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93B/9E,W
REPORT ON
INDUCED POLARIZATION SURVEY
ON SOME JJ, GA, AL, AND BK CLAIMS
MARGUERITE AREA, BRITISH COLUMBIA
ON BEHALF OF
CALTA MINES LIMITED (N.P.L.)

by

Jon G. Baird, B.Sc., P.Eng.

June 27, 1967

CLAIMS:

| <u>Titles</u> | <u>Record Numbers</u> |
|---------------|-----------------------|
| JJ 2 to 14 | 35466 to 78 |
| JJ 21 to 34 | 35485 to 98 |
| GA 1 to 12 | 35562 to 73 |
| GA 19 to 30 | 35576 to 87 |
| BK 4 to 8 | 35593 to 97 |

LOCATION:

8 miles NE of Marguerite, B.C.
- Cariboo Mining Division
52° 122° NE ~~32~~

DATES: April 22 to June 8, 1967

TABLE OF CONTENTS

| | <u>Page No.</u> |
|-----------------------------------|-----------------|
| SUMMARY | |
| INTRODUCTION | 1 |
| GEOLOGY | 2 |
| DISCUSSION OF RESULTS | 3 |
| AFFIDAVIT OF TIME AND EXPENDITURE | 3 |

PLATES:

(in text)

#1 Plate 1 - Property Location Map 1" = 16 miles

(in envelope)

#2, 3, 4 Plate 2 - Survey Grid and Claim Plan 1" = 500'

#5 Plate 3 - Geophysical Profiles 1" = 400'

SUMMARY

An induced polarization survey on this property has revealed no significant abnormal responses. We may conclude that there is little possibility that a large-tonnage, low-grade deposit of sulphide mineralization of economic significance may lie within about 300' of the ground surface in the area covered by this survey.

SEIGEL ASSOCIATES LIMITED

GEOPHYSICAL CONTRACTORS AND CONSULTANTS

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INTRODUCTION

During the period from April 22 to June 8, 1967 a geophysical field party under the direction of Mr. Harry King executed an induced polarization survey on some JJ, GA, AL and BK claims known as the "Bauchi Lake Group" near Marguerite, British Columbia on behalf of Calta Mines Limited (N.P.L.). Additional field supervision was provided by Mr. Charles O'Sullivan, M.Sc.

The property lies northeast of Marguerite at approximately $52^{\circ} 30'$ north latitude and $122^{\circ} 15'$ west longitude, and is reached by road. Plate 1, on the scale of $1'' = 16$ miles, shows the property location in relation to towns and various topographic features. Glacial drift covers most of the surface of the property and topographic relief is moderate. The mineral claims covered, in whole or part, by this survey are listed on the title page of this report and are shown on Plate 2 on a scale of $1'' = 500'$. These claims are held by Calta Mines Limited (N.P.L.).

Seigel MkVA time domain (pulse-type) induced polarization equipment has been employed on this property. These units have a current-on time of 1.5 seconds and an integrating time of 0.5 seconds. The

3

accompanying copy of H. O. Seigel's paper entitled "Three Recent Irish Discovery Case Histories Using Pulse Type Induced Polarization" gives a description of the phenomena involved in this type of survey, the equipment employed, the field procedures and the nature of the results obtained over various base metal ore bodies.

On the present property the survey lines were cut oriented N 70° E at 500' intervals. The three electrode array, with spacings of 400' was employed, for reconnaissance purposes, on this property. Station intervals are 200'.

The purpose of an induced polarization survey is to map the subsurface distribution of metallically conducting mineralization beneath the grids covered. In the present area such mineralization could include molybdenite, chalcopyrite, pyrite and other metallic sulphide minerals. As well, metallic conductors such as graphite and artificial installations such as pipelines, fences etc., can give responses not always distinguishable from sulphide mineralization. These latter anomalous sources are not expected to occur on this property.

GEOLOGY

A description of the geology of the area including and surrounding the present claims is found on G.S.C. Preliminary Map Sheet 93B, Quesnel Area, by H. W. Tipper, 1959. The area covered by this property is shown to be underlain by Pleistocene and Recent unconsolidated sediments. East of the claim group lies a Mesozoic granitic intrusive which rises above the surrounding countryside and is called Granite Mountain (El. 4587'). West of the property lies a north-south trending belt of Tertiary volcanic rocks, while outcrops of the Palaeozoic Cache Creek sediments are seen to the south.

Ore minerals have been observed in the Cache Creek rocks and the Granite Mountain intrusive and the area has a possible potential as a locale for large-tonnage, low-grade copper-molybdenum deposits.

DISCUSSION OF RESULTS

Plate 3, on the scale of 1" = 400', shows the geophysical survey results in profile form. Two parameters are plotted, chargeability (the induced polarization characteristic of the rock) and resistivity. The vertical scales of these profiles are 1" = 5 milliseconds for chargeability and 1" = 1000 ohm-metres for resistivity.

The observed chargeability values are everywhere less than 2.0 milliseconds and average about 1.0 millisecond. This is well within the non-metallic chargeability range for the rock types encountered in this area, where a uniform distribution of 1% conducting material in the subsurface is expected to add about 3 milliseconds to the observed background chargeability level.

The resistivity profiles are quite uniform with values ranging between about 300 and 1000 ohm-metres.

The present chargeability and resistivity results indicate that the present property is underlain by rocks of uniform character and it is concluded that there is little possibility of the presence of a large mass of disseminated sulphide mineralization of the usual porphyry copper dimensions lying within approximately 300' of the ground surface in the area covered by this survey.

AFFIDAVIT OF TIME AND EXPENDITURE

The appended affidavit presents the working days devoted by the

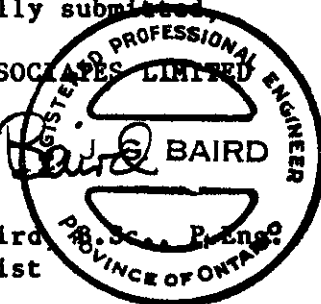
corresponding members of our staff who were occupied in the execution of the induced polarization services on some JJ, GA, AL and BK claims in the Marguerite area, British Columbia, on behalf of Calta Mines Limited (N.P.L.) over the period from April 22 to June 8, 1967, and our charges for these services.

Respectfully submitted,

SEIGEL ASSOCIATES LIMITED



Jon G. Baird
Geophysicist



Vancouver, B.C.
June 27, 1967

DOMINION OF CANADA:
 PROVINCE OF BRITISH COLUMBIA.
 To WIT:

In the Matter of a geophysical survey on behalf of
 Calta Mines Limited (N.P.L.)

I, Jon G. Baird
 of 115 - 744 West Hastings Street, Vancouver

in the Province of British Columbia, do solemnly declare that an induced polarization survey has been executed on some JJ, GA, AL, and BK claims situated in the Marguerite area of British Columbia between April 22 and June 8, 1967. The following expenses were incurred:

| | | | |
|--|--------------------|---------------|----------------|
| (1) Wages | | | |
| C. O'Sullivan | 4 days @ \$35/day | \$ 140.00 | |
| H. King | 34 days @ \$35/day | 1190.00 | |
| R. Higgins | 10 days @ \$20/day | 200.00 | |
| G. Payne | 10 days @ \$20/day | 200.00 | |
| P. Heiberg | 8 days @ \$20/day | 160.00 | |
| P. Antonik | 13 days @ \$20/day | 260.00 | |
| W. McAllister | 28 days @ \$20/day | 560.00 | |
| L. Paquette | 29 days @ \$20/day | 580.00 | |
| R. Cody | 24 days @ \$20/day | 480.00 | |
| Magee | 2 days @ \$20/day | 40.00 | |
| Unemp. Ins. & Canada Pension | | 61.24 | |
| Workmen's Comp. & Vac. Pay | | 137.94 | |
| Overhead and Administration | | 261.92 | |
| Accommodation and meals | | <u>74.20</u> | \$4345.30 |
| (2) Transportation and Shipping | | | |
| Truck - 2 days @ \$15/day | | \$ 30.00 | |
| 720 miles @ 15¢/mile | | <u>108.00</u> | 138.00 |
| (3) Rental of Geophysical Equipment and Consulting Fees | | | |
| 36 days @ \$144.06/day | | \$5186.16 | |
| 2 days @ \$ 71.92/day | | <u>143.84</u> | <u>5330.00</u> |
| | | | \$9813.30 |

And I make this solemn declaration conscientiously believing it to be true, and knowing that it is of the same force and effect as if made under oath and by virtue of the "Canada Evidence Act."

Declared before me at the city
 of Vancouver, in the
 Province of British Columbia, this 11th,
 day of July, 1967, A.D.

Jon G. Baird

Shirley Campbell Sub-mining Recorder
 A Commissioner for taking Affidavits for British Columbia or
 A Notary Public in and for the Province of British Columbia.

Department of
Mines and Petroleum Resources
ASSESSMENT REPORT

NO. 1029 MAP # 1

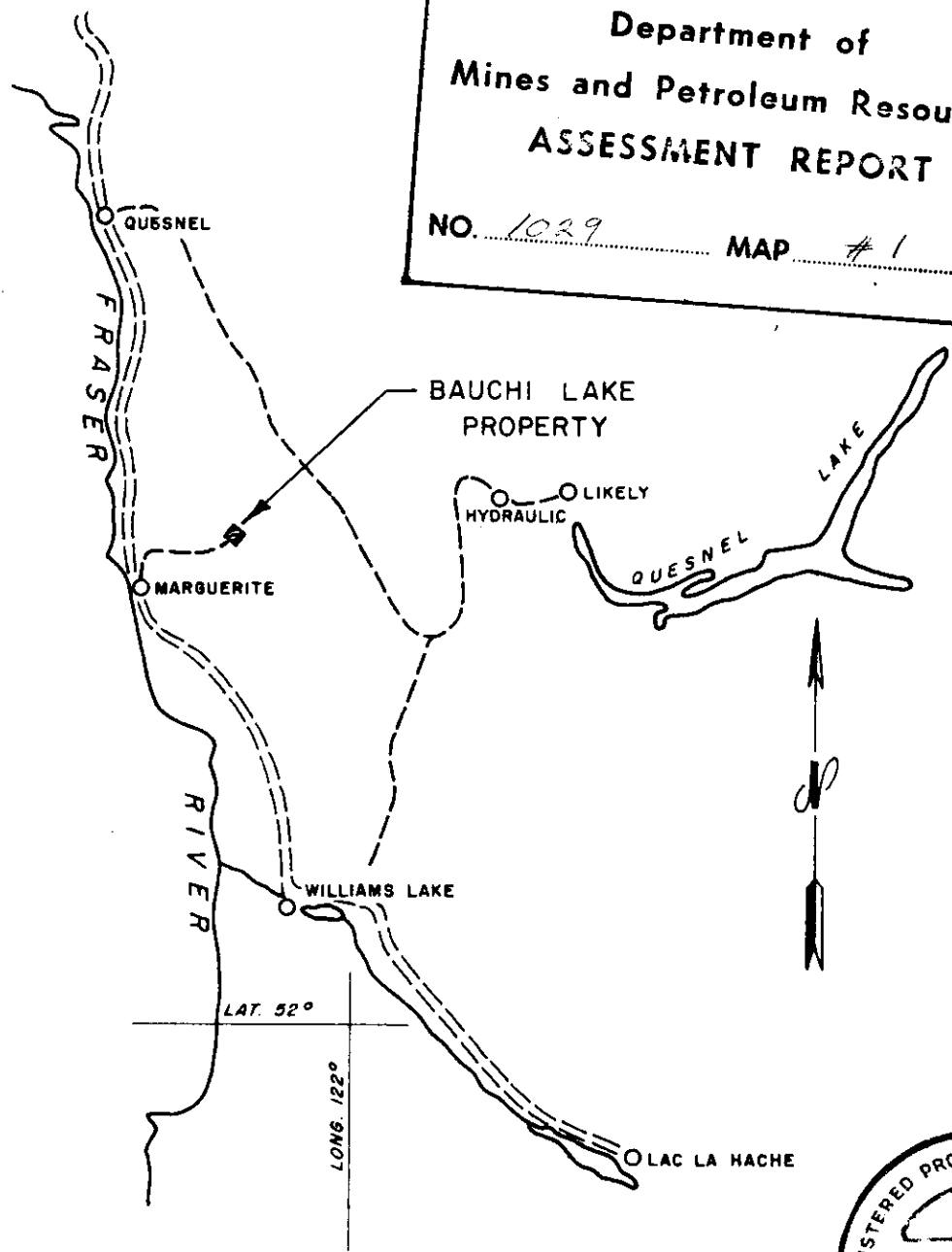
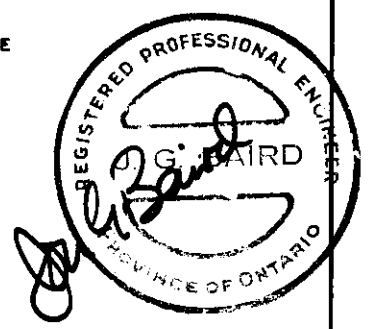


PLATE I



CALTA MINES LTD.

MARGUERITE AREA

BRITISH COLUMBIA

BAUCHI LAKE PROPERTY LOCATION MAP

SCALE : 1" = 16 MILES APPROX.

SURVEY BY SEIGEL ASSOCIATES LIMITED

Harold O. Seigel

President,
Harold O. Seigel & Assoc., Ltd.,
Downsview, Ontario

Annual General Meeting,
Toronto, March, 1965

Three Recent Irish Discovery Case Histories Using Pulse-Type Induced Polarization

Transactions, Volume LXVIII, 1965, pp. 343-348

ABSTRACT

In the intensive Irish exploration program which has followed the discovery of the Tynagh deposit (Northgate Exploration, Ltd.) in 1962, three base metal discoveries have been made to date. These include the lead-zinc-silver deposits at Silvermines (Consolidated Mogul Mines, Ltd.), which are now being readied for production, the copper-silver deposit at Gortdrum (Gortdrum Mines, Ltd.) and the lead-zinc deposits near Keel (Rio Tinto-Zinc Ltd.). Each of these discoveries is the result of a combined geological-geochemical-geophysical exploration sequence in which pulse-type induced polarization surveys defined the precise location and lateral extent of the near-surface metallic sulphide mineralization and guided the initial drilling program. Whereas the Silvermines mineralization is, in part, composed of massive sulphides, the other two deposits are characterized by generally less than 5 per cent conducting sulphides and constitute an excellent demonstration of the unique merits of the pulse-type induced polarization system.

Introduction

FOR the benefit of those who are unfamiliar with the induced polarization method in general or with the pulse-type method in particular, a few introductory remarks will be directed on the system employed in the present case histories. Those who wish a fuller treatment of the subject are directed to Seigel (1962),* which paper also includes an extensive list of references.

Induced polarization, in its broadest sense, means a separation of charge to form an effective dipolar (polarized) distribution of electrical charges throughout a medium under the action of an applied electric field. When current is caused to pass across the interface between an electrolyte and a metallic conducting body (Figure 1a) double layers of charge are built up at the interface, in the phenomenon known

*Seigel, H. O., "Induced Polarization and its Role in Mineral Exploration," *C.I.M. Bulletin*, Vol. 55, No. 600, pp. 242-249; *Transactions*, Vol. LXV, pp. 151-158; 1962.

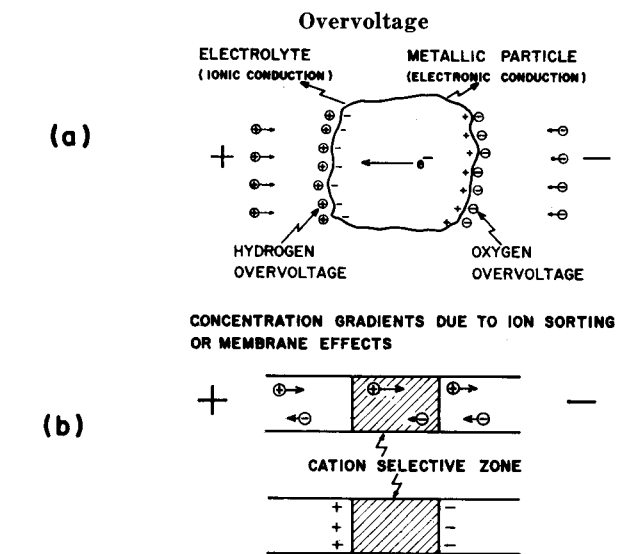


Figure 1.—Induced Polarization Agents.

to the electrochemists as "overvoltage." This is the phenomenon which can be utilized for the detection of the metallic conducting rock-forming minerals such as most sulphides, arsenides, a few oxides and, unfortunately, graphite. In addition, effective dipolar charge distributions occur to some extent in all rocks, due to ion-sorting or membrane effects in the fine capillaries in which the current is passing (Figure 1b). Induced polarization responses may therefore arise from metallic or non-metallic agencies. Fortunately, the latter generally fall within fairly low and narrow limits for almost all rock types, although there is still no reliable general criterion for differentiating overvoltage responses from graphite and metallic sulphides, or for distinguishing between the responses of one type of sulphide and another. Despite these limitations, the induced polarization method has amply demonstrated its value in mineral exploration since its initial development as a useful exploration tool in 1948. (Wait *et al.*, 1953).**

***"Overvoltage Research and Geophysical Applications," *Pergamon Press*, 1959, edited by J. R. Wait.

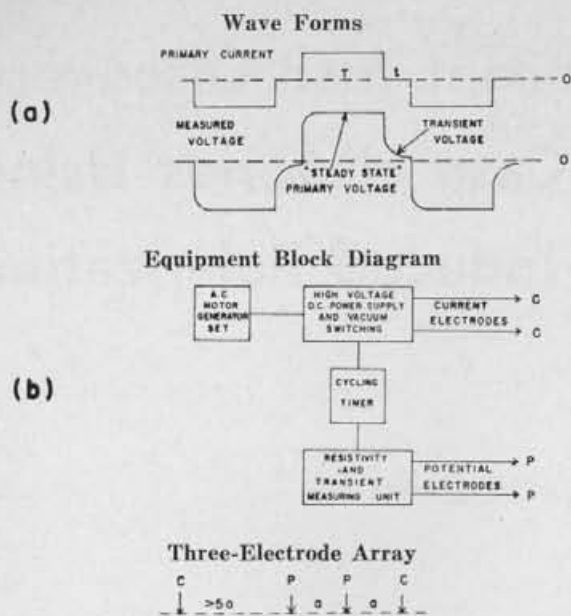


Figure 2.—The Pulse System.

Description of Method

For the present program, the pulse or time-domain system was employed. As shown in Figure 2a, the primary current wave form consists of square wave pulses of 1.5 seconds duration, separated by a 0.5-second gap and alternately reversed in direction. The polarization voltages established during the current-on time decay slowly during the current-off time. They are amplified, integrated over the current-off time and divided by the amplitude of the steady-state voltage measured during the current-on time. In this way, we determine the "chargeability;" i.e., the induced polarization property of the region under investigation. The units of chargeability are milliseconds. Normal (non-metallic) background chargeabilities in most rocks range from 1 millisecond to 5 milliseconds. A distribution of 1 per cent, by volume, of metallic conducting material of an average range of

particle size may be expected to increase the response level by about 3 milliseconds, which is readily visible.

The pulse system provides an absolute measurement of induced polarization; i.e., the significant measurement is made in the absence of the primary field. As such, it is inherently more sensitive than the frequency variation system, wherein two measurements are compared, both of which are made in the presence of the primary field. This is a critical consideration when mineralized bodies of low sulphide content, small size or great depth are being sought.

Figure 2b shows a block diagram of the apparatus employed and the electrode array used. The spacing "a" of the three-electrode array determines the effective depth of penetration of the survey and is selected to give adequate penetration to the depth desired. By varying the electrode spacing over an anomalous area and comparing the responses on the various spacings, one may obtain an estimate of the depth of burial of the source and its dip, etc.

A photograph of the type of apparatus employed on these surveys is shown in Figure 3. This is known as Seigel Mk V equipment and consists of the following major components: (a) a 1,200-watt A.C. motor-generator set, (b) a power control unit capable of supplying up to 1000 volts and 2 amperes D.C. output current and (c) a measuring unit. All of these items are packboard-mounted for maximum portability.

Figure 4 shows a typical instrumental set-up in Ireland. In the normal operating procedure, the electronic chassis are set up in a tent and cables are fed out to the line being surveyed. As the line crew is prepared, both mentally and by apparel, to work under all types of weather conditions, the survey is not stopped by rain, etc. This is important in Ireland, where, traditionally, there are no more than 60 rain-free days a year.

For the primary survey coverage on most properties, an electrode spacing of 200 to 300 ft. was generally employed, with a station interval of 200 ft. and a line separation of 300 to 500 ft. On anomalous areas located by the primary coverage, more closely spaced stations and lines are employed, as well as additional spacings to supply the detail necessary for subsequent drilling, etc.



Figure 3.—(above)—The Seigel Mk V Induced Polarization Unit.



Figure 4.—(right)—Typical Field Operational Base in Ireland.

Case Histories

In presenting the three case histories that follow, it must be made perfectly clear at the outset that these mineral discoveries are the product of teamwork, involving geological, geochemical and geophysical phases. It is on the basis of the first two phases that the areas for geophysical investigation have been selected. As the writer and his organization have been concerned only with the geophysical phase, this paper will, naturally, appear to emphasize it. The contribution of others to the broader exploration program must not be minimized, however.

In January, 1962, a large lead-zinc-silver deposit of a very unusual type was discovered near Tynagh, Co. Galway, in the Republic of Ireland. This deposit includes both a supergene enriched, partly oxidized upper zone and a sulphide primary zone and lies in dolomitic reef limestones of Carboniferous age near a fault contact with Devonian sandstones. Similar rock types and contacts occur in many parts of Ireland, so that an extensive program of exploration was initiated by a number of mining companies, starting in the summer of 1962. Although the pace has slowed up somewhat from the hectic days of 1962 and early 1963, this exploration program continues to the present time.

The usual exploration sequence, although not followed in detail by all companies, is as follows:

1

A selection of areas is made, based on the good government geological maps available. As nearly as possible, rock types and structures similar to those of the Tynagh deposit are sought. Those areas with known mineral showings are given high priority, of course.

2

The stream sediments in the drainage pattern are sampled and analyzed for significant amounts of copper, lead and zinc. Soil samples may also be taken, often on a regular grid basis, and analyzed. In this fashion, areas of abnormal metal content may be broadly defined. In detail, such geochemical sampling has often been hampered by man-made contamination and confused by soil transport by glacial, fluvial or human agencies.

3

Geophysical surveys, primarily the induced polarization type, are then conducted to map the subsurface distribution of sulphide mineralization and to provide guidance for a drilling program thereon.

This exploration program has already been remarkably successful, resulting, to date, in a new lead-zinc-silver mine-to-be at Silvermines, Co. Tipperary, for Consolidated Mogul Mines, Ltd., the probable copper-silver mine-to-be at Gortdrum, Cos. Tipperary and Limerick, for Gortdrum Mines, Ltd., and the interesting lead-zinc prospect at Keel, Co. Longford, for the Rio Tinto-Zinc group (Riofinex Ltd.). Figure 5 shows the location of the various recent mineral discoveries in Ireland. Despite a remarkable similarity in geological setting, the deposits are widely separated geographically, over a length of 80 miles, and no two are located on what can be called the same structure. This bodes well for the possibility of further discoveries being made in Ireland.

Each of the three case histories will be discussed below.

Silvermines Deposit

As the very name of the area implies, the Silvermines region had been known, for many centuries, as a locality mineralized with lead, zinc and silver. Metal production had taken place at several periods in the past, although at the time of the present investigations the mines were dormant. The very prominent Silvermines fault, striking about N 70°E, was known to be the significant control in the region, with the old mines and prospect pits scattered along its length over a distance of about 2 miles. Due to the past mining activity and transport by both drainage and man, a very extensive area gave rise to extremely high geochemical indications in lead and zinc. The induced polarization survey executed in late 1962 and early 1963 covered much of the concession area on 800-ft. sections and the geologically interesting portion thereof on 400-ft. sections. The three-electrode array, with 200-ft. electrode spacing, was employed on all lines, and spacings of 100 ft. and 400 ft. were also employed on the 400-ft. detail lines. In all, approximately 5 miles of the strike length of the Silvermines fault were covered by the present survey, 2½ miles in detail. At least ten distinct zones of abnormally high polarization were indicated, of which about half lay in the Silvermines mineralized belt and its extensions to the west and east.

One of these zones, designated the Garryard, has responded favourably to the subsequent drilling, resulting in the discovery of a mineable orebody.

To date, the announced proven tonnage figures include 12 million tons averaging approximately 8 per cent zinc, 3 per cent lead and 1 ounce of silver in the Garryard zone. This zone lies to the west of the zone from which the previous production had taken place.

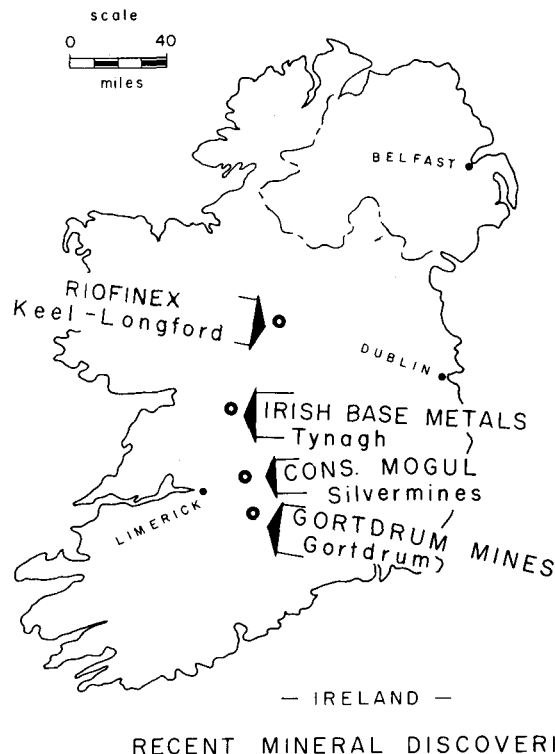


Figure 5.—Location Plan of Recent Mineral Discoveries in Ireland.

Figure 6 shows a typical discovery profile across the main ore zone, on the section 38,400E. The 200-ft. electrode spacing results, both chargeability and resistivity, are shown in profile form. The geologic section, as deduced from nine drill holes, is shown below the geophysical profiles. In a fashion almost identical

to that of the Tynagh deposit, the Silvermines ore-body is located in gently north-dipping dolomitic limestones adjacent to a fault contact with the Devonian "Old Red" sandstone. The mineralization here is composed of both massive and disseminated sulphides, with the former composed of a high percentage of pyrite. The mineralization is essentially conformable, in two distinct horizons, and is therefore flatly dipping except in the vicinity of the fault, where the dips are much steeper, perhaps due to "drag folding" on the fault.

Because of the high pyritic content of the mineralization near the fault, along which it comes closest to the ground surface, we see both a marked increase in chargeability and a sharp decrease in resistivity in that vicinity. From a normal background of 2-4 milliseconds, the chargeability curve rises to a peak response of 20 milliseconds over the sub-outcrop of the body on this section. The subsidiary peak of about 12 milliseconds near 11N is believed to be due to disseminated pyrite in the chert horizon.

Figure 7 shows the multiple spacing chargeability results on the same section, using electrode spacing of 100, 200 and 400 ft. and the three-electrode array. On comparing the results with the various spacings, two items of interest may be noted; firstly, the progressive increase in peak amplitude with spacing, testifying to the increase of mineralization with depth, even down to a depth of 300 ft., and, secondly, the presence of buried material of high polarization at depth beneath section 10N to 18N on this line. The latter is undoubtedly due to the down-dip extension of the upper mineralized horizon, which is present at depths of 300 to 400 ft. over this region.

The induced polarization results on the Silvermines deposit were quite definitive and have provided good guidance for the exploratory drilling. It is true, however, that the massive sulphide portions of this deposit would be amenable to detection by the more conventional electrical methods, such as electromagnetic induction or resistivity. As such, it is not as good a test of the capabilities of the induced polarization method as are the two case histories which follow.

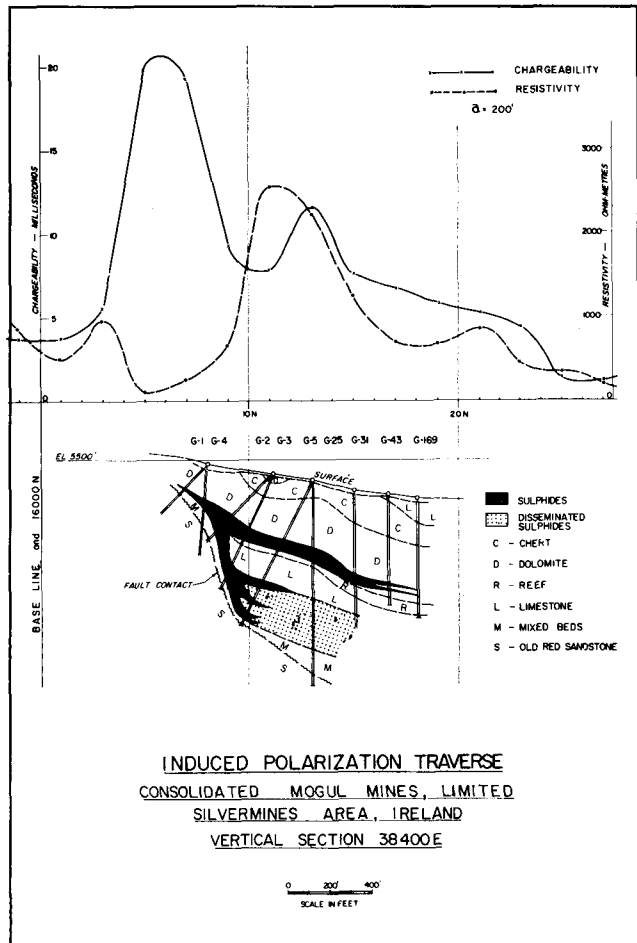


Figure 6.—Typical Discovery Traverse, Silvermines Deposit.

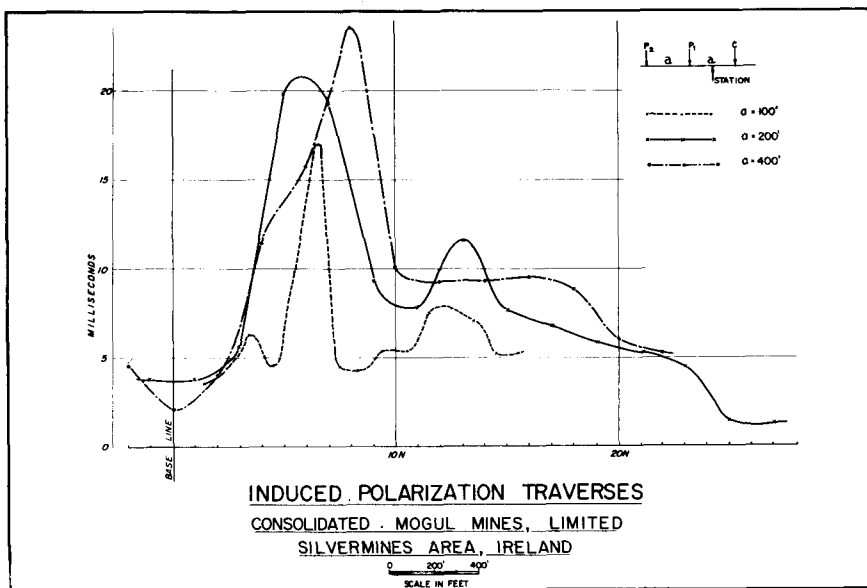


Figure 7.—Multiple Spacing Results, Silvermines Deposit.

Gortdrum Deposit

The Gortdrum area, near the mutual border of Cos. Limerick and Tipperary, was originally selected to cover the eastern extension of the former Oola Mines lead-zinc deposit, some 3 miles to the west. Regional geochemical sampling of the stream sediments in this area, followed by soil traverses, indicated a moderately strong copper soil anomaly. Induced polarization surveys were carried out in May, 1963, and January, 1964, leading to the localization of the sulphide mineralization associated with the geochemical anomaly. As there was a 300-ft. lateral displacement between the centers of the geophysical and geochemical indications and the surface topography is very gentle, it was initially queried as to whether the two indications

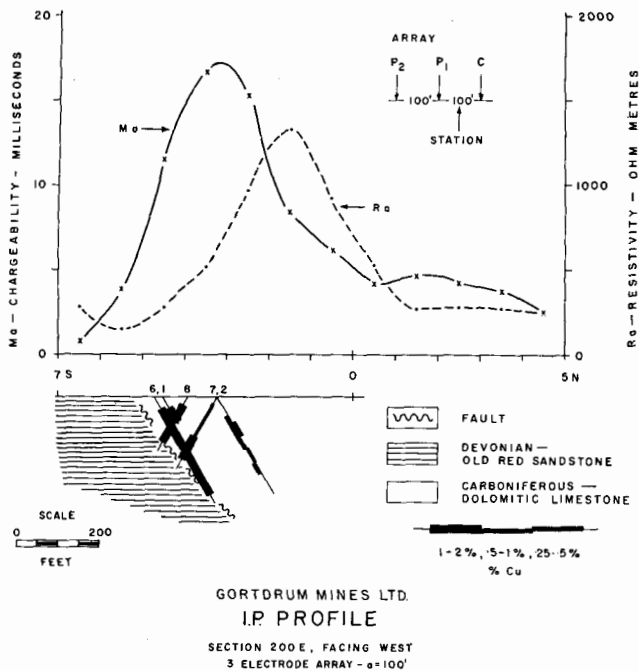


Figure 8.—Typical Discovery Traverse, Gortdrum Deposit.

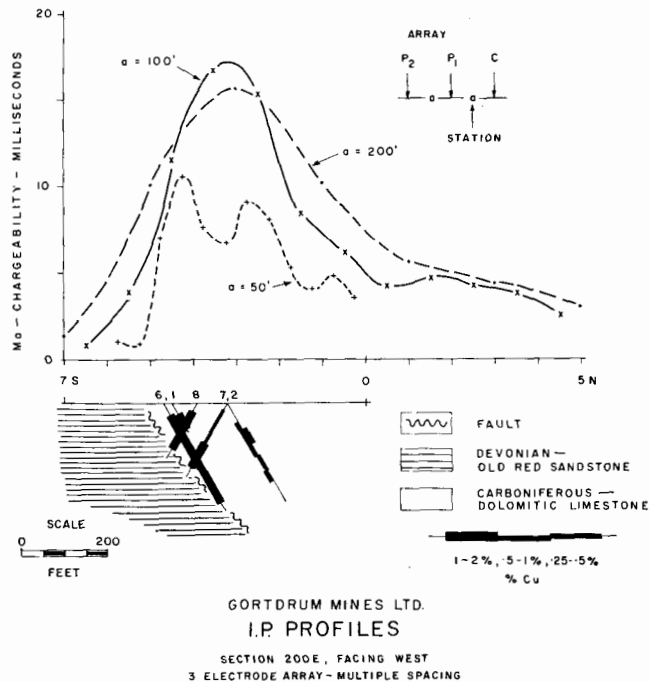


Figure 9.—Multiple Spacing Results, Gortdrum Deposit.

were related. The subsequent drilling has fully confirmed the geophysical predictions.

On the initial two geophysical programs, the three-electrode array with 100-ft. spacing was employed, as a relatively shallow source of the geochemical anomaly was expected. The survey lines were at 200-ft. intervals. Figure 8 presents a typical discovery traverse, showing both the chargeability and resistivity profiles as well as the corresponding geologic section. A peak chargeability of about 17 milliseconds is observed, rising from the normal background of 2-4 milliseconds. There is no resistivity expression of the mineralized zone, lying as it does on the flank of a high-resistivity area.

Figure 9 shows the chargeability profiles for electrode spacings of 50, 100 and 200 ft. Points of special interest deduced from these profiles include the following:

- 1.—The extremely sharp cut-off of the high chargeability levels on the south side of the area and the gradual drop-off in level on the north side. This was inconsistent with the thought of a bedded-type deposit conformable with the limestones, which are known to dip flatly to the south. A fault or other contact was postulated, dipping steeply, probably to the north. The initial drill holes on the section (Nos. 1, 2 and 6) were drilled to the north on the original geologic-dip premise, but the later holes (e.g., Nos. 7 and 8) have all been drilled to the south.

- 2.—The high-polarization material does not quite outcrop, but still comes within about 25 ft. of the ground surface across a width of about 200 ft., including two or more lenses. This material extends to at least 200 ft. in depth.

The actual drilling results confirm the presence of a zone of finely disseminated chalcocite and bornite, with very minor chalcopyrite, in dolomitic limestones. The mineralization is somewhat erratically distributed but, in general, increases as one approaches a north-

dipping fault, which brings the limestones into contact with the Devonian Old Red sandstones. This fault has been found to strike about N 70°E. Geologically, therefore, this environment is almost identical to that of the Tynagh and Silvermines deposits. The mineralization in the Gortdrum area is quite different, however, both in type and amount. The average grade of the deposit is less than 2 per cent copper, with about 0.65 ounce of silver for each 1 per cent copper (although considerable potential open-pit tonnage may exist), so that the average sulphide content, by volume, is 3 per cent or less. The high chargeability responses observed over this deposit are a remarkable tribute to the sensitivity of the pulse-type induced polarization method, particularly when dealing with truly disseminated-type sulphide mineralization with a small average particle size.

As development drilling is still in progress on this deposit, no over-all grade or tonnage figures have as yet been released.

Keel Deposit

The deposits near Keel and Longford, Co. Longford, occur on a known limestone-sandstone contact, which is, no doubt, one of the reasons why exploration interest was attracted thereto. Soil sampling traverses by Riofinex Ltd., an exploration subsidiary of Rio Tinto-Zinc Corporation, Ltd., established the presence of anomalous lead and zinc concentrations. A horizontal-loop electromagnetic survey was initially executed in another attempt to determine the source of the geochemical indications, but with negative results. This was followed by induced polarization surveys in November and December, 1962. The three-electrode array, with an electrode spacing of 200 ft., was employed on the reconnaissance survey. Anomalous chargeability zones were indicated and exploratory drilling commenced shortly thereafter. Although no publication of results has been made, they are of some potential interest, as drilling has continued, at intervals, to the present time.

Figure 10 shows a typical section across the prospect, presenting the geophysical and geochemical results in profile form, as well as the geological section interpreted from three holes. The relationship between the mineralized horizon, the geophysical peak and the geochemical peaks is a matter of considerable interest. The sub-outcrop of the mineralized horizon and the geophysical peak are in good agreement (see also Figure 11). The lead peak is displaced about 400 - 500 ft. down slope to the south. The zinc peak

is displaced still another 300 ft. to the south. The actual topographic slope is only 1-2 degrees to the south, so that this displacement is difficult to account for on the basis of soil creep. There is only a minor resistivity depression associated with the mineralization, indicating why the electromagnetic survey failed to give any positive response to it.

The mineralization itself is primarily sphalerite, with some galena and, on the average, less than 5 per cent pyrite. It is found to lie primarily in a dolomite horizon adjacent to a contact with sandstone. In this case, the contact may be largely a depositional one and not due to a fault. Mineralization occurs to a minor extent in the sandstone as well.

Figure 11 shows the chargeability results of the multiple spacing profiles on this section. Spacings of 50, 100 and 200 ft. were used. The progressive step-out of the peak values to the south with the increase in electrode spacing indicates the effect of the relatively flat dip to the south of the mineralization. The sub-outcrop of the mineralization is near station 26N, at a depth of less than 25 ft. As hole K3B, only 100 ft. away, intersected almost 60 ft. of overburden one must conclude that the bedrock surface is rather irregular in this area. The peak chargeability of 24 milliseconds would suggest a metallic conductor content of the order of 6 to 12 per cent, by volume, in this area.

It is the writer's hope that he has not given the impression that every induced polarization anomaly in Ireland inevitably defines an orebody, or that every exploration venture there is crowned with success. Aside from effects due to the many man-made conductors, such as grounded power lines, rabbit fences and buried pipe lines, there are certain carbonaceous sediments, in particular the Calp limestone, which overlies the ore-bearing dolomitic limestone in some places, which yield high polarization responses. Fortunately, the areal distribution of the latter is usually broad enough to suggest a formational origin. Also, fortunately, the Calp is, stratigraphically, sufficiently well separated from the ore-bearing limestones so that the effect from these two horizons may be resolved. With the geological and geochemical information available, one can usually determine whether a particular induced polarization indication warrants investigation by drilling. Despite its limitations, the pulse-type induced polarization method has well demonstrated its application to a broad range of base metal exploration problems in Ireland.

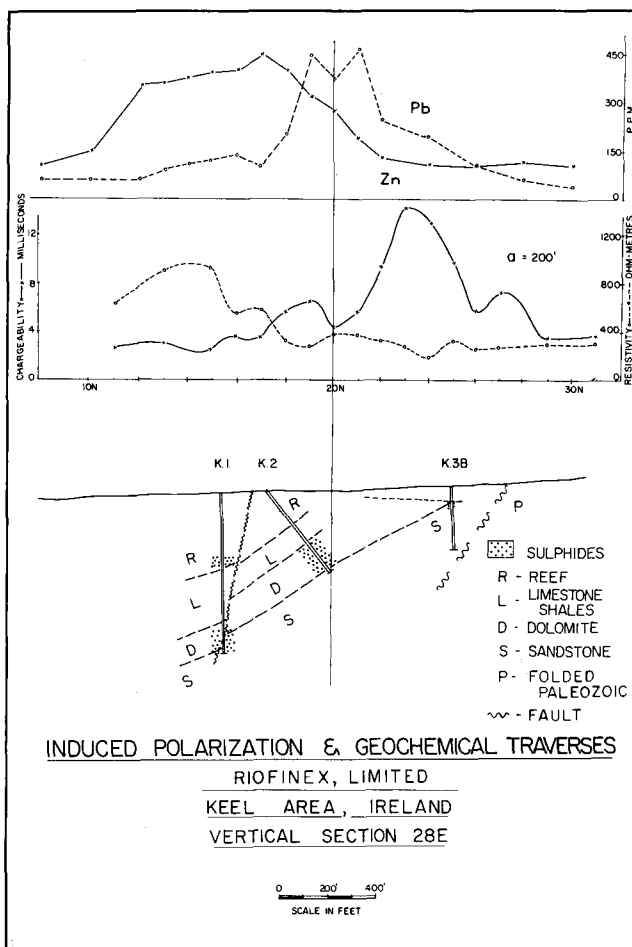


Figure 10.—Typical Discovery Traverse, Keel Deposit.

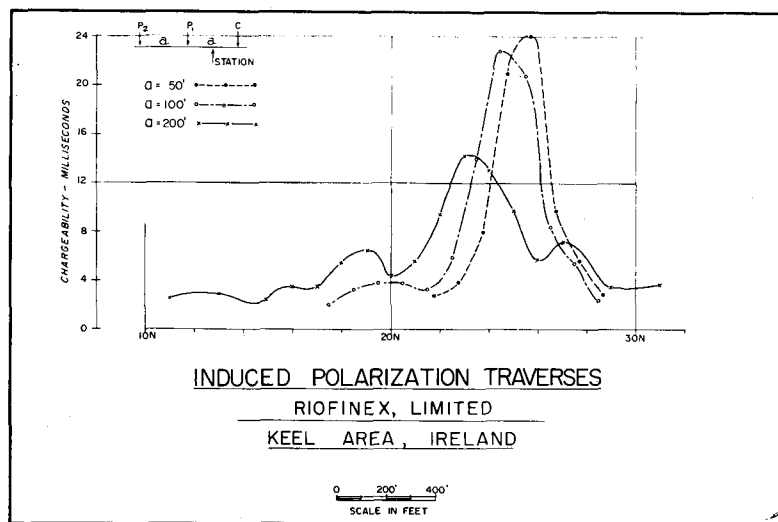


Figure 11.—Multiple Spacing Results, Keel Deposit.

Acknowledgments

The writer wishes to express his thanks to Consolidated Mogul Mines, Ltd., and Dr. W. W. Weber, to Gortdrum Mines, Ltd. and Dr. D. R. Derry, and to Rio Tinto-Zinc Corp. Ltd. and Mr. Jocelyn Pereira, for their kind permission to present the geophysical and other details relating to their respective mineral discoveries. In addition, the writer wishes to acknowledge the able assistance of the staff of Canadian Aero Mineral Surveys, Ltd., with which our company, Harold O. Seigel & Associates Ltd., has acted on a co-operative basis in Ireland.

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A DECADE OF DEVELOPMENT IN OVERVOLTAGE SURVEYING

by ROBERT W. BALDWIN

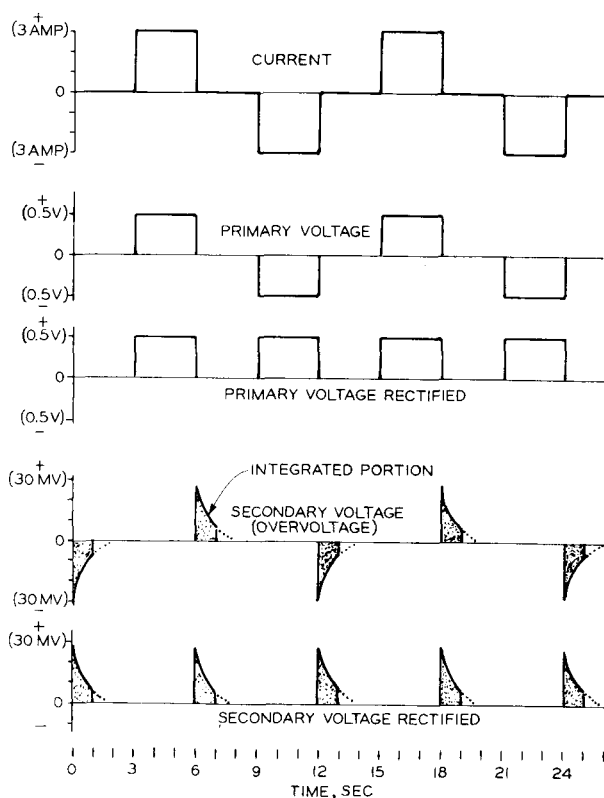
As used in geophysical exploration, the term **Overvoltage** applies to secondary voltages set up by a current into the earth which decay when the current is interrupted. These secondary effects may be measured by pick-up electrodes. The term *induced polarization* has often been employed to describe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

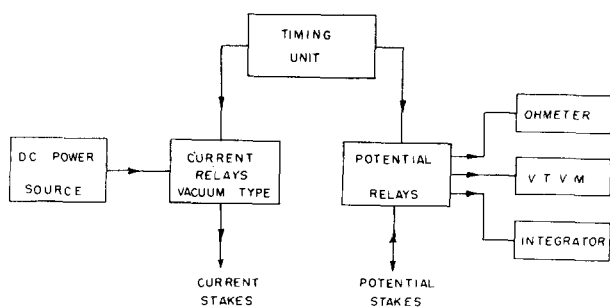


Fig. 2—Block diagram of typical field equipment.

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: 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: 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

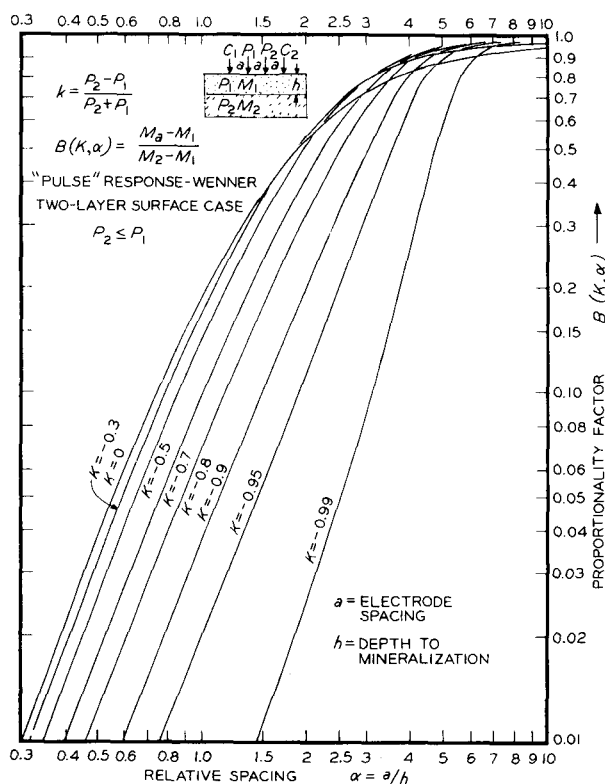


Fig. 3—Typical theoretical overvoltage response curves.

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

$$\frac{M_a - M_1}{M_2 - M_1} = \frac{\delta \log \rho_a}{\delta \log \rho_2}$$

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: 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: As is perhaps suggested by the condenser analogy mentioned above,

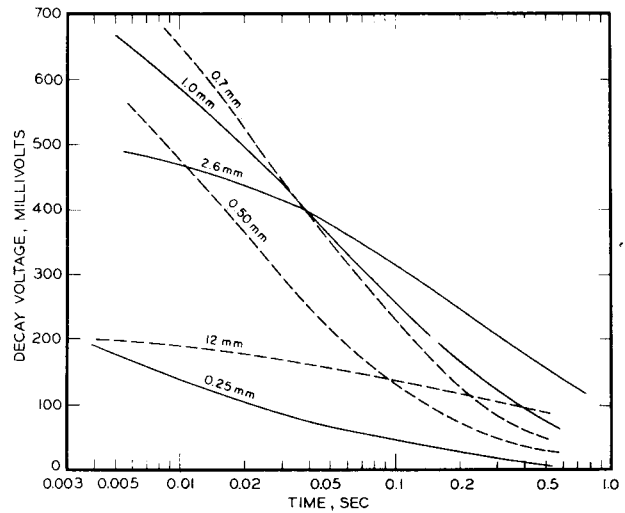


Fig. 4—Observed decay voltage $e(t)$ as a function of time. For $V = 15$ volts, $v = 0.02$ and $\sigma = 5 \times 10^{-3}$ mhos/m. This graph and Fig. 5 are examples of extensive overvoltage experiments at Newmont's laboratories in Jerome, Ariz. Fig. 4 illustrates work in transient domain, Fig. 5 work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

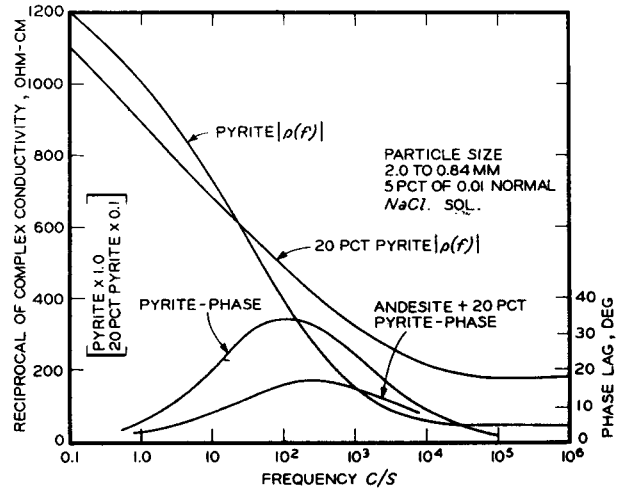


Fig. 5—Variation of complex conductivity with frequency. From experiments at Newmont laboratories.

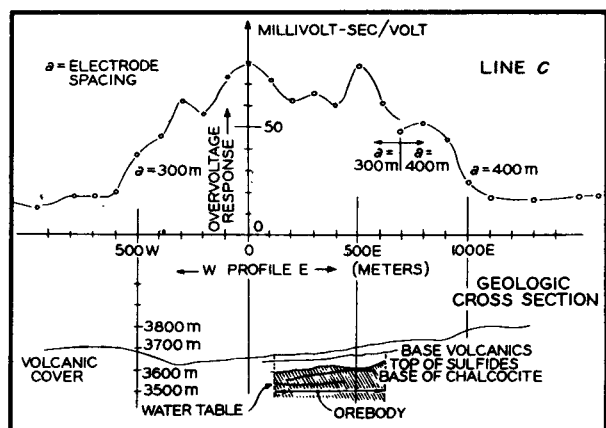


Fig. 6—Overvoltage profile, north end, Quellavaco.

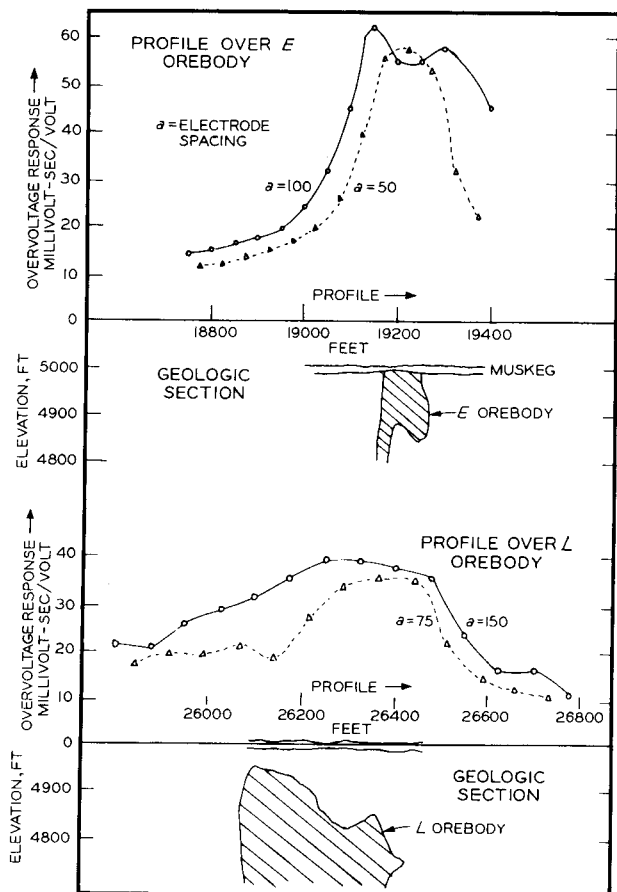


Fig. 7—Overvoltage profiles at Lynn Lake, Manitoba.

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-

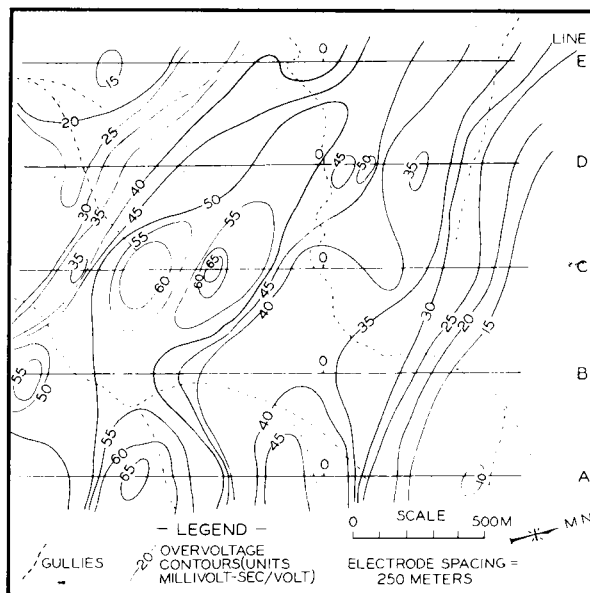


Fig. 8—Copper prospect, Peru. Overvoltage contours here directly outline distribution of sulfides.

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

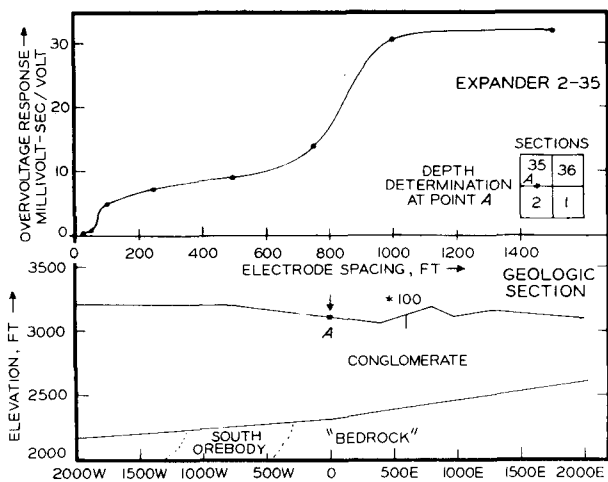


Fig. 9—Detection of deep mineralization is possible at San Manuel by use of large electrode spacings.

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

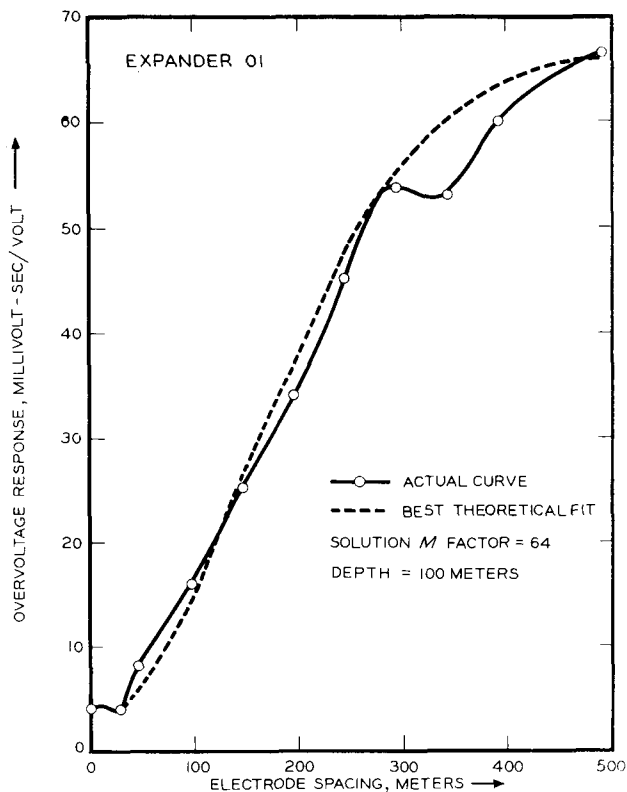


Fig. 10—Mineralization and depth, Cuajene.

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.

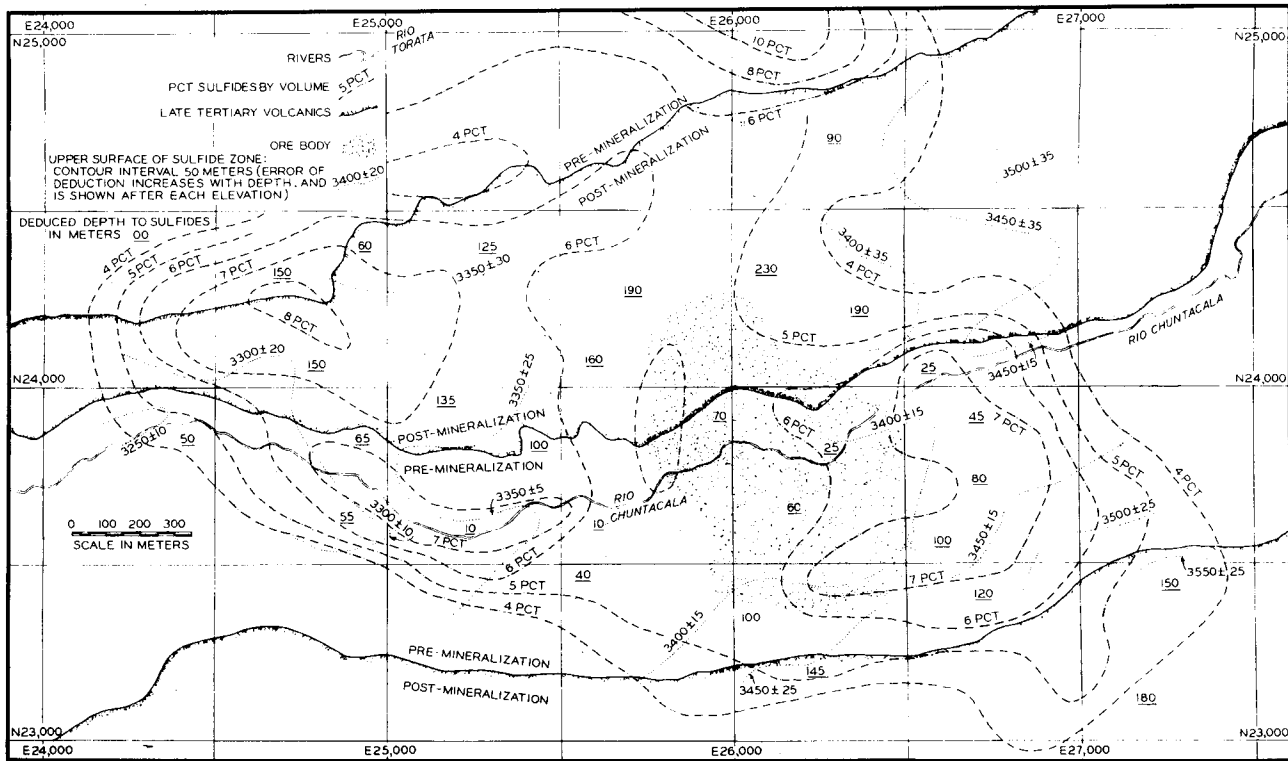


Fig. 11—The sulfide distribution at Cuajone, Peru, as deduced from the overvoltage data. Note the great variation in depth to the top of the sulfides. The mineralization that is outside the orebody consists mostly of pyrite.

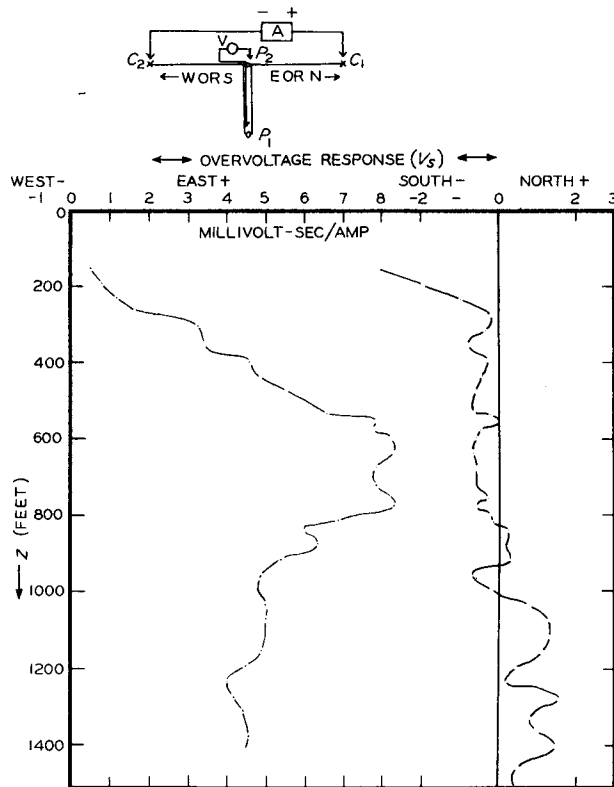


Fig. 12—NababEEP West, South Africa, borehole WP 12. The direction of mineralization from a drillhole is indicated here by the overvoltage azimuth survey.

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

* 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

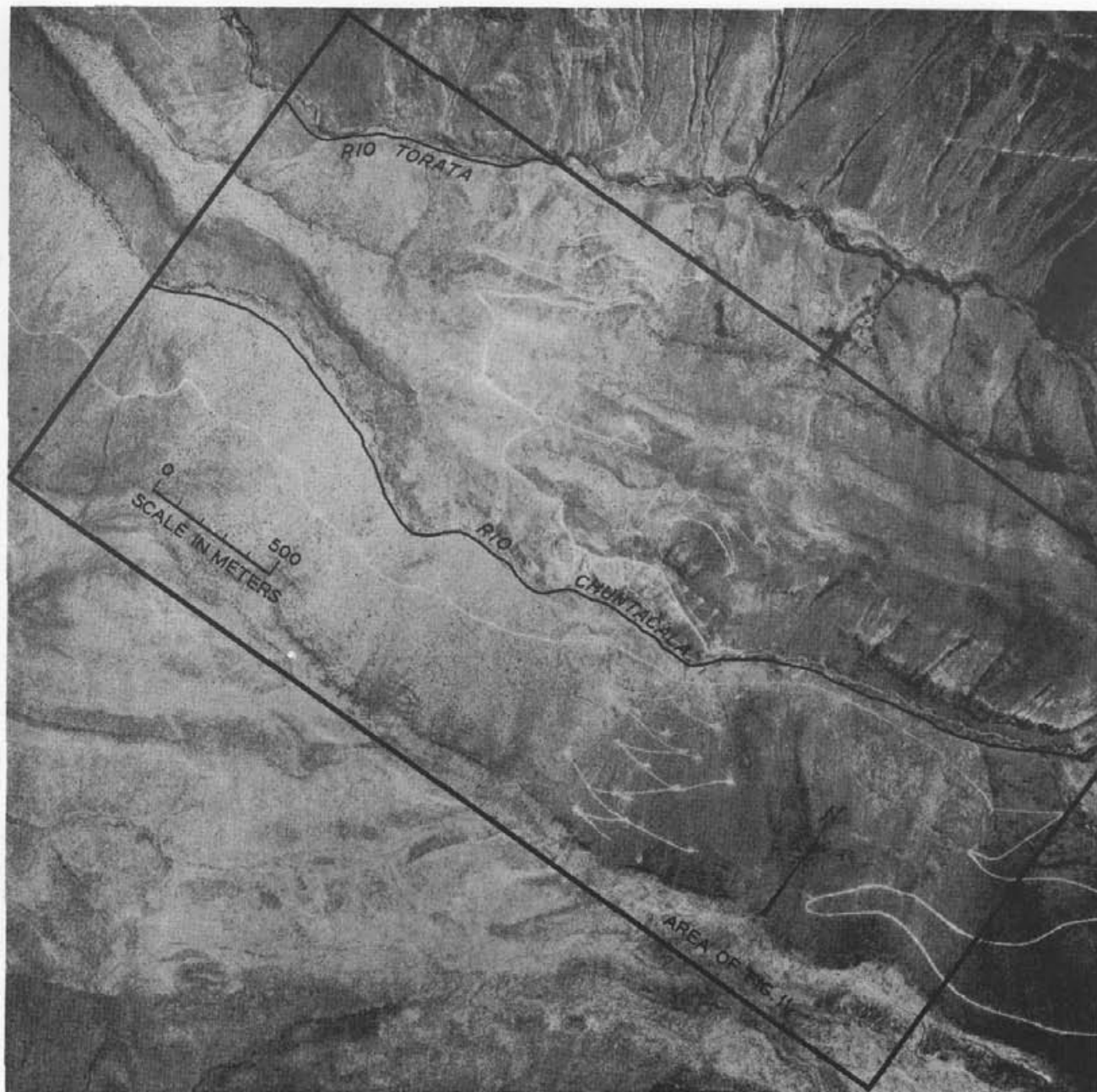


Fig. 11a—Air photo of Cuajene site shows steep hillsides, especially bordering the Rio Torata.

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 Cuajene 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.

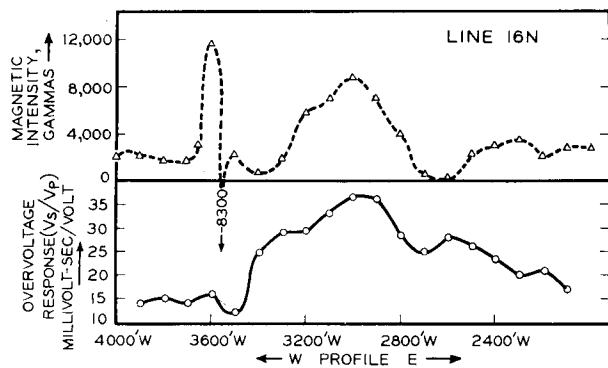


Fig. 13—Magnetic and overvoltage profiles at Engels, Calif. Overtoltage anomaly is attributed to magnetite.

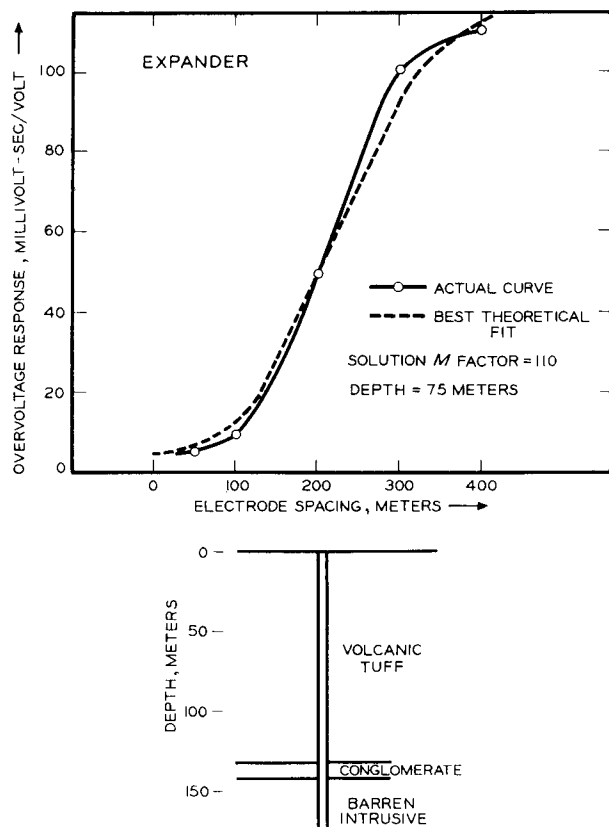


Fig. 14—Unexplained anomaly, Wildcat prospect, Peru.

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 Mayper⁸ 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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* 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*.

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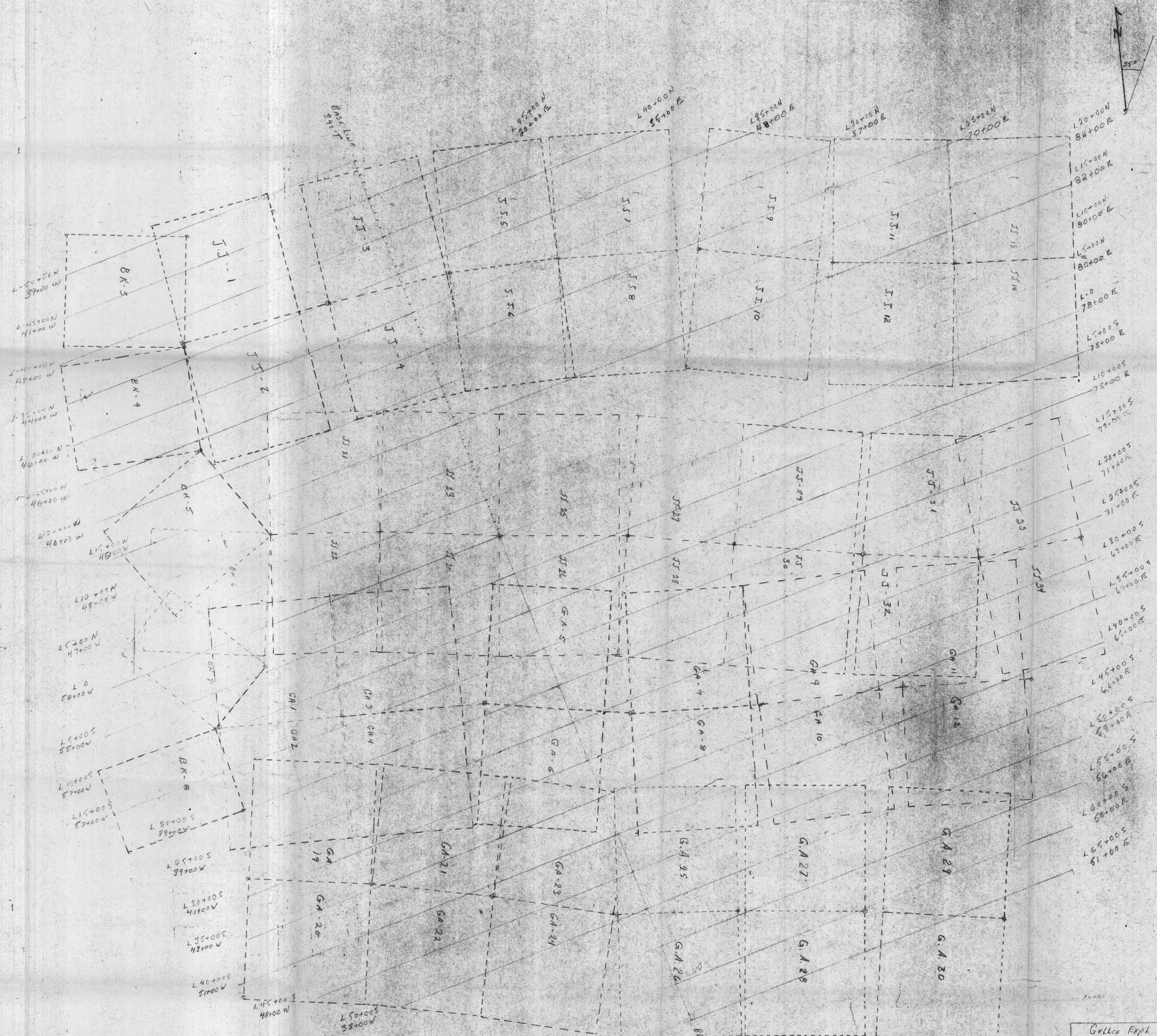
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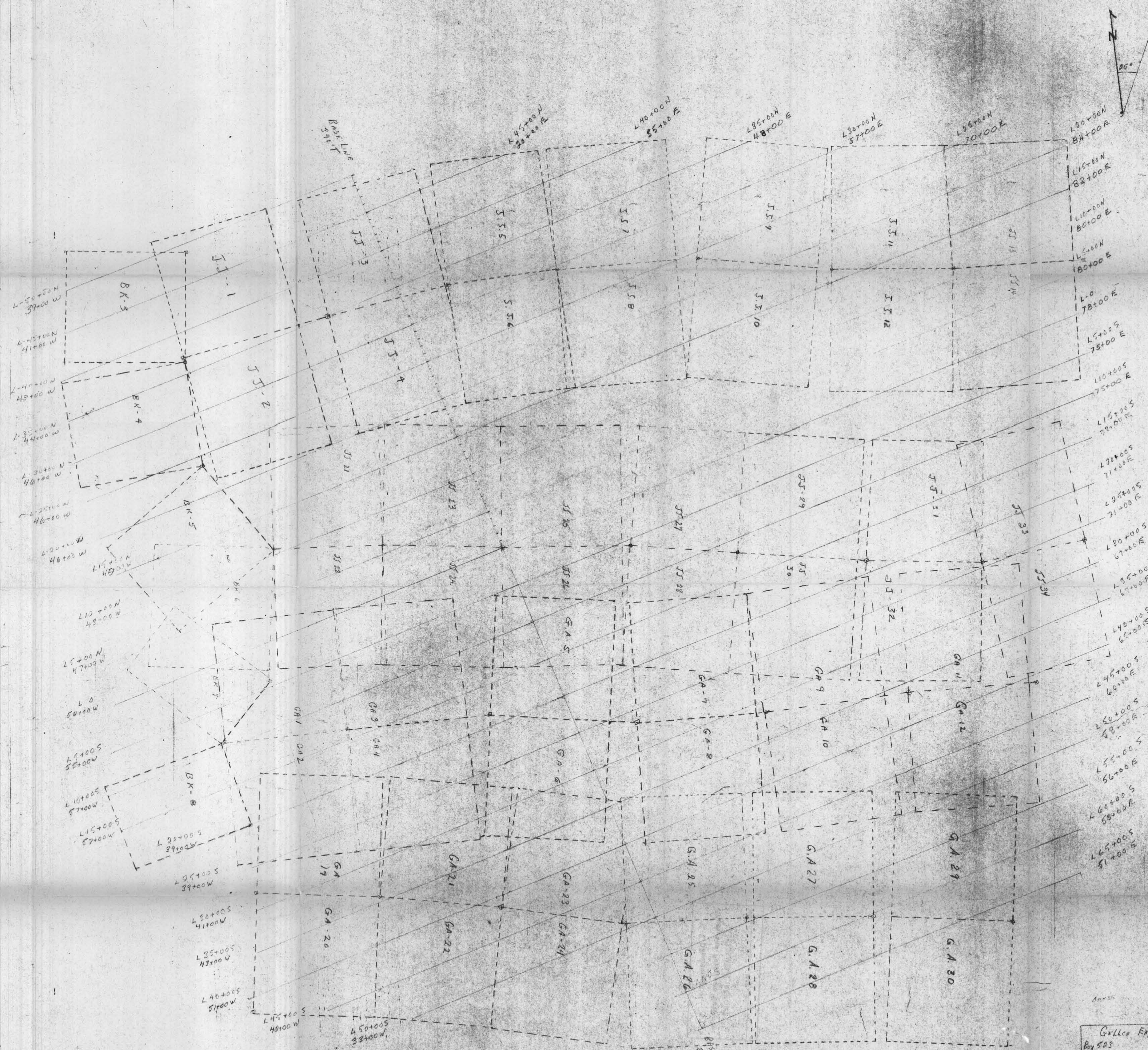


Claim Boundaries
 Picket Intervals
 Chain Posts

Scale 1 inch to 400 feet

Gelco Expl. Ltd
 Box 503 P. 395-4450
 100 Miha House, B.C.
 Grid and Claim Map
 CalTex Minerals Ltd
 G.A., J.J. and B.K. Claims
 Drawn By ERNEST F. NORTH
 Date JUNE 6, 1967
 Checked By GEO. LERCH

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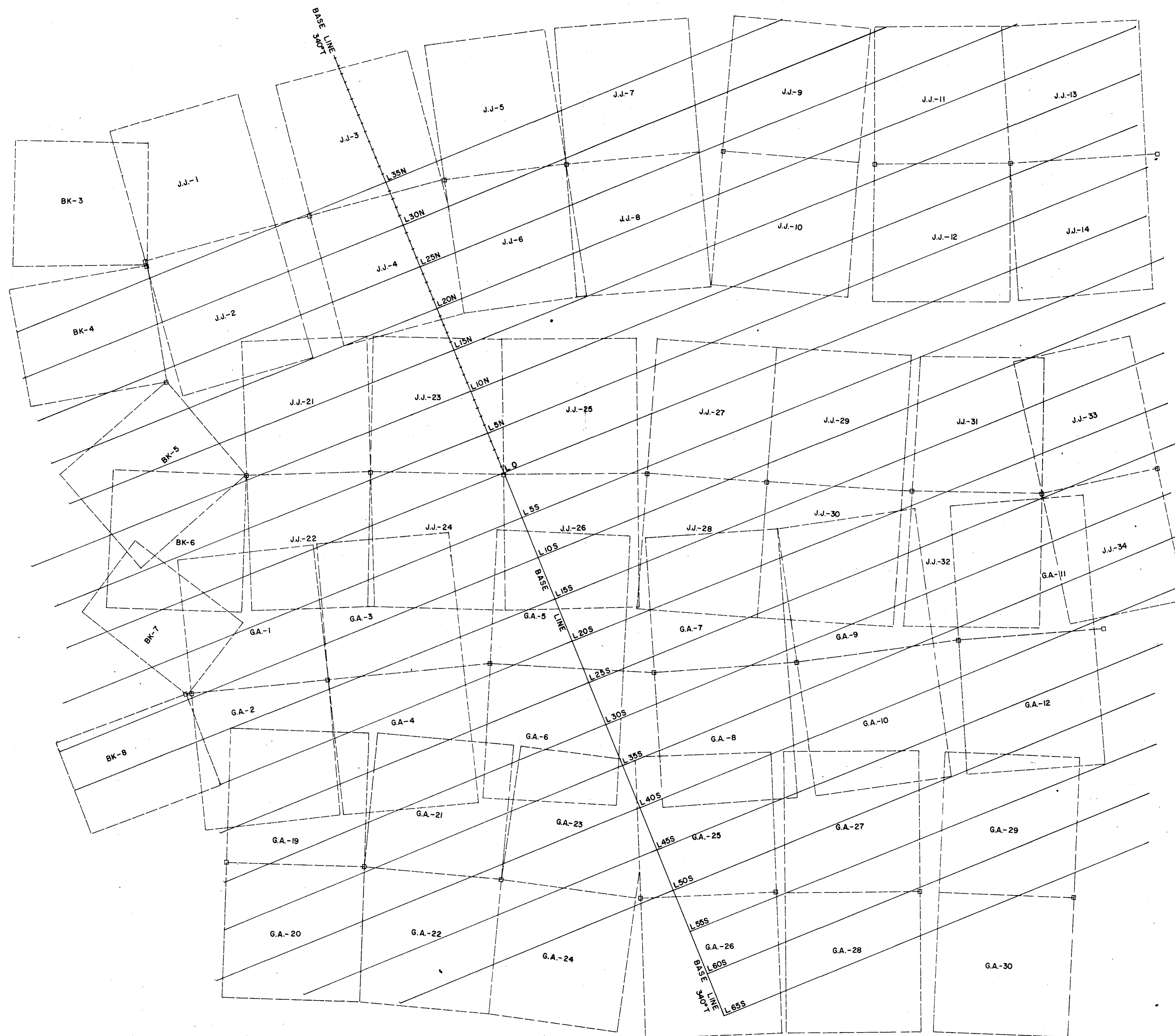


CLAIM BOUNDARIES
 PICKET INTERVALS
 CLAIM POSTS

Scale 1 inch = 500 ft

Gellco Expl Ltd
 Box 503 P395-4450
 100 Mile House, B.C.
 Grid and Claim Map
 CALTH Minerals Ltd
 G.A., J.J. and B.K. Claims
 Drawn By ERNEST E. NORTH
 Date JUNE 6, 1967
 Checked By GEO LERCH

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LEGEND :

CLAIM BOUNDARIES - - - - -
 PICKET INTERVALS + + + + +

Department of
 Mines and Petroleum Resources
 ASSESSMENT REPORT
 NO. 1029 MAP # 1

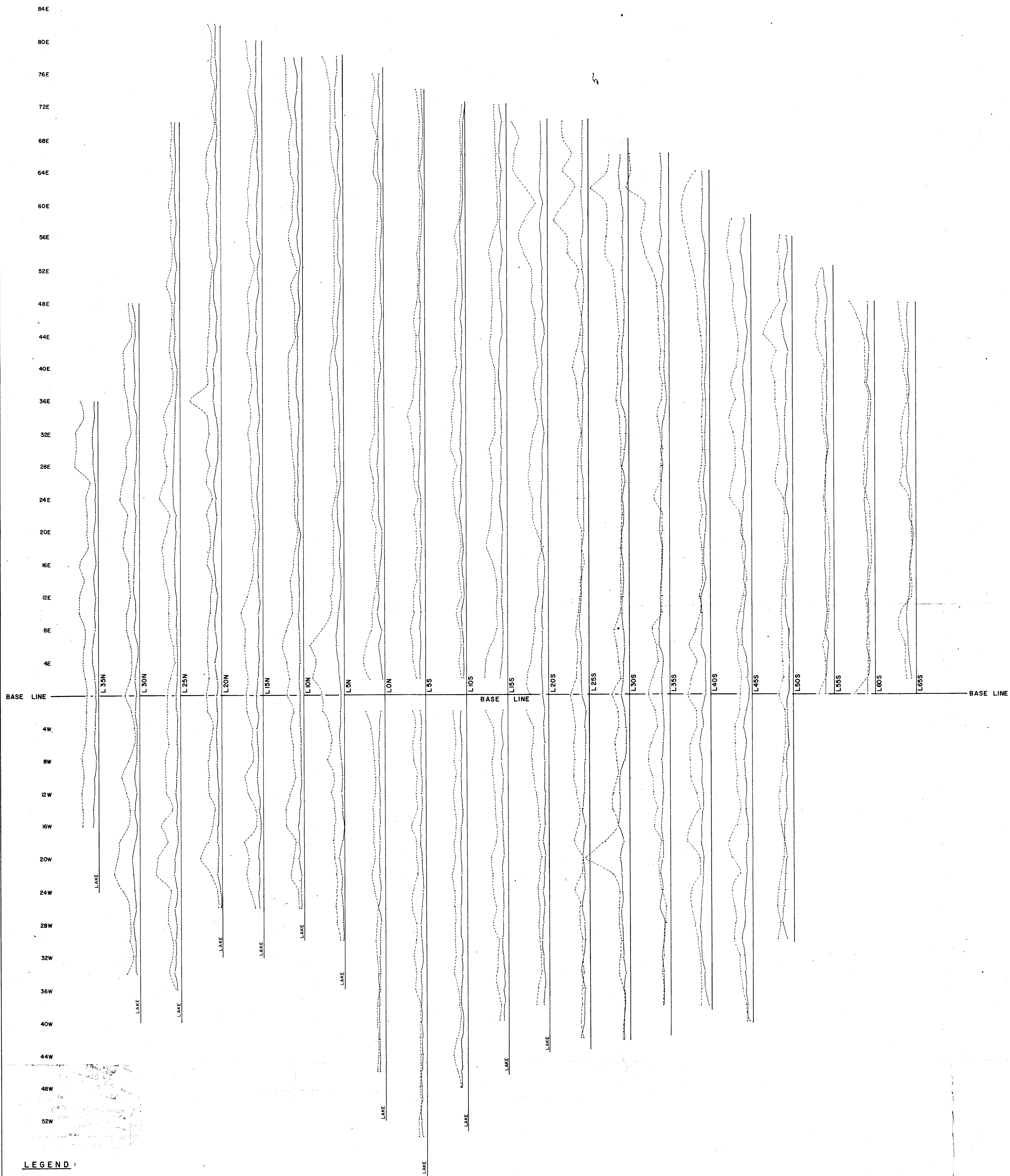
PLATE 2
 CALTA MINES LTD.
 MARGUERITE AREA, BRITISH COLUMBIA
 BAUCHI LAKE PROPERTY
 SURVEY GRID AND CLAIM PLAN



TO ACCOMPANY GEOPHYSICAL REPORT
 BY J.G. BAIRD, JUNE 27, 1967

SCALE: 1" = 500'
 SURVEY BY SEIGEL ASSOCIATES LIMITED
 APRIL TO JUNE, 1967

1029



LEGEND :

CHARGEABILITY : SCALE : 1" = 5 MILLISECONDS
ELECTRODE SPACING : 0 = 400'

RESISTIVITY : SCALE : 1" = 1000 OHM-METRES
ELECTRODE SPACING : 0 = 400'

NOTE : THREE ELECTRODE ARRAY.
ELECTRODE SPACING AS INDICATED

Department of
Mines and Petroleum Resources
ASSESSMENT REPORT
NO. 1029 MAP 1

PLATE 3

CALTA MINES LTD.

MARGUERITE AREA, BRITISH COLUMBIA
BAUCHI LAKE PROPERTY

INDUCED POLARIZATION SURVEY

SCALE : 1" = 400'

1029



TO ACCOMPANY GEOPHYSICAL REPORT
BY J.G. BAIRD, JUNE 27, 1967

SURVEY BY SEIGEL ASSOCIATES LIMITED
APRIL TO JUNE, 1967