010

REPORT ON GROUND GEOPHYSICAL SURVEYS CONDUCTED IN THE DEAN CREEK PROPERTY RED LAKE AREA, NOTHWESTERN ONTARIO

RECEIVED
FEB 12 1988
MINING LANDS SECTION

2.10824

On Behalf Of :

Noramco Explorations Inc.
1275 Main St.W.
North Bay, Ontario
P1B 2W7

Contact: Art Murdy
Telephone: (416) 472-8880

By:

JVX Limited
33 Glen Cameron Rd - Unit #2
Thornhill, Ontario
L3T 1N9

Contact: Blaine Webster
Tel.: (416) 731-0972

JVX Ref: 8766
December, 1987

TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

appendix 2 con't.:

Plate 8 : Stacked M7/Resistivity Pseudosections, scale 1:2500.
L-0E - L-8E
Plate 8a: Stacked M-IP/tau Pseudosections, scale 1:2500.
L-0E - L-8E
Plate 9 : Stacked M7/Resistivity Pseudosections, scale 1:2500.
L-1E - L-5E
Plate 9a: Stacked M-IP/tau Pseudosections, scale 1:2500.
L-1E - L-5E

Appendix 3: Literature

Spectral IP Parameters as determined through Time Domain Measurements by I.M. Johnson, Scintrex Limited, Toronto, Ontario, Canada, 1984.

Spectral IP: Experience over a number of Canadian Gold Deposits by B. Webster, JVX Ltd., and I.M. Johnson, Scintrex Limited, Toronto, Ontario, Canada, 1985.

Time domain Spectral Induced Polarization, some recent examples for gold, by Ian M. Johnson and Blaine Webster, JVX Limited, Thornhill, Ontario, Canada, 1987. Prepared for delegates to Exploration 87, 1987, Toronto, Canada

Data Listings

Data Summary and Spectral Analysis Summary in separate binder (one copy only)

REPORT ON GROUND GEOPHYSICAL SURVEYS
CONDUCTED IN THE DEAN CREEK PROPERTY
RED LAKE AREA, NORTHWESTERN ONTARIO

On Behalf Of

NORAMCO EXPLORATIONS INC.

1. INTRODUCTION

From September 11th to October 3th, 1987 Induced Polarization and Resistivity surveys were conducted on behalf of Noramco Exploration Inc. on the Dean Creek property, near Red Lake, Northwestern Ontario, by JVX Ltd.

The objective of the geophysical survey was to map areas of anomalous IP response that may be related to gold bearing sulphide mineralization.

The IP survey employed the time domain method and a pole-dipole array with an a-spacing of 25 meters. Six potential dipoles (n=1 to 6) were read. A total of approximately 30.3 line-kilometers of IP coverage was achieved.

This report describes the survey logistics, field procedures and data processing/presentation. An interpretation of the results is included. The results are presented as contour plan maps and pseudosections.

2. SURVEY LOCATION AND ACCESS

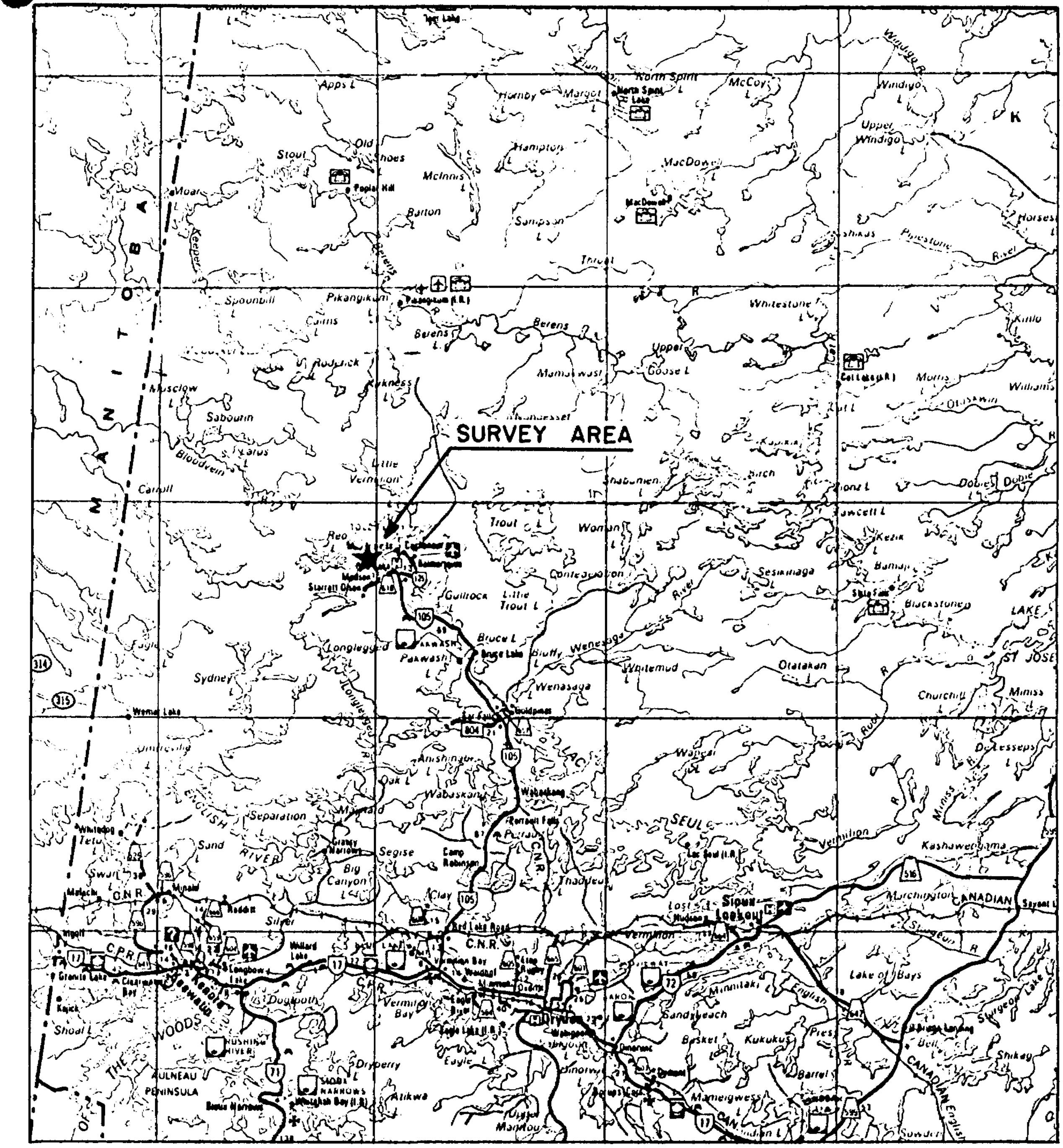
Figure 1 shows the location of the survey area with respect to nearby population centers at a scale of 1:2,000,000.

The Dean Creek Property is accessible by float plane from Red Lake.

3. SURVEY GRID AND COVERAGE

The survey grid is shown in Figure 2 at scale of 1:30,000.

Total of 47 lines have been achieved as follows in Table 1.



LOCATION MAP

NORAMCO EXPLORATIONS INC.

DEAN CREEK PROPERTY

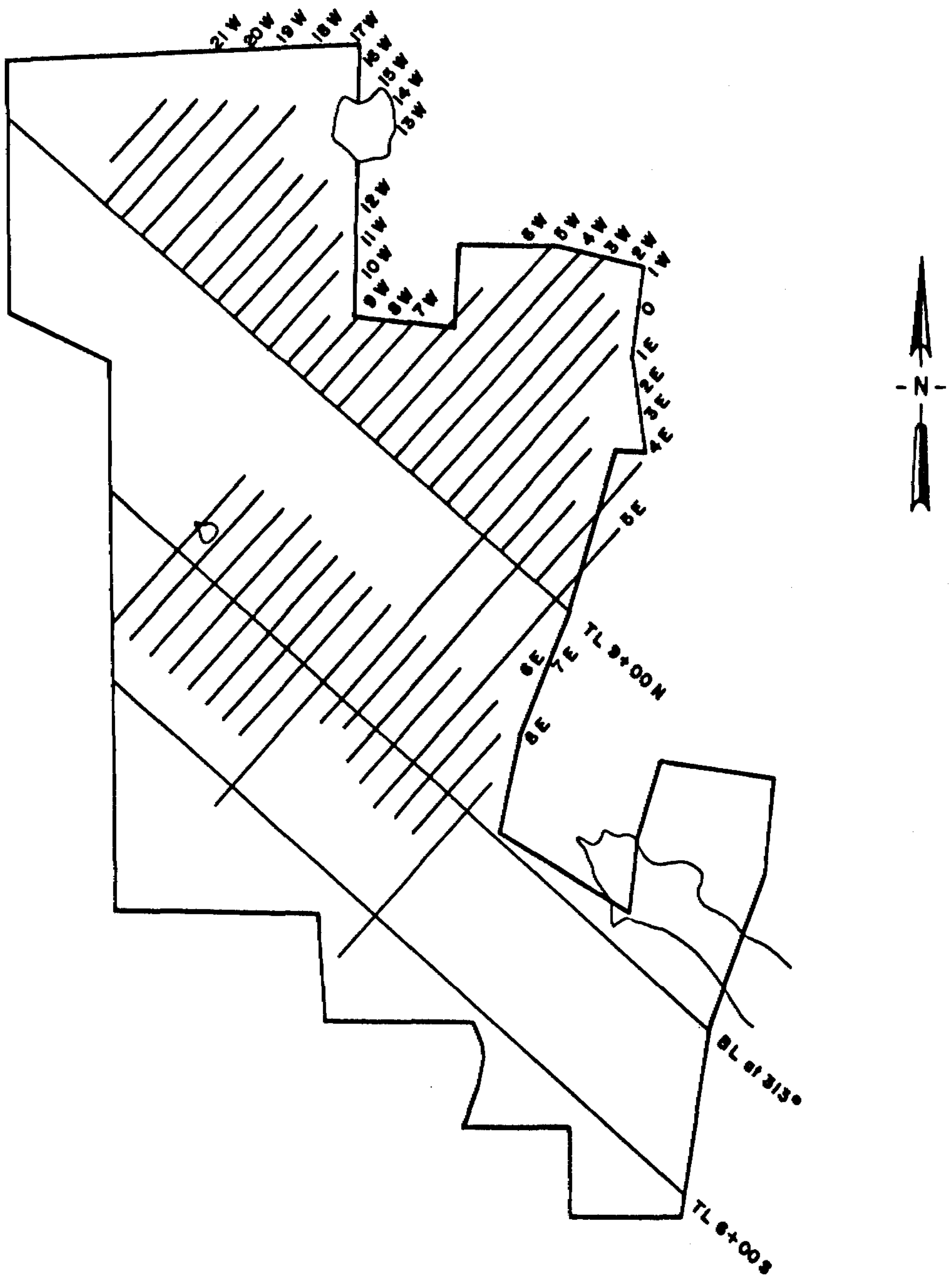
RED LAKE AREA, NORTHWESTERN ONTARIO

I.P. / RESISTIVITY SURVEY

Scale : 1 : 2,000,000

Survey by JVX Ltd.
Sept., 1987.

Figure 1



GRID MAP

NORAMCO EXPLORATIONS INC.

DEAN CREEK PROPERTY

RED LAKE AREA, NORTHWESTERN ONTARIO

I.P. / RESISTIVITY SURVEY

Scale : 1:30,000 (approx.)

Survey by JVX Ltd.
Sept., 1987.

Figure 2

TABLE 1
PRODUCTION SUMMARY

LINE	COVERAGE FROM	TO	LINE LENGTH (feet)	MEASUREMENT POINTS
L-8ES	800S	150N	950	176
L-7ES	200S	325N	525	126
L-6ES	200S	400N	600	144
L-5E	925N	1250N	325	78
L-5EM	325N	900N	575	144
L-5ES	275S	400N	675	156
L-4E	925N	1550N	625	150
L-4ES	250S	400N	650	143
L-3E	925N	1225N	300	68
L-3EM	325N	900N	575	144
L-3ES	200S	474N	675	155
L-2E	925N	1400N	475	114
L-2ES	100S	400N	500	120
L-1E	925N	1500N	575	138
L-1EM	325N	900N	575	144
L-1ES	150S	400N	525	119
L-0E	925N	1825N	900	216
L-0ES	600S	400N	1000	224
L-1W	925N	1975N	1050	252
L-1WS	300S	400N	700	144
L-2W	925N	1975N	1050	252
L-2WS	300S	400N	700	150
L-3W	925N	275N	1150	276
L-3WS	300S	400N	700	162
L-4W	925N	2050N	1125	270
L-4WS	300S	400N	700	168
L-5W	925N	1900N	975	234
L-5WS	300S	450N	750	180
L-6W	925N	1600N	675	162
L-6WS	300S	400N	700	169
L-7W	925N	1375N	450	108
L-7WS	300S	400N	700	168
L-8W	925N	1275N	350	84
L-8WS	300S	400N	700	124
L-9W	925N	1150N	225	54
L-10W	925N	1150N	225	54
L-11W	925N	1325N	400	96
L-12W	925N	1475N	550	132
L-13W	925N	1425N	500	120
L-14W	925N	1600N	675	162
L-15W	925N	1550N	625	150

Table 1 can't.

L-16W	925N	1525N	600	144
L-17W	925N	1725N	800	192
L-18W	925N	1625N	700	168
L-19W	925N	1550N	625	150
L-20W	925N	1475N	550	132
L-21W	1050N	1375N	325	78
	Total		30,300 meters	7094 mps.

Total IP/Resistivity coverage was approximately 30.3 km.

The lines at the table 1 are labeled as surveyed and stored in JVX records. Several lines were read in two or three separate parts so extensions "M" (middle) or "S" (south) appears in the line number.

4. PERSONNEL

Mr. Steve McMenemy - Geophysical Technician/Party Chief. Mr. McMenemy operated the IP receiver and compiled the data with the Corona microcomputer and Scintrex Soft][program. Mr. Northfield acted as party chief and was responsible for data quality and the day to day operation and direction of the survey.

Mr. Dennis Ruff - Geophysical Technician. Mr. Ruff operated the IP transmitter and assisted in the field data compilation.

Mr. Dave Healey - Geophysical Technician, Mr. Ken Wood and Mr.Glen Wood acted as field assistants.

Mr. Neil Hughes - Geophysicist. Mr.Hughes interpreted the geophysical results and prepared this report.

Mr. Blaine Webster - Consulting Geophysicist, JVX Ltd. Mr. Webster set survey specifications and provided overall supervision of the survey and reporting from the Toronto office.

5. INSTRUMENTATION

5.1 IP Receiver

The Scintrex IPR-11 Time Domain Microprocessor-based Receiver was employed. This unit operates on a square wave primary voltage and samples the decay curve at ten time gates or slices. The instrument continuously averages primary voltage and chargeability until convergence takes place and the averaging process is stopped. Accepted data is stored internally on solid-state memory.

5.2 IP Transmitter

The survey employed the Scintrex IPC-7 2.5 kw Time Domain Transmitter powered by an 10hp motor generator. The IPC-7 is designed for a selectable square wave output of 2, 4 or 8 seconds 'on' time. The current output was accurately monitored with a digital multimeter placed in series with the current loop.

5.3 Data Processing

The IP survey data were archived, processed and plotted with a Corona PC-400 microcomputer using an Epson FX-80 dot matrix printer. The system was configured to run the Scintrex Soft II software system, a suite of programs that was written specifically to interface with the IPR-11 receiver and to calculate the spectral parameters. At the conclusion of each day's data collection, data resident in the receiver's memory was transferred, via serial communication link, to the computer - thereby facilitating editing, processing and presentation operations. All IP data was archived on floppy disk. In the Toronto office the IP data was ink-plotted in either pseudosection or plan contour format on a Nicolet Zeta drum plotter interfaced to an IBM PC/XT microcomputer.

The instrumentation is described in detail in the specification sheets appended to this report.

6. EXPLORATION TARGET, SURVEY METHOD AND FIELD PROCEDURES

6.1 Exploration Target

The exploration target on the Dean Creek project was to delineate any areas of sulphide mineralization and to provide the subsurface resistivity information throughout the property. The exploration target is defined as moderate IP anomaly associated with short time constant, high theoretical chargeability and increased resistivity. The object of the survey is to provide Noramco with the above mentioned physical parameters and the geophysical compilation suggesting the exploration targets.

6.2 Survey Method

The phenomenon of the IP effect, which in the time domain can be likened to the voltage relaxation effect of a discharging capacitor, is caused by electrical polarization at the rock or soil interstitial fluid boundary with metallic or clay particles lying within pore spaces. The polarization occurs when a voltage is applied across these boundaries. It can be measured quantitatively by applying a time varying sinusoidal wave (as in the frequency domain measurement) or by an interrupted square wave (as in the time domain measurement).

In the time domain the IP effect is manifested by an exponential type decrease in voltage with time. The frequency domain measures either the difference in voltage as a function of frequency (maintaining constant current) or the real and quadrature components of the voltage compared to the transmitted current.

Both methods measure essentially the same phenomenon and theoretically the response of one can be translated to the other domain by Fourier analysis. The two methods are qualitatively comparable if only a change in relative response amplitude is required, i.e. an anomaly in the time domain will have a similar anomaly in the frequency domain provided the noise levels and resolution of the measuring devices are the same.

The direct current apparent resistivity is a measure of the bulk electrical resistivity of the subsurface. Electricity flows in the ground primarily through the groundwaters present in rocks either lying within fractures or pore spaces or both. Silicates which form the bulk of the rock forming minerals are very poor conductors of electricity. Minerals that are good conductors are the sulphide minerals, some oxides and graphite where the electrical flow is by electronic means rather than ionic.

The two methods of measuring the IP effect employ the same geometries of electrodes. The measurement is made by applying a current across the ground using the ground using two electrodes (current dipole). The potential field (voltage) and IP effect can then be mapped in an area around the current source using what is essentially a very sensitive voltmeter and a second electrode pair (potential dipole). The former parameter, when normalized for the amount of current flowing in the ground, reflects the bulk apparent electrical resistivity of the subsurface. The latter parameter, as previously mentioned, says something of the polarizability of the ground which is due to the content of metallic or clay minerals.

Gold mineralization, the target of this survey, does not occur in sufficient quantities to effect either the bulk polarizability or resistivity of the ground. The anomalous IP response will be engendered by the sulphides which are commonly associated with gold deposits.

The resistivity data is useful in mapping lithologic units and geologic structures such as faults and shear zones. For gold exploration it is particularly useful to delineate zones of silicification which is often associated with gold mineralization.

Historically the time domain IP response was simply a measure of the amplitude of the decay curve, usually integrated over a given period of time. Over the last decade, advances in technology have made it possible to measure the decay curve at a number of points, thus allowing the reconstruction of the shape of the curve. By measuring the complete decay curve in the time domain, the spectral characteristics of the IP response may be derived.

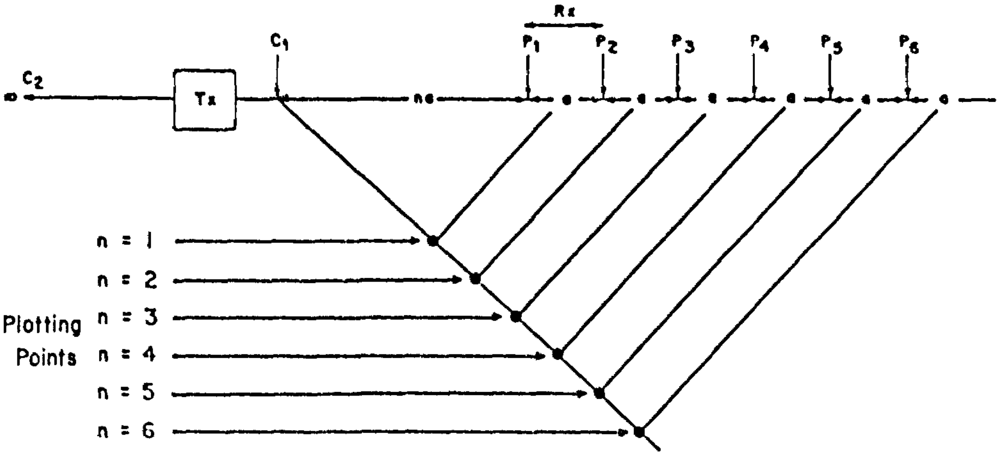
Recent studies have shown there is a relationship between the decay form and the texture or grain size of the polarizable minerals, i.e. the IP response is not only a function of the amount or type of the polarizable material. This could be important when it comes to ranking anomalies of equal amplitude or discriminating between economic and non-economic sources. The parameters that describe all the properties of the IP response are the spectral parameters m, c, and tau. These parameters are described further in a paper accompanying this report.

The spectral data has proved useful in differentiating between fine-grained and coarse-grained sulphides or graphite. Gold is often found associated with sulphides that are fine grained. Experience has shown the M-IP parameter (derived m) is helpful in ranking anomalies in areas of high resistivity, where the apparent chargeability is increased sympathetically. Also in areas of low conductivity, the parameter has proved advantageous in determining which anomalies have sulphide sources.

As the source discrimination capability of the IP measurement (either time or frequency domain) remains somewhat unclear, we might recommend that in areas with geologic control, the IP decay forms be studied for significant and systematic differences. If such differences appear, such may be applied elsewhere in the same geologic environment. Our experience has shown time constants (tau) are important interpretation aids in areas of moderate to high resistivities which occur with pyrite in zones of silicification.

6.3 Field Procedures

The IP/resistivity survey employed the time domain method with a pole-dipole electrode array. The geometry of the pole-dipole array is illustrated below.



Pole-Dipole Array
Figure 3

The electrodes marked C1 and C2 comprise the current electrodes. Those marked by a P1, P2, etc., are the potential electrodes. The receiver measures the voltage across adjacent pairs of potential electrodes, e.g. P1-P2, P2-P3, ... P6-P7. These potential pairs are labelled by an integer 'n' which indicates the multiple of the dipole width that the given dipole lies away from the near current electrode.

The further the potential dipole lies from the current dipole the greater is the depth of investigation. However, the effective limit of distance is restricted by the attenuation of the signal as the distance increases.

Resolution of the survey is increased by decreasing the 'a' separation (but a smaller 'a' also decreases the depth of investigation). The current survey employed a 25 m a-spacing. Six potential dipoles (n=1 to 6) were read.

The waveform of the transmitted current is a two second on-off alternating square wave. The IPR-11 measures the voltage (primary voltage) across each potential dipole at an appropriate time after the current begins its on cycle, which approximates a D.C. measurement of voltage.

For a pole-dipole array, the apparent resistivity (ρ_a) is given by:

$$\rho_a = 2\pi \, na \, (n+1) \, Vp/I$$

The equation for the dipole-dipole array is:

$$\rho_a = \pi \, na \, (n+1) \, (n+2) \, Vp/I$$

where ρ_a = apparent resistivity in ohmmeters
n = dipole multiple (dimensionless)
a = dipole separation in meters
Vp = voltage across potential dipole in millivolts
I = transmitted current in milliamperes

This equation includes a geometry dependent component ($2\pi na(n+1)$) and a component (Vp/I) dependent on ground resistivity. The geometry dependent factors pole-dipole electrode array with a=25m and n = 1-6 are given below:

Geometric Factor

	25m
n=1	314
n=2	942
n=3	1880
n=4	3140
n=5	4710
n=6	6590

For any array, the value of resistivity is a true value of subsurface resistivity only if the earth is homogeneous and isotropic. In nature, this is very seldom the case and apparent resistivity is a qualitative result used to locate relative changes in subsurface resistivity only.

The IPR-11 also measures the secondary or transient relaxation voltage during the two second off cycle of the current, which is a measure of the polarizability of the ground. Employing the two second cycle time, ten slices of the decay curve are measured at semi-logarithmically spaced intervals starting at 45 milliseconds after current turn-off and ending 1590 milliseconds after turn-off. The measured transient voltage when normalized for the width of the slice and the amplitude of the primary voltage yields a measure of the polarizability called chargeability in units of millivolts/volt.

Chargeability (M) as measured by the IPR-11, is averaged over several periods of the transmitted waveform and normalized for:

1. the length of the integration interval;
2. the steady state voltage and
3. the number of pulses.

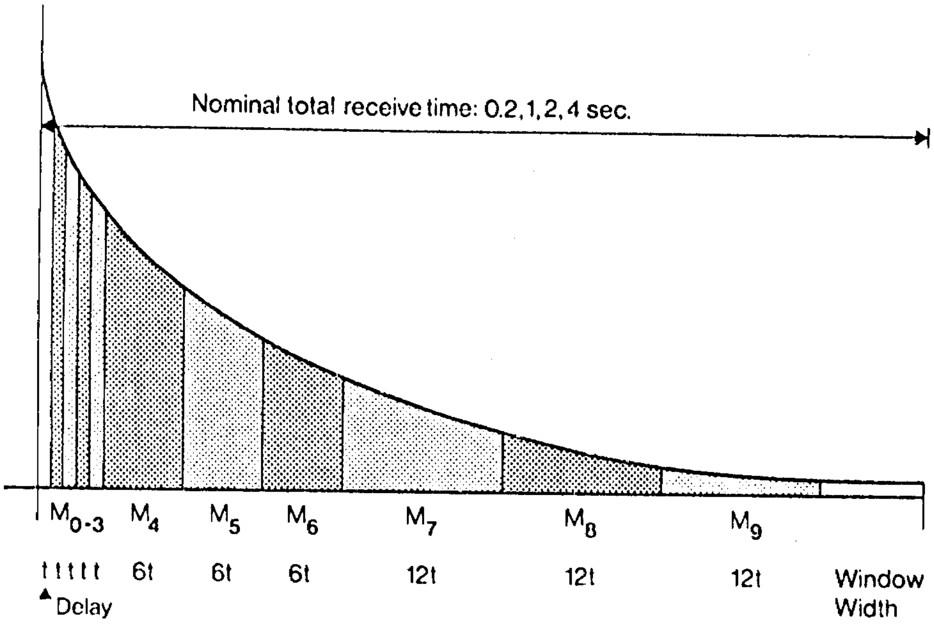
Mathematically this is described as:

$$M = \frac{1000}{Vp \cdot tr} \int_{t_1}^{t_2} Vs \; dt$$

where

M = chargeability (mV/V)
Vs = secondary voltage
Vp = primary voltage
tr = integration interval ($t_2 - t_1$)
t_1 = time at beginning of integration
t_2 = time at end of integration

By adjusting t_1 and t_2 the chargeability is sampled at different points of the decay. Figure 4 illustrates the decay waveform and the 10 slices of integration.



IPR-11 transient windows

Decay Waveform - Figure 4

For a 2 second transmit and receive time the slices of integration are as follows:

SLICE	DURATION msec	FROM msec	TO msec	MIDPOINT msec
M0	30	30	60	45
M1	30	60	90	75
M2	30	90	120	105
M3	30	120	150	135
M4	180	150	330	240
M5	180	330	510	420
M6	180	510	690	600
M7	360	690	1050	870
M8	360	1050	1410	1230
M9	360	1410	1770	1590

Traditionally slice M7 is chosen to represent chargeability in the pseudosections.

The spectral parameters M-IP, tau and "c" may be derived from the IPR-11 data with the Soft][software. Johnson (1984) summarizes the spectral parameters as follows:
M-IP: The chargeability (M-IP) is the relative residual voltage which would be seen immediately after shut-off of an infinitely long transmitted pulse (Seigel, 1959). M-IP is the numerically derived equivalent to Seigel's "m" or theoretical chargeability. It is related to the traditional chargeability, which is measured at discrete time intervals after the shut-off of a series of pulses of finite duration.

tau: The time constant (tau) and exponent (c) are those newly measurable physical properties which describe the shape of the decay curve in time domain or the phase spectrum in frequency domain. For conventional IP targets, the time constant has been shown to range from approximately .01 seconds to greater than 100 seconds and is thought of as a measure of grain size. Fine grained mineralization loses charge quickly, coarse grained mineralization holds charge longer.

c: The exponent (c) has been shown to have a range of interest from 0.1 to 0.5 or greater and is diagnostic of the uniformity of the grain size (0.5 single grain size - 0.1 - many grain sizes).

M-IP and tau are plotted in pseudosection form. The other spectral parameter, c, and the remaining slices of decay curve information (M0 to M6, M8, and M9) may be found in the bound volume of edited data listings.

7. DATA PROCESSING AND PRESENTATION

To allow for the computer processing of the IP data, the raw data stored internally in the IPR-11 system was transferred at the end of a survey day to floppy diskette by the in-field microcomputer and appropriate communications software. The raw data was filed on diskette in ASCII character format using an IBM compatible (MSDOS) microcomputer. Once the data was stored on diskette, a number of processing techniques were employed.

An archived edited data file, in binary format, was created in the field from the raw data file by the operator removing repeat or unacceptable readings and correcting any header errors such as station or line numbers. The concisely labelled and edited data was then dumped to a printer.

The spectral parameters M-IP, c, and tau were computed employing the Scintrex Soft][software package. This program compares the raw transient decay curve with a library of curves calculated from known parameters and by least squares fitting selects a best matching curve. A listing of the spectral parameters and a measure of fit with appropriate station and line labels were then generated on a printer. The computation of the spectral parameters was done in the evening.

The Soft][program generated in-field contoured pseudosections of the M7 slice/apparent resistivity and of M-IP/tau.

After the completion of the survey contoured plan maps of 1) the M7 slice of the n=2 dipole and 2) the apparent resistivity of the n=2 dipole were computer generated and machine-drawn on mylar at the Toronto office at a scale of 1:5000, with appropriate contour intervals. The maps show the grid lines and stations and have the geophysical values posted.

In the JVX office the resistivity/M7 and M-IP/tau pseudosections were re-plotted in ink on paper at a scale of 1:1250 employing a Nicolet Zeta drum plotter and an IBM PC/XT. The plots were photographically reduced on Vellum to a scale of 1:2500. The individual reduced pseudosections were then linked together to form a map set. The stacking of the pseudosections on one plate facilitates line to line correlation of the various IP and resistivity anomalies.

A listing of the final presentation products follows:

7.1 Presentation Plate Index

Plate No.

Plate 1 : Chargeability (M7) Contour Plan Map, scale 1:5000.
Plate 2 : Apparent Resistivity Contour Plan Map, scale 1:5000.
Plate 3 : Compilation/Anomaly Map, scale 1:5000.
Plate 4 : Stacked M7/Resistivity Pseudosections, scale 1:2500.
L-21W - L-13W
Plate 4a: Stacked M-IP/tau Pseudosections, scale 1:2500.
L-21W - L-13W
Plate 5 : Stacked M7/Resistivity Pseudosections, scale 1:2500.
L-12W - L-4W
Plate 5a: Stacked M-IP/tau Pseudosections, scale 1:2500.
L-12W - L-4W
Plate 6 : Stacked M7/Resistivity Pseudosections, scale 1:2500.
L-8W - L-1W
Plate 6a: Stacked M-IP/tau Pseudosections, scale 1:2500.
L-8W - L-1W
Plate 7 : Stacked M7/Resistivity Pseudosections, scale 1:2500.
L-3W - L-5E
Plate 7a: Stacked M-IP/tau Pseudosections, scale 1:2500.
L-3W - L-5E
Plate 8 : Stacked M7/Resistivity Pseudosections, scale 1:2500.
L-0E - L-8E
Plate 8a: Stacked M-IP/tau Pseudosections, scale 1:2500.
L-0E - L-8E
Plate 9 : Stacked M7/Resistivity Pseudosections, scale 1:2500.
L-1E - L-5E
Plate 9a: Stacked M-IP/tau Pseudosections, scale 1:2500.
L-1E - L-5E

In addition to the fine drafted plots, a complete data listing including all the field measurements made (Vp, SP, ρ_a, M0 to M9) and the spectral computation results (M-IP, tau, c, % Fit) is included under separate cover (one copy only).

7.2 Anomaly Classification

Chargeability (M7 slice) and resistivity anomalies have been rated as strong, moderate, weak and very weak. Areas of high resistivity have been noted with an H(n) where the 'n' represents the dipole in which the peak value occurs; accompanying arrows symbolize the high resistive blocks. Anomalous signatures are represented on the pseudosections and plan maps by anomaly bars that take the following form:

━━━━━	very strong chargeability high; >30 mV/V and well defined
─────	strong chargeability high; 20-30 mV/V and well defined
── ──	moderate chargeability high; 10-20 mV/V and well defined
_ _ _ _ _	weak chargeability high; 5-10 mV/V and well defined
. . . . . .	very weak chargeability high; <5 mV/V and poorly defined

The areas of high resistivity have been marked by arrows on top of the resistivity sections with symbols H(n), that means the peak of the anomaly and the dipole which was occurred.

If a given IP anomaly has a resolvable peak then the dipole in which the peak value occurs is indicated by the notation "n=1" or "n=4", etc., below or beside the anomaly bar. The dipole in which the peak IP response occurs suggests in a very qualitative sense the depth to the top of the source. The location of the notation with respect to the anomaly bar represents the interpreted center of the source body.

In addition to the dipole notation, the computed spectral M-IP of the peak response is indicated by the number following the n="x" notation. A third diagnostic parameter, the time constant, tau, is indicated after the M-IP value by an H(igh), M(edium), or L(ow). High indicates an average tau between 100. and 30. sec, Medium between 10. and 3.0 sec, and Low between .3 and 0.01 sec. Both the dipole and spectral notations are marked on the pseudosections and the compilation/anomaly plates.

IP anomalies showing line to line correlation have been grouped into anomalous zones and labelled on the compilation map by an identifying letter.

8.DISCUSSION OF RESULTS

8.1 Introduction

The IP/Resistivity survey conducted on the Dean Creek property is of uniform high quality. The data shows interesting variations over the entire survey area. It would appear that the resistivity and chargeability characteristics of the top 300ft of bedrock have been successfully mapped.

The interpretation of the IP/Resistivity data is based on criteria or rules that are set according to the experience of JVX over a number of surveys of a similar type and purpose. Unless otherwise noted, the data is interpreted on its own merits and no ancillary information has been taken into account.

Interpretation is based on the following criteria.

1/ All chargeability responses are picked, classified and located on the grid map.

2/ Every line is studied for lateral resistivity variations. The high resistivity areas are marked on the grid map.

3/ The areas of high resistivity are joined into zones where likely.

4/ The chargeability anomalies are studied in conjunction with resistivity responses and are joined into the chargeability zones.

5/ A chargeability anomaly associated with a sharp resistivity contrast is judged to be more interesting as an exploration target.

6/ The chargeability anomalies are priorized further by studying the associated spectral parameters. Their values are marked beside each anomalous chargeability bar on the grid map. The IP responses with high M-IP values and short time constants are thought to be of greater interest.

In summary the highest priority exploration targets are characterized as being of medium chargeability amplitude, in the area of a lateral change in resistivities, with high values of M-IP and very short time constants.

The geologic model for this ideal geophysical response is a volume of fine-grained disseminated metallic sulphides with an associated concentration of gold. The target is on the edge of or related to an area of silicification.

High resistivity zones as picked off the pseudosections are considered as possible areas of silicification. IP responses (which are not accompanied by a resistivity low) are probably the result of disseminated metallic sulphides. This conclusion may be supported by the calculated time constant, as short time constants are often diagnostic of disseminated (as opposed to massive or coarse-grained) sulphides. IP anomalies with short time constants have, however, depressed response in the traditional eighth slice. This is overcome by looking at the spectral parameter M-IP, which is a more honest measure of the volume percent metallic sulphides. In other words, a modest IP anomaly in M7 should be upgraded if MI-P values are high.

A brief description of the anomalous zones follows. The discussion is based on information which has been entered on the compilation map. The targets of interest have been shown on these maps with priority label L (low), M (medium), H (high).

8.2. Description of the IP responses.

The Dean Creek property can be divided into a southern and northern part. A total of 18 chargeable zones (A-1 through A-18) were found in the northern part and 8 zones (B-1 through B-8) in the southern part.

Five suggested geological cross structures are marked on the compilation map as F-1 through F-5. These explain the displacements within interpreted chargeability and/or resistivity zones.

Relatively high resistive areas are shaded on the compilation map, that indicate the general strike direction in the survey area. The high resistive zones can be related to partial silicification of the host rock. The chargeability responses coinciding with high resistivities could be significant for hydrothermal mineralization associated with quartz vein systems.

Beside each anomaly bar on the compilation map other physical parameters such as theoretical chargeability (M-IP) and calculated time constant (Tau) characterize the chargeability responses as described in the introduction.

We recommend to compare our geophysical compilation to the local geology and possibly to results of previous drilling or stripping of the areas of interest. The general compilation of the geological chemical and geophysical information would provide more information for priorizing the exploration targets.

The characteristics of the ideal geophysical exploration targets were specified in the previous paragraph. We recommend to apply these rules combined with geological knowledge and to carry out follow up work in the areas of interest along the suggested geophysical trends.

The areas considered as geophysical exploration targets are circled on the compilation map with priorizing label (HP - high priority, MP - medium priority and LP - low priority.

9. CONCLUSIONS

From September 11th to October 3th, 1987 JVX Ltd. carried out IP/Resistivity surveys on the Dean Creek property on behalf of Noramco Explorations Inc.

A total of approximately 30.3 line-kilometers of coverage was achieved.

The results are presented as stacked pseudosections, contour maps and anomaly compilation plan map.

The anomaly compilation map includes the interpreted IP zones and high resistivity areas. The physical characteristics of each chargeability response are marked beside each anomaly bar. The anomalies considered to be exploration targets are circled and labeled "LP, MP, or HP" (low, medium or high priority).

If there are any questions with regard to the survey please call the undersigned at JVX Ltd.

Respectfully submitted,

JVX LIMITED

Neil Hughes, B.Sc.
Consulting Geophysicist

Blaine Webster, B.Sc.
Consulting Geophysicist

Qual.
2.2328

Appendix 1

Specification Sheets

SCINTREX

IPR-11 Broadband Time Domain IP Receiver

Operator using the IPR-11

The microprocessor-based IPR-11 is the heart of a highly efficient system for measuring, recording and processing spectral IP data. More features than any remotely similar instrument will help you enhance signal/noise, reduce errors and improve data interpretation. On top of all this, tests have shown that survey time may be cut in half, compared with the instrument you may now be using.

The IPR-11 Broadband Time Domain IP Receiver is principally used in electrical (EIP) and magnetic (MIP) induced polarization surveys for disseminated base metal occurrences such as porphyry copper in acidic intrusives and lead-zinc deposits in carbonate rocks. In addition, this receiver is used in geoelectrical surveying for deep groundwater or geothermal resources. For these latter targets, the induced polarization measurements may be as useful as the high accuracy resistivity results since it often happens that geological materials have IP contrasts when resistivity contrasts are absent. A third application of the IPR-11 is in induced polarization research projects such as the study of physical properties of rocks.

Due to its integrated, microprocessor-based design, the IPR-11 provides a large amount of induced polarization transient curve shape information from a remarkably compact, reliable and flexible format. Data from up to six potential dipoles can be measured simultaneously and recorded in solid-state memory. Then, the IPR-11 outputs data as: 1) visual digital display, 2) digital printer profile or pseudosection plots, 3) digital printer listing, 4) a cassette tape or floppy disk record, 5) to a microcomputer or 6) to a modem unit for transmission by telephone. Using software available from Scintrex, all spectral IP and EM coupling parameters can be calculated on a microcomputer.

The IPR-11 is designed for use with the Scintrex line of transmitters, primarily the TSQ series of current and waveform stabilized models. Scintrex has been active in induced polarization research, development, manufacture, consulting and surveying for over thirty years and offers a full range of time and frequency domain instrumentation as well as all accessories necessary for IP surveying.

Major Benefits

Following are some of the major benefits which you can derive through the key features of the IPR-11.

Speed up surveys.

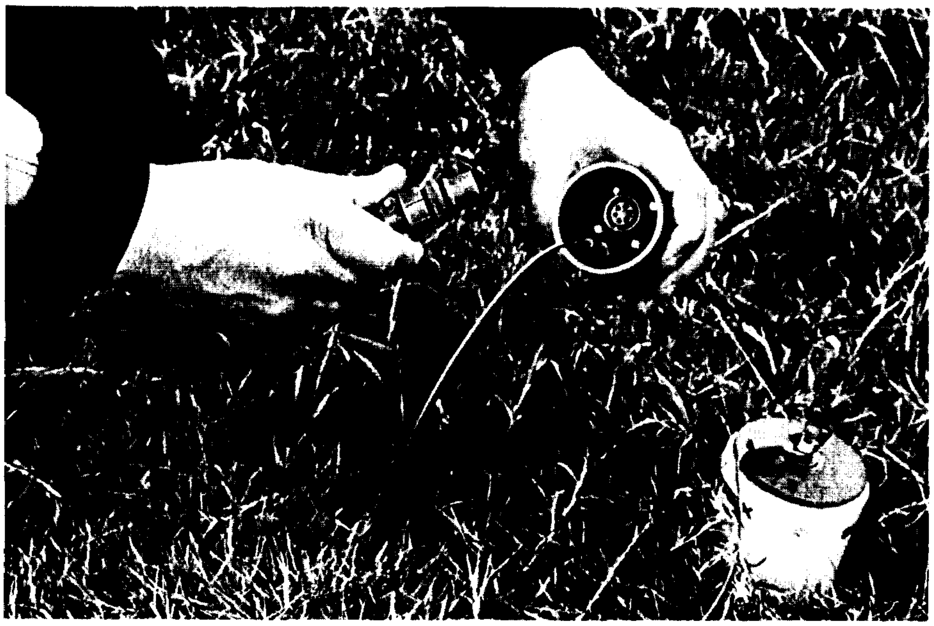
The IPR-11 is primarily designed to save you time and money in gathering spectral induced polarization data.

For example, consider the advantage in gradient, dipole-dipole or pole-dipole surveying with multiple 'n' or 'a' spacings, of measuring up to six potential dipoles simultaneously. If the specially designed Multidipole Potential Cables are used, members of a crew can prepare new dipoles at the end of a spread while measurements are underway. When the observation is complete, the operator walks only one dipole length and connects to a new spread leaving the cable from the first dipole for retrieval by an assistant.

Simultaneous multidipole potential measurements offer an obvious advantage when used in drillhole logging with the Scintrex DHIP-2 Drillhole IP/Resistivity Logging Option.

The built-in, solid-state memory also saves time. Imagine the time that would be taken to write down line number, station number, transmitter and receiver timings and other header information as well as data consisting of SP, Vp and ten IP parameters for each dipole. With the IPR-11, a record is filed at the touch of a button once the operator sees that the measurement has converged sufficiently.

The IPR-11 will calculate resistivity for you. Further time will then be saved when the IPR-11 data is dumped to a field computer in your base camp for processing. If no computer is available in the field then data can be output directly to a printer which will plot your data in profile or pseudo-section format. The same printer can also be used to make one or more copies of a listing of the day's results. If desired, an output to a cassette tape recorder or floppy disk drive can be made. Or, the IPR-11 data memory can be output directly into a modem, saving time by transmitting data to head office by telephone line.



High production rates are obtained using Multidipole Potential Cables which permit measurement of six dipoles simultaneously.

If the above features won't save as much time as you would like, consider how the operator will appreciate the speed in taking a reading with the IPR-11 due to: 1) simple keyboard control, 2) resistance check of six dipoles simultaneously, 3) fully automatic SP buckout, 4) fully automatic Vp self ranging, 5) fully automatic gain setting, 6) built-in calibration test circuits, and 7) self checking programs. The amount of operator manipulation required to take a great deal of spectral IP data is minimal.

Compared with frequency domain measurements, where sequential transmissions at different frequencies must be made, the time domain measurement records broadband information each few seconds. When successive readings are stacked and averaged, and when the pragmatic window widths designed into the IPR-11 measurement are used, full spectral IP data are taken in a minimum of time.

Improved interpretation of data.

The quasilogarithmically spaced transient windows are placed to recover the broadband information that is needed to calculate the standard spectral IP parameters with confidence. Scintrex offers its SOFTII software package which can take the IPR-11 outputs and generate the following standard spectral IP parameters: zero-time chargeability, M; time constant, TAU; and exponent, C.

Interpretability of spectral IP data are improved since time domain measurements are less affected by electromagnetic coupling effects than either amplitude or phase angle frequency domain measurements, due to the relatively high frequencies used in the latter techniques. In the field, coupling free data are nearly always available from the late time windows. Then, in the base camp or office, the Scintrex SOFTII software package may be used to resolve the EM component for removal from the IP signal. The electromagnetic induction parameters may also be interpreted in order to take advantage of the information contained in the EM component.

A further advantage of the IPR-11 in interpreting spectral IP responses is the amount of data obtainable due to the ability to change measurement windows and to allow for different transmitter pulse times.

Enhance signal/noise.

In the presence of random (non-coherent) earth noises, the signal/noise ratio of the IPR-11 measurements will be enhanced by $\sqrt{N}$ where N is the number of individual readings which have been averaged to

Major Benefits

arrive at the measurement. The IPR-11 automatically stacks the information contained in each pulse and calculates a *running average for Vp and each transient window.* This enhancement is equivalent to a noise decrease of $\sqrt{N}$ or a power increase of N. Since N can readily be 30 or more (a 4 minute observation using a 2 second on/off waveform), the signal/noise improvement realized by the IPR-11 cannot be practically achieved by an increase in transmitter power. Alternatively, one may employ much lower power transmitters than one could use with a non-signal enhancement receiver.

The automatic SP program bucks out and corrects completely for linear SP drift; there is no residual offset left in the signal as in some previous time domain receivers. Data are also kept noise free by: 1) automatic rejection of spheric spikes, 2) 50 or 60 Hz powerline notch filters, 3) low pass filters and 4) radio-frequency (RF) filters. In addition, the operator has a good appreciation of noise levels since he can monitor input signals on six analog meters, one for each dipole.

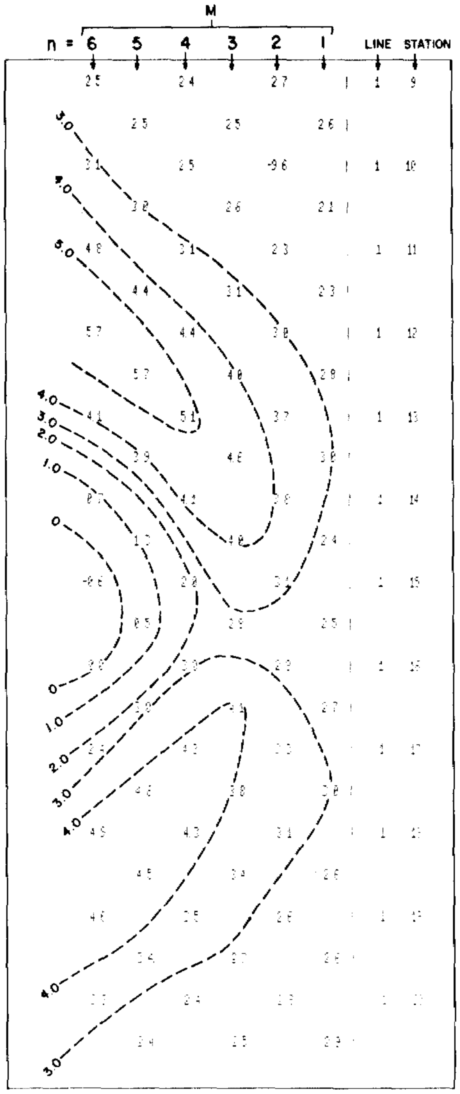
Observations can usually be made using the self-triggering feature of the IPR-11. The internal program locks into the waveform of the signal received at the first dipole (nearest a current electrode) and prevents mistriggering at any point other than within the final 2.5 percent of the current on time. In particularly noisy areas, however, synchronization of the IPR-11 and transmitter can be accomplished either by a wire link or using a high stability, *Optional Crystal Clock* which fits onto the lid of the instrument.

Reduce Errors.

The solid-state, fail-safe memory ensures that *no data transcription errors are made* in the field. In base camp, data can be output on a digital printer and/or some magnetic media such as floppy disks or cassette tapes and played back onto a digital printer for full verification. The fact that the IPR-11 calculates resistivity from recorded Vp and I values also reduces error.

The self check program verifies program integrity and correct operation of the display, automatically, without the intervention of the operator. *If the operator makes any one of ten different manipulation errors, an error message is immediately displayed.*

The Multidipole Potential Cables supplied by Scintrex are designed so there is no possibility of connecting dipoles to the wrong input terminals. This avoids errors in relating data to the individual dipoles. The internal calibrator assures the operator that the instrument is properly calibrated and the simple keypad operation eliminates a multitude of front panel switches, simplifying operation and reducing errors.



Pseudo-section printout on a digital printer. Chargeability data are shown for the sixth transient window (M_5) for the dipole-dipole array and six 'n' spacings. Line number and station number are also recorded. The contours have been hand drawn. Resistivity results can be plotted in a similar manner.

Features

Six Dipoles Simultaneously. The analog input section of the IPR-11 contains six identical differential inputs to accept signals from up to six individual potential dipoles. The amplified analog signals are converted to digital form and recorded with header information identifying each group of dipoles. Custom-made multi-dipole cables are available for use with any electrode array.

Memory. Compared with tape recording, the IPR-11 solid-state memory is free from problems due to dirt, low temperature, moving parts, humidity and mechanical shock. A battery installed on the memory board ensures memory retention if the main batteries are low or if the main batteries are changed. The following data are automatically recorded in the memory for each potential dipole: 1) receiver timing used, 2) transmitter timing used, 3) number of cycles measured, 4) self potential (SP), 5) primary voltage (Vp) and 6) ten transient IP windows (M). In addition, the operator can enter up to seventeen, four digit numerical headers which will be filed with each set of up to six dipole readings. The operator must enter at least four headers: line number, station number, current amplitude, and the K-factor. Other headers can include, for example, operator code, date, etc.

In the standard data memory, up to 200 potential dipole measurements can be recorded. Optional Data Memory Expansion Blocks can be installed in the IPR-11 to increase memory capacity in blocks of about 200 dipoles each to a total of approximately 800 dipoles.

Memory Recall. Any reading in memory can be recalled, by simple keypad entry, for inspection on the visual display. For example, the operator can call up sequential visual display of all the data filed for the previous observation or for the whole data memory.

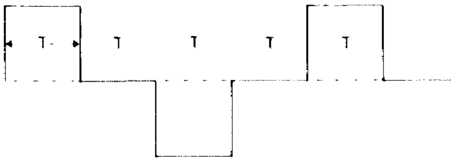
Carefully Chosen Transient Windows. The IPR-11 records all the information that is really needed to make full interpretations of spectral IP data, to remove EM coupling effects and to calculate EM induction parameters. Ten quasilogarithmically spaced transient windows are measured simultaneously for each potential dipole over selectable total receive times of 0.2, 1.0, 2.0 or 4.0 seconds.

After a delay from the current off time of t, the width of each of the first four windows is t, of the next three windows is 6t and of the last three windows is 12t. The smallest t values are 3, 15, 30 or 60 milliseconds. Thus, for a given dipole, up to forty different windows can be measured by using all four receive times. The only restriction is, of course, that the current off time must exceed the total measuring time. Since t is as low as 3 milliseconds and since the first four windows are narrow, a high density of curve shape information is available at short times (high frequencies) where it is needed for confident calculation of the EM coupling parameters.

Calculates Resistivity. The operator enters the current amplitude and resistivity geometry K-factors in the header with each observation. If the K-factors remain the same, only a code has to be entered with each observation. Then, using the recorded Vp values, the IPR-11 calculates the apparent resistivity value which can be output to the computer, printer, etc.

Normalizes for Time and Vp. The IPR-11 divides the measured area in each transient window by the width of the window and by the primary voltage so that values are read out in units of millivolts/volt (mils).

Signal Enhancement. Vp and M values are continuously stacked and averaged and the display is updated for each two cycles. When the operator sees that the displayed values have adequately converged, he can terminate the reading and file all values in memory.

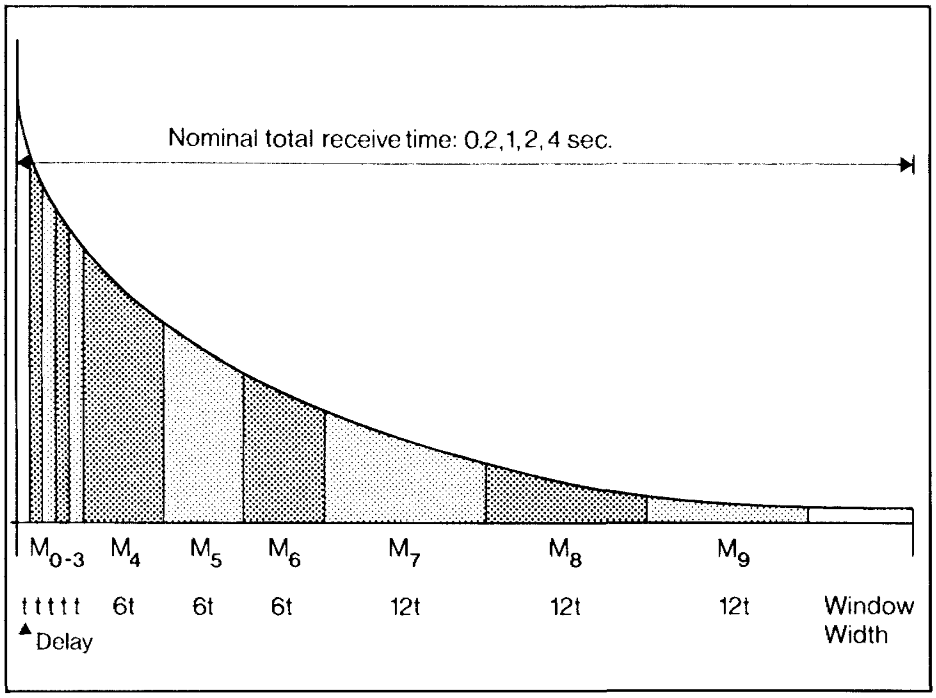


Time domain IP transmitted waveform

Vp Integration. The primary voltage can be sampled over 50 percent or more of the current on (T) time, depending on the transmit and receive programs selected. The integrated results is normalized for time. Long Vp integration helps overcome random noise.

Digital Display. Two, four digit LCD displays are used to display measured or manually entered data, data codes and alarm codes.

Automatic Profile Plotting. When connected to a digital printer with an industry standard RS-232C, 7 bit ASCII serial data port, data can be plotted in a base camp. The IPR-11 is programmed to plot any selected transient window and resistivity



IPR-11 Transient Windows

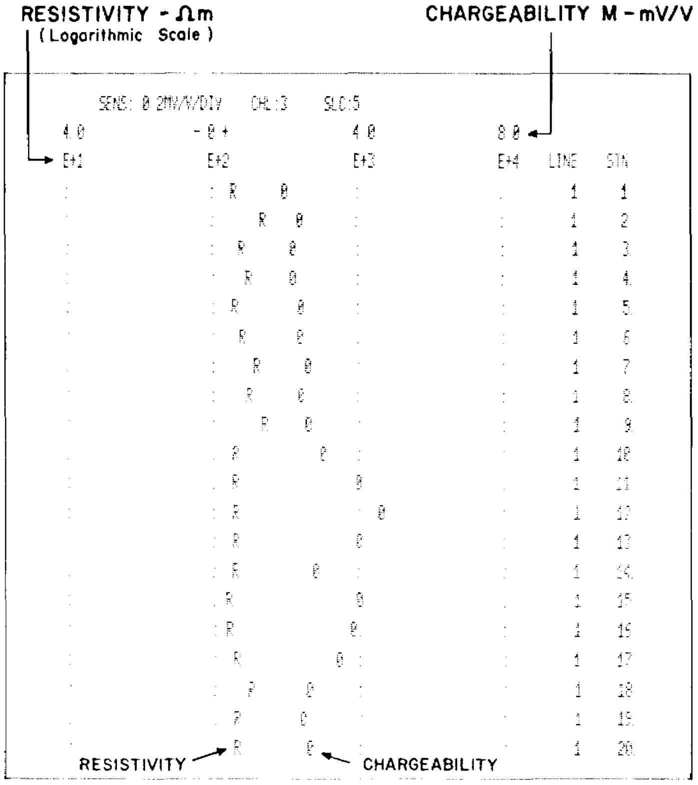
Features

in pseudo-section or profile form. In the profile plot, the scale of resistivity is logarithmic with 10 to 100,000 ohm-metres in four decades with another four decades of overrange both above and below. The chargeability scale is keypad selectable. In the pseudo-section plot, any one chargeability window can be presented in conventional pseudo-section form.

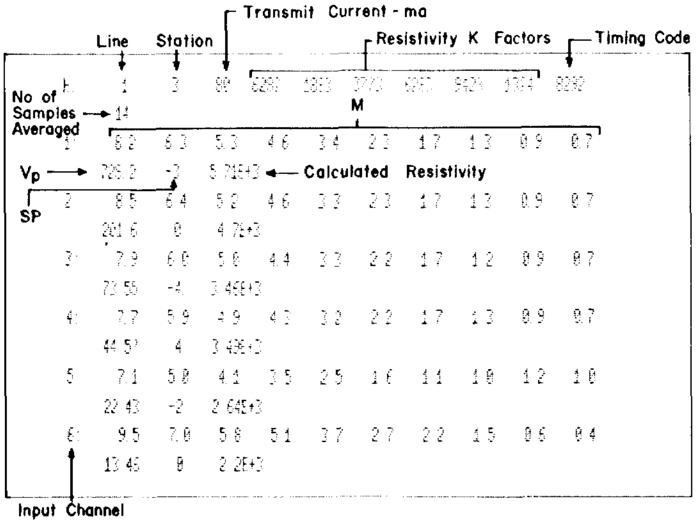
Printed Data Listing. The same digital printer can be used to print out listings of all headers and data recorded during the day's operation. Several copies can be made for mailing to head office or for filing in case copies are lost. Baud rate is keypad selectable at 110, 300 or 1200 baud, depending on the printer used.

Store Data. Data may be output from the IPR-11 and stored in computer compatible form in a microcomputer, on an independent floppy disk drive or on cassette tape, provided that these devices have the commonly available RS-232C, 7 bit ASCII serial interface.

Modem. Data in the IPR-11 memory can be output directly into a modem near the field operation and transmitted by telephone through a modem terminal in head office, where data can be output directly onto a computer, digital printer or digital storage device. In this way a geophysicist in head office can receive regular transmissions of data to improve supervision



Profile printout on a digital printer. R is resistivity on a logarithmic scale while Ø is one transient window (M_5) on a linear scale.



```
H    1      3      80    [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]  8292
     14
1    6.2    6.3    5.3    4.6    3.4    2.3    1.7    1.3    0.9    0.7
     726.2  -3     5.71E+3
2    8.5    6.4    5.2    4.6    3.3    2.3    1.7    1.3    0.9    0.7
     201.6  0      4.7E+3
3    7.9    6.0    5.6    4.4    3.3    2.2    1.7    1.2    0.9    0.7
     73.55  -4     3.45E+3
4    7.7    5.9    4.9    4.3    3.2    2.2    1.7    1.3    0.9    0.7
     44.57  4      3.43E+3
5    7.1    5.0    4.1    3.5    2.5    1.6    1.1    1.0    1.2    1.0
     22.43  -2     2.64E+3
6    9.5    7.0    5.6    5.1    3.7    2.7    2.2    1.5    0.6    0.4
     13.45  0      2.2E+3
```

Data listing output on a dot-matrix printer. Header information is shown in the first two lines. In this case, data are for Line 1, Station 3. Transmitted current is 80mA. Next are the resistivity K-factors for the six dipoles. 8292 indicates that receive and transmit times are each 2 seconds. The last header item records that fact that 14 cycles were stacked. Following the header are the geophysical data for six dipoles which were measured simultaneously. For each dipole, the values for the 10 transient windows are shown on one line. The next line shows Vp and Sp in mV and resistivity. 5.71 E + 3 indicates that the calculated resistivity is 5.71 x 10^3 ohm-metres.

Features

and interpretation of the data from field projects and no output device other than the modem is required in the field.

External Circuit Check. Six analog meters on the IPR-11 are used to check the contact resistance of individual potential dipoles. Poor contact at any one electrode is immediately apparent. The continuity test uses an AC signal to avoid electrode polarization.

Self Check Program. Each time the instrument is turned on, a check sum verification of the program memory is automatically done. This verifies program integrity and if any discrepancy is discovered, an error code appears on the digital display. Part of the self check program checks the LCD display by displaying eight ones followed sequentially by eight twos, eight fours and eight eights.

Manipulation Error Checks. Alarm codes appear on the digital display if any of the following ten errors occur: tape dump errors, illegal keypad entry, out of calibration or failed memory test, insufficient headers, header buffer full, previous station's data not filed, data memory full, incorrect signal amplitude or excessive noise, transmit pulse time incorrect, and receiver measurement timing incorrect.

Internal Calibrator. By adjustment of the function switch, an internal signal generator is connected across the inputs to test the calibration of all six signal inputs for SP, Vp and all M windows simultaneously. If there is an error in one or more parameters, an alarm code appears on the display. The operator can then scan all parameters of all input channels to determine where the error is.

Automatic SP Correction. The initial self potential buckout is entirely automatic - no adjustment need be made by the operator. Then, throughout the measurement, the IPR-11 slope correction software makes continual corrections, assuming linear SP drift during two transmitted cycles. There is no residual SP offset included in the chargeability measurement as in some previous time domain receivers.

Automatic Vp Self Ranging. There is no manual adjustment for Vp since the IPR-11 automatically adjusts the gain of its input amplifiers for any Vp signal in the range 100 microvolts to 6 volts.

Spheric Noise Rejection. A threshold, adjustable by keypad entry over a linear range of 0 to 99, is used to reject spheric pulses. If a spheric noise pulse above the set threshold occurs, then the IPR-11 rejects and does not average the current two cycles of information. An alarm code appears on the digital display. If the operator continues to see this alarm code, he can decide to set the threshold higher.

Powerline and Low Pass Filter. An internal switch is used to set the IPR-11 for either 50 or 60 Hz powerline areas. The notch filter is automatically switched out when the 0.2 second receive time is used since the filters would exclude EM signals.

RF Filter. An additional filter in the input circuits ensures that radio-frequency interference is eliminated from the IPR-11 measurement.

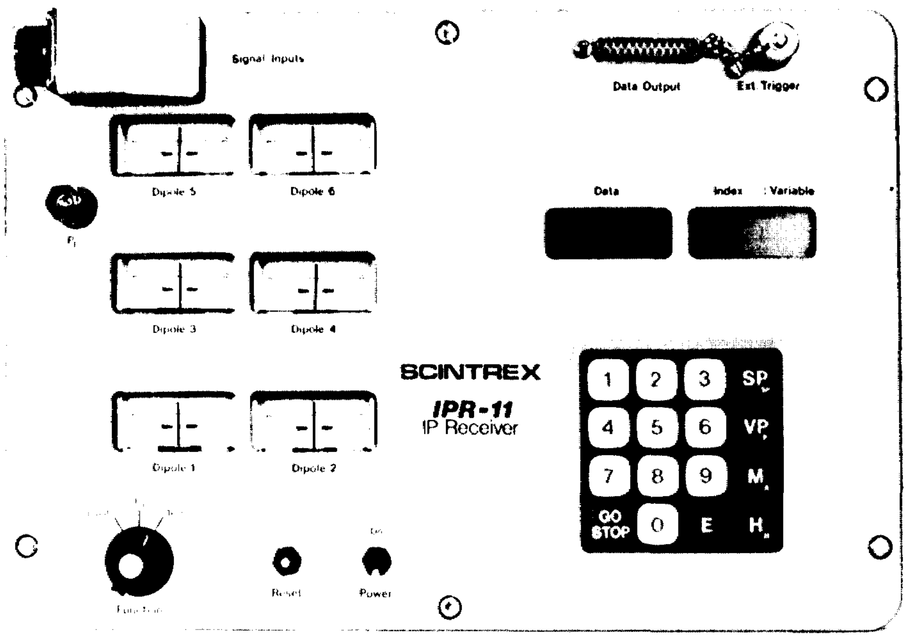
Input Protection. If signals in excess of 6V and up to 50V are applied to any input circuit, zener diode protection ensures that no damage will occur to the input circuits.

Synchronization. In normal operation, the IPR-11 synchronizes itself on the received waveform, limiting triggering to within 2.5% of the current on time. However, for operation in locations where signal/noise ratios are poor, synchronization can be done by using the Optional Crystal Clock which can be installed in the lid of the IPR-11.

Software for EM Coupling Removal. In transient measurements, the EM coupling component occurs closest to the current off time (i.e. it is primarily in the early windows). Thus, it is usually possible to obtain coupling-free IP data simply by using the later windows of the IPR-11 measurement program. If, however, full spectral information is desired, the data from the early windows must be corrected for the EM component. This can be done with confidence using a computer and the Scintrex SOFT II programs.

Software for Spectral IP Parameters. Using the chargeability data from the ten quasilogarithmically spaced IPR-11 windows, a computer and the Scintrex SOFT II programs, spectral IP parameters can be calculated. The basis for this calculation as well as for the EM coupling removal calculation is discussed in a technical paper by H.O.Seigel, R.Ehrat and I.Brcic, given at the 1980 Society of Exploration Geophysicists Convention, entitled "Microprocessor Based Advances in Time Domain IP Data Collection and In-Field Processing".

Operation



In relation to the efficiency with which it can produce, memorize, calculate and plot data, the IPR-11 is quite simple to operate, using the following switches and keypad manipulations.

Power On-Off. Turns the instrument on or off.

Reset. Resets the program to begin again in very poor signal/noise conditions.

Function Switch. Connects either the potential dipoles or the internal test generator to the input amplifiers or connects the external circuit resistance check circuitry to the potential dipoles.

Keypad. The ten digit and six function keys are used to: 1) operate the instrument, 2) enter information, 3) retrieve any stored data item for visual display, and 4) output data on to a computer, digital printer, digital storage device or modem. Examples of some of these manipulations, most of which are accomplished by three key strikes, follow. E is the general entry key.

A concise card showing the keypad entry codes is attached inside the lid of the IPR-11.

Example 1. Keying 99E commands the battery test. The result is shown on the digital display.

Example 2. Keying 90E tells the IPR-11 to use the 0.2 second receive time. 91, 92 and 94 correspond to the three other times.

Example 3. Keying 12M results in the display of the chargeability of the first dipole, window number 2. Similarly, 6SP or 4Vp would result in the display of the SP value of the sixth dipole or Vp of the fourth dipole respectively.

Example 4. Keying NNNNH, where N is any variable digit, records an item of header information. Seventeen such items can be entered with each file of up to six dipoles of data.

Example 5. 73E, 74E or 75E are used to output the data from the memory to the computer, digital printer or modem at 110, 300 or 1200 baud respectively.

IPR-11 Options

The following options are available for purchase with the IPR-11:

Multidipole Potential Cables. These cables are custom manufactured for each client, depending on electrode array and spacings which are to be used. They are manufactured in sections, with each section a dipole in length and terminated with connectors. For each observation, the operator need only walk one dipole length and connect a new section, in order to read a new six dipole spread. There is no need to move the whole spread. The connectors which join the cables are designed so that there is no possibility of connecting the wrong dipole to the wrong input amplifier. The outside jacket of these cables is flexible at low temperatures. About 5 percent extra length is added to each section to ensure that the cable reaches each station.

Field Wire Adaptor Kit. Depending on the survey method used, it may be preferable to connect the potential electrodes to the IPR-11 using standard single conductor wire rather than the Multidipole Potential Cables. When using the Field Wire Adaptor Kit each wire can be terminated on an individual binding post on a multi-pin receptacle. In this way, a set of electrodes are connected to the IPR-11 which can either lead or lag the current electrodes while advancing along a survey line.

Data Memory Expansion Blocks. The standard data memory of the IPR-11 allows for data for up to 200 dipole measurements to be recorded, assuming a common header for six dipoles. Up to three additional memory blocks can be installed in the instrument, each of about 200 dipole capacity.

Crystal Clock. Scintrex can provide a high stability clock to synchronize the IPR-11 with a similar clock in the TSQ series of transmitters. This option is, however, only required for work in extremely noisy and/or low signal environments.

Software. Scintrex offers its SOFT II software package for EM coupling removal, calculation of EM induction factors and calculation of the same spectral IP parameters as are in common use in frequency domain IP measurements.

Peripheral Devices. A number of printers, digital storage devices and modem units are available on the market which are compatible with the IPR-11. Scintrex stocks several of these peripheral devices which we would be pleased to supply and/or recommend other suitable equipment for your particular application.

Data can be transferred directly from the IPR-11 into an inexpensive personal computer which can use the SOFT II Programs to calculate spectral IP parameters, carry out other calculations, display data graphically on a video display and plot data.

IPR-11 SOFT II Time Domain Induced Polarization Data Processing and Spectral Analysis Software Package

The IPR-11 SOFT II Software Package comprises a cost effective series of programs designed to help you benefit from the fully automatic treatment of IP data collected by the IPR-11 Receiver. The following features describe what you can do with the SOFT II package running on an IBM PC or compatible computer.

Enter data many ways. The easiest way to use the SOFT II package is to enter data directly from the IPR-11 to the computer. This can be done in the field, resulting in data stored on floppy disks. Subsequent data processing may be done to ensure that data quality is high and to provide the possibility to immediate checking of anomalous conditions. Data can also be entered manually from data listings.

Data can be edited. Errors in header information such as line number, station number, resistivity constants and timing codes can be corrected. Data may be re-ordered for plotting. Dummy stations may be inserted if required.

Store data on floppy disks. Once in the computer, data is stored on a floppy disk. This increases the efficiency of data processing and management as well as transportation and long term storage. No longer will you have to sort through bulky paper records or scan through long tape recordings to access the data you need. A copy of a disk can easily be made to eliminate the possibility of loosing data in transportation.

Printouts can be formatted. Considerable time and effort are saved with the automatic tabulating and plotting programs. When compared with the plots directly output to the printer from the IPR-11, the SOFT II computer generated printouts and plots are more readable and of a quality more suitable for final reports.

Plot observed decay curves. IPR-11 decay curves can be plotted to provide a rapid means of ensuring data quality.

Compute spectral IP parameters. The SPCTRM program of the SOFT II package calculates the Cole-Cole spectral parameters. These parameters may be used to give information about the concentration and grain size of the IP responsive metallic mineralization in the subsurface. This may allow differentiation of sources of similar amplitude of IP response but which have different mineral textures. The standard example of such differentiation would be between sulphide mineralization and graphitic horizons.

Remove EM coupling. Depending upon the electrode array, electrode spacing, resistivity, and IP measuring time (or frequency), IP data may contain a component which is electromagnetically induced. The SPCTRM program may be used to calculate the residual EM effect and output a listing of parameters describing the EM contribution.

Plot and contour pseudo-sections. Like any dedicated software controlled device, the intelligence of the IPR-11 is limited. While it can adequately plot data listings and profiles directly on a simple printer, the pseudo-section printer plots can sometimes be erroneous. This occurs when an electrode array other than dipole-dipole has been used, since the IPR-11 can only plot this one array in pseudo-sections. Also, if more than one receive time or transmitted pulse time have been recorded for given station, the IPR-11 cannot sort the data.

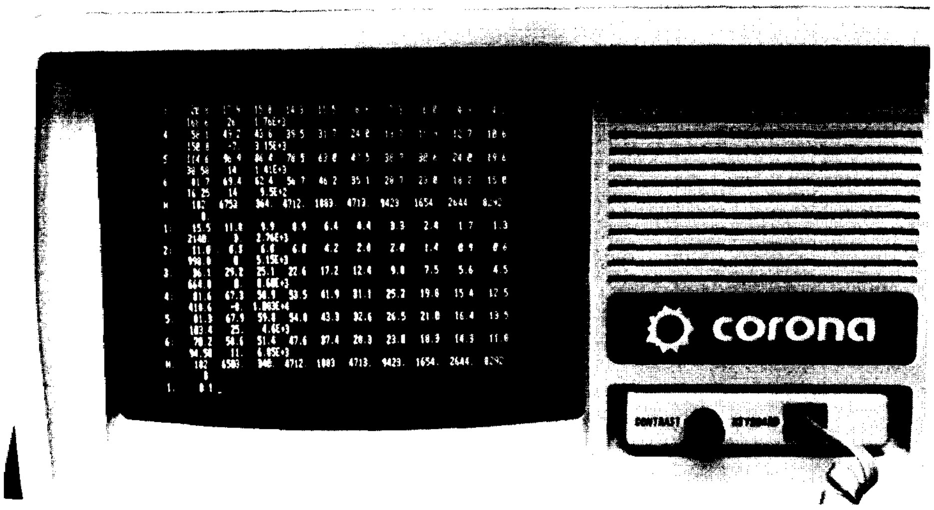
These inconveniences are removed when the SOFT II package is used with a microcomputer, since the software includes programs to sort, reformat and correctly plot pseudo-sections.

Two different programs in SOFT II can be used to plot pseudo-sections. PSEUDO posts that data at the correct plotting point for a dipole-dipole array so it may be hand contoured. CONTOUR draws contoured pseudo-sections for dipole-dipole or pole-dipole arrays on a dot-matrix printer or a pen plotter.

Runs on commonly available hardware. The SOFT II programs have been designed to run on microcomputer hardware which is readily available in many countries. The recommended system is as follows: 1) IBM PC or XT with 512K bytes of RAM, 2) 8087 math co-processor, 3) Two 5-1/4" flexible disk drives, 4) monochrome monitor, 5) parallel interface (for printer) 6) one or more serial interfaces, (2 suggested if a pen plotter is used), and 7) Epson FX-85 dot-matrix printer.

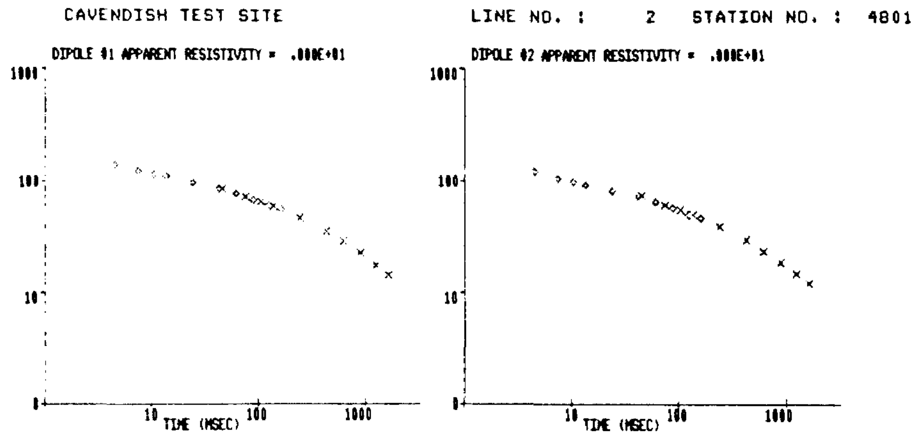
Other IBM compatible microcomputers using the PC/MS-DOS Version 2.1 or 3.0 Operating System may be used. Scintrex will be pleased to advise in this regard.

Complete with manual and diskettes. The SOFT II package consists of three program diskettes and a user's guide. The manual provides clear step-by-step instructions for running the package, as well as sample outputs and information on the microcomputer hardware and operating system.

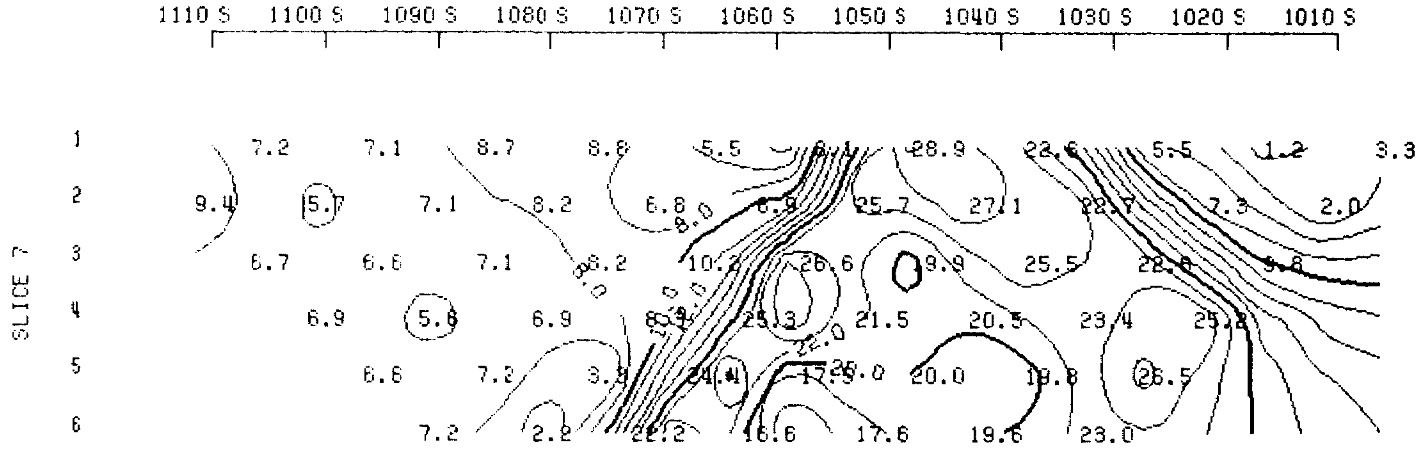


When the IPR-11 SOFT II software is used with an IBM PC or compatible computer data can be reviewed, edited, processed and archived.

IPR-11 SOFT II Time Domain Induced Polarization Data Processing and Spectral Analysis Software Package



The IPR-11 SOFT II allows plotting of chargeability decay curves for any given dipole in log-log space. This provides an excellent means of data quality control and visual determinations of the character of curve shapes to be made.



SOFT II application programs plot and contour pseudo-sections automatically.

```
LINE NO. = 351

Station Dipole     Vp    Apparent    M7                Cole-Cole Parameters                        Fit/IP   Fit/EM
                          Resist.             M-IP    TAU-IP    C-IP      M-EM     TAU-EM
------------------------------------------------------------------------------------------------------------------

  1458    1     5205.0    4457.0    11.6     391.53      .30     .10      2.88      .100          .70     4.54
          2     1028.0    3520.0    24.1     382.30    10.00     .20      2.04      .100          .48     1.41
          3      406.8    3483.0    20.9     343.01    10.00     .20      3.35      .100          .41     3.46
          4      139.1    2370.0    24.8     394.57    10.00     .20      4.07      .100          .69     3.44

  1459    1     6114.0    3893.9    11.8     404.96      .10     .10      2.56      .100          .69     4.59
          2     1369.0    3440.0    24.2     385.27    10.00     .20      2.97      .100          .42     2.01
          3      501.9    3151.0    23.8     379.63    10.00     .20      5.82      .030          .71     2.51
          4      189.2    2370.0    24.2     387.90    10.00     .20      7.75      .030          .96     3.33
```

Spectral analysis summary generated by the SPCTRM program of the SOFT II applications package and output on a digital printer. Header information is shown at the top of the printout. In this case, data are for Line 351 and Stations 1458 and 1459. Dipoles 1 thru 4 are listed for each station. At Station 1458, Dipole 1 has the following values: Vp is 5205.0 mV, Apparent Resistivity is 4457.0 ohm-metres and M7 is a chargeability slice of 11.6 mV/V taken approximately half way through the measured decay. Next are the Cole-Cole parameters, M-IP is 391.53 mV/V and TAU-IP is 0.30 seconds, C-IP is 0.10, M-EM is 2.88 mV/V and TAU-EM is 0.100 seconds. The Fit/IP and Fit/EM values describe the root mean square deviations between fitted curves and measured values.

Technical Description of the IPR-11 Broadband Time Domain IP Receiver

Input Potential Dipoles	1 to 6 simultaneously.
Input Impedance	4 megohms.
Input Voltage (Vp) Range	100 microvolts to 6 volts for measurement. Zener diode protection up to 50V.
Automatic SP Bucking Range	± 1.5 V.
Chargeability (M) Range	0 to 300 mV/V (mils or 0/00)
Absolute Accuracy of Vp, SP and M	Vp; ± 3% of reading for Vp > 100 microvolts. SP; ± 3% of SP bucking range. M; ± 3% of reading or minimum ± 0.5m V/V.
IP Transient Program	Ten transient windows per input dipole. After a delay from current off of t, first four windows each have a width of t, next three windows each have a width of 6t and last three windows each have a width of 12t. The total measuring time is therefore 58t. t can be set at 3, 15, 30 or 60 milliseconds for nominal total receive times of 0.2, 1, 2 and 4 seconds.
VP Integration Time	In 0.2 and 1second receive time modes; 0.51sec. In 2 second mode; 1.02sec. In 4 second mode; 2.04 sec.
Transmitter Timing	Equal on and off times with polarity change each half cycle. On/off times of 1, 2, 4 or 8 seconds with ± 2.5% accuracy are required.
Header Capacity	Up to 17 four digit headers can be stored with each observation.
Data Memory Capacity	Depends on how many dipoles are recorded with each header. If four header items are used with 6 dipoles of SP, Vp and 10 M windows each, then about 200 dipole measurements can be stored. Up to three Optional Data Memory Expansion Blocks are available, each with a capacity of about 200 dipoles.
External Circuit Check	Checks up to six dipoles simultaneously using a 31Hz square wave and readout on front panel meters, in range of 0 to 200k ohms.
Filtering	RF filter, spheric spike removal; switchable 50 or 60Hz notch filters, low pass filters which are automatically removed from the circuit in the 0.2 sec receive time.
Internal Calibrator	1000 mV of SP, 200 mV of Vp and 2.43 mV/V of M provided in 2 sec pulses.

Technical Description of the IPR-11 Broadband Time Domain IP Receiver

Digital Display	Two, 4 digit LCD displays. One presents data, either measured or manually entered by the operator. The second display: 1) indicates codes identifying the data shown on the first display, and 2) shows alarm codes indicating errors.
Analog Meters	Six meters for: 1) checking external circuit resistance, and 2) monitoring input signals.
Digital Data Output	RS-232C compatible, 7 bit ASCII, no parity, serial data output for communication with a computer, digital printer, digital storage device or modem.
Standard Rechargeable Power Supply	Eight rechargeable NiCad D cells provide approximately 15 hours of continuous operation at 25°C. Supplied with a battery charger, suitable for 110/230V, 50 to 400 Hz, 10W.
Disposable Battery Power Supply	At 25°C, about 40 hours of continuous operation are obtained from 8 Eveready E95 or equivalent alkaline D cells. At 25°C, about 16 hours of continuous operation are obtained from 8 Eveready 1150 or equivalent carbon-zinc D cells.
Dimensions	345 mm x 250 mm x 300 mm, including lid.
Weight	10.5 kg, including batteries.
Operating Temperature Range	-20 to + 55°C, limited by display.
Storage Temperature Range	-40 to + 60°C.
Standard Items	Console with lid and set of rechargeable batteries, RS-232C cable and adapter, 2 copies of manual, battery charger.
Optional Items	Multidipole Potential Cables, Data Memory Expansion Blocks, Crystal Clock, SOFT II Programs, Printer, Cassette Tape Recorder, Disk Drive or Modem.
Shipping Weight	25 kg includes reusable wooden shipping case.

At Scintrex we are continually working to improve our line of products and beneficial innovations may result in changes to our specifications without prior notice.

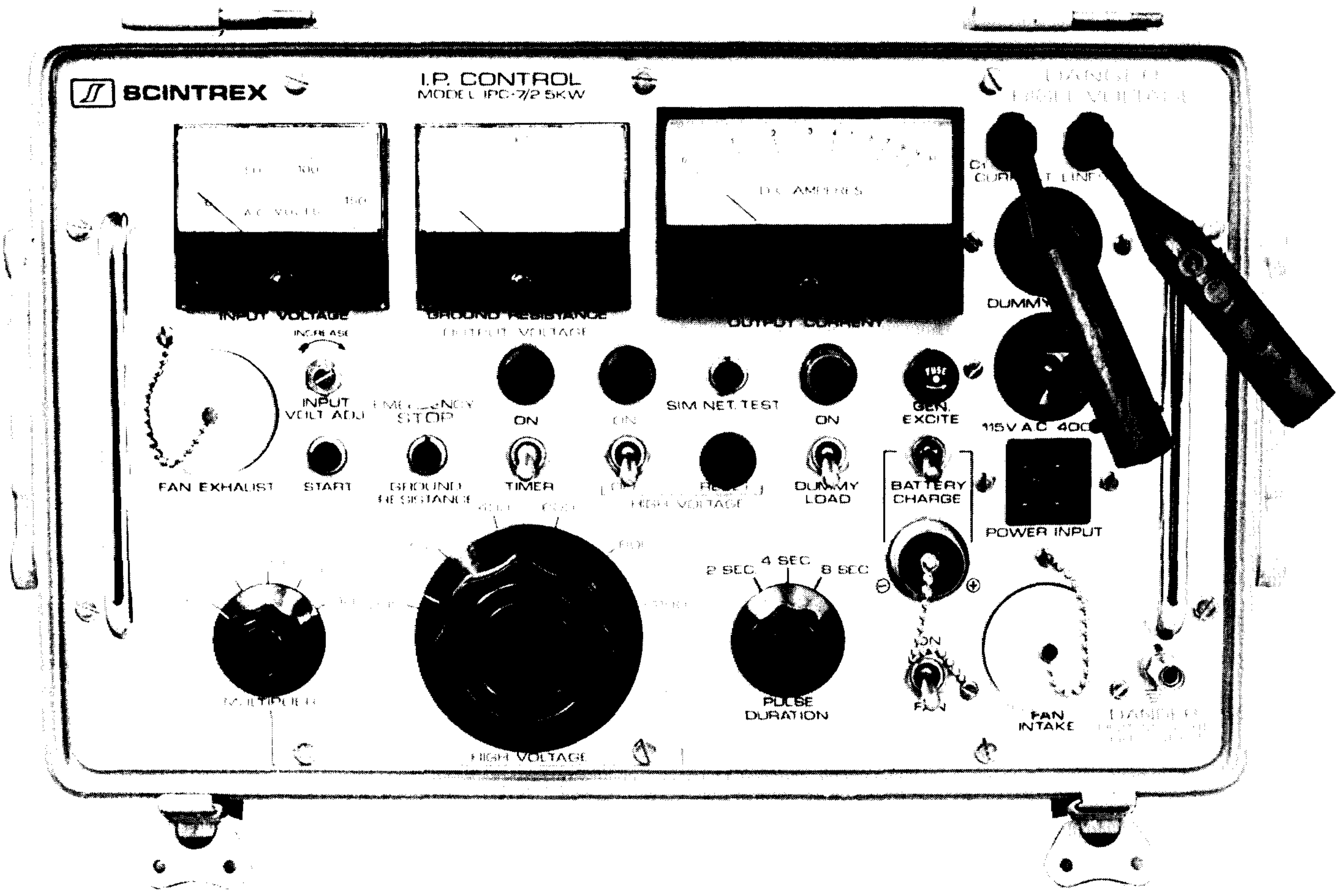
SCINTREX

222 Snidercroft Road
Concord Ontario Canada
L4K 1B5

Telephone: (416) 669-2280
Fax: (416) 669-5132
Telex: 06-964570

Geophysical and Geochemical
Instrumentation and Services

SCINTREX IPC-7/2.5kW Induced Polarization and Commutated DC Resistivity Transmitter System



Function

The IPC-7/2.5 kW is a medium power transmitter system designed for time domain induced polarization or commutated DC resistivity work. It is the standard power transmitting system used on most surveys under a wide variety of geophysical, topographical and climatic conditions.

The system consists of three modules: A Transmitter Console containing a transformer and electronics, a Motor Generator and a Dummy Load mounted in the Transmitter Console cover. The purpose of the Dummy Load is to accept the Motor Generator output during those parts of the cycle when current is not transmitted into the ground, in order to improve power output and prolong engine life.

The favourable power-weight ratio and compact design of this system make it portable and highly versatile for use with a wide variety of electrode arrays.

Features

Maximum motor generator output, 2.5 kW; maximum power output, 1.85 kW; maximum current output, 10 amperes; maximum voltage output, 1210 volts DC.

Removable circuit boards for ease in servicing.

Automatic on-off and polarity cycling with selectable cycling rates so that the optimum pulse time (frequency) can be selected for each survey.

The overload protection circuit protects the instrument from damage in case of an overload or short in the current dipole circuit.

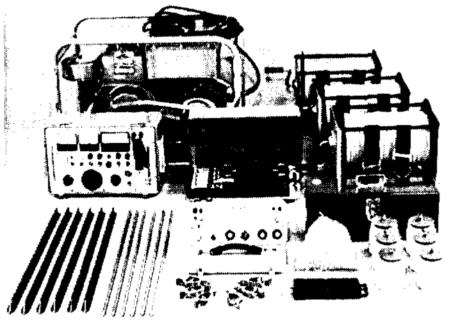
The open loop circuit protects workers by automatically cutting off the high voltage in case of a break in the current dipole circuit.

Both the primary and secondary of the transformer are switch selectable for power matching to the ground load. This ensures maximum power efficiency.

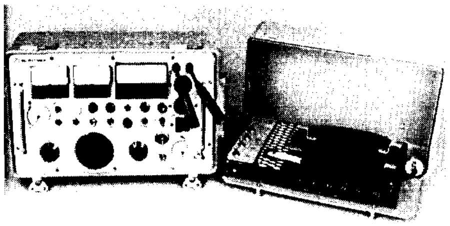
The built-in ohmmeter is used for checking the external circuit resistance to ensure that the current dipole circuit is grounded properly before the high voltage is turned on. This is a safety feature and also allows the operator to select the proper output voltage required to give an adequate current for a proper signal at the receiver.

The programmer is crystal controlled for the very high stability required for broadband (spectral) induced polarization measurements using the Scintrex IPR-11 Broadband Time Domain Receiver.

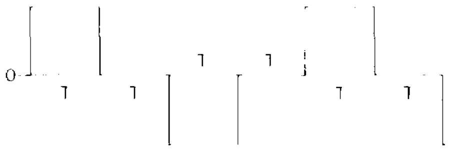
Technical Description of IPC-7/2.5 kW Transmitter System



Complete 2.5kW induced polarization system including motor-generator, reels with wire, tool kit, porous pots, simulator circuit, copper sulphate, IPR-8 receiver, dummy load, transmitter, electrodes and clips.



IPC-7 / 2.5kW transmitter console with lid and dummy load.



Time Domain Waveform

Transmitter Console	
Maximum Output Power	1.85 kW maximum, defined as VI when current is on, into a resistive load
Output Current	10 amperes maximum
Output Voltage	Switch selectable up to 1210 volts DC
Automatic Cycle Timing	T:T:T:T; on:off:on:off
Automatic Polarity Change	Each 2T
Pulse Durations	Standard: T = 2,4 or 8 seconds, switch selectable Optional: T = 1,2,4 or 8 seconds, switch selectable Optional: T = 8,16,32 or 64 seconds, switch selectable
Voltage Meter	1500 volts full scale logarithmic
Current Meter	Standard: 10.0 A full scale logarithmic Optional: 0.3, 1.0, 3.0 or 10.0 A full scale linear, switch selectable
Period Time Stability	Crystal controlled to better than .01%
Operating Temperature Range	-30°C to +55°C
Overload Protection	Automatic shut-off at output current above 10.0 A
Open Loop Protection	Automatic shut-off at current below 100 mA
Undervoltage Protection	Automatic shut-off at output voltage less than 95 V
Dimensions	280 mm x 460 mm x 310 mm
Weight	30 kg
Shipping Weight	41 kg includes reusable wooden crate

Motor Generator	
Maximum Output Power	2.5 kVA, single phase
Output Voltage	110 V AC
Output Frequency	400 Hz
Motor	4 stroke, 8 HP Briggs & Stratton
Weight	59 kg
Shipping Weight	90 kg includes reusable wooden crate

SCINTREX

222 Snidercroft Road
Concord Ontario Canada
L4K 1B5

Telephone: (416) 669-2280
Cable: Geoscint Toronto
Telex: 06-964570

Geophysical and Geochemical
Instrumentation and Services

Appendix 2

Plates 1 to 9

Plate 1 : Chargeability (M7) Contour Plan Map, scale 1:5000.
Plate 2 : Apparent Resistivity Contour Plan Map, scale 1:5000.
Plate 3 : Compilation/Anomaly Map, scale 1:5000.
Plate 4 : Stacked M7/Resistivity Pseudosections, scale 1:2500.
  L-21W - L-13W
Plate 4a: Stacked M-IP/tau Pseudosections, scale 1:2500.
  L-21W - L-13W
Plate 5 : Stacked M7/Resistivity Pseudosections, scale 1:2500.
  L-12W - L-4W
Plate 5a: Stacked M-IP/tau Pseudosections, scale 1:2500.
  L-12W - L-4W
Plate 6 : Stacked M7/Resistivity Pseudosections, scale 1:2500.
  L-8W - L-1W
Plate 6a: Stacked M-IP/tau Pseudosections, scale 1:2500.
  L-8W - L-1W
Plate 7 : Stacked M7/Resistivity Pseudosections, scale 1:2500.
  L-3W - L-5E
Plate 7a: Stacked M-IP/tau Pseudosections, scale 1:2500.
  L-3W - L-5E
Plate 8 : Stacked M7/Resistivity Pseudosections, scale 1:2500.
  L-0E - L-8E
Plate 8a: Stacked M-IP/tau Pseudosections, scale 1:2500.
  L-0E - L-8E
Plate 9 : Stacked M7/Resistivity Pseudosections, scale 1:2500.
  L-1E - L-5E
Plate 9a: Stacked M-IP/tau Pseudosections, scale 1:2500.
  L-1E - L-5E

Appendix 3

Literature

Spectral IP Parameters as determined through Time Domain Measurements by I.M. Johnson, Scintrex Limited, Toronto, Ontario, Canada, 1984.

Spectral IP: Experience over a number of Canadian Gold Deposits by B. Webster, JVX Ltd., and I.M. Johnson, Scintrex Limited, Toronto, Ontario, Canada, 1985.

Time domain Spectral Induced Polarization, some recent examples for gold, by Ian M. Johnson and Blaine Webster, JVX Limited, Thornhill, Ontario, Canada, 1987. Prepared for delegates to Exploration 87, 1987, Toronto, Canada

TIME DOMAIN SPECTRAL INDUCED POLARIZATION
SOME RECENT EXAMPLES FOR GOLD

by

Ian M. Johnson

and

Blaine Webster

JVX Limited
Thornhill, Ontario
Canada

Prepared for delegates to Exploration 87, September 27 to October 1, 1987, Toronto, Canada

TIME DOMAIN SPECTRAL INDUCED POLARIZATION
SOME RECENT EXAMPLES FOR GOLD

Spectral induced polarization was developed for the frequency domain in the 1970s. An early development was the establishment of the Cole-Cole model as that which best fit field results. The advantage to spectral IP was the ability to extract more usefull physical properties from survey data by way of the Cole-Cole model parameters. Among those are the time constant which is related to grain size and the chargeability amplitude which is related to the volume percent metallic sulphides. Application was not routine however because of the need to make sequential measurements of phase at a number of frequencies. This was and is too time consuming for most surveys.

The time domain equivalent was established in the early 1980s. In this case, the spectral parameters are extracted from the measured decays. This was an improvement on the frequency domain based method as all of the information needed for spectral IP is in a single measurement: survey production rates are unaffected.

The result has been the routine use by some of time domain spectral IP and the collection of a wide range of field experience. Methods of intepretation based on this experience have been developed. The spectral information has been found to be of particular use in gold exploration where the interest is often in fine grained disseminated sulphides. Coarse grained or massive sulphides may not be of interest. The spectral parameters may be the only indicators as to which is which.

The adoption of spectral analysis techniques for properly sampled time domain decays is a natural evolution of the IP method. IP receivers and transmitters, survey methods and analysis schemes are expected to evolve with time in response to the greater accuracy demands of spectral IP.

Spectral IP results from five areas in Ontario and Quebec are presented. All of the data has been collected in exploration projects for gold. The Scintrex IPR-11 receiver and IPC-7 or TSQ-3 transmitter has been used throughout. The data have been collected by JVX survey crews using the pole-dipole array and a 2 second pulse time.

1. CHIBOUGAMAU AREA, QUEBEC

Figure 1 shows the results from part of a survey conducted in the Chibougamau area of Quebec. The data was collected with an a spacing of 25 meters and six potential dipoles. The survey area is covered with up to 10 meters of sand and clay overburden.

The contoured pseudosections show the apparent resistivity divided by 100. The chargeability is that of the eighth slice (IPR-11 designation - M7) which is taken over the period from 690 to 1050 milliseconds after shut-off. The unit of measurement is millivolts per volt (mV/V). The spectral parameters tau (time constant) and M are derived by comparing the measured decay curve with a library of known curves. The best fit between the measured curve and the chosen master curve is often better than 2 % rms deviation. The time constant is shown in seconds. The Cole-Cole amplitude factor M is shown in mV/V.

The IP survey mapped two anomalous zones. The northern zone, Zone A, at station 825N is characterised by M7 chargeability values of 30 to 33 mV/V. There is a slight decrease in the coincident apparent resistivity. The southern zone, Zone B-1, at station 500N to 575N exhibits slightly higher M7 chargeabilities at from 33 to 39 mV/V and a resistivity response lower than background.

The most notable feature of these results is the clear difference in the derived time constant associated with the two zones. The spectral computation returned a high tau (time constant) for Zone A and a low tau for Zone B-1. The time constant is considered to be a semi-quantitative measure of grain size of the polarizable source. A high tau indicates a coarse grained source and a low tau indicates a fine grained source.

Diamond drilling has confirmed this interpretation. Drill testing of Zone B-1 encountered a wide zone of fine grained disseminated sulphides with a ten foot section running 0.5 oz Au/ton. Zone A was tested 200 meters along strike from the profile and barren course grained sulphides were intersected.

It should be noted that without the spectral information, the zone A anomaly might have been selected as the more promising drill target. This would have been based on the higher apparent resistivities as a possible indicator of silicification.

This case history demonstrates the capability of the time domain spectal IP method to discriminate between anomalies that exhibit similar values of chargeability amd resistivity. In this project, the spectral parameters proved to be a valuable diagnostic in separating IP anomalies with associated gold from those without.

2. RATIOS vs. SPECTRAL IP

The ratio of selected slices has been suggested as an alternative to the time constant derived from spectral analysis. The idea is that polarizable sources which are fine grained will show a faster decay than that from course grained or massive sources. The ratio of chargeabilities from early and late times would therefore be greatest for fine grained and least for course grained sources.

This is correct in a rough sense only. The routine use of ratios as a substitute for the Cole-Cole model time constant is an error. Some reasons are:

1. All of the work which has been done on spectral IP (time of frequency domain) supports the Cole-Cole model. This is a three parameter model for chargeability with one parameter for amplitude and two parameters to describe decay curve shape. These two parameters are the time constant (tau) and the exponent (c). They are linked in a complicated way and there is no simple method in the time domain to separate their effects.

   Characterizing the decay with a ratio assumes a two parameter model; amplitude and decay ratio. The ratio (or decay rate) is a mixture of time constant and exponent. Variations in the ratio can be due to variations in either time constant (ie. grain size) or exponent (ie uniformity of grain size).

   The assumption that the decay can be characterised by a ratio is equivalent to setting the exponent to a value of 1.0 (ie. modelling the decay as a negative exponential). All of the spectral IP work done to date suggests this is not the case. Exponent values between 0.1 and 0.5 are expected.

2. Spectral analysis uses a least squares fit over the whole measured decay. Ratios use two slices one of which is normally taken in the early part of the decay. Such slices arise from a short window width for which noise is greatest. Using one of the first four slices from the IPR-11 for example means the ratio is limited by data collected over 30 milliseconds. The spectral parameters are determined from data taken over almost 2 seconds.

3. For low exponent values (eg. c=0.1), the differences in ratios is least pronounced. This is the expected value of c however (the Newmont standard decay fits best to a c value of 0.1). The following table lists the theoretical ratios of the IPR-11 M3 (fourth slice centered at 135ms after shut off) to M7 (eighth slice centered at 870ms after shut off). A Cole-Cole exponent of 0.1 and time constants of 0.01 to 100 seconds are used.

Cole-Cole Time Constant (Sec)	M3/M7
0.01	2.61
0.03	2.59
0.10	2.58
0.30	2.57
1.00	2.56
3.00	2.54
10.00	2.53
30.00	2.51
100.00	2.50

The difference in the ratio between time constants for 0.01 and 100 seconds is only 4.2%. Assuming that M3=10.0mV/V and M7=3.9mV/V and that M7 is error free, the full range of ratios is found within the range for M3 of 10.0 +/- 0.4mV/V.

Spectral analysis using the whole decay is not so dependent upon the quality of chargeability values for a single slice.

A field example of ratios vs. Spectral IP is shown in figure 2. The data is taken from figure 1. Reading from top to bottom, pseudosections show the Cole-Cole time constant, the exponent and the M3/M7 ratio. It is clear from this example that variations in the ratio may be explained by either a change in time constant (ie grain size) or a charge in exponent (uniformity of grain size). The ratio alone cannot be relied upon to discriminate between coarse and fine grained metallic sulphides.

3. POWER LINE RESPONSE

Figure 3 shows the measured apparent resistivity, eighth slice chargeability and time constant. These results are from a survey in Joutel area. A pole-dipole array with an "a" spacing of 25m was used.

A power line is located at station 975N. The pseudosection of chargeability shows a distinct anomaly which could pass for that due to bedrock sources.

The time constant is uniformly long under the power line. This pattern was repeated at all points where the survey passed under the power line. This result might be expected given the nature of the cause of the response. This same signature can be seen for fences.

The spectral parameters have been determined in an area of only modest chargeabilities. Away from the power line, background chargeabilities are low. The rms deviation between the measured and theoretical decays is greater than 5% due mostly to the resolution limit of the IPR-11 (0.1 mV/V). Five percent is the limit beyond which spectral parameters are not plotted.

The long time constant characteristic of cultural sources could be exploited when exploring for fine grained sulphides in their vicinity. Identification might be made on the basis of time constant alone.

4. SUFFIELD, QUEBEC

Figure 4 shows the IP/resistivity results for one line in the area of the Suffield mine, Sherbrooke, Quebec. A pole-dipole array with an "a" spacing of 100 feet was used.

The resistivity low and associated chargeability high west of the base line suggest massive conductor. This is supported by the long time constant. This interpretation is correct. This is the area where a graphitic phyllite outcrops. This unit is known to be conductive and may be mapped using EM techniques.

There is a subtle IP response in the area of station 300E. There is no parallel variation in apparent resistivities and an interpretation without access to the spectal information might have passed over this part of the pseudosection.

The spectral parameters however suggest that this may be an area of fine grained disseminated sulphides. The Cole-Cole amplitude M is as large at 300E as over the graphities. This suggests an equal amount of polarizable material. This information is not available from single slice (or phase or PFE) presentation. The M7 results at 300E are as uninteresting as they appear because the time constant is so short. The decay is faster than would be seen with a long time constant source. The amplitude is depressed at M7.

The area around station 300E was identified as one for further investigation. Drilling immediately to the north of station 300E revealed fine grained disseminated sulphides. The locally high resistivities were explained by silicification.

5. JELLICOE DEPOSIT, ONTARIO

In 1983, the Ontario Geological Survey sponsored a series of geophysical surveys over known gold deposits in the Beardmore-Geraldton greenstone belt. Part of this work involved IP surveys on five lines over the Jellicoe deposit. Earlier gold production came from a sheared silicified and brecciated zone of quartz stringers and veinlets hosted by arkose. Mineralization consists of gold and disseminated sulfides (pyrite, arsenopyrite, and sphalerite) up to 10 percent locally. The deposit is centered some 50m subsurface. Overburden is moderately conductive and of 10 to 20 m thickness. The host rocks are Precambrian metasediments including arkose and greywacke. The deposit is some 200 m south of an extensive and prominent iron oxide formation.

The IP survey was carried out using a pole-dipole array with an a spacing of 25m and n=1 to 5. The results over one survey line are shown in pseudosection form in Figure 5. The apparent resistivity, eighth-slice chargeability, Cole-Cole time-constant, chargeability amplitude, and exponent values are shown in contoured pseudosection form.

The deposit is centered at station 450S and is seen as a broad chargeability high. The apparent resistivity section shows no marked coincident low. At the extreme north end of the line a resistivity low and strong chargeability high are indicated. This is most probably an area of barren sulfides, probably pyrite, associated with the iron formation.

The spectral IP results are interesting from a number of points of view. The time constant of the deposit is higher than the host and yet noticeably lower than that indicated by the barren sulfides near the baseline. The chargeability amplitude has amplified the anomaly over the deposit. As in the earlier examples, the amplitude M is a more reliable indicator of the volume percent metallic sulphides. The single slice (or phase or PFE) is less reliable. Variations therein can be caused by changes in grain size alone.

6. AVERAGE CHARGEABILITY

Figure 6 shows the results from a survey in the Casa Berardi area in which the M7 presentation showed little obvious variation and therfore no clear indication of areas of greater interest.

The lowest pseudosection shows the average of all ten slices. Where the eighth slice (M7) is of 380ms width, all ten lices occupy a window width of 1760ms. This is more than a fourfold increase in time averaging. A two times increase in signal to noise results. Subtle variations in chargeability are amplified and areas of possible interest are more easily identified.

In some ways, the average chargeability shown here is the chargeability parameter with the greatest signal to noise ratio possible. The survey operator is concerned with noise in the decay. Power or measuring time requirements are hence more severe than would be seen if looking at the average alone. The high quality of the average chargeability data is a result of the care needed to make IP measurements accurate enough to be used for spectral analysis.

CONCLUSIONS

The spectral paramters have been shown to be usefull compliment to the traditional chargeability data. This is particularly true where it is important to separate fine grain disseminated sulphides from their coarse grained equivalents. This is important in gold explortion as it is common to find gold associated with fine grained sulphides.

The calculated spectral parameter M is a more reliable indicator of the presence of metallic sulphides. The time constant reflects grain size. Fine grained disseminated sulphides may yield little or no IP response when viewed through the non-spectral measurement of single slice (or PFE or phase). Spectral analysis corrects this problem and the risk of missing interesting targets is less.

The spectral parameters may be used to separate cultural responses from those due to bedrock sources. The ratio of slices from time domain surveys is not equivalent to spectral analysis and the use of ratios will lead to errors where the ratio is related to the time constant or grain size. In addition, the ratio ignores the true chargeability amplitude which is used to indicate the concentration of disseminated sulphides.

The type of source discrimination seen with time domain spectral IP is not possible when measuring a single IP quantity such as a particular slice, PFE or phase at one frequency. These methods are restricted to a measurement of a quantity which is a mixture of source characteristics such as volume percent metallic sulphides and grain size. There is no way to extract each separately and the interpretation of such data is done and recommendations made while lacking important information.

The time domain spectral IP method does not suffer this limitation. The argument for spectral IP is particularly strong given that there is little effect on production rates when using the instrumentation, analysis software and field methods used for the results shown herein.

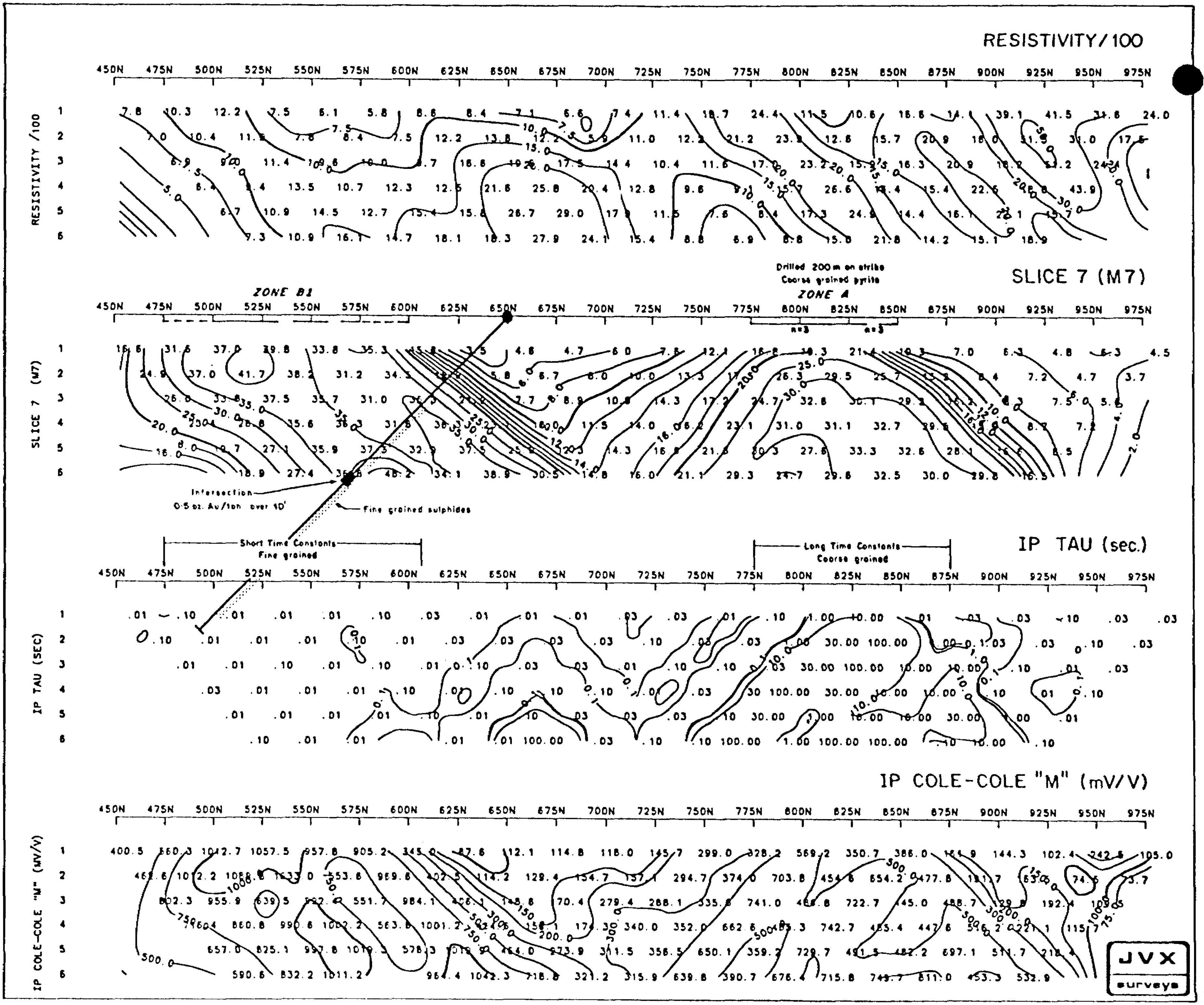

RESISTIVITY/100
450N 475N 500N 525N 550N 575N 600N 625N 650N 675N 700N 725N 750N 775N 800N 825N 850N 875N 900N 925N 950N 975N
RESISTIVITY /100
SLICE 7 (M7)
Drilled 200 m on strike
Coarse grained pyrite
ZONE B1
ZONE A
n=3
SLICE 7 (M7)
Intersection
0.5 oz. Au/ton over 10'
Fine grained sulphides
IP TAU (sec.)
Short Time Constants
Fine grained
Long Time Constants
Coarse grained
IP TAU (SEC)
IP COLE-COLE "M" (mV/V)
IP COLE-COLE "M" (MV/V)
JVX
surveys

Figure 1

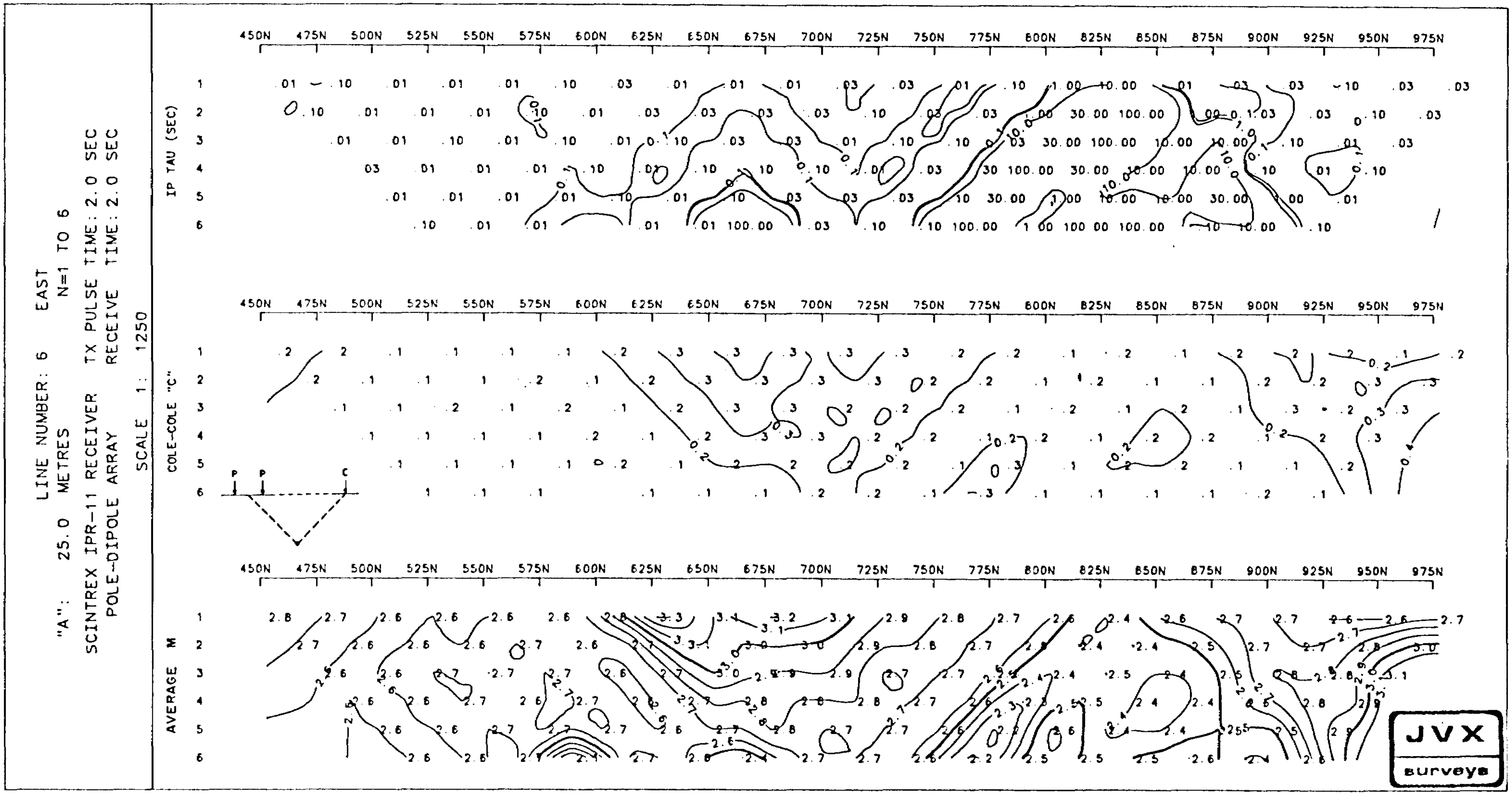

LINE NUMBER: 6 EAST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250
IP TAU (SEC)
COLE-COLE "C"
AVERAGE M
450N 475N 500N 525N 550N 575N 600N 625N 650N 675N 700N 725N 750N 775N 800N 825N 850N 875N 900N 925N 950N 975N
1 2 3 4 5 6
P P C
JVX surveys

Figure 2

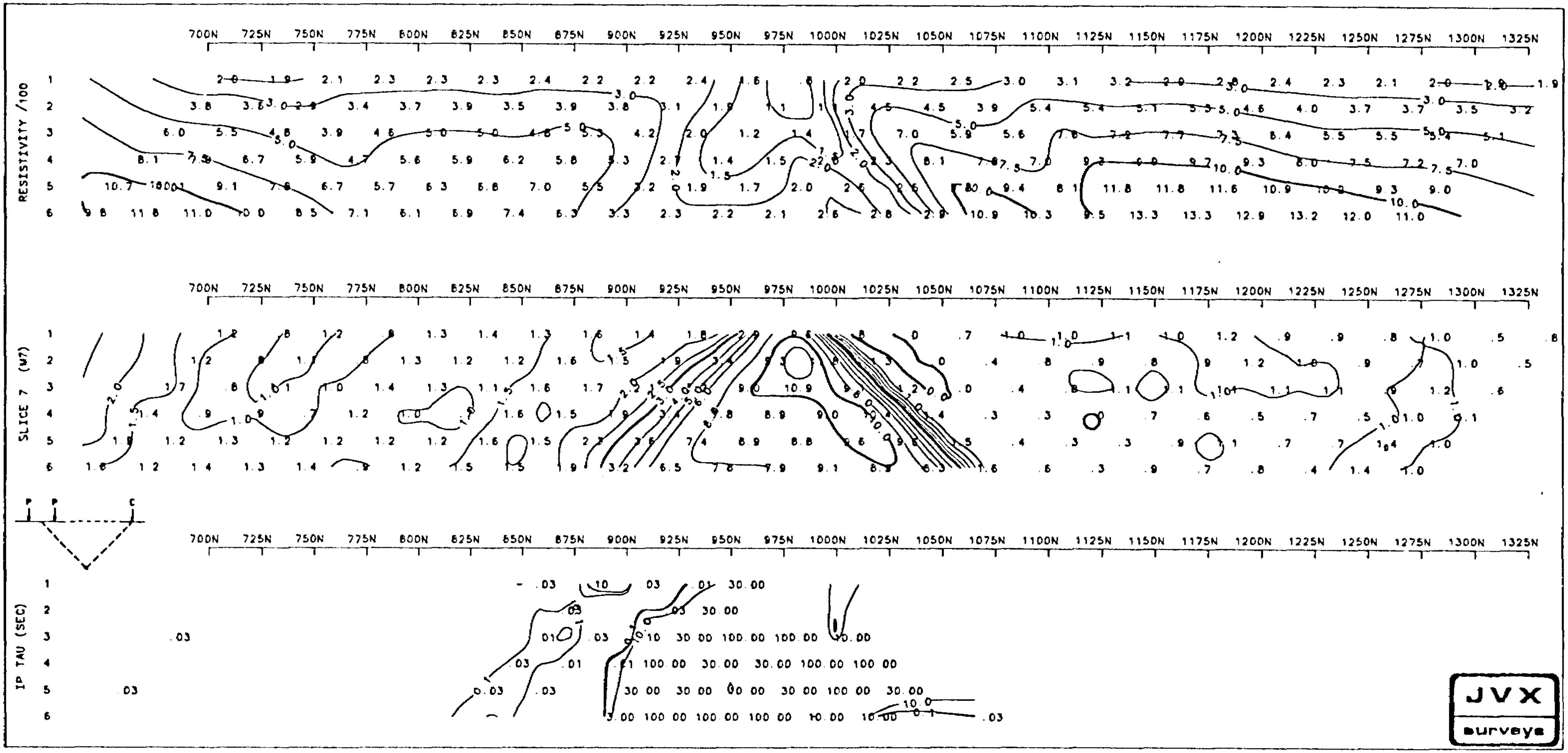

700N 725N 750N 775N 800N 825N 850N 875N 900N 925N 950N 975N 1000N 1025N 1050N 1075N 1100N 1125N 1150N 1175N 1200N 1225N 1250N 1275N 1300N 1325N
RESISTIVITY /100
SLICE 7 (M7)
IP TAU (SEC)
1
2
3
4
5
6
P
P
C
JVX
surveys

Figure 3

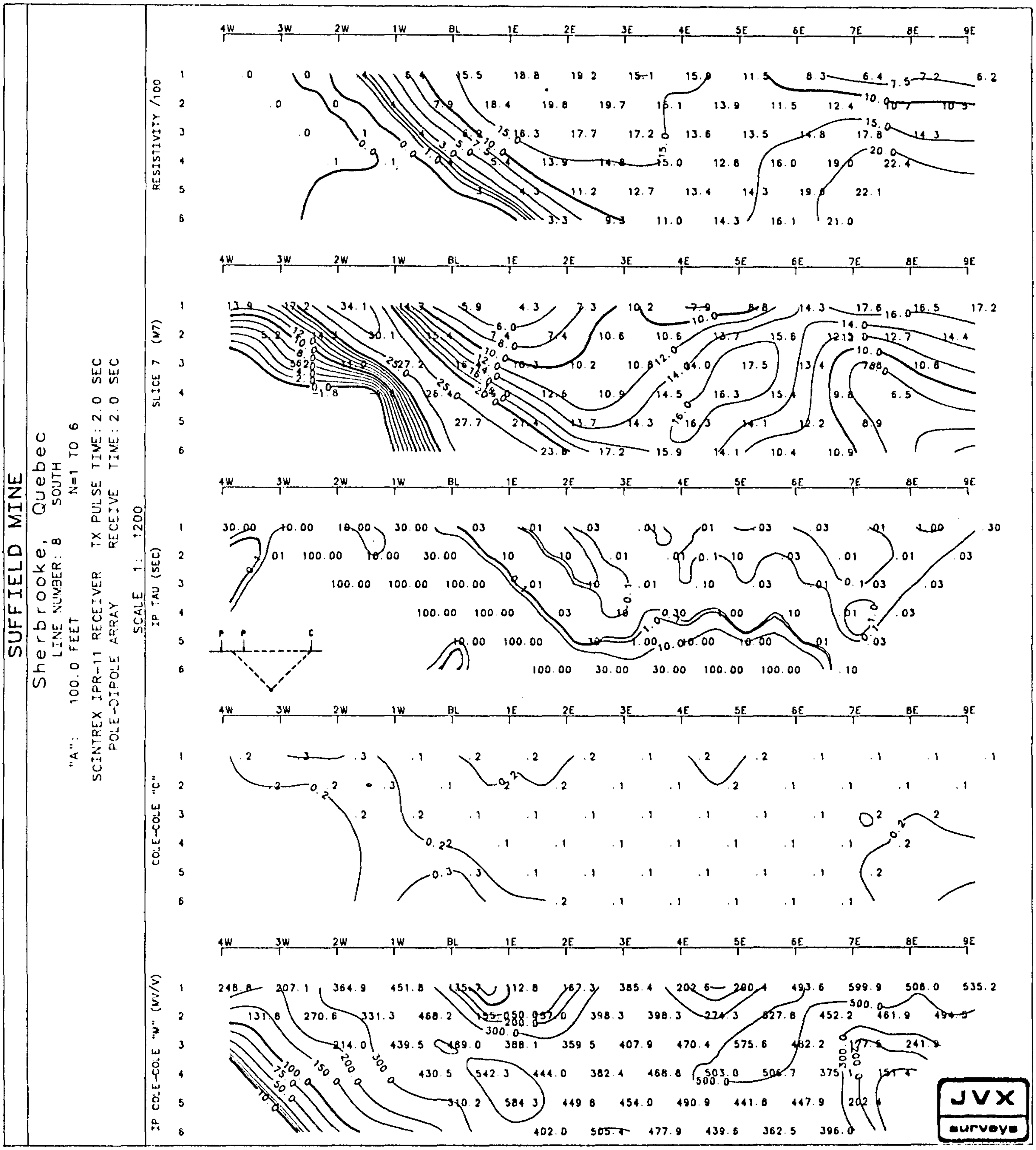
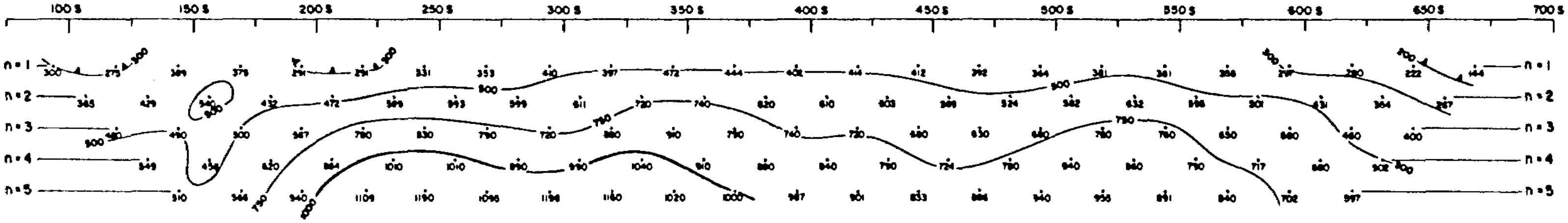
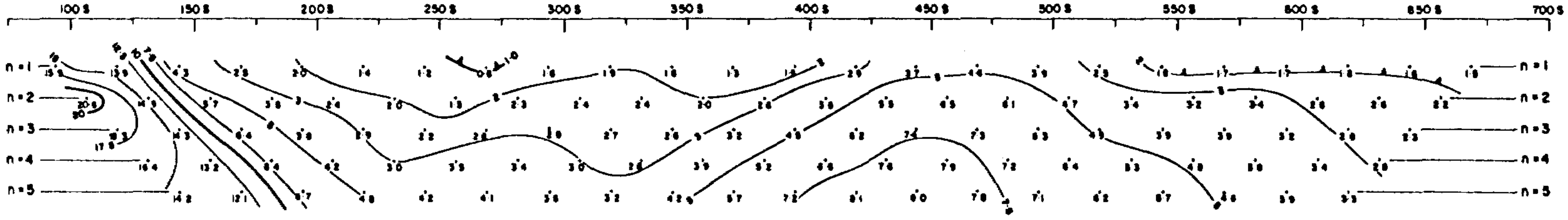

SUFFIELD MINE
Sherbrooke, Quebec
LINE NUMBER: 8 SOUTH
"A": 100.0 FEET N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1200
P P C
4W 3W 2W 1W BL 1E 2E 3E 4E 5E 6E 7E 8E 9E
RESISTIVITY /100
SLICE 7 (M7)
IP TAU (SEC)
COLE-COLE "C"
IP COLE-COLE "M" (MV/V)
1 2 3 4 5 6
JVX surveys

Figure 4

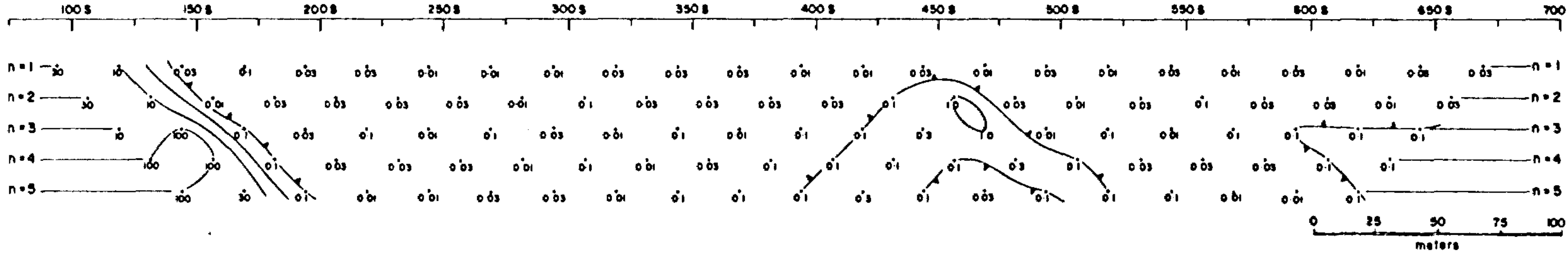
APPARENT RESISTIVITY (ohm-m)



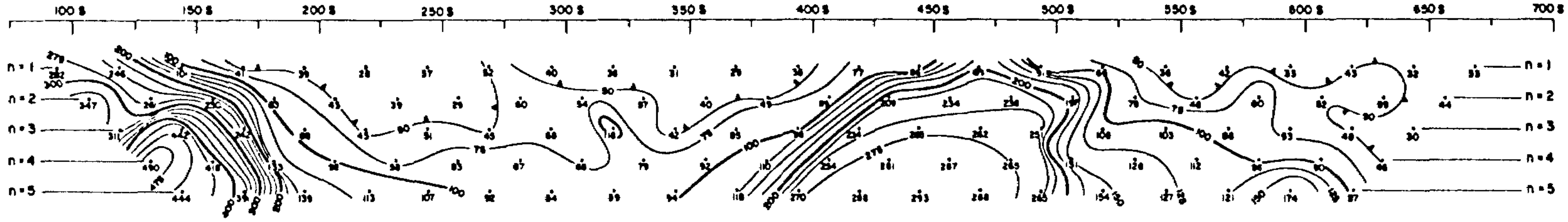
CHARGEABILITY (690-1050ms) mV/V



TIME CONSTANT - τ - (seconds)



CHARGEABILITY - m - (mV/V)



EXPONENT - C

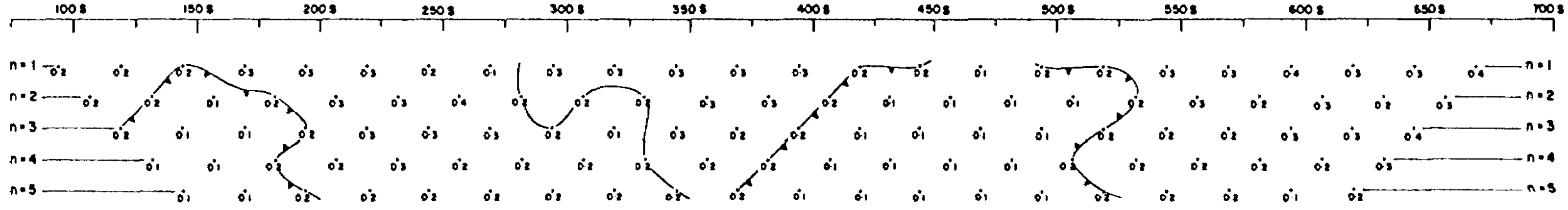


Figure 5

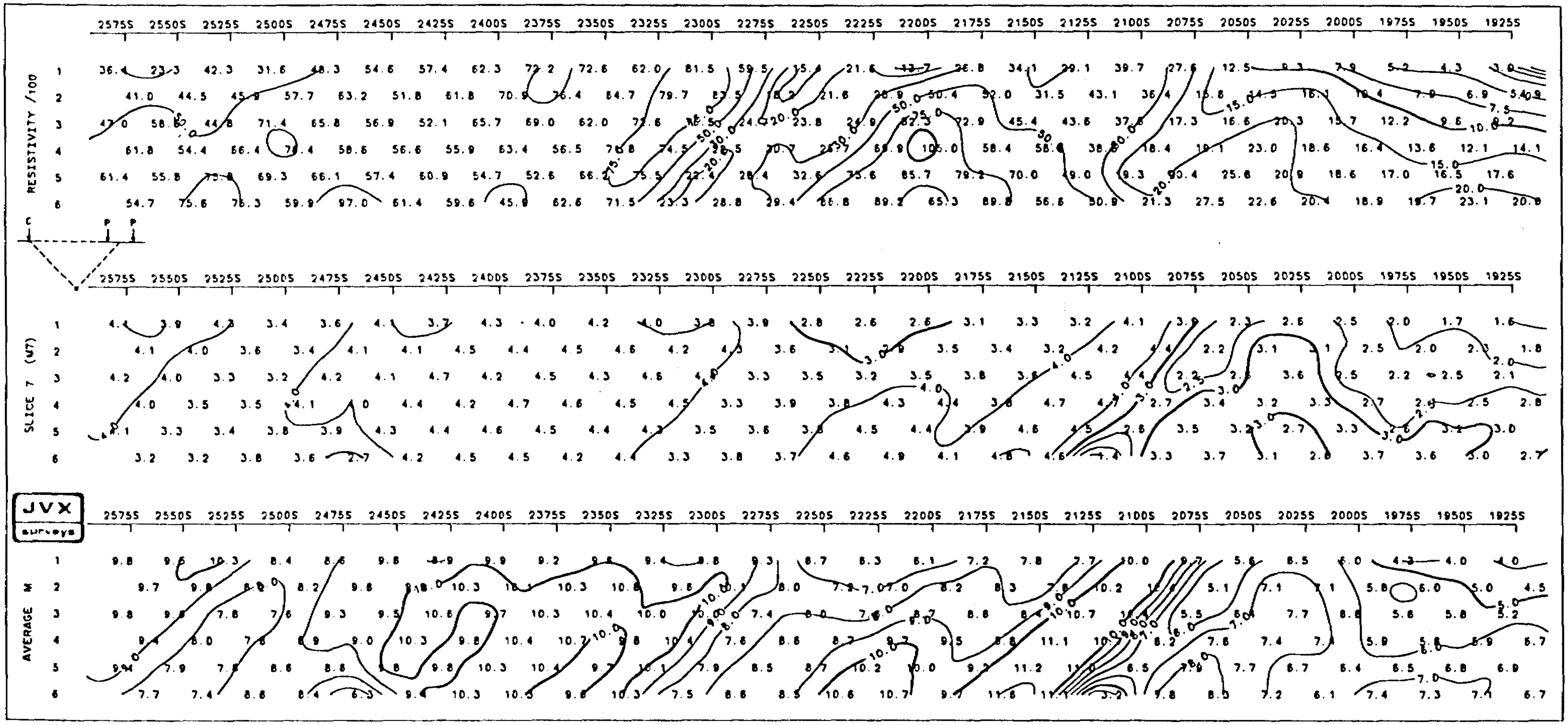

RESISTIVITY /100
SLICE 7 (MT)
AVERAGE M
2575S 2550S 2525S 2500S 2475S 2450S 2425S 2400S 2375S 2350S 2325S 2300S 2275S 2250S 2225S 2200S 2175S 2150S 2125S 2100S 2075S 2050S 2025S 2000S 1975S 1950S 1925S
1
2
3
4
5
6
C
P
P
JVX
surveys

Figure 6

Spectral induced polarization parameters as determined through time-domain measurements

Ian M. Johnson*

ABSTRACT

A method for the extraction of Cole-Cole spectral parameters from time-domain induced polarization data is demonstrated. The instrumentation required to effect the measurement and analysis is described. The Cole-Cole impedance model is shown to work equally well in the time domain as in the frequency domain. Field trials show the time-domain method to generate spectral parameters consistent with those generated by frequency-domain surveys. This is shown to be possible without significant alteration to field procedures. Cole-Cole time constants of up to 100 s are shown to be resolvable given a transmitted current of a 2 s pulse-time. The process proves to have added usefulness as the Cole-Cole forward solution proves an excellent basis for quantifying noise in the measured decay.

INTRODUCTION

The induced polarization (IP) phenomenon was first observed as a relaxation or decay voltage as a response to the shut-off of an impressed dc current. This decay was seen to be quasi-exponential with measurable effects several seconds after shut-off. Differences in the shape of decay curves seen for different polarizable targets have been recognized from the start (Wait, 1959). A systematic method of analyzing time-domain responses in order to generate an unbiased measure of source character has, until recently, been lacking. Developments in the frequency domain have been more pronounced.

In an attempt to improve our understanding of time-domain IP phenomenon, the Cole-Cole impedance model, developed and tested in the frequency domain, is used to generate the equivalent time-domain responses. Time-domain field data are then analyzed for Cole-Cole parameters and the results used to interpret differences in the character of the source.

The theoretical basis for the work will be presented. The instrumentation required to effect the measurement and analysis will be described. Field examples will be discussed.

SPECTRAL IP

The term "spectral IP" has been used to designate a variety of methods which look beyond the familiar resistivity and chargeability (or "percent frequency effect") as measured in electrical surveys. A number of geophysical instrument manufacturers/contractors have developed instrumentation and methodologies which, in essence, collect and analyze data from electrical surveys at a number of frequencies or delay times. The data analysis produces a set of quantities which characterize the information gained. These quantities or parameters are promoted by the sponsor for application in a variety of search problems for mineral and hydrocarbon resources.

In recognition of the pioneering work of Pelton (Pelton et al., 1978), the Cole-Cole impedance model has been adopted. The model has been extensively field tested and found to be reliable (Pelton et al., 1978). Pelton suggested that the complex impedance (transfer function) of a simple polarizable source may be best expressed as

$$Z(\omega) = R_0\left\{1 - m\left[1 - \frac{1}{1 + (i\omega\tau)^c}\right]\right\}, \qquad (1)$$

where

$Z(\omega)$ = complex impedance (in $\Omega \cdot$ m),
R_0 = the dc resistivity (in $\Omega \cdot$ m),
m = the chargeability (in volts/volt),
τ = the time constant (in seconds),
ω = the angular frequency (in seconds^{-1}),
c = the exponent (or frequency dependence), (dimensionless)

and

$$i = \sqrt{-1}.$$

The dc resistivity (R_0) is related to the apparent resistivity calculated in conventional electrical methods. The chargeability (m) is the relative residual voltage which would be seen immediately after shut-off of an infinitely long transmitted pulse (Siegel, 1959). It is related to the traditional chargeability as measured some time after the shut-off of a series of pulses of finite duration. The time constant (τ) and exponent (c) are those newly measurable physical properties which describe the shape of the decay curve in time domain or the phase spectrum in frequency domain. For conventional IP targets, the time constant has been shown to range from approximately 0.01 s to greater than 100 s and is thought of as a measure of grain size. The exponent has been shown to have a range of interest from 0.1 to 0.5 or greater and is diagnostic of the uniformity of the grain size of the target (Pelton et al., 1978).

Selection of the Cole-Cole model is the primary step in simulating the response of a single polarizable target. A number of other effects are present to a greater or lesser extent depending upon the geoelectric environment. Multiple targets of differing characteristics will cause overlapping effects. Measurements may contain an appreciable component due solely to inductive coupling effects. In very conductive terrain, this contribution may be large enough to dominate the IP effects (Hallof and Pelton, 1980). The inductive effect itself may be a valued measurement in its own right (Wynn and Zonge, 1977).

SPECTRAL IP IN THE TIME DOMAIN

The earlier work is well summarized in Wait (1959). By that time enough data had been gathered to point to differences in measured decay curves and a number of decay curve modeling schemes had been tried. Developments in instrumentation were less pronounced. In 1967 the Newmont Standard IP decay was introduced (Dolan and McLaughlin, 1967). Induced polarization receivers were subsequently introduced which used the Newmont Standard as a basis for IP measurements. The so-called L/M parameter was used for a number of years as a sensitive measure of agreement with the Newmont Standard and of source character (Swift, 1973).

IP receivers evolved in the mid 1970s through single dipole instruments which could be programmed to measure a number of points on the decay. Decay curve analysis was possible (Vogelsang, 1981), if tedious and inexact. Extremely long pulse times were suggested as a means of effecting some type of time-domain spectral discrimination given the equipment then available (Halverson et al., 1978). The late 1970s saw the introduction of time-domain IP receivers which could measure and record digitally a number of points on the decay. The performance of both transmitters and receivers was improving in parallel.

The first studies of the shape of the time-domain decay given a Cole-Cole impedance model were made by Jain (1981) and Tombs (1981). Both authors show a number of numerically generated decay curves as the steady-state response to a conventional (+, 0, −, 0) pulse train. Measured decays were compared to master curves with uncertain results.

Both contributions stopped short of routine application. Having generated a set of standard decays, the differences in curve shape could be quantified. A measure of the accuracy in the field measurement required to effect a reasonable resolution in spectral character could be gained. Routine application would better define the limitations of the method under average field conditions.

Although the master-curve approach is considered the most practical one for routine spectral IP work, other approaches are possible. The time-domain decay may be modeled as a series of decaying exponentials from which the frequency-domain phase spectrum is easily calculated (Gupta Sarma et al., 1981). Both input current and output voltage may be expressed as transform pairs of time-domain signals. The transfer function may be extracted directly.

NUMERICAL MODELING

From Tombs (1981), the (+, 0, −, 0) transmitted current of amplitude I_0 and of pulse time T s used in conventional time domain IP may be expressed in Fourier series form as

$$I(t) = I_0 \sum_{n=1}^{\infty} \frac{2}{n\pi} \left(\cos \frac{n\pi}{4} - \cos \frac{3n\pi}{4} \right) \sin \frac{n\pi t}{2T}. \tag{2}$$

A homogeneous earth whose electrical properties may be modeled by a single Cole-Cole impedance of $Z(\omega)$ is assumed. Ignoring the effect of array geometry, the steady-state voltage as measured at the receiving dipole pair is

$$V(t) = I_0 \operatorname{Im} \sum_{n=1}^{\infty} \frac{2}{n\pi} \left(\cos \frac{n\pi}{4} - \cos \frac{3n\pi}{4} \right) Z\left(\frac{n\pi}{2T}\right) e^{in\pi t/2T}. \tag{3}$$

For conventional time-domain IP receivers, it is common to sample the decay through a sequence of N slices or windows. The value recorded for each slice is

$$S_i = \frac{10^3}{V_p(t_{i+1} - t_i)} \int_{t_i}^{t_{i+1}} V(t)\, dt \qquad (\mathrm{mV/V}), \tag{4}$$

where t_i, t_{i+1} are the limits on the integration and V_p is the time average of measured voltage during the current on-time. In addition, it is common to average S_i over a number of cycles and to filter out those signals at frequencies well below the transmitted fundamental $f_0 (= 1/4T)$.

For ease of presentation, we define a function $G(t_i, t_{i+1}, \tau, c, T)$. This function describes the t, τ, c, and T dependence of S_i and is derived by inserting the expression for the Cole-Cole impedance from equation (1) and $V(t)$ from equation (3) into the right-hand side of equation (4) as follows:

$$\begin{aligned} G(t_i, t_{i+1}, \tau, c, T) = \frac{1}{(t_{i+1} - t_i)} \int_{t_i}^{t_{i+1}} & \operatorname{Im} \sum_{n=1}^{\infty} \frac{2}{n\pi} \\ & \times \left(\cos \frac{n\pi}{4} - \cos \frac{3n\pi}{4} \right) \\ & \times \left[\frac{1}{1 + \left(\frac{in\pi\tau}{2T} \right)^c} \right] e^{in\pi t/2T}\, dt. \end{aligned} \tag{5}$$

Combining equations (3) and (4) and using the notation of equation (5), the theoretical decay during the off-time is given by

$$S_i = \frac{10^3\, I_0 R_0 m}{V_p} G(t_i, t_{i+1}, \tau, c, T). \tag{6}$$

The measured theoretical primary voltage may be expressed

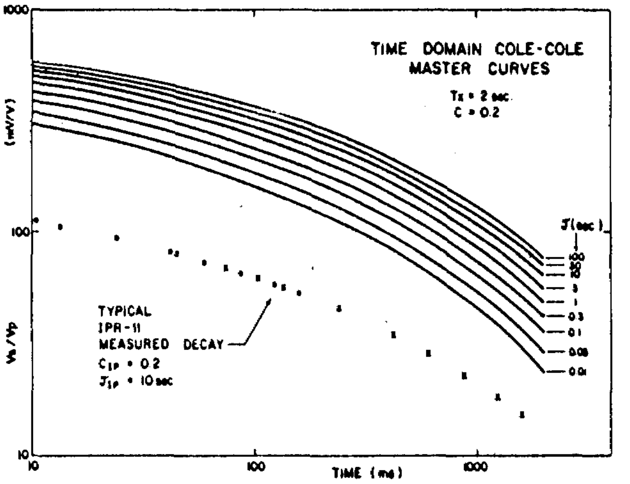


FIG. 1. Theoretical time-domain decay curves for fixed c and variable τ. A typical IPR-11 measured decay is shown as a series of dots (0.2 s receiver mode) and x's (2 s receiver mode).

as

$$V_p = I_0 R_0 - I_0 R_0 m + I_0 R_0 m G(t_a, t_b, \tau, c, T), \tag{7}$$

where t_a, t_b are the limits of integration during the current on-time.

Combining equations (6) and (7), the theoretical decay is given by

$$S_i = \frac{10^3\, mG(t_i, t_{i+1}, \tau, c, T)}{1 - m + mG(t_a, t_b, \tau, c, T)} \quad (\text{mV/V}),\ i = 1, N. \tag{8}$$

Preferred Cole-Cole spectral parameters may be determined by a "best-fit" match of measured data to a suite of master curves. The process used may be summarized as follows.

The master-curve set is numerically generated through equation (8) by allowing c and τ to vary in discrete steps over ranges of interest. The chargeability is set to 1 V/V and the pulse time to 2 s. Both S_i and $G(t_a, t_b, \tau, c, T)$ are retained in the master-curve set.

If the measured decay is given by M_i mV/V ($i = 1, N$), an observed chargeability m_0 V/V is defined as the weighted average amplitude shift in log amplitude space between measured and master curves, i.e.,

$$\log m_0 = \frac{1}{N} \sum_{i=1}^{N} (\log M_i - \log S_i) w_i. \tag{9}$$

Observed chargeability values are determined for all master curves. The weighting factors w_i bias the averaging to late delay times where integration intervals are longest.

The "best-fit" master curve is selected by minimizing

$$\mathrm{SD} = \sum_{i=1}^{N} [\log M_i - \log (m_0 S_i)]^2 w_i, \tag{10}$$

where the m_0 used is that value appropriate to the master curve under consideration.

The true chargeability m may be found by setting

$$\frac{mG(t_i, t_{i+1}, \tau, c, T)}{1 - m + mG(t_a, t_b, \tau, c, T)} = \frac{m_0\, G(t_i, t_{i+1}, \tau, c, T)}{G(t_a, t_b, \tau, c, T)}. \tag{11}$$

Hence,

$$m = \frac{m_0 \times 10^3}{G(t_a, t_b, \tau, c, T) + m_0 [1 - G(t_a, t_b, \tau, c, T)]} \quad \text{mV/V}. \tag{12}$$

Confidence in the spectral parameters so determined is related to the agreement between measured data and the selected master curve. This agreement is quantified by the root-mean-square (rms) deviation defined as

$$D = \left\{ \frac{1}{N} \sum_{i=1}^{N} \left(1 - \frac{M_i}{m_0 S_i} \right)^2 \times 10^4 \right\}^{1/2} \text{ percent.} \tag{13}$$

The process outlined above will yield spectral parameters which are only apparent. Polarizable targets of interest are most often of finite size and embedded in a medium which may itself possess characteristic impedances. The theoretical problem of greater generality is a complex one with no reasonably general forward solution yet available.

Pelton et al. (1978) presented the case of a simple polarizable target buried in a nonpolarizing host. They showed that as the relative size of the target, as defined by the dilution factor decreases, the exponent is effectively unchanged. The time constant is similarly unaffected as long as the true chargeability is not large. The apparent resistivity and apparent chargeability are, however, not as stable under large changes in the dilution factor.

This implies that the shape of the time-domain decay and therefore the apparent time constant τ and exponent c are relatively stable under large changes in the dilution factor. The apparent chargeability is not.

By inspection,

$$G(t_i, t_{i+1}, \tau, c, T) = G(nt_i, nt_{i+1}, n\tau, c, nT). \tag{14}$$

If for example, the receiver timing, pulse time, and Cole-Cole time constant are all doubled, the master-curve values are unaffected. This is a useful result for predicting the pulse length required to resolve spectral parameters given that one already has a complete understanding of the resolution capabilities of the method for one pulse time (e.g., $T = 2$ s). As an example, let us assume that time-domain IP surveys using a pulse time of 2 s are known to result in spectral discrimination (i.e., decay curve shape differences) for time constants up to 100 s. If it is suspected that it may be important to resolve time constants of 1 000 s, for example, all other things being equal, a pulse time of 20 s would be required.

All of the above applies for a homogeneous earth whose behavior is described by a single Cole-Cole impedance. Measured decays may be the result of the superposition of effects due to more than one source type. Resolution of more than one impedance type should be possible if all types are sufficiently different in time constant (Major and Silic, 1981). If this condition is met, the net impedance may be expressed as the sum of impedances of each type. This implies that measured voltages may be modeled as the sum of voltages due to both IP and inductive coupling effects and the mathematical summary shown above will apply equally well to both. At a minimum, any analysis should be capable of measuring and resolving IP effects (relatively low c, large τ) and inductive coupling (IC) effects (relatively high c, small τ).

Further developments are based on the timing characteristics of the IP receiver involved. The Scintrex IPR-11 receiver is assumed through the remainder of the paper and all results are specific to this receiver.

IPR-11 MODEL CURVES

The Scintrex IPR-11 time-domain IP receiver is a microprocessor-controlled unit which measures ten semi-logarithmically spaced points on the decay for up to six dipoles simultaneously. Receiver slice-timing can be reset to fill in other parts of the decay curve in 10 point sets. The measured decay is recorded to a resolution of 0.1 mV/V.

The master curves are numerically generated per equation (8). In the calculation of $G(t_i, t_{i+1}, \tau, c, T)$ the integration is done before the summation. The coding used is taken in part from that published by Tombs (1980).

The master curves are generated assuming $m = 1$ V/V and $T = 2$ s. The exponent c is allowed the values 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, and 1.0. The time constant τ is allowed the values 0.01, 0.03, 0.1, 0.3, 1.0, 3.0, 10.0, 30.0, and 100.0 s. The exponent values reflect the expected range for polarizable targets (0.1 to 0.8) and inductive coupling effects ($c = 1.0$) (Pelton et al., 1978). The time-constant values are limited at the low end by the minimum sampling interval (3 ms) and at the high end by what curve shape differences can reasonably be resolved given a pulse time of 2 s. The time constant values chosen are thought to give reasonably uniform rms deviations between different master curves.

Master curve data for longer pulse times is immediately available given the identity of equation (14).

The weighting factors used in equations (9) and (10) have the values 0.773, 0.800, 0.823, 0.843, 0.897, 0.978, 1.048, 1.143, 1.306, and 1.389.

Figure 1 shows simulated IP decays for variable time constant and fixed exponent. A simulated decay as sampled by the IPR-11 is shown, assuming that both 0.2 and 2 s IPR-11 receive modes have been used.

Figure 2 shows simulated IP decays for variable c and fixed τ. Also shown is the Newmont Standard curve (Dolan and McLaughlin, 1967) for a pulse time of 2 s. It has been found to fit best to the master curve given by a time constant of 1 s and c value of 0.1. The rms deviation of the fit is 0.3 percent. A time constant of 1 s is consistent with the fact that the Newmont Standard was influenced by the average of a large number of measured decays. With regard to the c values, Pelton (1978) noted an average value for c of 0.25 as seen in most field surveys. The c value of 0.1 for the Newmont Standard decay is, however, understandable. Averaging time-domain decay curves of fixed c and variable τ will generally result in a curve with an exponent value less than that of the individual decays.

Numerical experiments have been conducted to examine the stability of the curve-matching process. In essence, the measured decay is set to one of the master curves. The rms deviation between this decay and each of the master curves is then calculated. The master curves are arranged in order of increas-

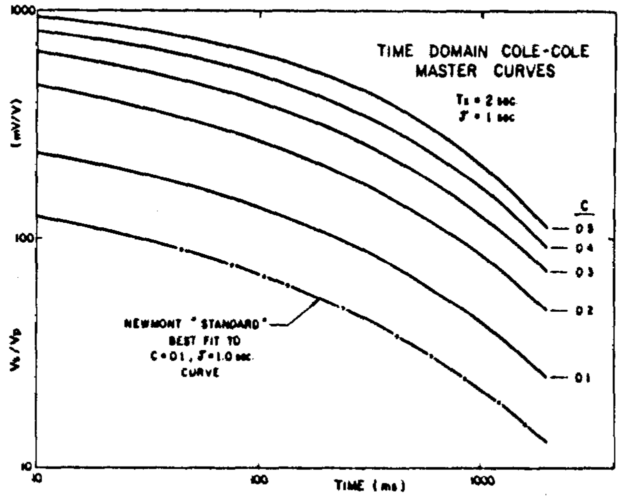


FIG. 2. Theoretical time-domain decay curves for fixed τ and variable c. The Newmont Standard decay for a 2 s pulse time is shown with fitted time constant and exponent.

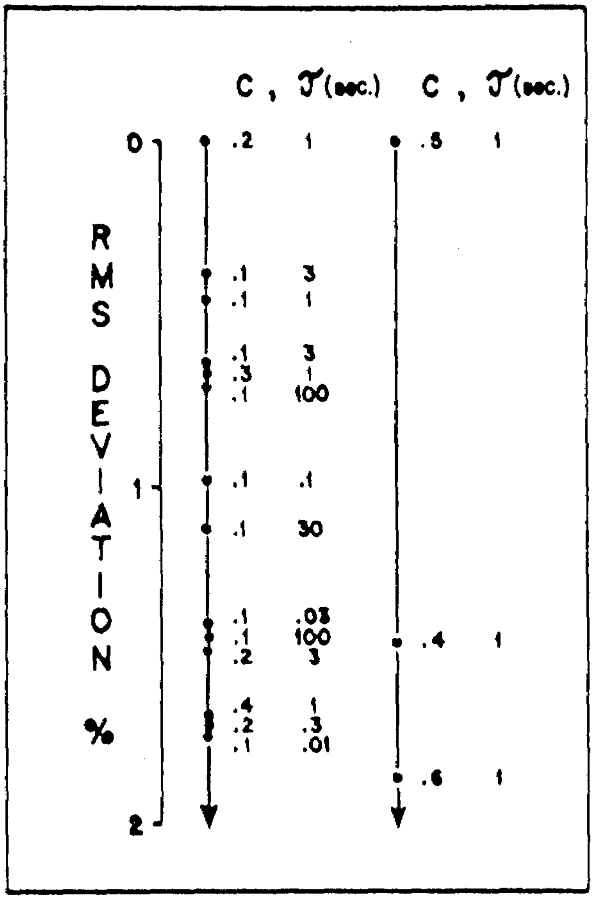


FIG. 3. Curve shape differences (or rms deviation) between selected master curves. Arranged in order of increasing deviation from the $c = 0.2, \tau = 1$ and the $c = 0.5, \tau = 1$ curves.

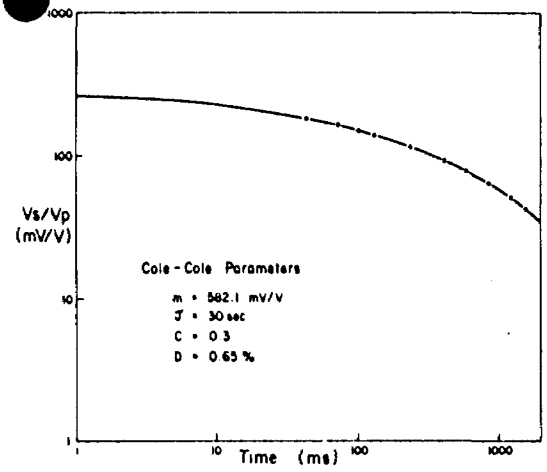


FIG. 4. Measured data (10 point), best-fit master decay curve, and calculated spectral parameters. Array is pole-dipole with $a = 10$ m, $n = 6$ with $V_p = 1.2$ mV. Rms deviation = 0.65 percent. V_s designates the voltage measured during the transmitter off-time.

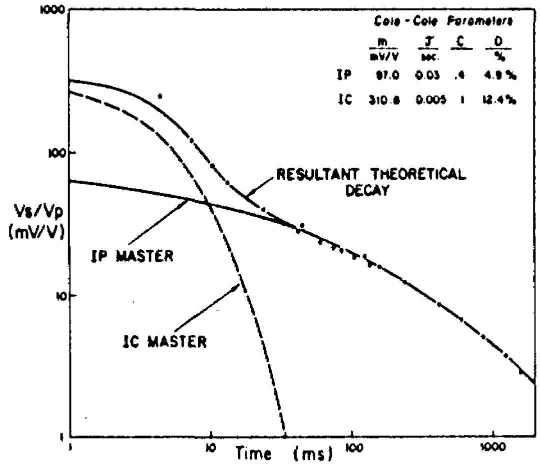


FIG. 5. Measured data (20 point composite), best-fit master curves, and calculated spectral parameters. Both IP and inductive coupling (IC) effects are modeled. Array is dipole-dipole with $a = 100$ m, $n = 6$ with $V_p = 2.6$ mV.

ing rms deviation. The results for part of this work are shown in Figure 3. The left-hand column shows the ranking in order of increasing curve shape difference away from a measured decay as given by the $c = .2$, $\tau = 1$ s master curve. The right-hand column shows the ranking away from a measured decay as given by the $c = .5$, $\tau = 1$ s master curve. These results serve to illustrate the following.

(1) As c is reduced from 0.5 to 0.2, the differences in the shape of the curve between master curves of different τ are reduced and the confidence in the time-constant determination is lessened. This is no more than the familiar result obtained in the frequency domain. That is, as c approaches 0.1, the phase spectrum flattens, the peak in the phase spectrum becomes less distinct, and the time constant becomes more poorly determined.

(2) Figure 3 gives an indication of the order of rms deviation required to achieve reasonably reliable spectral parameters. An rms deviation between the measured and master curve data on the order of 1 percent is indicated.

An important consideration in any time-domain spectral IP approach is the maximum resolvable time constant given a fixed transmitted pulse time. Resolution will be in part a function of the differences in master curves as quantified by the rms deviation. The differences measured between the $\tau = 30$ s and the $\tau = 100$ s master curves are 3.06 percent for $c = 0.5$ and 0.12 percent for $c = 0.1$.

A number of unknown factors will be introduced when the method is taken into the field. The performance of various IP transmitters under the normal variety of load conditions is not precisely known. Measured decays will display a reliability which is a complex function of the design of the receiver, field procedures, natural noise, etc. Most conventional IP targets are not well modeled as a homogeneous earth. The role of spectral IP parameters in minerals exploration is still in debate.

Given all of these factors, the method described herein has been designed with reasonable compromise such that basic spectral parameters can be determined using traditional field procedures. Through such a scheme, spectral data over a wide variety of targets may be collected to improve understanding of the method reliability and function and to modify strategy to best fit the exploration problem at hand.

FIELD WORK

The results shown below have been taken from a variety of field IP surveys. Most of these surveys have been undertaken without modification or special consideration for the determination of spectral parameters. The IPR-11 receiver was used exclusively. All of the data were gathered with a pulse time of 2 s. A variety of crystal-controlled transmitters were used. Analysis was, in all cases, effected by a specially prepared application software set which is resident on a microcomputer of common manufacture.

Decay curve analysis

Measured decays are shown in Figures 4 and 5.

The time-domain decay shown in Figure 4 is taken from a survey over a near-surface Canadian volcanogenic sulfide zone. Array geometry was pole-dipole with a spacing of 10 m and $n = 1$ to 6. The decay shown is from the $n = 6$ dipole. The measured primary voltages were 3 685 mV ($n = 1$) and 1.2 mV ($n = 6$). Apparent resistivity for the sixth dipole was 290 Ω · m. Eight transmit cycles were stacked or averaged to make the reading.

The fit is quite good with a deviation of 0.65 percent. The observed chargeability (m_0) is 283.1 mV/V. The Cole-Cole spectral parameters are given as 582 mV/V (m), 30 s (τ), and 0.3 (c).

Given the array style, a spacing, and a relatively resistive host, no significant IC component was expected (Dey and Morrison, 1973). Figure 5 shows a measured decay from dipole-dipole survey in an area of Australia with a considerable thickness of conductive cover. More than 100 m of 50 Ω·m ground are involved. The a spacing (100 m) and the n value (6) were additional reasons to measure the early-time portion of the decay. The decay shown is measured by sampling both early- and late-time 10 point decays to give a composite 20 point decay.

For the early-time measurement, 8 cycles were averaged with a V_p of 2.6 mV. For the late-time measurement, 10 cycles were averaged with a V_p of 2.6 mV. Acceptable data quality is possible for such low primary voltages in large part because the IPR-11 receiver timing is triggered off the signal from the first potential dipole pair. Primary voltages in the $n = 1$ dipole in both cases were greater than 400 mV.

For the IC component a c value of 1 was assumed. The fitted parameters for both IP and IC effects are shown on Figure 5. The theoretical decays for IP, IC, and the summed responses are superimposed.

The IP fit is based on the 10 points of the late-time measurement. The IC component decayed rapidly and had no measurable influence after 40 ms following shut-off. The theoretical IC curve is a good approximation to the early-time decay after

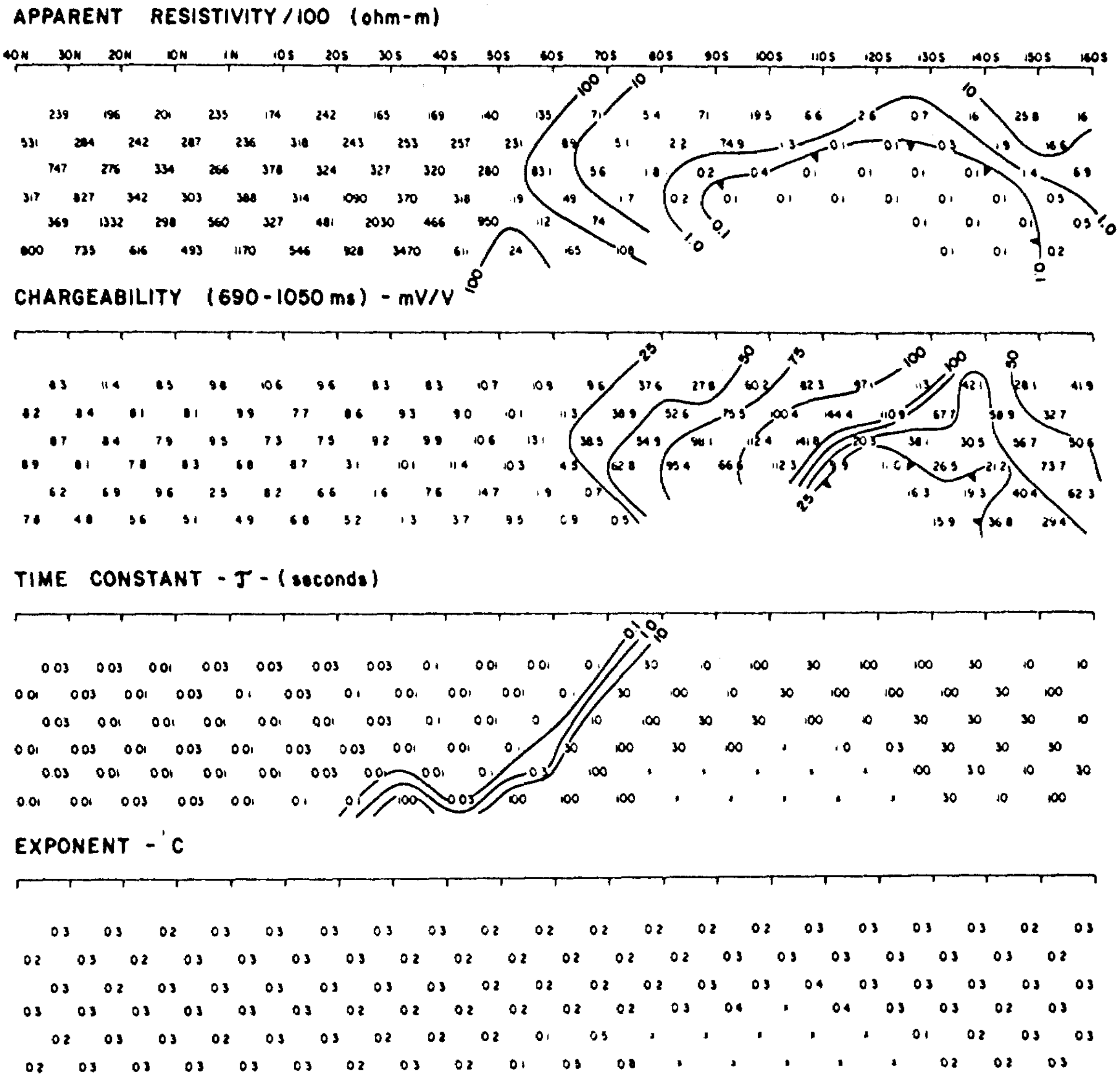


FIG. 6. Segment of results from an IPR-11 survey using the pole-dipole array with $a = 10$ m and $n = 1$ to 6. Shown are apparent resistivity/100 (Ω·m) eighth-slice chargeability (mV/V), Cole-Cole time constant (seconds) and exponent (c). Near-current electrode is to the left of the potential electrode string.

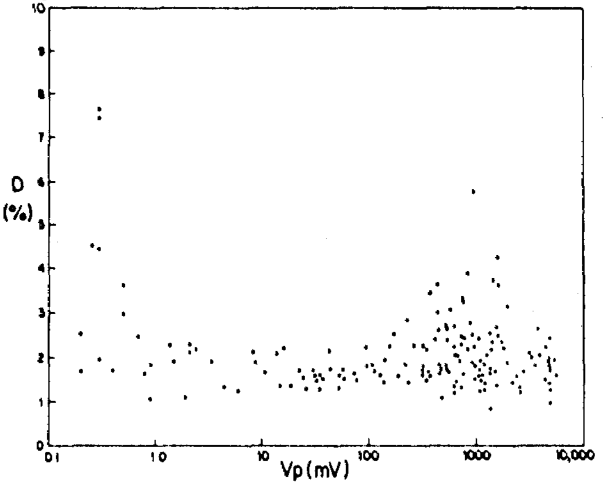


FIG. 7. Rms deviation as a function of primary voltage (V_p) for spectral fits from data shown in part in Figure 6.

Table 1. Spectral parameters, average values. Spectral parameter summary for different array geometries. The data set for the survey line is a portion of that shown in Figure 6.

	c			τ	D
Array	Host	Anomaly	Total	Agreement (%)	(%)
Pole-dipole	0.26	0.27	0.27	100	2.17
Dipole-dipole	0.27	0.29	0.28	88	2.59
Gradient	0.10	0.17	0.13	75	2.40

subtraction of the IP effect. The first measuring point at 4.5 ms after shut-off shows an anomalously high value. This value causes the large rms deviation seen for the IC component.

It was remarked earlier that impedances could be summed without excessive error if time constants were sufficiently different. Figure 5 shows the effective decomposition of a decay curve into IP and IC components where respective time constants are less than one order of magnitude apart. The difference in c values is influential in giving recognizably different forms.

In the example cited, the IC component has died out before seriously affecting the 10 point IP measurement from which the spectral IP parameters are determined. In extreme cases, inductive effects may persist and the early sample points of the 10 point IP decay will be corrupted. Spectral parameters determined without removal of such inductive effects may be unreliable. In such cases, the early-time measurement is important to the proper definition of IC effects, separation of IP and IC decays, and determination of spectral parameters.

Pseudosection plots

The results of a portion of a time-domain induced polarization survey are shown in Figure 6. Shown are the apparent resistivity (divided by 100) in Ω·m, the 8th slice chargeability (690 to 1 050 ms) in mV/V, the time constant in seconds, and the exponent c. Array geometry was pole-dipole, with a = 10 m. The current trailed the potential electrode string, the whole advancing to the right. The standard 10 point decay of the 2 s receive mode was used throughout.

The area is one of very resistive Precambrian basic volcanics with little or no overburden. The line segment shown passes into a broad zone of near-surface metallic sulfides of which pyrite is the most common.

Two distinct zones are seen in the pseudosections. The left-hand portion or host rock is an area of high resistivities and low chargeabilities. The right-hand portion is an area of extremely low resistivities and high chargeabilities. The ground is indeed so conductive under the "anomaly" as to reduce primary voltages below that point at which a reliable IP measurement can be made.

The time constant shows a strong correlation with the two zones. The time constant is uniformly low in areas of the host rock and uniformly high over the anomaly. The spatial stability of the calculated time constant is promising given the low inherent chargeabilities of the host and the sometimes low primary voltages over the anomaly.

The c values averaged 0.26 for the host and 0.27 for the anomaly. These exponent values compare well with the 0.25 value suggested by Pelton et al. (1978) as the most expected value.

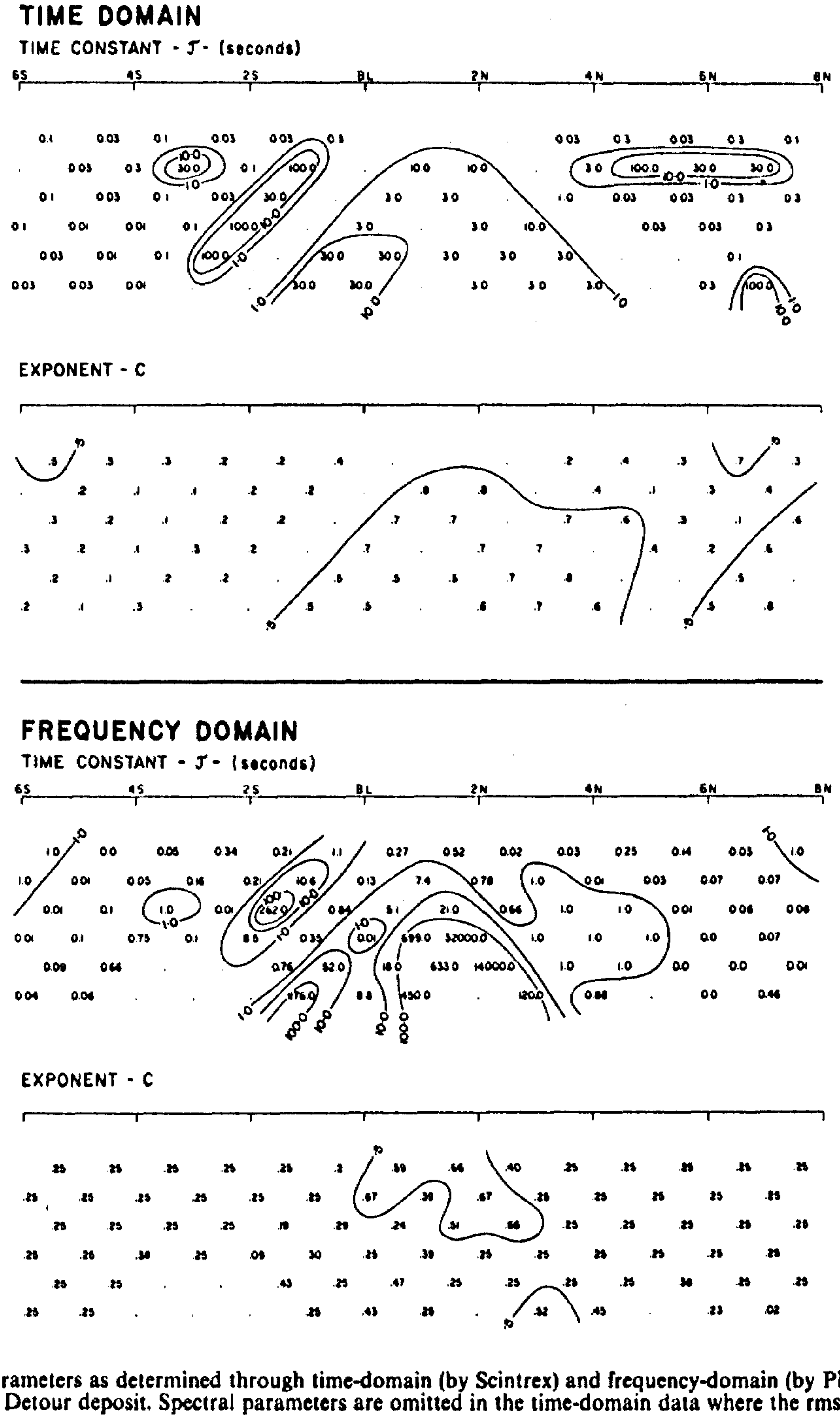
The distribution of rms deviations as a function of primary voltages is shown in Figure 7. In this example, the spectral fits are equally good down to primary voltages of 1 mV below which the rms deviations have become large, and the spectral IP results are judged unreliable.

The same line segment was surveyed with both dipole-dipole and gradient arrays. Average values of the c value for the three arrays used, for host and anomalous regions, are shown in Table 1. The time-constant agreement column shows the percentage of calculated time constants which are within a factor of three of those calculated using the pole-dipole array. The gradient array time constants are compared with the nearest plotted vertical average of time constants as determined using the pole-dipole array.

The calculated time constants are reasonably stable and independent of array geometry. The gradient array gives consistently lower c values. This is a reasonable result given that the primary field in the gradient array will, in general, energize a wider variety of polarizable targets. The measured decay may be the result of the superposition of responses of possibly different time constants from more than one source.

Comparison with frequency-domain spectral results

In 1981, Selco Mining Corporation contracted Scintrex Ltd. and Phoenix Geophysics Ltd. to conduct spectral IP surveys on five selected lines over the Detour deposit. Cole-Cole parameters were determined independently by Scintrex working in the time domain and by Phoenix working in the frequency domain. Array setups were in each case dipole-dipole with a = 100 m, n = 1 to 6. Surveys were completed within one month of each other over the same grid.



TIME DOMAIN

TIME CONSTANT - τ - (seconds)

EXPONENT - C

FREQUENCY DOMAIN

TIME CONSTANT - τ - (seconds)

EXPONENT - C

FIG. 8. Cole-Cole parameters as determined through time-domain (by Scintrex) and frequency-domain (by Phoenix) measurements over line 8 W of the Detour deposit. Spectral parameters are omitted in the time-domain data where the rms deviation exceeds 7.5 percent.

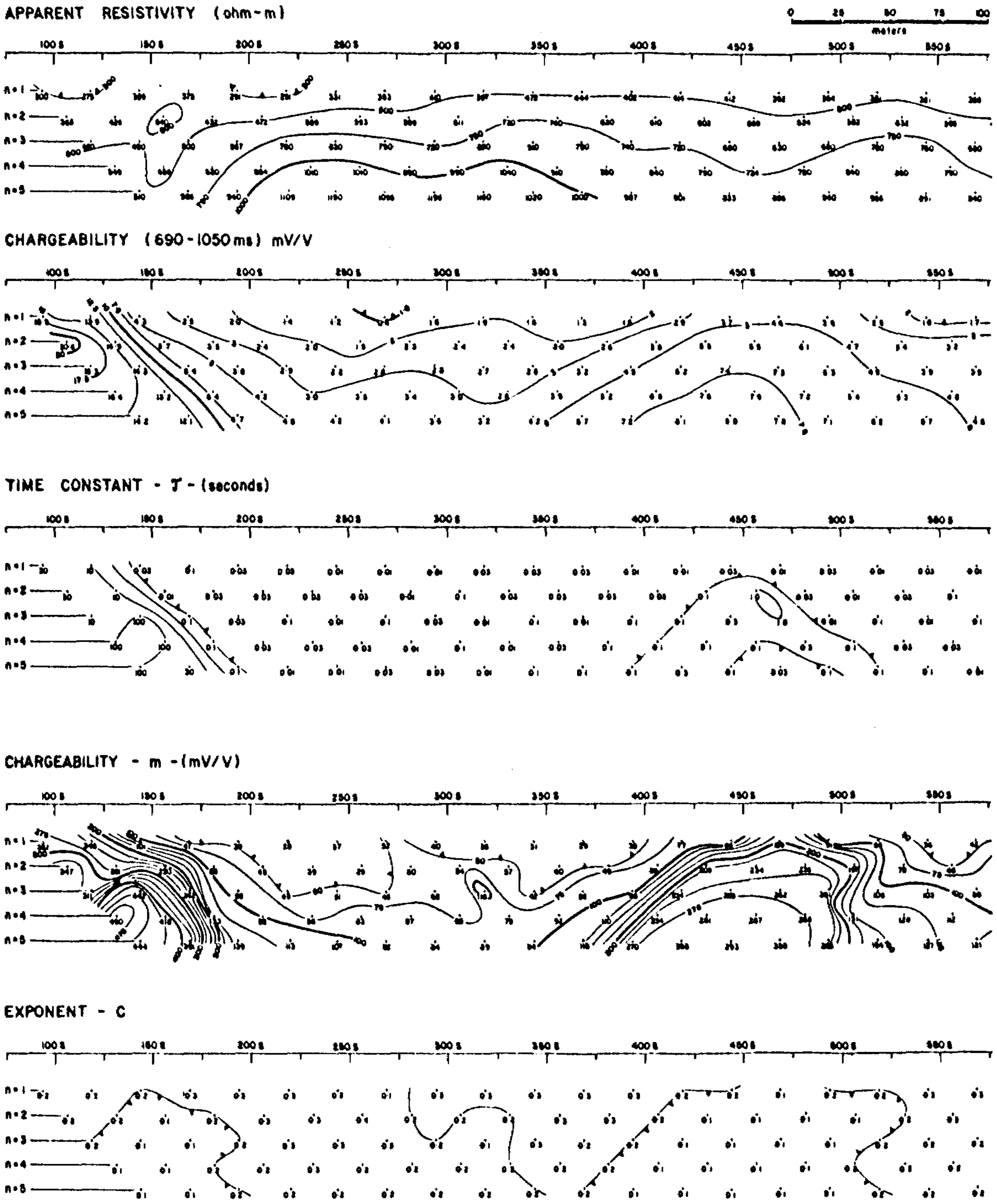


FIG. 9. Time-domain spectral IP results over a known gold producer. Deposit is centered some 50 m below station 450 S. An iron formation is located near the baseline.

The Detour zinc-copper-silver deposit is situated in the Abitibi volcanic belt in northwestern Quebec. Three mineralized zones have been identified. Most prominent metallic sulfides are sphalerite, pyrite, and to some extent chalcopyrite. The distribution patterns of zinc, copper, and silver are irregular at times and inconsistent.

The Cole-Cole parameters c and τ as determined by both methods for a portion of line 8 W are shown in pseudosection form in Figure 8. The line was traversed from north to south with the current dipole trailing. Economic mineralization is known at depths of 10 to 150 m and from stations 1 S to 3 N. Both methods produced a coincident apparent chargeability high/apparent resistivity low with anomalous values from 5 S to 7 N. From the time-domain data, average apparent chargeabilities (610 to 1 050 ms) were up to 3 mV/V away from the anomaly and, over 100 mV/V near station 1 N. Apparent resistivities were on the order of 1 000 to 3 000 $\Omega \cdot$ m (host) and less than 100 $\Omega \cdot$ m over limited segments of the anomaly.

Both pseudosection pairs in Figure 8 show relatively higher time constants and exponent values over the center of the deposit. A detailed comparison reveals a number of differences, some of which may be caused by the following. The time-domain data by current standards are noisy. Spectral parameters were not plotted when the rms deviation exceeded 7.5 percent. Even with this rather high cut-off a number of plot points in the time-domain pseudosection remain blank. Fixing the exponent in the frequency-domain analysis may affect the comparison.

This comparison suggests that both methods will produce spectral parameters which are at least roughly equivalent. Results of this type would be more informative if they were of better quality and more extensive. The work cited is, however, the only controlled in-field comparison of the two methods available at this time.

An exploration application

In 1983, the Ontario Geological Survey sponsored a series of geophysical surveys by Scintrex Limited over known gold deposits in the Beardmore-Geraldton greenstone belt. The results of this work are described in the open file report by Marcotte and Webster (1983). Part of this work involved an IPR-11 survey on five lines over the Jellicoe deposit. Earlier gold production came from a sheared silicified and brecciated zone of quartz stringers and veinlets hosted by arkose. Mineralization consists of gold and disseminated sulfides (pyrite, arsenopyrite, and sphalerite) up to 10 percent locally. The deposit is centered some 50 m subsurface. Overburden is moderately conductive and of 10 to 20 m thickness. The host rocks are Precambrian metasediments including arkose and greywacke. The deposit is some 200 m south of an extensive and prominent iron oxide formation.

The IP survey was carried out using a pole-dipole array with an a spacing of 25 m and $n = 1$ to 5. The results over one survey line are shown in pseudosection form in Figure 9. The apparent resistivity, eighth-slice chargeability, Cole-Cole time-constant, chargeability, and c value are shown in contoured pseudosection form.

The deposit is centered at station 450 S and is seen as a broad chargeability high. The apparent resistivity section shows no marked coincident low. At the extreme north end of the line a resistivity low and strong chargeability high are indicated. This is most probably an area of barren sulfides, probably pyrite associated with the iron formation.

The spectral IP results are interesting from a number of points of view. The time constant of the deposit is higher than the host and yet noticeably lower than that indicated by the barren sulfides near the baseline. The true chargeability pseudosection has amplified the anomaly over the deposit. The c values show an average value consistent with expectations. The low c values of 0.1 over the deposit suggest more than one Cole-Cole dispersion may be present.

CONCLUSIONS

A method for extracting Cole-Cole spectral parameters from routine time-domain IP measurements was developed, exercised, and applied. Resolution over a broad range of time constants was shown to be possible given time-domain decays from transmitted waveforms with a pulse time of 2 s. The apparent c values are governed in part by the type of array geometry used. Limited field tests demonstrated a coarse agreement with results seen in the frequency domain.

Independent of the direct use of the spectral parameters, the analysis procedure using the Cole-Cole model was found to give a number of useful side effects. The agreement between measured and theoretical decay curves is an excellent way to quantify the noise quality of the measured decay. Method performance using a 2 s pulse time suggests a maximum resolvable time constant of approximately 100 s. This may be used to predict pulse times required to resolve targets of longer time constants.

Further developments could make good use of a forward solution which can more adequately predict the spectral response of more complex geologic models. More field work involving both the time- and the frequency-domain spectral IP methods is required. More spectral IP data from surface and downhole surveys would extend our understanding of the method and would contribute to its evolution.

The method appears a promising one for systematic application to a variety of exploration problems. Field experience with the method should suggest the best uses of the information gained. Spectral IP results may be most useful when judged on a prospect-by-prospect basis. In-field spectral calibration through downhole and small-scale array studies and close liaison between geologists and geophysicists will be important.

ACKNOWLEDGMENTS

The cooperation of Selco, Campbell Resources, Geopeko, and the Ontario Geological Survey is greatly appreciated.

REFERENCES

Dey, A., and Morrison, H. F., 1973, Electromagnetic coupling in frequency and time domain induced polarization surveys over a multilayered earth: Geophysics, 38, 380–405.

Dolan, W. M., and McLaughlin, G. H., 1967, Considerations concerning measurement standards and design of IP equipment, parts I and II, *in* Proc. of the symposium on induced electrical polarization: Univ. of California, Berkeley, 2-31.

Gupta Sarma, D., Jain, S. C., and Reddy, B. S., 1981, True and apparent spectra of buried polarizable targets: Rep. no. IND/74/012-18, Nat. Geophys. Res. Inst., Hyderabad, India.

Hallof, P. G., and Pelton, W. H., 1980, The removal of inductive coupling effects from spectral IP data: Presented at the 50th Annual International SEG Meeting, November, in Houston.

Halverson, M. O., Zinn, W. G., McAlister, E. O., Ellis, R., and Yates, W. C., 1978, Some results of a series of geologically controlled field tests of broadband spectral induced polarization: Presented at the 48th Annual International SEG Meeting, November 1 in San Francisco.

Jain, S. C., 1981, Master curves for derivation of Cole-Cole parameters from multichannel time domain data: Rep. no. IND/74/012-20, Nat. Geophys. Res. Inst., Hyderabad, India.

Major, J., and Silic, J., 1981, Restrictions on the use of Cole-Cole dispersion models in complex resistivity interpretation: Geophysics, v. 46, 916-931.

Marcotte, D., and Webster, B., 1983, A report on geophysical surveys conducted in the Beardmore-Geraldton greenstone belt: Ontario Geol. Survey open-file rep. 5469.

Pelton, W. H., Ward, S. H., Hallof, P. G., Sill, W. P., and Nelson, P. H., 1978, Mineral discrimination and removal of inductive coupling with multifrequency IP: Geophysics, 43, 588-609.

Seigel, H. O., 1959, Mathematical formulation and type curves for induced polarization: Geophysics, 24, 547-565.

Swift, C. M., 1973, The L/M parameter of time domain IP measurements—A computational analysis: Geophysics, 38, 61-67.

Tombs, J. M. C., 1980, A study of induced polarization decay curves: Rep. no. 102, Inst. Geol. Sci. (London), Appl. Geophys. Unit, London.

——— 1981, The feasibility of making spectral IP measurements in the time domain: Geoexpl., 19, 91-102.

Wait, J. R., Ed., 1959, Overvoltage research and geophysical applications: Pergammon Press.

Voglesang, D., 1981, Relations of IP decay curve statistics and geology: Geophys. Prosp., 29, 288-297.

Wynn, J. C., and Zonge, K. L., 1977, Electromagnetic coupling: Geophys. Prosp., 25, 29-51.

Expanded Abstract

SPECTRAL IP: EXPERIENCE OVER A NUMBER OF CANADIAN GOLD DEPOSITS

By

Blaine Webster
JVX Limited
Toronto, Ontario

and

Ian Johnson
Scintrex Limited
Toronto, Ontario

February, 1985

Submitted to the Society of Exploration Geophysicists for consideration for inclusion into the technical program of the 55th Annual International Meeting of the SEG, Oct. 6-10, 1985, Washington, D.C.

SUMMARY

Time domain induced polarization survey results over a variety of Canadian volcanogenic gold deposits are presented. The results are accompanied by the interpreted spectral parameters and the usefulness of such parameters is discussed. A variety of geological interpretation problems are shown to be simplified by spectral IP survey results. The time constant may be used to map areas of fine grained disseminated metallic sulphides which experience has shown to be favourable targets for gold. The true chargeability may be used as a more accurate representation of the volume percent metallic sulphides. Spectral IP parameters may be used to prioritize areas which may appear uninteresting in conventional IP surveys.

SPECTRAL IP: EXPERIENCE OVER A NUMBER OF CANADIAN GOLD DEPOSITS

Discussions about spectral IP have appeared regularly in the literature for more than ten years. Despite a high academic profile, the method has failed to make a significant impact on routine IP surveys. The result to date has been a well developed theory with too few examples of application to exploration problems. Geophysicists remain unsure about cost benefits and cautious about recommending spectral analysis in their IP surveys.

This paper is intended to present data from a variety of surveys over a number of gold prospects. All are taken from essentially routine time domain surveys in which the spectral requirement was not considered important in advance and did not result in significant additional survey costs. It is intended that these examples will better illustrate the strengths and limitations of the method. The cost benefits are examined.

When conducting spectral IP surveys in the time domain, field procedures are effectively unaltered from conventional methods. That extra time required to produce the better quality data at each station is compensated for by the efficiencies of the new microprocessor controlled receivers. The spectral analysis which is done in the field on a microcomputer is of value in the first instance as a quality control device. Measured decays are compared to a suite of master curves. The comparison yields an rms deviation which is used by the operator to check data quality. Independent of the use of spectral parameters, spectral analysis is an essential tool in high quality production IP surveys. The spectral parameters so derived are, in essence, "free".

Spectral IP should therefore be viewed more as the next step in the natural evolution towards better IP/resistivity surveys and not as some exotic or hybrid technique suitable for special applications only. The latter is a more common attitude when using frequency domain techniques where production rates suffer from the requirement of sequential measurements at a number of frequencies.

Figure 1 shows the contoured chargeability data over the Jellicoe deposit in the Beardmore-Geraldton area of Ontario. The gold is found in a sheared silicified and brecciated zone of quartz stringers hosted by arkose. Disseminated metallic sulphides (mainly pyrite), with concentrations greater than 10 percent locally, are found in association with the gold. The deposit is centered some 60 m below surface and under some 10 to 20 m of moderately conducting transported overburden. Hole to hole correlation of the mineralization is often complicated by faulting and folding. An oxide iron formation lies 200 m north of the deposit.

The IP survey was done with a pole-dipole array employing an a spacing of 25 m and n values of 1 to 5. The Scintrex IPR-11 receiver was used with a two second pulse time.

The topmost contour map shows the seventh slice chargeability (690 to 1050 ms after shutoff) from the n=2 dipole. This type of presentation is common for conventional IP surveys. The deposit is roughly outlined by the 4 mV/V contour line in the center of the survey area. The largest IP response is moderate (less than 8 mV/V) above relatively low (less than 2 mV/V) background values. The pseudosections show this to be true for dipoles 2 to 5. There is no coincident resistivity response. The iron formation to the north is seen as a more prominent chargeability high. A pipeline running NE-SW gives an equally large response in the northwest corner of the area.

The lower contour map shows the Cole-Cole chargeability as derived from the spectral analysis of measured decays. The IP anomaly over the deposit is enhanced relative to background levels. The response is now more suited to that expected from some 15% sulphides by volume at these depths. The conventional IP response is quite modest and might be overlooked in a more complex electrical environment. The Cole-Cole chargeability is thus more sensitive to small variations in volume percent sulphides. The spectral IP presentation appears to define the complex structure of the deposit more so than conventional IP.

Figure 2 is taken from an IP survey in an area of Manitoba with a geological model similar to that described above - that is, gold in a relatively resistive environment in association with disseminated metallic sulphides adjacent to an iron formation. This type of model is thought to give an IP response characterized by:

- high apparent resistivities due to silicification
- higher chargeabilities due to the metallic sulphides
- short Cole-Cole time constants resulting from the fine-grained nature of the sulphides

Experience has shown this to be a promising IP signature for some types of volcanogenic gold deposits.

The IP survey was conducted using a pole-dipole array with an a spacing of 100 feet and n values of 1 to 6. The IPR-11 receiver was used with a two second pulse time.

The pseudosection in Figure 2 shows a broad chargeability high in an area of moderate to high apparent resistivities. The chargeability anomaly is quite wide and a drill location would be difficult to assign if no other information were available. The Cole-Cole time constants as determined from spectral analysis of the measured decays does show a segmentation of the IP anomaly into areas of different time constants. The areas of low time constant values are the preferred areas for follow-up.

Limited trenching has revealed a two foot thick zone of massive arsenopyrite and pyrite with pods of sphalerite and galena at station 29+50S. Prospecting away from the showing indicates disseminated sulphides. HLEM surveys over the same ground gave no response. Drilling is currently in progress.

The spectral IP results illustrate the possibility of mapping based solely on the IP characteristics (as opposed to volume percent) of metallic sulphides. Conventional IP data are handicapped by the inability to map these characteristics and by the mixing of different types of geological information, i.e. grain size and percent sulphides.

These and other examples which illustrate the use of time domain spectral IP data are presented. The spectral parameters so determined are shown to be important in assessing data quality and useful in interpreting IP survey results. With modern receivers and analysis techniques, the method is very cost-effective given the small additional cost associated with spectral IP in the time domain.

ACKNOWLEDGEMENTS

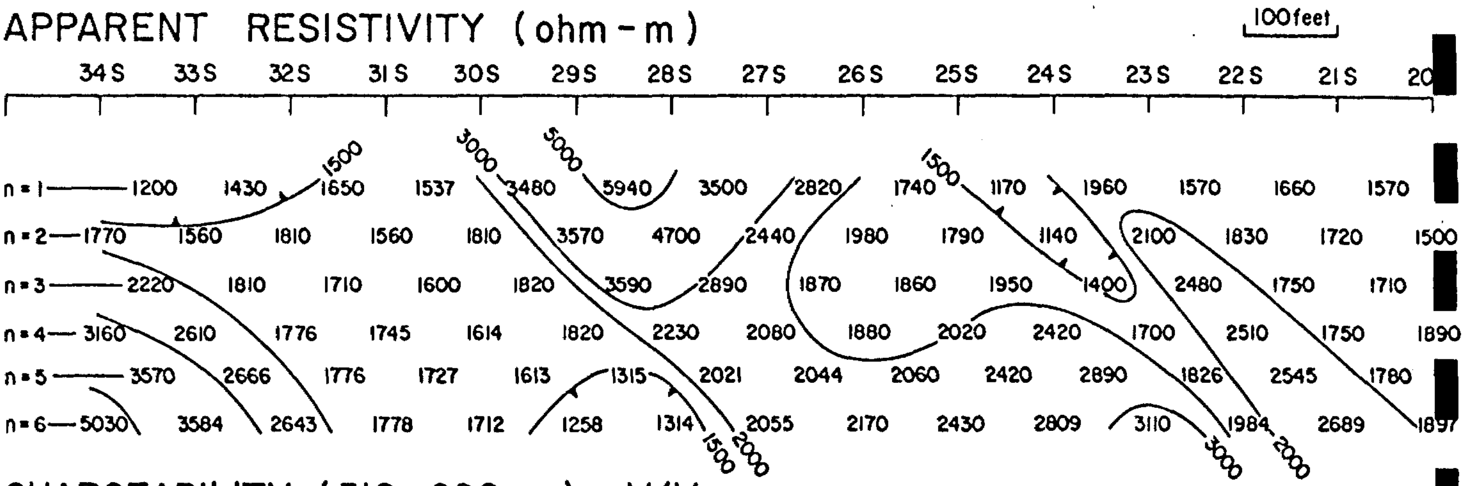
The cooperation of Dome Mines and Manitoba Mineral Resources Limited is gratefully acknowledged.

FIGURE CAPTIONS

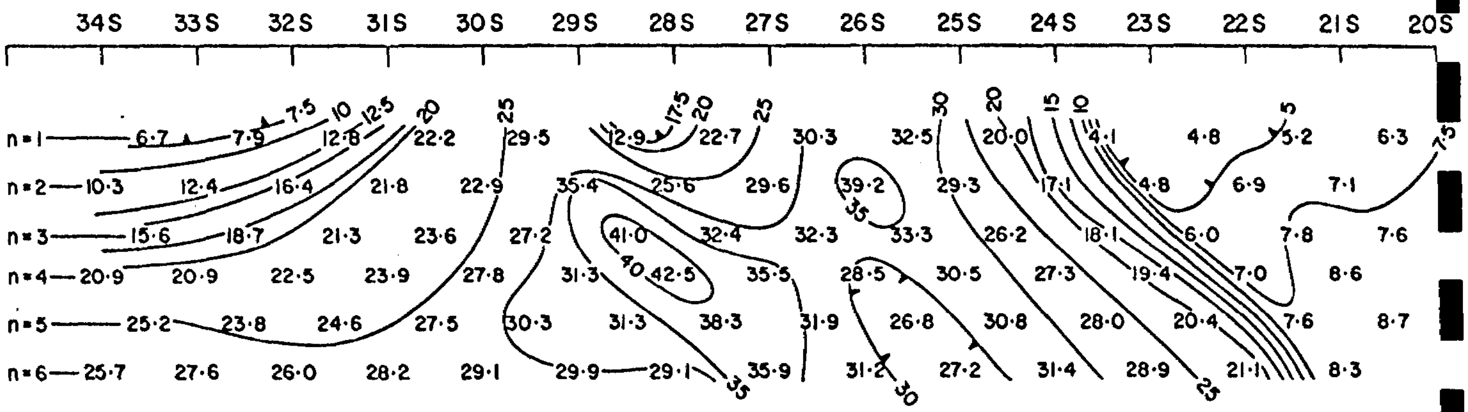
Figure 1: Contoured chargeabilities in mV/V. Pole-dipole array with a=25 m, n=1 to 5. Seventh slice IPR-11 (690 to 1050 ms after shutoff) data for the n=2 dipole shown in upper half. Cole-Cole chargeabilities in mV/V for the same area and dipole number shown below.

Figure 2: Pseudosections showing apparent resistivity, sixth slice IPR-11 (510 to 690 ms after shutoff) and Cole-Cole time constant. Pole-dipole array with a=100 feet and n values from 1 to 6.

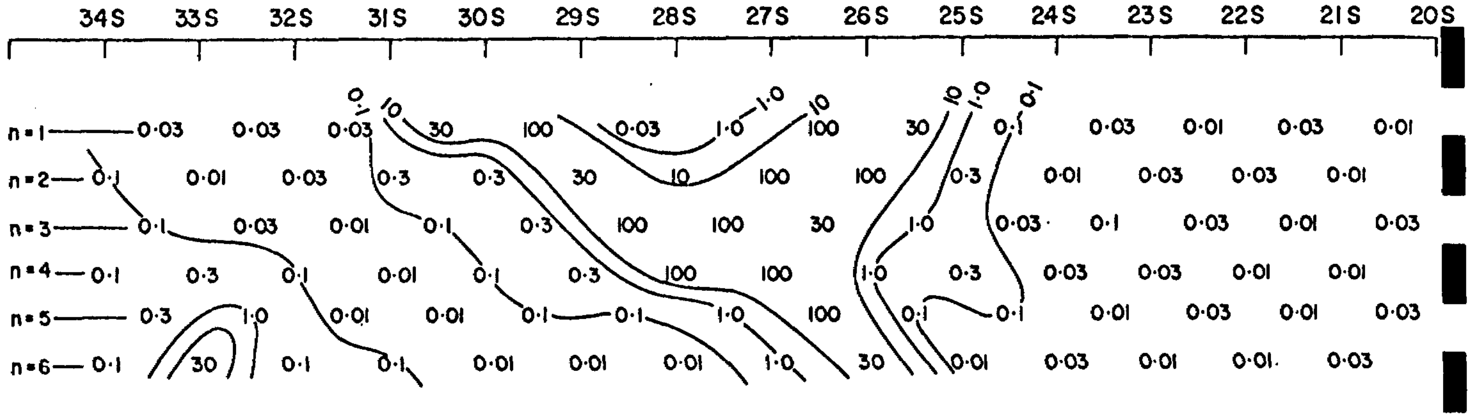
APPARENT RESISTIVITY (ohm-m)



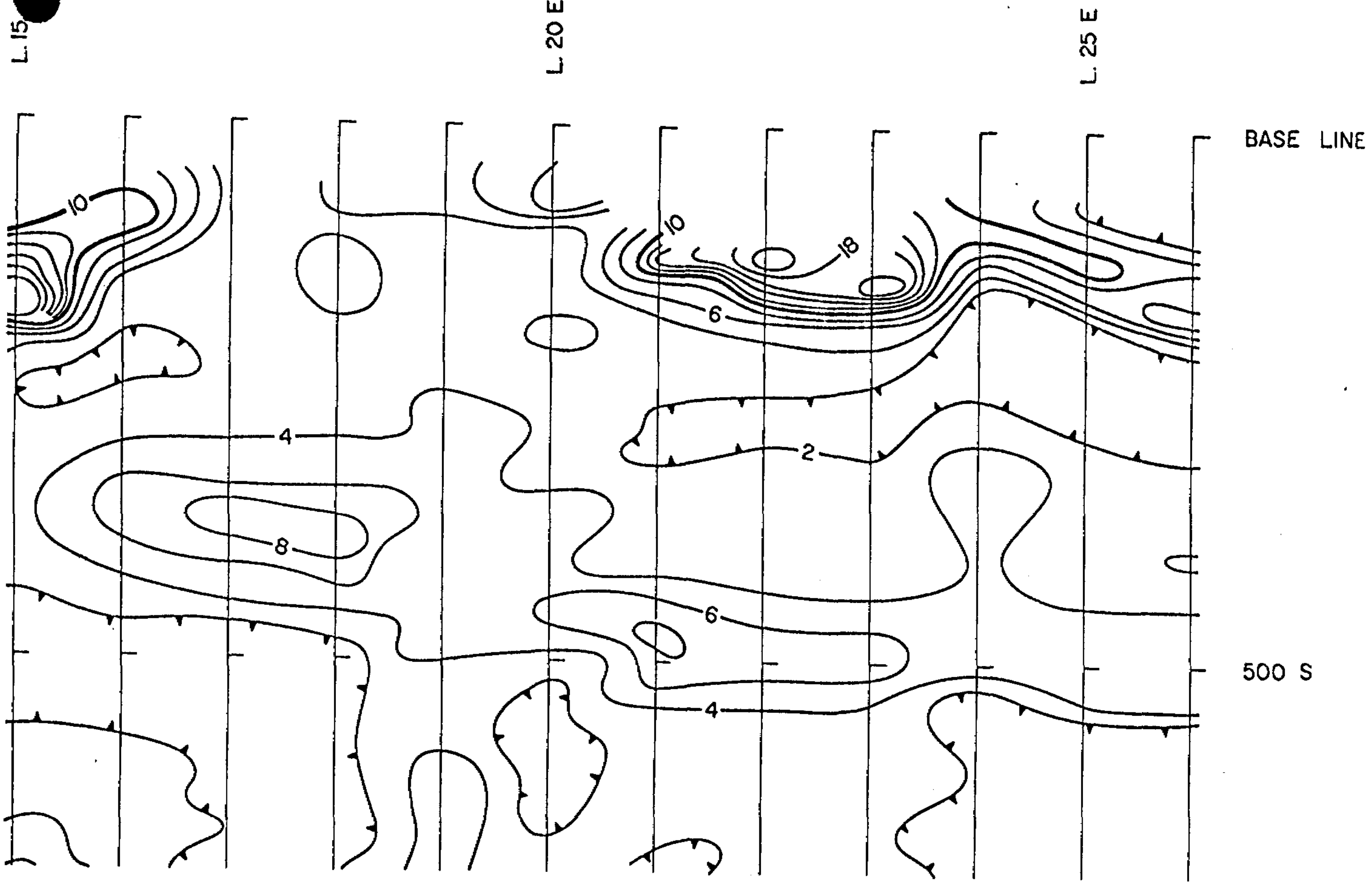
CHARGEABILITY (510-690ms) mV/V



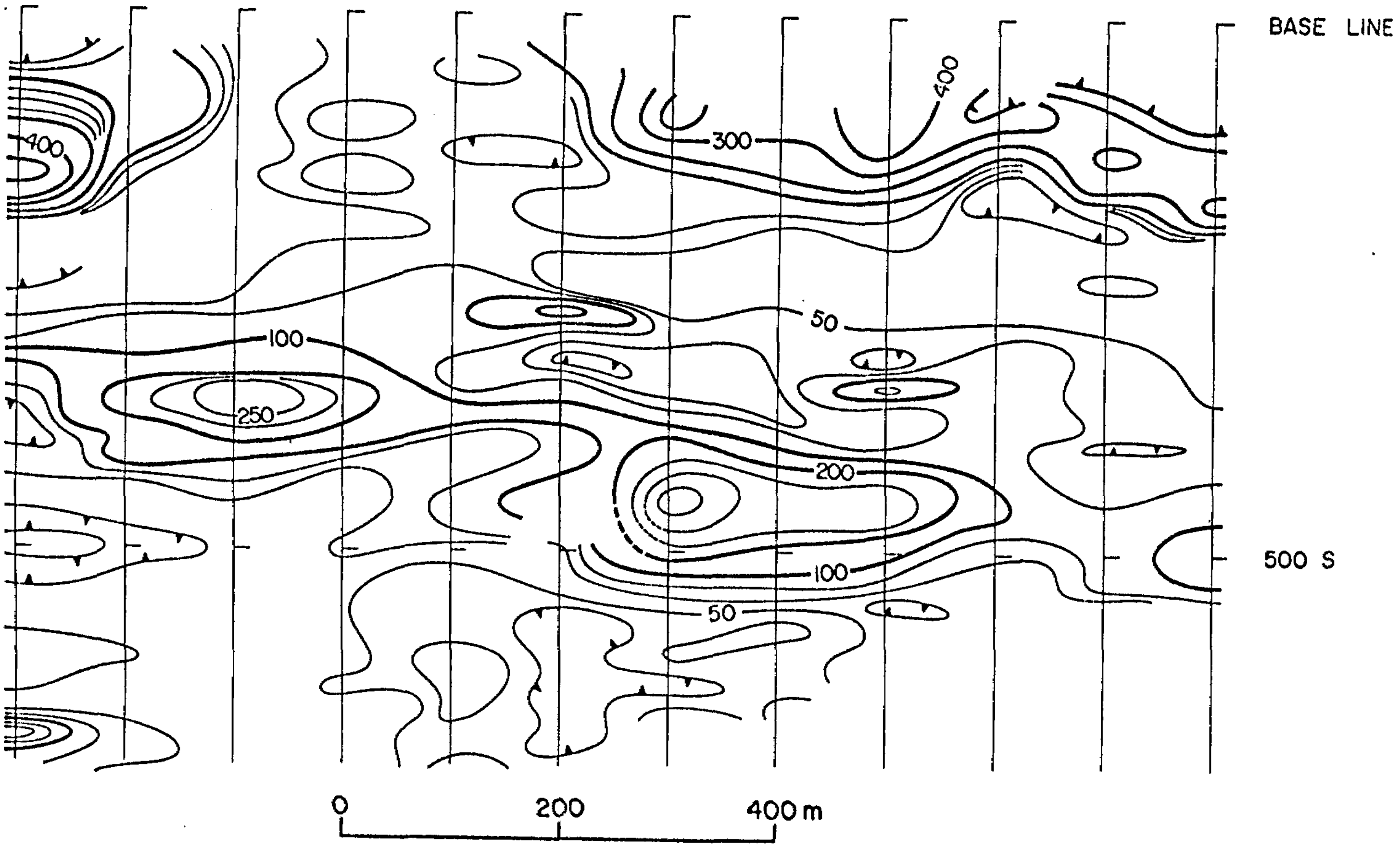
TIME CONSTANT - τ - (seconds)

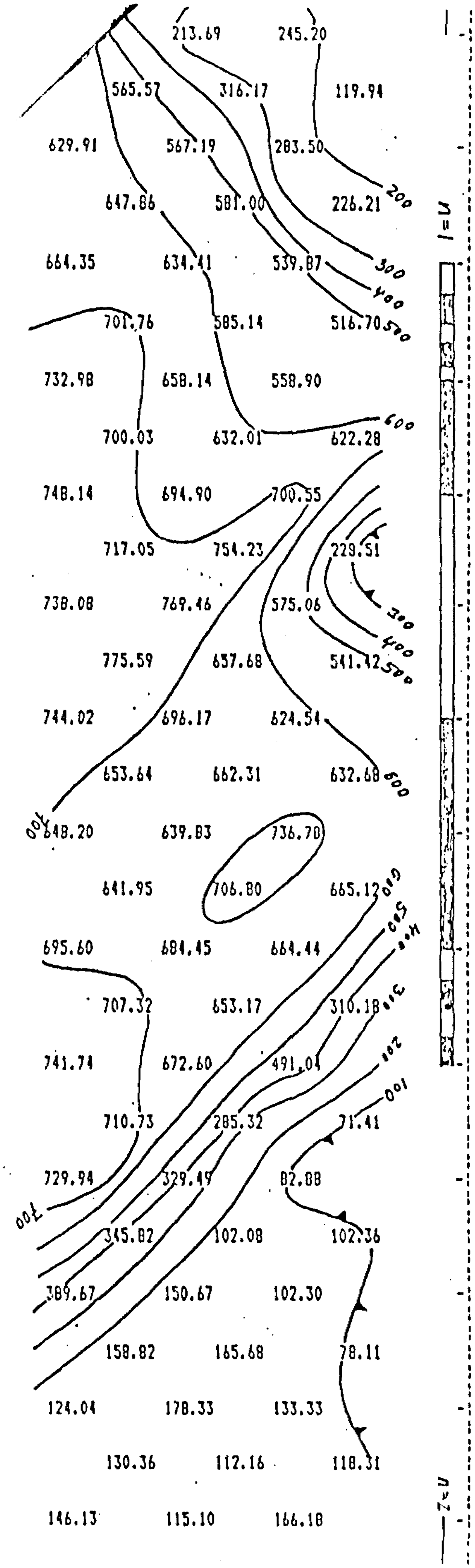


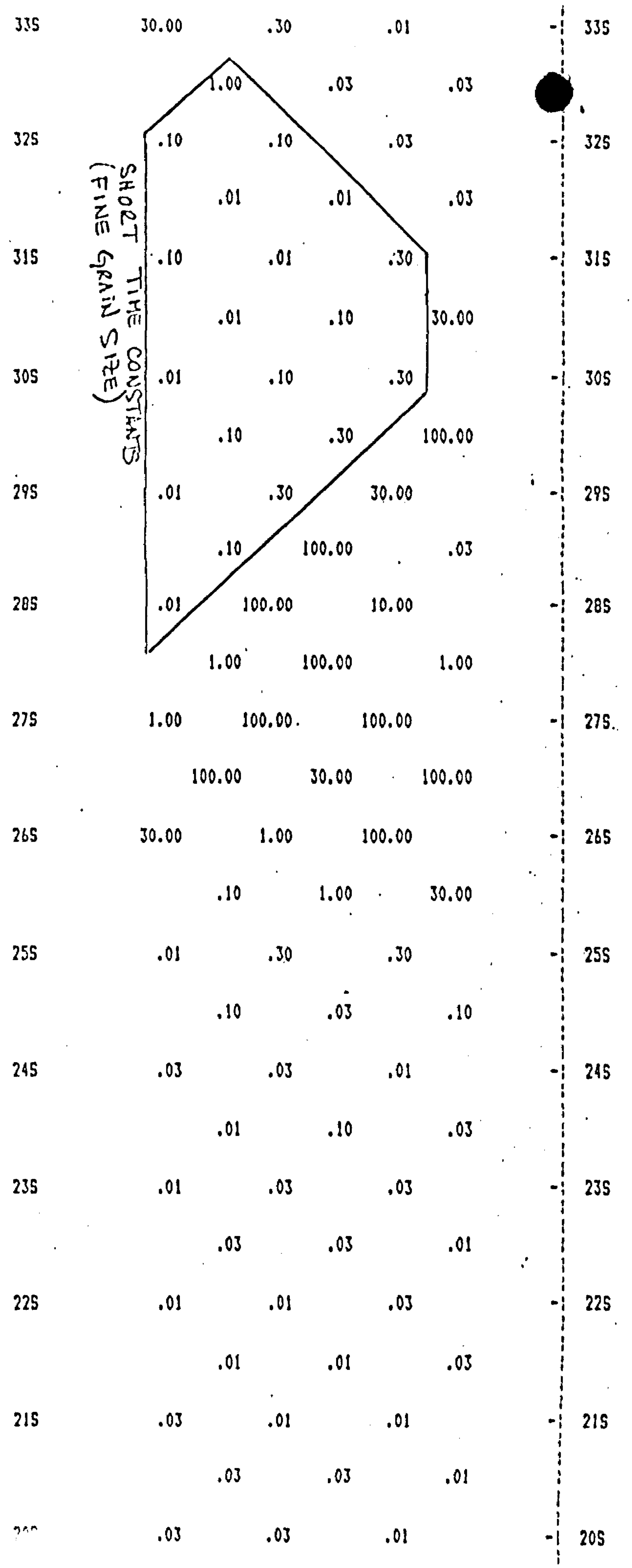
CONVENTIONAL CHARGEABILITY



SPECTRAL CHARGEABILITY







SHORT TIME CONSTANTS (FINE GRAIN SIZE)

33S	30.00		.30		.01		33S
		1.00		.03		.03	
32S	.10		.10		.03		32S
		.01		.01		.03	
31S	.10		.01		.30		31S
		.01		.10		30.00	
30S	.01		.10		.30		30S
		.10		.30		100.00	
29S	.01		.30		30.00		29S
		.10		100.00		.03	
28S	.01		100.00		10.00		28S
		1.00		100.00		1.00	
27S	1.00		100.00		100.00		27S
		100.00		30.00		100.00	
26S	30.00		1.00		100.00		26S
		.10		1.00		30.00	
25S	.01		.30		.30		25S
		.10		.03		.10	
24S	.03		.03		.01		24S
		.01		.10		.03	
23S	.01		.03		.03		23S
		.03		.03		.01	
22S	.01		.01		.03		22S
		.01		.01		.03	
21S	.03		.01		.01		21S
		.03		.03		.01	
[illegible]	.03		.03		.01		20S

Mar 3

Ministry of
Northern Development
and Mines
Ontario

[illegible]NDS

Report of Work

(Geophysical, Geological, Geochemical and Expenditures)

2

Minir

DOCUMENT No.
W8802·4

Instructions: – Please type or print.
– If number of mining claims traversed exceeds space on this form, attach a list.

52M01SW0006 2.10824 BALL TWP

900

Dean Creek Property

Type of Survey(s): Induced Polarization & Resistivity

Claim Holder(s): Inlet Resources Ltd.

T-4897

Address: 1275 Main St. W. North Bay, Ontario P1B 2W1

Survey Company: JVX Limited

Date of Survey (from & to): 11 09 87 / 03 10 87 (Day Mo. Yr. / Day Mo. Yr.)

Total Miles of line Cut:

Name and Address of Author (of Geo-Technical report): 33 Glen Cameron Rd. Unit #2 Thornhill, Ontario L3T 1N9

Credits Requested per Each Claim in Columns at right

Special Provisions	Geophysical	Days per Claim
For first survey: Enter 40 days. (This includes line cutting)	- Electromagnetic	
	- Magnetometer	
For each additional survey: using the same grid: Enter 20 days (for each)	- Radiometric	
	- Other IP.	20
	Res.	20
	Geological	
	Geochemical	

Man Days	Geophysical	Days per Claim
Complete reverse side and enter total(s) here	- Electromagnetic	
	- Magnetometer	
	- Radiometric	
	- Other	~~20~~ ~~20~~
	Geological	
	Geochemical	

RECEIVED
JAN 22 1988
MINING LANDS SECTION

Airborne Credits		Days per Claim
Note: Special provisions credits do not apply to Airborne Surveys.	Electromagnetic	
	Magnetometer	
	Radiometric	

RECEIVED
JAN 13 1988
RED LAKE MINING DIV.

Expenditures (excludes power stripping)

Type of Work Performed:

Performed on Claim(s):

Calculation of Expenditure Days Credits

Total Expenditures $ ÷ 15 = Total Days Credits

Instructions
Total Days Credits may be apportioned at the claim holder's choice. Enter number of days credits per claim selected in columns at right.

Date	Recorded Holder or Agent (Signature)
Jan. 11, 1988	Michelle Dubeau

Mining Claims Traversed (List in numerical sequence)

Prefix	Number	Expend. Days Cr.	Prefix	Number	Expend. Days Cr.
KRL	938863		KRL	938889	
	938864			938890	
	938865			938891	
	938866			938892	
	938867			938893	
	938868			938894	
	938869			938895	
	938870			938896	
	938871			938897	
	938872			938898	
	938873			938899	
	938874			938900	
	938875			904018	
	938876			904019	
	938880			964479	
	938881			964480	
	938882			964481	
	938883			964482	
	938884			964485	
	938885			964486	
	938886			964487	
	938887			964488	
KRL	938888		KRL	964489	

Total number of mining claims covered by this report of work: 55

For Office Use Only

Total Days Cr. Recorded	Date Recorded	Mining Recorder
2200	Jan 13/88	Barbara Thompson
	Date Approved as Recorded	Branch Director
		See revised work statement

Certification Verifying Report of Work

I hereby certify that I have a personal and intimate knowledge of the facts set forth in the Report of Work annexed hereto, having performed the work or witnessed same during and/or after its completion and the annexed report is true.

Name and Postal Address of Person Certifying: Noramco Explorations Inc. 1275 Main St W North Bay Ontario

KRL 904018

Date Certified	Certified by (Signature)
Jan. 11, 1988	Michelle Dubeau

1362 (85/12)

DEAN CREEK CLAIMS CONTINUED

CLAIM NUMBER	
KRL	964490
KRL	964491
KRL	964492
KRL	964493
KRL	967654
KRL	967655
KRL	967656
KRL	967657
KRL	967659

Ontario

Ministry of
Northern Development
and Mines

March 2,1988

Your File: W8802-4
Our File: 2.10824

Mining Recorder
Ministry of Northern Development and Mines
P.O. Box 324
Red Lake, Ontario
POV 2MO

ONTARIO GEOLOGICAL SURVEY
ASSESSMENT FILES
OFFICE
MAR 15 1988
RECEIVED

Dear Madam:

RE: Notice of Intent dated February 16, 1988
Geophysical (Induced Polarization) Survey
submitted on Mining Claims KRL-938863, et al
in the Township of Ball

The assessment work credits, as listed with the above-mentioned Notice of Intent, have been approved as of the above date.

Please inform the recorded holder of these mining claims and so indicate on your records.

Yours sincerely,

Cowan

W.R. Cowan, Manager
Mining Lands Section
Mines and Minerals Division

Whitney Block, Room 6610
Queen's Park
Toronto, Ontario
M7A 1W3

Telephone: (416) 965-4888

DV DK:pl
Enclosure: Technical Assessment Work Credits

cc: Mr. G.H. Ferguson
Mining & Lands Commissioner
Toronto, Ontario

Resident Geologist
Red Lake, Ontario

Inlet Resources Ltd.
1275 Main Street W.
North Bay, Ontario
P1B 2W7

Ministry of
Northern Development
and Mines
Ontario

Technical Assessment Work Credits

File	2.10824
Date	February 16, 1988
Mining Recorder's Report of Work No.	W8802-4

Recorded Holder: Inlet Resources Ltd.

Township XXXX: Ball

Type of survey and number of Assessment days credit per claim	Mining Claims Assessed
Geophysical	KRL - 938864
Electromagnetic ______ days	938867 to 71 inclusive
Magnetometer ______ days	938874 to 76 inclusive
Radiometric ______ days	938880 to 83 inclusive
Induced polarization 15 days	938885 to 93 inclusive
Other ______ days	938896 to 98 inclusive
Section 77 (19) See "Mining Claims Assessed" column	904018-19
Geological ______ days	967654 to 57 inclusive
Geochemical ______ days	967659
Man days ☐ Airborne ☐	
Special provision ☒ Ground ☒	
☒ Credits have been reduced because of partial coverage of claims.	
☐ Credits have been reduced because of corrections to work dates and figures of applicant.	

Special credits under section 77 (16) for the following mining claims

No credits have been allowed for the following mining claims

☒ not sufficiently covered by the survey	☒ insufficient technical data filed
KRL-938863	KRL-964479 to 82 inclusive
938865-66	964485 to 93 inclusive
938872-73	
938884	
938894-95	
938899-900	

No additional credits approved for the Resistivity as this is part of the Induced Polarization Survey.

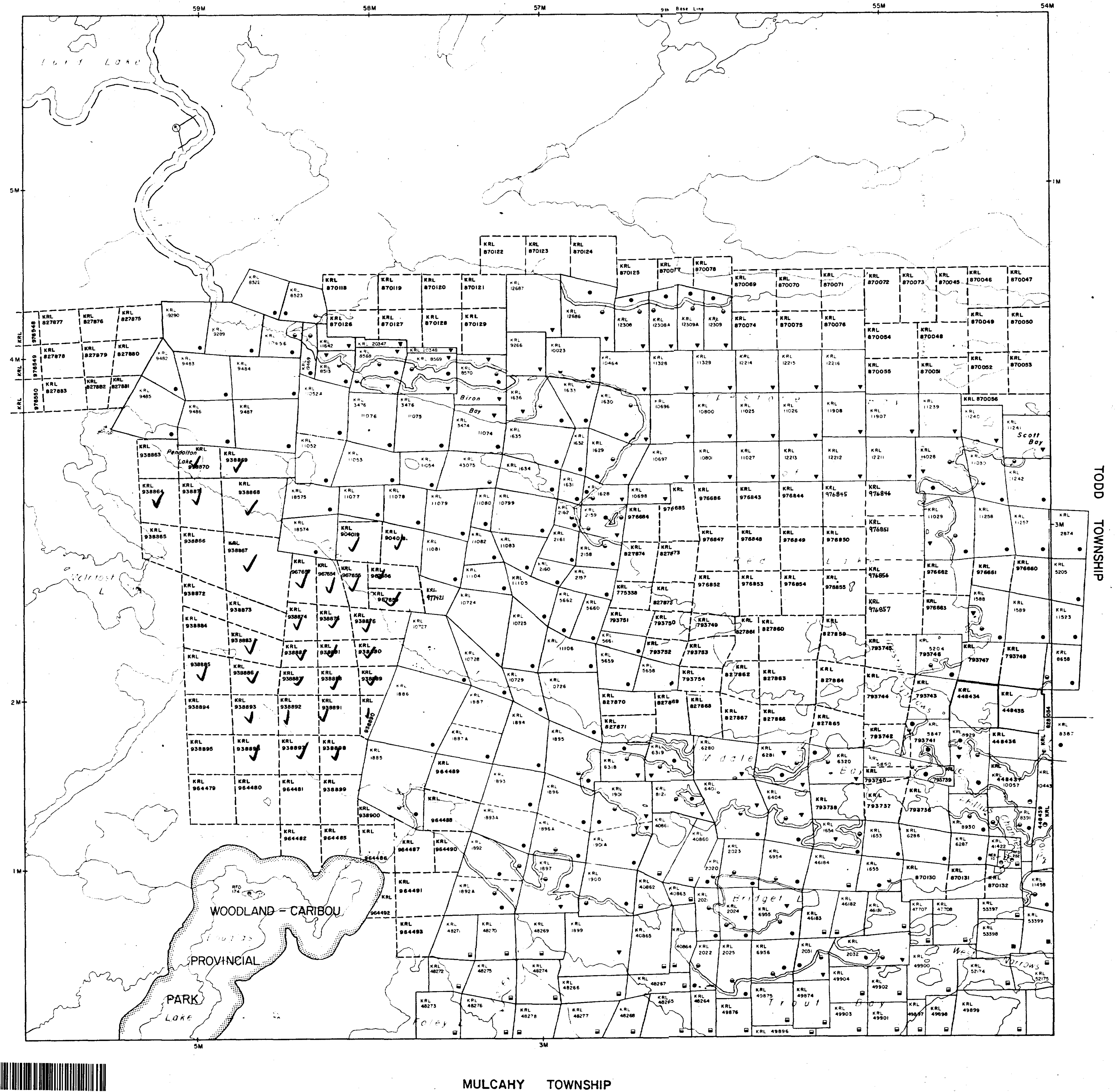
The Mining Recorder may reduce the above credits if necessary in order that the total number of approved assessment days recorded on each claim does not exceed the maximum allowed as follows: Geophysical - 80; Geologocal - 40; Geochemical - 40; Section 77(19) - 60.

828 (85/12)

AREAS WITHDRAWN FROM DISPOSITION

M.R.O. – MINING RIGHTS ONLY
S.R.O. – SURFACE RIGHTS ONLY
M.+S. – MINING AND SURFACE RIGHTS

Description	Order No.	Date	Disposition	File
(R1) PROPOSED PARK RES.		77/10/28	M&S	171523
R2	W7a/5	57		M+O



52H01SW0006 2.10824 BALL TWP

200

LEGEND

HIGHWAY AND ROUTE No	
OTHER ROADS	
TRAILS	
SURVEYED LINES	
TOWNSHIPS, BASE LINES, ETC	
LOTS, MINING CLAIMS, PARCELS, ETC	
UNSURVEYED LINES	
LOT LINES	
PARCEL BOUNDARY	
MINING CLAIMS ETC	
RAILWAY AND RIGHT OF WAY	
UTILITY LINES	
NON-PERENNIAL STREAM	
FLOODING OR FLOODING RIGHTS	
SUBDIVISION OR COMPOSITE PLAN	
RESERVATIONS	
ORIGINAL SHORELINE	
MARSH OR MUSKEG	
MINES	⚒
TRAVERSE MONUMENT	◆

DISPOSITION OF CROWN LANDS

TYPE OF DOCUMENT	SYMBOL
PATENT, SURFACE & MINING RIGHTS	●
SURFACE RIGHTS ONLY	◒
MINING RIGHTS ONLY	◓
LEASE, SURFACE & MINING RIGHTS	■
SURFACE RIGHTS ONLY	⬒
MINING RIGHTS ONLY	⬓
LICENCE OF OCCUPATION	▼
ORDER IN COUNCIL	OC
RESERVATION	ⓡ
CANCELLED	⊗
SAND & GRAVEL	ⓢ

NOTE MINING RIGHTS IN PARCELS PATENTED PRIOR TO MAY 6, 1913, VESTED IN ORIGINAL PATENTEE BY THE PUBLIC LANDS ACT, R.S.O. 1970, CHAP. 380, SEC. 63, SUBSEC. 1

Metres 500 0 1000 Metres
Chains 10 0 10 20 30 40 50 60 70 Chains
Feet 500 0 1000 2000 3000 4000 5000 Feet

SCALE 1:20 000

RED LAKE MINING DIVISION
OCT 23 1987
RED LAKE, ONTARIO

JUL 17
RED LAKE MINING DIV.

TOWNSHIP

BALL

M N R ADMINISTRATIVE DISTRICT

RED LAKE

MINING DIVISION

RED LAKE

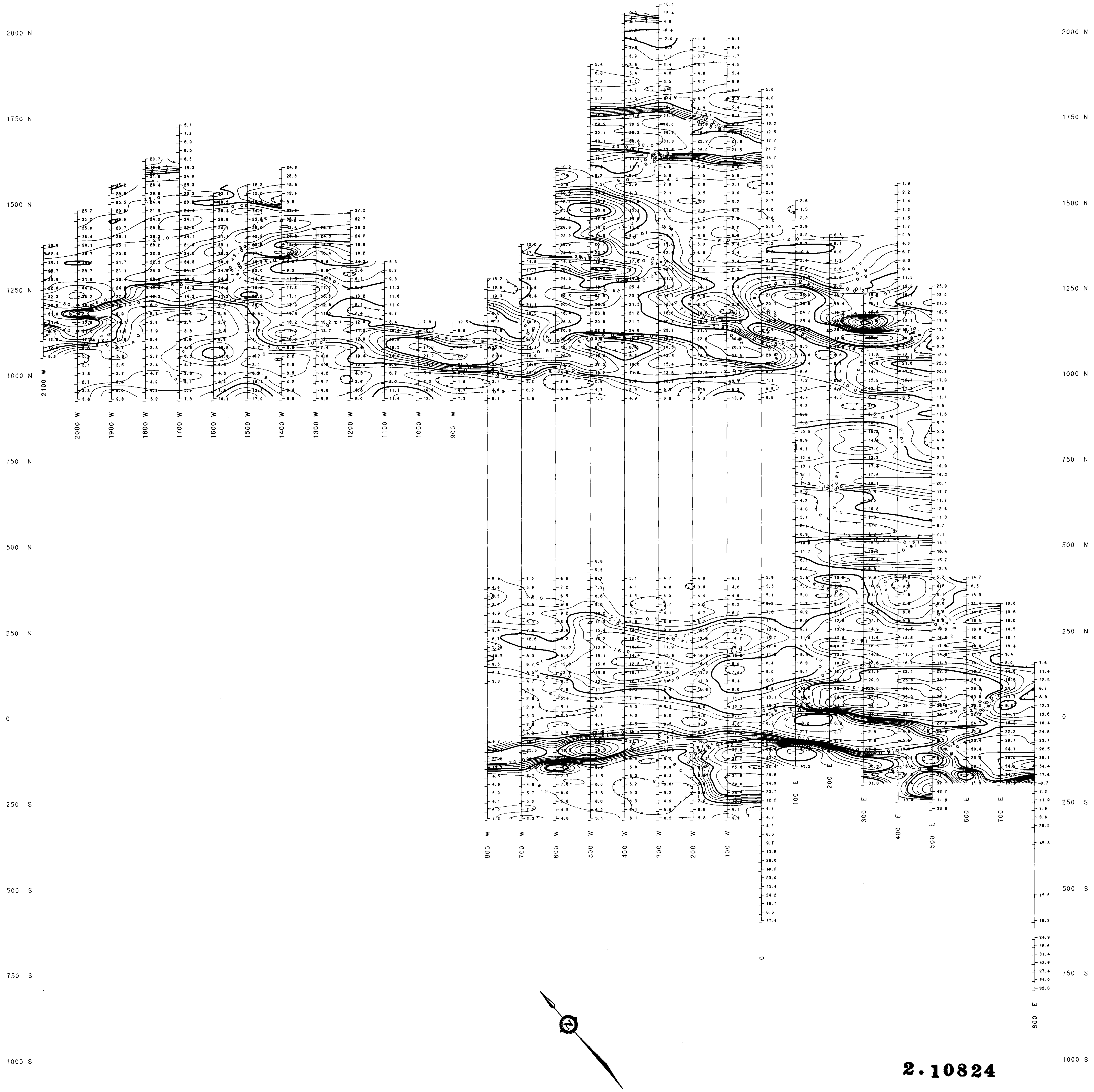
LAND TITLES / REGISTRY DIVISION

KENORA (Patricia Portion)

Ontario
Ministry of Natural Resources
Ministry of Northern Development and Mines

Date SEPTEMBER 1986

Number G-3740



2.10824

LEGEND

CHARGEABILITY CONTOUR
0,10,20,30...mV/V ____________________ ～
2,4,6,8,12,14...mV/V ____________________ ～
DEPRESSION ____________________ ～

NORAMCO EXPLORATIONS INC.

DEAN CREEK PROPERTY
RED LAKE WEST AREA, NORTHWESTERN ONTARIO

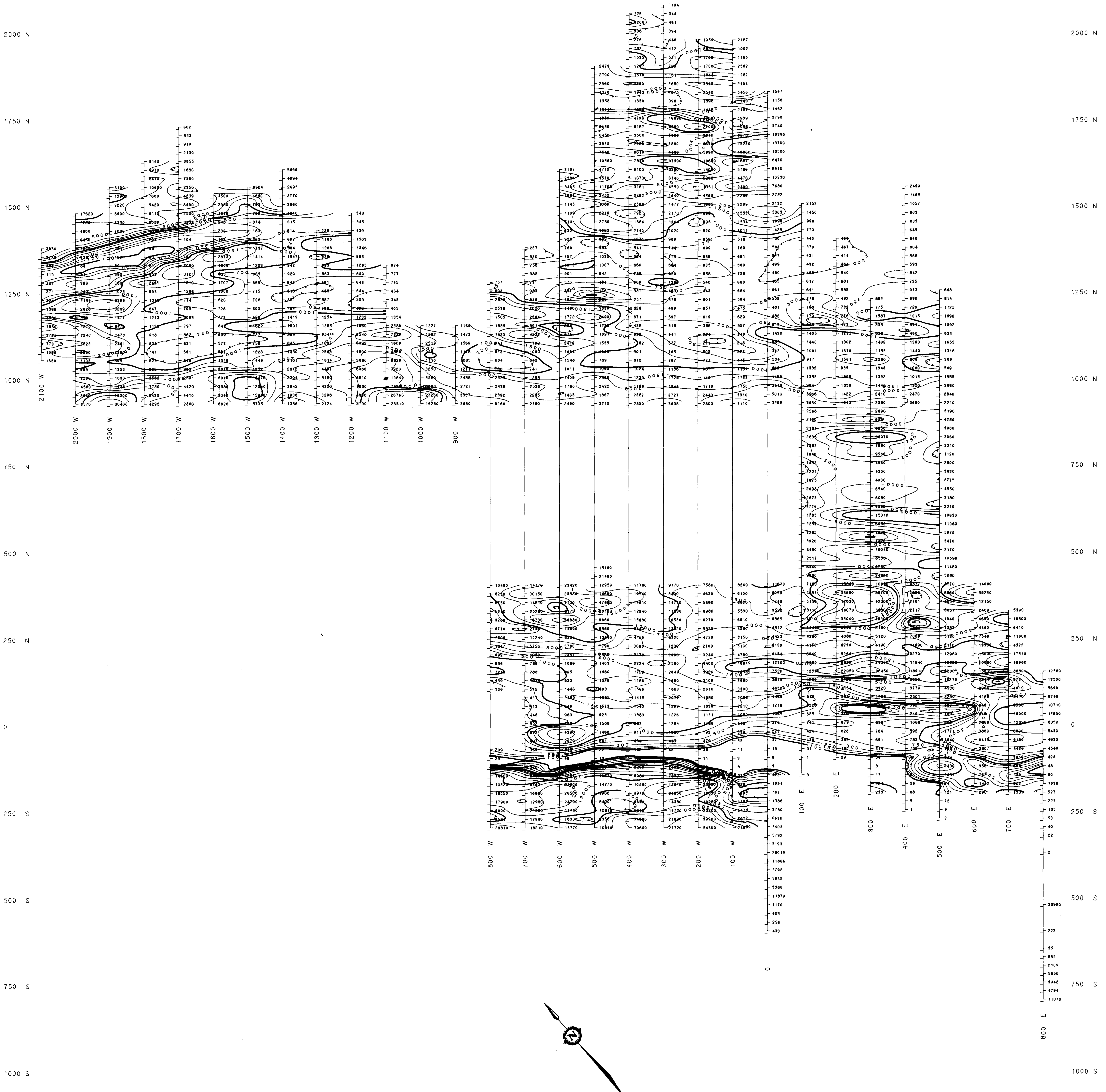
CHARGEABILITY (M7) CONTOUR MAP
POLE-DIPOLE ELECTRODE ARRAY
N=2, A=25M
SCINTREX IPR-11 RECEIVER
SCINTREX IPC-7 2.5 KW TRANSMITTER

SCALE 1 : 5000

SURVEY BY
JVX LTD.
OCTOBER, 1987

PLATE 1

210



2.10824

NORAMCO EXPLORATIONS INC.

DEAN CREEK PROPERTY
RED LAKE WEST AREA, NORTHWESTERN ONTARIO

RESISTIVITY (RHO) CONTOUR MAP
POLE-DIPOLE ELECTRODE ARRAY
N=2, A=25M
SCINTREX IPR-11 RECEIVER
SCINTREX IPC-7 2.5 KW TRANSMITTER

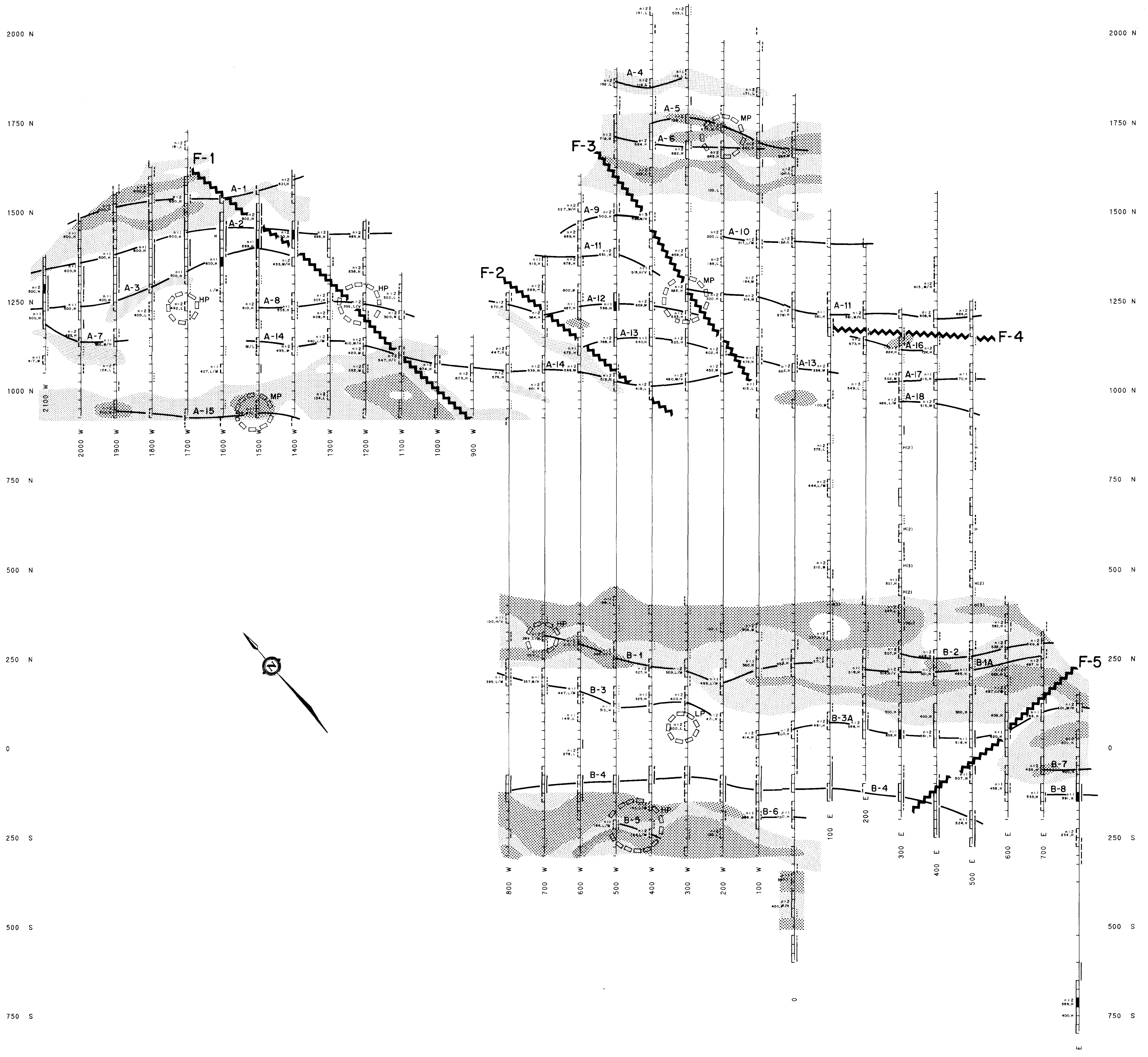
SCALE 1 : 5000

SURVEY BY
JVX LTD.
OCTOBER, 1987

PLATE 2

LEGEND

RESISTIVITY CONTOUR IN MULTIPLES (*1, *10, *100, etc.) OF
10 ohm-m ____________________ 〜
1·5, 2, 3, 5, 7·5 ohm-m ______________ 〜
DEPRESSION ____________________ 〜



ANOMALY LEGEND

CHARGEABILITY ANOMALY	RESISTIVITY ANOMALY
VERY STRONG ▌	⋮ VERY WEAK
STRONG |	H(2) - High resistivity, n=2
MEDIUM ╻ M-IP(mV/V)-181,L/V Time constant - Low/Variable	VH(1) - Very high resistivity, n=1
WEAK ⋮	

HIGH APPARENT RESISTIVITY (>3000 ohm-m)__________ ░

VERY HIGH APPARENT RESISTIVITY (>10,000 ohm-m)______ ▒

GEOLOGIC FAULT___________________________F-4 ⩘⩘⩘

ANOMALOUS CHARGEABILITY ZONES AXES_______A-2 ——

HIGH PRIORITY TARGET ZONES________________MP ⬭

2.10824 Ball Twp

NORAMCO EXPLORATIONS INC.

DEAN CREEK PROPERTY
RED LAKE WEST AREA, NORTHWESTERN ONTARIO

COMPILATION MAP

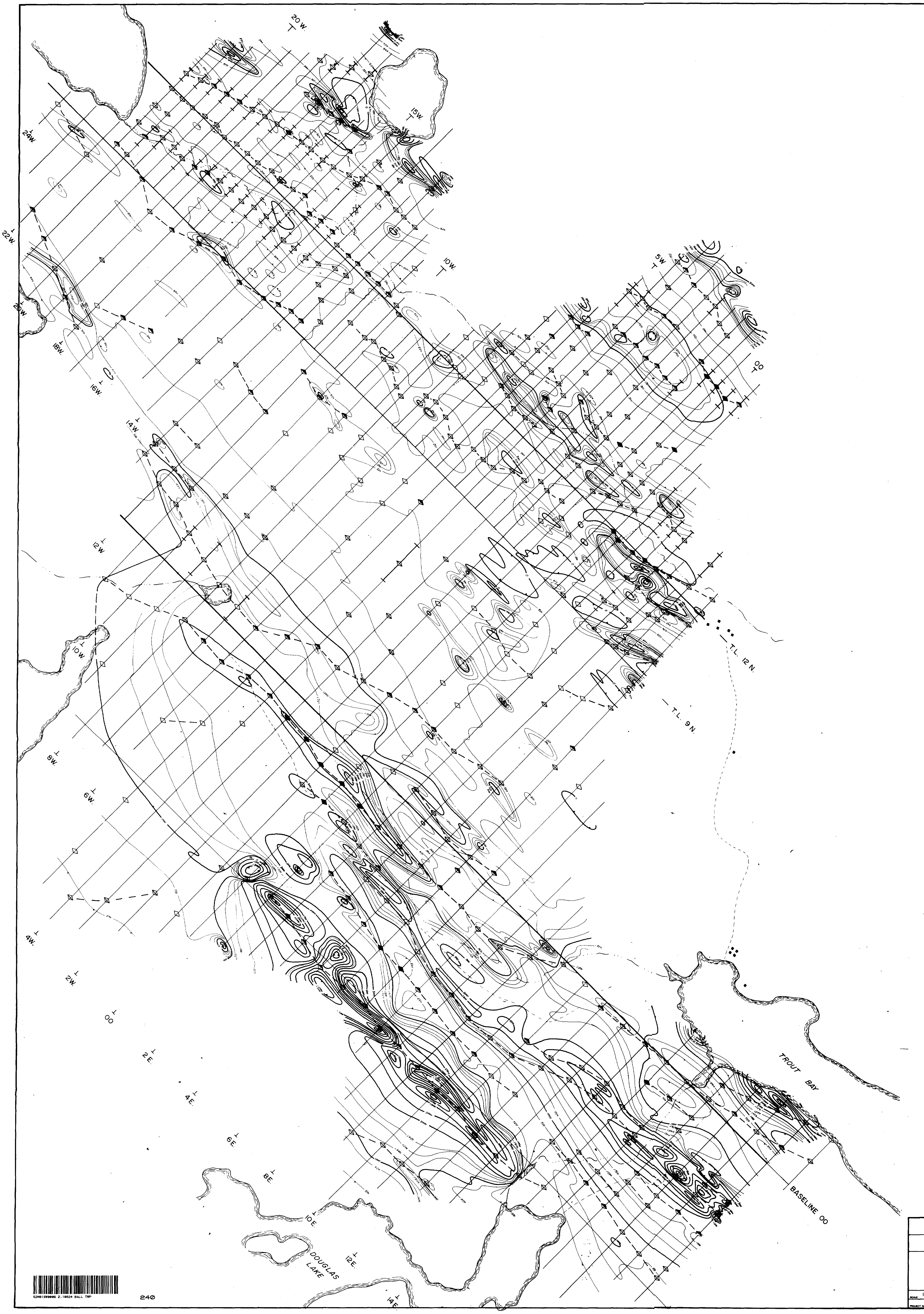
SCALE 1 : 5000

SURVEY BY
JVX LTD.
OCTOBER, 1987

PLATE 3

Ball

230



LEGEND

◇ - -	VLF EM CONDUCTOR – INDETERMINATE
◇	VLF EM CONDUCTOR – LOW CONDUCTIVITY-THICKNESS (< 2 SIEMENS)
⬗	VLF EM CONDUCTOR – MEDIUM CONDUCTIVITY-THICKNESS (2-15 SIEMENS)
◆	VLF EM CONDUCTOR – HIGH CONDUCTIVITY-THICKNESS (>15 SIEMENS)
⌶	WIDE CONDUCTOR
— — —	VLF EM TREND

25,000nt (add 60,000nt to all values)
20,000
15,000
10,000
5000
3000
1750, 1500, 1250 1750, 1500, 1250
1000
750
500
250
0
-1000
-2000
-3000

2.10823 Ball Twp

0 100 200 300 400 500

NORAMCO EXPLORATIONS INC.

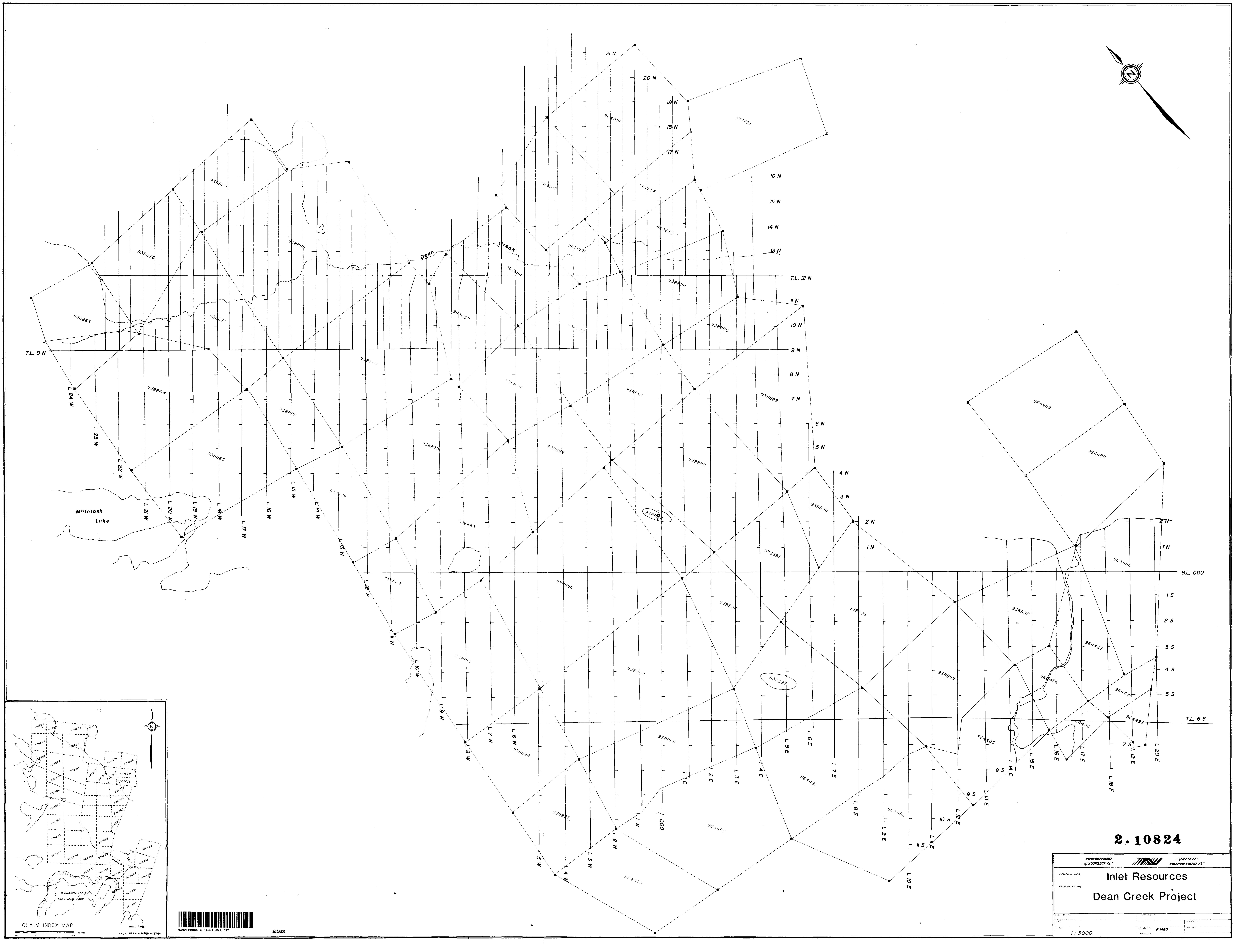
DEAN CREEK AREA

GEOPHYSICAL COMPILATION

PATTERSON MINING GEOPHYSICS LTD.

SCALE 1 : 5000	DATE 09 / 1987	DRAWN BY DrafTECH	
PROJECT No.	DRAWING No. 12	CHECKED BY	

240



52H01SW0006 2.10824 BALL TWP

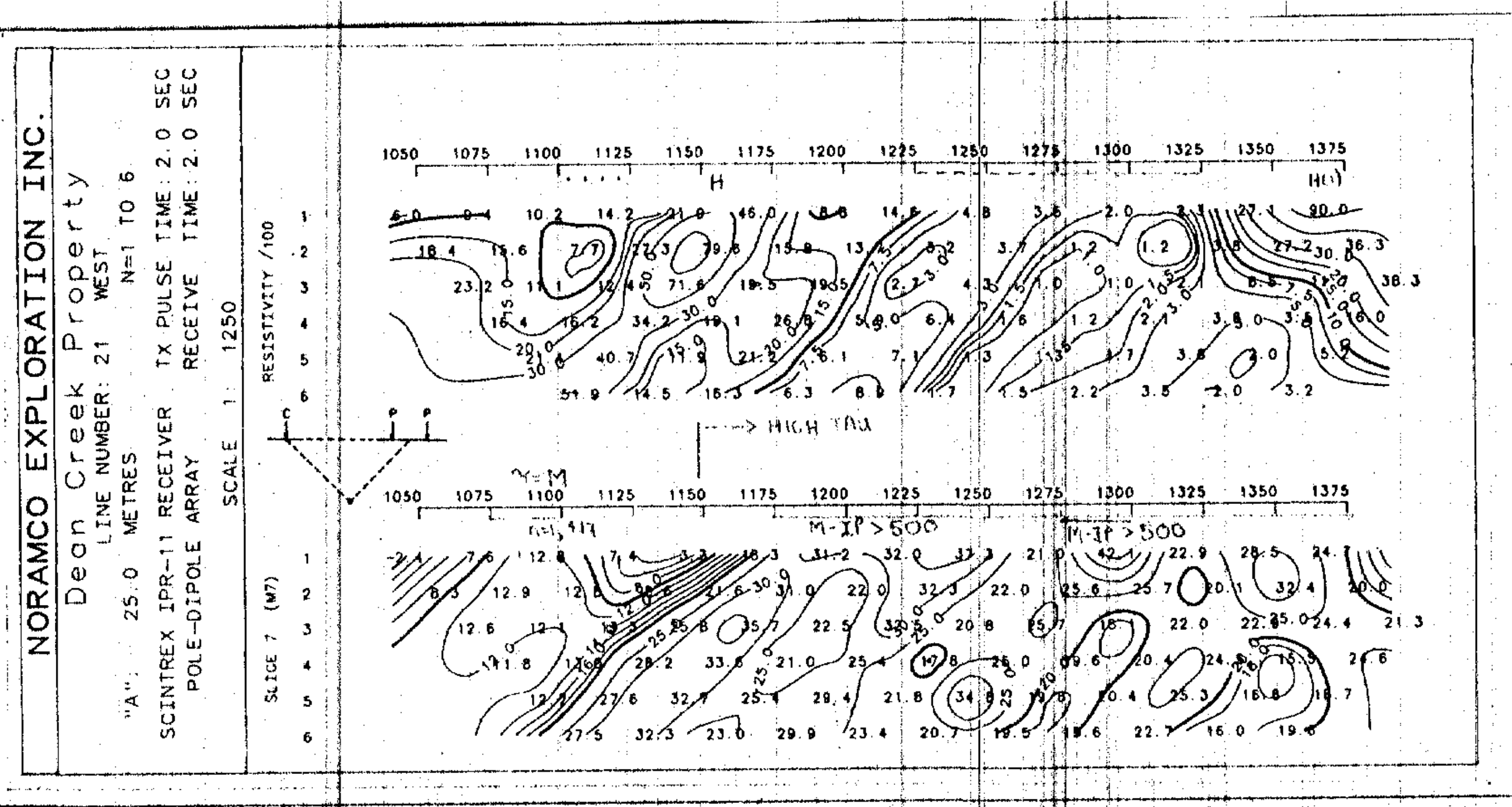
250

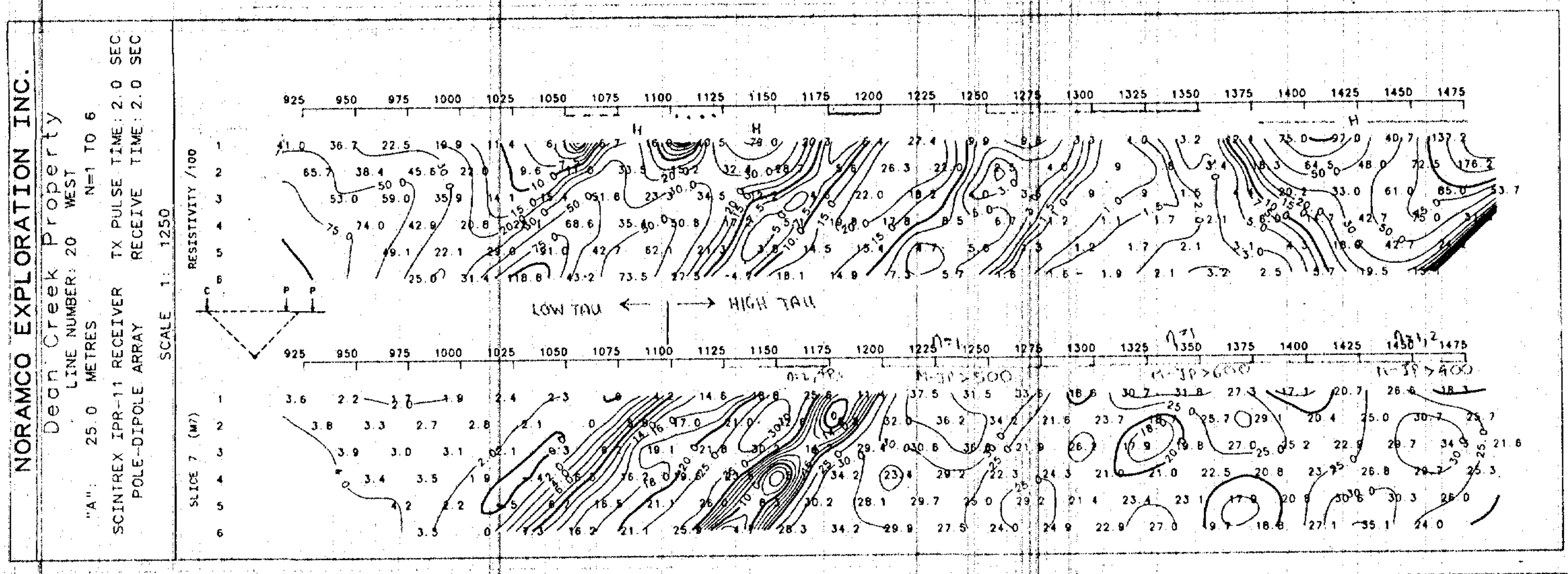
2.10824

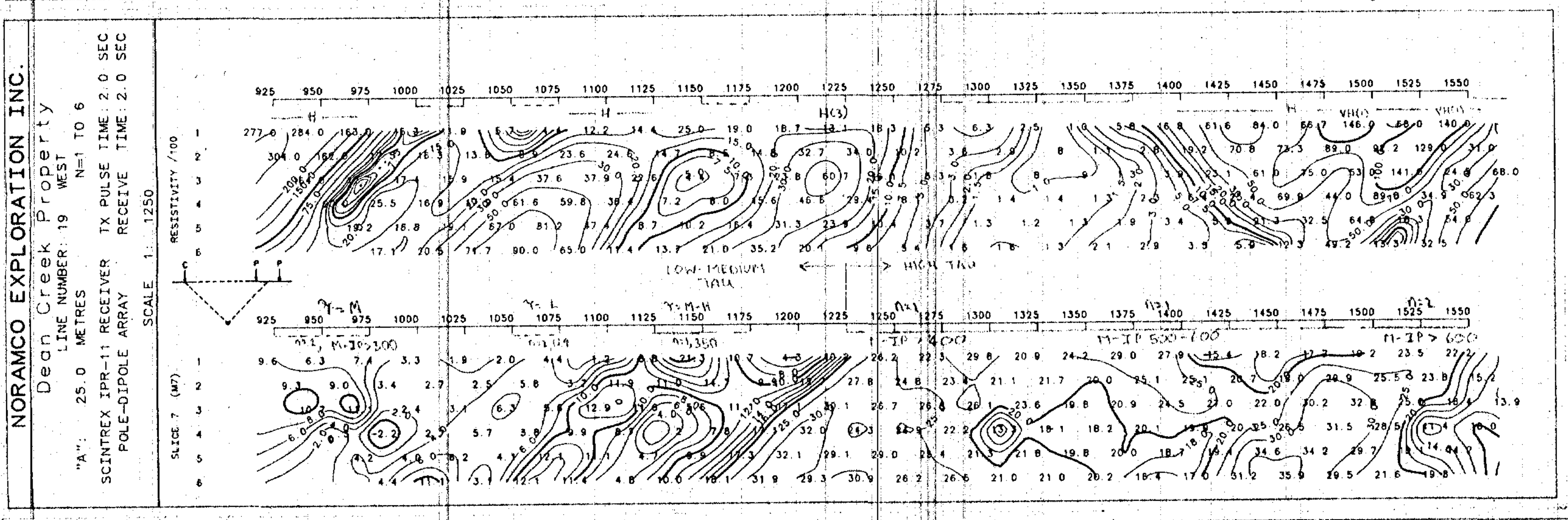
noramco explorations inc
explorations noramco inc

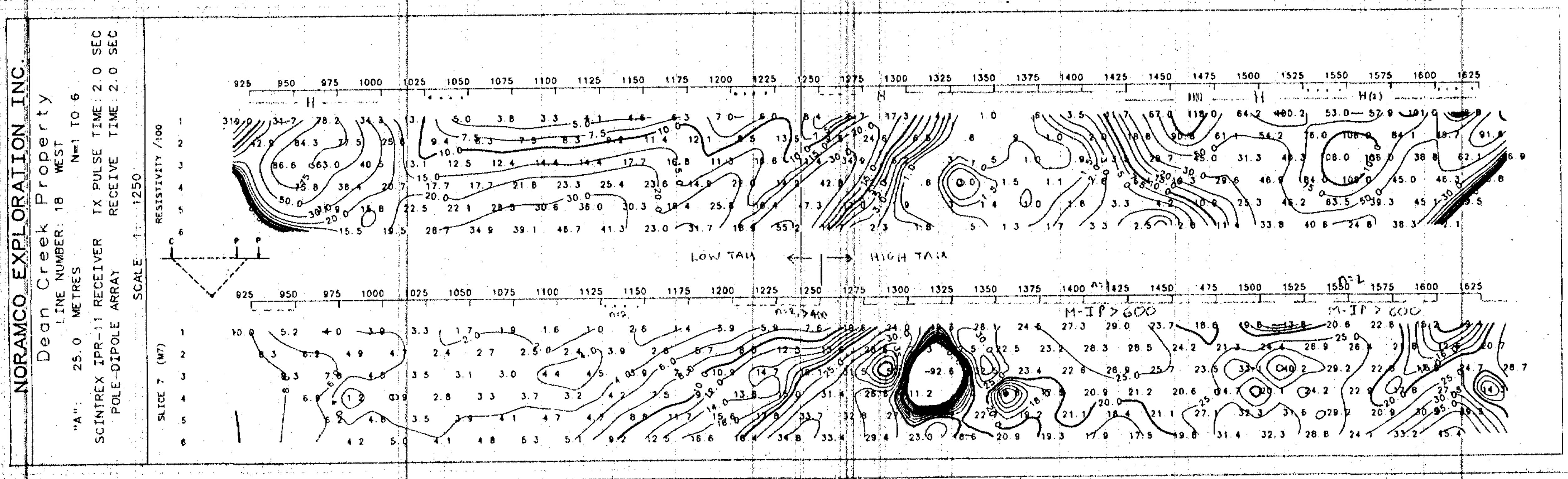
COMPANY NAME
Inlet Resources
PROPERTY NAME
Dean Creek Project

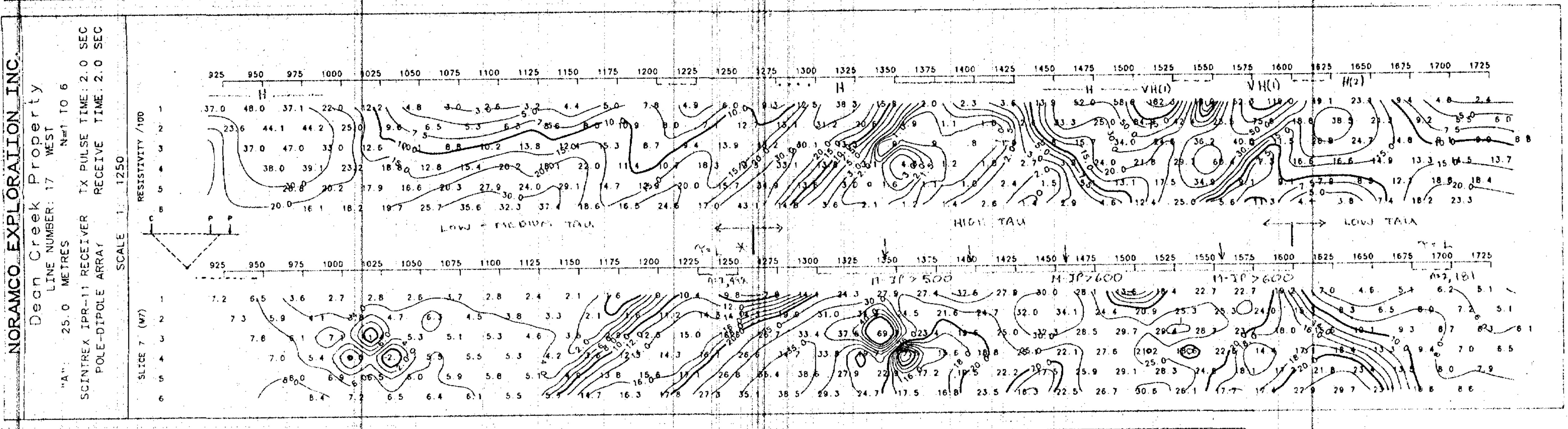
EXECUTED BY	COMPILATION BY	
DATE	N.T.S.	DRAWN BY
SCALE 1 : 5000	PROJECT No. P 1480	CHECKED
	DRAWING No.	

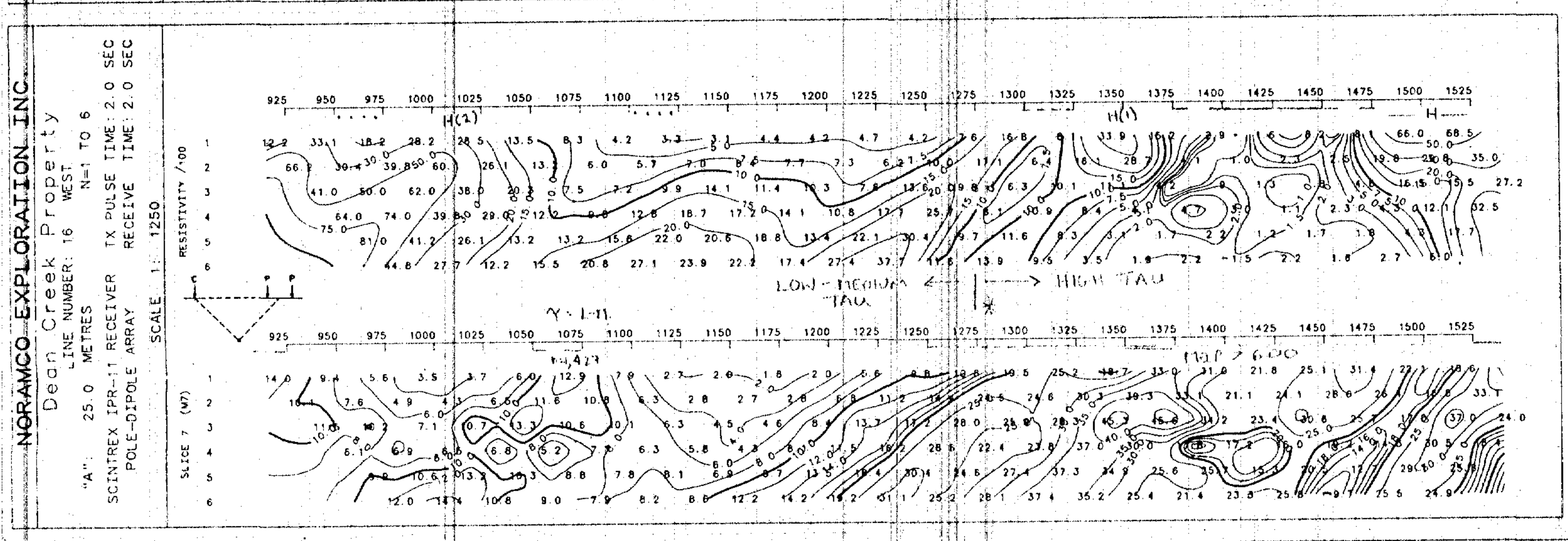

NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 21 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250

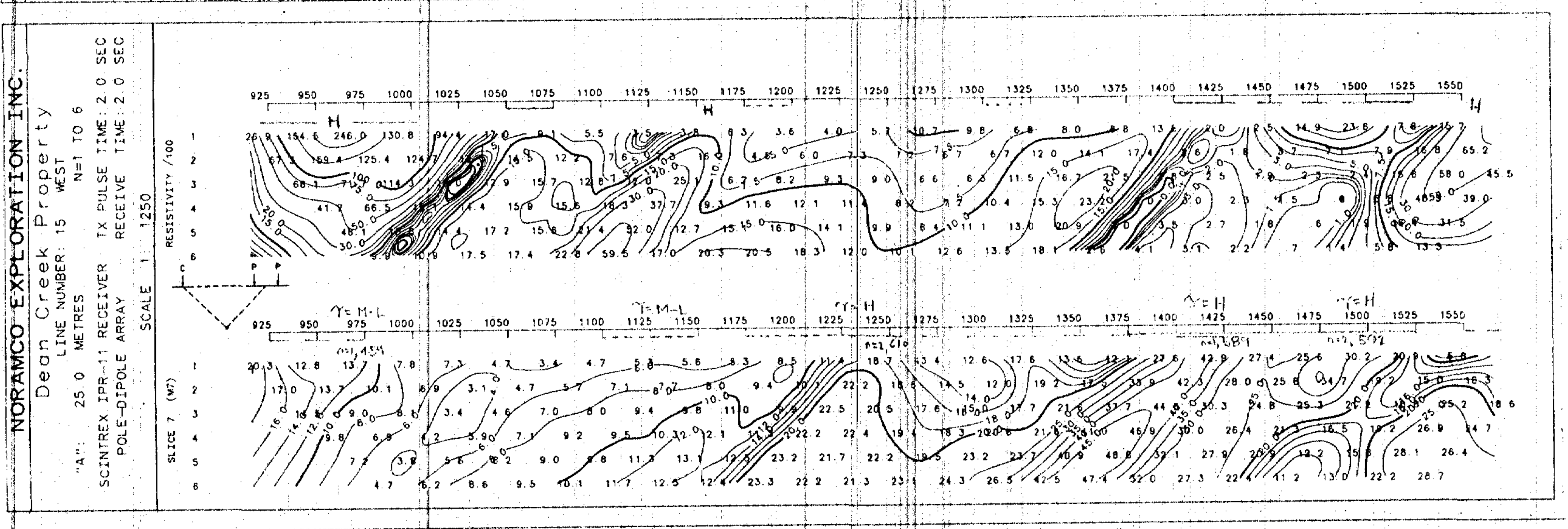

NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 20 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250

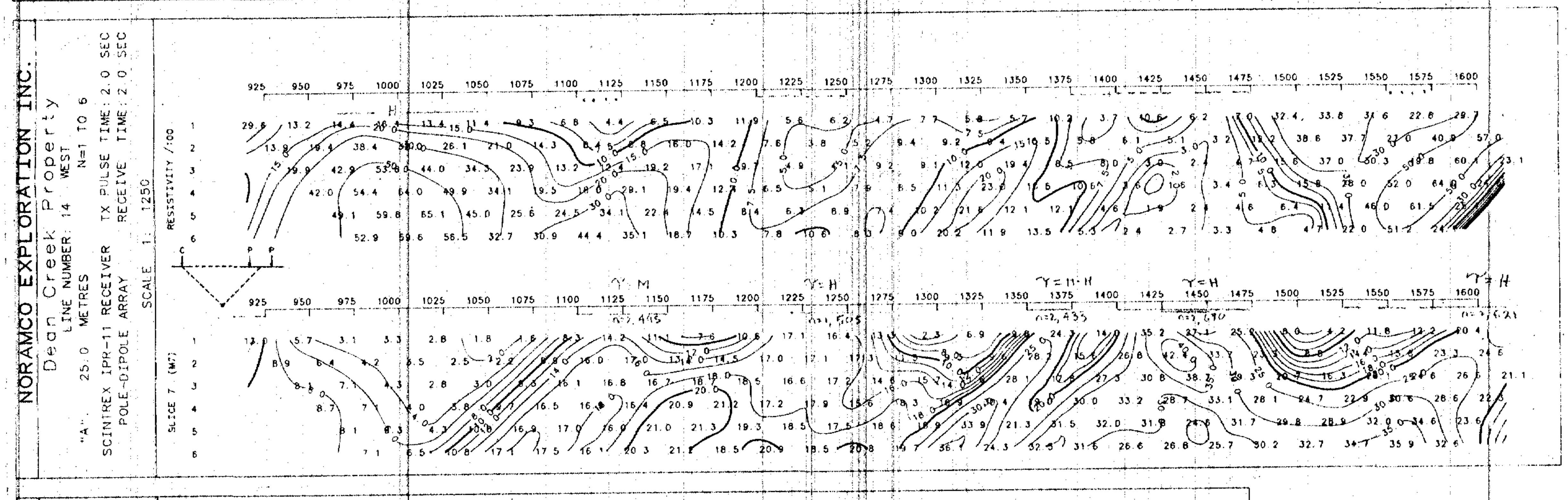

NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 19 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250

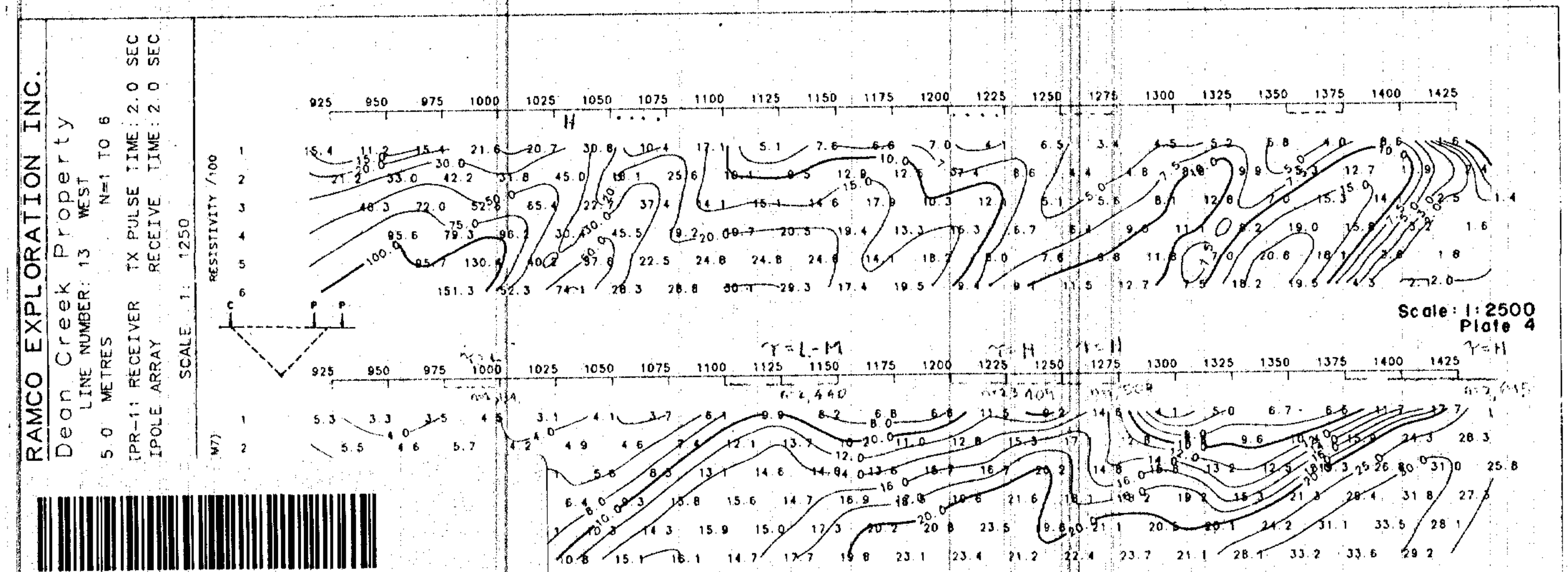

NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 18 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250


NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 17 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250


NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 16 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250


NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 15 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250


NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 14 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250


RAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 13 WEST N=1 TO 6
5.0 METRES
IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
IPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250

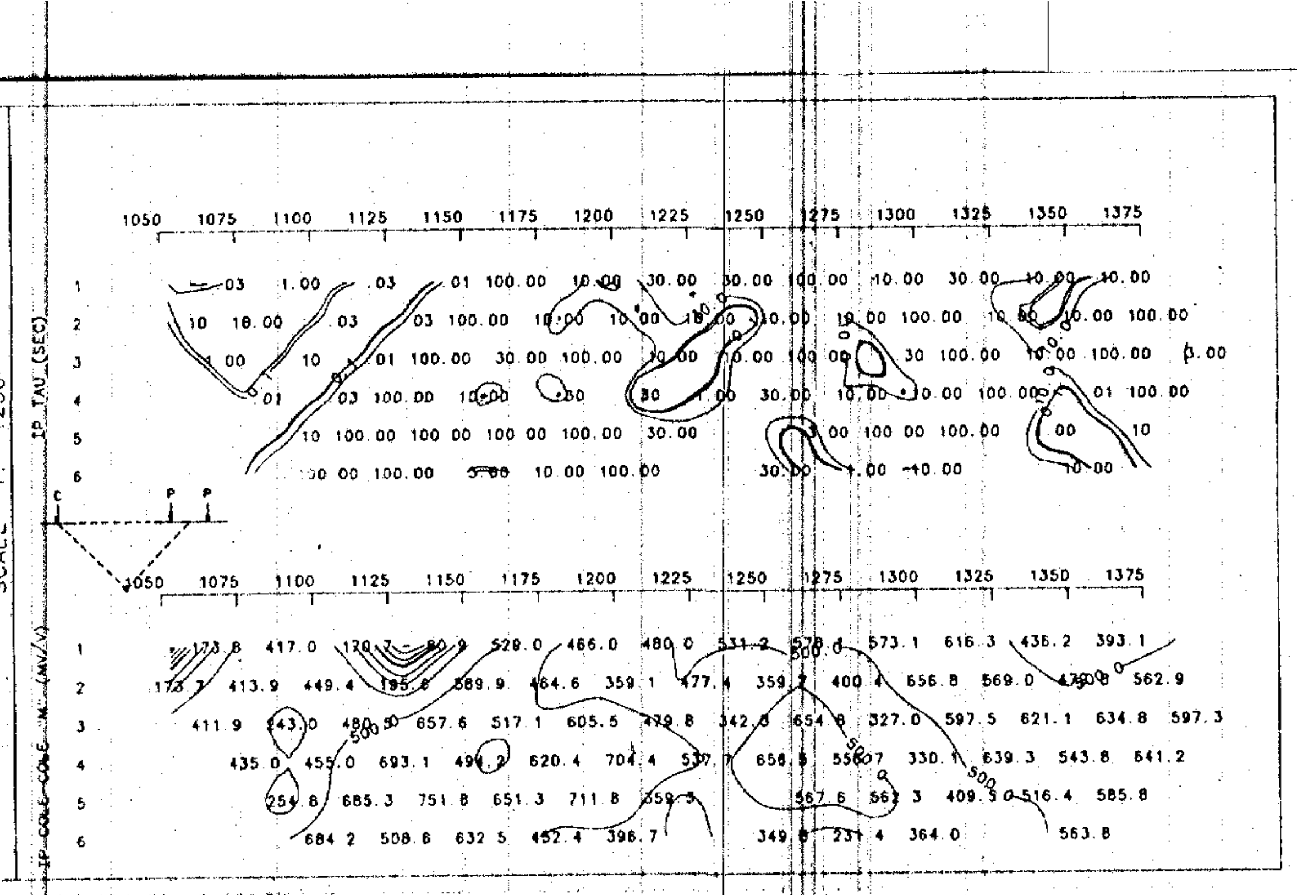
Scale: 1:2500
Plate 4

2.10824

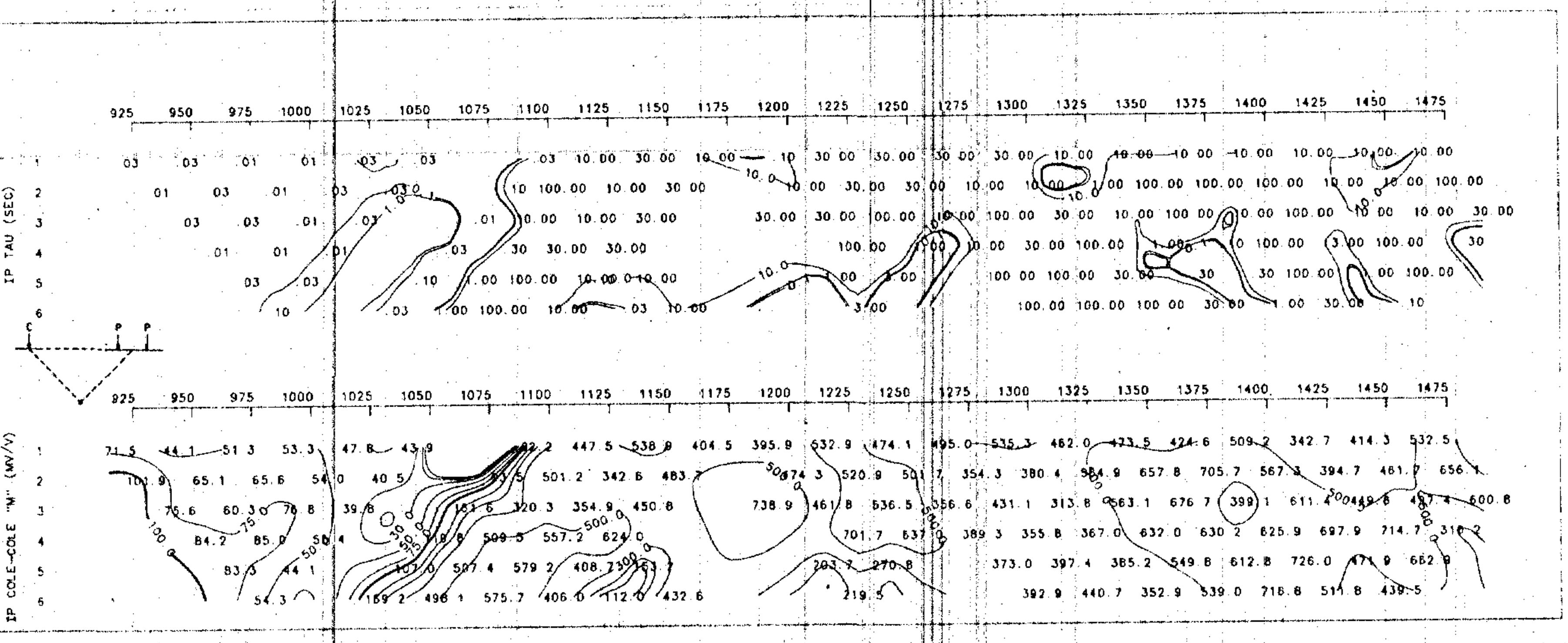
52H01SW0006 2.10824 BALL TWP

260

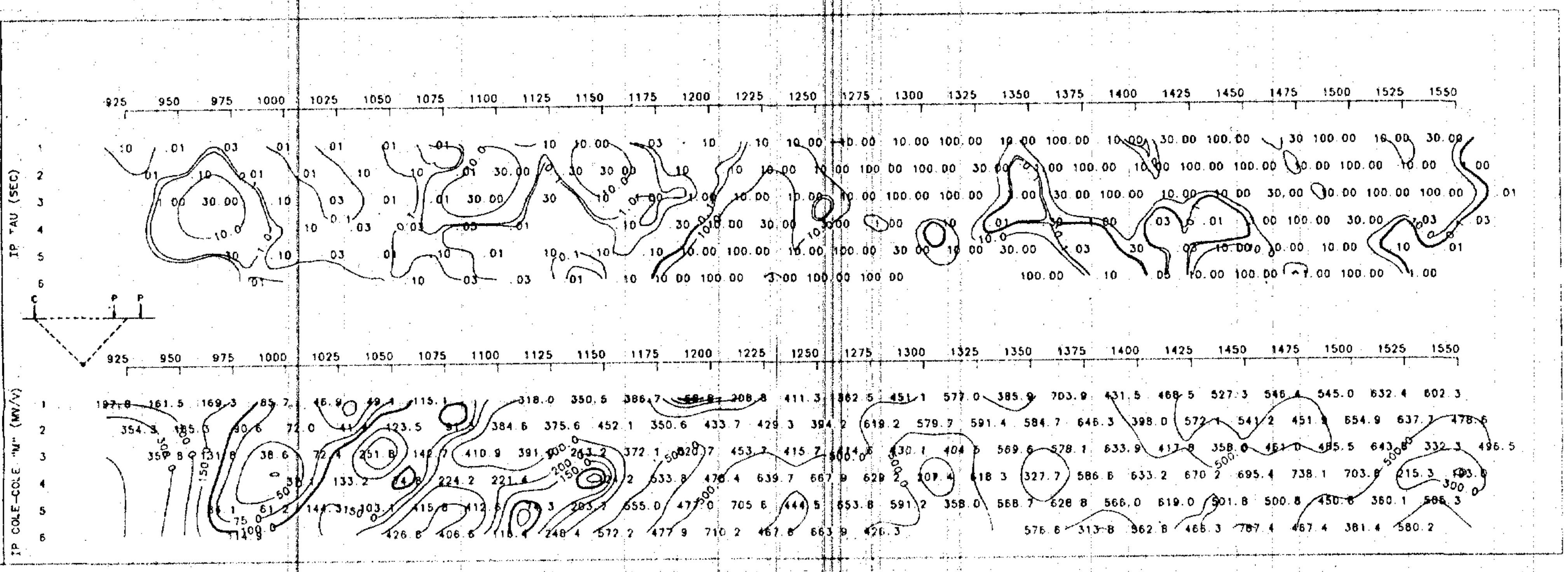
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 21 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



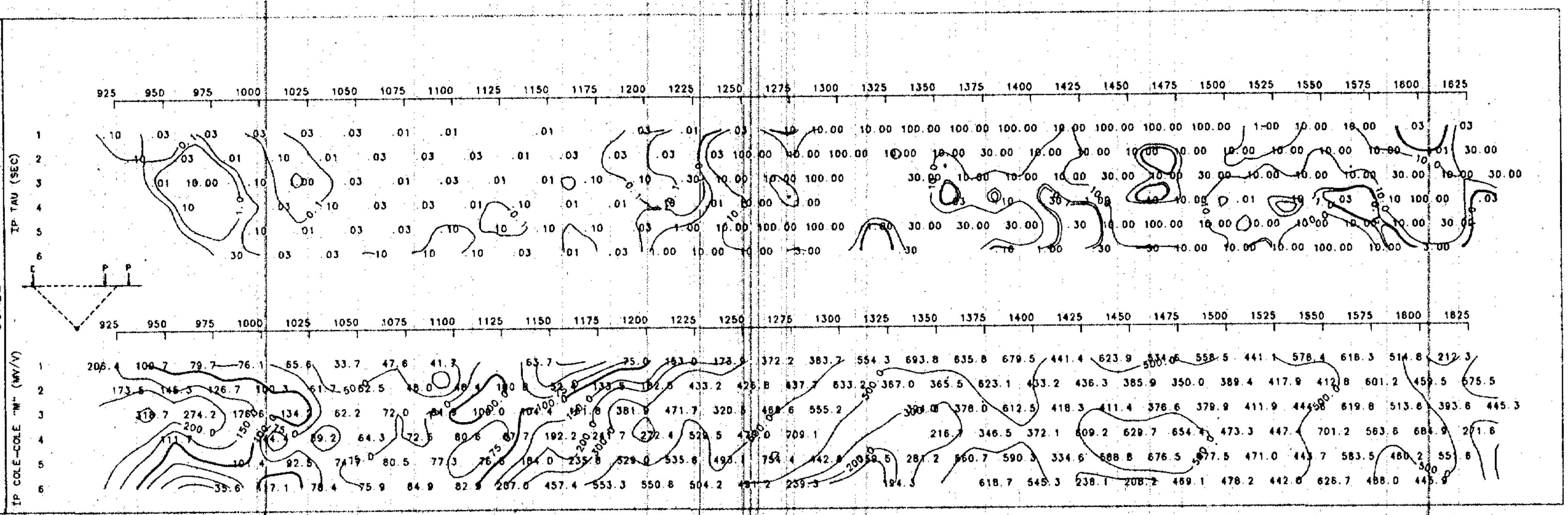
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 20 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



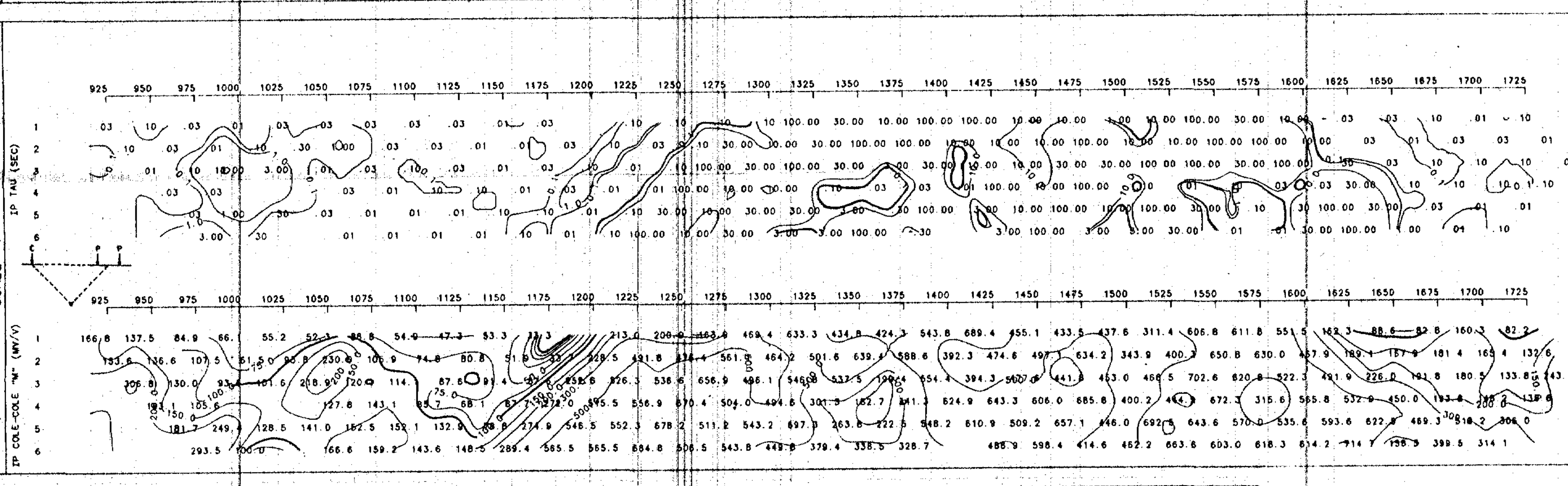
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 19 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



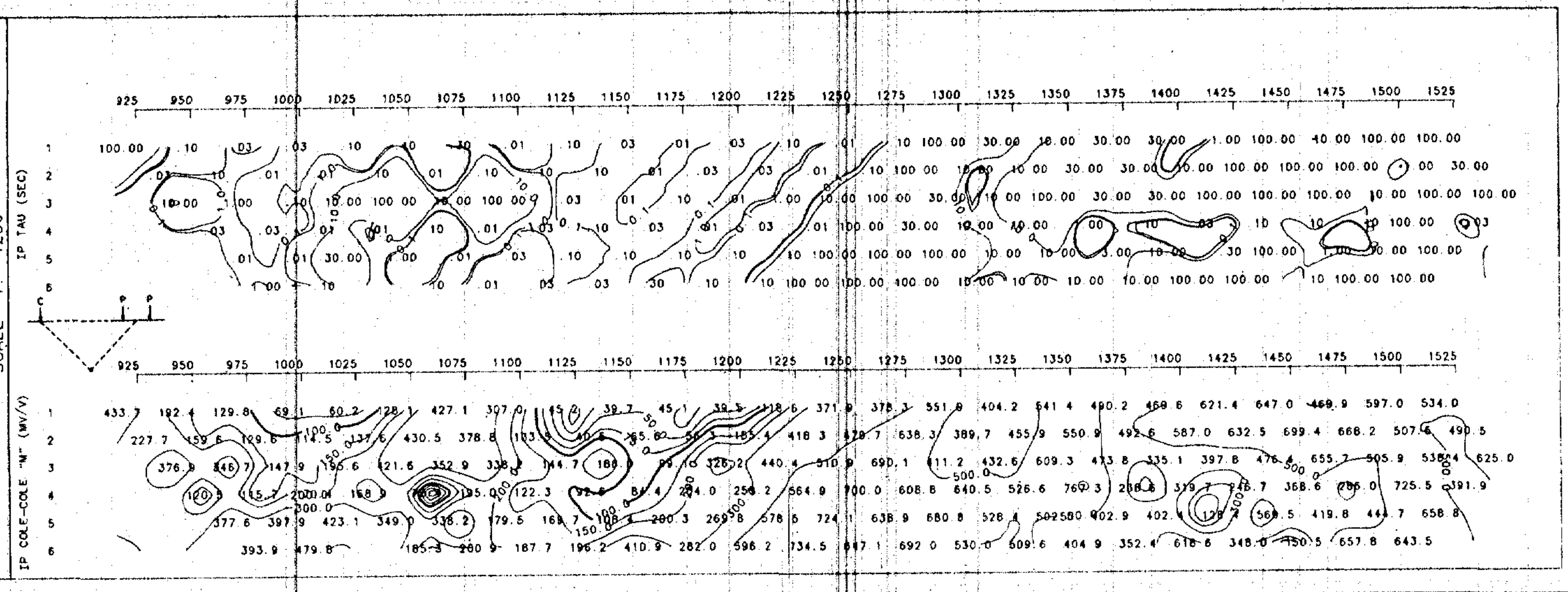
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 18 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



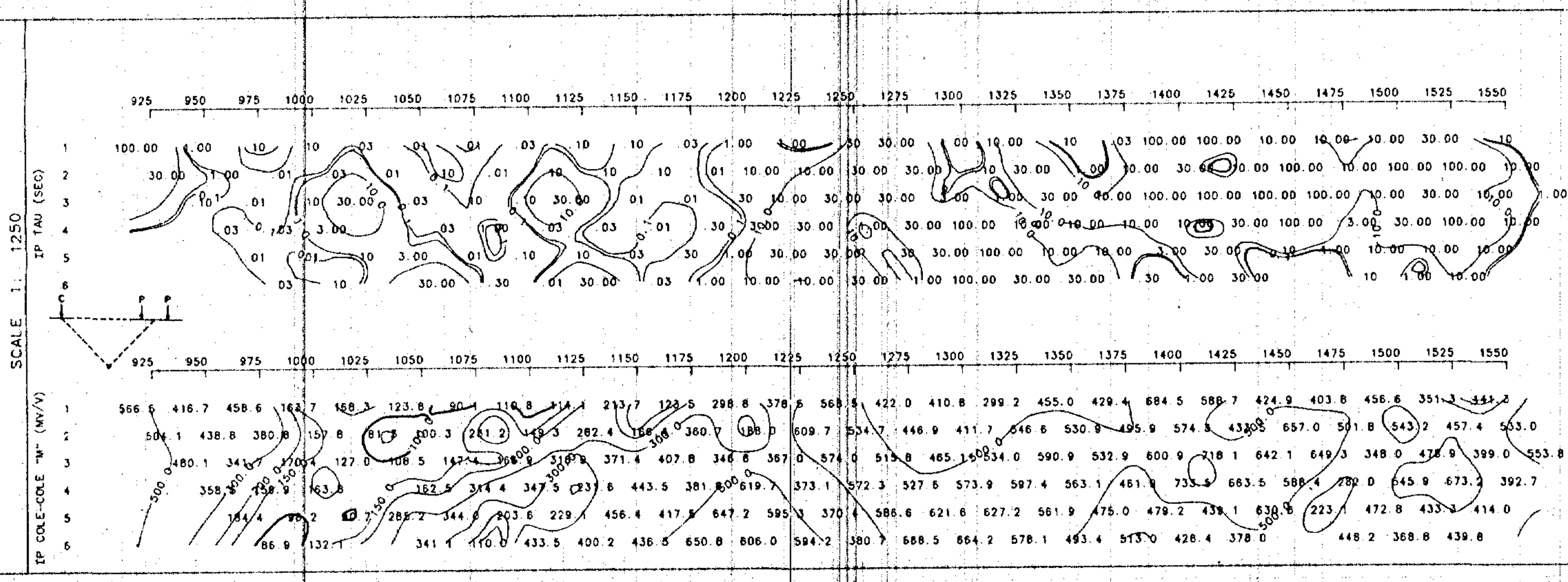
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 17 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



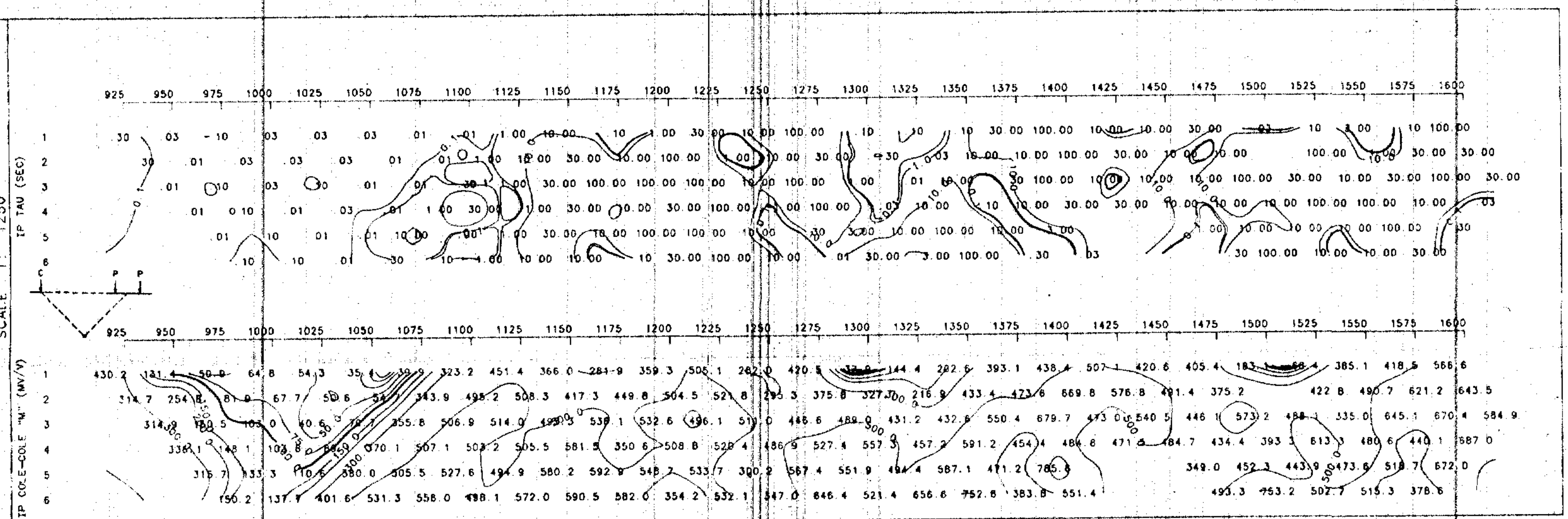
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 16 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



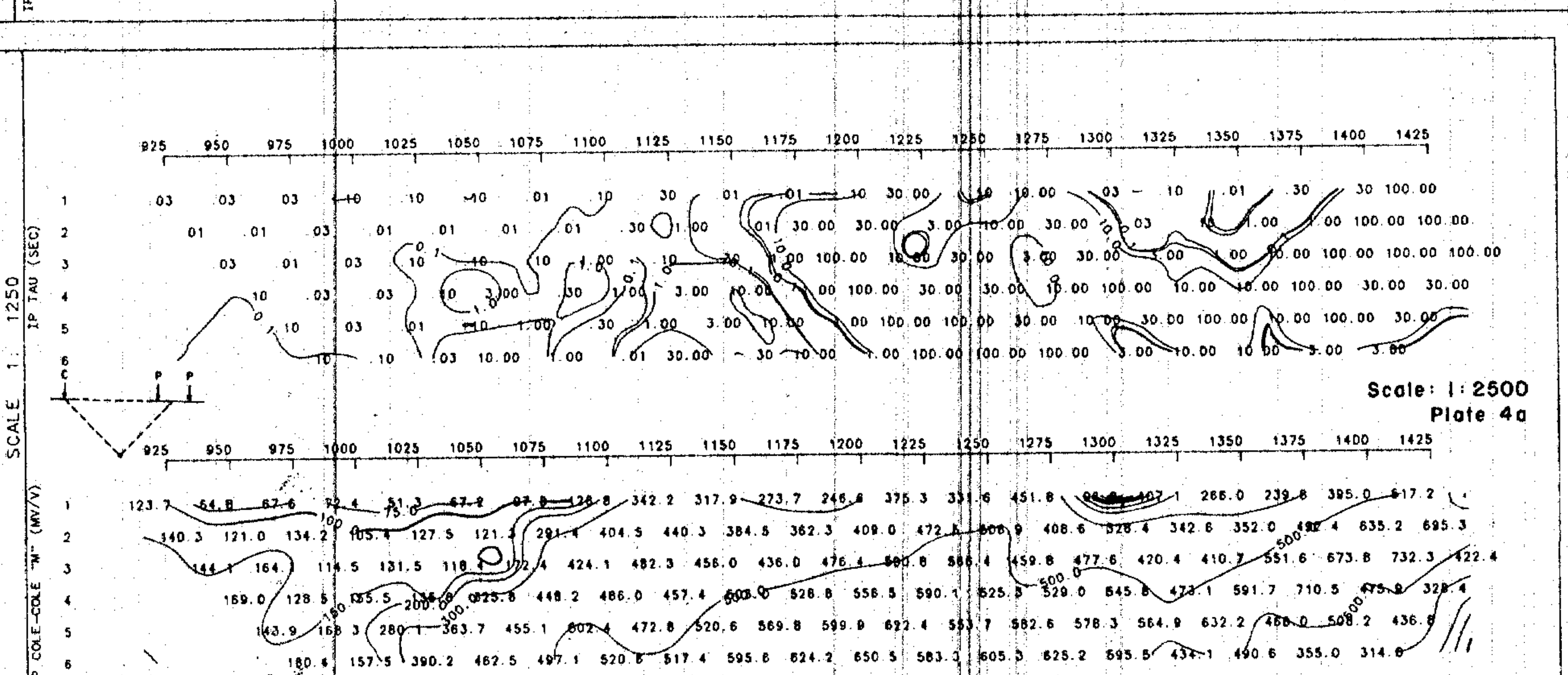
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 15 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 14 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 13 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



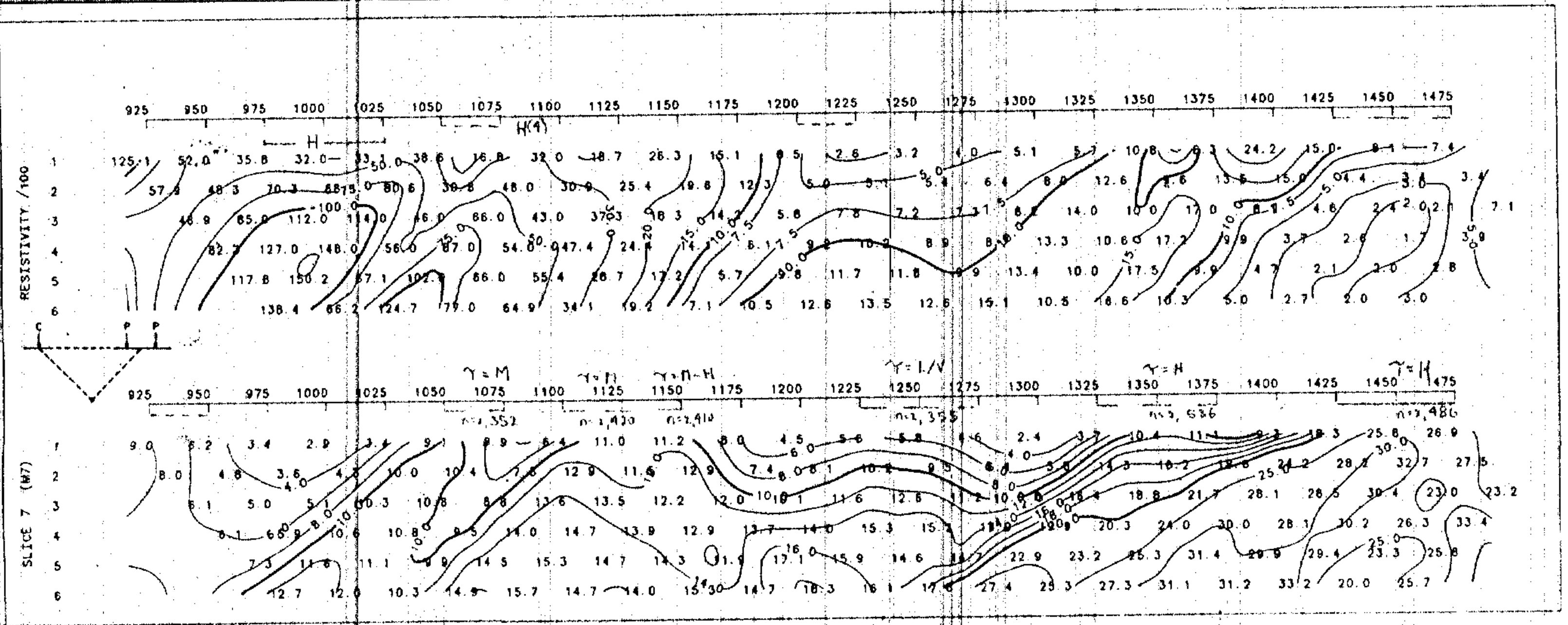
Scale: 1:2500
Plate 4a

2.10824

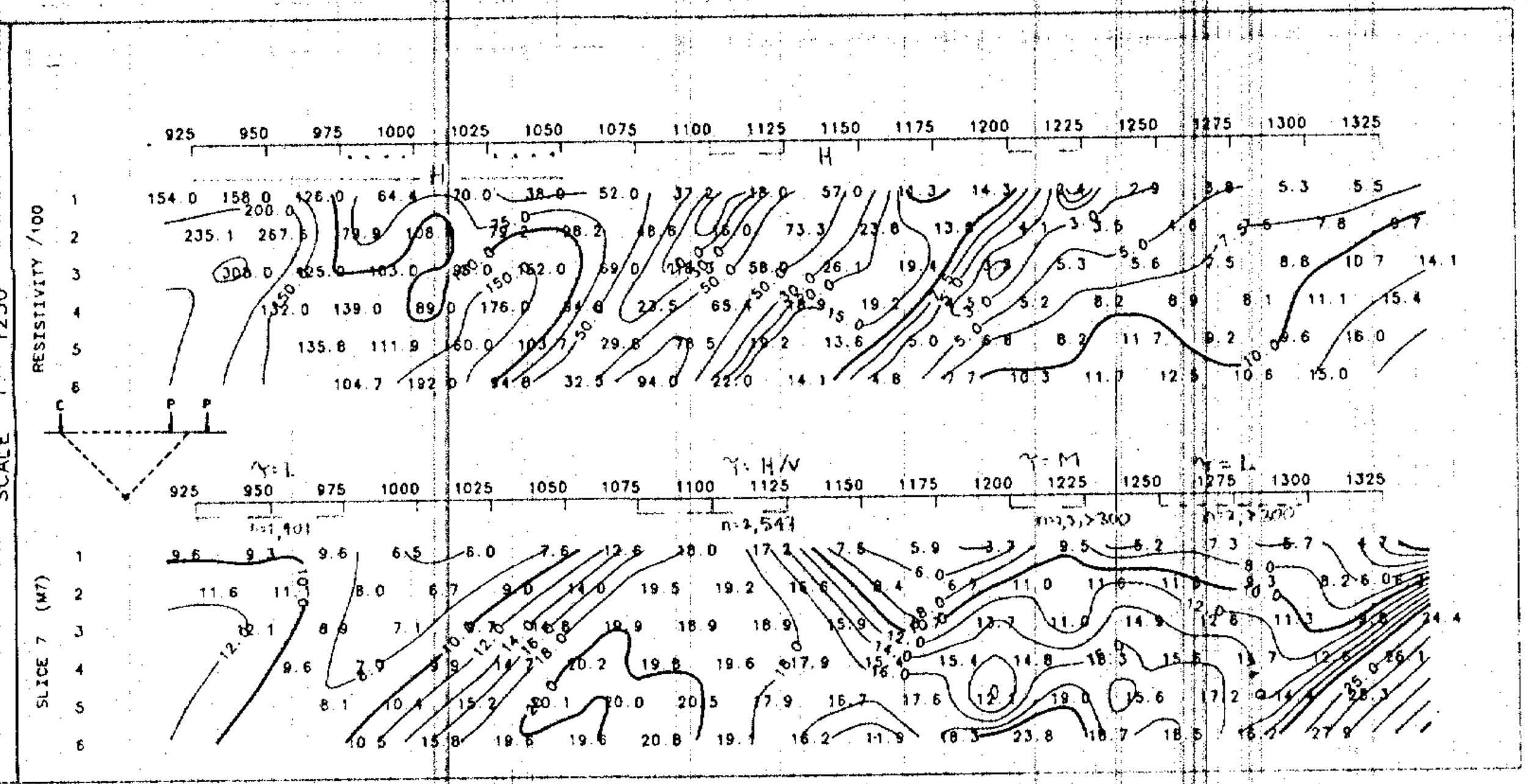
270

2.10824

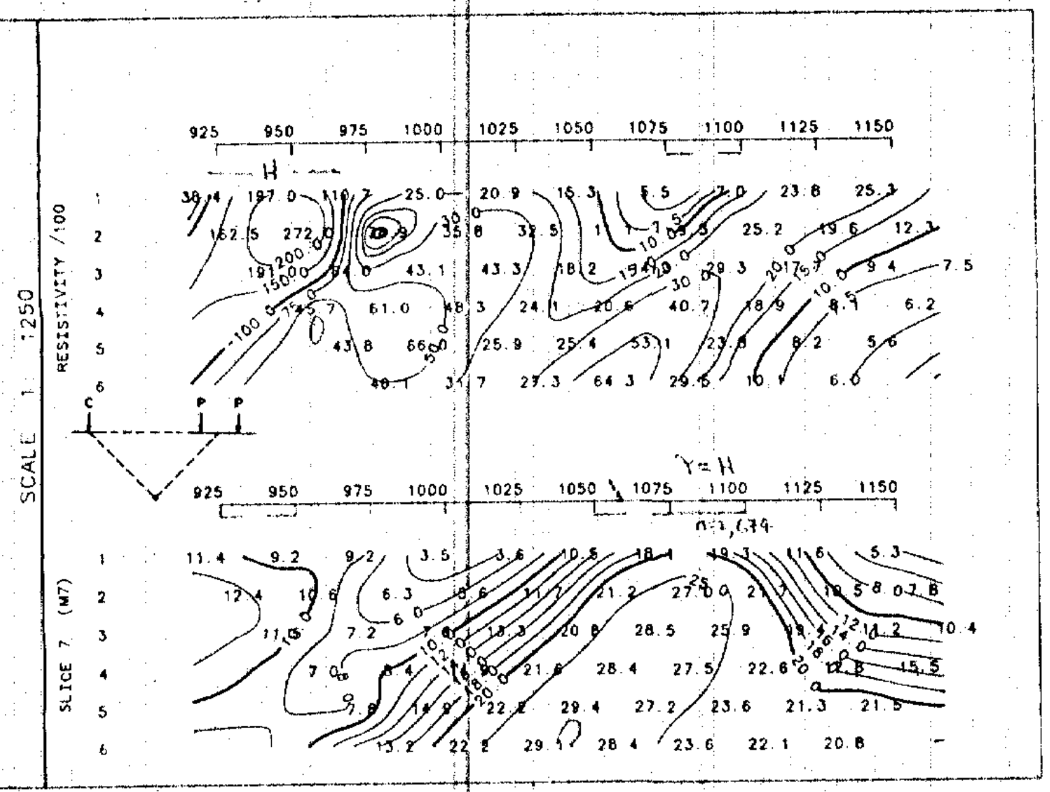
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 12 WEST N=1 TO 6
"A": 25.0 METRES
SCINTREX IPR-11 RECEIVER TX PULSE TIME 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME 2.0 SEC
SCALE 1: 1250



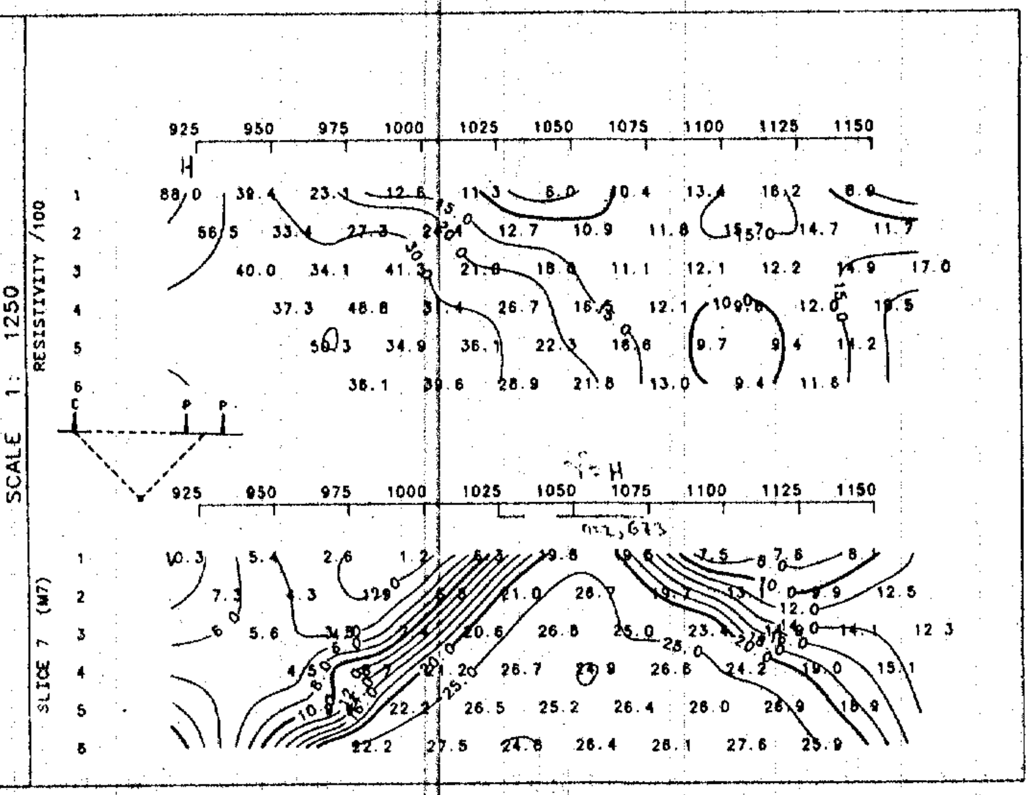
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 11 WEST N=1 TO 6
"A": 25.0 METRES
SCINTREX IPR-11 RECEIVER TX PULSE TIME 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME 2.0 SEC
SCALE 1: 1250



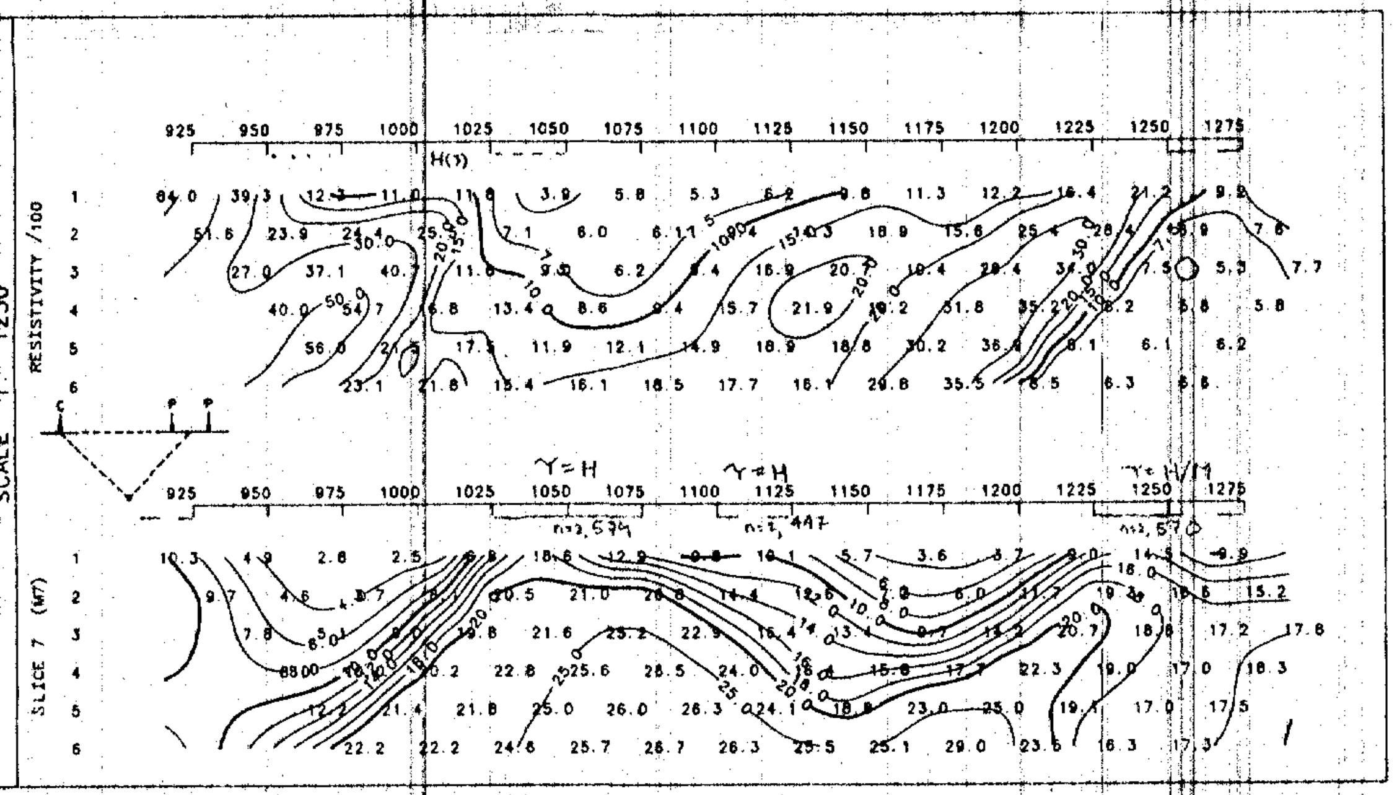
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 10 WEST N=1 TO 6
"A": 25.0 METRES
SCINTREX IPR-11 RECEIVER TX PULSE TIME 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME 2.0 SEC
SCALE 1: 1250



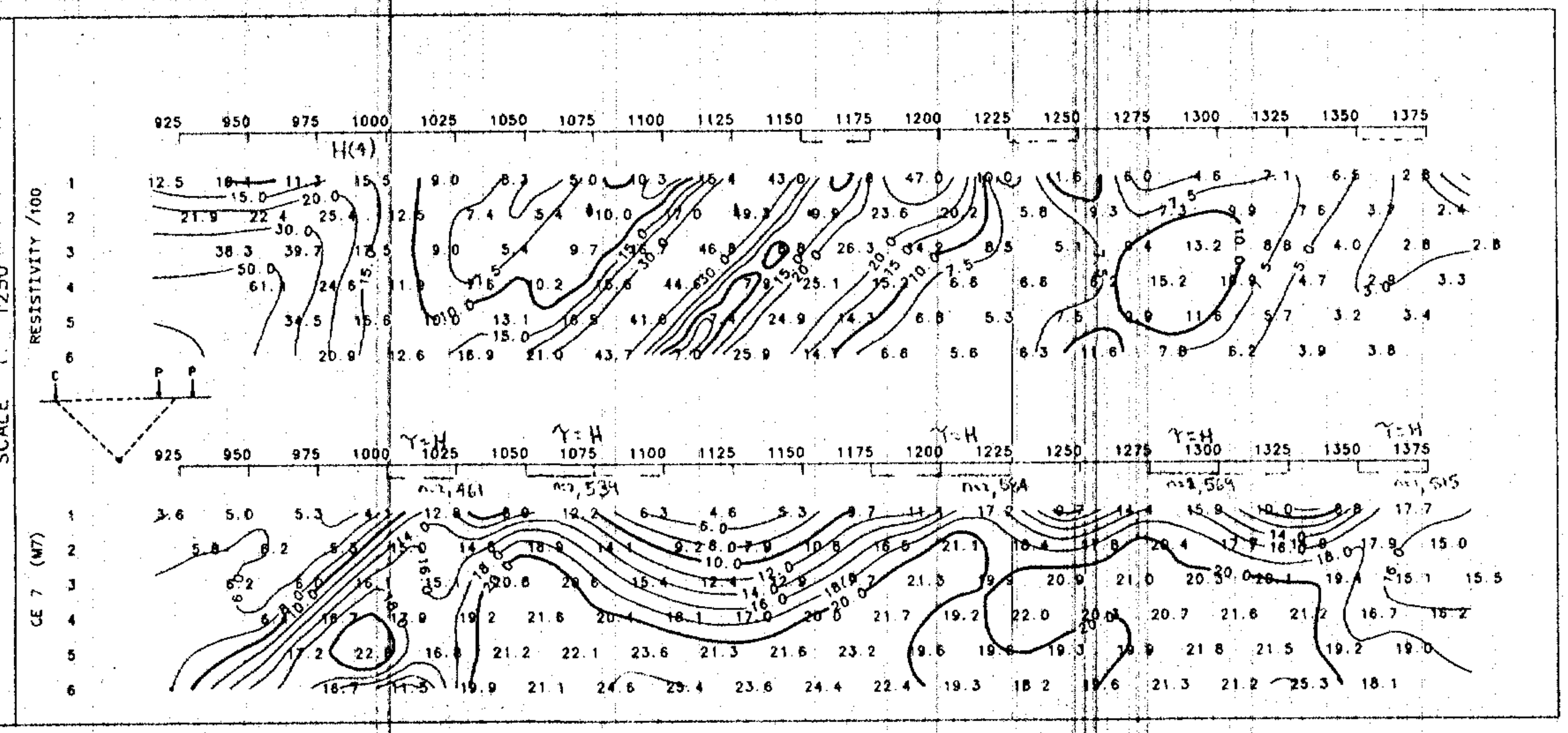
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 9 WEST N=1 TO 6
"A": 25.0 METRES
SCINTREX IPR-11 RECEIVER TX PULSE TIME 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME 2.0 SEC
SCALE 1: 1250



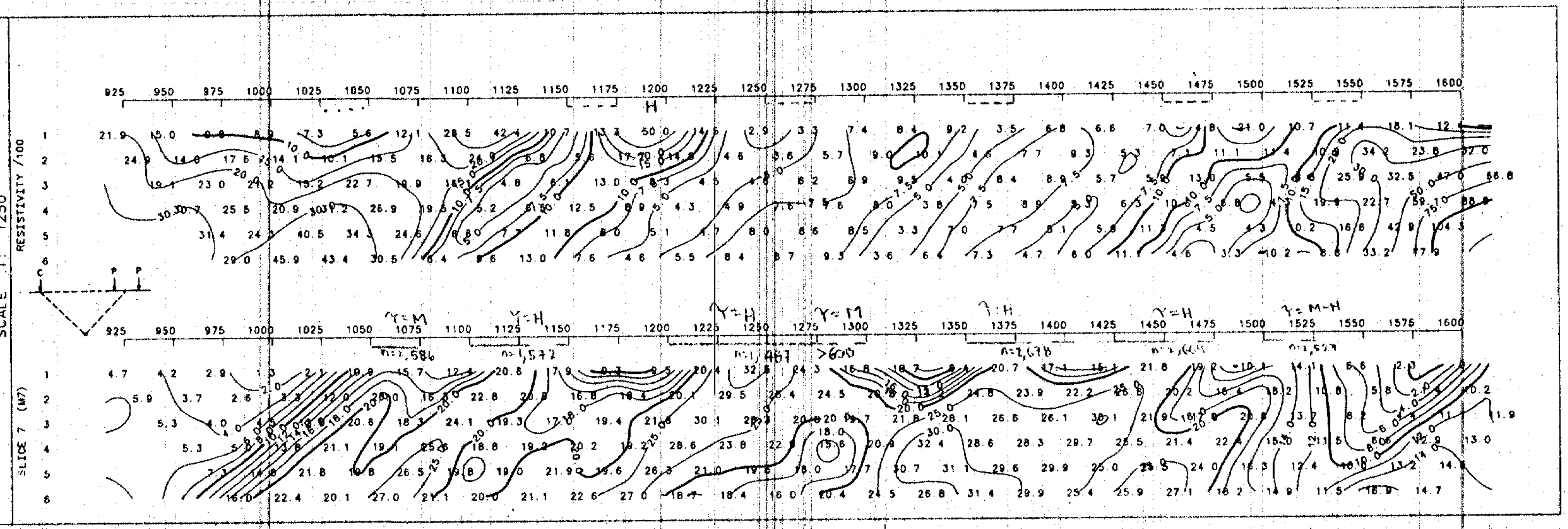
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 8 WEST N=1 TO 6
"A": 25.0 METRES
SCINTREX IPR-11 RECEIVER TX PULSE TIME 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME 2.0 SEC
SCALE 1: 1250



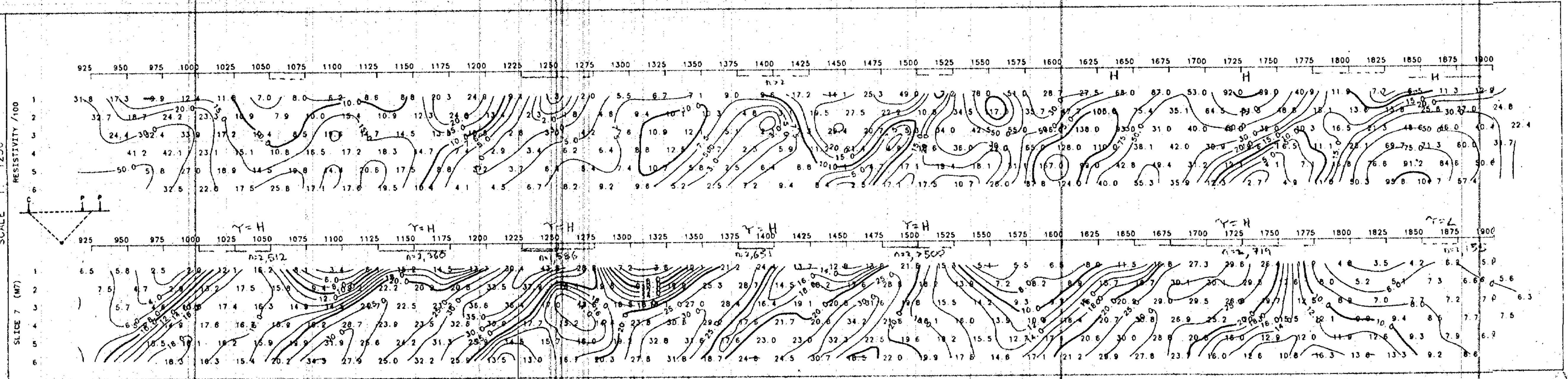
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 7 WEST N=1 TO 6
"A": 25.0 METRES
SCINTREX IPR-11 RECEIVER TX PULSE TIME 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME 2.0 SEC
SCALE 1: 1250



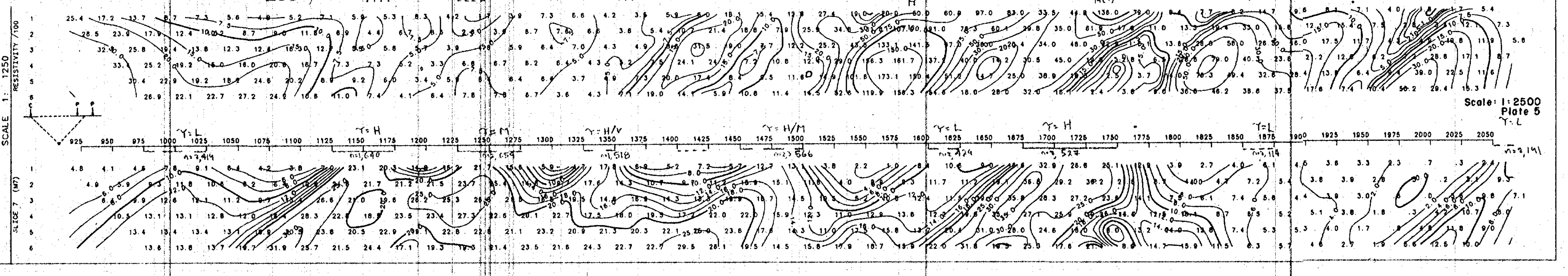
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 6 WEST N=1 TO 6
"A": 25.0 METRES
SCINTREX IPR-11 RECEIVER TX PULSE TIME 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME 2.0 SEC
SCALE 1: 1250



NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 5 WEST N=1 TO 6
"A": 25.0 METRES
SCINTREX IPR-11 RECEIVER TX PULSE TIME 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME 2.0 SEC
SCALE 1: 1250



NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 4 WEST N=1 TO 6
"A": 25.0 METRES
SCINTREX IPR-11 RECEIVER TX PULSE TIME 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME 2.0 SEC
SCALE 1: 1250

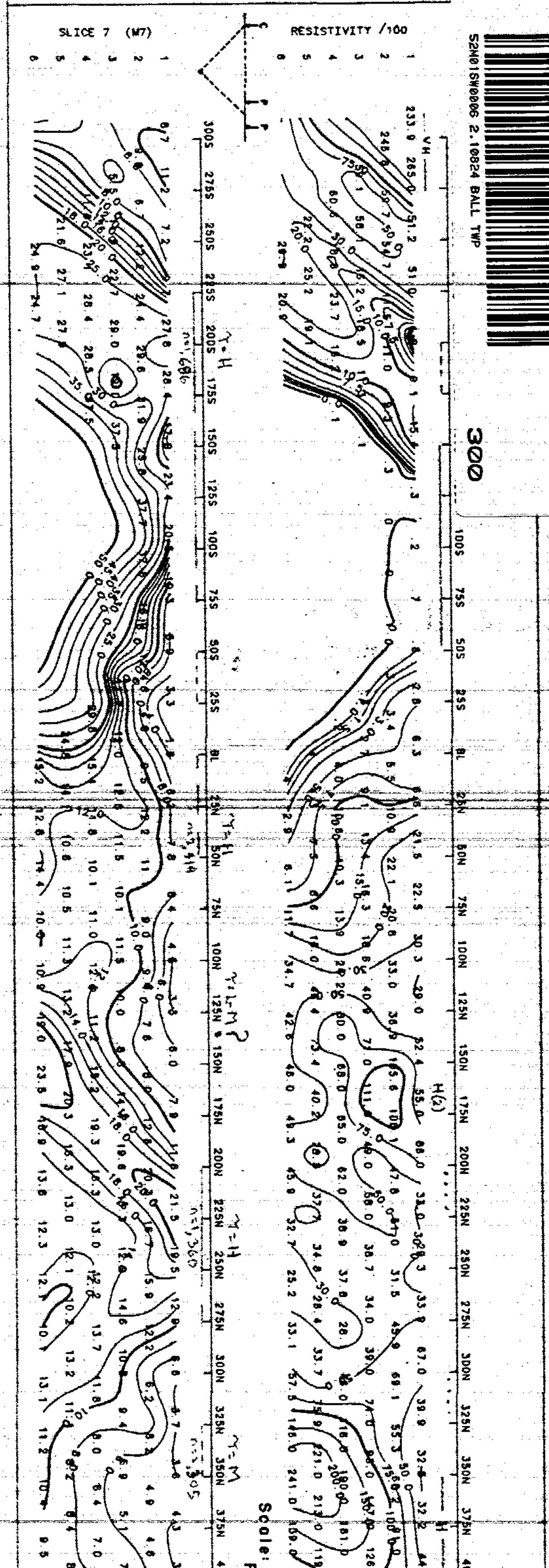


Scale: 1:2500
Plate 5

2.10824

NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 12 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250
IP TAU (SEC)
IP COLE-COLE "M" (MV/V)
C
P
P
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 11 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 10 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 9 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 8 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 7 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 6 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 5 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 4 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250
925
950
975
1000
1025
1050
1075
1100
1125
1150
1175
1200
1225
1250
1275
1300
1325
1350
1375
1400
1425
1450
1475
1500
1525
1550
1575
1600
1625
1650
1675
1700
1725
1750
1775
1800
1825
1850
1875
1900
1925
1950
1975
2000
2025
2050
Scale: 1:2500
Plate 5a

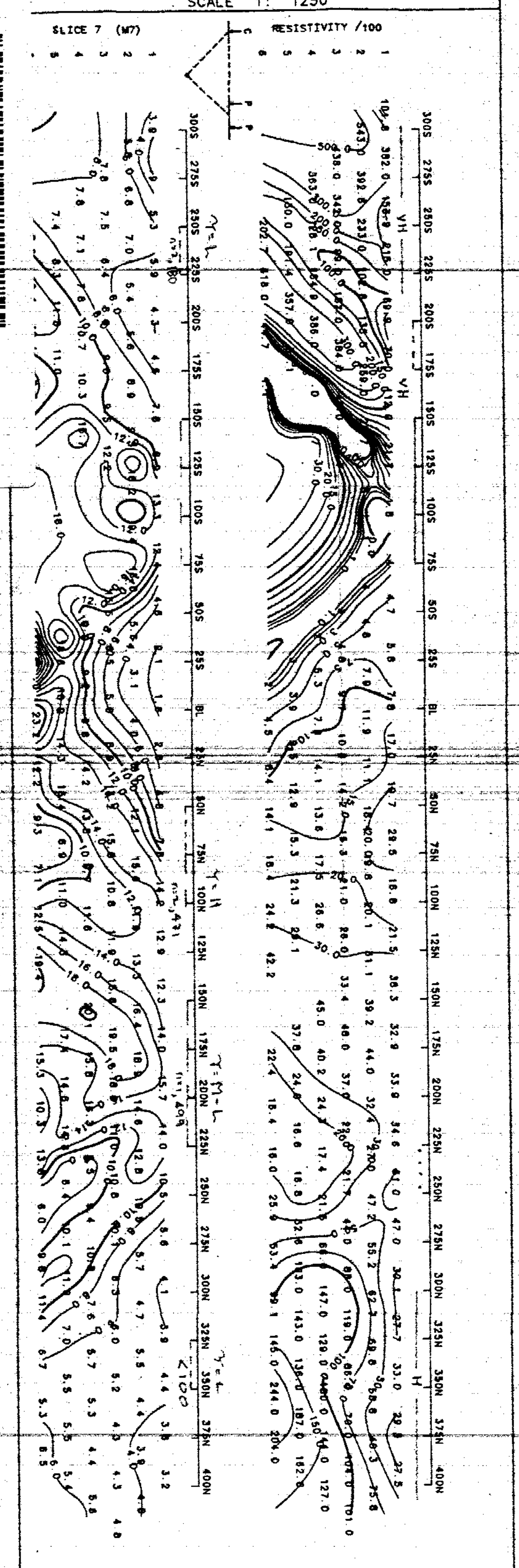
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 1 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



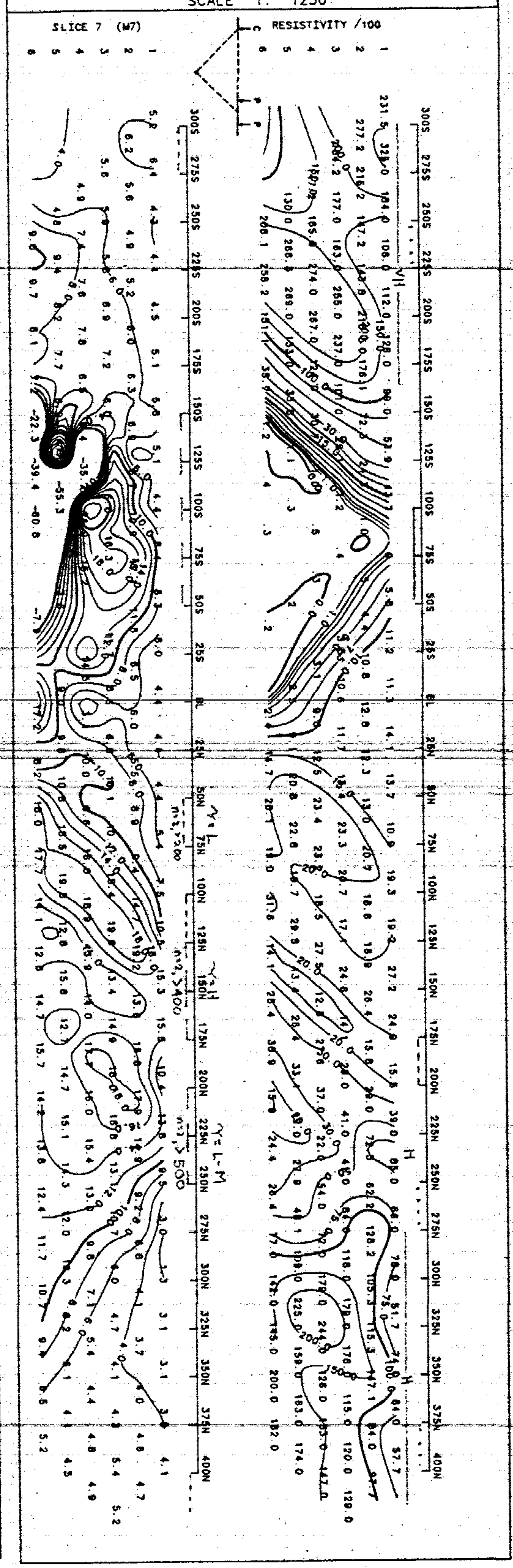
Scale 1:2500
Plate 6

2.10824

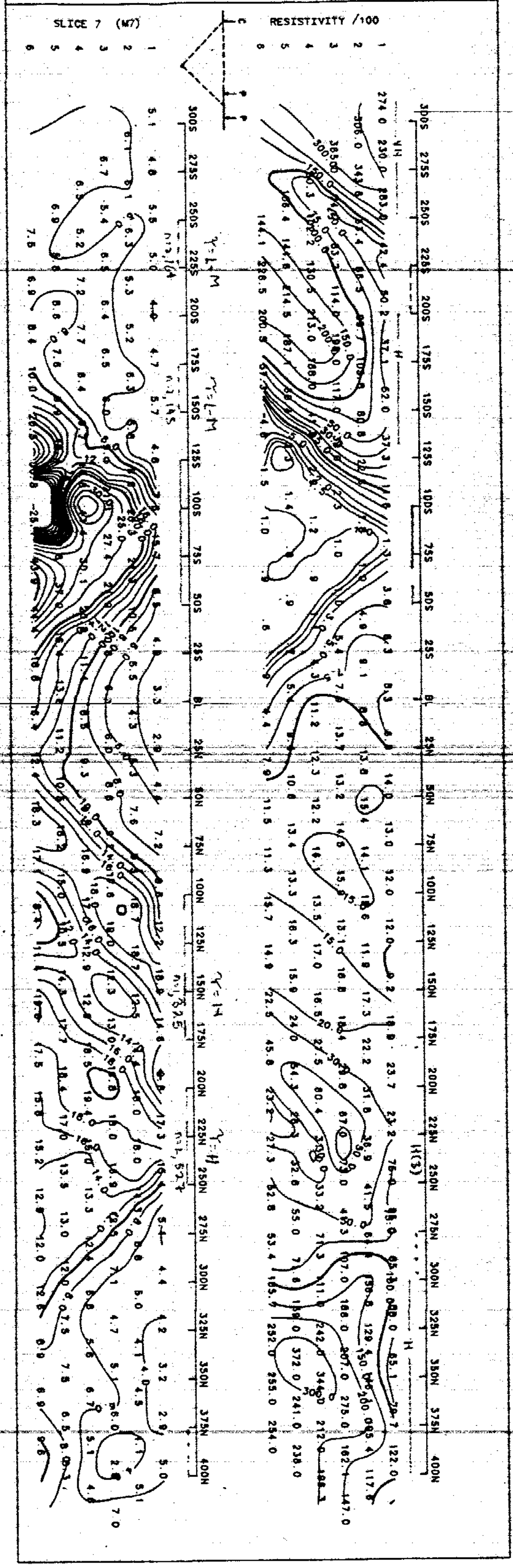
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 2 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



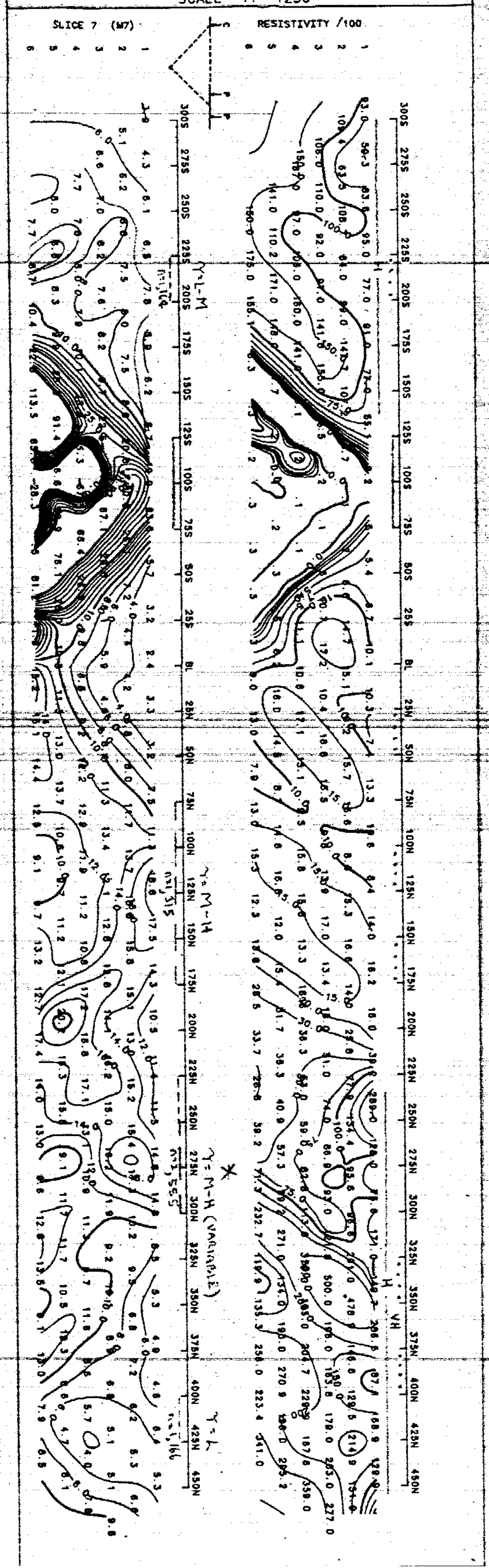
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 3 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



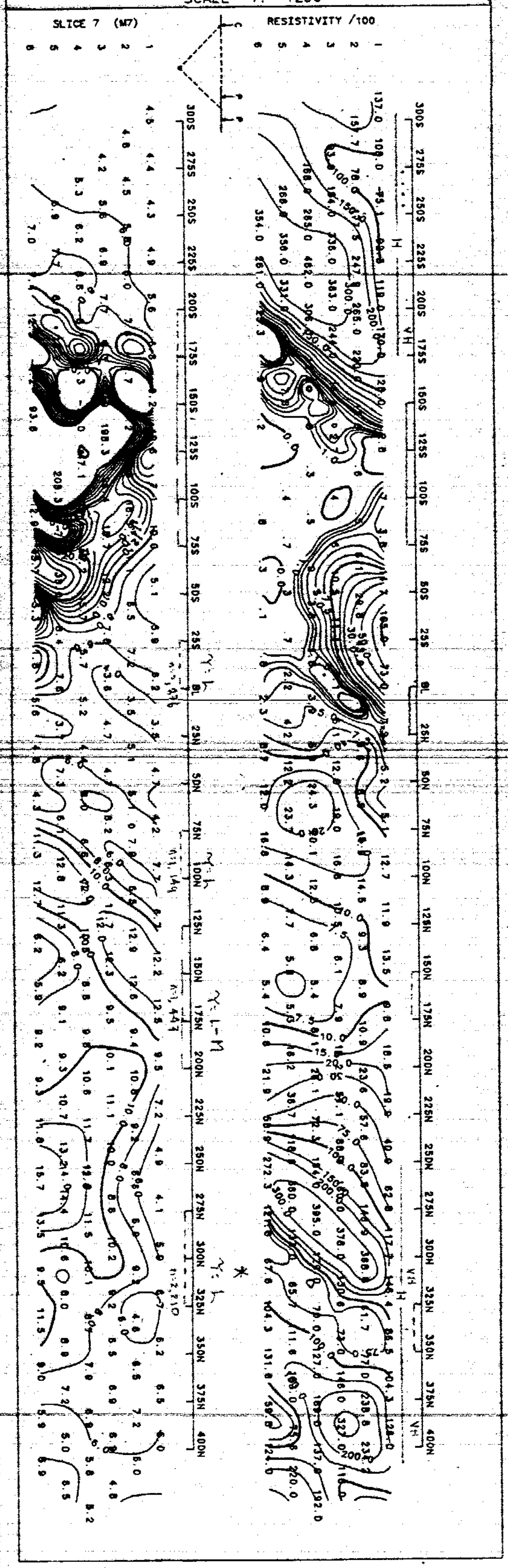
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 4 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



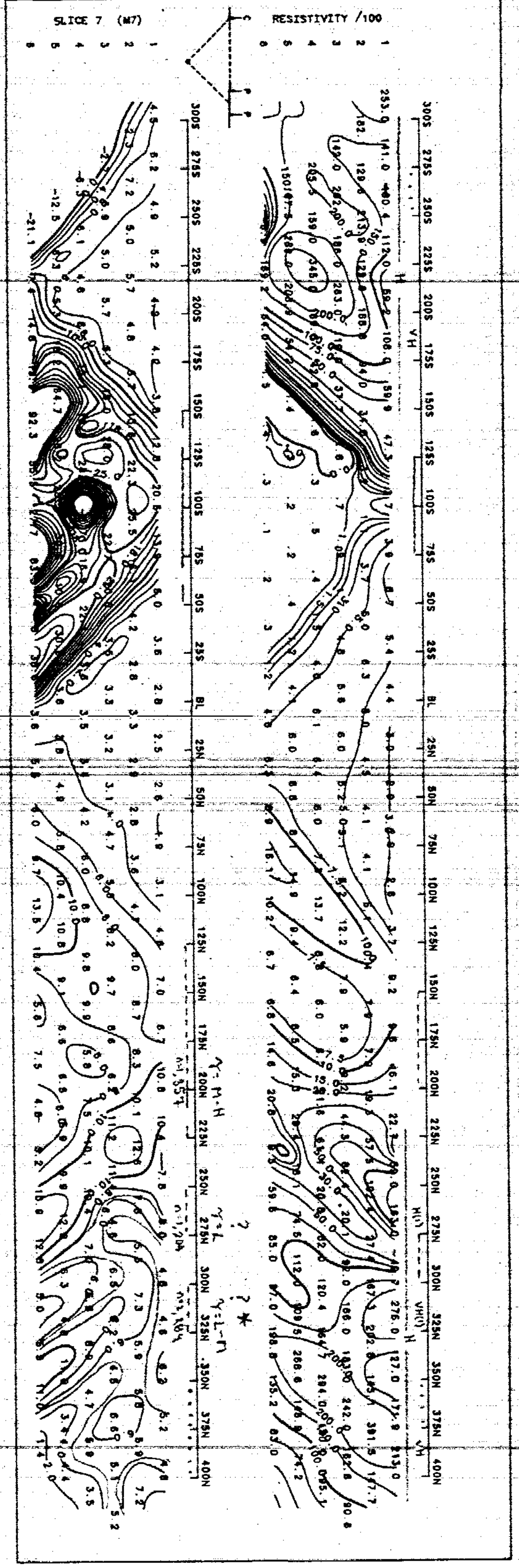
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 5 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



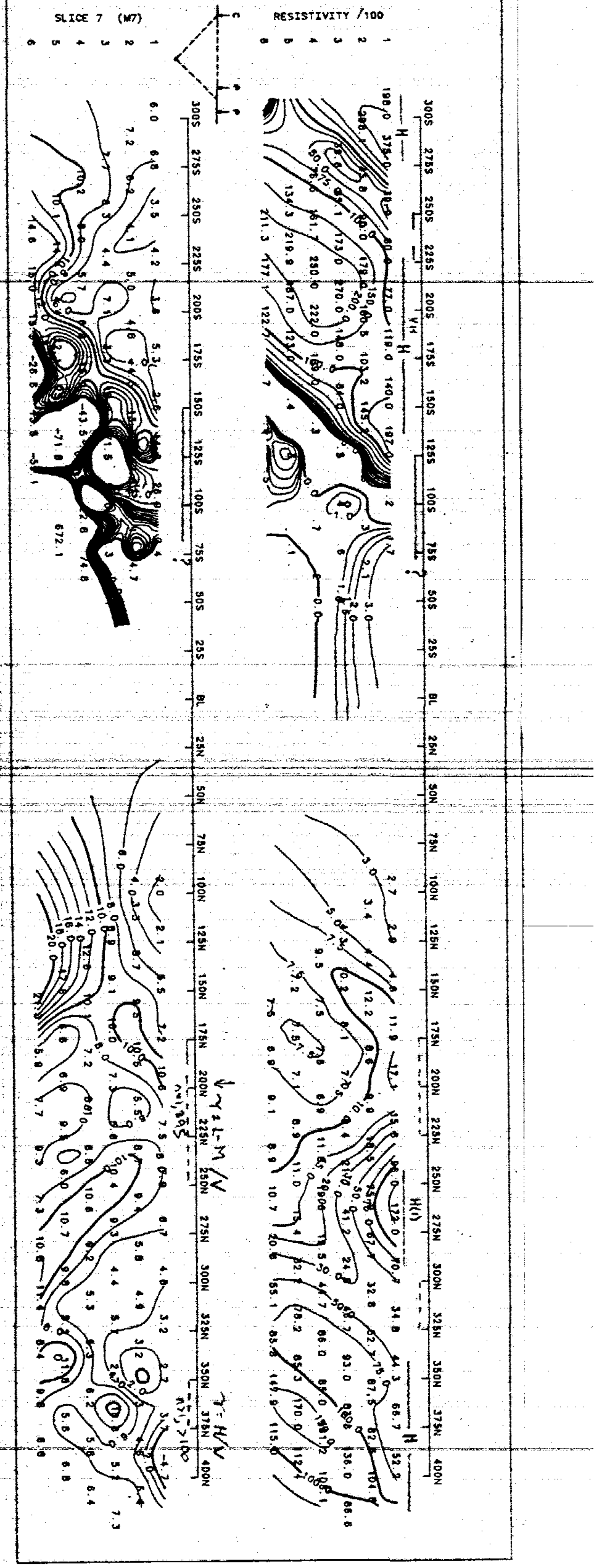
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 6 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250

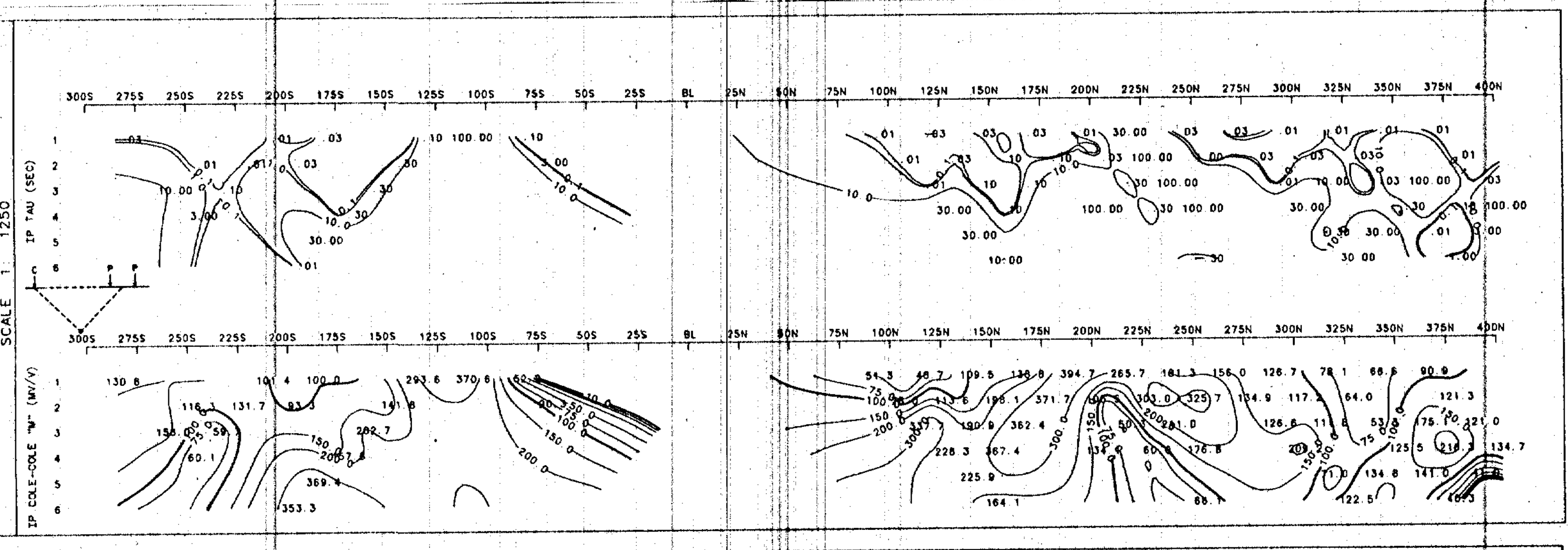


NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 7 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250

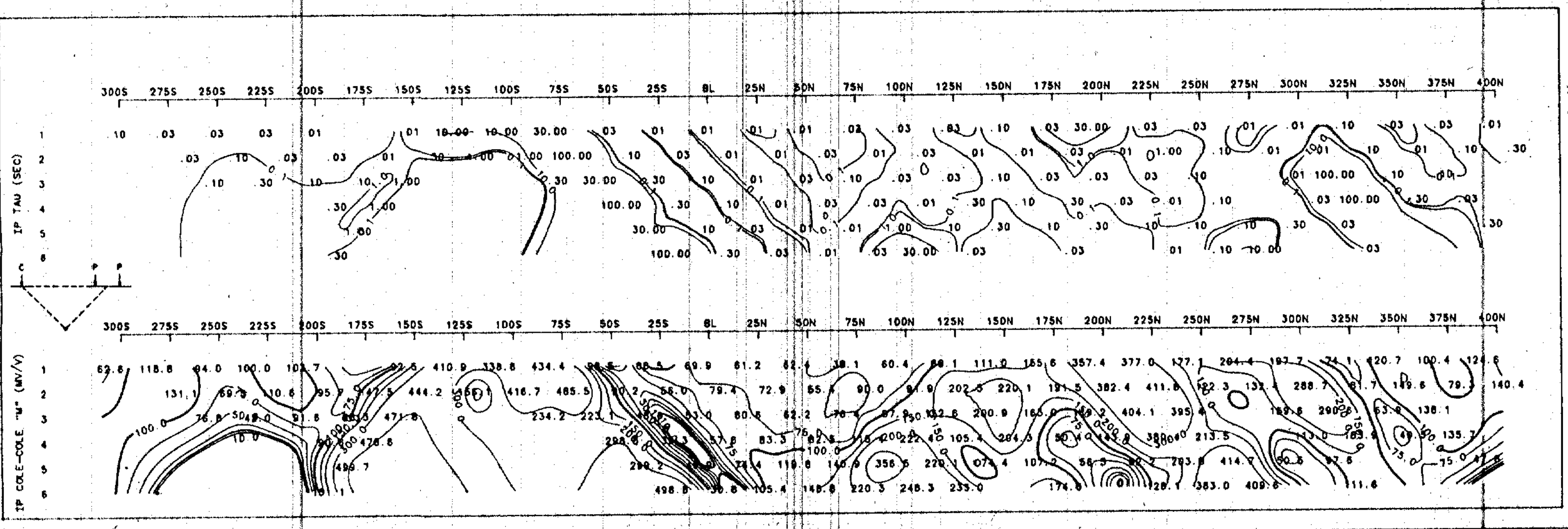


NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 8 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250

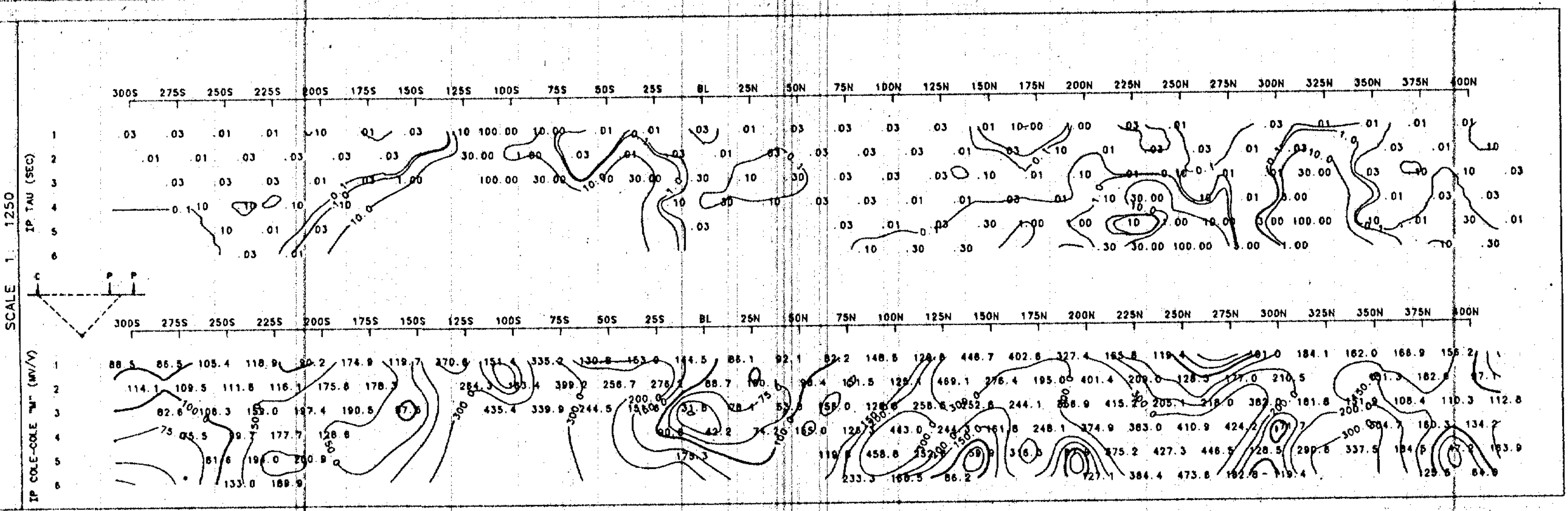




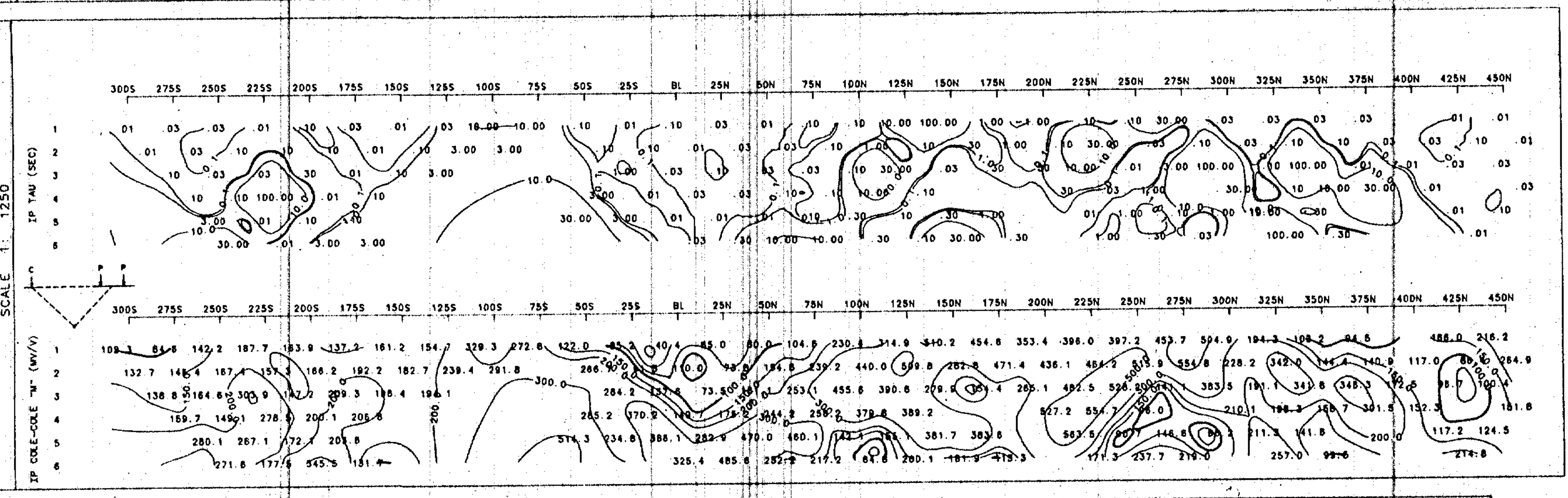
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 8 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



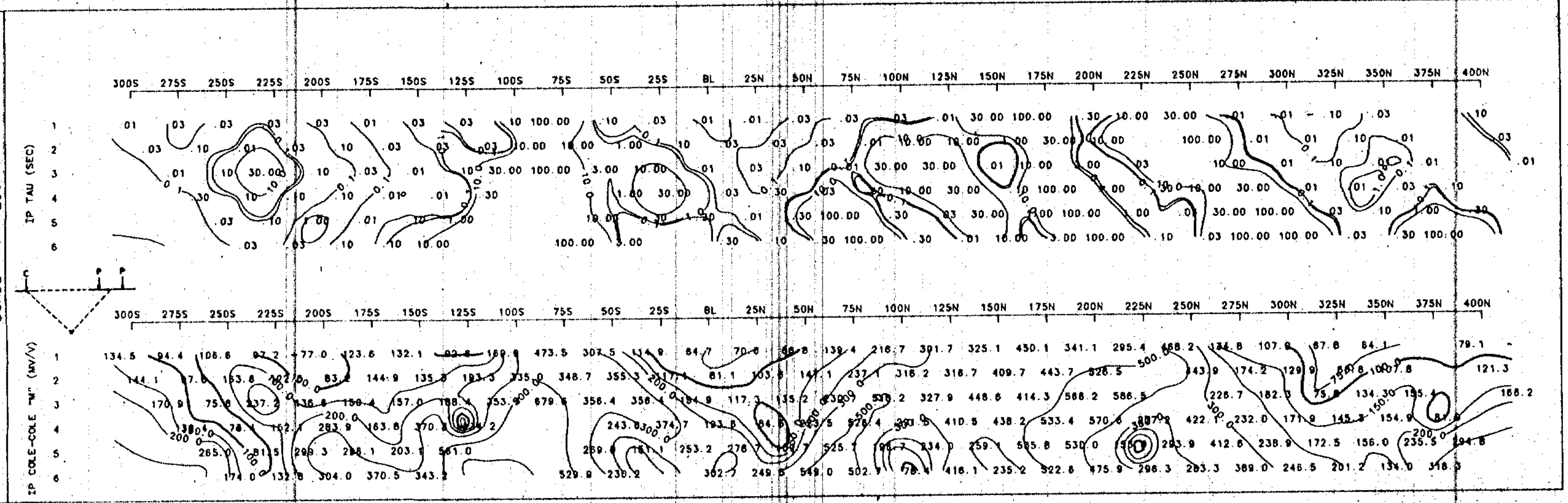
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 7 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



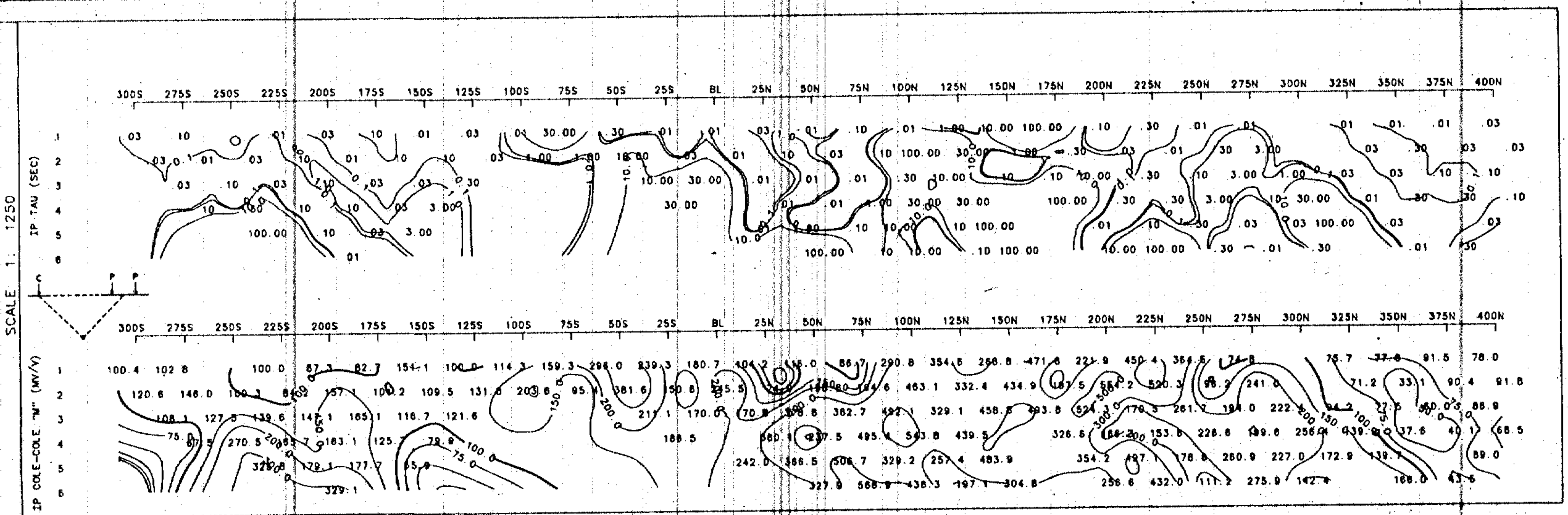
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 6 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



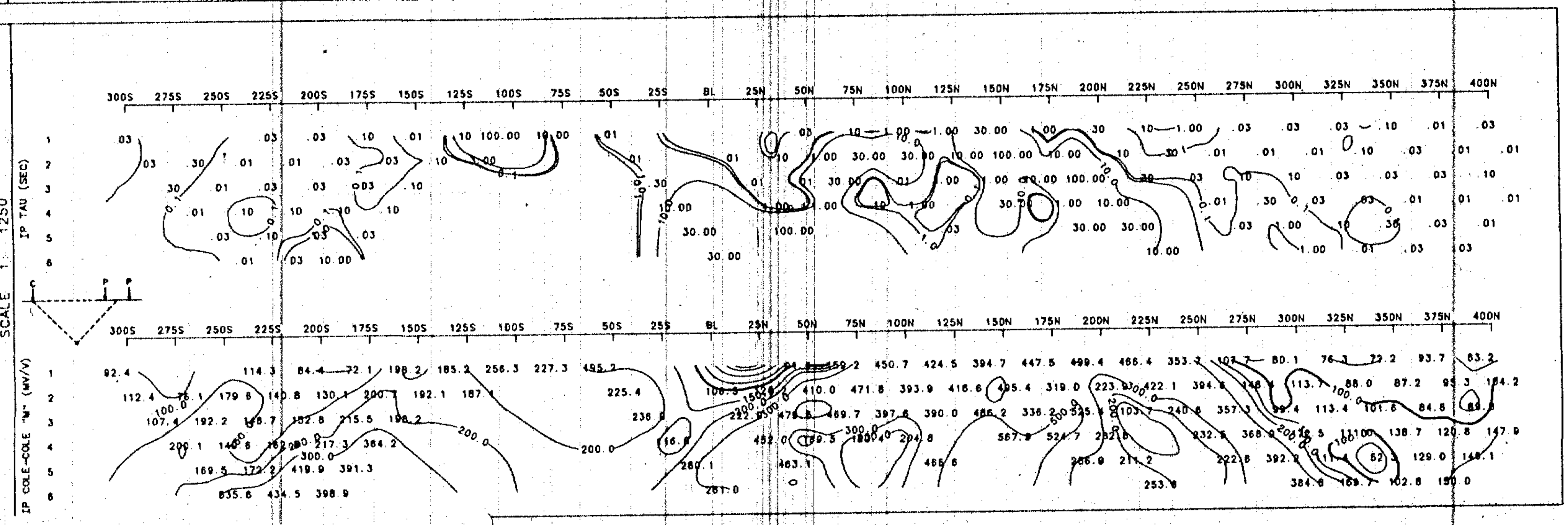
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 5 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



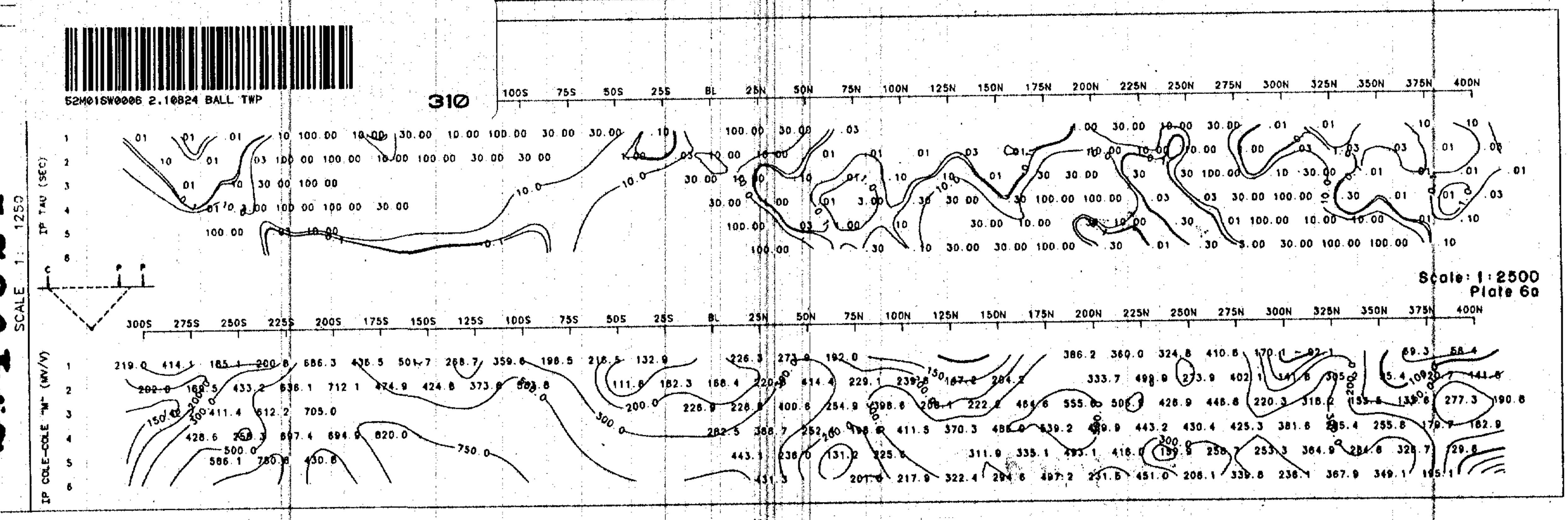
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 4 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 3 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 2 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 1 WEST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250

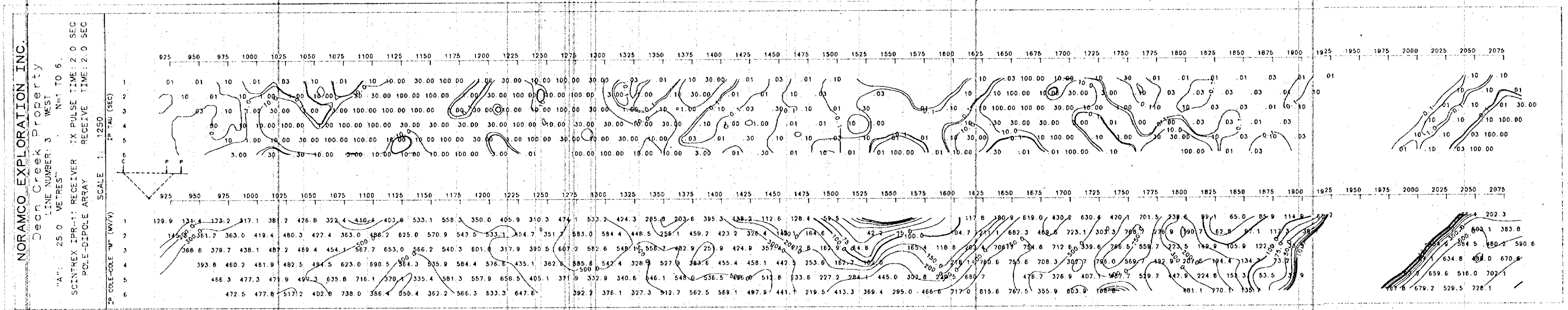
2.10824

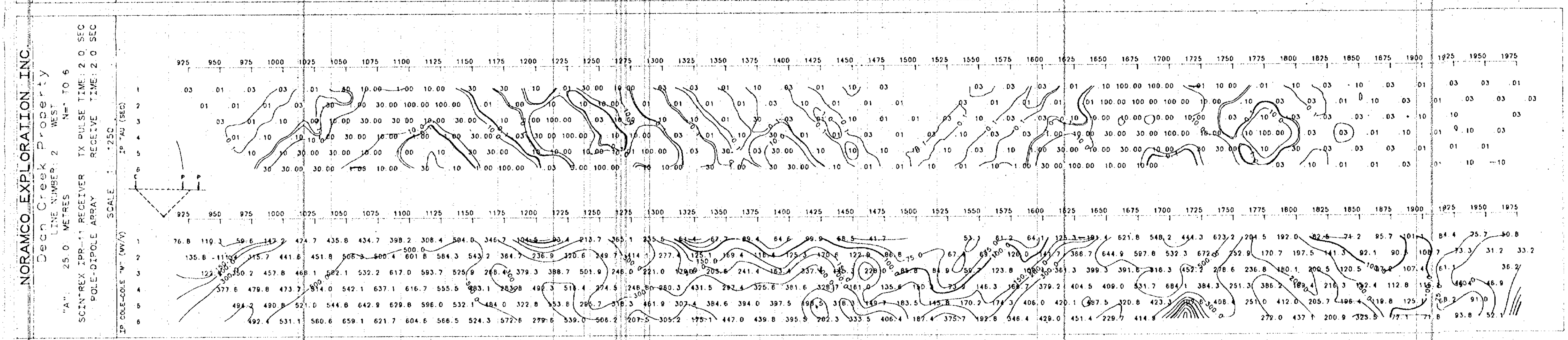
Scale: 1:2500
Plate 6a

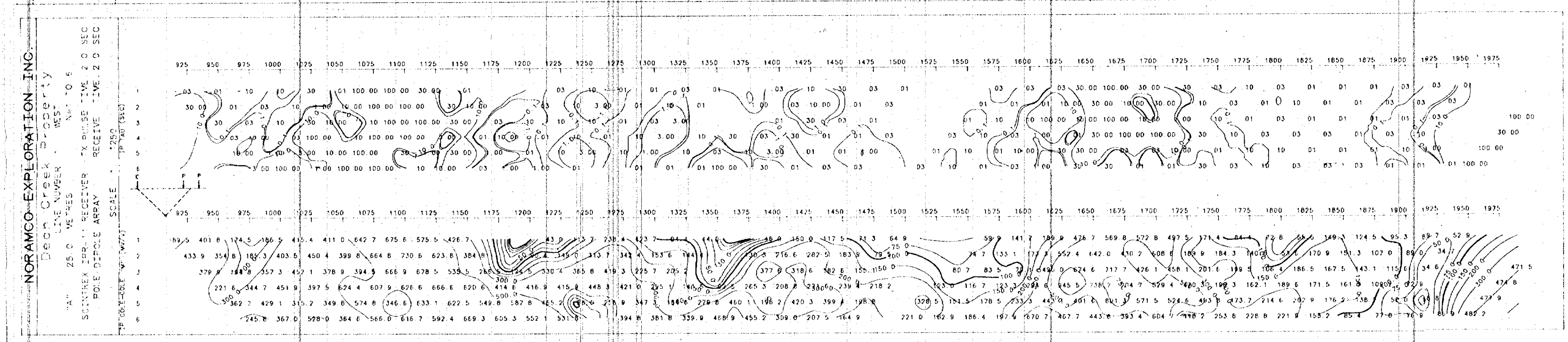
52H01SW0006 2.10824 BALL TWP

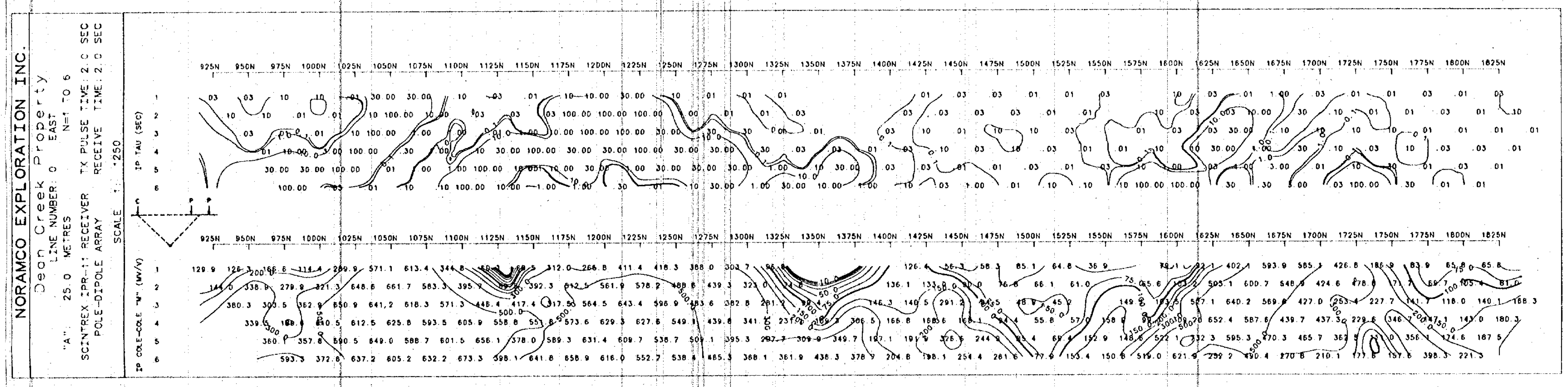
320

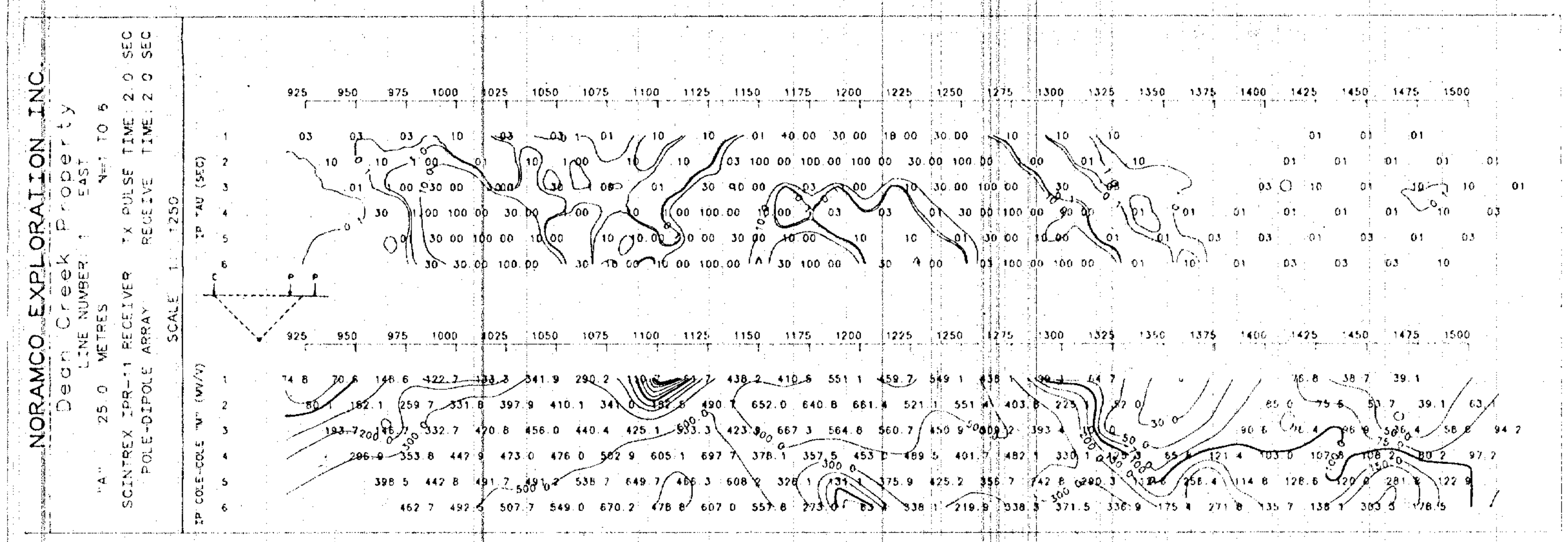
2.10824

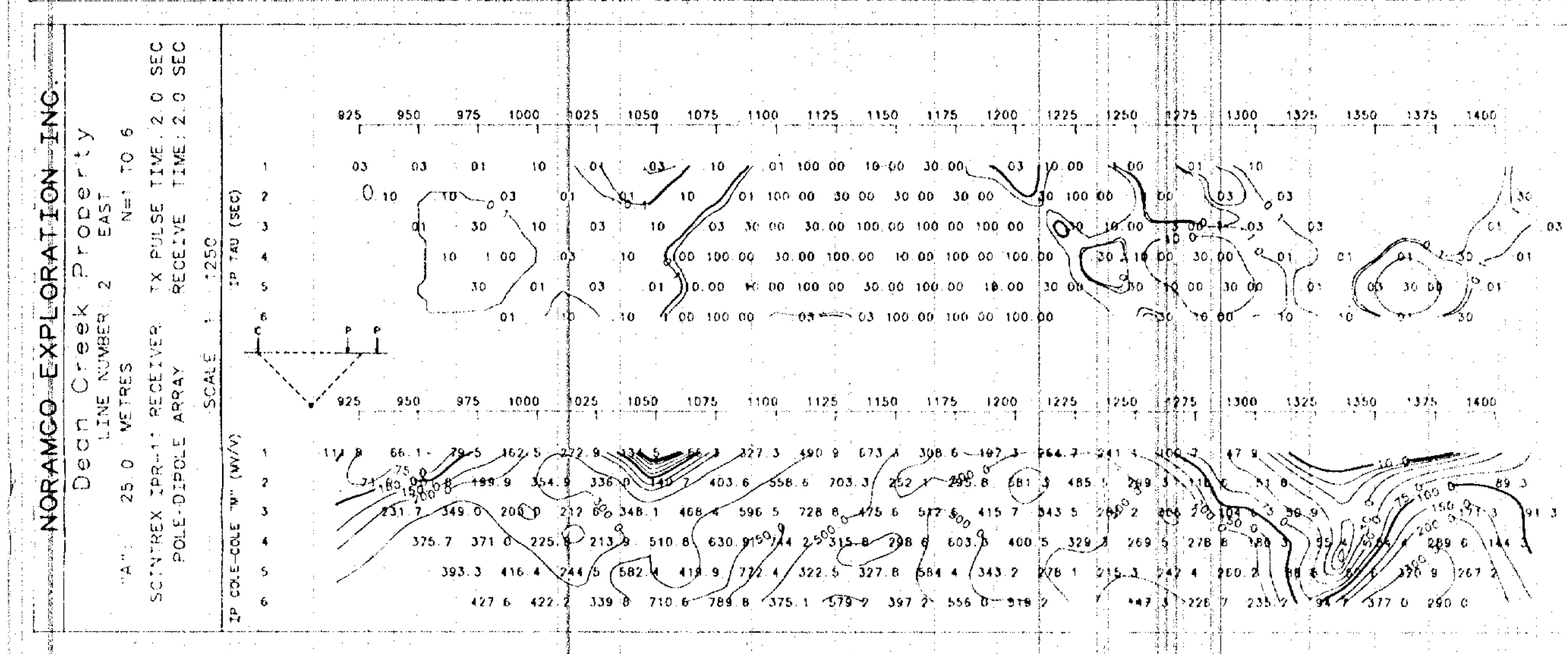


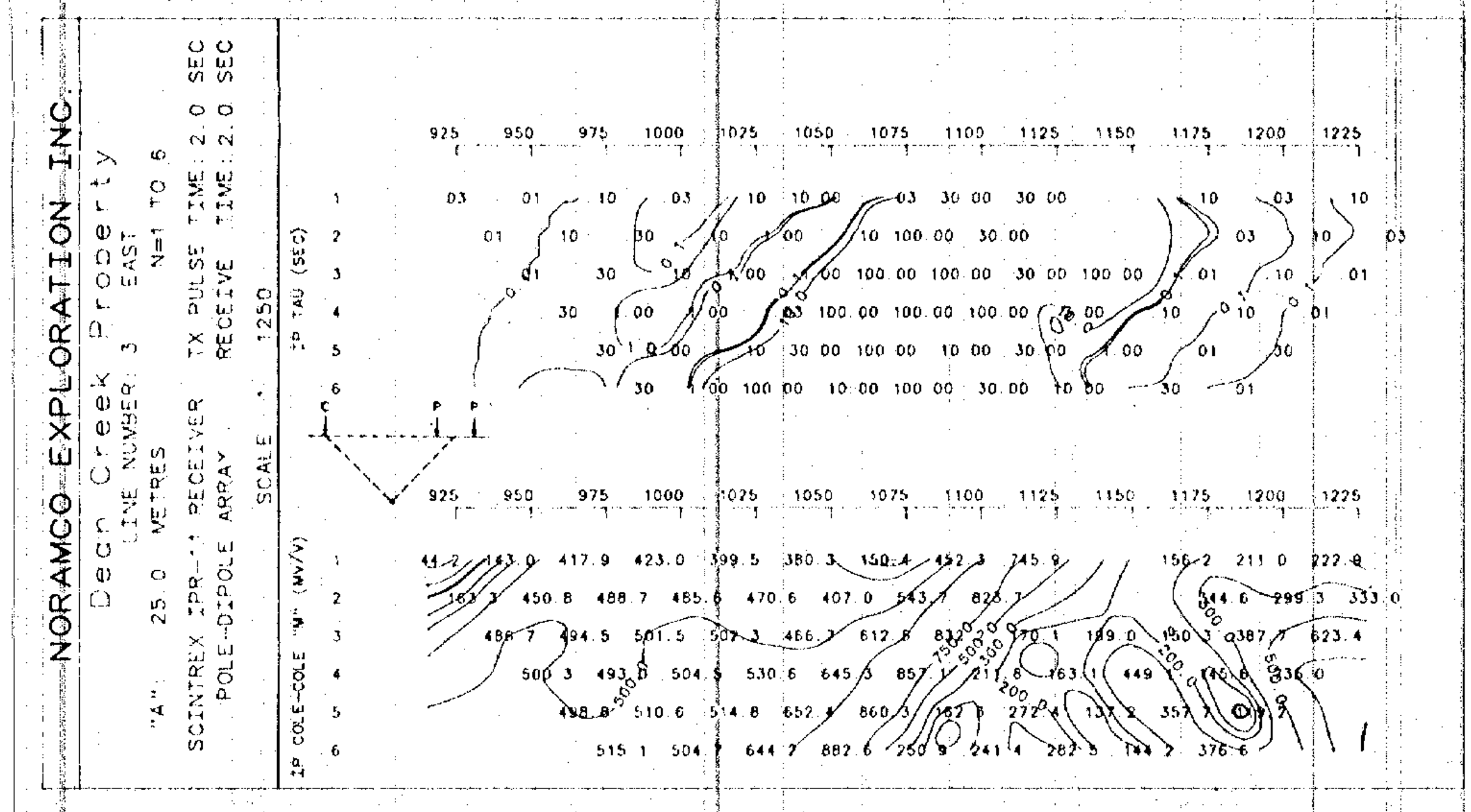


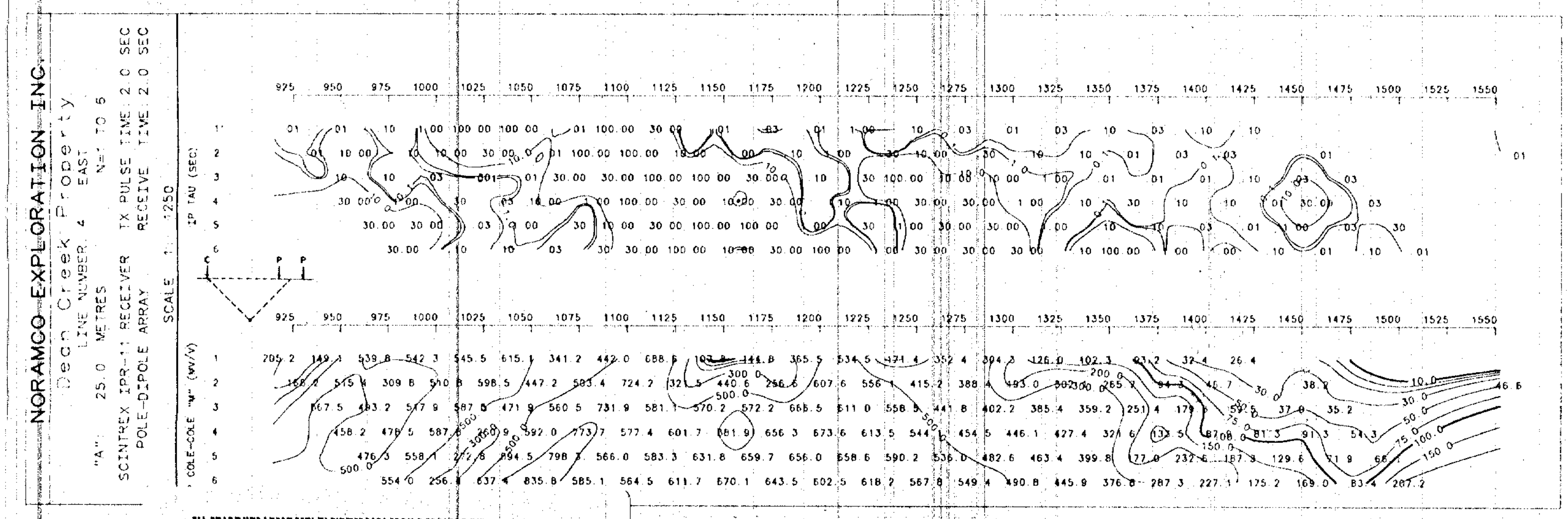


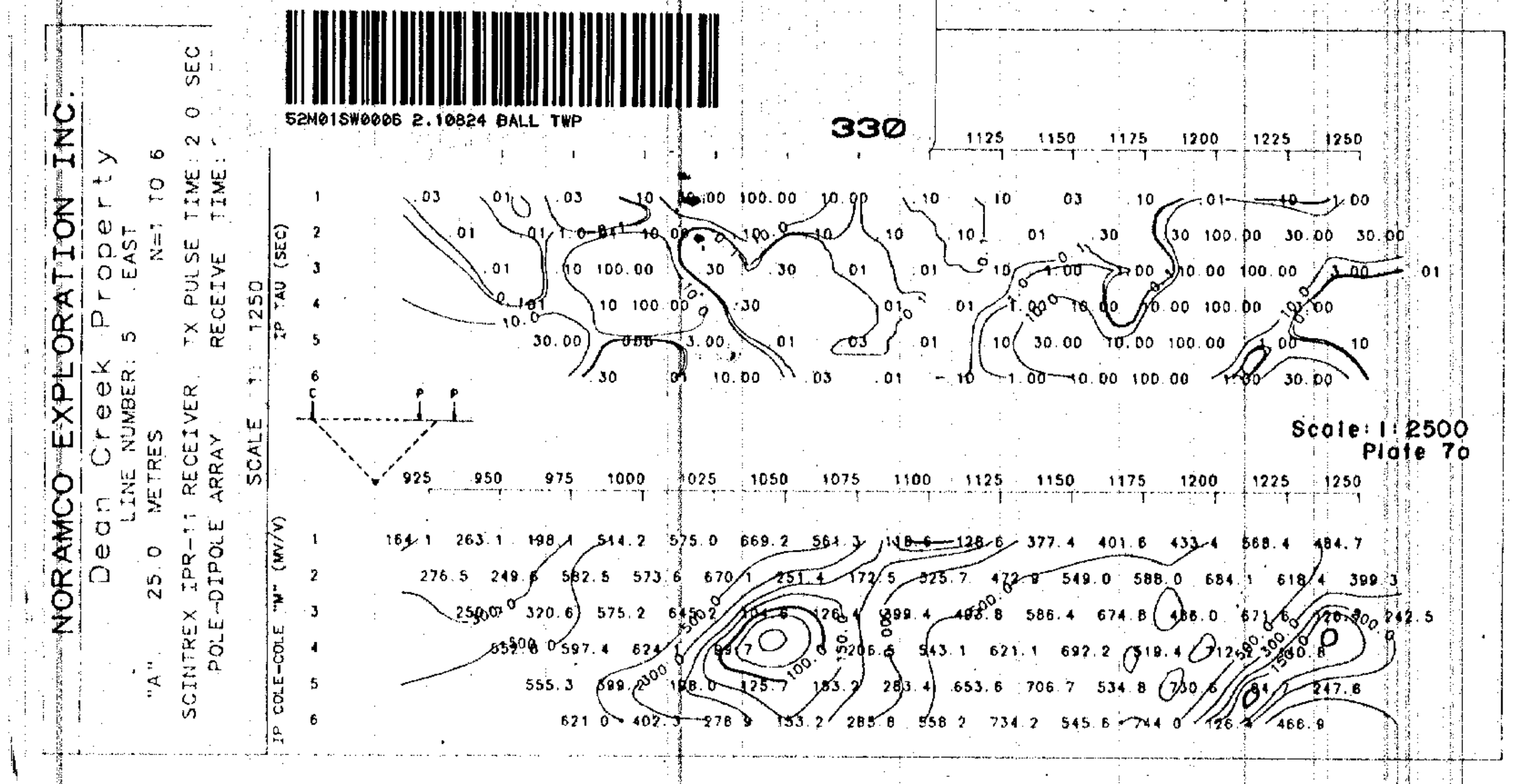












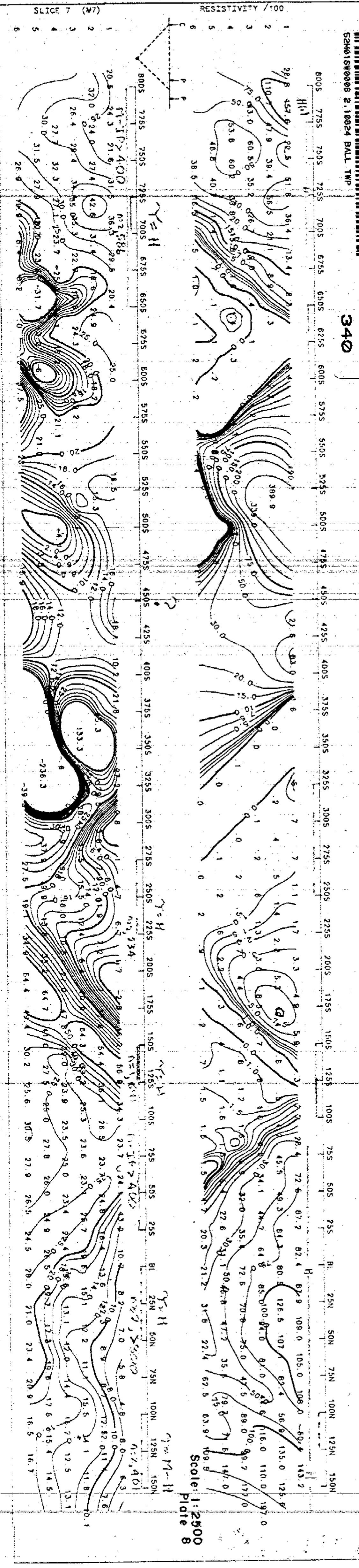
Scale 1:2500
Plate 7a

2.10824

2.10824

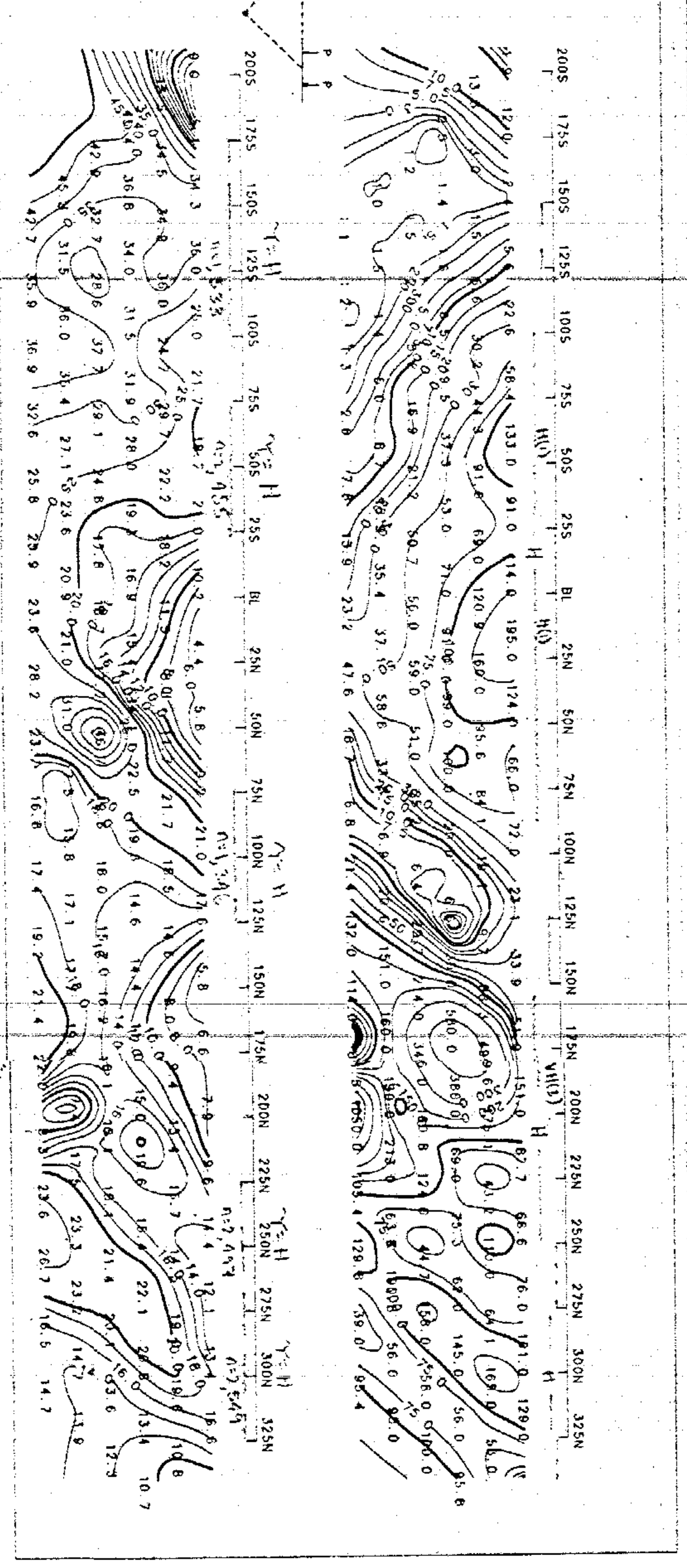
340

NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 8 EAST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250

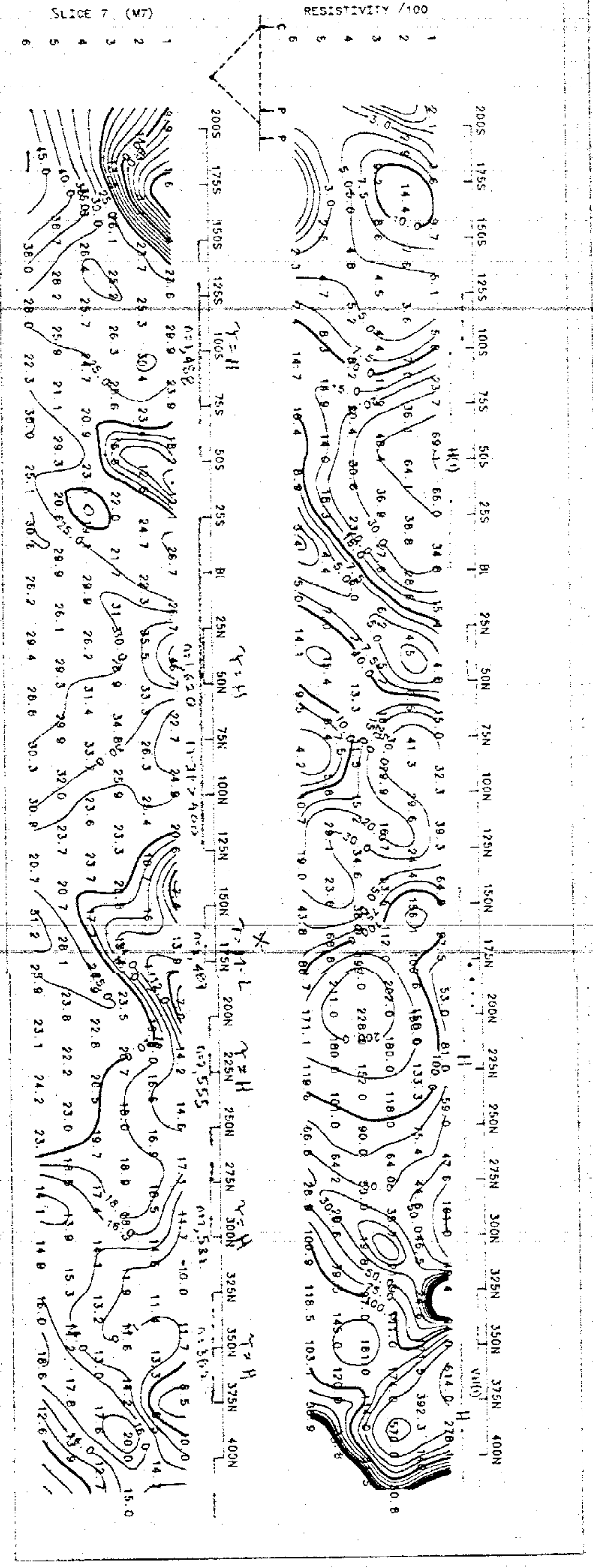


Scale 1:2500
Plate 8

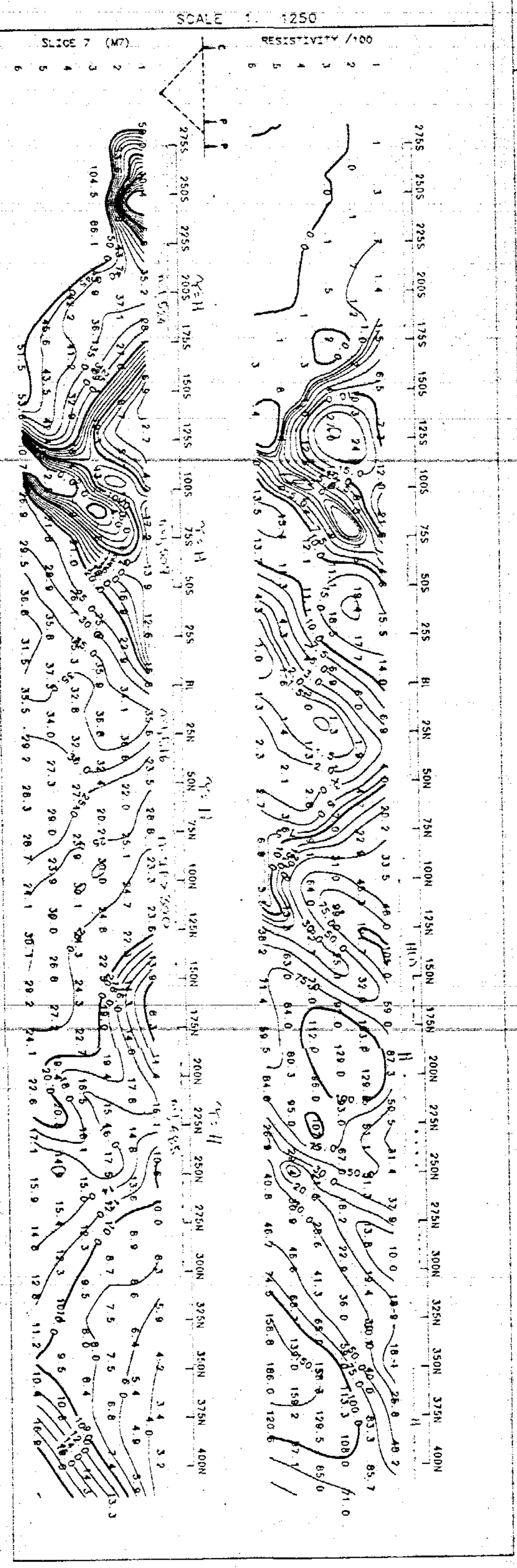
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 7 EAST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



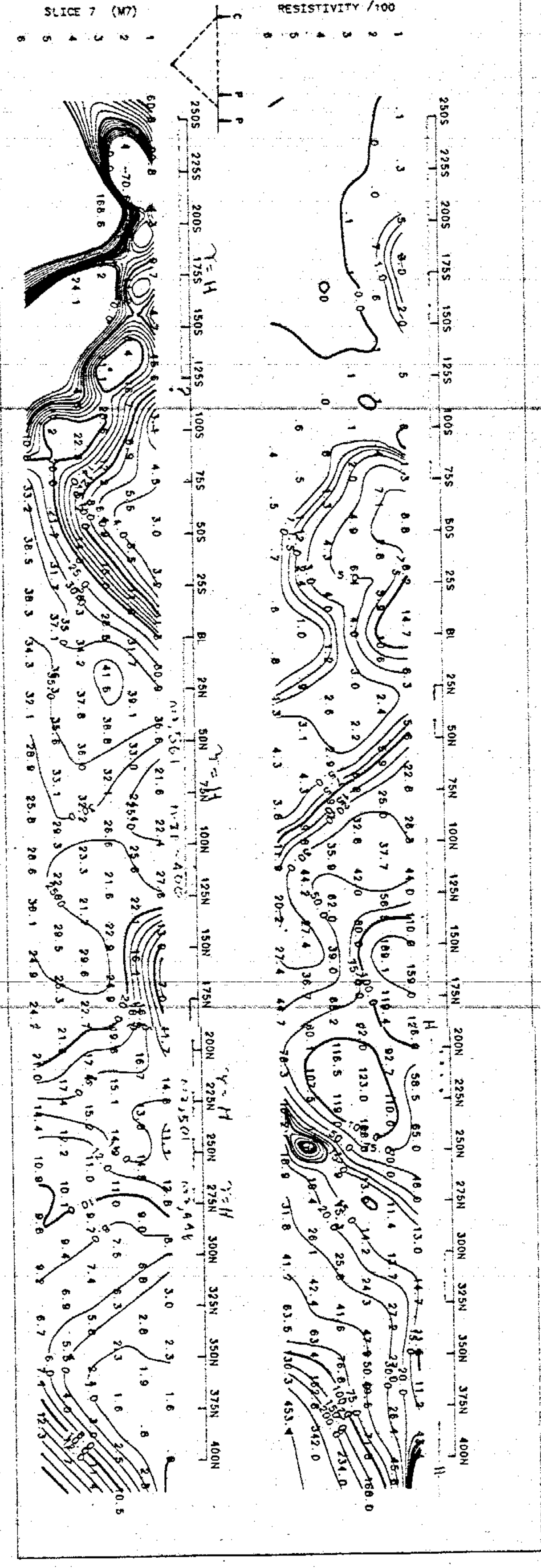
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 6 EAST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



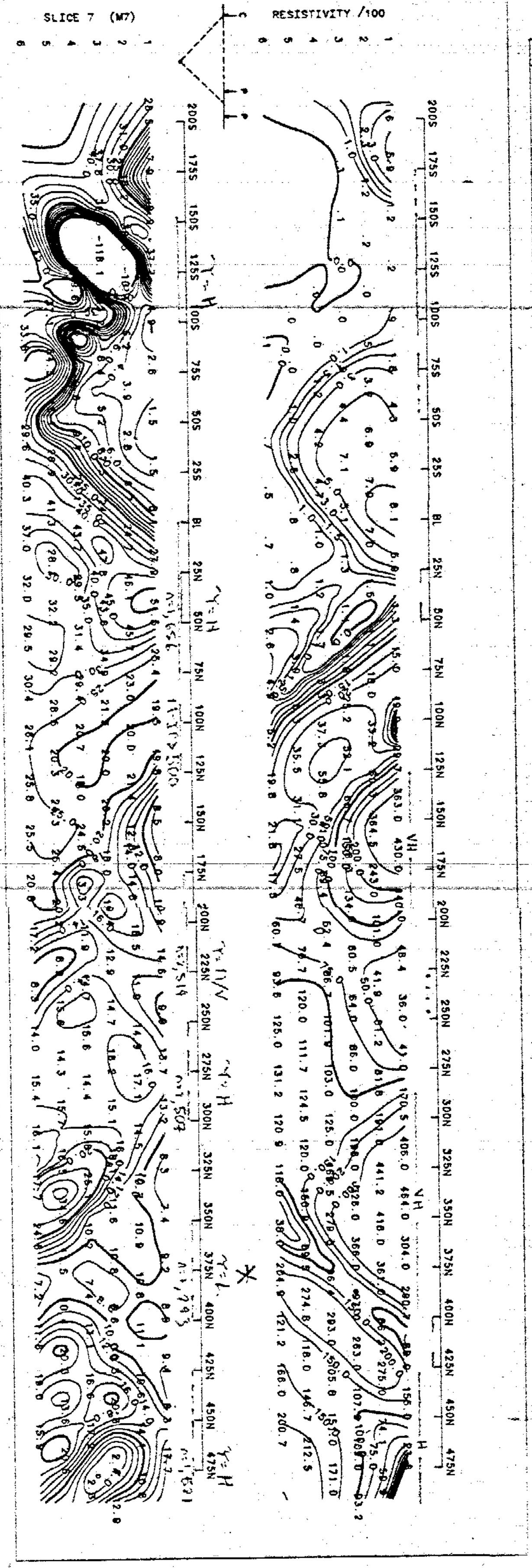
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 5 EAST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



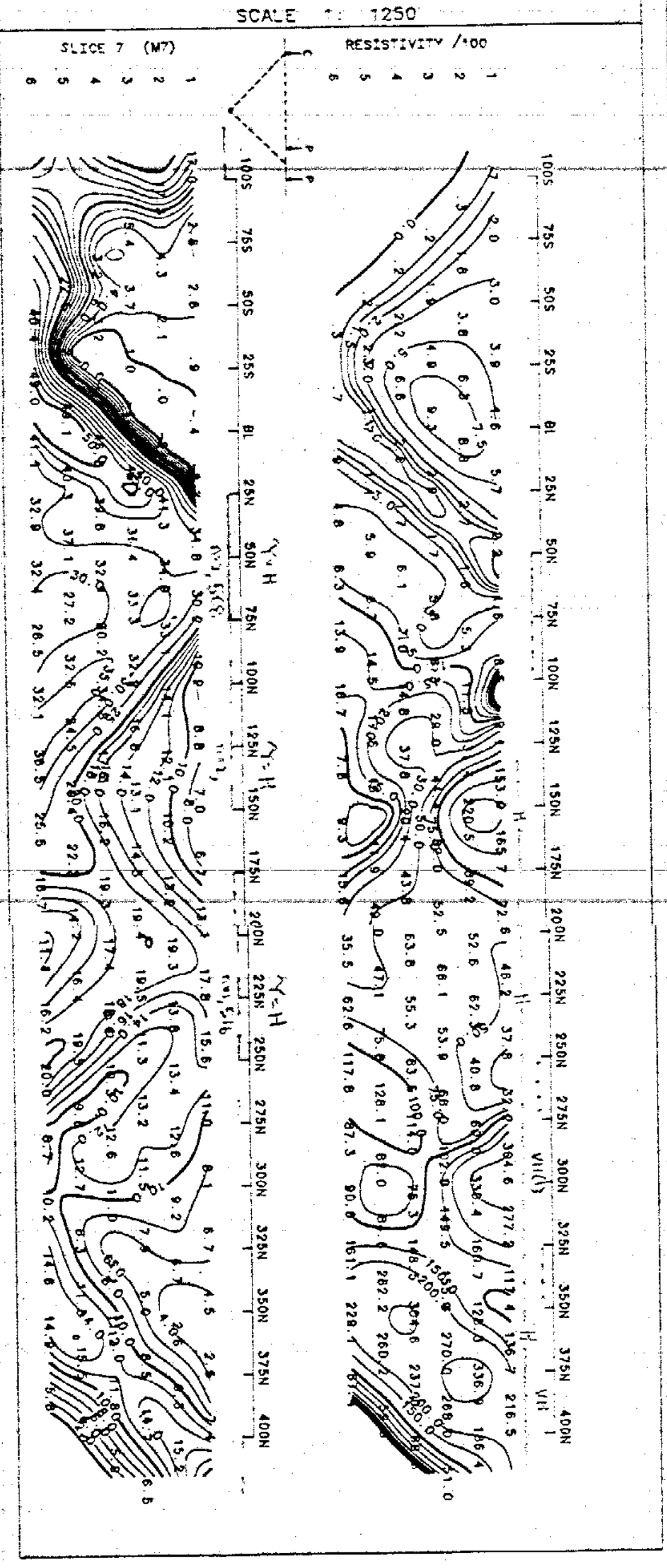
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 4 EAST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



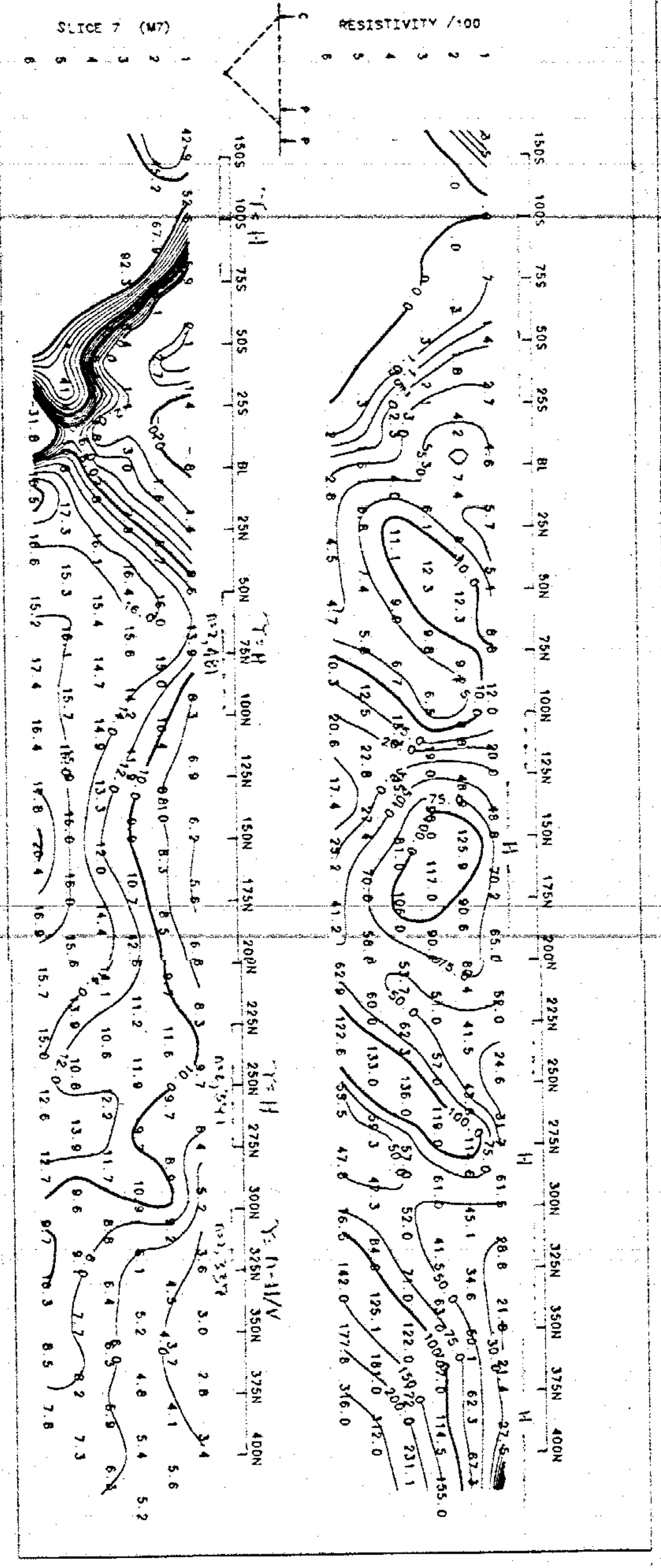
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 3 EAST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



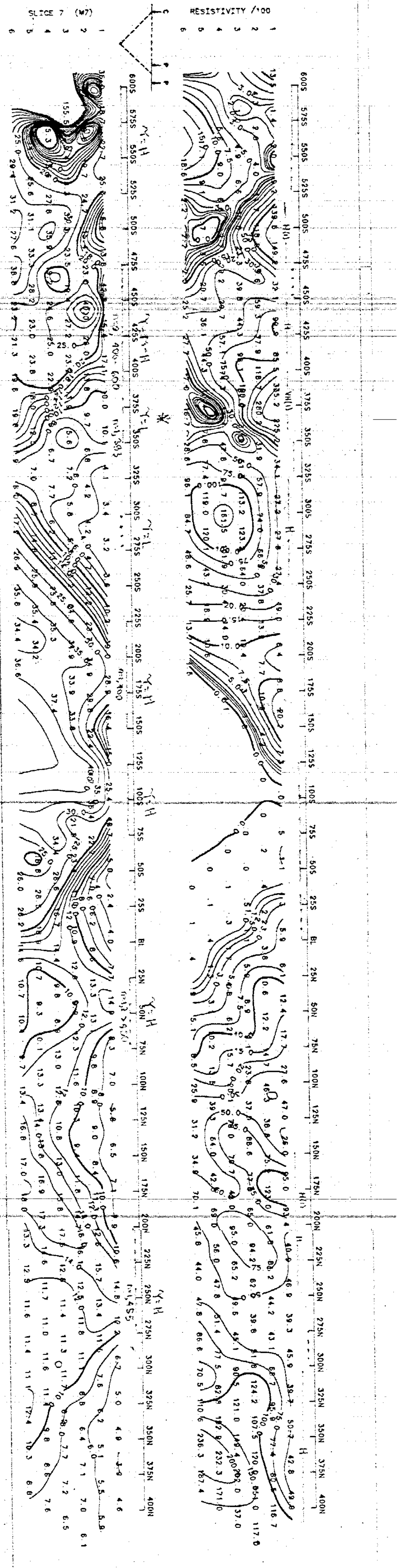
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 2 EAST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



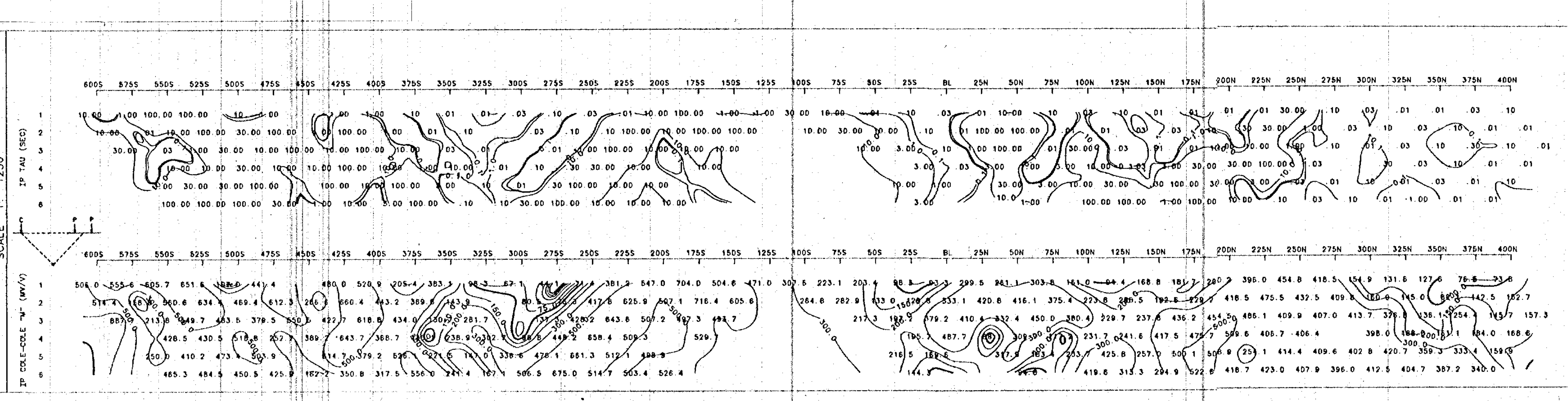
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 1 EAST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250

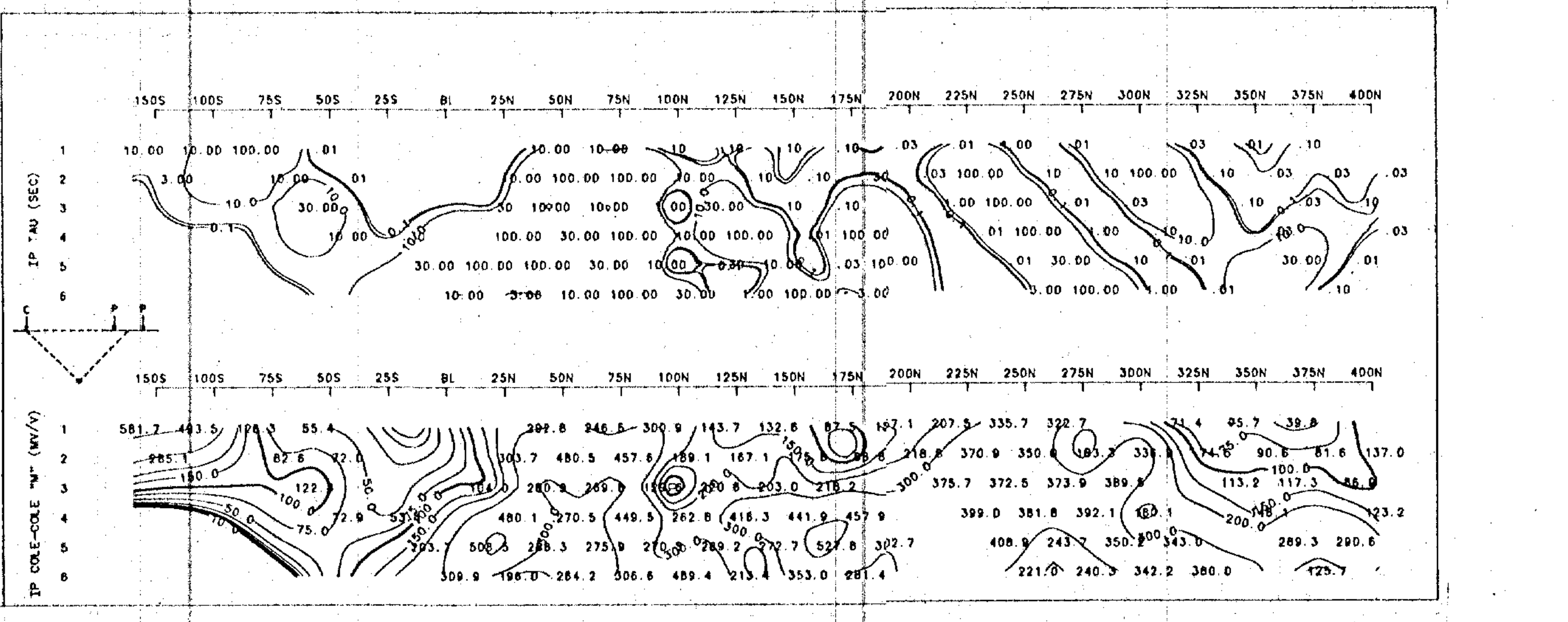


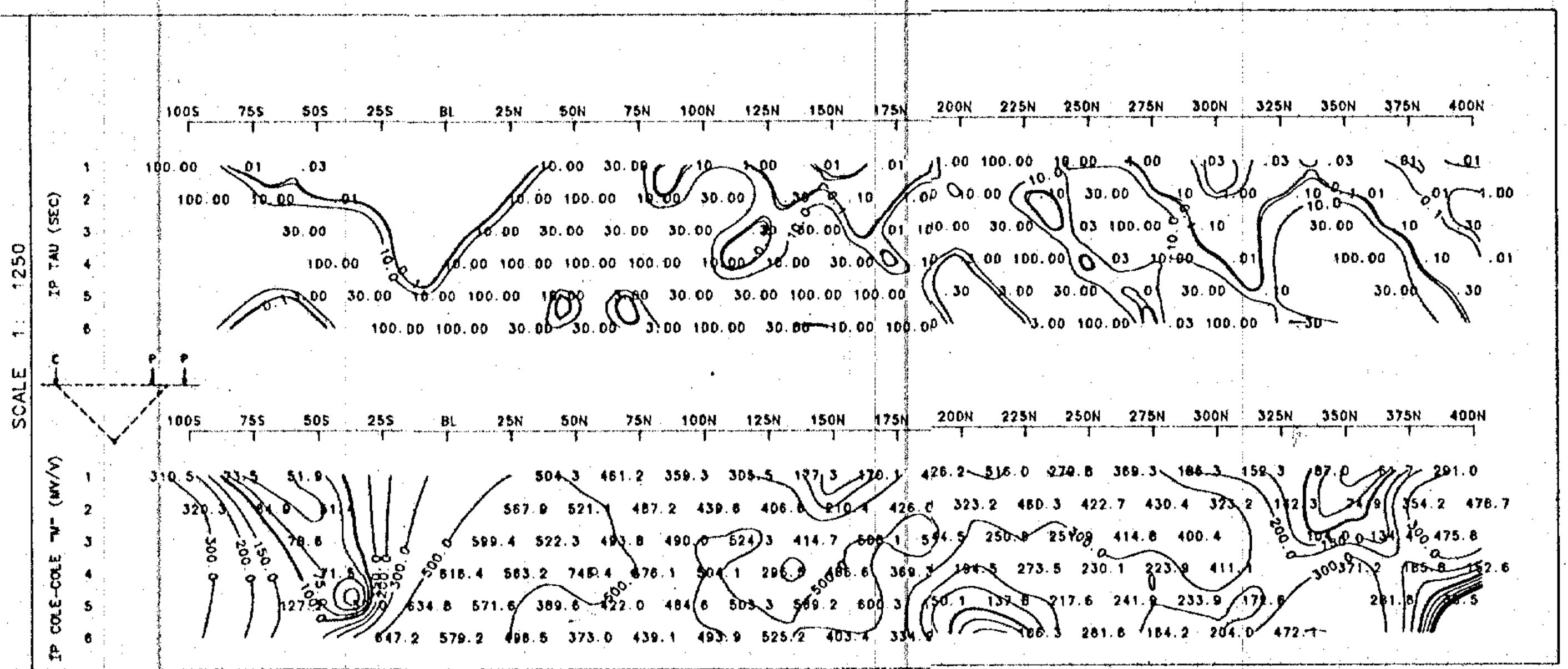
NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 0 EAST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250

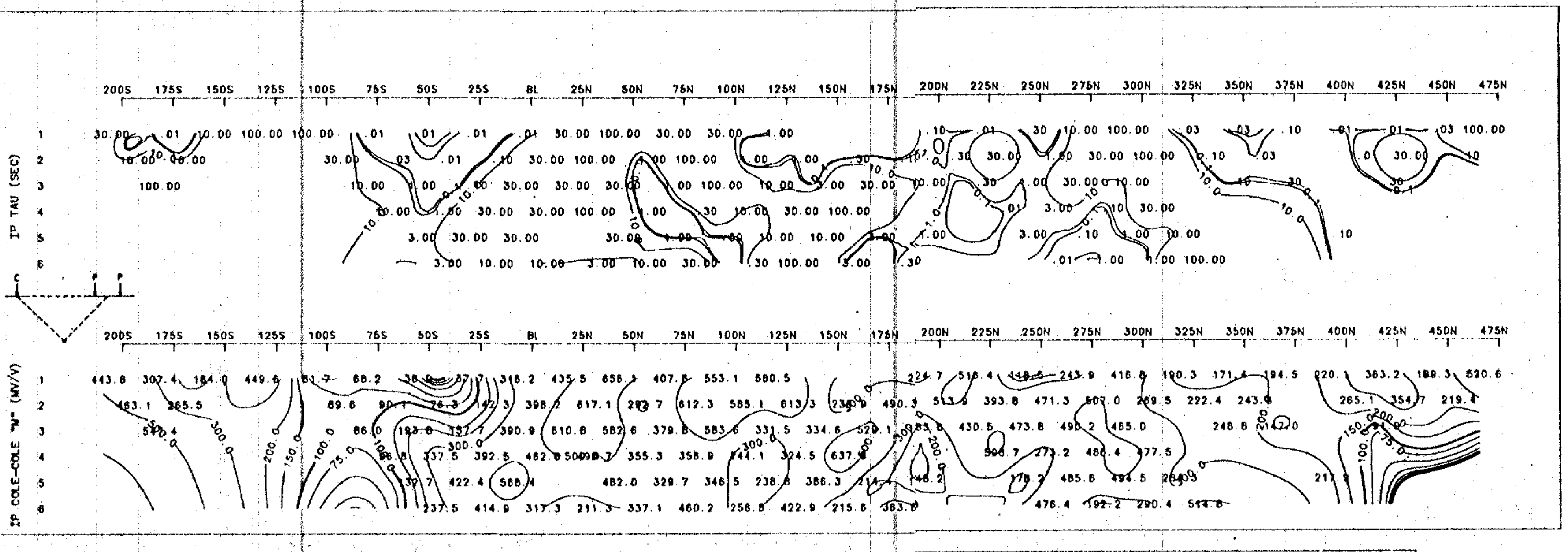


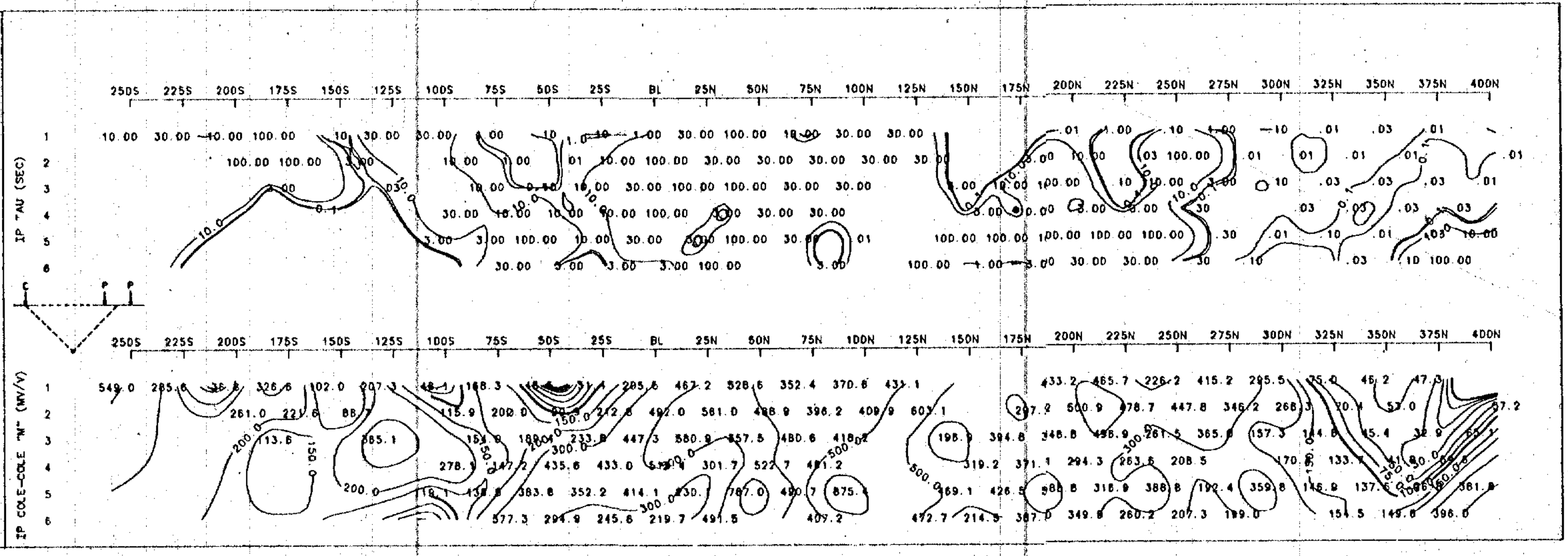
2.10824

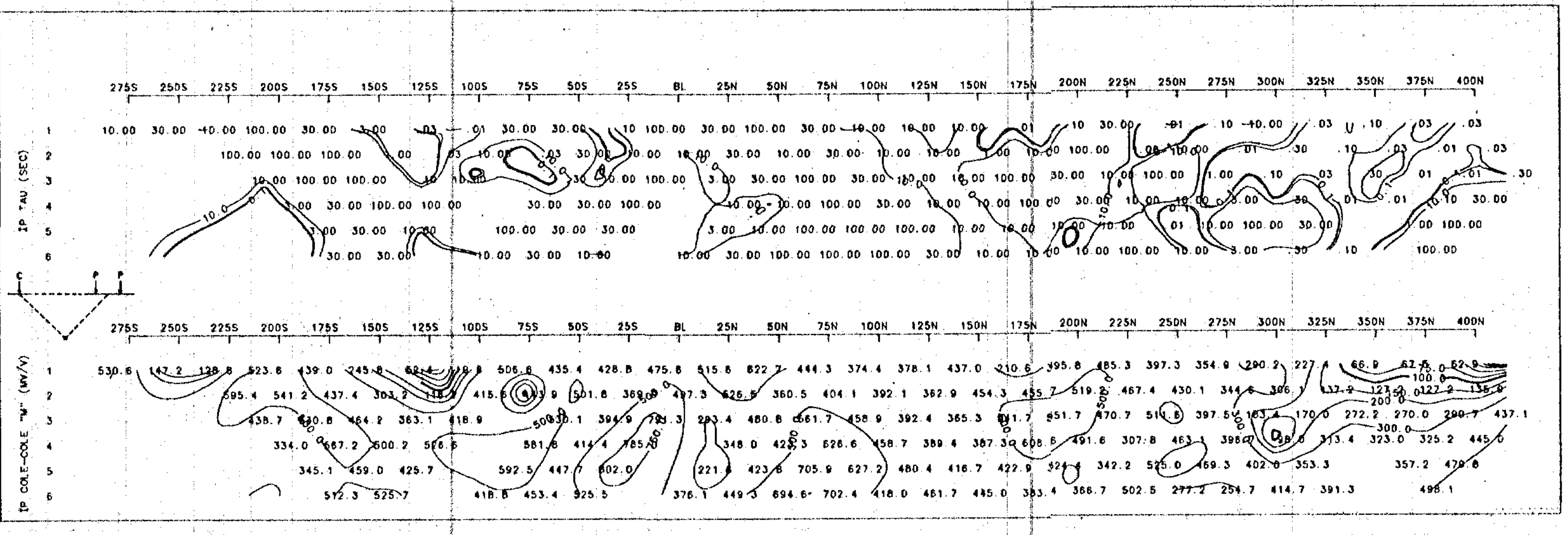

NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 0 EAST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250

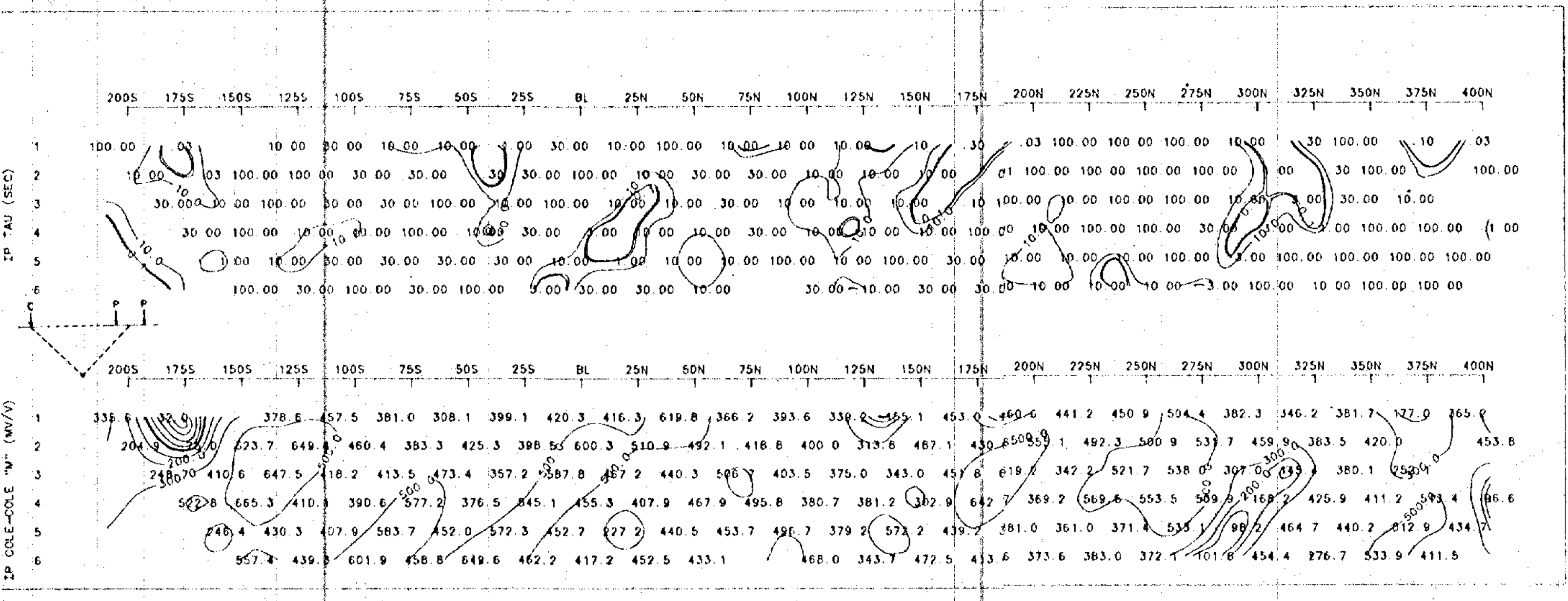

NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 1 EAST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250

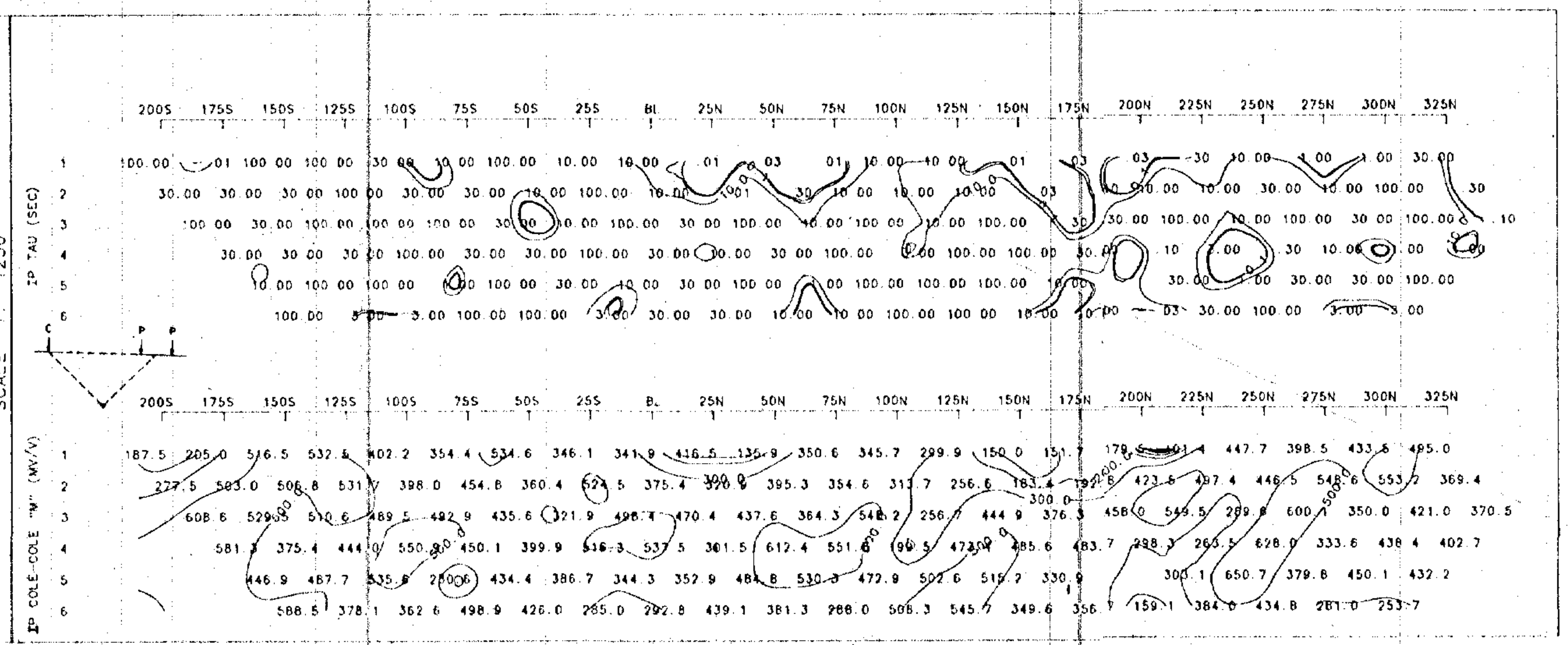

NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 2 EAST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250


NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 3 EAST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250


NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 4 EAST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250

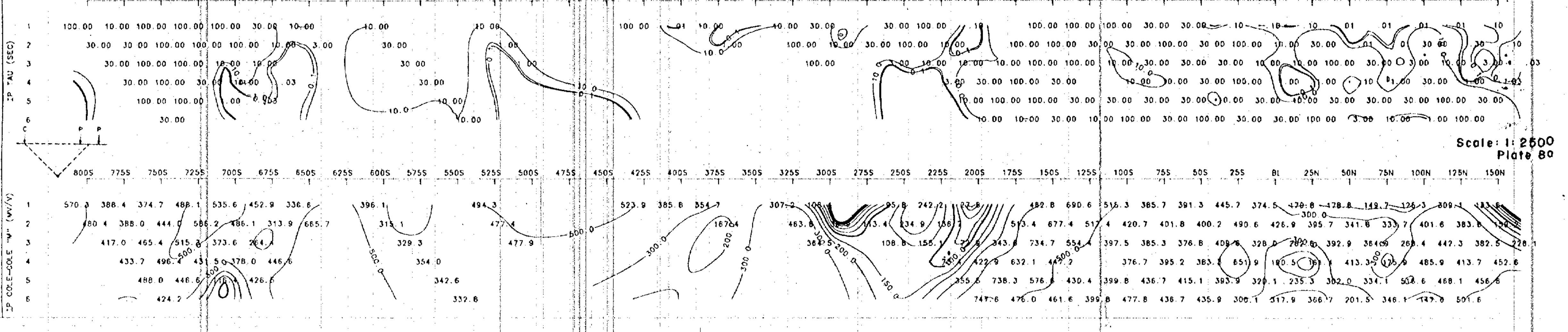

NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 5 EAST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250


NORAMCO EXPLORATIONS INC.
Dean Creek Property
LINE NUMBER: 6 EAST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250


NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 7 EAST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250

52M01SW0006 2.10824 BALL TWP

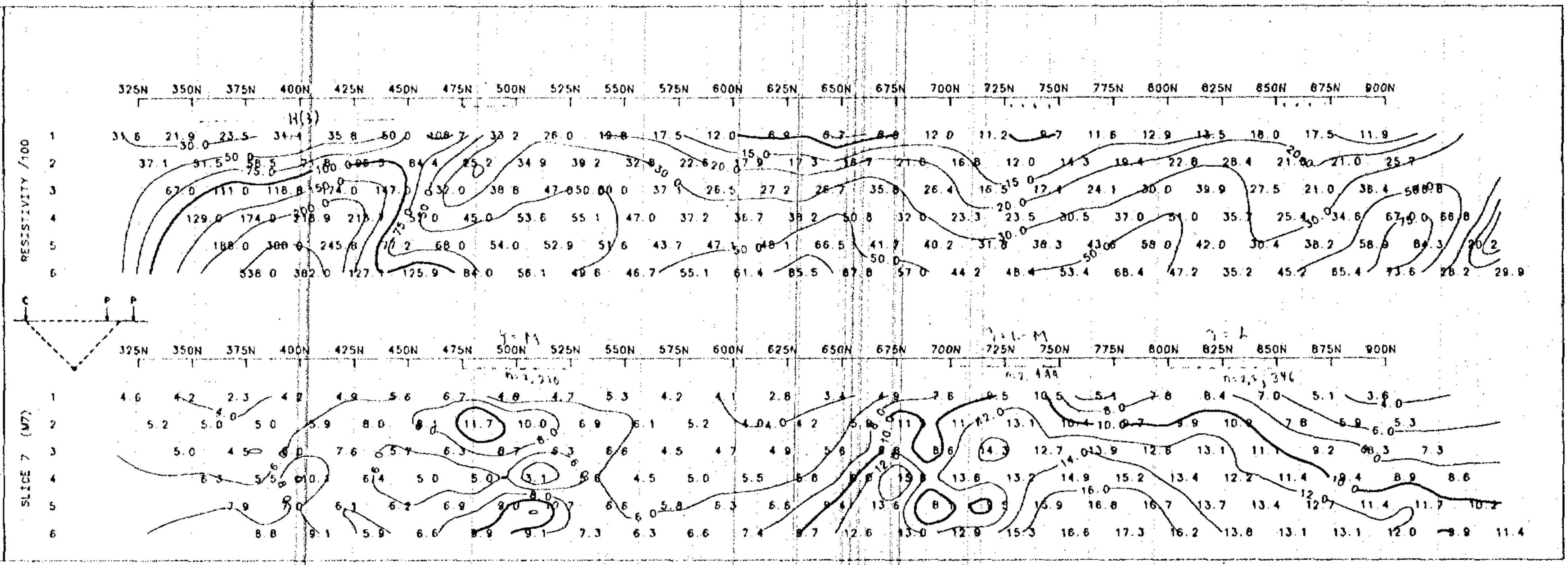
350


NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 8 EAST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250

Scale: 1:2500
Plate 80

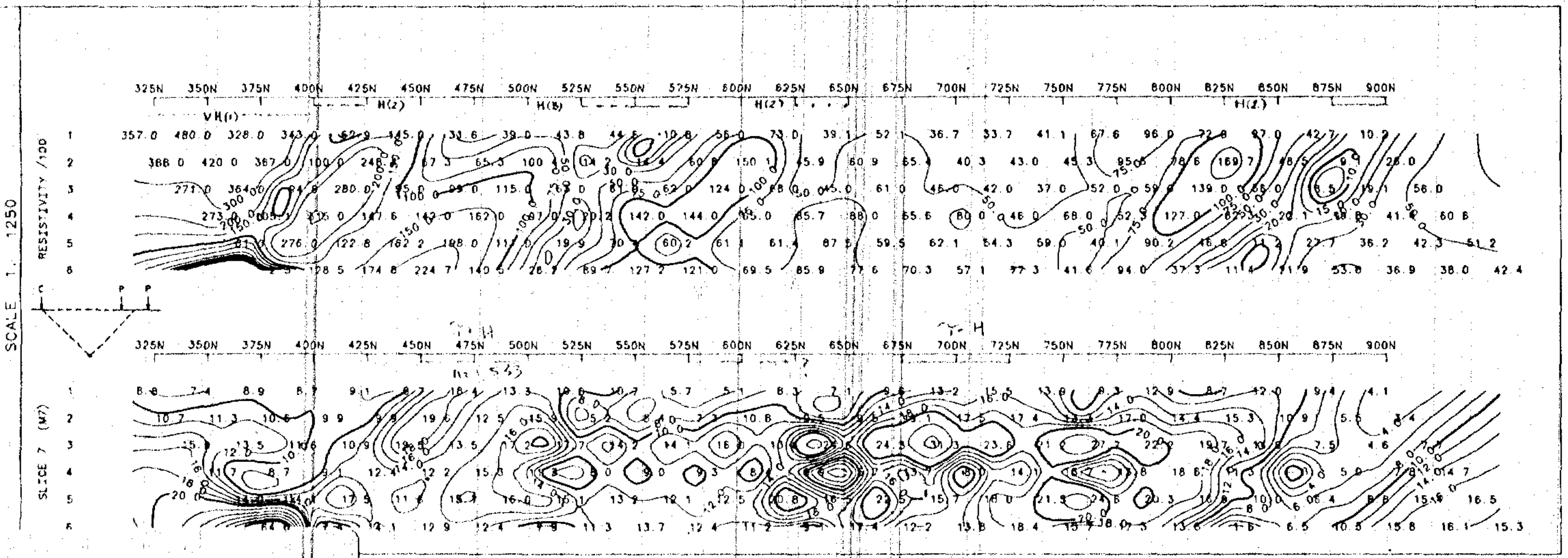
NORAMCO EXPLORATION INC.

Dean Creek Property
LINE NUMBER: 1 EAST
"A" 25.0 METRES N=1 TO 5
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



NORAMCO EXPLORATION INC.

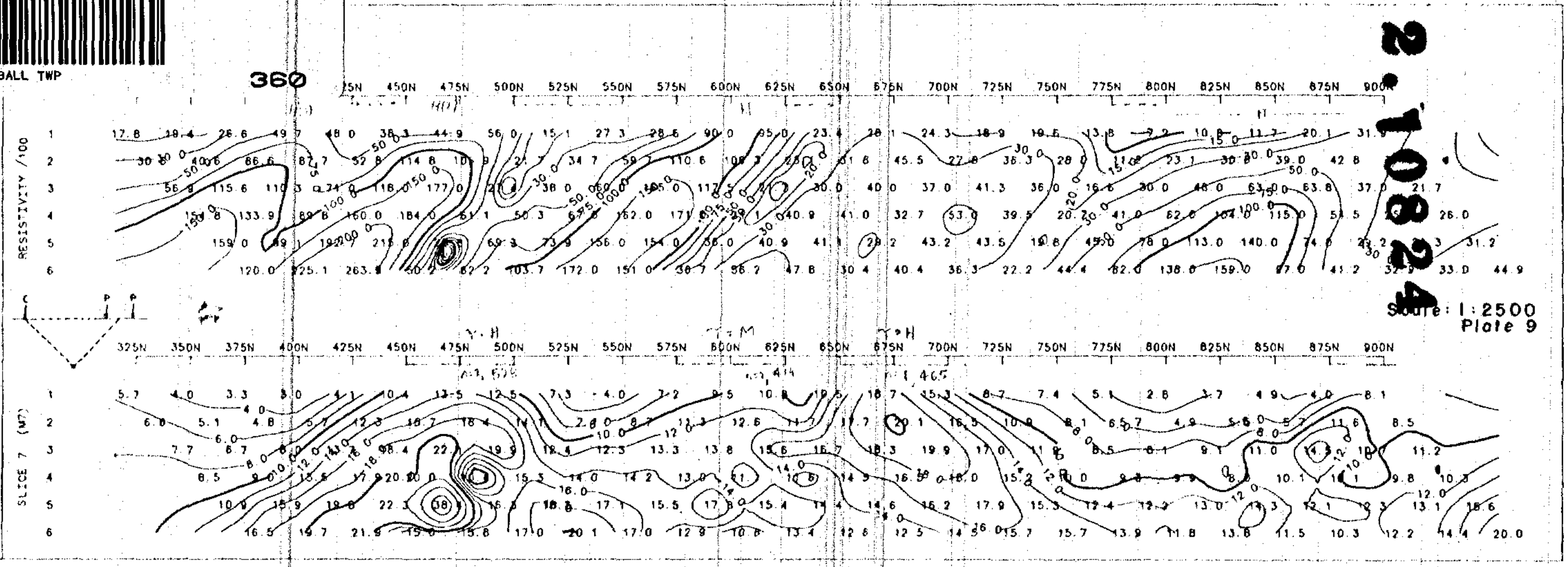
Dean Creek Property
LINE NUMBER: 3 EAST
"A" 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



360

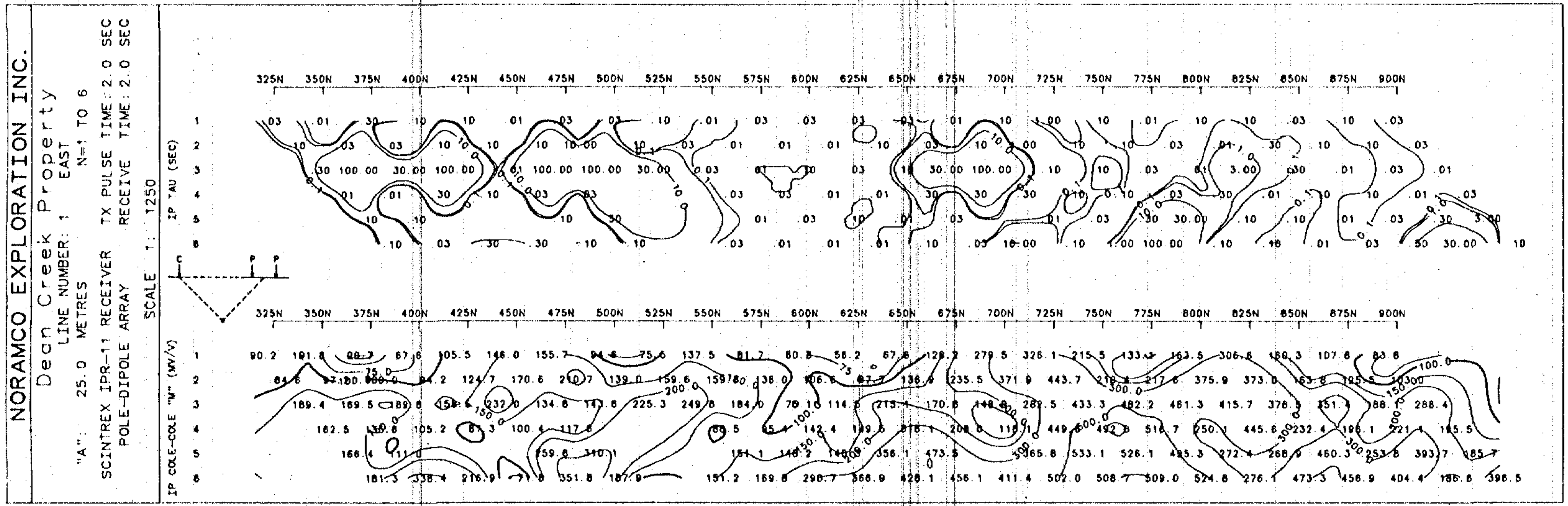
NORAMCO EXPLORATION I

Dean Creek Property
LINE NUMBER: 5 EAST
"A" 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME
POLE-DIPOLE ARRAY RECEIVE TIME
SCALE 1: 1250

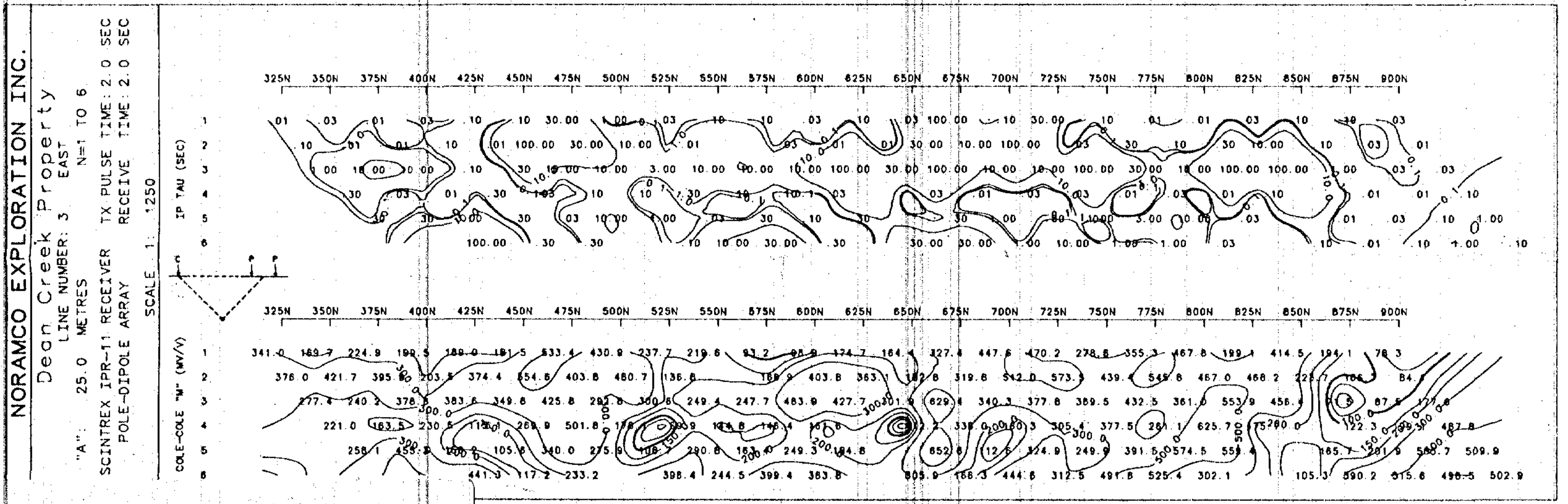


2.10824

Scale: 1:2500
Plate 9

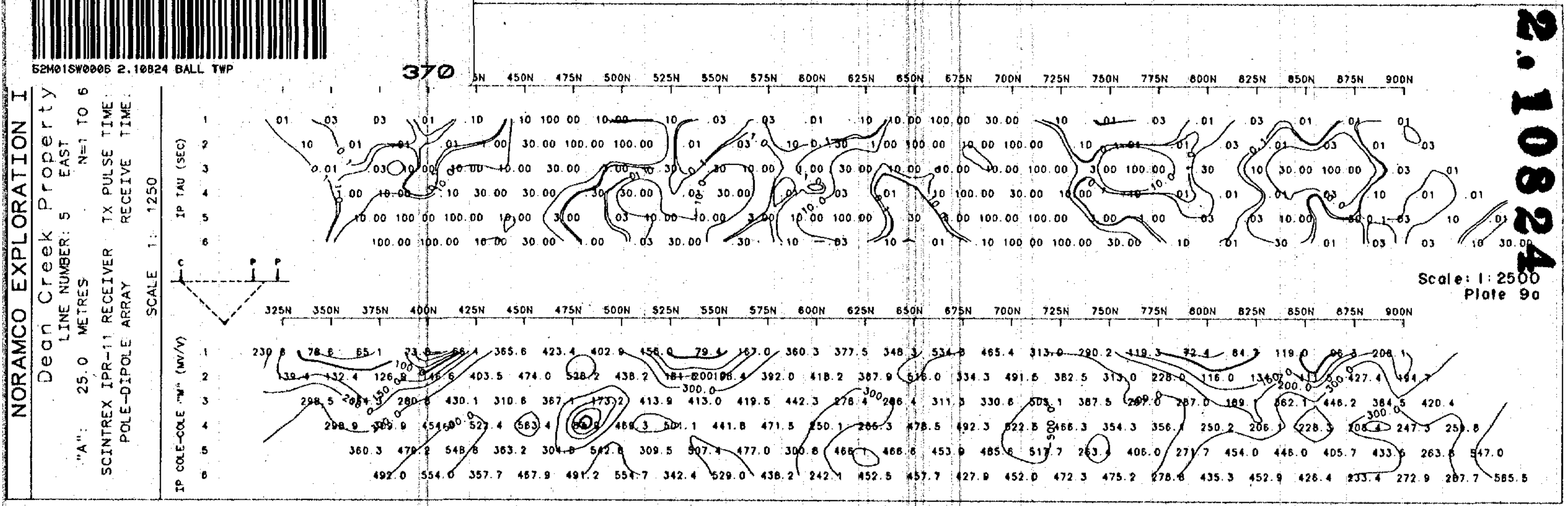


NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 1 EAST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250



NORAMCO EXPLORATION INC.
Dean Creek Property
LINE NUMBER: 3 EAST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250

370



NORAMCO EXPLORATION I
Dean Creek Property
LINE NUMBER: 5 EAST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME:
POLE-DIPOLE ARRAY RECEIVE TIME:
SCALE 1: 1250

2.10824

Scale: 1:2500
Plate 9a