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FINAL REPORT ON
INDUCED POLARIZATION SURVEYS
IN THE MISTY VALLEY AREA, NEAR RENISON BELL, TASMANIA
ON BEHALF OF
RENISON LIMITED

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PRIVATE AND CONFIDENTIAL

FINAL REPORT ON
INDUCED POLARIZATION SURVEYS
IN THE MISTY VALLEY AREA, NEAR RENISON BELL, TASMANIA
ON BEHALF OF
RENISON LIMITED

BY

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GEOPHYSICIST

SYDNEY, N.S.W.

MARCH, 1974

TAS-019AF

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GEOPHYSICAL CONSULTANTS AND CONTRACTORS

S U M M A R Y

Reconnaissance electrical induced polarization surveys followed by pole-dipole and three-array detail and magnetic induced polarization detail, recorded a number of chargeability anomalies of significance. These, together with the results of the ground magnetometer survey are discussed and recommendations for further work are made.

FINAL REPORT ON
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INTRODUCTION

On about six days between 18th and 31st December, 1973, Scintrex Pty. Ltd. executed reconnaissance gradient electrical induced polarization surveys over eight lines of the Misty Valley grid in EL 2/63 near Renison Bell, Tasmania.

Additional pole-dipole detail to determine the depths, and small MIP current dipoles to determine the mode of decay, were carried out on selected zones on the 13th and 14th February, 1974.

The survey was carried out at the request of Mr. L.A. Newnham, Chief Geologist, of Renison Limited on behalf of a syndicate under the direction of Renison Limited.

The survey was under the immediate direction of Mr. D. Robson, BSc, and Mr. P. McHugh of the staff of Scintrex Pty. Ltd. while Mr. A.W. Howland-Rose, MSc, provided such technical direction as was required. During the

course of the survey, additional Scintrex operators, Mr. B. Ekstrom and Mr. H. Mueller provided assistance.

The objectives of the survey were as follows:

- 1 - To locate and define the Turair anomaly recorded in the area on the February, 1973 Turair survey.
- 2 - To locate and define anomalous zones of induced polarization together with the apparent resistivity, in a rapid reconnaissance mode. After which ground follow-up and geophysical detailing was to be employed to assess any anomalous responses.

Appendix 'I.P.' briefly describes the Electrical Induced Polarization methods employed, Appendix 'MIP' describes the Magnetic Induced Polarization system and Appendix 'IPR-8' describes the operation of the induced polarization receiver used in both methods on this project.

PRESENTATION OF RESULTS

The data profiles are presented in Plate 1 at the horizontal scale of 1:5000 with chargeability shown at the scale of 1 centimetre = 10 millivolts per volt while the resistivity is expressed in ohm-metres and displayed on a 5 centimetre log cycle.

Plates 2 and 3 show a contour interpretation of the above data at horizontal scales of 1:5000 and contours at appropriate intervals, while Plate 4 is an interpretation of the proton precession magnetometer data at the same scale over the grid area.

Plate 5, also at the scale of 1:5000 is an interpretation of the three physical properties available, namely, resistivity, chargeability and magnetic intensity.

Plate 6 displays the EIP pole-dipole, three-array detail together with the limited MIP surveys done on lines 1, 4 and 7.

THE RECONNAISSANCE GRADIENT SURVEY

The reconnaissance survey employed two Scintrex IPR-8 receivers to read large applied gradient fields. The standard transmitter cycle was two seconds, while the receiver was operated on Mode 2 (see Appendix IPR-8) The relationship between the units of induced polarization employed in the present survey with those recorded using the Scintrex IPR-7 receiver are detailed in the abovementioned Appendix, but as a rule the readings plotted on the present survey are about $1\frac{1}{2}$ times greater than the equivalent IPR-7 readings recorded over the Mine area on previous surveys, and are expressed in millivolts/volt rather than milliseconds.

The IPR-8 programme selected was Mode 2 and although M_1 , M_3 and M_5 were recorded, only M_3 is displayed on the profiles as M_1 and M_5 are virtually the same.

The current dipoles employed were large, of the order of 2000 metres, while the potential dipole was restricted to 50 metres moved at 50 metre or 25 metre intervals as was determined by the data.

The two current dipoles employed to cover the eight lines of the Misty Valley grid are as follows:

<u>Current Electrodes</u>	<u>Lines Surveyed</u>
Line 2 at 1450E and 750W	0, 1, 2, 3
Line 5 at 1550E and 450W	4, 5, 6, 7

The distances along lines are surface, not horizontal, distances and, as such, small but insignificant errors will be introduced into the calculation of apparent resistivity. Similarly the extreme topographical form will also introduce errors in the calculation of the apparent resistivity, but these would also be expected to be of a minor nature only. These factors will not, however, affect the apparent chargeability to any significant degree.

On each profile the origin for station identification is on the eastern side of the road (see Plate 2). The data has been placed on Plate 1 in their true relative position.

THE EIP DETAIL

This was carried out using a pole-dipole array having $n = 1$ and 2 at $a = 50$, and a three array with $a = 25$ metres and 50 metres over four zones of interest to obtain depth information and improved resolution than the 50 metre gradient reconnaissance potential dipole afforded.

MIP DETAIL

Very short dipoles were used on lines 1 and 7 to obtain fundamental information on the mode of decay of the internal polarization currents over a number of anomalies. This data is incomplete due to the very limited time allotted.

The parameters utilised in the MIP data profiles and tables include the following:

1 - The normalised magnetic field H_N is calculated from the primary magnetic field H_P by dividing it by the magnetic field that would be observed for a given current if a uniform medium existed. That is, if uniform conductivity existed in the ground, the value H_N would be 1.00 at all

locations. This parameter is a dimensionless quantity and is expressed as a percentage.

2 - The chargeability M is expressed in terms of milligammas per gamma being the ratio of the secondary magnetic field for a particular slice divided by the primary magnetic

MAGNETOMETER SURVEY

The magnetic data presented in profile and contour form was acquired and provided by Renison Limited. Only those portions of this data within the induced polarization survey areas have been utilised.

DISCUSSION OF RESULTS

Plate 2 depicts a contour interpretation of the resistivity data which, although not unique, is considered to be the best fit after careful examination of the form of each profile.

Only slight modifications to the north easterly extremity of the grid was necessary as a result of the additional information provided by the magnetic survey carried out subsequent to the completion of the preliminary report.

The main strike within the survey area varies from grid north south in the west, to grid north-north-east in the east, while to the extreme north, all parameters indicate a sharp swing in strike to grid north-east between lines 6 and 7.

The apparent resistivities range from in excess of 1500 ohm-metres to less than 150 ohm-metres. Superimposed on the above described strike is the suggestion of an approximate grid north-east to south-west discontinuity as shown on Plate 5.

The most prominent feature is a ridge of high resistivity trending grid north-south across the centre of lines 0 to 3 and on the western flanks of lines 4 to 7. A second grid north-north-east trending high resistivity ridge was recorded on the eastern flanks of lines 0 to 4 inclusive while a less prominent resistivity high was recorded on lines 2, 3 and 4 at 525E, 475E and 325E respectively.

A contour interpretation of the chargeability data is displayed on Plate 3 at the scale of 1:5000. These show that the base levels for induced polarization in Misty Valley are a high 25 to 30 millivolts/volt which are equivalent to 17 to 21 milliseconds as measured by the IPR-7. This is still at least twice normal background. In contrast to the relatively clear trends recorded on apparent resistivity and magnetic contour maps, the chargeability response can rarely be traced across more than two lines with certainty, nor is there any definite correlation between the level of the induced polarization response and the apparent resistivity.

The significant anomalies on each line are discussed below.

Line 0 The chargeability remains between 20 and 25 millivolts/volt with a distinct 17 millivolts/volt above background response at 375E. A very slight reduction in apparent resistivity was also recorded at this point. However, the absolute level of about 160 ohm-metres does not confirm this to be a conductive zone. This anomaly may correlate with one of two defined between 025E and 225E on Line 1, probably that at 200E. No other significant anomalies were located on this line.

No magnetic relief was recorded on this line.

Line 1 A substantial 35 millivolts/volt above background induced polarization high was defined centred at 125E. This response is accompanied by a 60% reduction in apparent resistivity. A smaller response of some 10 milliseconds was centred at 200E and is not clearly related to any reduction in resistivity level. Both these responses show normal decay forms.

Pole-dipole detail confirms the position of the response at 125E and indicates a maximum depth of the order of 30 metres. The pole-dipole data also infers a narrow conductive zone close to surface in the vicinity of the

maximum chargeability response.

A very limited MIP profile was surveyed on stations 100E, 125E, 150E and 175E. This limited survey did not yield diagnostic data, but M_1 was recorded to be larger than M_5 .

Two further significant anomalies of 15 and 12 millivolts/volt were defined at 687E and 787E respectively.

The gradient data clearly infers the former has a conductive host as shown by a material reduction in apparent resistivity from 600-700 ohm-metres to about 160 ohm-metres. The pole-dipole data confirms this relationship and indicates a maximum depth of 25 metres for this 25 metre wide body.

A very limited MIP survey carried out between 600E and 725E utilised a current dipole 75N and 100S of 650E. This yielded a peak chargeability of 9 milligammas/gamma centred at 687E. At this point the average decay curve recorded was as follows:

M_1	M_2	M_3	M_4	M_5	M_6
-5.3	-6.5	-7.7	-8.4	-9.0	-9.75

Although not as spectacular either in the amplitude of the induced polarization response recorded, or the ratio of

M₁ to M₆, it shows a similar response to that recorded over the massive pyrrhotite in the Renison area, described in a separate report.

The normalised horizontal magnetic field H_N shows a 300% of normal current concentration between 630E and 680E coincident with the lowest apparent resistivities recorded in the gradient and moving source EIP surveys.

The second material response centred at 787E when detailed with three-array at 25 and 50 metres, indicated a maximum depth of some 25 metres to the top of the resistive source. Unfortunately no magnetic induced polarization data was surveyed sufficiently far east to cover this zone.

For practical purposes the decay characteristics on both the moving source and fixed source electrical induced polarization data on this line show entirely normal decay form, whereas with MIP a radical departure from the norm was recorded at 687E.

Both the induced polarization zones described above at 687E and 787E have an associated magnetic response. This response over the former is about 200 gammas, a response not out of order for pyrrhotite. The magnitude of the total field on the easterly zone was about 50% of this against

background.

The inferred dip of these zones is steeply to the east.

Line 2 A broad 20 millivolts/volt induced polarization high centred at 075W is considered to correlate with the response recorded at 200E on the previous line and a response of similar form and amplitude on Line 3 at 200E. There is no significant change in the apparent resistivity over this zone and in this respect this zone is unique in Misty Valley. The decay form is normal, $M_1 = M_3 = M_5$. The source material within this zone is therefore considered to be disseminated, electrically discontinuous material having a "normal" grain size distribution.

Two significant zones were defined at 340E and 425E of some 12 and 10 millivolts/volt respectively. The whole zone in which these induced polarization responses occur is conductive, showing about a 90% fall in resistivity (a 10 fold increase in conductivity), although the most conductive portion of the anomaly is not precisely coincident with either of the chargeability highs. The anomaly at 340E is not seen to the south but correlates with a minor high on Line 3 at 250E while the anomaly at 425E is considered to be the correlative of that recorded at 687E on Line 1.

The two significant responses recorded at 340E and 425E both have an associated magnetic signature. The former is minimal, being less than 100 gammas while the latter is in excess of 200 gammas. The correlation with the zones of maximum induced polarization response is excellent. The source material for the induced polarization effect also contains the source of the magnetic response, which may or may not be identical. Should the magnetic response be due to magnetite only, this material could not alone produce the induced polarization effect. However, should pyrrhotite be present it could explain both the EIP and magnetic data at this point.

Smaller broad highs were recorded at 575E, 740E and 950E which can be correlated with similar zones to the north and south.

Line 3 The most significant high on this line was recorded at 200W and is described above.

A 10 millivolts/volt response considered significant, was recorded at 125E coincident with a five fold increase in resistivity. This can be traced north and south but is material only on this line. The increase in resistivity clearly indicates an electrically resistive host and as such this zone is also unique at Misty Valley. The source is clearly a disseminated one. The EIP decay form is normal.

Anomalies of much reduced amplitude at 250E and 350E on this line form the correlatives of those recorded at 340E and 425E on the previous line. As on Line 2 these zones are (1) contained wholly within a more conductive unit and (2) lie within a zone of higher magnetic background.

A 20 millivolts/volt chargeability high recorded at 675E probably correlates with a broad 10 millivolts/volt response centred at 725E on Line 2 and 575E on Line 4. The resistivity data clearly indicates the host unit to be more conductive and furthermore there is a very rapid increase in resistivity to the east, indicating a material change in rock type. The zone is characterised by a normal decay form.

Line 4 A small but definite 12 millivolts/volt response is situated at 025E and is associated with a somewhat depressed resistivity profile. The host is, however, not truly conductive. The probable correlative on Line 5 is the minor response situated at 075E.

A second more substantial, 20 millivolts/volt anomaly centred at 337E is situated to the immediate west of a 30% to 50% depression in the resistivity. The host rock for the induced polarization zone is, however, of a resistive nature. No clear correlation is seen either to the north or south, but the resistivity data enables a correlation between Line 4 and Line 5 and this would

indicate that 300E is the equivalent position of a region of particularly high chargeability.

The most significant anomaly of some 20 to 30 millivolts/volt above background was defined at 575E on Line 4. This response is clearly associated with a depression in the resistivity data of 40% to 50%, inferring some conduction within the chargeable source. The EIP decay form is normal. This anomaly is open to the north and correlates with that discussed above on Line 3 at 675E.

The three-array and pole-dipole detail over this zone confirm its interest. The maximum depth is assessed to be of the order of 25 metres and the width of the source is estimated to be less than 20 metres. The source of the anomalous chargeability is situated within a somewhat more conductive host.

Line 5 The whole line has a particularly high induced polarization background of the order of 30 millivolts/volt. Superimposed on this high background are a number of somewhat higher chargeability highs at 225W, 112W, 075E and 200E but it is difficult to assess their individual importance. The resistivity data allows an almost perfect correlation to be made between lines and indicates a north-north-east south-south-west strike to the sequence

between these lines.

Line 6 The background chargeability remains high at about 30 millivolts/volt while the resistivity data cannot be correlated clearly with the previous line or the line to the north. There are no significant chargeability highs above background.

Line 7 The resistivity data cannot clearly be correlated with the previous line, but this is no doubt due to the sharp change in strike direction between lines 6 and 7 which results in a longer section on line 7. The magnetic and induced polarization data confirm this change in strike. The background chargeability on this line, at about 25 millivolts/volt, is slightly lower than to the immediate south.

Superimposed on this background, a broad chargeability high was recorded between 325E and 400E of some 15 millivolts/volt, which at 375E is coincident with a marked resistivity low. To the immediate east of the anomaly, the resistivity rises rapidly from 400 ohm-metres to in excess of 2000 ohm-metres, indicating that the chargeable response comes from polarizable material on, or in very close proximity to, a material change in rock type. The EIP decay curve shows M_1 slightly higher than M_5 inferring a slightly more

disseminated source than observed on most other anomalies.

Detailed three-array and pole-dipole surveys between 200E and 425E on this line confirmed the broad high defined on the gradient array. The detail showed two narrow zones, each conductive, situated at about 288E and 338E, having maximum depths of less than 25 metres.

The magnetometer survey indicated only background values over this anomaly. However, MIP stations using a short transverse current dipole yielded the following data:

<u>Station</u>	M ₁	M ₂	M ₃	M ₄	M ₅	M ₆
330E	-25	-27	-31	-33	-34	-37
350E	-16.7	-18.5	-19.2	-19.8	-21.8	-22.3

The decay form infers a coarser grain size for the chargeable source material. The absolute levels of 20 to 40 milligammas/gamma are of the same order as the Renison test lines, but the M₁/M₆ ratio is not as pronounced as at Renison.

Geological Interpretation

At this time no geological outcrop map is available, however, the three physical properties of induced polarization, resistivity and magnetic intensity make it possible to delineate the area surveyed into zones of similar physical

properties which will reflect the rocks immediately beneath. An interpretation of the three parameters recorded in this survey is presented in Plate 5.

The centre section of the survey area is characterised by a zone whose magnetic response is some 150 to 250 gammas above background in the south and central areas. This 50 to 100 metres wide zone, strikes grid north-north-east to north but north of Line 6 the strike is grid north-east. This magnetic feature is associated with moderate to low apparent resistivities of 200 to 400 ohm-metres but tends not to form a distinct resistivity unit.

Two narrow but distinct magnetic "markers" were defined on the present survey. Both are conformable with the interpreted strike as inferred by the resistivity and chargeability data. These have been marked by a continuous line of circles on Plate 5. Neither zone appears to have a constant relationship with either chargeability or resistivity. The source is therefore inferred to be magnetite rather than pyrrhotite.

A narrow resistive horizon marked by a series of crosses on Plate 5 between lines 0 and 3 form a distinct feature and is often, but not always, associated with higher chargeabilities. Preliminary mapping suggest that this feature

is due to a chert horizon; and the chargeability infers a sulphide content in part.

A marked change in the apparent resistivity and apparent chargeability contour plans across an approximate grid north-east axis, suggested the presence of a dislocation, as shown by the possible fault on Plate 5. However, a lack of field evidence together with an inferred continuity of the magnetic data across this line throws doubt on this interpretation.

Zones of relatively high apparent resistivity have been diagonally shaded on Plate 5, while areas of relatively low apparent resistivity have been left blank. Zones of high induced polarization have been marked by a thick black line.

Each of the zones marked on Plate 5 has definite physical characteristics and it is suggested that each represents a unique geological unit. Comparison of Plate 5 with the outcrop map should materially assist in placing of geological boundaries.

CONCLUSIONS

- 1 - The range in apparent resistivity of less than 100 ohm-metres to in excess of 2000 ohm-metres is considered

normal for the area.

- 2 - The high background chargeabilities of 20 to 30 millivolts/volt are, however, considered to be at least twice normal background and, therefore, anomalous. This suggests pyrite or graphite in the host rocks of the order of perhaps $\frac{1}{2}\%$ by volume.
- 3 - The electrical induced polarization decay form is, for practical purposes, everywhere "normal". (See Appendix IPR-8). This is, however, considered to be due to the fact that the induced polarization external current flow would tend to take on the character of the medium through which it flows, rather than that of the source (or of the internal current flow). It is significant that the limited magnetic induced polarization infers a number of different decay forms on the Misty Valley grid.
- 4 - The variation in the resistivity data from line to line has allowed an interpretation of strike and continuity of the rock units to be made. Although not unique, this contour map is considered to represent the most likely situation. Although no rock types can be defined, it is considered that the more resistive and conductive

units defined, represent materially different rock types which have been further differentiated by the proton precession magnetometer data. The units defined on Plate 5 as a result of a study of the three parameters of chargeability, resistivity and magnetics, define distinct rock units. In conjunction with the outcrop map, Plate 5 will assist in the construction of an improved geological map.

The significant induced polarization anomalies can generally be traced along strike over only one or two lines, inferring only limited strike lengths for the chargeable material. In the construction of the contour plan it has been assumed that any chargeable bodies would lie parallel or semi-parallel to the strike as gauged from the resistivity and magnetic data.

- 5 - Those electrical induced polarization anomalies considered to be of interest from a geophysical standpoint and recommended for further ground follow-up in the preliminary report were as follows:

Line 0 375E
Line 1 125E*, 200E, 687E*, 775E
Line 2 075W*, 337E, 425E*
Line 3 200W*, 125E, 675E*
Line 4 025E, 337E, 575E

Line 5 No significant anomalies.

Line 6 No significant anomalies.

Line 7 375E

(* Primary interest)

Of these anomalies, those underlined were subject to close-coupled EIP detail and/or limited MIP detail.

As a result of this work the zone of greatest interest is judged to be that at 687E which has both magnetic induced polarization response, where $M_6 \gg M_1$, a magnetic response, and is conductive. This feature, although not as spectacular as those observed over the Type deposit, are nevertheless of the same form. At this point the depth is estimated to be of the order of 25 metres and the width less than the minimum dipole used, namely 25 metres.

6 - With gradient array, the depths are extremely difficult to predict with accuracy. However, in all cases the maximum inferred depths of 25 metres estimated from the gradient array data were confirmed in the limited pole-dipole and three-array detail.

7 - The very limited MIP test work carried out over known

disseminated graphite and massive pyrrhotite deposits in the Renison Mine area infers a very clear difference in MIP response between these two very different mineral assemblages. (This is discussed in a different report) Unfortunately time permitted only limited MIP work at Misty Valley, and of the work done, only that carried out on Line 1 between 600E and 725E can be considered complete. At this locality (see above) decay characteristics similar to those observed over massive pyrrhotite were noted.

- 8 - The Turair anomaly located in the area during the February, 1973 survey was probably a zone of greater conduction within the resistivity low on Lines 1, 2 and 3 at 650E, 375E and 375E respectively. It should be noted that the large 50 metre dipole employed on the Misty Valley grid will tend to average out narrow zones of significantly higher conductivity which are the causative source of any electromagnetic anomalies. The detailed EIP will tend to resolve these zones close to surface.

- 9 - Similarly the magnetic anomaly defined during the proton precession ground survey located the source of the aeromagnetic anomaly (HM-18) defined during the Turair-Magnetometer survey in the 72/73 season.

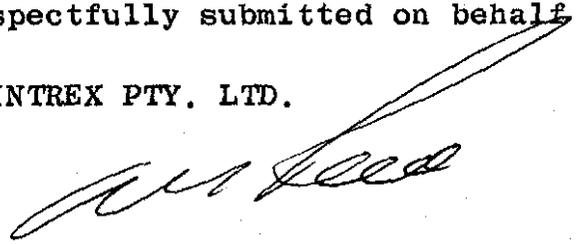
10 - Finally, at this stage it appears that the rapid reconnaissance gradient array electrical induced polarization survey followed by limited detail was the most cost effective approach in the Misty Valley area.

RECOMMENDATIONS

- 1 - Those anomalies listed under section 5, page 20/21, and not detailed to date, should be investigated in detail by geological mapping and geochemical sampling in the vicinity of the response.
- 2 - The electrical and magnetic induced polarization anomaly located at 687E on Line 1 should be investigated by diamond drilling to identify the source. The magnetic data and geochemistry confirm the interest of this zone.
- 3 - Should further experimentation and evaluation confirm the extremely low frequency induced polarization response of the massive, electrically continuous pyrrhotite, which serves as a host to the tin mineralisation in the Renison area, it is strongly recommended that geophysical anomalies, considered to be of geological significance in the area, undergo further MIP testing prior to expensive diamond drilling.

Respectfully submitted on behalf of:

SCINTREX PTY. LTD.

A handwritten signature in dark ink, appearing to read 'A.W. Howland-Rose', written over the company name.

A.W. HOWLAND-ROSE, MSc, DIC, AMAusIMM, FGS.

GEOPHYSICIST

APPENDIX 'I.P.'

INTRODUCTION

For the benefit of those who are unfamiliar with the Induced Polarization method in general, or with the pulse-type method in particular, a few introductory remarks will be directed on the Induced Polarization, or overvoltage, phenomenon. Those who wish a fuller treatment of the subject are directed to Seigel (1962), which paper also includes an extensive list of references.

Induced Polarization in its broadest sense means a separation of charge to form an effective dipolar (polarised) distribution of electrical charges throughout a medium under the action of an applied electric field. When current is caused to pass across the interface between electrolyte and a metallic conducting body, double layers of charge are built up at the interface, in the phenomenon known to electrochemists as "overvoltage". This is the phenomenon which can be utilised for the detection of metallic conducting, rock-forming, minerals such as most sulphides, arsenides, a few oxides and, unfortunately, graphite. In addition, effective dipolar charge distribution occurs to some extent in all rocks, due to ion-sorting in the fine capillaries in which the current is passing.

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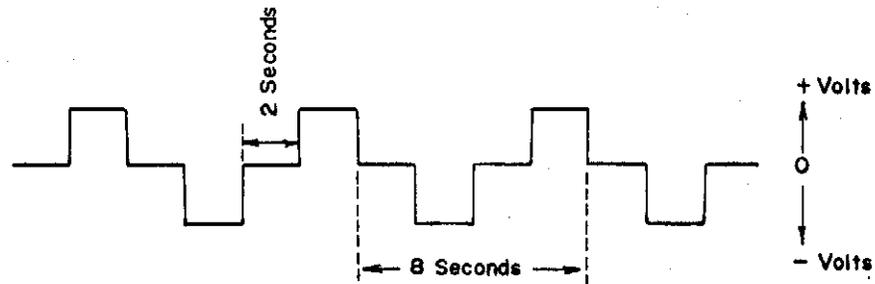
Induced Polarization responses may therefore arise from metallic or non-metallic agencies. Fortunately, the latter generally falls within fairly low and narrow limits. for almost all rock types, although there is still no reliable criterion for differentiating overvoltage responses from graphite and metallic sulphides, or for distinguishing between the responses of one type of sulphide and another. Despite these limitations the Induced Polarization method has amply demonstrated its value in mineral exploration since its initial development as a useful exploration tool in 1948 (ed. Wait, 1959).

DESCRIPTION OF METHOD AND EQUIPMENT

For the present programme the pulse or time domain system was employed, using a Scintrex Induced Polarization unit. The standard current-wave form with the unit is two seconds on-time and two seconds off-time. (see Figure 1). This unit features the Newmont type self-triggered receiver which operates remote from the current transmitting equipment. Three fundamental quantities are measured with this unit - the chargeability of 'M' measurement, the 'L' measurement and the resistivity.

The receiver integrates the area under the decay curve during the time interval from 0.45 seconds to 1.1. seconds

MEASUREMENTS TAKEN



Energising frequency is a square wave having a frequency of 0.125 cps.

FIELD MEASUREMENTS MADE

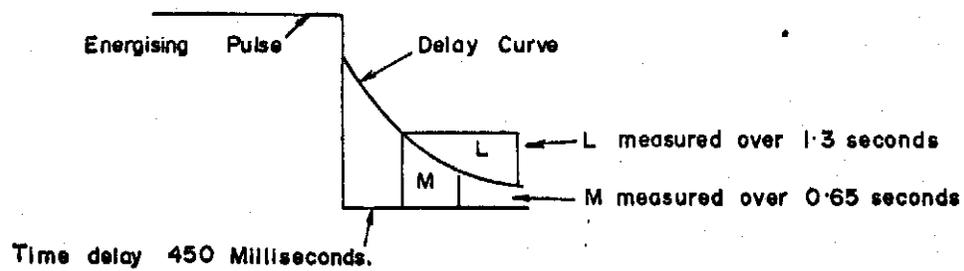


Fig. 1

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after termination of the primary current pulse. This integral normalised with respect to its corresponding primary voltage is the chargeability or 'M' measurement, that is, the fundamental Induced Polarization characteristic. It is in units of milliseconds. The Induced Polarization phenomena is dependent on the existence of electronically conducting material within the matrix of ionically conducting material. The chargeability is therefore a measure of the presence of electronically conducting material within the ground being tested.

The second quantity measured is the area over the transient decay curve between 0.45 seconds and 1.75 seconds of the current off-time. This measurement is designated the 'L' measurement and is also in units of milliseconds. The ratio L/M gives a curve factor related to the shape of the transient voltage curve, and is a measure of the rate of decay of the transient voltage. This is of secondary diagnostic value in that the rate of decay of the transient voltage is partially a function of particle size. A large L/M ratio reflects a short time constant, commonly associated with finely disseminated sulphide or graphite, whereas a small L/M ratio reflects the longer time constants associated with the larger sized metallic particles.

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The L/M ratio is also effective in determining the presence of electromagnetic coupling effects. With the Scintrex Induced Polarization unit, electromagnetic coupling effects are essentially eliminated by an 0.45 second delay-time following termination of the primary current pulse before measurement of the transient voltage commences. However, in extremely low resistivity areas coupling may occur. Under these conditions the presence of electromagnetic coupling can distort the Induced Polarization response, and it is extremely important to know when this occurs. The presence of such coupling is immediately recognizable from the L/M ratios.

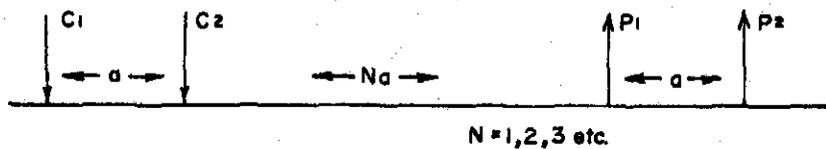
Resistivity measurements are also made as an integral part of all Induced Polarization measurement using the Scintrex Induced Polarization unit. The resistivity values are of primary importance in determining subsurface geological features such as contact zones, faulting, etc., and are of assistance in mapping the geology in general.

Electrode geometries (see Figure 2) utilised in obtaining field measurements are important and no one electrode array is applicable for all conditions. In areas where a low resistivity oxidised surface layer overlies a much higher resistivity freshrock, a high degree of

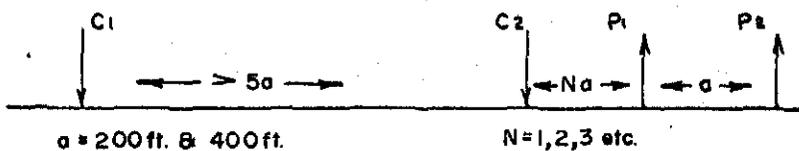
COMMONLY USED ELECTRODE ARRAYS

CLOSE - COUPLED ARRAYS

DIPOLE - DIPOLE



POLE - DIPOLE



GRADIENT ARRAY

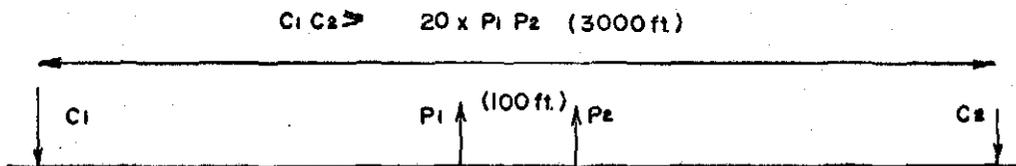


Fig. 2

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masking occurs using any of the close-coupled arrays, such as pole-dipole or dipole-dipole. An electrode spacing many times greater than the depth to freshrock must be used in order to obtain responses reasonably representative of the freshrock. With such large electrode spacings the physical properties are effectively averaged over so large a volume that we lose the ability to detect moderate sized bodies of polarizable material. However, under these conditions the gradient array is both feasible and desirable in that it minimises the effects of masking and at the same time has a high degree of resolution for small targets.

In the present areas of investigation, abnormal induced polarization responses may be expected to arise from the electronically conducting sulphide minerals such as pyrite, pyrrhotite, chalcopyrite and pentlandite, plus graphite and magnetite. The response from magnetite has been found to be quite variable and somewhat unpredictable, reflecting the great variation in the mode of electrical conduction in this material. It is not always possible to differentiate between these potential sources of high chargeability from the Induced Polarization and resistivity data alone. Complementary geophysical, geochemical and geological data enable a more complete interpretation to be made of the Induced Polarization data.

Page - six

REFERENCES

Seigel, 1962

"Induced Polarization and Its Role in Mineral Exploration" H.O. Seigel, Canadian Mining and Metallurgical Bulletin, April, 1962.

ed. Wait, 1959

"Overvoltage Research and Geophysical Applications" editor J.R. Wait, Pergamon Press, London, 1959.

APPENDIX 'MIP'

MAGNETIC INDUCED POLARIZATION

The MIP method measures the magnetic response due to the polarization currents flowing in the ground that are made up of the fundamental polarization current within the chargeable body and its return currents. Being able to measure the magnetic field due to the polarization current within the chargeable body a far more fundamental measurement with associated characteristics is obtained. The polarization current within the body is very concentrated and is in the opposite sense to the inducing current and the return current.

The magnetic field due to the inducing current shows where the primary current is flowing and hence where conductive or resistive zones are.

FIELD PROCEDURE

A longitudinal current array is normally applied so that the current is passed along the long axis or strike direction of sulphide bodies likely to be encountered in the survey area. A fixed current electrode configuration is employed with current electrodes separated by $2A$ where A is the minimum length of bodies desired to locate in the survey area. If there is one well defined horizon of interest then the current electrodes are normally placed reasonably on this line. The cable joining the current electrodes may be the shortest

Page - two

distance between them or when a single well-defined horizon of interest is present, then the current is layed in a U shape avoiding the horizon. In this way the magnetic field from the cable will not obscure the favourable horizon.

With a current electrode separation of $2A$, a block about $2A$ long x A wide may be covered. This is not a rigid limitation, however, and they may be exceeded somewhat providing the magnetic field has an adequate strength.

The horizontal magnetic field at right angles to the current flow is measured, that is, along the direction of the survey line. The distance between stations may vary between 25 and 60 metres depending on the size of body of interest and its depth.

The primary current into the ground is a standard two seconds on-off wave form. Using the IPR-8 receiver, the primary magnetic field H_p due to the primary current I_p flow in the ground is measured. When this is switched off, the decaying secondary current produces a secondary magnetic field H_s . The IPR-8 receiver can measure up to six slices in the decay curve produced by the secondary magnetic field, as shown in Appendix IPR-8. Each slice

Page - three

is normalised for a standard decay curve, and the primary magnetic field, to give the chargeability parameter.

The chargeability with the induced polarization phenomena is defined as the constant relating the primary to the secondary magnetic field, or current or electric field depending on what measuring technique is applied.

APPENDIX IPR-8

I INTRODUCTION

The basic equipment required for an Induced Polarization survey consists of a transmitter, a receiver, wire and electrodes.

Most time domain induced polarization transmitters transmit square waves with equal "on" and "off" times. Polarity is automatically changed between the pulses. The waveform shown below indicates how the current is usually transmitted. The pulse times range from 1 to 8 seconds.

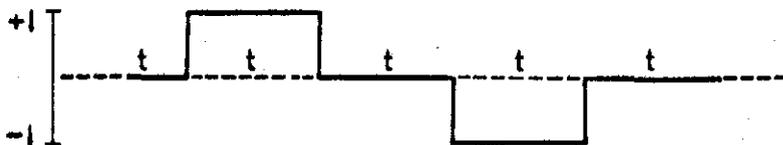


FIGURE 1A

The transmitter is powered by batteries (portable type units or a motor driven generator. Scintrex manufactures various time domain induced polarization transmitters ranging in power from 25 watts to 15 kW. The choice of a transmitter depends on various factors such as: the electrode spacings to be employed, contact resistance and the resistivity of the subsurface. The IPR-8 receiver is designed for use with any time domain induced polarization transmitter.

The IPR-8 time domain induced polarization receiver is of the state-of-the-art design, packaged in a rugged and portable manner. Using integration and automatic normalization, it measures the characteristics of an induced polarization decay curve set up by overvoltage and other effects occurring in rocks. When induced polarization effects (such as due to metallic-non metallic interfaces in rocks) occur, the waveform received at the receiver is not the same square wave as transmitted by the transmitter. The waveform shown below indicates the sort of wave distortion which is caused by the induced polarization phenomena.

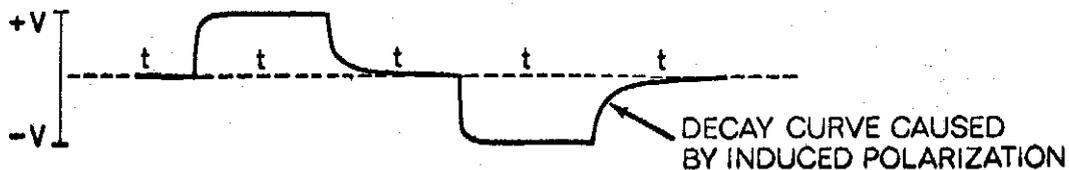
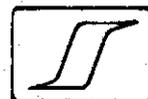


FIGURE 1B



II SPECIFICATIONS

The IPR-8 has the following specifications:

Input Impedance	3 megohms
Primary Voltage (Vp) Range	300 microvolts full scale to 40 volts full scale in 10 ranges
Accuracy of Vp Measurement	$\pm 3\%$ of full scale
Vs/Vp Ranges	20 and 100 mV/V full scale
Vs/Vp Accuracy	$\pm 3\%$ of full scale
Primary SP Buckout Range	± 1 volt
Accuracy of SP Measurement	$\pm 3\%$, ± 5 mV
Automatic SP Tracking Range	6 x Vp, maximum ± 1 volt
Continuity Meter Reading	0 - 500 k ohms
50 or 60 Hz Powerline Rejection	-50 db (300x)*
Low Pass Filter	6 db/octave with $f_c = 20$ Hz and 12 db/octave with $f_c = 36$ Hz
Required Stability of Transmitter Timing	Need only exceed measuring program selected (1 or 2 seconds)
Operating Temperature Range	-30°C to +60°C
Dimensions	320 mm x 135 mm x 160 mm
Weight, Complete with Lid and Batteries	3.6 kg
Power Supply	4 D cells - Eveready No. 1050 or equivalent; estimated battery life 2 months intermittent duty at 25°C 1 Alkaline cell Eveready No. E91 or equivalent; estimated life 1 year

* 50 or 60 Hz depending on power system.



III QUANTITIES MEASURED BY THE IPR-8

Figure 2 shows the different parameters measured by the IPR-8. The usual measurements are V_p , the received primary voltage and "M", a parameter related to the transient curve. The V_p measurement is used in resistivity calculations while M is the chargeability (induced polarization) parameter. In addition, absolute values of the self-potential (SP) can be measured.

In all cases, the M quantity measured by the IPR-8 is the mean value of the transient voltage over a selected time interval to which the following normalizations have been applied:

- normalization for the length of the integration interval
- normalization for the primary steady state voltage (V_p)
- normalization for curve shape
- normalization for number of pulses

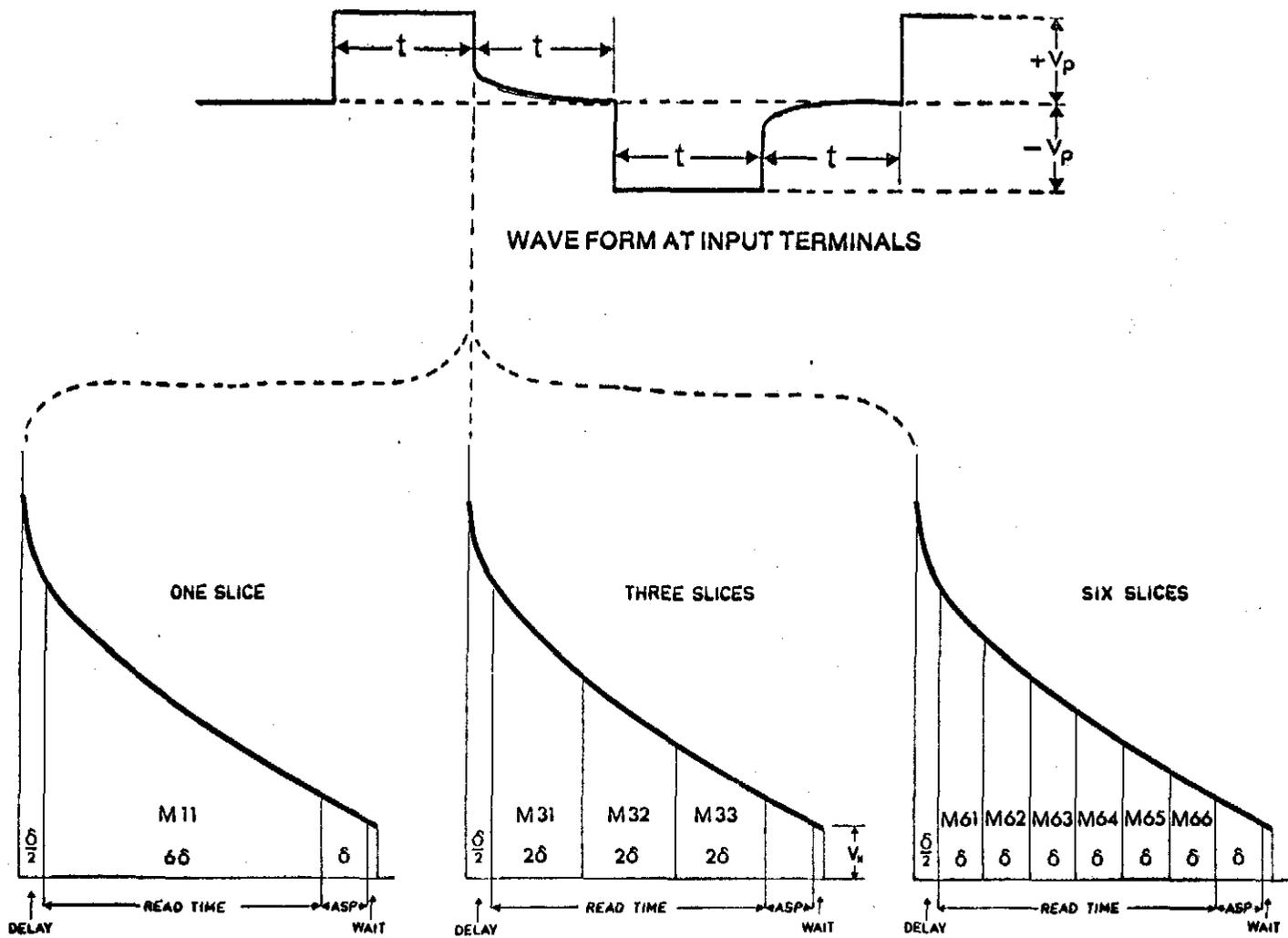
The units of the quantities measured are, therefore, dimensionless and are normally expressed in "millivolts per volt".

In the various modes of operation the transient voltage following the interruption of the primary current pulse is either integrated over one long period of time or sliced into either 3 or 6 slices. By using 6 slices, a good record of the decay curve shape can be obtained. The 3 slice mode gives some curve shape information and provides an economical standard mode in which to operate. The centre slice of this mode is reasonably close to the measurement made by the Scintrex IPR-7 and other receivers of the "Newmont Type", while the first and last slices can be used for a rapid check of curve shape. A more precise relationship is, however, presented later in this section.

Figure 2 shows the actual times used. For the receiver to operate, the transmitter timing may be any time period of one second or greater (i.e. $t \geq 1$ second) although transmitter and receiver timings of 2 seconds are considered normal for most surveys. Equal on and off timing assures the best noise rejection as the signal is averaged over the longest possible time, and the automatic self-potential adjustment is made closest to the reading time.

With the receiver set at $t = 1$ second, the decay ($\delta/2$) from the current-off time to the commencement of the measurement is 65 milliseconds and the slice width (δ) is 130 milliseconds. With the receiver set at $t = 2$ seconds the delay is 130 milliseconds and the slice width is 260 milliseconds. Fuller information on the programs is available from the tables in Figure 2.





SECONDARY DECAY CURVE SHAPES AS APPLIED TO THE INTEGRATORS

t sec.	δ	delay time	waiting time	M 11				M 31			M 32			M 33			length
				from	to	mean	length	from	to	mean	from	to	mean	from	to	mean	
1	130	65	25	65	845	455	780	65	325	195	325	585	455	585	845	715	260
2	260	130	50	130	1690	910	1560	130	650	390	650	1170	910	1170	1690	1430	520

t sec.	M 61			M 62			M 63			M 64			M 65			M 66			length
	from	to	mean	from	to	mean	from	to	mean	from	to	mean	from	to	mean	from	to	mean	
1	65	195	130	195	325	260	325	455	390	455	585	520	585	715	650	715	845	780	130
2	130	390	260	390	650	520	650	910	780	910	1170	1040	1170	1430	1300	1430	1690	1560	260

FIGURE 2

PARAMETERS MEASURED WITH TIMES OF RECEIVER PROGRAM IN MILLISECONDS.

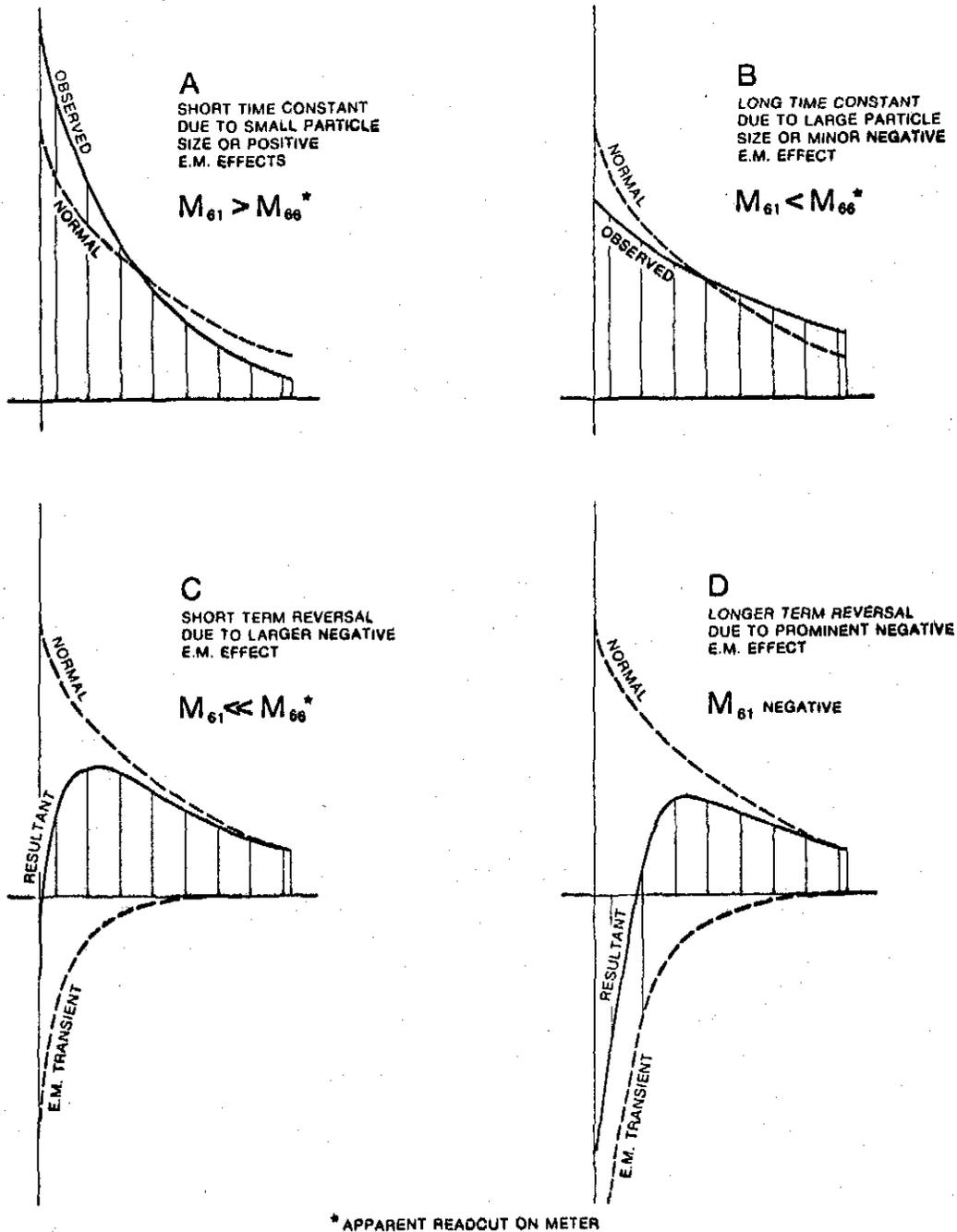


FIGURE 3

THE SIGNIFICANCE OF CURVE SHAPE INFORMATION GAINED USING 6 SLICE READINGS.

JA-

Each integration is normalized with respect to the Standard Induced Polarization Decay Curve which has been established by Newmont Exploration Limited. (ref. Dolan and McLaughlin in bibliography) This is achieved by choosing the sensitivities of the integrators so, that if the curve shape is normal, all slices within a given mode show the same amplitude of measurement. A further normalization is built in for the slice width, be it full, one-third or one-sixth of the total integration period. The net effect is that the reading will be the same regardless of the slice measured, providing that a standard transient decay curve form is present and that the same measuring cycle is used for transmitter and receiver (1 second or 2 seconds). Any departure from this standard curve form will be immediately obvious to the operator, without performing any calculations. For instance, a steeper decay will give a higher reading on earlier slices than on later slices. Reconstruction of the actual decay curve is easily effected by using the correction factors given in Table 1.

The shape of a time domain induced polarization decay curve can be altered by electromagnetic or interline coupling, by variations in the average size or degree of interconnection of the metallic particles in the bedrock or by other I.P. sources. Figure 3 illustrates the advantage of breaking the decay curve into slices. Utilizing only one wide slice, there is no indication of the shape of the decay curve. Positive electromagnetic coupling effects or small particle size may give rise to an abnormally short time constant (Case A) which, for multi-slice modes will be indicated by higher normalized readings of the earlier slices with respect to the later slices. An increase in the later slices over the earlier ones (Case B) may imply a longer time constant due to a minor negative EM transient or I.P. responses from large metallic particles, etc. Cases C and D, where the values of the initial slices are considerably reduced or are even negative, show the effect of negative EM transients of increasing amplitude.

A system of symbols has been created to indicate each of the measurable slices.

The general symbol is M_{txy} where:

- t is the timing chosen (i.e. 1 or 2 seconds)
- x is the number of slices in the mode chosen (i.e. 1, 3 or 6)
- y is the number of the slice referred to (i.e. 1, 2, 3, 4, 5 or 6)



Wherever two subscripts only are given, eg. M_{32} , it is understood to apply equally for $t = 1$ sec. or $t = 2$ sec.

A chargeability reading is defined by the following formula:

$$M = \frac{V_s \cdot 1000}{V_p} \quad \text{in mV/V}$$

where
$$V_s = \frac{t_1 \int^{t_2} V_s dt}{t_r} + V_x$$

and $t_1 =$ time at beginning of slice

$t_2 =$ time at end of slice

$V_x =$ residual transient voltage at the end of the automatic self potential correction

$t_r = t_2 - t_1$, i.e. the integrating period

Chargeability values, uncorrected for curve shape, can be easily calculated if required. Normalizations for all slices are made using the M_{232} value as reference. In other words, there is no curve shape normalization applied to this slice; the M_{232} readout is, therefore, directly as measured. The same statement holds for the M_{132} slice, however, its value is one-half the value for M_{232} provided that the transmitter timing matches the receiver timing.

To restore the true transient curve shape (M true), the observed M readings (M read) are multiplied by the factors in Table 1.

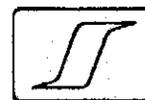


TABLE 1

$$M_{\text{true}} = M_{\text{read}} \cdot k_1$$

Slice	k_1
M ₁₁	1.09
M ₃₁	1.47
M ₃₂	1.00 ← NORMAL
M ₃₃	0.81
M ₆₁	1.68
M ₆₂	1.27
M ₆₃	1.06
M ₆₄	0.94
M ₆₅	0.85
M ₆₆	0.78

For the ideal "normal" I.P. transient curve form $M_{2xy} = 2M_{1xy}$ where M_{2xy} is for a 2-second on-off transmitter cycle and M_{1xy} is for a 1-second on-off cycle. The relationship between readings taken with differing transmitter and receiver timings is more complicated, particularly if the curve shapes are not normal.

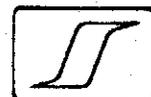
Table 1 still applies for the case where the transmitting times are longer than the receiving times in order to reconstruct the relative curve shape.



Relationship between IPR-8 and
"Newmont Type" Receiver Measurements

The "Newmont Type" receivers (eg. Scintrex IPR-7) integrate the area under the transient curve from 0.45 seconds to 1.1 seconds. This is then multiplied internally by an instrumental factor to obtain the chargeability M in milliseconds.

For a normal decay curve form, the approximate relationship between the IPR-8 measurements and the Newmont Type chargeability is given by M_{232} (in mV/V) = M_N (in milliseconds) • 0.7.



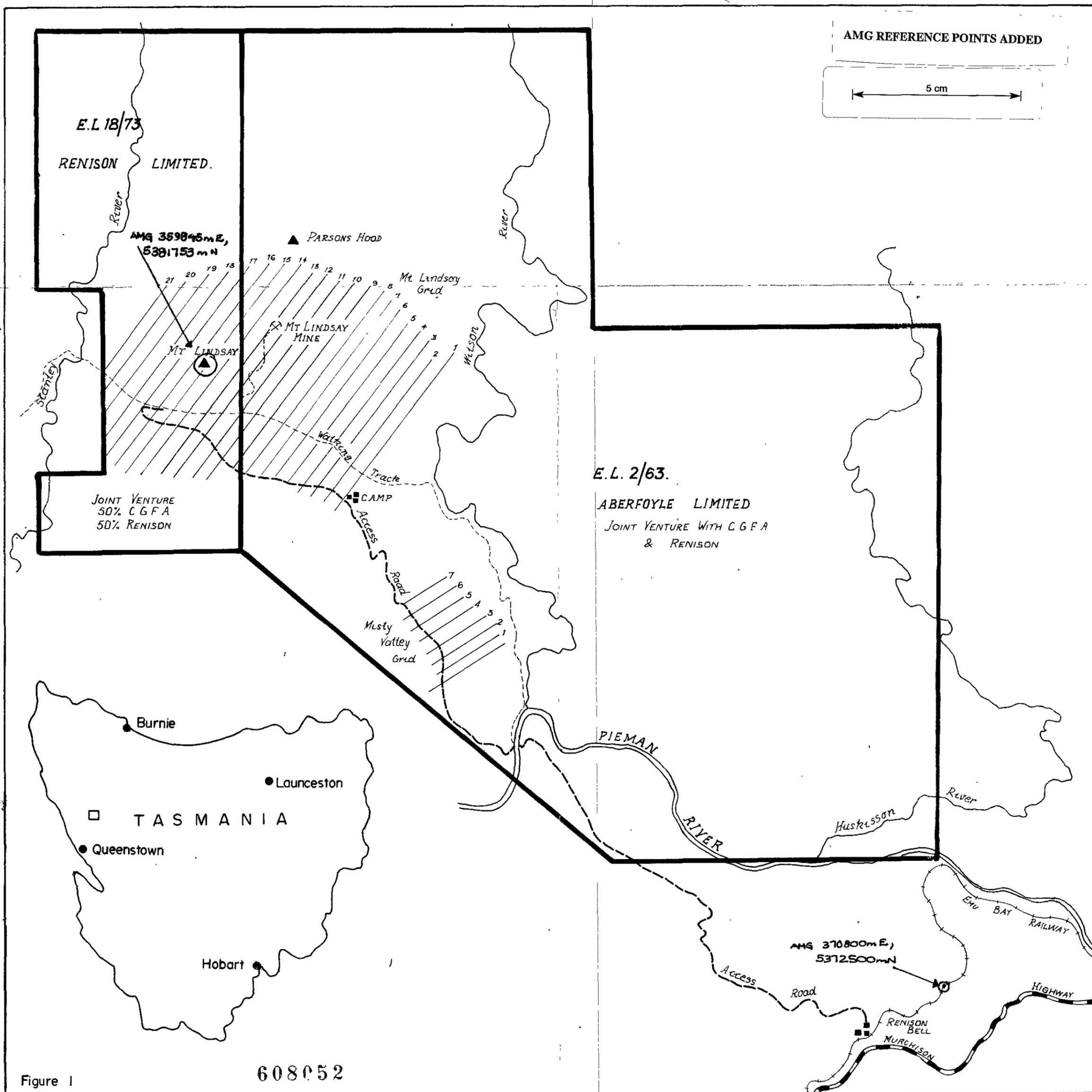
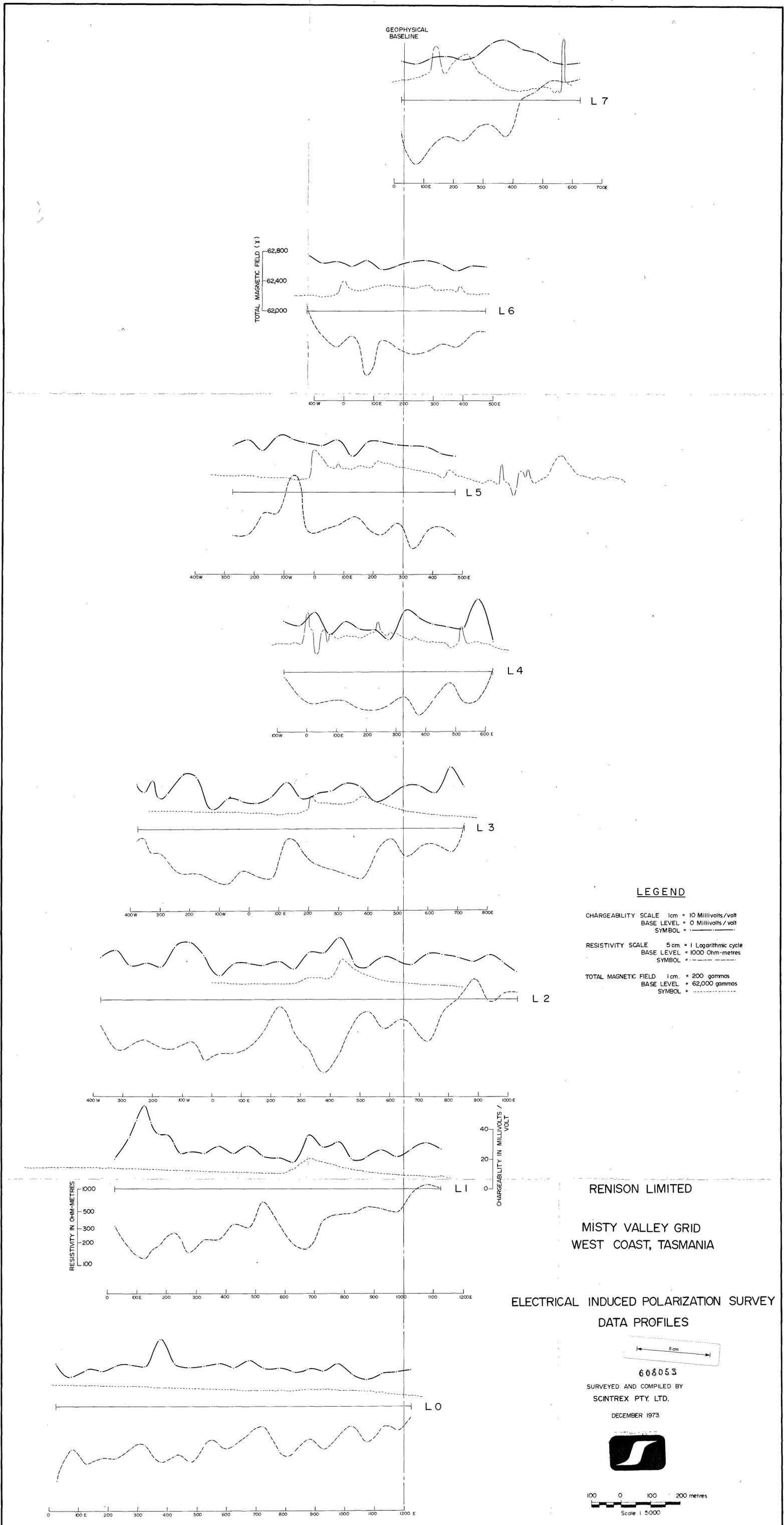


Figure 1

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LEGEND

CHARGEABILITY SCALE 1cm = 10 Millivolts/volt
 BASE LEVEL = 0 Millivolts/volt
 SYMBOL = - - - - -

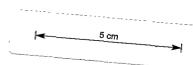
RESISTIVITY SCALE 5 cm = 1 Logarithmic cycle
 BASE LEVEL = 1000 Ohm-metres
 SYMBOL = - - - - -

TOTAL MAGNETIC FIELD 1cm = 200 gammas
 BASE LEVEL = 62,000 gammas
 SYMBOL = - - - - -

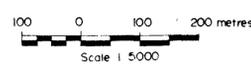
RENISON LIMITED

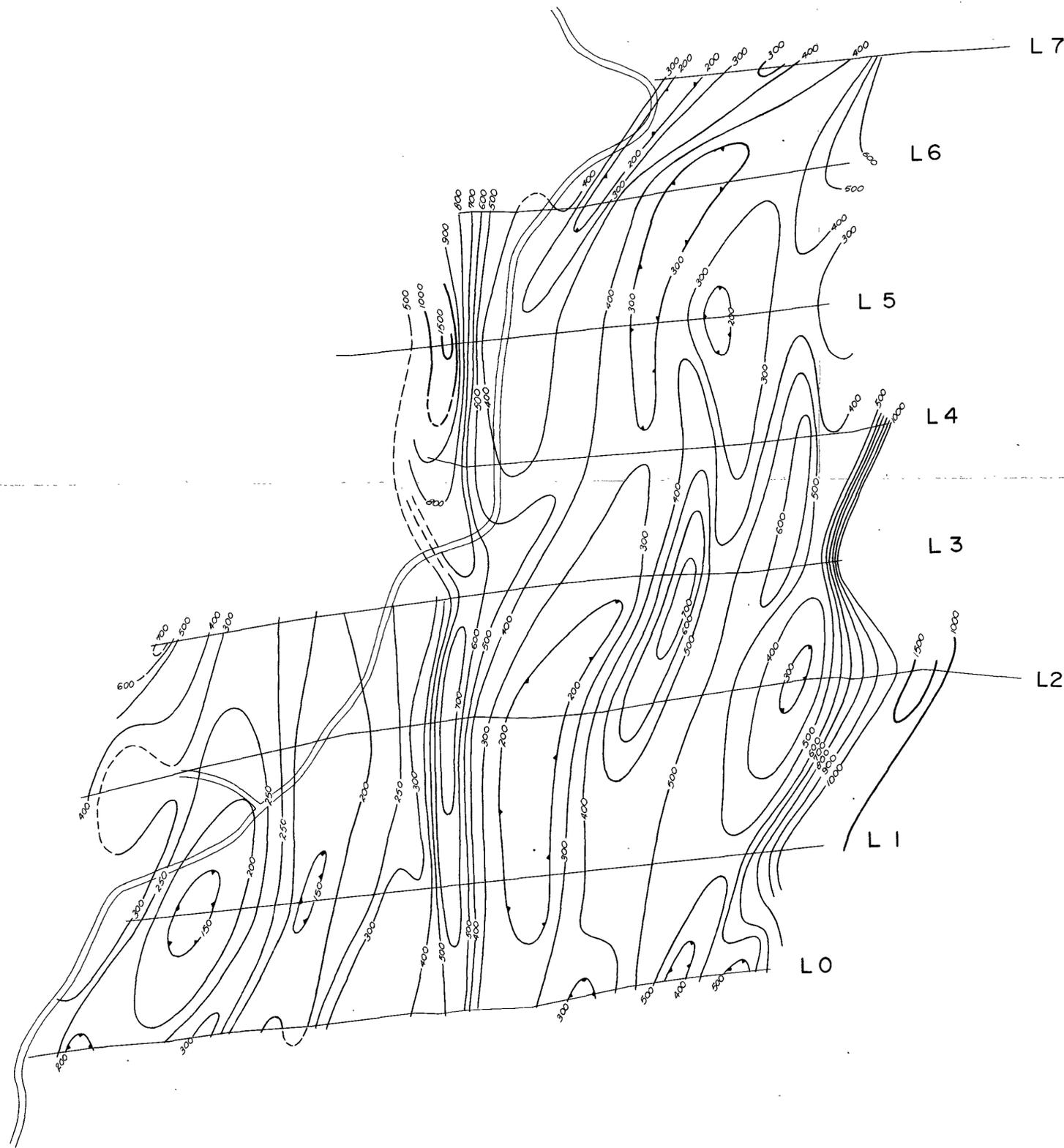
MISTY VALLEY GRID
 WEST COAST, TASMANIA

ELECTRICAL INDUCED POLARIZATION SURVEY
 DATA PROFILES



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 SCINTREX PTY. LTD.
 DECEMBER 1973

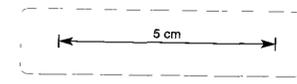




RENISON LIMITED

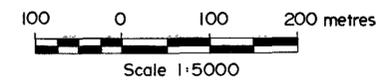
MISTY VALLEY GRID
WEST COAST, TASMANIA

RESISTIVITY CONTOUR MAP

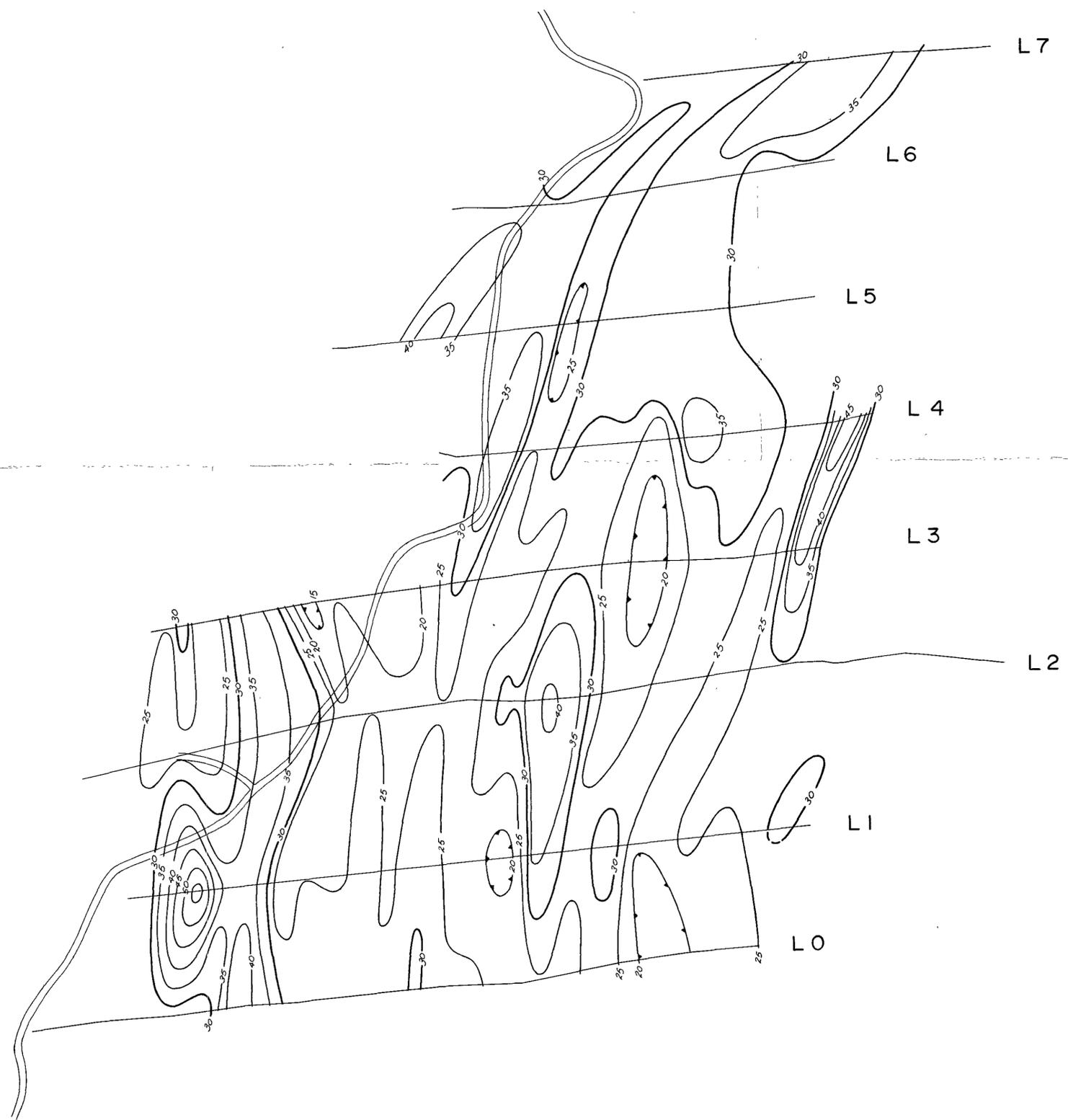


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CHARGEABILITY CONTOUR MAP



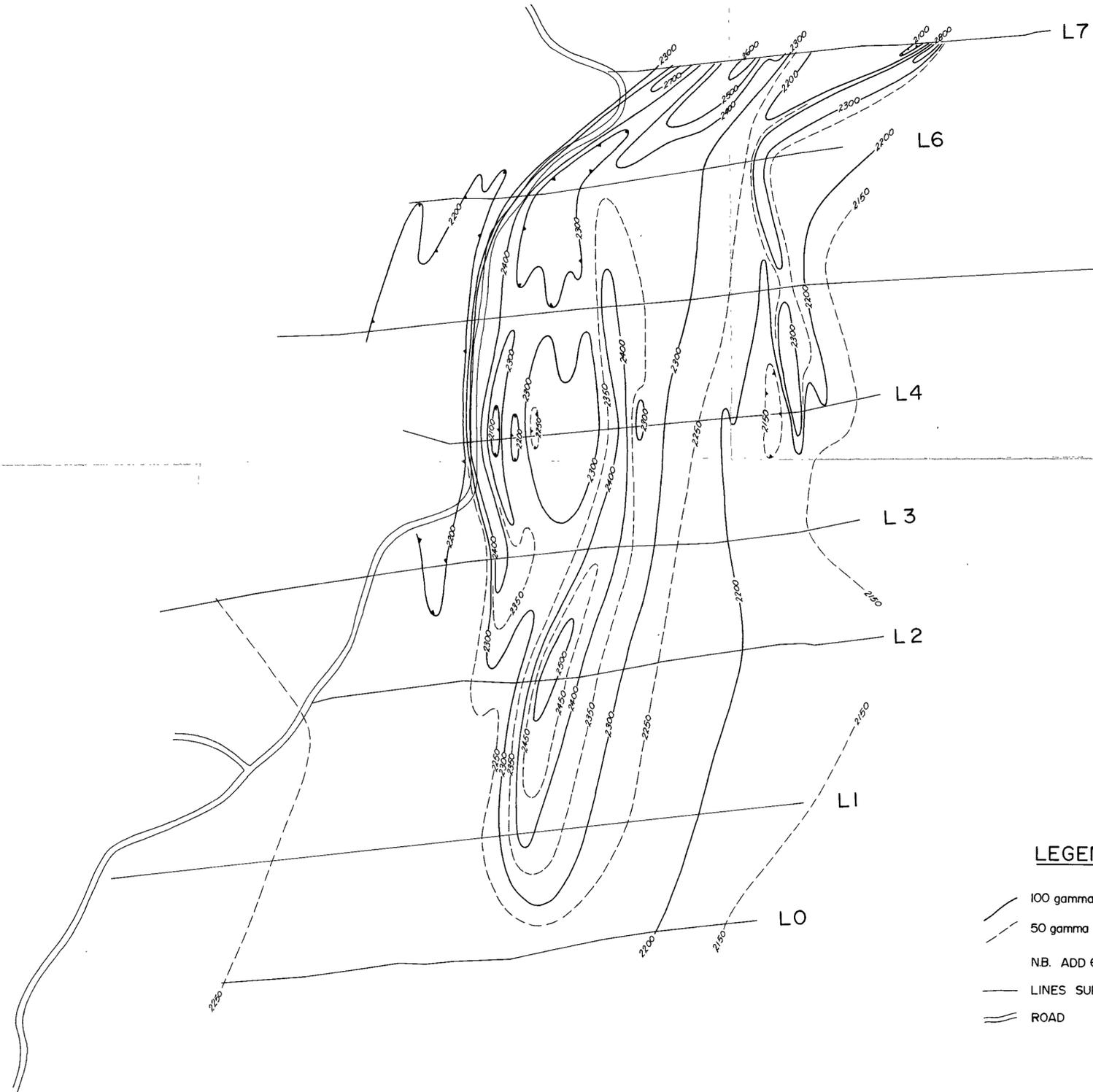
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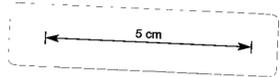
3360 74-1001



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MISTY VALLEY GRID
WEST COAST, TASMANIA

MAGNETIC CONTOUR MAP
(TOTAL FIELD)



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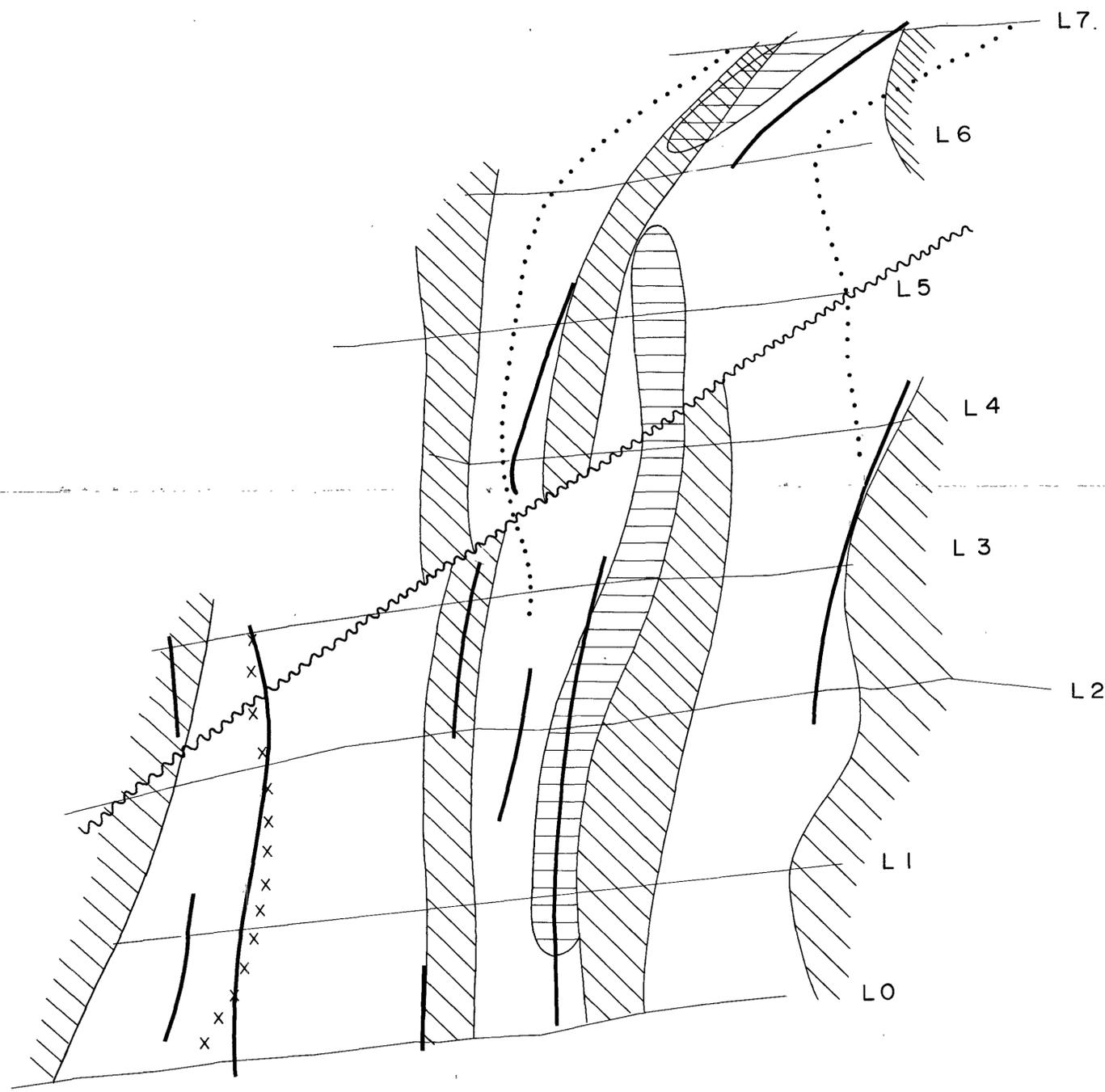
LEGEND

- 100 gamma
- 50 gamma
- NB. ADD 60000 GAMMAS
- LINES SURVEYED
- ROAD

608056

JOB No. TAS. 019 AF SHEET 1 of 1 PLATE 4

3361 74-1001

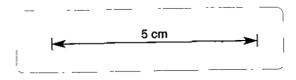


LEGEND

-  LOW RESISTIVITY CONTACT
HIGH RESISTIVITY
- X X X X NARROW HIGH RESISTIVITY ZONE
-  SIGNIFICANT INDUCED POLARIZATION HIGHS
-  POSSIBLE FAULT
-  LINES SURVEYED
-  BROAD MAGNETIC ZONES
-  NARROW MAGNETIC RIDGES

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 MISTY VALLEY GRID
 WEST COAST, TASMANIA

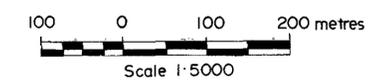
INTERPRETATION PLAN

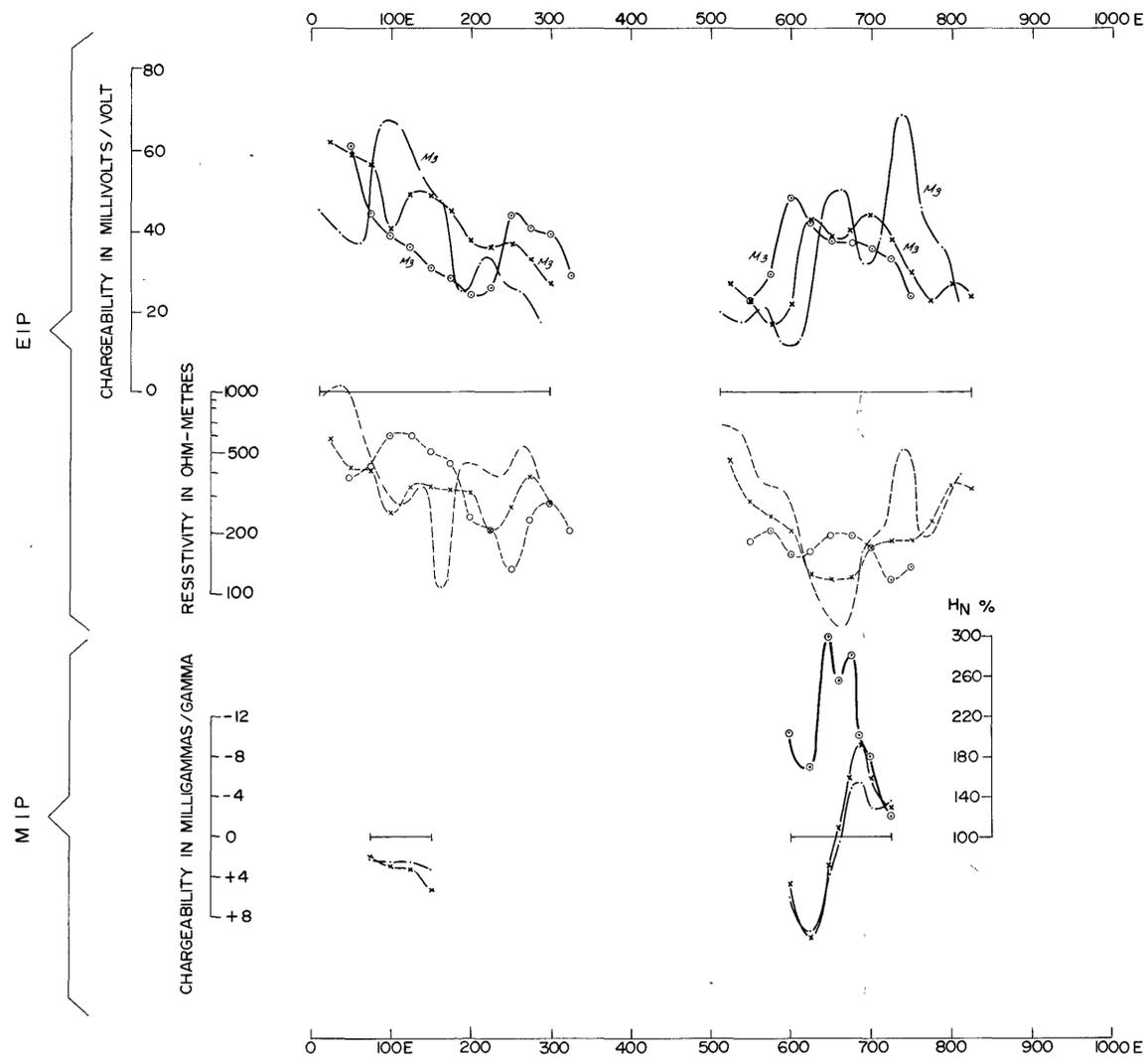


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LEGEND

EIP

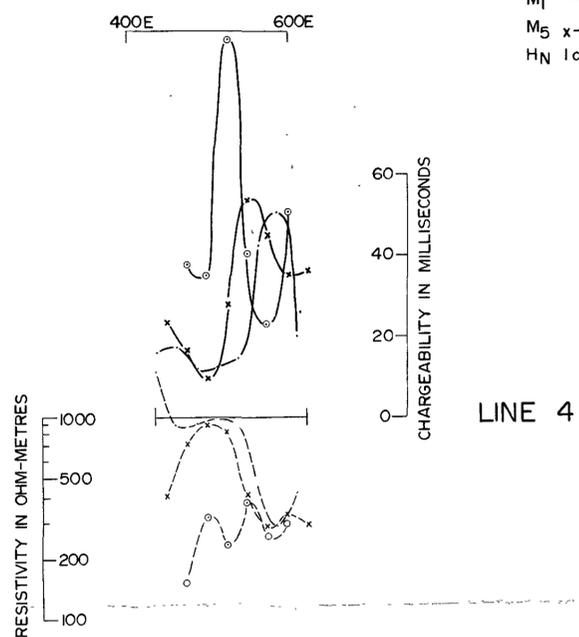
	CHARGEABILITY	RESISTIVITY
	1cm. = 10 millivolts/volt	5cm = logarithmic cycle
THREE ARRAY	a = 25 m a = 50 m x-----x
POLE - DIPOLE	a = 50 m n = 2	o-----o o-----o

MIP

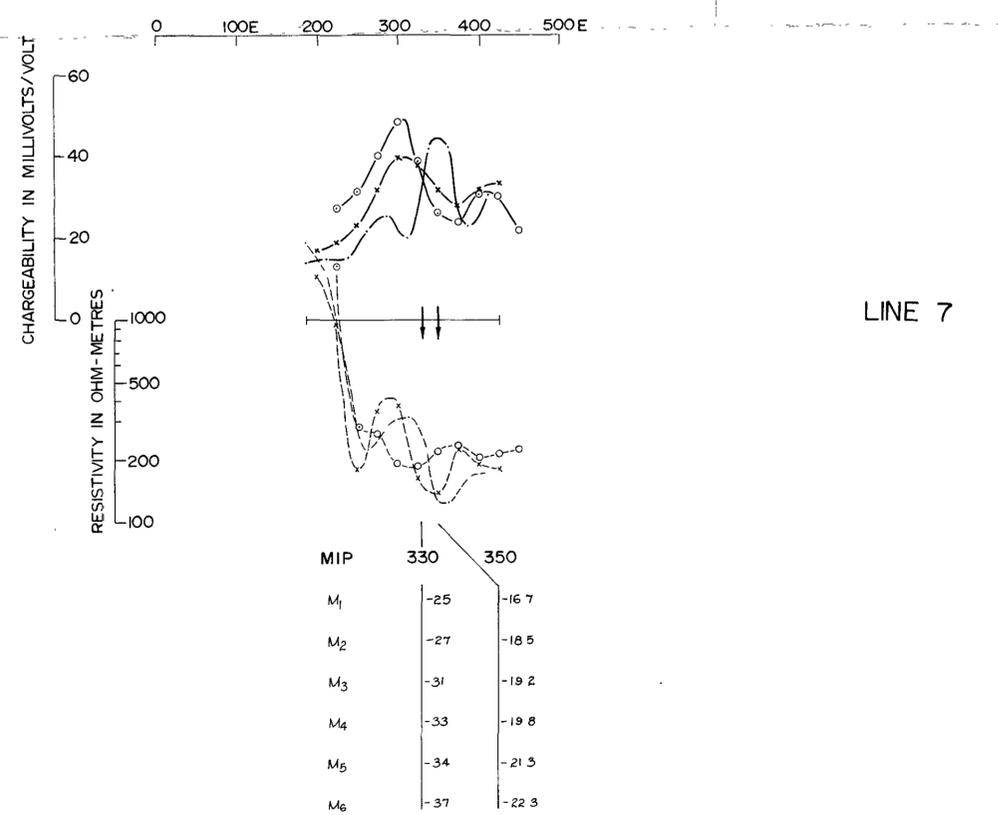
CHARGEABILITY, M, 1cm. = 4 milligammas / gamma
Subscript denotes slice presented

M ₁
M ₅	x-----x
H _N	1cm. = 40 %

LINE 1



LINE 4



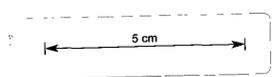
LINE 7

MIP	330	350
M ₁	-25	-16.7
M ₂	-27	-18.5
M ₃	-31	-19.2
M ₄	-33	-19.8
M ₅	-34	-21.5
M ₆	-37	-22.3

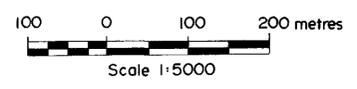
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MISTY VALLEY GRID
WEST COAST, TASMANIA

MAGNETIC & ELECTRICAL
INDUCED POLARIZATION DETAIL



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