REPORT ON AN INDUCED POLARIZATION AND RESISTIVITY SURVEY IN DUFF TWP., COCHRANE AREA NORTHEAST ONTARIO

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JVX

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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

REPORT ON AN INDUCED POLARIZATION/RESISTIVITY SURVEY IN DUFF TWP. COCHRANE AREA, NORTHEAST ONTARIO

On Behalf Of

CENTRAL CRUDE RESOURCES LTD.

1. INTRODUCTION

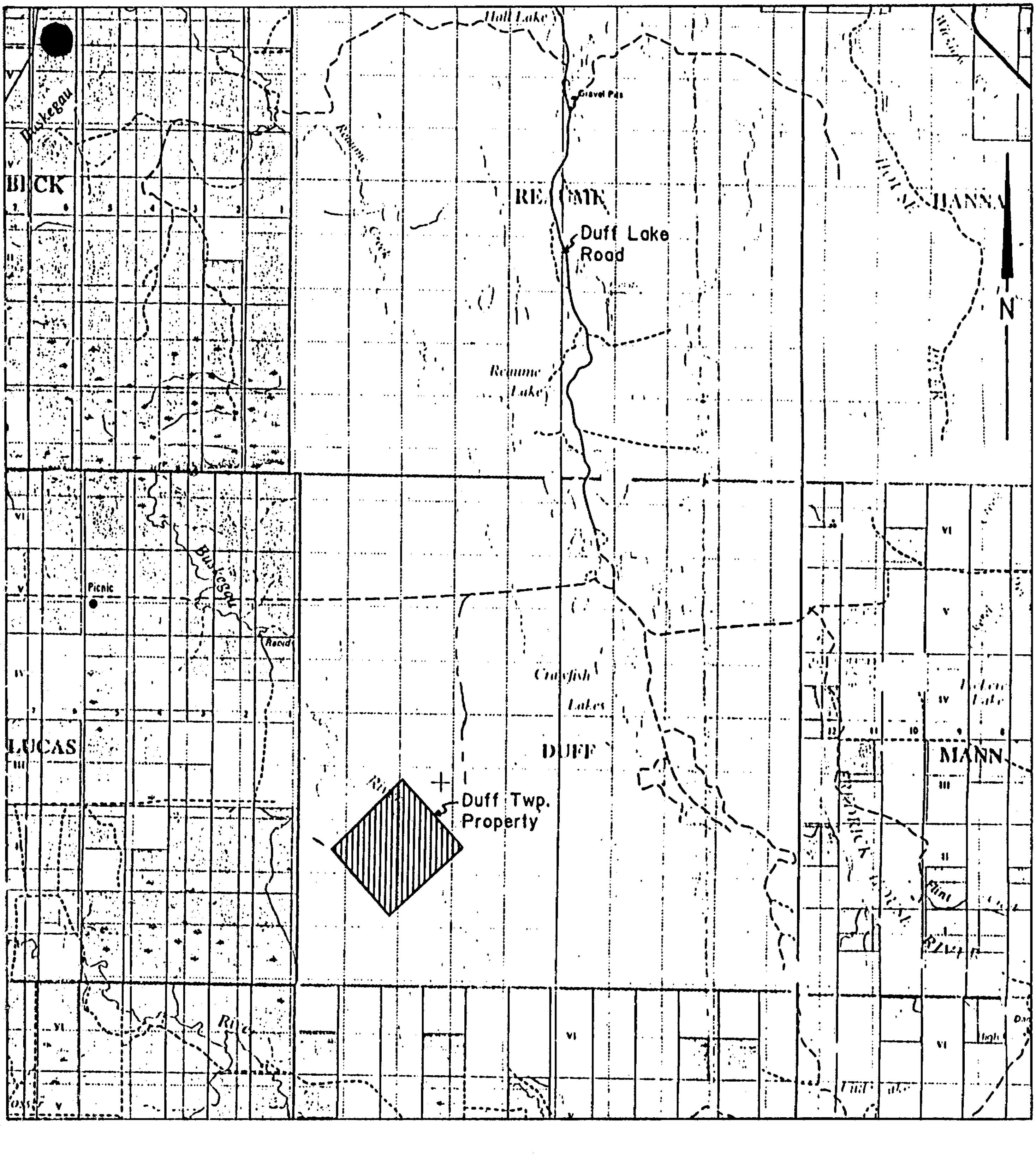
During November and early December, 1988, JVX Ltd. carried out a Time-Domain Spectral IP/Resistivity survey on the Duff Twp. property of Central Crude Resources Ltd.(JVX Project 8861).

A total of 21.8 line-km was achieved on 8 survey lines. A pole-dipole array with n=1 to 6 and an a-spacing of 50 metres was employed.

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

2. SURVEY LOCATION

The survey grid is located in the southeast corner of Duff Township, in the Cochrane Area, Porcupine Mining Division. The latitude and Longitude of the property is 48 45'N and 81 10'W respectively. Figure 1 shows the survey area with respect to nearby townships at a scale of 1:100,000.



LOCATION MAP

CENTRAL CRUDE RESOURCES LTD.

DUFF TWP. PROPERTY

COCHRANE AREA, ONTARIO

I.P. / RESISTIVITY SURVEY

Survey by JVX Ltd.

Figure 1

3. SURVEY GRID AND COVERAGE

A total of 21.8 line-kilometres of geophysical survey coverage was achieved over the grid shown in Figure 2. A detailed production summary is given in Table 1 below.

TABLE 1

PRODUCTION SUMMARY

LINE	COVERAGE FROM	TO	LINE LENGTH (metres)	MEASUREMENT POINTS
L-2N	300E	3100W	3400	399
L-4N	350E	2950W	3300	392
L-6N	300E	2850W	3150	369
L-8N	250E	2550W	2800	327
L-10N	250E	2450W	2700	265
L-12N	200E	2250W	2450	285
L-14N	250E	2050W	2300	267
L-16N	200E	1500W	1700	204
		Total	21800km	2508

4. PERSONNEL

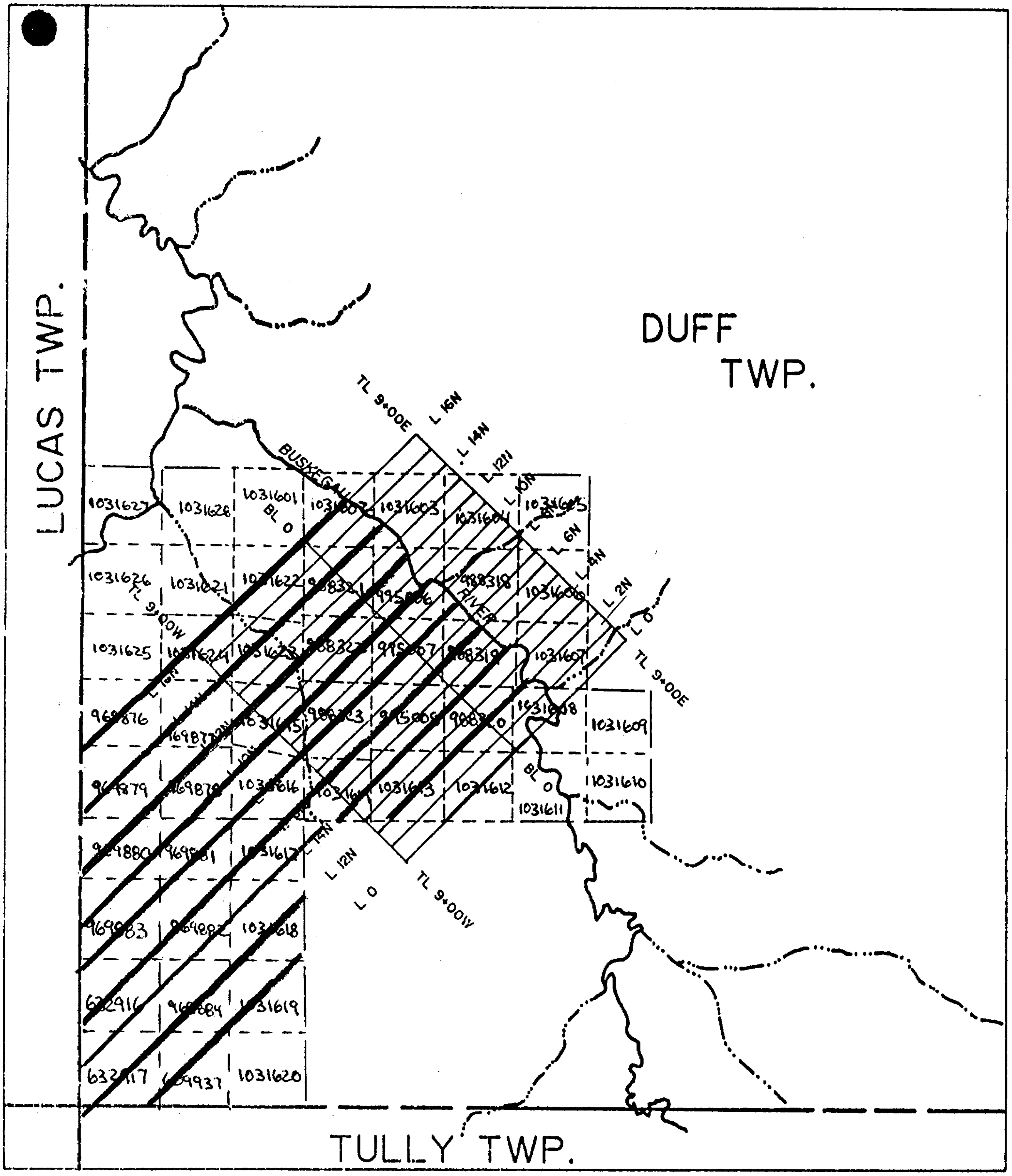
Mr. Steve Bortnick - Party Chief. Mr. Bortnick operated the IP receiver and compiled the data with the Corona microcomputer and Scintrex Soft II program.

Mrs. Charlotte Bortnick - Geophysical Operator. Mrs. Bortnick operated the IP transmitter and assisted in data compilation.

T. Webster, M. Denis, and S. Bortnick, Jr. acted as field assistants.

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

Mr. Blaine Webster - President, JVX Ltd. Mr. Webster provided overall supervision of the survey and the preparation of this report.



GRID MAP

CENTRAL CRUDE RESOURCES LTD.
DUFF TWP. PROPERTY
COCHRANE AREA, ONTARIO

I.P. / RESISTIVITY SURVEY

Scale : 1 inch = 1/2 mile

Survey by JVX Ltd.

Figure 2

5. INSTRUMENTATION

5.1 IP Receiver

For the IP/Resistivity survey 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 gates or slices. The instrument continuously averages primary voltage and chargeability until convergence takes place. At this point, the averaging process is stopped. Data is stored internally in solid-state memory.

5.2 IP Transmitter

The survey employed the Scintrex IPC-7/2.5 kW time domain transmitter powered by a motor generator. This instrument is capable of putting out a square wave of 2, 4 or 8 seconds 'on-off' time. The current output was accurately monitored with a digital multimeter placed in series with the current loop.

5.3 Data Processing

The 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 systems, a suite of programs that was written specifically to interface with the IPR-11 receiver and to calculate the IP 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 data was archived on floppy disk.

In the Toronto office the data were ink-plotted in contour plan map and pseudosection formats on a Nicolet Zeta drum plotter interfaced to an IBM PC/AT microcomputer.

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

6.SURVEY METHOD

6.1 Exploration Target

Gold mineralisation, the target of this survey, does not occur in sufficient quantities to affect either the bulk polarizability or resistivity of the ground. Induced Polarization anomalies will results from disseminated metallic sulphides if they are of sufficient concentration and volume. Gold may in turn be found in association with the sulphides. The resistivity data is useful in mapping lithologic units and zones of alteration, shearing or silicification, all of which may help define the geological / geophysical character of the area.

6.2 Quantities Measured (IP/resistivity)

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 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 current flow is electronic rather than electrotlytic.

Measurements are made by applying a current across the ground using two electrodes (current dipole). The current is in the form of an interrupted square wave with on-off periods of 2 seconds. The primary voltage and IP effect is mapped in an area around the current source using what is essentially a sensitive voltmeter connected to a second electrode pair (potential dipole). The primary voltage determines the apparent resistivity after corrections for transmitter current and array geometry. (See Figure 3).

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. Ten slices of the decay curve are measured at semi-logarithmically spaced intervals between 45 and 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.

For a 2 second transmit and receive time the slices are located 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, the M7 slice (from 690 to 1050 ms after shut-off) is chosen to represent chargeability in pseudosection form.

6.3 Field Procedures (IP/resistivity)

The IP/resistivity survey employed the time domain method with a pole-dipole electrode array. The geometry of the pole-dipole array is illustrated in Figure 3.

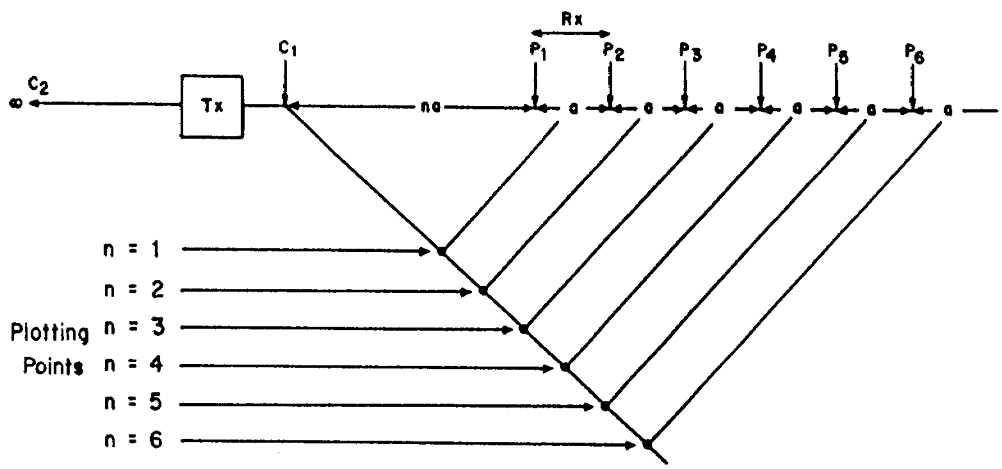
The electrodes marked C1 and C2 are the current electrodes. Those marked as P1, P2, etc., are the potential electrodes. The receiver measures the voltage across adjacent pairs of potential electrodes; e.g. P1-P2, P2-P3, ... P6-P7. These potential pairs are labelled by an integer 'n' which indicates the 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. Resolution of the survey is increased by decreasing the 'a' separation. The current survey employed a dipole spacing of 50 metres.

7.DATA PROCESSING AND PRESENTATION

7.1 Summary

To allow for the computer processing of the survey data, the raw data stored internally in the IPR-11 receiver was transferred at the end of a survey day to floppy diskettes. The raw data were filed on diskette in ASCII character format using an IBM compatible (MS-DOS) microcomputer.



ARRAY GEOMETRY

Apparent Resistivity:

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

where ρ_a = apparent resitivity (ohm.m)
n = dipole number (dimensionless)
a = dipole spacing (m)
Vp = primary voltage (mV)
I = primary current (mA)

Pole-Dipole Array
Array Geometry and Formula for Apparent Resistivity

Figure 3

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 spectral parameters (c, tau and MIP) are derived from the IPR-11 data with the Soft II software. The edited data were then dumped to a printer as formatted data listings, contoured pseudosections and profiles.

After completing the survey, contoured plan maps and/or offset profiles of the average chargeability and resistivity were machine drawn on mylar in the Toronto office. Map scale is 1:5000. The maps show the grid lines and stations along with posted geophysical values.

The apparent resistivity and average chargeability data were machine contoured in pseudosection form and then photoreduced to a scale of 1:5000 feet. Pseudosection pairs (resistivity and chargeability) were then joined according to the survey grid to form 'offset' pseudosections. (See Plates 4 to 5).

IP anomalies were picked from the pseudosections and entered on a compilation map as anomaly bars parallel to the grid lines. IP characteristics of average chargeability amplitude, time constant and MIP amplitude are shown as range or numerical values. Areas of relatively high (or low) resistivity are outlined. Based on all of the information available particular anomalies are suggested for follow-up.

The results of the survey are presented on the following plates:

Plate 1: Average Chargeability Plan Map, scale: 1:5000
Plate 2: Apparent Resistivity Plan Map, scale 1:5000
Plate 3: Anomaly/Compilation Map scale 1:5000
Plate 4: Pseudosections, Avg Chargeability and Resistivity scale 1:5000
Plate 5: Pseudosections, Spectral tau and M-IP, scale 1:5000

Elements of the data processing are discussed in greater detail below.

7.2 Spectral Analysis

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 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 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.

IP decay forms are quantified using the Cole-Cole model developed by Pelton et al (1978). Pelton was one of the first to use the term Spectral IP. The Cole-Cole model is determined by the resistivity and three spectral parameters , m, tau and c. These parameters are interpreted as follows;

m (or MIP) - Chargeability Amplitude (mV/V). This is related to the volume percent metallic sulphides (although there is no simple quantitative relationship between the two).

tau - Time Constant (s). A short time constant (e.g. 0.01 to 0.1 s) suggests a fine grained source. A long time constant (e.g. 10 to 100 s) suggests a coarse grained (or inter-connected or massive) source.

c - Exponent (dimensionless). A high c value (e.g. 0.5) implies one uniform polarizable source. A low c value (e.g. 0.1) implies a mixture of sources.

Conventional chargeability is a mixture of these spectral parameters and a change in any one parameter will produce a change in the apparent chargeability. In the absence of spectral analysis, such changes are always ascribed to a change in the volume percent metallic sulphides, even though the cause may be a shift from fine to coarse grained material.

In practice, the spectral parameters are used to characterise and priorize IP anomalies which have been picked from the pseudosections of conventional single slice (or average) chargeability. In this regard, the chargeability amplitude (MIP) and the time constant are the most usefull. IP anomlies which are similar in all other respects may be separated based on their spectral characteristics.

Spectral parameters are extracted from all measured decay curves by finding a best fit between the measured decay and a suite of master curves. The process yields a fit parameter which is the root mean square difference (expressed as per cent) between the ten values of the measured and best fit master decays. The fit parameter is low (i.e. less than 1%) for high quality data of moderate to high amplitude. The fit parameter is high (i.e. greater than 10%) for poor quality or low amplitude data.

Normally fit values in excess of 5% are considered too high and spectral values are not posted on the pseudosections. This condition may be waved however if chargeability amplitudes are low and the data appears to be of good quality.

7.3 <u>Anomaly Selection and Classification</u>

IP anomalies are picked off the pseudosections of chargeability. The selection is based in part on some idea of what a true bedrock IP or resistivity anomaly should look like in contoured pseudosection form. Such ideas are normally taken from model results.

With a pole-dipole array the IP response is skewed to one side of the target (the current side). All IP anomalies of this form, regardless of amplitude, are selected, assigned characteristics such as location, peak amplitude, MIP value and time constant and entered on the pseudosections and compilation map.

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. Areas of low resistivity are rated as very weak, weak, medium or strong and are shown as anomaly bars.

Chargeability anomalies 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

_ _ _ _ _ weak chargeability high; 5 - 10 mV/V

. . . . very weak chargeability high; < 5 mV/V and poorly defined

These are somewhat subjective categories and can only be used as qualitative descriptions of the IP anomalies. The amplitude limits of each category are guidelines only: individual anomalies may be rated higher or lower depending on clarity and confidence.

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., 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 centre of the source body.

The numerical value of the chargeability amplitude (MIP) of the peak response and the time constant range value (H(igh),M(edium),or L(ow)) are shown beside the IP anomaly bar. H(igh), M(edium) and L(ow) indicate values between 30 and 100 s, 1 and 10 s and .01 and .3 s respectively.

7.4 Compilation Map:

The IP and resistivity anomalies are fine drawn onto a grid map using anomaly bar symbols which parallel the grid lines. IP anomalies are shown to the left of the grid lines; resistivity anomalies are shown to the right of the grid lines.

IP anomalies showing line to line correlation have been grouped into anomalous zones. Resistivity highs (or lows) which show good line to line correlation may be grouped into anomalous zones. Defineable resistivity peak highs (or lows) which show good line to line correlation may be joined as axes.

Known geological contacts are marked on the pseudosections; the code used for mafic and felsic volcanics is Vm and Vf respectively. Airborne EM anomalies are noted by a semi-solid circle. Horizontal Loop (Max-Min) anomalies are noted on the plan map and on the pseudosections. On the latter plates the anomaly is indicated by a square.

8. DISCUSSION OF RESULTS AND RECOMMENDATIONS

A favourable IP target is considered to have the following properties:

- a well defined shape (as viewed in the pseudosections). Anomaly amplitudes (particularly in M7) need not be high as relatively modest concentrations of metallic sulphides may be of interest.

- a short (or low) spectral IP time constant. Such would characterise disseminated metallic sulphides. Massive sulphides should be seen as a resistivity low and a coincident IP anomaly with long time constants.

- a moderate to high MIP value. The MIP parameter is the most reliable measure of the volume % metallic sulphides. Changes in M7 (or average chargeability) may be the results of changes in tau alone.

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

In general the resistivity results of the Duff Twp. survey show layering of the iso-resistivity contours with increasing "n" reflecting the horizontal geometry of the conductive clay cover. Disturbances of the contours can be interpreted as a thinning/thickening of the cover or a lateral change in the bedrock resistivity.

The IP anomalies encountered on the property fall into two categories, those showing good definition, moderate amplitude and line to line correlation and those exhibiting poor definition, amplitudes in the order of the geological and instrument noise levels (+/-0.3mV/V) and poor or no line to line correlation.

Two IP zones fall into the first category. Zone A, to the west, was transected by three survey lines and is marked by M7 chargeability amplitudes of around 8mV/V. The zone is open along strike at both ends. The apparent resistivity results show a coincident low resistivity zone. The anomaly is not pronounced but washed out somewhat due to the clay cover. The spectral results suggest a fine grained sulphide source. The proximity of this zone to a gold discovery on the adjacent property makes this a very favourable target. The best intersection for drill testing is L-400N at station 2775. The IP method is not capable of determining dip with much degree of accuracy. It can only be said whether a body is steeply dipping or roughly vertical. The results suggest the source of this anomaly is steeply dipping.

Zone B was encountered on all eight survey lines and remains open along strike at both extremities. The zone is well defined on all survey lines except the most northerly L-1600N. The IP amplitude varies between 2.5 and 4.5mV/V with the weaker values towards the north end of the anomaly. The spectral results gave an M-IP value ranging between 20 and 90 and a low tau value suggesting a minor amount of fine-grained sulphides.

The resistivity results suggest a change in the electrical conductivity of the zone along strike. It indicates the zone is resistive relative to the host rock in the north end and conductive with respect to the host rock at the southern end of the zone. The airborne EM survey detected a conductive zone on L-4N, L-6N, and L-8N coincident with the resistivity low detected by the IP survey. A max-min anomaly lies on L-6N coincident with IP zone B. Drill testing of this horizon should concentrate where the geophysical response is best defined and that is on L-600N at station 350W. The source has a near vertical dip.

JVX

The remaining anomalies are, for the most part not well defined and have poor if any line-to-line correlation. The anomalies are marked by an amplitude above background that is within the instrument and normal geological noise levels. The skewed anomaly shape and a hint of line-to-line correlation were the criterea used for picking these anomalies. They are borderline picks. The anomalies may have a bedrock source, however, and may indeed warrent diamond drill testing if they lie on some favourable stratigraphic horizon.

However, given the HLEM coincidence and some known geology two anomalies are recommended for drill testing; at L-400N station 700W with a coincident HLEM anomaly and L-600N station 1150W at a major stratigraphic contact.

Respectfully submitted,

JVX Limited

Neil Fiset, B.Sc.

Blaine Webster, B.Sc.
President

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.

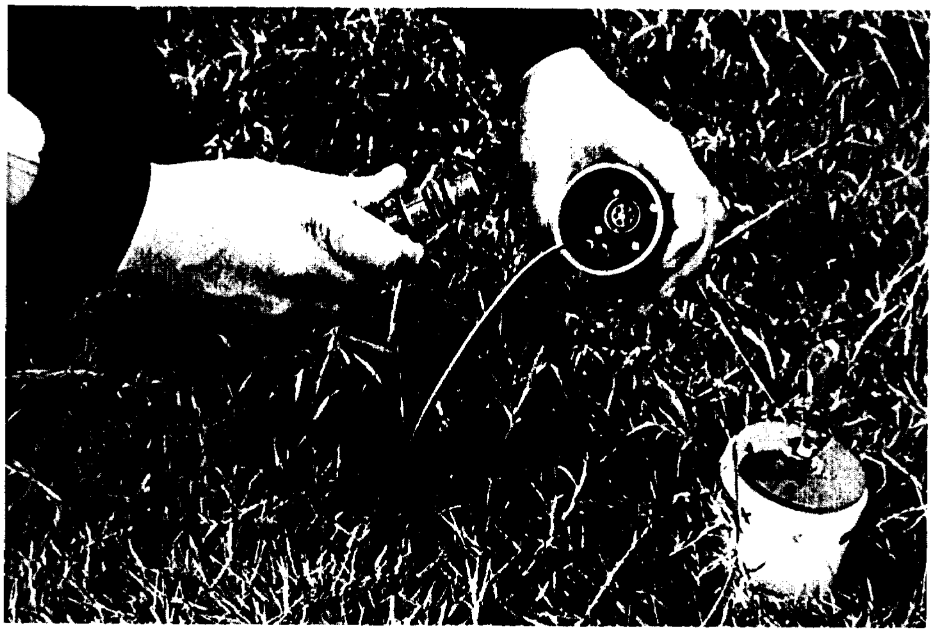
For example, consider the advantage in gradient, dipole-dipole or pole-dipole surveying with multiple 'n' or 'a' spacings, of measuring up to six potential dipoles simultaneously. If the specially designed Multidipole Potential Cables are used, members of a crew can prepare new dipoles at the end of 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.

If the above features won't save as much time as you would like, consider how the operator will appreciate the speed in



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

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.

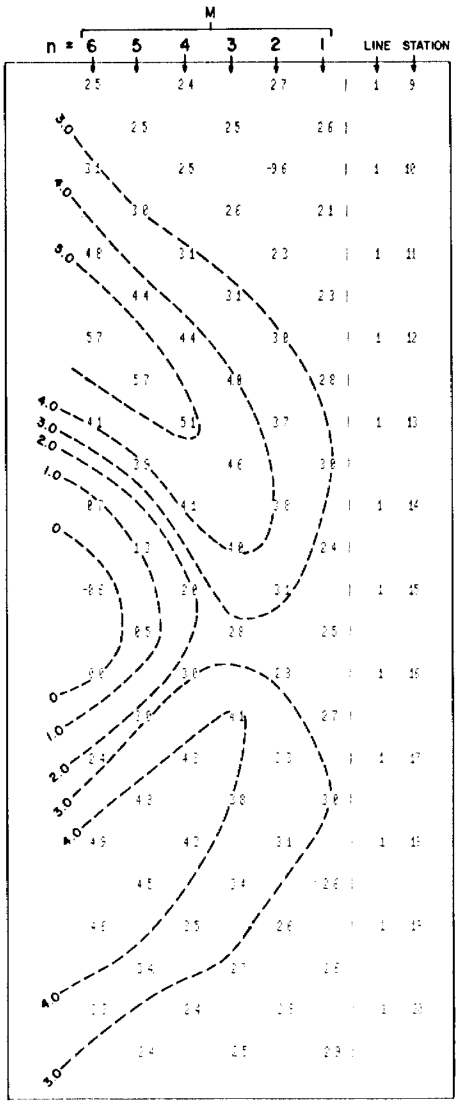
Observations can usually be made using the self-triggering feature of the IPR-11. The internal program locks into the waveform of the signal received at the first dipole (nearest a current electrode) and prevents mistriggering at any point other than within the final 2.5 percent of the current on time. 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.

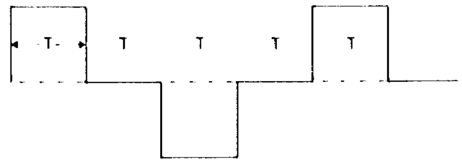
Carefully Chosen Transient Windows. The IPR-11 records all the information that is really needed to make full interpretations of spectral IP data, to remove EM coupling effects and to calculate EM induction parameters. Ten quasilogarithmically spaced transient windows are measured simultaneously for 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.

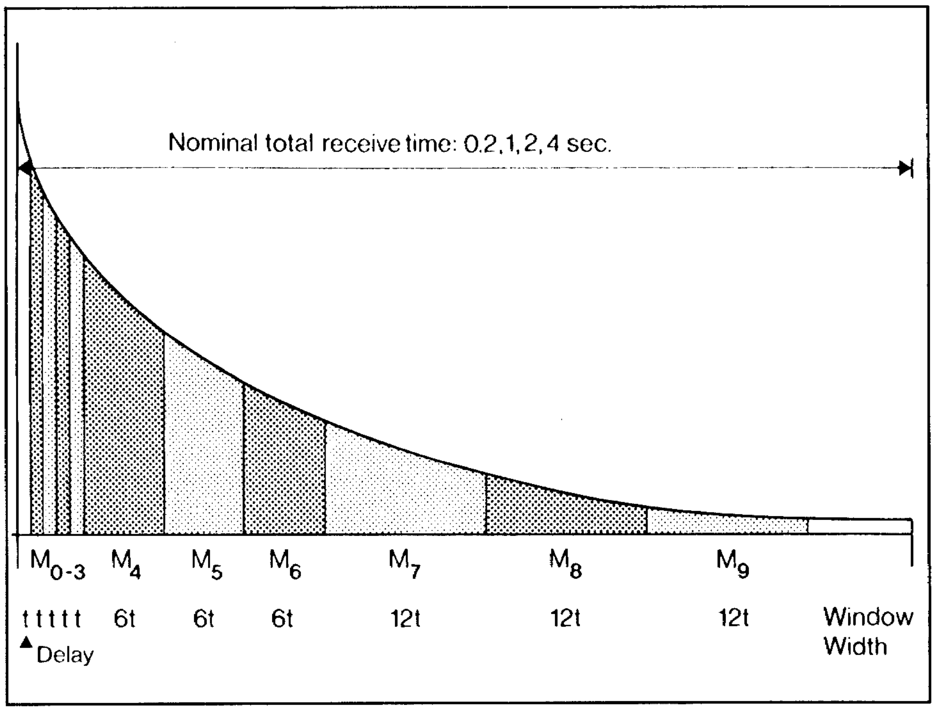


Time domain IP transmitted waveform

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

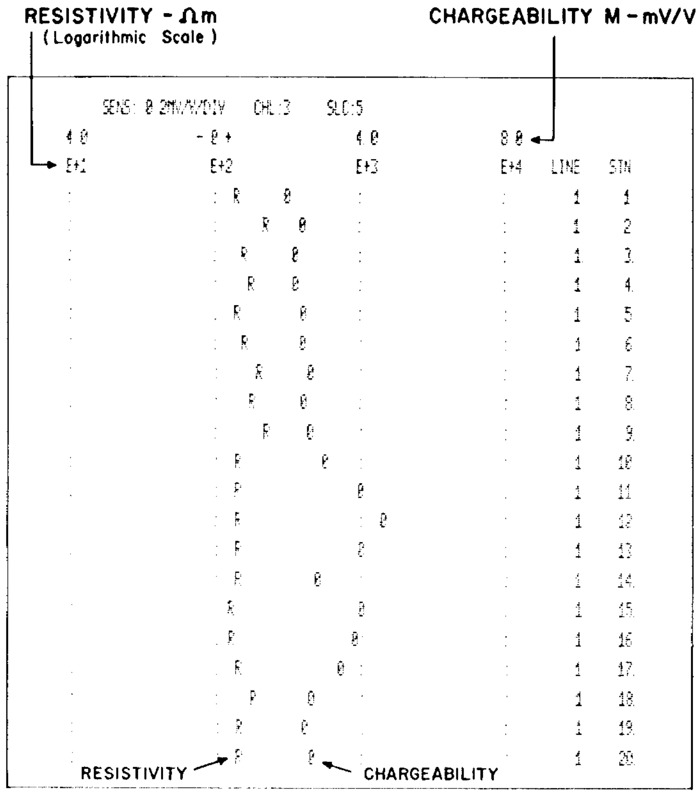
Features

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.

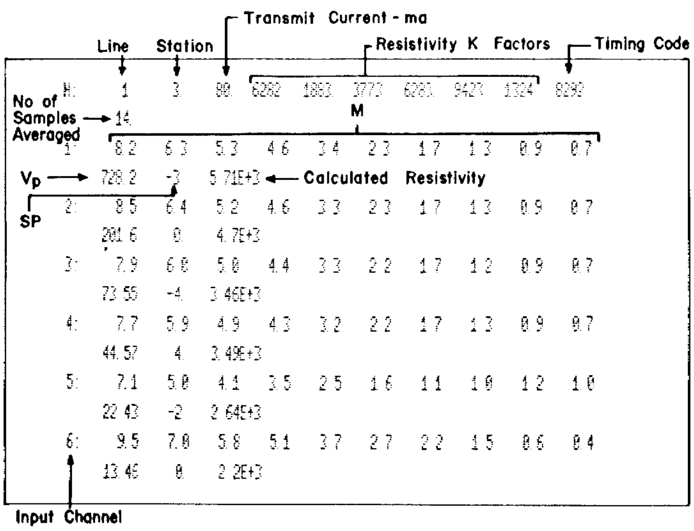
Printed Data Listing. The same digital printer can be used to print out listings of all headers and data recorded during the day's operation. Several copies can be made for mailing to head office or for filing in case copies are lost. Baud rate is keypad selectable at 110, 300 or 1200 baud, depending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



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.

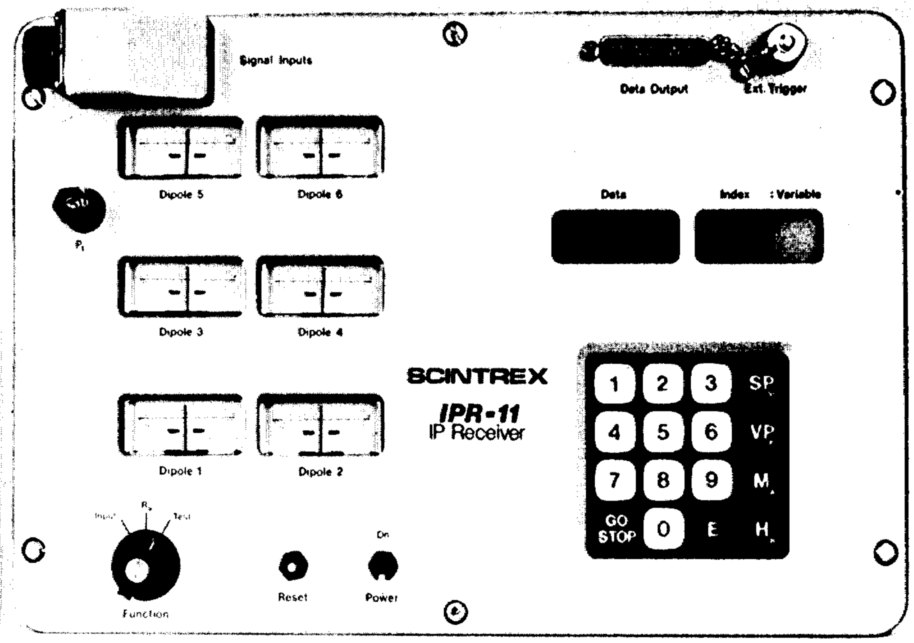
Input Protection. If signals in excess of 6V and up to 50V are applied to any input circuit, zener diode protection ensures that no damage will occur to the input circuits.

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.

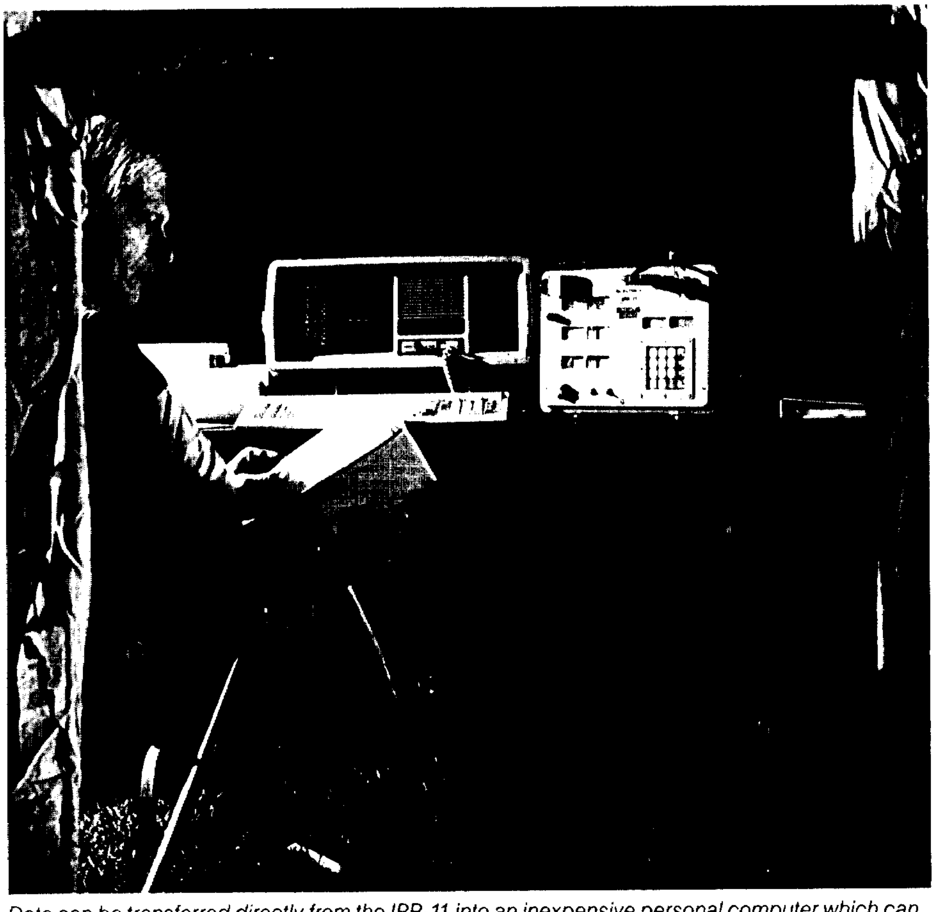
Field Wire Adaptor Kit. Depending on the survey method used, it may be preferable to connect the potential electrodes to the IPR-11 using standard single conductor wire rather than the Multidipole Potential Cables. When using the Field Wire Adaptor Kit each wire can be terminated on an individual binding 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.

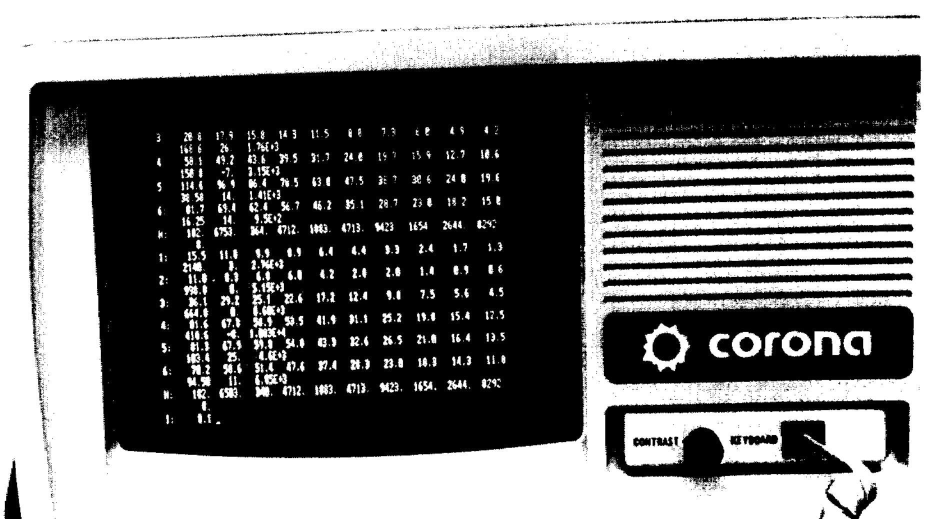
Store data on floppy disks. Once in the computer, data is stored on a floppy disk. This increases the efficiency of data processing and management as well as transportation and long term storage. No longer will you have to sort through bulky paper records or scan through long tape recordings to access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



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

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.

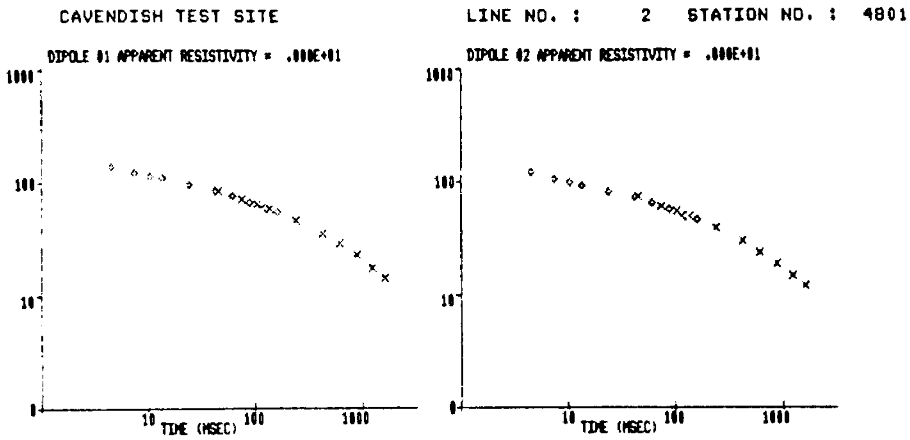
Two different programs in SOFT II can be used to plot pseudo-sections. PSEUDO posts that data at the correct plotting point for a dipole-dipole array so it may be hand contoured. CONTOUR draws contoured pseudo-sections for dipole-dipole or pole-dipole arrays on a dot-matrix printer or a pen plotter.

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.

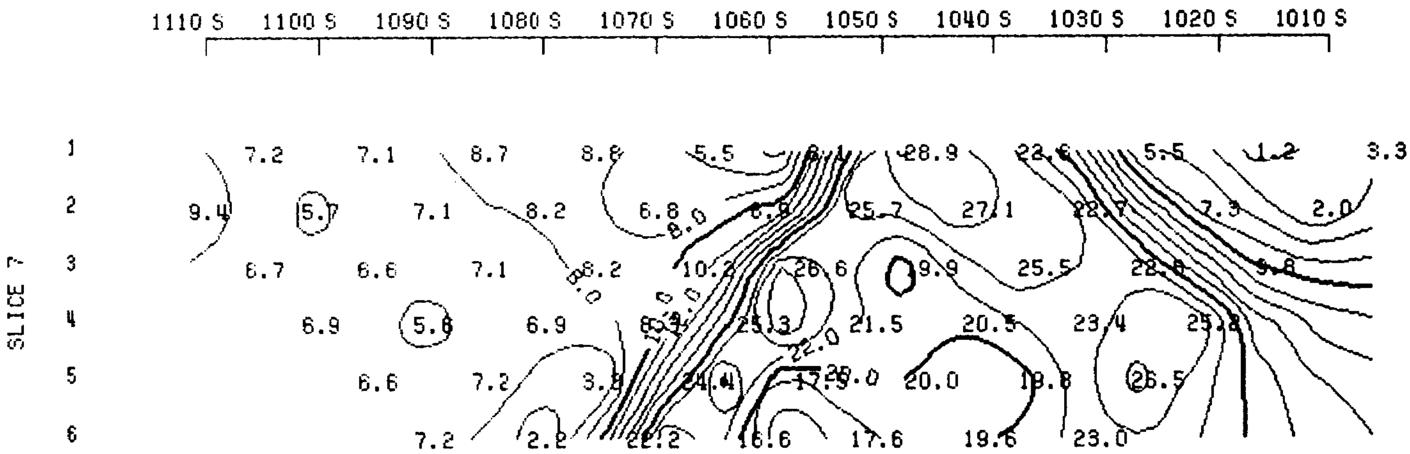
Other IBM compatible microcomputers using the PC/MS-DOS Version 2.1 or 3.0 Operating System may be used. Scintrex will be pleased to advise in this regard.

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.

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 Resist.	M7	Cole-Cole Parameters M-IP	TAU-IP	C-IP	M-EM	TAU-EM	Fit/IP	Fit/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 1 second receive time modes; 0.51 sec. 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.

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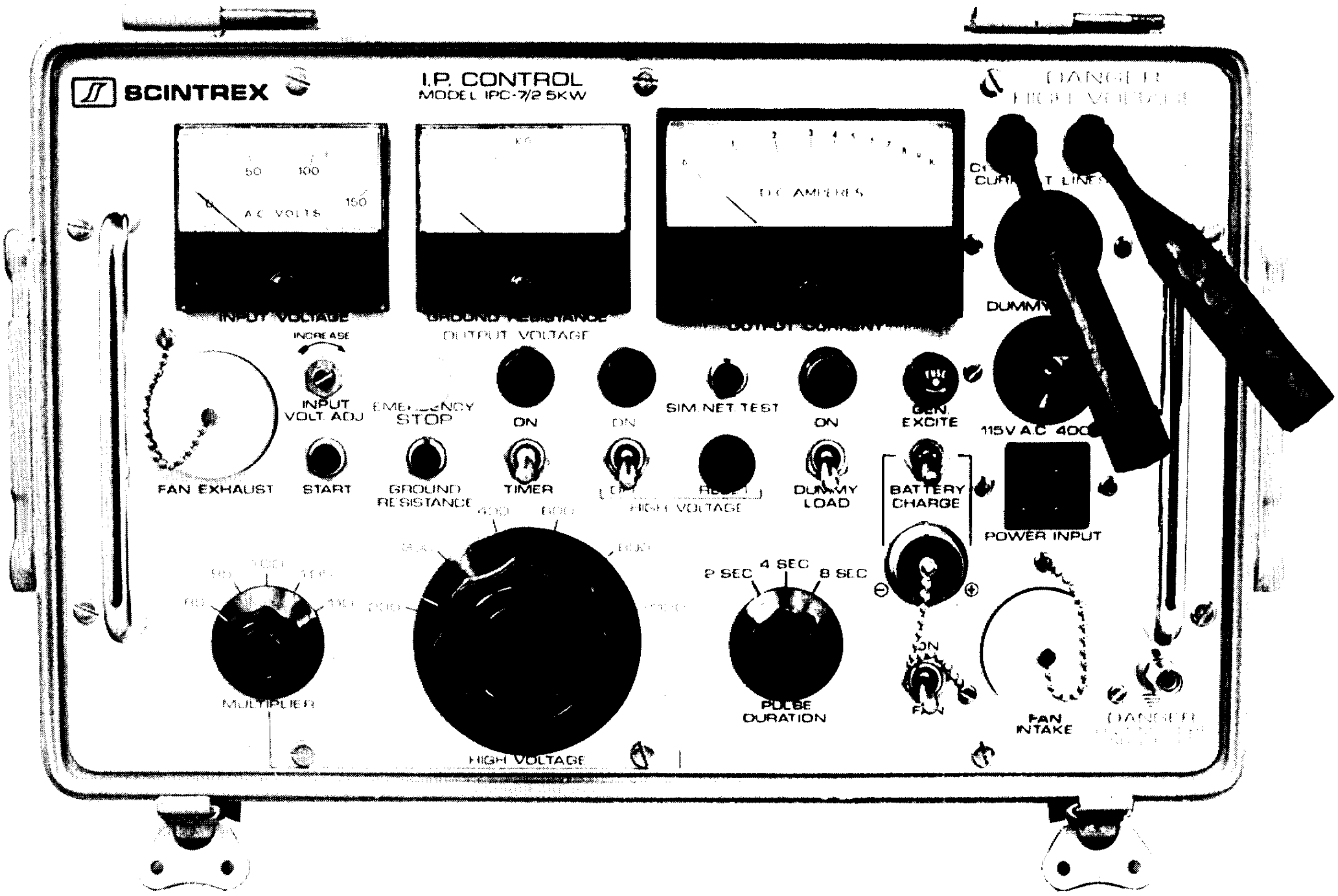
Geophysical and Geochemical
Instrumentation and Services

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.

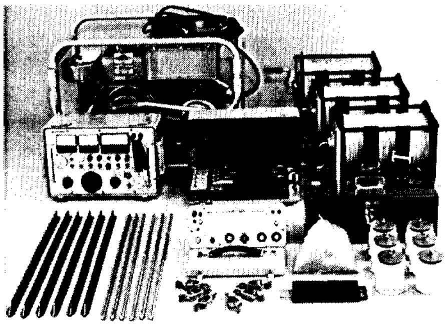
The open loop circuit protects workers by automatically cutting off the high voltage in case of a break in the current dipole circuit.

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

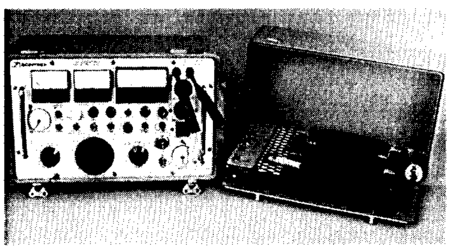
The built-in ohmmeter is used for checking the external circuit resistance to ensure that the current dipole circuit is grounded properly before the high voltage is turned on. This is a safety feature and also allows the operator to select the proper output voltage required to give an adequate current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

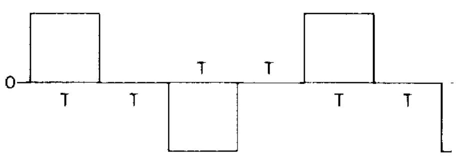
Technical Description of IPC-7/2.5 kW Transmitter System



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

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Appendix 2

Plates 1 to 5

Plate 1: Average Chargeability Plan Map, scale: 1:5000
Plate 2: Apparent Resistivity Plan Map, scale 1:5000
Plate 3: Anomaly/Compilation Map scale 1:5000
Plate 4: Pseudosections, Avg Chargeability and Resistivity scale 1:5000
Plate 5: Pseudosections, Spectral tau and M-IP, scale 1:5000

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

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

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

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

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:

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

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

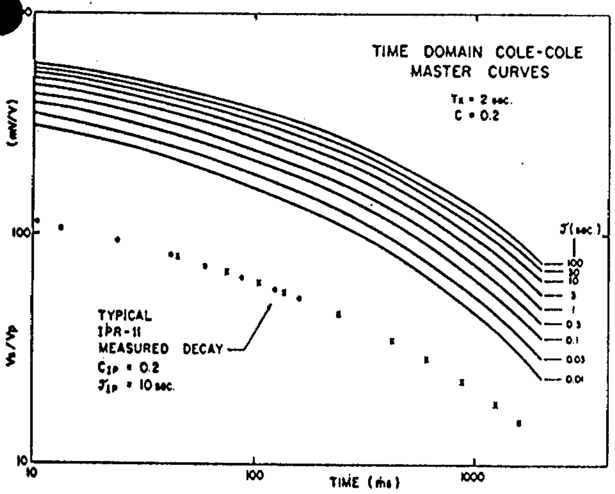

FIG. 1. Theoretical time-domain decay curves for fixed c and variable τ. A typical IPR-11 measured decay is shown as a series of dots (0.2 s receiver mode) and x's (2 s receiver mode).

as

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

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

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

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.,

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

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

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

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

The true chargeability m may be found by setting

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

Hence,

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

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

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

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,

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

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-

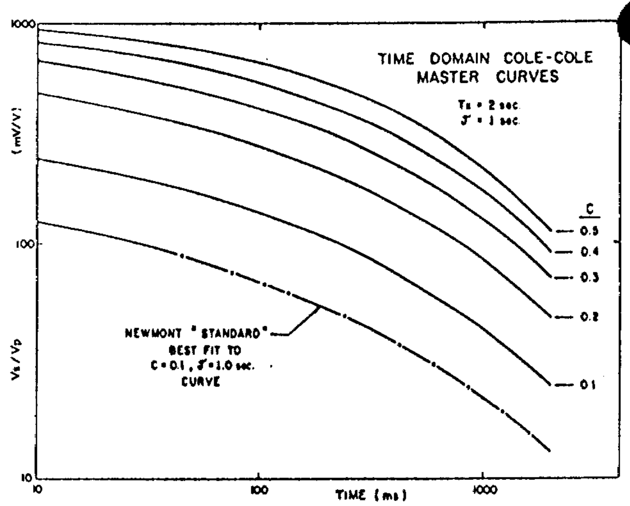

FIG. 2. Theoretical time-domain decay curves for fixed τ and variable c. The Newmont Standard decay for a 2 s pulse time is shown with fitted time constant and exponent.

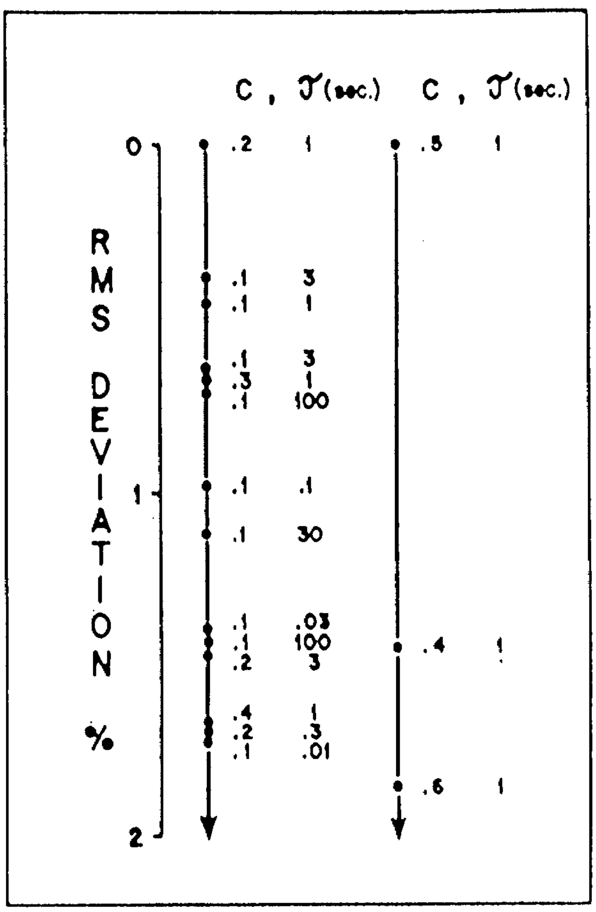

FIG. 3. Curve shape differences (or rms deviation) between selected master curves. Arranged in order of increasing deviation from the $c = 0.2, \tau = 1$ and the $c = 0.5, \tau = 1$ curves.

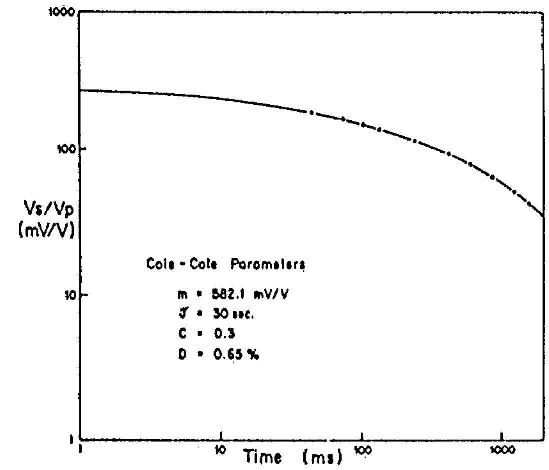

FIG. 4. Measured data (10 point), best-fit master decay curve, and calculated spectral parameters. Array is pole-dipole with $a = 10$ m, $n = 6$ with $V_p = 1.2$ mV. Rms deviation = 0.65 percent. V_s designates the voltage measured during the transmitter off-time.

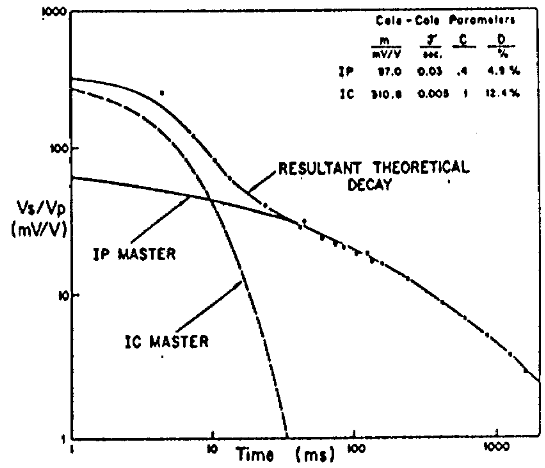

FIG. 5. Measured data (20 point composite), best-fit master curves, and calculated spectral parameters. Both IP and inductive coupling (IC) effects are modeled. Array is dipole-dipole with $a = 100$ m, $n = 6$ with $V_p = 2.6$ mV.

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

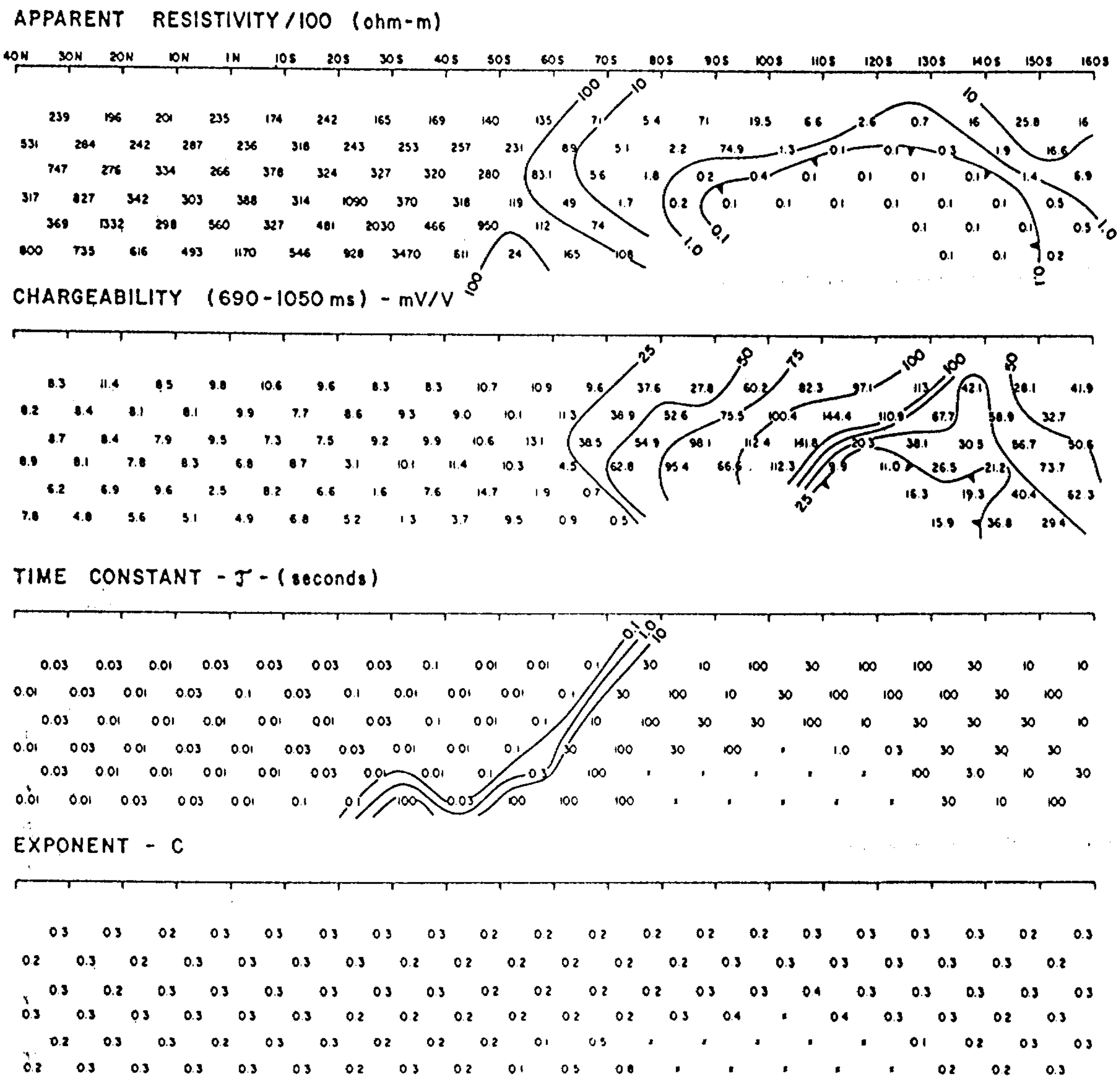

FIG. 6. Segment of results from an IPR-11 survey using the pole-dipole array with $a = 10$ m and $n = 1$ to 6. Shown are apparent resistivity/100 (Ω · m) eighth-slice chargeability (mV/V), Cole-Cole time constant (seconds) and exponent (c). Near-current electrode is to the left of the potential electrode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

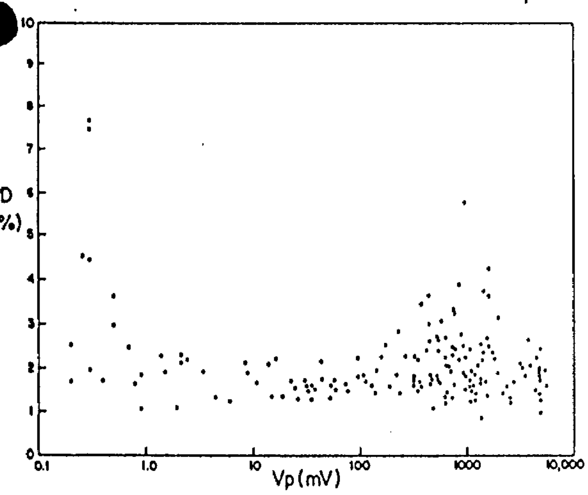

FIG. 7. Rms deviation as a function of primary voltage (V_p) for spectral fits from data shown in part in Figure 6.

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 $\Omega \cdot$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.

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

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.

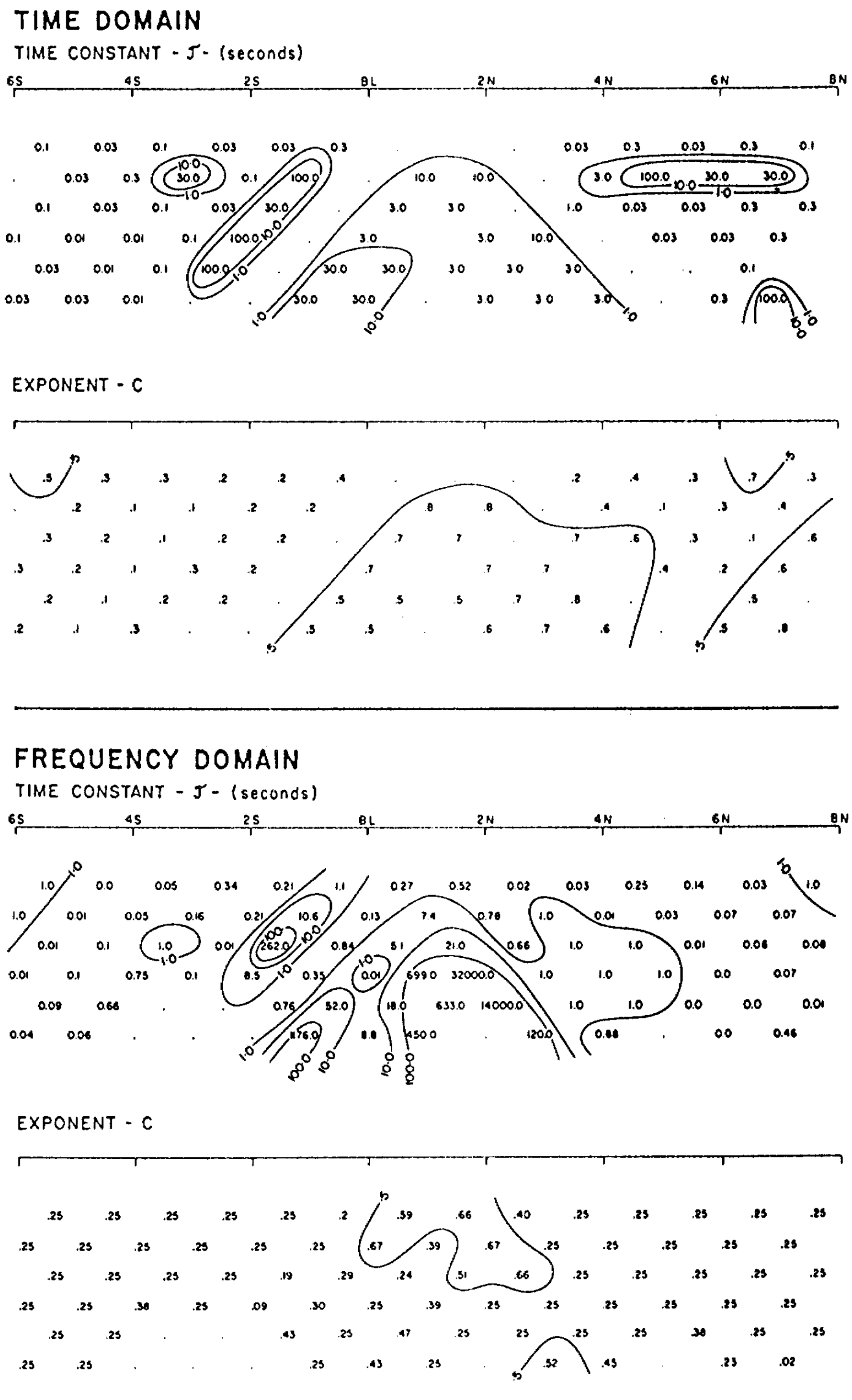

FIG. 8. Cole-Cole parameters as determined through time-domain (by Scintrex) and frequency-domain (by Phoenix) measurements over line 8 W of the Detour deposit. Spectral parameters are omitted in the time-domain data where the rms deviation exceeds 7.5 percent.

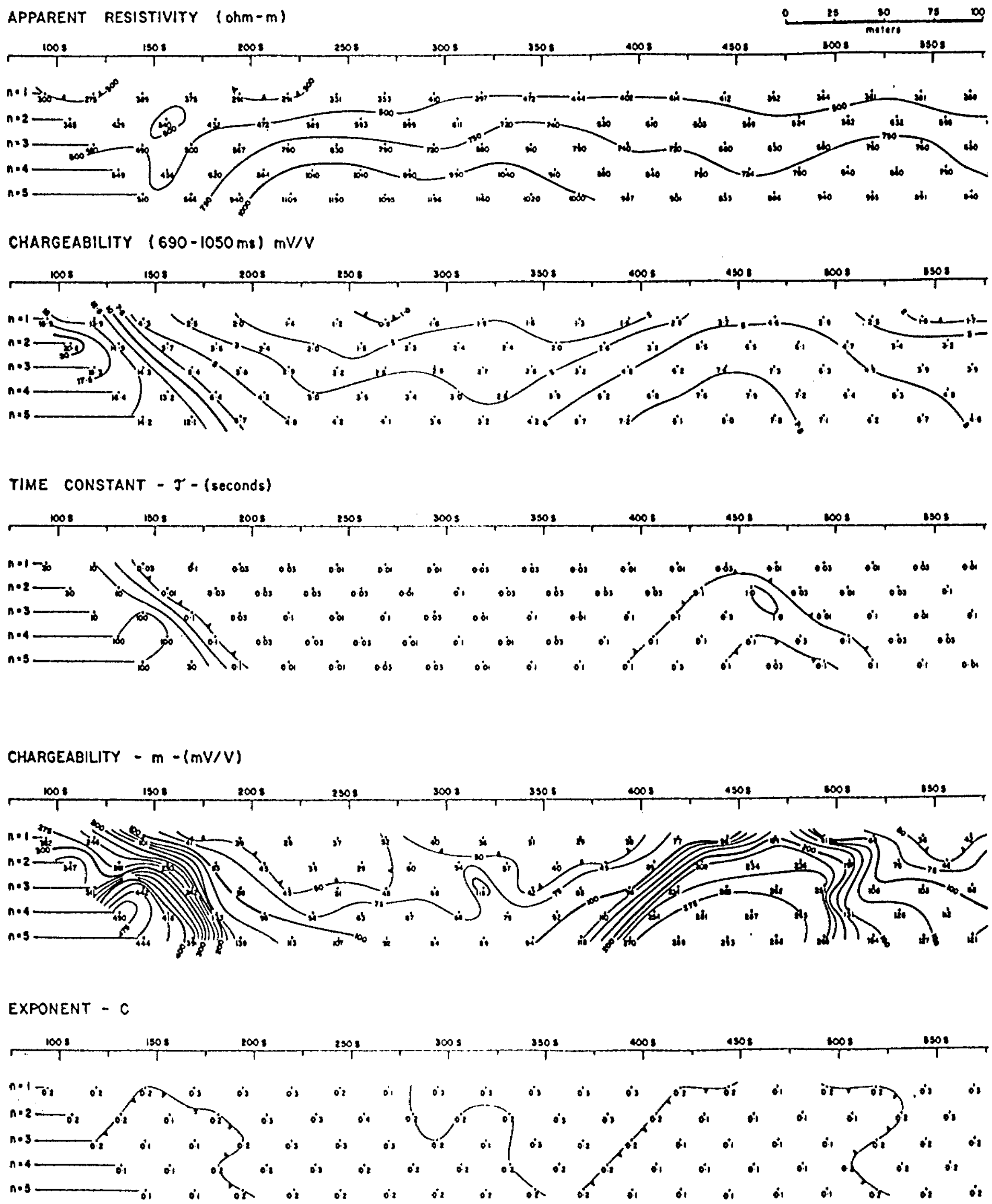

FIG. 9. Time-domain spectral IP results over a known gold producer. Deposit is centered some 50 m below station 450 S. An iron formation is located near the baseline.

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. Th[illegible] 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.

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Expanded Abstract

SPECTRAL IP: EXPERIENCE OVER A NUMBER OF CANADIAN GOLD DEPOSITS

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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.

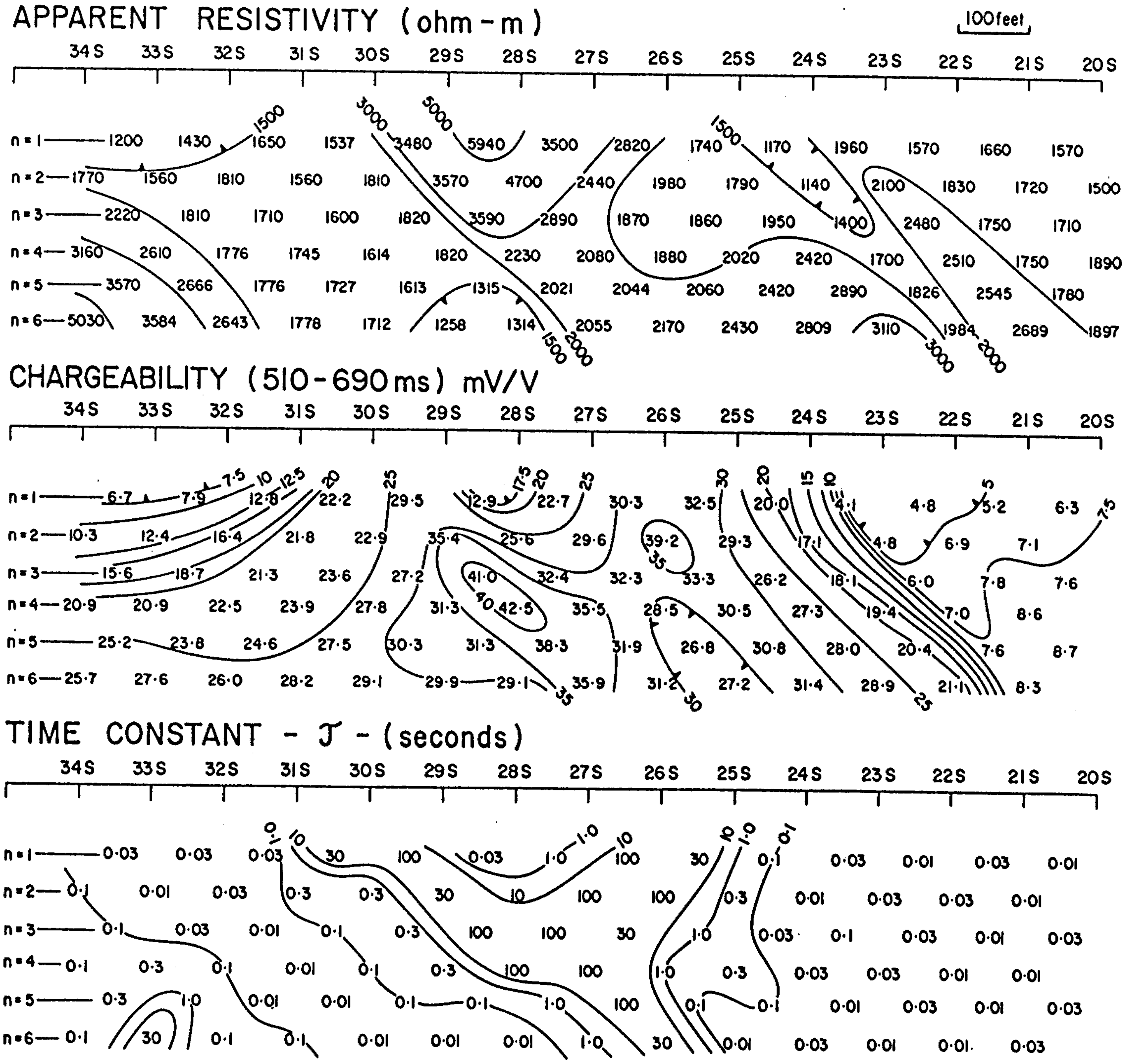
ACKNOWLEDGEMENTS

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

FIGURE CAPTIONS

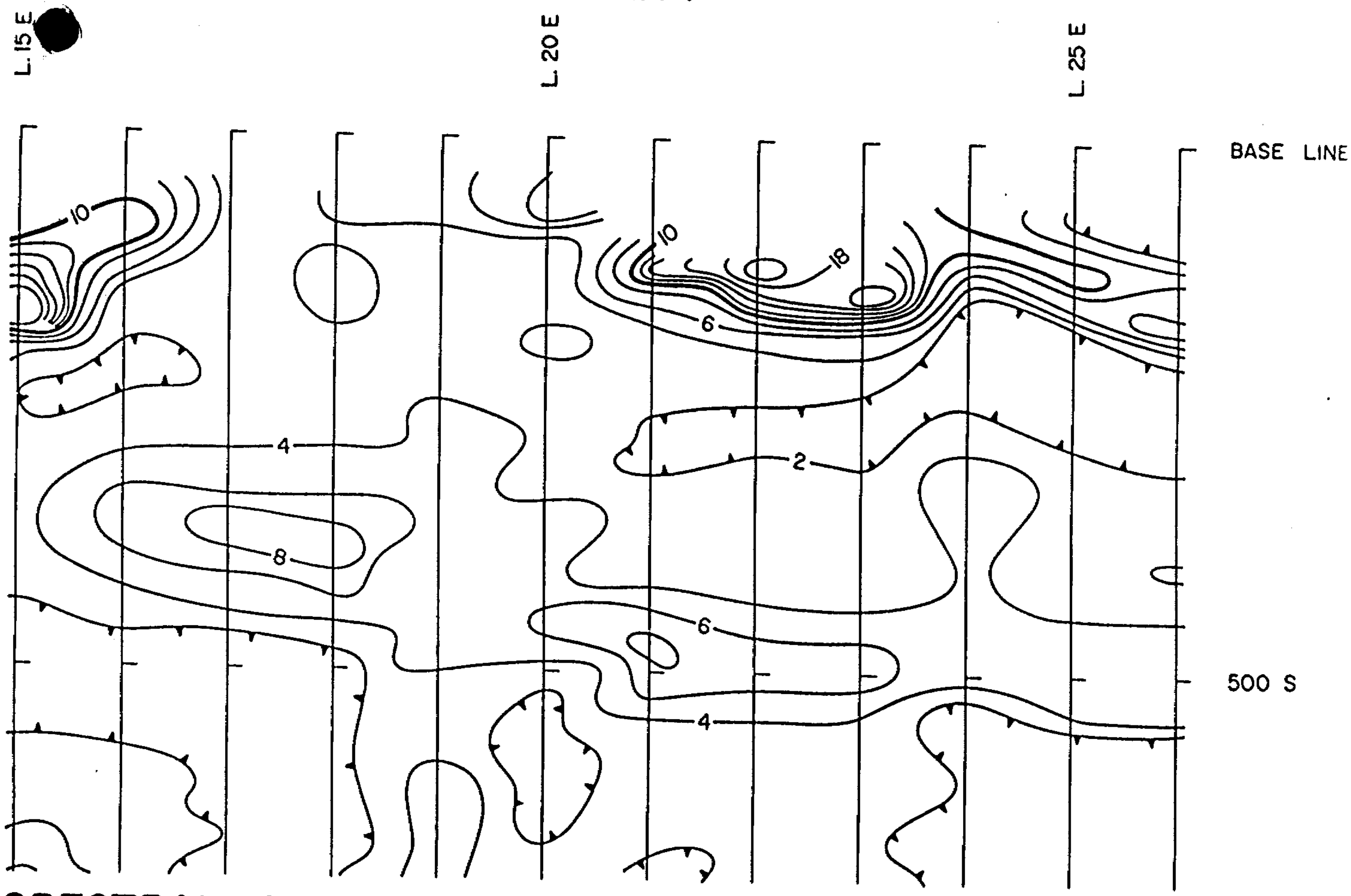
Figure 1: Contoured chargeabilities in mV/V. Pole-dipole array with a=25 m, n=1 to 5. Seventh slice IPR-11 (690 to 1050 ms after shutoff) data for the n=2 dipole shown in upper half. Cole-Cole chargeabilities in mV/V for the same area and dipole number shown below.

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.

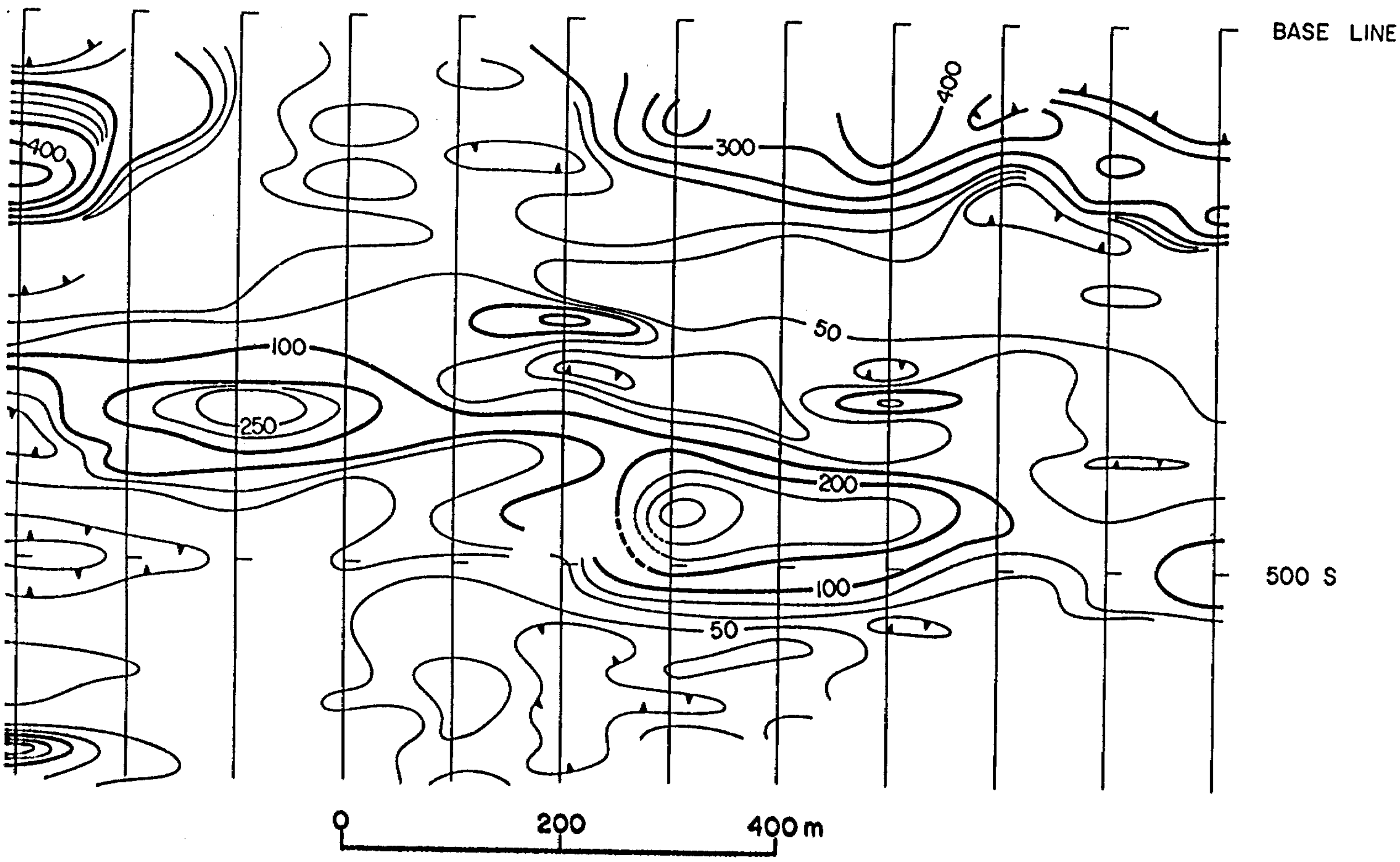


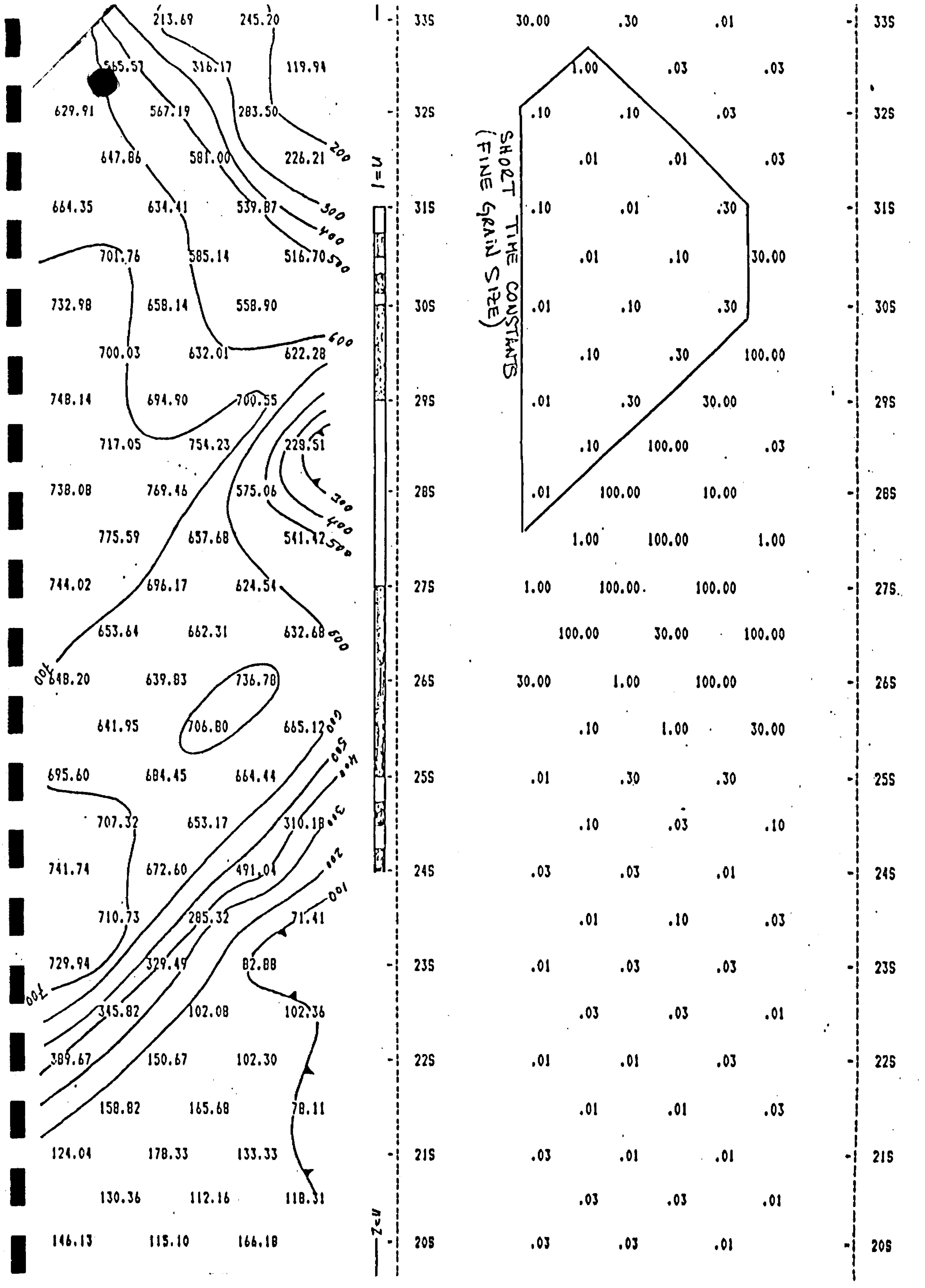
APPARENT RESISTIVITY (ohm-m)
100 feet
34S 33S 32S 31S 30S 29S 28S 27S 26S 25S 24S 23S 22S 21S 20S
n=1
n=2
n=3
n=4
n=5
n=6
CHARGEABILITY (510-690 ms) mV/V
34S 33S 32S 31S 30S 29S 28S 27S 26S 25S 24S 23S 22S 21S 20S
TIME CONSTANT - τ - (seconds)
34S 33S 32S 31S 30S 29S 28S 27S 26S 25S 24S 23S 22S 21S 20S

CONVENTIONAL CHARGEABILITY



SPECTRAL CHARGEABILITY





213.69 245.20
565.57 316.17 119.94
629.91 567.19 283.50
200
647.86 581.00 226.21
664.35 634.41 539.87
300
400
701.76 585.14 516.70
500
732.98 658.14 558.90
700.03 632.01 622.28
600
748.14 694.90 700.55
717.05 754.23 229.51
738.08 769.46 575.06
300
400
775.59 657.68 541.42
500
744.02 696.17 624.54
653.64 662.31 632.68
600
700
648.20 639.83 736.78
641.95 706.80 665.12
600
500
400
695.60 684.45 664.44
707.32 653.17 310.18
300
741.74 672.60 491.04
200
710.73 285.32 71.41
100
729.94 329.49 82.88
700
345.82 102.08 102.36
389.67 150.67 102.30
158.82 165.68 78.11
124.04 178.33 133.33
130.36 112.16 118.31
146.13 115.10 166.18
n=1
n=2
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
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24S .03 .03 .01 24S
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.03 .03 .01
22S .01 .01 .03 22S
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21S .03 .01 .01 21S
.03 .03 .01
20S .03 .03 .01 20S

TIME DOMAIN SPECTRAL INDUCED POLARIZATION
SOME RECENT EXAMPLES FOR GOLD

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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.

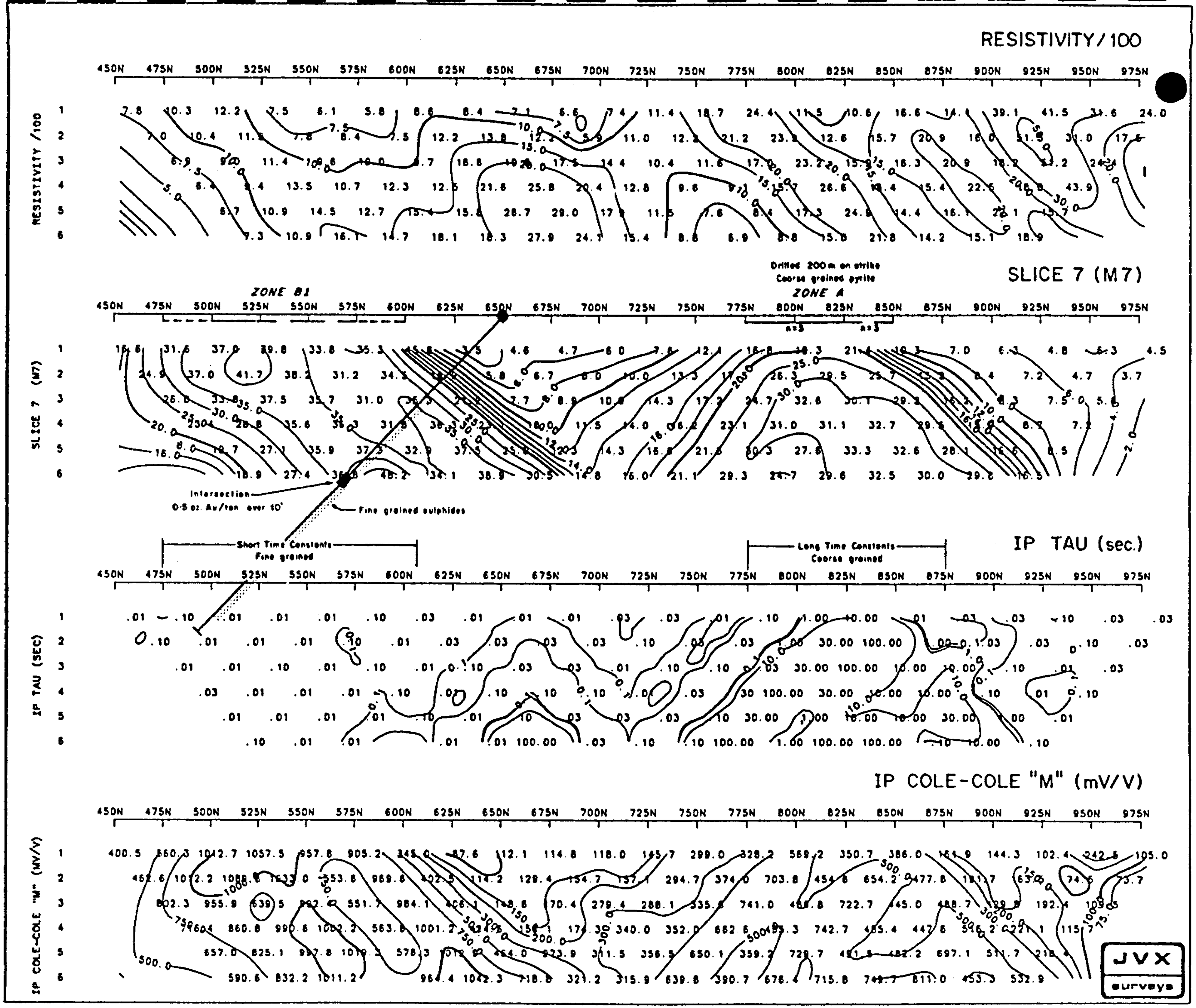

RESISTIVITY/100
SLICE 7 (M7)
IP TAU (sec.)
IP COLE-COLE "M" (mV/V)
ZONE B1
ZONE A
Drilled 200 m on strike
Coarse grained pyrite
Intersection
0.5 oz. Au/ton over 10'
Fine grained sulphides
Short Time Constants
Fine grained
Long Time Constants
Coarse grained
JVX
surveys

Figure 1

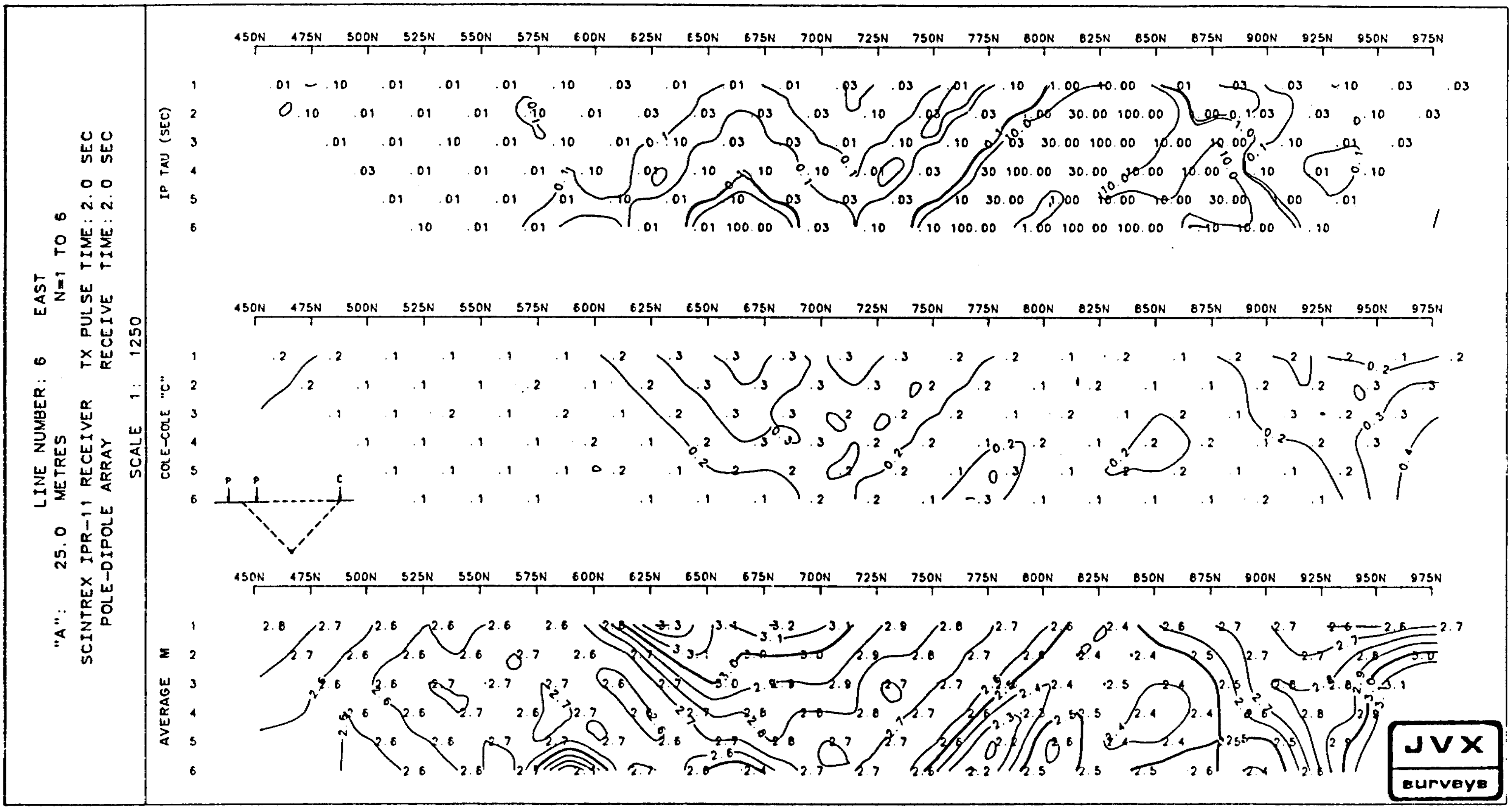
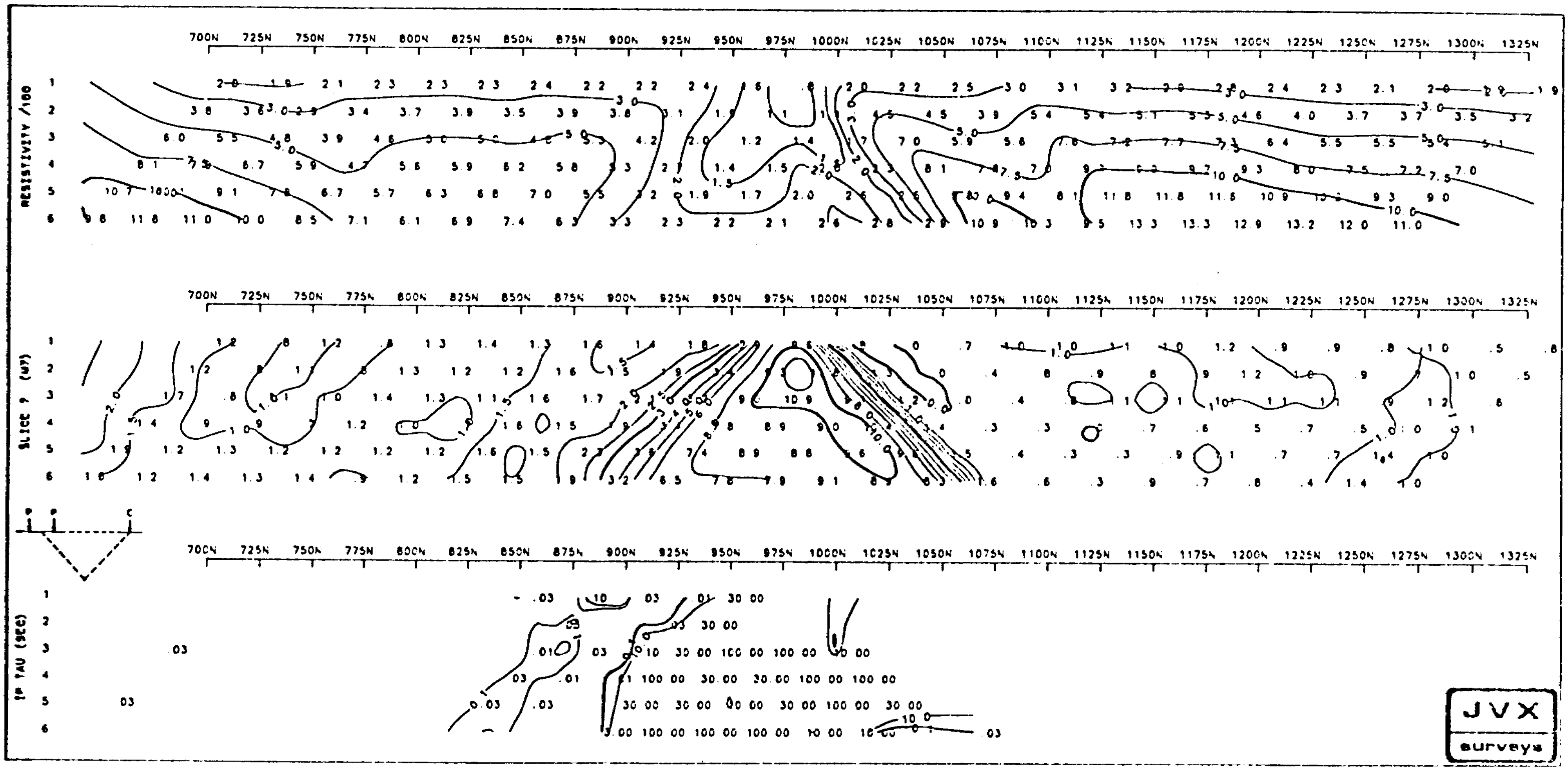

LINE NUMBER: 6 EAST
"A": 25.0 METRES N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1250
IP TAU (SEC)
COLE-COLE "C"
AVERAGE M
JVX
surveys

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 9 (MT)
IP TAU (SEC)
JVX
surveys

Figure

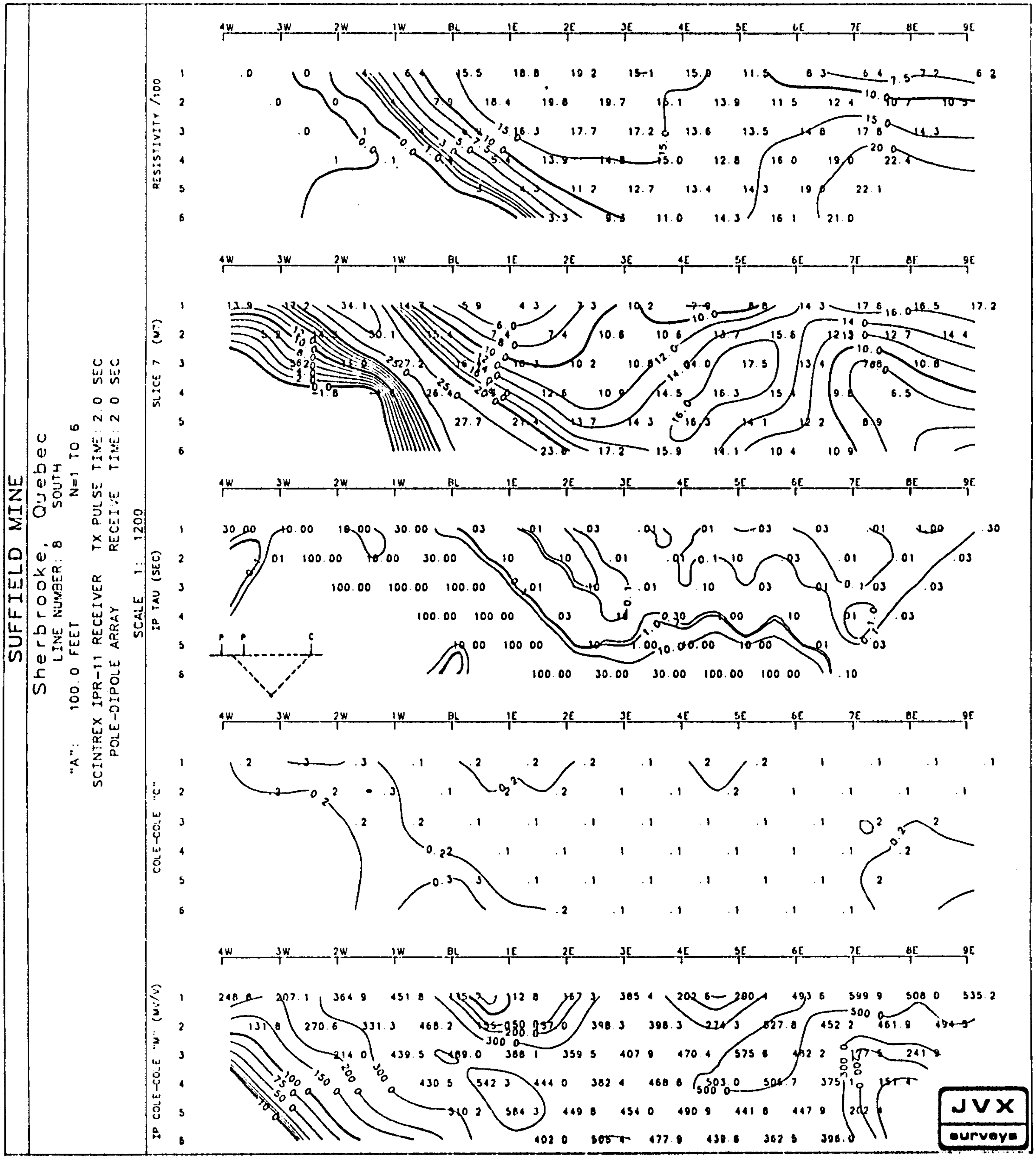

SUFFIELD MINE
Sherbrooke, Quebec
LINE NUMBER: 8 SOUTH
"A": 100.0 FEET N=1 TO 6
SCINTREX IPR-11 RECEIVER TX PULSE TIME: 2.0 SEC
POLE-DIPOLE ARRAY RECEIVE TIME: 2.0 SEC
SCALE 1: 1200
RESISTIVITY /100
SLICE 7 (M7)
IP TAU (SEC)
COLE-COLE "C"
IP COLE-COLE "M" (MV/V)
4W 3W 2W 1W BL 1E 2E 3E 4E 5E 6E 7E 8E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

Figure 4

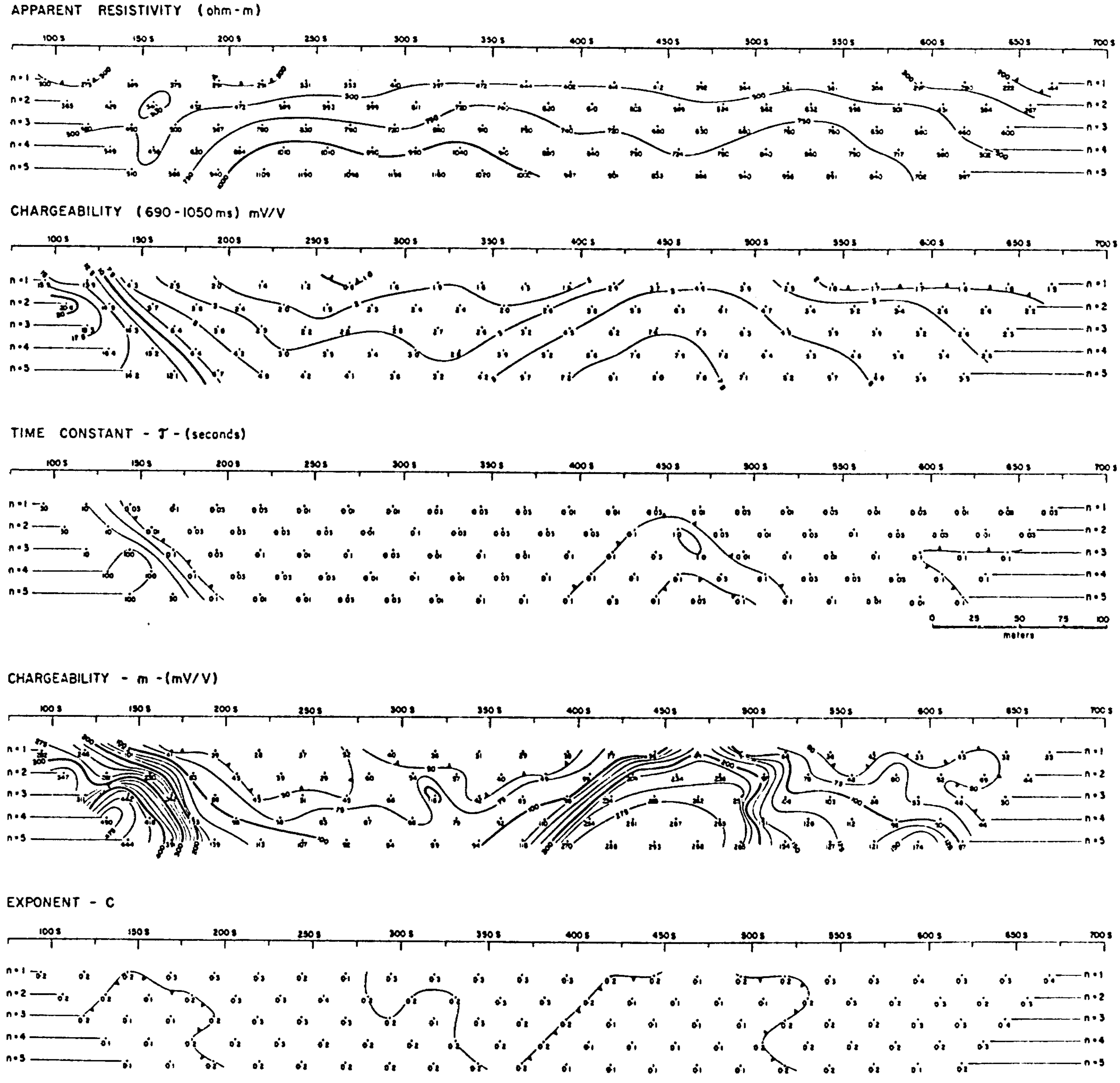

APPARENT RESISTIVITY (ohm-m)
CHARGEABILITY (690-1050 ms) mV/V
TIME CONSTANT - τ - (seconds)
CHARGEABILITY - m - (mV/V)
EXPONENT - C
100 S
150 S
200 S
250 S
300 S
350 S
400 S
450 S
500 S
550 S
600 S
650 S
700 S
n=1
n=2
n=3
n=4
n=5
0
25
50
75
100
meters

Figure 5

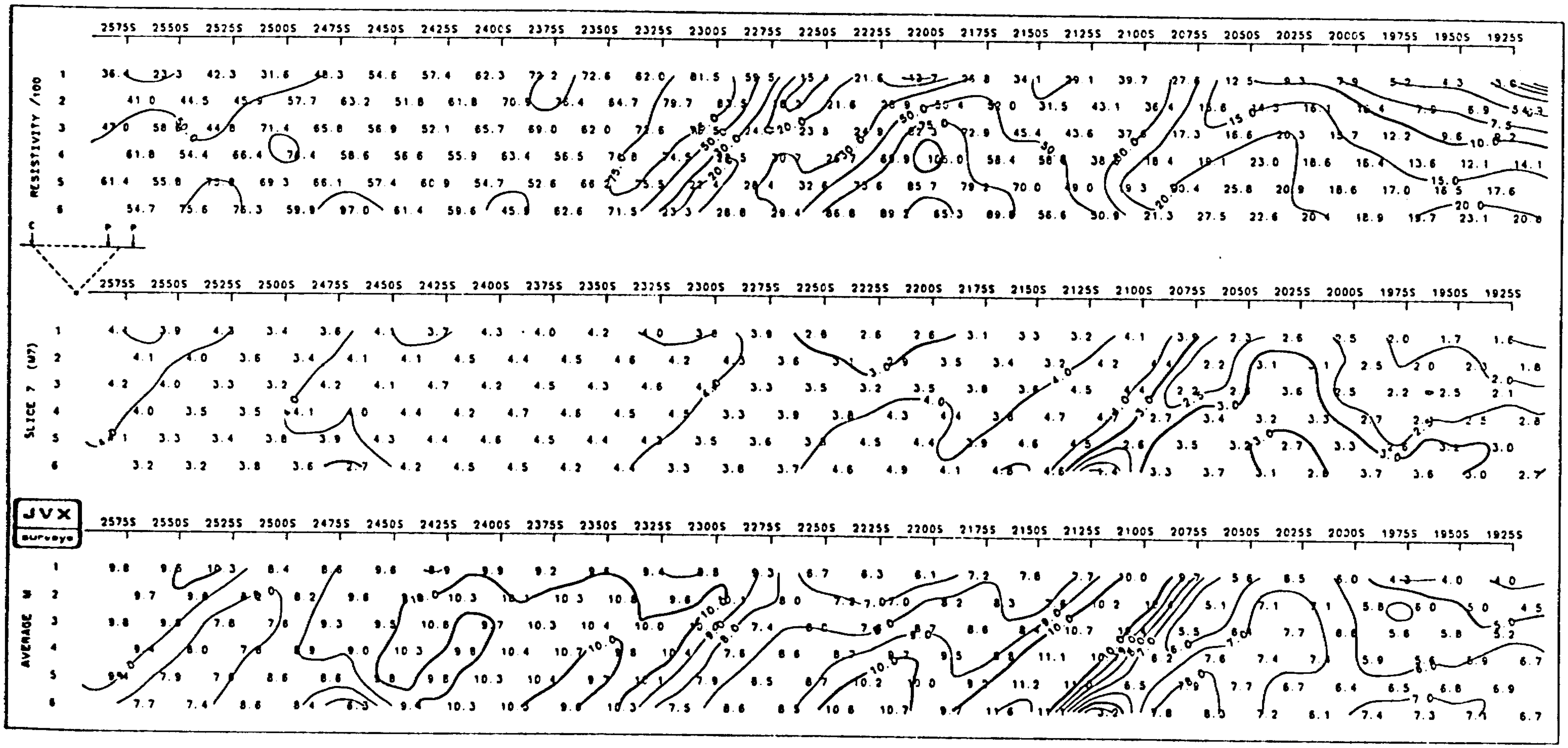


Figure 6

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

Ontario — Ministry of Northern Development and Mines

Report of Work (Geophysical, Geological, Geochemical and Expenditures)

W8906.106

2.12218

42A14SE0060 2.12118 DUFF 900

If number of mining claims traversed exceeds space on this form, attach a list.

Type of Survey(s): Induced Polarization

Claim Holder(s): Larry Gervais

Address: 73 Hudson Crescent, Timmins, Ontario

Survey Company: JVX Ltd.

Date of Survey (from & to): 14 11 88 – 02 12 88 (Day Mo. Yr.)

Total Miles of line Cut: 16.15 miles

Name and Address of Author (of Geo-Technical report): Neil Fiset 60 West Wilmot St, Unit #22 Richmond Hill, ONT.

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	40
	Geological	
	Geochemical	

Man Days	Geophysical	Days per Claim
Complete reverse side	Electromagnetic	
	Magnetometer	
	Radiometric	
	Other	
	Geological	
	Geochemical	

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

Mining Claims Traversed (List in numerical sequence)

Prefix	Number	Expend. Days Cr.
P	995006	*
	995007	*
	995008	*
	988318	*
	988319	*
	988320	*
	988321	*
	988322	*
	988323	*
	609937	

RECEIVED PORCUPINE MINING DIVISION JAN 27 1989 10:45 am BB

RECORDED JAN 27 1989

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.

*MAXIMUM 31.4 DAYS ALLOWED UNDER SEC. 77(9)

Total number of mining claims covered by this report of work: 10

For Office Use Only

Total Days Cr. Recorded: 322.6 — Date Recorded: JAN. 27/89 — Mining Recorder: [signature] — Date Approved as Recorded — Branch Director — See revised work statement.

Date: Jan. 27th/89 — Recorded Holder or Agent (Signature): Larry Gervais

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: LARRY GERVAIS 73 Hudson Crescent, Timmins Ont. P4N 7R1

Date Certified: Jan. 27th/89 — Certified by (Signature): Larry Gervais

FROM:M.R. PORCUPINE MIN.DIV. TO:1 416 489 1724 MAR 22, 1989 1:41PM P.03

Ontario Northern Development and Mines

W8800-101

(Geophysical, Geological, Geochemical and Expenditures)

2.12118

Mining Act

Note: • If number of mining claims traversed exceeds space on this form, attach a list.
• Only days credits calculated in the "Expenditures" section may be entered in the "Expend. Days Cr." columns.
• Do not use shaded areas below.

Type of Survey(s): Induced Polarization

Township or Area: Duff Twp.

Claim Holder(s): Central Crude Ltd.

Prospector's Licence No.: T 1361

Address: 436 Adelaide Street West, Toronto Ont. M5V 1S7

Survey Company: JVX Ltd.

Date of Survey (from & to): 11 1 88 02 12 88

Total Miles of line Cut:

Name and Address of Author (of Geo-Technical report): Neil Fiset 60 West Wilmot St, Unit #22 Richmond Hill, Ont.

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	[illegible]
	Magnetometer	
For each additional survey using the same grid: Enter 20 days (for each)	Radiometric	
	Other	40
	Geological	
	Geochemical	

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

RECEIVED JAN 27 1989 10:45am. RB

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

Mining Claims Traversed (List in numerical sequence)

Prefix	Number	Expend. Days Cr.
P	1031602	*
	1031603	*
	1031612	*
	1031613	*
	1031614	*
	1031615	*
	1031616	
	1031617	
	1031618	
	1031619	
	1031620	
	1031621	
	1031622	*
	1031623	*
	1031624	*
	1031625	

RECORDED JAN 27 1989

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.

* MAXIMUM 31.4 DAYS ALLOWED UNDER SEC 77(9)

Total number of mining claims covered by this report of work: 16

For Office Use Only

Total Days Cr. Recorded	Date Recorded	Mining Recorder
502.6	JAN. 27/89	[signature]
	Date Approved as Recorded	Branch Director
		See Revised work statement

Date: Jan. 27th/89 Recorded Holder or Agent (Signature): Larry Gervais

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: LARRY GERVAIS 73 Hudson Crescent, Timmins, Ont. P4N 7R1

Date Certified: Jan. 27th/89 Certified by (Signature): Larry Gervais

1362 (85/12)

FROM:M.R. PORCUPINE MIN.DIV. TO:1 416 489 1724 MAR 22, 1989 3:47PM P.03

105

Ontario and Mines

(Geophysical, Geological, Geochemical and Expenditures)

2.12118

Mining Act

Note: – ... exceeds space on this form, attach a list.
– Only days credits calculated in the "Expenditures" section may be entered in the "Expend. Days Cr." columns.
– Do not use shaded areas below.

Type of Survey(s): Induced Polarization	Township or Area: Duff Twp.
Claim Holder(s): Larry Gervais and (Henry Gonzalez Sr.)	Prospector's Licence No.: M20385 (M13940)
Address: 73 Hudson Cres. Timmins, Ont. P4N 7R1	Box 695 Timmins Ont. P4N 7G2
Survey Company: JVX Ltd.	Date of Survey (from & to): 14 11 88 – 02 12 88 (Day Mo. Yr.) — Total Miles of line Cut: 16.15 miles
Name and Address of Author (of Geo-Technical report): Neil Fiset 60 West Wilmot St. Unit #22 Richmond Hill, Ont.	

Credits Requested per Each Claim in Columns at right

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

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

PORCUPINE MINING DIVISION
RECEIVED
JAN 27 1989
10:45 am BB

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

Mining Claims Traversed (List in numerical sequence)

Prefix	Number	Expend. Days Cr.
P	969876	
	969877	
	969878	
	969879	
	969880	
	969881	
	969882	
	969883	
	969884	
	~~632~~	
	(632916)	
	(632917)	

RECORDED
JAN 27 1989

Total number of mining claims covered by this report of work: 11

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.

For Office Use Only

Total Days Cr. Recorded	Date Recorded	Mining Recorder
80	JAN. 27/89	[signature]
	Date Approved as Recorded	Branch Director: See ... work statement

Date: Jan. 27th/89 — Recorded Holder or Agent (Signature): Larry Gervais

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: LARRY GERVAIS 73 Hudson Crescent, Timmins Ont. P4N 7R1

Date Certified: Jan. 27th/89 — Certified by (Signature): Larry Gervais

FROM:M.R. PORCUPINE MIN.DIV. TO:1 416 489 1724 .104 MAR 22, 1989 3:46PM P.02

and Mines

(Geophysical, Geological, Geochemical and Expenditures)

2.12118

Mining Act

Note: – Only days credits calculated in the "Expenditures" section may be entered in the "Expend. Days Cr." columns. Do not use shaded areas below.

Type of Survey(s): Induced Polarization	Township or Area: Duff Twp.
Claim Holder(s): Larry Gervais and Henry Gonzalez Sr.	Prospector's Licence No: M20385 M13940
Address: 73 Hudson Cres. Timmins, Ont. P4N 7R1 ‖ Box 695 Timmins Ont. P4N 7G2	
Survey Company: JVX Ltd.	Date of Survey (from & to): 14 11 88 / 02 12 88 (Day Mo. Yr.) — Total Miles of line Cut: 16.15 miles
Name and Address of Author (of Geo-Technical report): Neil Fiset 60 West Wilmot St. Unit #22 Richmond Hill, Ont.	

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	~~40~~
	Magnetometer	
For each additional survey: using the same grid: Enter 20 days (for each)	Radiometric	
	Other	40
	Geological	
	Geochemical	

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

RECEIVED JAN 27 1989 10:45 am BB

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

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.

Mining Claims Traversed (List in numerical sequence)

Prefix	Number	Expend. Days Cr.
P	969876	
	969877	
	969878	
	969879	
	969880	
	969881	
	969882	
	969883	
	969884	
	~~632~~ L.G.	
	632916	
	632917	

RECORDED JAN 27 1989

Total number of mining claims covered by this report of work: 11

For Office Use Only

Total Days Cr. Recorded	Date Recorded	Mining Recorder
360	JAN. 27/89	[signature]
	Date Approved as Recorded	Branch Director

Date: Jan. 27th/89 — Recorded Holder or Agent (Signature): Larry Gervais

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: LARRY GERVAIS 73 Hudson Crescent, Timmins Ont. P4N 7R1

Date Certified: Jan. 27th/89 — Certified by (Signature): Larry Gervais

1362 (85/12)

Ontario

Ministry of
Northern Development
and Mines

Ministère du
Développement du Nord
et des Mines

Mining Lands Section
3rd Floor, 880 Bay Street
Toronto, Ontario
M5S 1Z8

Telephone: (416) 965-4888

June 3, 1989

Your file: W8906-104,5,6,7
Our file: 2.12118

Mining Recorder
Ministry of Northern Development and Mines
60 Wilson Avenue
Timmins, Ontario
P4N 2S7

Dear Sir:

Re: Notice of Intent dated May 2, 1989 Induced Polarization Survey submitted on Mining Claims P 995006 et al in Duff Township.

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,

W.R. Cowan
Provincial Manager, Mining Lands
Mines & Minerals Division

D.K. DK:eb
Enclosure

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

Neil Fiset
Richmond Hill, Ontario

Central Curde
Toronto, Ontario

Resident Geologist
Timmins, Ontario

Larry Gervais
Timmins, Ontario

Ministry of Northern Development and Mines
Ontario

Technical Assessment Work Credits

File
2.12118

Date	Mining Recorder's Report of Work No.
May 2, 1989	W8906-104

Recorded Holder
Larry Gervais and Henry Gonzalez Sr..
Township or Area
Duff Township

Type of survey and number of Assessment days credit per claim	Mining Claims Assessed
Geophysical	P 969876 to 84 incl.
Electromagnetic ______ days	
Magnetometer ______ days	
Radiometric ______ days	
Induced polarization 32 days	
Other ______ days	
Section 77 (19) See "Mining Claims Assessed" column	
Geological ______ days	
Geochemical ______ days	
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

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.

Ministry of Northern Development and Mines

Ontario

Technical Assessment Work Credits

File
2.12118

Date	Mining Recorder's Report of Work No.
May 2, 1989	W8906-105

Recorded Holder
Henry Gonzalez Sr..
Township or Area
Duff Township

Type of survey and number of Assessment days credit per claim	Mining Claims Assessed
Geophysical	P 632916-17
Electromagnetic ______ days	
Magnetometer ______ days	
Radiometric ______ days	
Induced polarization 32 days	
Other ______ days	
Section 77 (19) See "Mining Claims Assessed" column	
Geological ______ days	
Geochemical ______ days	
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

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.

Ministry of Northern Development and Mines
Ontario

Technical Assessment Work Credits

File
2.12118

Date	Mining Recorder's Report of Work No.
May 2, 1989	W8906-106

Recorded Holder
Larry Gervais

Township or Area
Duff Township

Type of survey and number of Assessment days credit per claim	Mining Claims Assessed
Geophysical	P 995006 to 08 incl.
Electromagnetic ______ days	988318 to 23 incl.
Magnetometer ______ days	609937
Radiometric ______ days	
Induced polarization 29 days	
Other ______ days	
Section 77 (19) See "Mining Claims Assessed" column	
Geological ______ days	
Geochemical ______ days	
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

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.

Ministry of Northern Development and Mines
Ontario

Technical Assessment Work Credits

File
2.12118

Date	Mining Recorder's Report of Work No.
May 2, 1989	W8906-107

Recorded Holder: Central Crude Ltd.

Township or Area: Duff Township

Type of survey and number of Assessment days credit per claim	Mining Claims Assessed
Geophysical	P 1031602-03 1031612 to 19 incl. 1031621 to 24 incl.
Electromagnetic ______ days	
Magnetometer ______ days	
Radiometric ______ days	
Induced polarization 28 days	
Other ______ days	
Section 77 (19) See "Mining Claims Assessed" column	
Geological ______ days	
Geochemical ______ days	
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

P 1031620
1031625

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.

Ministry of Northern Development and Mines

Ontario

Geophysical-Geological-Geochemical Technical Data Statement

File ________

TO BE ATTACHED AS AN APPENDIX TO TECHNICAL REPORT
FACTS SHOWN HERE NEED NOT BE REPEATED IN REPORT
TECHNICAL REPORT MUST CONTAIN INTERPRETATION, CONCLUSIONS ETC.

Type of Survey(s) Induced Polarization

Township or Area Duff.

Claim Holder(s) Central Crude Ltd.
436 Adelaide St. West.
TORONTO, ONTARIO.

Survey Company JVX Ltd.

Author of Report Neil Fiset

Address of Author 60 west Wilmot St, unit #22 Richmond Hill, Ont.

Covering Dates of Survey Nov. 14, 1988 - Dec. 2, 1988.
(linecutting to office)

Total Miles of Line Cut 16.15 miles

SPECIAL PROVISIONS CREDITS REQUESTED

ENTER 40 days (includes line cutting) for first survey.

ENTER 20 days for each additional survey using same grid.

	DAYS per claim
Geophysical	
—Electromagnetic	40
—Magnetometer	
—Radiometric	
—Other	
Geological	
Geochemical	

AIRBORNE CREDITS (Special provision credits do not apply to airborne surveys)

Magnetometer ______ Electromagnetic ______ Radiometric ______
(enter days per claim)

DATE: JAN 25, 1989 SIGNATURE: David Graham
Author of Report or Agent

Res. Geol. ________ Qualifications ________

Previous Surveys

File No.	Type	Date	Claim Holder

TELEPHONE (416) 489-1382

R. Bruce Graham & Associates Ltd.
MINING CONSULTANTS

DAVID B. GRAHAM

54 ST. LEONARDS AVENUE
TORONTO M4N 1K3

OFFICE USE ONLY

MINING CLAIMS TRAVERSED
List numerically

(prefix)	(number)
P	1031620
P	1031621
P	1031622
P	1031623
P	1031624
P	1031625

If space insufficient, attach list

TOTAL CLAIMS 6

837 (85/12)

GEOPHYSICAL TECHNICAL DATA

GROUND SURVEYS – If more than one survey, specify data for each type of survey

Number of Stations ______ Number of Readings ______

Station interval ______ Line spacing ______

Profile scale ______

Contour interval ______

MAGNETIC

Instrument ______

Accuracy – Scale constant ______

Diurnal correction method ______

Base Station check-in interval (hours) ______

Base Station location and value ______

ELECTROMAGNETIC

Instrument ______

Coil configuration ______

Coil separation ______

Accuracy ______

Method: ☐ Fixed transmitter ☐ Shoot back ☐ In line ☐ Parallel line

Frequency ______ (specify V.L.F. station)

Parameters measured ______

GRAVITY

Instrument ______

Scale constant ______

Corrections made ______

Base station value and location ______

Elevation accuracy ______

INDUCED POLARIZATION RESISTIVITY

Instrument Scintrex IPR-11 receiver / IPC-7 / 2.5 Kw transmitter

Method ☑ Time Domain ☐ Frequency Domain

Parameters – On time 2 sec Frequency ______

– Off time 2 sec Range ______

– Delay time 2 sec

– Integration time 2 sec.

Power 2.5 Kw.

Electrode array Pole - Dipole

Electrode spacing 50 metres

Type of electrode stainless steel.

SELF POTENTIAL

Instrument ______________________ Range ______________________

Survey Method ______________________

____

Corrections made ______________________

____

RADIOMETRIC

Instrument ______________________

Values measured ______________________

Energy windows (levels) ______________________

Height of instrument ______________________ Background Count ______________________

Size of detector ______________________

Overburden ______________________

(type, depth – include outcrop map)

OTHERS (SEISMIC, DRILL WELL LOGGING ETC.)

Type of survey ______________________

Instrument ______________________

Accuracy ______________________

Parameters measured ______________________

____

Additional information (for understanding results) ______________________

____

____

AIRBORNE SURVEYS

Type of survey(s) ______________________

Instrument(s) ______________________

(specify for each type of survey)

Accuracy ______________________

(specify for each type of survey)

Aircraft used ______________________

Sensor altitude ______________________

Navigation and flight path recovery method ______________________

____

Aircraft altitude ______________________ Line Spacing ______________________

Miles flown over total area ______________________ Over claims only ______________________

GEOCHEMICAL SURVEY – PROCEDURE RECORD

Numbers of claims from which samples taken ______________________________

____

____

Total Number of Samples ______________

Type of Sample ______________
(Nature of Material)

Average Sample Weight ______________

Method of Collection ______________

____

Soil Horizon Sampled ______________

Horizon Development ______________

Sample Depth ______________

Terrain ______________

____

Drainage Development ______________

Estimated Range of Overburden Thickness ______________

____

____

SAMPLE PREPARATION
(Includes drying, screening, crushing, ashing)

Mesh size of fraction used for analysis ______________

____

____

____

General ______________

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____

ANALYTICAL METHODS

Values expressed in: per cent ☐ p. p. m. ☐ p. p. b. ☐

Cu, Pb, Zn, Ni, Co, Ag, Mo, As,-(circle)

Others ______________

Field Analysis (______________ tests)

Extraction Method ______________

Analytical Method ______________

Reagents Used ______________

Field Laboratory Analysis

No. (______________ tests)

Extraction Method ______________

Analytical Method ______________

Reagents Used ______________

Commercial Laboratory (______________ tests)

Name of Laboratory ______________

Extraction Method ______________

Analytical Method ______________

Reagents Used ______________

General ______________

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Ministry of Northern Development and Mines

Ontario

Geophysical-Geological-Geochemical Technical Data Statement

File ______

TO BE ATTACHED AS AN APPENDIX TO TECHNICAL REPORT
FACTS SHOWN HERE NEED NOT BE REPEATED IN REPORT
TECHNICAL REPORT MUST CONTAIN INTERPRETATION, CONCLUSIONS ETC.

Type of Survey(s) ______

Township or Area ______

Claim Holder(s) Larry Gervais ~~& Henry J. Gervais~~ (subject to agreement with Central Crude Ltd)

Survey Company JVX Ltd.

Author of Report Neil Fiset

Address of Author 60 West Wilmot St. Unit #22 Richmond Hill, Ont.

Covering Dates of Survey Nov. 14 - Dec. 2, 1988 (linecutting to office)

Total Miles of Line Cut 16.15 miles

SPECIAL PROVISIONS CREDITS REQUESTED

ENTER 40 days (includes line cutting) for first survey.

ENTER 20 days for each additional survey using same grid.

	DAYS per claim
Geophysical	
—Electromagnetic	40
—Magnetometer	
—Radiometric	
—Other	
Geological	
Geochemical	

AIRBORNE CREDITS (Special provision credits do not apply to airborne surveys)

Magnetometer ______ Electromagnetic ______ Radiometric ______ (enter days per claim)

DATE: JAN 25, 1989 SIGNATURE: [signature] Author of Report or Agent

MINING CLAIMS TRAVERSED
List numerically

(prefix)	(number)	
P	995006	LG
P	995007	"
P	995008	"
P	988318	"
P	988319	"
P	988320	"
P	988321	"
P	988322	"
P	988323	"

If space insufficient, attach list

TOTAL CLAIMS 9

OFFICE USE ONLY

Res. Geol. ______ Qualifications ______

Previous Surveys

File No.	Type	Date	Claim Holder

837 (85/12)

GEOPHYSICAL TECHNICAL DATA

GROUND SURVEYS – If more than one survey, specify data for each type of survey

Number of Stations ______ Number of Readings ______

Station interval ______ Line spacing ______

Profile scale ______

Contour interval ______

MAGNETIC

Instrument ______

Accuracy – Scale constant ______

Diurnal correction method ______

Base Station check-in interval (hours) ______

Base Station location and value ______

ELECTROMAGNETIC

Instrument ______

Coil configuration ______

Coil separation ______

Accuracy ______

Method: ☐ Fixed transmitter ☐ Shoot back ☐ In line ☐ Parallel line

Frequency ______ (specify V.L.F. station)

Parameters measured ______

GRAVITY

Instrument ______

Scale constant ______

Corrections made ______

Base station value and location ______

Elevation accuracy ______

INDUCED POLARIZATION RESISTIVITY

Instrument Scintrex IPR-11 receiver / IPC-7 / 2.5 Kw transmitter

Method ☐ Time Domain ☐ Frequency Domain

Parameters – On time 2 sec Frequency ______

– Off time 2 sec Range ______

– Delay time 2 sec

– Integration time 2 sec

Power 2.5 Kw.

Electrode array Pole - Dipole

Electrode spacing 50 metres

Type of electrode stainless steel.

SELF POTENTIAL

Instrument ______________________ Range ______________________

Survey Method ______________________

____

Corrections made ______________________

____

RADIOMETRIC

Instrument ______________________

Values measured ______________________

Energy windows (levels) ______________________

Height of instrument ______________________ Background Count ______________________

Size of detector ______________________

Overburden ______________________

(type, depth – include outcrop map)

OTHERS (SEISMIC, DRILL WELL LOGGING ETC.)

Type of survey ______________________

Instrument ______________________

Accuracy ______________________

Parameters measured ______________________

____

Additional information (for understanding results) ______________________

____

____

AIRBORNE SURVEYS

Type of survey(s) ______________________

Instrument(s) ______________________

(specify for each type of survey)

Accuracy ______________________

(specify for each type of survey)

Aircraft used ______________________

Sensor altitude ______________________

Navigation and flight path recovery method ______________________

____

Aircraft altitude ______________________ Line Spacing ______________________

Miles flown over total area ______________________ Over claims only ______________________

GEOCHEMICAL SURVEY – PROCEDURE RECORD

Numbers of claims from which samples taken ____________________

____

____

Total Number of Samples ____________________

Type of Sample ____________________
(Nature of Material)

Average Sample Weight ____________________

Method of Collection ____________________

____

Soil Horizon Sampled ____________________

Horizon Development ____________________

Sample Depth ____________________

Terrain ____________________

____

Drainage Development ____________________

Estimated Range of Overburden Thickness ____________________

____

____

SAMPLE PREPARATION
(Includes drying, screening, crushing, ashing)

Mesh size of fraction used for analysis ____________________

____

____

____

General ____________________

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ANALYTICAL METHODS

Values expressed in: per cent ☐ p. p. m. ☐ p. p. b. ☐

Cu, Pb, Zn, Ni, Co, Ag, Mo, As,-(circle)

Others ____________________

Field Analysis (____________________ tests)

Extraction Method ____________________

Analytical Method ____________________

Reagents Used ____________________

Field Laboratory Analysis

No. (____________________ tests)

Extraction Method ____________________

Analytical Method ____________________

Reagents Used ____________________

Commercial Laboratory (____________________ tests)

Name of Laboratory ____________________

Extraction Method ____________________

Analytical Method ____________________

Reagents Used ____________________

General ____________________

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REFERENCES

AREAS WITHDRAWN FROM DISPOSITION

M.R.O. – MINING RIGHTS ONLY

S.R.O. – SURFACE RIGHTS ONLY

M.+ S. – MINING AND SURFACE RIGHTS

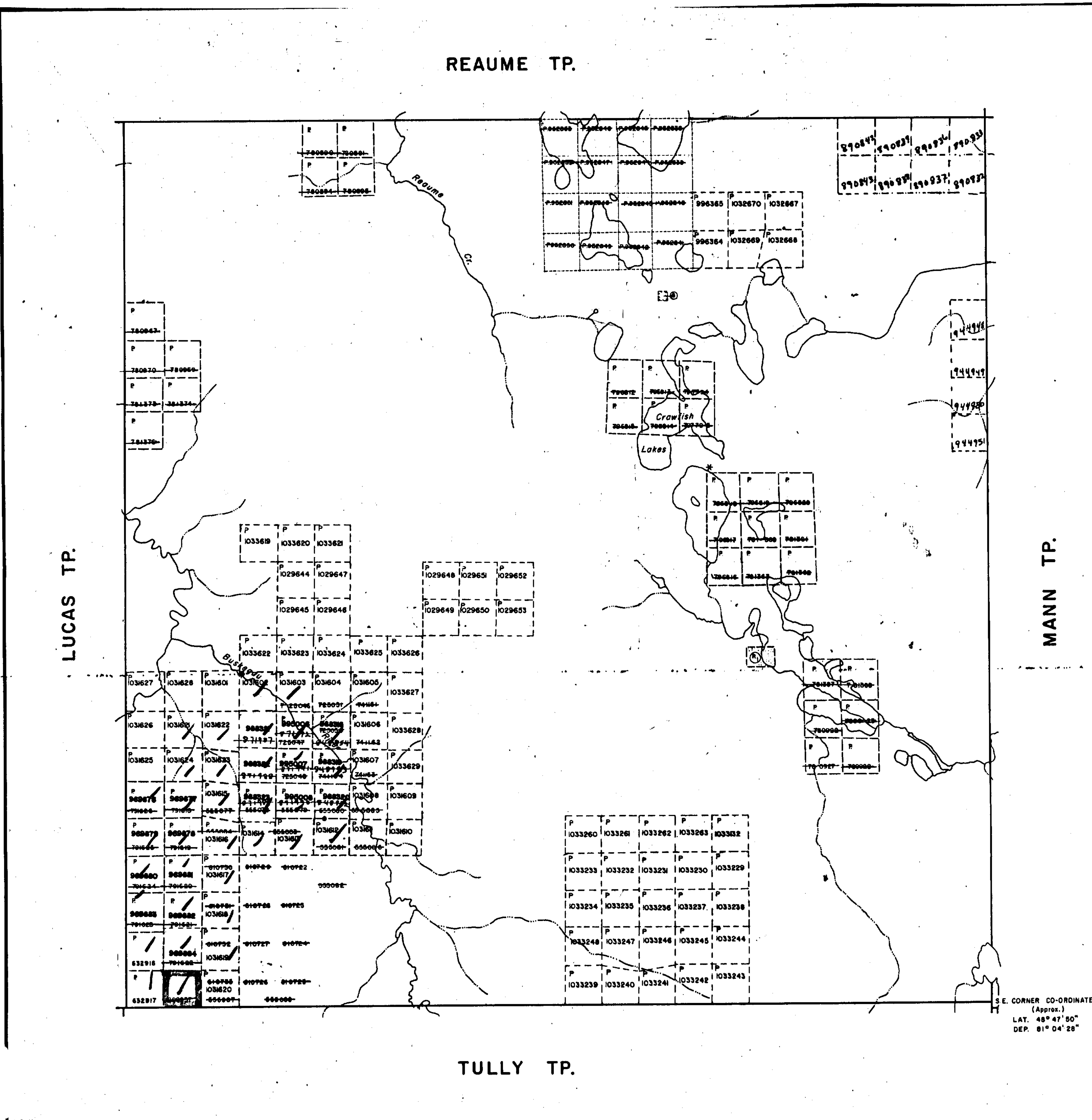
Description	Order No.	Date	Disposition	File
Ⓦ SEC 36/80	W.1/80	8/6/80	M + S	

The Mining & Surface Rights of the former Mining Claim P-609937, are withdrawn from staking by Order MNW 16/87

Subdivision of this township into lots and concessions was annulled May 10, 1963.

SAND and GRAVEL

Ⓠ QUARRY PERMIT



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	Ⓢ
LAND USE PERMIT	

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.

SCALE: 1 INCH = 40 CHAINS

FEET 0 1000 2000 4000 6000 8000

METRES 0 200 1000 (1 KM) 2000 (2 KM)

TOWNSHIP

DUFF

M.N.R. ADMINISTRATIVE DISTRICT

COCHRANE

MINING DIVISION

PORCUPINE

LAND TITLES / REGISTRY DIVISION

COCHRANE

Ontario Ministry of Natural Resources — Land Management Branch

Date MARCH, 1985

Number G-3234

Rec'd Apr. 10/89

100 0 100 200 300

METRES

2.12118

CENTRAL CRUDE RESOURCES LTD.

DUFF TOWNSHIP PROPERTY

COCHRANE AREA, ONTARIO

AVERAGE CHARGEABILITY (AVG) PLAN MAP

POLE-DIPOLE ELECTRODE ARRAY

AVERAGE = (M0 + M1 + M2 +...+ M9) / 10

N=2,A=50.0M : TO=WEST : C1=TRAILING

SCINTREX IPR-11 RECEIVER

SCINTREX IPC-7 2.5KW TRANSMITTER

SCALE 1 : 5000

SURVEY BY
JVX LTD.
DECEMBER, 1988

PLATE 1

2.12118

CENTRAL CRUDE RESOURCES LTD.

DUFF TOWNSHIP PROPERTY
COCHRANE AREA, ONTARIO

APPARENT RESISTIVITY (RHO) PLAN MAP
POLE-DIPOLE ELECTRODE ARRAY
N=2,A=50.0M : TO=WEST : C1=TRAILING
SCINTREX IPR-11 RECEIVER
SCINTREX IPC-7 2.5KW TRANSMITTER

SCALE 1 : 5000

SURVEY BY
JVX LTD.
DECEMBER, 1988

PLATE 2

42A14SE0060 2.12118 DUFF

220

100 0 100 200 300
METRES

2.12118

LEGEND

Chargeability anomalies :
- Strong
- Medium
- Weak
- Very weak

H, M, L .... Time Constant (High, Medium, Low)

88 .... M-IP (mV/V)

H .... High resistivity

A .... IP anomalous zone

.... HLEM conductor (Exsics Expl., 1988)

.... Airborne EM (OGS Map No. 81048)

.... Geological Contact

42A14SE0060 2.12118 DUFF

230

CENTRAL CRUDE RESOURCES LTD.

DUFF TOWNSHIP PROPERTY
COCHRANE AREA, ONTARIO

COMPILATION PLAN MAP

SCINTREX IPR-11 RECEIVER
SCINTREX IPC-7 2.5KW TRANSMITTER

SCALE 1 : 5000

SURVEY BY
JVX LTD.
DECEMBER, 1988

PLATE 3

42A14SE0068 2.12118 DUFF

240

PLATE 5

42A14SE0068 2.12118 DUFF

250