

SCINTREX

812001

OPEN FILE

95-3712

MICROFILMED

FICHE No. 013526-28

COMMENTS ON

GEOPHYSICAL TEST SURVEYS

CARRIED OUT AT PIONEER, NORTH-EAST TASMANIA

ON BEHALF OF

AMDEX MINING LIMITED

HOWLAND-ROSE

95-3712.

**SCINTREX**

812002

PRIVATE AND CONFIDENTIAL

COMMENTS ON  
GEOPHYSICAL TEST SURVEYS  
CARRIED OUT AT PIONEER, NORTH-EAST TASMANIA  
ON BEHALF OF  
AMDEX MINING LIMITED

BY

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

SYDNEY, N.S.W.

MAY, 1979

TAS-067R/069

**CONTENTS**

Summary	
Introduction	Page 1
Method	Page 2
Discussion of Results	Page 3
Standard RRMIP	Page 4
Pole-Source Array	Page 5
Total Magnetic Field	Page 8
Conclusions	Page 9

**Appendix 'MIP'**

Data Profiles - Pole-source Array	
Plate 1 - Distribution of Heavy Mineral Fraction	
Plate 2 - MMR Contour Plan	
Plate 3 - RPS Contour Plan	
Plate 4 - Total Magnetic Field Contour Plan	

**SUMMARY**

*While the results of a standard RRMIP survey and an attempt at a moving source RRMIP survey of themselves have not been successful in identifying the known distribution of heavy minerals at Pioneer, the Author considers that it is not impossible that a moving source array could be developed which would be successful in locating such deposits. Further theoretical work will be carried out with this objective in mind.*

*The magnetic field survey was not successful in delineating the known mineralisation.*

**SCINTREX**

COMMENTS ON  
GEOPHYSICAL TEST SURVEYS  
CARRIED OUT AT PIONEER, NORTH-EAST TASMANIA  
ON BEHALF OF  
AMDEX MINING LIMITED

---

*INTRODUCTION*

A series of RRMIP and total field magnetometer surveys were carried out on the projected extensions of the Pioneer Mine, near Derby north-east Tasmania on behalf of Amdex Mining Limited. These surveys were requested by Mr. I. Shulman.

The RRMIP test surveys were carried out on two double and five single operator days between 13th and 21st December, 1978, while the magnetic field surveys were carried out on 1.5 single operator days on 1st and 2nd March, 1979.

The purpose of these test surveys was to find whether a method could be developed for the location of the cassiterite and/or the associated heavy mineral assemblage, or the 'structure' where the cassiterite was situated. Little is known about the distribution of the heavy mineral with respect to the cassiterite, but it was reasonable to assume that there may be a contact between it and the enclosing quartz sands and clays, both with respect to magnetic field and perhaps also with chargeability. It was hoped that the success with heavy mineral sands (ilmenite) may be able to be

**SCINTREX**

Page - two

repeated here.

The RRMIP surveys were conducted by Mr. R. Stahl assisted by Mr. A. Kamaleshwar, B.Sc. and directed by Mr. Leon McDonald of Amdex, while the magnetic field surveys were undertaken by Mr. D. Webb, B.Sc., assisted by Mr. P. List. The author visited the site on 14th and 15th December. 1978.

*METHOD*

The magnetic induced polarization method is described in Appendix 'MIP' appended to this report. The conventional method using a 1 kilometre dipole in two end-on arrays was tried and the results of this survey are displayed in Plates 2 and 3 which depict MMR and RPS respectively.

Certain lines were surveyed using a 'pole-source' array employed in this survey for the first time. While the geometry is complex, the overall aim was to sample only a small volume of material concentrated within the tin bearing overburden. No response diagrams are available for such an array, but are being prepared to assist in ascertaining the meaning of the results obtained.

Figure 1 displays the configuration of this array. It should be noted that the grid at Pioneer is exceptionally flat, and care was taken to lay out the wire in a dead straight line along the traverse for the pole-source array.

# SCINTREX

## Pole Source Array

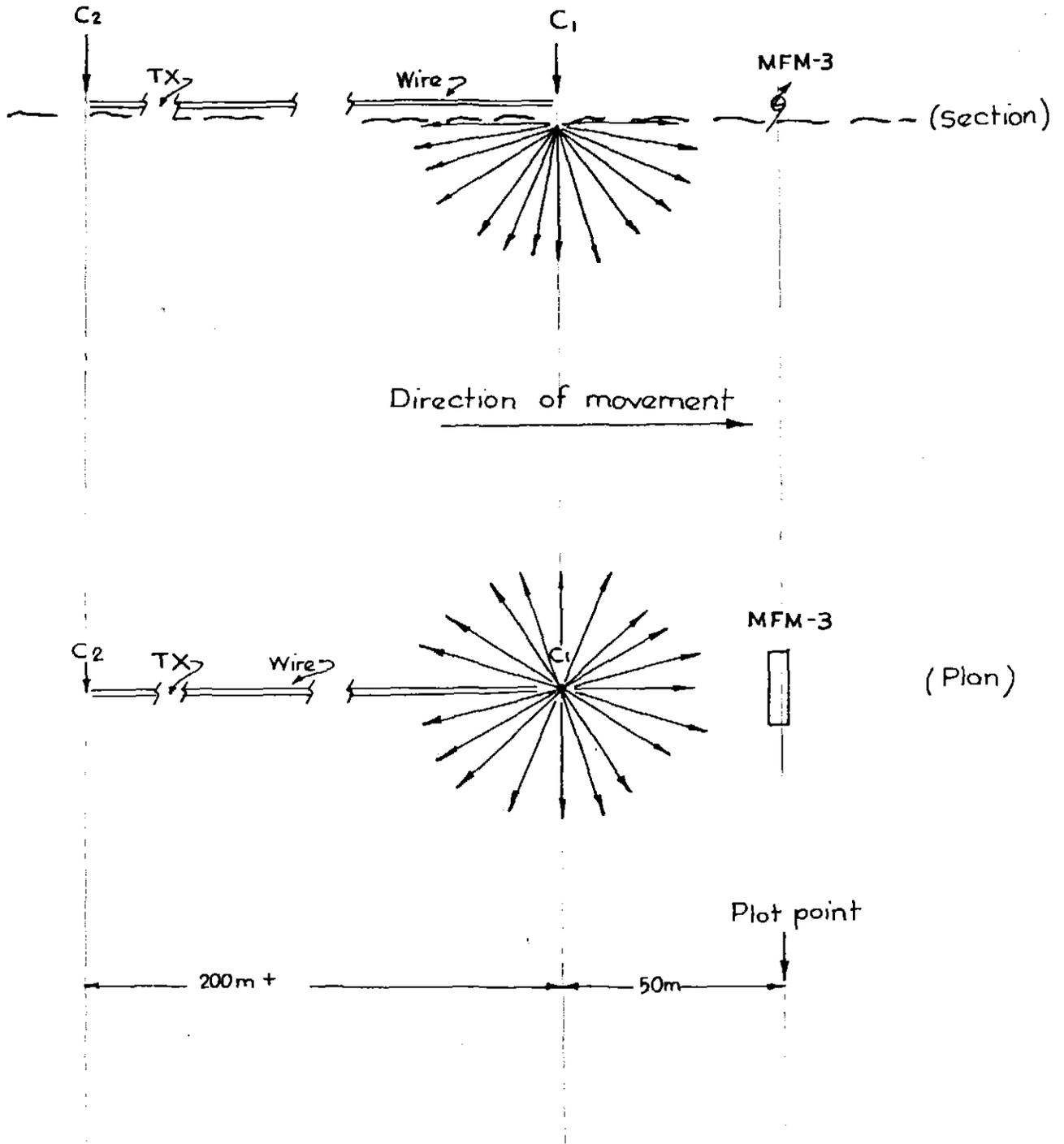


Fig. 1

**SCINTREX***DISCUSSION OF RESULTS*

Plate 1 shows the distribution of the heavy mineral fraction from the drill holes K18 to K70 in grams per standard sample per hole. It is considered likely that the heavy mineral fraction would bear some relation *as a whole* to the accompanying tin values.

Opinions have varied over recent time as to whether the tin was deposited in leads or desposited as a result of tidal action near estuaries. Thus the relationship of sub-basement and tin is not known or understood, except in broad outline.

The target will consist of narrow black seams as shown in the accompanying photograph (As a guide to scale, the coin is an Australian 20¢ piece)



Each of the tests are discussed separately below:

*STANDARD RRMIP*

Two standard RRMIP arrays were employed to cover the area to the west of the working mine, over the drilled sections referred to on Plate 1. The MMR data shows three zones where the MMR indicates the underlying rocks to be less resistive. The most prominent is centred at about 52550N+50 metres, on all three lines. The northerly unit was centred on lines 76800E, 77000E and 77200E at 53100N, 53100N and 53175N or 53025N. The southern most 'resistivity low' is at or south of 51975N on 77200E and south of 51950N on the other two lines.

The geological meaning of these trends is not known, but may represent bulk resistivity changes in the basement rocks. It may be significant that the known extensions of the Pioneer tin deposits occur on the inflexion between the higher MMR values at 52550N+50 metres, and the lower (resistive) section at 52800N+25 metres. In this context, electrically resistive rocks are in general more resistive to weathering, thus the MMR results may indirectly reflect subcrop relief.

The chargeability data varies about the zero level, with the maximum relief being +0.50° from this level. A small but perhaps significant internal polarization response was recorded on line 77000E at 52700N of +0.45° which is confirmed by a similar PFE and is therefore considered genuine. To the east it would appear that a much

**SCINTREX**

smaller response of  $+0.15^\circ$  at 52650N on line 77200E may be the correlative, while to the west this anomaly could correlate with a  $+0.25^\circ$  response at 52725N or a  $+0.15^\circ$  response at 52675N. Of all the polarization responses recorded in the standard RRMIP survey, only that at 52700N can be considered truly significant.

*POLE-SOURCE ARRAY*

The data profiles are described line by line in order of execution. The horizontal scales are 1:2500 while the vertical scales are 1 centimetre =  $0.2^\circ$  relative phase shift (chargeability) and 1 centimetre = 0.2 for HP/I (some function of resistivity of the volume sampled).

*Profile 'A' (line 77000E) . . . . . pole-source array 50 metres between current pole to the north and MFM-3 in the south.*

Three prominent internal polarization responses were recorded at 52337N, 52600N and 52875N. These are respectively approximately  $+2.00^\circ$ ,  $+2.70^\circ$  and  $+1.80^\circ$  above the local background. The most southerly maximum is associated with a depression in the HP/I ratio which infers a more resistive underlying host, while the central and northern sources show little material change.

The maxima do not occur in proximity to known mineralisation, as a comparison with Plate 1 shows. However, the central and northern maxima do occur on the flanks of a known zone centred at about K59.

**SCINTREX**

Consideration of the array geometry itself suggests that it is in fact the edges of an essentially horizontal chargeable source which the array will couple best to. The horizontal section should not respond as the horizontal current flow has no component which the horizontal fluxgate (MFM-3) can monitor. (See Appendix MIP). Thus it seems likely that the anomalies observed are due to edge effects.

*Profile 'B' (line 77200E) . . . . . pole-source array 50 metres between current pole in the south and MFM-3 (MIP sensor) in the north.*

This line shows three maxima on the RPS at approximately the same general positions on the grid as for line 77000E. A sharp single station reading at 52850N of  $+1.60^\circ$ , a similar response of  $+1.40^\circ$  at 52550N with a broader response of  $+1.80^\circ$  at 52275N and to the south, were recorded. A fourth response of the order of  $+3.00^\circ$  at 52125N was also recorded which is further to the south than surveyed on line 77000E.

The general similarity between these two lines infers a continuity across them of whatever features cause the RPS responses observed.

As with line 77000E, the chargeability maxima at 52550N and at 52850N occur either side of the position of the higher heavy mineral fraction and thus may be related to the edge of a horizontal plate of chargeability.

*Profile 'C' (line 77200E) . . . . . Pole-source array, 50 metres between*

**SCINTREX**

current pole to the north and MFM-3 to the south.

The profile form one would have expected would have borne some relationship to Profile 'B' even if amplitudes and positions of RPS anomalies would have been displaced. The reason for this large divergence is not understood.

*Profile 'D' (line 77200E).....* As above, only with infinite electrode not in line with reading but 200 metres north.

This data is similar to Profile 'C' but with the positive RPS points being of slightly greater amplitude.

*Profile 'E' (line 72200E) .....* A moving gradient array was employed using a current pole separation of 50 metres, with the MFM-3 (MIP sensor) placed midway between. The section of line surveyed was 52450N to 52750N centred over some of the better heavy mineral concentrations around 52600N. No significant response was recorded.

It is now considered that this array would have no chance of coupling with horizontal sources as the current flow is horizontal and so would the discharge be also essentially horizontal. Such an array may well have potential with the sensor *vertical* instead of horizontal.

*Profile 'F' (Endurance line P132E).....* 3Hz pole-source array, electrode to the north. Distance between current pole and sensor 50

and 75 metres (plotting position over the sensor).

South of 3N higher internal RPS of  $+0.40^\circ$  to  $+0.50^\circ$  was noted while north of 2N the values were *about*  $+0.30^\circ$  higher on both spacings.

Between these sections the overall level of RPS is lower but the 50 metre spacing shows a maximum at 7.5N (+25 metres) of about  $+0.20^\circ$  and between 13N and 16N of the same amount.

*Profile 'G' (Endurance line Pl28)..... pole-source array, electrode to the north.*

The chargeability profile is without feature except for a response at 5N of  $+0.30^\circ$  above background. Substantial responses of  $+0.80^\circ$  and  $+2.60^\circ$  above background at 16N and 19N are considered to be related to the powerlines which were recorded as being at 18N.

HP/I shows a gentle change, with the maximum values being between 4N(+) and about 13N(+). This infers less resistive rocks beneath this section.

#### *TOTAL MAGNETIC FIELD*

The data is presented in contour form on Plate 4. A stationary magnetometer was read every 1 to 3 minutes and the data from the survey magnetometer corrected for drift to an accuracy of +1 gamma or better.

**SCINTREX**

As can be seen, no correlation with the known mineralisation can be seen.

*CONCLUSIONS*

- 1 - The standard RRMIP surveys over Pioneer using a 1 kilometre spread recorded only one significant anomaly defined on line 77000E at 56700N. This appears to strike approximately grid east west. In retrospect the line spacing should have been 50 metres or even 25 metres, rather than the 100 metres used. This may have allowed a far more detailed picture to have been seen.
  
- 2 - The pole-source array gave large RPS anomalies which may relate to the edges of horizontal polarizable sheets. Certainly these results are encouraging in that anomalies *do occur*. Lack of repeatability for a reversal of configuration is not fully understood, but is certainly due to inhomogeneity and different geometry as the chargeable sources are approached from either side.

While these surveys as such cannot be considered successful, they have given data which shows anomalism occurs, and is related to some unit within the sequence, the most likely of which is total heavy mineral distribution. While the possibility of clays cannot be ignored, the lack of information as to the true relationship of heavy mineral content and tin, and of the actual

**SCINTREX**

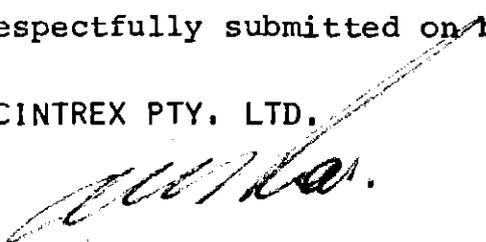
geometry of the deposits surveyed and of the nature of the chargeability thereof, makes it well worthwhile pursuing this research.

The requirement is for a moving source array which allows rapid reading, and couples to horizontal curve flow. One possibility is a *vertical* MFM-3 sensor combined with a moving gradient source. Prior to proceeding to test such a configuration, further theoretical work requires to be done.

- 3 - The accurate total magnetic field survey was not successful in locating the leads. While the artificial sources precluded a meaningful test in this area, a further survey conducted by Amdex at Endurance subsequently gave no significant anomalies over known zones.

Respectfully submitted on behalf of:

SCINTREX PTY. LTD.



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

GEOPHYSICIST

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 four 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 opinion 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

**SCINTREX**

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

# SCINTREX

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 ( $\Delta M$ ):-* 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*

EIP & MIP  
ENERGIZATION

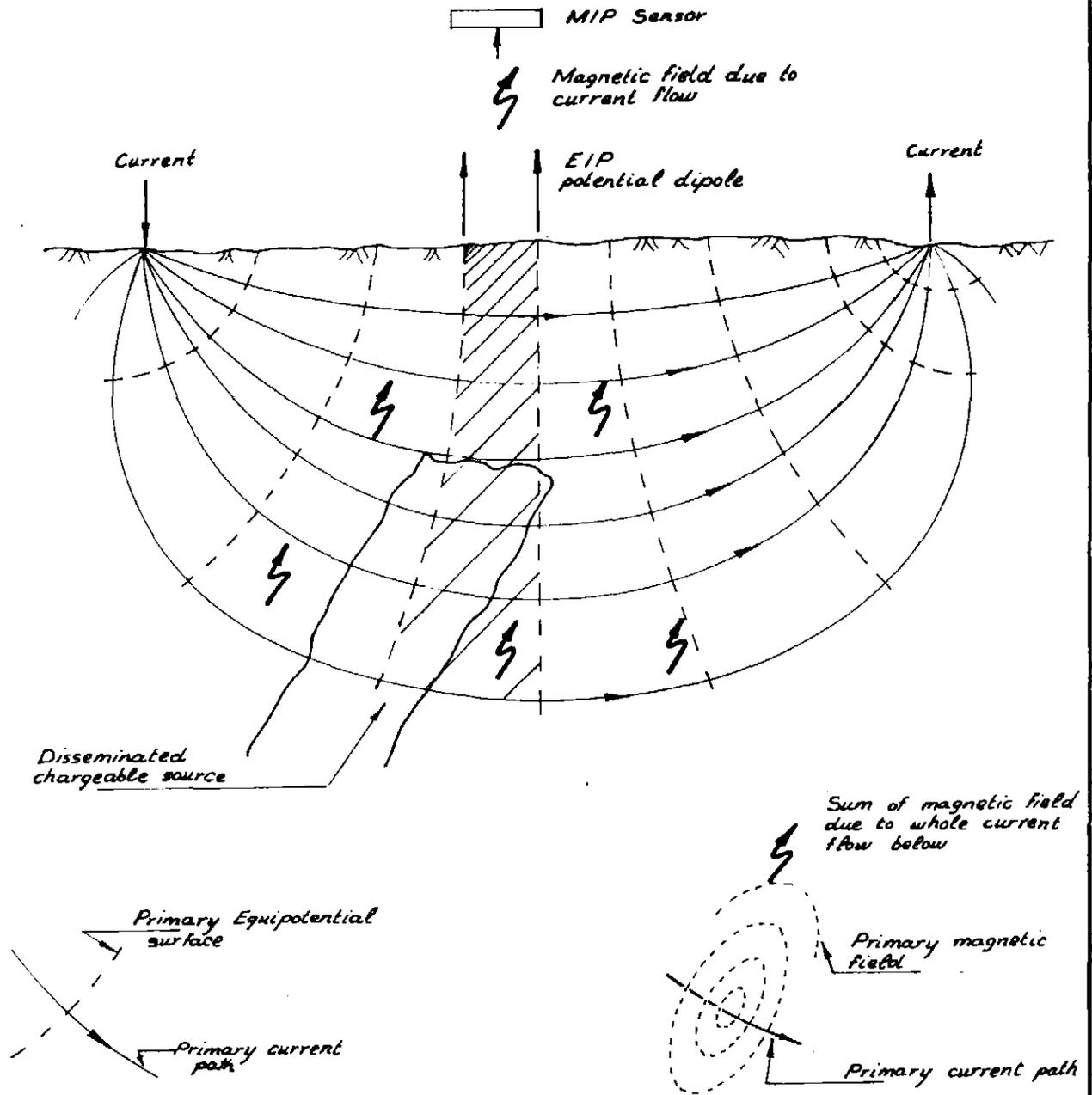


Fig. 1

**SCINTREX**

EIP & MIP  
DISCHARGE OF INDUCED POLARIZATION

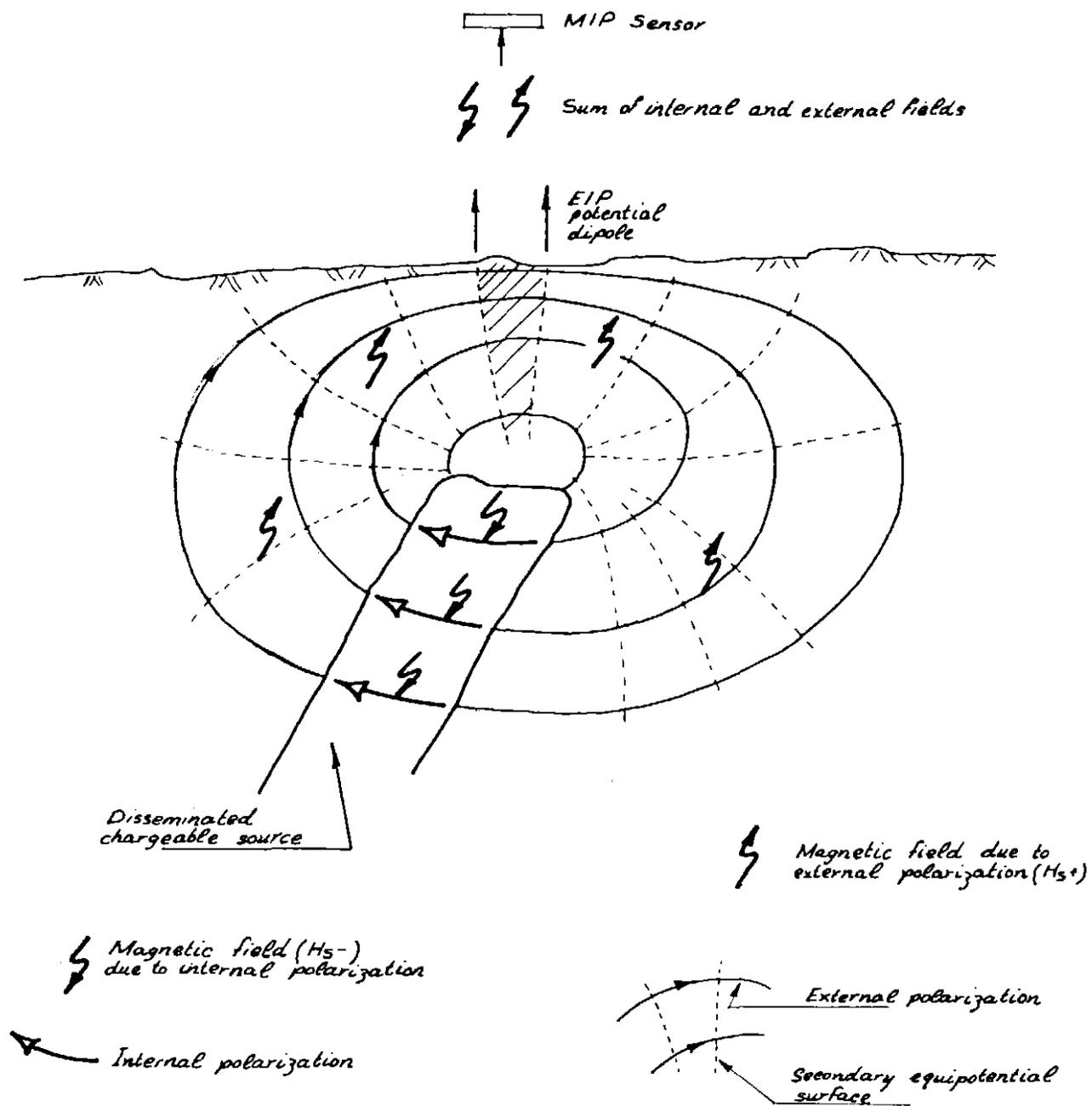


Fig 2.

# SCINTREX

*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 .....*

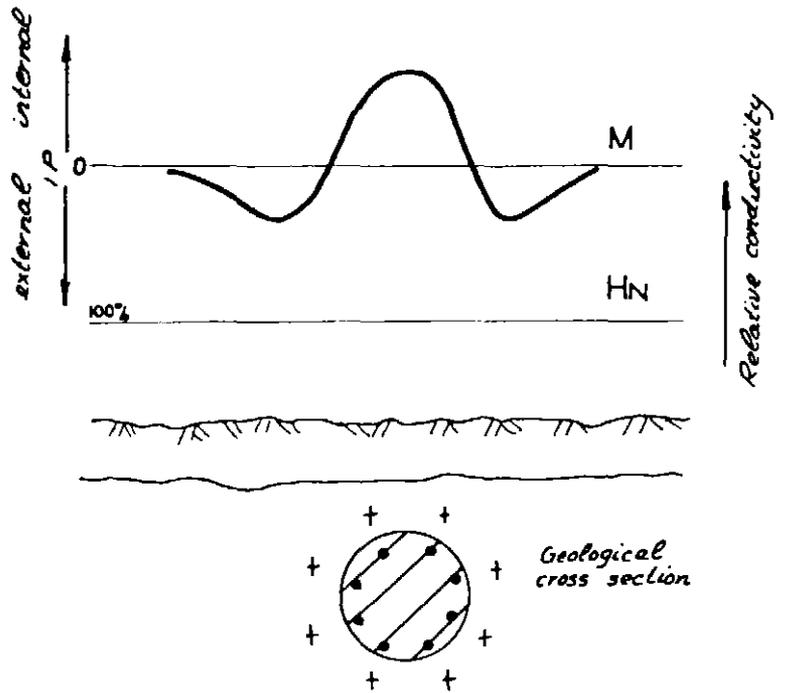
In the MIP method, the energising field is normalised with respect to the energising current electrodes. Details of this procedure are given later in this paper. In the description Figures 3 to 6, the magnetic field due to the primary passage of the energising field  $H_N$ , can be regarded as "relative bulk conductivity" plotted upwards. In these figures, *internal* polarization (which is negative in sign because 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.)

TYPICAL M.I.P ANOMALY FORMS

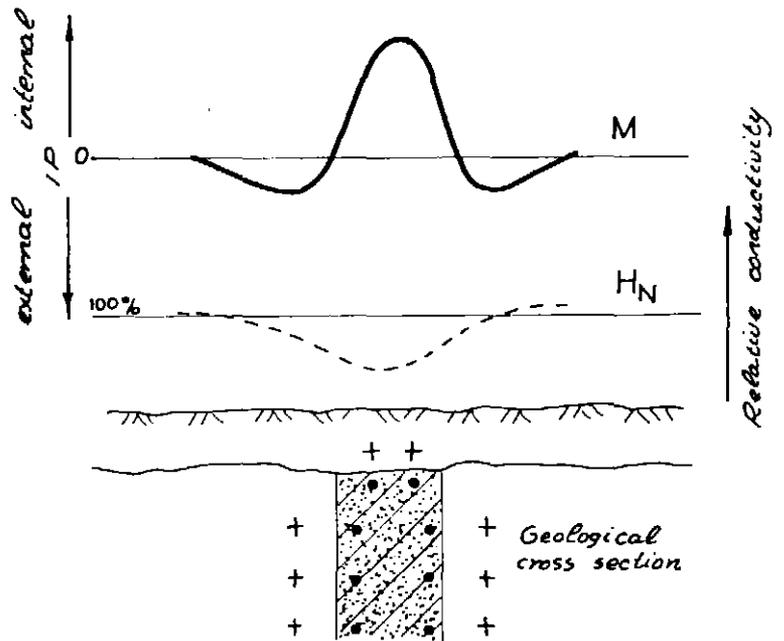
THEORETICAL MODEL

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

# SCINTREX

Page - six

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.

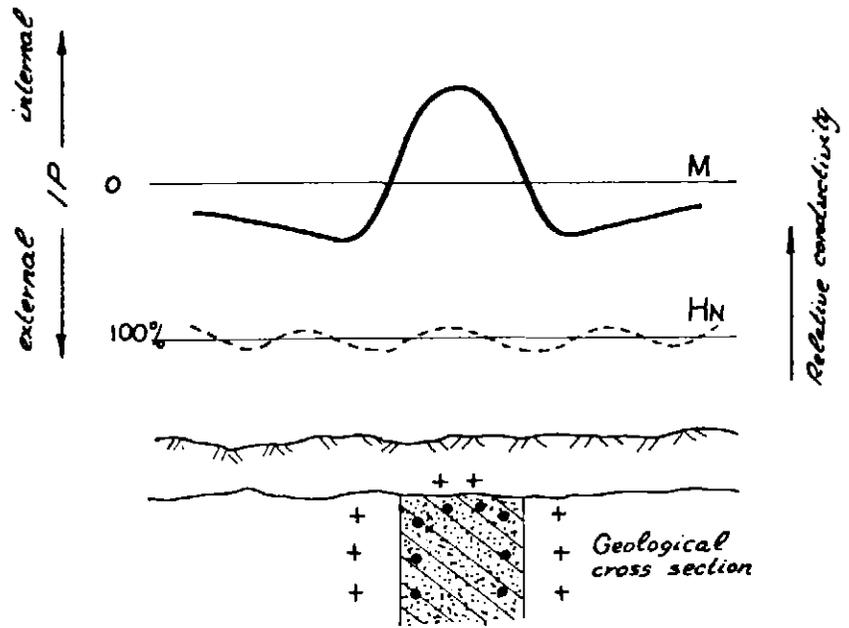
*TYPE 'C'* (Figure 4) ..... In this case the source of the chargeable material is itself more conductive than the enclosing rock type. When the observed  $H_N$  values are *less than* 180% - 200%, a normal "*head and shoulders*" anomaly is observed over the source. In practice, observed  $H_N$  values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

**SCINTREX**

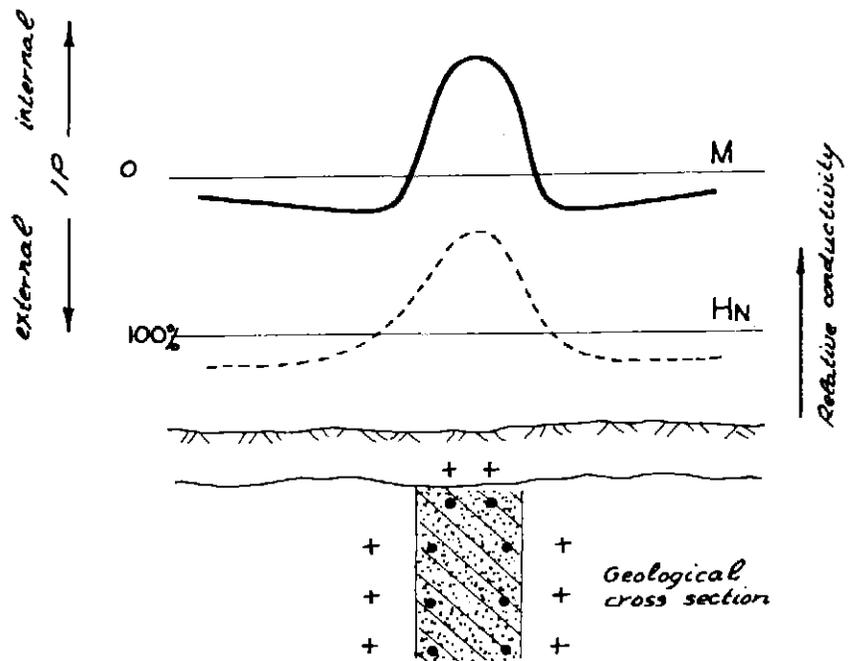
**TYPE B**

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.

# SCINTREX

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.

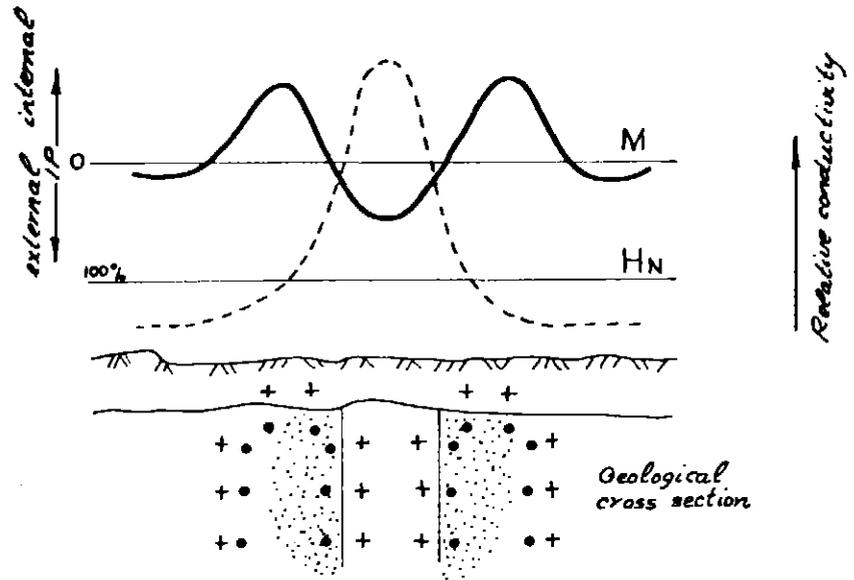
## *Composite Anomalies . . . . .*

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'.

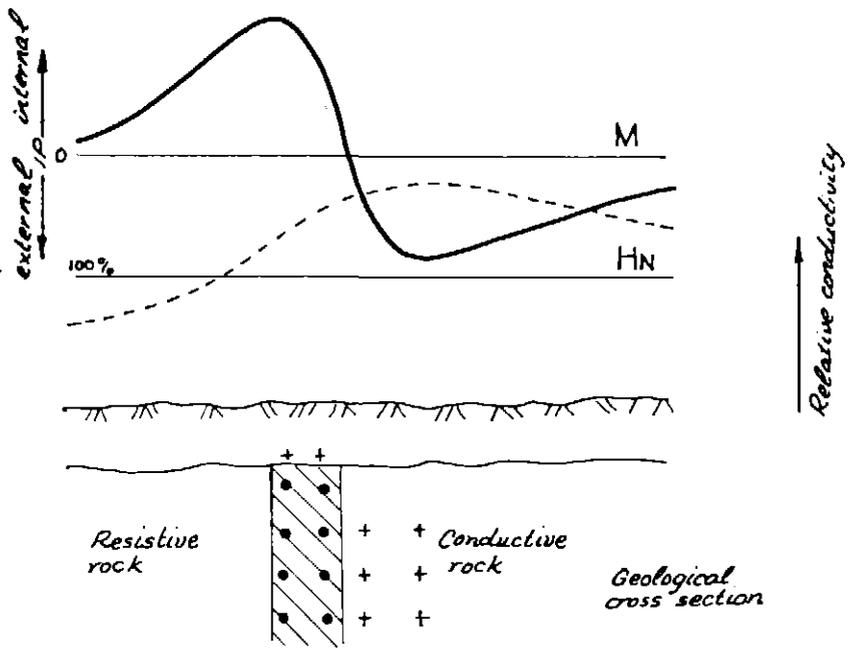
In the interpretation of MIP therefore, the electrical characteristics of known 'Type Deposits' similar to those being sought, together with local information as to the possible range of structure in the area, is of primary importance. In other words, geological input is often of greater importance than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

*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	MIP
		External Polarization Dominating over Body	Internal Polarization Dominating over Body*
Time	Chargeability (M)	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

# SCINTREX

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. However, the *decay form* cannot be as readily acquired in the frequency domain as it can in the time domain. Therefore, where this information is required, time domain is preferable.

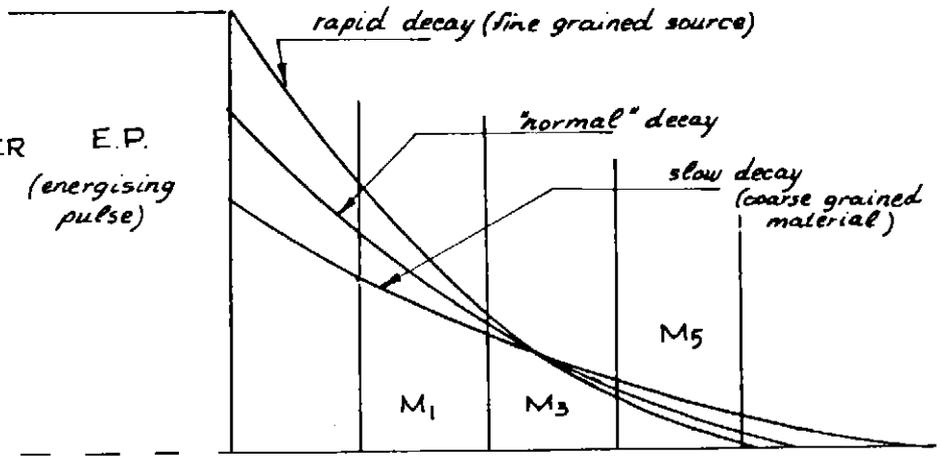
## *The Importance of Decay Curve Information .....*

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

(A)  
 DECAY AS OBSERVED  
 BY IPR-8 MIP RECEIVER  
 PRIOR TO PROCESSING  
 (energising pulse)



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

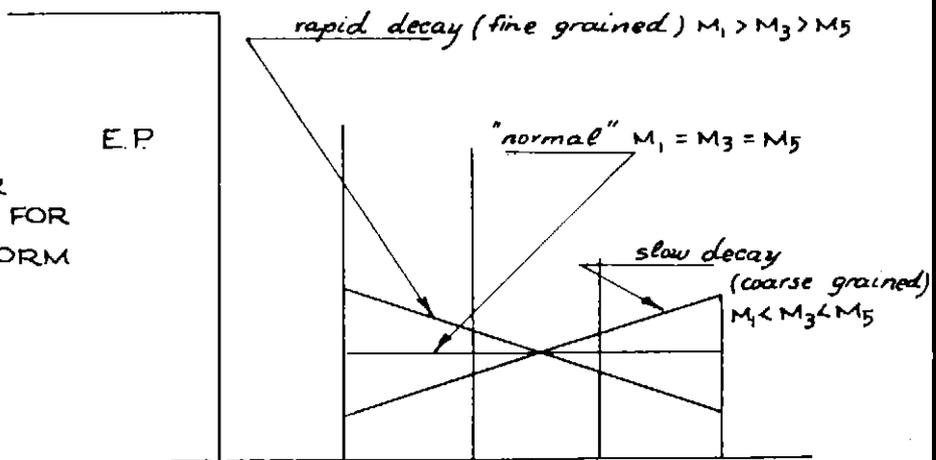


Fig 6.

**SCINTREX**

Page - ten

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

The normalised decay form  $\Delta M_n\%$

$$= \frac{|M_5| - |M_1|}{M_3} \times 100$$

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

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.

*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.*

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. The percentage current penetrating the freshrock can be estimated using the following formula, the basic information for which can be obtained from electrical soundings carried out for this purpose. Down-hole electrical logs are also valuable input into this equation where available.

$$\alpha = \frac{2 \times \rho_2 \times d}{\rho_1 \times L}$$

where:-  $\rho_1$  is resistivity of overburden/oxidation in ohm-metres

$\rho_2$  is resistivity of freshrock in ohm-metres

$d$  is depth of oxidation in metres and  $L$  is size of current dipole in metres

# SCINTREX

Where  $\alpha = 1$  approximately 50% of current will penetrate the freshrock. This rises to approximately 80% for  $\alpha = 0.2$  and falls to approximately 20% for  $\alpha = 3.0$ . The accompanying Figure 3 from *Edwards and Howell, 1976*, shows the total relationship (Note that this relationship holds for ANY current dipole of any domain in magnetic or electric mode). Thus much of the short spaced dipole-dipole work *MUST* be suspect, particularly in areas of masking where the *external* (EIP) component is often shorted out, and does not reach surface.

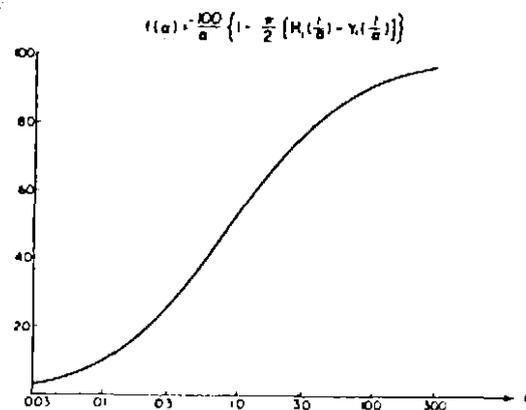


FIG. 3. The function  $f(\alpha)$  which determines the percentage of current remaining in a conductive thin surface layer above a resistive half-space.

## Data Processing and Presentation .....

For large scale, large current dipole frequency domain surveys, the data is processed by computer. In so doing, the MMR together with HSP/I and HSQ/I are presented first as line printergraphs. Some of the components, normally MMR and HSQ/I are then 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  $\pm$  100 metres) precludes a meaningful contour presentation in most cases. Again, a scale of about 1:2500 is favoured.

## Units and Parameters .....

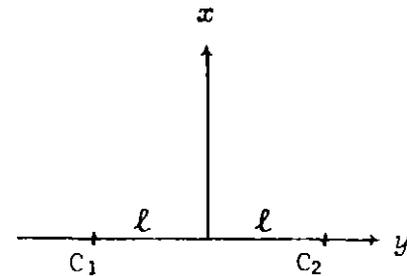
### A - Measurements of relative conductivity of the earth:-

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 ( $H_p$ ), 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:-

**SCINTREX**

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

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 distance between electrodes.



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

$$H_N = \frac{H_P \times 100\%}{M_{\text{Norm}}}$$

$H_N$  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:-

$$\text{MMR} = \frac{H_P - H_{\text{Norm}}}{\frac{200I}{l}} \times 100\%$$

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 the IP 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:-

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

where  $\theta_f$  and  $\theta_{3f}$  are the phase shifts of the fundamental and third harmonic of the transmitted square wave.

**SCINTREX**

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

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

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

*C - 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:-

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

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

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

(ii) In-phase change  $\Delta\text{HSP/I}$

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

**SCINTREX**

Page - fourteen

Both HSQ/I and  $\Delta$ HSP/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 comprehensive understanding of the method.

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

*Significant References:-*

Edwards, R.N. and Howell, E.L. 1976. A Field Test of the Magnetometric Resistivity (MMR) Method. Geophysics Vol. 41 P 1170-1183

Howland-Rose, A.W., 1976. The Magnetic Induced Polarization Method-A Simple Method of Interpretation of Typical Anomaly Forms. 25th International Geological Congress, P 392.

Howland-Rose, A.W., Linford, J.G., Pitcher, D.H., and Seigel, H.O. Field Experience with the Magnetic Induced Polarization (MIP) Method. Geophysics, 1978 (in publication)

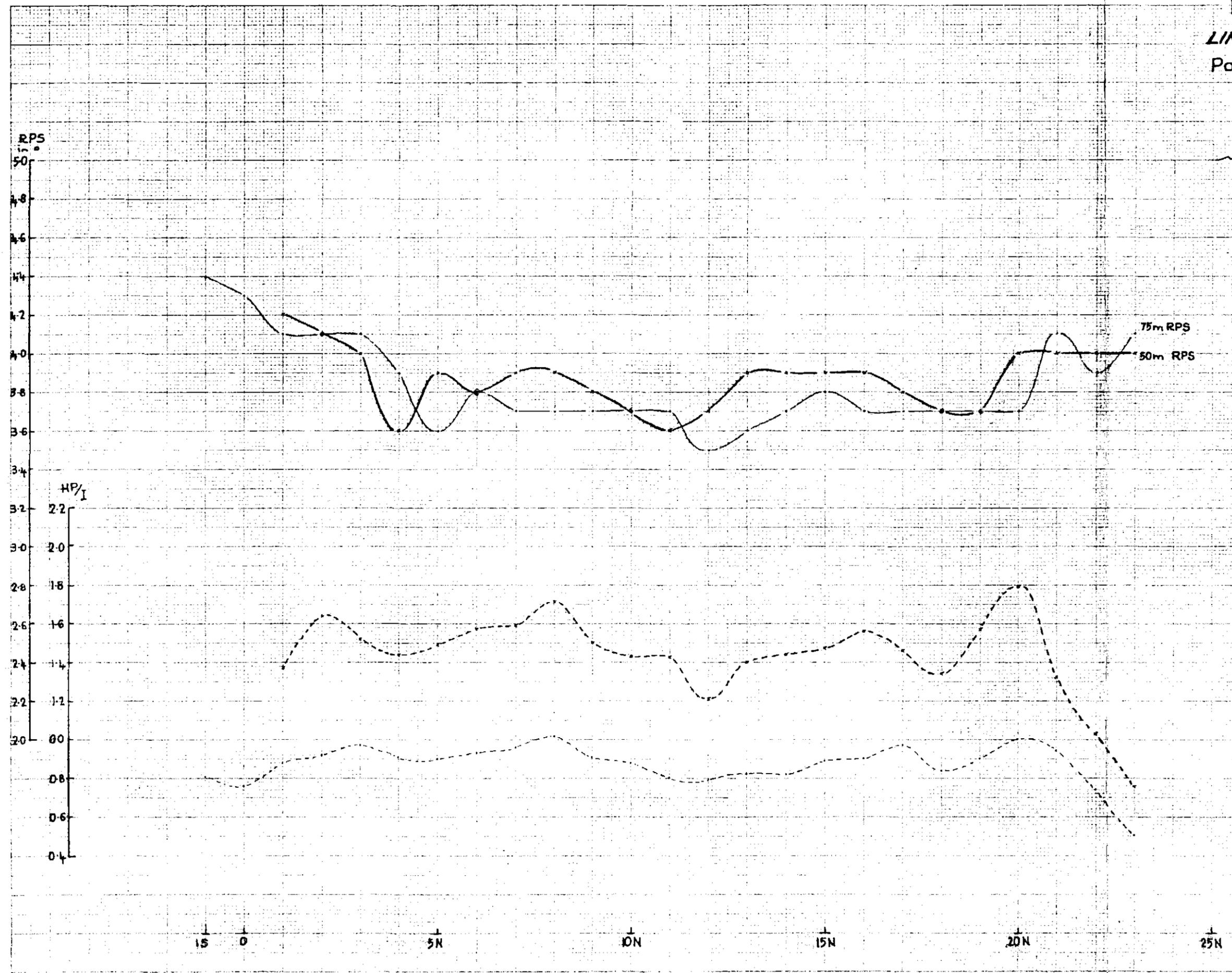
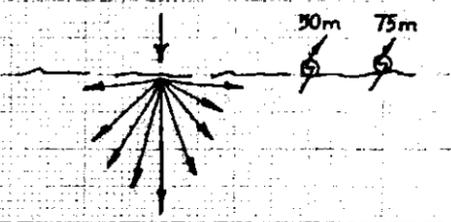
Seigel, H.O., 1959. Mathematical Formulation and Type Curves for Induced Polarization. Geophysics Vol.24, P 547-565.

Seigel, H.O., 1974. The Magnetic Induced Polarization Method. Geophysics Vol.39, P 321-339

Seigel, H.O., Brcic, I, 1976. Frequency Domain IP Measurements using Harmonically Related Components. Scintrex Applications Brief #76-1.

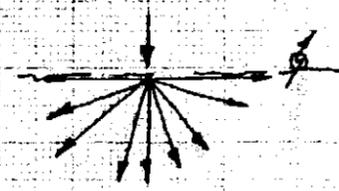
Scintrex Manual on IPR-8 Time Domain Receiver.

Profile 'F' - ENDURANCE  
 LINE P132E  
 Pole source array  
 3Hz  
 TAS-067R



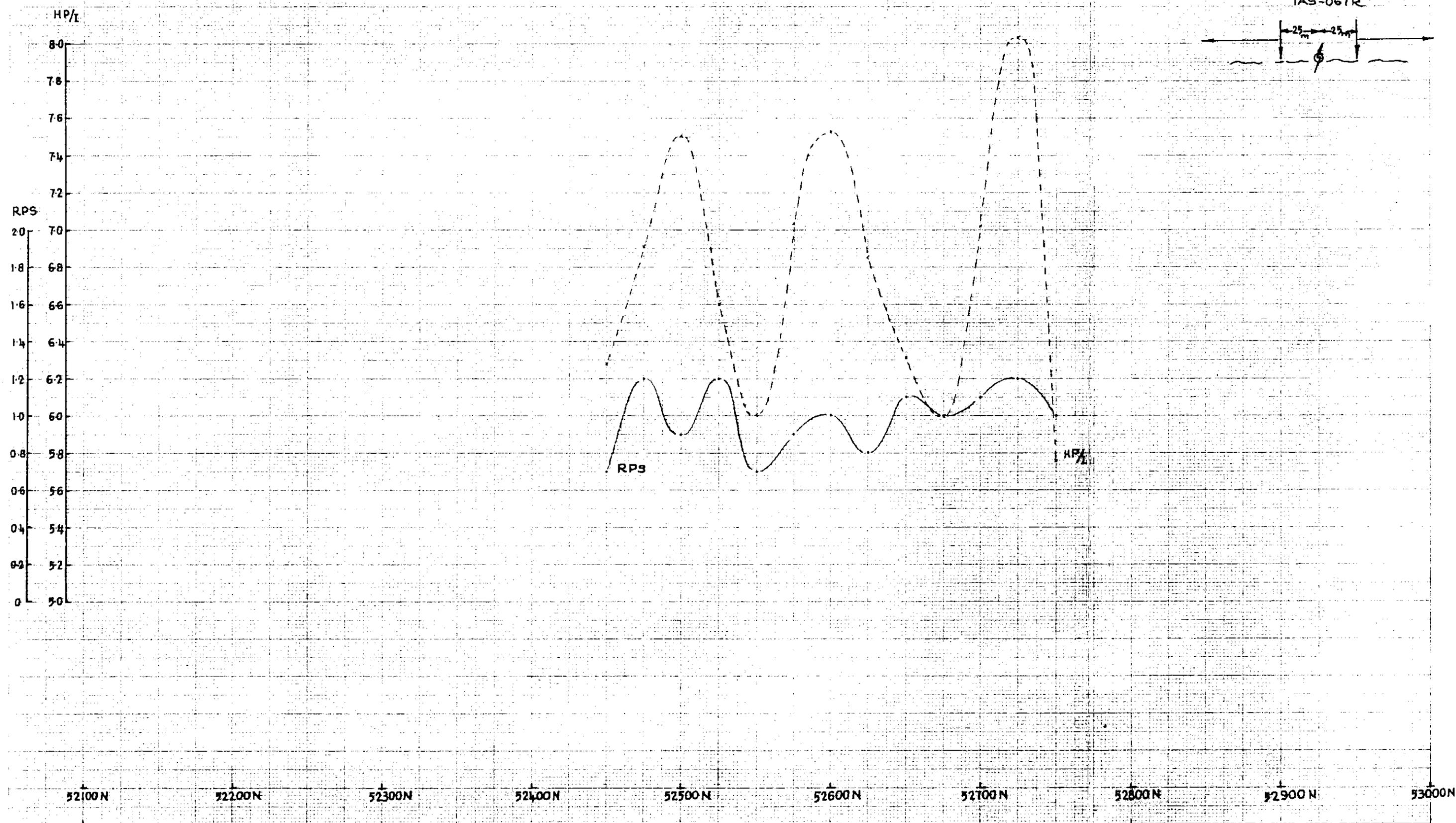
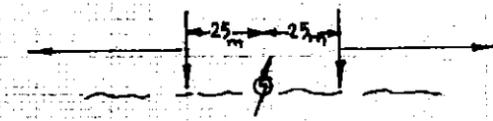
Profile G - ENDURANCE

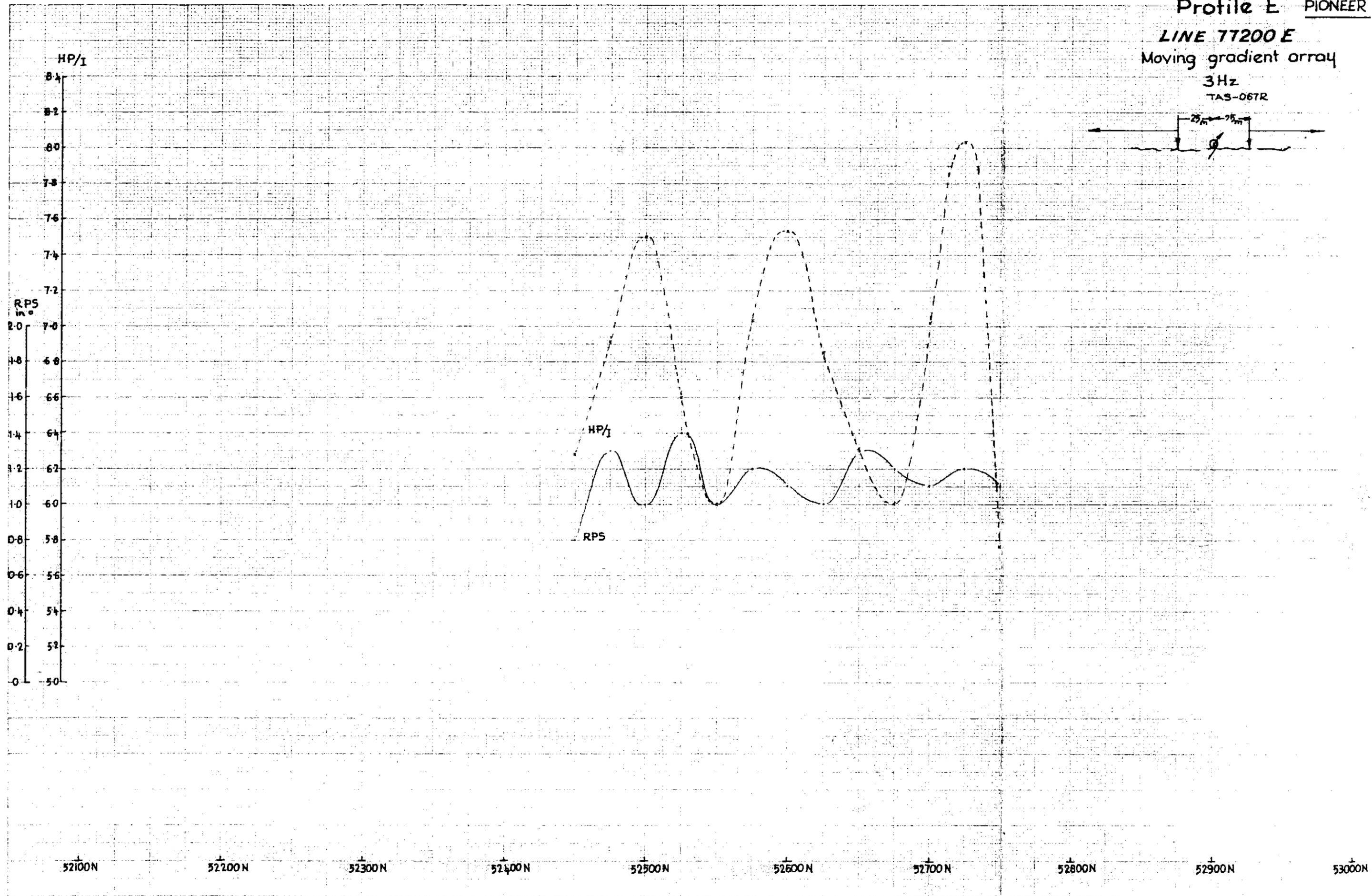
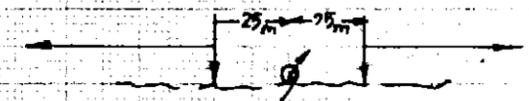
LINE P128  
pole source array  
3Hz TAS-067R



Profile 'E' PIONEER  
LINE 77200E  
Moving gradient array

1 Hz  
TAS-067R





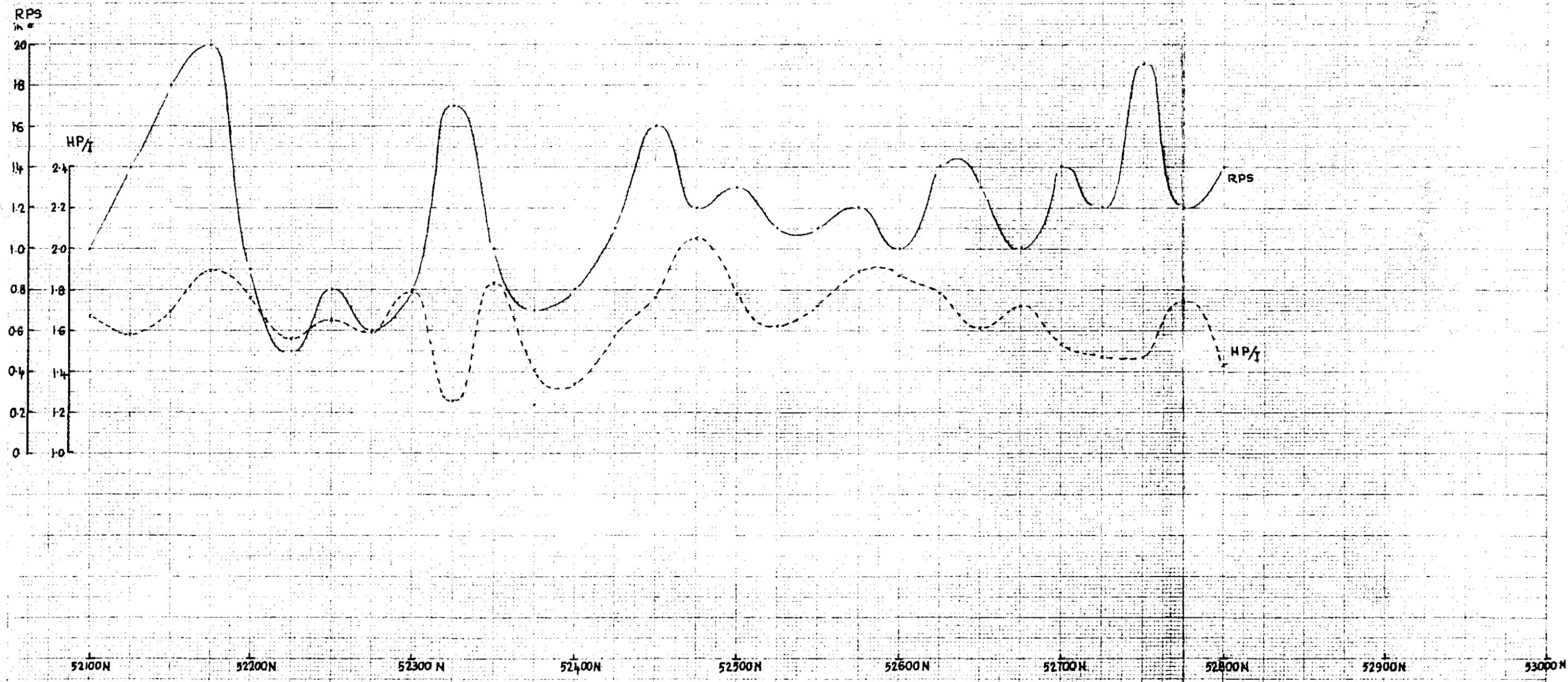
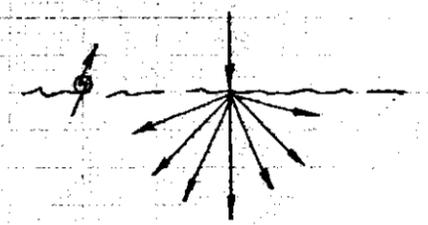
Profile 'D' PIONEER

LINE 77200 E

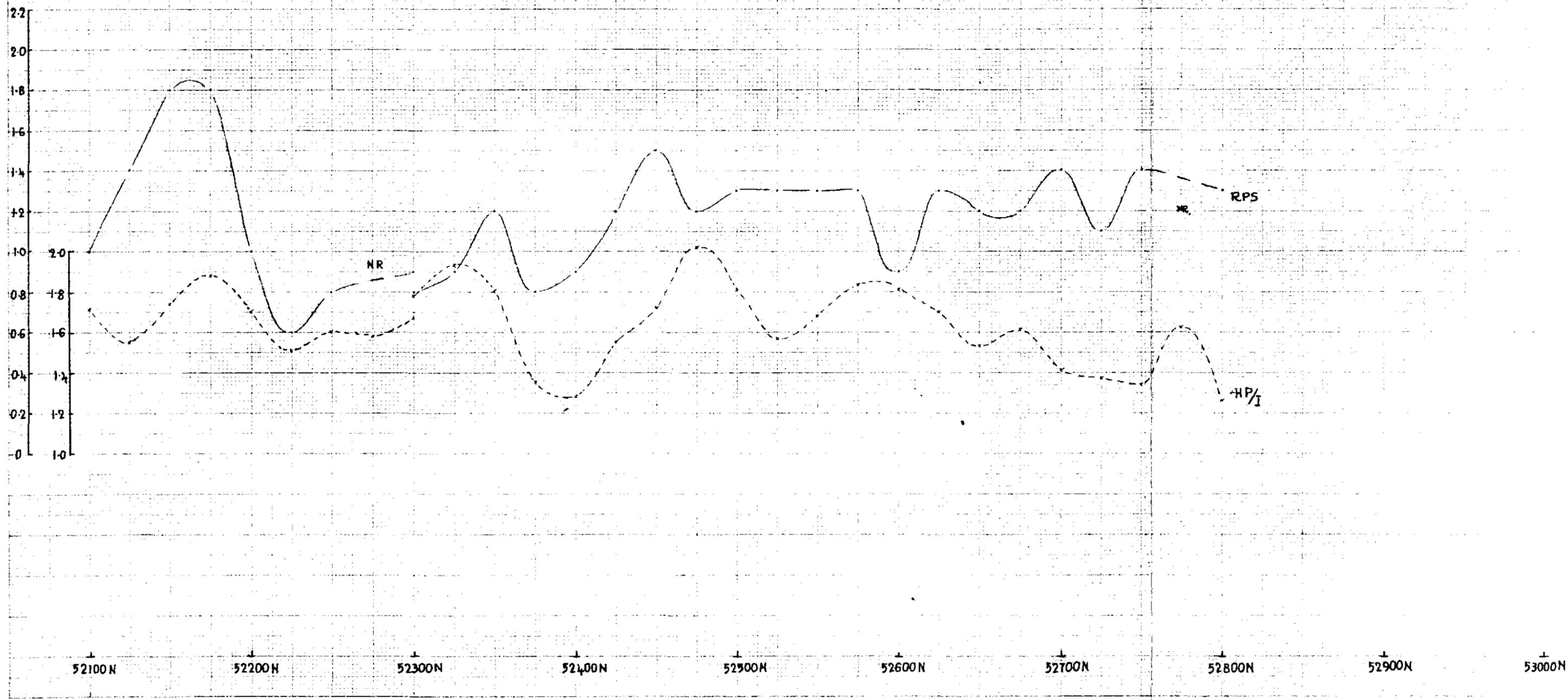
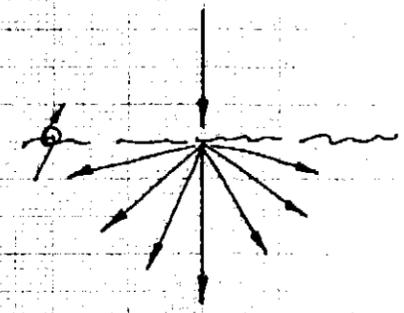
Pole source array

3 Hz

TAS-067R



Profile 'C' PIONEER  
LINE 77200E  
Pole source array  
1 Hz  
TAS-067 R



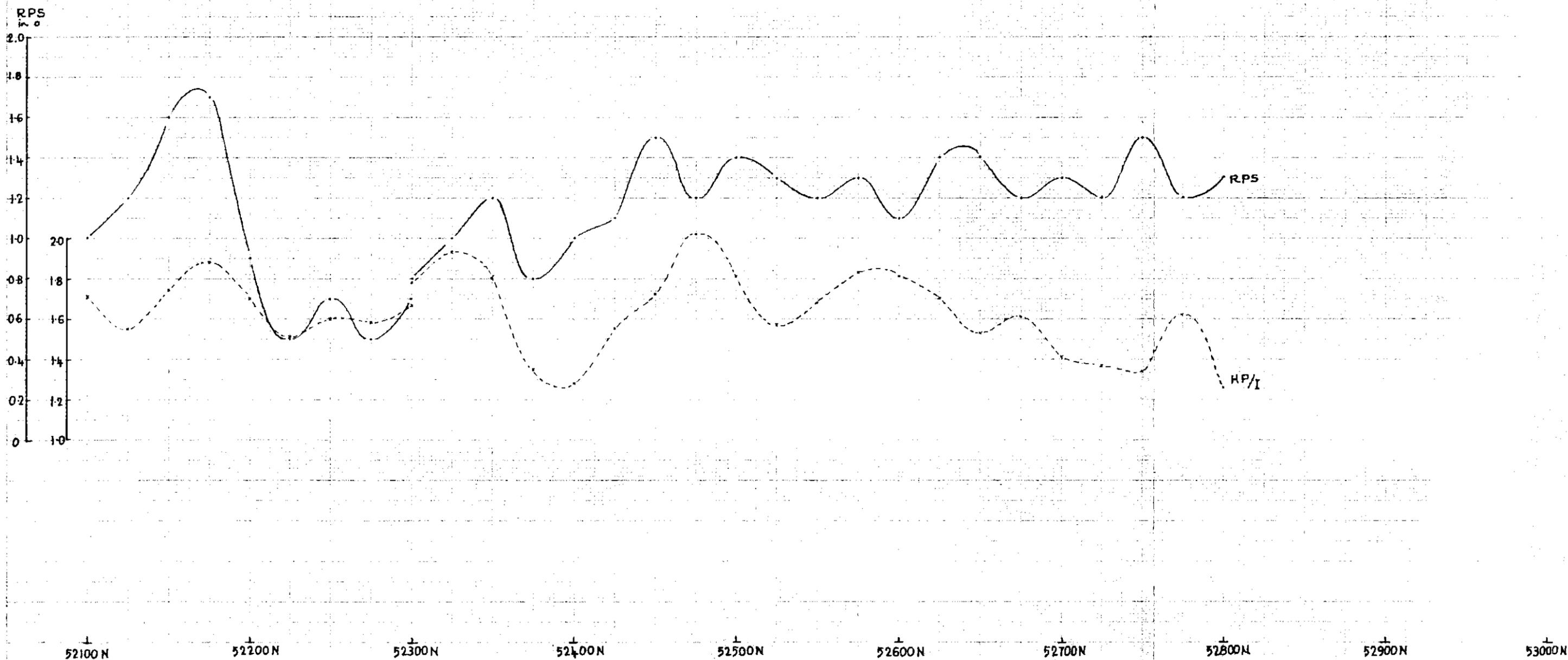
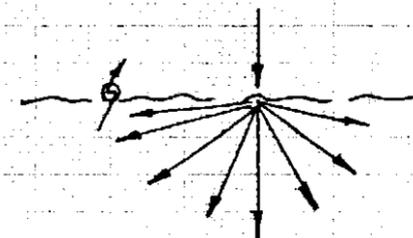
Profile 'C' PIONEER

LINE 77200E

Pole source array

3 Hz

TAS-067R



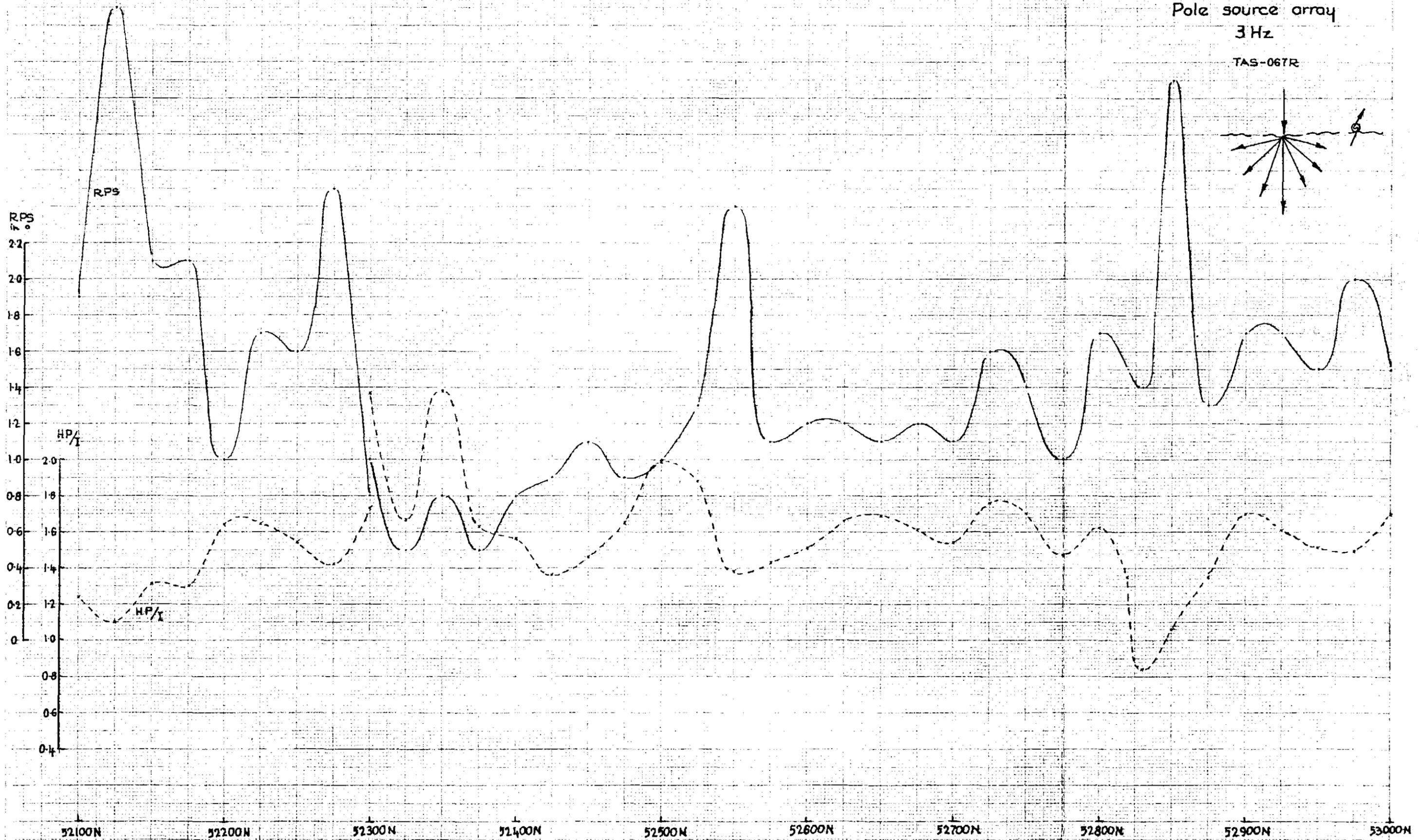
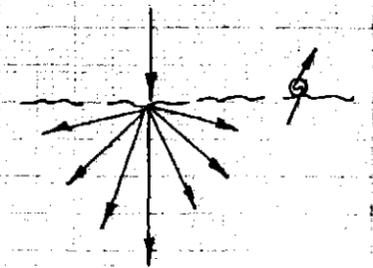
Profile 'B' PIONEER

LINE 77200 E

Pole source array

3 Hz

TAS-067R

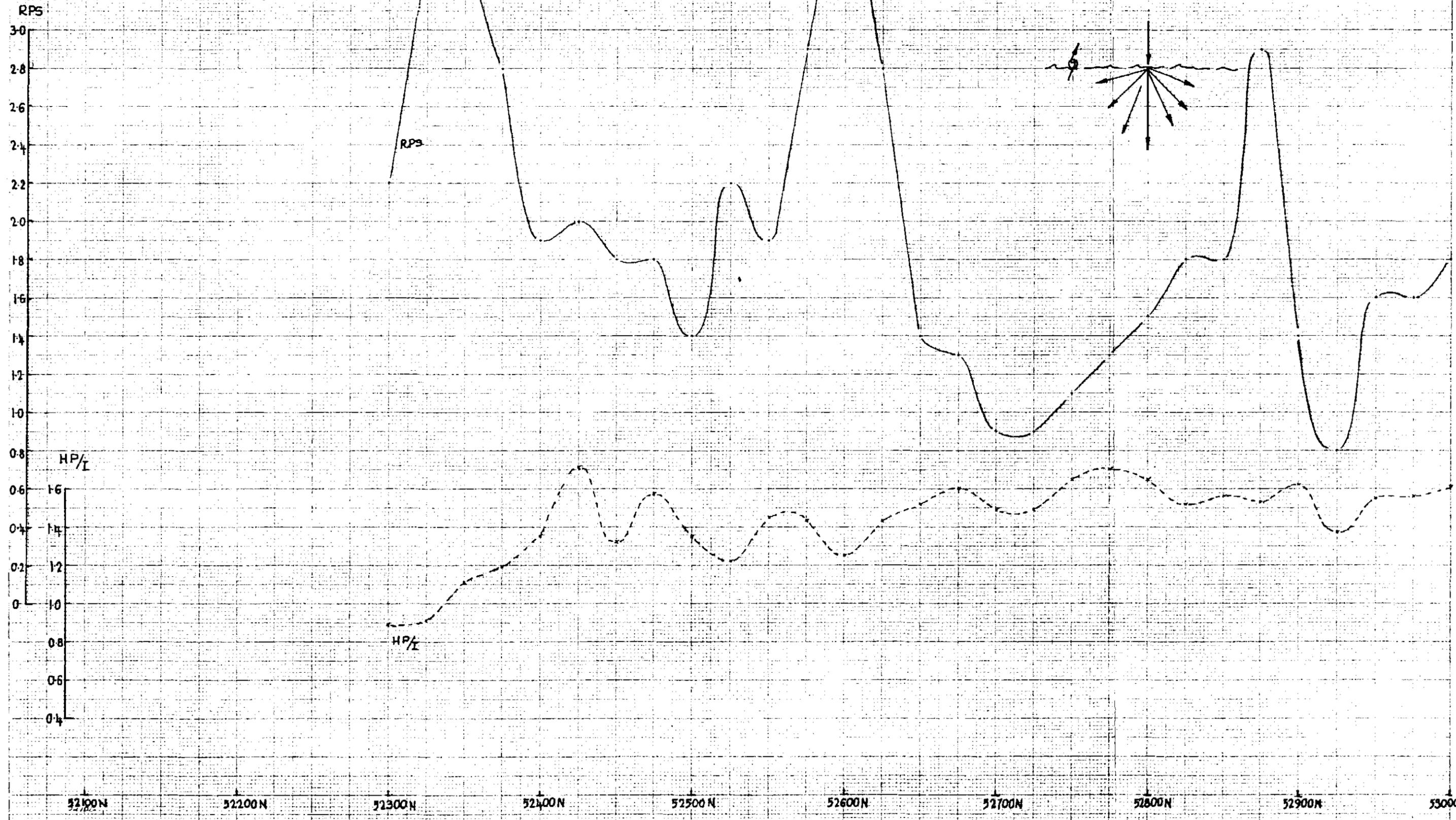


LINE 7700 E

Pole source array

3 Hz

TAS-067R

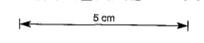




812046  
**95-3712.**

AMDEX MINING LIMITED  
 PIONEER TIN MINE  
 N.E. TASMANIA.

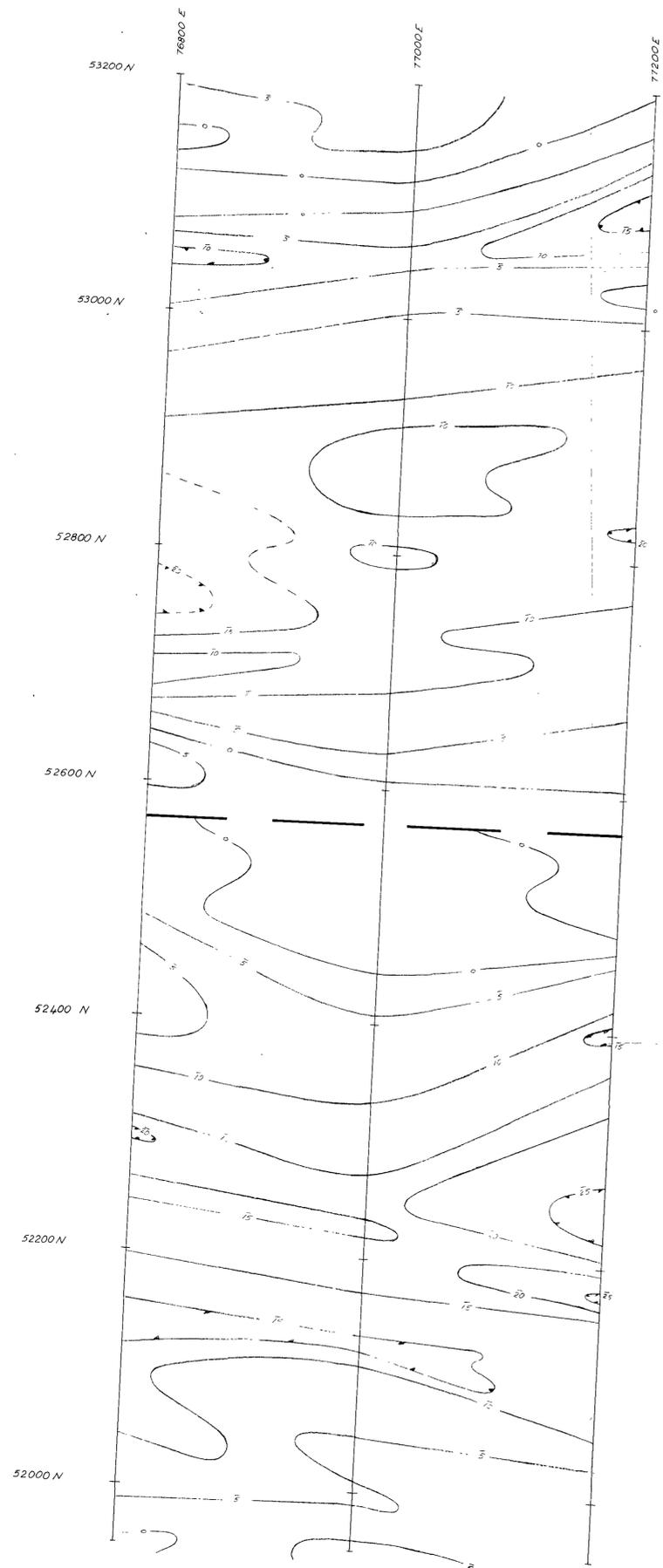
DISTRIBUTION OF  
 HEAVY MINERAL FRACTION



COMPILED BY  
 SCINTREX



SCALE 1:2500



812045

**95-3712.**

AMDEX MINING LIMITED  
PIONEER TIN MINE  
N.E. TASMANIA

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

SURVEYED & COMPILED BY  
SCINTREX



DECEMBER 1978

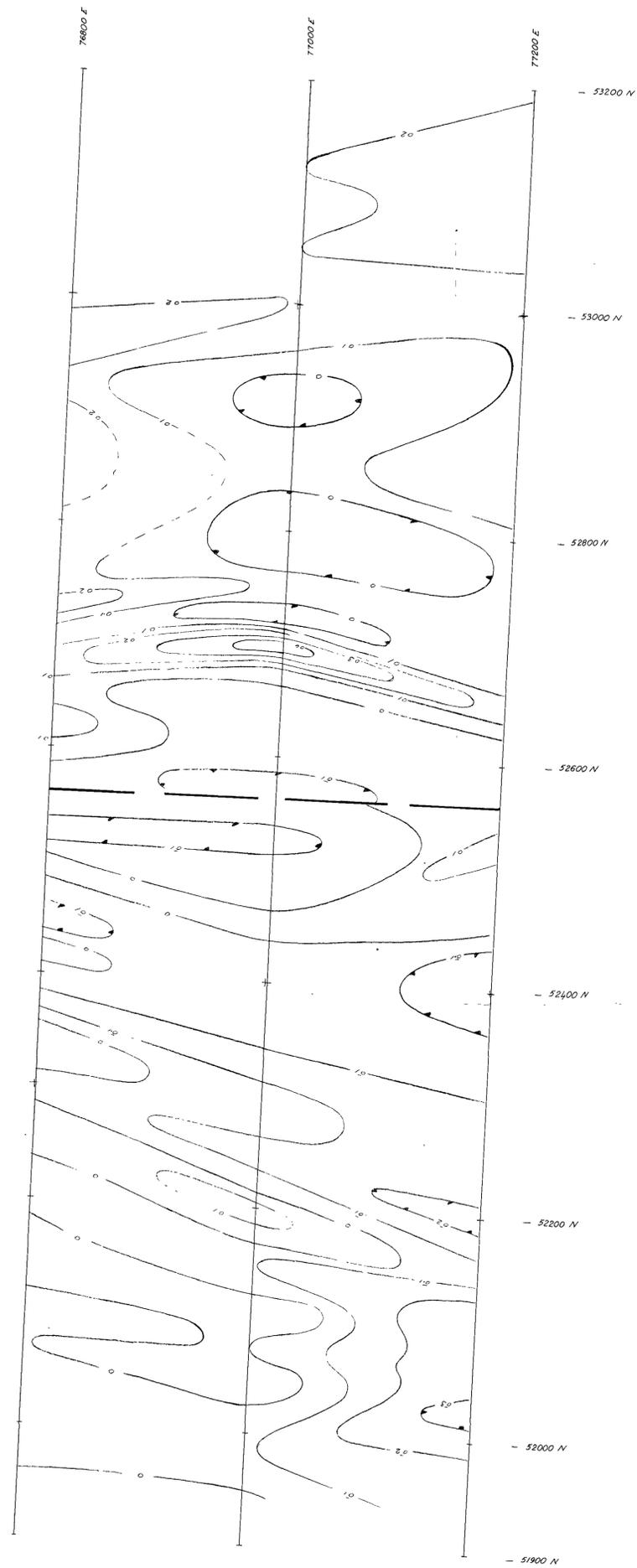
SCALE 1:2500

Job N° TAS-067 R

SH 1 of 1

PLATE 2





812047

**95-3712.**

AMDEX MINING LIMITED  
PIONEER TIN MINE  
NE TASMANIA

R.R.M.I.P SURVEY  
RELATIVE PHASE SHIFT (m°)  
CONTOUR PLAN

SURVEYED & COMPILED BY  
SCINTREX

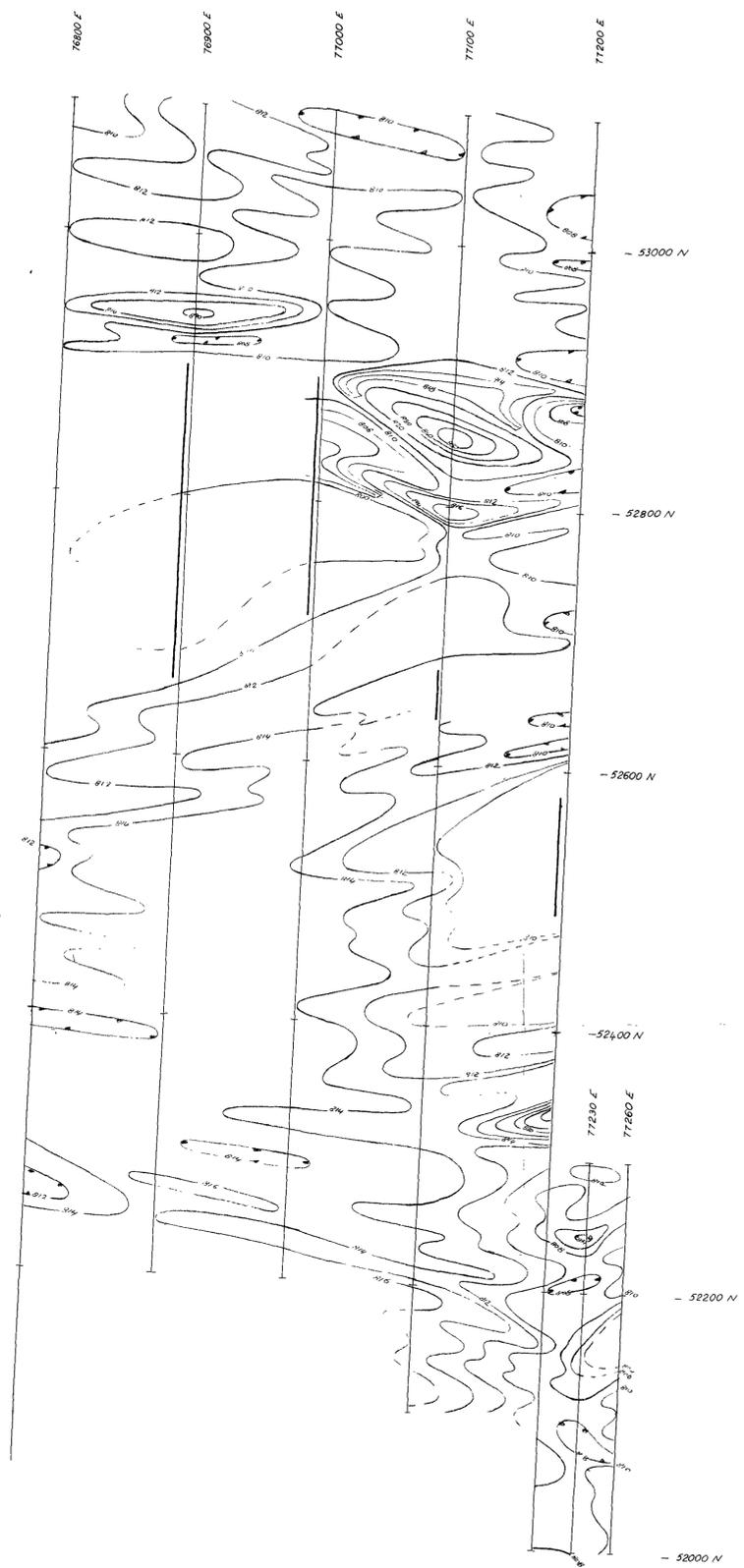


DECEMBER 1978

SCALE 1:2500

Job No TAS-06TR Sht 1 of 1 PLATE 3





**Legend**

 Readings affected by artificial objects

Add 61,000 gammas to all values for total magnetic field

812048

**95-3712.**

AMDEX MINING LIMITED  
PIONEER TIN MINE  
N.E. TASMANIA

TOTAL MAGNETIC FIELD SURVEY  
CONTOUR PLAN

SURVEYED & COMPILED BY  
SCINTREX



MARCH 1979

SCALE 1:2500

JOB NO TAS-069      Sht 1 of 1      PLATE 4

