

**INDUCED POLARIZATION SURVEY
OVER THE
MAM, VISCOUNT AND MARN CLAIM GROUPS,
BRITISH COLUMBIA
FOR
KEL GLEN MINES LTD.,
BY
ADIAN AERO MINERAL SURVEYS LIMITED.**

MARN - # 1 to 29, 31, 33, 35 and 37
ROB - # 1 to 8, 11, 12, and 15 to 30
CAM - # 1 to 8, 11 to 14, 16, 18 and 20 to 26
VISC - # 1 to 6
BOB - # 1 and 2
TOM - # 1 and 2 3 parts
KEL-FR. - # 1
GLEN-FR. - # 1

92 H/16E

PART 3 OF 3

875

PART 3

OF 3

875

REPORT ON
INDUCED POLARIZATION SURVEY
OVER THE
ROB, CAM, VISCOUNT AND MARN CLAIM GROUPS,
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CANADIAN AERO MINERAL SURVEYS LIMITED,
Project No. 6092.

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OTTAWA, Ontario,
August 27, 1966.

P. Morgeard, P.Eng.,
Sr. Geophysicist.

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S U M M A R Y

In the period from June 13 to August 3, 1966, an induced polarization survey was carried out by Canadian Aero Mineral Surveys Limited on part of a property comprised of claims of the Rob, Cam, Viscount and Marn groups, British Columbia, on behalf of Kel Glen Mines Ltd.,

One zone of mineralization was noted in the greywacke at the greywacke--granodiorite contact on the Marn group claims 15, 16 and 18. 4%-8% average by volume of polarizable material is suggested.

Four zones with polarization characteristics in the 3.0-4.0 millisecond range with two observations of 5.0-6.0 were outlined or partially outlined during the survey. These zones are suspected of being expressions of bedrock but all are recommended for further check work as responses of this magnitude could be significant in view of the fact that the target material sought is mainly molybdenum.

REPORT ON
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ROB, CAM, VISCOUNT AND MARN CLAIM GROUPS,
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I. INTRODUCTION

In the period from June 13 to August 3, 1966, an induced polarization survey was carried out by Canadian Aero Mineral Surveys Limited on part of a property comprised of claims of the Rob, Cam, Viscount and Marn groups located in the Brenda Lake area in British Columbia. The survey was conducted on behalf of Kel Glen Mines Ltd. A total of about 29 miles of line was surveyed from five different instrument locations in about 40 working days. The field work was conducted by R. Pedersen, B.Sc.

The purpose of the induced polarization survey was to map the sub-surface distribution of metallic sulphide mineralization in order to localize the presence of any copper-molybdenum deposits.

A reprint of the paper entitled "A Decade of Development in Overvoltage Surveying" by Robert W. Baldwin, which is attached to this report describes the phenomena involved and the methods of measurement and interpretation in this type of survey. For the present survey, high sensitivity, pulse-type equipment was employed with a current on-time of 1.5 seconds and a measuring time of 0.5 seconds.

At each observation point both the primary and secondary voltages are measured. The primary voltages (steady state voltages) are converted by formula to apparent resistivities in units of ohm meters. The secondary voltages (polarization voltages) are measured by integration and then divided by the corresponding primary voltages to obtain the apparent chargeability, the resulting polarization property characteristic of the region. It is expressed in units of milliseconds or millivolt seconds per volt.

The chief application of induced polarization is in the direct detection of disseminated metallic sulphides. However, any transition in conduction from ionic to electronic and vice versa will give rise to IP effects. For this reason, all metallic conducting sulphides, including pyrite, pyrrhotite, chalcopyrite and chalcocite, etc., and arsenides will be detectable as well as graphite. The latter may be expected to occur primarily in carbonaceous shales and limestones. Occasionally, abnormal IP effects may be experienced from magnetite concentrations and from serpentines. There is no way at present in which IP effects from any one of these sources can be differentiated from those arising from any of the others using the IP data alone.

Throughout the reconnaissance survey a standard, equispaced three-electrode array was used employing an electrode spacing of 400'. Readings were taken at 200 foot intervals along lines spaced at approximately 800 foot intervals. In areas of interest, the reading interval was changed to 100 feet.

II. DISCUSSION OF RESULTS

The results of the IP survey are presented in profile form on plates I(a) and I(b) and I(c) at the scale of 1 inch = 200 feet, along the profiles. For the sake of clarity of presentation the lines are not spaced to scale in the profile presentation. The apparent resistivity values in ohm meters are plotted on a logarithmic scale of 2 inches = 1 cycle (100-1000 ohm meters); apparent chargeabilities are plotted at the scale of 1 inch = 5.0 milliseconds.

The apparent chargeability values are also presented in contour form on plates II(a) and II(b). One must bear in mind the rather large line spacing (800 feet) in relation to the electrode spacing employed (400 feet) when considering the accuracy of the contours. However, quite a good outline of zones of higher chargeability is given by the contour plans. The base maps for these plans were supplied by Kel Glen Mines Limited. The scale is approximately 1 inch = 400 feet.

Most of the area covered by the present survey has been geologically mapped as granodiorite. In the southwest corner of the property surveyed, on Marn claim No. 16 there is a contact between the granodiorite and greywacke. The field maps of the geology in the area were supplied by Kai Glen Mines Limited; the maps were prepared by Dr. E. J. Lees.

The normal background chargeability responses observed in this region using an electrode spacing of 400 feet are in the order of 1.5-2.5 milliseconds. Chargeabilities of 2.0 and greater have been contoured on plates II(a) and II(b).

Since molybdenum is the prime target sought in this area and consequently less than 1% average by volume of sulphides could be of interest, any zones with a chargeability of 3.0 milliseconds and higher is considered anomalous in this discussion.

Five zones with chargeabilities of 3.0 milliseconds and greater were noted by the present survey.

Zone I

A maximum apparent chargeability response of 28.0 milliseconds was observed at 31W on line 96 south during the reconnaissance survey. This zone of higher polarization characteristics is still open towards the west and south. Extended coverage of the zone is required for a complete interpretation of this anomalous situation.

Detailed work over the anomalous section of line 96 south in the form of traverses using electrode spacings of 200 feet and 800 feet shows a distinct shift of the anomaly peak towards the west with an increase in electrode spacing. This gives an apparent dip towards the west for the source material. Near surface material of a concentration of 4%-8% average by volume is indicated. The polarizable material is situated in the greywacke.

More IP coverage of this zone is recommended before drilling is attempted. However, if drilling has to be carried out on the data presently available the following drill hole location is suggested:

Collar at 200 feet southwest of station 28West on line 96 South. Drill towards the northeast at an inclination of -45° for at least 300 feet.

Zone II

Chargeability values in the 3.0-5.0 millisecond range were observed in zone II which extends from line 16 South at about 22 West to line 16 North at about 7 West. It is still open towards the north. The zone corresponds in general with an area covered by moraine material. An increase in clay content could give the type of response observed here and the close correlation with the moraines does suggest the properties of the glacial material as a cause for the higher polarization characteristics.

Zone III

Apparent chargeabilities in the 3.0-4.0 millisecond range were observed at the east end of line 48 South on Viscount Claim No. 2. Considerable outcrop was mapped over the region of slightly higher than background chargeabilities. The decrease in overburden thickness or in this case the disappearance of overburden could give an increase of 1.0 milliseconds. The true chargeability of the granodiorite is probably in the 3.0-4.0 millisecond range.

Zone IV

The polarization characteristics of zone IV along with the correlating apparent resistivities again suggest a decrease in overburden as the cause of the slightly higher than background apparent chargeabilities observed here. The chargeability values are in the order of 3.0-4.5 milliseconds with a single high value of 6.3 milliseconds on line 8 North at 146 East. Values in excess of 3.0 were observed on lines 40 North, 32 North, 16 North and 8 North on claims Cam 2, 4, and . The zone is still open towards the north. Less than 1% average by volume of polarizable material is indicated on line 8 North but in view of the fact that molybdenum is the target material sought, a careful check of the zone is recommended on lines 8 North and 16 North. Geochemistry might be employed as an aid in further evaluating this zone although its use might be limited in an area largely covered by glacial debris. No detailed work was carried out over the zone. Further IP coverage across the zone using various electrode spacings

is recommended for line 8 North.

Zone V

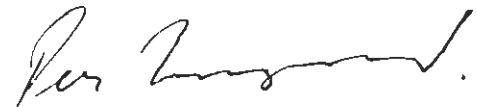
A maximum apparent chargeability value of 5.5 milliseconds was observed on lines 8 N at 182 East on claim Cam 26. This zone does not extend north to line 16 North and no coverage was obtained to the south as line 0 did not extend far enough to the east. No detailed work was carried out on this anomaly. The correlating resistivities are very high which suggests a decrease in overburden (assuming that there is not a change in rock type), as being at least partially responsible for the increase in apparent chargeability. Further IP coverage to the south and detailed work using various electrode spacings is recommended as a means of further evaluating this zone. Geochemistry might also be of some assistance here.

III. CONCLUSIONS

One zone of high polarization characteristics suggesting mineralization of a concentration of 4% - 8% average by volume was noted on line 96 South. This zone is open both towards the West and South. The mineralization is located in the greywacke and appears to commence at the geological contact between the greywacke and granodiorite. Further IP coverage is recommended before drilling of this zone is attempted.

Four zones with polarization characteristics in the 3.0-4.0 millisecond range with two observations of 5.0-6.0 milliseconds were outlined or partially outlined during the survey. All these zones have direct correlation of high apparent resistivity which suggests a decrease in overburden thickness as the reason for the increase of about 1.0 millisecond in the polarization responses. However, since molybdenum is primarily the target material sought in the area, it is recommended that zones which chargeabilities greater than 3.0 milliseconds be thoroughly checked. Geochemistry might be of value in further investigation of these zones. Additional IP work is suggested on zones IV and V.

Respectfully submitted,




OTTAWA, Ontario,
August 27, 1966.

Peer Norgaard, P.Eng.,
Senior Geophysicist.

A P P E N D I X I

The following Canadian Aero Mineral Surveys Limited personnel were necessary to the completion of the induced polarization survey carried out on the Rob, Cam, Viscount and Marn Claim groups in the period from June 13 to August 3, 1966.

	<u>No. of Man Days</u>
Rolf Pedersen, Geophysicist (Field) Box 468, R.R. 5, Ottawa, Ontario.	41
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Ramon Paradella, Draughtsman, Ottawa, Ontario.	
Brian Perry, Helper 2020 Alexander St. S.E., Calgary, Alta.	41
John Perry, Helper	<u>33</u>
TOTAL	<u>125</u>



Peer Norgaard, P. Eng.,
Senior Geophysicist.

A DECADE OF DEVELOPMENT IN OVERVOLTAGE SURVEYING

by ROBERT W. BALDWIN

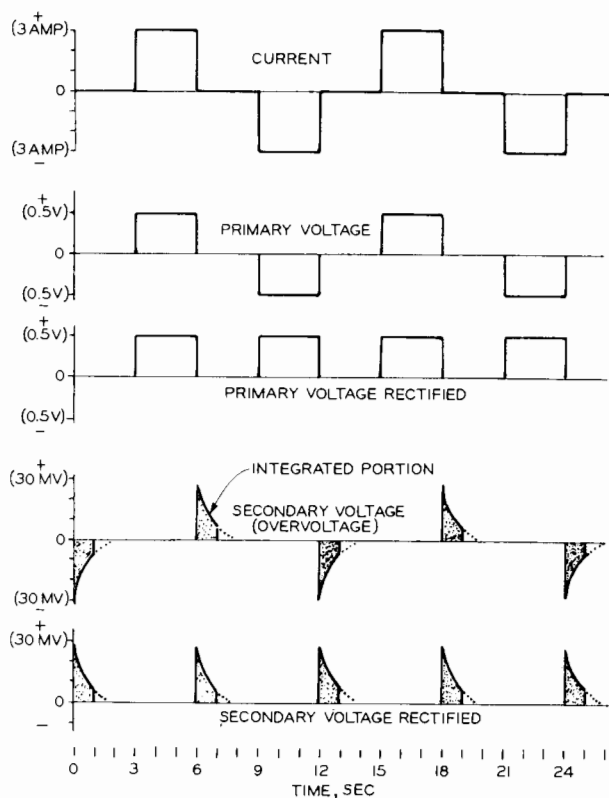
As used in geophysical exploration, the term *Overvoltage* applies to secondary voltages set up by a current into the earth which decay when the current is interrupted. These secondary effects may be measured by pick-up electrodes. The term *induced polarization* has often been employed to describe this same phenomenon. In its own operations Newmont Exploration Ltd. commonly uses the word *pulse*.

The basis of this method in prospecting is that metallic particles, sulfides in particular, give a high response, whereas barren rock, with certain exceptions, gives a low response. Overvoltage has been tried in searching for many types of mineral occurrence but has been most successful in outlining the widespread disseminated mineralization associated with porphyry coppers.

History:¹ Newmont Mining Corp. has been interested in overvoltage since 1946, when Radio Frequency Laboratories of Boonton, N. J., drew the company's attention to phenomena observed in the laboratory. At the instigation of A. A. Brant further model studies were undertaken, and the first tests were performed in 1947. Tests at San Manuel, Ariz., in 1948 were very encouraging, clearly demonstrating that the method could be used to distinguish scattered sulfides at depth. H. O. Seigel followed up the San Manuel work with a study to determine the phenomena involved.²

R. W. BALDWIN, Member AIME, is with the Geophysical Department, Newmont Exploration Ltd., Danbury, Conn. TP 4793L. Manuscript, June 25, 1958. New York Meeting, February 1958. AIME Trans., Vol. 214, 1959.

Fig. 1—Current and voltage sequences, typical measurement. Overvoltage response to be plotted equals integrated secondary voltage divided by primary voltage.



Further field experiments took place at Jerome, Ariz., in 1949-1950. Since 1950 this method has been a standard prospecting tool of Newmont Exploration Ltd. Overvoltage surveys have been carried out in the U. S., Canada, Latin America, and Africa. Field equipment has been constantly improved.

Concurrent with field exploration, theoretical and experimental investigations were pursued at Jerome. H. O. Seigel, J. R. Wait, V. Mayer, E. H. Bratnober, and L. S. Collett were notable contributors. Work at the Jerome laboratories included:

- 1) Study of the phenomena involved, with extensive investigation into the causes of background nonsulfide effects.
- 2) Study of the possibilities of taking induced polarization measurements with low-frequency alternating current instead of pulsed direct current.
- 3) Mathematical development of type curves showing the anomalies to be expected from mineralized bodies of various shapes and sizes under varying depths and conditions of cover.

- 4) Laboratory testing of rock samples, study of the form of overvoltage decay and the a-c response for various types and sizes of mineral particles, and model orebody studies.

Operational Methods: The overvoltage method requires direct connection to the ground, by means of two current electrodes and two potential electrodes. Field methods are thus similar to those of resistivity surveys. Various electrode arrays have been used; electrode spacings are chosen according to the type of target and expected depth. Spacings as wide as 1500 ft have been regularly employed. In laboratory work also, four direct connections must be made to the specimen or model.

Fig. 1 illustrates, in idealized form, the sequences encountered in a typical d-c overvoltage measurement.* While the current is on there is a primary

* The voltage and current values quoted are samples to indicate an order of magnitude.

voltage across the potential electrodes which may be measured with a vacuum tube voltmeter—a simple resistivity measurement. On cessation of current (allowing 10 to 15 milliseconds for inductive and capacitive coupling effects to disappear) the decaying secondary voltage or overvoltage appears at the potential electrodes. This decay curve may be presented on an oscilloscope and photographed—the procedure in many laboratory experiments. Field practice is to integrate the decay voltage over an interval following current cessation. Common operating times are 3 sec of current pulse and 1 sec of integrating time. To obtain a reading the integrated secondary voltage is divided by the primary voltage. The units are then millivolt-seconds per volt.

In practice, of course, not just one pulse of current is applied but a succession of pulses as shown, every second pulse being of reversed polarity. Rectifying relays are provided so that the primary and secondary voltages always read positively.

Field Equipment:³ Fig. 2 is a block diagram of typical field equipment. The heart of the equipment is the timing unit, which controls both current switching and the connections of potential electrodes to the vacuum tube voltmeter for primary voltage and to the integrator for secondary voltage measurement. Two types of timing units have been employed: the first electronic, using multivibrators, and the second mechanical, using a constant-speed motor and cam-operated switches. The integrating device is a General Electric fluxmeter, model 32C248. The d-c power supply has usually consisted of a gasoline-motor a-c generator followed by a high-voltage d-c rectifier unit. The smaller units (order of 1000 to 1500 w) are relatively mobile and have been transported by burros; the larger units (up to 25,000 w) are mounted in heavy-duty trucks.

Most field equipment was designed and constructed in the Jerome laboratories by A.W. Love, K. E. Ruddock, and W. E. Bell.

Type Curves:⁴ H. O. Seigel has developed mathematical expressions for the overvoltage response to be expected from mineralized bodies of various geometric forms. The analysis is equally applicable if the source of overvoltage effects is not mineralization. Seigel uses an electrodynamic model of overvoltage which considers the effect of resistivity contrasts within the region of measurement on both primary and secondary fields. His basic postulate is that the action of the primary field sets up a volume distribution of current dipoles—all antiparallel to the primary field—whose moment equals the product

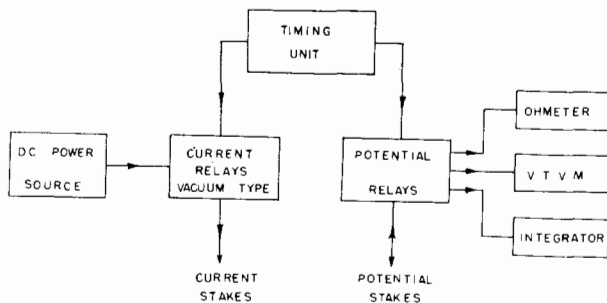


Fig. 2—Block diagram of typical field equipment.

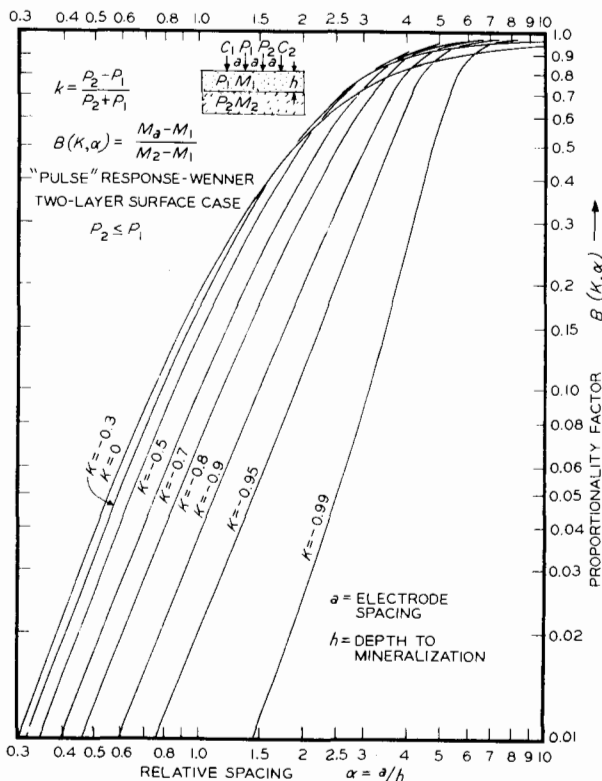


Fig. 3—Typical theoretical overvoltage response curves.

of the primary current density and a mineralization*

* The term *mineralization* is understood to include other sources of overvoltage effects.

factor which is a property of the medium. He then develops a procedure for calculating overvoltage responses from associated resistivity curves by weighting the overvoltage contribution of any medium according to the logarithmic derivative of apparent resistivity with respect to the resistivity of that medium.

Mathematically,

$$M_a = \sum_i M_i \frac{\partial \log \rho_a}{\partial \log \rho_i}$$

where M_i and ρ_i are the *mineralization* factor and apparent resistivity of the i th medium, M_a and ρ_a are the overvoltage response and apparent resistivity at the point of measurement and \sum represents

a summing of the terms for all media.

Where there are only two media concerned the above formula reduces to

$$\frac{M_a - M_1}{M_2 - M_1} = \frac{\delta \log \rho_a}{\delta \log \rho_1}$$

where the subscripts 1 and 2 refer to media 1 and 2.

An important approximation of overvoltage surveys is the two-layer case. This assumes a horizontal layer of barren material overlying an infinite layer of mineralized material. The overvoltage responses have been derived directly from the well known resistivity two-layer formula. Fig. 3 gives the type curves when the lower layer has the lower resistivity. The abscissa is relative electrode spacing (i.e., in terms of thickness of top layer) and the ordinate, in effect, indicates what proportion of the lower layer mineralization factor should appear in the observed reading. The different curves are for different resistivity contrast conditions. Note that the plotting is logarithmic. Examples of the use of these curves are given in the field results to follow.

Phenomenological Theory:⁵ To account for overvoltage effects, J. R. Wait has proposed the following theoretical model:

Each conducting particle is considered to be coated with a thin dielectric film that poses a block action to current flow into the particle. Thus the action at the interface of each particle is somewhat comparable to that of a lossy condenser, and any ground exhibiting an overvoltage response may be considered to contain in effect a large number of tiny condensers. It should be noted, however, that the dielectric constant of these condensers may vary with frequency.

Wait applied his model theory to predict the form of the decay curve and its variation with particle size. His predictions have been borne out by laboratory experiments. Some typical results are shown in Fig. 4. The tests were performed on a compact mixture of 98 pct andesite and 2 pct pyrite particles, plus a weak electrolyte. Different samples contained different sizes of pyrite particles, ranging from 0.25 to 12-mm diam. Duration of current pulse was 1 sec. Primary voltage was the same in all cases. Note that the time scale is logarithmic. It will be observed that decay is more rapid with the smaller sulfide particles. It can also be noted that at any time following the cessation of current there is an optimum particle size for which the decay voltage is maximum.

A-C Overvoltage Methods:⁶ As is perhaps suggested by the condenser analogy mentioned above,

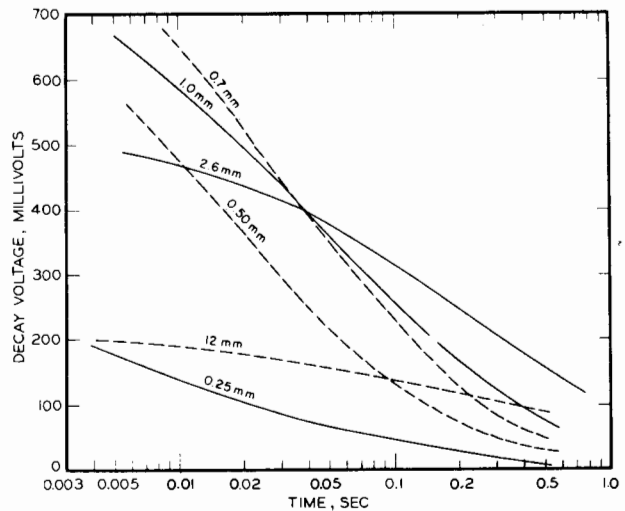


Fig. 4—Observed decay voltage $e(t)$ as a function of time. For $V = 15$ volts, $v = 0.02$ and $\sigma = 5 \times 10^{-3}$ mhos/m. This graph and Fig. 5 are examples of extensive overvoltage experiments at Newmont's laboratories in Jerome, Ariz. Fig. 4 illustrates work in transient domain, Fig. 5 work in frequency domain.

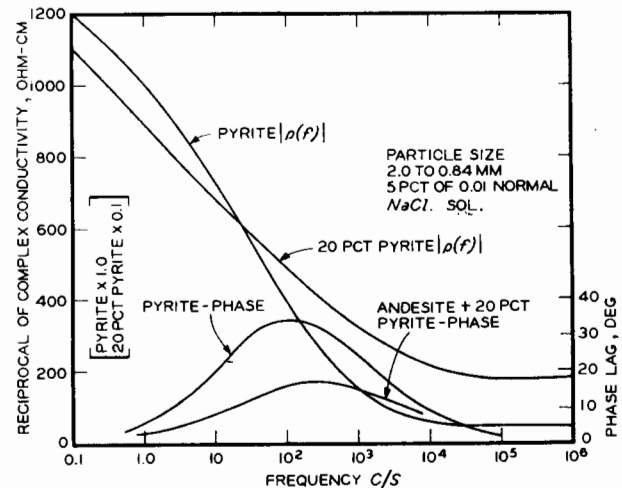


Fig. 5—Variation of complex conductivity with frequency. From experiments at Newmont laboratories.

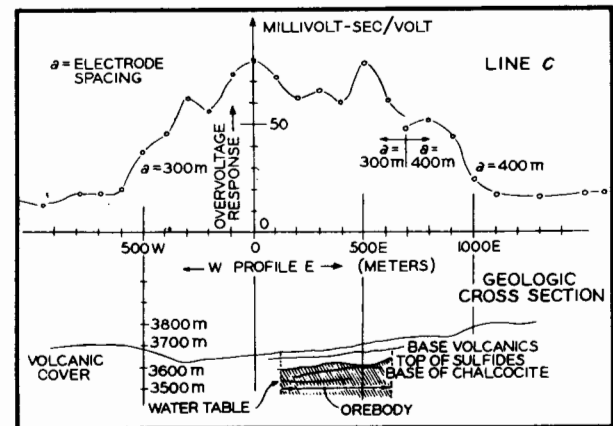


Fig. 6—Overvoltage profile, north end, Quellavaco.

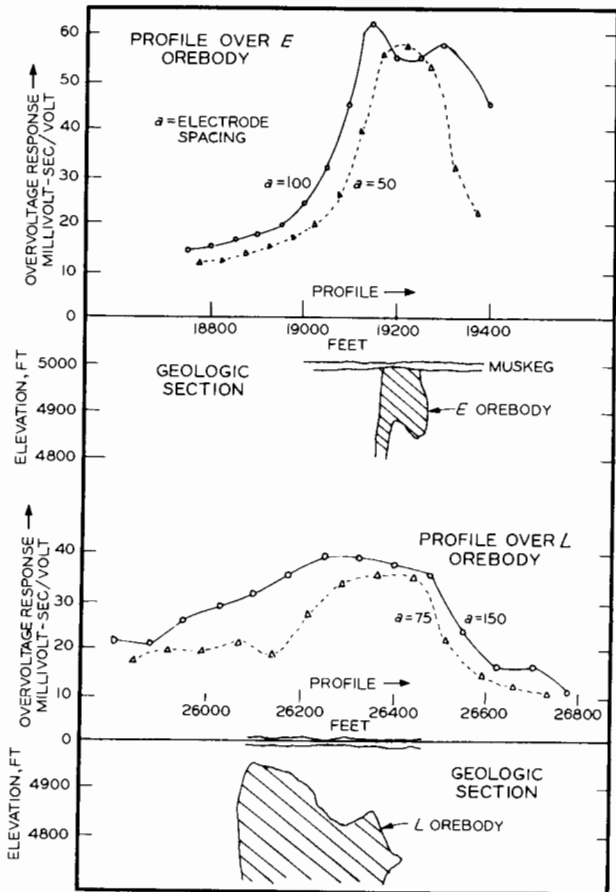


Fig. 7—Overvoltage profiles at Lynn Lake, Manitoba.

the overvoltage phenomena may be measured in the frequency domain instead of in the transient domain, that is, by applying alternating current instead of pulsed direct current. The earth in general has a complex impedance in which the d-c resistivity is a pure resistive component and the overvoltage contributes a somewhat complicated combination of capacitance and resistance. The complex impedance and the phase angle vary with frequency. This variation is especially pronounced in the case of sulfides.

Results of some complex impedance measurements in the laboratory are shown in Fig. 5. Complex impedance and phase angle for pyrite and for pyrite in andesite particles are plotted against log frequency. The maximum slope of the impedance curve occurs at that frequency at which phase angle is a maximum. In comparison, impedance vs frequency curves for barren rock material (over the frequency range up to the order of several hundred cycles) are almost flat and the phase angle remains low.

It should be noted that a-c overvoltage measurements should be made in the low frequency range where electromagnetic propagation effects are negligible. Caution should also be taken to avoid excessive line coupling between the current and potential circuits. Probably several tens of cycles is about the upper frequency limit for operations in the field.

Wait has demonstrated the relation between the response in the frequency domain and that in the transient domain. From experimentally observed frequency response data he derived the overvoltage decay curve to be expected following a pulse of di-

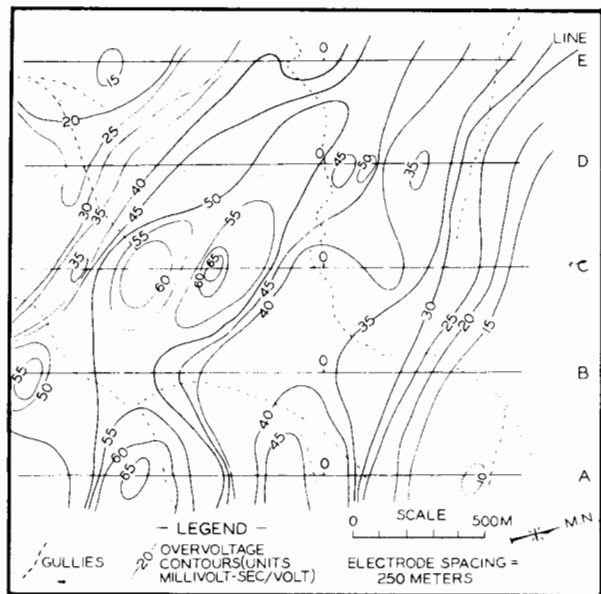


Fig. 8—Copper prospect, Peru. Overvoltage contours here directly outline distribution of sulfides.

rect current. The agreement with the experimentally observed decay curve was excellent.

Field Results: To date pulsed d-c methods have been used in field exploration. The technique of measurement is described above under Operational Methods and Field Equipment.

To repeat, the basis of the overvoltage method as a prospecting device is that metallic particles, especially sulfides, give a high response, whereas barren rock, with certain exceptions, gives a low response.

In the earlier days it was not realized that barren rock could display a considerable range of response, and minor anomalies of less than 50 pct of background were deemed evidence of sulfides. At Jerome, Ariz., anomalies of this order were found to be caused by certain portions of the Pre-Cambrian basement beneath the Palaeozoic cover. At the present time overvoltage readings of two to three times background are usually necessary to excite interest. Even then it must be recognized that some anomalies may have causes other than sulfides.

In overvoltage surveys results fall into four classes:

- 1) No significant anomalies.
- 2) Anomalies due to economic sulfides.
- 3) Anomalies due to noneconomic sulfides.
- 4) Anomalies due to nonsulfides.

Groups 2 and 3 above may both be considered geophysical successes if not exploration successes. The ratio of noneconomic to economic mineralization disclosed is certainly no worse than for other geophysical methods. The chief villain has been disseminated pyrite. Many porphyry copper deposits have a surrounding halo of disseminated pyrite, and the zone of maximum sulfides is not necessarily the zone of maximum copper.

While there have been a few striking examples of nonsulfide anomalies, most major anomalies have been explained by sulfides. For example, in almost four years of work in Peru, only one recommended

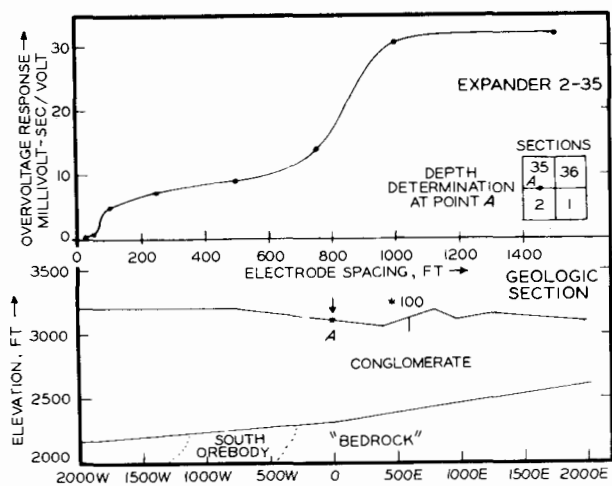


Fig. 9—Detection of deep mineralization is possible at San Manuel by use of large electrode spacings.

drillhole completely failed to find a reasonable quantity of sulfides.

Over a disseminated sulfide deposit the anomalous overvoltage response (i.e., in addition to the rock background) will depend on:

- 1) The percentage by volume of sulfides.
- 2) The geometry of the deposit with respect to surface and the electrode array in use. Geometry thus includes size and depth below surface.
- 3) The resistivity contrast conditions between the sulfide zone and the cover and surroundings.

In any one area the overvoltage response of a mineralized zone has been found to vary more or less directly with the percent of volume of sulfides for moderate percentages of sulfides. It is not safe, however, to project from one area and type of mineral occurrence to another.

A fair number of the examples to follow were obtained over known or later proven orebodies. In attacking any new area, it has been the general policy to test over known mineralization first, where possible, and work out from there, so that the type of anomaly to be sought is known.

Fig. 6 shows an overvoltage profile over the north end of the orebody at Quellaveco, Peru. The ore zone is covered by about 40 meters of postmineral volcanics, and depth to sulfides is from 60 to 100 meters. The orebody is well detected; however, it is to be noted that the anomaly is some 800 meters wider than the orebody, presumably because of a surrounding zone of disseminated pyrite.

Fig. 7 shows the response over an entirely different type of orebody, the *E* and *EL* orebodies at Lynn Lake, Manitoba. The scale of operations is reduced here: to discriminate those relatively narrow bodies, an electrode spacing of about 100 ft was used as opposed to 300 meters at Quellaveco, and readings were taken every 50 ft instead of every 100 meters. The smaller *E* body gives a better response than the *EL*. Some reasons for this are: 1) the *EL* body has massive sulfides, whereas the *E* is more disseminated,*

* The overvoltage method works best with disseminated sulfides.

and 2) the overburden is deeper over the *EL*. While both these bodies are adequately detected from their immediate surroundings, varying rock backgrounds reduce the certainty of the method in this area. For

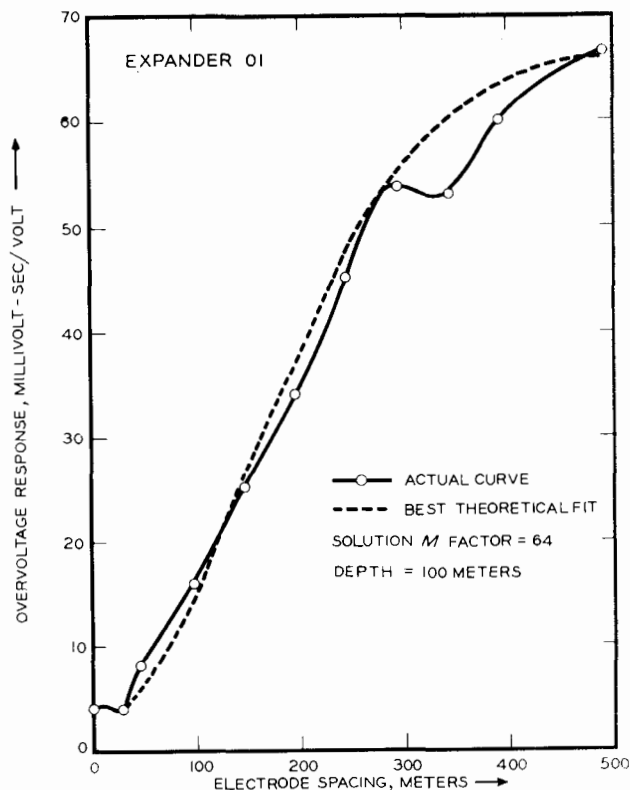


Fig. 10—Mineralization and depth, Cuaajone.

instance, not far to the west of the *EL* a quartzite formation gave response in the 50's, higher than that obtained over the *EL* itself. Disseminated pyrite possibly contributed to the high quartzite response.

A contour map of anomalous overvoltage response provides a good picture of the distribution of sulfide mineralization; in regions where the depth to top of sulfides is less than about a third the electrode spacing and resistivity contrasts are not extreme. An example is given in Fig. 8, which is from a prospect in Peru; the contours here include a background response of about 5. Drilling in the highs provided approximate confirmation of the distribution in a limited portion.

A reading on one electrode spacing only gives no indication of depth of cover. This information can be obtained from expanders. An expander is a series of readings at different electrode spacings taken at one station. The results are then compared with type curves. In a great many cases the simple two-layer approximation is adequate. The derivation of two-layer type curves has been discussed under Type Curves. The investigator solves for depth and for anomalous response or mineralization factor of the underlying zone. The examples below are plotted linearly for greater clarity, but the method of solution requires the field results to be plotted on two-cycle logarithmic paper of the same size as the type curve paper. An expander is entirely analogous to the vertical profile of resistivity surveys.

Fig. 9 shows an expander taken at San Manuel, Ariz., plus a geological section in the region. The surrounding pyrite mineralization presumably renders the two-layer case applicable. This example is particularly interesting in illustrating how such deep mineralization as San Manuel's is detectable.

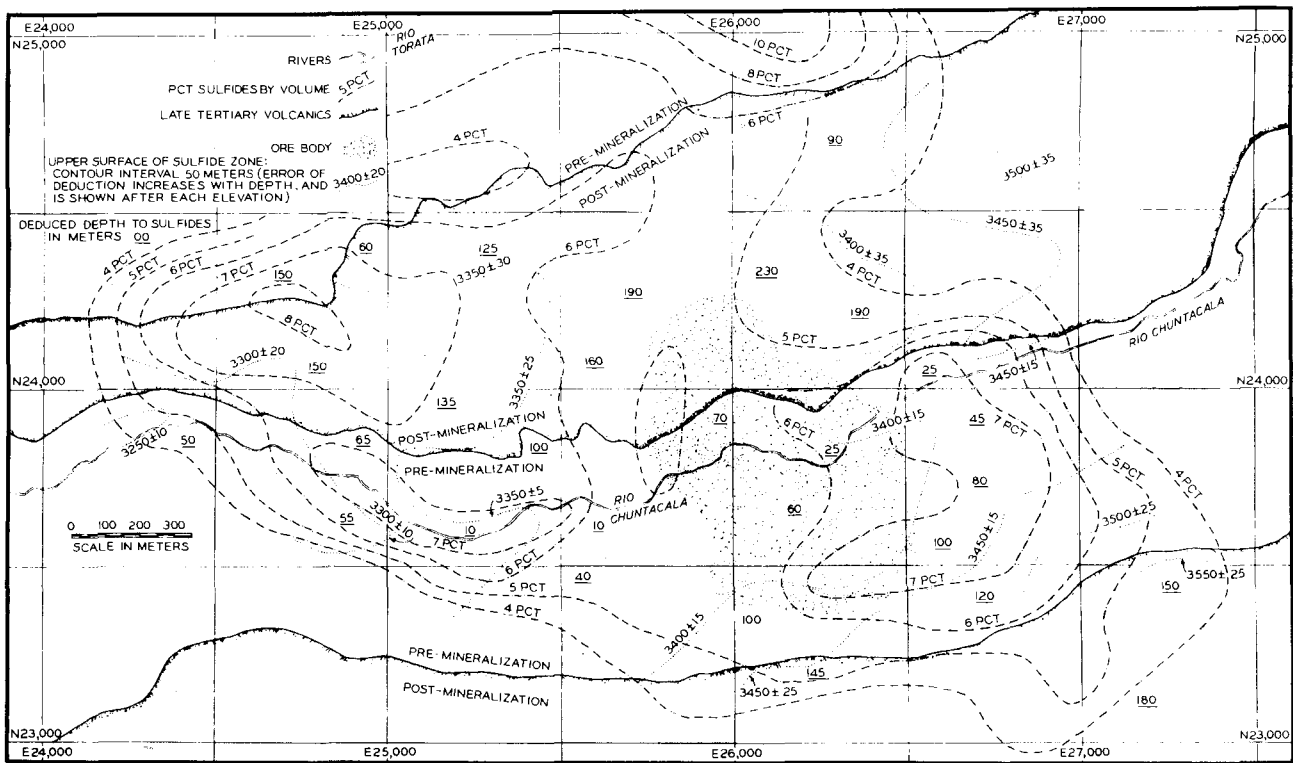


Fig. 11—The sulfide distribution at Cuajone, Peru, as deduced from the overvoltage data. Note the great variation in depth to the top of the sulfides. The mineralization that is outside the orebody consists mostly of pyrite.

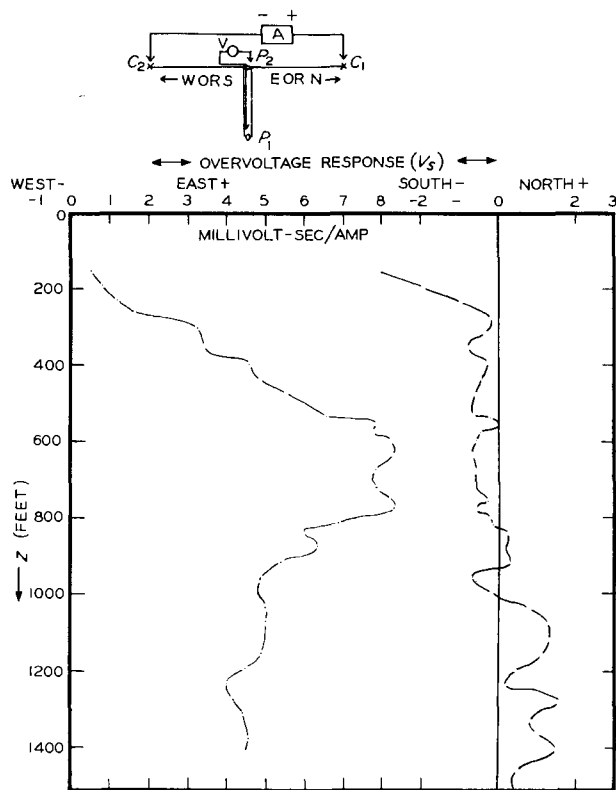


Fig. 12—Nababep West, South Africa, borehole WP 12. The direction of mineralization from a drillhole is indicated here by the overvoltage azimuth survey.

An expander across the south end of the orebody at Cuajone, Peru (Fig. 10) gives depth to sulfides as 100 meters. Depth actually is about 90 meters.

With the aid of readings on more than one electrode spacing over a large area, it is possible to obtain mineralization factors and depths at a great number of points and then to contour this deduced data. At Cuajone two electrode spacings, one twice the other, were used on every line throughout the anomalous area, and additional control was provided by short spacing readings on several lines and by a few formal expanders. Fig. 11 shows a portion of the deduced mineralization and top of sulfide contour map; Fig. 11a, an aerial photograph of the region, illustrates to some extent the type of topography. For mineralization, it was assumed that a mineralization factor of 10 represented 1 pct sulfides by volume.* Depth to sulfides varies from less than 10

* This factor was based on tests made in Arizona.

meters in the Chuntacala Valley to more than 160 meters where the late Tertiary volcanics cap the pampa or mesa to the north. The Cuajone orebody has now been extensively drilled and a rough outline is shown on the map. The deduced mineralization extends more than a kilometer to the west and more than half a kilometer to the east of the orebody, also (not shown here) far to the northwest. The deduced mineralization is at some points actually higher on the rim than directly over the orebody. The mineralization rim is disseminated pyrite. The drilling has in general verified the deduced mineralization pattern, but only relatively. A recent study of the assays from 35 drillholes has revealed that predicted sulfide content was on the average 1.95 times actual



Fig. 11a—Air photo of Cuajone site shows steep hillsides, especially bordering the Rio Torata.

sulfide content. If this correction had been known in advance, the probable error of mineralization prediction at any point would have been about 30 pct of the predicted sulfide content, or less than 1 pct sulfides by volume. The probable error of depth prediction at Cuajone was 10 meters.

The overvoltage method has been tried in drillholes. This application, though it has given useful indications, has not had the widespread success that was first expected. One major problem has been correcting for the masking effect of low resistivity fluid in the drillhole, especially when working in very high resistivity Pre-Cambrian formations.

One important sideline to drillhole work is azimuth determinations. Once a significant anomaly is obtained in a drillhole using normal electrode arrays, direction is determined by placing the two current

electrodes on surface an equal distance on each side of the collar, lowering one potential electrode down the hole, and measuring the overvoltage response with respect to a reference electrode. A positive response indicates that the source of the anomaly lies in the direction of the negative current electrode and vice versa. Two azimuth runs (north-south and east-west) are necessary to fully establish direction. Results in Nababeep West, South Africa, drillhole No. 12 (Fig. 12), suggest that in the upper part of the hole mineralization lies chiefly west, whereas in the lower part it lies chiefly to the south. These deductions were confirmed in the course of drilling the orebody.

There remain to be mentioned those unfortunate cases where overvoltage anomalies are not caused by sulfides.

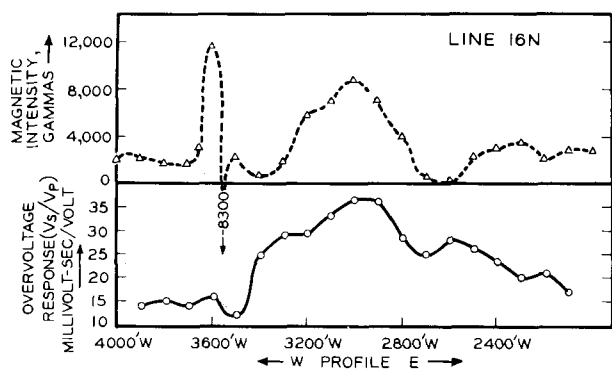


Fig. 13—Magnetic and overvoltage profiles at Engels, Calif. Overtoltage anomaly is attributed to magnetite.

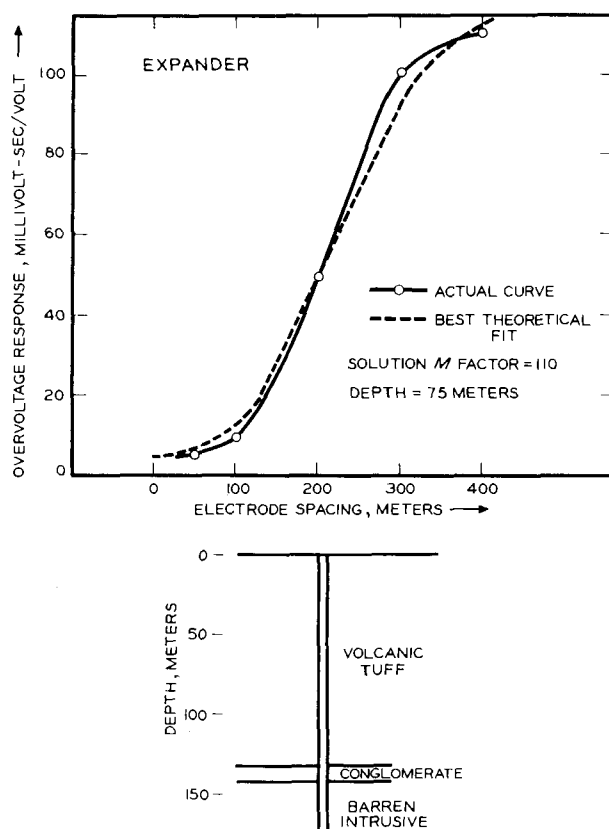


Fig. 14—Unexplained anomaly, Wildcat prospect, Peru.

Magnetite, being a metallic substance, gives an overvoltage response. An example of an anomaly presumably caused by disseminated magnetite comes from Engels, Calif. (Fig. 13). There is good correlation between the overvoltage and magnetic profiles. Of course the presence of an associated magnetic anomaly is not necessarily unfavorable. The two Lynn Lake examples both had excellent magnetic anomalies also.

Response from graphite has been observed in the laboratory, and in Southern Rhodesia a field anomaly was attributed to this mineral. However, graphite has not proved generally troublesome, for the simple reason that most surveys have not been in graphitic areas.

A wildcat anomaly obtained in Peru is still not satisfactorily explained. This occurred in a trough of post-mineral volcanic tuff. The expander taken at the center of the anomaly is shown in Fig. 14. Mineralization was predicted at less than 100 meters, the best solution being about 75 meters. In fact, drilling disclosed no lithological change for nearly twice this depth and the basement was only negligibly mineralized.

Victor Mayer⁹ has shown that clay minerals with high ion exchange capacity can give a considerable overvoltage response. Notable extraneous anomalies were obtained in low resistivity phyllites in South West Africa and in certain schists in British Columbia.

The process of taking an overvoltage reading provides a resistivity reading automatically. The resistivity data are of direct use to the overvoltage survey in providing information necessary in depth calculations. A resistivity survey also has many well known applications—such as determining depth of overburden—and in itself is often a guide to mineralization. Porphyry coppers, for example, offer a fairly limited range of resistivity values. Most of the examples given in this article have accompanying resistivity anomalies. It is standard practice always to consider overvoltage results in conjunction with resistivity data.

Despite some unforeseen complications, e.g., the high response from certain nonsulfide material, the overvoltage method has proved its usefulness in detecting and outlining disseminated sulfide mineralization, even at depths as great as 200 meters.

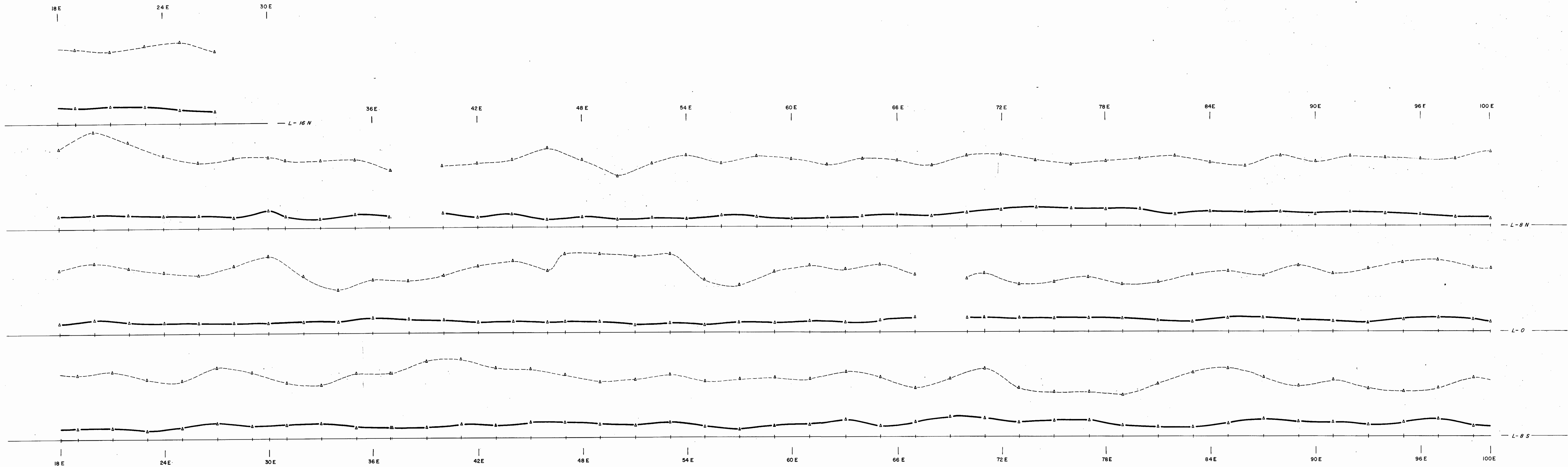
The following firms have kindly granted permission to publish various items of information: Newmont Mining Corp., American Smelting & Refining Co., Cerro de Pasco Corp., San Manuel Copper Corp., Sherritt Gordon Mines Ltd., and O'okiep Copper Co. Ltd.

REFERENCES

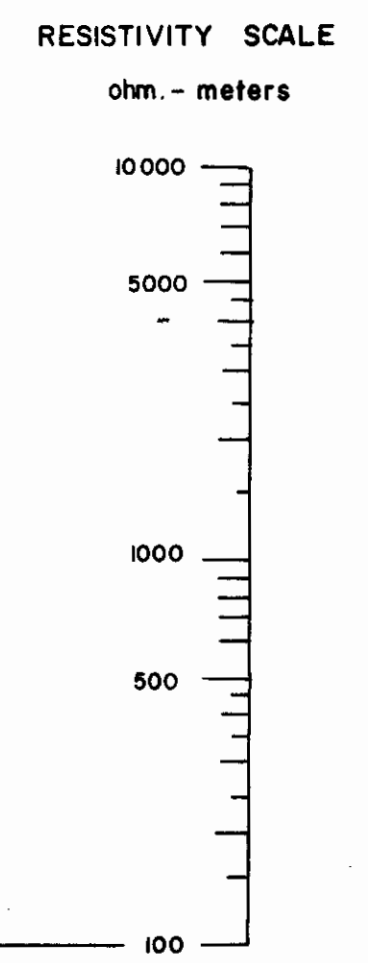
- ¹ A. A. Brant: *Overtoltage Developments and Geophysical Application by Newmont Exploration Limited 1946-1955.**
- ² H. O. Seigel: *Theoretical and Experimental Investigations into the Application of the Phenomenon of Overtoltage to Geophysical Prospecting.* University of Toronto doctoral thesis, May 1949.
- ³ K. A. Ruddock: *Field Equipment for Prospecting by the Overtoltage Method.**
- ⁴ H. O. Seigel: *A Theory of Induced Polarization Effects for Step-Function Excitation.**
- ⁵ J. R. Wait: *A Phenomenological Theory of Induced Electrical Polarization.**
- ⁶ J. R. Wait: *The Variable-Frequency Overtoltage Method in Electrical Prospecting.**
- ⁷ R. W. Baldwin: *Overtoltage—Field Results.**
- ⁸ V. Mayer, Jr.: *The Normal Effect.**
- ⁹ A. A. Brant: U.S. Patent 2,611,004, Sept. 16, 1952. Geophysical Exploration.
- ¹⁰ S. Glasstone: *Textbook of Physical Chemistry*, p. 1017.
- ¹¹ J. A. V. Butler: *Electrical Phenomena at Interfaces*, especially Chapter VII, by J. O'M. Bockris.
- ¹² V. Vacquier, C. R. Holmes, P. P. Kintzinger, and M. Lavergne: *Prospecting for Ground Water by Induced Electrical Polarization.* *Geophysics*, July 1957, vol. 22, no. 3, p. 660.
- ¹³ R. Frische and H. von Buttlar: *A Theoretical Study of Induced Electrical Polarization.* *Geophysics*, July 1957, vol. 22, no. 3, p. 688.
- ¹⁴ D. F. Bleil: *Induced Polarization: A Method of Geophysical Prospecting.* *Geophysics*, July 1953, vol. 22, no. 3, p. 636.
- ¹⁵ J. H. Henkel and R. G. Van Nostrand: *Experiments in Induced Polarization.* *AIME Trans.*, March 1957, vol. 208, p. 355.
- ¹⁶ L. S. Collett: *Laboratory Investigation of Overtoltage.**

* These items are private company papers, but it is hoped that they will soon be presented in a monograph to be published by the Pergamon Press.

Discussion of this article sent (2 copies) to AIME before April 30, 1959, will be published in *MINING ENGINEERING*.



Department of
Mines and Petroleum Resources
ASSESSMENT REPORT
NO. 875 MAP # 8



LEGEND
ELECTRODE CONFIGURATION..... 3 ARRAY
ELECTRODE SPACING..... 400'
CHARGEABILITY..... RESISTIVITY
●——●..... ————

SCALE
APPARENT CHARGEABILITY..... 1" = 5.0 MILLISECONDS
APPARENT RESISTIVITY..... 2" / CYCLE LOG. P₀
SCALE..... 1 INCH = 200'
(NOTE: LINES NOT SPACED TO SCALE)

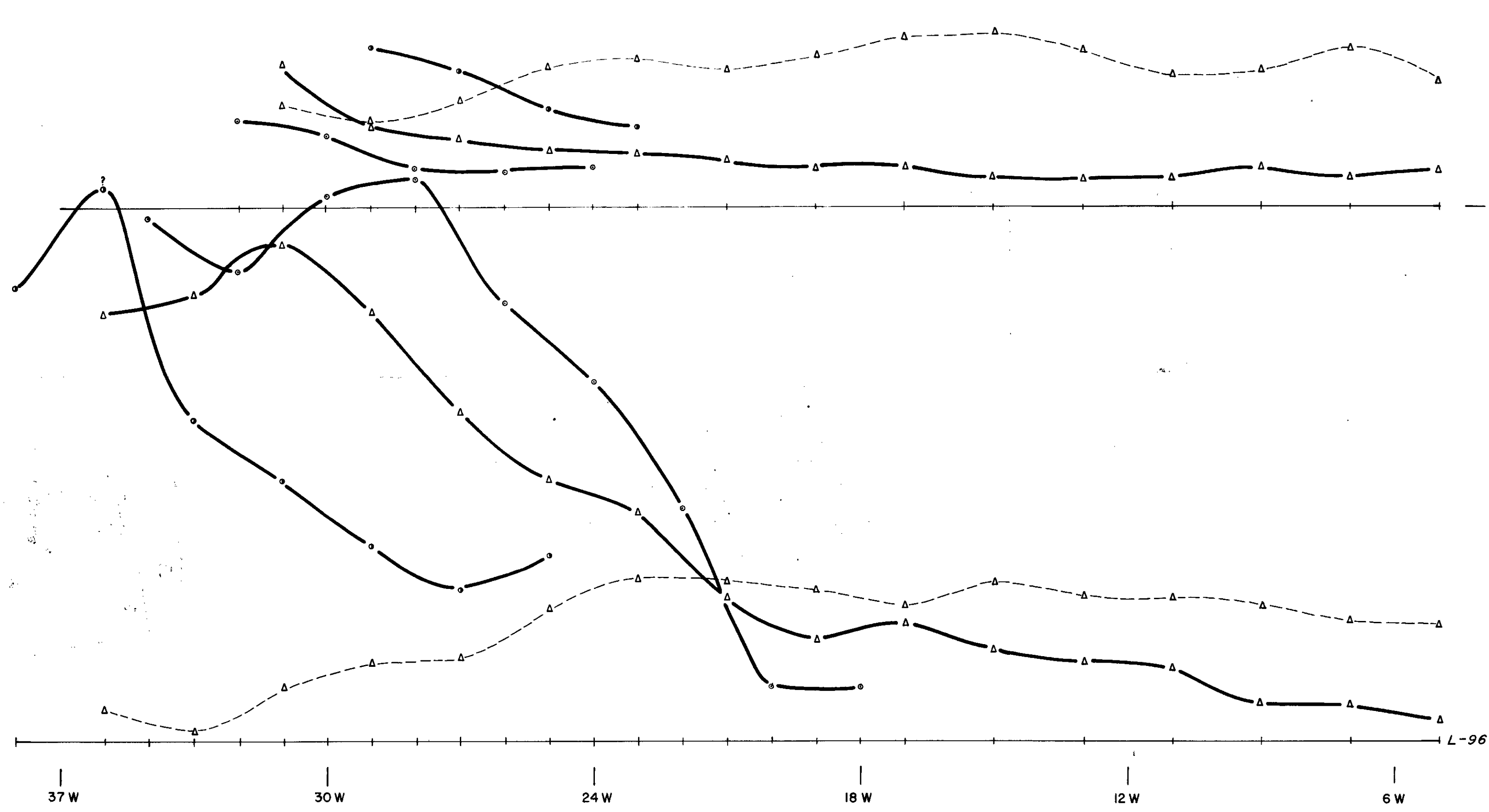
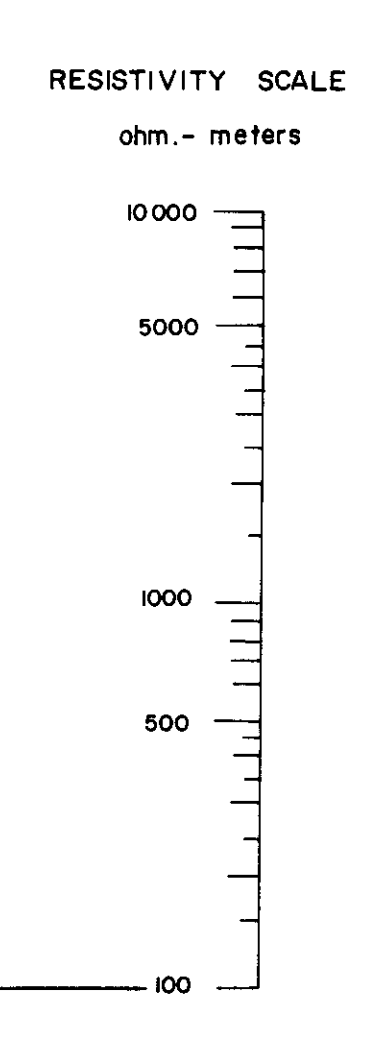
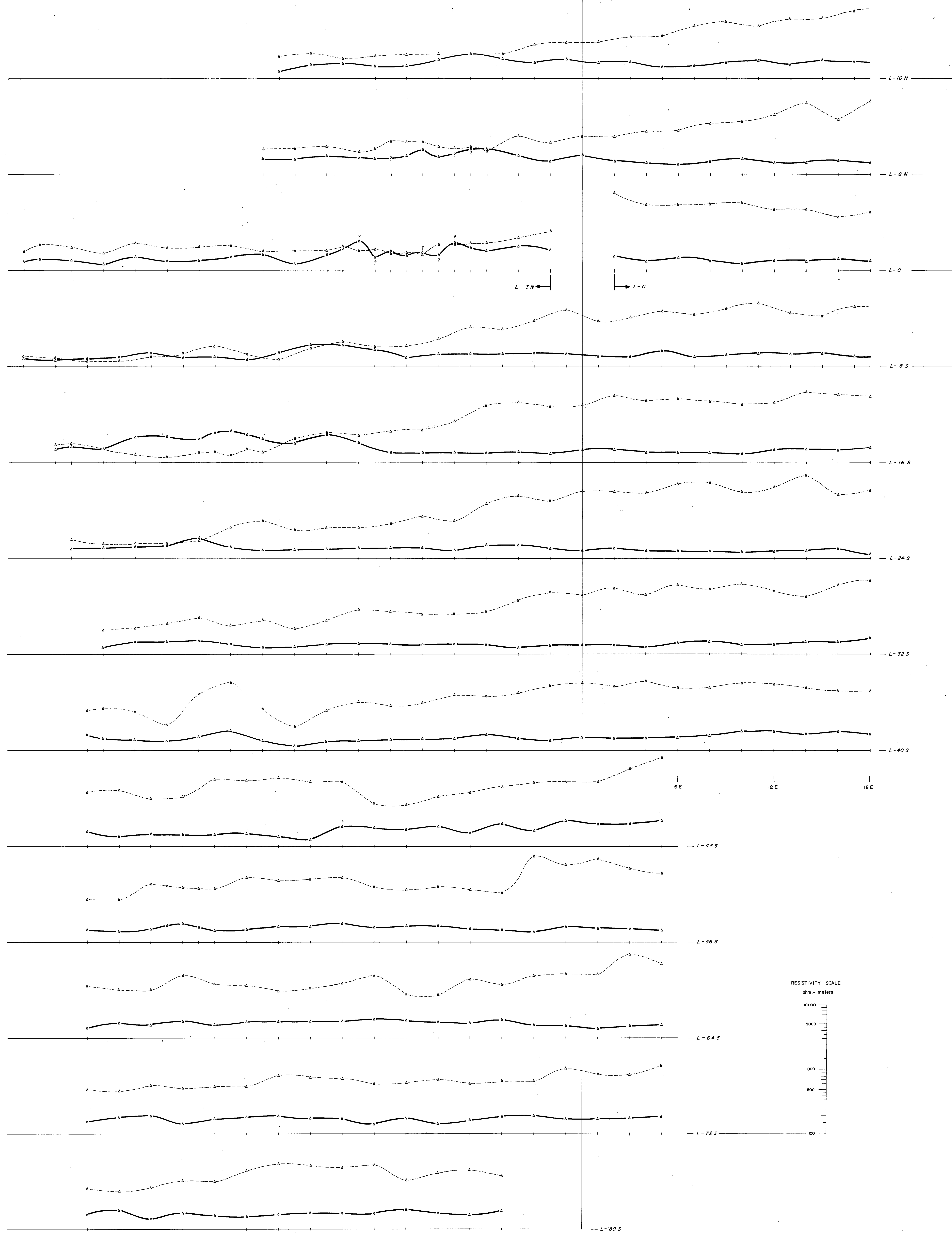
INDUCED POLARIZATION SURVEY
PROFILE PRESENTATION
BRENDA LAKE AREA, B.C.
ROB, CAM, VISCOUNT & MARN GROUPS
FOR



KEL GLEN MINES LTD
BY
CANADIAN AERO
Mineral Surveyors LTD.
OTTAWA & TORONTO
ONT, CANADA

875

36W | 30W | 24W | 18W | 12W | 6W | 0 | 6E | 12E | 18E



LEGEND
 ELECTRODE CONFIGURATION 3 ARRAY
 ELECTRODE SPACING SEE INDEX
 CHARGEABILITY RESISTIVITY
 ● 0° 200'
 △ 0° 400'
 ○ 0° 800'

SCALE
 APPARENT CHARGEABILITY 1" = 5.0 MILLISECONDS
 APPARENT RESISTIVITY 2" CYCLE LOG. f_0
 SCALE 1 INCH = 200'
 (NOTE: LINES NOT SPACED TO SCALE)

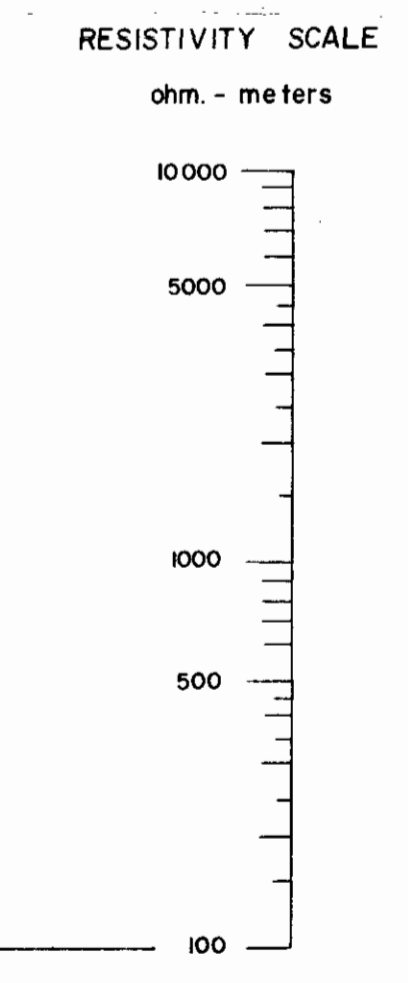
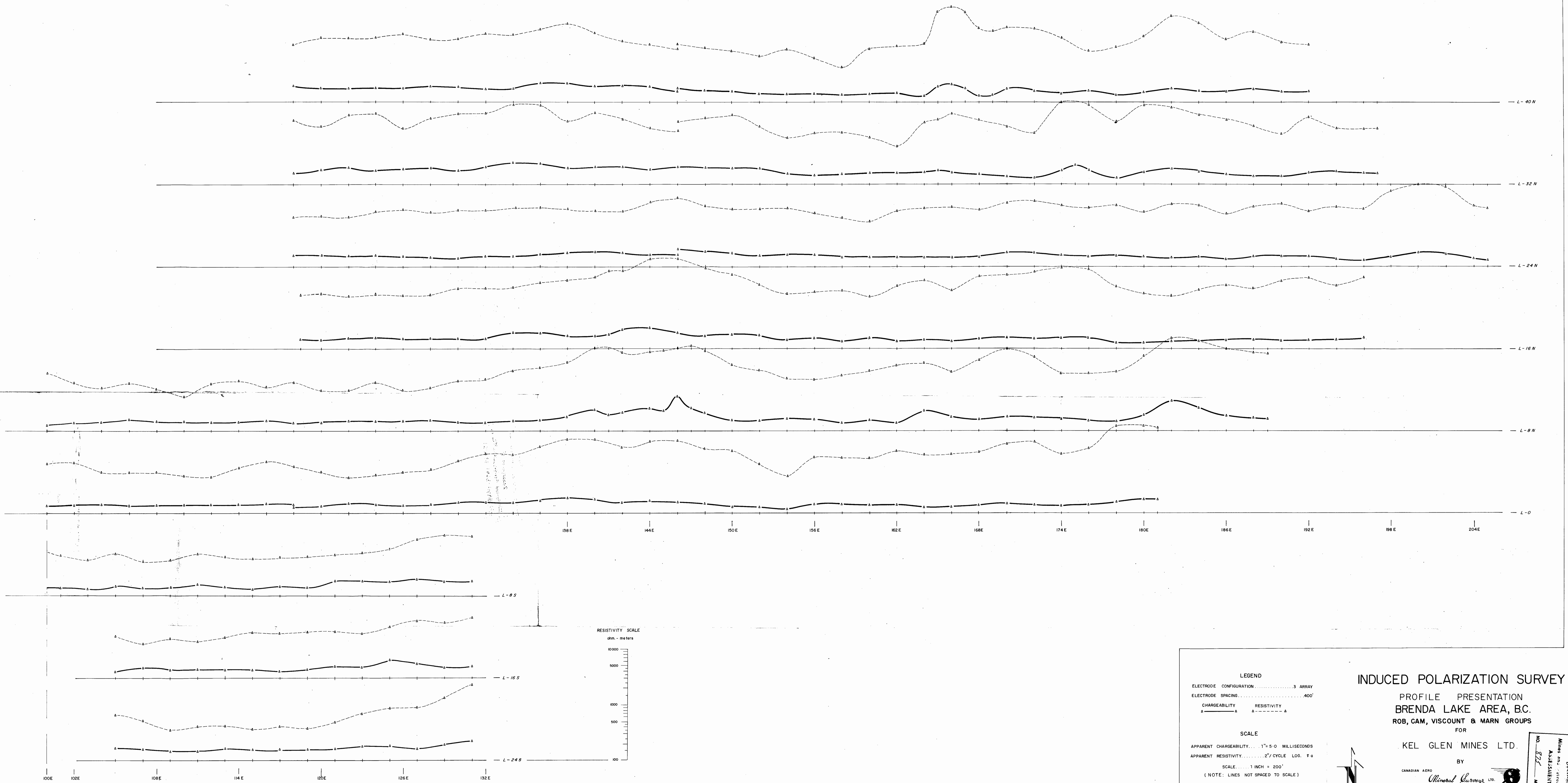
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 FOR
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 BY
 CANADIAN AERO
Mineral Surveys LTD.
 OTTAWA & TORONTO
 ONT., CANADA

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MINES AND MINERAL SERVICES
 ASSESSMENT REPORT
 NO. 178
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(APPROX.)

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 PROFILE PRESENTATION
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 FOR
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BY
 CANADIAN AERO
Mineral Services Ltd.
 OTTAWA & TORONTO
 ONT, CANADA

875

(APPROX.)

LEGEND
 ELECTRODE CONFIGURATION 3 ARRAY
 ELECTRODE SPACING 400'
 CHARGEABILITY RESISTIVITY
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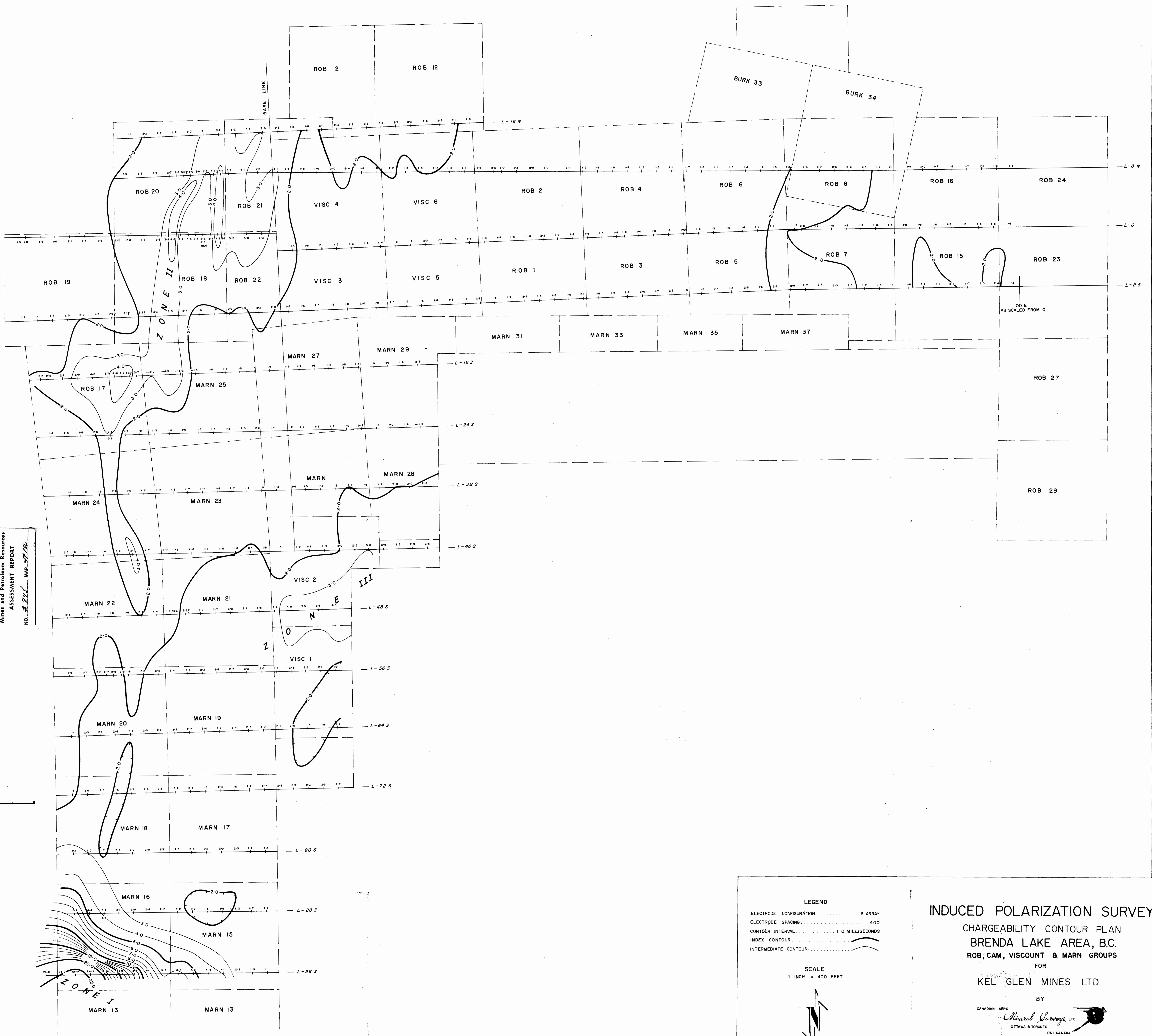
SCALE
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 APPARENT RESISTIVITY 2" / CYCLE LOG. P. 0
 SCALE 1 INCH = 200'
 (NOTE: LINES NOT SPACED TO SCALE)

NO. 875
 M.S. 875
 Assessment Report
 Date: 10/10/80

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Department of
Mines and Petroleum Resources
ASSESSMENT REPORT
NO. 875 MAP 12



LEGEND
 ELECTRODE CONFIGURATION 3 ARRAY
 ELECTRODE SPACING 400'
 CONTOUR INTERVAL 1.0 MILLISECONDS
 INDEX CONTOUR
 INTERMEDIATE CONTOUR

SCALE
 1 INCH = 400 FEET



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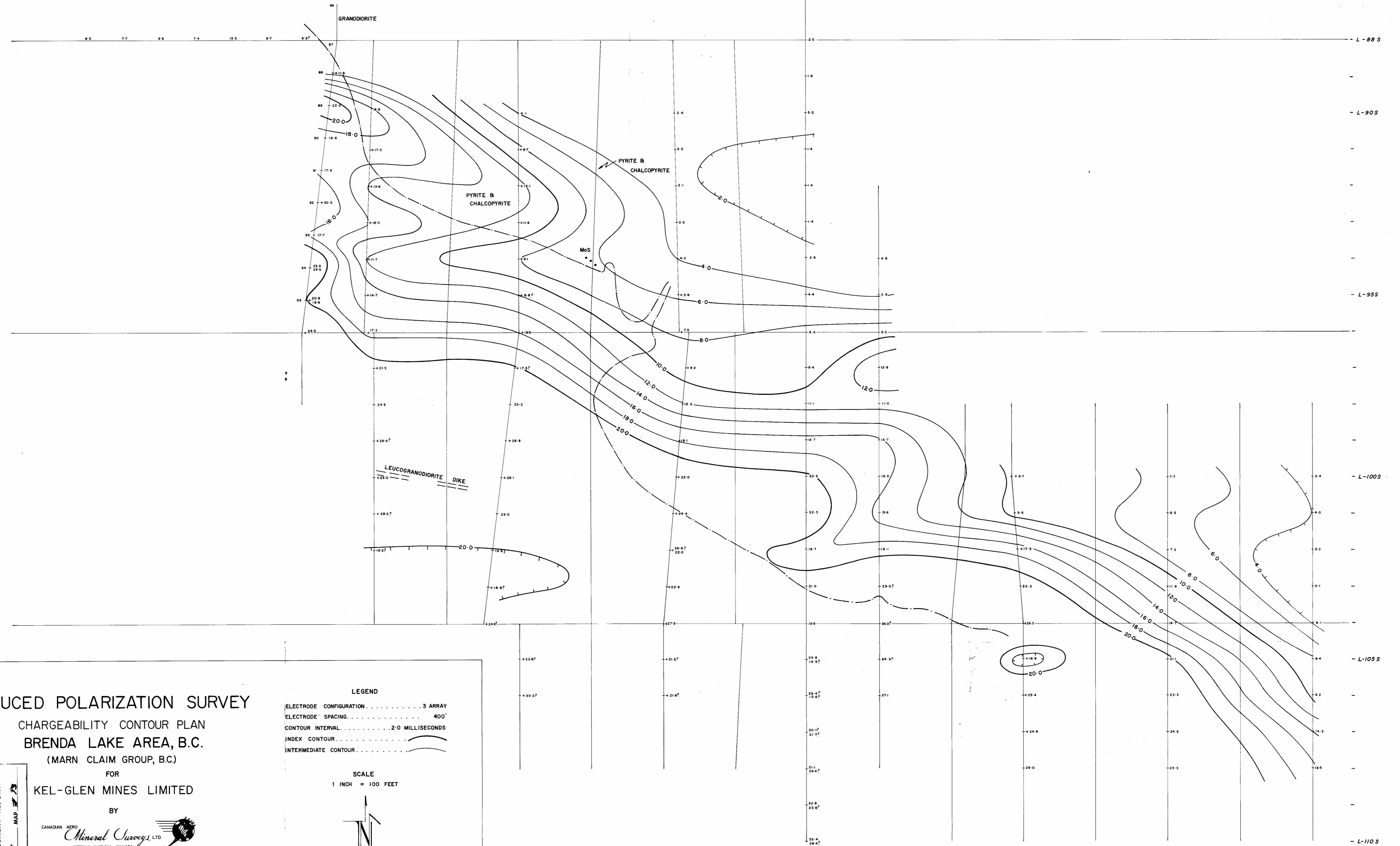
INDUCED POLARIZATION SURVEY
 CHARGEABILITY CONTOUR PLAN
 BRENDA LAKE AREA, B.C.
 ROB, CAM, VISCOUNT & MARN GROUPS

FOR
 KEL GLEN MINES LTD.

BY
 CANADIAN AERO
Mineral Surveys LTD.
 OTTAWA & TORONTO
 ONT., CANADA

875

40W 35W 30W 25W 20W 15W 10W 5W 3W



INDUCED POLARIZATION SURVEY
 CHARGEABILITY CONTOUR PLAN
 BRENDA LAKE AREA, B.C.
 (MARN CLAIM GROUP, B.C.)

FOR
KEL-GLEN MINES LIMITED

BY

CANADIAN AERO
Mineral Survey LTD.
 OTTAWA, ONTARIO, CANADA

LEGEND

- ELECTRODE CONFIGURATION 3 ARRAY
- ELECTRODE SPACING 400'
- CONTOUR INTERVAL 2.0 MILLISECONDS
- INDEX CONTOUR (solid line)
- INTERMEDIATE CONTOUR (dashed line)

SCALE

1 INCH = 100 FEET



(APPROX.)

Department of
 Mines and Petroleum Resources
 ASSESSMENT REPORT
 NO. 875 MAP 2/8

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