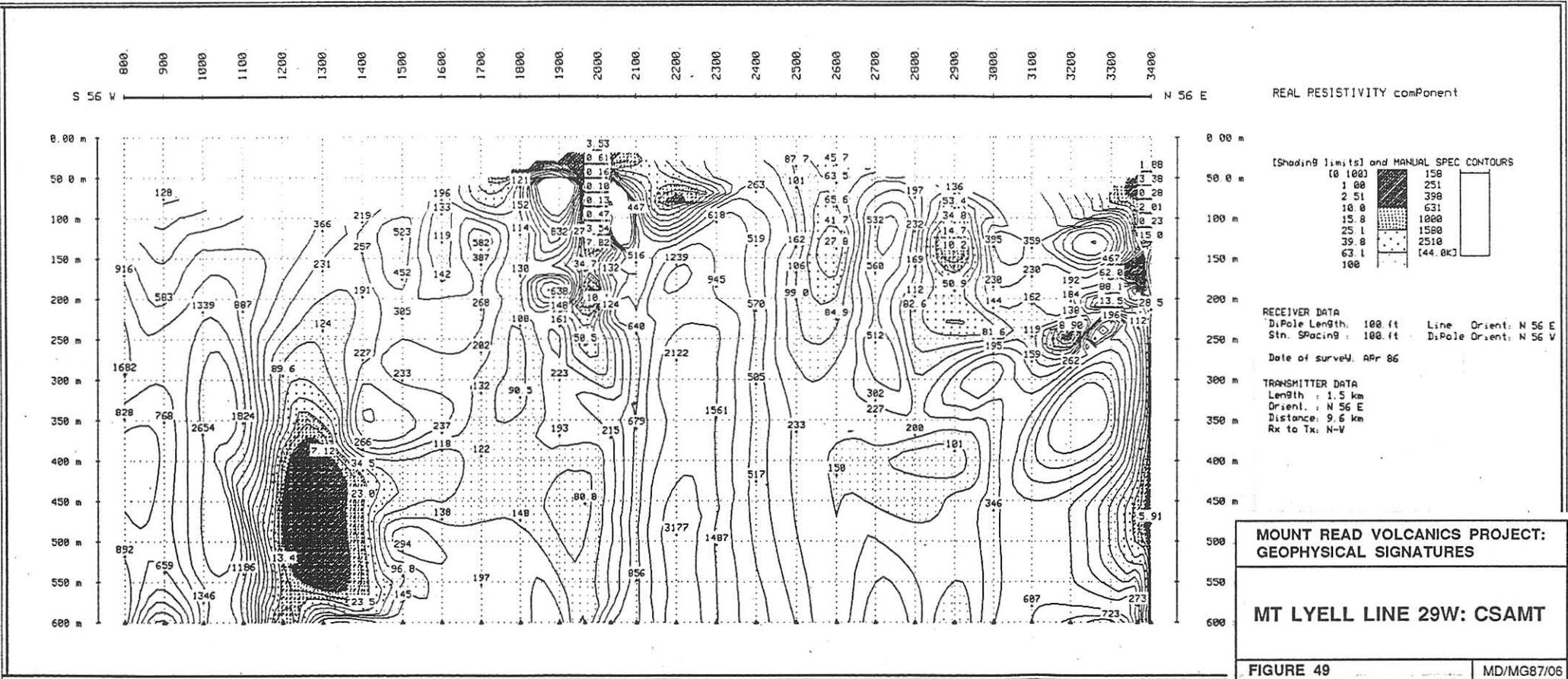


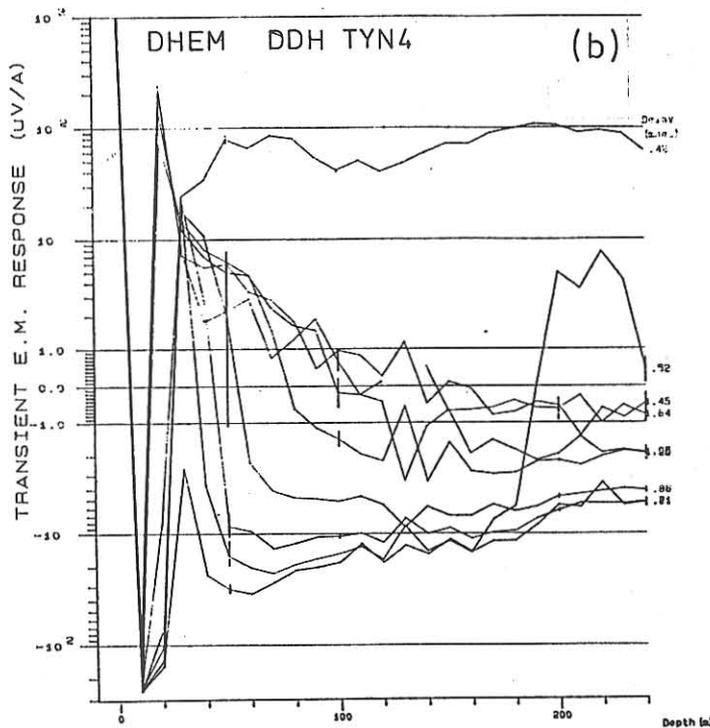
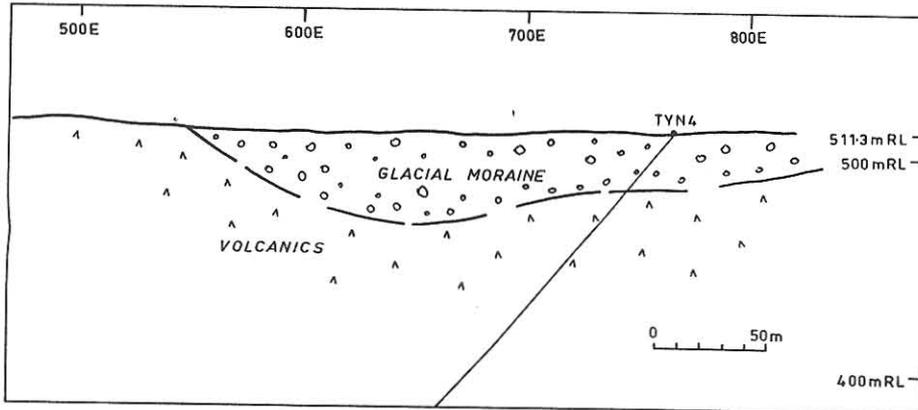
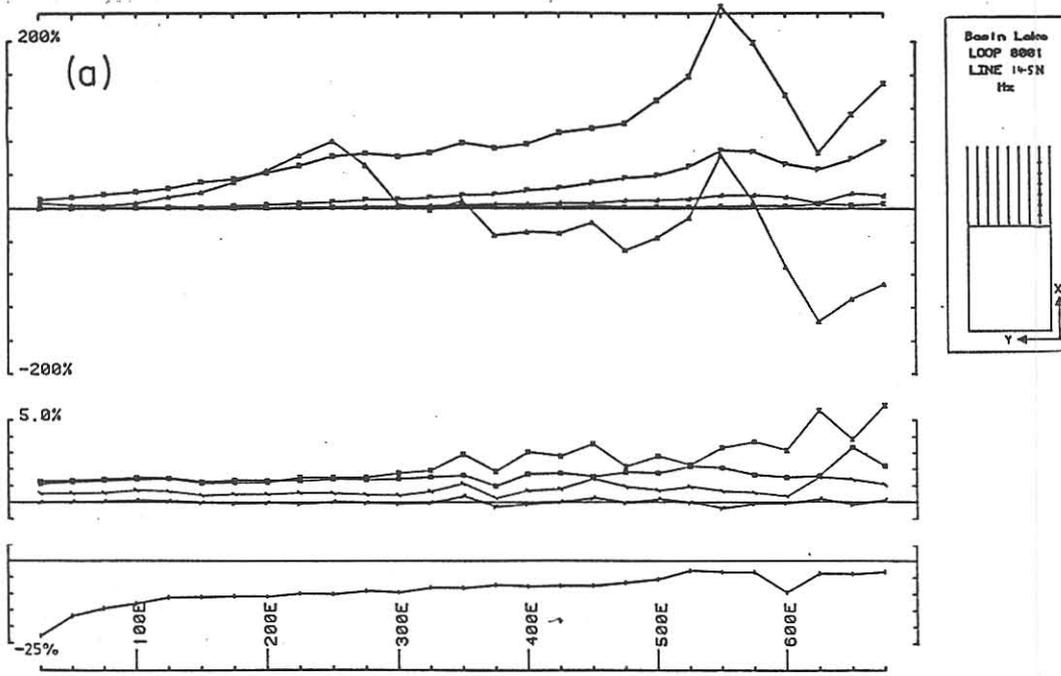
<b>MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES</b>	
<b>MT LYELL LINE 29W: GDP-12</b>	
<b>FIGURE 48</b>	<b>MD/MG87/06</b>

are remarkably similar but compare poorly with the galvanic Turam. Each system has responded to good (and broad) mineralisation at the Footwall lens and to a much weaker conductor at EP17, but not to the two outer zones. Presumably these have been shielded by the conductors closer to the loop. Thus the results illustrate one of the limitations of fixed-loop surveys. In strong contrast, a CSAMT survey over 29W has defined each of the four zones, indicating a good deep conductor at Western Tharsis (Figure 49).

The results from this and other surveys carried out in western Tasmania suggest that CSAMT is capable of deep penetration with a good lateral resolution, however the method is in its infancy and has a number of shortcomings - from the production of data to its interpretation. Improved receivers may permit an increasing use of natural field AMT surveys which have fewer logistical problems, however noise radiated by the numerous high voltage power lines in western Tasmania may require that we stay with controlled sources. It is probably appropriate to also mention here the recent work by Macnae and Lamontagne (1987) on imaging TEM data. This was developed primarily for petroleum exploration, but a very early example is shown in Figure 26 using the Renison UTEM data. Macnae and Lamontagne expect the technique to have depth capabilities comparable to CSAMT, however it requires (at least) a three-fold coverage of data and would thus be operationally difficult in most of western Tasmania.

As previously mentioned, fixed loop TEM surveys are now enjoying considerable popularity in western Tasmania. The very subtle TEM response recorded over the large Hellyer deposit has justified interest in even weaker responses, in the expectation that they may be due to smaller or less conductive, but nevertheless still economic, bodies. This has led to a number of disappointing drilling results, where not even sulphides have been intersected. The tendency of EM surveys to produce spurious anomalies was of course the original impetus behind the development of IP, which responds only to mineralisation (and graphite) and not to faults and other conductive features. Although EM techniques and interpretation have made large gains in the 30 years since IP was first tried, there may still be the need for either a confirming IP survey, or particularly if the target is deep, for a second EM survey. An illustration of such a TEM 'prospect' is given in Figure 50, which shows a short time-constant UTEM anomaly from a survey within the Mount Read Volcanics. The anomaly, at 585E, occurs near the end of the line over what was interpreted to be a trough of glacial material. Despite these negative factors, the response which was part of an anomalous zone, was in an area of high base metal soil and rock chip values and inferred favourable lithology. The target interpreted from the UTEM survey was drilled and failed to intersect any mineralisation. A DHEM survey was carried out and produced no response (Figure 50b). It was therefore concluded that the surface EM response was due to current gathering in porous sands at the base of the glacials. This phenomena of current gathering from the host rock into a 'conductor,' rather than by induction from within the body often occurs when large transmitting





MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES

BASIN LAKE AREA LINE 14.5N:  
UTEM AND DHEM RESULTS

FIGURE 50 MD/MG87/06

loops are placed adjacent to faults, weathered zones, conductive strata, etc. It is more noticeable at longer distances from the loop. The smaller loop used for the DHEM survey has not energised the source of the surface response and it is recommended that small moving loop TEM or possibly IP surveys be used to check poor anomalies which it is planned to drill. If the target is interpreted to be deep, a survey with a large loop on the opposite side should indicate whether the source of the response is a discrete target or an unconfined conductive feature\*.

#### POTENTIAL FIELD METHODS

Leaman (1987) has presented the magnetic and gravimetric responses for west coast mineralisation and has demonstrated that relatively subtle magnetic lows may indicate regions of alteration around mineralised areas. Leaman (1987) also shows that carefully executed and properly reduced gravity surveys can be used to evaluate a prospect's economic potential and he argues for a greater use of both of these methods.

Skarn deposits such as Kara are strongly magnetic and magnetics has been used as a direct-search technique for tin and tungsten deposits around the margins of the west coast granites, as it has in the search for Renison or Cleveland style replacement tin deposits. However, the known volcanogenic massive sulphides in Tasmania (and eastern Australia) are not magnetic (although one section of Rosebery contains a significant amount of magnetic pyrrhotite) and thus the method is not expected to provide direct targets for follow up in the Mount Read Volcanics. Nevertheless most prospects in western Tasmania are routinely surveyed with magnetics, with the data being used to aid local structural and lithologic mapping. A more recent development has been the image processing of aeromagnetic (and gravity) data to provide regional structural information.

#### MISCELLANEOUS METHODS

The methods described above are those most commonly used in exploration. Here we briefly mention some others which have also been tried or which are available. Radiometrics has been flown in conjunction with most of the recent aeromagnetic surveys. To our (perhaps limited) knowledge, this data has received little attention. The conventional wisdom has been that the soil cover and thick canopy of trees over most areas would absorb too much of the 'signal'. However properly processed data, gathered with large volume sensors flown at low altitudes, might well aid lithological mapping and locate areas of alteration, etc.

-----  
\* One could also argue that since this is a prospective zone, a hole should be drilled anyway and a large volume of it tested by a DHEM survey.

The application of the seismic reflection method was briefly referred to under 'Hellyer'. This technique may well find application in locating, at depth, tabular massive sulphide bodies such as occur at Renison and other localities where the dips are relatively flat. Some use has also been made of density and (passive) gamma logging, particularly for correlation of beds in the Palaeozoic sedimentary sequences. It is possible that similar logging within the Mount Read Volcanics might also assist hole to hole correlations, since the local structure is often poorly known.

### EXPLORATION IN AREAS OF THICK COVER

Only recently have prospective areas (i.e., areas along strike from known mineralisation) covered by thick sequences of glacial till or basalt, begun to be properly investigated. Examples of such areas are Boco between Rosebery and Que River which is covered by glacial material, in places more than 100m thick, and to the north of Hellyer where Tertiary basalt flows may be a few hundreds of metres thick. In these regions geophysics has a three fold application. Firstly it can be used to try and determine the depth to basement, since clearly there is an economic limit to the depth of exploration. Secondly, geophysics may be used to try and determine whether the basement rocks belong to the prospective horizons; for example, whether they are Mount Read Volcanics or Ordovician sediments. Thirdly, after defining an area of potential host horizon with minimum cover, geophysics may be used to directly search for sulphides.

### **TERTIARY BASALT COVER**

#### WARATAH

The Tertiary basalts in the Waratah area overlie PreCambrian sediments to the west (with the possibility of another Mount Bischoff-type tin deposit) and Ordovician and Mount Read Volcanics to the east. Previous geophysical work on the basalt cover has been largely based on the use of spectral analysis of aeromagnetic data to determine basalt thickness and isolate sub basaltic magnetic anomalies (e.g. Isles et al, 1984; Leaman, 1984; Lucas, 1988). A study of some magnetic properties of the basalt in a hole penetrating the whole basalt column has been made by Lucas (1988). A recently completed drilling program in the basalt covered areas was undertaken by the Mines Department. It appears from this work that the basalt cover consists of more than 20 flows with some interbedded lake sediments and that the lower part of the sequence is dominated by hyaloclastites and has reverse remanent magnetization (Lucas, 1988). The two fold petrographic character of the basalts is probably reflected in their electrical properties, the lower part (i.e. the hyaloclastites) being more conductive. While magnetic methods have been successful in estimating basalt thickness and have located sub-basalt anomalies, no economic discoveries appear to have been made to this time.

The Mines Department and exploration company holes in the Waratah area have been used as control for a series of TEM soundings and CSAMT stations which were commissioned for this report.

The CSAMT data covers two approximately east-west traverses using a dipole source on the North Goderich Road (Figure 51). The northernmost traverse lies along the Waratah - Guildford Road and has two points controlled by drill holes. The western part of the line was also covered by limited TEM soundings using two different systems, Zonge GDP-12 and EM37. The southern traverse employed CSAMT only and lies along the Pearsefield and Clipper Roads, approximately parallel to the first traverse but some 6km further south. Mount Pearse lies another

3km further south and exposes Ordovician material through the basalt cover. It is unlikely that areas with a significant thickness of post Mount Read (i.e. post Cambrian) lithologies will be prospective - the basalts are a sufficient problem in their own right.

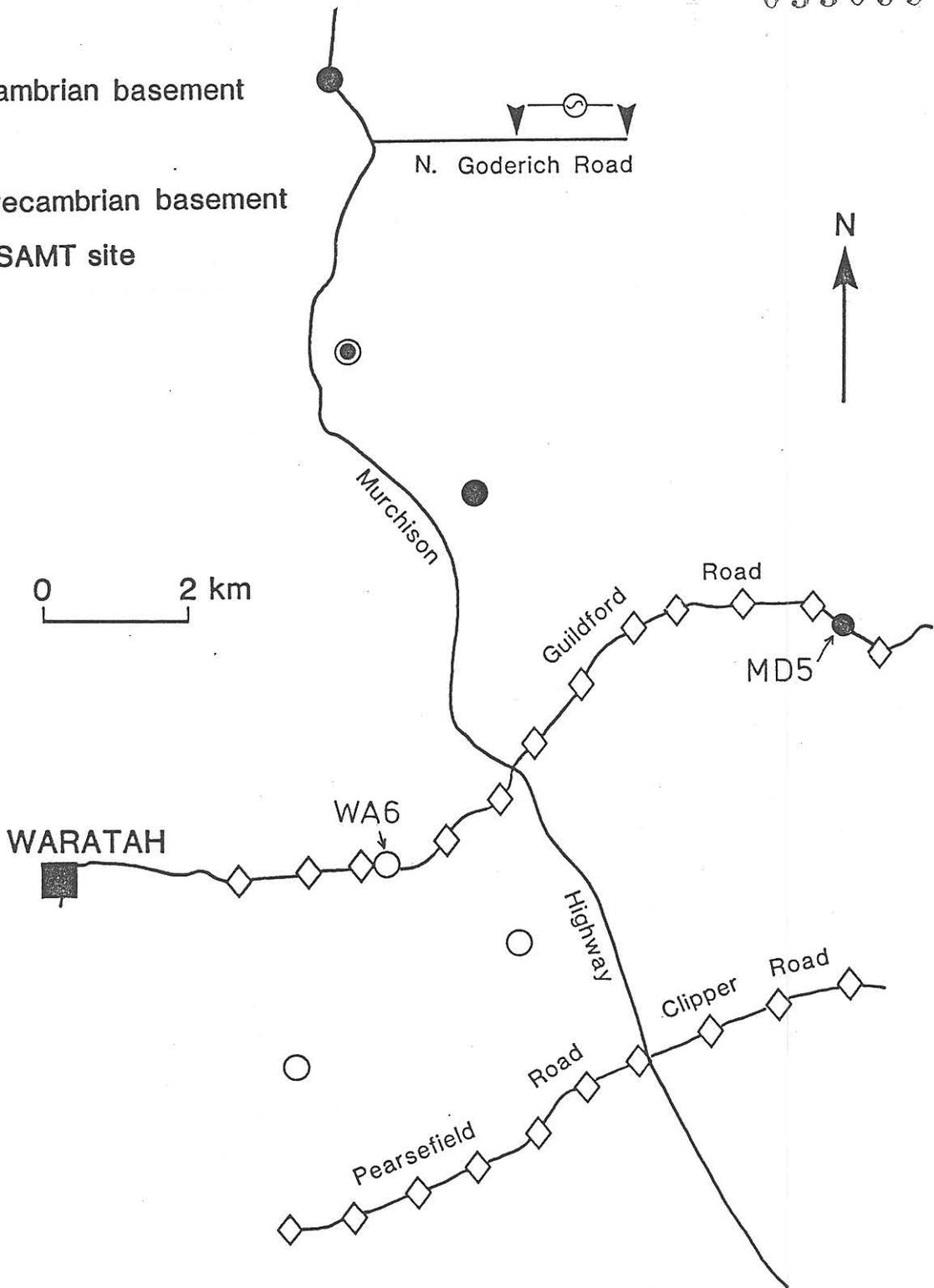
The CSAMT results as received from the contractors are presented in a variety of ways. Figure 52 gives two examples. A universal feature of the data, taken as a plot of Cagniard resistivity versus period (from raw data), is an asymptote at almost 45 degrees at long periods indicating a highly resistive basement (Figure 53). There are also a set of consistent offsets or displaced points in the data which probably represent instrumental problems. As none of the presentations in Figure 52 is quantitative, the data from each site was inverted to a layered model and used to construct a section which could be compared with the drill hole data. Between 2 and 4 layers were required to adequately fit the results. In general the 4 layer cases include a very thin surface layer which affects only the high frequency data. It became apparent during the inversion process that occasionally a site was found which only poorly fits a layered model e.g. site 3 on the first line. These sites seem to be associated with a topographic high in the basement and a thinning of the basalt cover.

The northern section (line 1, Figure 54) shows a gross structure of two conductive layers over a very resistive basement which is interpreted as representing the PreCambrian basement; an interpretation confirmed in drill hole WA6 where the depth correlation is excellent. The two conductive layers cover the whole section. Clearly in the west both represent basalt with a lower section much more conductive than the upper part. To the east drill hole MD5 enters the Cambrian section within the conductive lower layer. This suggests that here at least, CSAMT cannot distinguish between the lower basalt and the Mount Read Volcanics.

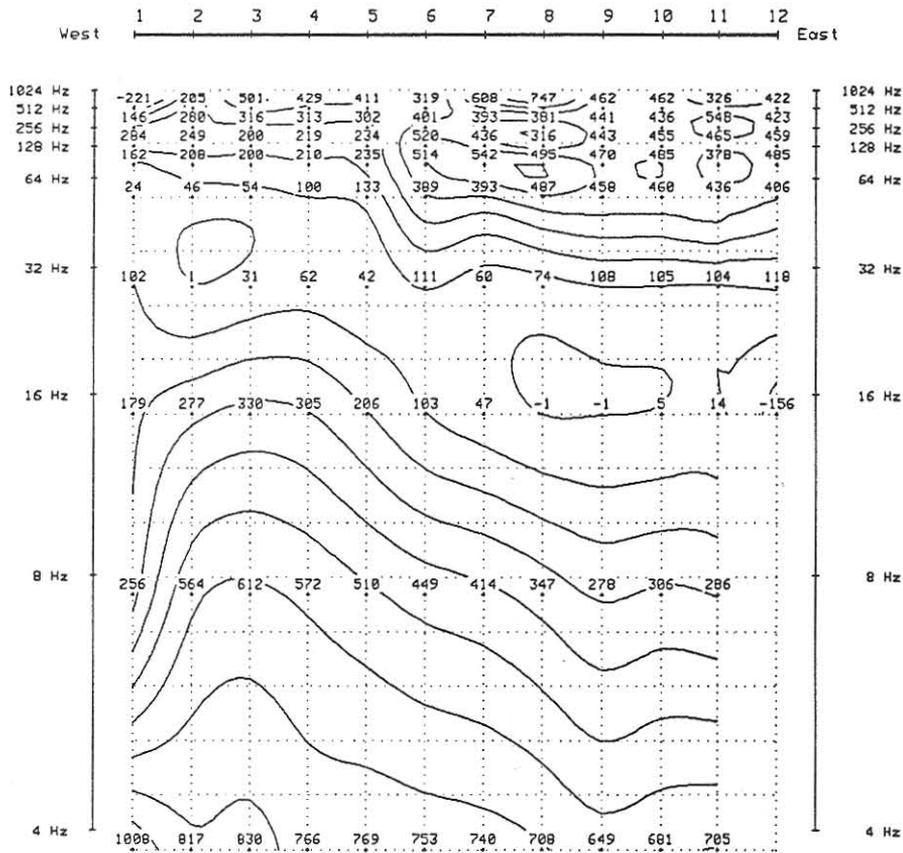
The southern section (line 2, Figure 54) shows a broadly similar structure to that seen on line 1; i.e. there are two basement highs with a significant depression between. However, the cover structure is somewhat different in that the two fold division of the basalt seen on line 1 is almost absent and a drape of very conductive material covers the topographic highs. The only place where there seems to be a twofold division of the basalt is directly north of Mount Pearce. Again the essential character of the section is cover/basement and it does not seem possible to discriminate the type of material above the presumed PreCambrian high resistivity basement. In any event, if this interpretation of the high resistivity basement is accepted, there is a quite thin section of cover or possible volcanics. This may downgrade the prospectivity for massive sulphides but increase the interest in possible tin mineralization within the basement.

Two sets of TEM data are available for points on or near line 1 of the CSAMT traverse. The set by Zonge is extremely noisy with poor repeatability and again emphasises the difficulties that power lines pose for this method. When inverted, no deep features are revealed but a few thin highly conductive layers are suggested (Figure 55). The only

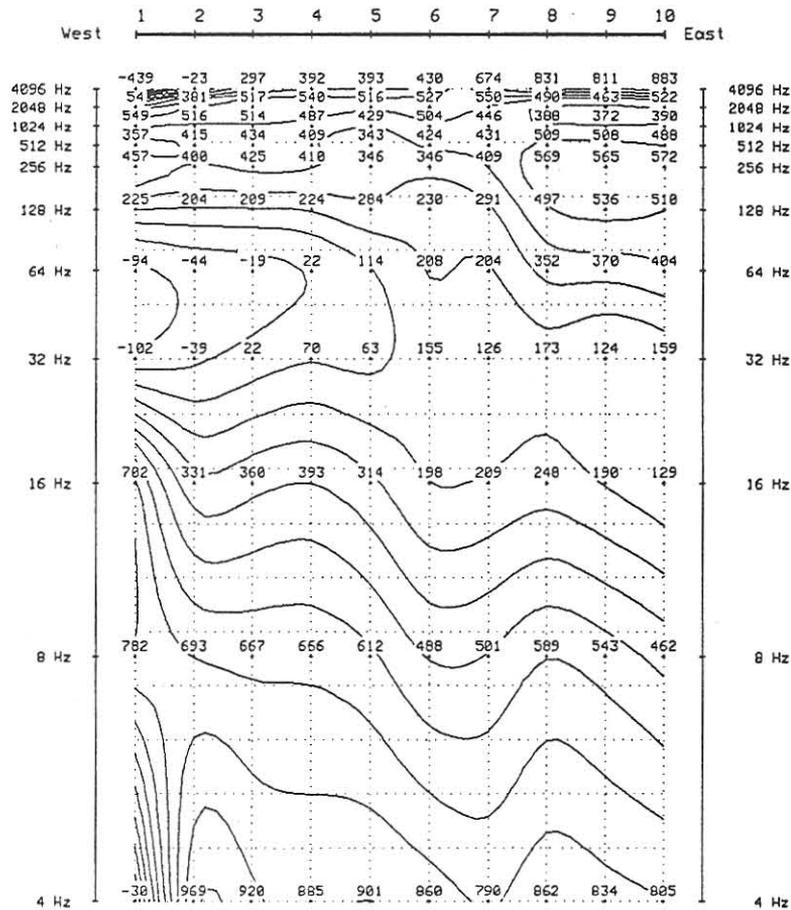
- Cambrian basement
- ⊙ ?
- Precambrian basement
- ◇ CSAMT site



MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
WARATAH LOCALITY MAP	
FIGURE 51	MD/MG87/06



LINE 1



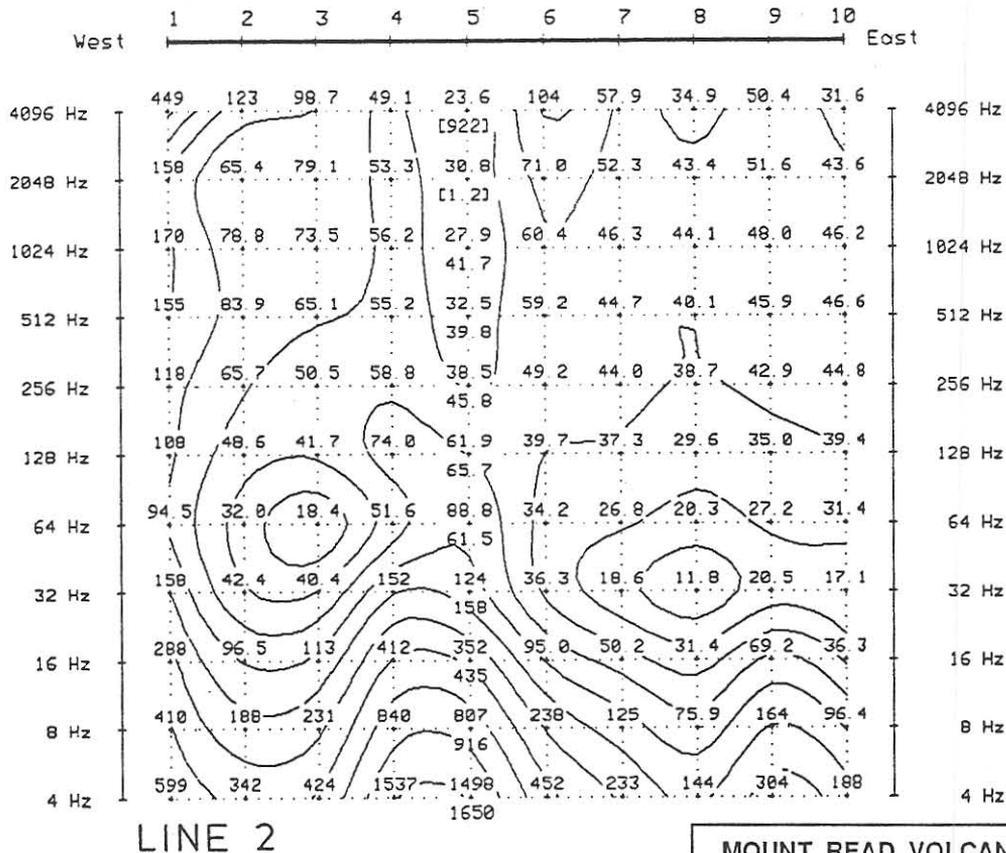
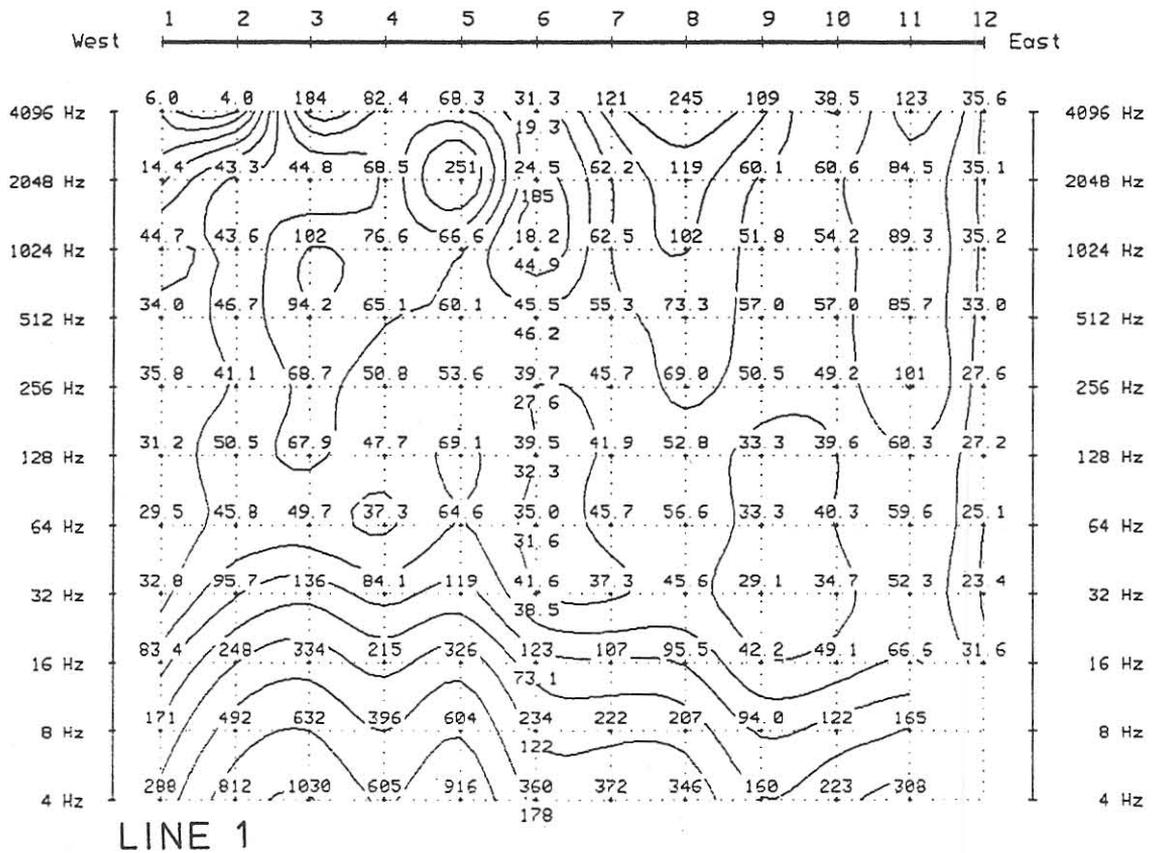
LINE 2

MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES

WARATAH CSAMT RESULTS  
Slope of log(H-field MAG)  
vs log(FREQ)

FIGURE 52a

MD/MG87/06

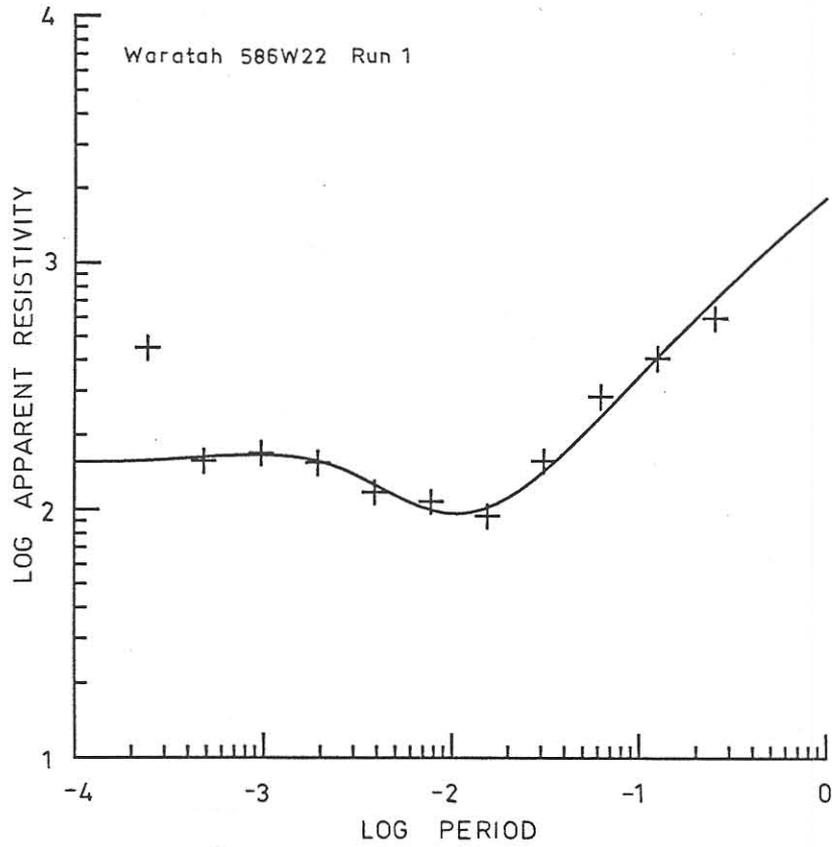


MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES

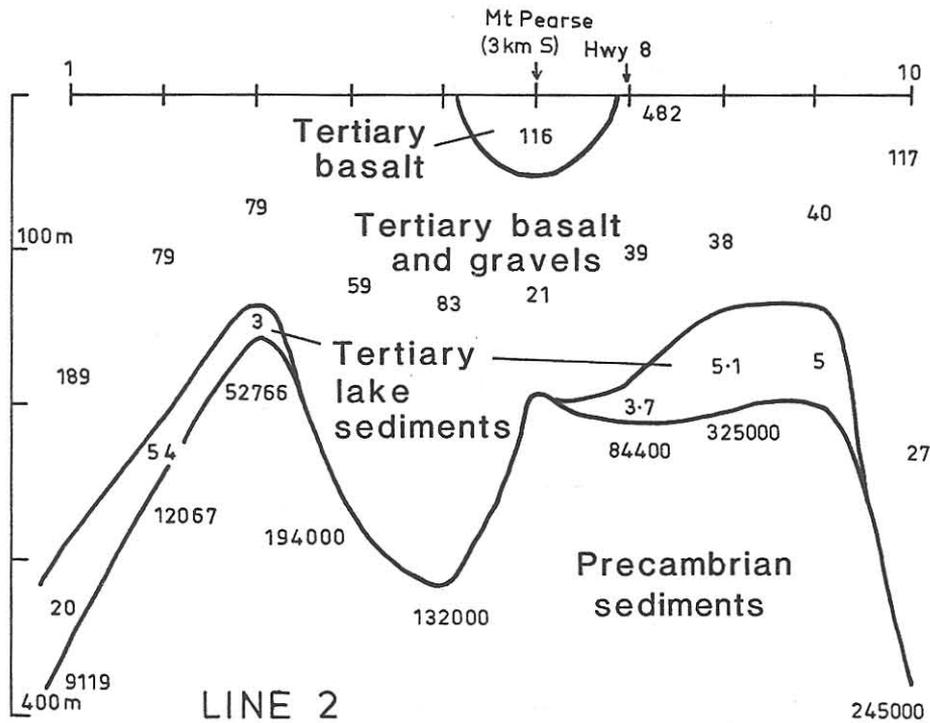
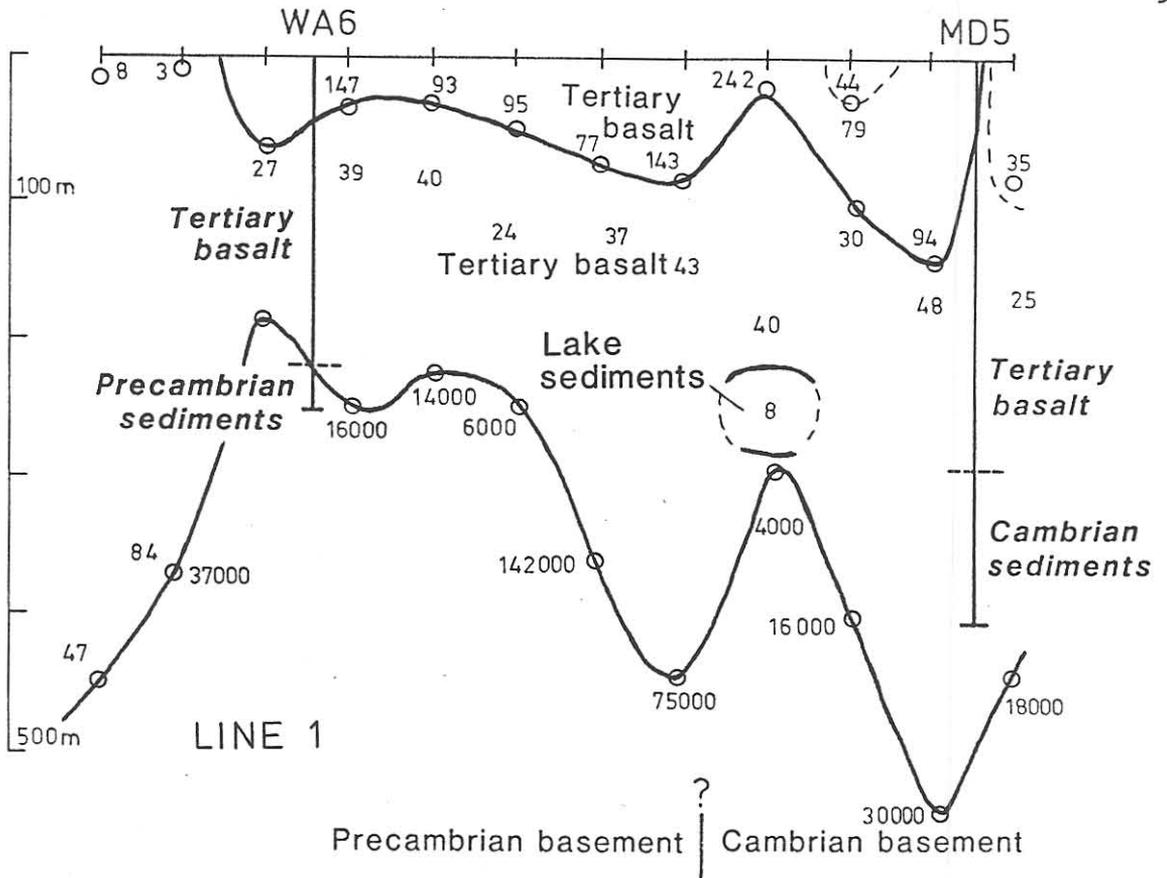
WARATAH CSAMT RESULTS  
Cagniard resistivity

FIGURE 52b

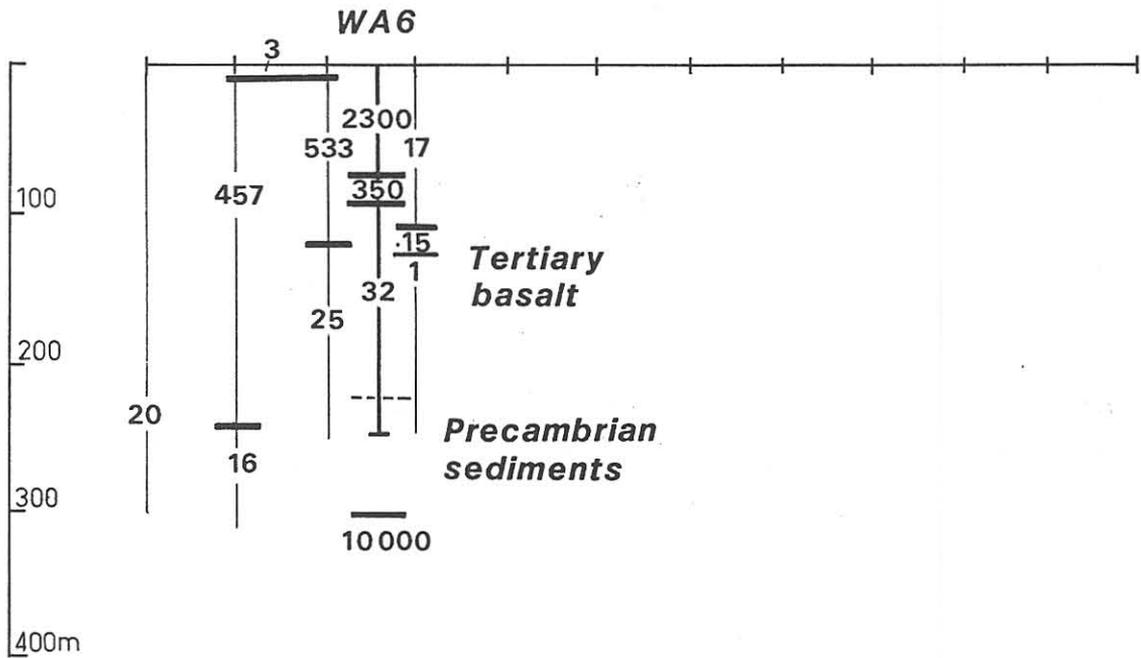
MD/MG87/06



MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
WARATAH CSAMT CAGNIARD RESISTIVITY FROM RAW DATA	
FIGURE 53	MD/MG87/06



MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
WARATAH CSAMT INTERPRETATIONS	
FIGURE 54	MD/MG87/06



-?-

MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
WARATAH TEM INTERPRETATION	
FIGURE 55	MD/MG87/06

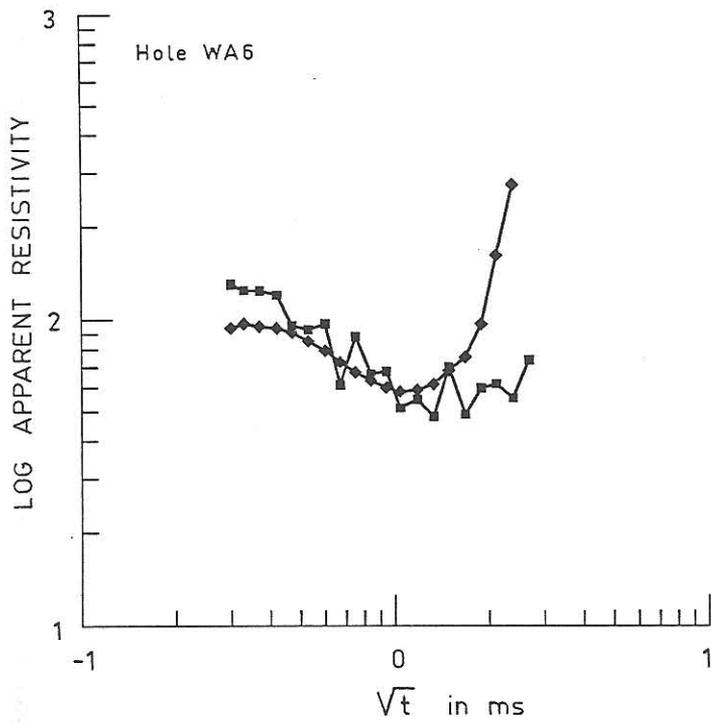
plausible interpretation geologically is that these represent interbedded lake sediments. The second set of soundings by Geoterrex appear to be of good quality but the apparent resistivity curves obtained with receivers in and out of the loop show marked discrepancies at late times (not shown here) and there are also differences between results from symmetrically placed points outside the loop (Figure 56). In view of this problem no detailed interpretation was attempted. These problems may be due to the power line.

At Mount Cattley, to the east of Waratah, the basalt thickness is greatly reduced as the margin is approached. Where the thickness approaches 100m, TEM soundings for Pancontinental Mining Ltd. have been reasonably successful in determining the thickness of cover (Figures 57, 58) so that in modest thicknesses of basalt away from power lines the TEM method may be valuable in cover studies.

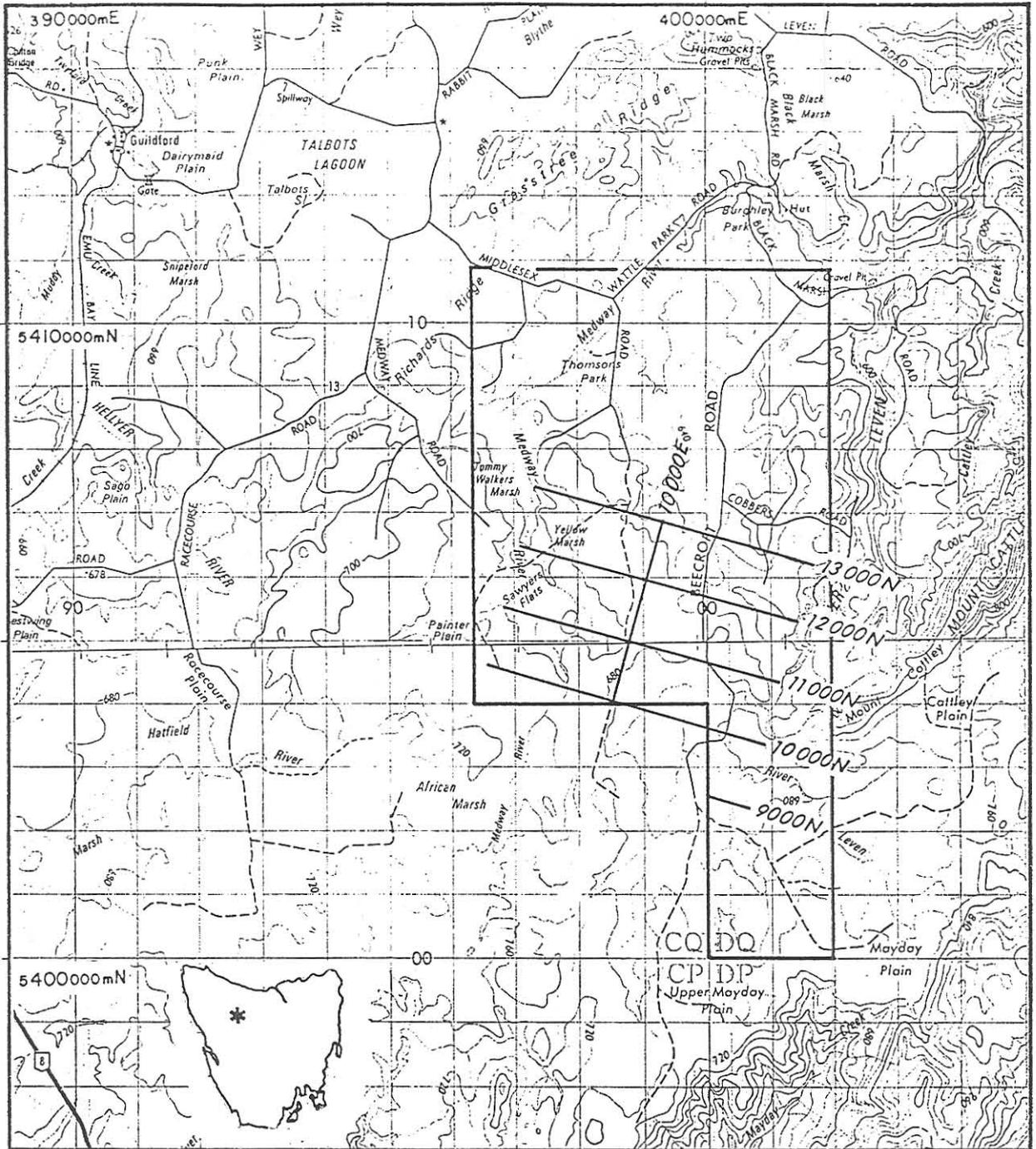
In summary, the basalt cover around and to the east of Waratah is of considerable thickness (up to 500m) with pronounced basement relief. The great thickness and the low resistivity of the lower part of the section do not augur well for sub basalt exploration. The CSAMT method appears to have adequately outlined the PreCambrian basement and this may be important in the selection of styles of mineralization known to be located close to the contact. CSAMT apparently failed to discriminate between the lower basalt units and the Cambrian rocks. Provided that the Cambrian section is not too magnetic, a combination of spectral magnetic methods and CSAMT should be able to define the non-magnetic conductive Cambro-Ordovician section thickness. The Mines Department drilling program affords further constraints on the basalt thickness and actual Cambrian/Ordovician nature of the sub basalt surface. Where the basalts are thin, TEM soundings appear to offer a reasonable method of mapping their thickness and investigating the sub basalt material for conductors.

#### SKARNS

Several companies have explored over basalt covered areas in the vicinity of the granite margins for skarns and in the Waratah region for replacement tin deposits. For the former, the Shell company have tried many geophysical methods: they include, aeromagnetism, radiomagnetism, gravity, AMT, DC resistivity, TEM soundings and airborne EM. Many of the EM and magnetic anomalies produced by the airborne surveys were found to be caused by the basalt, however these were usually easily and quickly distinguished by ground follow up surveys. Although there was a limited amount of drill-hole verification, the company found that the various geophysical methods gave consistent results, indicating the basalt in the Guildford area to have a thickness greater than 200m. TEM soundings were considered to be particularly effective (Hungerford, pers. comm.). The conclusions obtained by Shell from a series of test surveys over a buried skarn in the Moina area, are also worth repeating here. Magnetic, IP, Turam, Maxmin, VLF and MMR surveys were carried out. The magnetics recorded high frequency anomalies with amplitudes of 100 to 200nt over the basalts and recorded larger responses over the skarn.



MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
WARATAH TEM APPARENT RESISTIVITIES	
FIGURE 56	MD/MG87/06

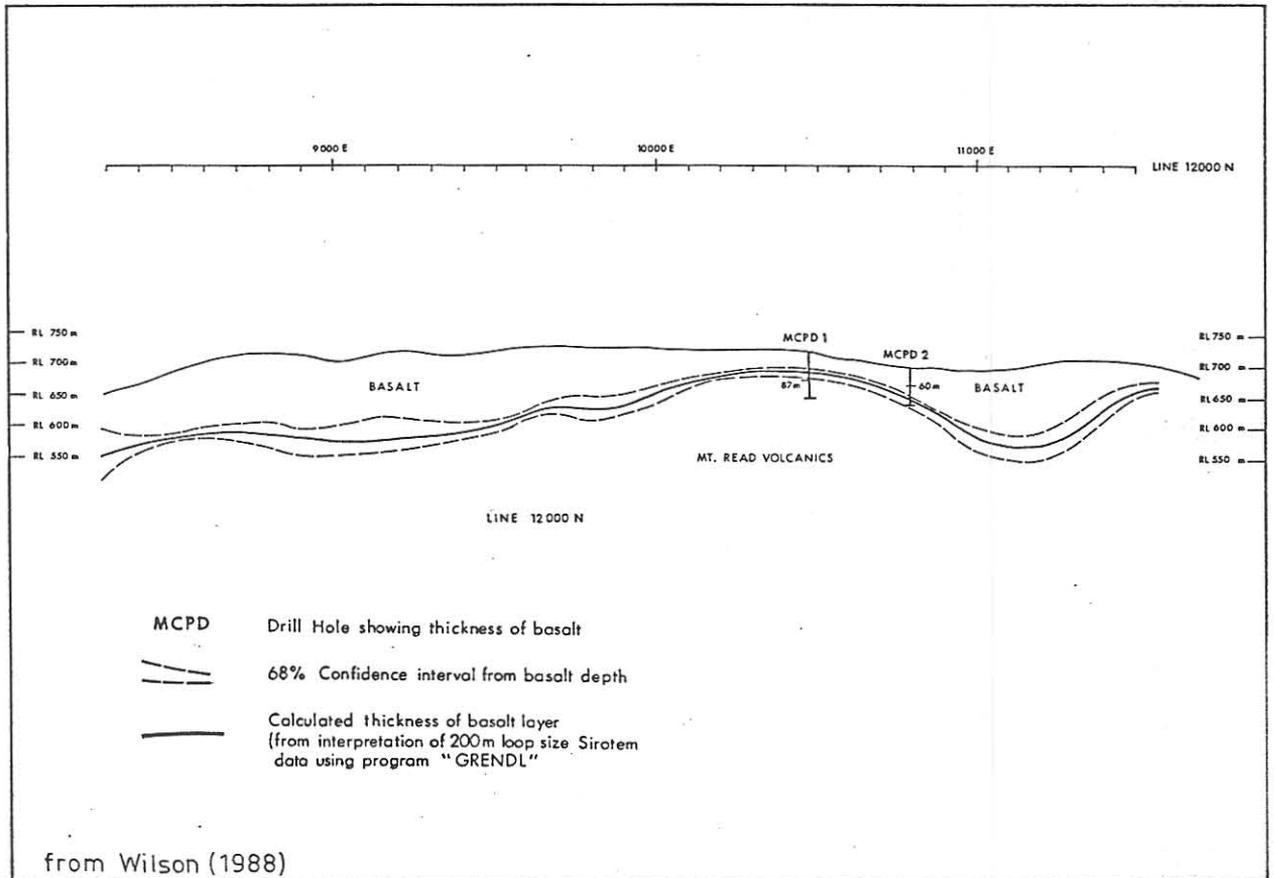


**MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES**

**MOUNT CATTLE TEM  
SOUNDINGS: LOCATION MAP**

**FIGURE 57**

**MD/MG87/06**



MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
BASALT THICKNESSES AT MOUNT CATTLELY FROM TEM SOUNDINGS	
FIGURE 58	MD/MG87/06

Hungerford (1981) concluded that this was the only method capable of directly detecting the magnetite-pyrrhotite skarn to a depth of about 100m below surface. The failure of the electrical methods was attributed to the probable low concentration of sulphides. This conclusion was reinforced by the low (40 to 70 mv/v) chargeabilities and relatively high resistivities recorded by down-hole IP surveying. Testing of DC resistivity and seismic techniques for determining depth to basement had been carried out in the same area a few years previously. Bartlett (1977) concluded that the former was useful for thicknesses up to 30m, and that seismic reflection was "remarkably efficient and accurate in determining the depths of various strata." In one example given, a seismic reflection survey carried out over a drill-hole defined the depth of basalt as 29m (logged at 31m in the drill-hole) and the siltstone contact at 93m (logged at 88m). (The velocities used to determine the depths were obtained from seismic refraction surveys.)

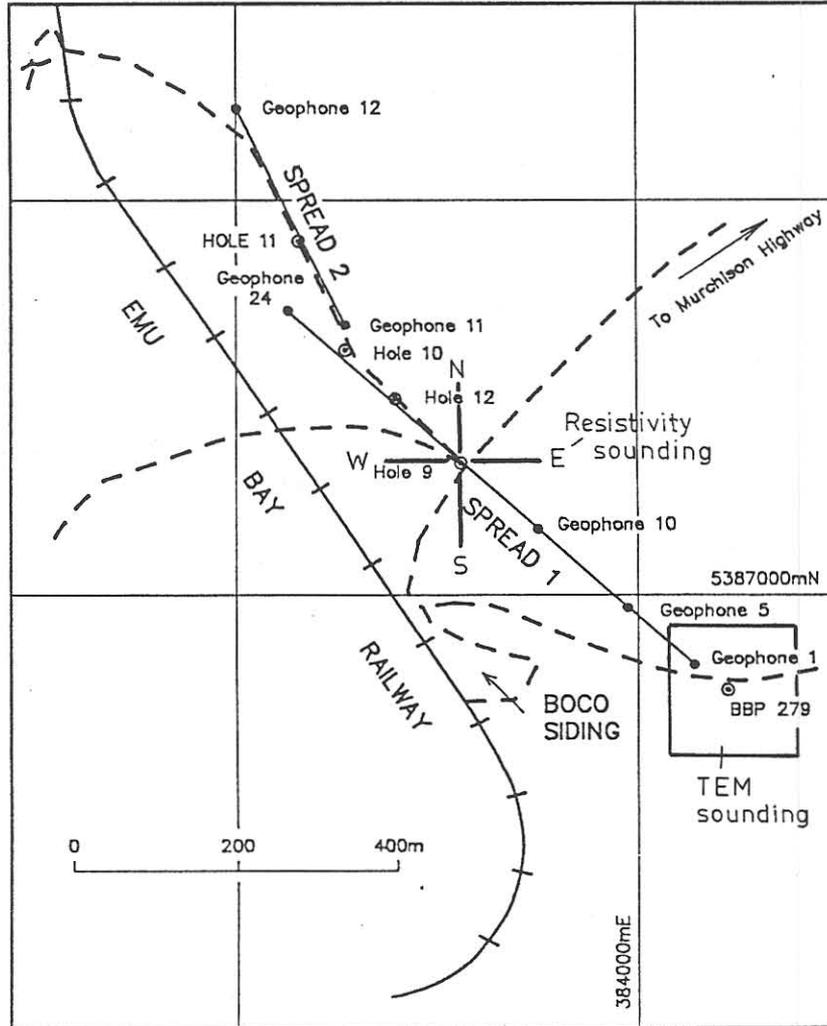
#### GLACIAL COVER

##### BOCO

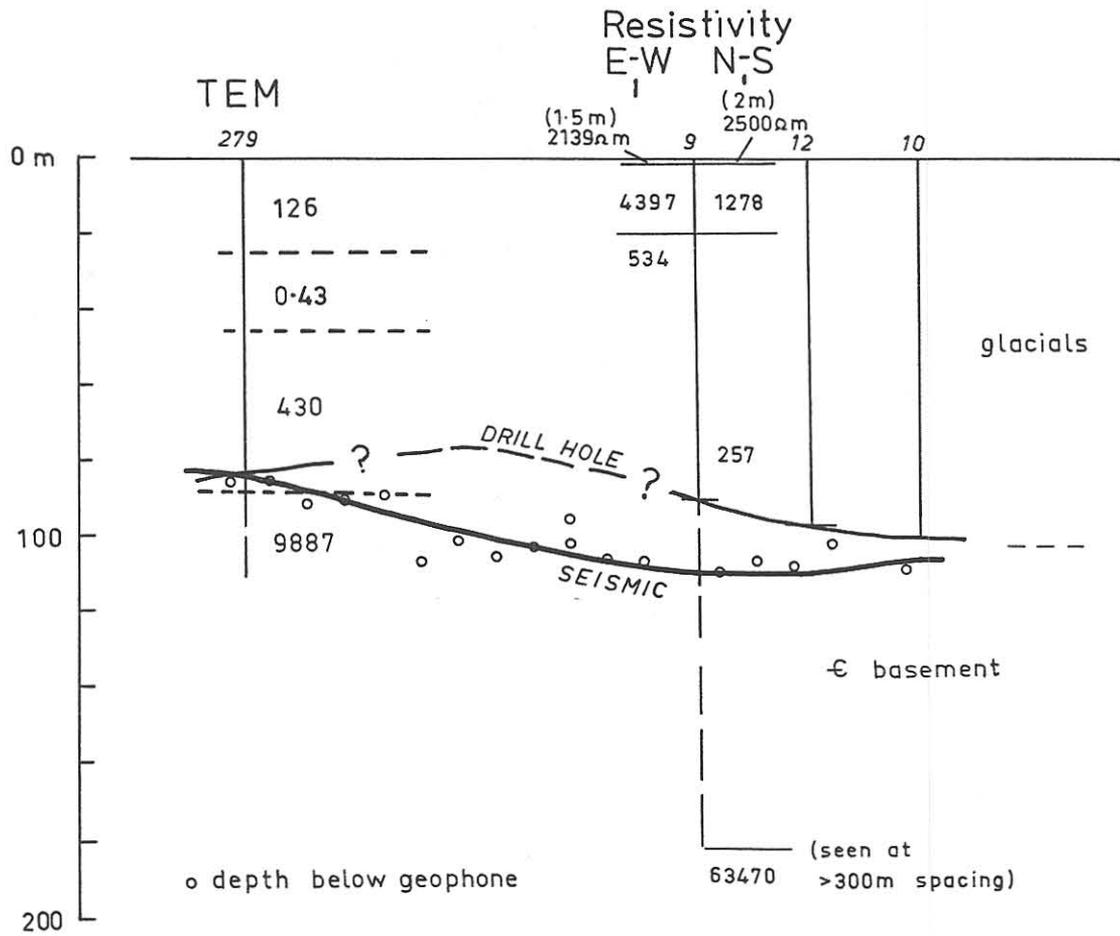
This area, which is covered by up to 100m of Pleistocene glacial deposits, lies immediately to the north of the Rosebery mine and has been the subject of several exploration programs over the last twenty five years. Several holes have been drilled on the prospect and these have defined an area of faulted pyrite - quartz - sericite alteration. Geophysical contributions to the exploration programs have included airborne EM and airborne and ground magnetics, gradient array and dipole-dipole IP and fixed-loop TEM. DHEM surveys have been carried out down many of the drill-holes. It typifies areas of interest which, because of the problems posed by the cover, are not attractive exploration targets. In places parts of the cover may themselves be of interest as exploration targets: gold is currently being produced on a small scale from within glacial material at Williamsford.

A number of different surveys have also been specifically carried out for the Mount Read Volcanics project. These include gravity, seismic refraction, TEM and DC resistivity soundings. The purpose of the surveys was the hope that it could be demonstrated that the depth and shape of the basement rocks could be achieved with some accuracy and relatively easily by appropriate methods. The relevance of this exercise may be illustrated by referring to a program of vertical percussion holes which had to be changed to angled diamond drill holes because of the unexpected depth of glacial overburden. The seismic and gravity results have been interpreted by Richardson (1986) and are reproduced in part in Figure 60. Magnetic surveys were not useful here but might possibly be so in areas with magnetic basement rocks and non magnetic cover.

The location of electrical/EM surveys at Boco are shown in Figure 59. Basically they consist of Sirotem soundings and Schlumberger resistivity measurements at localities where drill hole control was available; the data are in large part coincident with Richardson's



MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
BOCO SIDING LOCALITY MAP	
FIGURE 59	MD/MG87/06



MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
BOCO SIDING COMPOSITE SECTION	
FIGURE 60	MD/MG87/06

seismic/gravity/magnetics profiles. The Sirotem data was collected using both early and standard times but much of it is of very poor quality, probably due to the presence of the railway line, power lines and other cultural features. In all only two sets of data warranted detailed interpretation, one a composite of early and standard times, the other of standard times only. The composite data set extended to a delay of only 2.6 ms; this is inadequate for these investigations (basement is not 'seen'). Further, this data set is inconsistent with a layered model and is not discussed further.

The standard times Sirotem sounding was interpreted by inversion using layered models. The depth to basement obtained is in excellent agreement with the drill hole results and analysis shows that the depth to basement is the best resolved parameter present. This confirms the utility of the technique in estimating basement depths as found in the areas of modest basalt cover east of Waratah. The overburden appears to consist of 3 layers of quite different resistivities. The top layer, some 28m thick with a resistivity of 130  $\Omega\text{m}$  probably represents till. The second layer appears the most crucial for electrical exploration. The resistivity of .42  $\Omega\text{m}$  is very low and the thickness of 18m appreciable. It seems likely that areas with a significant thickness of such material will remain inaccessible to surface electrical methods. The bottom layer has a resistivity of 450  $\Omega\text{m}$  and sits on a very resistive basement.

Two Schlumberger soundings at right angles were made centred on drill hole 9. The sounding along the main traverse line used spacings extending to 700m, the other was limited by access to 200m spacings. The Schlumberger resistivity sounding appeared to give good data and inversion produced an excellent fit to a 4 layer model. However, at a spacing of 700m the method was only just starting to detect the resistive basement, due to the very low layer 2 resistivity which was also detected by Sirotem. There are problems with any method that assumes a plane layered structure over a distance of 700m at Boco. There is clearly significant bedrock topography in places and it is not reasonable to expect an accurate interpretation assuming a layered structure extending over seven times the depth to bedrock. Thus the poor comparison with the drill hole controls is not surprising (Figure 60). The results grossly over-estimate the depth to basement. There is poor correlation with the TEM derived structure, the chief concordance being the approximate agreement of the significant top layer thickness for both methods.

The results from Boco suggest two quite different materials in the glacial cover. The probable tills with resistivities of 130-450  $\Omega\text{m}$  present a modest problem for electrical methods. The probable clays with resistivity of .42  $\Omega\text{m}$  are a much more serious problem. This suggests that exploration in areas with glacial cover might well start with some TEM soundings to determine the presence/absence of very low resistivity material and possibly the depth to basement. If there is a great thickness of low resistivity material it seems unlikely that the area should be explored by surface electrical methods; the possible use of borehole methods to examine large volumes of rock below the cover might be considered.

Both TEM and the Seismic methods have good potential for determining depth to basement in areas of glacial cover. Three factors favour the TEM method. Firstly it is quicker, secondly it determines the parameters for electrical/ EM methods and thirdly areas of glacial cover are known where the velocity does not increase with depth resulting in hidden layer problems for the seismic refraction method. An excellent example of an area where refraction fails but seismic reflection works well occurs at the proposed King River diversion of the Lyell Highway and is described in Robertson (1986). Also, mineral exploration firms are more likely to be familiar with, and have the equipment for, the TEM method.

The results of all the methods may be summarised thus: TEM soundings, if of good quality and sufficient time range, estimated the basement depth to a very high precision (2%). Seismic refraction results overestimated the basement depth by of the order of 10% in places but if the usual refraction situation applies the depths could be adequately corrected from the borehole control. Resistivity soundings were of limited utility, grossly overestimating the basement depth by 100%. The conclusion is that only the TEM and seismic methods are useful for the glacial cover problem. We would, on the basis of these limited tests, recommend TEM sounding as the preferred method.

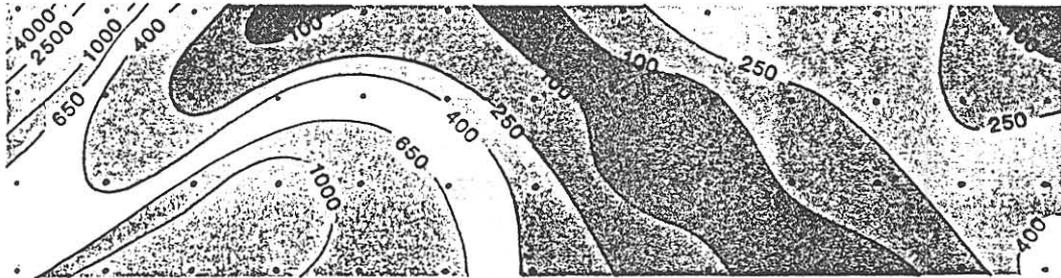
The Mines Department intends to carry out a further set of surveys at Boco between basement outcrops, to better define the shape of the basement and its depth.

#### BASIN LAKE

The Basin Lake grid, to the north of Queenstown covers an area of prospective Mount Read Volcanics. The area is overlain with glacial till of varying thickness. On line 30S, it is only about 20m thick and the following case history is presented, not to demonstrate the penetrative capabilities of particular geophysical techniques, but rather to illustrate some of the difficulties that may occur in trying to resolve sulphides from adjacent black shales in covered areas. Figure 61 shows chargeability and resistivity pseudosections from a dipole-dipole IP survey along line 30S. The survey used a dipole spacing of 61m and obtained double the usual data density from a 'second' survey offset by half a dipole spacing. The chargeability pseudosection shows a well defined anomaly beneath the black shales, slightly offset towards the sulphides which have not been resolved. The resistivity also shows a well-defined response, but with no offset towards the pyrite body. This area was subsequently surveyed with UTEM (Figure 62) which shows the black shales to be poorly conductive, but does not respond at all to the sulphides. A later Sirotem survey (Figure 63) also failed to find the sulphides. An SP survey gave a strong response to the western contact of the black shales, but not to the sulphides (Figure 64). Only the original gradient array IP survey resolved the two bodies (Figure 64). That is, 20m of massive to semi-massive sulphide, buried beneath 20m of glacials, was only detected by a method which is now usually regarded as having less depth penetration than either dipole-dipole IP or TEM. There are a number of explanations for this; e.g., the width of the

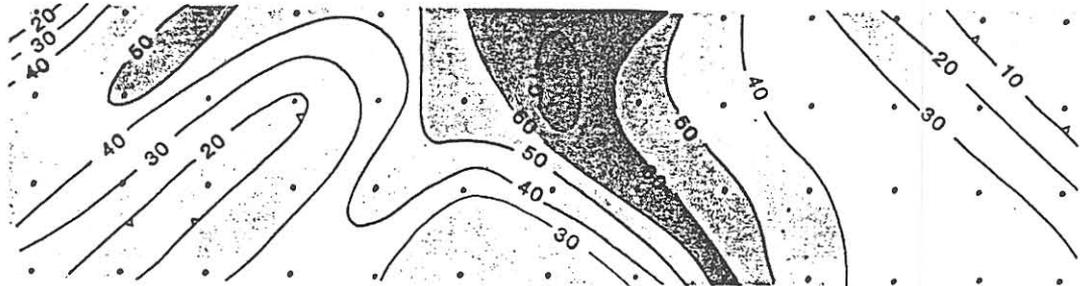
pyrite was probably too thin for the large dipole spacing of the dipole-dipole IP survey. Although the gradient array IP results suggest that the sulphides are resistive, laboratory measurement of core (Table 1) gave (a low) conductivity of between 2 and 3 S/m and a DHEM survey, run to 60m where the hole was blocked, shows a sudden 'kick' at 55m which is attributed to the pyrite (Figure 65). It is suggested that the sulphides are sufficiently conductive to produce an anomaly from a surface TEM survey, but here they have been shielded by the black shales which lay between the loops and the sulphides.

BASIN LAKE: L30S Dipole-Dipole IP RESISTIVITY (ohm-m)

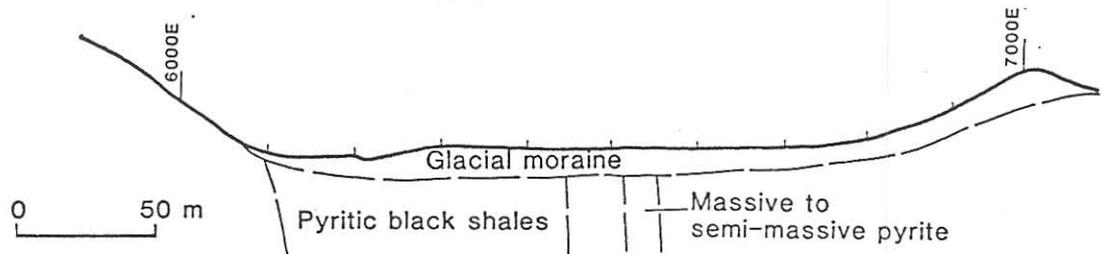


Dipole = 61 m + 1/2 dipole offset survey

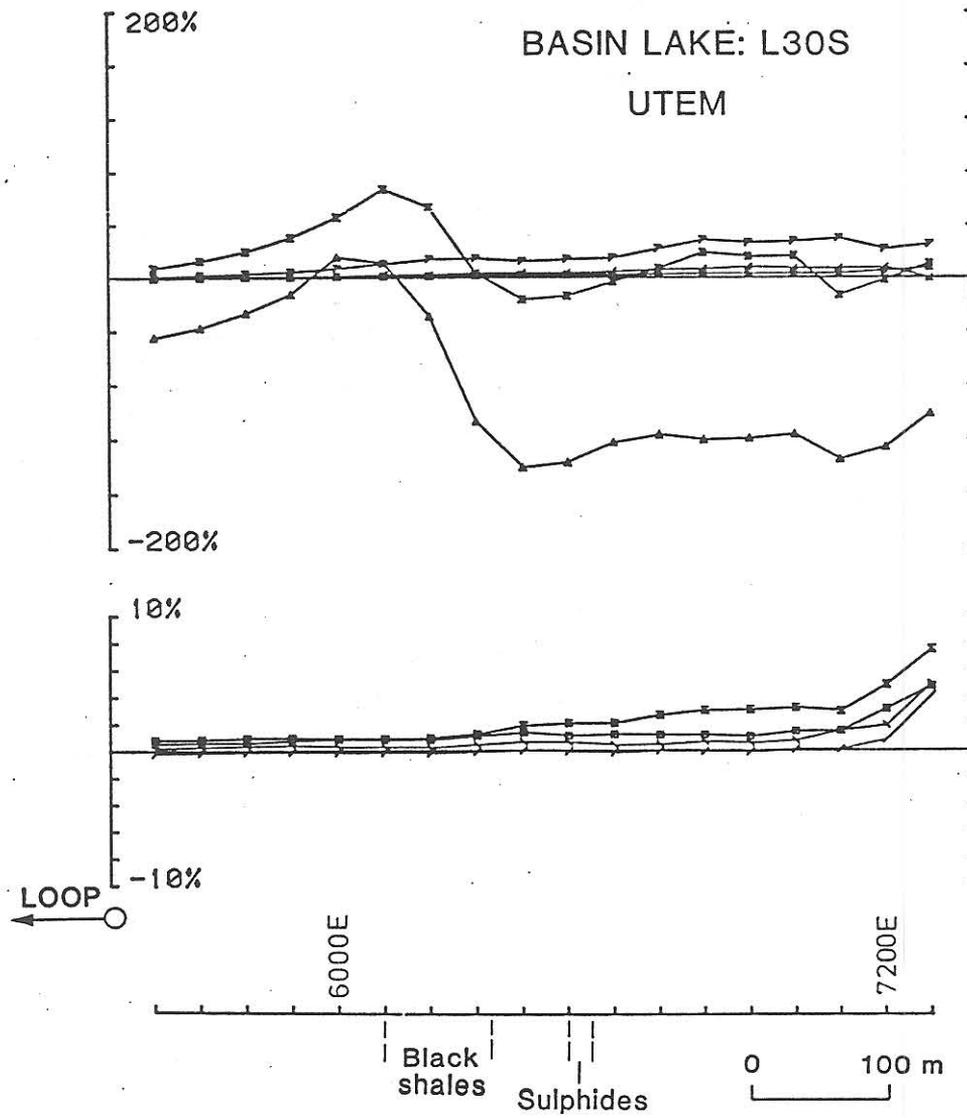
BASIN LAKE: L30S Dipole-Dipole IP CHARGEABILITY (mV/v)



Dipole = 61 m + 1/2 dipole offset survey



MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
BASIN LAKE, LINE 30S: CHARGEABILITY AND RESISTIVITY PSEUDOSECTIONS	
FIGURE 61	MD/MG87/06

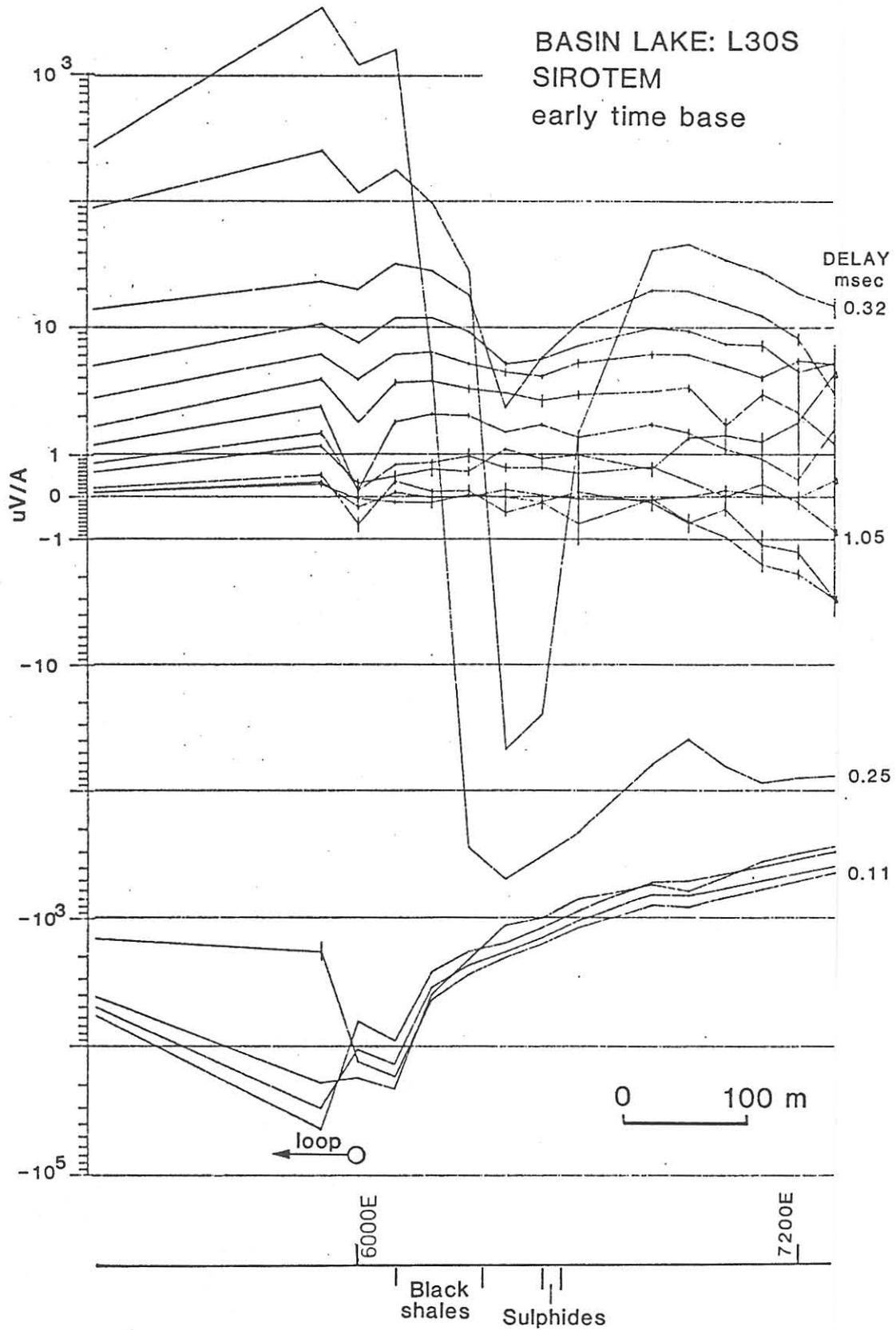


MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES

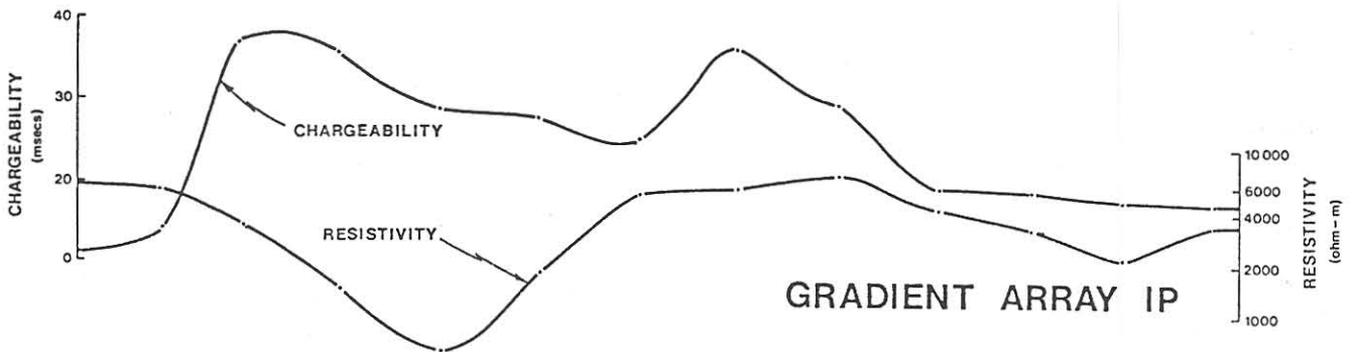
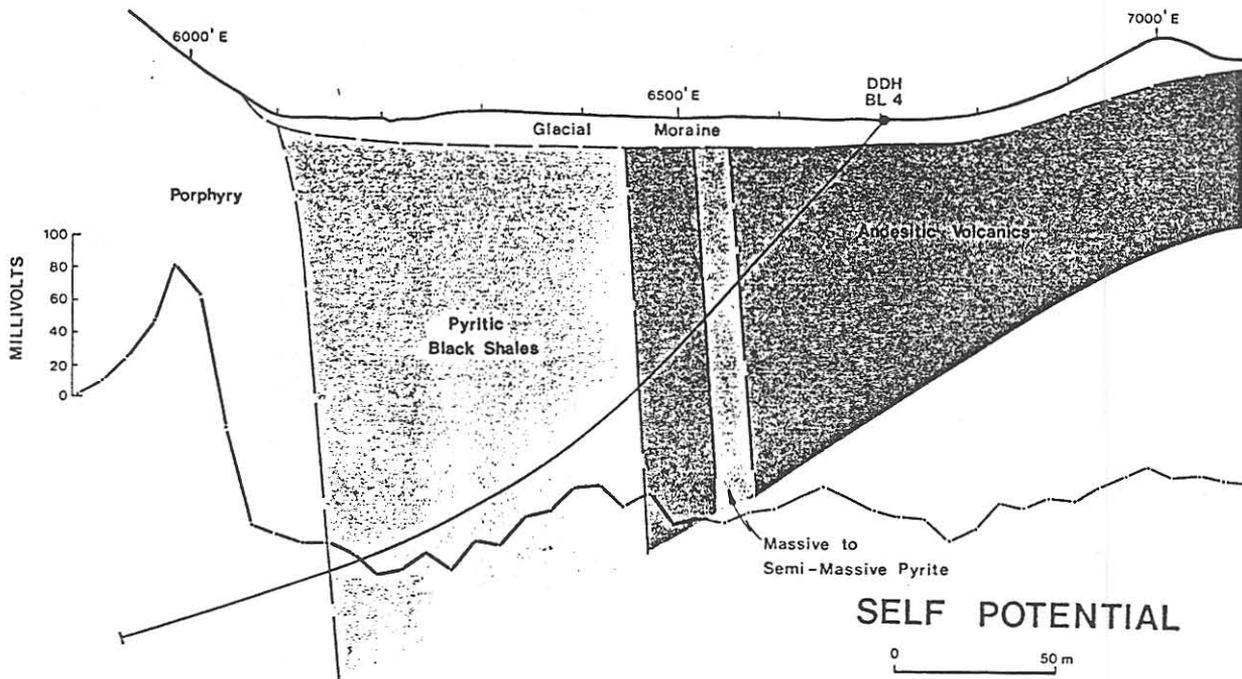
BASIN LAKE, LINE 30S: UTEM  
PROFILE

FIGURE 62

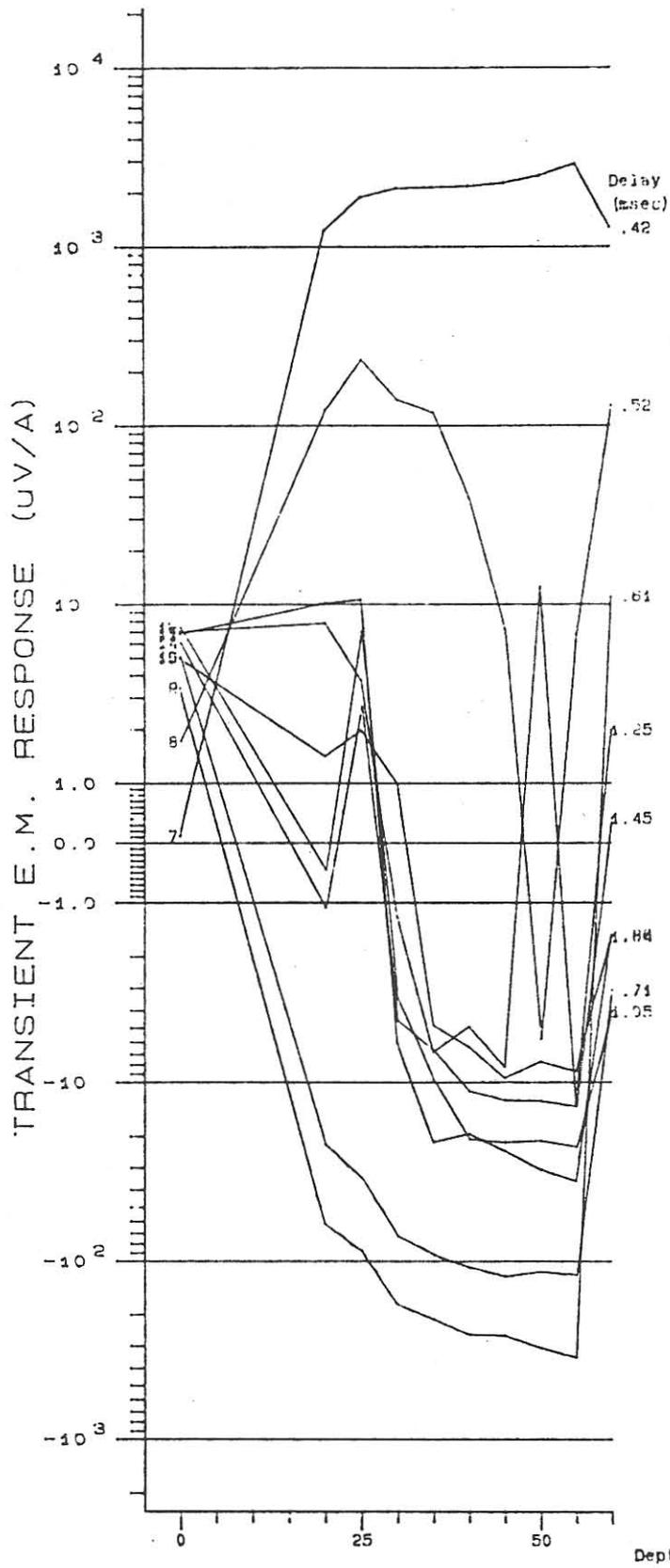
MD/MG87/06



MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
BASIN LAKE, LINE 30S: SIROTEM PROFILE	
FIGURE 63	MD/MG87/06



MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
BASIN LAKE, LINE 30S: SP AND GRADIENT ARRAY IP PROFILES	
FIGURE 64	MD/MG87/06



MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
BASIN LAKE, LINE 30S, DDH BL4: DHEM PROFILE	
FIGURE 65	MD/MG87/06

### EXPERIMENTAL TECHNIQUES

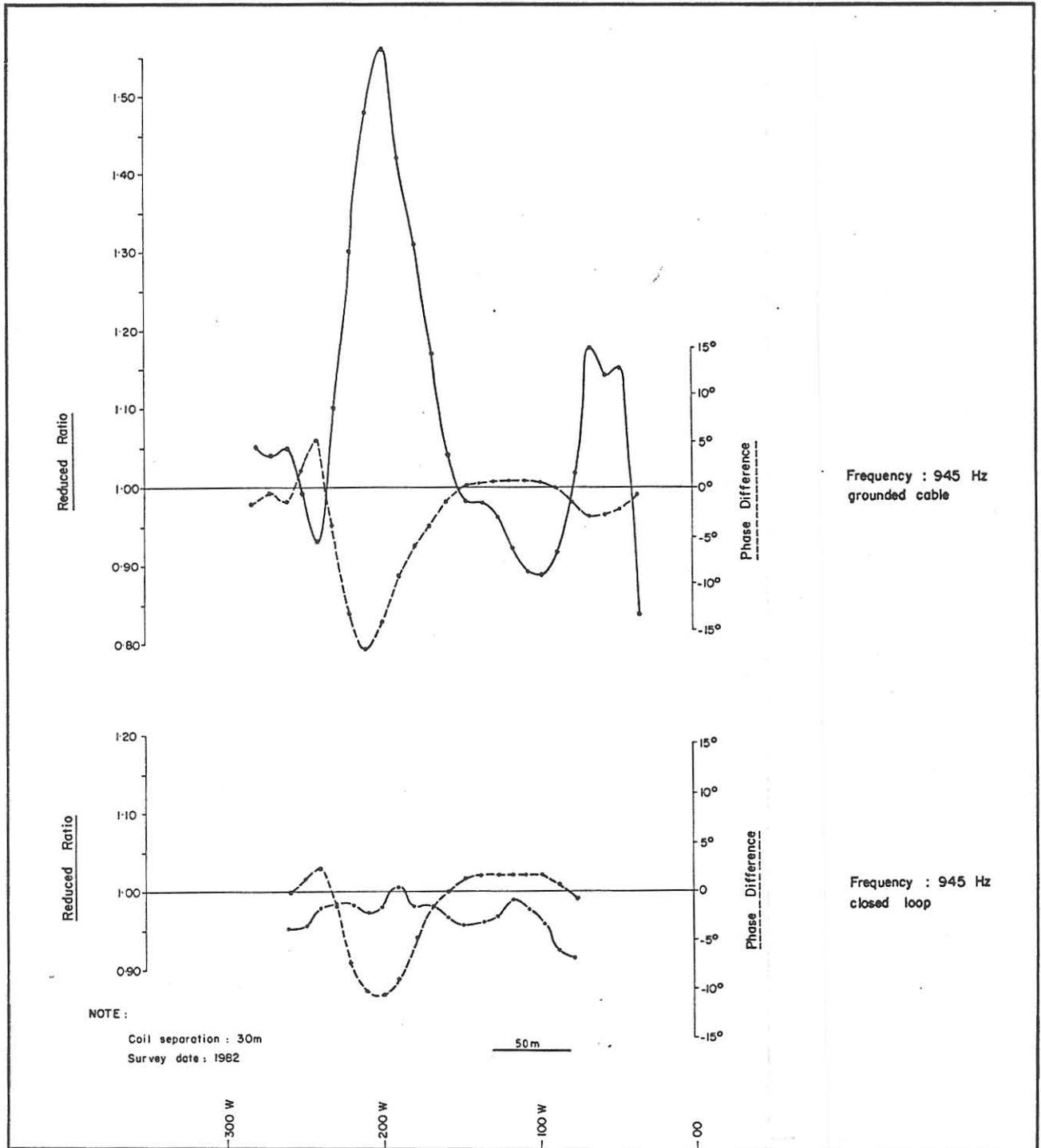
Part of the charter for this report was to examine ways in which geophysical techniques in western Tasmania could be made more effective. Two main exploration problems were recognised: (1) separating electrical responses of sulphides from black shales and (2) the enhanced detection of deeply buried and possibly poorly conducting sulphides. Other experimental work encouraged by the Mount Read Volcanics project, such as a magnetotelluric traverse across the Mount Read Volcanics and their correlates in northern Tasmania, were or are occurring at the University of Tasmania, but these fall outside of the scope of this report.

#### **GROUNDING WIRE TEM**

All of the early Turam surveys in Tasmania used grounded wire sources. A change to closed loops occurred with improved interpretation techniques for inductive rather than galvanic (i.e., current gathering) responses (Horvath, 1965). Also, a grounded source survey will often give strong responses over unwanted features such as faults and contacts. Because of the enhanced results from grounded wire Turam compared with inductive surveys at Western Tharsis (line 29W; Figure 35) and elsewhere on the Mount Lyell field (Figure 66), it was decided to try a TEM survey with a grounded source along line 29W. A Zonge system was used since its transmitter had a high enough output impedance to energise a grounded wire. A Sirotem roving receiver was input to the Zonge GDP-12. A number of tests were carried out prior to obtaining the data shown in Figure 67; earlier trials having problems with apparent receiver ringing near the wire and with the frequency response of the buffer amplifier. The final data is disappointing; only one good response, over the F/W lens has been obtained, with a poorly defined second anomaly at about 2500'N which corresponds with a small response on the 1986 Turam survey. As previously mentioned, a grounded wire survey was also tried at Hellyer, but the high noise levels from the power line and mine equipment prevented the collection of any useful data (Figure 5b). Further experimentation is required with this technique to see if it offers any advantages over closed loop TEM.

#### **SPECTRAL IP**

This part of the experimental work is presented in Volume II of this report.

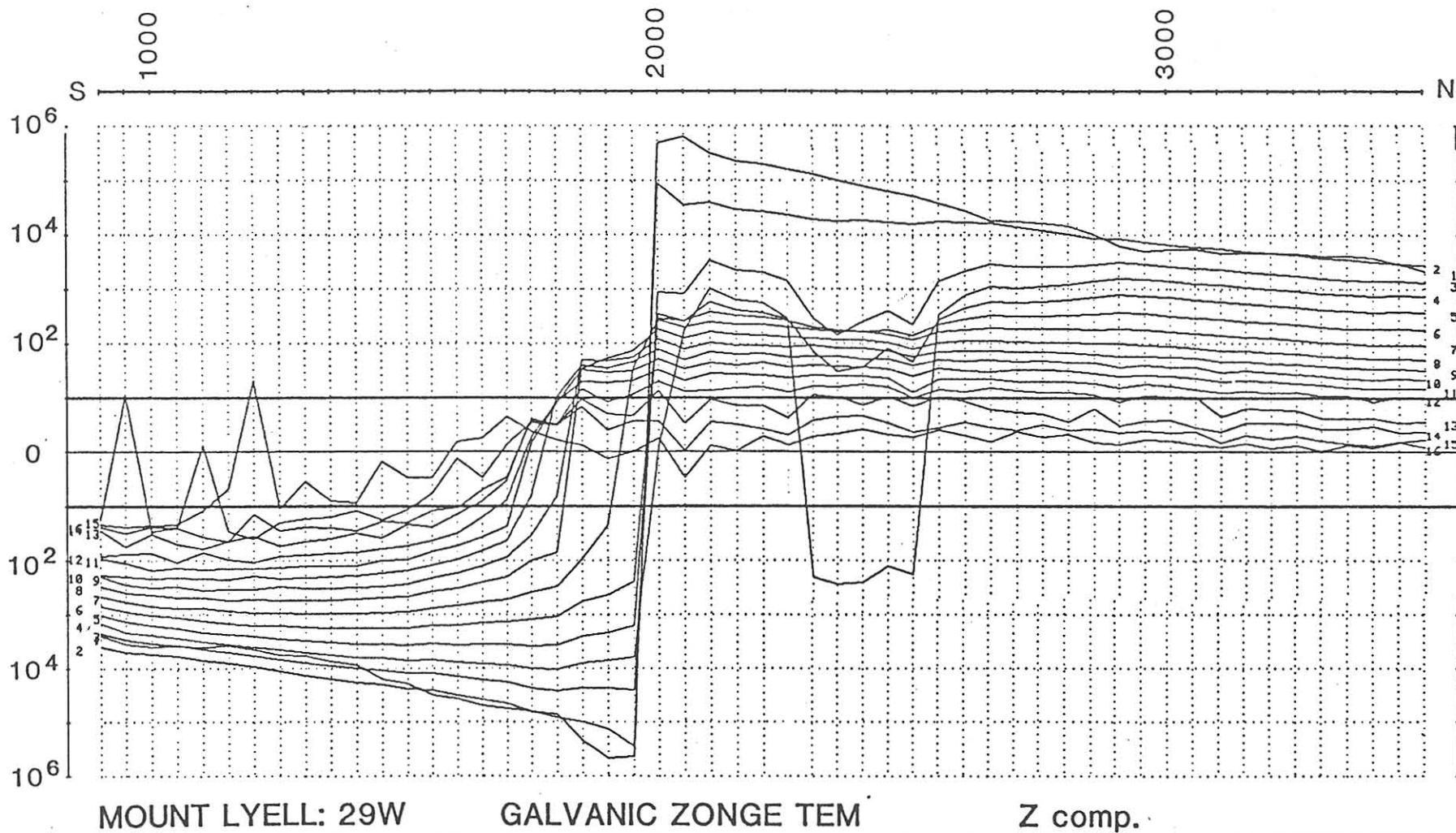


MOUNT READ VOLCANICS PROJECT:  
GEOPHYSICAL SIGNATURES

COMPARISON OF GROUNDED  
WIRE AND CLOSED LOOP  
TURAM: MT LYELL (EP24,  
LINE 225N)

FIGURE 66

MD/MG87/06



MOUNT READ VOLCANICS PROJECT: GEOPHYSICAL SIGNATURES	
MT LYELL LINE 29W: GROUNDED WIRE TEM	
FIGURE 67	MD/MG87/06

### CONCLUSIONS

The data in this report constitutes a compendium of geophysical responses for the significant deposits and geophysical problems which, together with the other geophysical reports for the Mount Read Volcanics project, provide a representative body of data on a significant mineralized area. The geophysical attributes of the various mineral deposits of western Tasmania are summarised below, classified by deposit type.

#### **VOLCANOGENIC POLYMETALLIC MASSIVE SULPHIDES**

A synthesis of the geophysical measurements from and over the Hellyer, Que River and Rosebery mines suggests that the 'type' massive sulphide deposit from the Mount Read Volcanics is dense, non-magnetic, chargeable and a good, but not excellent conductor. It will probably lie within a large area of pyritic alteration and may occur, as at Rosebery, in close association with graphitic shales which may have similar electrical properties. In the past, geophysical interpretations have generally assumed the shape of the type deposit to be tabular and its attitude steeply dipping. However the relatively flat (~45 degree) dip of Rosebery and the near-horizontal 'broadening sausage' or elongate cone shape of Hellyer suggests that such assumptions are unfounded. Deposits with geometries similar to Hellyer will produce weaker electrical anomalies than the 'type' tabular shape.

#### **REPLACEMENT TIN DEPOSITS**

There are four tin deposits in western Tasmania which may be broadly classified as carbonate replacement bodies. They are Renison, Cleveland, Mount Bischoff and Severn and, when tin is more highly priced than it is at present, they make an attractive target. Related to Devonian granites, they are more distant than the skarn deposits described below. Economic sized deposits away from existing mines, would probably occur within 200m or 300m of the surface and can be expected to have a distinct magnetic signature. Deeper and possibly smaller deposits in the vicinity of existing mines may still be economic and may not have a recognisable magnetic response. DHEM methods can be used most effectively, since the massive pyrrhotite ore is highly conductive. CSAMT surveys may also be useful in locating relatively flat-lying conductors at depth.

#### **TIN AND TUNGSTEN SKARNS**

The tin-tungsten skarns such as Kara, King Island and Bold Head and Moina are hosted by calcareous sediments in close proximity to Devonian granites, they vary between magnetite-rich/sulphide-poor and magnetite-poor/sulphide-rich (often pyrrhotite). Most are magnetic targets, whilst the latter type are also chargeable and conductive.

### COPPER-GOLD DEPOSITS

There is only one example of this type of deposit, which is the Mount Lyell field, however this covers a large area (5km x 1km) and contains at least fifteen separate bodies. Hosted by the Mount Read Volcanics, it is quite different to the volcanogenic massive sulphides described above, although one of the fifteen bodies is a base-metal deposit. The Mount Lyell mining field contains both high and low grade copper bodies, all with minor gold credits. Pyrite is widespread on the field and the chargeability responses of low grade deposits may not be distinguishable from barren sulphides. However present exploration is restricted to high grade bodies which should be highly conductive, since the addition of only a small amount of copper (e.g., 1%) dramatically increases the conductivity of the sulphides. Some of the deposits contain magnetite and are weakly magnetic, however the large area of alteration has given rise to a magnetic low.

### SILVER-LEAD-ZINC

The only recent economic deposit of this type has been the Oceana mine. Hosted in Palaeozoic limestones, this (?) Irish-style deposit is non-magnetic and only weakly conductive. It is chargeable, but disseminated pyrite is ubiquitous in the country rock. The sulphides have a strong density contrast with the host rocks, but weathering can be deep and irregular, making interpretation of gravity data uncertain. It represents a difficult target.

### GOLD

So far, there have been no gold-only mines in western Tasmania, however there are a number of promising prospects. In the volcanics, these deposits may be structurally controlled; associated with intrusives or perhaps replacement type. They are very likely to occur with disseminated sulphides (although these may be in low concentration in quartz veins) and IP should be an effective direct search technique. For grass-roots exploration a combination of aeromagnetics and perhaps radiometrics can help define areas of interest, with magnetics and VLF helping to provide structural information on a more local scale. Spectral IP may be able to assist in the discrimination of auriferous targets.

### OTHER CONCLUSIONS

The geophysical techniques commonly used in western Tasmania have been evaluated. It was stated that fixed loop TEM surveys are widely and successfully used, however some shortcomings of the technique have been illustrated in this report. These include incorrect positioning of the loop, which results in poor coupling and, when there are multiple conductors, the possible shielding of more distant deposits. Other problems, such as the influence of large conductors behind a loop are discussed in Macnae (1985). The example from Basin Lake given above illustrates the benefits of coverage with multiple methods.

It is interesting to speculate whether the Hellyer response would have been recognised if the deposit had been in close proximity to conductive shales or if it had been considerably smaller. (One can presume that a body of the same high grade as Hellyer and in the same favourable position for extraction, could be considerably smaller than Hellyer and still be economic.) CSAMT surveys are being tried for greater depth penetration and horizontal resolution and they may help, but the technique requires further development before it is routinely used. Of more immediate assistance is the use of DHEM. Eadie (1987) has shown that well defined signals can be obtained from holes which are more than 100m from the Hellyer deposit. Thus holes may be drilled into prospective zones rather than specific targets, with subsequent DHEM surveys exploring large volumes of ground around the holes.

One may also speculate on the possibility of there being economic-sized deposits with a much lower conductivity than Hellyer. The Voyager 19 mineralisation at Elliott Bay, which was found during an augering program for soil samples, consists of a few small high grade pods of zinc-rich sulphide in an area of altered but unpyritised rocks. It is apparently not conductive. If the V19 sulphides are not transported clasts from a deposit which in bulk is conductive, but are in situ and represent a style of possible economic mineralisation, then it represents a difficult geophysical target; possibly an appropriate one for grounded wire EM surveys\*.

'Difficult', however, is not a reason for not exploring in areas perceived to be highly prospective. Thus companies are looking under large areas of thick basaltic cover for further volcanogenic, skarn or replacement deposits. It has been shown in this report and elsewhere that geophysics can effectively determine the thickness of the cover, can in some instances determine the lithology of the basement, can map the PreCambrian basement at depths to at least 0.5km and then may be used in favourable regions for direct ore search. It was seen that, perhaps contrary to expectation, the Tertiary basalts were of low resistance. Similar electrical properties were recorded over the glacials, which are however, rarely as thick as the basalts. Some preliminary work, at least, has been carried out by exploration companies on areas of Ordovician sediments overlying the Mount Read Volcanics. These rocks are generally resistive and greater depths of penetration can be expected from electrical techniques. Experimental work carried out for the Mount Read Volcanics project included testing of grounded wire TEM surveys to see if larger anomalies could be obtained over poor conductors and whether greater penetration might be obtained, particularly in resistive rocks. The galvanic technique gave higher amplitudes than the closed loop survey, with a slower decay rate due to current channeling. However the results were by no means conclusive and further testing is required. The greater part of the investigative surveys were spectral IP measurements carried out over

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\* Apart from its density, the only geophysically anomalous property of sphalerite is piezoelectricity.

most of the rock types in western Tasmania. The important results here are that massive sulphides can be discriminated from pyritic mineralization and black shales on the basis of in situ measurements. There remains the challenge of applying such technique to typical exploration surveys.

#### ACKNOWLEDGEMENTS

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J.R. Bishop



R.J.G. Lewis

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Table 1

PETROPHYSICAL MEASUREMENTS

SAMPLE LOCATION	DESCRIPTION	MAGNETIC SUSCEPTIBILITY ( $\times 10^{-6}$ cgs)	DENSITY ( $t/m^3$ )	CONDUCTIVITY (inductive) (S/m)	IP EFFECT (PFE)	RESISTIVITY ( $\Omega m$ )
Hellyer	massive sulphides	30	4.1-4.9	4-100	100	20.
Que River	PQ Lens		4.4-4.5	20	100	6.0
	S Lens			9	100	8.0
Rosebery	massive sulphides	20	4.2	20 (1-142)	50	1.0
Elliott Bay (V19)	massive sulphides			negligible	0-20	1-800
Basin Lake	massive pyrite		4.1-4.2	2-3	30	100.
	black shale			negligible	0-48	3-416
Kara	magnetite skarn	400,000-1,000,000	3.5			
Mt Lyell	low grade copper ore	0-100 (20 samples)	2.76-3.15			
		2000-2650 (3 samples)				
Renison	tin in pyrrhotite	2,790-21,400	3.2-4.0	270-410		

This table contains a few measurements specifically referred to in the report. A comprehensive listing is given in Richardson and Hudspeth (1988) and in Volume II of this report.