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REPORT ON

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DETAILED ELECTRICAL INDUCED POLARIZATION SURVEYS

USING DIPOLE-DIPOLE AND GRADIENT ARRAYS

OVER THE WAXMAN AND WESTON PROSPECTS

EL 11/76, NEAR ZEEHAN, TASMANIA

ON BEHALF OF

RENISON LIMITED

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REPORT ON
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USING DIPOLE-DIPOLE AND GRADIENT ARRAYS
OVER THE WAXMAN AND WESTON PROSPECTS
EL 11/76, NEAR ZEEHAN, TASMANIA
ON BEHALF OF
RENISON LIMITED

BY

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SYDNEY, N.S.W.

DECEMBER, 1980
TAS-081A

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GEOPHYSICAL CONSULTANTS AND CONTRACTORS

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SUMMARY

Detailed gradient array and dipole-dipole surveys over the Waxman and Weston prospects and the eastern workings have implied that the former consists of a series of chargeability highs of a limited strike length contained within an overall general resistivity low. It would appear likely that Waxman and Weston extends east across line 650E as a wholly disseminated sulphide expression, and westwards across lines 550E and 500E as a low resistivity/moderate chargeability series of events.

The eastern workings are implied to extend north to about 200N on the line on which they occur (700E), terminated between lines 700E and 650E, and perhaps continue across line 750E between 210N and 310N at least as a zone of alteration.

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INTRODUCTION

A series of dipole-dipole and gradient array surveys were carried out in the vicinity of the Waxman and Weston prospects on EL 11/76 to follow-up reconnaissance electrical induced polarization anomalies located in a gradient array survey carried out over a wider area in November-December, 1977 and described in Scintrex report TAS-052 by the author dated May, 1978.

The surveys were carried out at the request of Mr. L.A. Newnham, Chief Geologist for Renison Limited. On-site geological supervision was carried out by Mr. P. Roberts, Area Geologist, while geophysical supervision was provided by the author and on-site geophysicist Mr. G. Street, M.Sc., DIC, who also executed a portion of the survey. The remainder of the survey work was carried out under crew leader Mr. I. Newby.

The work was undertaken over some six production days between 19th November and 30th November, 1980.

SCINTREX*DATA PRESENTATION*

The dipole-dipole data is presented in standard pseudosection format, while the detailed gradient arrays are shown in both profile and contour format at a horizontal scale of 1:1000. The vertical scales employed in the profile format were 1 centimetre = 4 millivolts/volt, with resistivity on a 10 centimetre log cycle expressed in ohm-metres. The decay form is not presented as no material changes were observed other than those referred to in the text.

SCOPE OF SURVEY

Dipole-dipole surveys were carried out on sections of six lines with arrays centred as indicated below:

<u>Line</u>	<u>Transmitter Centre</u>
750E(1)	270N
750E(2)	120N
700E	120N
650E	120N
600E	00
550E	00
500E(1)	00
500E(2)	150N

The α spacing was 30 metres with values from $n = 1$ to 5 being read.

The gradient array was carried out on sections of lines 500E to 750E from a 750 metres current dipole placed on line 600E at 570N and 180S. The potential electrode spacing was 10 metres.

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*DISCUSSION OF RESULTS**Data over Waxmans and Westons Prospect*

On the original gradient reconnaissance survey, anomalies associated with this zone were designated F and G and discussed on pages 7 and 8 of the report TAS-052, and are repeated below:

ZONE 'F'An 8 millivolts/volt response above the 12 millivolts/volt background was recorded at 080N on line 7E coincident with a sharp increase in resistivity to 3500 ohm-metres from 1500 ohm-metres. The source is interpreted as being due to disseminated sulphides within a relatively resistive host. On line 6E a 6 millivolt/volt response at 045N may be related. The maximum depth to source on each line is 20 metres.

ZONE 'G' A significant 10 millivolts/volt response was recorded on line 6E at 030S from within resistivities of about 1000 ohm-metres. At 00, no chargeability readings were obtained, however, the resistivity falls by about 50% to 500 ohm-metres. These low resistivities were recorded over a swamp area, but are not due to that, but to the underlying rocks. Both the chargeability highs and resistivity lows are of interest in this case. The maximum depth to source at 030S is 20 metres.

In that reconnaissance survey, anomaly F was considered of secondary/tertiary interest, while anomaly G was considered of primary interest.

The detailed gradient array data over this line shows a lower resistivity background overall, and lower resistivities within the deposit, which extends from about 60S to 70N on line 600E. This is due to the fact that the volume of

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the alteration makes up a greater percentage of the energised volume with the smaller electrode separation. (This feature is seen in an even more pronounced form on the dipole-dipole data.)

The chargeability data has a slightly higher background of 16 millivolts/volt as against 12 millivolts/volt for the first survey for the same general reason.

The detailed gradient array on line 600E showed a very similar profile form for the chargeability response, with the most significant being a 12 millivolts/volt above background response at 045S(G), an 11 millivolts/volt above background response at 005N (not recorded on the reconnaissance survey due to 'noise') and a 7 millivolts/volt response at 045N (F). The maximum depths estimated are respectively 30 metres, 20 metres and 20 metres.

The apparent resistivity profile is also similar in form (but of lower background) to about 80N, after which *lower* resistivities (relatively) were observed on the detailed survey than on the reconnaissance survey. This is almost certainly due to the southern current electrode for the detailed array being at 180S and preferentially passing current through the southern dipping alteration zone.

The gradient data when viewed in contour form gives the clear impression of a series of chargeability responses grid east and west of Waxman and Weston which have not been resolved by the 50 metres line spacing. The inference, as far as the chargeability is concerned, is that the chargeable sources have strike lengths of less than 100 metres and occur within an overall zone of increased chargeability. While the 'best fit' is presented in the contour map, it is considered that the contoured highs may represent individual chargeability events

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which do not extend more than say 25 metres(+) east and west of the survey line. However, the background certainly shows these individual events occur in a zone of overall anomalism which terminates on the Waxman and Weston trend on, or close to 700E, but is apparently still present on line 500E and open to the west. This was not so apparent on the reconnaissance array, perhaps because the bodies causing the anomalies are small.

Detailed Discussion of Waxman and Weston Trend

Line 600E The dipole-dipole data on this line gives a higher background than expected - a good 10 millivolts/volt above the background observed in the original gradient array.

The most significant anomaly defined was from zone 'G' centred at 045S. Immediately to the south the 'background' falls to 22 millivolts/volt, but chargeabilities on the $n = 4$ reading at 120S increases to 30 millivolts/volt. To produce this increase, either a source at depth or a broad increase in chargeability between 150S and 210S would be required. Both are indeed possible as higher gradient EIP readings were observed on the reconnaissance array on line 700E. The geological data shows a 'greisen vein complex' mapped at this locality which certainly enhances the interest of this feature.

It is concluded from the dipole-dipole data that a broad source of chargeability lies between 210S and 150S closer to surface and/or at a depth of the order of 100 metres at 150S \pm 30 metres but most likely off line to the east or west of this line, as no such chargeable source was intersected in drill hole FED-12 (or at least not observed in that hole).

SCINTREX*Lines to the West of Waxman and Weston*

Line 550E The gradient array on this line shows a significant anomaly above the 15 millivolts/volt background values between 090S and 010N which culminates in a significant 11 millivolts/volt above background anomaly centred at 045S. The background resistivity does not change over the anomaly although it is a low 200 to 400 ohm-metres. The maximum depth to source is 15 to 20 metres and it may represent the western extension of zone 'G' (but see above).

The dipole-dipole data shows a definite maximum indicative of a source between 30S and 60S at a depth of less than 30 metres. This correlates well with the gradient array.

A significant increase in the westernmost data series from $n = 2$ to $n = 5$, implies, in a similar fashion to line 600E, a source in the volume of material from 210S to 120S either within 30 metres of surface or more likely at a depth of the order of 80 metres(+) below 150S +30 metres.

The 'distortion' seen on the eastern flank of the 'double peak' anomaly due to the nearer surface source at 040S is due to a second distinct source defined at 110N and discussed separately below.

The gradient array shows a most distinctive 8 millivolts/volt anomaly centred at 110N associated with the contact between a less resistive (800 ohm-metres+) rock unit to the south and a two fold increase just north of this point.

The resistivity actually shows a slight depression, implying some minor conduction within the source. The dipole-dipole data shows only a distortion,

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however, the spread did not adequately cover this feature. This response should be further investigated on the ground.

It is concluded that the Waxman and Weston zone crosses this line, and that the most chargeable section 'G' on line 600E at 045S probably correlates with an anomaly of similar magnitude and form on this line (550E) at 040S. As for line 600E, higher values on the most westerly data series shows a chargeable source, shallow, beneath 150S and 210S and/or at depths of 80 metres± below 150S.

A significant gradient anomaly has been defined at 110N which should also be followed up on the ground.

Line 500E While the gradient data confirms the form of the original reconnaissance survey, the smaller current dipole has emphasised the changes in induced polarization background. In particular a much increased above background response between 050S and 015N was noted, with distinct above background peaks of 10 millivolts/volt at 025S and 7 millivolts/volt at 005N, from sources estimated to have maximum depths of 30 metres and 20 metres respectively. Generally lower resistivity backgrounds of less than 500 ohm-metres were noted over these anomalous sections. The profile form on lines 550E and 500E cannot be precisely correlated, so these maxima may be separate from anomaly 'G' or part of it.

A second most distinctive and narrow anomaly of 8 millivolts/volt above background was defined at 085S from a source whose resistivity is 250 ohm-metres against a background of 400 to 600 ohm-metres. This source has a maximum

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depth of 10 metres and cannot be directly related to any feature seen on line 550E.

The dipole-dipole work consisted of two transmitter set-ups with a considerable overlap. (The overlap data is good, however, it should be remembered that current paths generating the data are almost at right angles and only in homogeneous conditions will data be *precisely* repeated on such overlaps.)

The along strike extension to Waxman and Weston is probably marked by the much lower resistivities of 500 ohm-metres and lower. Of note are the $n = 1$ resistivity values of 1000 ohm-metres(+) between 045S and 015S which are underlain by markedly lower resistivity. This is interpreted as being due to a resistive surface layer of limited thickness (say 15 to 20 metres maximum) underlain by 300 ohm-metres values or less. The former may represent the granites, and the latter the altered zone. The horizontal contouring of the chargeability data south of the zero baseline also suggests this, while the higher chargeability values at depth below 030S ($n = 4$ and 5) suggest a more chargeable source at a depth of the order of 50 to 80 metres maximum at 30S +30 metres.

The sharp chargeability maximum/resistivity low seen on the gradient array at 085S is seen only as a resistivity low on the dipole-dipole data. This is presumably because the source is narrow. However, the data implies that the low resistivity is part of the same broad source seen under the resistive capping to the north and is thus of interest in its own right.

A most significant twice background induced polarization anomaly was defined on the northern flank of the dipole-dipole data. The source is situated at *about*

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150N and as per line 550E, the anomaly lies on or close to a marked change in apparent resistivity. (This is not seen on the gradient array data) Certainly this response needs to be further investigated. While not directly associated with the eastern workings, this source lies along strike of the proposed southern extensions of the eastern workings and therefore may represent a repetition.

It is concluded that the data along the strike trend of the Waxman and Weston prospect strongly suggests that on this line a thin (15 to 20 metres) layer of more resistive granite overlies a more chargeable less resistive section which has the characteristics of the Waxman and Weston alteration observed on line 600E. Increased chargeabilities at 30S \pm 30 metres for $n = 4$ and 5 implies a more chargeable source at a maximum depth of 50 to 70 metres. The sharp chargeability response from a 10 metres maximum depth source centred at 085S may represent the up dip, near surface expression of the above described zone.

The dipole-dipole anomaly located from a source at about 150N, which, from the gradient array data is associated with the contact between a resistive and a less resistive rock unit, should receive careful ground study.

Lines to the East of Waxman and Weston

Line 650E The gradient array data shows a significant induced polarization response of about 10 to 12 millivolts/volt above background situated from about 030S to 030N. The form of the anomaly suggests a south dipping source. The northern contact (at precisely 030N) has a maximum depth of 5 to 10 metres, and may in fact subcrop. The resistivity data shows only a gradual change from higher (in the north) to lower (in the south), which shows that the source in no way influences the conductivity of the host rock. The profile form cannot be

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directly correlated with line 600E, however, a guess at correlation would suggest that the anomaly at 005N on line 600E correlates with this source. This suggests a wholly disseminated sulphide extension to Waxman and Weston which shows little correlation with specific resistivity lows (a sulphide halo?).

The dipole-dipole data confirms the resistivity change, and the location of the chargeability high at zero, but depresses the significance of the latter. No correlation is seen between the resistivity and chargeability data, again confirming the independence of both parameters on this feature.

It is concluded that the significant induced polarization anomaly defined on line 650E between 015S and 030N represents a wholly disseminated source on a transition between less resistive rocks to the south and more resistive rocks to the north. While it cannot be directly related to anomaly G (Waxman and Weston), it could be an easterly extension thereof. Perhaps it represents a disseminated sulphide 'halo' to the deposit. The maximum depth to source is considered to be 5 to 10 metres at 030N.

Line 700E The gradient array data shows only a minor 6 millivolts/volt response on the strike extension of Waxman and Weston. This is associated with a significant *increase* in resistivity. Distinctly lower resistivities of less than 100 ohm-metres were, however, recorded at 025S and these are quite atypical of granites, and as such may represent the location of alteration without the presence of accompanying sulphides. The dipole-dipole data gives a similar picture, but in addition implies that the lower chargeability background seen on earlier n values (15 millivolts/volt) is underlain by higher values at $n = 4$ and 5 at 015S. While these differences are subtle, a mere 5 millivolts/volt, they may

well imply the presence of sulphides at depth in association with the low resistivity values (alteration?).

At 080N a distinct increase in the chargeability to 22 millivolts/volt was noted on the gradient array, which is accompanied by a two fold increase in resistivity to 1600 ohm-metres. This feature is confirmed on the dipole-dipole data. The source is chargeable material within a resistive host, estimated to lie at a maximum depth of 15 to 20 metres below 080N. The gradient data shows higher resistivities between 070N and 180N, and on both ends, the depth to the contact is less than 10 metres. The dipole-dipole data strongly suggests that this unit is underlain by a much less resistive unit at a depth of the order of 60 metres(+). The dipole-dipole data does not indicate that this lower resistivity rock unit (alteration?) shows any increase in chargeability.

It is concluded that the Waxman and Weston zone does not cross this line as a significant feature, although the low resistivity recorded at 025S together with the small chargeability maximum at 00 may be related.

High gradient array resistivities between 070N and 180N are confirmed on the dipole-dipole data which implies a more resistive layer some 60 metres(±) thick. The southern margin shows a resistive, chargeable source at a maximum depth of 15 to 20 metres.

Line 750E The Waxman and Weston strike extension is barely covered by the dipole-dipole survey but shows little anomalism by contrast.

The significant chargeability response from a resistive source located at 080N

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on line 700E is, however, present on this line as a distinct $n = 2$ anomaly centred at 090N. This lies in a broad zone of high (2000 ohm-metres) resistivities, and higher 20 millivolts/volt chargeabilities than background. The source has a disseminated sulphide origin within a resistive host whose maximum depth is of the order of 30 metres(+).

It is concluded that the most significant response seen on or near the extension to Waxman and Weston is a 24 millivolts/volt anomaly at $n = 2$ at 090N which correlates to a similar gradient feature observed on line 700E at 080N. The source is disseminated and the host resistive.

Data over the Eastern Workings (and possible strike extensions)

The eastern workings were recorded between about 240N and 315S on line 700E and have been cut by DDH-FED8. The detailed gradient array shows these workings to lie within a much broader zone of lower than background resistivities of 800 ohm-metres(+) between about 180N and 300N. Anomaly E defined in the 1977 reconnaissance survey in fact lies outside the southern margin of the deposit, however, the chargeability over the entire low resistivity section remains about 4 millivolts/volt(+) above the background observed over the more resistive rocks. Zone E was described as follows in the original report on the reconnaissance survey.

ZONE 'E' Within the background of about 12 millivolts/volt, a significant 10 millivolts/volt response was recorded at 205N on line 7E in close proximity to a significant change in resistivity background from 2000 ohm-metres in the south to 900 ohm-metres to the north. The anomaly itself shows a minor depression in this level. The depth to source is not greater than 20 metres. The anomaly is

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open to the east, and to the west may continue as a sharp 6 to 8 millivolts/volt above background response at 225N on line 6E. Here the maximum depth is less than 10 metres, and the source wholly disseminated.

The anomaly was considered of secondary geophysical interest.

The dipole-dipole data shows a significant (but incomplete) double peak anomaly centred at about 210N which is precisely coincident with the gradient array maximum recorded at 205N. The depth to source is less than 20 metres and no significant change in resistivity was defined, which implies the source to be wholly disseminated, but within a rock type which has lower than background resistivities (600 ohm-metres+). The form of both the gradient array and dipole-dipole data suggests a north dip shallower than 40° - 30° .

It is concluded that disseminated sulphides, albeit in slightly more resistive rocks than observed over the Eastern workings, occur to the south of these workings at 205N. An increase in resistivity at 180N probably marks the most southern margin of the likely host to any alteration/mineralisation.

It therefore appears likely that the eastern workings could extend as far south as 190N, with sulphides at 205N. The dip thereof is implied to be shallow and to the north (30° - 40°)

Line 750E The gradient array surveyed over this line shows higher background values in chargeability from 305N to 215N (where they are still open), but no significant anomalies superimposed thereon. While the resistivity profile is difficult in detail, the overall appearance is very similar to that seen on line 700E. The along strike correlation with the *known* extent of the eastern

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workings would be between 260N and 320N on this line.

A dipole-dipole survey was carried out over the possible extensions of the eastern workings with two transmitter points at 120N and 270N. The overlap is good considering the different current paths taken and the inhomogeneity of the section. The dipole-dipole data shows the least resistive sections to be present between 240N and 300N/330N. The chargeability background varied between 12 to 15 millivolts/volt as against half this over the more resistive rocks to the north. However, no truly anomalous section was recorded. However, it should be remembered that the known eastern workings were not characterised by chargeability anomalies as such, merely higher backgrounds such as those observed here.

It is concluded that lower resistivities and higher chargeability backgrounds MAY imply the extension to the east of the alteration zones associated with the eastern workings. There were, however, no significant increases in these higher than normal backgrounds associated with the lower resistivities.

Line 650E The gradient line laid some 50 metres west of the eastern workings showed no material increase in chargeability background, merely a contact between more resistive rocks to the south of 225N, and less resistive rocks to the north thereof.

It is concluded that the eastern workings do not extend across line 650E.

SCINTREX*GENERAL CONCLUSIONS*

- 1 - The lack of chargeability contrast and of a clear cut correlation with the known deposits of Waxman and Weston and the eastern workings is disappointing. However, what is clear is that both deposits appear in resistivity lows quite abnormal for granitic rocks and both are associated with higher than background chargeabilities.
- 2 - The moderate but significant chargeability anomalies which have been defined superimposed on this background must be associated with greater segregations of sulphides in essentially disseminated form within these zones of alteration.
- 3 - The conditions of lower resistivity and higher chargeability extend beyond the limits of the known deposits, and in the case of Waxman and Weston on line 500E at 300S(+) are inferred to exist under 30 metres(+) of granite cover.
- 4 - The chargeability data over the Waxman and Weston deposit shows a series of moderate chargeability highs which have strike lengths of the order of the line spacing, however, all occur within a broad resistivity low. The eastern workings are characterised by lower resistivities and higher background chargeabilities, but no truly anomalous values.
- 5 - While some of the inferences from the dipole-dipole data are subtle, they are nevertheless considered reasonable, and are worthy of careful geological evaluation.

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The author looks forward to discussing the details of these comments with Renison geologist in the near future.

Respectfully submitted on behalf of:

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APPENDIX

*BRIEF SIMPLE COMMENTS ON THE GRADIENT, DIPOLE-DIPOLE AND POLE-DIPOLE ARRAYS
AND ON DECAY FORM**INTRODUCTION*

In the case of the surveys discussed in this report, it is important that the geologist can relate the geophysical data to the underlying geology if he is to make the best use of this data. It is the author's opinion that *only* the geologist will be able to relate the data to geology. For this reason brief, simple comments follow on the salient features of the gradient, dipole-dipole and pole-dipole arrays. These comments show how the data relates to the volume of underlying rock which influences it. Comments are also made on the decay form.

DISCUSSION

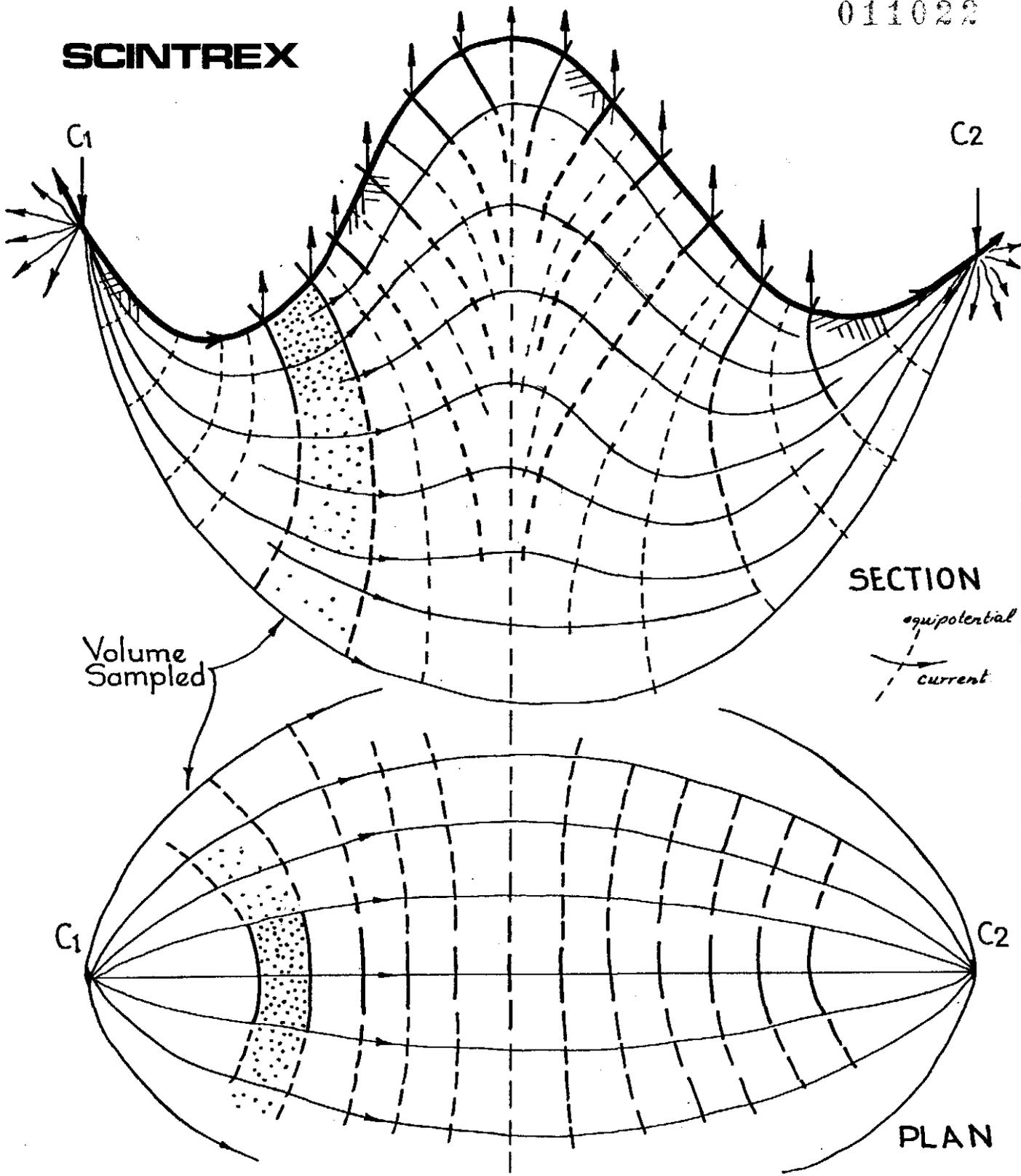
Gradient Array:- In this array both current electrodes are distant from the potential dipole. Figure 1 displays the salient features of the *primary* current flow and primary equipotential field generated during energisation and shows the influence of terrain on the current paths. From this diagram it can be seen that the *apparent resistivity* measurement is a summation of a volume of material normal to the local slope, *beneath* the surface and at *right angles* to the line.

The apparent resistivity will be *biased by* the influence of each current electrode, but the *relative* values of *adjacent* readings can be considered to be *reliable*. As each electrode is approached, the readings become *increasingly biased by* that electrode.

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Diagrammatic Representation of Primary Current and Potential Field in Steep Topography.

FIGURE 1.

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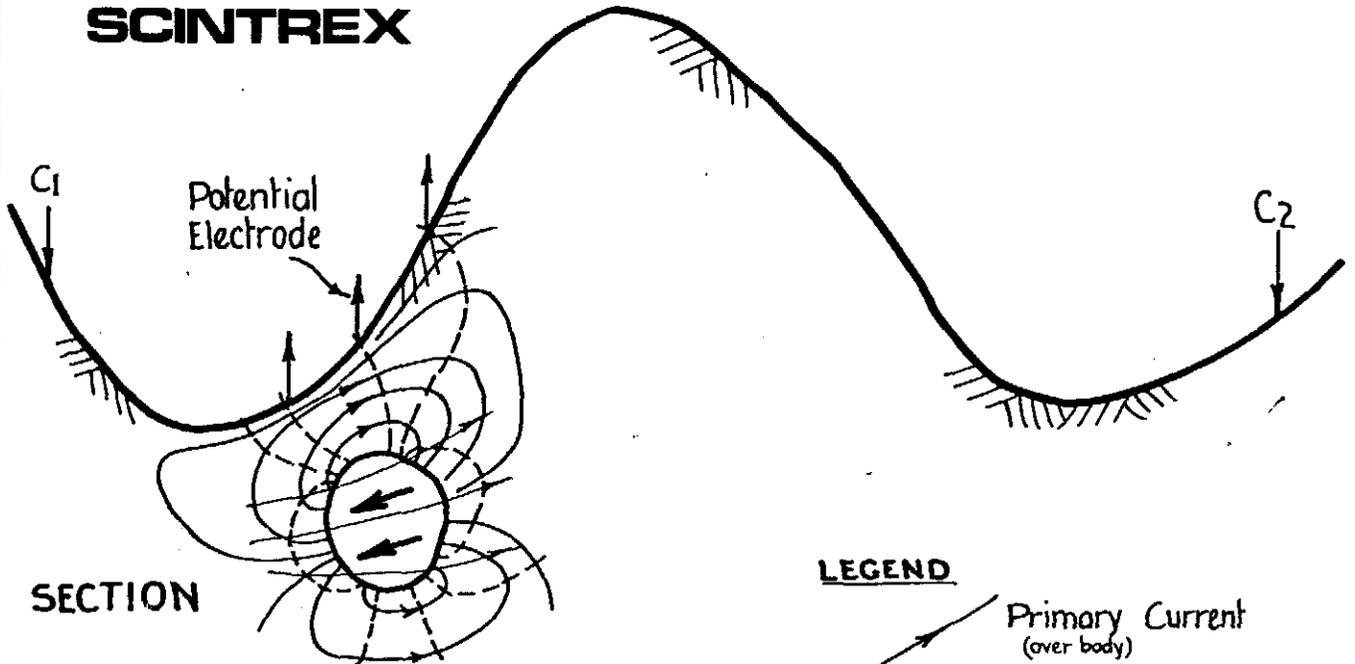
Note particularly that the *source volume* is *normal to slope* and not vertically beneath the potential dipole. Therefore all maximum depths refer to depths below surface *normal to the slope*.

Note also that the volume of material *closest to* the potential electrodes will influence the data most. It is difficult to easily quantify the complex relationship between the volume of material sampled and its distance from the potential dipole.

Figure 2 displays the secondary current pattern generated from the decay of induced polarization effect *within* a chargeable sulphide source, together with the equipotential field generated by that decay. Note that due to the necessarily curved nature of the current flow outside the body, the on-surface manifestation is *wider than the source width*. Note also that the volume sampled in the primary potential field (apparent resistivity ρ_a) is not necessarily the same volume as is the secondary potential field (apparent chargeability Ma). This is, of course, true for *any* array.

Dipole-Dipole:- In this array the current dipole is generally small, generally 20 to 100 metres. Figure 3 displays the current pattern in section and in plan for a dipole-dipole array. The equipotential P_1 and P_2 tap a volume as shown in this diagram whose characteristics are read on the $n = 1$ station and plotted as a single point midway between the transmitting dipole C_1 to C_2 and the potential dipole P_1 to P_2 . As progressively higher n values are read, a deeper and wider volume of material is sampled, this always being plotted midway between the transmitting and receiving dipole, and at a deeper level in the pseudo-section presentation used in this report. It is *vital* to realise that this data point

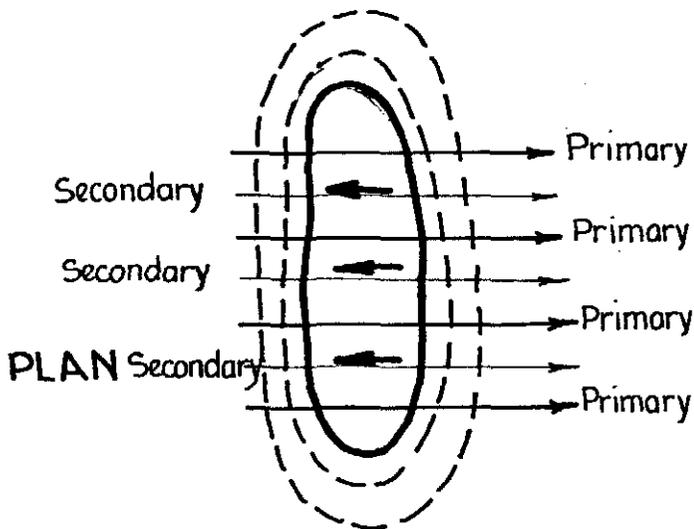
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SECTION

LEGEND

-  Primary Current (over body)
-  Internal Polarization (at depth within body)
-  Secondary Current (I.P)
-  Secondary Potential Field



PLAN

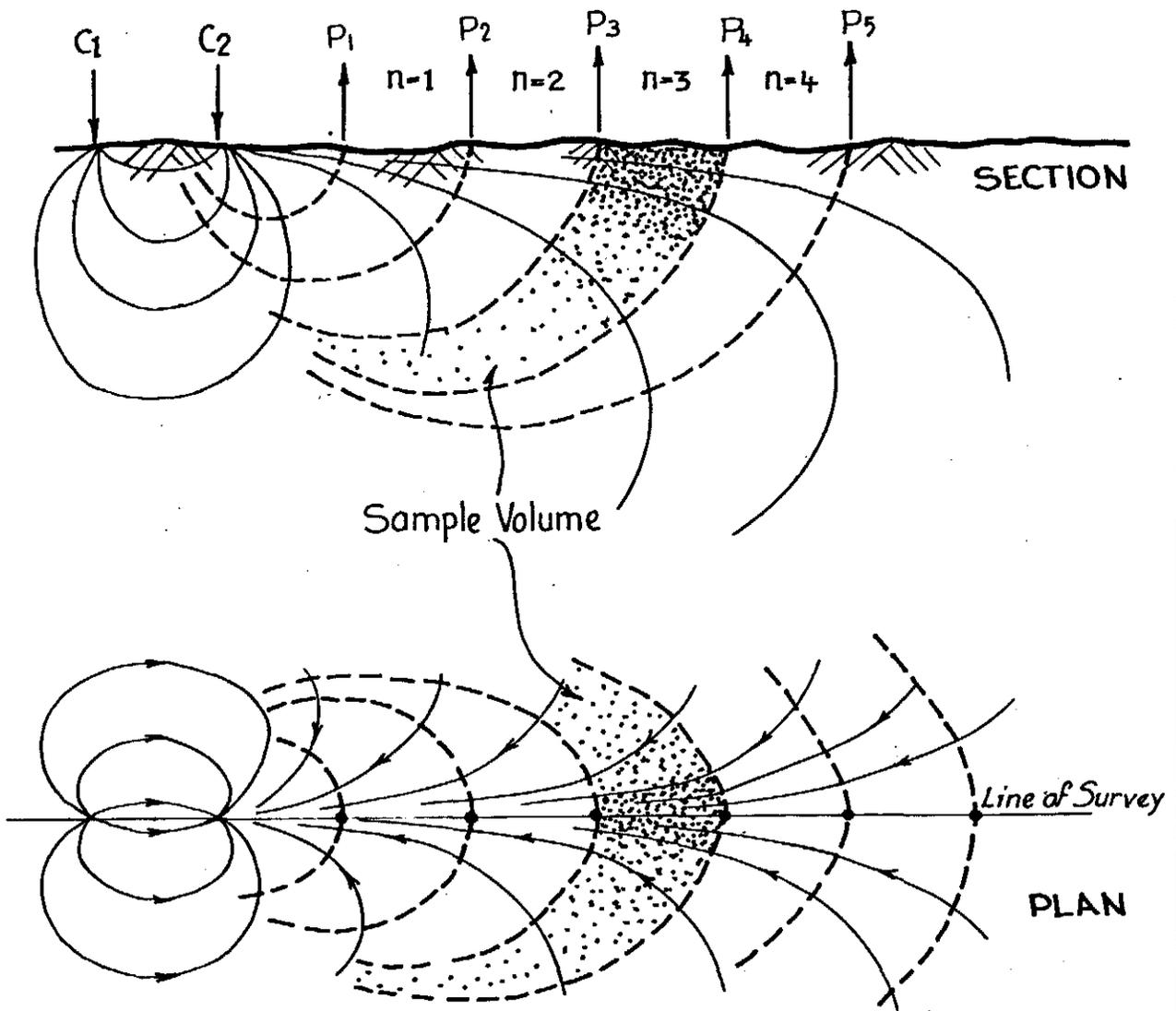
Diagrammatic representation of secondary current (I.P.effect) and secondary potential field in steep terrain.

FIGURE 2.

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Dipole - Dipole Array
Primary current paths and equipotential field
Showing volumes sampled

FIGURE 3.

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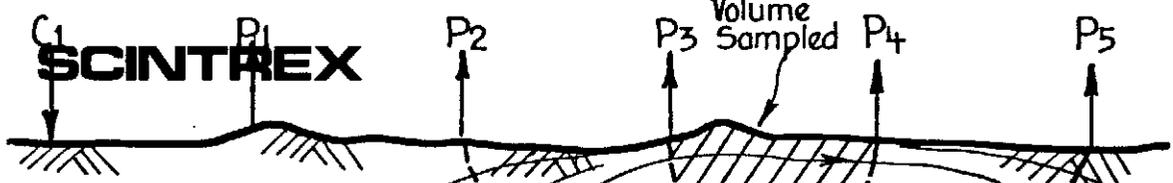
does not represent the characteristics of the ground at the point plotted, but that of the *total volume* sampled.

A further characteristic of the array is that where the effective spacing ($n \times a$) is greater than the depth to the source, a 'high' (or 'low', depending on characteristics) will occur as each of the dipoles (i.e. transmitting C_1 and C_2 and potential P_1 and P_2) pass over the source of that anomaly. The resultant 45° patterns on the pseudo-section DO NOT represent dip, or even depth extent, but merely represent a complex interference pattern over the source due to the potential and current dipoles. For a single source, this *double peak effect* can be recognised as it tends to have two maxima displaced by $(n \times a + w)$ where w is the width of the source. For multiple bodies this is difficult if not impossible to resolve by dipole-dipole arrays alone.

The enclosed Figure 4 shows the discharge of the energy stored in the body. As can be seen, the area sampled in section is tapped between the equipotentials generated by the discharge of the stored energy. These will not necessarily be of the same form as those for the resistivity data, although they are, for convenience, plotted in the same format as for resistivity. Again, it is vital to note that they represent the volume sampled as shown in Figure 4, *and not* the characteristics of the point at which they are plotted. Double peaks also occur as each of the two sets of electrodes pass over a source, where $n \times a$ is greater than the depth to source. Where $n \times a$ is less than the depth to source, a single maximum will be produced midway between the energising and measuring dipoles C_1/C_2 and P_1/P_2 .

Pole-Dipole:- This array is similar in principle to the dipole-dipole array,

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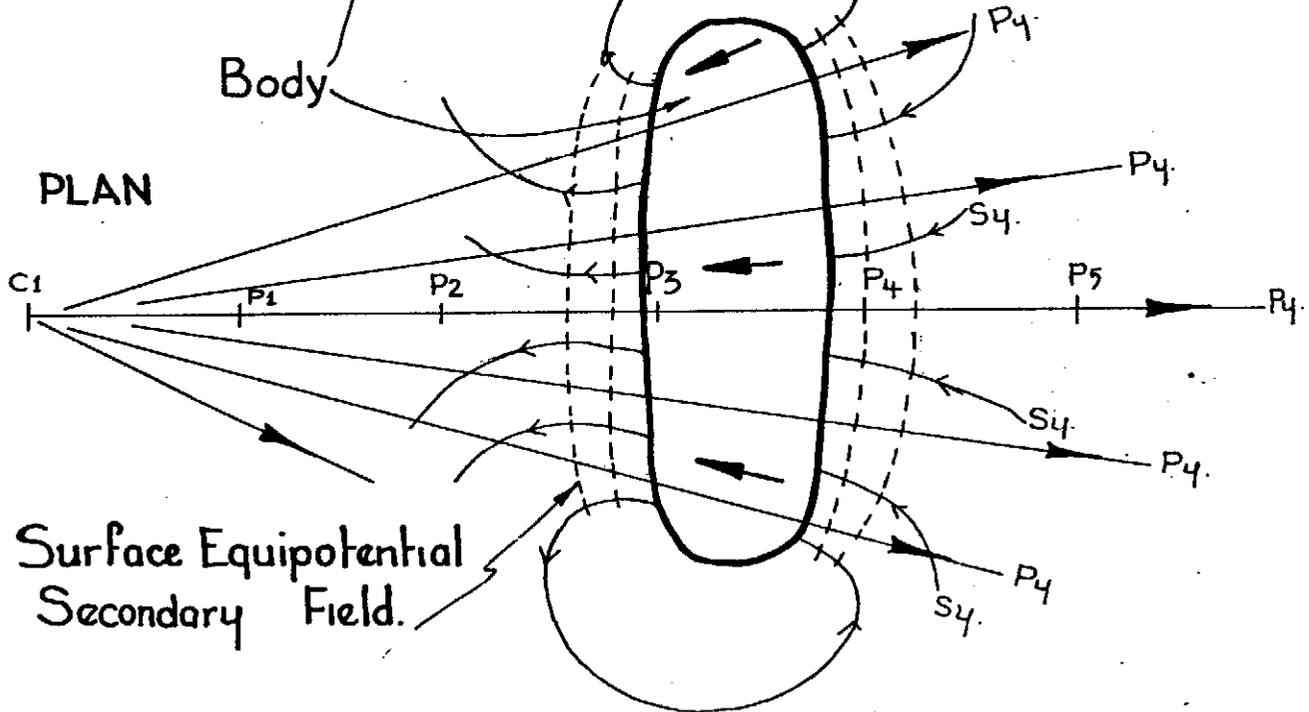
SECTION

LEGEND

- ↘ Primary Current (over body)
- ← Internal Polarization (at depth within body)
- ↘ Secondary Current (I.P)
- - - Secondary Potential Field

Body

PLAN



Current path and secondary equipotential field due to discharge of stored energy (I.P. effect) in the case of Pole-Dipole or Dipole-Dipole.

FIGURE 4.

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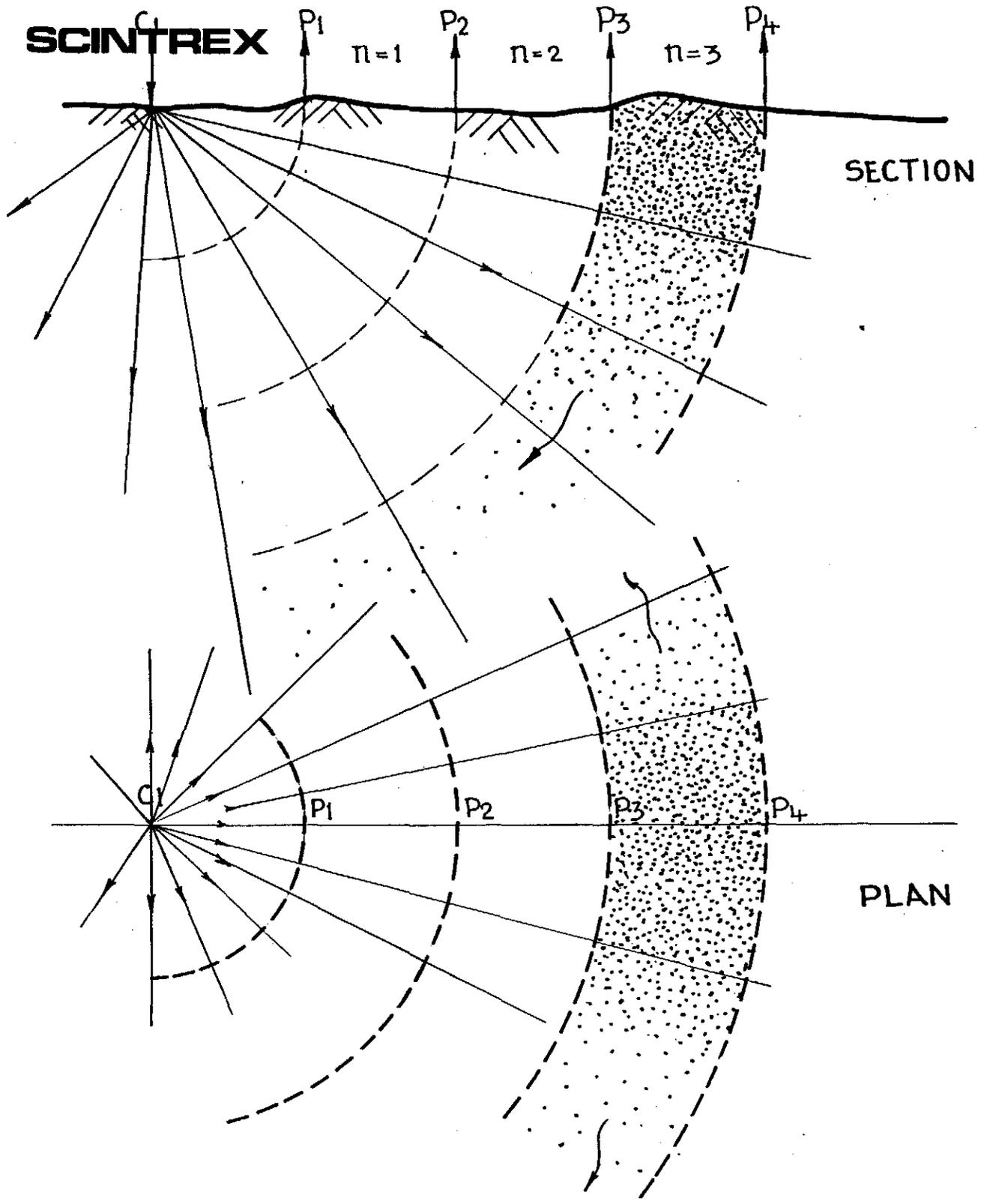
except that a single electrode is placed 'close' to the potential dipole, with an 'infinite' electrode placed $10 \times n \times a$ away from the 'pole-dipole' set-up, and, where practical, at right angles to it. The enclosed Figure 5 shows the distribution of current flow in section and in plan, about the pole source C_1 . The potential electrodes P_1 and P_2 tap off the volume between them, which is contained between spheres whose centres are the pole source. The primary current reading is normalised for the geometry and plotted in profile or pseudo-section format as per dipole-dipole, namely, midway between the closest potential and current dipoles, which in the pseudo-section format is 45° towards the pole source. The chargeability reading is generated in a similar fashion to that described for dipole-dipole (Figure 4).

As with the dipole-dipole array, a double peak will result when $n \times a$ is greater than the depth to source, however, with pole-dipole it will be asymmetric. This will be true for both major resistivity features as well as for chargeability features. An example of this asymmetry for different depth to spacing arrays is shown for the three-array. (The three-array is a pole-dipole array when $n = 1$ and the a spacing is varied.)

The Choice Between Arrays:- Even after some thirty years of active use of gradient, dipole-dipole and pole-dipole arrays, controversy still reigns as to the relative merit of the various arrays. Much depends on the object of the programme, the terrain, the type of source sought, the type and complexity of the overburden/oxidation. Table 1 shows a comparison between arrays which may be helpful, taken from a fairly recent Canadian Geological Survey publication. In resistive mountainous terrain the author prefers the gradient array as the prime reconnaissance method due to the high productivity (2 to 5 times that for

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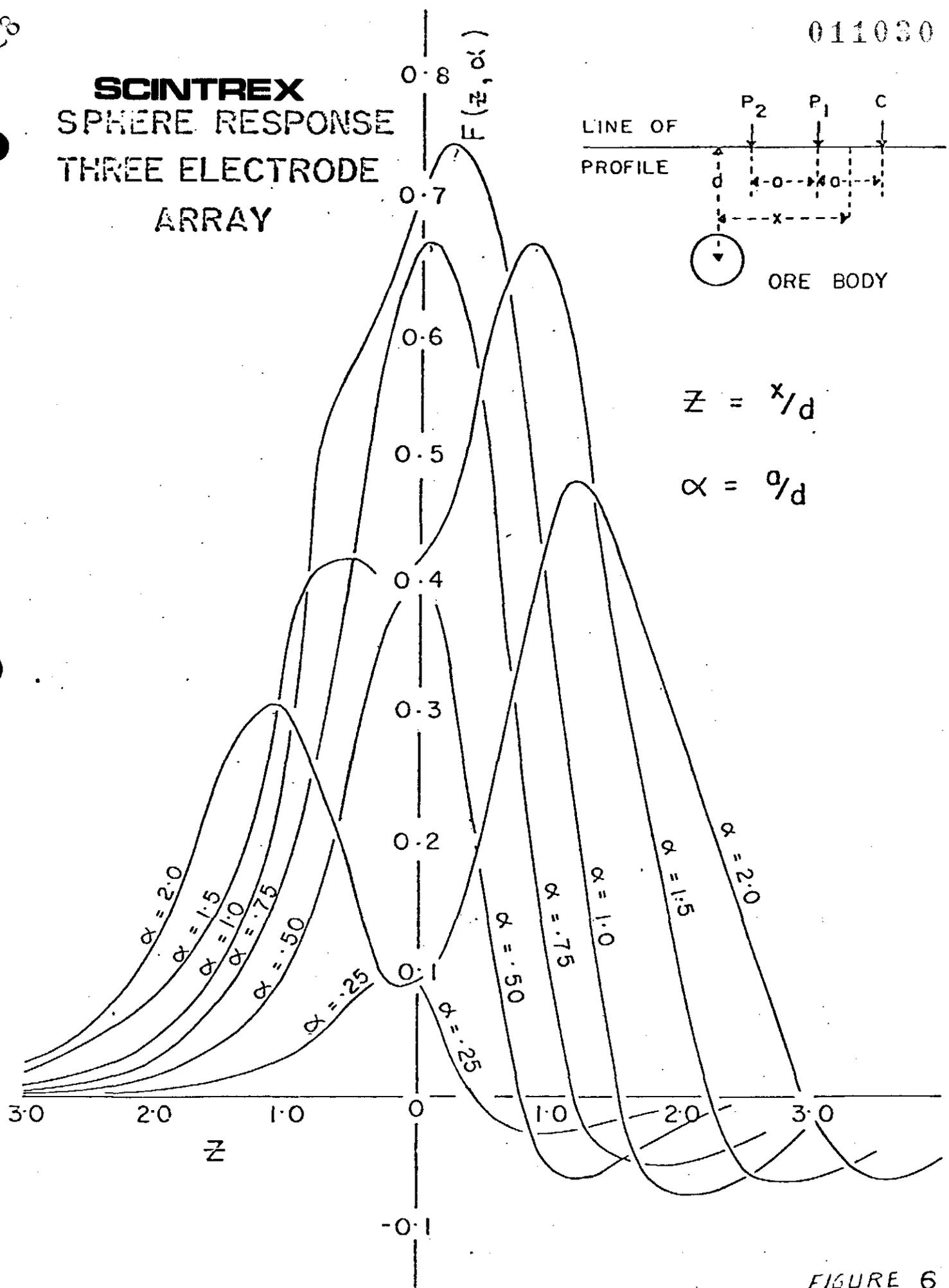
Current Path and Primary Equipotential Field from Pole-Dipole Array

FIGURE 5

028

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SCINTREX SPHERE RESPONSE THREE ELECTRODE ARRAY



$$z = x/d$$

$$\alpha = a/d$$

FIGURE 6

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TABLE 1
 (Table 3. 1)

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SCINTREX Comparison of IP Survey Electrode Arrays

(after Sumner, 1972)

	Advantages	Disadvantages	Survey Speed	Signal to-Noise	EM Coupling Rejection
Parallel Field Arrays Wenner	Anomalies symmetrical Synchronous detector possible Many case histories available	Requires more wire: larger field crew Poor resolution Unfavourable in capacitive coupling situations	Fair	Good	Fair
<u>Schlumberger</u>	Symmetrical array Synchronous detection possible Fewer men required Works well in layered earth Type curves available	Less horizontal resolution Unsuitable for horizontal profiling Capacitive coupling possible	Fair	Fair	Fair
<u>Gradient</u>	Map interpretation easier Less masking by conductive overburden Penetration good; safer Communications easier Can use two or more receivers Less topographic effect Data easily contoured in plan Useful where difficulty in making good current contacts	Poor resolution with depth Poor in low resistivity areas Geometric factor varies complexly	Good	Fair	Poor
Potential-About-a-Point Three-Array	Good reconnaissance array Fairly good resolution	Asymmetrical More wire needed	Fair	Good	Good
<u>Pole-Dipole, Collinear</u>	Good resolution Good subsurface coverage	Asymmetrical Asymmetrical	Fair	Fair	Fair
Perpendicular Three-Array, Pole-Dipole, Pole-Pole Pole-Pole (Two-Array)	Virtually eliminates EM coupling Smaller crew needed Less wire needed than for some arrays Good penetration in nonconductive overburden	More wire needed Susceptible to masking by conductive over-burden	Fair to Poor	Fair	Very Good
PDR (Potential Drop Ratio)	Sensitive to lateral variations "Common mode" noise rejection	Complex interpretation	Fair	Good	Fair
<u>Dipole Field Array</u>					
<u>Dipole-Dipole Collinear</u>	Symmetrical, good resolution Good penetration Less survey wire needed	Slow unless equipment is portable Resistivity topographic effects Interpretation somewhat involved	Fair	Poor	Fair
Dipole-Dipole, Parallel	Special use for EM coupling interpretation	Not used for routine surveying	Poor	Poor	Fair
Down-the-Hole Arrays					
Azimuthal Array (One Potential Electrode Down the Hole)	Fair for exploration purposes Useful in finding the best search direction	Interpretation complex Negative anomalies Strong geometric effects Mainly measures changes in resistivity	Fair	Good	Good
Radial Array (One Current Electrode Down the Hole, mise-à-la-masse)	Good for exploration purposes Useful in finding the best search direction Hole need not stay open	Interpretation complex Negative anomalies Not good for obtaining rock properties	Fair	Good	Good
In-Hole Arrays (More than One Electrode in the Hole)	Good for obtaining rock properties Good for assaying Interpretation simple	Current densities may be too large Possible capacitive coupling problems Not designed for exploration purposes Special equipment, expensive	Good	Fair	Good

Extract from: Geological Survey of Canada - Paper 75-31 "Borehole Geophysics Applied to Metallic Mineral Prospecting: A Review"

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dipole-dipole), but this should be followed-up by detailed dipole-dipole or pole-dipole surveys as the gradient array, while giving 'maximum depths', cannot give 'minimum depths' as moving source arrays can. Similarly pole- or dipole-dipole surveys which have complex or multiple sources can very often be resolved by use of limited gradient array detail. While pole-dipole is more efficient to apply in mountainous terrain, it tends to yield asymmetric double peak anomalies, however, to the trained observer, this is no disadvantage.

Brief Comments on Decay Form:- In most surveys three 'slices' of the decay form for the induced polarization response are acquired for each station as shown in Figure 7. While six slices are capable of being measured (M_1 to M_6), they are normally combined into pairs $M_1 + M_2 = M_3$ etc. as shown in Figure 7(C). Each of the slices M_1 to M_6 is normalised for a 'normal' decay form such that should the decay form be 'normal' $M_1 = M_3 = M_5$. Thus the operator can immediately recognise any anomalous decay forms which may arise from one of two major sources. Firstly the type of the source can influence the decay form. Coarse grained efficient sources such as sulphides show *slow* decay forms, magnetic and fine grained sulphides often show *fast* decay forms. This can be shown as $\Delta M = M_5 - M_1$, where positive ΔM infers *slow* decay form and negative ΔM *fast* decay form. A superior parameter is ΔM_n where

$$\Delta M_n = \frac{M_5 - M_1}{M_3} \times 100 \text{ (in percent)}$$

which is essentially ΔM normalised for the amplitude of the decay. ΔM and ΔM_n are merely short hand ways to profile changes in decay form and are essentially qualitative and relative.

Decay forms can also demonstrate the presence of electromagnetic coupling as Figure 7 shows. This is a regional effect as shown on Figure 7(b). This will

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normal decay

7(a)

decay curve modified by coupling

7(b)

electromagnetic coupling

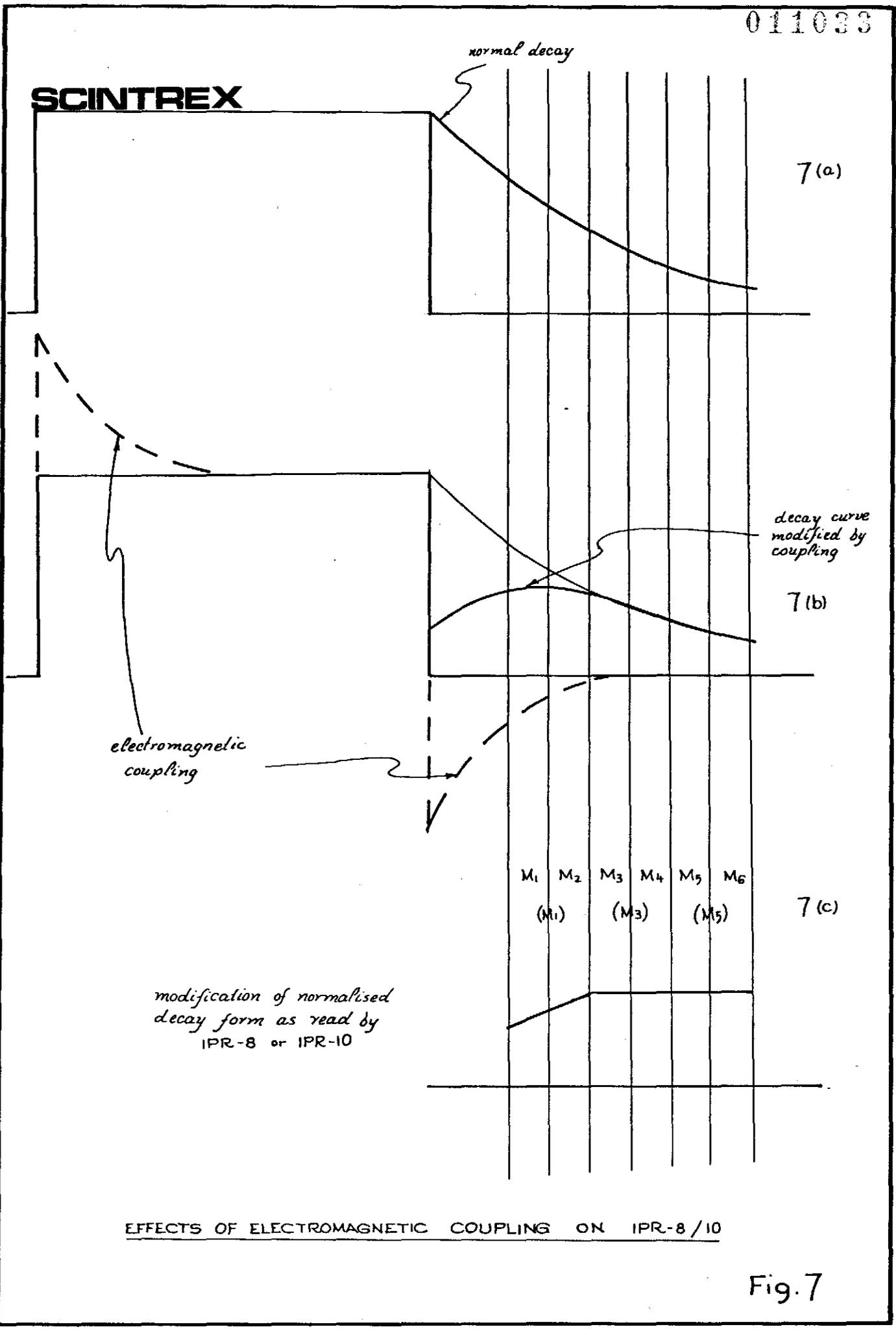
M ₁	M ₂	M ₃	M ₄	M ₅	M ₆
(M ₁)		(M ₃)		(M ₅)	

7(c)

modification of normalised decay form as read by IPR-8 or IPR-10

EFFECTS OF ELECTROMAGNETIC COUPLING ON IPR-8/10

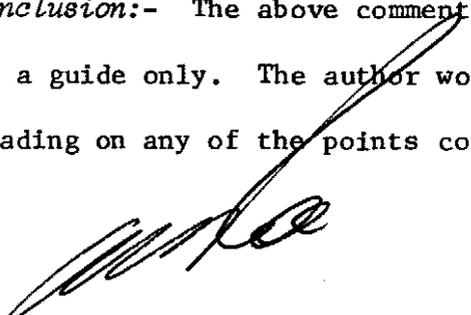
Fig. 7



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produce a normalised M_1 smaller than either M_3 or M_5 .

Conclusion:- The above comments are indeed simplistic, and should be considered as a guide only. The author would be pleased to supply references on additional reading on any of the points commented upon.



A.W. HOWLAND-ROSE, MSc, DIC, AMAus IMM, FGS.

033



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INDUCED POLARIZATION AND RESISTIVITY SURVEY
DIPOLE - DIPOLE ARRAY

DATE 21-11-1980

PLOTTED BY L.K.

PULSE 2 sec

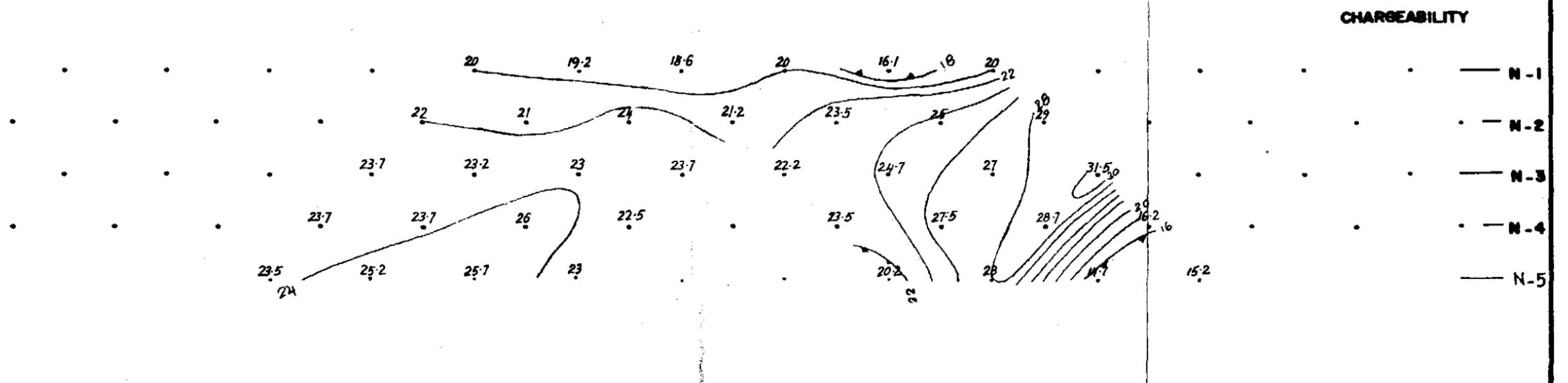
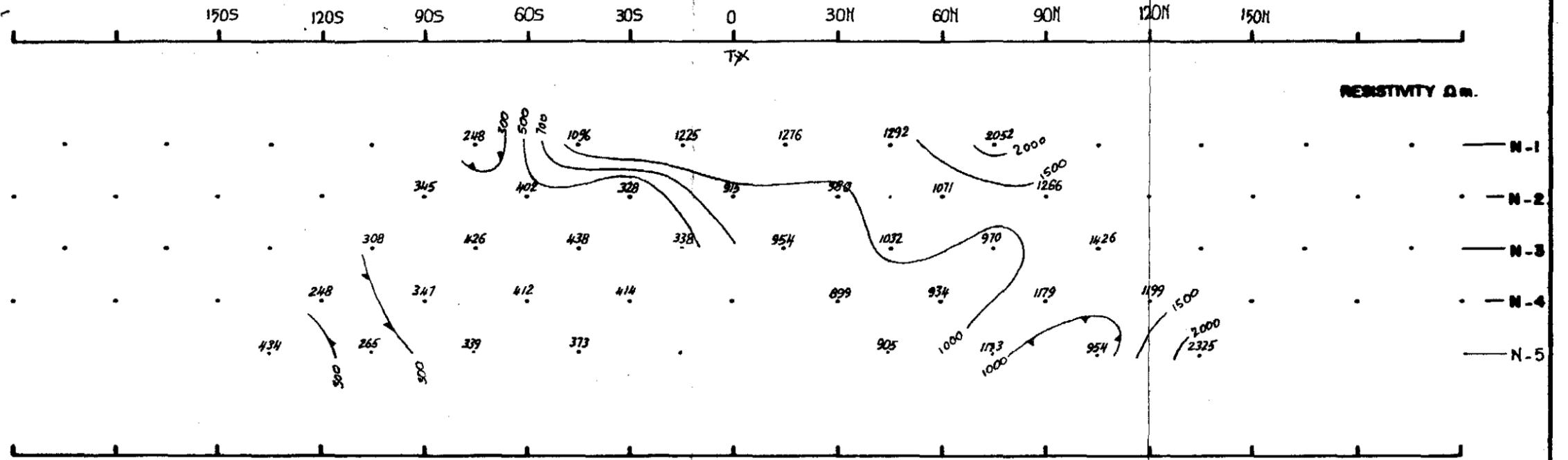
Rx. 311147

DIPOLE SPACING 30m

LINE No. 500E (Sheet 1)

PROSPECT WAXMAN & WESTON

JOB No. TAS-081A



034



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INDUCED POLARIZATION AND RESISTIVITY SURVEY
DIPOLE - DIPOLE ARRAY

DATE 1-12-1980

PLOTTED BY L.K.

PULSE 2 sec

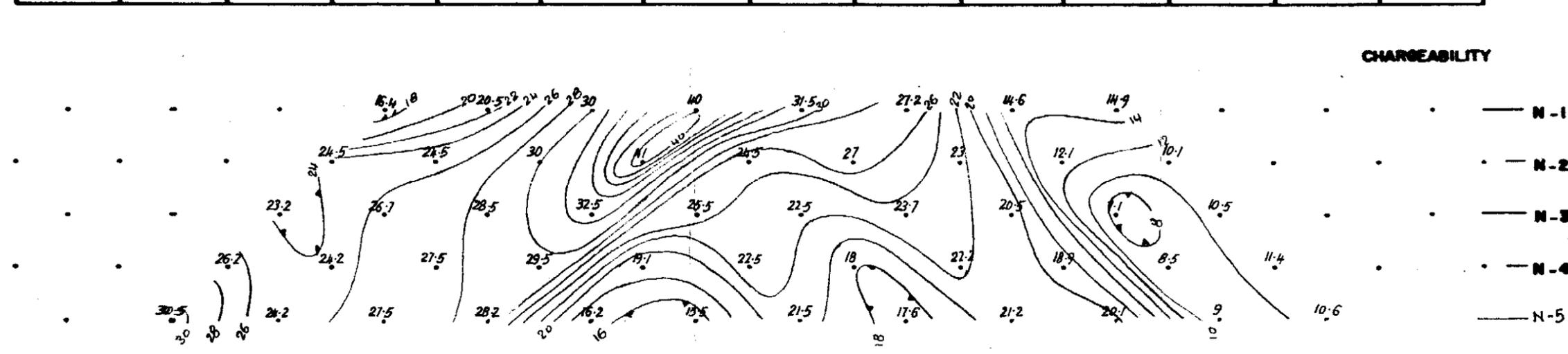
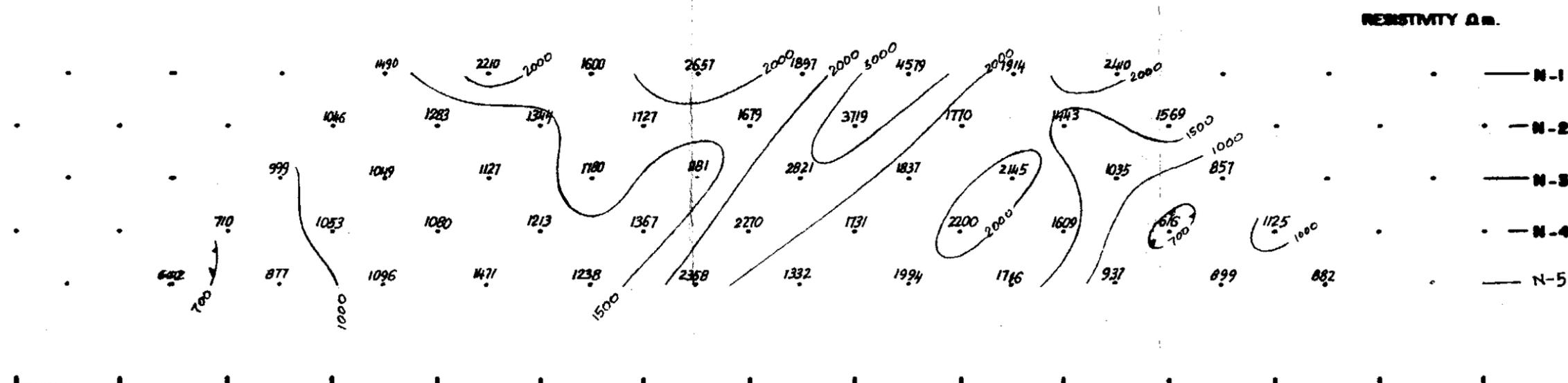
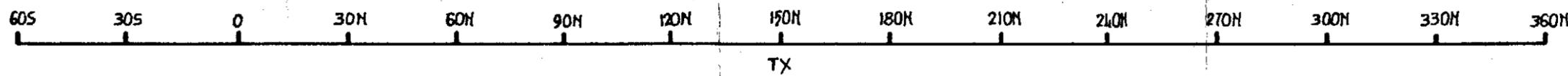
Rx. T909273

DIPOLE SPACING 30m

LINE No. 500E (sheet 2)

PROSPECT WAXMAN & WESTON

JOB No. TAS-081-A



035



SCINTREX PTY. LTD.

INDUCED POLARIZATION AND RESISTIVITY SURVEY
DIPOLE - DIPOLE ARRAY

DATE 22-11-80

PLOTTED BY L.K.

PULSE 2 Sec

Rx. 311147

DIPOLE SPACING 30m

LINE No. 550E

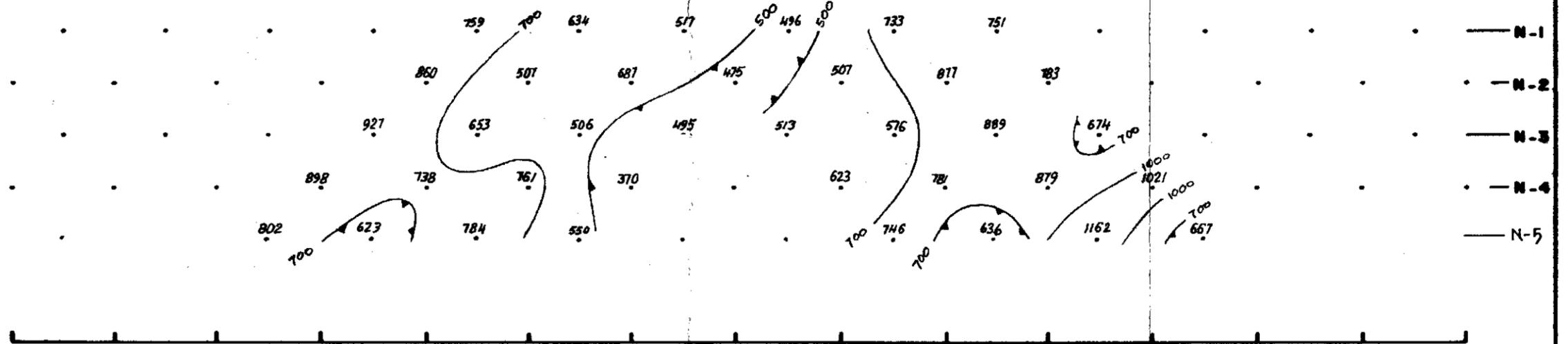
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JOB No. TAS-081-A

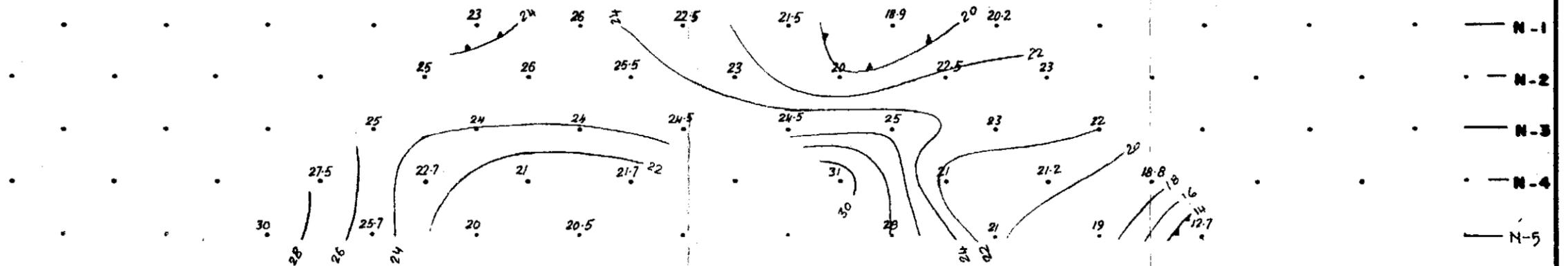


TX

RESISTIVITY $\Omega m.$



CHARGEABILITY



036



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INDUCED POLARIZATION AND RESISTIVITY SURVEY
DIPOLE - DIPOLE ARRAY

DATE 22-11-80

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PULSE 2 Sec

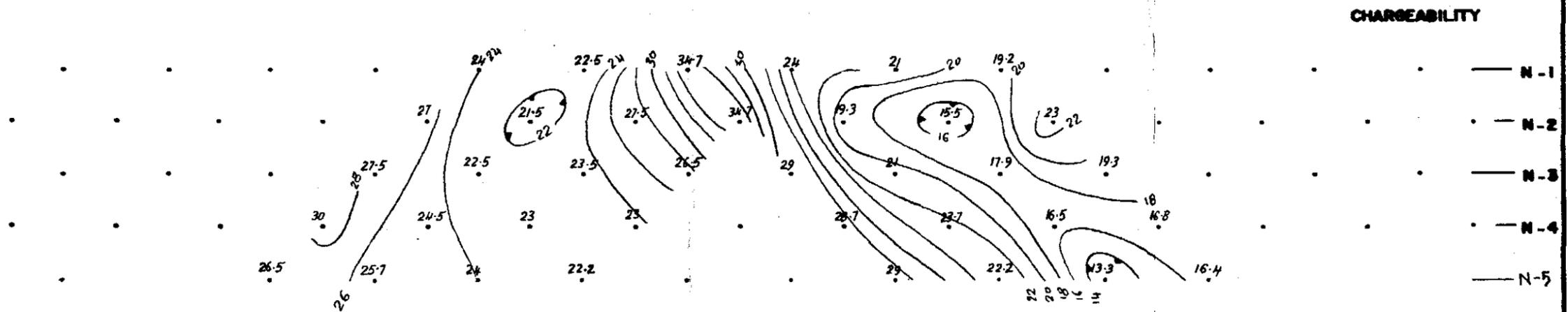
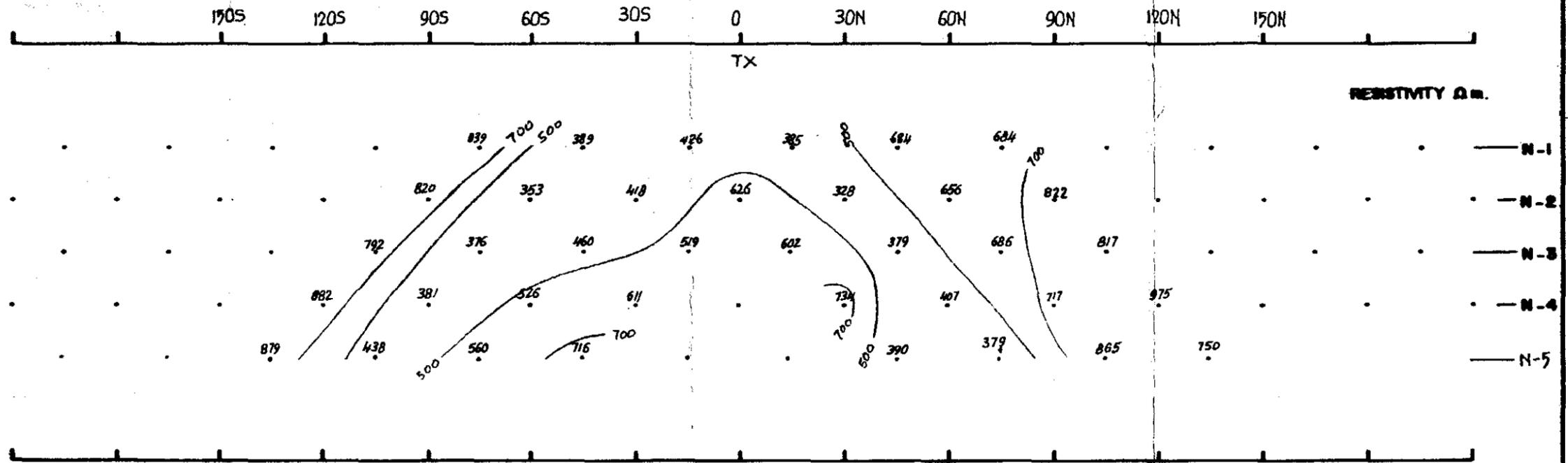
Rx. 311147

DIPOLE SPACING 30m

LINE No. 600E

PROSPECT WAXMAN & WESTON

JOB No. TAS-081-A



038



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INDUCED POLARIZATION AND RESISTIVITY SURVEY

DIPOLE - DIPOLE ARRAY

DATE 23-11-80

PLOTTED BY L.K.

PULSE 2 Sec

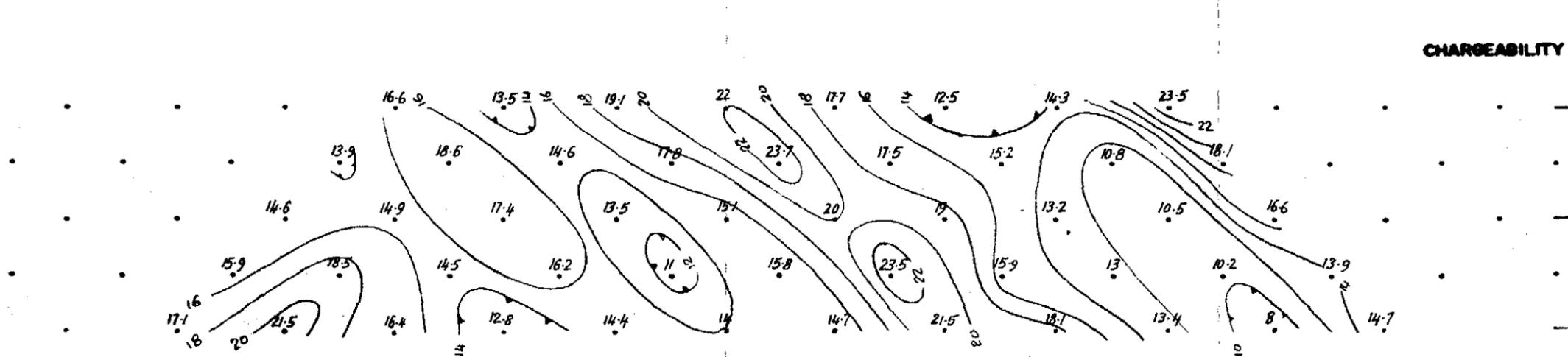
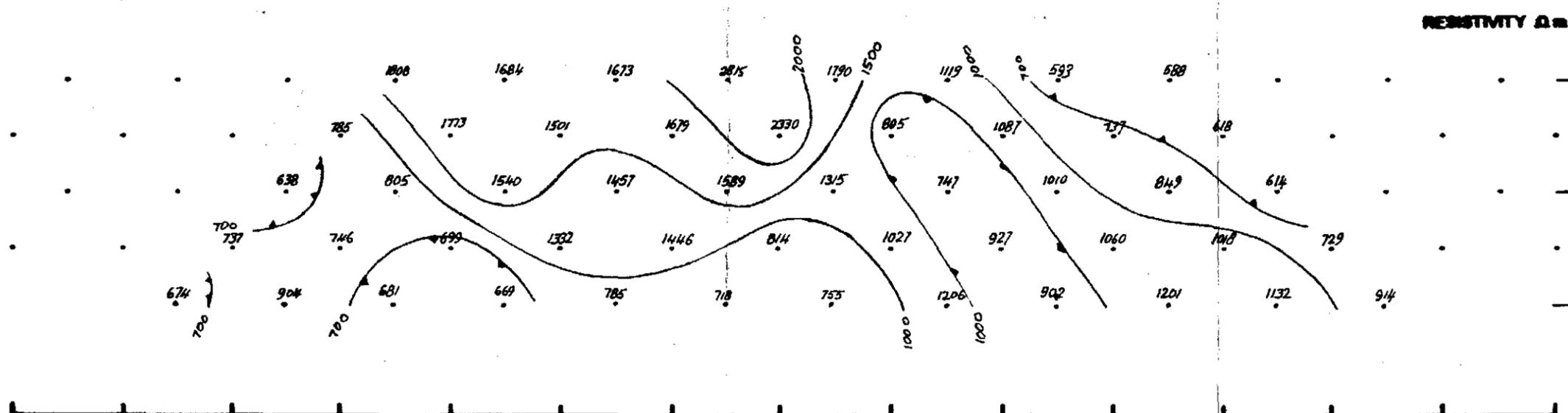
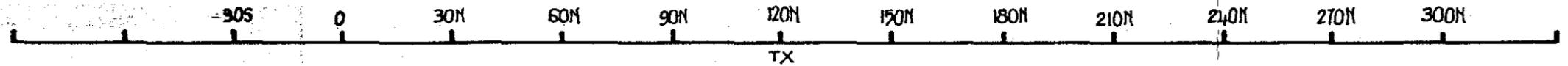
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DIPOLE SPACING

LINE No. 700E

PROSPECT WAXMAN & WESTON

JOB No. TAS-081-A



- N-1
- N-2
- N-3
- N-4
- N-5

040



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INDUCED POLARIZATION AND RESISTIVITY SURVEY
DIPOLE - DIPOLE ARRAY

DATE 30-11-1980

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PULSE 2. Sec

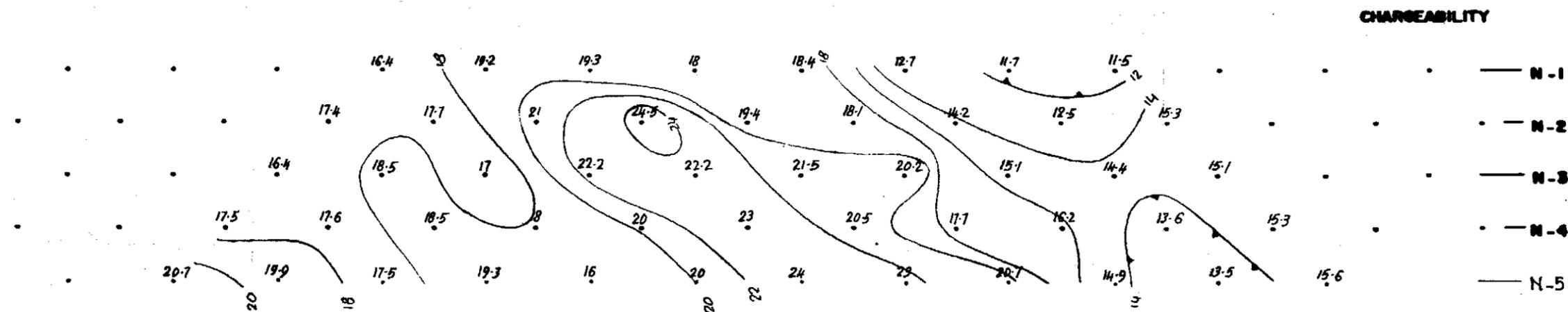
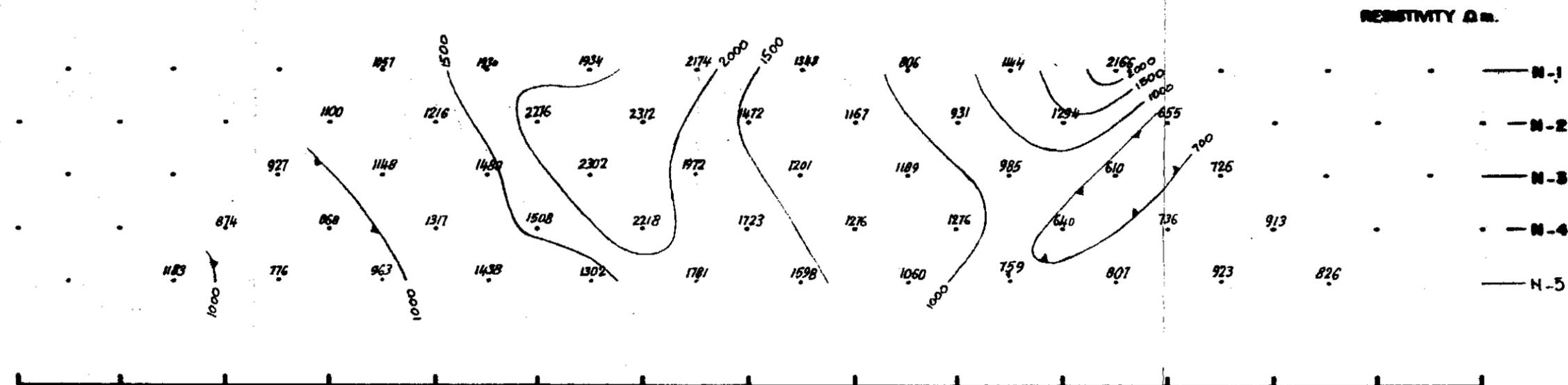
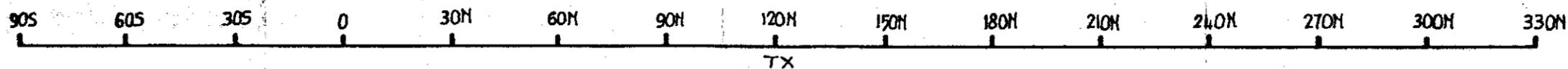
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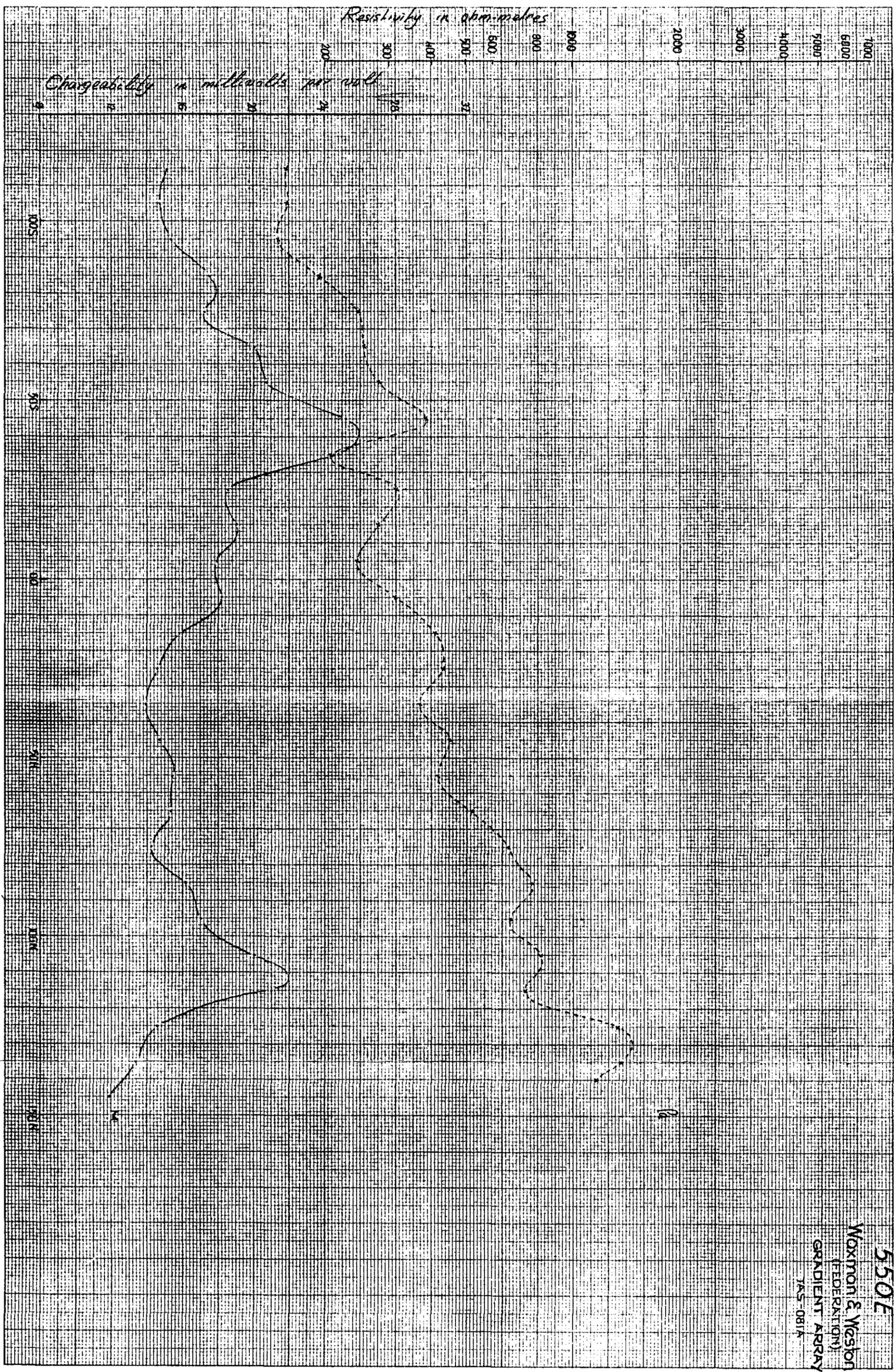
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LINE No. 750E (sheet 2)

PROSPECT WAXMAN & WESTON

JOB No. TAS-081A

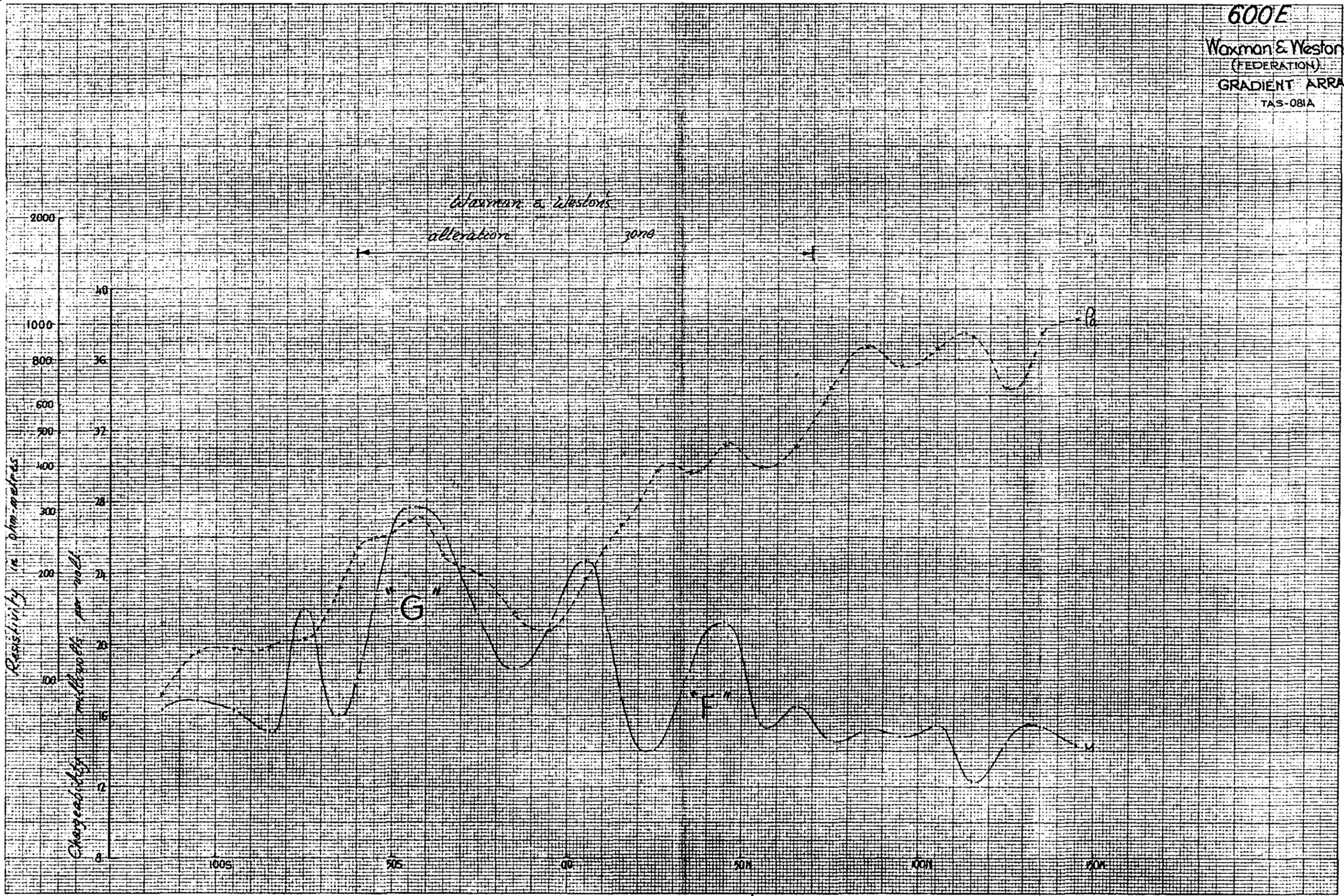




550E
 Woxman & Weston
 (FEDERATION)
 GRADIENT ARRAY
 7AS-081A

600E

Waxman & Weston
(FEDERATION)
GRADIENT ARRAY
TAS-081A



WAXMAN & WESTON (FEDERATION) CENTIMETER TAPE

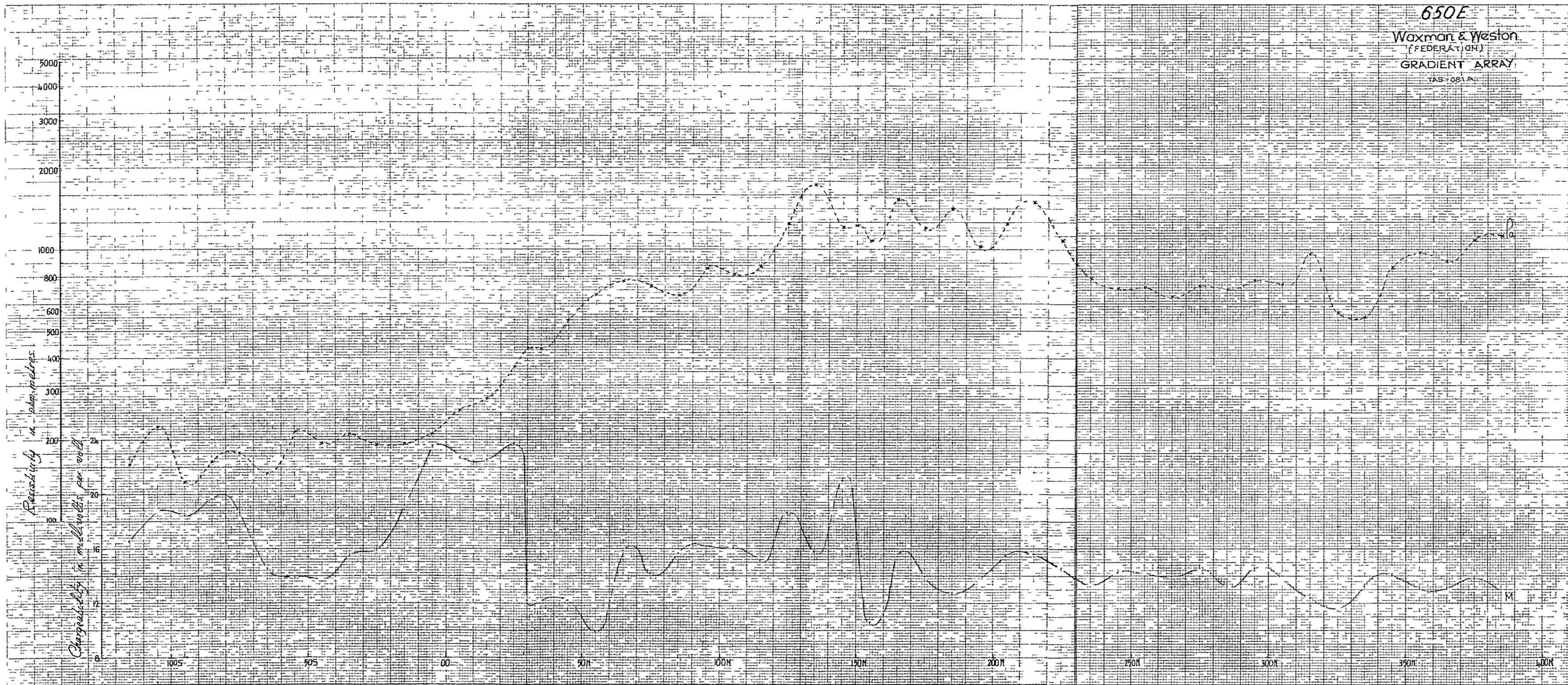
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(FEDERATION)
GRADIENT ARRAY
TAS-081A



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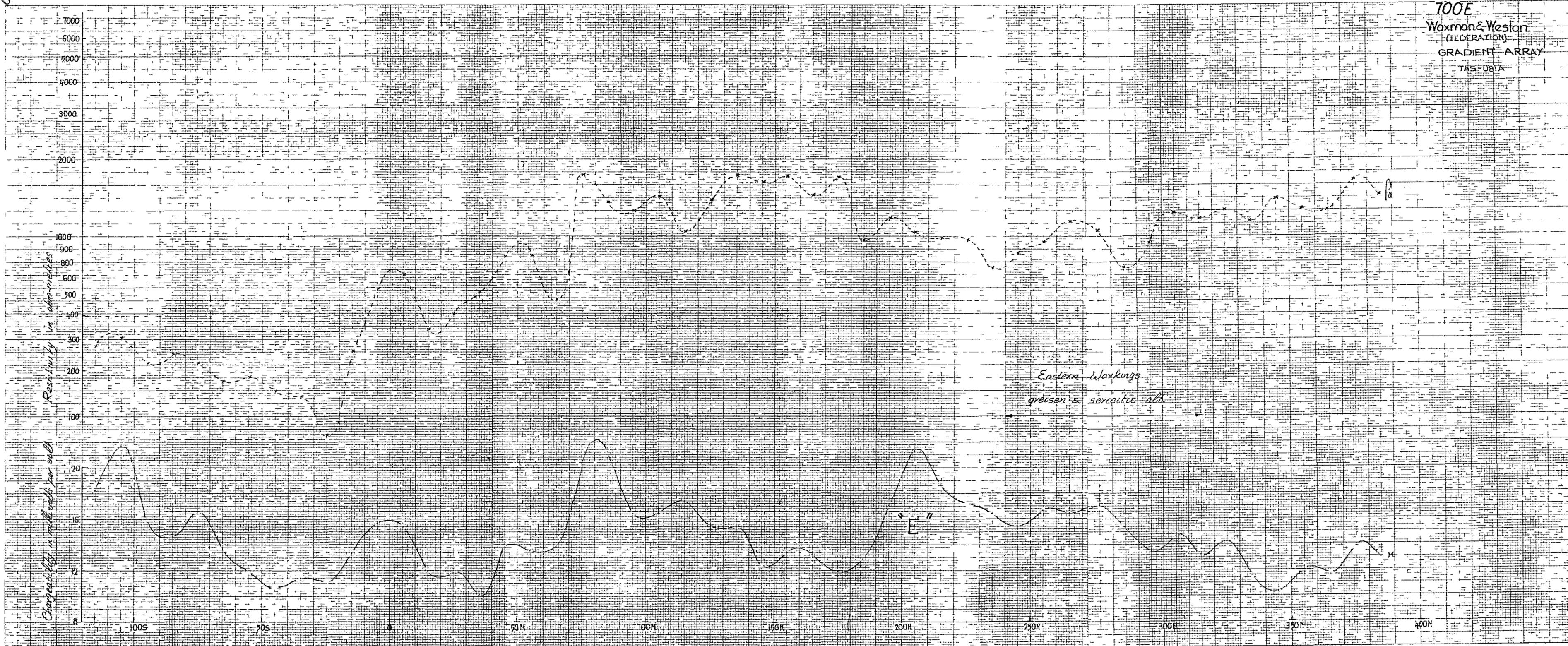
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700E
Waxman & Weston
(FEDERATION)
GRADIENT ARRAY
TAS-081A



048

011018

750E
Woxman & Weston
(FEDERATION)
GRADIENT ARRAY
TAS-081A

Pressure in dynes/cm²

Temperature in millivolts per volt

5000
4000
3000
2000
1000
800
600

8
7
6
5
4

210N

250N

300N

350N

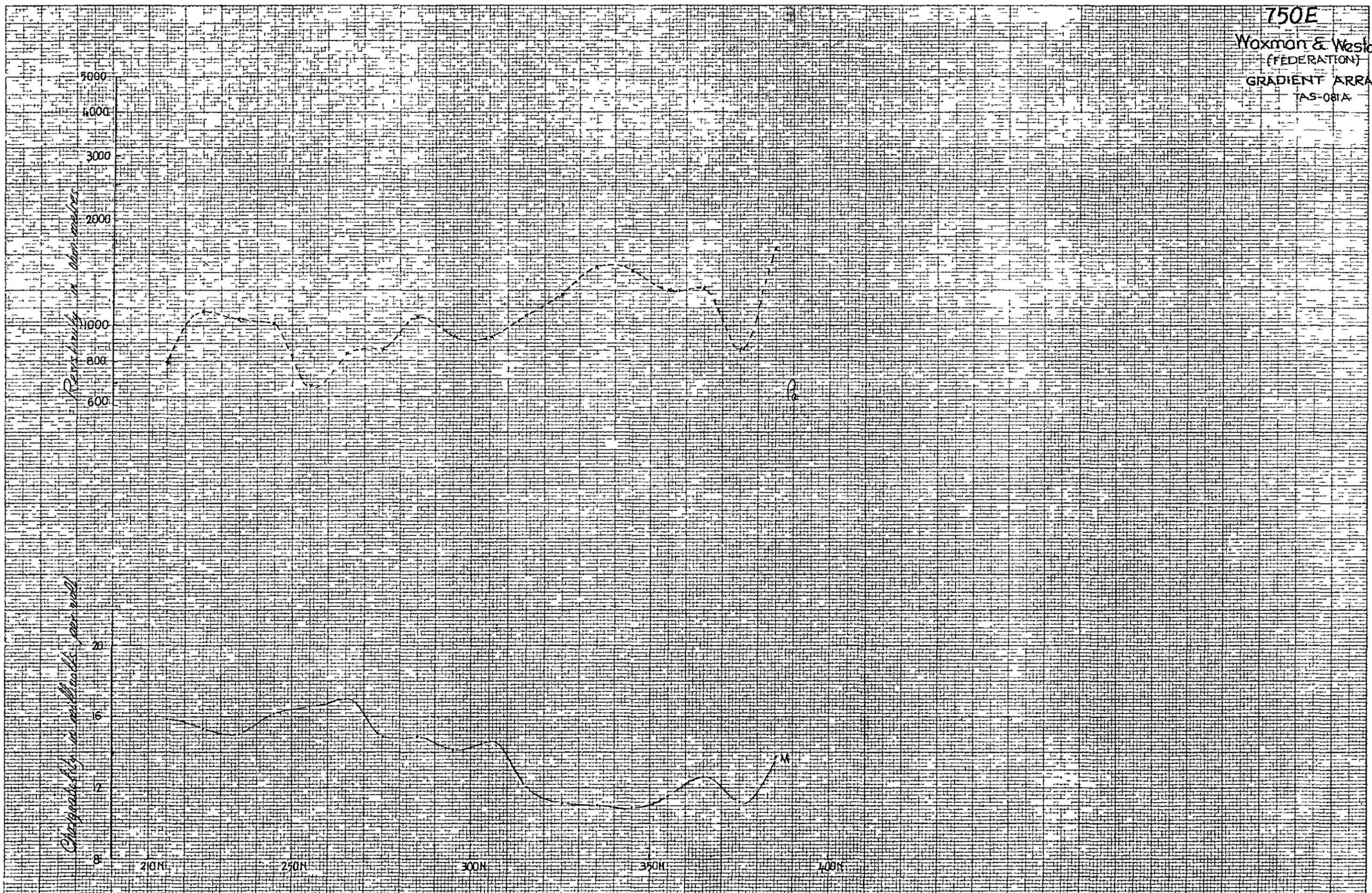
400N

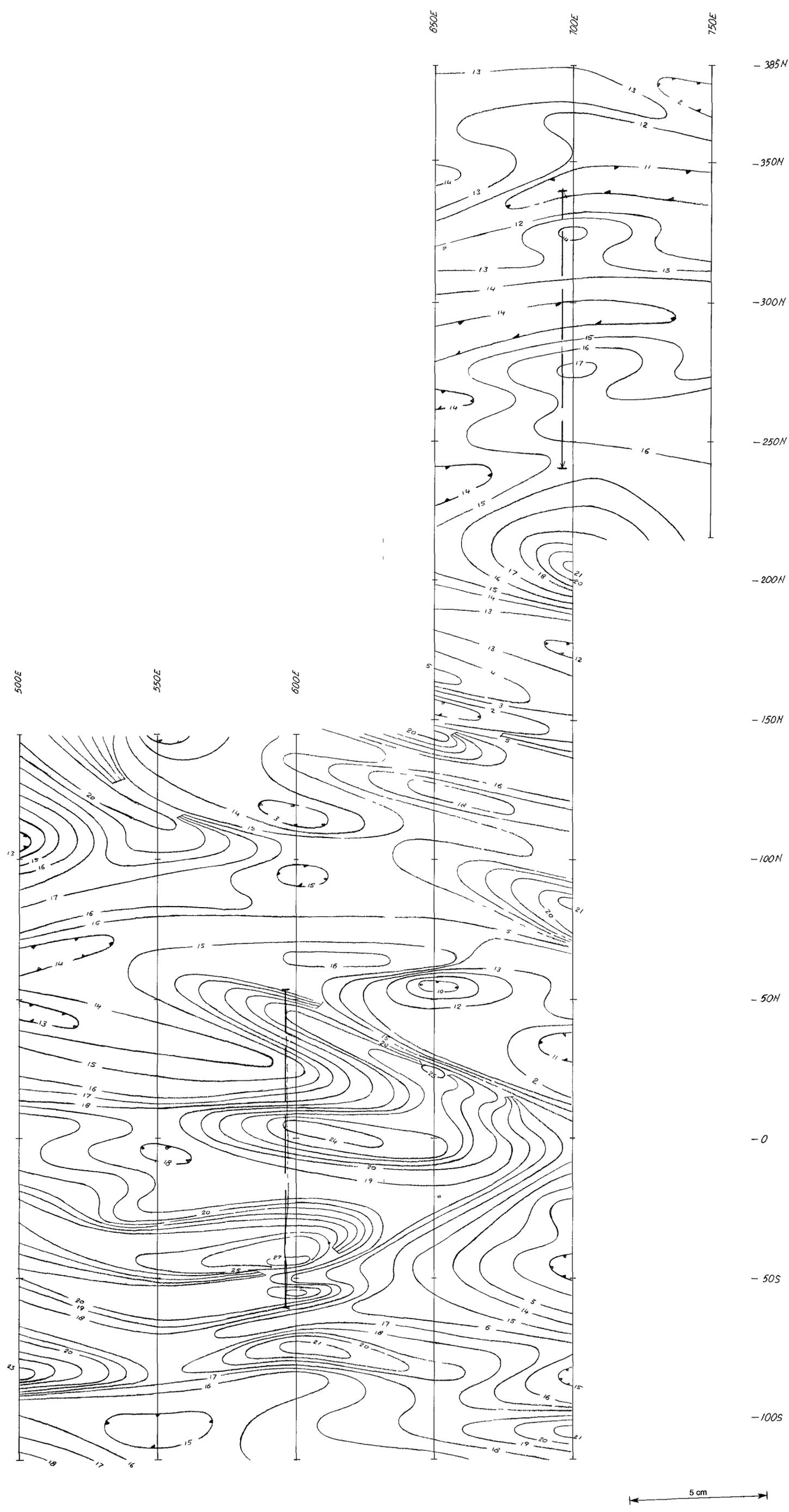
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011018





Legend

- Chargeability in millivolts per volt
- Zones of alteration

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CHARGEABILITY
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SCALE 1:1000 m

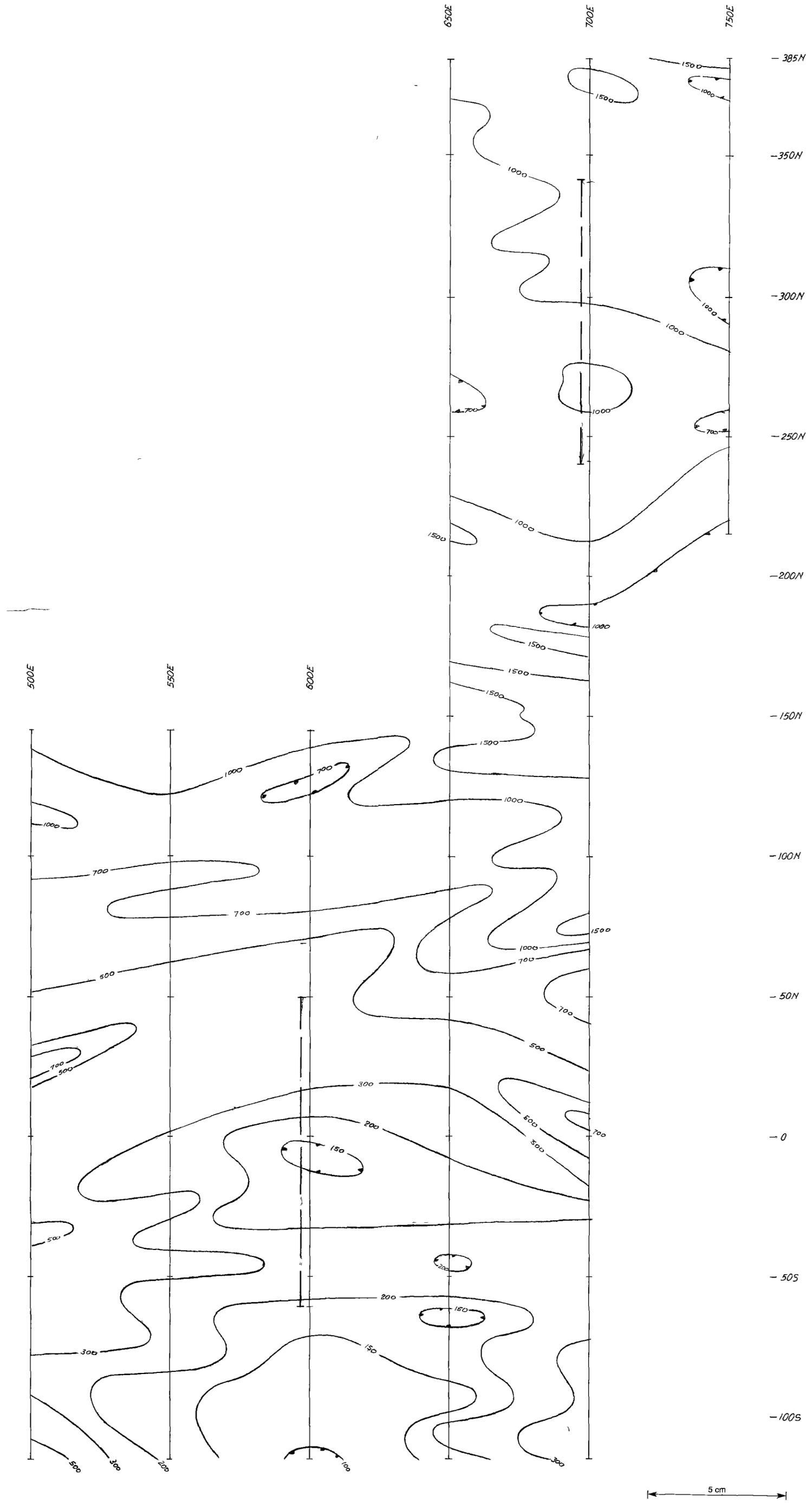
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PLATE 1

81-1515

011049

3010



Legend

- Resistivity in ohm metres
- Zones of alteration

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PLATE 2

011050

81-1515

3011