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AN EVALUATION OF GEOPHYSICAL SURVEYS

OVER THE FEDERATION GRID, HEEMSKIRK GRANITE,

WEST TASMANIA

FOR

RENISON LIMITED

BY

DR. J.R. BISHOP

RN/MG81/10

SEPTEMBER, 1981



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## SUMMARY

The Federation Grid covers most of the old workings and prospects of the South Heemskirk tin field. Geophysical surveys over the grid include I.P., magnetics, a trial E.M. survey and some radiometric data. I.P. has been the most useful.

Roberts (1980a) has identified four types of targets on the Federation Grid. They are: (1) stanniferous greisen; (2) sericitic alteration; (3) quartz-tourmaline-topaz alteration 'dykes' (the so-called 'white dykes'); (4) polymetallic sulphides. Most of the tin won from this field has been taken from small tin-rich lodes within the white dykes, however the largest proven reserve of cassiterite is at Sweeney's, a type - 4 target. A gradient array I.P. survey was conducted over Sweeney's and, based on the excellent chargeability anomaly obtained, a similar survey was made over what is now the Federation Grid.

The survey showed a definite division within the granite. A roughly NW-SE boundary running through Lake Cumberland separates the grid into two zones: to the south, higher resistivities and chargeabilities, and to the north, lower resistivities and chargeabilities. This line had previously been thought to separate the 'red' and 'white' granite phases, however this interpretation is not supported by the present geological map, and I suggest that the lower values of the northern area (which contains most of the old workings) may be the result of a higher degree of alteration.

The magnetic coverage produced a similar boundary, though in a quite different position and direction (approx. NW-SW, south of Lake Cumberland). The boundary is wholly within the 'red' granite. To the south east, the area is magnetically very 'active'; to the north west (which includes



nearly all the old workings), the magnetics are very 'quiet'. Nevertheless, several workings show small, but well defined magnetic anomalies. Both the IP and magnetic boundaries are parallel to major lineaments within the granite.

The trial EM survey used a Crone PEM system which was tried, unsuccessfully over Sweeney's (potentially the best target) and over two mineralised areas on the grid. The mineralisation and/or alteration is not sufficiently conductive to produce significant EM anomalies. However, the limited petrophysical measurements and the resistivity lows of the IP surveys over the old workings suggest that areas of alteration (and mineralisation) might be usefully mapped by EM systems capable of producing resistivity maps or pseudo-sections.

Spectrometer data has been collected in two separate surveys. In the first, mineralised altered and unaltered core from Sweeney's was tested, but no significant variations were found (Wells, 1977). In the second survey, part of a much broader project by the Bureau of Mineral Resources (assisted in Tasmania by the Department of Mines), a few samples from the North and South Heemskirk tin fields were tested. The three samples from mineralised areas within the Federation Grid do not appear to fit the regional model (that tin-bearing granites have a relatively high u:th ratio), however more samples from a larger survey could perhaps produce a useable, local model for the Heemskirk granite.

IP was the most appropriate geophysical method for the initial reconnaissance of the Federation Grid: this is shown by the chargeability and/or resistivity anomalies over all the old workings (as well as by laboratory measurements of a limited number of samples from drill core). The detailed gradient array survey was (correctly) designed to find another Sweeney's, however it probably would not detect some of the other target-types, particularly if these are buried. This conclusion



was reached from an examination of coincident dipole-dipole and gradient array IP surveys on the grid; the gradient array results generally correlated with the shallower dipole-dipole readings and the resistivity lows were not as well developed. Thus for the more subtle alteration targets, with or without (minor) sulphides, deeper-looking, dipole-dipole or pole-dipole IP surveys are necessary.

The gradient IP survey did not find any anomalies comparable to the 60+ mv/v over Sweeney's, however several anomalies were defined. The better anomalies are being followed up with dipole-dipole (or pole-dipole) surveys and results from some of these are promising, (e.g. off the south-west corner of the grid): other anomalies have yet to be followed up and these are listed at the end of this summary. A comparison between the follow up surveys and the original gradient array surveys shows most of the gradient anomalies to be poor targets, and clearly, multi-separation array surveys are needed to verify and better define the gradient array results before drilling.

Where worthwhile anomalies are found, the results should be thoroughly interpreted, i.e. the size, shape and position of a likely causative body should be established prior to siting a drill hole. A rough interpretation can usually be obtained from type curves over idealised bodies (in published books), but computer modelling is often required to obtain a good approximation to the field results. An interpretation has been done for two dipole-dipole and one pole-dipole survey on the Federation Grid; this includes computer modelling of the interesting results on 1700W. (Modelling is also useful for determining parameters of a survey, e.g. the best dipole spacing for dipole-dipole surveys over deep alteration type targets.)



An examination of those holes sited on geophysical targets shows that some have not effectively tested the target, however if the expectation is for a large-volume, low-grade deposit, then the hole has probably adequately tested the area, if not the cause of the anomaly. The examination also showed that at several holes the IP did not penetrate to the depth of interest: as stated above, deeper multi-separation array IP surveys are needed for exploration of these deeper zones.

The geophysics is only one aspect of the exploration effort on Heemskirk and to be effective, the results must be meaningfully represented when integrating the geophysics into the overall program. To date all IP anomalies have been shown as narrow axes, with no classification as to type (chargeability or resistivity) or grade. In this report the chargeability and resistivity anomalous areas are shown separately, with high value (chargeability) and low value (resistivity) contours to indicate grade. Gradient array anomalies which are recommended for follow-up by dipole-dipole (or pole-dipole) surveys, are listed below with the approximate location of the centre of the spread.

<u>Line</u>	<u>Spread Centre (Approx.)</u>	<u>Line</u>	<u>Spread Centre (Approx.)</u>
1700W	1200S	300W	510S, Fed 7
1600W	570S	250W	540S
700W	810S	200W	540S
500W	450S	100E	420N, 660N
450W	420S	200E	420N
400W	510S	300E	720S
350W	510S	400E	420N

The above recommendations are for detailed surveys for a small Sweeney-type deposit. To evaluate the effectiveness of large dipole multi-separation arrays for large volume low-grade (and probably low-sulphide) deposits, a



100m dipole-dipole spread is recommended over Waxman and Weston's along line 600E. (And if another drill hole is planned in this area, then over this proposed site also.) A similar survey is also recommended across the grid to see if there are any bulk changes at depth: line 300W is recommended, over its entire length.

Despite the above recommendations for follow-up of gradient array anomalies, the likelihood of another (or better) Sweeney's on the Federation Grid does not appear to be high, and the tin assays from the drilling of the old prospects have mostly been sub-economic: the promising chargeability anomalies off the south-west corner of the grid, suggest that exploration could be extended to include more of the granite outside of the present grid boundaries; and the fact that the near-surface mineralisation has either been worked out, was too small, or perhaps weathered away (areas of soft alteration?), suggests that exploration within the present grid should look deeper.



## AIM AND INTRODUCTION

The Heemskirk Granite is a Devonian adamellite-granite situated on the West Coast of Tasmania, due west of the township of Zeehan. Alluvial tin was first found at North Heemskirk in 1876 and lode tin in 1879. The total recorded production from the Heemskirk field was at least 1,300 tons of concentrates containing some 814 tons of metallic tin (Blisset, 1962). The Federation Mine was the biggest mine, producing about 322 tons of cassiterite (194 tons of metallic tin) up to 1938 when the leases were relinquished. Since then, there has been a small annual production mainly from small detrital or alluvial workings.

The Federation Mine is situated in the South Heemskirk tin field and the Federation Grid covers the west, central and eastern Federation workings as well as several other old mines and prospects. The Grid totals about 50 line km with lines spaced 100m apart and pegged at 30m intervals. The direction of the lines is approximately NNW-SSE.

The tin occurs as cassiterite (with only minor occurrences of stannite) in various favourable zones, some of which contain sulphides. Geophysics, unable to directly detect cassiterite, has been used to detect associated sulphides, with an expectation that it may also help to define other target areas, e.g. the various alteration zones. The whole grid has been covered by gradient array IP and magnetics; portions of several lines have subsequently been surveyed with dipole-dipole or pole-dipole IP.

The purpose of this report is to establish the effectiveness of the geophysical surveys carried out so far, and to make suggestions for any further programmes.

## GEOLOGICAL TARGETS

The geological settings of the various old mines and prospects.



on Heemskirk are often quite different: some contain large percentages of associated sulphides, others none; some are associated with quartz-tourmaline, others are not. The Renison Annual Reports (1976 to 1980) show a series of evolving models which have attempted to categorise these mineralised occurrences. These models are used to try and predict where tin may be expected and hence to help decide a target priority for drilling: obviously the models have changed as more holes have been drilled. Roberts (1980a) has described the current models and there have been several briefing periods with the writer. The models are discussed below following a brief description of the general geology. Unless otherwise stated, the material has been taken from Roberts (1980a).

The granite has been classified into two phases; a 'red' older granite, and a 'white' younger granite. A possible third phase is an aplite, occurring in dykes or small intrusions: this generally has been classified with the 'white' granite, but it has also been mapped intruding it. The 'red' granite is characterised by pink k-feldspar, fresh character of biotite and an absence of muscovite. It ranges from coarse to fine grained and is sometimes porphyritic. The 'white' granite is characterised by white k-feldspar, a presence of muscovite (particularly in the coarse grained variety) and the presence of disseminated tourmaline away from (intra-granite) contacts. From the above, it is evident that the granite type may not necessarily be classified by its colour in the field, Wells (1978) states that the colour in both types varies considerably, with the 'red' granite in particular varying from bright red through pink and blue/green to white. The contacts between the 'red' and 'white' granites are sharp, although the 'white' is generally not chilled. There is often a high concentration of tourmaline/quartz nodules in both 'red' and 'white' granites near the contact. The contacts are regionally near horizontal although locally they are irregular. A plan of the geology of the South Heemskirk area is shown in Figure 1.



Petrologically the two granites are very similar both varying between granite and adamellite. They may be distinguished by their accessories: the 'red' granite contains zircon, magnetite, apatite, xenotime, fluorite (with sphene, allanite and haematite); the 'white' granite contains tourmaline, muscovite and fluorite (all introduced?). Historically the 'white' granite has been referred to as the 'tin' granite.

Before any geophysical program is embarked upon, the target must be clearly defined: the expected physical contrasts stated, so that the appropriate method is used; the size, depth, etc estimated, so that the appropriate survey parameters can be calculated. This may be difficult for projects such as Heemskirk, where the commodity sought (cassiterite) is not directly detectable. (Its one contrasting property is density, but unfortunately it never (?) occurs in sufficient concentrations to permit the use of gravity as a direct exploration tool.) Nevertheless, Renison have developed a series of models used to classify and predict the occurrence of cassiterite at Heemskirk.

Roberts (1980a) has identified four types of targets for tin mineralisation. They are:-

1. Stanniferous greisen - quartz/muscovite/topaz  $\pm$  cassiterite  $\pm$  sulphides. An orebody in this environment would be large (>10 million tonnes) and low grade (.1 - .5% Sn). The anticipated shape would be roughly equidimensional, with a (?) flat top, if controlled by granite contacts. The Black Face at Central Federation is the main (sub-grade) example of this type of mineralisation. A tourmaline-quartz dyke, (which envelopes a breccia pipe) is surrounded by a halo of argillic alteration. The tourmaline-quartz contains variable amounts of tin (from <0.01% to >1.0%); the alteration generally contains <.01% tin, but locally this may be much higher. This is contained within a



relatively fresh red granite which is dissected by numerous greisen veins: these increase in frequency towards the main 'lode'. Tin values range from about 0.01 to .09%, rarely higher (see Figure 2).

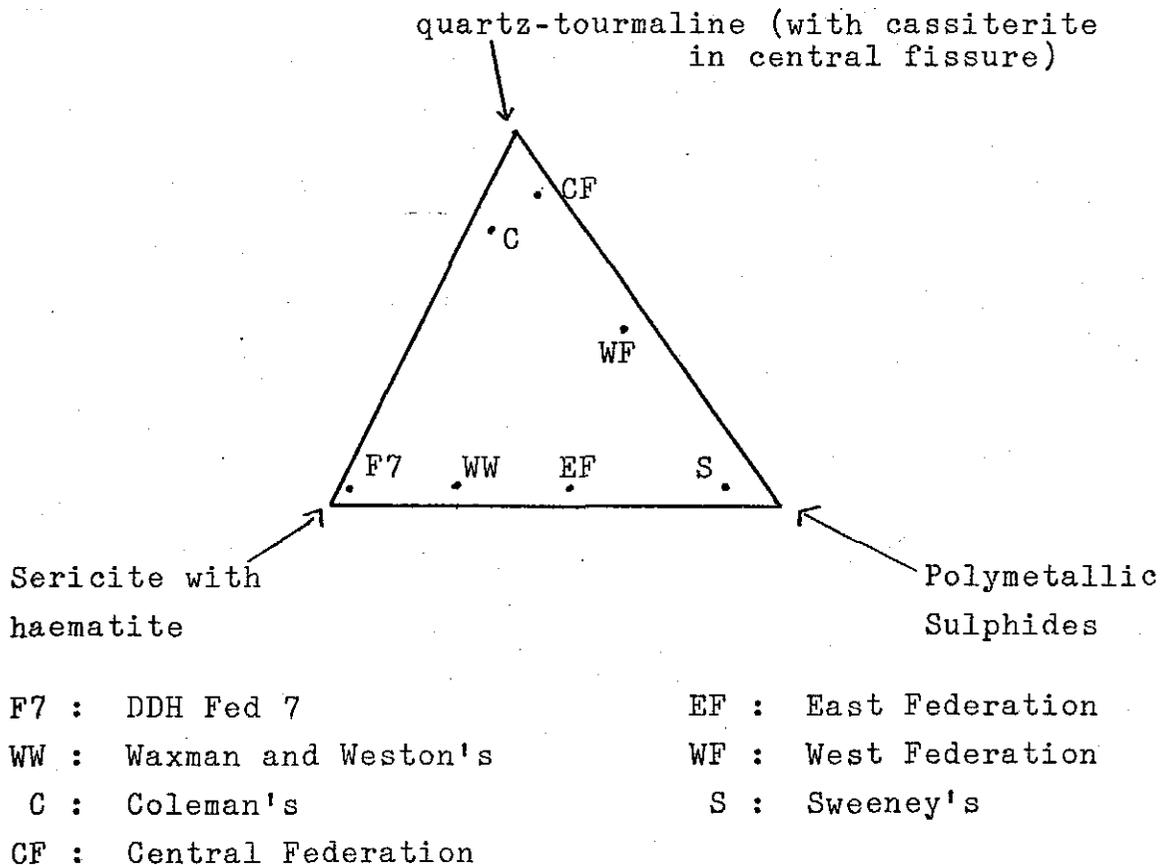
2. Sericitic Alteration - This rarely outcrops but is common in drill holes. The mineralogy is sericite ± pyrite (upto 4% sulphur) ± haematite/magnetite ± residual quartz ± sphalerite: tin is patchy. The significance of this type of mineralisation type is unknown but it may halo a higher grade orebody in a pipe or fault-bound situation. Shape is probably roughly equidimensional or elongate, parallel to fault orientations. An example is the Waxman & Weston's workings (Figure 3) or the area drilled by diamond drill hole Fed 7.
3. Quartz-tourmaline-topaz alteration 'dykes' (so called 'white' dykes). These have been the main source of tin on the Federation tin field. Short tin-rich shoots often occur within the dykes which may or may not contain pyrite and/or sphalerite. Larger bodies generally contain sulphides in patches within the dyke. The dykes are generally enclosed in an argillic alteration envelope. An example is Coleman's workings (Figure 4).
4. Polymetallic Sulphides - The main example is Sweeney's where a significant body of mineralisation has been located. It has a high sulphide content (ave. 10% sulphur); the ore mineralogy is pyrite, sphalerite, cassiterite, stannite, arsenopyrite, jamesonite, galena and chalcopyrite. Gangue mineralisation is sericite, chlorite, siderite and quartz: it lies in a sericitic envelope. The body is possibly a contorted cylinder, flattening near the surface and sub-vertical at depth. In fact 18 drill holes have been sited



at Sweeney's and the extended shape of the mineralisation is still not well defined (Figure 5).

Although the most important target on Heemskirk, it is the least discussed in this report, since it will be the subject of a separate report.

It will be seen later that these target-types have quite variable geophysical responses; as an aid to classification and integration of the geophysics to the models, Roberts has devised the diagram below.



(Roberts' unpublished figure, with permission.)



## GEOPHYSICAL SURVEYS

This section describes the surveys that have been conducted over the Federation Grid up to July, 1981.

### GRADIENT ARRAY INDUCED POLARISATION

#### Data

The gradient array IP was carried out by Scintrex in two main stages: the first survey was conducted in November and December, 1977 and consisted of 34 line km; the coverage is listed in Table 1 and shown in Figure 6. The potential dipole spacing was 10m (with a 10m station interval) and the lines were spaced 100m apart (with a few short intermediate lines).

The survey was done in four blocks with current electrode spacings of 2150m or 2300m (not 1600m as stated in TAS-052) plus one small block east of Lake Cumberland. An IPR-8 receiver recorded three slices of the decay curves  $M_1$ ,  $M_3$ , and  $M_5$  using the normal pulse wave form of 2 seconds on, 2 seconds off:  $M_3$  was used for the plotting. The data was presented in Scintrex Report TAS-052 (Howland-Rose, 1978) as line profiles and contour maps of chargeability and resistivity; the profiles at a scale of 1:2,500, the maps at 1:2,000.

An extension to the south and southwest of the grid was carried out in December, 1979 and consisted of about 18 line kms; the coverage is listed in Table 2. The same survey parameters and types of equipment were used as for the first survey; the survey was done in three blocks. The data was presented in Scintrex Report TAS-074D (Howland-Rose, 1980a) as line profiles and contour plans of chargeability and resistivity, all at a scale of 1:2,000. (The results of both surveys have also been plotted onto Renison composite profiles at a scale of 1:2,000).



Detailed gradient array surveys have been carried out in two areas as part of a follow-up program which has consisted mostly of dipole-dipole and pole-dipole surveys (see below). The work was done in November, 1980 and the data is presented in Scintrex Reports TAS-081A and 081B (Howland-Rose, 1980b, 1980c). The former report gives the results of the detail work (gradient plus dipole-dipole) over Waxman and Weston's: the gradient survey data is presented as profiles and contours of chargeability and resistivity at a scale of 1:1,000. The latter report gives the results of detail gradient surveys over the SW corner of the grid: data is presented as profiles at 1:2,000. Intermediate lines were surveyed, so that the line spacing was 50m; all other survey parameters (except of course, current electrode spacing) appear to have been the same as for the previous two surveys. The lines and coverage are listed in Table 3.

### Results

In the 1977 survey, Scintrex defined 19 chargeability anomalies (designated A to S). From the 1979 survey a further 12 zones were picked (labelled 1 to 12). The results were generally disappointing with values only occasionally in excess of 20mv/v and none approaching the 60+ mv/v of Sweeney's, which was the type deposit for the survey. Nevertheless several areas of interest were defined and these are discussed here and later in the report.

The original 1:2,000 contour plans of the chargeabilities and resistivities (on idealised grids) were reduced to 1:5,000 for this report (again on idealised grids, Figures 7 and 8 respectively). An examination of the results shows that they may be classified into two areas: a northern area of lower resistivities and chargeabilities, and a (larger) southern area of higher resistivities and chargeabilities. An approximate boundary between these two zones is shown in Figure 8 and in



TABLE 1 - GRADIENT ARRAY IP SURVEY - FEDERATION GRID

Survey by: Scintrex  
 Date: Nov-Dec., 1977  
 Dipole Spacing: 10m  
 IP Receiver: IPR-8; M<sub>3</sub> plotted (2 secs on  
 2 secs off)

Current Electrodes

Line	Line Coverage
	<u>1000S and 1150N on 700W</u>
900W	695S - 835N
800W	715S - 805N
700W	745S - 895N
600W	745S - 815N
550W	565S - 155S
500W	805S - 865N
	<u>1150S and 1150N on 200W</u>
450W	575S - 305S
400W	865S - 875N
350W	605N - 745N
300W	895S - 865N
250W	655S - 395S, 605N - 825N
200W	895S - 865N
100W	955S - 865N
50W	485S - 715N
00W	945S - 805N
	<u>1275S and 1025N on 300E</u>
50E	215N - 505N
100E	1015S - 775N
200E	1045S - 705N
250E	305N - 595N
300E	1045S - 685N
400E	1105S - 655N
500E	1105S - 565N
	<u>1470S and 680N on 700E</u>
600E	1075S - 755S, 715S - 635S, 295S - 565N
700E	1035S - 775S, 755S - 655S, 235S - 185S, 165S - 475N
800E	835S - 545S
900E	835S - 445S
	<u>970S and 370S on 1100E</u>
1000E	835S - 485S
1100E	865 - 485S
1200E	835S - 485S

(Data in Scintrex Report No. TAS-052)



TABLE 2 - GRADIENT ARRAY IP SURVEY - FEDERATION GRID  
(EXTENSION)

Survey by: Scintrex  
 Date: December, 1979  
 Dipole Spacing: 10m  
 IP Receiver: IPR-8; M<sub>3</sub> plotted (2 secs on  
 2 secs off)

Current Electrodes

Line	Line Coverage
	<u>1420S and 325N on 1300W</u>
1600W	1025S - 15N
1500W	995S - 5S
1400W	965S - 5S
1300W	1025S - 5S
1200W	1055S - 5S
1100W	1085S - 5S
1000W	1105S - 5S
900W	1095S - 715S
	<u>1900S and 450S on 600W</u>
900W	1105S - 715S
800W	1195S - 725S
700W	1355S - 755S
600W	1375S - 755S
500W	1555S - 815S
400W	1615S - 875S
300W	1705S - 905S
	<u>2460S and 690S on 00</u>
300W	1705S - 1615S
200W	1795S - 895S
100W	1985S - 895S
00	2075S - 985S
100E	2165S - 1015S
200E	1985S - 905S

(Data in Scintrex Report No. TAS-074D)



TABLE 3 - DETAILED GRADIENT ARRAY IP SURVEYS

Survey by: Scintrex  
 Date: November, 1980  
 Dipole Spacing: 10m  
 IP Receiver: IPR-8;  $M_3$  plotted ( 2 secs on,  
 2 secs off)

	<u>Current Electrodes</u>	
Line	Line Coverage	
(a)	<u>1300S and 500S on 1650W</u>	
1700W	1245S	- 555S
1650W	1245S	- 555S
1700W	1245S	- 555S
(b)	<u>180S and 750N on 600E</u>	
500E	115S	- 145N
550E	115S	- 145N
600E	115S	- 145N
650E	115S	- 385N
700E	115S	- 385N
750E	215N	- 385N

((a) Data in Scintrex Report No. TAS-081B)

((b) Data in Scintrex Report No. TAS-081A)



Figure 1. In this latter figure, Renison's geological interpretation of the area, it can be seen that the boundary sub-parallel a major lineament trending roughly ESE-WNW across the area.

In attempts to determine the significance of this boundary, it was noted that a large proportion of the mines are in the northern area, including the largest producer, the Federation Mines (largest because it includes three separate workings?). The northern area also contains a larger proportion of white granite, however this by itself is not the cause of the contrasts in properties, since white granite occurs in the southern block of higher resistivities and chargeabilities in the southwestern corner of the grid. (Wells (1978) in agreement with Howland-Rose (1978) states that the two zones "appear to correspond, in general, with the 'red' granite (to the south) and the 'white' granite (to the north)" however, the position of the boundary as shown in Figure 1 suggests that this is too simplistic an interpretation, or that the mapping is incorrect.) The lower IP values north of the boundary are interpreted as reflecting an area of greater alteration, which has resulted in slightly larger permeability, reducing both the resistivity and chargeability. It is noted that this area is open to the north.

Figure 1 also shows the Scintrex anomalies, transferred (by Renison) from the 1:2,000 scale chargeability contour maps onto the 1:5,000 geology map as 'axes'. Anomalies A, B, C and D east of Lake Cumberland and O, over West Federation, have been omitted; and Anomaly R adjoining Lake Cumberland has been incorrectly labelled 'K'. I consider the geophysical results poorly represented on Figure 1; the system shows no grading and all anomalies are portrayed as narrow lineaments. Figure 9 shows the 20 mv/v contours which outline the most anomalous areas. Also shown is a re-interpretation of the results to define anomalous zones. These do not follow any contour value and, being taken from the idealised grid, are



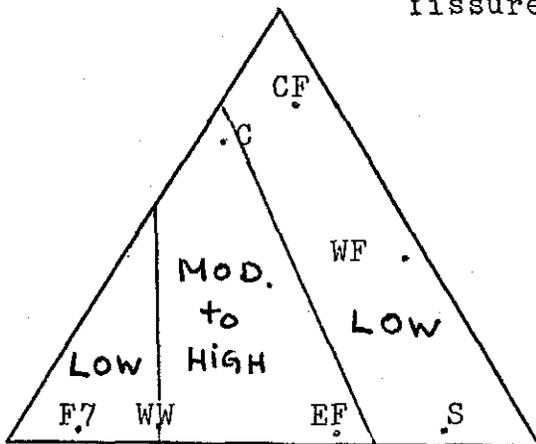
very approximate boundaries. The Scintrex anomaly labels, on Figure 9, shows that all major anomalies were picked, however there are several areas which were not picked by Scintrex; these are as least as 'good' as the Scintrex minor anomalies, some of which were defined by one data value only. Figure 10 shows a similar treatment for the resistivity.

Figure 9 shows that good anomalies ( $>20$  mv/v) occur over the larger workings, with the exception of the east and west Federation workings; both of these contain sulphides, but recorded moderate and low anomalies respectively. Also defined are areas of equally strong anomalies, in which no mining has occurred (none of these are in the 'alteration' area discussed above). Figure 10 shows that though there is little coincidence with the chargeability, resistivity lows may be associated with mineralisation (e.g. west and central Federation). On Figures 9 and 10 are also shown anomalies which may not have sufficient absolute amplitude to be identified on the contour map, but which, on the profiles, are significantly larger than the immediate background. (With regard to the resistivity profiles, I found that most of the 1977 values were incorrect, sometimes by a factor of 4! These errors arose by obtaining the resistivities from 'books' rather than by calculation; future surveys should have all parameters calculated - with a calculator - during the survey period. The errors have not been corrected, and are thus contained in Figure 8.)

Roberts' triangular distribution diagram discussed in the previous section may be used to summarise the gradient array IP results.



quartz-tourmaline (with  
cassiterite in central  
fissure)



Sericite with  
haematite

Polymetallic  
Sulphides

Resistivity

F7 : DDH Fed 7

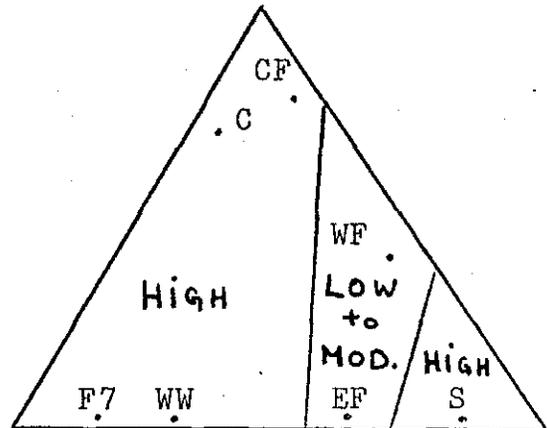
WW : Waxman and Weston's

C : Coleman's

CF : Central Federation

(Roberts' unpublished figure, with permission)

quartz-tourmaline (with  
cassiterite in central  
fissure)



Sericite with  
haematite

Polymetallic  
Sulphides

Chargeability

EF : East Federation

WF : West Federation

S : Sweeney's

The relationship between the geophysical results and the old mines and prospects is discussed at greater length under Drilling and Geophysics.

Gradient array IP surveys using current electrodes of 800 and 930m rather than the 2,000 plus metres of the earlier surveys, were carried out at the north-eastern and south-western corners of the Federation Grid, in conjunction with detailed dipole-dipole surveys. The same dipole spacing of 10m was used. 'Detailed' gradient surveys such as these, might be expected to give better resolution and possibly larger anomalies. Some workers (e.g. Lajoie and Klein, 1979) have found that a smaller current dipole (and potential dipole) may be needed before anomalies over mineralisation could be



detected (in the example cited, the current electrode separation was reduced from 1036m to 610m and the potential dipole from 61m to 30m).

Four lines on the grid have 'detailed' and 'regional' gradient IP coverage; 1600W, 500E, 600E and 700E. Profiles of both sets of data for lines 600E and 700E are shown in Figures 11 and 12 respectively. On line 600E, the resistivities are quite different, the detailed survey having a definite slope; however the low at 10S is still well developed. The detailed gradient data does show more resolution in as much as there are more 'anomalies' (i.e. variations): the chargeabilities are higher, but so is the background. On line 700E, again the detailed resistivity has a steeper gradient than the original survey, but the two chargeability profiles agree fairly closely. Comparison of the two sets of data for line 1600W and 500E, show very similar results. Thus, from this rather limited amount of comparative data, it appears that the detailed gradient surveys have served little purpose.

#### DIPOLE-DIPOLE INDUCED POLARISATION

##### Data

Several areas on the Federation Grid have been surveyed in detail by dipole-dipole IP. Intermediate lines were surveyed (i.e. a line separation of 50m), and the dipole (and station) spacing was 30m. Readings were taken from  $n=1$  to  $n=5$  except for one area where readings were taken to  $n=6$ . The IPR-8 decay parameters  $M_1$ ,  $M_3$  and  $M_5$  were recorded, and  $M_3$  has been plotted onto pseudo-sections at a scale of 1:1500: the results over Waxman and Weston's and East Federation are presented in Scintrex Report No. TAS-081A (Howland-Rose, 1980b) and the rest are presented in Scintrex Report No. TAS-081B (Howland-Rose, 1980c). All surveys (including that on line 1800W, which does not appear elsewhere) have also been plotted onto



the Renison composite profiles of the Federation Grid (at 1:2,000). The lines and coverage of the dipole-dipole surveys are listed in Table 4.

### Results

The dipole-dipole (and pole-dipole) IP surveys were undertaken for the detailing and better definition of some chargeability and/or resistivity anomalies which were defined from the 1977 and 1979 gradient array surveys. In this section brief comments are made on salient features of the results; in later sections comparisons are made with the gradient surveys and, where applicable, with drilling results. The results are discussed below, area by area.

### Waxman and Weston - East Federation

Six lines were surveyed with dipole-dipole IP over the Waxman and Weston - East Federation area. The lines were at 50m intervals between 500E to 700E. The results from lines 550E, 600E, 700E and 750E have been included in this report.

The dipole survey on line 500E has shown that the gradient anomaly over 150N is caused by a shallow chargeable body. (This is one of the most useful aspects of dipole-dipole surveys; some idea of the (possible) extent of the body can be obtained. The point is further pursued with the discussion on modelling of IP results.) The southern end of the resistivity pseudo-section shows lower values (not seen in the original gradient survey) and these have been interpreted by Roberts, correctly I believe, as reflecting a volume of alteration at depth. A similar zone, though with higher resistivities, is seen at the southern end of the dipole-dipole data on line 700E (Figure 12).

The results on line 550E are shown in Figure 13. The dipole data is from a single spread or 'setup' of five transmitter electrodes and readings have been made from  $n=1$  to  $n=5$ .



This means that (as shown) there are three missing data points from the bottom centre of the pseudo-section. And since a spread is often set up directly above the area of interest, values are missing where they are most wanted. This has occurred on line 550E, where the highest chargeability values and low resistivity values are adjacent to the 'blind spot'. To fill the gap, two more transmitting electrodes are needed (readings should then be made to  $n=6$ , with one data point missing at the centre). Figure 13 shows that the (detail) gradient chargeability anomaly at 45S is coincident with the highest  $n=1$  value from the dipole-dipole survey. This latter shows the real area of interest to be below 30W at  $n=4$  and 5. This is weakly reinforced by the resistivity results which show a central low; they do not show the steep gradient of the gradient results. Diamond drill hole Fed 18 has been drilled on this line and this is discussed in greater detail in a later section.

The importance of the 'blind spot' in dipole-dipole surveys is again evident on line 600E (Figure 11). The gradient array again appears to have responded to the near surface chargeability (anomaly G) and the dipole-dipole data suggests that the single point 'F' (repeated in the detail survey) is probably due to an even shallower source\*, too small to be detected by the dipole-dipole array (the better resolution of the gradient array?).

Footnote:

\* Howland-Rose (1978) gives the maximum depth as 20m. Quick (1974) gives the following relations: for a sphere, depth to centre is  $2.63 x_{\frac{1}{2}}$ ; for a horizontal cylinder,  $2.00 x_{\frac{1}{2}}$ ; and for a vertical tabular prism of infinite depth, depth to the top is  $1.00 x_{\frac{1}{2}}$  where in each case  $x_{\frac{1}{2}}$  is half the width of the anomaly at half its value. Anomaly F has a  $x_{\frac{1}{2}} = 7.5\text{m}$  on line 600E and thus Howland-Rose presumably used a sphere for his depth estimate ( $2.63 \times 7.5 = 19.7\text{m}$ ) even though this anomaly is shown on 700E, 100m to the east.



TABLE 4 - DIPOLE-DIPOLE SURVEYS OVER THE FEDERATION GRID  
(Coverage defined by the extreme data points)

Survey by: Scintrex  
 Date: November, 1980  
 Dipole Spacing: 30m  
 IP Receiver: IPR-8; M<sub>3</sub> plotted (2 secs on,  
 2 secs off)

<u>Line</u>	<u>Coverage</u>	
1. Results in Scintrex Report No. TAS-081A		
500E	135S	- 315N
550E*	135S	- 135N
600E*	135S	- 135N
650E	45S	- 285N
700E*	45S	- 285N
750E*	45S	- 405N
2. Results in Scintrex Report No. TAS-081B		
300W	1830S	- 1410S
350W	1800S	- 1335S
400W	1770S	- 1440S
1100W	780S	- 510S
1100W*	180S	- 180N
1150W	825S	- 495S
1200W	795S	- 450S
1250W	810S	- 450S
1300W	1095S	- 870S
1300W	830S	- 435S
1350W	765S	- 465S
1400W	765S	- 495S
1600W	1095S	- 765S
1650W	1185S	- 765S
1700W*	1095S	- 765S
3. Results not included in a Scintrex Report		
1800W	1050S	- 735S

\* Results reproduced in this report.



On line 650E, the detailed gradient array showed the best anomaly over 00 (approximately 50m wide). The dipole-dipole survey (carried out the next day) did not extend far enough to the south to cover this anomaly. The highest value on the pseudo-section is the southern most reading at  $n=1$ . Thus the dipole-dipole survey has inadequately tested the anomalous area on line 650E; and, although what results there are do not suggest a very promising target, the survey illustrates the need to evaluate results while the crew is in the area.

The geological profile for line 650E shows that alteration has again been interpreted beneath the dipole-dipole survey; the values at the southern end (around 600 ohm-m) are not as low as those on 500E (300-400 ohm-m) suggesting perhaps that the alteration is less intense, and again the southern boundary is not defined by the resistivity pseudo-section. The low beneath 180N is more readily interpreted as alteration at depth. But there is a real danger of over interpreting geophysical data and questionmarks could be placed after the "sericitic alteration" label on the geological profile, unless there is evidence (e.g. outcrop) confirming its presence. It is noted that there are no chargeability anomalies corresponding to the resistivity lows, whereas our models show mineralised zones of sericitic alteration (sericite + haematite, e.g. Fed 7) as having accompanying high chargeability anomalies (see 'triangle' diagrams in previous section). Therefore these alteration zones are probably not mineralised.

The dipole-dipole survey over 700E, like 650E inadequately covered a (1977) gradient IP anomaly. Anomaly E (see Figure 12) is between the two northernmost readings of the dipole-dipole survey: to properly test for 'E' at least three more readings ( $n=1$  to  $n=5$ ) are needed to the north, particularly since the dipole-dipole anomalies may be well off set from the gradient anomaly (e.g. anomaly F, some 50m south of the



dipole-dipole anomaly). The low resistivities at the northern and southern ends of the pseudo-section suggest that the dipole-dipole spread has been centred over fresh rock with alteration zones occurring to depth at either end, as interpreted in the geological section.

A narrow distinct chargeability anomaly has been defined by the dipole-dipole survey, situated between the gradient anomalies E and F. It dips steeply to the north and extends to depth. It also extends, little altered, to line 750E except that it is associated with a definite resistivity high (which does not fit any of the simplistic models discussed in the previous section). The southern side of the resistivity pseudo-section also suggests (a thinning) zone of alteration (again shown in the geological section by Roberts).

#### Anomaly '10'

A resistivity low on the southern ends of lines 300W and 400W, defined by the 1979 gradient array IP, was surveyed by three dipole-dipole surveys; on 300W, 350W and 400W. These latter surveys have shown that the zone is shallow and limited in volume. Although on 400W there is a deeper zone south of the gradient array survey (beneath 1650S and coincident with a slight chargeability anomaly). The dipole-dipole survey on 300W, shows that Scintrex gradient IP anomaly '10' is not worth following up.

Unlike the surveys over Waxman and Weston's, the dipole-dipole IP on lines 300W, 350W and 400W have been taken to  $n=6$ , however only one more transmitting electrode has been added, so that the 'blind spot' still consists of 3 missing values.

#### Anomaly '7'

One line of dipole-dipole IP was surveyed over gradient anomaly '7' on line 1100W at the baseline. The gradient anomaly



was insufficiently surveyed and should have extended further to the north. The chargeability pseudo-section shows a classic 'trouser-leg' or 'butterfly' type of anomaly. The resistivity anomaly is less well developed. These results are compared with scale model results which suggest a very shallow, limited source (Figure 15). (Mathematical modelling by computer, of more complex bodies is discussed later in this report.) The higher value at  $n=5$  on the northern limb may be due to an addition of the body shown in Figure 15 plus another surface feature north of the spread limit, below 135N (?). This survey was executed in the manner previously suggested; readings to  $n=6$ , with one missing data point at the centre of the spread at  $n=6$ .

#### Montague Workings

Seven lines from 1400W to 1100W with a 50m spacing were surveyed to define the anomalous area labelled '4' by Scintrex. As shown on Figure 9 this appears to be one of the better areas for detailed work with high chargeability values persisting over a sizeable area (250 x 50m): there is no resistivity anomaly. Figure 1 shows that the Montague Mines are on the southern edge of an argillic zone and anomaly '4' is 50 to 100m north of these workings.

Line 1400W is situated between two workings of the Montague Mine. The gradient chargeability anomaly is poorly defined on this line and the dipole-dipole results show only a weak anomaly closed off at depth. Line 1350W should, at 720S, be very close to the eastern area of the Montague workings, although it is not shown on the geological cross-section. The chargeability results are uninteresting with a moderate anomaly at depth. However, the change from coarse grained red granite in the south to fine grained white granite in the north, shown in the geologic profile, may be reflected in the resistivity results which show high values dipping south under lower resistivities. (This interpretation is opposite to the



regional interpretation of Wells (1978) mentioned above, where the white granite apparently has the lower resistivity (and chargeability).) The greisen vein shown at the contact has not responded to either resistivity or chargeability, unless it has caused a slight drop in the latter.

Line 1300W shows a similar (possible) correlation with geology, that is, a lower resistivity at the southern end with an apparent southern dip at the contact. (The dipole-dipole array is an extremely poor indicator of dip and may even indicate dip in a direction opposite to true dip.) Thin greisen veins at 660E are not evident from the dipole-dipole survey.

The gradient chargeability anomaly on 1300W is very poorly defined; and this is also true of the dipole-dipole survey: chargeability values over 20 mv/v were obtained, but there is no distinct anomaly.

Line 1250W shows a better defined chargeability anomaly, but it is closed off at depth. The resistivity shows a shallow, horizontal layer of low resistivity at the 'surface' of the pseudo-section, which, unlike lines 1350W and 1300W does not reflect the geology indicated in the profiles. (The geological profiles of all seven 'Montague' lines are very similar.)

The chargeability zone on line 1250W, extends east to 1200W, where it has an associated lower resistivity zone. The position of the gradient array anomaly on this latter line has been confirmed and the better definition of the dipole-dipole array suggests that the chargeable zone does not extend to depth, and like lines 1250W and 1400W, the geology has not been reflected in the resistivity results.

Line 1150W, is an infill line and, like all the other '50m' lines is without gradient array coverage. It shows the anomaly diminishing and weakening east of 1200W. The



resistivity pseudo-section is complex, with a series of highs and lows through the section. This complexity continues to line 1100W, which shows a near-surface, low resistivity zone which corresponds in position with the greisen zone. The chargeability zone has weakened further. The gradient array chargeability shows two highs (with questionmarks beneath them; it is not clear why), the northern one corresponds with a dipole-dipole chargeability low and the southern one with the edge of another (dipole-dipole) low.

Thus the dipole-dipole detailing of this area has shown, in isolation (i.e. without comparison with other zones on the granite) that the chargeability anomalies defined by the gradient array are generally closed off at depth and not in strong contrast to the surrounding rock. Given the type of targets; subtle targets may be important, however volume is certainly needed and 'open' targets would be a first priority.

#### Anomaly '3'

A second dipole-dipole spread was conducted on line 1300W, over gradient anomaly '3', which has a resistivity low (about 1000 ohm-m) and a moderate chargeability anomaly of about 22 mv/v. The dipole-dipole survey defined a very weak chargeability anomaly, but a definite, shallow resistivity zone with a minimum value of 228 ohm-m. As is discussed later, the dipole-dipole survey typically shows resistivity zones much lower in value (and which are usually much nearer the true value).

#### Anomaly '1'

The gradient array survey defined an anomaly (no. '1' - but the anomalies were apparently not labelled in order of merit), in the south-western corner of the grid on line 1600W. Dipole-dipole surveys were carried out over lines 1600W, 1650W and 1700W. Line 1800W was surveyed later and is not included in Scintrex Report No. TAS-081B with the other results. A



distinct chargeability anomaly was defined on line 1600W, which was reinforced by a resistivity low. The anomaly is a 'separated trouser-leg' type (one leg torn-off) and it is not clear whether the anomaly is caused by one or more bodies. On line 1650W the anomaly has strengthened and covers a larger cross-section. The shape of the resistivity pseudo-section is more in sympathy with the chargeability. On line 1700W the anomaly has slightly narrowed but is more intense; the shape is now classical trouser-leg. On line 1800W, the anomaly is weak, it has an associated resistivity low and may be much deeper.

Thus 1700W is a most promising target; before interpreting the results, a few comments are made on the gradient results (a detail gradient array was done at the same time as the dipole-dipole survey). On line 1600W the gradient shows a clear anomaly over the southern dipole-dipole 'leg', the resistivity low is offset and coincident with the centre of the dipole-dipole chargeability anomaly and with the  $n=1$  resistivity results. The anomaly is clear, but not outstanding, it has width and reaches about 26 mv/v.

On line 1650W, the gradient is much stronger (about 35 mv/v) - again very wide, both chargeability and resistivity approximately coincident with the 'top of the trousers'. The gradient anomaly on 1700W is not as good as that on 1650W (anomaly stronger at depth on 1700W?). The resistivity anomaly is very weak (1700W is not the best section for a dipole-dipole resistivity anomaly either) and the chargeability anomaly has a lot of superimposed 'noise' - the typical minor ups and downs of gradient results. The peak value is probably as high as that on 1600W, but the anomaly is not symmetric and suggests a southern dip (gradient array results should have much better dip resolution than dipole-dipole).

To confidently site drill holes on IP targets, computer modelling is recommended. But for classical pseudo-sections



such as 1700W, approximations can often be made with the use of type-curves. Figure 16 shows a comparison between the chargeability results for 1700W and the response from a flat tabular body (10m x 40m x 75m). The matching of shape is reasonable, but the 'legs' of the model pseudo-section are much narrower than those of the field curve and the anomaly to background ratios are wrong. Thus the field case will be a larger causative body; extending, with different parameters, east to 1600W, but not to 1800, i.e. 1700W appears to be close to one end of a tabular shallowly dipping chargeable body.

Some computer modelling of the dipole-dipole and gradient array IP results over 1700W was undertaken by Prof. K. Vozoff and Dr. N. Smith, both of Macquarie University, Sydney. A much better fit was obtained for the resistivity pseudo-section than was the case for the scale model (results not shown). (The resistivity modelling was done using an 'inversion' program which determines the causative body, given the response and certain constraints.) The chargeability pseudo-section (calculated using a 'forward' program, i.e. a program which calculates the response given the body) has a poorer shape than the scale model results but has a better magnitude and size (it is a little too big, rather than far too small, as was the scale model).

The gradient results were calculated to try and utilise that array's ability to discriminate dip. Although a poor match was obtained, the modelling suggests that the bottom of the body may slope rather than the top. Deepening the model (in minimum steps of 7.5m) rapidly reduced the amplitude of the anomaly; thus the body seems likely to be very close to the surface.

Thus a limited amount of modelling (both scale and computer) has produced some approximate parameters of the causative bodies. Whilst better fits could be obtained by further



modelling, a target has probably been sufficiently well defined to site a drill hole.

Figures 16 and 17 suggests that the top of the body is 'above' the IP coverage. It is often good practice to better define such a body with a more detailed survey using smaller dipole-dipole lengths, e.g. 10m. Such a survey should confirm the depth and extent of the causative body. (It is pointed out that the costs of more precisely defining the target are very small when compared with the cost of drilling.) An extension of the dipole-dipole survey to the south (using the 30m dipole spacing) is recommended on line 1700W since there is a gradient anomaly comparable to that over 900S.

#### POLE-DIPOLE INDUCED POLARISATION

##### Data

Three lines of pole-dipole IP were carried out over Scintrex gradient chargeability anomalies '11' and '12' on line 00, some 300 or 400m west of Sweeney's Mine. A multi-separation array was (well) chosen to better define the shape and extent of the anomalies. The surveys were carried out on lines 50W, 00 and 50E. The coverage is given in Table 5, data is presented as pseudo-sections at 1:1,500 in Scintrex Report No. TAS-081B.

##### Results

Pole-dipole surveys were carried out over areas of steeper (topo.) gradient. It would be interesting to compare the cost and effectiveness of this array with the dipole-dipole array: the latter is discussed in more detail later in the report. But pole-dipole and dipole-dipole arrays give very similar results, although the pole-dipole pseudo-sections are a little more complex because of the asymmetry of the arrays. The array geometry needs to be known when interpreting the results; also



TABLE 5 - POLE-DIPOLE SURVEYS - FEDERATION GRID  
(Coverage defined by the extreme data points)

Surveys by: Scintrex  
Date: November, 1980  
Potential Dipole: 30m  
IP Receiver: IPR-8, M<sub>3</sub> plotted (2 secs on,  
2 secs off)

<u>Line</u>	<u>Coverage</u>
50W	1485S - 1215S
00*	1575S - 1215S
50E	1545S - 1155S

\* Results presented in this report.



the various conventions for the plotting of the data (Dodds, 1976, gives three possibilities). Scintrex Report TAS-081B which presents the data as pseudo-sections, doesn't give the array geometry with respect to the grid, however the data cards note the direction of movement and hence, by inference, the geometry. The plotting convention can be derived from the relationship between the pseudo-section data positions and the grid.

The chargeability field data for line 00 has the best anomaly, lines 50W and 50E have weaker, less distinct anomalies. Figure 18 shows the pseudo-section for line 00 with a mathematically generated pseudo-section for the two-dimensional model shown. The model results are not dissimilar to those of line 00, however they have been included primarily to show the asymmetry of the results; the 'stronger' side being closer to the current electrode (a little of the model asymmetry is due to the fact that the model is offset from the electrodes).

The gradient array profiles have been included in Figure 18 and these show that anomalies 11 and 12 are very similar. Both anomalies coincide with the pole-dipole highs on  $n=1$ , where those beneath anomaly 11 are the more substantial, forming part of the fairly well defined pole-dipole anomaly.

### MAGNETICS

The magnetic survey was completed in two stages; the original Federation Grid was completed in December, 1977 and the south west extension (the area surveyed by the later gradient array IP) in October, 1979. The total magnetic field was measured with a station spacing of 10m. The results are plotted in the composite profiles (except for lines 800E to 1200E) which are at a scale of 1:2,000. They have also been plotted as



contours at 1:2,000 (six sheets cover the area of the grid). These have been photo-reduced for this report to 1:5,000 (Figure 19). The same contours were used as for the 1:2,000, namely a 50 $\gamma$  interval from 62300 $\gamma$  to 62450 $\gamma$  and from 62550 $\gamma$  to 62700 $\gamma$ . The intervening values, 62450 $\gamma$  to 62550 $\gamma$ , were contoured at 25 $\gamma$ . (The errors in the 1:2,000 contour map, discussed below, have not been corrected in the 1:5,000 map, Figure 19.)

Figure 19 shows a clear division in the magnetic properties of the granite. The south east corner of the grid is magnetically 'active', whilst the rest is 'quiet'. A line approximating the boundary between the two zones, sub-parallel to the lineament that passes through Sweeney's (see Figure 1) approximately 500m to the south east. Apart from this, the magnetic zones are not related to the indicated geology, the boundary being entirely within coarse red granite. The shape of the anomalies suggests a very shallow source. This could be verified by testing fresh rock samples for magnetic susceptibility (samples being taken from both zones). The differences in magnetic properties presumably reflect differing conditions of temperature and/or pressure, either in the formation of the granite or during subsequent tectonism.

There are errors in the contour plan: for example, the 50 $\gamma$  anomaly on 600E at Waxman and Weston's has not been contoured (with either of the 62500 $\gamma$  or 62525 $\gamma$  contours); on 700E at the Eastern Workings the 32 $\gamma$  anomaly has not been contoured (by the 62500 $\gamma$  contour). But even with these contours the shape of the very distinct anomalies over these two areas would not be evident, and the profiles must be used when examining the magnetics of the area. (Two different sets of contours could be used for the two areas, i.e. a small, e.g. 5 $\gamma$ , contour interval in the magnetically quiet zone.)



Distinct, though not large anomalies (less than 50%) are associated with some of the old workings; included among these, are Waxman and Weston's, Eastern Workings and the Cross Lode of West Federation. There is also a magnetic anomaly over Fed 7. There are evidently cultural effects at Coleman's and no readings were taken, similarly for parts of West Federation and other workings. There are also some anomalies similar to those mentioned above, that are not associated with any known mineralisation, e.g. 600N on 100W. These do not have good coincident IP anomalies, although there may be weak anomalies, e.g. 70S on 1500W. Possibly one of these should be examined as a possible target-type which does not respond to IP, e.g. magnetite or haematite (+cassiterite) in relatively fresh rock.

#### ELECTROMAGNETICS

Experimental tests of the Crone Pulse EM method (PEM, a time domain method) were carried out in 1978. Profiles were run over Sweeney's, Black Face (line 250E, 360N to 600N) and east of Coleman's (line 560W, 480S to 0); no anomalies were recorded. A bore hole survey was run down DDH 486 (on the Renison Mine Lease) which extended to 340m and showed two definite responses.

The report does not give any survey details other than the grid spacing (90m and 100m). It is likely that a small transmitting loop of 9m diameter was used with the usual receiver (a small, portable instrument).

The IP results show that there are no concentrations of conductive minerals (sulphides) sufficient to cause EM anomalies and the limited PEM surveys confirm this, but a possible application for EM might be (deep) resistivity mapping of alteration zones. The Sirotem system outputs data both in the usual response (anomaly) format and as apparent resistiv-



ities. If a large volume of alteration, possibly at depth, was postulated as a target, Sirotem might be an appropriate method. (For deep exploration, a square loop 100m x 100m is commonly used: smaller loops down to 25m square are also used.) A helicopter EM method, Dighem, has a resistivity contour map as one of its data outputs. To be useful, this method requires a resistivity contrast of <sup>at least</sup> ~~about~~ three times. (The system also records high resolution magnetics.) Dighem would not have as good a penetration as Sirotem, but should be quite adequate in the resistive environment of the Heems-kirk granite. A good way to evaluate the possible application of electromagnetics would be to run test lines with Sirotem over suitable targets and, if worthwhile responses were obtained, to then consider the merits of continuing with Sirotem or of using the airborne system (which would be used over a large area and would also provide good magnetic data). It is appreciated that pseudo-sections of apparent resistivity can be obtained from multi-separation IP arrays, however better resolution should be obtained from EM. (But one should note here that DC electrical methods, e.g. IP, are better discriminators of 'resistive' bodies, while AC electrical methods, i.e. EM, are better discriminators of 'conductive' bodies.)

A borehole receiver is being developed for the Sirotem system, and it is possible that this would have an application at Sweeney's in defining the extent and shape of the mineralisation. Although I think that other downhole methods should be tried first, e.g. more applied potential surveys. (An evaluation of the Sweeney's data will be made in a separate report, but it is discussed in this report as an example of one of the target types.)

RADIOMETRICS

Drill core from three Sweeney DDH's were tested with a gamma ray spectrometer (a Scintrex GAD-4). The holes were Swy 3, 11 and 15, and the core from these holes represented mineralised, altered, and unaltered granites. The results were presented as tables (total count, 'potassium' count, 'uranium' count, and 'thorium' count in Appendix 4 of Wells (1977)). The values have not been examined and the conclusion of Wells (1977), that the technique has no practical application, has been accepted.

There has been some research into the use of radiometrics on tin granites, by the BMR, and their work has included Tasmania in co-operation with the Dept. of Mines (Collins et al, 1981). The work (of which I have seen a draft) has concentrated on classifying granites as barren, or as potentially tin bearing, using various diagnostic ratios of certain radioactive elements. The number of samples from the Heemskirk Granite is too few to draw many conclusions (a total of twenty nine samples of which two were from greisenised granite and three from quartz-topaz-tourmaline-chlorite alteration), although the authors claim to be able to distinguish the 'red' and 'white' phases of the granite. The three alteration samples are from the East Federation and Montague Workings, all three gave low uranium: thorium ratios ( $<1:5$ ), whereas tin-bearing granites on the west coast are, according to the model,  $>1:3$  ( $>1:2$  for east coast granites). Clearly more data is required before any firm conclusions can be drawn and it is possible that a better local model exists rather than trying to fit too few data to models derived from other, better sampled, granites.

Thus spectrometry has potential for defining areas of alteration or possible tin-rich (the most fractionated) areas of the granite, but the measurements of core from Sweeney's suggest that any investigation would not be straight forward.



All samples were measured for magnetic susceptibility; all were effectively zero, except East Federation with  $168 \times 10^{-6}$  and Federation,  $215 \times 10^{-6}$  (SI units).

#### PETROPHYSICAL MEASUREMENTS

The success of a geophysical survey relies on a measureable contrast in some physical property. It is good practice when planning, or interpreting the results of a geophysical survey to make measurements of a suite of typical host and target rocks.

Ten samples were tested from the Federation Grid which included four samples from Sweeney's. Such a small number was not expected to establish parameters for the area as a whole, but rather to give some values representative of the rock types tested. The samples were measured for dry bulk density, effective porosity, magnetic susceptibility, resistivity and IP effect and the results are listed in Table 6. A petrological description of the samples by Roberts is given in Table 6A.

The wet bulk density data (i.e. the density of the rocks when saturated with water - the most likely condition) shows that those samples containing some sulphides are heavier, in some cases significantly heavier, than those samples free of sulphides. Thus gravity could be entertained as a possible tool for the definition of concentrations of massive sulphides (say Sweeney-style). However, very large masses are required to show an effect, and gravity could not be recommended as an exploration technique over Heemskirk. But there may be an application for down hole density logging e.g. to assist in the definition of the Sweeney sulphide body.

The magnetic susceptibility values in Table 6 show an apparently large variation, over one order or magnitude, however these are



all low values, and the samples are essentially non-magnetic. (Note however, that magnetic anomalies do occur over some of the old workings, e.g. Waxman and Weston's.)

There is a very large difference in the resistivities listed in Table 6, with fresh unaltered granite having values greater than 2000 ohm-m and altered granites averaging around 500 ohm-m. Altered granite with sulphides are lower, down to 37 ohm-m for a Sweeney's sample with an estimated 60% sulphides. The samples were tested when saturated with a solution measuring 5 ohm-m (at 20°C), this is probably considerably lower than the field situation (away from mineralisation) since apparent resistivities from the dipole-dipole IP surveys have shown the fresh granite to have values 1000-3000 ohm-m. (Field resistivity measurements are generally much lower because of the effect of joints etc, which increase the porosity of the rock). If there is a sufficient contrast, resistivity could be used as a tool (in its own right) for detecting alteration zones. From the figures it could also be used for the detection of mineralised zones, however this would be far better done by IP. (Resistivity surveys are much cheaper and much quicker than IP surveys.)

Electromagnetic methods may also be used to measure contrasts in resistivity, in a manner analogous to resistivity soundings. The Sirotem and Dighem systems were discussed above in the Electromagnetics section. Partly from the (very) limited laboratory tests, but mostly from the resistivity pseudo-sections of the dipole-dipole IP surveys, it appears that there may be a sufficient contrast between fresh and altered granite to be detectable by these systems.

The IP effects show a very good contrast between the fresh granite and the altered and altered/mineralised zones. The three types of 'fresh' granite all showed no IP effect; the altered granite, intermediate values; and the mineralised samples, up to a 17% frequency effect (about 100ms chargeability).

TABLE 6 - PETROPHYSICAL MEASUREMENTS

No.	Sample DDH	Depth	Brief Petrological Description	Dry Bulk Density gm/cc	Effective Porosity %	Wet Bulk Density gm/cc	Magnetic Susc. cgs units $\times 10^{-6}$	Resistivity (at 10 HZ, $R_w = 5\Omega\text{-m}$ at 20°C)	I.P. Effect 1 HZ to 10 HZ %
1.	Fed 8	20.5	Fresh, red granite	2.63	0.9	2.64	20	2076	0
2.	Fed 12	222.0	Haematite with sericite	3.42	1.3	3.43	180	476	17
3.	Fed 12	230.7	Sericite, siderite, coarse pyrite (10%)	3.01	1.8	3.03	210	563	17
4.	Fed 12	208.9	Sericitised, c.g. granite	2.68	3.7	2.72	40	520	5
5.	Fed 18	250.6	White f.g. granite	2.49	0.8	2.50	10	6010	0
6.	Fed 12	43.1	Porphyritic granite	2.57	2.4	2.59	20	2398	0
7.	SWY 8	48.5	Sericitised c.g. granite, pyrite 15%	3.08	3.1	3.11	110	143	10
8.	SWY 11	72.9	Altered granite, c.g. sulphides 60%	3.48	4.6	3.53	130	37	12
9.	Fed 18	171.3	Sericitised, intensely altered granite. 10% c.g. pyrite	2.84	2.0	2.86	10	192	12
10.	Fed 18	175.2	Altered aplite, minor v.f.g. pyrite	2.67	4.0	2.71	20	633	2.4

1% freq. effect  $\approx$

5 mv/v chargeability

022

33.  
937043



TABLE 6A - PETROLOGICAL DESCRIPTIONS OF PETROPHYSICAL SAMPLES

(by P.A. Roberts)

Sample 1.	Fed 8, 20.5m	Fresh 'red' granite - 60% feldspars, 35% quartz, 5% biotite, c.g. (grainsize for qtz-felds: 0.5-1cm). Approx 60% of feldspars pink K-feldspar, 40% yellow (v. weakly argillized) plagioclase.
Sample 2.	Fed 12, 222m	Haematite rock with lesser green sericite, blebs of f.g. black tourmaline, v. minor sideritic carbonate, pyrite (specular and/or micaceous haematite).
Sample 3.	Fed 12, 230.7m	Sericitic-sideritic, carbonate-pyrite rock. Pyrite in coarse euhedra (2-3mm) ~10% of total. Possibly some illitic clays.
Sample 4.	Fed 12, 208.9m	Sericitised c.g. granite - sericite-quartz rock, 55% sericite, 45% quartz. Grainsize 0.5-1cm.
Sample 5.	Fed 18, 250.6m	F.g. 'white' granite - quartz and feldspar in roughly equal proportions. Grainsize 0.5-1mm. Minor tourmaline in f.g. nodules 1-3cm diameter.
Sample 6.	Fed 12, 43.1m	Porphyritic granite - phenocrysts ~40% red K-feldspar, ~30% yellow (weakly argillized) plagioclase, ~30% quartz; groundmass roughly equal amounts qtz, feldspar, lesser biotite. Some rimming of K-feldspar by plagioclase? Minor chloritization of biotite.
Sample 7.	SWY 8, 48.5m	Sericite-pyrite rock (sericitized c.g. granite). Pyrite ~15% of total. Pyrite in blebs 2mm-1cm but fairly f.g.
Sample 8.	SWY 11, 72.9m	Mineralised altered granite (?) c.g. texture - pyrite - sericite ?? - sphalerite rock. Vuggy. 60% sulphides of which pyrite is 75% of total sulphides.
Sample 9.	Fed 18, 171.3m	Green sericite-talc rock, probably intensely altered granite, comprising ~75% sericite-talc, ~15% c.g. euhedral pyrite, ~10% c.g. brown siderite carbonate - Slightly vuggy. Soft.
Sample 10.	Fed 18, 175.2m	Altered aplite. Grainsize 0.5mm. Comprising ~40-50% each (?) quartz and sericite. Minor very f.g. pyrite (~5%). Relatively hard c.f. Sample 9.

f.g. = Fine grained  
 m.g. = Medium grained  
 c.g. = Coarse grained



It is emphasised that these latter values would be diluted by barren host rock for in-situ measurements. Sample 8 (SWY 11, 72.9m) with a estimated 60% sulphides gave an IP effect of 12%, which is lower than values from samples with less sulphide. Although all samples containing sulphides, except No. 10, are described as 'coarse grained', it is likely that the relatively low value for sample 8 is due to the interconnection of the sulphide and/or coarseness of the grain size. Wells (1978) noted the lack of an IP anomaly over Phar Lap where the pyrite mineralisation is quite coarse (single crystals typically 10mm), and he also attributed the weaker-than-expected response at Tributor's workings to the coarse grain size: the results of the petrophysical tests suggest that Wells is probably correct although the Phar Lap workings are situated midway between lines 200W and 100W, i.e. 50m from the IP survey.

Spectral IP (or complex resistivity - CR) is the study of shape of the decay curve or, since more work has been done on CR in the frequency domain, the study of the in-and-out-of-phase responses over a large range of frequencies. The ultimate aim of CR is (or perhaps was) to be able to discriminate different sulphide minerals; a more realistic goal may be the discrimination of graphitic shales from sulphides. An early paper in CR literature (Wynn and Zonge, 1975) claimed that different types of alteration could be distinguished, although this has not been verified by other workers.

Some very simple conductivity spectra were run on samples 1 to 8 (1 to 1000Hz, no phase information). The results are shown in Figure 20. The lowest resistivity (highest conductivity) for each sample is given a value of 100% (this is usually at the highest frequency). Measurements at other frequencies are plotted as a percentage of the highest value. Figure 20 shows that samples 1 and 6 did not change their conductivity over the whole frequency range i.e. there was no IP effect. Sample 8 shows the largest effect, Sample 5 which showed no IP effect at low frequencies (and, being unaltered granite,



would be expected to follow 1 and 6) is probably showing an erroneous effect at higher frequencies associated with the measuring electrodes (from Emerson, director of Uni. of Sydney's petrophysical laboratory - pers. com.). But it is the shape of the curves that may be diagnostic for mineral discrimination. The samples with the greatest amounts of sulphide mineralisation are 7 and 8 and these both show clear concave-up shaped curves. The altered granites with little sulphide show either straight or more concave-down curves. This is in agreement with Emerson and Smith (1969) who showed with a limited number of samples that a clay-type (membrane) IP effect (from the Hawkesbury sandstone, Sydney basin) gave this shaped curve while various sulphide minerals gave the concave-up curve observed here. (This study by Emerson and Smith also showed that IP effect was dependant upon the pore water conductivity; increasing the magnitude of the effect with increasing conductivity for the sulphide IP effect, and decreasing it for the clay IP effect.)

Related to the discussion above is the use of (time domain) IP decay curve shape to show different textures within sulphides. (e.g. Howland-Rose, 1980c, P 15, "... a markedly fast decay form of  $\Delta M_n = -10\%$ . This infers the source to be finely disseminated".) Tyne (1981) suggests that "... there may be some difficulties in using the relaxation time parameter (i.e. decay form) as a means of discriminating between sulphides of different textural form". I plotted ' $\Delta M$ ' (a decay parameter) over various zones on the Federation Grid and could detect no differences. I also understand that Scintrex has not published any case histories on such a use of decay form (its use in detecting EM coupling is more widely accepted). Thus it is probably a little premature to make such claims as that quoted above. (Nevertheless, Wells', 1977, comment that "Decay forms also suggest a very fine grain size to the mineralisation (within Sweeney drill holes SWY 7 and 8)" was confirmed by petrographic work.)



Obviously spectral IP (CR) is a major breakthrough if it can discriminate graphitic shales from sulphides: it may eventually be able to tell us more about alteration zones, but it is not yet routinely used (at least in Australia). Any use of it on Heemskirk could only be experimental and, given the intimate association of alteration types and of sulphides with alteration, it would be unlikely to prove useful. Nevertheless it is an important concept, and the above discussion was included, to (a) inform the reader of its possibilities and (b) to show the uncertainties in using decay form to define grain size.

#### DRILLING AND GEOPHYSICS

Eighteen holes have been drilled by Renison on the Federation Grid. Holes by earlier lease holders are not considered here, nor are the eighteen holes over Sweeney's, which, although a type-area for tin on Heemskirk, will be discussed in more detail elsewhere.

This section examines the results of those drill holes over which, or near which, there are IP results and it compares those drilling results with the IP and magnetics. A detailed evaluation is given, since, for any exploration program, it must be established if the geophysical anomalies can be explained by the drill hole intersections.

Nine of the drill holes are coincident with geophysical profiles: Fed 8 over the Eastern Workings; Fed 5, 12 and 18 over Waxman and Weston's; Fed 9 over Central Federation; Fed 2 over Western Federation; and Fed 7, 4 and 3 drilled into 'new' ground. Of these only the first 4, Fed 8, 5, 12 and 18 have coincident dipole-dipole data (and detailed gradient array data). Fed 17 is also discussed, although this is at a high angle to the geophysical coverage.



It is appreciated that there are often other factors besides geophysics when starting or stopping a drill hole (even if geophysical anomalies are the stated reason in the drill log). However, the comments and criticisms made below are concerned only with the geophysical factors. Apologies are offered if the tone becomes too critical. It is much easier to write with the advantage of hindsight and without the pressures of deadlines, etc., than to be actually doing the job.

Fed 17 was sited on line 750E to test "the down-dip extension of alteration intersected in Fed 8" (see Figure 14). This expected northerly dip was based on "geological mapping, IP and ground magnetics" (Fed 17 drill core records). The result is discussed below, but it is suggested first, that before siting Fed 17, geophysical modelling, particularly of the magnetics, should have been carried out to determine more precisely the dip and extent of the magnetic material. Also, if on line 700E (i.e. Fed 8) magnetics has appeared to be useful, then a magnetics survey should have been made of line 750E before siting Fed 17: the amount of magnetics shown on the composite profiles (90m) is too short to be of use (and did not cover the area intersected by the drill hole).

The siting of Fed 17 was very restricted by topography and the preferred site was actually on line 700E, north of Fed 8 (Roberts, pers. com.). Nevertheless the following comments can be made concerning the relationship of the geophysics on line 750E to Fed 17. The dipole-dipole data shows no chargeable zone beneath Fed 17, but the resistivity pseudo-section does show a volume of lower resistivity corresponding to that shown on the geological cross section (from where the latter presumably originates). A moderately chargeable, but resistive zone occurs further to the south, which appears to extend to depth. The very limited gradient coverage shows nothing of interest. The resistivity pseudo-section suggests that the alteration stops at the northern limit of the survey and Fed 17 would appear to confirm this, (both sets of IP data were completed 2 months before the start of drilling).



Fed 8 on 700E was sited to test IP anomaly 'E' which coincides with the Eastern Federation Workings, (see Figure 12). However it does not do this in as much as the hole does not extend as far south as the peak of the anomaly; presumably the hole was stopped when fresh granite was intersected. The dipole-dipole survey (done after the drilling), showed the gradient anomaly to be shallow, and the only zone of geophysical interest to be further to the south. (This zone is similar to that on 750E, and is again chargeable, but resistive.) Fed 8 has also been drilled beneath the magnetic anomaly: the magnetic susceptibility of the core should be sampled at regular intervals to see if the hole has intersected the magnetic body; and, if there is doubt, the anomaly should be remodelled using the susceptibility value from the core. (It may be worth mentioning here that, for any geophysical anomaly, there is no unique solution, e.g., for the magnetic anomaly over the Eastern Workings, there is an infinite number of situations which will give rise to this one anomaly. The only constraints are geological plausibility or other geophysical results (IP in this case). The drill log mentions some haematite between 65 and 75m but not elsewhere. Certainly a model (i.e. a plausible magnetic body) should have been fitted to the data, and should have been taken into account when designing the drill hole. The assays for Fed 17 had not been recorded at the time of writing, and Fed 8 recorded only a very small concentration of tin ( $\leftarrow .2\%$  for a total of 4m).

Three holes have been drilled at the Waxman and Weston's workings, Feds 5, 12 and 18. Feds 5 and 12 are parallel to each other on line 600E and dip to the north (see Figure 11), Fed 5 intersected approximately  $.5\%$  tin for a total of 7m and Fed 12, beneath Fed 5, intersected 10m of  $0.2\%$ , plus other minor occurrences. Fed 5 was designed "to test coincident magnetic, IP anomalies near Waxman and Weston's workings". Similar comments to those made about Fed 8 on 700E apply here. Namely, magnetic modelling should have been done to define the position and attitude of the magnetic target: a dipole-dipole survey



should have been done before the drilling to define the chargeable/conductive target.

The subsequent dipole-dipole survey (with the magnetic anomaly) suggests that the hole has not been optimally sited, (consideration could be given to a hole drilled from the northern side dipping south, after modelling of at least the magnetics, but it is recommended below that a deep-looking dipole-dipole or pole-dipole survey should be carried out first.

The disparity between effective depth coverage of the dipole-dipole IP survey and drilling is illustrated in Figure 13 which shows Fed 18 extending to a depth of nearly 250m below surface, while the IP 'sees' 80 to 90m. The geophysical survey should cover the likely targets. If a large volume of altered granite is to be defined by geophysics (as at Waxman and Weston's) then a large spacing multi-separation array should be used - not the same survey parameters that were appropriated for detecting a small sulphide body. At the time of writing, the tin assays for Fed 18 had not been recorded in the log. They were however, disappointing.

Fed 9 was drilled on the eastern side of the central workings on in-fill line 250E. Its stated purpose was to test the "Black Face Lode at north end where it coincides with IP anomaly 'I'". The hole is not parallel to the grid line and in the geological profile, the hole is shown to only 90m, at which depth it is 10m east of the line (total depth was 155m). Anomaly 'I' is composed of two chargeability highs, (see Figure 9) although on line 250E, the eastern edge of the anomaly, the northern high has diminished and the southern anomaly is defined by only one point, (which does appear to be correlateable with a similar, single point anomaly on line 200E). On both 250E and 200E, there are well defined resistivity lows coincident with the chargeability highs. Fed 9 seems to have been well positioned to test the anomaly (although it is argued that a dipole-dipole survey would have been a much better prior test of it), and it intersected minor amounts of pyrite (total



S = 1.1%) from 96 to 124m. (Tin at a maximum of .29% was intersected for a total of 4m.) Figure 9 shows three anomalies in this area (the central workings) that I consider promising. On 200E the northern part of Anomaly 'I' has width as well as value, there is also a good resistivity low; it is a 'substantial' anomaly. Further to the west on 100E, the chargeable anomalies are again narrower (and the resistivity low has weakened), but both peaks of the anomalies are in excess of 30 mv/v.

It is interesting to consider the size of a potential ore-body here; for example, could it fit between Fed 1 and 9, beneath one of the favoured anomalies (see Figure 9)? A vertical pipe is probably the most inconspicuous target and it takes up the least surface area; a ten million tonne orebody in this shape with a depth of 50m would have a radius in excess of 150m; if the depth extent is 100m its radius is greater than 100m. At 500m deep; it still has a radius of more than 50m.

Fed 7, near line 300W was drilled to test anomaly 'M' an anomaly with 'width' but not much 'height' (<20 mv/v), nevertheless, is one of the more attractive anomalies in profile. There is an associated magnetic anomaly similar to that over Waxman and Weston's. A zone of sericite and haematite alteration was intersected. While a dipole-dipole survey could better define the anomaly and possibly demand a repositioning of the drill hole, the limited volume of alteration defined by the drill hole suggests that this area does not warrant further exploration. The highest tin assay (.4%) was restricted to a narrow greisen vein.

The stated purpose of Fed 2 was "to test beneath West Federation where coincident with a weak IP anomaly". The composite profile for line 400W shows that there is a weak chargeability anomaly north of the old workings and it also shows three readings missing over the workings. Scintrex anomaly 'N' is marked over two missing chargeability data points, but is coincident with a narrow, weak resistivity low. The hole,



collared in red granite, intersected altered white granite beneath a zone of alteration (as shown on the geological profile). It is interesting to speculate whether a dipole-dipole survey would define the alteration along the contact (probably using a larger dipole spacing than 30m). In the comments in the Fed 2 log, it is suggested that although no tin was found in Fed 2, a further hole might be considered a few metres to the north under the Cross Lode. (The Cross Lode has a Waxman and Weston's-type magnetic anomaly ( $>30\%$ ), but only a very weak chargeability anomaly.) Feds 10 and 16 have since been designed and drilled to intersect the Cross Lode. The unsuccessful attempts of these holes, leads one to suggest that some time and effort could be spent in determining how useful multi-separation array IP surveys might be in helping to define alteration boundaries. Certainly one such survey is recommended over the Cross Lode.

Fed 3 was drilled near the edge of Lake Cumberland on line 400E: its stated purpose was "to test IP anomaly 'Q'". Anomaly 'Q' is a chargeability anomaly of a little over 25 mv/v although it is only about 5 mv/v above background. A vertical hole was drilled in an attempt to intersect the red/white granite contact, however the hole was still in red granite at its termination at 131.5m. Little alteration was encountered, but some thin 'white dykes' and greisen veins were intersected. The Log give no record of any tin values.

Anomaly 'Q' is typical of many of the isolated 'anomalies' of gradient array surveys, and Fed 3 is perhaps a good example of the futility of drilling solely on the gradient array results. All examples discussed before Fed 3 have been over old workings and hence other criteria, apart from the gradient IP, have been used to site the holes. Fed 4 on 200E is probably another example: anomaly 'H' is a larger anomaly than 'Q' (and is larger again elsewhere, e.g. line 300E) and again some fine grained dykes were intersected, but little alteration.



"Traces of sulphide were encountered in some of these dykes" (sufficient to account for the anomaly?), and sub-economic tin values over 5m.

The high values and width of anomaly 'H' on 350E make it a very attractive target and it is suggested that dipole-dipole surveys at 50m intervals from and including, Fed 4 to Fed 3 would be worthwhile. Since the contact between the red and white granite is greater than 100m below the surface, a dipole spacing of 100m might be appropriate for defining a contact, however a spacing of nearer 30m would be better for defining a possible Sweeney's-type target (small body with good IP responses). Thus either a compromise survey is carried out, or two surveys with two different spacings. This question is further discussed below.

#### DISCUSSION

The IP over the Federation Grid was planned from the experience of the survey over Sweeney's (Wells, 1978), where a gradient array IP survey using a 10m dipole and station spacing had defined a small area (less than 50m across strike and probably less than 100m along strike) of high chargeabilities ( $>60$  mv/v) (Howland-Rose, 1977). Significant amounts of tin have been found at Sweeney's and hence the desire to find similar occurrences elsewhere in the Heemskirk granite. (The precise shape and attitude of the mineralisation at Sweeney's have proved difficult to define, but the IP, provided the survey is close enough, has clearly outlined the near-surface area.)

No Sweeney-sized anomalies were obtained from the IP over the Federation Grid (including the extension), however the small areal extent of Sweeney's suggests that infill lines are worthwhile over 'promising' anomalies (Roberts, 1980). There still appear to be several such anomalies that should be followed



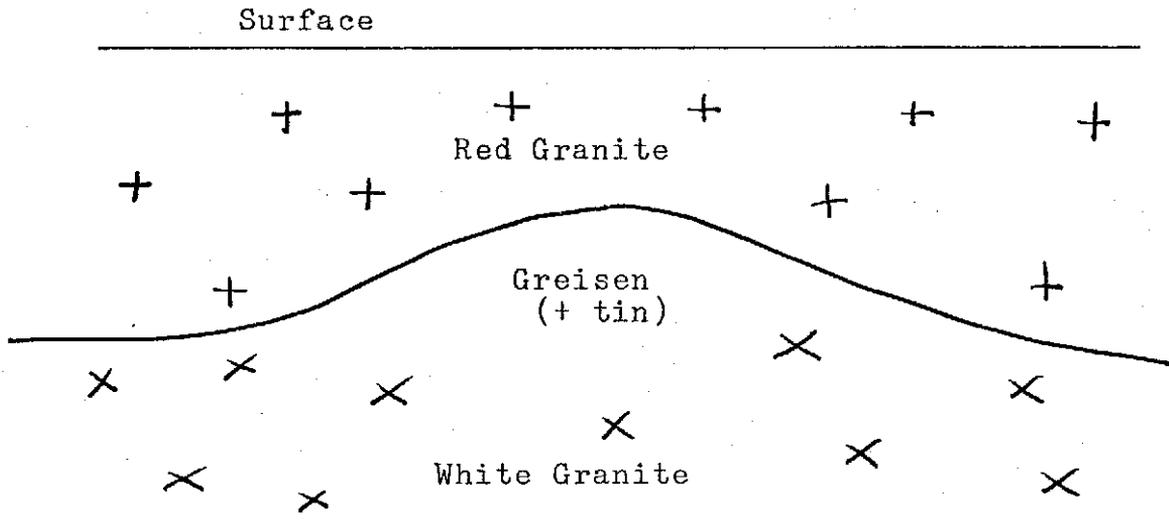
053

up - those areas noted on Figure 9 would probably include most of these. Even though I consider that the gradient surveys over Federation have been adequate for initial location of a Sweeney's-type deposit, I hope that the previous section has shown that the infill should be done with dipole-dipole (or pole-dipole) arrays, rather than by more gradient IP.

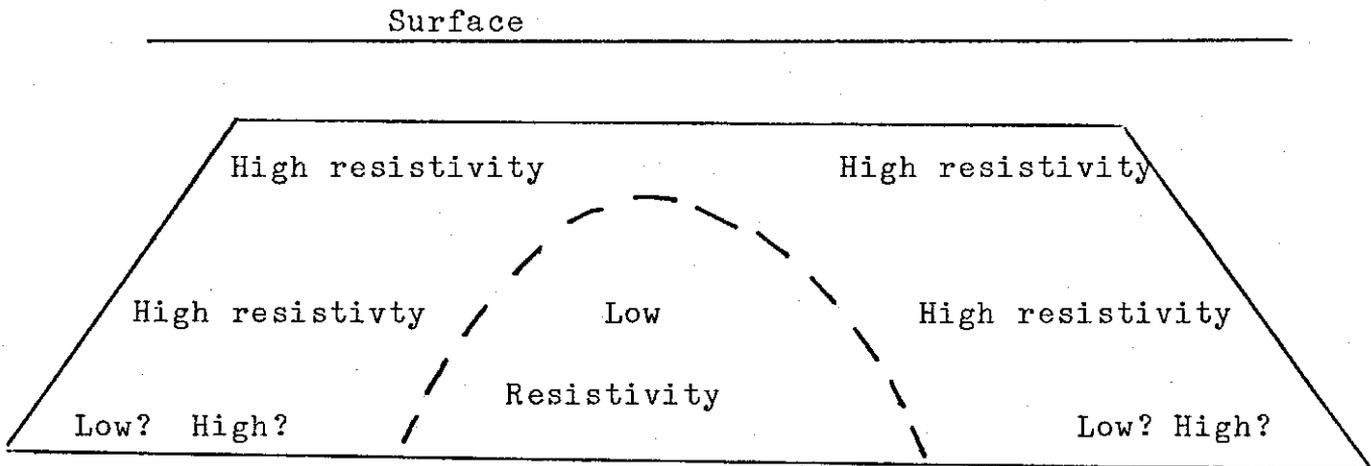
The Sweeney area itself is or perhaps, given the large number of holes already there, was an ideal site for follow up with dipole-dipole surveys: detailed yet 'deep-looking'; this can be achieved by doing a survey (with say 50m dipoles) and then off-setting the spread by half a dipole (25m). Thus the second survey fills in the 'gaps' of the first. A series of orthogonal surveys at Sweeney's could possibly have been considerable help in defining the shape of the volume of mineralisation.

For the other possible target-types, lumped under the general classification of 'alteration targets', the gradient array may not suffice; for these large-volume targets, the apparent near-surface response of the gradient array and that array's general lack of depth discrimination probably mean that any such occurrences would go undetected.

The results of the detail dipole-dipole surveys examined above suggest that alteration zones may be roughly outlined in the resistivity pseudo-sections (e.g. Figure 12) and thus large-dipole, multi-separation arrays may be the best geophysical means of detecting the alteration target (which has so far failed to yield economic concentrations of tin). A particular target within this broad category of 'alteration targets' is the type '1' target discussed under Geological Targets; but at depth, rather than outcropping as, e.g., is Black Face at Central Federation. This then, is the classic greisen-cupola style of mineralisation (e.g. Taylor, 1979 figs. 3.7, 3.8), where at Heemskirk, the greisen would be capped or contained by some thickness of red granite. A very simplified cross-section is shown below:



and a very simplified resistivity pseudo-section would be



A chargeability response would come from the likely (but not necessary) associated sulphides; a weaker but broader response may come from a sericitic or argillic halo. (Roberts, 1980, has stated that the contact between the two granite types has not been an effective barrier for tin mineralisation in the South Heemskirk field, however this may not be true everywhere on the granite.) A dipole spacing of 100m may be appropriate. It was noted earlier in the report, that some of the dipole-dipole surveys only extended to n=5, with three



data points missing; it was pointed out that the extra transmitting electrodes needed to 'fill in' these points meant that  $n=6$  could be read, with one point missing (on  $n=6$ ). The only limitation on reading to  $n=6$  is the poorer signal to noise ratio and hence, sometimes, the slower rate of reading. Where possible the deeper survey should be specified.

Roberts (1980) notes the difficulties in distinguishing the two granite types; it is possible that the larger dipole-dipole or pole-dipole surveys needed to search for the above target would detect (a subtle) bulk difference in the granites. And it is repeated here that the strong geophysical contrasts in magnetics, resistivity and chargeability as shown on their respective contour plans should be incorporated into any theory of petrologic and/or tectonic histories of the granites.

A significant part of this report has been devoted to a comparison of the various electrode arrays used on the Federation Grid. The relative merits of different arrays is still an emotional subject among geophysicists. I have contended, in this report, that the gradient array, while undoubtedly superior logistically, is inferior to multi-separation arrays in penetration and in depth discrimination; and while normally conceding a better horizontal resolution for the gradient array, that advantage does not seem to have been applicable here (e.g. Figure 11). Below are the conclusions from two mathematical model studies and one field case-history, on the response of array type to chargeable bodies. The examples are not (consciously) selective, there is little published on comparisons of various arrays.

Dodds (1976) made a parameter study of IP models, i.e. he studied the effect, for dipole-dipole, pole-dipole and gradient arrays, of altering the target depth, the target-host resistivity contrast, the overburden-host resistivity contrast, and the overburden thickness. The target was a horizontal



cylinder. Dodds' results showed that the gradient array response weakened in comparison to the other arrays as the target got deeper. However he considered that this may have been due to the relatively small current electrode separation used (other studies, e.g. Lajoie and Klein, 1979, have found gradient anomalies to be enhanced as the current electrode spacing has shortened). The effect of (conductive) overburden probably does not greatly concern us for exploration over Heemskirk, but again "the gradient array always yields a weaker response, the difference becoming more marked as the overburden thickness" (depth constant, overburden substituted for upper layers of hostrock)(Dodds, 1976).

Coggon (1973), testing a series of tabular bodies with and without overburden, concluded that the dipole-dipole array (out of dipole-dipole, pole-dipole and gradient) gave the largest anomalies and the best resolution and "only the gradient array provides dip information and horizontal resolution is good but there is no depth discrimination". The Table below is from Coggon, where the letters A, B, C and D indicate relative rating with A highest and D lowest.

Summary of Array Performance - (Coggon, 1973)

Characteristic	Dipole-Dipole	Pole-Dipole	Gradient
Magnitude of response	A	B	C
Dip of structure	C	C	A
Overburden penetration	A	A	A
Overburden irregularities	A	B	B
Freedom from interference of overburden irregularities	B	A	C
Horizontal resolution and location	B	C	A
Depths	A	B	D
Freedom from inductive coupling, layered earth	A	B	C
Freedom from inductive coupling, finite inhomogeneities	A	B	D



Tyne and Whiteley (1981) tested various arrays over the Woodlawn, N.S.W. massive sulphide orebody. And although they wrote that the gradient array has a larger depth of investigation (based on the response over footwall alteration) their table reproduced below suggests that anomalies from the gradient array with a signal to noise ratio of only 2 would be the first to disappear as the targets deepened. Such large differences in signal to noise ratio between gradient and dipole-dipole arrays are not seen in the Federation Grid results, however dipole-dipole is consistently better; typical values might be 1.7:1 for gradient and 2.2:1 for dipole-dipole.

I have not compared the resistivities from the different arrays over Heemskirk, but at Woodlawn the dipole-dipole array came much nearer (by a factor of 30) to measuring the true resistivity of the deposit and I have noticed elsewhere in Tasmania, the inability of the gradient array to define, in the resistivity results narrow conductive tabular sulphide bodies.

Summary of Electrical Responses of the Woodlawn Orebody  
(Tyne and Whiteley, 1981)

Features of Response over the Woodlawn Orebody	Array			
	<u>Gradient</u>	<u>Pole- Dipole</u>	<u>Dipole- Dipole (n=1)</u>	<u>Wenner</u>
Min. app. resistivity (ohm-m)	60	3.6	2	10
Minimum resistivity anomaly to background	1:9	1:16	1:25	1:7
Max I.P. anomaly (ms)	43	40	38	27
Max I.P. anomaly to background	2:1	5:1	15:1	4:1



One strong criticism I have of the gradient array, is the large number of single point anomalies it generates. In other geophysical methods, e.g. magnetics or gravity, such points would define the noise level, anomalies are defined by a series of points. (Technically this is known as aliasing, where a waveform (i.e. an anomaly) has been under-sampled and hence may contain higher frequencies (i.e. multiple anomalies).) That such points may not be noise is shown in Figure 11, where the original and detailed gradient surveys both define anomaly 'F' (anomaly 'E' is another example in this Figure from the original survey only). If genuine, such anomalies must of course define very shallow bodies; at best they serve to clutter the data, at worst to mislead. It is probable that the gradient array data would benefit from some form of filtering: it is unlikely that anything worthwhile has been found beneath a single point 'anomaly' and the data could well be enhanced by their suppression.

Filtering could also be applied to the resistivity (and chargeability) data to overcome the anisotropy in the sampling (100m in one direction, 10m in the other) which has resulted in the predominantly, east-west contouring. The effect of such filtering would be to remove the local effects and to emphasise the 'broader view'. Thus, for example' the division into the 'high' and 'low' zones previously discussed should be enhanced. It is possible that the filtered maps could be used to define areas of fresh and altered granite.

On all the geophysical contour maps of the Federation Grid, Lake Cumberland is a large, obvious, gap in the data. And if mineralised and/or altered areas are more easily weathered, it may not be too fanciful to assume that the Lake, an area of low topography, may overlie prospective zones. Therefore it should be noted that it is quite possible to conduct IP surveys over, or on, the bottom of the Lake. Magnetometer surveys can be done either from an aluminium (or wooden) boat or by using a marine magnetometer (towed by any sort of boat).



### CONCLUSIONS

The IP method is the most appropriate for the detection of sulphide and alteration zones on the Heemskirk granite, zones which hopefully have associated (economic) tin mineralisation. The original gradient surveys have adequately surveyed the Federation Grid for a Sweeney-type deposit, i.e. a small but highly chargeable, near-surface sulphide deposit. Whilst the 100m line spacing is rather large, it is unlikely that such a deposit would be completely missed: but this does mean that all areas of interest should be surveyed with infill lines (i.e. a line spacing of 50m; more detail is not warranted for the first follow-up surveys). For the weaker anomalies, thought unlikely to be prospective, but which nevertheless need checking, the gradient array could be used; but for those anomalies from which more information is desired, the dipole-dipole array would be the most effective. Detailed gradient IP with the follow up dipole-dipole surveys has contributed little (e.g. Waxman and Weston's).

The gradient surveys have not revealed another Sweeney's, but they have yielded several, mostly weak, anomalies. Some of these have been detailed with dipole-dipole or pole-dipole surveys. The results of these 'multi-separation' arrays have generally shown the gradient anomalies to be due to weak, near-surface effects. Since these follow-up surveys, have (necessarily) used small dipole spacing, IP so far, has probably only explored the near-surface. The gradient data should not be considered to have adequately searched for a deep zone, particularly a large volume, alteration-type target, with possibly only a few percent sulphides (a body as chargeable as Sweeney's should still be detectable at 50+ m).

Such a target, a large volume, low-grade tin deposit in an alteration zone, should be looked for by using large dipole multi-separation arrays (probably pole-dipole for long profiles); the optimum spacings can be determined by (computer) modelling of the expected, or rather desired, parameters of the target.



Modelling of the results should also be done when siting drill holes based on geophysical results. As an example this exercise has been done for the northern anomaly on line 1700W: a very approximate model was chosen from a limited number of type curves and this was refined by computer modelling.

The geophysics is of course only one aspect of the overall exploration effort on Heemskirk and it must be integrated with the other techniques or approaches. I consider that representation of the geophysical anomalies as 'axes' on the geological map has been an inadequate way of incorporating the IP results. It is hoped that the anomalous zones and contours of Figure 9 and 10 of this report will enable better use to be made of the geophysics. These maps show further and different anomalies to the 'axes' and hence further and alternative zones are recommended for detailed coverage (listed in the Recommendations).

With respect to the integration of geophysics and geology, the geophysics is at variance with the petrological classifications: the resistivity and chargeability contour maps both show a definite division of the Federation Grid into two areas; a north-eastern area of lower resistivities and chargeabilities, and a south-western area of higher values. The roughly NW-SE boundary cuts across all geological divisions. Similarly with the magnetics, the clear division into 'quiet' and 'active' areas has no apparent relationship to the geological mapping. All of these geophysical boundaries represent strong, definite contrasts which should be incorporated into the geological descriptions of the granite.

It was stated above that IP was the best geophysical method to be used: an inspection of the chargeability and resistivity anomaly maps (Figures 9 and 10) shows that all the major old workings or prospects responded to one or other or both properties. These responses have been summarised in Roberts' 'triangular' diagrams. Few of the drill holes in these



areas have been sited on the geophysical anomalies. Some that have, e.g. Fed 8 can not be said to have effectively tested the anomaly. Fed 8 (Figure 12) is also a good example of the need for dipole-dipole surveys for follow-up surveys. A subsequent survey to the drilling shows that the drill hole has intersected a chargeability low, that the gradient anomaly ('E') is not significant (though the dipole-dipole survey should have extended further north to thoroughly prove this) and that the best (geophysical) target lies about 100m to the south.

Petrophysical testing of a limited number of core samples from Sweeney's, the Eastern Workings, and Waxman and Weston's has shown that there are definite chargeability and resistivity contrasts between fresh and altered or mineralised granite. Some simple spectral IP measurements suggest that it may be possible to differentiate alteration/mineralised zones, however the mixing of types within the one area reduces the potential of this method.

The fact that the targets show up as resistivity anomalies (confirmed by core tests and the field surveys), Coleman's being the main exception, means that EM techniques may be considered. Airborne methods allow larger areas to be covered and are not restricted to cut lines; ground methods such as Sirotem are capable of deep penetration and give resistivity as a direct output.

The magnetics appears to have been little used, yet some of the old workings show definite anomalies, usually under 50 gammas. A more detailed contouring of the 'quiet' zone of the magnetic map would enhance these anomalies. Most, if not all, old workings fall into the 'quiet' area. (A further argument for a helicopter-borne EM survey, would be the accompanying high resolution magnetics. This could be particularly useful for the south-eastern area of the granite if Roberts' theory of Sweeney-type deposits occurring in 'holes'



in the magnetic map, i.e. 'quiet' areas within the 'active' zone, warrants further investigation.)

Although I have argued that in many cases the geophysical anomalies have not been optimally tested by the drill-holes, this may only be of concern if it is considered that some of these areas could contain small, high-grade (and economic) tin deposits. If the expectation is for a large-volume, low-grade deposit, then the holes have probably tested the area, if not the cause of the geophysical responses.

#### RECOMMENDATIONS

Further work already planned for the Federation Grid includes a drill hole on line 1700E; this should be sited using the results of the IP modelling (Figures 16 & 17). Consideration should also be given to extending the gradient array and to conducting a dipole-dipole survey over the southern anomaly on line 1700W (1200S) well before the drilling, since this area is comparable to, and possibly better than, the 900S gradient anomaly. This would enable the best dipole-dipole anomaly to be drilled first.

Whilst there are no other gradient anomalies as promising as those on line 1700W, there are several that still need following up. The large area of high chargeabilities south-east of Coleman's Workings has several anomalies worthy of follow-up (see Figure 9). A proposed dipole-dipole survey of the area using 30m dipoles is given below. For this area a detailed list is given and the proposed coverage for 500W is shown in Figure 21. (This figure has been included, with the list, to emphasise the advisability of giving complete specifications to the contractor.)



<u>Line</u>	<u>Sub-surface Coverage</u>	<u>Surface Coverage</u>	<u>Transmitting Electrodes</u>
500W	600S - 270S	690S - 180S	540S-330S (8 electrodes, read to n=6)
450W	" "	" "	" " "
400W	720S - 330S	810S - 240S	660S-390S (10 electrodes, read to n=6)
350W	" "	" "	" " "
300W	" "	" "	" " "
250W	710S - 390S	780S - 300S	630S-450S (7 electrodes, read to n=6)
200W	" "	" "	" " "

Obviously these proposals are only a guide that may be changed as the survey progresses. It can be seen in Figure 21 that three more readings are possible at the extremities of the spread; these have been left out on a time-effectiveness basis, but should be filled in, if the operator is recording anomalous values at his last stations.

Other anomalies that should be detailed are (from the west):

Line 1700W; 1200S (900S, already covered)

Line 1600W; 570S (930S, already covered)

Line 700W; 810S

(500W to 200W described above)

300W (drilled by Fed 7, but should be checked by dipole-dipole)

100E; 360N, 420N, 600N, 690N

200E; 420N

300E; 720S

400E; 420N

These areas are marked on Figure 9 where they have been (rather arbitrarily) classified into two grade of anomalies.

The above detailed surveys are for small polymetallic sulphides (Sweeney-type) orebodies; for large volume deposits, a larger dipole spacing is required. I understand that another drill hole is planned for the Waxman and Weston's alteration



zone; a 100m dipole-dipole spread is recommended over that area. A long profile, of pole-dipole or dipole-dipole (the former is usually more cost-effective on profiles) is also recommended over a line with drill holes, detailed dipole-dipole and gradient coverage; 600E over Fed 5 and 12 is suggested. Lastly one line across the whole grid is recommended to see if there are any bulk changes, at depth, between granites; line 300W is recommended between 1710S and 870N (i.e. the line end points).

If a Dighem (or other airborne) EM system is to be flown over Renison's Leases it is recommended that small test surveys be conducted over two areas of the Heemskirk granite (1) Sweeney's to determine the airborne EM response to this type of deposit and (2) over Waxman and Weston's. Such test surveys should obviously include sufficient of the surrounding unaltered granite to give a contrast. The purpose of these proposed airborne surveys is to determine the technique's effectiveness for exploring the rest of the granite.

Since the geophysics is not detecting tin, the best geophysical anomalies are not necessarily those with the most tin: Sweeney's with the most sulphides (and the biggest geophysical response) has the most tin, but there may well be higher grade tin deposits that are poor in, or free of, sulphides (but which may still have a significant geophysical response).

*J. R. Bishop*

J.R. BISHOP

SEPTEMBER, 1981

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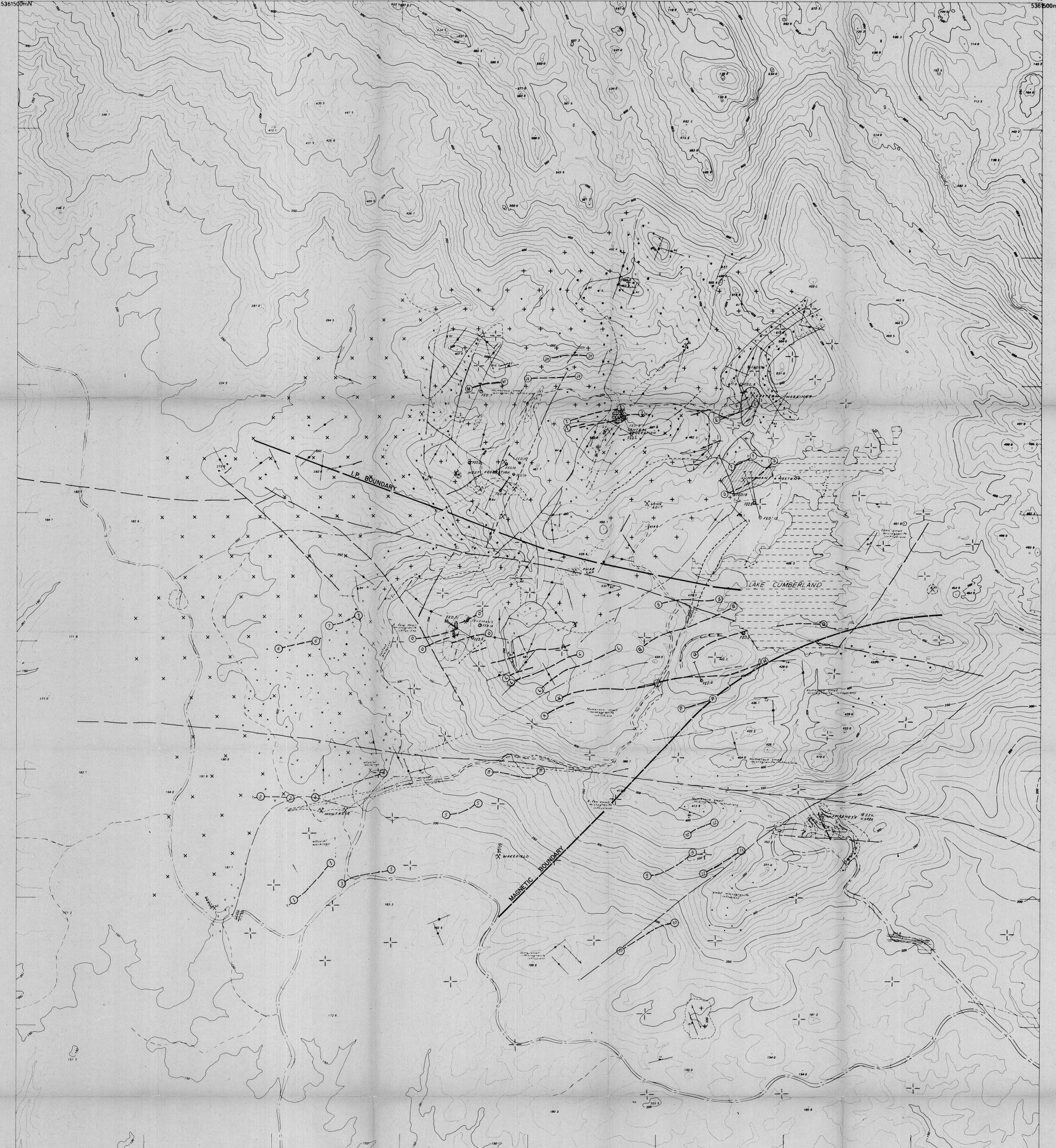
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348000mE

352000mE



535700mN

535700mN

LEGEND

ALTERATION

- Argillite Alteration
- Quartz and Tapes and/or Turmaline
- Sulfide mineralization associated with Argillite
- Hydrothermal Alteration
- Chalcopyrite
- Quartz - mica greisen
- Area of Turmaline nodules
- Silver alteration (mostly magnetite) and associated arsenic in quartz

ROCK TYPES

- Fine grained
- Medium grained
- Medium grained, usually porphyritic
- Coarse grained
- White younger granite
- Red older granite

- Major Lineament
- Joint with slip
- Joint, vertical
- Fault line
- Definite Geological Boundary
- Approximate Geological Boundary inferred
- Old mine or prospect

- Chargeability axis/ anomaly and symbol (1977 survey)
- Reason representation of terrain geophysical anomalies
- Chargeability axis/ anomaly and number (1978 survey)
- Diamond drill hole

10 boundaries higher resistivities and chargeabilities south of the boundary, lower resistivities and chargeabilities north of the boundary.

Magnetic boundary boundary represents active south-east of the boundary.

**COMPILATION NOTE**  
This sheet is a composite of litho, geomorphic contours superimposed on a half tone reproduction of composite orthophotos from aerial photography dated 12/77.

**REFERENCE**  
Contours  
Depressions  
Spot Heights  
Contours  
N.B. Broken lines indicate lower reliability  
Contour interval 10 metres  
Spot heights to 0.5 metres  
Reduced levels to Australian Height Datum  
Coordinates Australian Map Grid  
Grid interval 500 metres

**SHEET LOCATION**  
535700mN  
348000mE

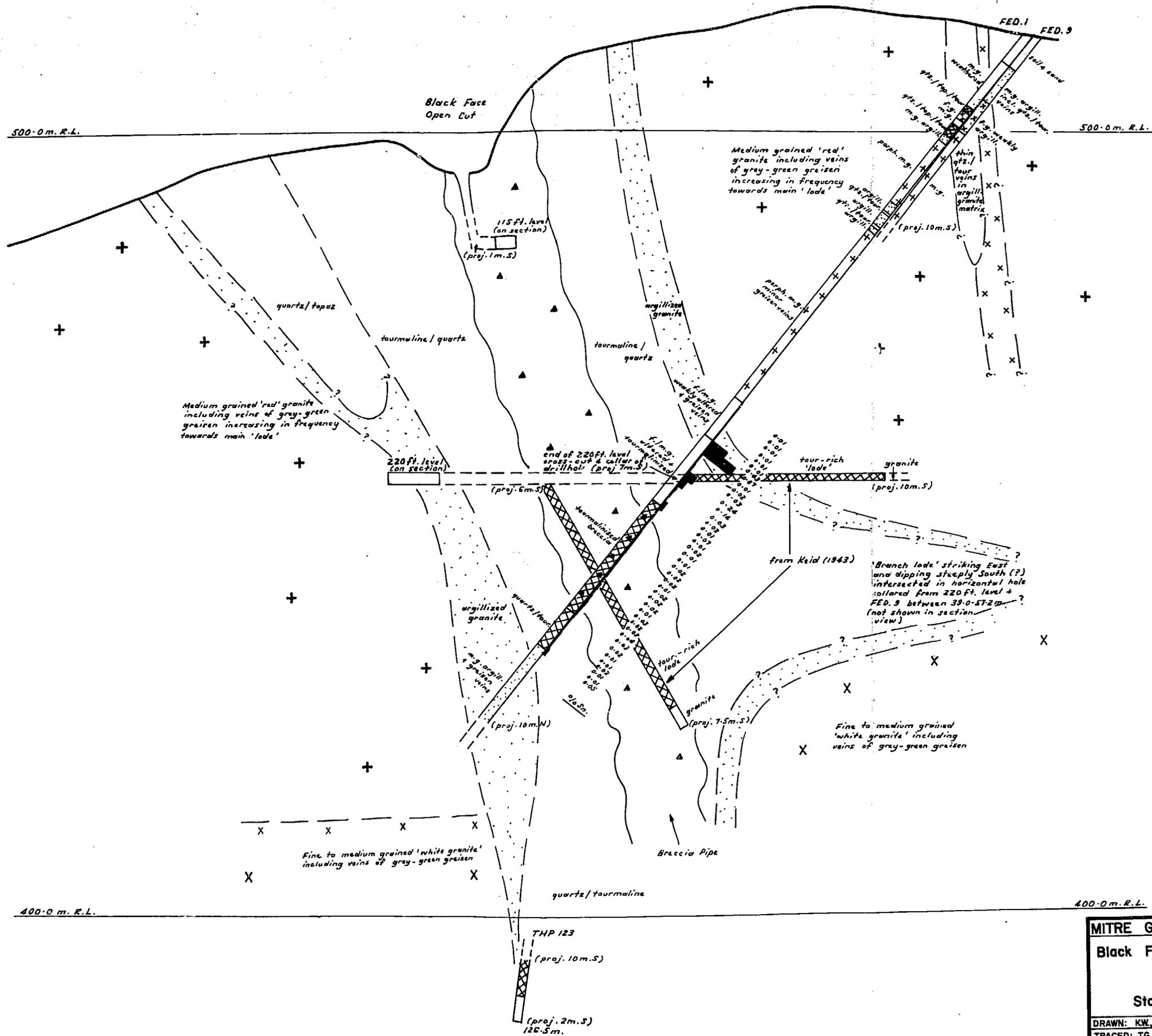
**REVISIONS**  
31-1590  
RENSON LIMITED  
937069  
HEEMSKIRK AREA  
GEOLOGICAL INTERPRETATION  
GEOLOGIST: K. Heale  
DRAUGHTSMAN: F. Colson  
DATE: June 1978  
REVISIONS: F. Colson May 1980  
F. Colson Aug 1980  
A. Roberts July 1980

**SCALE 1:6000 METRES**  
0 100 200  
SCALE BAR

**FIG. 1**

N.W.

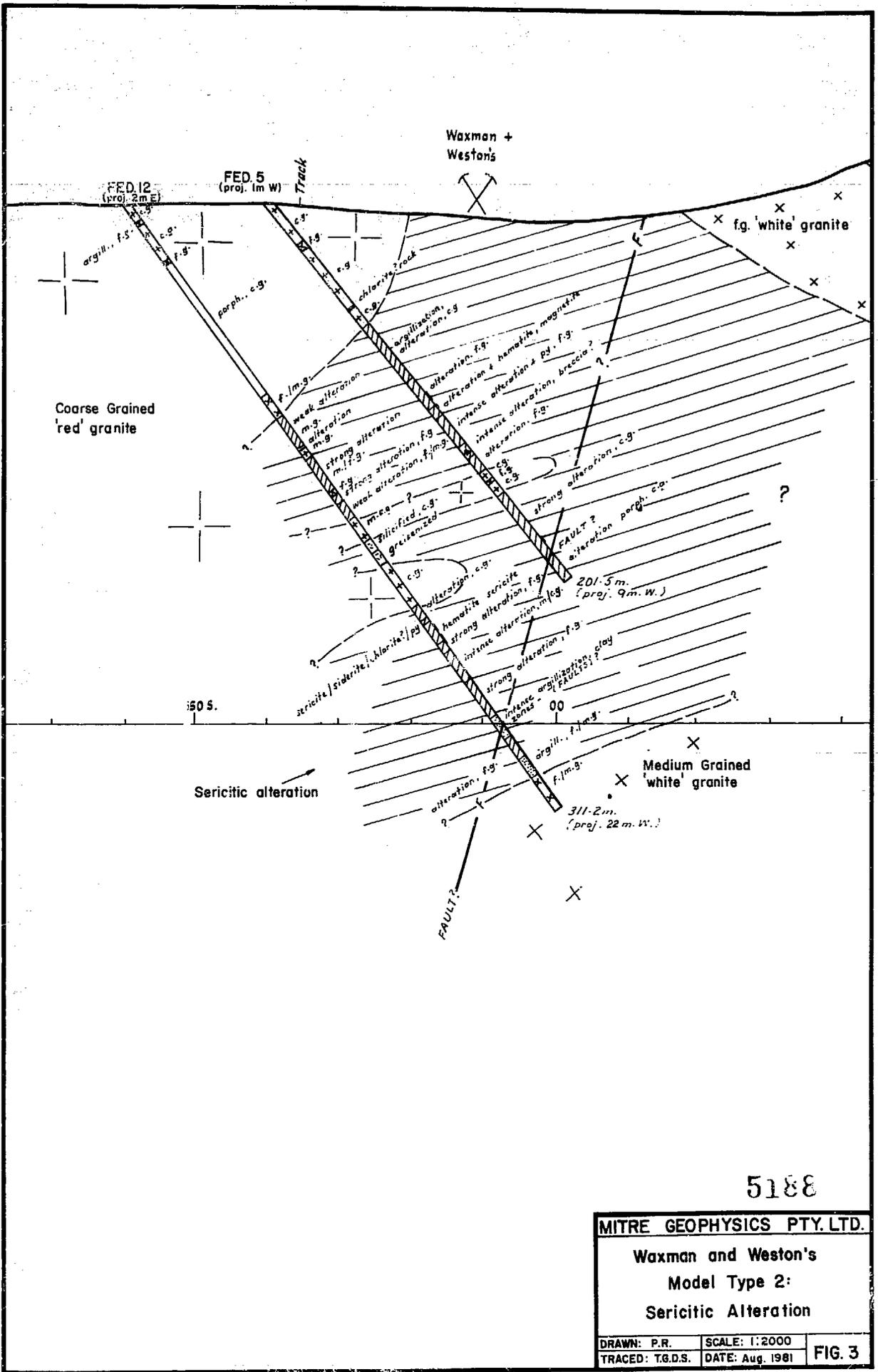
S.E.



5187

**MITRE GEOPHYSICS PTY.LTD.**  
 Black Face, Central Federation  
 Model Type I:  
 Stanniferous Greisen

DRAWN: KW, P.R.	SCALE: 1:500	FIG. 2
TRACED: T.G.D.S.	DATE: Aug. 1981	



5188

MITRE GEOPHYSICS PTY. LTD.		
Waxman and Weston's		
Model Type 2:		
Sericitic Alteration		
DRAWN: P.R.	SCALE: 1:2000	FIG. 3
TRACED: T.G.D.S.	DATE: Aug. 1981	

N.W.

S.E.

FED. 11  
(proj. 3.5m.S.)

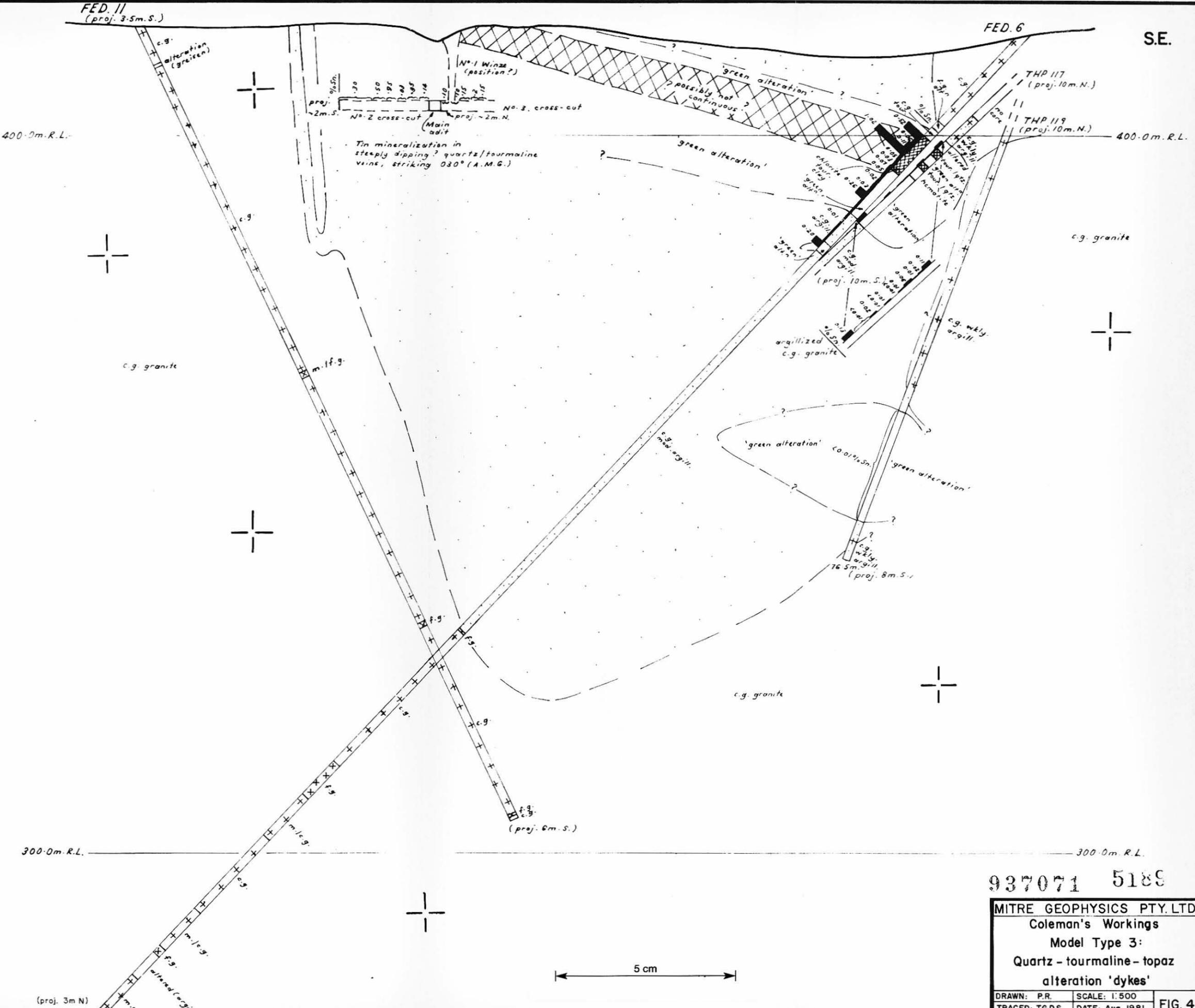
FED. 6

400.0m.R.L.

400.0m.R.L.

300.0m.R.L.

300.0m R.L.



937071 5189

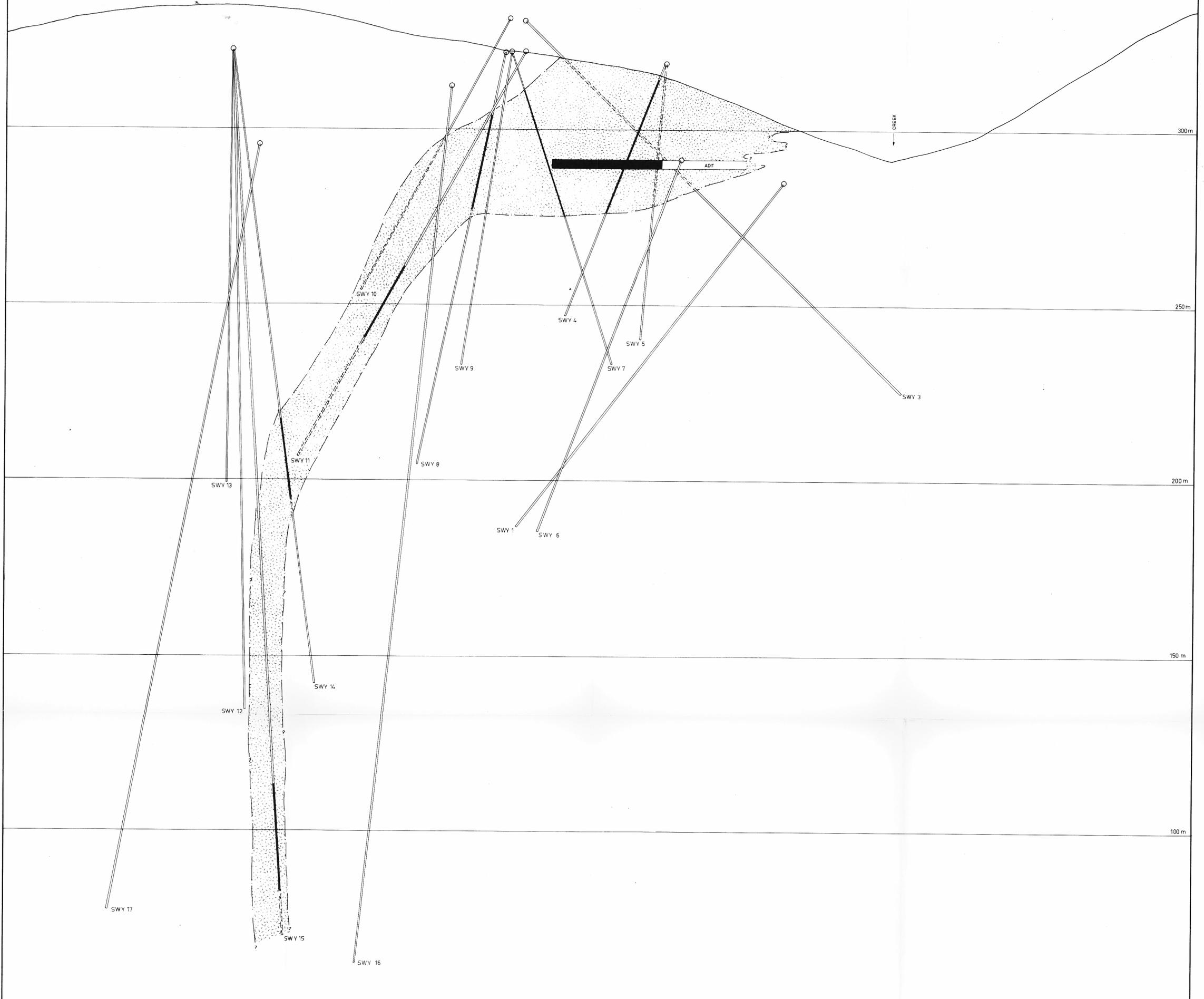
MITRE GEOPHYSICS PTY.LTD.  
 Coleman's Workings  
 Model Type 3:  
 Quartz - tourmaline - topaz  
 alteration 'dykes'

DRAWN: P.R. SCALE: 1:500  
 TRACED: T.G.D.S. DATE: Aug. 1981

FIG. 4

SOUTH

NORTH



937072 50 m

5180

To accompany Mitre Geophysics report 81/10

81-1590		RENISON LIMITED	
SWEENEY'S MINE AREA			
LONGITUDINAL PROJECTION			
ON BEARING		358° GRID	
GEOLOGIST:	P.R. STEPHENSON	SCALE: 1:500 METRES	
DRAUGHTSMAN:	J.M. MATTHEWS	0 10 20	
DATE:	APRIL 1978	REVISIONS:	

LEGEND.

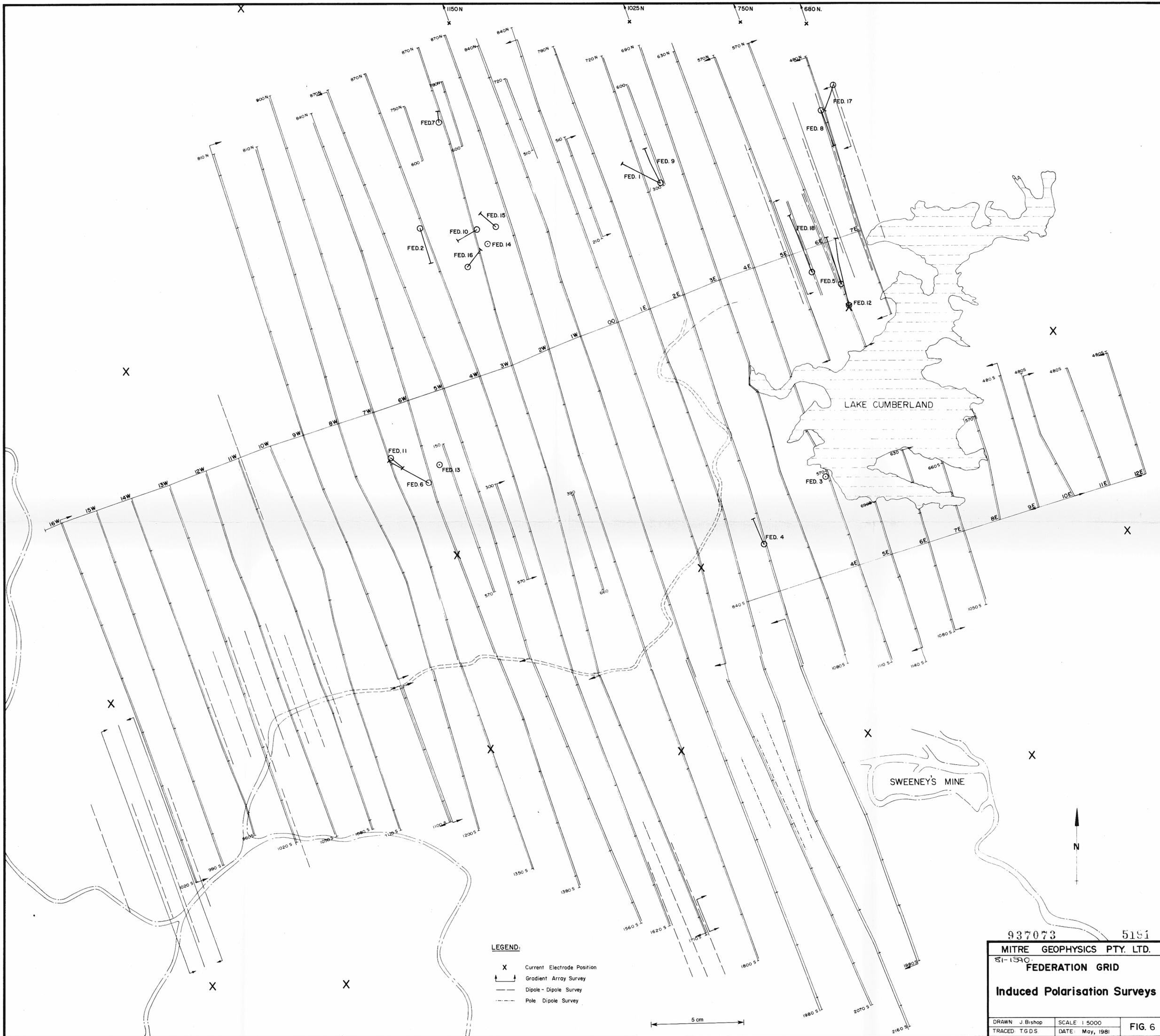
ALTERATION ZONE

DIAMOND DRILL HOLE INTERSECTION OF LODGE

5 cm

FIG 5

81-1590



**LEGEND:**

- X Current Electrode Position
- Gradient Array Survey
- - - Dipole - Dipole Survey
- · · Pole Dipole Survey

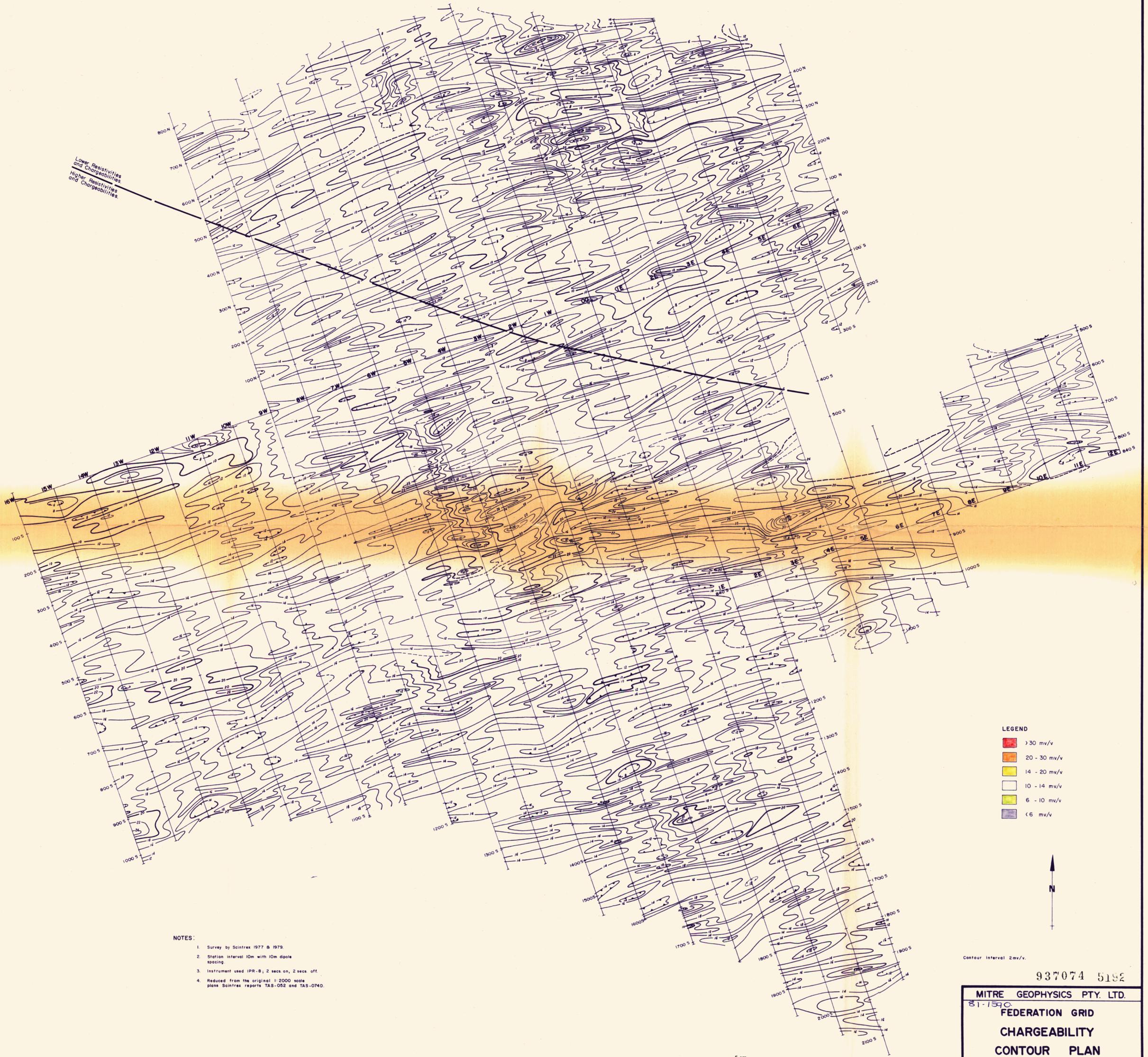
937073 5181

MITRE GEOPHYSICS PTY. LTD.

81-1590  
FEDERATION GRID

**Induced Polarisation Surveys**

DRAWN J Bishop	SCALE 1:5000	FIG. 6
TRACED TGD S	DATE May, 1981	



- NOTES:
1. Survey by Scintrex 1977 & 1979.
  2. Station interval 10m with 10m dipole spacing.
  3. Instrument used IPR-B; 2 secs on, 2 secs off.
  4. Reduced from the original 1:2000 scale plus Scintrex reports TAS-052 and TAS-074D.

LEGEND

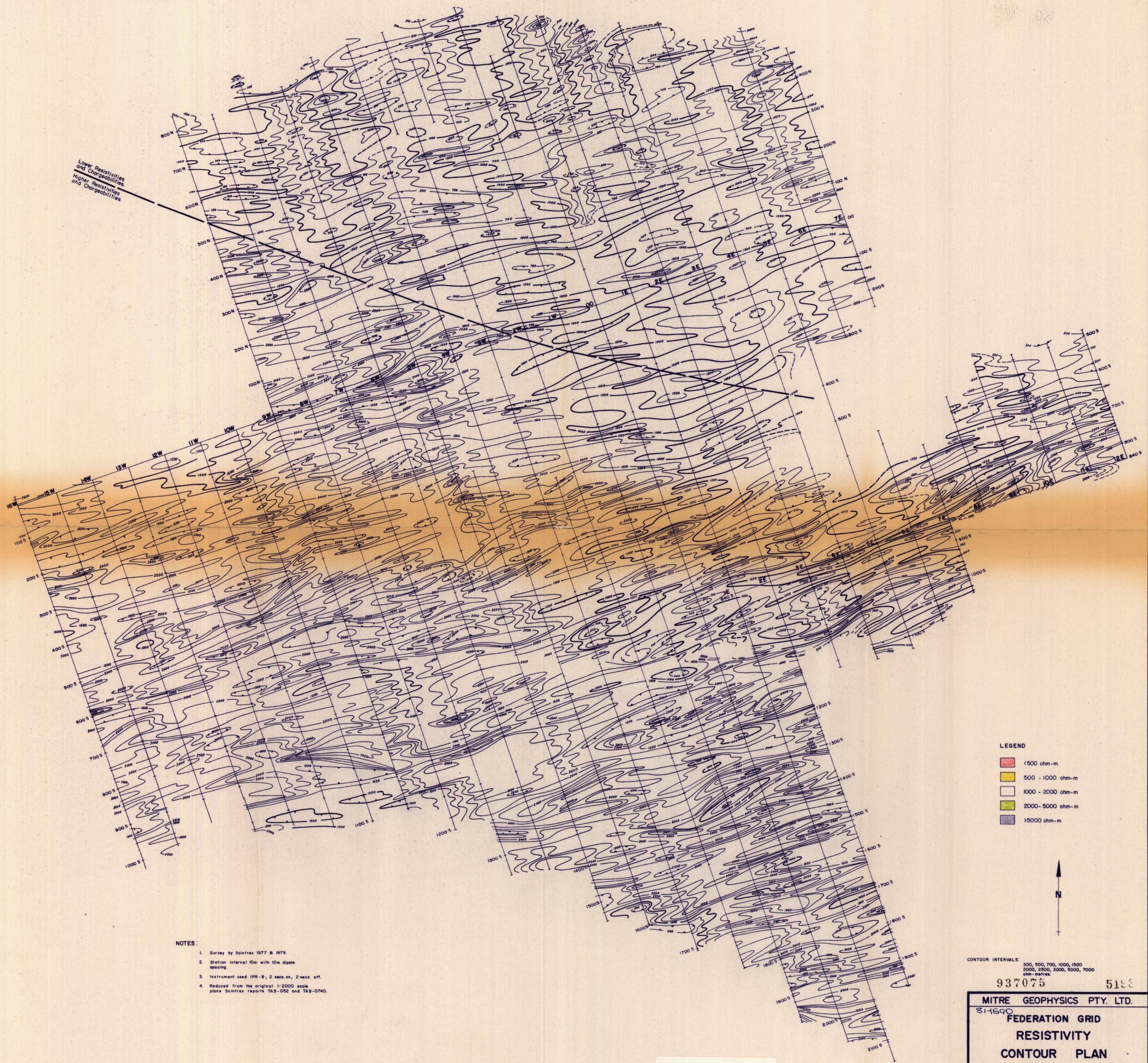
	> 30 mV/v
	20 - 30 mV/v
	14 - 20 mV/v
	10 - 14 mV/v
	6 - 10 mV/v
	< 6 mV/v

Contour interval 2mV/v.

937074 5192

MITRE GEOPHYSICS PTY. LTD.  
 81-1590  
**FEDERATION GRID**  
**CHARGEABILITY**  
**CONTOUR PLAN**

DRAWN: Scintrex	SCALE: 1:5000	FIG. 7
TRACED: T.G.D.S.	DATE: May, 1981	



Lower Resistivities  
and Chargeabilities  
Higher Resistivities  
and Chargeabilities

- NOTES:
1. Survey by Scintrex 1977 & 1979.
  2. Station interval 10m with 10m dipole spacing.
  3. Instrument used IPR-B; 2 sec. on, 2 sec. off.
  4. Reduced from the original 1:2000 scale plans Scintrex reports TAS-052 and TAS-0740.

LEGEND

	<500 ohm-m
	500 - 1000 ohm-m
	1000 - 2000 ohm-m
	2000 - 5000 ohm-m
	>5000 ohm-m

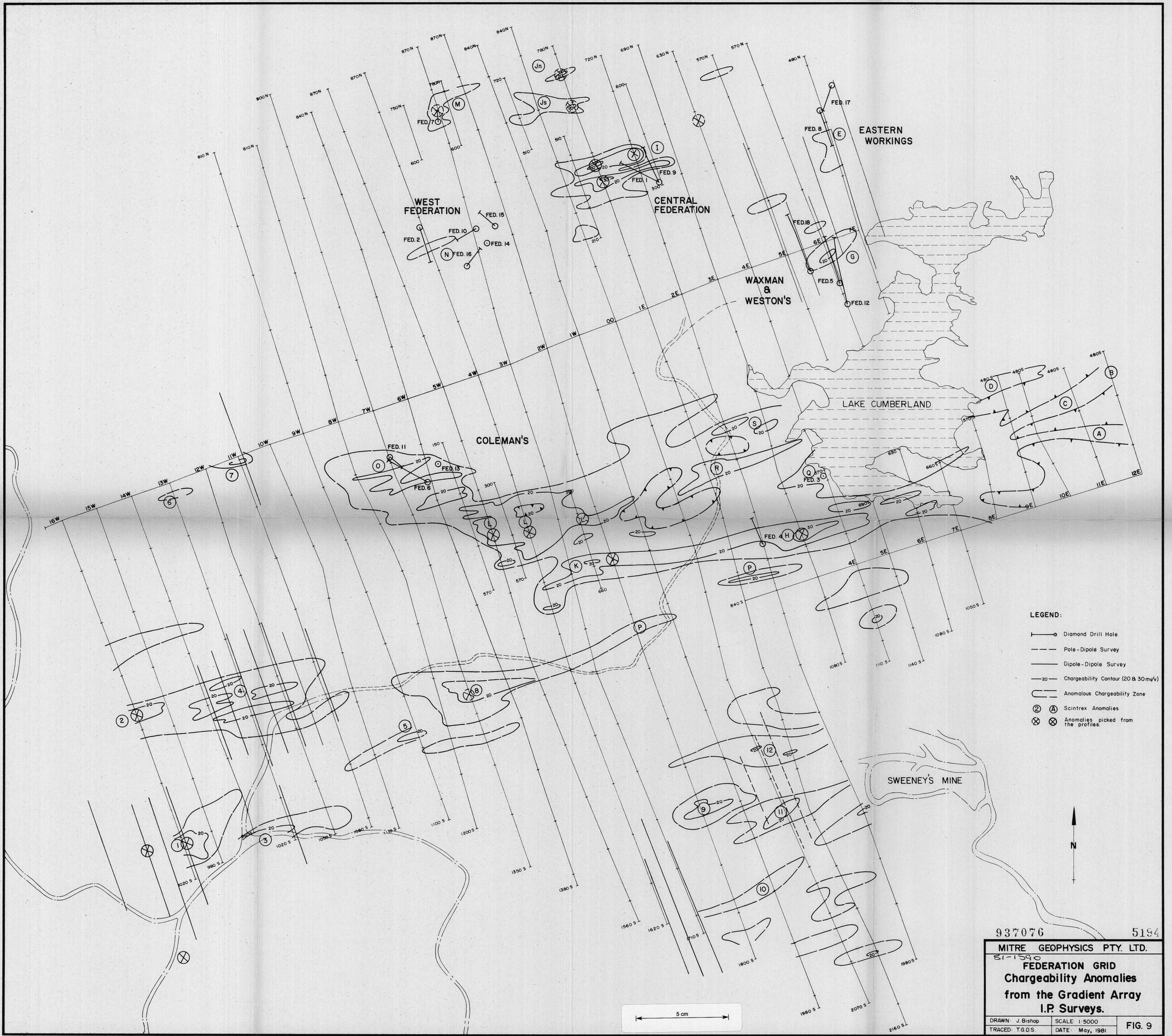
CONTOUR INTERVALS:  
300, 500, 700, 1000, 1500  
2000, 2500, 3000, 5000, 7000  
ohm-metres

937075 5198

MITRE GEOPHYSICS PTY. LTD.  
814590  
**FEDERATION GRID  
RESISTIVITY  
CONTOUR PLAN**

DRAWN: Scintrex	SCALE: 1:5000	FIG. 8
TRACED: T.G.D.S.	DATE: May, 1981	

5 cm



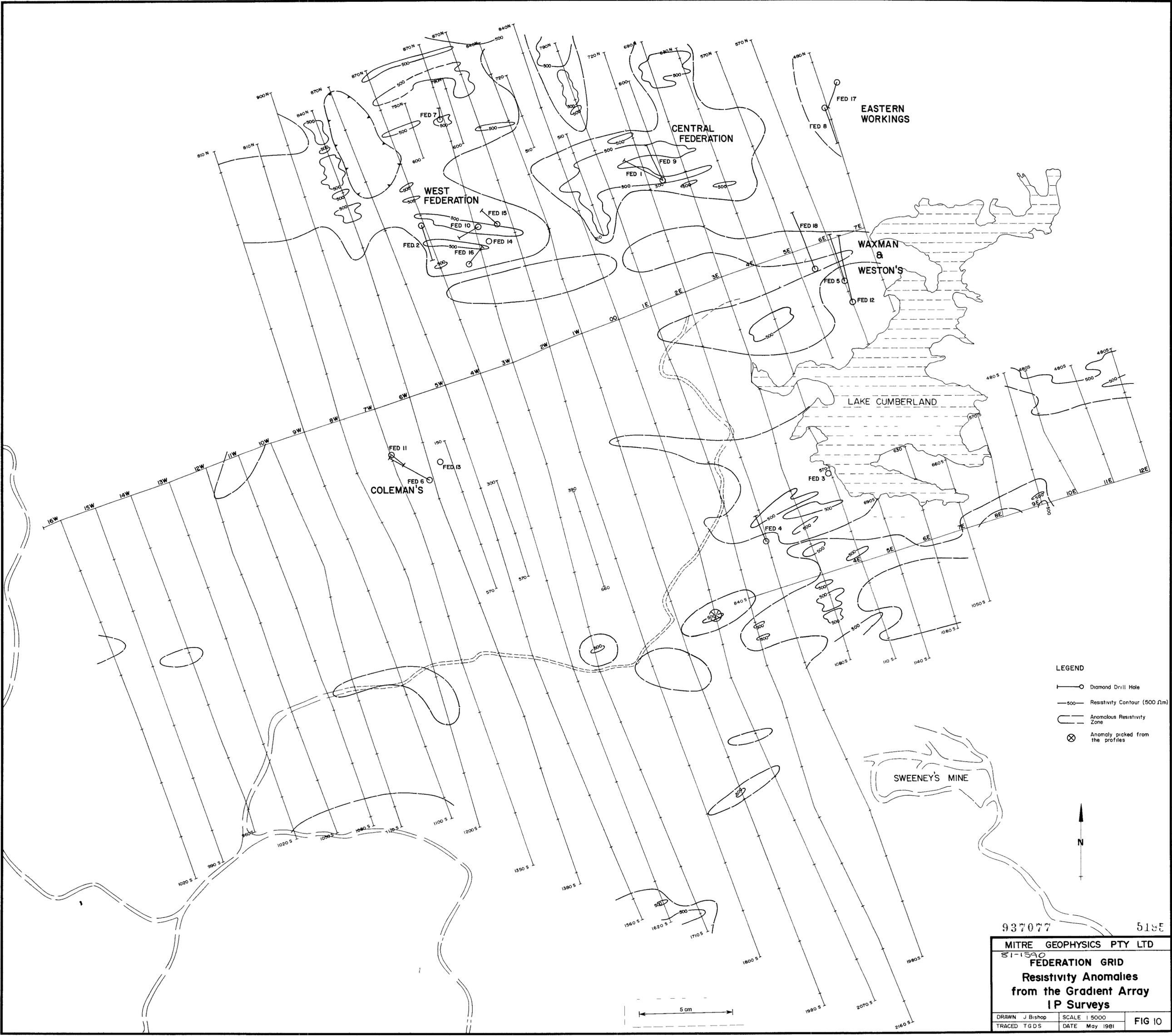
- LEGEND:**
- Diamond Drill Hole
  - Pole-Dipole Survey
  - Dipole-Dipole Survey
  - 20- Chargeability Contour (20 & 30mV)
  - Anomalous Chargeability Zone
  - ⊙ ⊙ Scintrex Anomalies
  - ⊗ ⊗ Anomalies picked from the profiles.

937076 5194

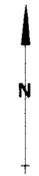
**MITRE GEOPHYSICS PTY. LTD.**  
 81-1590  
**FEDERATION GRID**  
**Chargeability Anomalies**  
**from the Gradient Array**  
**I.P. Surveys.**

DRAWN: J. Bishop	SCALE: 1:5000	<b>FIG. 9</b>
TRACED: T.G.D.S.	DATE: May, 1981	

5 cm

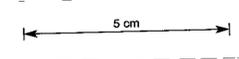


- LEGEND**
- Diamond Drill Hole
  - 500— Resistivity Contour (500 Ωm)
  - ⊖ Anomalous Resistivity Zone
  - ⊗ Anomaly picked from the profiles

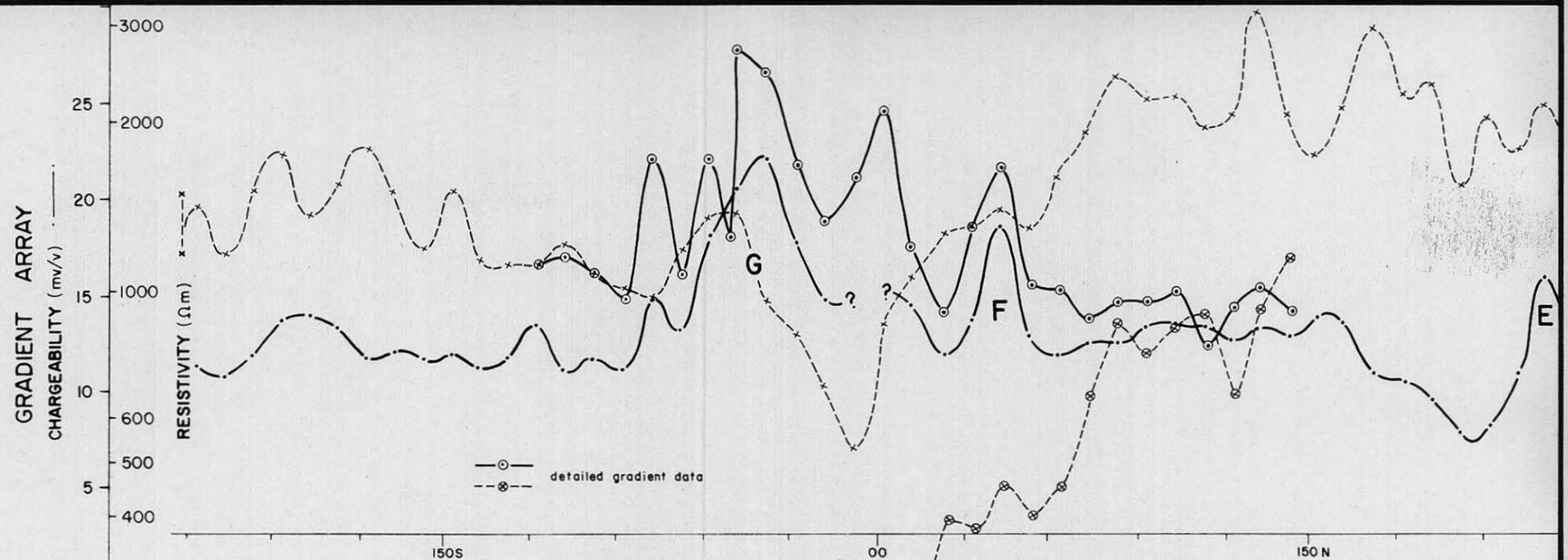


937077 518E

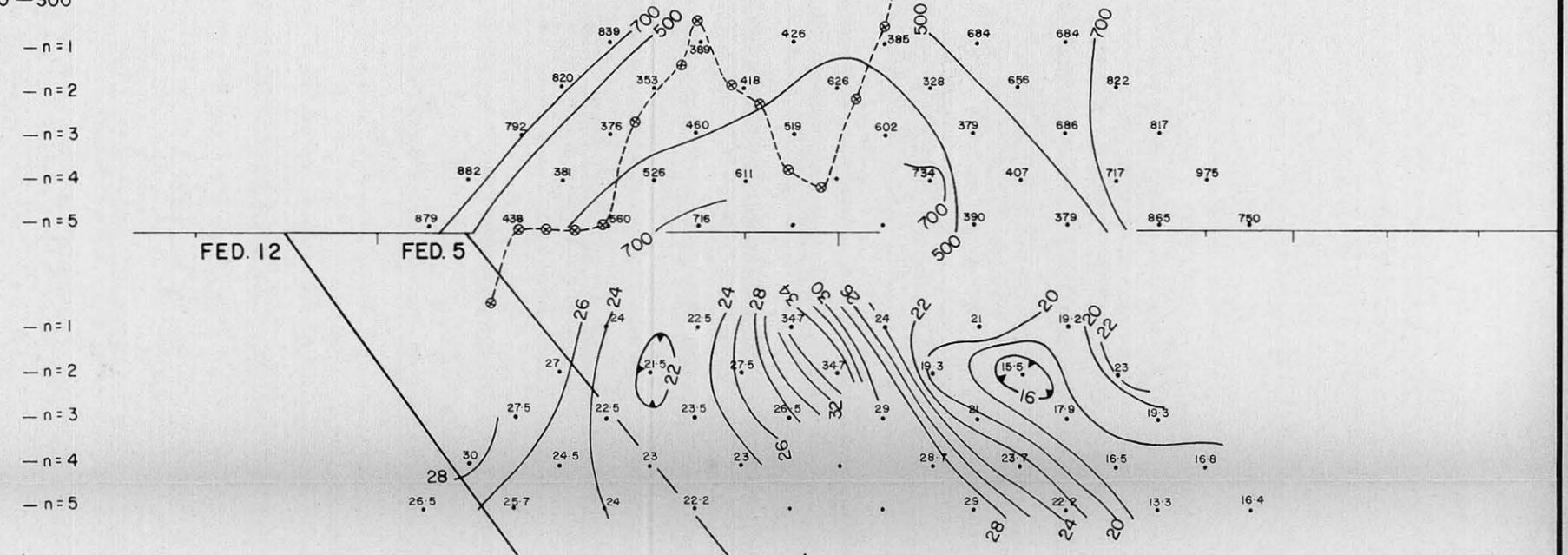
<b>MITRE GEOPHYSICS PTY LTD</b>	
81-1590	
<b>FEDERATION GRID</b>	
<b>Resistivity Anomalies</b>	
<b>from the Gradient Array</b>	
<b>IP Surveys</b>	
DRAWN J Bishop	SCALE 1:5000
TRACED T.G.D.S	DATE May 1981
<b>FIG 10</b>	



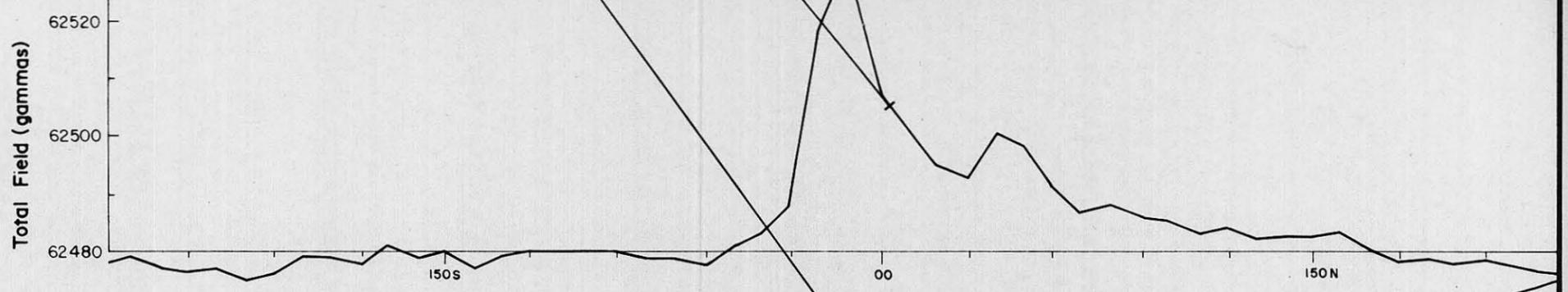
I.P. Data



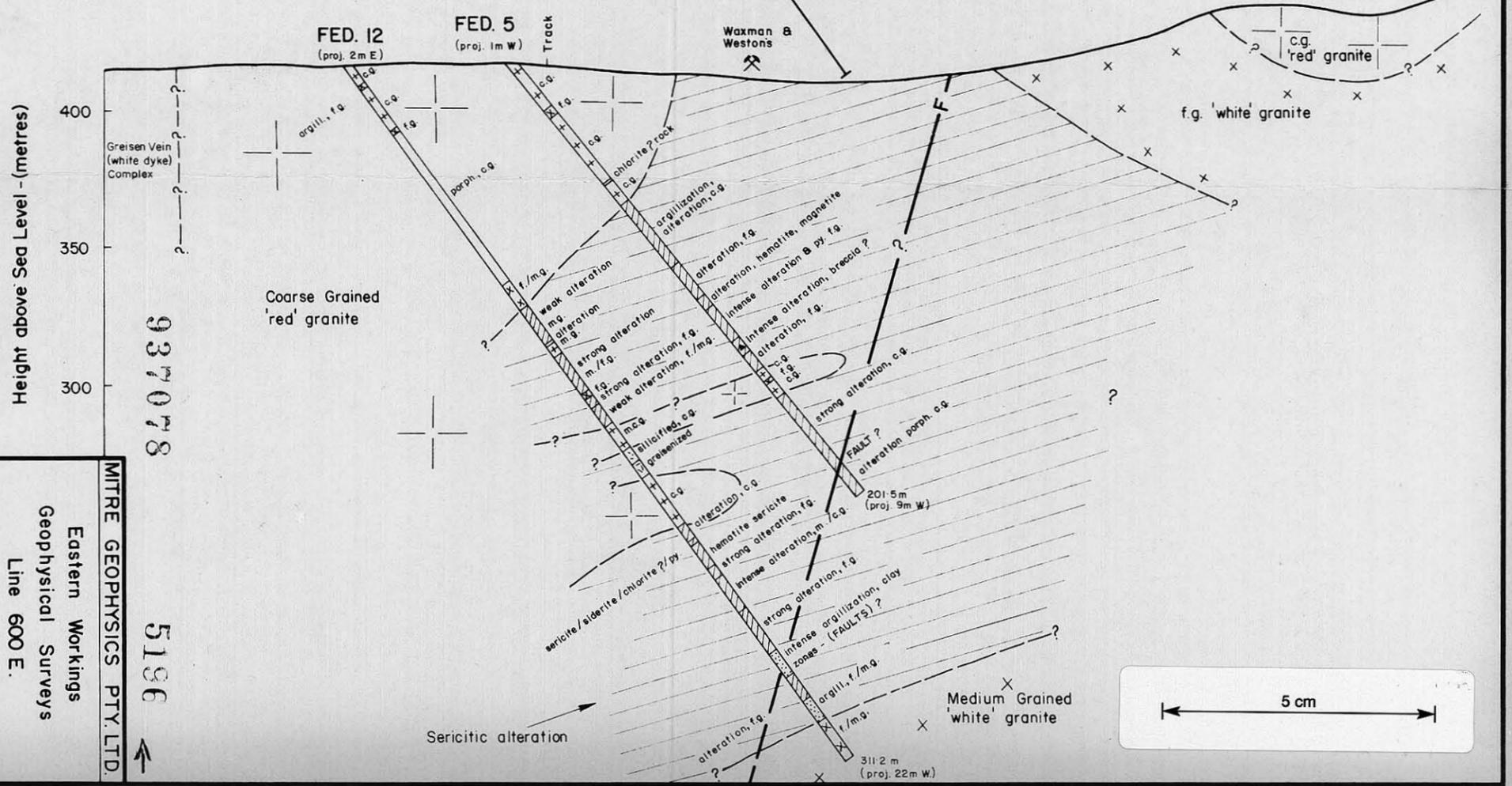
DIPOLE — DIPOLE  
CHARGEABILITY (mv/v)  
RESISTIVITY (Ωm)



Magnetics



Topography & Geology

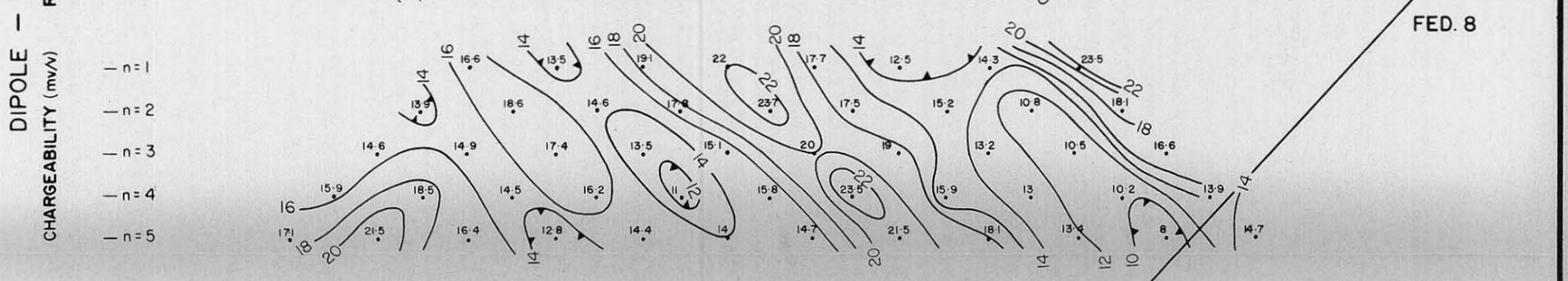
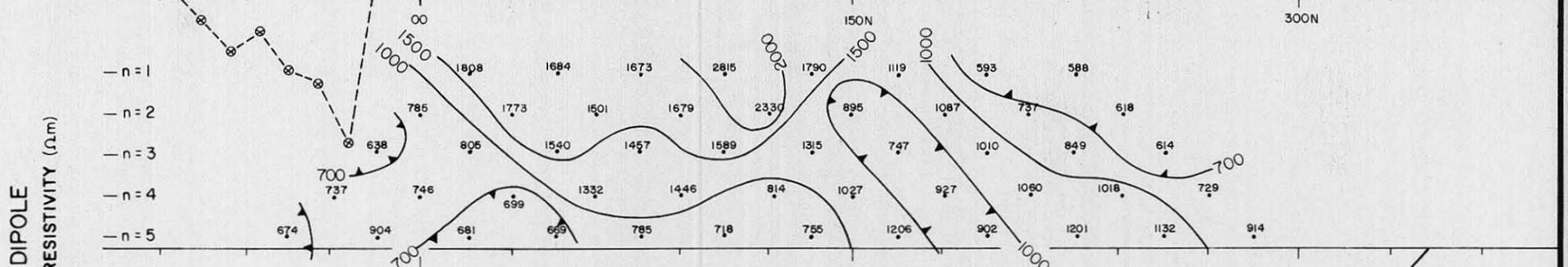
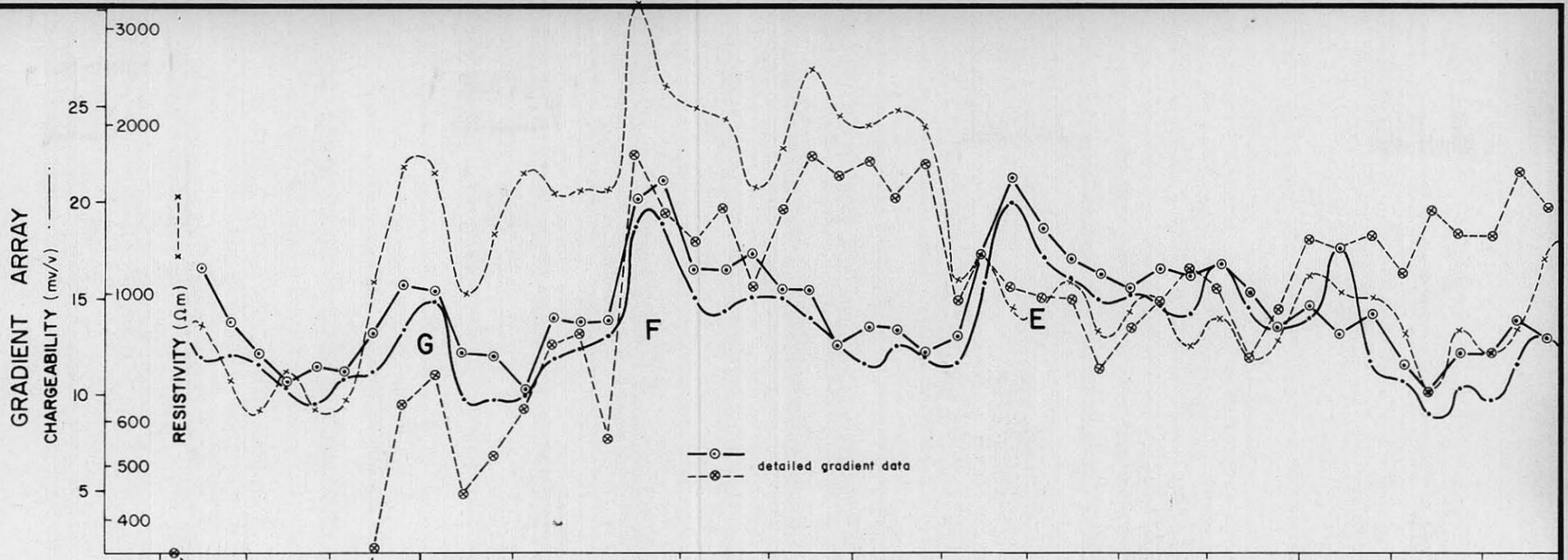


MITRE GEOPHYSICS PTY. LTD.  
Eastern Workings  
Geophysical Surveys  
Line 600 E.

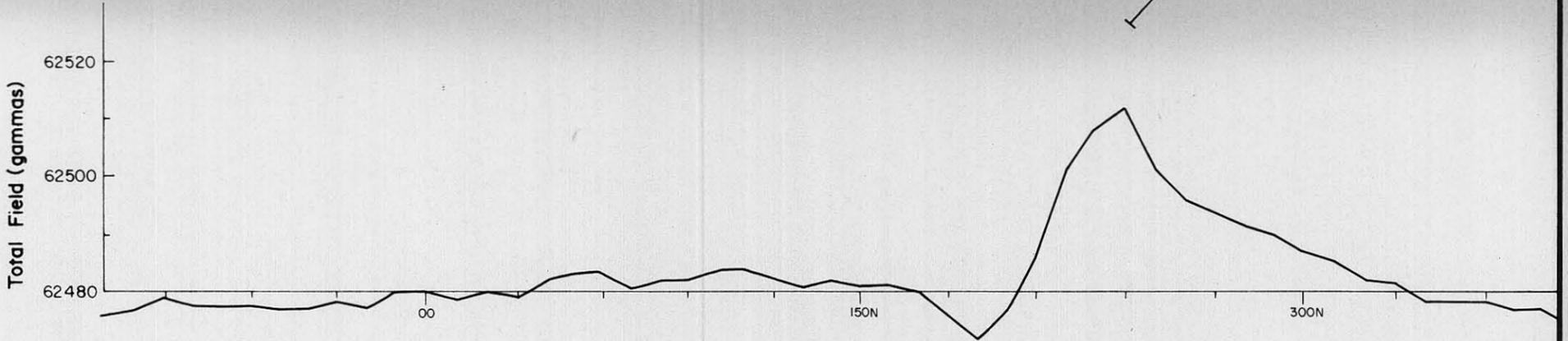
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TRACED: T.G.S. DATE: Aug. 1981

FIG. 11

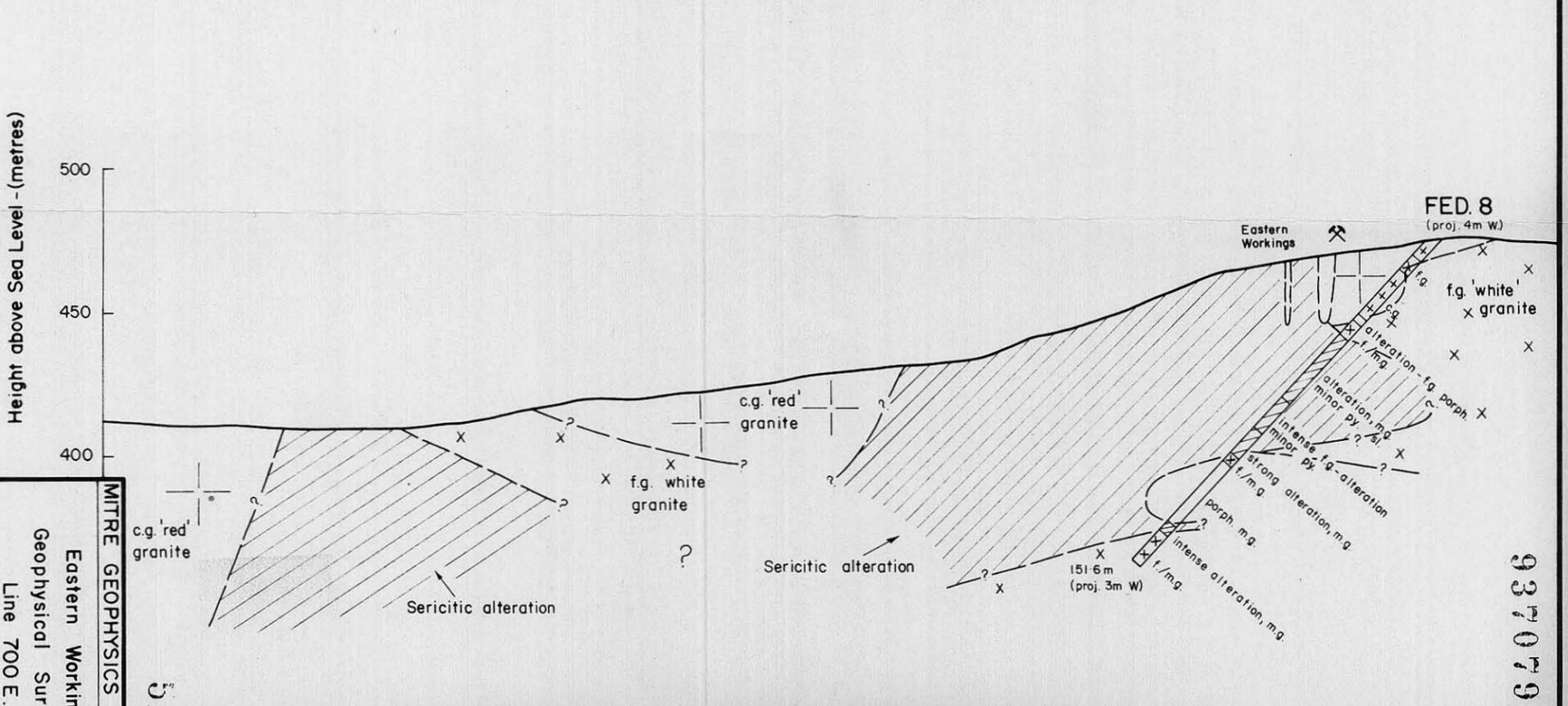
I.P. Data



Magnetics



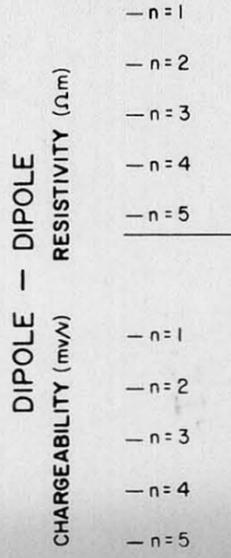
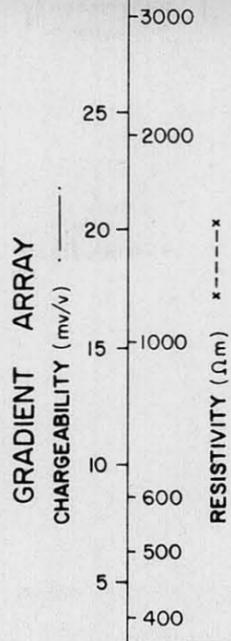
Topography & Geology



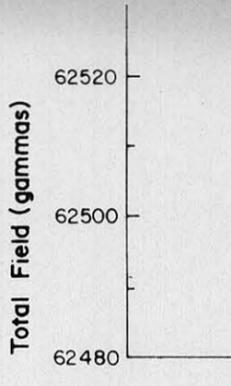
MITRE GEOPHYSICS PTY. LTD.  
 Eastern Workings  
 Geophysical Surveys  
 Line 700 E.  
 DRAWN: JB SCALE: 1:2000  
 TRACED: T.G.S. DATE: Aug 1981  
 FIG. 12

937079

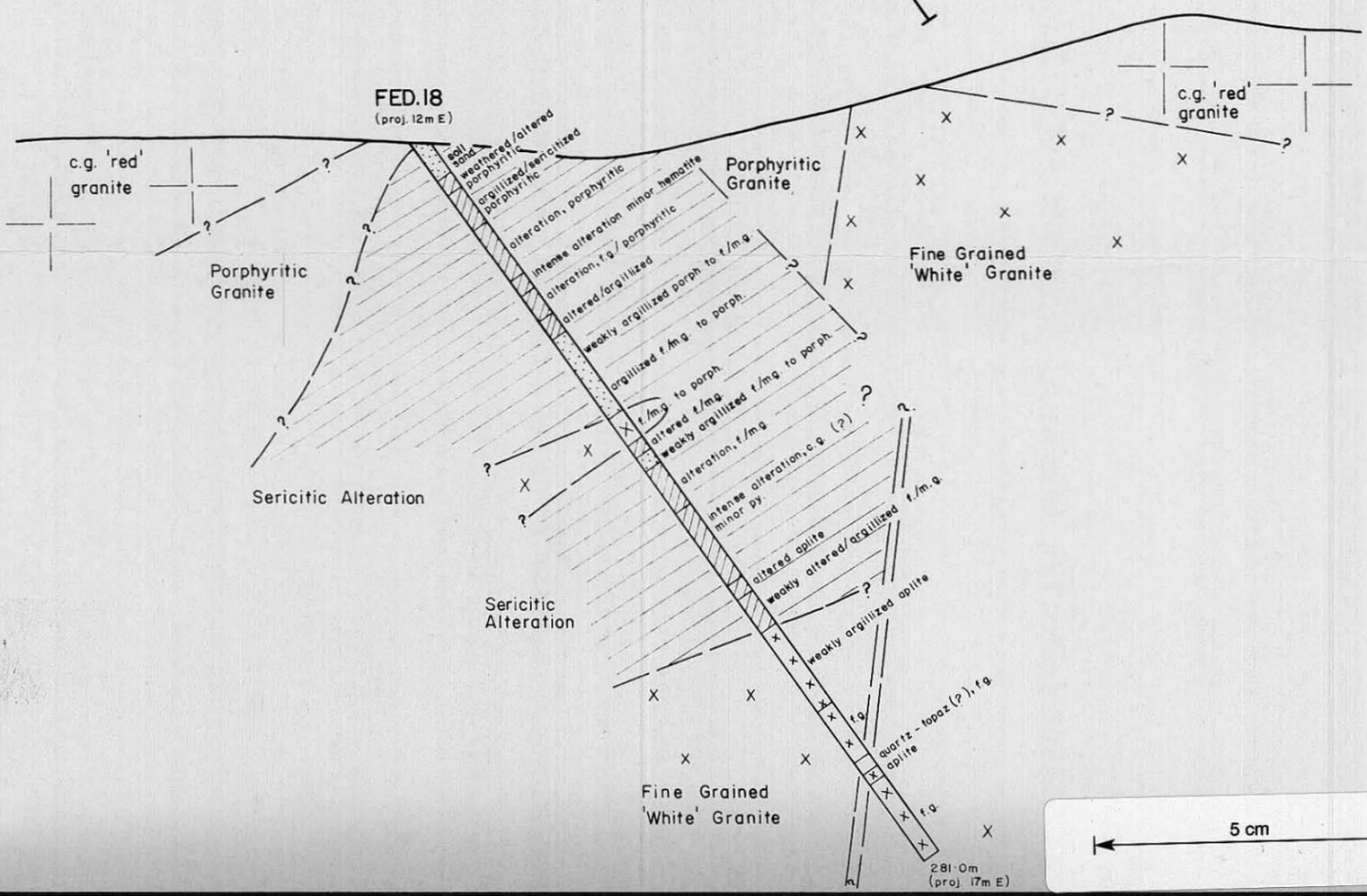
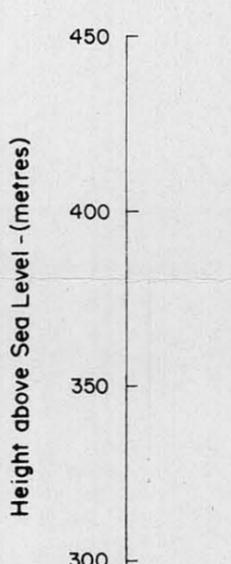
I.P. Data



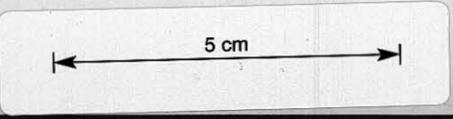
Magnetics



Topography & Geology

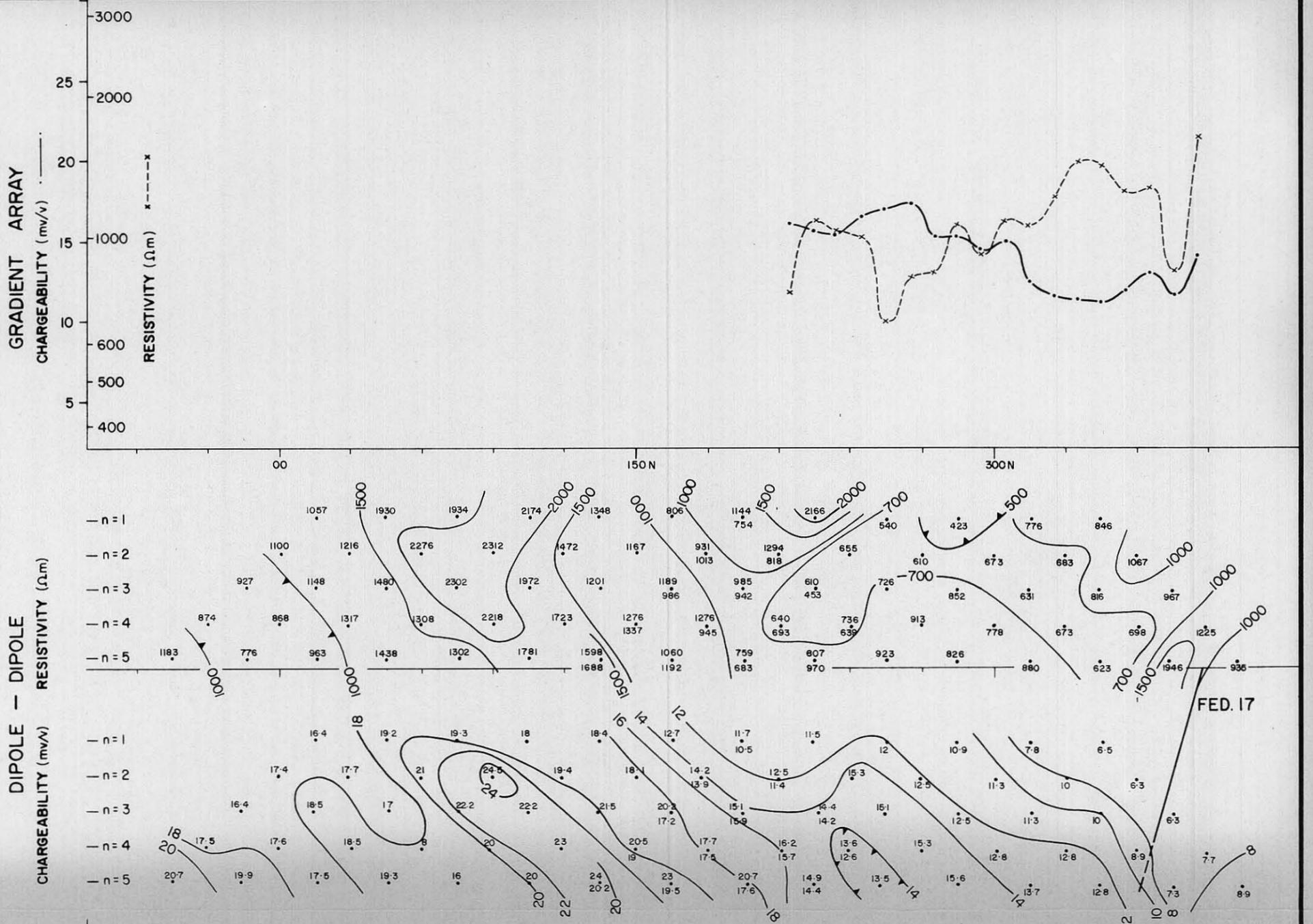


DRAWN: J.B. SCALE: 1:2000  
 TRACED: T.G.D.S. DATE: Aug. 1981  
 MITRE GEOPHYSICS PTY. LTD.  
 Eastern Workings  
 Geophysical Surveys  
 Line 550 E.  
 5198

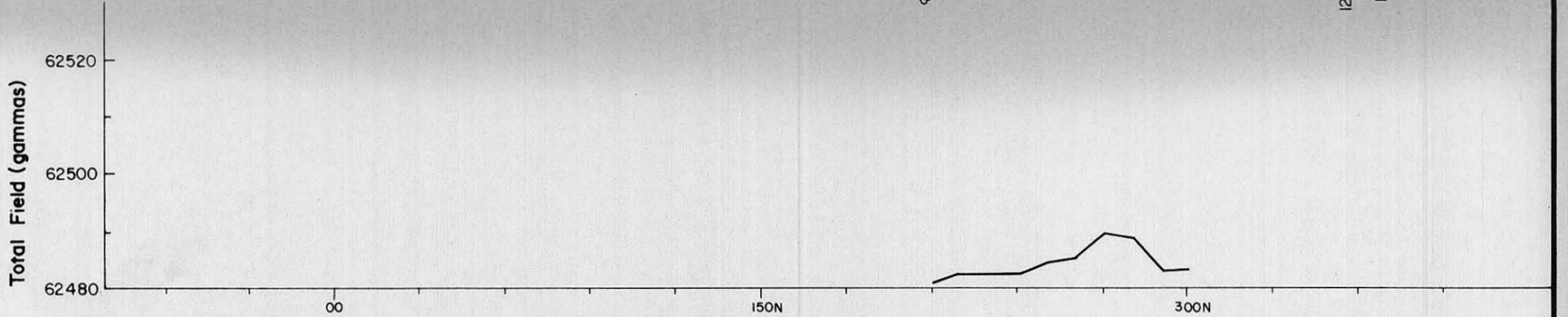


937080

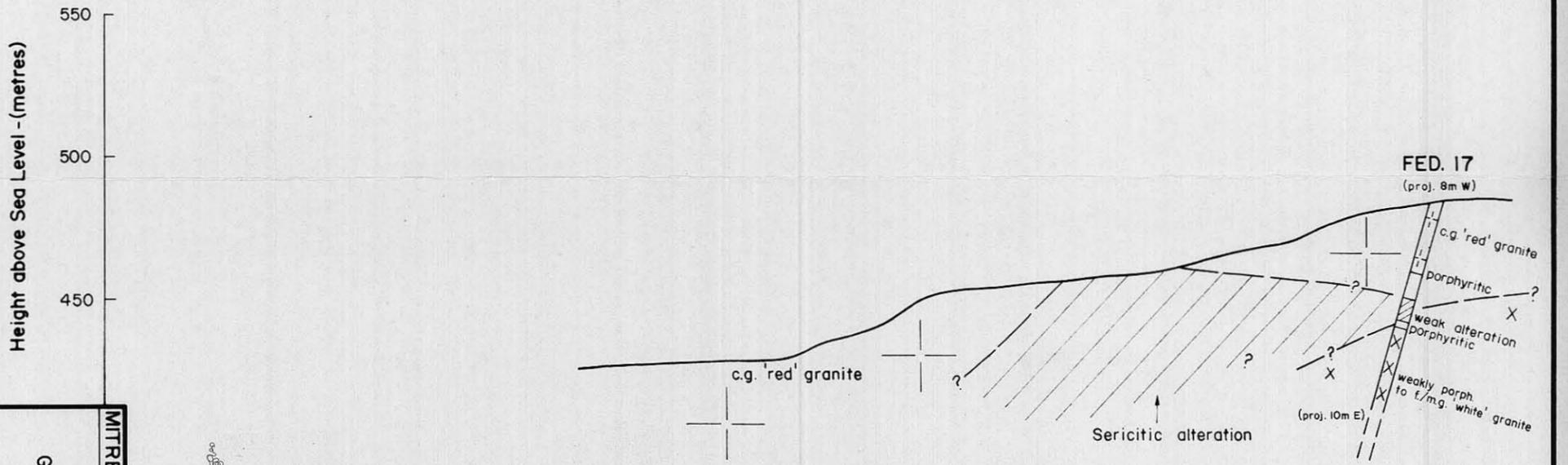
I.P. Data



Magnetics



Topography & Geology



MITRE GEOPHYSICS PTY. LTD.  
Eastern Workings  
Geophysical Surveys  
Line 750 E.

DRAWN: J.B. SCALE: 1:2000  
TRACED: T.G.D.S. DATE: Aug. 1981  
FIG. 14

5199

937081

I.P. Data

GRADIENT ARRAY

DIPOLE - DIPOLE

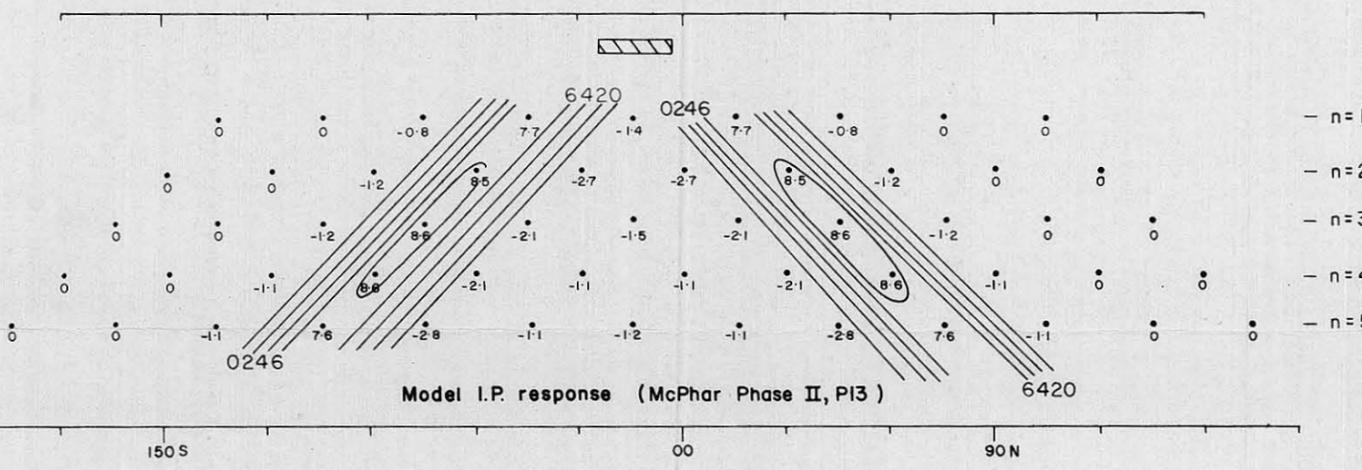
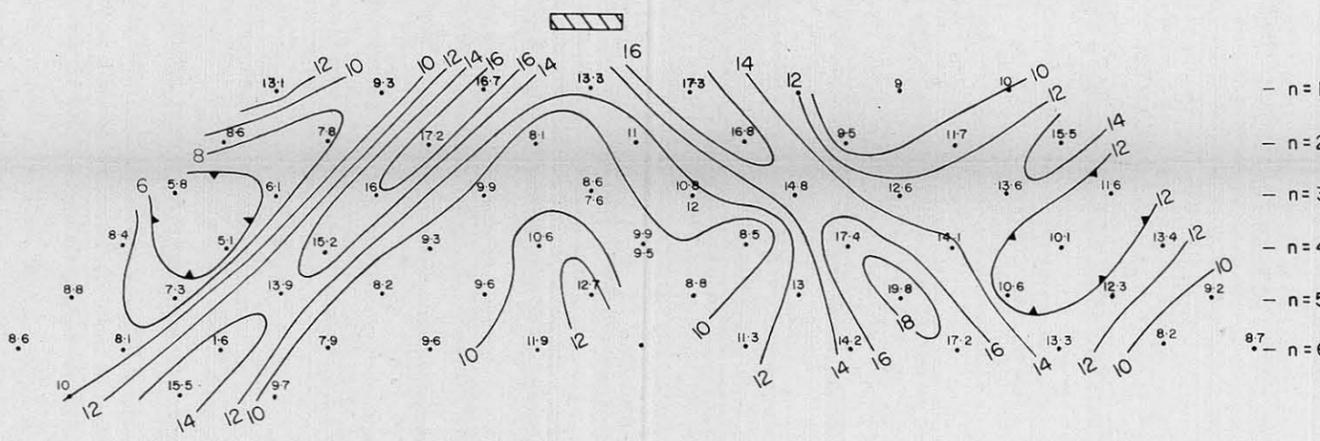
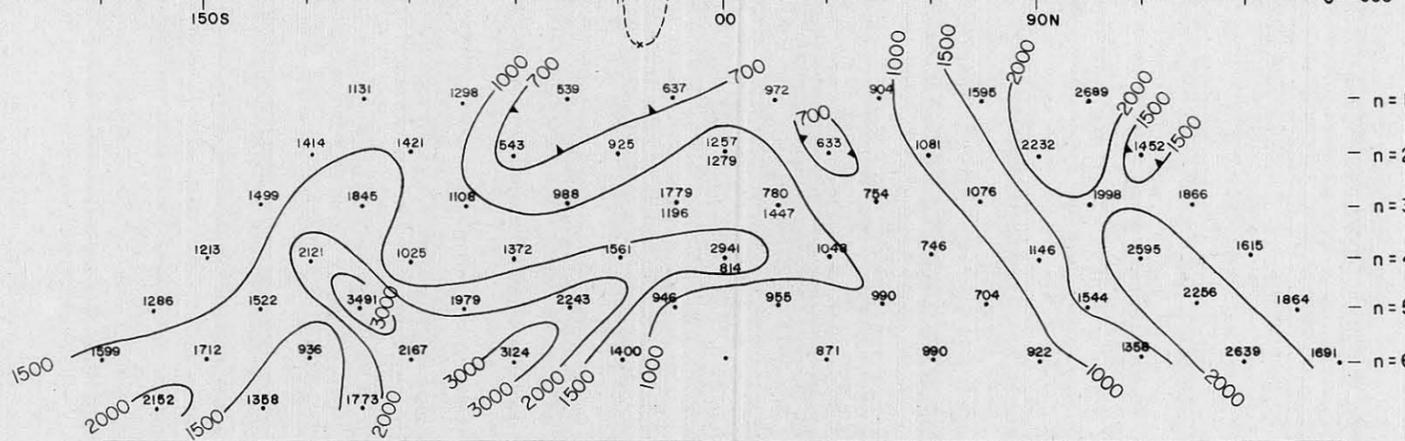
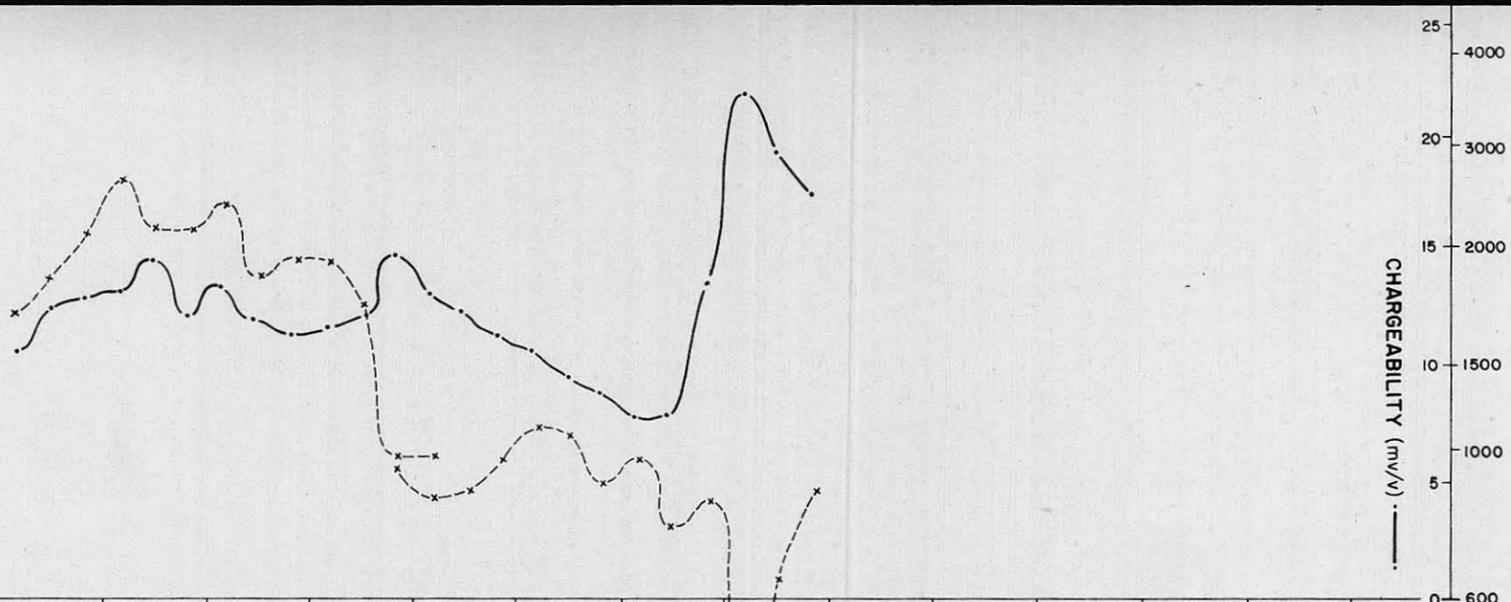
RESISTIVITY ( $\Omega m$ )

RESISTIVITY ( $\Omega m$ )

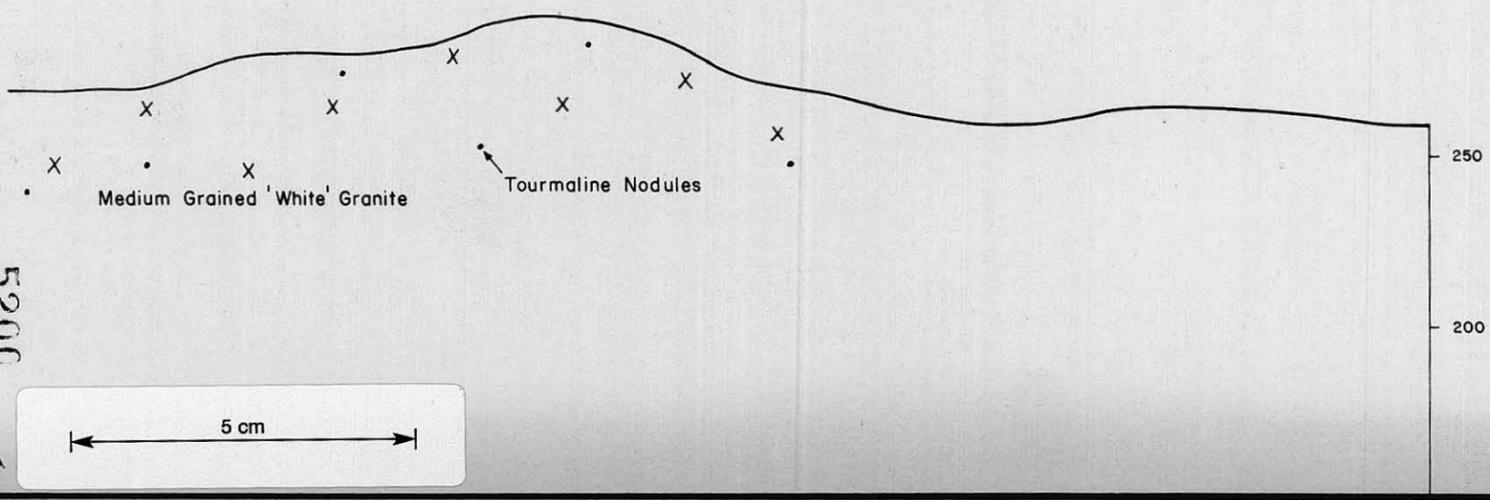
CHARGEABILITY (mv/v)

FREQUENCY EFFECT (%)

CHARGEABILITY (mv/v)



Model I.P. response (McPhar Phase II, PI3)



Topography & Geology

937082

Height above Sea Level - (metres)

MITRE GEOPHYSICS PTY. LTD.

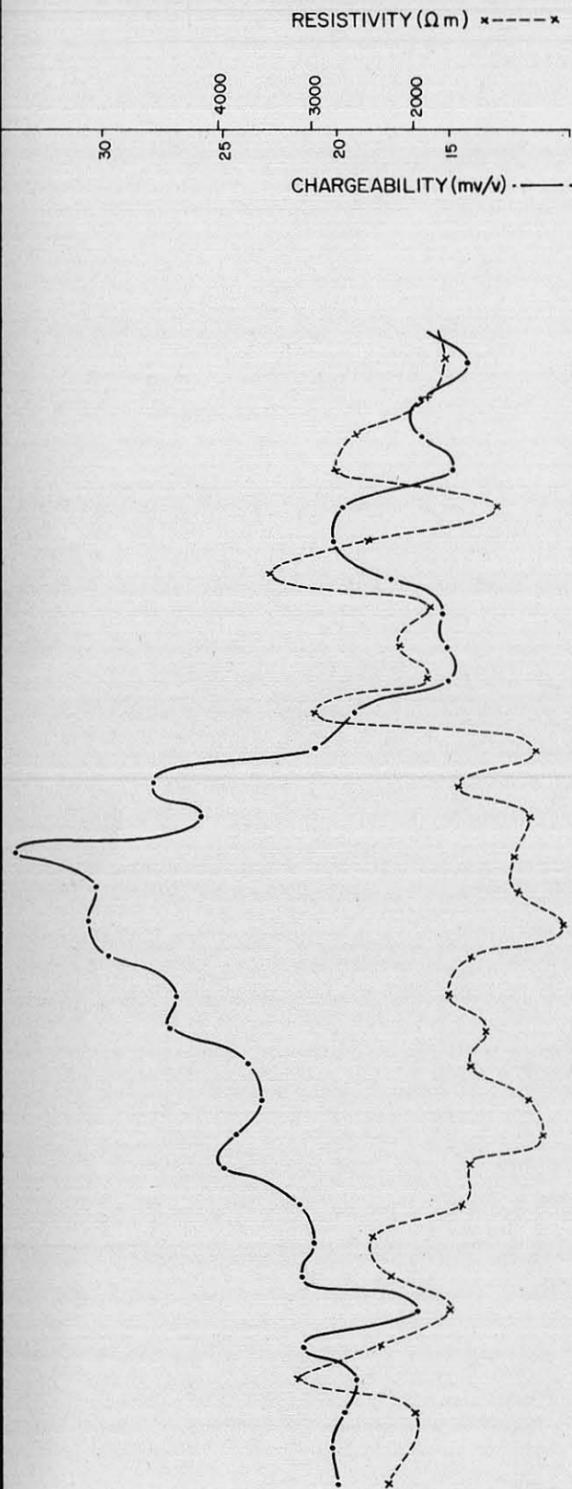
Federation Grid

Field and model

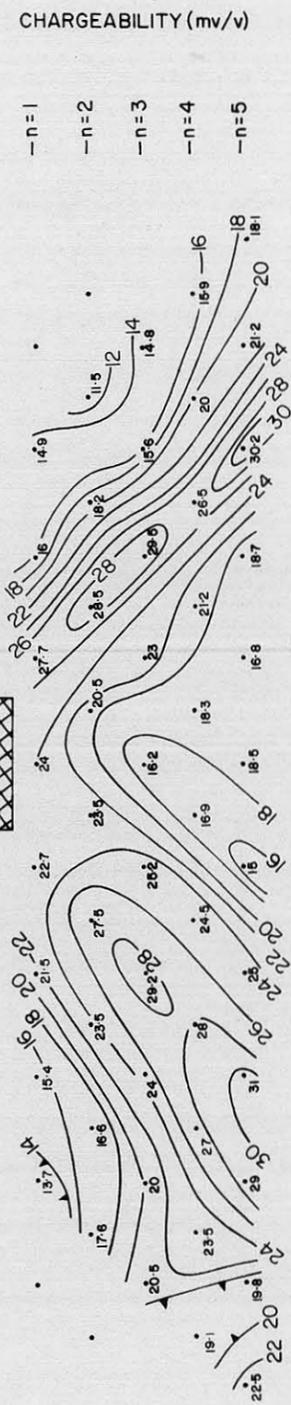
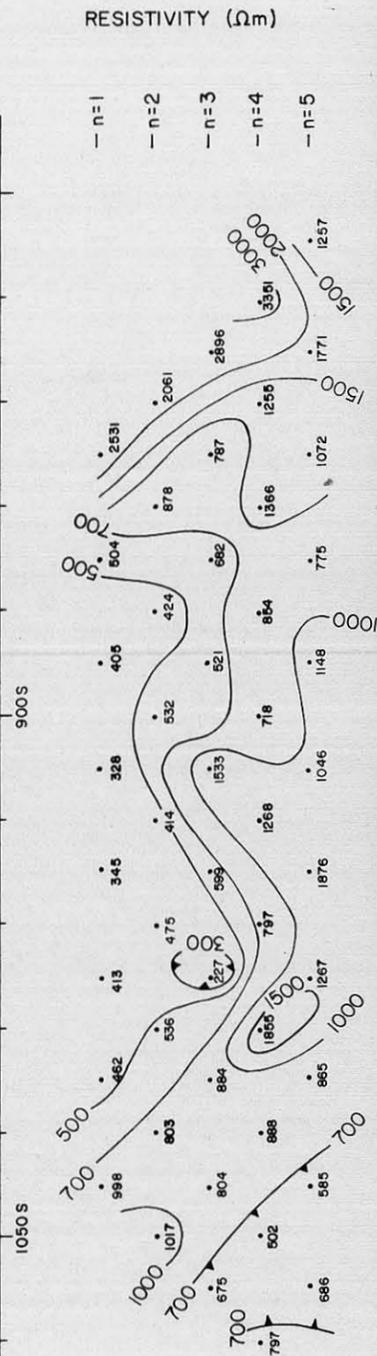
I.P. results for line 1100 W.

DRAWN: J.B. SCALE: 1:2000  
TRACED: T.G.S. DATE: Aug. 1981  
FIG. 15

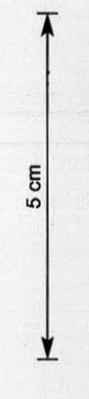
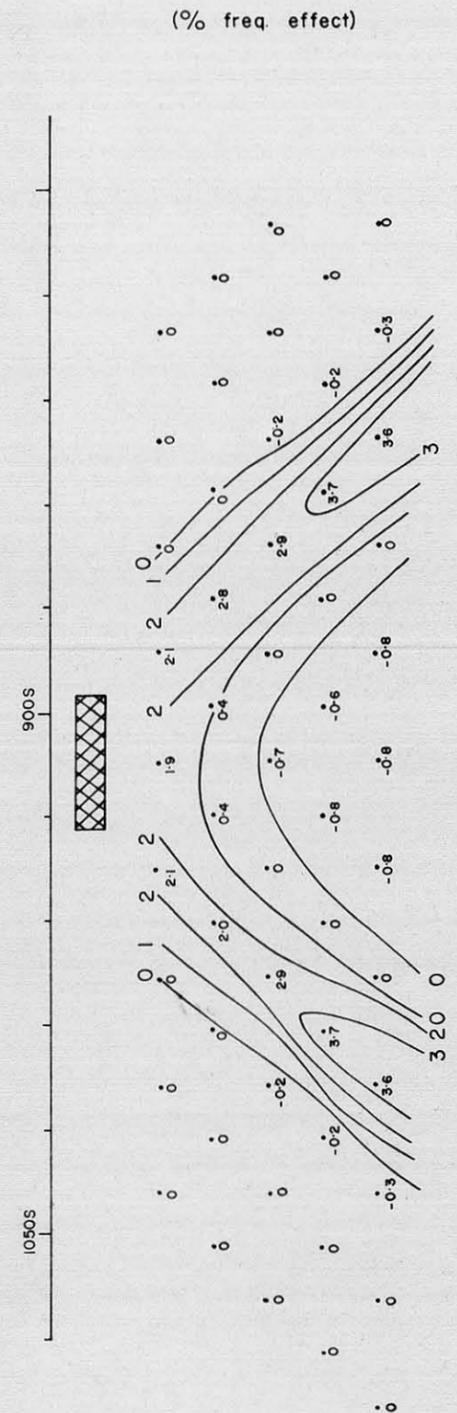
GRADIENT ARRAY I.P.  
MODEL RESULTS



DIPOLE - DIPOLE I.P.  
FIELD RESULTS

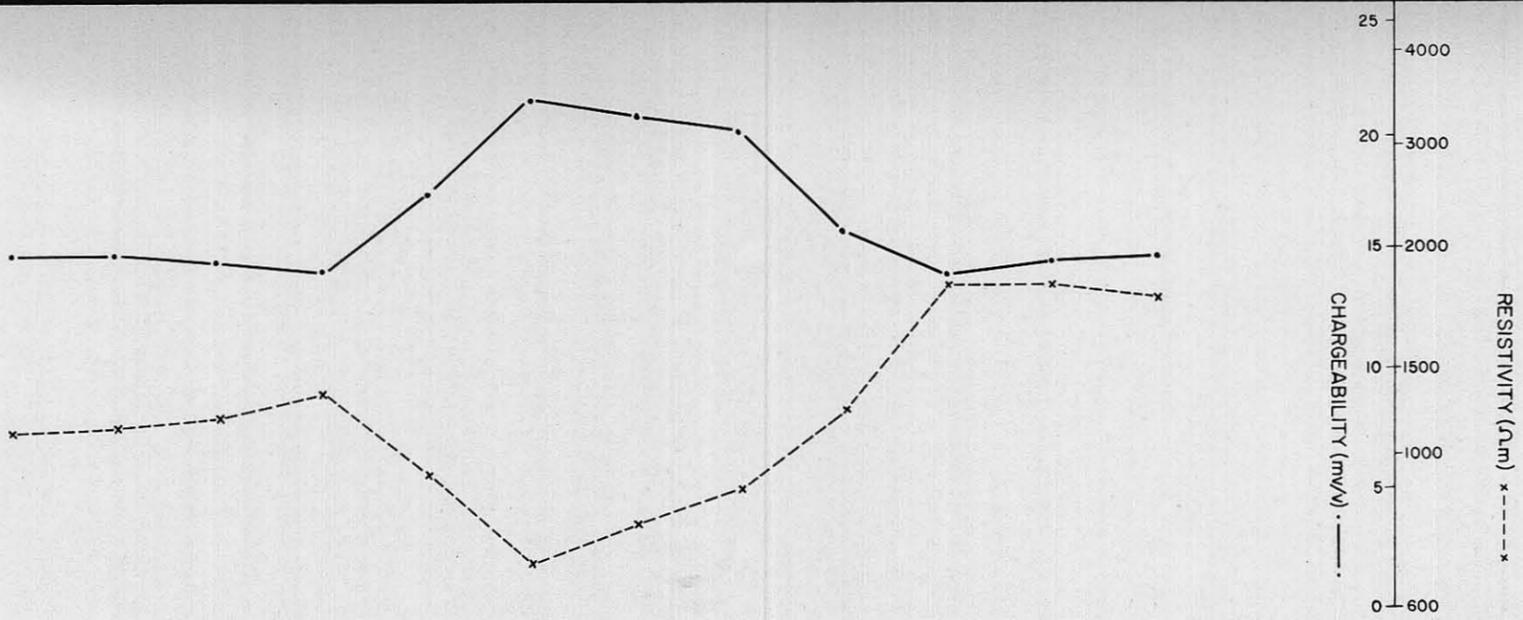


937083  
SCALE  
MODEL RESULTS

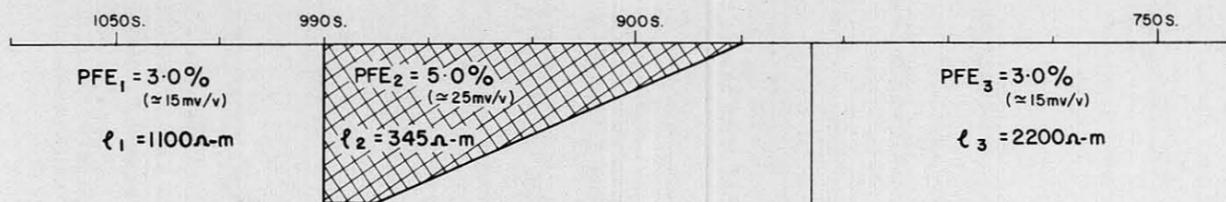
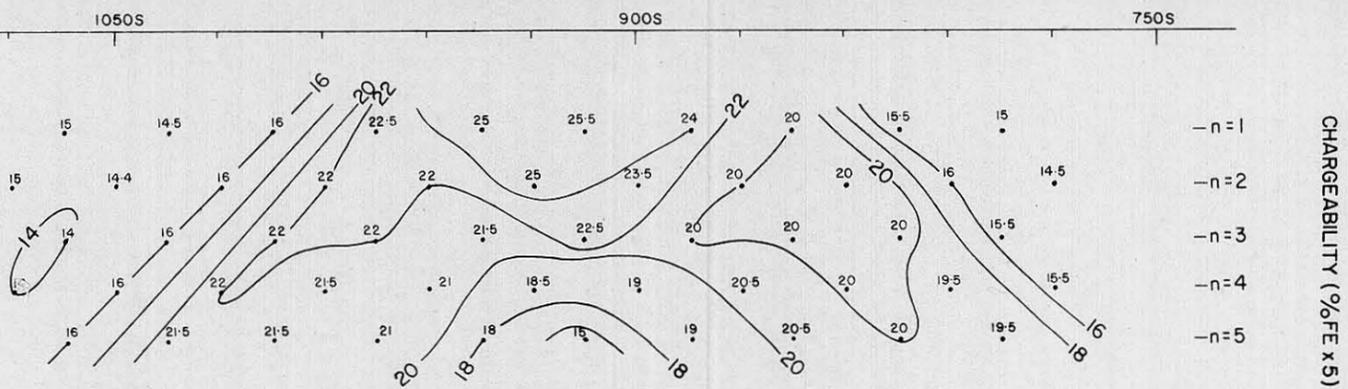
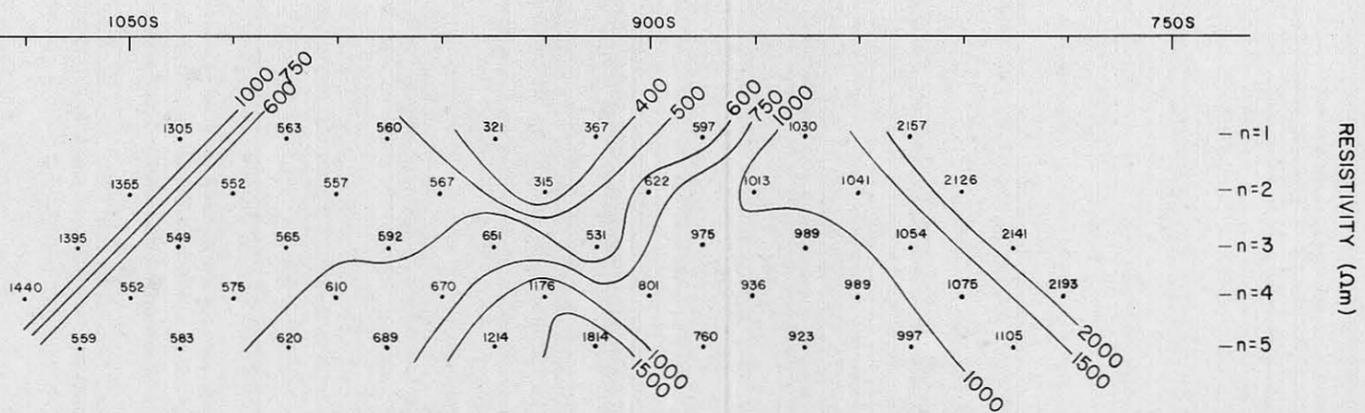


5201 ←  
MITRE GEOPHYSICS PTY. LTD.  
Federation Grid  
Field and model  
I.P. results for line 1700 W.  
DRAWN: J.B. SCALE: 1:2000  
TRACED: T.G.D.S. DATE: Aug. 1981 FIG. 16

GRADIENT ARRAY I.P.  
MODEL RESULTS



DIPOLE - DIPOLE I.P.  
MODEL RESULTS



THE MODEL

937084

5 cm

5202

MITRE GEOPHYSICS PTY. LTD.

Federation Grid

Computer Model I.P. results

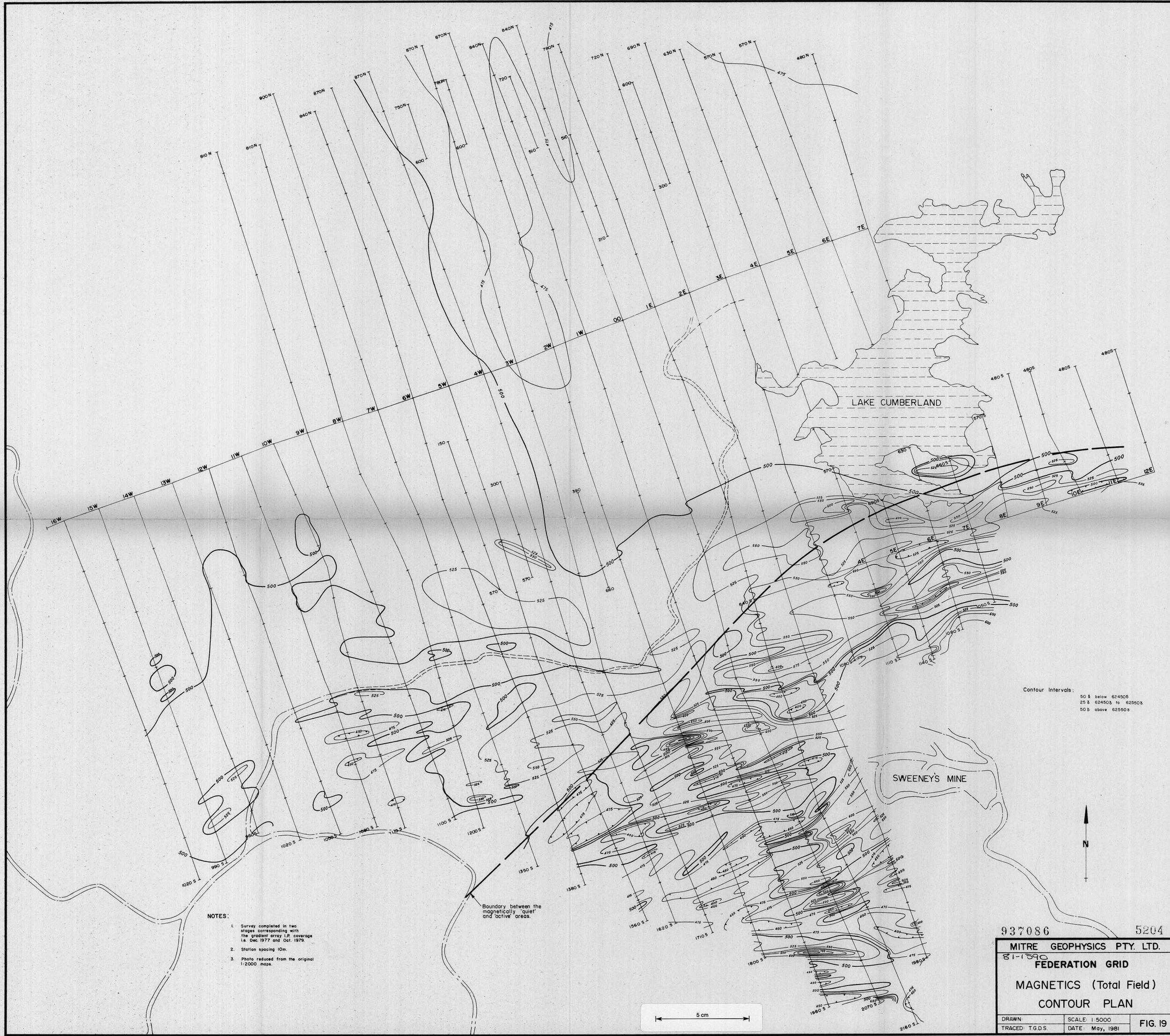
for line 1700 W.

DRAWN: J.B. SCALE: 1:2000

TRACED: T.G.D.S. DATE: Aug. 1981

FIG. 17





Contour intervals:  
 50 & below 624505  
 25 & 624505 to 625505  
 50 & above 625505

**NOTES:**

1. Survey completed in two stages corresponding with the gradient array I.P. coverage i.e. Dec. 1977 and Oct. 1979.
2. Station spacing 10m.
3. Photo reduced from the original 1:2000 maps.

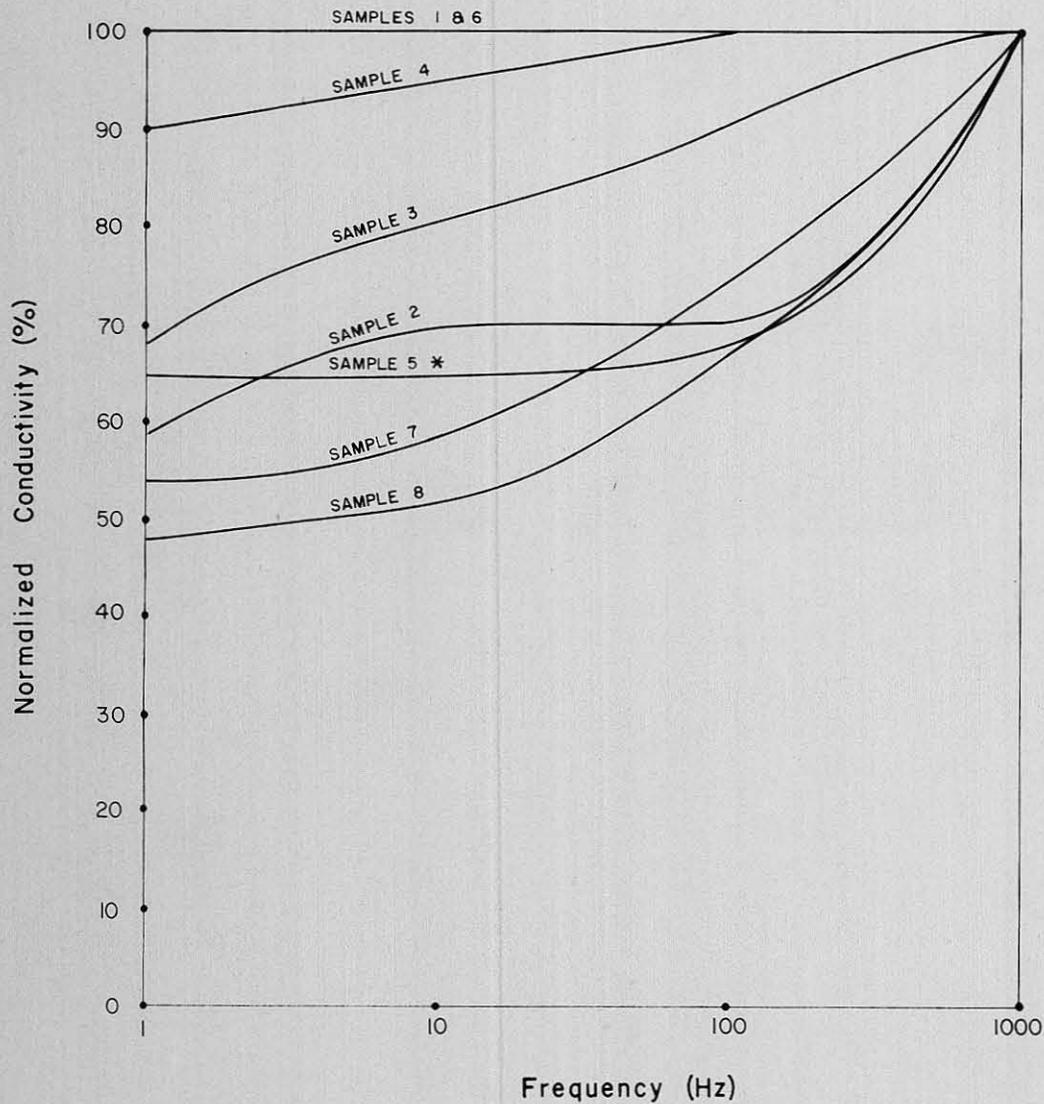
Boundary between the magnetically 'quiet' and 'active' areas.

5 cm

937086 5204

**MITRE GEOPHYSICS PTY. LTD.**  
 81-1590  
**FEDERATION GRID**  
**MAGNETICS (Total Field)**  
**CONTOUR PLAN**

DRAWN	SCALE: 1:5000	FIG. 19
TRACED: T.G.D.S.	DATE: May, 1981	



Sample No.	Location	Petrological Description
1	Fed.8 20.5m	Fresh, red granite
2	Fed.12 222.0m	Hematite with sericite
3	Fed.12 230.7m	Sericite, siderite, coarse pyrite (10%)
4	Fed.12 280.9m	Sericitised, coarse grained pyrite
5*	Fed.18 250.6m	White, fine grained granite
6	Fed.12 43.1m	Porphyritic granite
7	Swy.8 48.5m	Sericitised coarse grained granite (pyrite 15%)
8	Swy.11 72.9m	Altered granite, coarse grained, sulphides 60%

\* No I.P. effect at low frequency, probable electrode error at >100 Hz.

5205

MITRE GEOPHYSICS PTY. LTD.

FEDERATION GRID

Spectral I.P. Curves

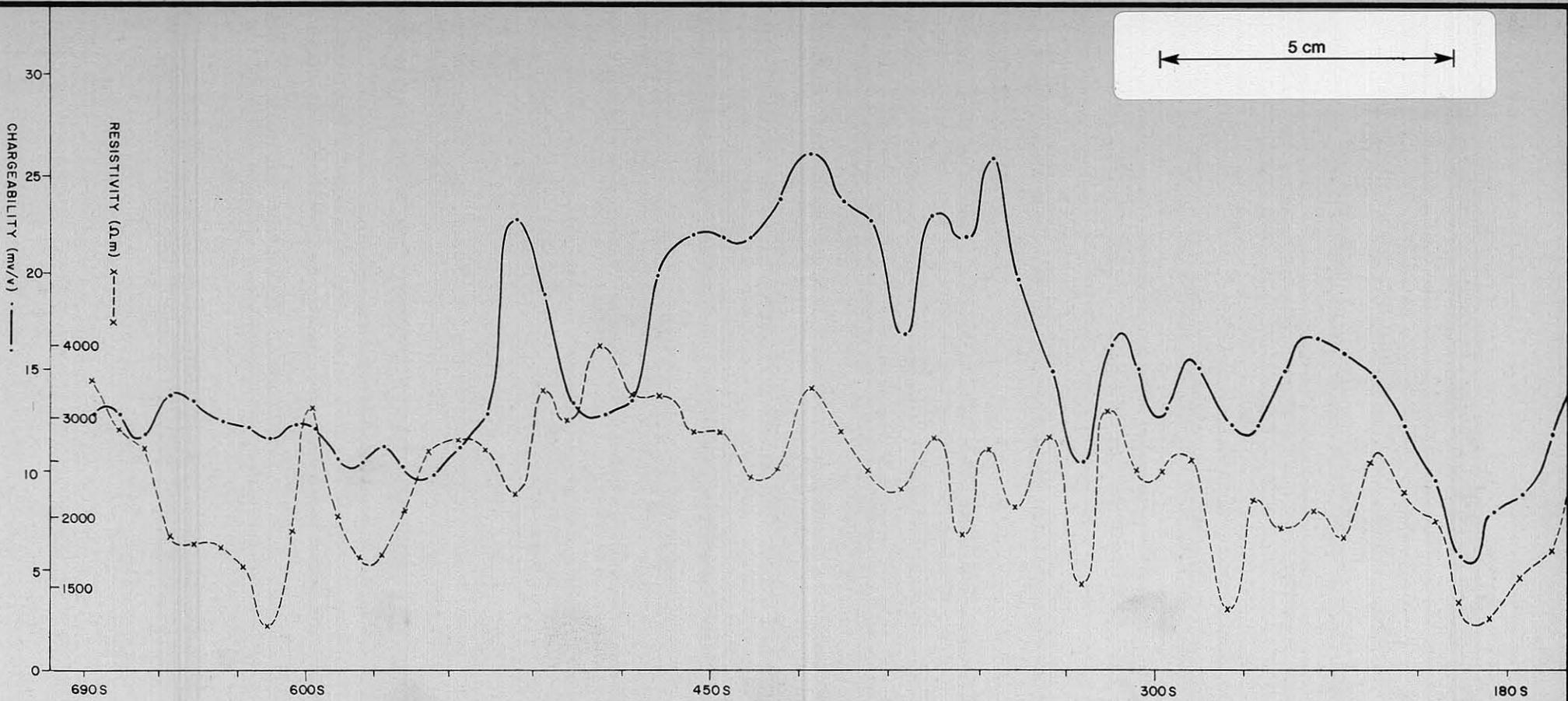
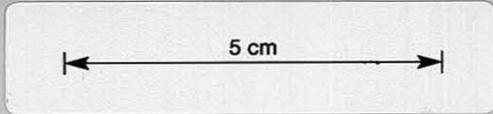
DRAWN: J.B.

SCALE:

TRACED: T.G.D.S.

DATE: Aug. 1981

FIG. 20

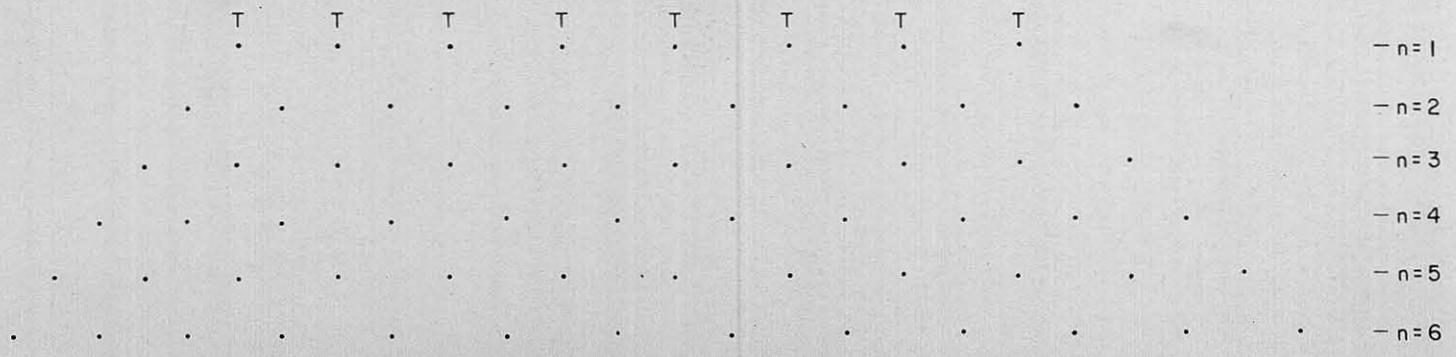


I.P. Data

MITRE GEOPHYSICS PTY. LTD.  
 Federation Grid  
 Proposed Dipole - Dipole  
 Survey on Line 500W

5206 ←

DRAWN: J.B. SCALE: 1:2000  
 TRACED: T.G.D.S. DATE: Aug 1981  
 FIG.21



T = transmitting electrode  
 Receiving electrodes  
 from 690S to 180S.

- n = 1
- n = 2
- n = 3
- n = 4
- n = 5
- n = 6

937088  
 Dipole - Dipole