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REPORT ON
INDUCED POLARIZATION SURVEY
ON THE PROPERTY OF
ROLLING HILLS MINING COMPANY LIMITED
FOR
VANCO EXPLORATION LIMITED
BY
CANADIAN AERO MINERAL SURVEYS LIMITED
Project No. 6018.

The mining property of Rolling Hills Copper Mines Limited (N.P.L.) located in the vicinity of the Iron Mask Butholith, some two to eight miles south and southwest of Kamloops, B.C. is currently under option to Vanco Explorations Limited (N.P.L.).

Geophysical surveys were carried out by Sulmac Exploration Services Limited on parts of the property from March to October 1965 and by Canadian Aero Services for Vanco Explorations Limited in October and November of 1965.

All of the Rolling Hills claims are shown on four claim maps (sheets 1-4, scale 1" = 400 feet) contained in Sulmac's Geophysical Report.

This report is being submitted for assessment purposes in conjunction with the Sulmac Report. As the same grid system was used for both surveys, specific reference should be made to claim map sheet 3 in the Sulmac Report which shows the location of grid lines and claims over which the later work was completed.

REPORT ON

INDUCED POLARIZATION SURVEY

ON

THE PROPERTY OF

ROLLING HILLS MINING COMPANY LIMITED

FOR

VANCO EXPLORATION LIMITED

BY

CANADIAN AERO MINERAL SURVEYS LIMITED

Project No. 6018.

OTTAWA, Ontario,
December 22, 1965.

J. G. Denholm,
Geophysicist.

A. R. Rattew, P.Eng.,
Geophysicist.

CANADIAN AERO *Mineral Surveys* LIMITED

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Accompanying this Report:-

- #1 One Profile Presentation at the scale of 1" = 400 feet
- #2 One Chargeability Contour Plan at the scale of 1" = 400 feet

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SUMMARY

From October 13 to November 12, 1965, Canadian Aero Mineral Surveys Limited conducted induced polarization surveys in the Iron Mask Area near Kamloops in British Columbia on behalf of Vanco Exploration Limited. One area covered was the property of Rolling Hills Mining Company Limited.

The purpose of the survey was to use IP as a reconnaissance tool in looking for futher mineralization on claims adjoining those previously surveyed by Sulmac Exploration Limited.

A large anomalous zone characterized by moderately high chargeabilities and closely related high magnetics was located in the northern portion of the survey area. It appears that magnetite contributes considerably to the response here.

A major masking problem due to conductive overburden in much of the southern portion of the Rolling Hills grid rendered IP of limited use.

Geochemical reconnaissance surveying and further drilling is recommended.

REPORT ON INDUCED POLARIZATION SURVEY ON THE PROPERTY OF ROLLING HILLS MINING COMPANY LIMITED, FOR VANCO EXPLORATION LIMITED.

I. INTRODUCTION

In the period from October 13 to November 12, 1965, Canadian Aero Mineral Surveys Limited conducted induced polarization surveys in the Iron Mask Area near Kamloops, British Columbia on behalf of Vanco Exploration Limited. One of the areas covered in this period was the property of Rolling Hills Mining Company Limited.

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 deposits on claims adjoining those previously surveyed by Sulmac Exploration Limited.

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 of 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 characteristics 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 or 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 this survey a standard, equispaced three electrode array was used employing an electrode spacing of 400 feet. Readings were normally taken at 200 foot intervals along parallel lines spaced at 800 foot intervals. In areas of low background response or where problems with masking effects prevailed, the reading interval was 400 feet along the survey lines.

About 23 line miles of survey coverage was completed on the Rolling Hills property.

About two line miles of surveying was done on the Galaxy and Western Beaver Lodge properties for the purpose of detailing anomalies located during the Sulmac IP survey and for comparing the results obtained with the Sulmac and Canadian Aero Mineral Surveys' instruments.

II. DISCUSSION OF RESULTS

The apparent chargeabilities and apparent resistivities are presented in profile form at the following scales: 1" = 400 feet, 1" = 5.0 milliseconds for chargeability and the resistivity results on a logarithmic scale as shown.

The apparent chargeabilities are also presented in contour form on a plan of 1" = 400 feet.

The check work on the Galaxy and Western Beaver Lodge properties shows good correlation in the apparent chargeabilities both in profile shape and in absolute magnitude. This should be the case since both instruments are of the same design and employ approximately the same charging time and measuring time. The apparent resistivities were in some cases slightly lower than those obtained by Sulmac. However, this is accounted for by the very wet ground surface on the day of the repeat survey.

On the Rolling Hills property one widespread anomalous zone was located on the northern portion of all lines from L80E to L200E. This anomalous zone is characterized by peak chargeabilities of 10-12 milliseconds on lines 200E, 184, 176, and 168E. These chargeabilities are indicative of from one to three percent polarizable material in a disseminated form. Because of the excellent correlation between the chargeability and the magnetics on lines 104E to 200E, it appears that magnetite in the gabbro, which prevails in the anomalous zone, is largely responsible for the high chargeabilities. The anomalous zone from L80E to L96E is characterized by chargeabilities up to 15 milliseconds and lower magnetics. This part of the anomalous zone which is on the claims of Canadian Mining and Smelting Limited is indicative of from 2% to 6% mineralization by volume from 10S to 30S on lines 80E, 88E and 96E. This zone has been drilled extensively and appreciable quantities of pyrite and chalcopyrite are known to be present.

A masking problem, due to a combination of conductive overburden and a conductive leached oxidized zone present in some areas, ranged from moderate to severe over a large part of the southern portion of the Rolling Hills grid. In these areas, such as between 20S and 80S on almost all lines, chargeabilities range from 0 to 1.2 milliseconds and the resistivities are less than 150 ohm-meters. These resistivities and chargeabilities are indicative of barren conductive overburden and not of igneous bedrock.

Two zones, one between 40S and 56S on lines 104E to 120E and the other from 80S to 100S on lines 80E to 112E are both characterized by higher resistivities and chargeabilities from 2 to 5 milliseconds. Both zones are large hills composed of a barren diorite with little or no overburden.

III. CONCLUSIONS

One large anomalous zone characterized by moderately high chargeabilities and closely related high magnetics was located in the northern part of the grid area.

It appears that magnetite contributes considerably to the anomalous response which indicates from 1% to 3% average mineralization by volume in the gabbro which underlies the zone.

A major masking problem due to conductive overburden in much of the southern portion of the Rolling Hills grid rendered IP of limited use.

IV. RECOMMENDATIONS FOR FUTURE EXPLORATION

Widespread reconnaissance geochemical surveying is suggested particularly in areas where "masking" due to conductive overburden has limited the effectiveness of IP as a mapping tool.

Since it is known that copper is associated with magnetite in the Iron Mask Area, vertical drill holes are suggested on the anomalous zone. The positions of these holes are to be determined on the basis of further geological and geochemical surveying.

Respectfully submitted,

John G. Denholm per pp.

John G. Denholm,
Geophysicist.

A. R. Rattew, P.Eng.,
Geophysicist.

OTTAWA, Ontario,
December 22, 1965.

P E R S O N N E L

The following is a list of the Canadian Aero Mineral Surveys Limited personnel engaged in the work necessary to the IP survey of the Rolling Hills Mining Company Limited property located in the Iron Mask Area of British Columbia:

J. G. Denholm, Geophysicist,
Elora, Ontario.

P. Norgaard, Geophysicist,
Ottawa, Ontario.

A. R. Rattew, P.Eng., Geophysicist,
Ottawa, Ontario.

P. Tallyhoe, Draftsman,
Ottawa, Ontario.

Time spent by the above geophysicists on interpretation and reporting totals three (3) days. Time spent by drafting personnel totals two (2) days.

A. R. Rattew, P.Eng.,
Geophysicist.

December 22, 1965,
OTTAWA, Ontario.

NAME: Arthur Robert Rattew

BIRTH DATE: December 26, 1932

POSITION: Geophysicist and Vice-President, Canadian Aero Mineral Surveys Limited

NATIONALITY: Canadian

EDUCATION:

School: University of Toronto

Major: Geophysics

Degree: B.A.Sc., 1955

PRE AERO EXPERIENCE:

Mr. Rattew was employed with Newmont Mining Corporation as a Geophysicist associated with ground geophysical and airborne electro-magnetometer surveys for over three years.

AERO EXPERIENCE:

Mr. Rattew joined Aero Service in 1958, primarily associated with airborne electro-magnetometer operations and their interpretation. He has also participated in the operation and interpretation of ground geophysical surveys and magnetic interpretation, and was project manager and geophysicist in Aero Service's first overseas electro-magnetometer program.

In 1958 he joined Canadian Aero Service Limited, and with that organization was associated primarily with airborne EM operations and their interpretation.

In 1961 he joined Canadian Aero Mineral Surveys Limited as Vice-President, and as such is involved in all aspects of airborne and ground geophysical operations.

SOCIETY MEMBERSHIPS:

Canadian Institute of Mining, Metallurgy

Association of Professional Engineers of Ontario

Society of Exploration Geophysicists

A.I.M.E.

PERSONELL EMPLOYED ON ROLLING HILLS

I.P. SURVEY October - November 1965

J. Denholm	Geophysicist	Oct 18, Oct23-Nov 6, Dec. 20-22
P. Horgaard	Geophysicist	Dec. 20-22
A.R. Rattew	Geophysicist P. Eng.	Dec. 20-22
P. Tallyhoe	Draftsman	Dec. 17-18
R. Burgess	Geophysical Asst.	Oct 18, Oct 23-Oct 26
R. Curzon	Geophysical Asst.	Oct 18, Oct 23-Nov 6
D. Nichol	Geophysical Asst.	Oct. 18, Oct23-Nov 6
R. Hadley	Geophysical Asst	Oct. 18, Oct23-Nov 6
P. Zamborski	Geophysical Asst.	Oct. 27 - Nov 6
R. Brown	Linecutter	Oct 18- Oct 20
G. Gillmor	Linecutter	Oct 18- Oct 20
J. Smith	Linecutter	Oct 18- Oct 20
J. Smith	Rod Man	Oct 22- Oct 27
S. Selke	Linecutter	Oct 18- Oct 20
S. Selke	Surveyor	Oct 22- Oct 27
J. Delatre	Supervisor (Geologist)	Oct 18- Oct 20

A DECADE OF DEVELOPMENT IN OVERVOLTAGE SURVEYING

by ROBERT W. BALDWIN

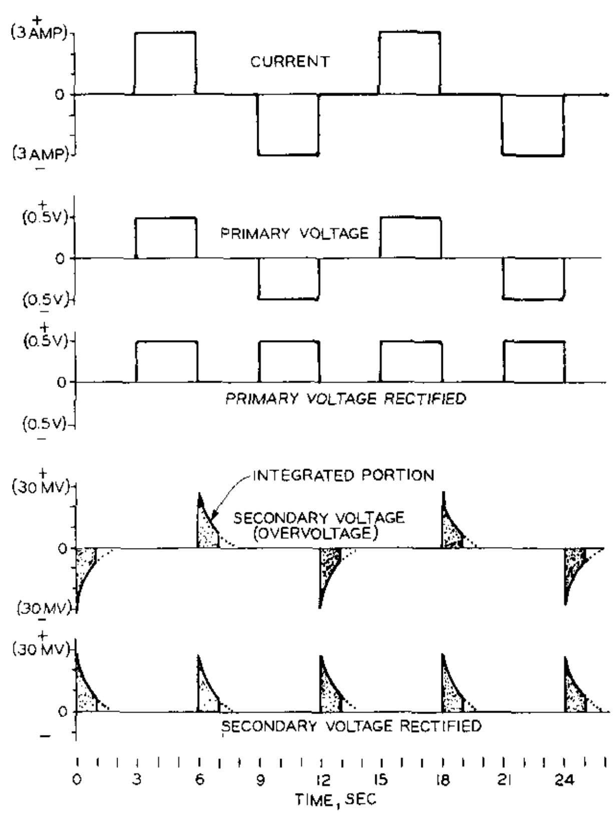
As used in geophysical exploration, the term *overvoltage* applies to secondary voltages set up by a current into the earth which decay when the current is interrupted. These secondary effects may be measured by pick-up electrodes. The term *induced polarization* has often been employed to describe this 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. Mayper, 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.

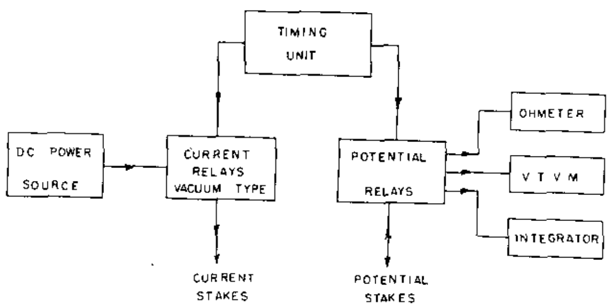


Fig. 2—Block diagram of typical field equipment.

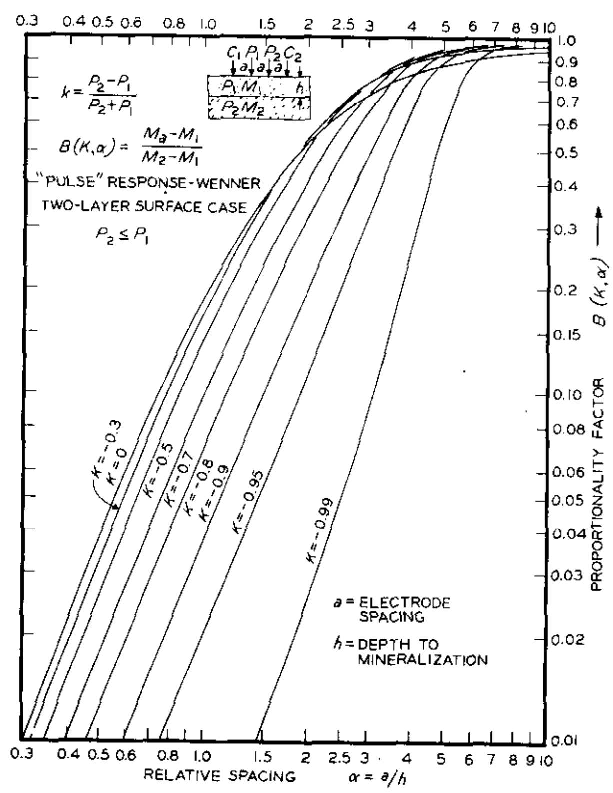


Fig. 3—Typical theoretical overvoltage response curves.

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 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.

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

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 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 ith medium, M_a and ρ_a are the overvoltage response and apparent resistivity at the point of measurement and $\sum_i$ represents a summing of the terms for all media.

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

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

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 abcissa 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 condensor, 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,

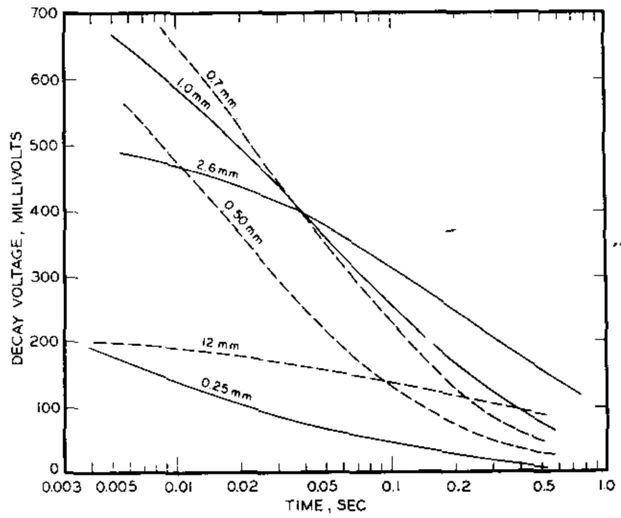


Fig. 4—Observed decay voltage e(t) as a function of time. For V = 15 volts, v = 0.02 and · σ = 5x10⁻³ mhos/m. This graph and Fig. 5 are examples of extensive overvoltage experiments at Newmont's laboratories in Jerome, Ariz. Fig. 4 illustrates work in transient domain, Fig. 5 work in frequency domian.

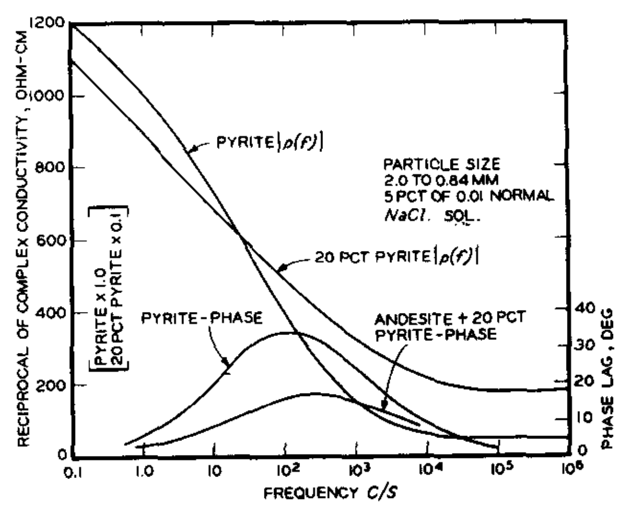


Fig. 5—Variation of complex conductivity with frequency. From experiments at Newmont laboratories.

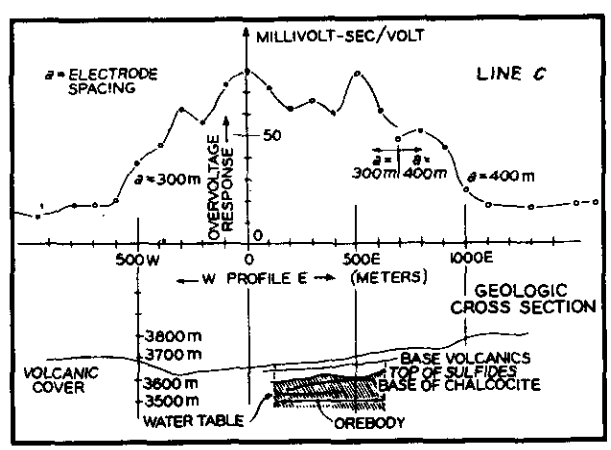


Fig. 6—Overvoltage profile, north end, Quellavaco.

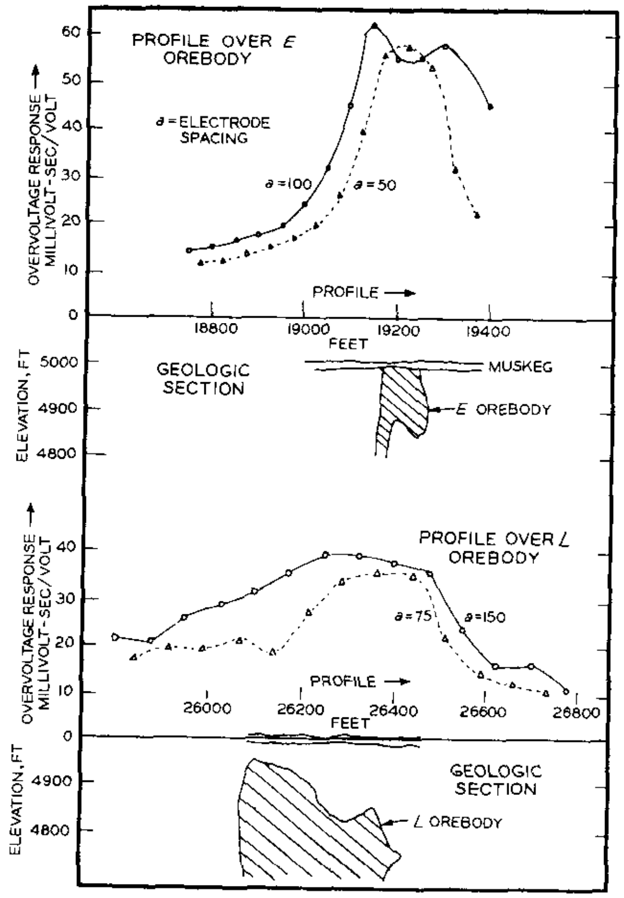


Fig. 7—Overvoltage profiles at Lynn Lake, Manitoba.

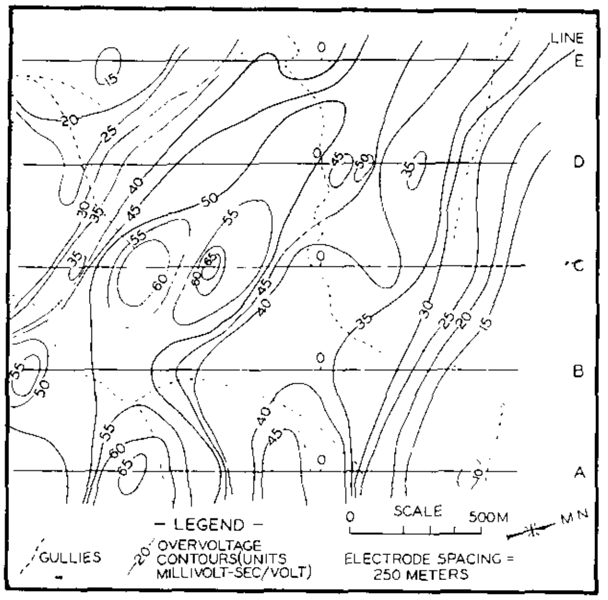


Fig. 8—Copper prospect, Peru. Overvoltage contours here directly outline distribution of sulfides.

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

Field Results:[7] 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

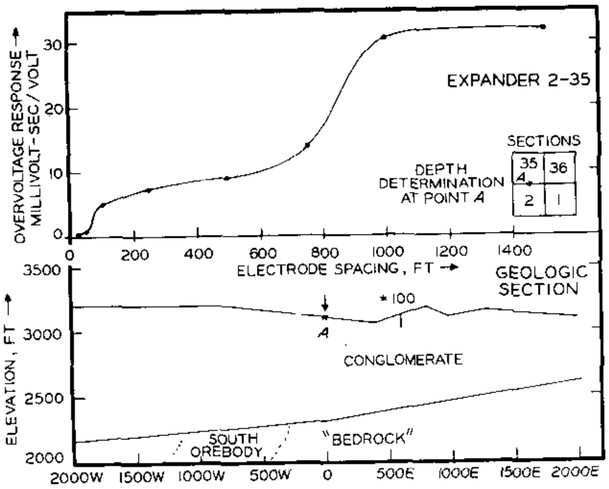


Fig. 9—Detection of deep mineralization is possible at San Manuel by use of large electrode spacings.

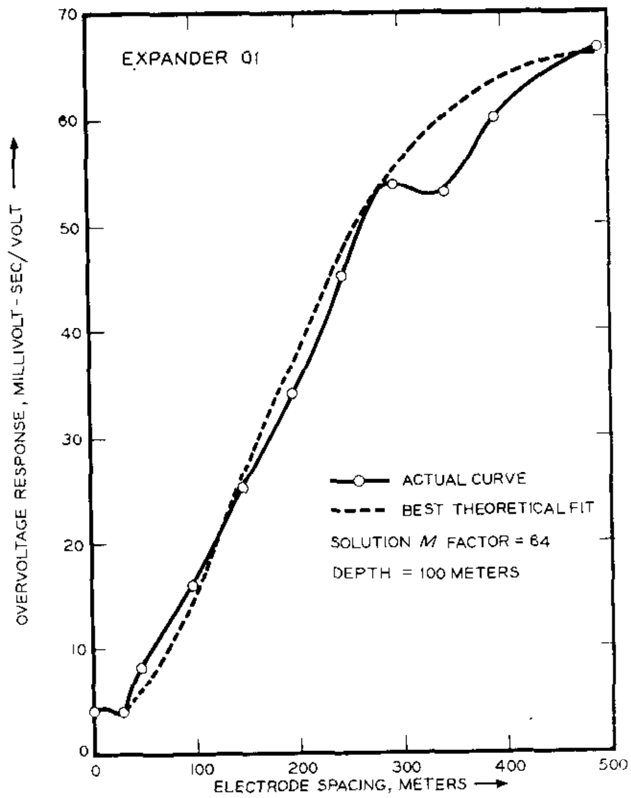


Fig. 10—Mineralization and depth, Cuajone.

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,* 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 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.

* The overvoltage method works best with disseminated sulfides.

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.

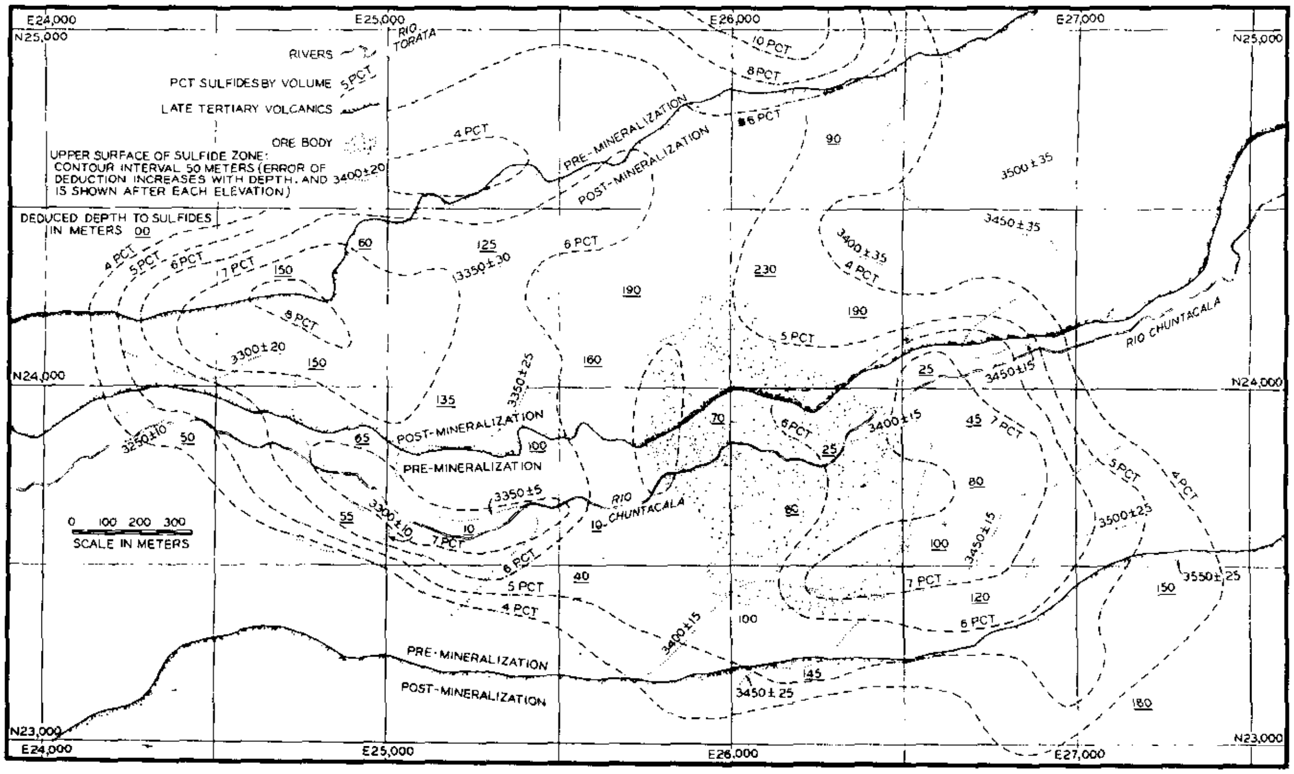


Fig. 11—The sulfide distribution at Cuajone, Peru, as deduced from the overvoltage data. Note the great variation in depth to the top of the sulfides. The mineralization that is outside the orebody consists mostly of pyrite.

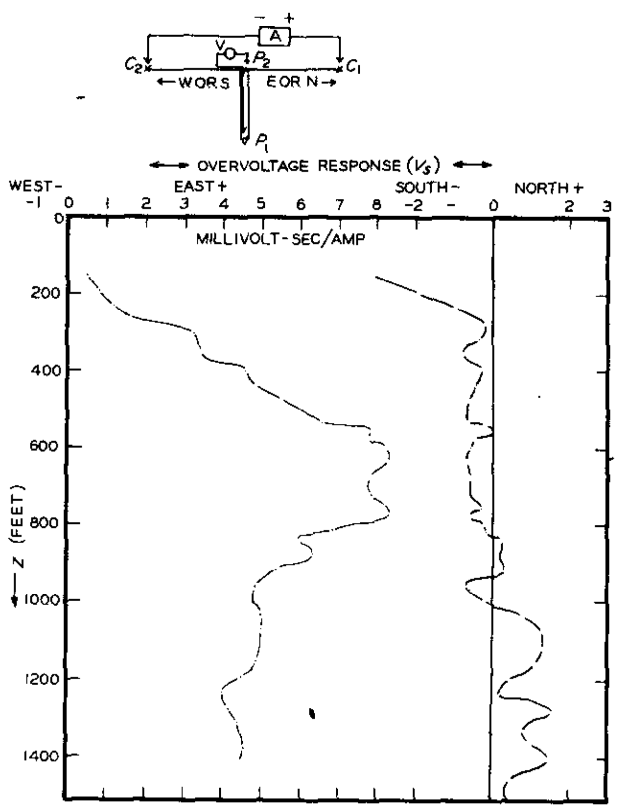


Fig. 12—Nababeep West, South Africa, borehole WP 12. The direction of mineralization from a drillhole is indicated here by the overvoltage azimuth survey.

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 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

* This factor was based on tests made in Arizona.

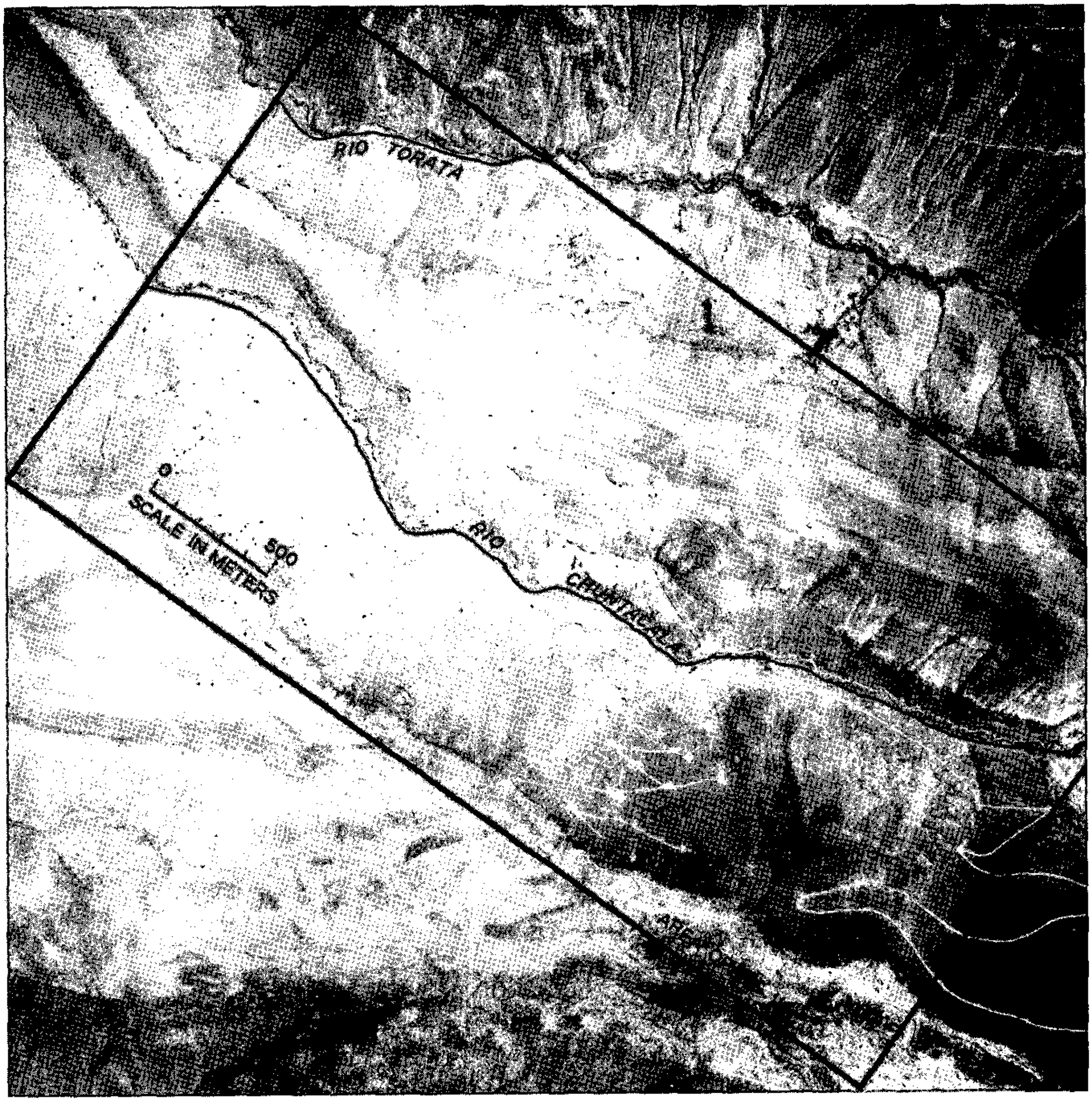


Fig. 11a—Air photo of Cuajone site shows steep hillsides, especially bordering the Rio Torata.

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[a] 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.

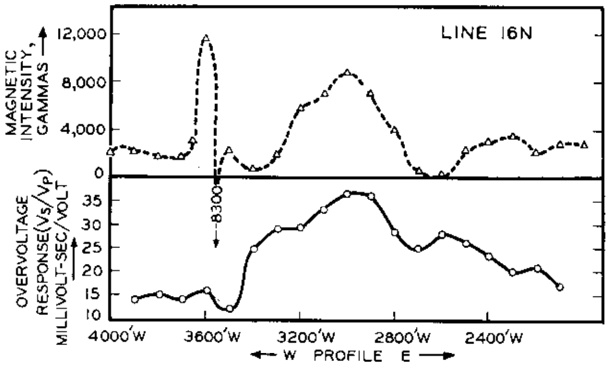


Fig. 13—Magnetic and overvoltage profiles at Engels, Calif. Overvoltage anomaly is attributed to magnetite.

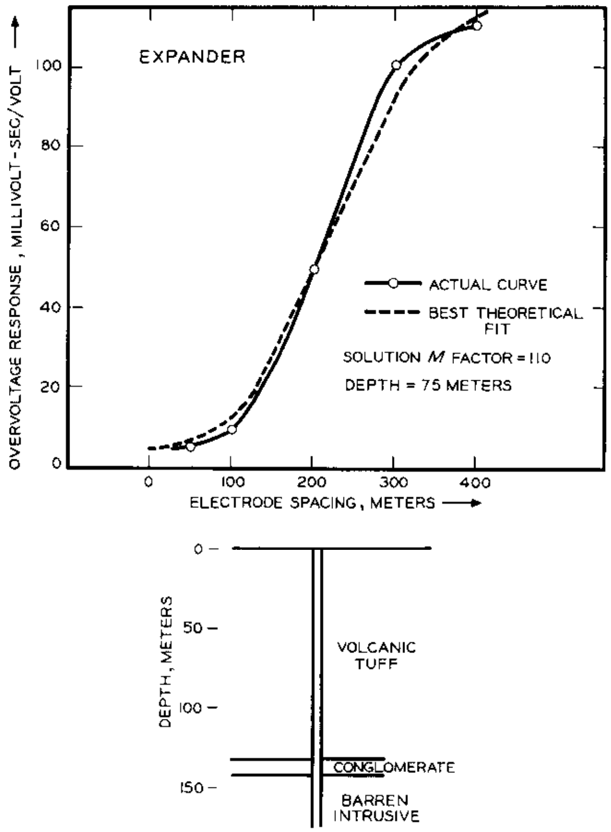


Fig. 14—Unexplained anomaly, Wildcat prospect, Peru.

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 Mayper[8] 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.

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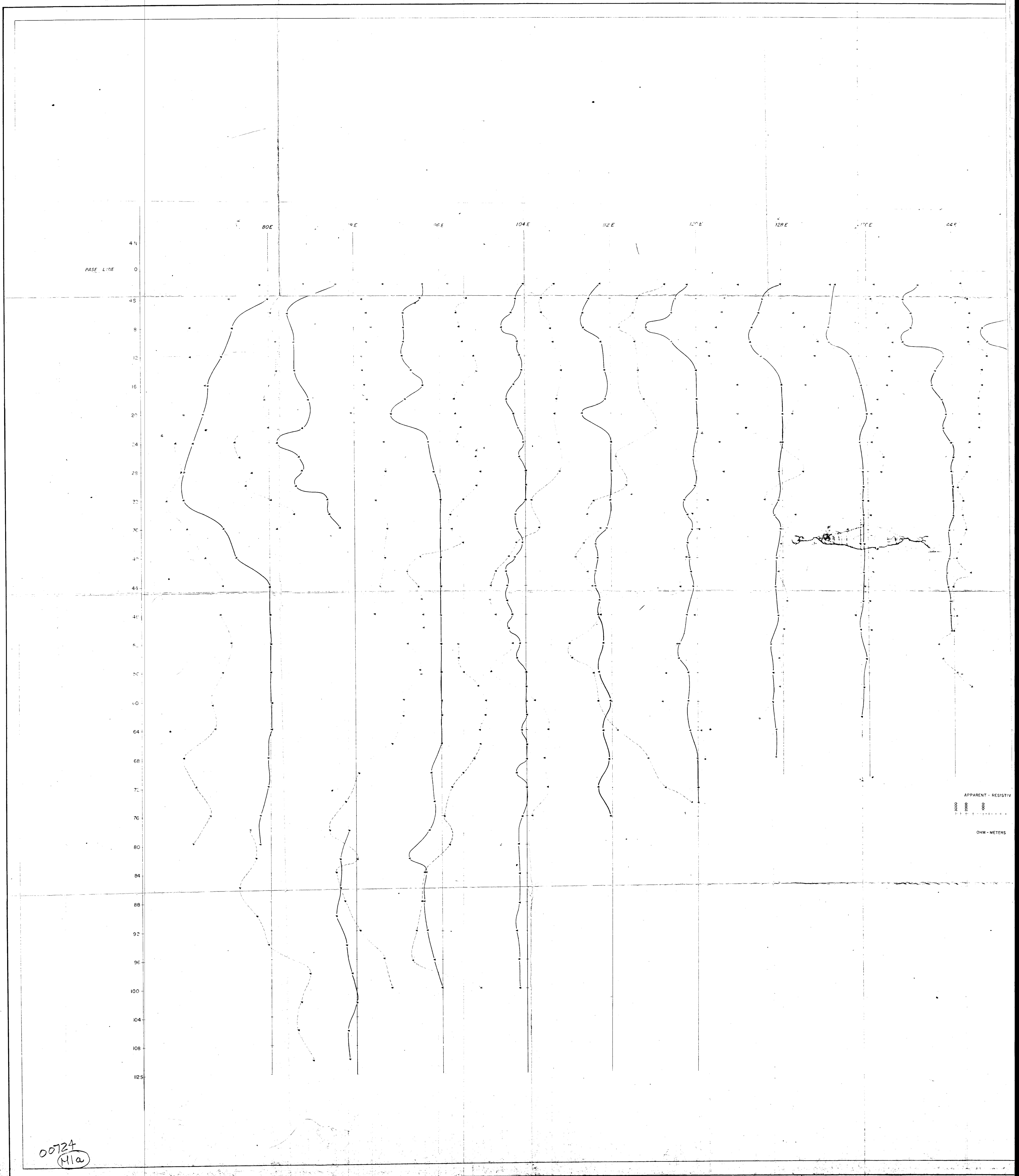
[16] L. S. Collett: *Laboratory Investigation of Overvoltage.**

* 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.


80E
104 E
112 E
128 E
4 N
PASE LINE
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4S
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16
20
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112S
APPARENT - RESISTIV
3000
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OHM - METERS
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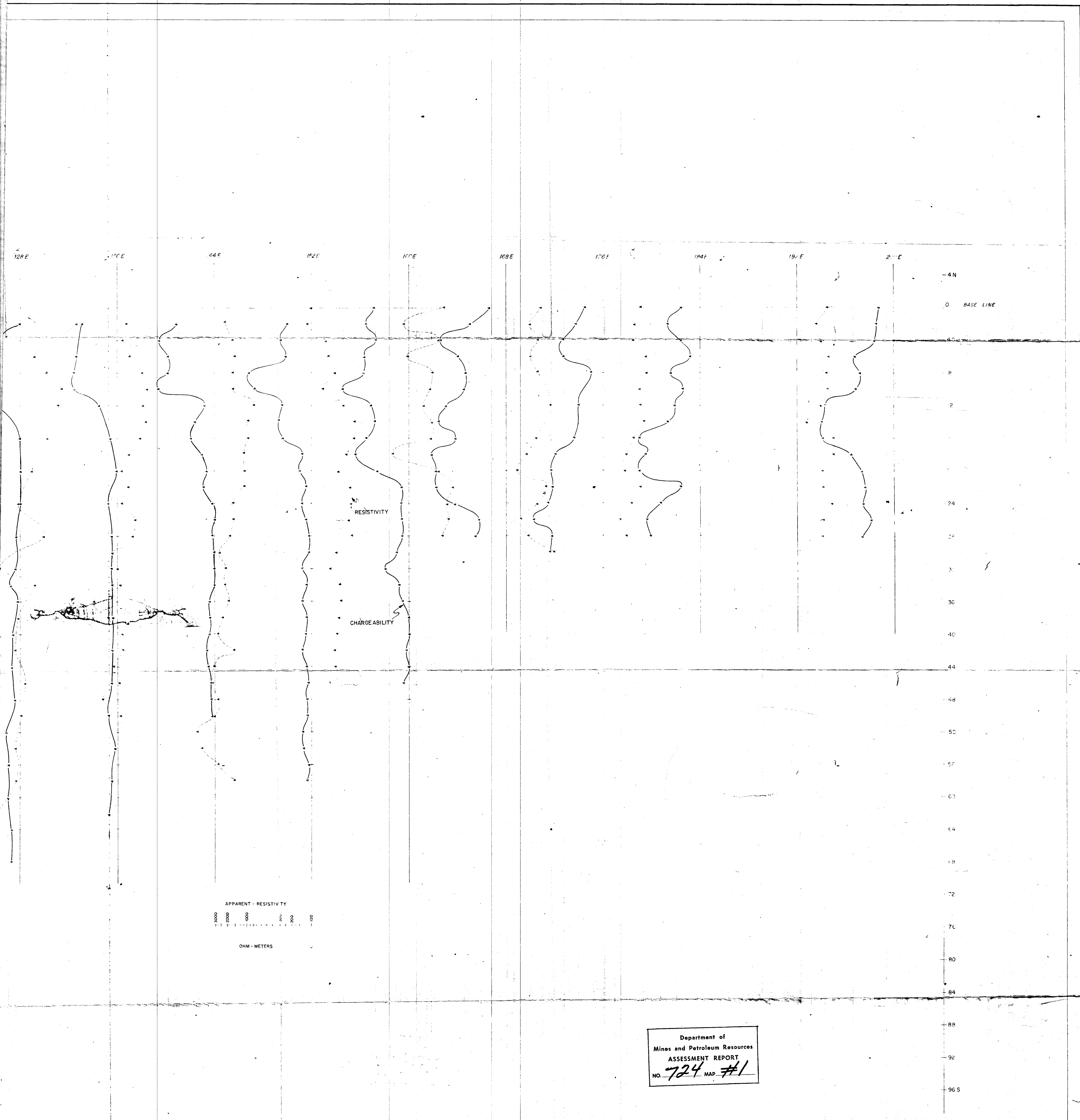


LEGEND

ELECTRODE CONFIGURATION	3 ARRAY
ELECTRODE SPACING	400 FEET
APPARENT CHARGEABILITY	1" = 50 MILLISECONDS
APPARENT RESISTIVITY	2" = 1 log. cycle. 0 – 100 – 1000 ohm – meters

SCALE

1 INCH = 400 FEET

NOTE: LINES NOT SPACED TO SCALE

INDEX

CHARGEABILITY RESISTIVITY

a = 400'

(APPROX)

INDUCED POLARIZATION SURVEY

PROFILE PRESENTATION

ROLLING HILLS AREA

724

FOR

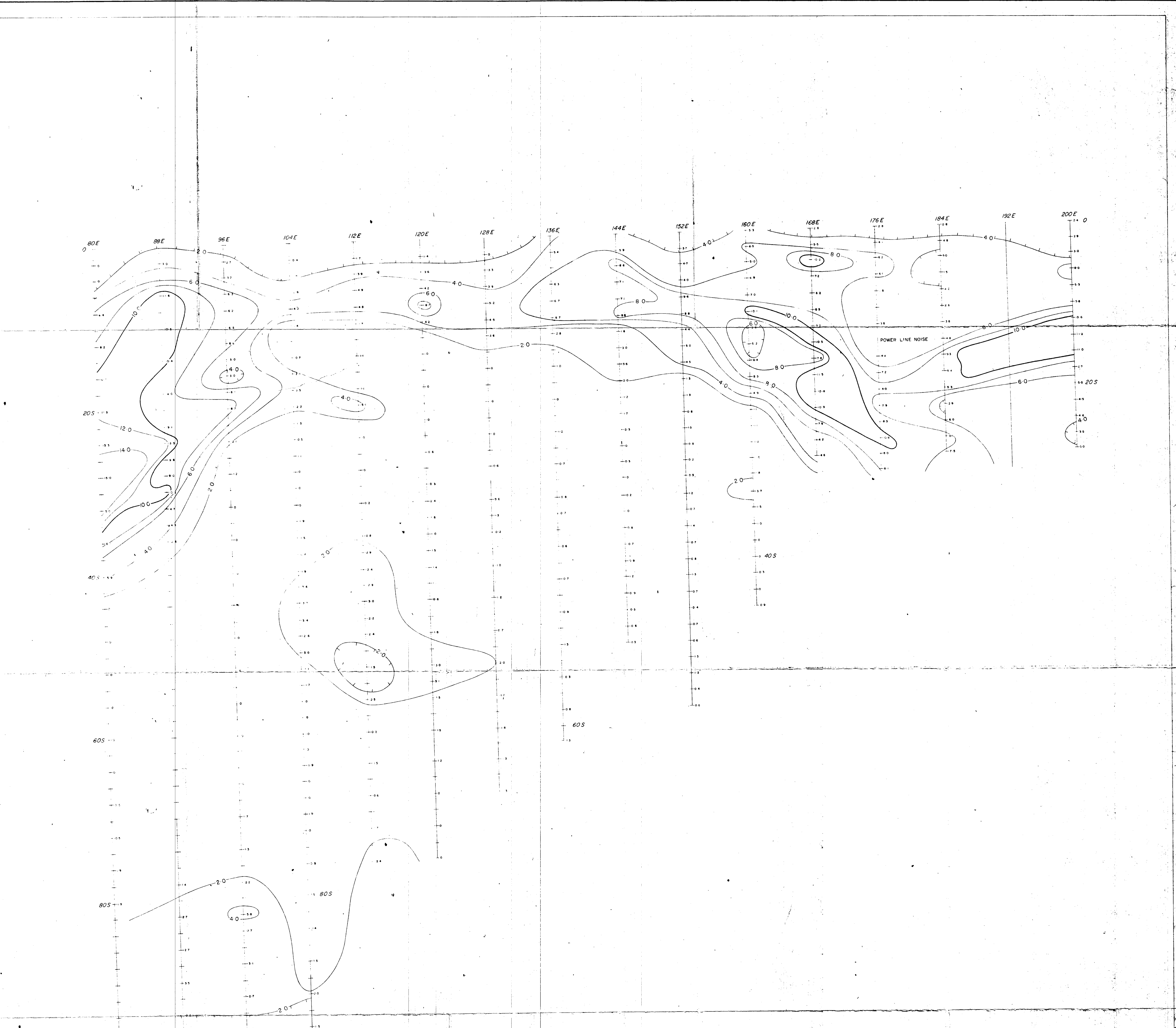
VANCO EXPLORATION LIMITED

BY

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

this map accompanies the report: "Induced Polarization Survey on the Property of Rolling Hills Mining Co. Ltd." dated Dec 22/65

CAMS - 5018



Department of
Mines and Petroleum Resources
ASSESSMENT REPORT
NO. 724 MAP #2

INDUCED POLARIZATION SURVEY

CHARGEABILITY CONTOUR PLAN

ROLLING HILLS AREA

724

FOR

VANCO EXPLORATION LIMITED

BY

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

LEGEND

ELECTRODE CONFIGURATION.............3 ARRAY
ELECTRODE SPACING..................400 FEET
CONTOUR INTERVAL...........2.0 MILLISECONDS
INDEX CONTOUR
INTERMEDIATE CONTOUR

SCALE

1 INCH = 400 FEET

N (APPROX.)

This map accompanies the report: "Induced Polarization Survey on the Property of Rolling Hills Mining Co. Ltd." dated Dec 22/65.
AKR.

CAM.

To accompany report on Induced Polarization Survey on the property of Rolling Hills Mining Co. Ltd. dated Dec 22, 1965 by A.R. [illegible] and J.G. Denholm