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SCINTREX

A REPORT ON
A RAPID RECONNAISSANCE
MAGNETIC INDUCED POLARIZATION SURVEY
OVER A SECTION OF THE HARE CLAIM GROUP
HIGHLAND VALLEY, NEAR ASHCROFT, BRITISH COLUMBIA
ON BEHALF OF
CENTURION EXPLORATION INC.
IN ASSOCIATION WITH
TECHNOMIN AUSTRALIA N.L.

PART 3 of 3

SCINTREX

PRIVATE AND CONFIDENTIAL

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CENTURION EXPLORATION INC.

IN ASSOCIATION WITH

TECHNOMIN AUSTRALIA N.L.

BY

A.W. HOWLAND-ROSE

MSC,DIC,AMAUSIMM,FGS.

GEOPHYSICIST

SYDNEY, N.S.W.

NOVEMBER, 1981

T- 2107

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Plate 2 (2 sheets) RPS Compositve Contour Plan

Plate 3 (2 sheets) Interpretation Plan

CENTURION EXPLORATION INC.

Statement of Exploration and Development
For Period Covering July 1981 - October 1981

(a) WAGES:

--Laborers:
6 men employed for approximately
300 man days @ approximately
$65.00/day..$19,380.01

--Geophysicist #1: $12,200.00
Geophysicist #2: $ 7,925.00
Geophysicist #3: $ 960.00..................$21,085.00...........$ 40,465.01

(b) FOOD AND ACCOMMODATION:

--Camp and Supplies...$ 17,597.74

(c) TRANSPORTATION:

--Vehicle and Insurance.........................$ 7,433.40

--Fuel..$ 5,722.55...........$ 13,155.95

(d) INSTRUMENT RENTAL:

--One Scintrex TSQ4 8 kw RRMIP Transmitter
Three Scintrex IPRF2 RRMIP Receivers
Three Scintrex MFM3 Horizontal Eluxgate
Magnetometers
July 27, 1981 - October 1, 1981................$14,740.00

--Additional Equipment
67 days @ $100.00/day.........................$ 6,700.00...........$ 21,440.00

(e) SURVEYS:

--RRMIP: 2 months (see attached)

(f) ANALYSIS:

--None

(g) REPORTS: (see attached)

--Geophysical:
(Howland-Rose) $ 8,781.42
$ 2,000.00..................$10,781.42

--Geological:
(Rayner)....................................$ 2,537.00...........$ 13,318.42

$105,977.12

CENTURION EXPLORATION INC.
per:

James K. Byberg, Director

SCINTREX PTY. LTD.

GEOPHYSICAL CONSULTANTS AND CONTRACTORS

SUMMARY

An RRMIP survey covering about 120 kilometres of line within the Hare Claim Group on behalf of Centurion Exploration Inc. has revealed a series of internal polarization anomalies which are considered to be due to chargeable material in disseminated form beneath the basalts. The interpretation of the data must be considered tentative and subject to continuing review as the testing programme proceeds, as the Highland Valley represents an environment materially different to that surveyed elsewhere to date.

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INTRODUCTION

At the request of Mr. J. Blair, Chairman of Centurion Exploration Inc. Scintrex Pty. Ltd. of Sydney, Australia in co-operation with Scintrex Limited of Toronto, Canada, executed a series of 18 rapid reconnaissance magnetic induced polarization (RRMIP) arrays over the Hare Claim Group, the location of which is shown on the Ashcroft, B.C. survey map 92 I/NW.

The work took place between 2nd August and 29th September, 1981, and during this period just under 120 kilometres of line were surveyed, and two electrical soundings taken. Production details are given in the accompanying table.

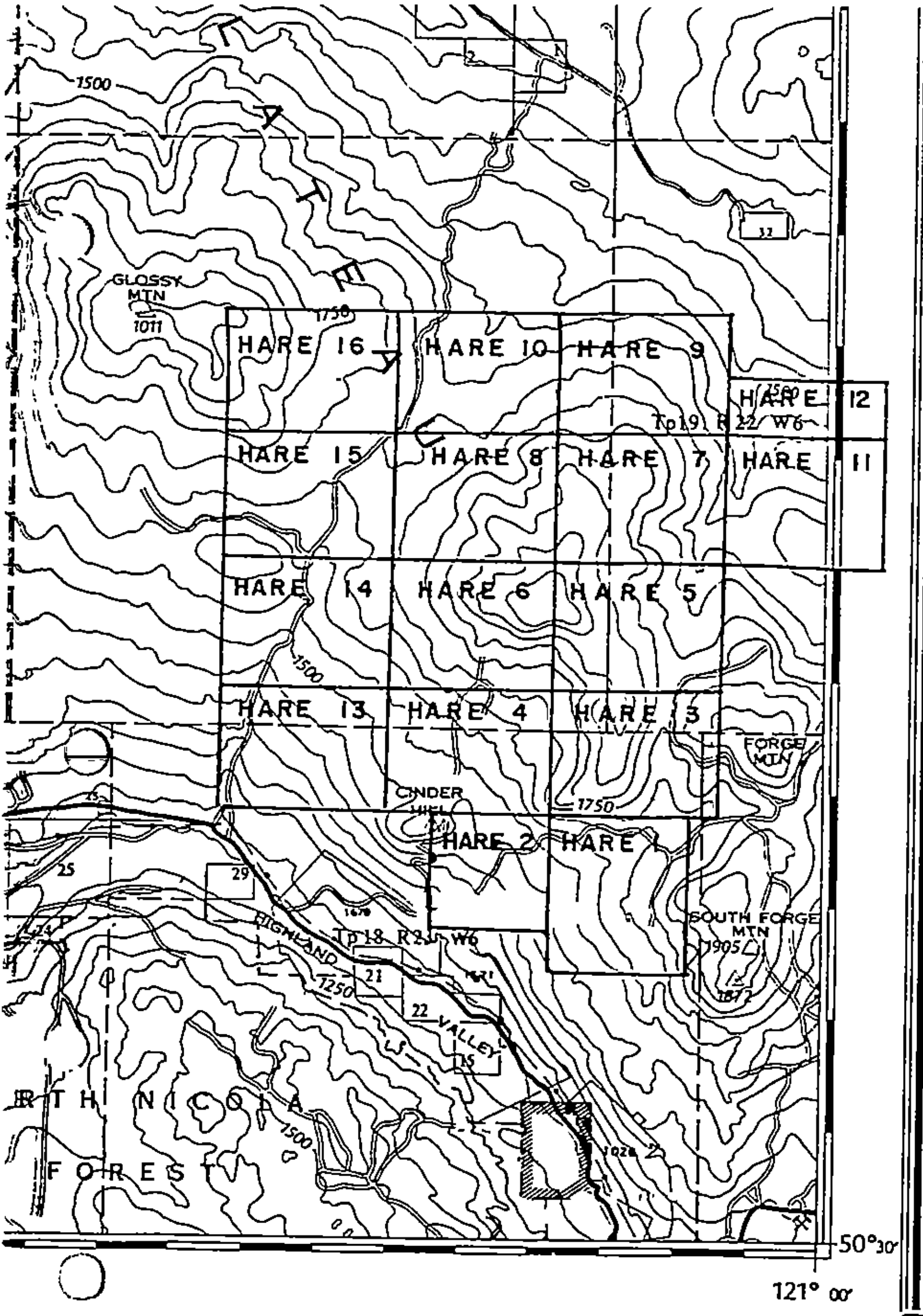
The RRMIP surveys were under the direction and supervision of Mr. A. James, B.Sc., (Geol.)Hons of Scintrex Sydney, assisted by D. Marcotte, B.Sc. of Scintrex, Toronto. Overall on-site supervision and organisation was undertaken by J. Byberg of Centurion.

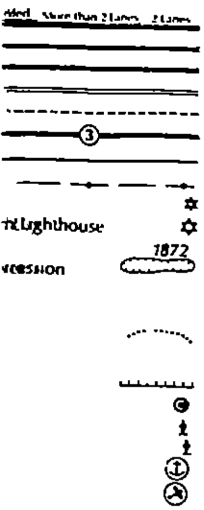
PRODUCTION

Dates	Line Kilometres	
2-8 August	8.1 kilometres	
9-15 August	17.4 kilometres	
16-22 August	6.25 kilometres	magnetc storms
23-29 August	5.5 kilometres	magnetic storms
30 August-5 September	9.35 kilometres	magnetic storms
6-12 September	23.65 kilometres	
13-19 September	20.5 kilometres	snow
20-26 September	22.5 kilometres	
27-29 September	5.05 kilometres	
	118.3 kilometres	

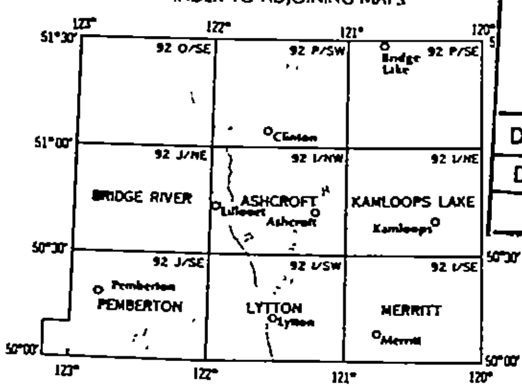
Approximate production rate (including magnetic storms and inclement weather) 14 kilometres/week

Approximate production rate (excluding magnetic storms and inclement weather) 18 kilometres/week





INDEX TO ADJOINING MAPS



ASHCROFT, B. C.

MAP 92 I/NW

THIRD STATUS EDITION

CENTURION EXPLORATION INC.	
HARE CLAIM	GROUP MAP
DRAWN BY: NLT	Fig No 2
DATE: NOV. 15, 1980	
N. TRIBE & ASSOCIATES LTD.	

METHOD

A brief and simp e description of the method is given below for those unfamiliar with the basic principles behind the Rapid Reconnaissance Magnetic Induced Polarization (RRMIP) method. However, it is strongly recommended that the enclosed appendix be studied in detail for a more complete description of the method, and for those who are to make a geophysical assessment of the data, it is recommended that the papers referred to in the appendix be read also. The references therein give the current major papers dealing with MMR and MIP methods by various authors.

There are two significant electrical properties of rocks and ore bodies which are of great assistance in identifying zones of potential economic interest. The first is *resistivity*. This can be described as the resistance of a rock to the passage of electric current through it. Obviously those sections which are less resistive will allow greater quantities of current to flow than those which are more resistive. Massive sulphide zones, fault zones, zones of deeper and more intense oxidation and graphite horizons, are examples of units which will allow greater quantities of current to pass. In RRMIP, the measurement of resistivity is made with a very sensitive horizontal field magnetometer. This senses the volume of current flowing in the section below by virtue of the fact that current is simply the number of electrons flowing, and each of these electrons carries a magnetic field with it as it moves. Thus the magnetic field observed by the magnetometer is proportional to the current flowing through the volume of overburden and rock below the sensor. This measurement is called Magnetometric Resistivity (MMR). Positive values define areas of relative conductors, and negative values areas which are relatively resistive. This property can be used as a method for tracing rocks having different resistivities beneath conductive overburden, as well as to define specific conductors which may of themselves be of potential economic interest.

The second and more significant property is known as *induced polarization*. This phenomenon involves the storage of some of the electrical energy at the grain boundaries of sulphide (or graphite) grains, and the water contained between grain boundaries in rocks and ore bodies. If a pulsed current is used, the sulphide (or graphite) zones will charge during periods of current flow, and discharge during periods when the current ceases to flow. It is this discharge of stored energy which is the induced polarization effect, and the magnetic sensor is sufficiently sensitive to define these minute magnetic fields. The magnetic induced polarization effects are measured in terms of Relative Phase Shift (RPS). Positive values denote *internal* polarization from *within* sulphides or graphite, while negative values generally denote the discharge of the polarization effect *external* to the source.

The reason for a magnetic sensor being used rather than simple electrical contact with the surface of the ground is that the conductive surface areas effectively mask the major changes in resistivity (MMR) beneath the conductive surface layer, and invariably either completely short out the induced polarization effect, or render it unrecognisable against background noise. The current is injected into the ground through current electrodes placed from 1 to 3 kilometres apart. These large current electrodes enable current to penetrate the weathering into the fresh rocks below that hold the sulphides which are the subject of our exploration search.

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EIP & MIP ENERGIZATION

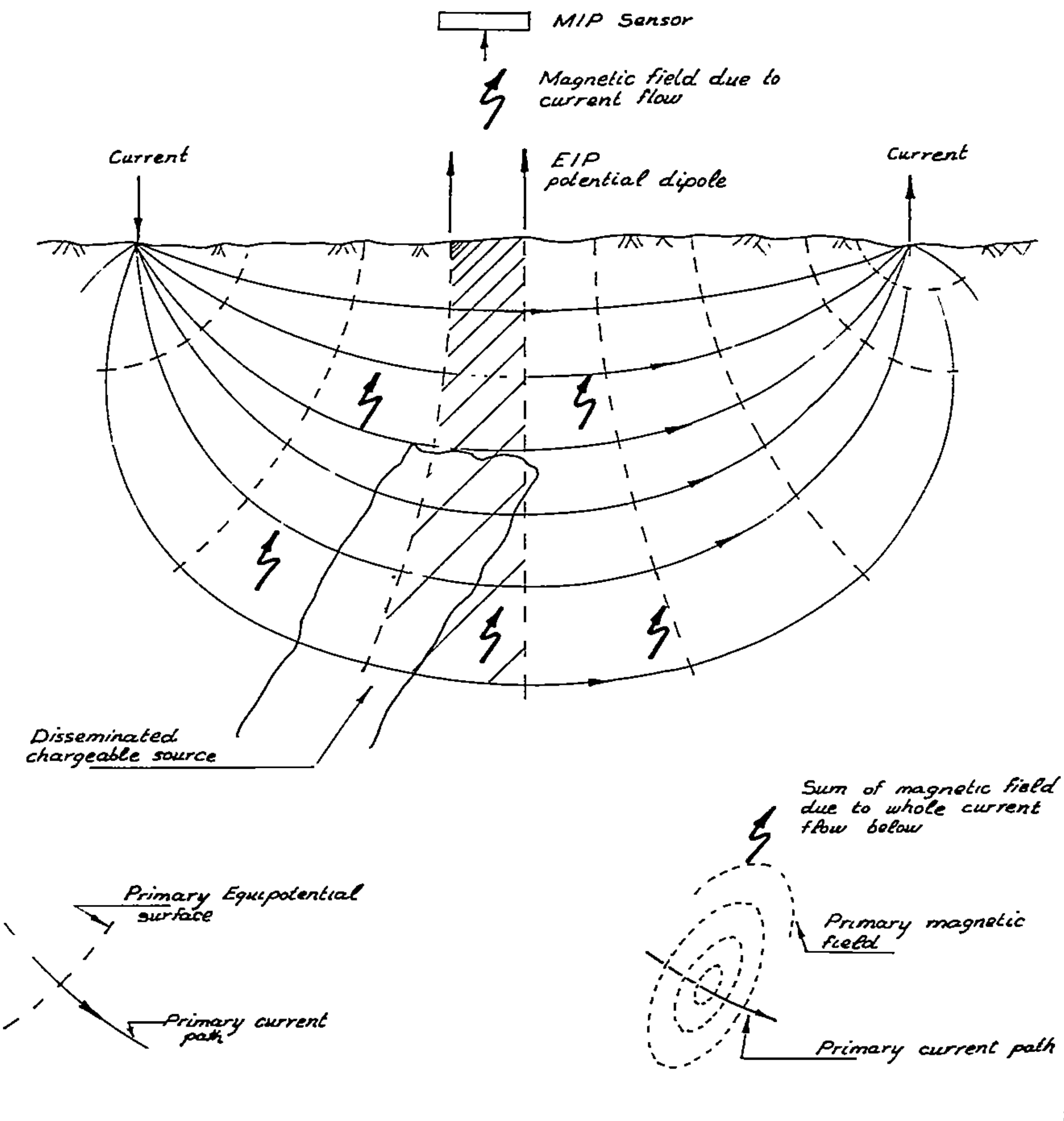

Fig. 1

SCINTREX

EIP & MIP
DISCHARGE OF INDUCED POLARIZATION

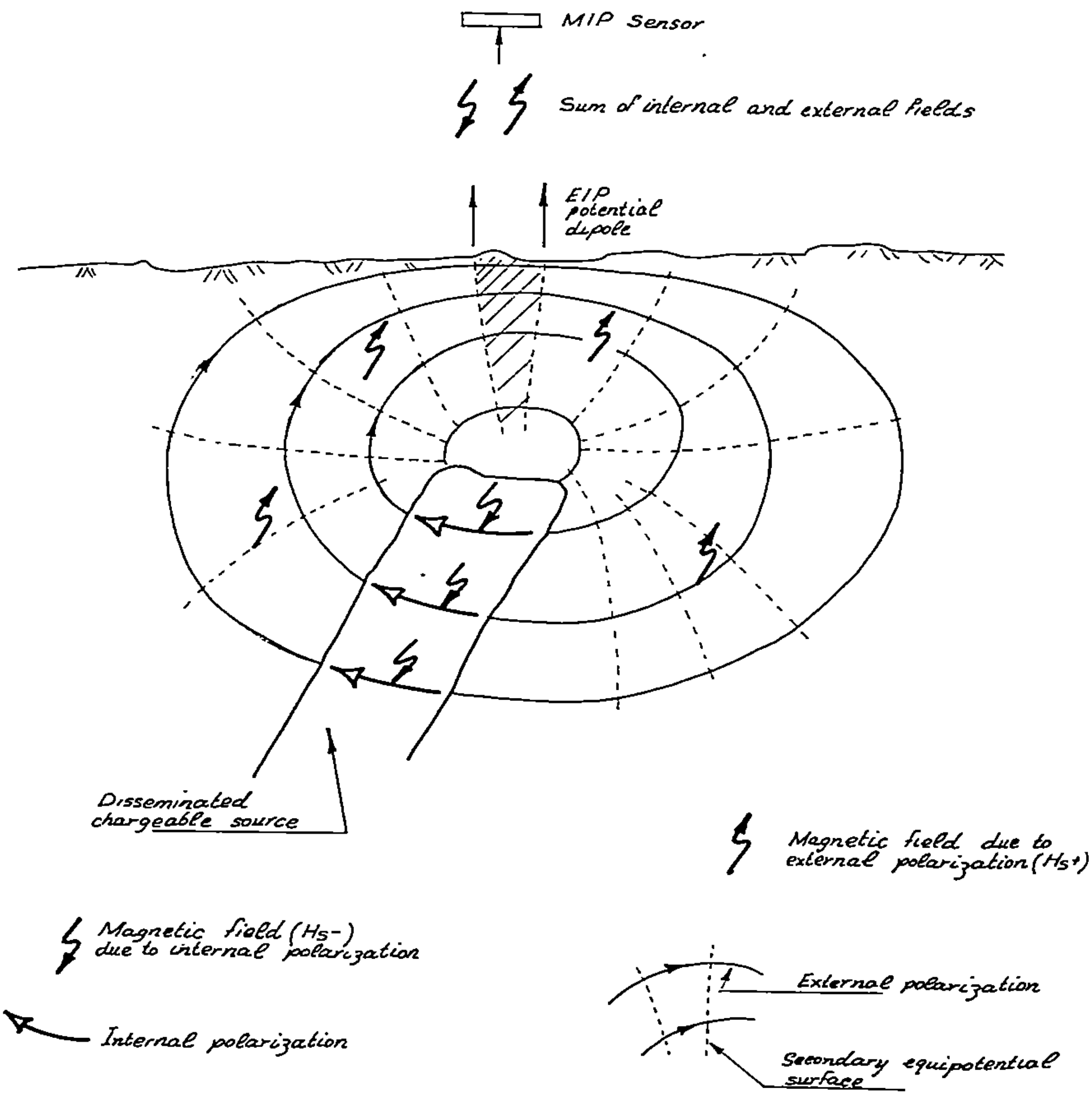

Fig 2.

DATA ACQUISITION AND PRESENTATION

Data Recorded:-

The following parameters were recorded:-

- Hp, the incident magnetic field due to the current flow in the current dipole
- RPS, the magnetic induced polarizat`on effect at each station by reference to the Relative Phase Shift of the primary and third harmonics.
- PFE, the magnetic induced polarization effect by reference to the Percent Frequency Effect observed from the relative amplitudes of the first and third harmonics.
- The offsets for RPS and PFE for each array.
- The energising current (I) and the frequency of energisation (1Hz).

Data Processsing:-

The data has been computed and the following parameters have been calculated for each station.

MMR	Magnetometric resistivity
H_N	Normalised horizontal magnetic field
Hu	Geometric factor
RPS	Relative Phase Shift (in °)
PFE	Percent Frequency Effect (in %)
HSQ/I	Secondary field (derived from RPS)
HSP/I	Secondary field (derived from PFE)
PFE/RPS	ratio, an indication of the presence of coupling.

Data Presentation:-

The data has been displayed in table form with the selected parameters of MMR, RPS and HSQ/I being shown in computer printergraph format by array.

In addition, the parameters of MMR and RPS have been contoured and presented as individual sheets by array at the scale of 1:2500. The MMR is printed in blue, RPS in red and interpretation in black (see below).

Each individual RPS and MMR contour map has been reduced on a Xerox to a scale of approximately 1:5000 and compiled into a composite. From these two parameters an interpretation map showing the main electrical features has been drawn up. These are presented in two sets of three plates:- 1 - MMR, 2 - RPS 3 - interpretation. Suffix 'N' refers to the northern section and 'S' to the southern section.

The array prefix M or R refers to the data being MMR or RPS respectively, while the suffix W or E denotes the current line lies to the west or east of the array respectively. The figure below the array number depicts the array size in hundreds of metres, while the circle denotes the array centre.

THE EXPECTED SIGNATURE

The RRMIP method has been applied for the most part to flat conductive overburden situations with steeply to moderately dipping bodies thereunder.

In the present case the overburden consists of basalts whose resistivity has been measured by electrical soundings to be of the order of 250 to 500 ohm-metres($\pm$); the terrain moderate to rough in places, with the underlying rocks being shown to be of lesser resistivity in the limited area of the electrical soundings.

As a model of the type of deposit likely, the results of a Scintrex (discovery!) survey over one line are shown in enclosure 1. Here it can be seen that the bulk resistivity of the sulphide body is of the order of 250 ohm-metres($\pm$). The resistivity of the enclosing material is not known, but would be expected to be somewhat higher than the quartz diorites. In the case of the Hare group, the overburden (basalts) could well have a higher resistivity than the rocks at depth. As can be seen, the *apparent* chargeability over the 2% to 3% sulphide source within the body is 10 to 12 milliseconds, as against an inferred 5 milliseconds or less outside the body. Thus the *apparent* contrast *as seen at the surface* is 2 to 2.5 fold. It would be expected that the *actual* contrast between the sulphide source and the enclosing material would be greater than this. With the MIP/RRMIP methods, it is the *contrast* in bulk resistivities and the *contrast* in bulk chargeabilities of the underlying rocks which produce contrasts in MMR and MIP readings as seen at surface.

One other important aspect to bear in mind when these results are studied is that while a "small" source within a "large" array will be seen as a discrete

Lornex deposit, British Columbia, Canada (Seigel, 1970)

The Lornex porphyry copper deposit, currently being brought into production in the Highland Valley area, British Columbia, Canada, is estimated to contain of the order of 300 million tons of ore grading 0.43% Cu and 0.04% Mo. The total sulphide content is rather low, being about 2–3% by volume of which about 1% is, therefore, chalcopyrite and the remainder pyrite.

Fig.3 shows one of the discovery geophysical sections over this body. The current cycle was 1.5 sec on-time and 0.5 sec off-time and integration-time. The total sulphide content and copper grade increase somewhat, as well as the thickness of overburden, as one progresses west along the traverse to about 9,000 E. The ore lies in Skeena quartz diorite.

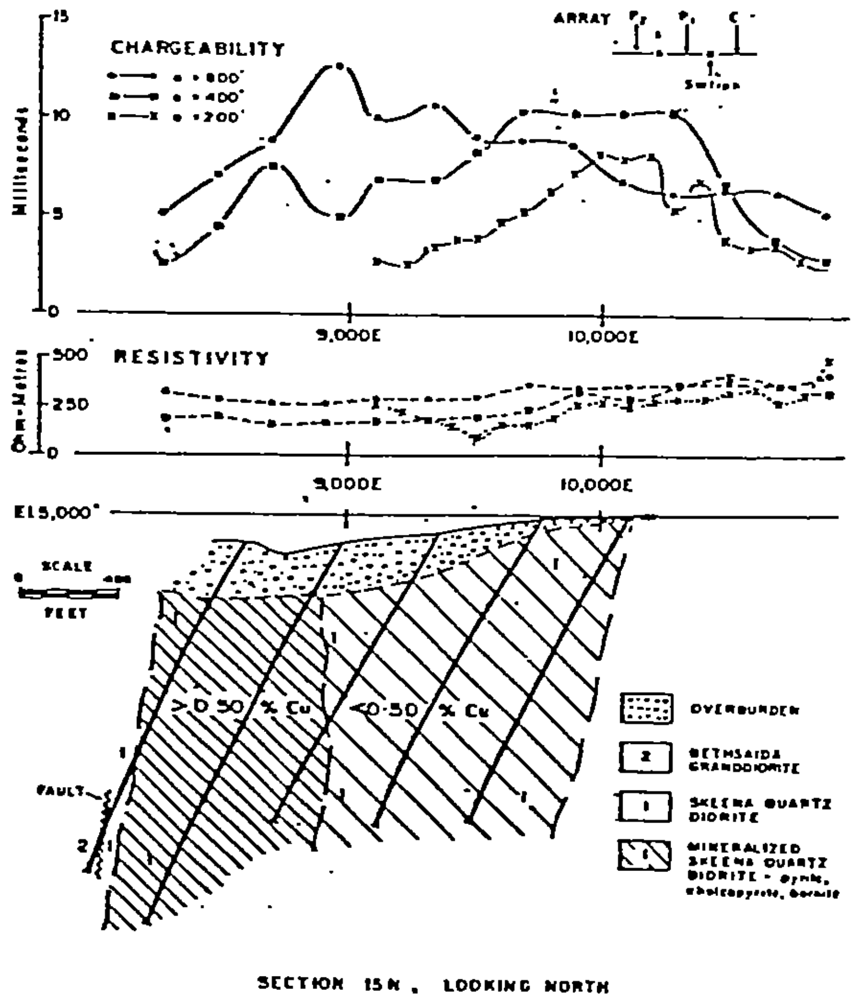

Fig.3. Geophysical and geological section, Lornex porphyry copper deposit, British Columbia, Canada.

At about 9,000 E the interpretation of the three spacing information gives a two layer equivalent of 170 ft. of overburden of resistivity about 65 ohm-m and chargeability about 0.5 msec, overlying bedrock of about 550 ohm-m resistivity and 23 msec chargeability. The relatively high order of resisitivity of the ore is not too surprising in view of the low total sulphide content of the ore.

anomaly (see MIP Appendix), the possibility of the source being "large" with respect to the energising dipole must be considered. Two contrasting examples are chosen for demonstration. Figure 3 shows the response expected over a section containing a chargeable and a relatively non-chargeable zone. An anomaly in RPS as shown would be expected. This is of course quite straightforward. However, in the second case, a horizontally layered situation is shown (figure 4). Here, *no appreciable RPS changes will be recorded* as horizontally layered media will give no net primary or secondary horizontal field (i.e. no MMR or RPS anomaly will occur). However, in the latter case, should zones of greater or lesser sulphide concentrations occur, then these zones will be seen as discrete anomalies.

The result of this situation is that in the case of sources which are large with respect to the current electrodes, is that a "good" fit between adjacent arrays will not necessarily occur.

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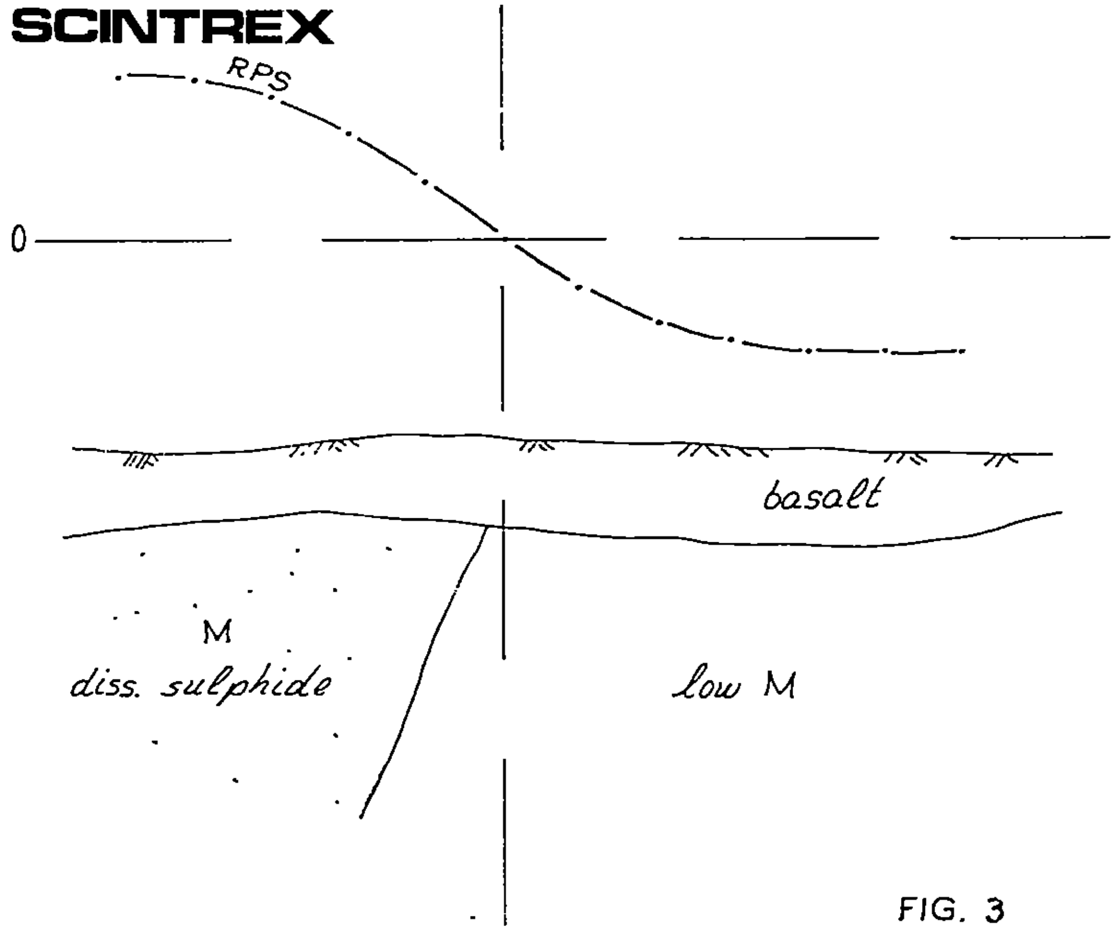

FIG. 3

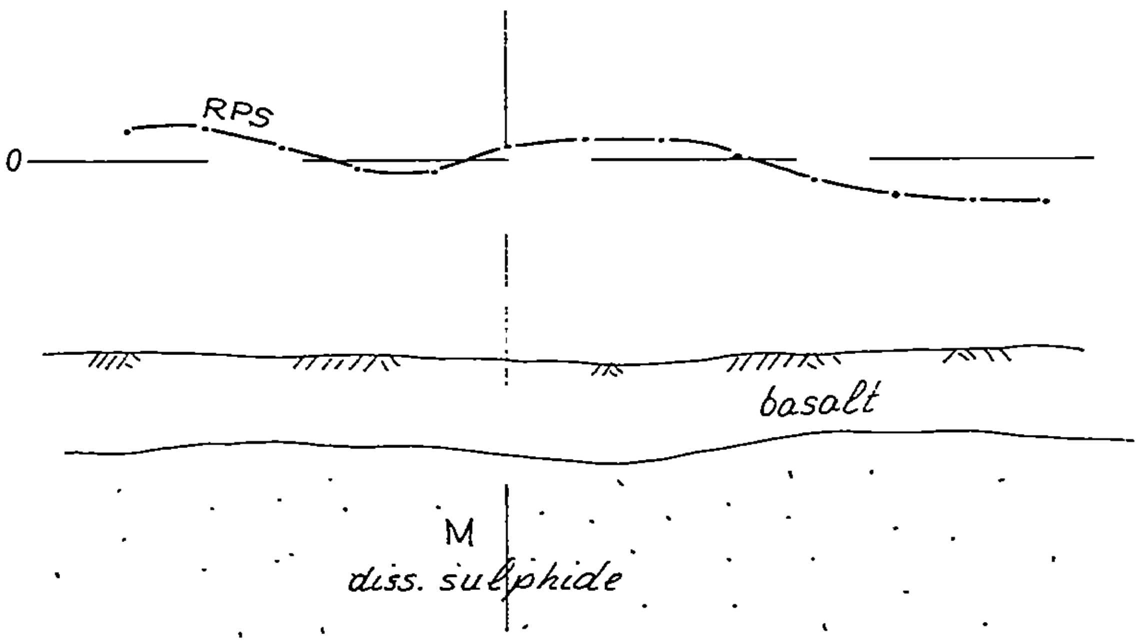

FIG. 4

THE PHYSICAL MEANING OF RRMIP PARAMETERS, AND COMMENTS ON THE PROBLEMS OF INTERPRETATION IN THIS AREA

A summary of the main characteristics of each of the features highlighted in the interpretation map follow in order that the reader can fully appreciate the geological implications of the data.

GENERAL

Conductor Axes

These represent the axes of the MMR conductor. To be significant they must have (i) a significant cross-sectional area conductivity contrast with the immediate enclosing rocks, and (ii) a significnat strike length with respect to the current dipole used to energise the array. A diminution of either (i) or (ii) with respect to background resistivity of the rocks, or current dipole respectively, will result in a diminution of the observed response.

One further consideration with respect to the magnitude of the response is that should the current dipole be "small" and the conductivity width of the overburden "great", then a diminution of response will occur also. (For details see MIP Appendix, page 12, figure 7)

One major point to bear in mind is that horizontal layering will not be observed on the MMR, while lateral changes will be emphasised.

Resistor Axes

These represent the axes of the significant MMR resistors, which in turn represent the areas of the most resistive rock units. All the remarks above for conductors apply also to the resistor axes.

Contacts

Where significant gradients are observed in the MMR data, a line has been drawn along the inflexion point (or approximately so, allowing for various 'local' distortions). This line will, for vertical dipping bodies show the approximate location, and certainly the strike length of major rock type changes.

Dislocations

These are located on the interpretation maps to emphasise a significant along strike discontinuity in both MMR and RPS features. They represent faults, flexures in strike direction or perhaps lensing of significant resistors and conductors.

Internal Polarization Axes

These represent above background zones of anomalous internal polarization. They are caused by segregations of sulphides, graphite and more rarely, by serpentine, mafic mineral content and magnetite.

These features can be distorted by electromagnetic coupling, by current channelling, particularly when MMR curves show a steep (25° to 30°) angle with the energising current, and by wire effects should the energising frequency be excessive with respect to the conductivity width of the overburden.

On the flanks of arrays, the precise location of the axes may not necessarily be mapped, but can be inferred. In such cases additional limited detail work is required. Where this is so, the axes are identified.

Significance of the Three RRMIP Parameters, MMR, RPS and HSQ/I

As discussed elsewhere, the positive MMR values denote relative bulk conductors, while the negative values denote relative bulk resistors. The positive RPS values emphasise internal polarization w thin low current density areas, while positive HSQ/I values emphasise internal polarization within high current density areas. (Please refer to the papers for further explanation.)

INTERPRETATION

Features Seen in the MMR Data

As would have been expected, little material change in MMR background away from zero is noted over the area. This basically means that either the area is horizontally layered or is of relatively uniform bulk resistivity. Certainly few major lateral changes in bulk resistivity are inferred to be present in the survey area:

On many arrays resistive (or negative MMR) cones were noted fanning out from electrodes. This is a feature associated with the resistive nearer surface material as against the less resistive material at depth. As the sensor location becomes distant from the current electrodes, the reading is increasingly influenced by the less resistive rocks at depth.

There are a number of low amplitude conductors and resistors as seen via MMR. These are considered to represent features in the bedrock below the basalts, or alternatively faulting or weathering within the basalts, although this is considered unlikely. The resistor axes on the whole tend to have much more limited strik length than the conductor axes. In a number of cases the MMR data, by termination of significant axes, implies dislocation by either folds or more likely faults in the bedrock. It is perhaps significant that these features can also be seen to terminate zones of internal polarization.

Features seen on the RPS

Following on the comments made under the heading of "The Expected Signature", it should be appreciated that good visual correlation between array boundaries will not necessarily occur. However, there are some additional considerations in assessing this data.

Firstly, on a number of arrays a distinct increase in internal polarization was noted towards the side of the array where the wire is laid. This is almost certainly due to the underlying rocks being more chargeable, however, such wire effects have been noted in regions of high surface conductivity. While these conditions are not expected here, this phenomenon should nevertheless be borne in mind when considering the data.

Secondly, on a number of lines (e.g. 750S array 15E and 2250S array 17E), high internal polarization was recorded on a section of the line only. The nature of the area did not permit additional interline spacing to be surveyed to validate the anomaly located. Thus some caution must be exercised during the assessment of these anomalies.

For the most part, however, the internal polarization as expressed by positive

RPS, is considered to be due to chargeable material at depth, at least the rocks at depth are considered to be of higher polarization than the enclosing rocks. In general, as there is no material correlation of internal polarization with resistive or particularly with more conductive rocks, the origin of the chargeable material is inferred to be disseminated.

The source of the chargeable material may of course be sulphides, however, graphite and segregations of mafic minerals may also increase the contrast in polarization, so contributing to an internal polarization anomaly.

GEOLOGY

The geology is described in a report by Mr. N.L. Tribe,P.Eng. of N. Tribe & Associates Ltd. of Kelowna B.C., dated 15th November, 1980.

Tribe reports that in a general way the Highland Valley ore bodies are associated with the contact between the Bethlehem Phase and the Bethsaida Phase intrusives of the Guichon batholith and in breccia zones. The major deposits are reported by Hollister (1975) to be associated with junctions of the Lornex and Highland Valley fault systems.

The western edges of claims 11 and 12 and/or the eastern edges of claims 1,3,5,7 and 9 are considered by Tribe to lie close to the projected northerly extension of the Lornex fault. (This lies sub-parallel to and close to the 00 baseline used in the geophysical survey.) Other lineaments sub-parallel to the Highland Valley fault have also been observed within the area covered by the geophysical survey and are considered to be due to post basaltic movements along the sub-basalt faults.

Tribe concluded in his assessment of the Hare Group that while all the structural and geological parameters of the known ore bodies are not observed in the Hare Group, some of these conditions can be interpreted to exist on the property. He suggested that while the entire group should be prospected, concentration should be on the eastern side of the claim group. This survey follows the latter recommendation.

It is recommended that the complete Tribe report be studied prior to evaluation of this data.

DISCUSSION OF RESULTS

The size of the current dipoles used in this survey varied from 1750 metres to 2250 metres. The dipole was placed north-south, while 50 metre readings were taken along a series of lines at 250 metre intervals. The energising frequency used was 3 Hz.

During the course of the survey two electrical soundings were made to ascertain the geophysical environment. These are briefly described below.

ELECTRICAL SOUNDINGS

Two electrical soundings were carried out, the first at 360E/1000N and the second at 360E/1500N

360E/1000N ..... The data is not capable of meaningful interpretation in terms of horizontal layering. What it does imply is higher resistivities of 250 to 700 ohm-metres within the top 100 metres, and resistivities of perhaps as low as 100 ohm-metres below that level.

360E/1500N ..... The shallower levels show apparent resistivities of the order of 400 ohm-metres with apparent resistivities of 150 ohm-metres for the larger spacings. An approximate two layer case indicates about 10 metres ± 5 metres of 400 ohm-metres ($\pm$) material, with 130 ohm-metres below this level.

The point is that the resistivities at depth are lower than those within the basalts, and that implies that the basalts will be easily penetrated by the energising current and large dipoles employed in this survey.

ANALYSIS OF SIGNIFICANT ANOMALIES

Each of the significant anomalies is discussed in detail below.

Zone 1 *Arrays 3E & 8W*

A zone of about 1.5 kilometre strike length was defined on the western extremity of array 3E between lines 1000N and 2750N at coordinate 1300W ±50 metres. Two distinct sections designated 1S and 1N were defined centred on line 1250N and 2250N at 1375W and 1300W respectively.

Sub-zone 1N ..... A maximum of about +0.60° above the local background was observed centred at 1300W on line 2250N. The maximum depth to source is less than 100 metres. There is a significant depression in MMR from a background value of -20% to -50%. Thus in this case the source is disseminated sulphides within a relatively resistive host. There is practically no response on the HSQ/I, confirming that any source must be wholly electrically discontinuous. Only slight inferences of extensions are seen to the north and south.

Sub-zone 1S ..... On line 1250N at 1375W a +0.40° RPS above high background of about +1.60° RPS (±) was defined. The zone continues in even more reduced form to cross line 1500N at 1350W as a +0.20° phase shift.

SUMMARY

This zone is of secondary to tertiary geophysical interest only at its two centres 1375W/1250N (1S) and 1300W on 2250N. At both sites disseminated chargeable material is inferred at a depth of less than 100 metres.

No drilling targets are recommended at this time.

Zone 2 *Array 3, 8, 4, 7*

Between lines 3500N and 1750N and coordinates 350W and 900W a series of high internal polarization anomalies was defined. The most important manifestation of the zone lies on the eastern flank of array 8W, where the cable lies to the west, and thus the anomaly cannot be due to the influence of the energising cable.

The contact between the chargeable material to the east and the less chargeable material to the west was as set down below.

Line 3500N	600W	+4.30° at 450W
Line 3250N	700W (Shoulder at 650W)	+5.00° at 450W
Line 3000N	650W	+2.90° at 450W
Line 2750N	700W($\pm$)?	
Line 2500N	600W	+2.20° at 450W

Now, it can be seen that the PFE/RPS ratio is abnormal towards the east, which map imply some coupling effects, however, any such influences are not considered to *cause* the response. The MMR data shows the chargeable sources to be of lower resistivity. This results in secondary field responses of two to three times background. Source depth is extremely difficult to judge but less than 100 metres is suggested by slope changes in the internal polarization responses. On the western flank of the overlapping array (7), much reduced internal polarization responses were recorded, which may in part be due to the phenomenon described on pages 6 and 7.

On line 3500N a maximum was recorded centred at about 250W, with maxima at 300W and 200W. The response is about +0.40° above the background of about +1.00° RPS. While the apparent fit between arrays 7 and 8 is not precise, it is possible that the effects displayed in diagrams 3 and 4 may be present. The maximum depth to source on line 3500N is difficult to assess, but anomaly shape after allowing for 'noise' suggests no deeper than 150 metres. To the south, maxima of +0.40° and +0.30° at 400W and 250W almost certainly represent the southerly extension of this feature, but on line 3000N only a higher background was logged.

On line 2250N in the north of array 3E, significant internal polarization anomalies of +3.40° and +4.65° RPS were defined at 650W and 500W respectively. While the current wire lies to the east, the high RPS readings are not considered to be due to this source. The low negative MMR values coincident with this response and its continuation across line 2000N suggests a disseminated source to the chargeable material. The closures on line 2250N suggest maximum depths to source of the order of 100 to 150 metres. A major change in MMR occurs on *about* line 1750N, with the MMR to the north indicating more resistive rock than those observed to the south. This suggests a grid east west break. In spite of this, the anomaly seen on lines 2000N and 2250N extends south across lines 1750N and 1500N, but with reduced amplitude.

SUMMARY

This zone which is located between two suggested dislocations on about lines 3750N and 1750N, and centred on a 200-250 metres(±) wide zone at 400W±, is considered highly significant. The source is considered to be disseminated in nature. The depth to source can nowhere be defined, but is inferred to be of the order of 100 to 150 metres.

Two sites in particular are su; gested as possible drilling targets.

(A) 500W on 2250N

(B) 550W on 3250N

Minimum depth 150 metres.

Zone 3N *Array 11, 10*

The MMR and RPS both suggest a dislocation between lines 3500N and 3750N between 500W and 1100E. To the north thereof, on the eastern section of array 11 and western section of array 10, anomalous internal polarization was defined which is considered significant.

On array 10 on the eastern flank of line 4500N, significant internal polarization values were recorded which reach +2.00° at 350E and +2.50° at 500E. The corresponding section of array 10W shows only a rise in internal values towards the boundary. To the south, line 4250N again shows a similar situation, as does 4000N. The MMR shows a slight decrease in amplitude, implying a resistive host to any chargeable material present.

SUMMARY

The anomaly defined on the eastern flank of array 11W cannot be due to 'wire effect' as the wire is to the west. Thus the zone is considered of significance as a disseminated chargeable zone at depth. The depth to source is impossible to estimate from this data.

A site at 500E on line 4500N is suggested as a secondary target only.

Zone 3 — *Array 4E, 7E, 2W, 6E*

Zone 3 is located on the western flanks of arrays 2 and 6 and the eastern flanks of arrays 4 and 7 between lines 1000N and 3750N. In both cases some exaggeration *may* occur on the eastern ends of arrays 4 and 7 by virtue of the loop being to the east, however, the loops are to the east on arrays 2 and 6 also, and in both cases the *western* flanks of those arrays are relatively anomalous.

The western and eastern extremities of the anomaly are estimated to be about as follows:

Line	Array	Western	Array	Eastern
3250N	7	150E±	6	650E±
3000N	7	250E±	6	600E±
2750N	7	300E±	6	700E±
2500N	7	100E(350E)	6	700E
2250N	4	250E	2	600E
2000N	4	350E	2	600E±
1750N	4	300E	2	500E±
1500N	4	350E	2	600E±
1250N	4	325E	2	600E(?)
1000N	4	350E±	2	600E

The boundary of the internally polarized zone with the enclosing material is probably gradual, and thus the above guesstimates will be bulk averages only. This zone is associated with a weak conductor of +10% to +20% above background over the entire anomaly length and zone 3N is related to zone 3 via this conductor.

SUMMARY

Between line. 3250N and 1000N a significant increase was defined centred at about 400E±. This 250 metres wide zone is associated with a weak continuous conductor. The zone is interpreted as being due to disseminated chargeable material situated below the a omaly, and making a gradual transition rather than a sharp contact with the enclosing rocks. The form of the anomalism is such that no depth estimate is possible, however, a guesstimate is 100 to 150 metres at 400E on line 2250N.

The most significant sector of the anomaly is centred at 400E on 2250N, and drilling is recommended to investigate the source at this site. A secondary site is suggested at 450E on 1250N.

COMMENTS ON THE AREA BETWEEN ZONES 2 AND 3

As discussed in the section on the expected signature, there could be an ambiguity in the interpretation of a horizontal uniform layered chargeable source at depth. Certainly such a source would be clearly detailed at the edge as an anomaly similar in fact to that seen over zone 2. However, if a chargeable slab were to continue east towards zone 3, arrays 4E and 7E would depress the response. There is one inference that this may be the case. On the junction of arrays 4 and 7 at 100W± on line 2500N, a 'circular' depression in RPS was noted. This essentially is due to the electrodes being relatively close. In this case it would imply that the overburden (basalt) which has a proportionally greater response 'close' to the electrode, has a lesser internal polarization than the rocks at depth. While it is not certain that the rocks beneath the basalt could be chargeable, this possibility should be borne in mind should either zone 2 or zone 3 be shown to contain significant mineralisation.

Zone 4 *Array 5E, 6E, 1W*

On the overlap of arrays 1, 5 and 6, a significant internal polarization response was defined from about 1500E on 3000N to 1500E on 2250N. The anomaly has a curvilinear form, but a general north south strike. The clearest manifestation of the zone was seen on 2500N at 1500E (from array 1). Here an anomaly of about +0.60° above the +0.40° background was observed. Within relatively high MMR, the actual internal polarization occurs as a low. Thus, the source would appear to be slightly resistive with respect to the immediately enclosing material. While an internal polarization maximum is confirmed on array 5, the magnitude is barely above background. (Obviously the current electrode for array 1 [2750N/2000E] must couple best with the source.)

On array 5 the zone is seen best on line 2750N. The response, while broad, is a well defined +0.50° above background (+0.20°). Unlike line 2500N, the source is associated with broad relative conduction. The maximum depth to the top of the source is 125 metres, but allowing for width, this may be of the order of 100 metres.

SUMMARY

This lenticular source was defined over a strike length of 500 to 750 metres and is seen best at 1500E/2500N and 1575E/2750N at which sites the maximum depths to the top of the source are estimated at 100 metres and 125 metres respectively. The southern source is seen as being resistive, while the northern source is more conductive than the enclosing rocks. At this time no drilling recommendations are made, however, should such be contemplated, vertical holes at either of the *above sites would be recommended.*

Zone 5 *Array 5*

Weak internal polarization responses were defined at 2300E/3000N, 2400E/2750N and west of 2500E/2500N. Over the length of the anomaly the response is about +0.40° above backround. On lines 2500N and 2750N the anomalies are open to the east. On line 2750N the anomaly form suggests a maximum depth of the order of 100/200 metres at 2375E. On line 3000N, the anomaly is a mere 0.30°, but is considered to be the most northerly extension of this zone. On all three lines, the source lies within a resistive host.

SUMMARY

The small amplitude internal polarization response on lines 2500N, 2750N and 3000N at 2300E, 2400E and east of 2500E is considered to be due to chargeable material within a resistive host at a maximum depth to the top of the body of the order of 100 to 120 metres. At this stage no further investigation of this response is recommended.

Zone 6 *Array 13*

A series of high anomalous internal polarization responses were recorded on the south-western section of array 13 which is of a most irregular shape. The influence of the terrain is impossible to predict, but it is not considered that the terrain can *cause* an anomaly of the form observed here. The wire was placed some 500 metres west of the ends of the surveyed lines, and while an increase in *apparent* internal polarization is noted towards the wire, this is not considered to be due to a wire effect as such effects are seen in cases of highly conductive surface layers, which cannot be the case here. In any case, a distinct closure is inferred on the western flank of lines 00 and 250S. An inspection of the data shows that the lines were surveyed sequentially, and there appears to be no reason to doubt the anomalous conditions on line 00. In the vicinity of line 00, the MMR contours lie sub-parallel to the line. This may indicate a geological boundary at some steep angle to the current flow. All lines within this array are anomalous west of 1600W(±) with the exception of 00 which is anomalous west of about 1200W. A distinct maximum was defined on the extreme west of lines 250S and 00 at 2000W and at or west of 2050W respectively. In both cases these local anomalies are associated with sharp local decreases in MMR.

SUMMARY

Between lines 250S to 750N west of 1700W (and on line 00, west of 1200W), strongly internal polarization values were recorded. While caution should be exercised in the evaluation of these anomalies due to the presence to the west of the cable and the steep terrain in the area, the anomalism is nevertheless significant, and a drill should be considered on a secondary basis at 2050W/00 to investigate the source.

Zone 7 *Array 15E*

A single line of anomalism was recorded on line 750S with maxima at 1650W, 1200W and 1350W. While the responses are up to +0.60° above the level observed to the north and south, the form of the anomaly suggests only limited areal extent. However, there is an inference of an extension of the zone both north and south in reduced form. At this time no further recommendations are made for further work on this zone. There is little change in MMR which suggests a disseminated source. No estimate of dip can be made.

Zone 8 *Array 17E*

The general appearance of z ne 8 is similar to zone 7, namely high internal polarization along a single line. What enhances the interest of this zone is that it lies close to a marked change in the MMR. At this point a dislocation is marked from 2000S/2000W to about 800W on 2750S. To the south a broad conductor was defined, while the rocks to the north are seen as being relatively resistive.

A second zone from 1500W/2000S across line 2250S at 1450W and line 2500S at 1500W to line 2750S at 1600W was recorded. The amorphous nature of this anomaly is difficult to interpret in any conventional manner, except to say that the rocks underlying the basalts must contain chargeable material such as sulphides and/or mafic minerals. The form of the anomalies suggests a 100 metres maximum depth to source at 1600W but nowhere else can meaningful depth estimates be made.

The north south conductor south of the dislocation is sub-parallel to the Lornex fault, while the dislocation itself is sub-parallel to the Highland Valley fault. This may enhance the interest of this zone of internal polarization.

SUMMARY

Anomalous internal polarization along lines 2250S from 2300W to 1400W and at right angles to this from 1500W/2000S to 1600W/2750S, may be associated with a fault inferred from the MMR data which traverses from 2000S/2000W to 800W/2750S. The amorphous form of the anomaly makes interpretation difficult, however, the source is considered to be disseminated sulphides (and/or mafic minerals and *graphite) at an unknown depth below the surface. The anomaly form suggests a maximum depth of 100 metres (but this is at only a single site).*

An exploratory hole is suggested at 1475E on line 2750S on a secondary interest basis.

CONCLUSIONS AND RECOMMENDATIONS

A - GENERAL

1 All the work carried out with RRMIP to date has been over conductive to highly conductive overburden conditions. In the Highland Valley the soundings demonstrate that the overburden has bulk resistivities *higher than* the underlying bedrock. It is understood that the difficulties in applying conventional electrical induced polarization techniques has been the existence of conductive semi-horizontal clay layers within interbasaltic horizons. The author, however, has no personal experience of the problems, and the data obtained on the present survey appears to be unaffected by conductive horizontal layering.

2 Most RRMIP work to date has been carried out in relatively flat terrains. In the present case the undulating to steep terrain encountered does not appear to have influenced the data in a systematic form. However, in detail the influence of terrain features cannot be predicted or accounted for. It is the author's opinion that such effects, if present, have not materially influenced the data.

3 The productivity varied with the degree of magnetic disturbance. Beyond a certain critical level, no meaningful work was possible. During such periods the productivity was 5 to 10 kilometres per week, but during quiescent periods the productivity was in excess of 21 kilometres per week. In areas towards the pole, such patchy productivity must be expected and allowed for.

4 The anomalies located on this survey are of completely different form to those seen to date. This of course is quite expected. Essentially they are of two types; lenticular such as zones 1, 2 and 4, and amorphous such as 6 and 7. Some have both a lenticular and an amorphous tendency, such as zone 8.

5 As was expected, there is little major variation in magnetometric resistivity. Two series of semi-continuous low amplitude conductors were defined between 1300W/1750S and 850W/1500N, and between 700E/1000N and 300E/4250N. While of low magnitude, both these conductors represent distinct marker horizons and are considered to reflect sub-basaltic features.

6 As plates 3N and 3S will show,.'dislocations' in the continuity of MMR resistors and conductors occur along well defined lines. Such 'dislocations' probably represent faulting in the rocks underlying the basalts. On a number of occasions zones of anomalous induced polarization are terminated by such dislocations (such as zone 2) and on others amorphous internal polarization anomalies were recorded in close proximity to a dislocation (e.g. zone 8).

B - DETAILED CONCLUSIONS

1 In spite of the uncertainty borne of applying a new geophysical tool to an environment not hitherto tested, it can be confidently concluded that areas of anomalous internal polarization have been defined. A number of these zones will require testing by drilling to ascertain the source of the anomalism, as it is difficult to recommend any other geophysical (or geochemical) follow-up procedure in the area.

2 Based wholly on the geophysical data, the following sites are suggested as locations for drill holes. While no detailed geological data is available. the sites may be varied due to regional trends or structural interpretations unavailable to the author.

Zone		Co-ordinate	Priority
2		500W/2250N	primary
	or	550W/3250N	primary
3N		500E/4500N	secondary
3		400E/2250N	primary
	or	450E/1250N	secondary
6		2050W/00	secondary
8		1475W/2750S	secondary

In all cases angled holes are recommended to traverse the maximum horizontal distance.

3 The conclusions and recommendations made as a result of this RRMIP survey are based wholly on the geophysical data. A study of the surrounding geology, together with the projected structural features may well enhance the interest of some of the zones defined on this survey. For instance, the weak conductor defined at 500E± between lines 1000N and 4500N may either trace the Lornex fault, or some sub-parallel structure, while the north south conductor at about 1000W between 1500N and 1500S, while also of low amplitude, could represent a sub-parallel fault to the Lornex fault. The intersection of, and displacement of this weak conductor by a dislocation sub-parallel to the Highland Valley fault is certainly of interest. The author, however, does

not feel competent to judge the impact of these essentially geological features on the anomalies defined.

While the internal polarization responses defined on this survey are considered significant, it is nevertheless recommended that a geological evaluation of these results be made prior to a final allocation of priority for the recommended investigation by drilling.

Respectfully submitted on behalf of:

SCINTREX PTY. LTD.

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

GEOPHYSICIST

SCINTREX

THE PRESENT APPLICATION OF THE MAGNETIC INDUCED POLARIZATION (MIP) METHOD IN THE TIME AND FREQUENCY DOMAIN

INTRODUCTION

Since the Magnetic Induced Polarization (MIP) method was introduced into Australia some six years ago, very considerable field experience has been gained. The purpose of these comments is to discuss the application of the method, the form of the responses observed, and how the standard anomaly forms are generated. This is a simple non-mathematical description designed to enable the geologists to visualise just how the energising and induced polarization currents flow in the ground, and how to interpret these in a qualitative sense, for it is the geologist who is far better qualified to interpret this data in a structural context. It is the author's opinon that MIP data is more often than not, simpler and more diagnostic to interpret than EIP or EM data in the conductive conditions which exist over much of Australia's land mass.

The Uniqueness of the MIP Method .....

It is essential to grasp the very basic differences between the magnetic mode of acquiring induced polarization data (MIP) and the more conventional electrical mode (EIP). As even geophysicists of some experience have had difficulty in appreciating the full significance of this method, it is necessary to state in simple terms some of the unique attributes of the method.

1 - Conventional EIP data monitors *ONLY* the current flow *AT THE SURFACE* generated by the storage of charge (IP effect) *WITHIN* the body. With MIP both the current flow *OUTSIDE*, but more importantly *INSIDE* the chargeable

source, are *DIRECTLY MONITORED.* Thus the external (EIP) polarization from mineralisation *NEED NOT NECESSARILY COME TO THE SURFACE* for it to be monitored.

2 - In conventional EIP, the transfer of the induced polarization signal from the source mineralisation to the *surface* involves a considerable loss of energy by "friction" and "chemical reactions" en route, whereas for MIP, as the movements in current *at depth* are monitored *from depth* via their associated magnetic fields, very much less loss of energy is involved. Thus, the fall off in response with distance from a chargeable source is very much less as seen with MIP than that seen with EIP.

3 - With conventional EIP methods, the external induced polarization effect is monitored via two potential electrodes placed some distance apart (commonly 25 to 100 metres), effectively *averaging* the response over this distance. However, as the MIP sensor is about 60 centimetres in length only, in the MIP method it is essentially a *point source* measurement which improves resolution very considerably.

4 - Where conventional EIP techniques are applied to highly conductive overburden/ oxidation regions, the multi-layering within this zone very considerably reduces or even eliminates the EIP signal en route to the surface. With MIP, both primary and secondary (IP) current flow within this zone has *NO MATERIAL INFLUENCE* on the data. Thus the problems of "masking" are eliminated with MIP.

5 - As the EIP induced polarization signal flows from source to surface, the medium through which it passes not only reduces its amplitude (see 2 above), but also modifies the *form* of the signal. Thus the decay form observed at the surface will tend to be that of the *medium* rather than the *source*. However, as the MIP monitors the magnetic field from the decay *within* the source itself, no such distortion in the *internal* polarization decay form can be expected.

6 - The EIP method is essentially a measurement of *absolute* levels of apparent resistivity and chargeability as observed at the surface. However, the MIP

method measures the *relative* properties of chargeability and resistivity, and is thus more sensitive to these differences.

7 - In the EIP method, the electric field is often severely distorted by local and often insignificant inhomogeneities in resistivity. However, as the primary (resistivity) and secondary (IP) magnetic field measurements are summed over a large volume of rock, they are not *distorted or masked* by local inhomogeneities.

A Definition of Terms .....

Before going into the detailed qualitative discussion of the principles of operation, it is best to define the terms used in the description.

Energisation:- The process by which current is introduced into the volume of rock which is the subject of the survey. *Primary Current Flow:-* The flow of current through this medium as a result of this energisation. *Primary Magnetic Field (H_P):-* The magnetic field generated by virtue of the primary current flow in the subsurface.

Induced Polarization Effect:- The "condenser like" storage of energy on an electronic/electrolytic boundary, for instance on sulphide/electrolyte boundaries. *Internal Polarization:-* The induced polarization effect *within* the body, which is the *source* of all induced polarization phenomenon, whose discharge is always in the *OPPOSITE DIRECTION* to the primary current flow which caused it.

External Polarization:- The induced polarization effect which flows *outside* or *external* to the causative source which is always of the same sign as it is in the same direction as the energising primary current. *Secondary Magnetic Field (H_S):-* This is the magnetic field caused by the flow of secondary currents within (internal) and outside (external) of the causative source.

Decay Form (ΔM):- This term describes the decay of the energy stored within the body. It may be more rapid than "normal" or slower than "normal". (A detailed description follows on Page 9).

Comparison of the Electrical and Magnetic Modes of Acquiring Induced Polarization Data .....

By far the most meaningful way in which to visualise the nature of MIP (and indeed EIP) data, is to consider the *energy storage concept* and to look at the primary current flow pattern and the resultant equipotential field caused by this energising current, and then the consequent secondary current flow pattern and its associated secondary potential field caused by the decay of the energy stored on electronic/electrolytic contact boundaries, which is known as induced polarization. As this is most easily visualised in the time domain, this description is confined to that domain.

Energisation Process ..... Normally current is applied to the volume to be sampled by means of two electrodes placed semi-parallel to the expected strike of the target mineralisation. In the diagram shown in Figure 1, the fine solid lines represent the current flow pattern so generated. The dashed faint lines represent the equipotential surfaces (lines in the section).

In the *electrical mode*, the two potential electrodes (see Figure 1) will measure the *resistivity* of a volume of material defined by the equipotential surfaces which are always at right angles to the current flow.

Energy Storage Process ..... The material through which the current passes will store some portion of the energy in a way determined by the properties of the storage material. The amount of energy stored will depend on the total area of the sulphides (or graphite etc.) presented to the current, and thus, the greater this surface area with respect to the volume of material, the greater will be the energy stored. Finely disseminated material will store substantially more energy than coarse grained material.

The Discharge of Stored Energy ..... On cessation of the energising current flow, the energy stored by the *chargeable source* will discharge *internally* within the source as shown by the solid arrows in Figure 2, and *externally* around the body in the medium surrounding the source as shown by the solid heavy lines in Figure 2. These currents are respectively known as *internal* and *external* current flow. The former is of *negative sign* as it is in the *opposite direction* to the original energising current, and the latter is of *positive sign* as it is in the *same*

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EIP & MIP ENERGIZATION

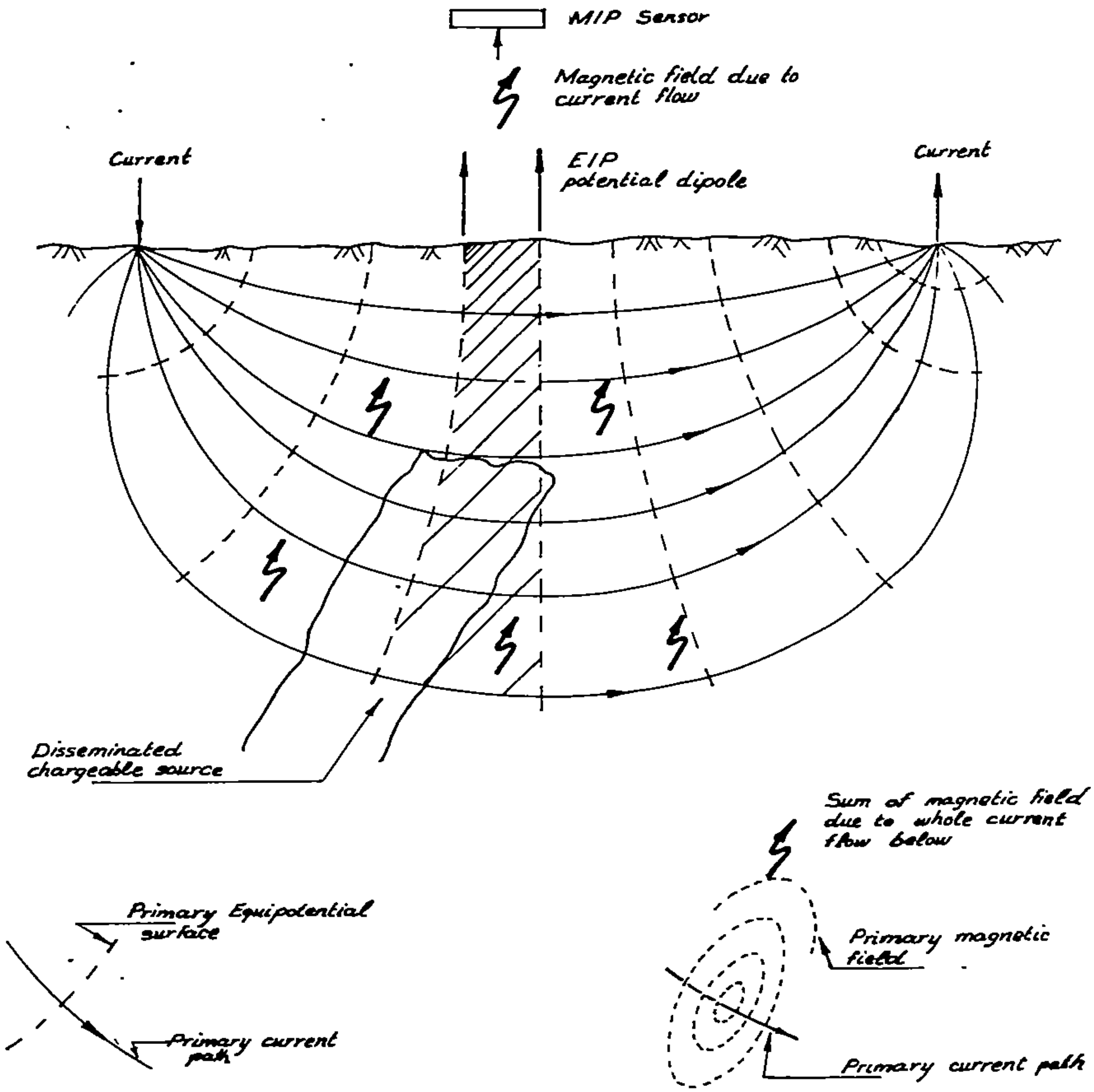

Fig. 1

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EIP & MIP
DISCHARGE OF INDUCED POLARIZATION

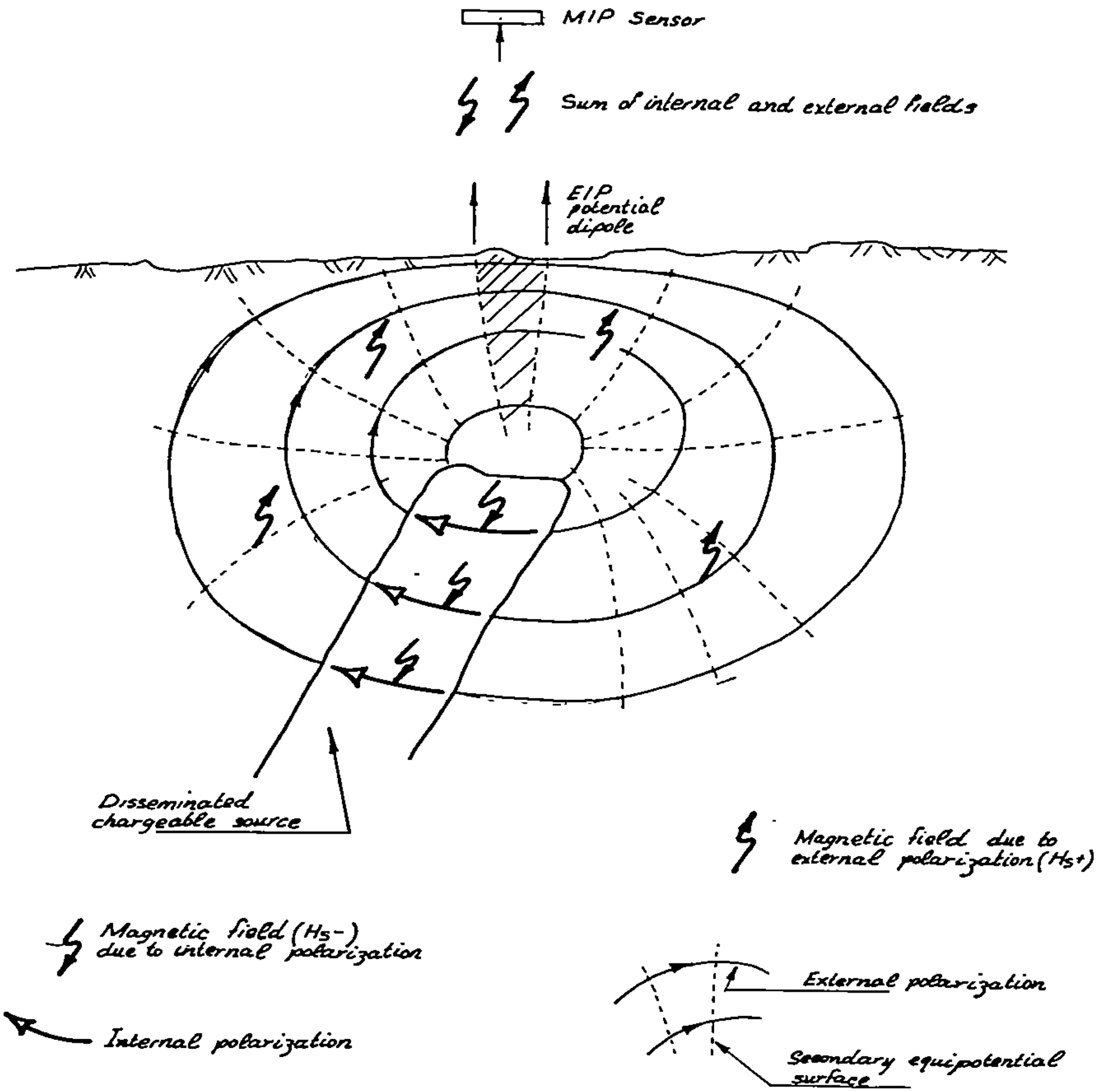

Fig 2.

direction as the energising current.

In the electrical mode,. only the discharge *external* to the body is investigated. In Figure 2 the thick solid lines show this discharge together with the *equipotential surfaces* (thick broken lines) which this current imposes. As with the charging process. these surfaces must be at right angles to the current lines which impose them. The potential electrodes will therefore measure the stored energy (chargeability) as seen via the secondary equipotential field. It is important to note that *(i)* this is *NOT* the same volume as the resistivity measurements and *(ii)* it is *NOT* the original IP signal as stored by the body, but a measurement distorted and processed by the environment through which it has passed.

In the *magnetic mode* a very sensitive magnetometer (Scintrex MFM-3) is used to "sense" the horizontal component of the magnetic field due to the current flow both *inside* and *outside* of the *source material*. This is possible because each electron which flows in the ground carries with it an associated magnetic field. This magnetic field will pass *unhindered* through the environment and thus both the discharge *internally* and *externally* to the source can be monitored on the surface.

The Form of MIP Anomalies .....

In the MIP method, the energising field is normalised with respect to the energising current electrodes. Details of this procedure are given later in this paper. In the description Figures 3 to 6, the magnetic field due to the primary passage of the energising field H_N, can be regarded as "relative bulk conductivity" plotted upwards. In these figures, *internal* polarization (which is negative in sign becuase it flows in the opposite direction to the energising current), is plotted upwards, while *external* polarization (which flows in the same direction as the energising current and is therefore positive in sign) is plotted downwards.

The enclosed Figure 3 demonstrates the theoretical form of an MIP anomaly from a source which has no electrical contrast with the enclosing material, but has the property of retaining charge. (In nature such anomalies are in fact observed from the ilmenite fraction within heavy mineral deposits in beach sands.)

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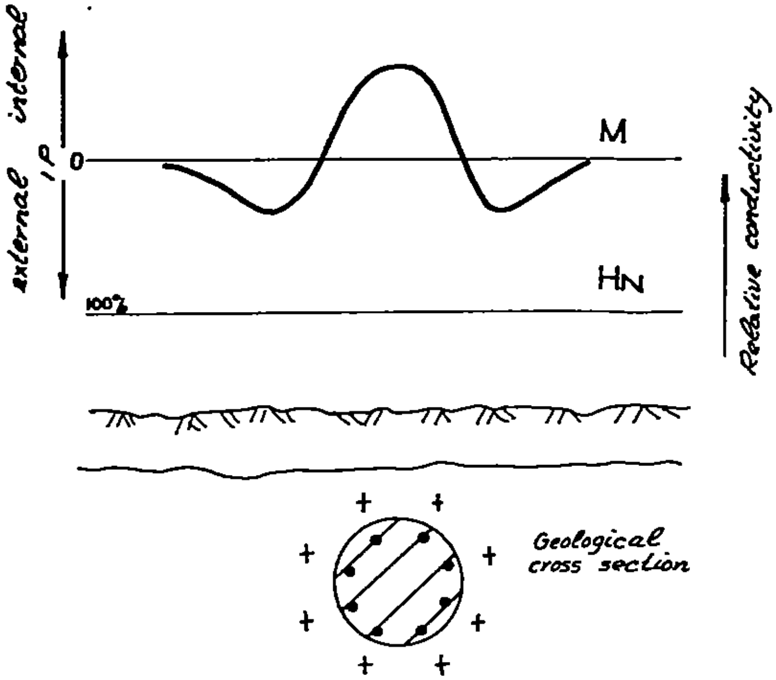
TYPICAL M.I.P. ANOMALY FORMS

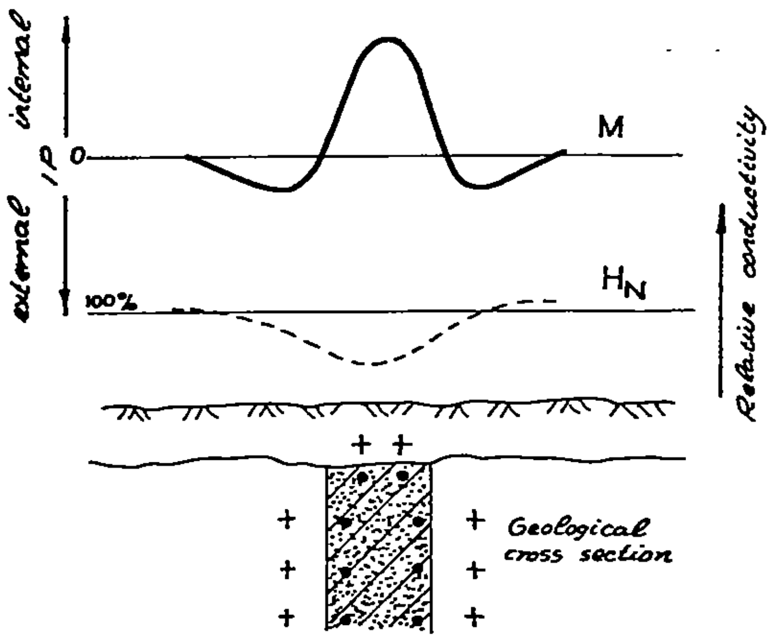
THEORETICAL MODEL

CHARGEABLE SOURCE
NO RESISTIVITY CONTRAST



TYPE A

CHARGEABLE SOURCE
RESISTIVE SOURCE



NOTE:

+ *External current flow into plane of paper*
• *Internal current flow out of plane of paper*

Fig. 3

Energisation is along strike, into the plane of the paper. In all figures the current flow direction is represented by arrows, with dots representing current flow *out of* the plane of the paper, and crosses represent the current flow into the plane of the paper.

In Figure 3, over the source, the magnetometer will "see" a surplus of internal (negative) current flow, while on the flanks of the body, the external (positive) current flow will become predominant. The *"head and shoulders"* MIP anomaly shown is *always* seen over all sources. It is the distortions in shape, form and zero level that yield vital information as to conductivity of the source, conductivity of the environment above and about the source, the depth to the source and the nature of the mineralisation in and around the source.

TYPE 'A' (Figure 3) ..... shows the typical anomaly form over a chargeable source which is more resistive than the surrounding medium. In such cases the normal *"head and shoulders"* anomalies coincident with a depression in the H_N are observed. An example of such an anomaly form is chalcopyrite/pyrite in quartz veins itself within a more resistive conductive rock unit.

TYPE 'B' (Figure 4) ..... In this case the chargeable source has no resistive contact with the enclosing material. This example is very similar to the theoretical model. An example of such an anomaly form would be over disseminated sulphides within a homogeneous rock unit.

TYPE 'C' (Figure 4) ..... In this case the source of the chargeable material is itself more conductive than the enclosing rock type. When the observed H_N values are *less than* 180% - 200%, a normal *"head and shoulders"* anomaly is observed over the source. In practice, observed H_N values rarely exceed 150% of normal.

TYPE 'D' (Figure 5) ..... In this most important anomaly form which invariably is associated with massive sulphides which are both conductive and electrically continuous, a massive sulphide *must* be surrounded by a disseminated halo within more resistive host rocks. In this case the disseminated sulphides will naturally store the induced polarization charge *far more efficiently* than the massive electrically continuous core. Thus, on completion of the energisation process,

TYPICAL M.I.P. ANOMALY FORMS

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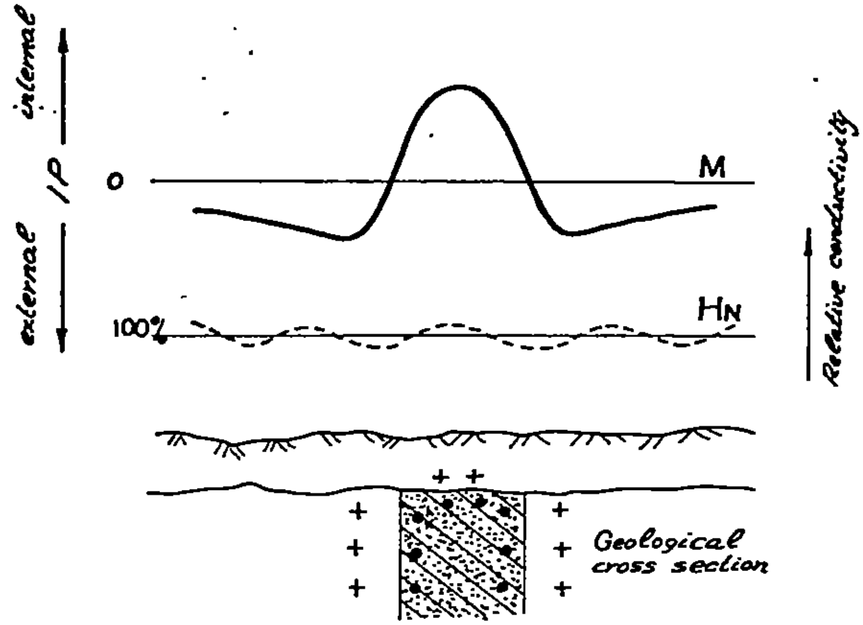
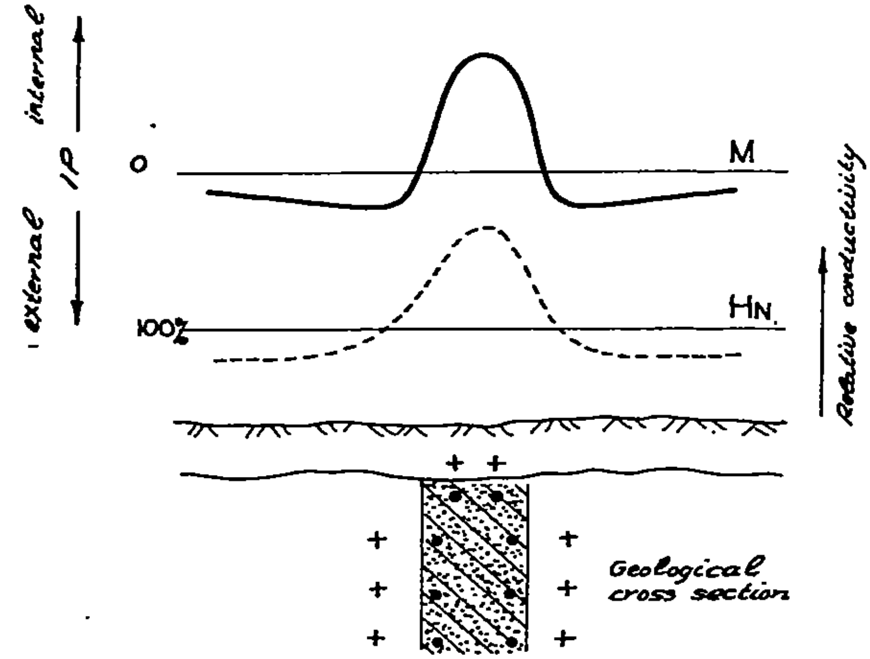
TYPE B

CHARGEABLE SOURCE
HOMOGENOUS



TYPE C

CHARGEABLE SOURCE
CONDUCTIVE



NOTE:

+ *External current flow into plane of paper*
• *Internal current flow out of plane of paper*

Fig. 4.

the charge stored within the disseminated halo will preferentially discharge through the conductive massive sulphide core. This effect has *NEVER* been observed where H_N values have been less than 180% of normal. This anomaly form due to its high H_N and coincident predominantly external (positive) current flow, is diagnostic when observed. An example of such a response is the Mt. Windarra pyrrhotite/nickel / copper deposits in Western Australia.

TYPE 'E' (Figure 5) ..... A distorted MIP response curve is generated when a polarizable body is located on a contact between rocks of quite different resistivities. This is rather common in Western Australian nickel deposits. In such a case the return polarization current flow will be concentrated in the more highly conductive rock type instead of being symmetrically distributed on both sides of the body. The resultant MIP response is an asymmetric curve, with its *internal* (negative) maximum lying on the more resistive side of the body and the *external* (positive) current peak lying on the more conductive side. Sometimes the asymmetry is so large that the "crossover" is almost directly over the polarizable body. The H_N peak is shifted over the conductive rock side of the polarizable body.

Composite Anomalies .....

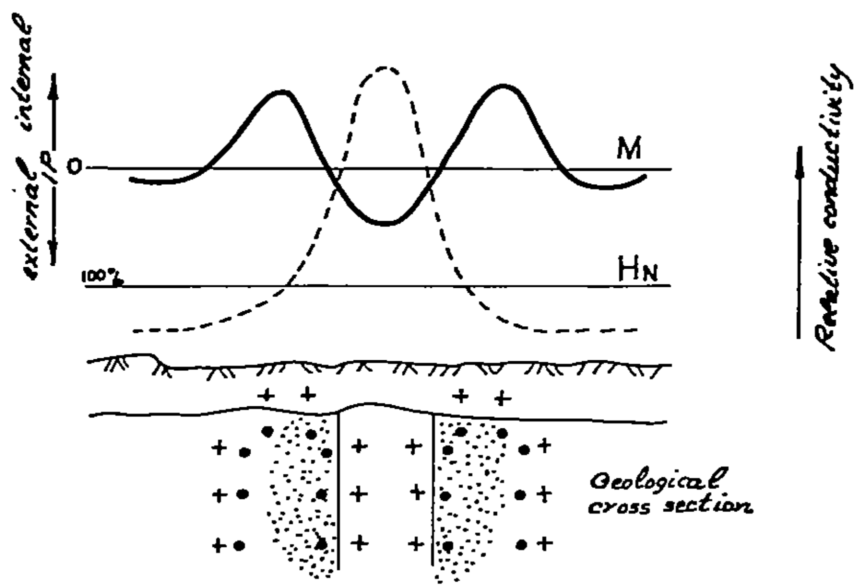
As can readily be appreciated, the above examples 'A' to 'E', represent single simple bodies. In the field, more often than not, the sources vary in composition and therefore in chargeability and resistivity *across strike, along strike* and *down dip*. For example, while the *form* of Type 'C' and Type 'D' anomalies are very different in appearance, the geological situation which gives rise to them requires relatively little change in conductivity to materially change their form from 'C' to 'D'.

In the interpretation of MIP therefore, the electrical characteristics of known 'Type Deposits' similar to those being sought, together with local information as to the possible range of structure in the area, is of primary importance. In other words, geological input is often of greater importance than quantitative geophysical data.

SCINTREX TYPICAL M.I.P ANOMALY FORMS

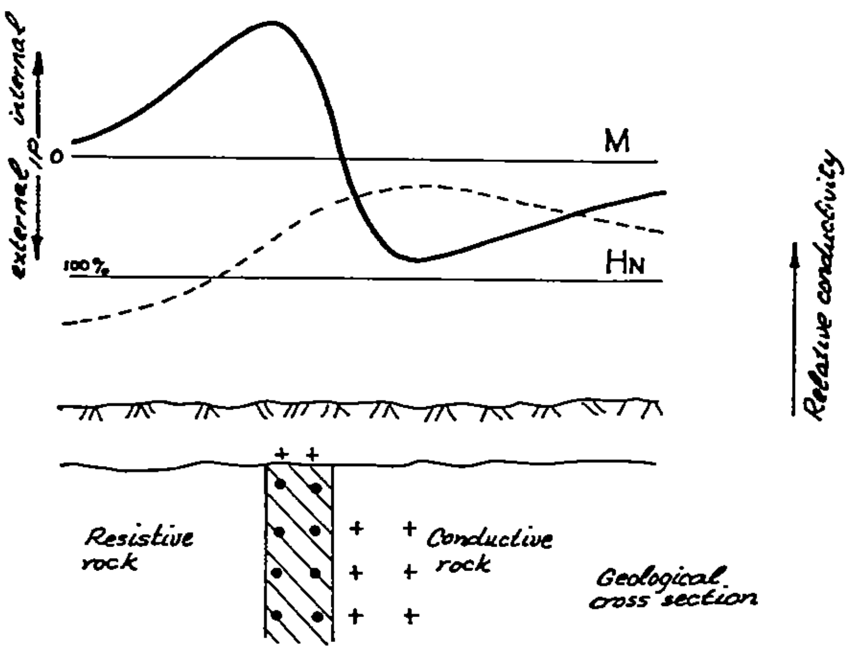
TYPE D

CHARGEABLE SOURCE VERY CONDUCTIVE WITH DISSEMINATED HALO



TYPE E

CHARGEABLE SOURCE ON CONTACT BETWEEN TWO ROCK TYPES OF DIFFERING RESISTANCE



NOTE:

+ *External current flow into plane of paper*

• *Internal current flow out of plane of paper*

Fig. 5.

The Alternative Way of Acquiring MIP Data .....

The initial work in Australia was carried out in the Time Domain, and the chargeability was measured in terms of *milligamma/gamma*. In the Frequency Domain, a single operating frequency of either, 3, 1, 0.3 or 0.1 Hz with a frequency stability of better than 0.01% is transmitted. The induced polarization effect is then measured in terms of the first and third harmonic of the fundamental frequency in Relative Phase Shift (RPS) which to the first approximation is free of electromagnetic coupling effects, or as Percent Frequency Effect (PFE).

The relationship between these modes of measurement of the induced polarization phenomenon in the magnetic induced polarization method is as follows:-

Domain	Time	Frequency	
Equipment	IPR-8 (or 10)	IPRF-2	
Units	milligamma/gamma	.degrees(°)	Percent Frequency Effect (%)
equivalence	15 milligamma/gamma ≡	1.6° ≡	1%

It is important to note that in common with the electrical mode of measurement, the induced polarization effect will be identical regardless of the way in which the measurement is made, providing always that (i) the frequencies of energisation and (ii) the geometry of the energising current electrodes and sensor remain the same with respect to the body.

The Polarity of EIP and MIP Anomalies .....

The polarity of the three ways in which the induced polarization effect can be measured varies, depending on which mode (magnetic or electric) or which domain (Time or Frequency) we are operating in. The table below sets out the differences in detail.

Domain	Parameter	Mode of Measurement: EIP : External Polarization Dominating over Body	Mode of Measurement: MIP Internal Polarization Dominating over Body*
Time	Chargeability	positive	negative
Frequency	Relative Phase Shift (RPS)	negative	positive
Frequency	Percent Frequency Effect (PFE)	positive	negative

* *For Type 'A', 'B' and 'C' anomalies only*

"Noise" and its influence on MIP Data .....

The "noise" in magnetic induced polarization data is essentially relatively minor variations in the earth's magnetic field which decreases in amplitude as the equator is approached. In the Time Domain where the IP Phenomenon is summed over a relatively long period, the influence of a "noisy" magnetic field is maximum. In the Frequency Domain, the time required to acquire a single reading is very considerably less, hence the noise component is also less. The following table derived from field experience shows the primary magnetic field (Hp) required in order to take a meaningful measurement of the induced polarization effect for the time and frequency domain.

For <u>time domain</u> these are:

Hp	Accuracy of M Reading
6 gamma (plus)	±0.2 milligamma/gamma
4 gamma	±0.4 milligamma/gamma
2 gamma (minus)	an educated guess!

For <u>frequency domain</u> (at 3Hz)

Hp	Accuracy of PFE and RPS
1 gamma (plus)	±0.05% or ±0.05°
0.6 gamma	±0.10% or ±0.10°
0.4 gamma (minus)	an educated guess!

Note: for lower frequencies, higher Hp is required.

The Importance of Decay Curve Information .....

Considering the time domain first, fine grained mineralisation absorbs the charge *rapidly*, and once the passage of the energising current is stopped, the stored charge is *rapidly* discharged. If the mineralisation is *effectively* coarse grained (i.e. either coarse grained as such, or agglomerates of finer grain), the charging and consequent discharging will be much *slower*. Only with MIP is the actual decay within the source monitored, therefore major differences in decay characteristics can be observed. Figure 6 shows how this is accomplished using the IPR-8 time domain receiver. In sketch (A), EP represents the energising pulse, while the rapid decay form is due to fine grained material discharge, and the slow decay form is due to coarse grained mineralisation. You will note from the figure that the rapid decay form has a greater amplitude to start with. This is due to the fact that as the IP effect depends on the total surface area of the sulphides present, the disseminated material per sulphide volume present will give a greater IP effect.

Normally three "slices" are measured which are shown in Figure 6 as M_1, M_3 and M_5. The red decay form included in Figure 6A is the 'normal' or 'average' decay form usually observed over normal rocks. The IPR-8 processes the data by dividing this normal decay into each of the slices M_1, M_3 and M_5. This is done so that any deviation from 'normal' is readily apparent. Figure 6B displays the result of this processing of data. The rapid decay form (e.g. fine grained disseminated) will result in $M_1 > M_3 > M_5$, while the slow decay form (e.g. coarse grained massive, but not necessarily electrically continuous) will result in $M_1 < M_3 < M_5$.

The ΔM parameter is a shorthand display of the decay form: $\Delta M = |M_5| - |M_1|$. Thus, when this quantity is *positive* it implies *coarse* grain size, and when *negative* implies *fine* grain size for a given mineral.

Where a substantial range in chargeability is recorded in an area, it is necessary to normalise the decay factor ΔM by the amplitude of the chargeability. This is done by dividing ΔM by M_3 and multiplying the factor by 100%.

The normalised decay form $\Delta Mn\% = \dfrac{|M_5| - |M_1|}{M_3} \times 100\%$

and displays the variation in decay form from 'normal' in percent.

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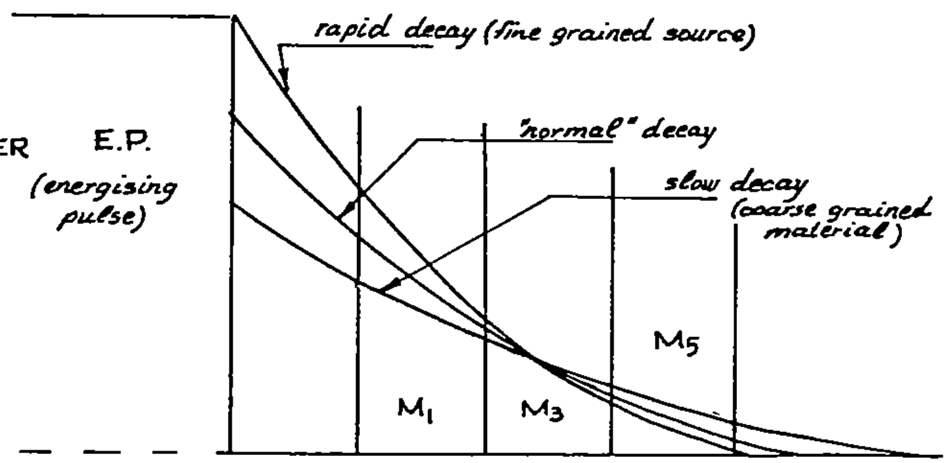
(A)

DECAY AS OBSERVED BY IPR-8 M.I.P. RECEIVER PRIOR TO PROCESSING



(B)

DECAY AS OBSERVED BY IPR-8 MIP RECEIVER AFTER NORMALISATION FOR A "NORMAL" DECAY FORM

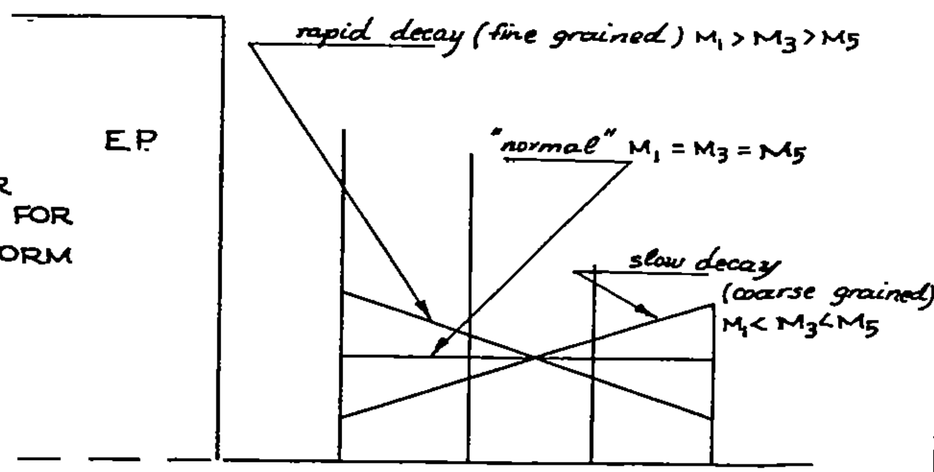


Fig 6.

This decay form can be seen by varying frequency domain measurements over a wide frequency. For a slow decay form, MIP data acquired at a lower frequency will be relatively larger in amplitude than that acquired at higher frequencies, while conversely for fast decay forms the MIP will be emphasised by higher energising frequencies.

Electromagnetic Coupling .....

In common with electrical induced polarization magnetic induced polarization can be subject to electromagnetic coupling. In the *time domain* this can readily be identified by abnormal distortions in the decay curve, a typical example would be where:-

$$M_1 \ll M_3 \equiv M_5$$

In the *frequency domain* the magnetic induced polarization effect is read in both RPS and PFE. The former is *free of electromagnetic coupling to a first approximation,* while the latter is not. Therefore an observation of the variation of the RPS and PFE from their theoretical relationship of 1%PFE + 1.6°RPS can warn of the presence of EM coupling.

The Influence of the Size of the Current Dipole .....

The current dipole is normally placed parallel to the expected strike of the mineralisation. This array will couple best to lenticular bodies with depth extent and with a strike extent of about one-third the size of the current dipole or larger. *Therefore, to maximise the "focus" of the current dipole for "small" bodies, small current dipoles should be employed.* From an operational point of view the current dipole is normally about three to five times the expected length of the target ore body.

A more important influence on the determination of the current dipole size is the depth and intensity of oxidation. The deeper and/or the more intense the oxidation, the larger the current dipole must be to get a significant proportion of the current to penetrate the freshrock target volume.

Current Penetration into Freshrock Through Conductive Overburden .....

The MIP method was developed for conductive overburden situations we encountered in the Kalgoorlie nickel belt in the late 1960's. As we saw the problem then, there were two quite separate problems. The first was to energise the volume of rock that the geologist wished to search and the second was to obtain at the surface a meaningful signal which did indeed represent the electrical characteristics of the underlying freshrocks and ore zones.

Basically the first part of the problem was capable of solution even in the late 1960's. Electrodes down holes and/or large generators with large current dipoles were (and are) capable of deep energisation. Nigel Edwards in his paper with Howell in Geophysics Vol. 41-6A page 1172 demonstrates this point well in Figure 3 reproduced below.

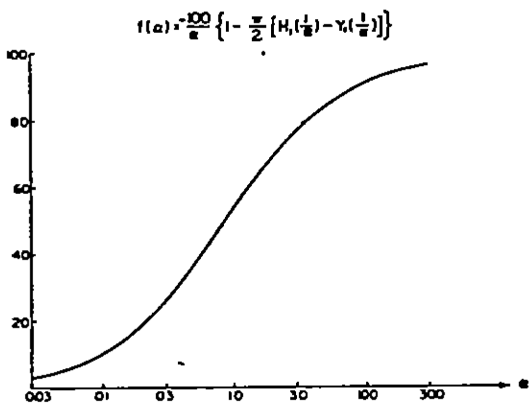


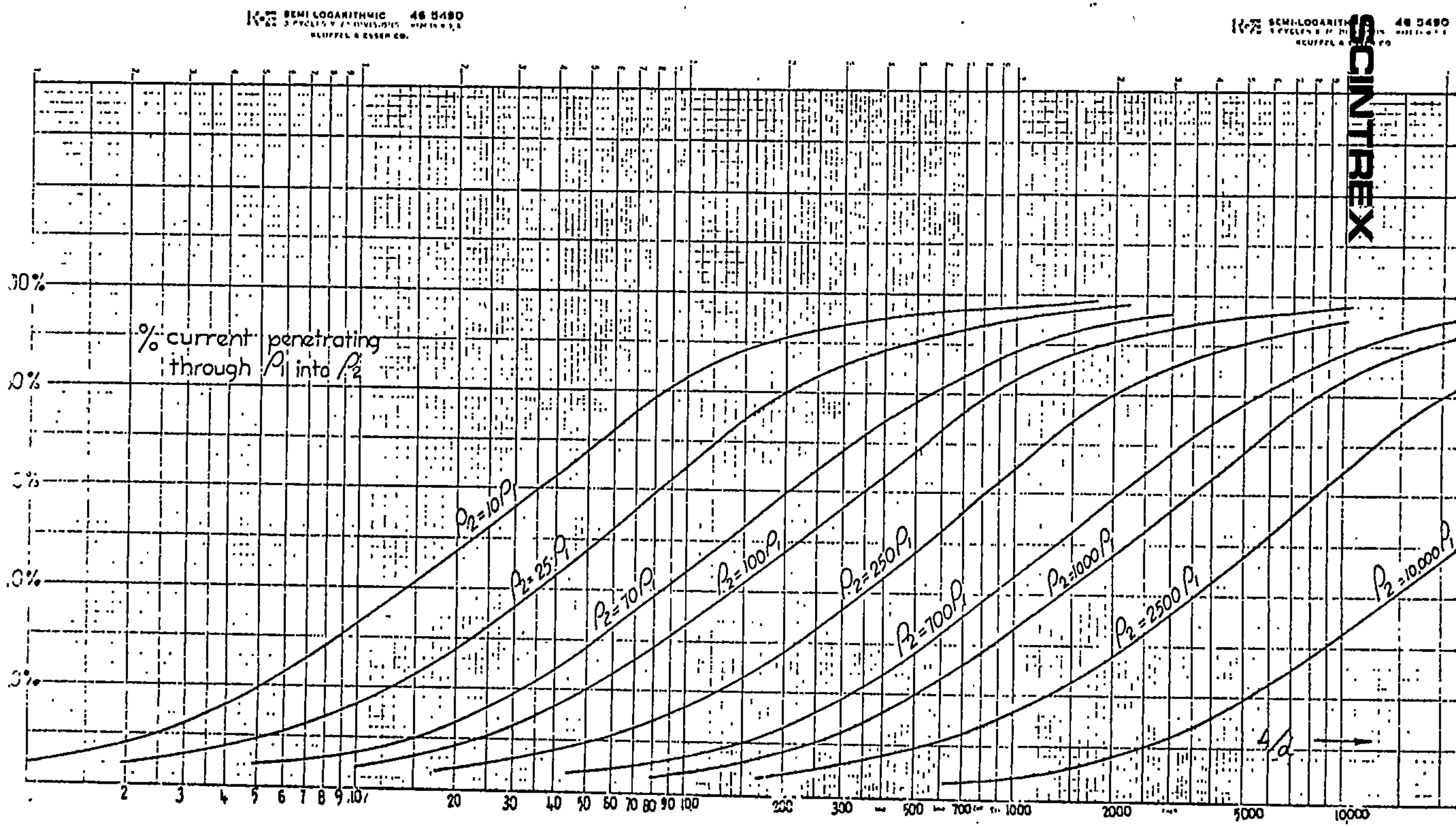
FIG. 3. The function $f(\alpha)$ which determines the percentage of current remaining in a conductive, thin surface layer above a resistive half-space.

The vertical axis represents the percentage of the current remaining in the overburden, while the horizontal axis represents the f(α).

$\alpha = 2S\rho_2/L$

Where S is the conductivity thickness product of the overburden and ρ_2 the resistivity of the freshrock and L the current dipole. This can be rewritten as $\alpha = 2\rho_2/\rho_1 \times d/L$ where ρ_1 and ρ_2 are the resistivities of the overburden/oxidation and freshrock respectively, and d and L are the depth of oxidation and the current dipole respectively. For ease of field use it can be recast as a series of curves for different ratios of ρ_1/ρ_2 to show percentage current penetration of the freshrocks for the various ratios of d/L. (Figure 7)

In practice electrical soundings will yield diagnostic information as to the bulk resistivity (ρ_1) and thickness (d) of the weathered zone. As the resistivities of rock types are known and can be reasonably estimated for any area if drill hole information is not available, ρ_2 can be reasonably estimated. As an example, take an area where the overburden/oxidation has a bulk resistivity (ρ_1) of 50 ohm-metres, and a depth (d) of 25 metres over bedrock (ρ_2) known to average 2000 ohm-metres. Thus ρ_2 will equal about 40 ρ_1, therefore for 40% of the current generated to penetrate the bedrock the current dipole is required to be 50 times


K&E SEMI-LOGARITHMIC 46 5490
KEUFFEL & ESSER CO.
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% current penetrating through ρ_1 into ρ_2
$\rho_2 = 10\rho_1$
$\rho_2 = 25\rho_1$
$\rho_2 = 70\rho_1$
$\rho_2 = 100\rho_1$
$\rho_2 = 250\rho_1$
$\rho_2 = 700\rho_1$
$\rho_2 = 1000\rho_1$
$\rho_2 = 2500\rho_1$
$\rho_2 = 10{,}000\rho_1$
L/d
2 3 4 5 6 7 8 9 10 20 30 40 50 60 70 80 90 100 200 300 500 700 1000 2000 5000 10000

FIG. 7

the depth of oxidation of 25 metres, i.e. 25 × 50 = 1250 metres. (Figure 7)

Data Processing and Presentation .....

For large scale reconnaissance surveys carried out in the frequency domain (known as rapid reconnaissance magnetic induced polarization - RRMIP), the data is processed by computer and presented in terms of RPS, PFE, MMR, H_N, HSQ/I and HSP/I, some of which are presented as line printergraphs (usually RPS, MMR and HSQ/I). For ease of interpretation and for structural information, RPS and MMR are normally also contoured, generally at the scale of 1:2500.

In the time domain, the chargeability, M, together with H_S and H_N are usually hand plotted. The generally smaller size of the current dipoles (500 ±100 metres) precludes a meaningful contour presentation in most cases. Again, a scale of 1:2500 is favoured.

Field Procedures .....

Most (but not all) fieldwork to date has been carried out using *gradient arrays* as shown in Figure 8. In practice the current dipole (L) is laid parallel to strike and varies up to 600 metres for time domain surveys and 3000 metres in the case of frequency domain (RRMIP) surveys. From each gradient set-up a block some 0.6 kilometres in strike length by about 0.4 kilometres in width can be surveyed. The line interval depends on the minimum strike length of the target zone, while the reading intervals along lines are normally about 25 to 50 metres.

In the time domain some 40 to 60 stations can be read per operator in good conditions while the figure in the frequency domain is about 100 to 120 per operator per day. Normally two operators are used.

From a practical point of view, as MMR/MIP*is a magnetic field method, it necessarily depends on strong current flow. Thus the method works best in areas which are conductive rather than those which are highly resistive. Areas where MIP/MMR appears to have been particularly useful are Kalgoorlie, Western Australia, western New South Wales, north-west Queensland and northern Australia, always in areas of conductive overburden.

* See page 15

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Edwards Array .....

Edwards has developed a multi-source MMR/MIP sounding array designated the Edwards array (Edwards & Howland-Rose, 1979). The array is designed to ascertain the depth to source and depth to the centre of current flow for infinite slabs, and are used to follow-up in detail significant features located on reconnaissance surveys.

The configuration of the array is shown in Figure 9. The main features are (i) an infinite current electrode C_2 placed along strike (ii) close electrodes C_1^1 to C_1^n placed at distances y along strike, (iii) the MFM-3 sensor is placed at various stations along χ. For each location the Hp and RPS readings are taken for each current electrode separation C_1^n to C_2. The data is then computed and plotted either as profiles or as pseudosections as shown in Figure 9. In this figure each data point is plotted in the pseudosection with the horizontal distance x along the survey line against y the distance of the close current electrode C_1^n from the survey line χ. It must be emphasised that the Edwards multi-source array is a very recent development, the first field data having been acquired in late 1979 over Elura (Howland-Rose, 1980).

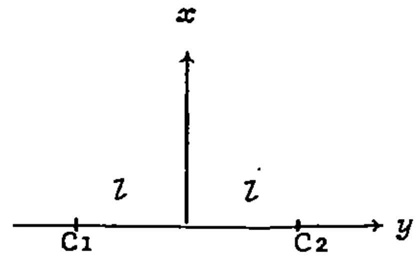
As yet there are few computer models and those available (Edwards & Howland-Rose, 1979) are for tabular infinite bodies. Therefore the comments must necessarily be descriptive. The significant factors are considered to be the *relative* values of interior and exterior polarization, for should induced polarization be uniform, no anomalism will be observed. Similarly should the resistivity be uniform, the expected MMR will be zero. Variations in resistivity alone will not produce an MIP response (Howland-Rose et al, 1980, p.41). The MIP method will be sensitive only to lateral inhomogeneities (Howland-Rose et al, 1980, p.40) which, in most circumstances where steep dipping rocks occur is the significant factor.

Units and Parameters .....

A - Measurements of relative resistivity of the earth for gradient array:

The MIP sensor senses the horizontal magnetic field due to the passage of the primary current in the ground. Unlike EIP resistivity data, it sums *all* current to depth by virtue of its magnetic field. The field at any point in the survey area (Hp), must be adjusted for the position of the current dipole. The formula for the calculation of the normal (H_{Norm}) field at any point is:-

$$H_{Norm} = 100I \left[\frac{y + l}{x^2 + (y + l)^2} - \frac{y - l}{x^2 + (y - l)^2}\right]$$



Where I is current in amps, y is distance from the centre line and, x is the distance from centre line joining the electrodes, and $2l$ is the distance between electrodes.

H_N, the *normalised horizontal field* is given by the expression:-

$$H_N = \frac{Hp \times 100\%}{H_{Norm}}$$

H_N is expressed in percent variation from normal, normally being either a homogeneous underlying resistivity *or* any complex horizontal layering. Normal will be 100%.

MMR, the *Magnetometric Resistivity* is given by the expression:-

$$MMR = \frac{Hp - (Hu \times I)}{\frac{400I}{l}} \times 100\%$$

MMR is expressed in percent variation from normal, 0 being normal. This parameter will tend to emphasise conductivities in regions of high current density.

B - Measurements of Relative resistivity of the earth for a multi-source (Edwards). array:-

$$MMR\ (\%) = \frac{B^a \times 100}{\frac{100I}{y_1} - \frac{100I}{y_2}}$$

Where $B^a = B^m - B^p$

and $$B^p = \frac{100y_1}{(x^2 + y_1^2)} - \frac{100y_2}{(x^2 + y_2^2)}$$

y_1 = distance of station from C_1 parallel to Y axis, y_2 = distance to C_2 parallel to Y axis, x = distance from centre line, B^a = anomalous field, B^m = measured field and B^p = normal field (see Figure 9)

C - Measurements of the Induced Polarization Effect

In the time domain *chargeability* (M) is measured in terms of milligamma/gamma.

In the frequency domain two independent measurements of chargeability are taken.

(i) RPS, *Relative Phase Shift*, is given by the expression:-

$$RPS = 3\theta_f - \theta_{3f}$$

where θ_f and θ_{3f} are the phase shifts of the fundamental and third harmomic of the transmitted square wave.

(ii) PFE, *Percent Frequency Effect*, is given by the expression:-

$$PFE = \frac{A_1 - 3A_3}{3A_3} \times 100\%$$

where A_1 and A_3 are amplitudes of the fundamental and third harmonic of the transmitted square wave.

D - Derived Parameters

In areas of large variations in current density due to conductivity inhomogeneities, or close to electrodes it is more meaningful to present the secondary current magnetic fields due to polarization effects. These derived parameters will *emphasise* induced polarization effects *in areas of high current density* whereas the original induced polarization data in terms of M, PFE or RPS will *emphasise* induced polarization effects in areas of *low current density*.

It should be noted that by examining the induced polarization phenomenon in terms of chargeability (M, RPS or PFE) AND by means of the secondary magnetic field, we can observe induced polarization effects from both high *and* low current density areas.

In the time domain the secondary field is calculated as follows:

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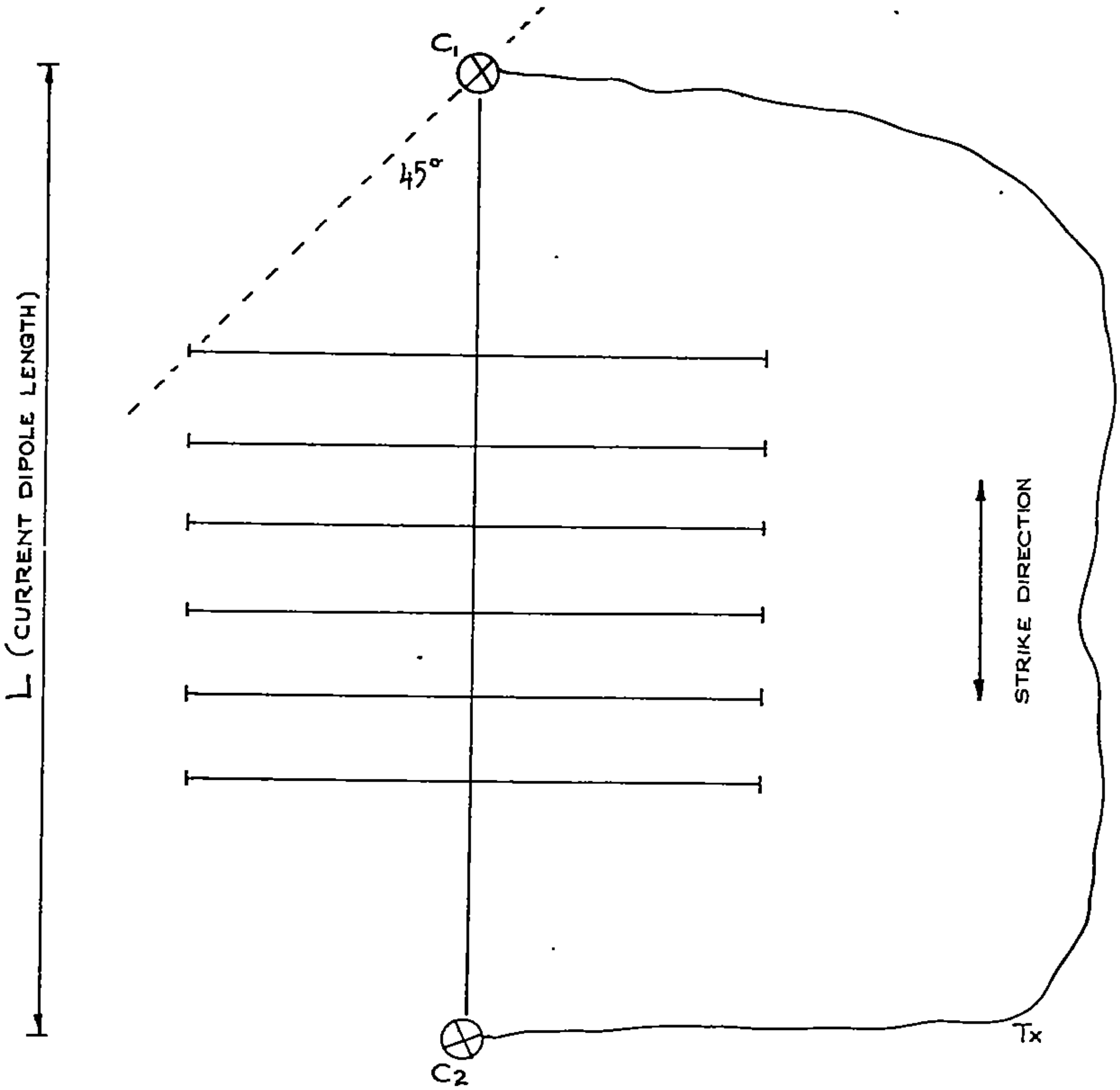

GRADIENT ARRAY

Fig 8

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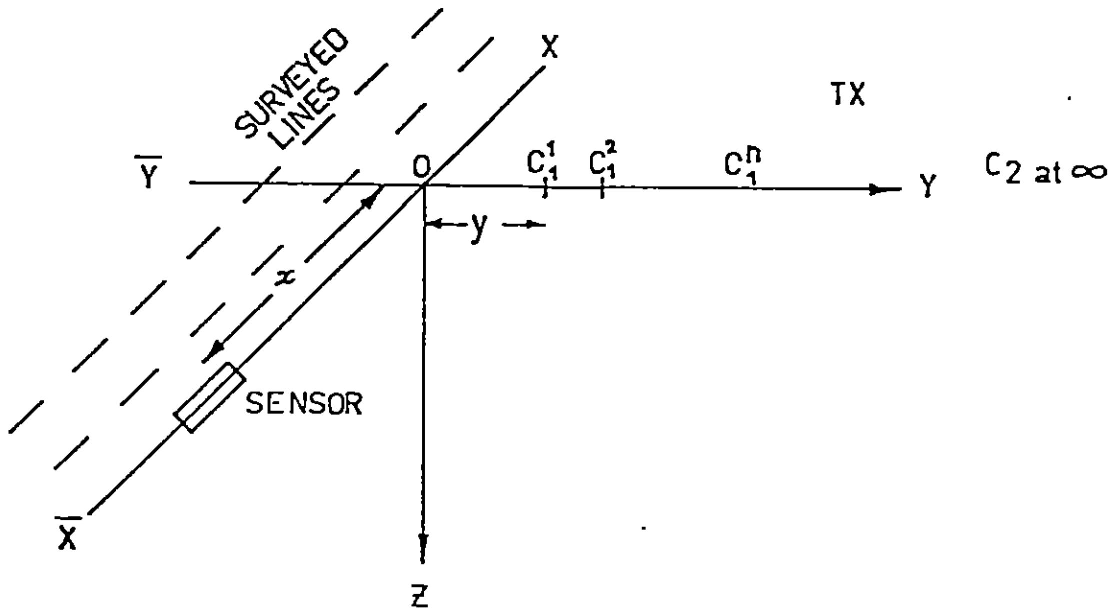
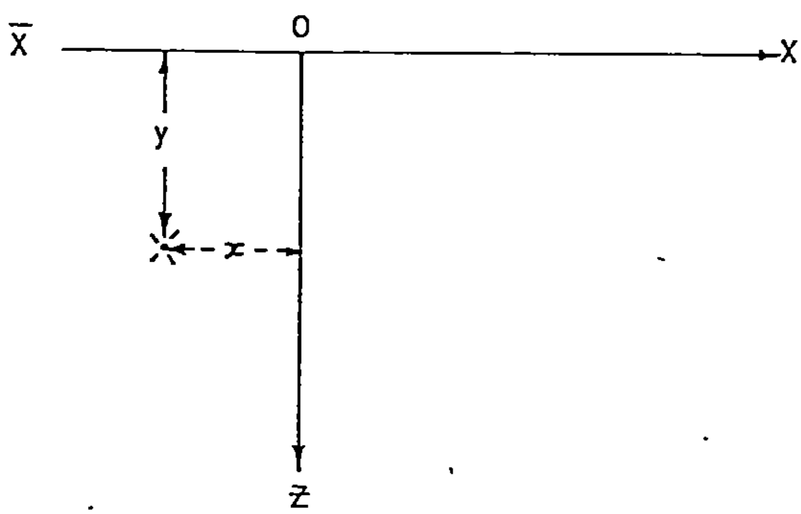


Field setup



Pseudosection plotting format

⁘ plotting point

Fig. 9

MULTI - SOURCE (EDWARDS) ARRAY

$$H_{Si} = \frac{Hp}{I} \times Mi \times 100 \quad \text{(milligamma/amp)}$$

where I is the current in amps, and M is the chargeability of the *i*-th slice of the decay curve.

In the frequency domain these secondary fields are termed:-

(i) Quadrature change HSQ/I

$$HSQ/I = \frac{Hp}{I} \sin\theta \times 1000, \quad (\theta = \frac{RPS}{2})$$

(ii) In-phase change ΔHSP/I

$$HSP/I = \frac{Hp}{I} \times \frac{PFE}{100} \times 1000$$

Both HSQ/I and ΔHSP/I are expressed in milligamma/amp of primary current strength.

Final Comment .....

The above remarks briefly outline the present procedures in the execution, computation and interpretation of Magnetic Induced Polarization data in the time and frequency domain. It is recommended that the reader should now study the papers listed in the "References" to obtain a more corprehensive understanding of the method.

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

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REFERENCES

Magnetic Induced Polarization

EDWARDS, R.N. and HOWLAND-ROSE, A.W., 1979. Modern EM & IP exploration techniques *Australian Mineral Foundation, V.III, Sections a & b, pp.607-748*

HOWLAND-ROSE, A.W., LINFORD, J.G., PITCHER, D.H., and SEIGEL, H.O., 1980. Some recent magnetic induced polarization developments. *Geophysics, V.45, Parts I & II pp.37-74.*

SEIGEL, H.O., 1974. The magnetic induced polarization method. *Geophysics, V.39, pp. 321-339.*

HOWLAND-ROSE, A.W., 1980. Early electrical and magnetic induced polarisation surveys over the Elura ore body - results and comments. *A.S.E.G. Bulletin, 1980 (In publication).*

Rapid Reconnaissance Magnetic Induced Polarization (RRMIP)

EDWARDS, R.N. and HOWELL, E.C., 1976. A field test of the magnetometric resistivity (MMR) method. *Geophysics, V.41, pp.1170-1188.*

EDWARDS, R.N., and GOMEZ-TREVINO, E., 1979. MMR2D A programme to compute the magnetometric resistivity (MMR) anomalies of two dimensional structures. *Unpublished Report, Macquarie University.*

GOMEZ-TREVINO, E., and EDWARDS, R.N., 1979. Magnetometric resistivity (MMR) anomalies of two-dimensional structures. *Geophysics, V.44, pp.947-958*

HOWLAND-ROSE, A.W., 1980. Magnetometric resistivity and frequency domain magnetic induced polarization test surveys using gradient and multi-source arrays over the Elura ore body. *A.S.E.G. Bulletin, 1980 (In Publication).*

Decay Form

GEDDE, R.W., and HOWLAND-ROSE, A.W., 1970. Adapting IP to W.A. conditions. *Southern Miner, V.1, No.26, pp.14-22.*

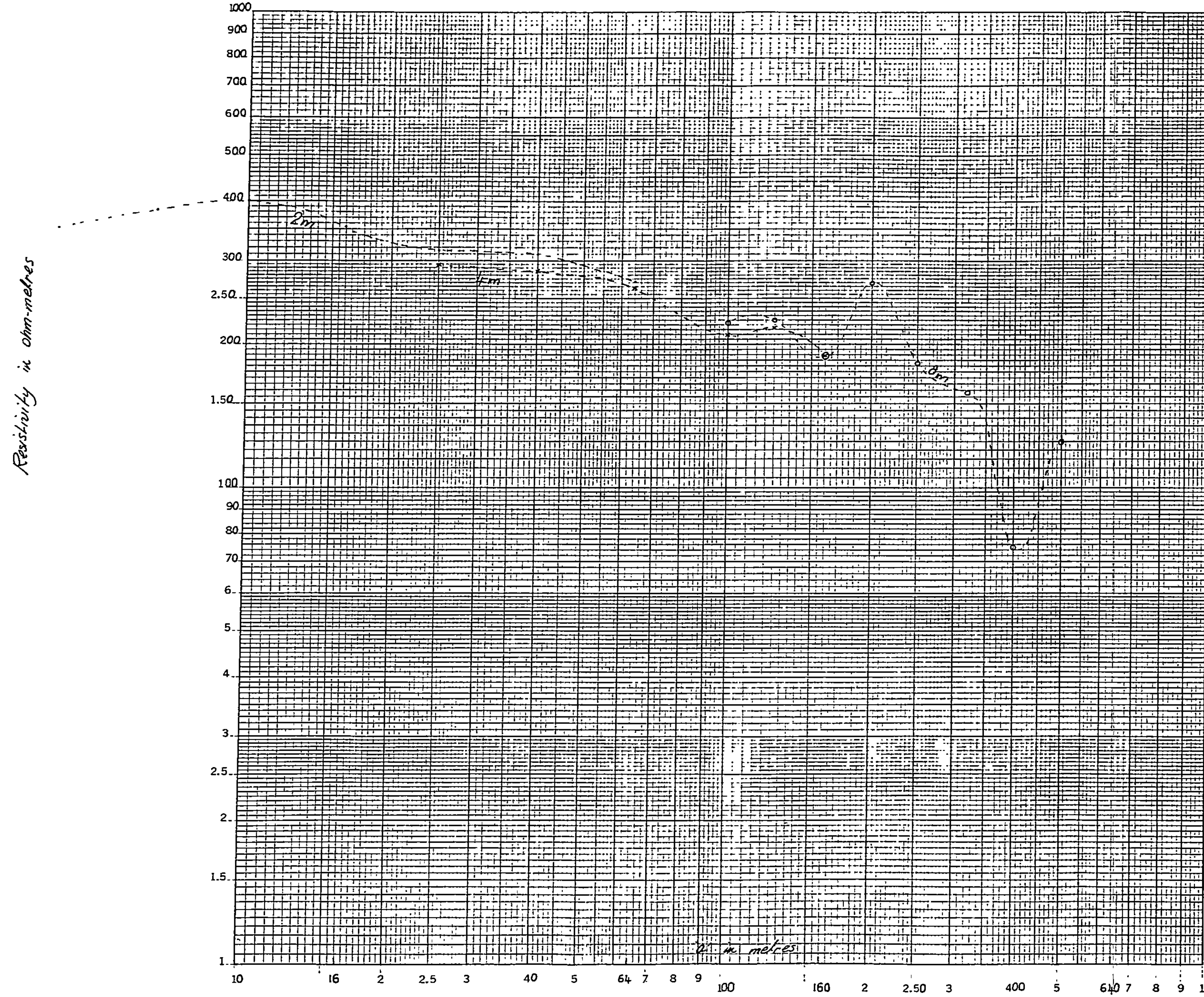
SWIFT, C.M., 1973. The L/M parameter of time-domain IP measurements - A computational analysis. *Geophysics, V.38, pp.61-67.*

WAIT, J.R., 1958. A phenomenological theory of induced electric polarization. *Canadian Journal Physics, V.37, pp.1634-1644.*

Instrumentation

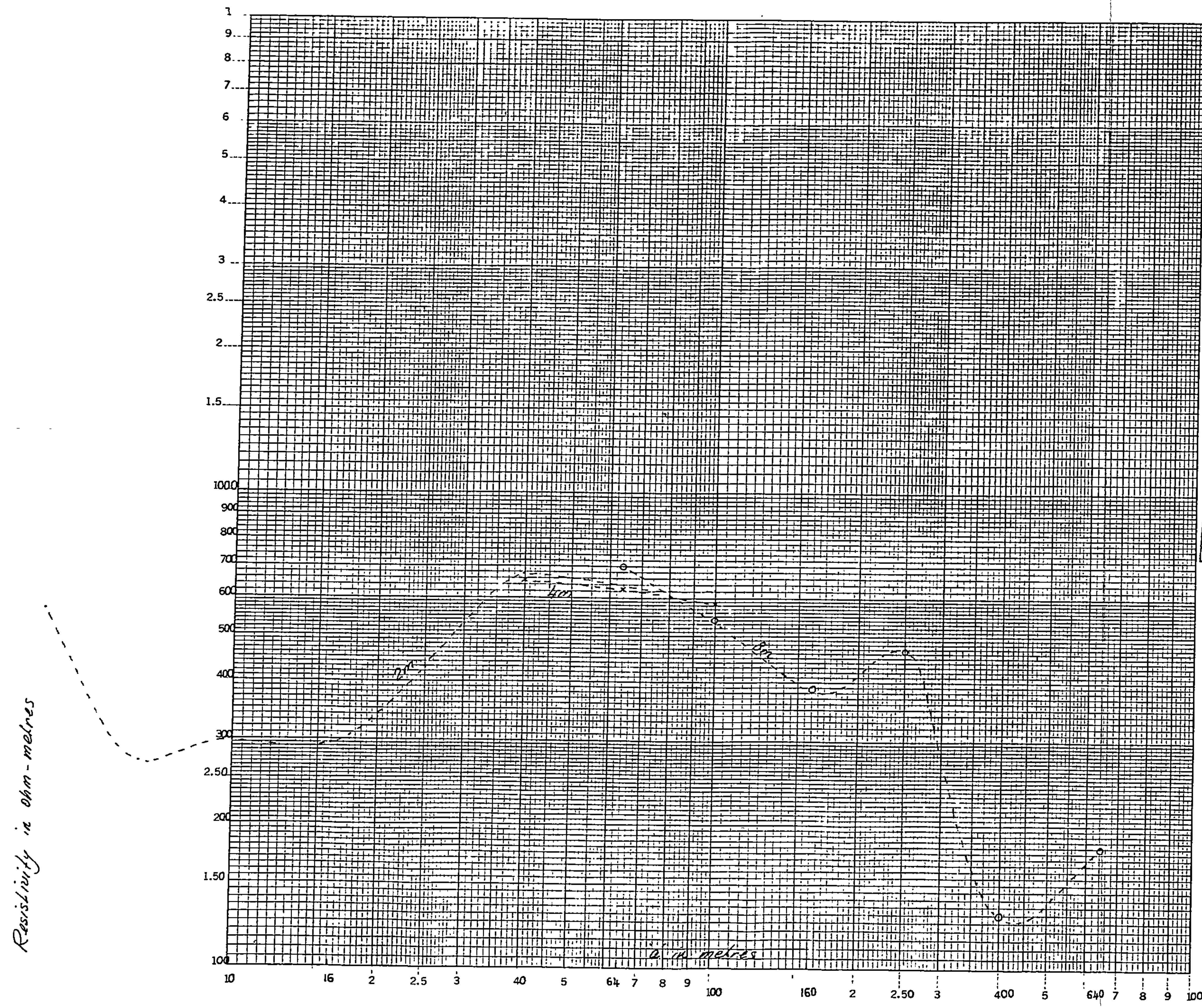
SEIGEL, H.O., and BRCIC, I., 1976. Frequency domain IP measurement using harmonically related components. *Scintrex Applications Brief, 76-1*

Scintrex manual on IPR-8 time domain receiver.



360E/1500N
ALIGNMENT NORTH/SOUTH
HIGHLAND VALLEY
Schlumberger Array
T2107

360E/1000N
ALIGNMENT NORTH/SOUTH
HIGHLAND VALLEY
Schlumberger Array
T2107



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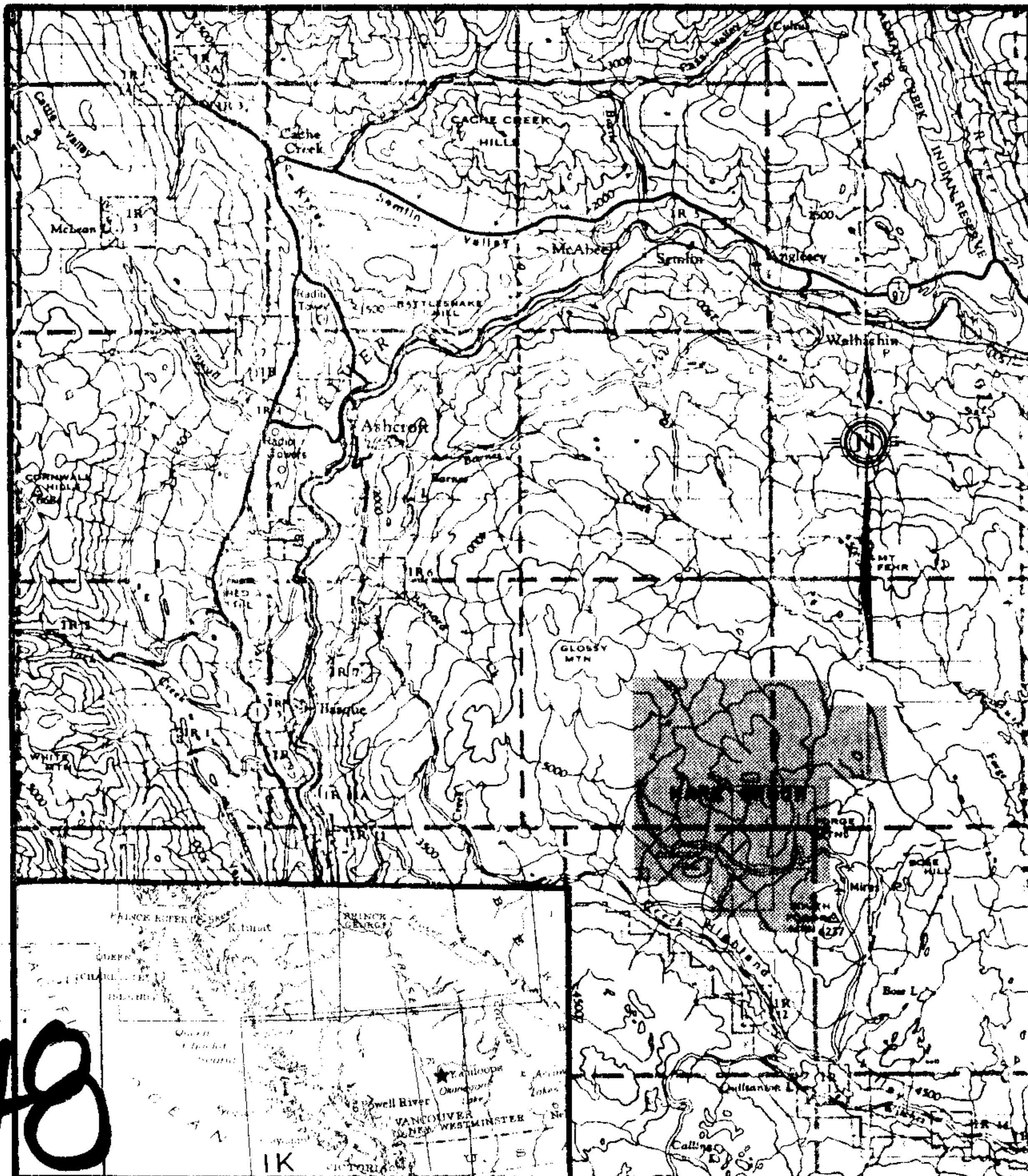

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PART
3 of 3

FIGURE Nº 1

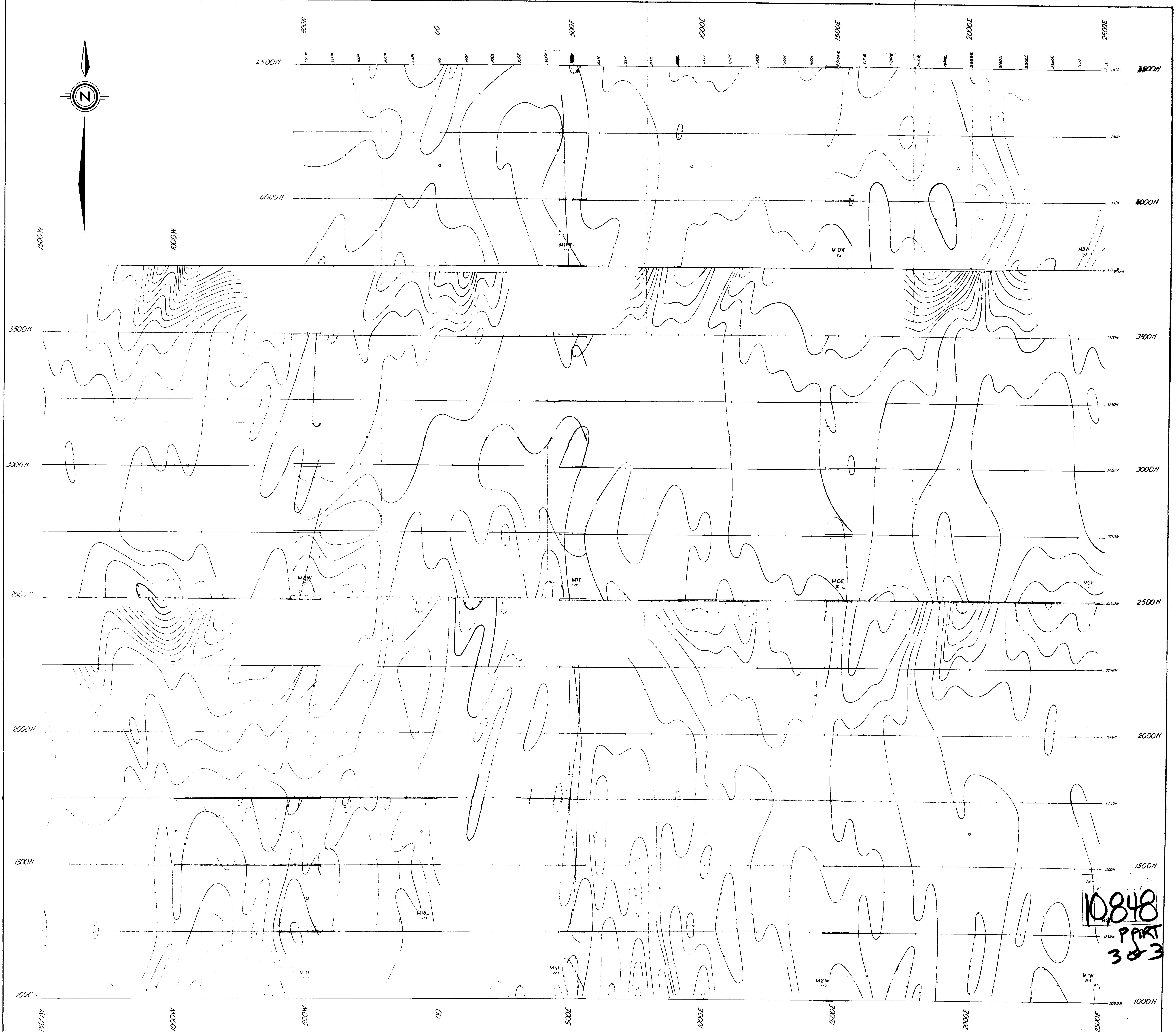
CENTURIAN EXPLORATION INC.

HARE GROUP OF MINERAL CLAIMS
LOCATION MAP

SCALE 1 : 250,000

0 5 10 15 20 25 30 km.

92 I/NW & NE	DATE: MAR. 15, 1983



CENTURION EXPLORATION INC.
IN ASSOCIATION WITH I. SHULMAN

HIGHLAND VALLEY
B.C. CANADA

R.R.M.I.P. SURVEY
M.M.R. CONTOUR PLAN

SURVEYED & COMPILED BY
SCINTREX

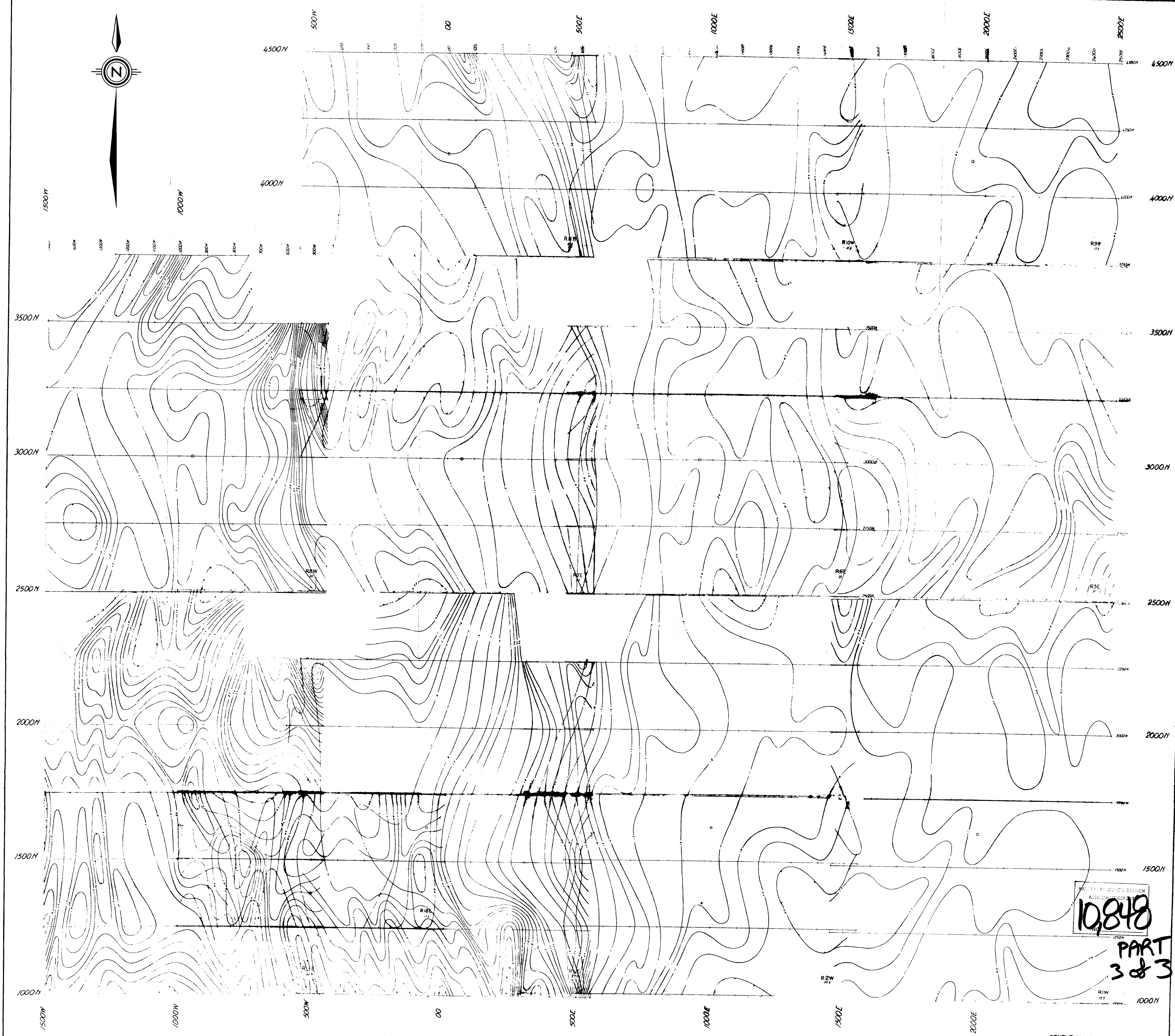
AUGUST 1981

SCALE 1:5000

0 100 200 300 400 500 m.

Job No T-2107

PLATE 1 N



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HIGHLAND VALLEY
B.C. CANADA

RRMIP SURVEY
RPS CONTOUR PLAN

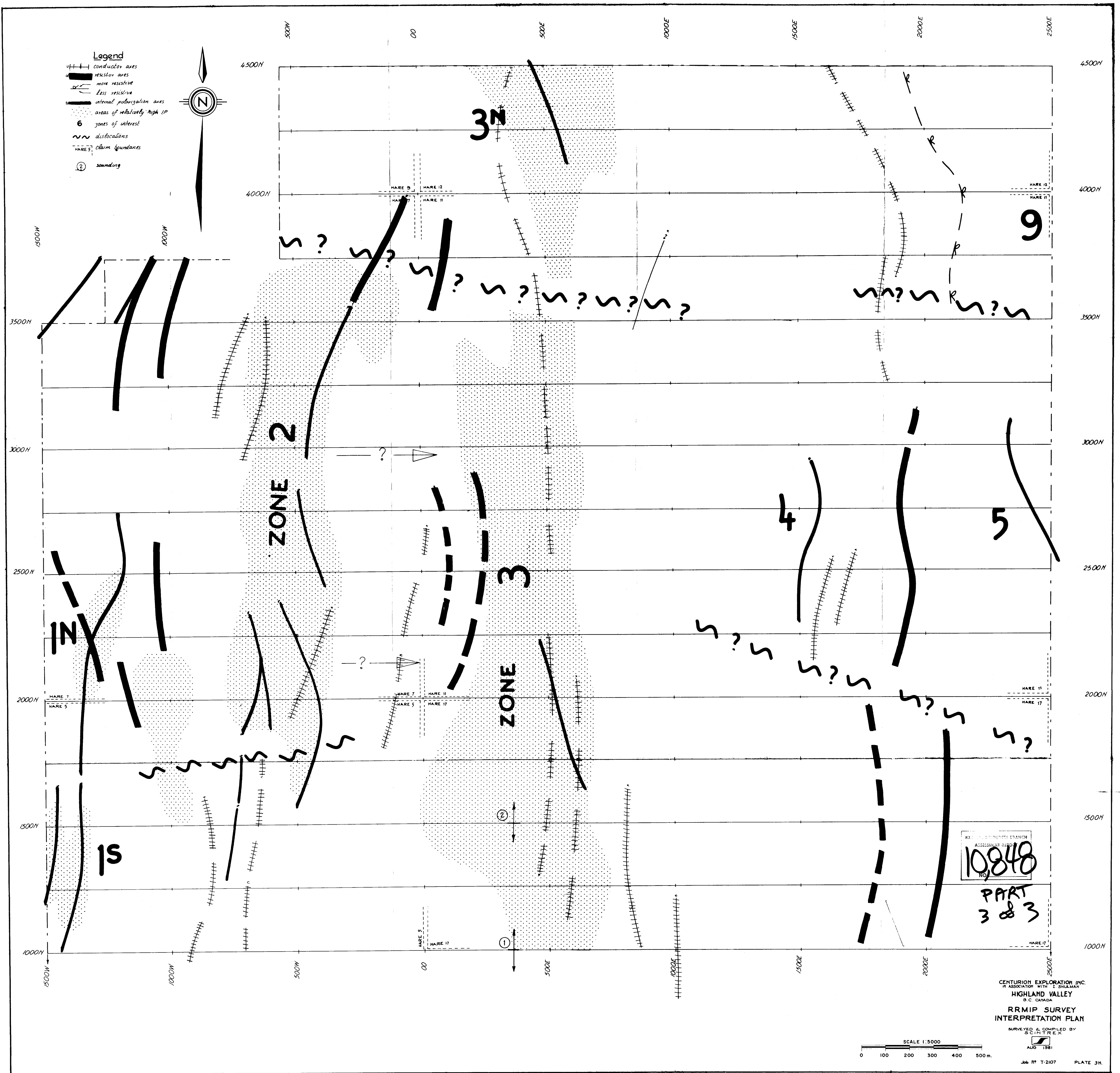
SURVEYED & COMPILED BY
SCINTREX

AUGUST 1981

SCALE 1:5000
0 100 200 300 400 500 m.

Job № T-2107

PLATE 2H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HARE 9
HARE 12
HARE 11
HARE 7
HARE 5
HARE 17
3N
9
2
ZONE
3
ZONE
1N
1S
4
5
ASSESSMENT REPORT
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INTERPRETATION PLAN
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Job No T-2107
PLATE 3N.


2000W
1500W
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1500S
2000S
2500S
3000S
M13W
M12W
M15E
M14W
M17E
M16W
N
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MMR CONTOUR PLAN
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PLATE 15


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SCALE 1:5000
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R.P.S. CONTOUR PLAN
SURVEYED & COMPILED BY
SCINTREX
AUGUST 1981
Job No T-2107
PLATE 2S

2000W
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HARE 5
HARE 3
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Legend
conductor axes
resistor axes
more resistive
less resistive
contacts
internal polarization axes
areas of relatively high IP
6 zones of interest
dislocations
claim boundaries
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B.C. CANADA
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INTERPRETATION PLAN
SURVEYED & COMPILED BY
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AUGUST 1981
SCALE 1:5000
0 100 200 300 400 500 m.
Job No T-2107
PLATE 35