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Department of
Mines and Petroleum Resources
ASSESSMENT REPORT
NO. 2919 MAP

REPORT ON
A TURAM ELECTROMAGNETIC SURVEY
TEXADA ISLAND AREA, BRITISH COLUMBIA
ON BEHALF OF
BELLEX MINES LTD. (N.P.L.)

by

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

June 12, 1970

CLAIMS:

Name	Record Numbers
LOYAL and	30584 - 86
PARIS GROUPS	30909 - 12
	29162

LOCATION:
On Texada Island
About 8 miles northwest of Vananda, B. C.
Nanaimo Mining Division
124° 49° NW

DATES:
June 4 to June 11, 1970

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SUMMARY

Some eight line miles of Turam electromagnetic surveying has been carried out. The electromagnetic responses over much of the survey are not anomalous. Abnormal responses near the ends of the grid lines are interpreted to be caused by powerline interference in the west, and the effect of the ocean in the east.

It is possible that some sulphide bodies may underlie the survey area which are either too small in size or contain too little sulphide to provide the electrical interconnectability required for electromagnetic response. Further geophysical exploration employing the induced polarization method may therefore be warranted.

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INTRODUCTION

During the period from June 4 to June 11, 1970, a field party under the direction of Peter Fominoff, B.A.Sc. executed a Turam electromagnetic survey on Texada Island, British Columbia, on behalf of Bellex Mines Ltd. (N.P.L.)

As shown on Plate 1, the survey area is located near Blubber Bay, about 8 miles northwest of Vananda. The topography of the survey area is in places quite rugged and the terrain is covered with underbrush and second growth timber.

The Turam fixed source compensation method was chosen for the electromagnetic survey since, in comparison with other electromagnetic techniques, it is relatively unaffected by orientation errors caused by rough topography, provides deep penetration and allows accurate interpretation of anomalous characteristics. The attached copy of a paper by R. A. Bosschart and H. O. Seigel entitled "Some Aspects of the Turam Electromagnetic Method" describes the equipment, the field procedures, the nature of results and the interpretative procedures involved in this type of survey.

Electromagnetic methods detect massive sulphide bodies by means of measurement of the secondary electromagnetic field produced by eddy currents induced by a transmitted or primary electromagnetic field. The Turam method employs a large closed loop or wire as transmitter, while the field strength ratio and phase difference at two nearby observation points are measured by means of two receiver coils.

The claims covered by the present survey are listed on the cover page of this report and are shown on the accompanying plates on a scale of 1" = 200'. These claims are held by Bellex Mines Ltd. (N.P.L.).

The presence of a subsurface conductor will be indicated by abnormal field strength ratios and phase differences. A typical anomaly will show a correspondence between high values of the field strength ratio and negative phase differences. The depth of burial of the current axis is reflected in the shape of the anomaly, and the ratio of the maximum amplitudes of field strength and phase is a measure of the conductivity/thickness (r/d) ratio of the body.

A base line approximately 0.7 miles in length was laid out oriented due north and grid lines were established perpendicular thereto at 300' separations. The grid lines were approximately 3600' in length and the entire grid totalled approximately 8 line miles.

A Sharpe SE-71 instrument was employed with a receiving coil separation of 100'. Transmitting loops approximately 3600' X 1500' were used and the operating frequency was 400 Hz.

GEOLOGY

The geology of the property has been studied by Mr. John R. Boissoneault, B.Sc., Consulting Geologist, for Bellex Mines Ltd. (N.P.L.) and is the subject of his report.

The claims are underlain by Lower-Jurassic or Triassic limestone of the Marble Bay Formation which is intruded in places by medium to small sized diorite bodies, probably of Cretaceous age. This geological environment has given rise to several magnetite deposits, some containing copper sulphides, which may be sufficiently massive to be electromagnetic conductors. The Texada deposit, currently under production near the southern end of the limestone belt, would be typical of the type of target sought in the present survey.

DISCUSSION OF RESULTS

Plate 2 shows the results of the electromagnetic survey on the scale of 1" = 200'. The parameters plotted in profile form are the field strength ratios on a scale of 1" = 20% and the phase differences on a scale of 1" = 10°.

Both the field strength ratio and the phase shift profiles can be seen to be rather flat and there are very few distortions which are not within the normal response range allowing a certain latitude for the effects of errors caused by rough topography.

Slight field strength ratio decreases, some with and some without corresponding phase shifts, are noted at the east and west ends of most grid lines. On the east side they may be due to survey inaccuracies caused by rough topography and/or by the electromagnetic damping effect of the sea water. On the west side the low field strength ratios are interpreted to be due to powerline interference. Minor distortions near 17 W on lines 33 and 36 S, appear to arise from an iron water pipe.

Distortions of the field strength ratio profiles near the loop locations shown on the map are most likely due to errors in the relative locations of the transmitting loop and receiver, possibly because of rough topography. These errors only arise when the receiver is close to the edge of the transmitting loop.

CONCLUSIONS AND RECOMMENDATIONS

In order to respond to electromagnetic survey techniques sulphide bodies must exhibit conductivities many times higher than normal rocks which usually requires at least 25% by volume of metallically conducting mineralization. Such bodies are termed "massive sulphides". It is possible therefore that mineralized bodies which do not fall into the "massive sulphide" classification may lie undetected within the present survey grid. Further geophysical investigations of this area would be best executed using the induced polarization method which can detect small percentages by volume of metallically conducting mineralization under suitable conditions of body size and depth of burial.

Respectfully submitted,

SEIGEL ASSOCIATES LIMITED

Jon G. Baird

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

Vancouver, B. C.
June 12, 1970

Some Aspects of the Turam Electromagnetic Method

Robbert A. Bosschart
and
Harold O. Seigel

Harold O. Seigel & Associates, Geophysical Contractors and Consultants, Downsview, Ontario

Transactions, Volume LXIX, 1966, pp. 156-161

ABSTRACT

Most electromagnetic methods presently used in mining exploration are of the moving source type; i.e., the primary field source is moved simultaneously and in a fixed configuration with the receiver.

Of the fixed-source methods, which employ a stationary primary field and a moving receiver, the Turam method is the most effective and has marked advantages over alternative electromagnetic methods.

The results are little affected by topographic relief, and a high degree of resolution can be obtained because of the constant relation between source field and investigation area.

Another inherent advantage of the Turam configuration is that it provides more favourable dimensional relations. Thus, the primary field attenuates at a much lower rate than in moving-source configurations and, secondly, the method is size sensitive; i.e., conductor size affects the strength of the response, which is not the case with moving-source methods.

These factors result in a considerably better potential depth penetration.

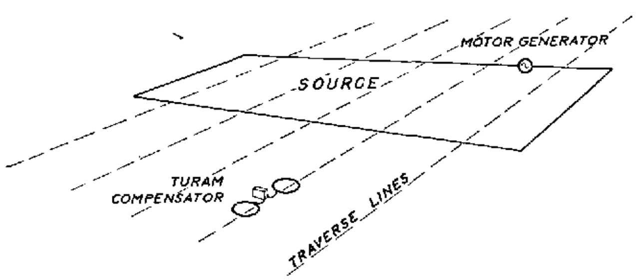

Figure 1.—General layout of the Turam method.

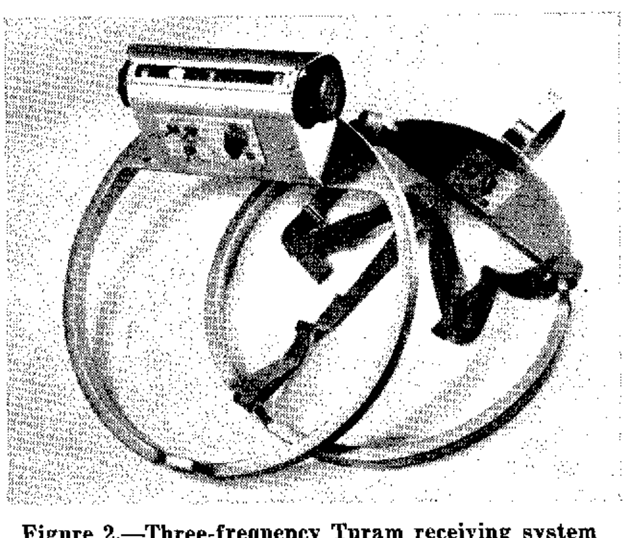

Figure 2.—Three-frequency Turam receiving system (Sharpe SE-700).

Introduction

IN the period following the first world war, Scandinavia became the cradle of geo-electrical prospecting. The Swedish "Tvaram" (Sundberg, 1931) and "Compensator" (Sundberg & Hedstrom, 1933) were the forerunners of the large majority of present-day electromagnetic methods. From the Compensator method were derived, in quick succession, the "Turam" (Hedstrom, 1937) and the "Slingram" (Hedstrom, 1945) methods. Both techniques are still being used in virtually unmodified form, although the "Slingram" has been adapted to a variety of airborne applications and has, in the course of time, assumed a confusing array of pseudonyms, such as "Loop Frame," "Horizontal Loop," "E.M. Gun," "Minigun," "Ronka," "Magniphase," etc., as well as a number of names for the airborne adaptations. The Slingram-derived methods are characterized by a constant transmitter-receiver configuration, which is moved over the target area. They are called "Moving Source Compensation Methods."

The Turam method has been in active use since its development in 1932. In principle, it comprises a fixed transmitting layout of large dimensions and a moving receiver system which measures the gradients of phase and amplitude of the induced electromagnetic field. The coupling between the field source and a conductor, which is variable in the moving-source systems, is constant in the Turam or related configurations, resulting in a response of a somewhat different character. Therefore, a distinction is made between "Fixed Source" and "Moving Source" Compensation methods.

A typical Turam layout (*Figure 1*) consists of a rectangular transmitting loop of insulated wire with sides several thousand feet long, to which alternating current of one or more frequencies between 10^2 and 10^3 c.p.s. is fed by a gasoline-engine-driven alternator. The receiver system embodies two induction coils, carried at a constant separation (e.g., 100 ft.) and connected to a compensator which measures the intensity ratio and the phase difference between the fields received by the two coils.

As a rule, profiles are measured outside the transmitting loop, perpendicular to the long axis of the loop and not exceeding the length of the short axis.

The intensity of the induced primary field depends on the size and shape of the transmitting loop and the location of the observation point. The free air field strength ratios between stations successively occupied by the receiving coils are determined by calculation, and the observed ratios are normalized through division by these values. The presence of secondary fields is characterized by abnormal field strength ratios and phase differences.

Although in practice Turam measurements are, because of the light, mobile receiving system (*Figure 2*), made rapidly (at the rate of 3 to 6 miles per day), a change of primary layout at least each alternate day is required under average conditions. In order to maintain this rate of coverage, a crew of four men is employed—two to measure and two to lay out and recover loops. In terms of line miles per man-day, the Turam method is therefore rather less efficient than the moving-source methods. On the other hand, it has specific advantages in results over the latter, as will be shown below.

Quantitative Interpretation

When a block of ground is energized by means of an alternating electromagnetic (E.M.) field, the resulting field at the surface is, when conductors are present, elliptically polarized. This is because the secondary fields are phase-shifted relative to the primary field. With methods measuring a geometrical component (e.g., Vertical Loop E.M. methods), field ellipticity has the effect of blurring the observations; i.e., instead of a precise angle of zero induction a "null width" of minimum induction is obtained, and this null width widens with increasing phase shift. As a result, such methods may become less definitive in the presence of medium to poor conductors, such as conductive overburden or relatively disseminated mineralization.

A major advantage of Compensation methods is that phase shifts are compensated and field components can be measured accurately, independent of the degree of field ellipticity. Moreover, two related components are usually measured (either phase and amplitude, or in-phase and out-of-phase components), which greatly diminishes the possibility of obtaining spurious anomalies, and, more importantly, because the relation between these components depends on the conductor characteristics, renders possible a quantitative interpretation of the obtained data.

In recent years, much work has been done to investigate the response of mathematical or reduced-scale models of geological conductors in moving-source or fixed-source configurations and so provide a basis for the quantitative interpretation of field data (Wait, 1952, '53, '60; West, 1960; Hedstrom & Parasnis, 1958; Paterson, 1961; Bosschart, 1961, '64). As a result, some conductor characteristics can often be closely enough determined to discriminate between anomalies arising from potential ore conductors and those arising from electrolytic conductors (overburden, weathered shear zones, etc.) and the conducting bodies, even at considerable depth, can be accurately located for diamond drilling. The possibility of assigning significance to anomalies on the basis of amplitude ratios rather than on amplitude strength, and giving precedence to weak anomalies among larger and stronger ones, in itself signifies a considerable extension of the capabilities of these methods.

The response of conductors, calculated theoretically or observed in model experiments in a particular measuring configuration, are usually presented in the form of response diagrams showing a set of two curves which represent the variation of peak amplitudes of the in-phase and out-of-phase components with the variation of a response parameter. The latter includes, in some form, the exciting frequency and the relevant conductor characteristics. For instance, for an infinite sheet the response parameter may be written as $\lambda = 10^3 \frac{r}{fd}$, in which r = resistivity in ohm-cm, f = frequency, and d = thickness in m.

Such a diagram, representing the response of a medium-size tabular conductor (1000 ft. strike length) in a Turam configuration, is shown in *Figure 3A*. The straight line marked Q is the in-phase to out-of-phase ratio. This ratio varies with the response parameter and the strike length and thus gives, for a determinate frequency, a value for the resistivity/thickness ratio of the conductor. The validity of this particular diagram is limited to the specified strike length, but it illustrates the general relations. As they show the relation between the relative amplitudes of the response and the frequency, an important function of such diagrams is to indicate how anomalies caused by bodies of different conductivity can be emphasized or de-emphasized by changing the exciting frequency. An example of this application is described below.

In some areas, the overburden is both conductive and of irregular configuration and thickness. At standard prospecting frequencies, the strong field distortion arising from this condition could mask the response of underlying conductors, even when these would have appreciably better conductivity. In *Figure 3B-1*, an example of extreme overburden distortion at a frequency of 800 c.p.s. is shown, with anomalies as strong as 40 per cent field strength ratio (R) and a 24-degree phase difference (P). The same traverse at a frequency of 200 c.p.s. is shown in the bottom profile. The field strength anomaly has almost disappeared; from 40 per cent it has decreased to 4.5 per cent. The phase difference is down to 7.5 from 24 degrees. When these results are compared with the response diagram (*Figure 3-1*) they appear to be entirely predictable. The overburden anomalies have a r/d value of approximately 50 ohm-cm./m. and thus λ equals 62 ohm-cm.sec./m. at 800 c.p.s. and 250 ohm-cm.sec./m. at 200 c.p.s. As the curves show, the in-phase component drops 80 per cent and the out-of-phase component 60 per cent with the change of λ from 62 to 250 ohm-cm.sec./m. This example shows that the overburden response can be drastically reduced by lowering the frequency. The process would, however, be futile if the response from underlying better conductors would be proportionally decreased. With the use of properly selected exciting frequencies, however, this is not the case; for a good conductor with, say, an r/d value of 1.5, the change in frequency would represent a change from $\lambda = 2$ to $\lambda = 8$, with a corresponding drop of the in-phase amplitude of only 25 per cent and an actual gain in out-of-phase amplitude of 75 per cent (*Figure 3A-2*).

Under 200 ft. of cover, this conductor might (subject to size and over-all geometry), at a frequency of 800 c.p.s., give rise to a 22 per cent in-phase and a 4 per cent out-of-phase anomaly (approximately 20 per cent field strength ratio, 2.5 degree phase difference) *(Figure 3B-2)*, and would be difficult to distinguish from the 800-c.p.s. overburden noise shown in *Figure 3B-1*. At the lower frequency, the anomaly would be 17 per cent in-phase and 7 per cent out-of-phase (15 per cent field strength ratio, 5-degree phase difference), and it would stand out clearly from the reduced overburden response.

Potential Depth Penetration

In assessing the capabilities of electromagnetic methods, the effective depth penetration is among the most important factors to consider. It can be defined as the maximum depth at which the response of conductors of potential economic interest can be clearly distinguished from electromagnetic fields arising from other sources.

An examination of the descriptions of some fifty producing orebodies on the Canadian and Baltic Pre-cambrian shields shows that the large majority are steeply dipping, lenticular or tabular bodies of concentrated sulphides, with strike lengths varying from 300 to 3,000 ft. *(see Figure 4A)* and depth extensions, where known, of a comparable order of of magnitude. An example of the response of good conductors within this size range in typical moving-source and fixed-source configurations is shown in the same diagram *(Figure 4B)*. The conductor is a tabular body of good conductivity (λ = 10.3 ohm-cm.sec./m.) at a depth of 60 ft. The strike length and height have been increased simultaneously from 10^2 to 10^4 feet. It can be seen that, up to a strike length of 400 ft.,

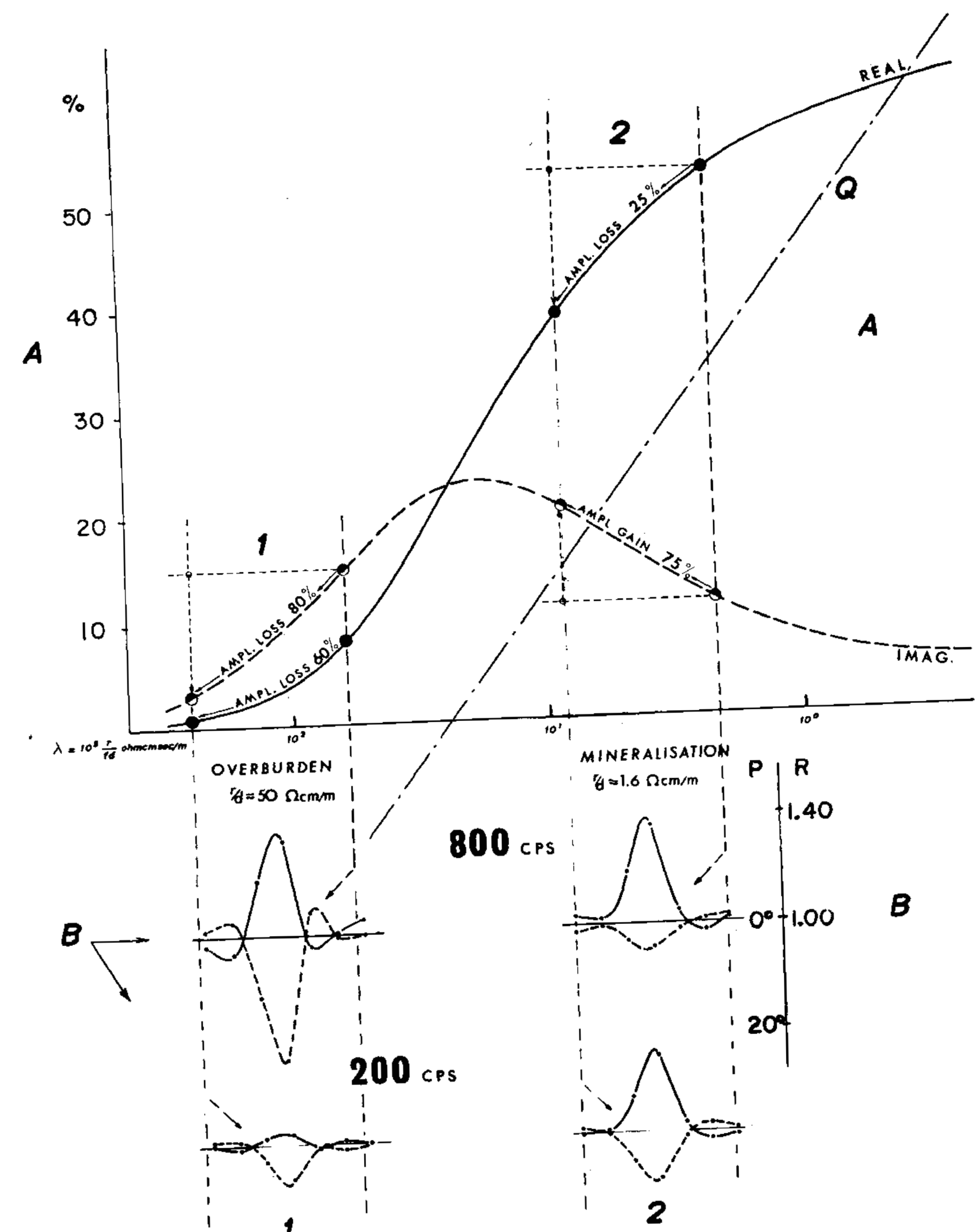

Figure 3.—Response of a thin, medium-size tabular conductor (1000-ft. strike length) in a fixed-source measuring configuration.

the response in both configurations is comparable. In the moving-source configuration (Horizontal Loop), a further increase in size results in very little gain in the response. Saturation is reached at a strike length of 600 to 800 ft.

In the fixed-source (Turam) configuration, the response shows its steepest gain where the moving-source response flattens off; for an increase in strike length from 300 to 3,000 ft., the fixed-source response increases from 6 per cent to 80 per cent, or

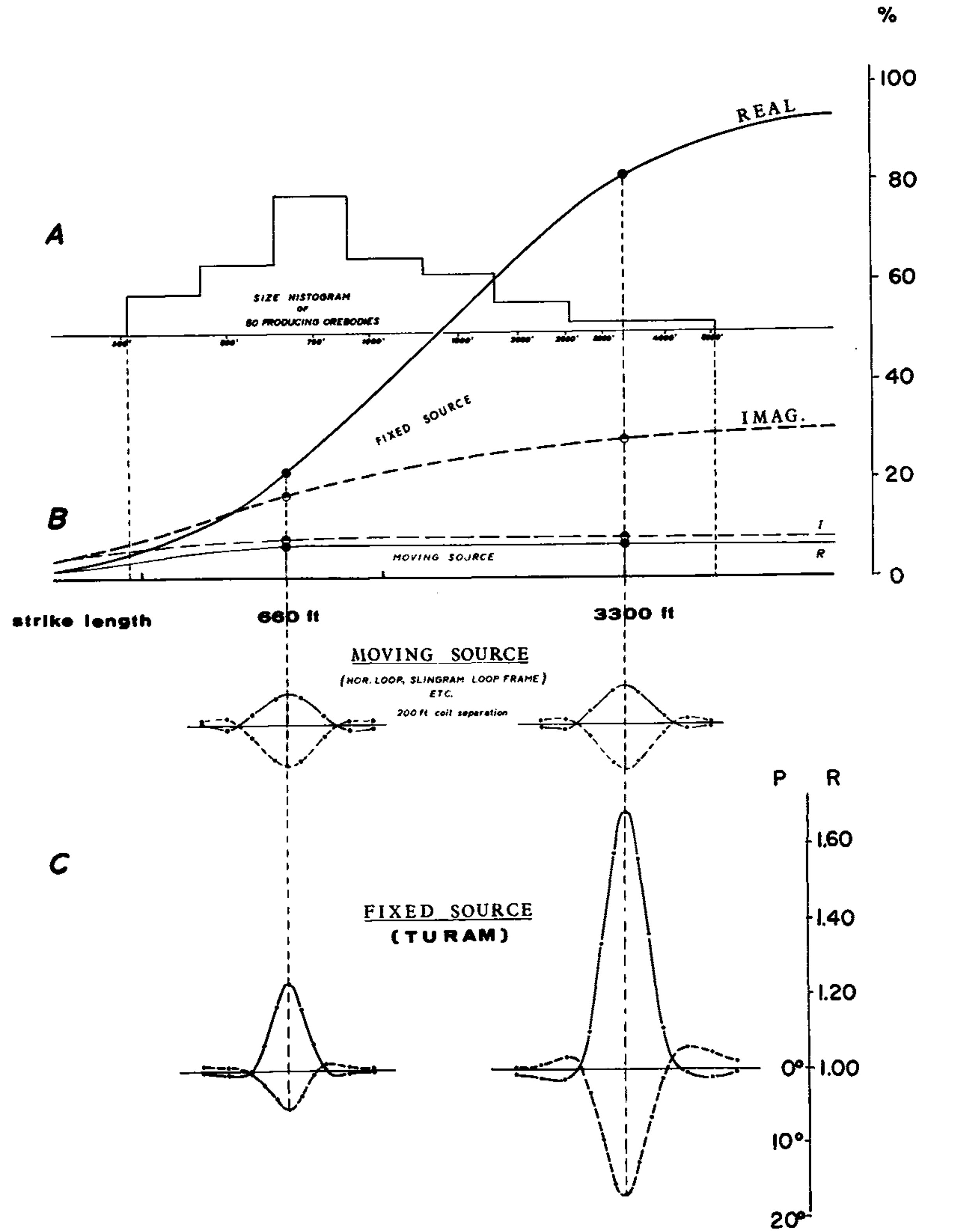

Figure 4.—A comparison of the response of conductors of varying size in moving-source and fixed-source measuring configurations.

more than 13 times, whereas the moving source response increases from 4 per cent to 7.5 per cent, or by a factor of less than 2.

In practical terms, this means that size has a negligible effect on the detectability of a conductor in a moving-source configuration, but contributes materially to its detectability in a fixed-source system. The larger the body, the greater the depth at which it can be found with the Turam method. A major reason for the observed difference in potential depth penetration of the two types of configuration is the different rate of fall-off of the response of bodies of the shapes and dimensions discussed above.

For moving-source configurations, this question has been examined by Hedstrom & Parasnis (1958). In a diagram, for instance, they show the variation of the response of a 2,000 by 2,000 ft. sheet conductor of good conductivity (λ = 4 ohm-cm.sec./m.) with the depth. *(Figure 5)*. Between depth to coil separation ratios of 0.2 and 0.8 the rate of fall-off increases from the 1st to the 5th power of the depth. In ground surveys, where the in-phase noise level is, under average conditions, rarely less than 2 per cent, a discernable anomaly will thus have to have an in-phase amplitude of at least 4 per cent. As the diagram shows, the response falls below this value at a depth to coil separation ratio of 0.57. At 300 ft., which is the largest separation practical, the potential depth penetration is therefore less than 170 ft.; at the standard 200 ft. separation, it is less than 115 ft.

The variation with depth of the response of a smaller conductor (1,000 by 1,000 ft) of comparable conductivity (λ = 3.5) in a Turam configuration is shown in *Figure 6*. To a depth of 200 ft. the response falls off at a rate of less than the 1st power; to depths of well over 600 ft., it falls off at a rate of less than the 2nd power.

At a 600-ft. depth, the in-phase amplitude is still better than 4 per cent. For a 2,000 by 2,000-ft. body, it would be approximately 6 per cent, and, with a further increase in size, it could reach 8 per cent. The potential depth penetration can thus be conservatively estimated to be 600 ft.

Figure 7 is a field example of a 400-c.p.s. Turam traverse over two steeply dipping mixed graphite and sulphide conductors under 340 ft. of overburden (Timmins area). The field strength ratio anomaly of the strongest conductor is 23 per cent, which is approximately three times stronger than the field strength ratio anomaly of the smaller conductor shown in *Figure 6* at the same depth of burial. This example indicates that the present body could be found at much greater depth and that the estimate of the potential depth penetration, based on the smaller body, is indeed conservative. It may be noted that the in-phase response in a moving-source system (300 ft. coil separation) would be less than 1 per cent and that the body would be undetectable with such a method.

Effect of Topographic Relief

Neglecting external sources, the noise level of moving-source compensation methods is strongly dependent on the coupling between transmitter and receiver; i.e., if the configuration is not rigidly maintained during operation, spurious in-phase anomalies result. For instance, an error of 5 per cent in the

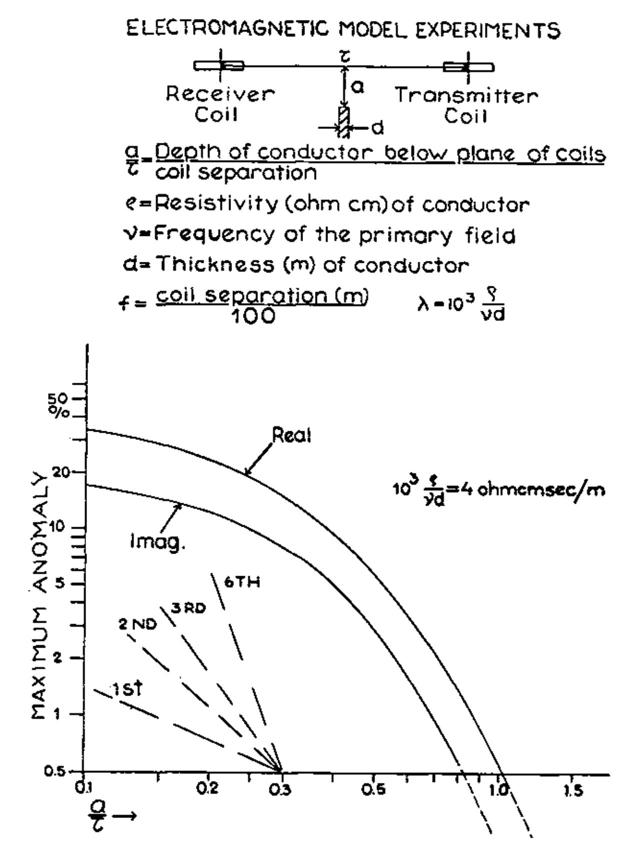

Figure 5.—Variation of the response with depth of a thin tabular conductor of infinite strike length in a moving source configuration.
(Hedstrom and Parasnis, 1958).

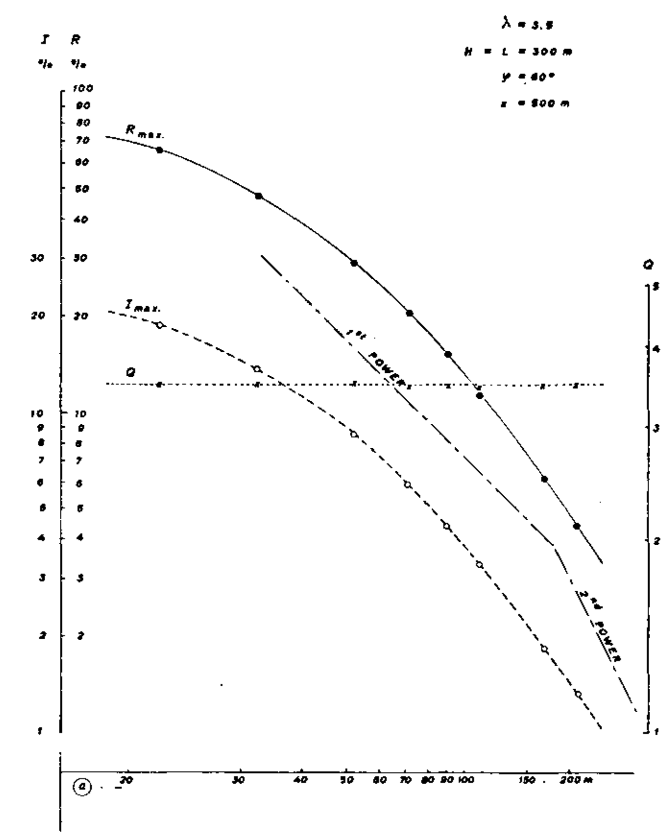

Figure 6.—Variation of the response with depth (a) of a thin tabular conductor of finite strike length (1000 ft.) in a fixed-source measuring configuration.

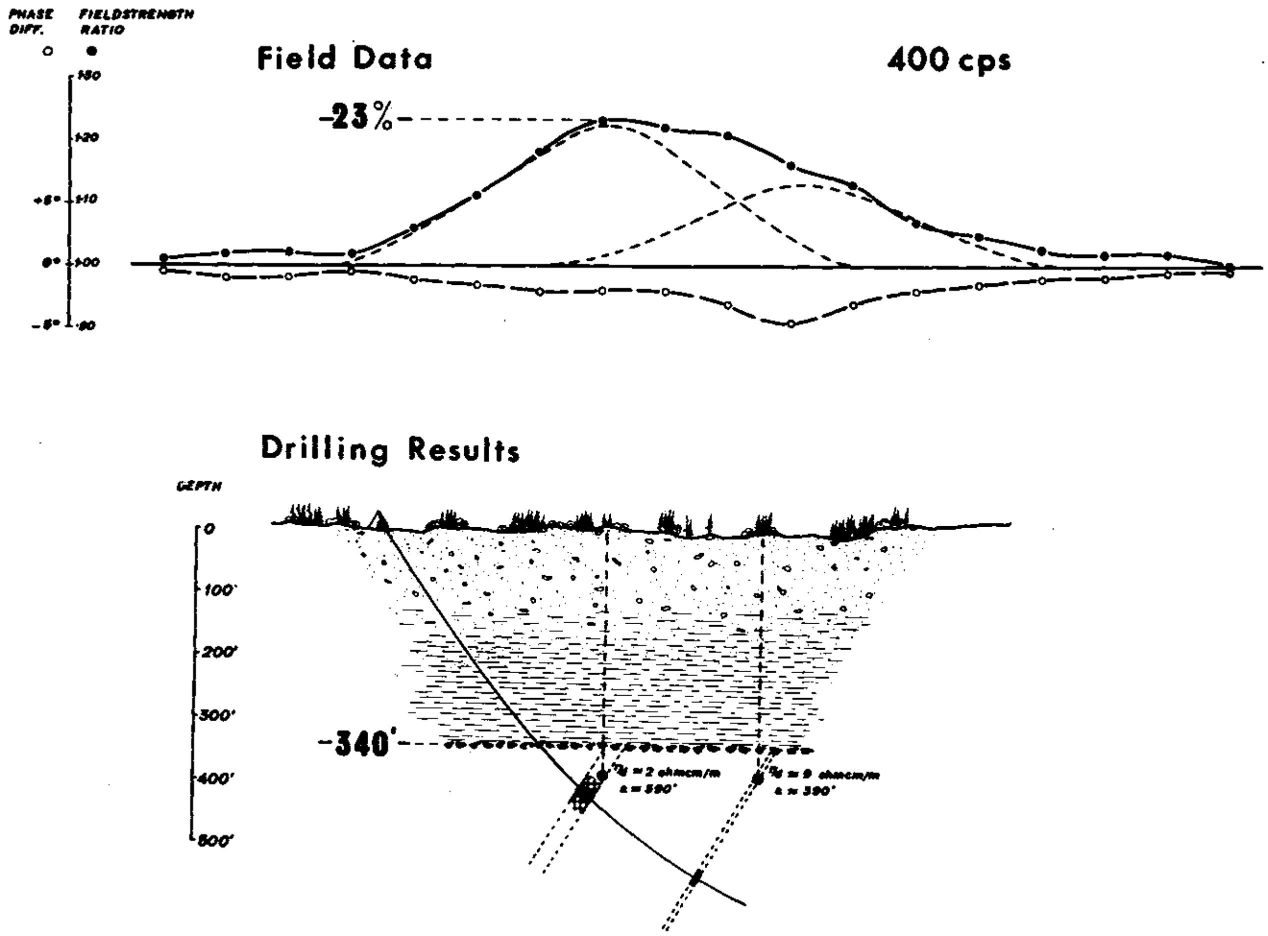

Figure 7.—Turam traverse over deeply buried conductors in the Timmins area.

coil separation causes a change of 15 per cent in the in-phase component. In the presence of secondary fields, both components are affected. Elevation differences between the coils produce a comparable effect. As a result, these methods become impractical in areas of appreciable topographic relief.

With the Turam system, a 5 per cent error in coil separation causes a change of 2 per cent at a distance of 300 ft. from the source, 0.5 per cent at 500 ft. and 0.2 per cent at 1000 ft. The effect of elevation differences between coils is, because the field at the surface is predominantly vertical, even smaller.

The effect of terrain relief on the measurements is therefore negligible, except in areas of very rugged topography. Moreover, where corrections are required, they can be made, because of the fixed relation between source and terrain, in a simple and straightforward manner.

Conclusions

In the foregoing, those aspects of the Turam method that have marked advantages over alternative methods have been stressed. It is, at present, the most powerful electromagnetic prospecting tool at our disposal.

It is also a rather elaborate method and therefore does not necessarily represent the most efficient approach under all circumstances.

In areas of thin cover and level topography, systematic surveys may, for instance, be done more economically with moving-source compensation methods. Also, for fast ground follow-up of airborne electromagnetic surveys, where the problem is usually confined to determining the accurate location of preselected anomalies, methods measuring geometrical components will yield the desired information more rapidly and at less expense.

The proper field of application of the Turam method lies where conditions are more difficult and the requirements severe; in particular in cases where a high degree of discrimination between conductors is desired, where the depth of overburden limits the use of other methods or where appreciable topographic relief occurs.

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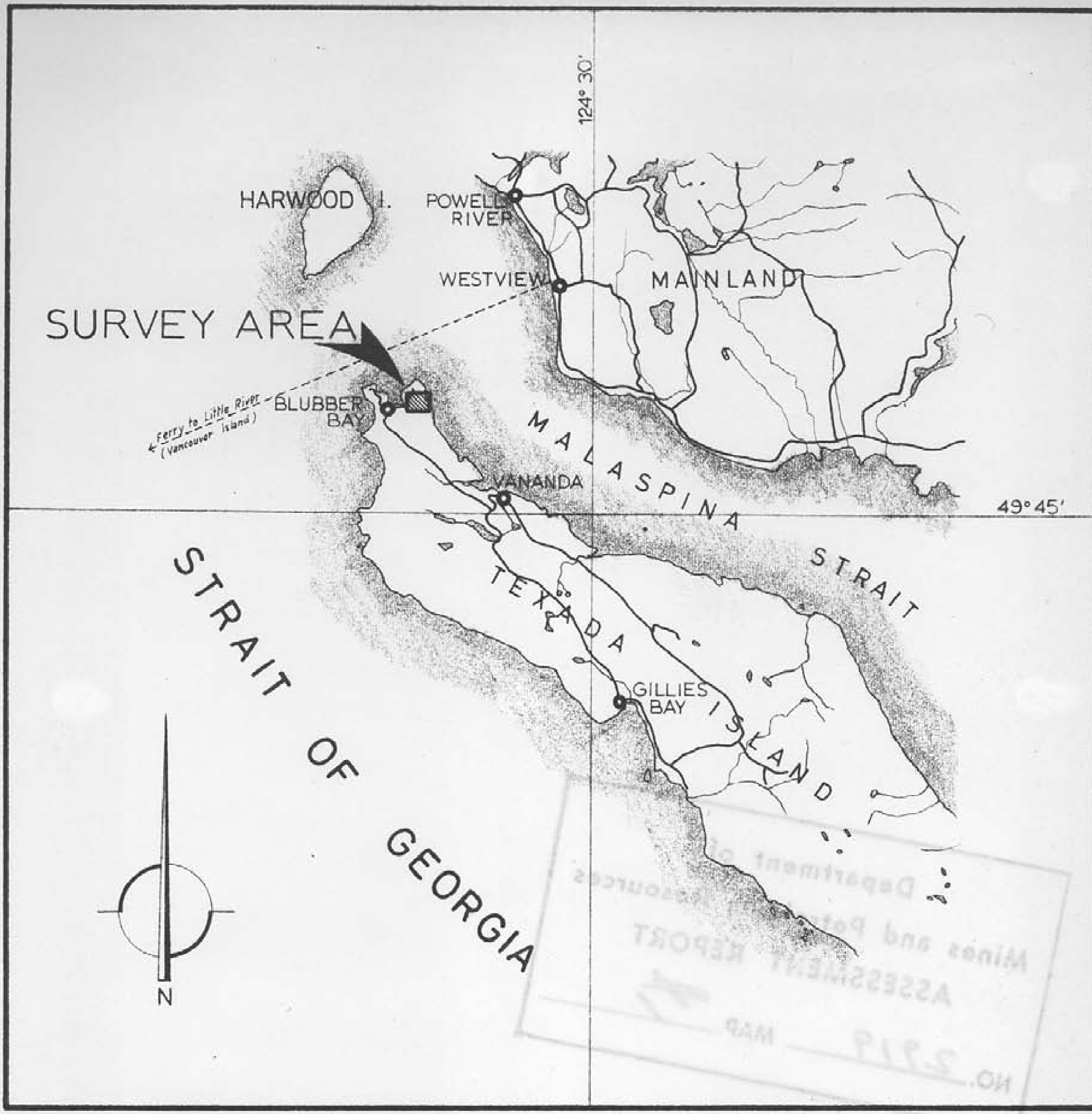
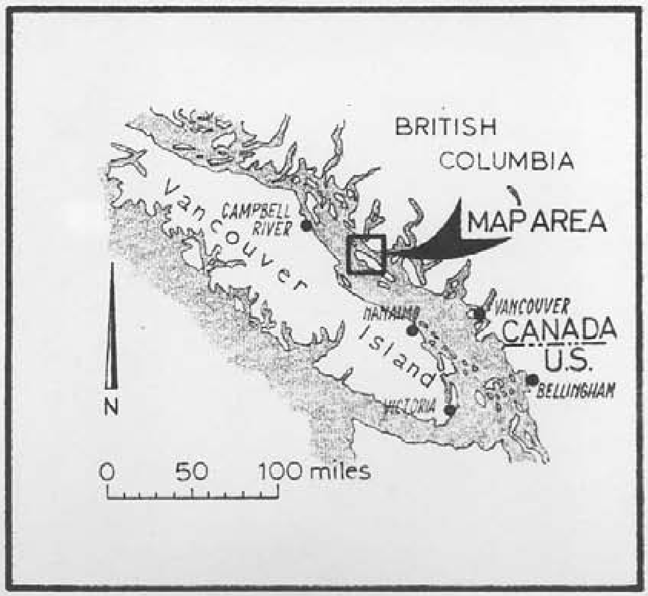




BELLEX MINES LTD. (N.P.L.)

LOCATION MAP

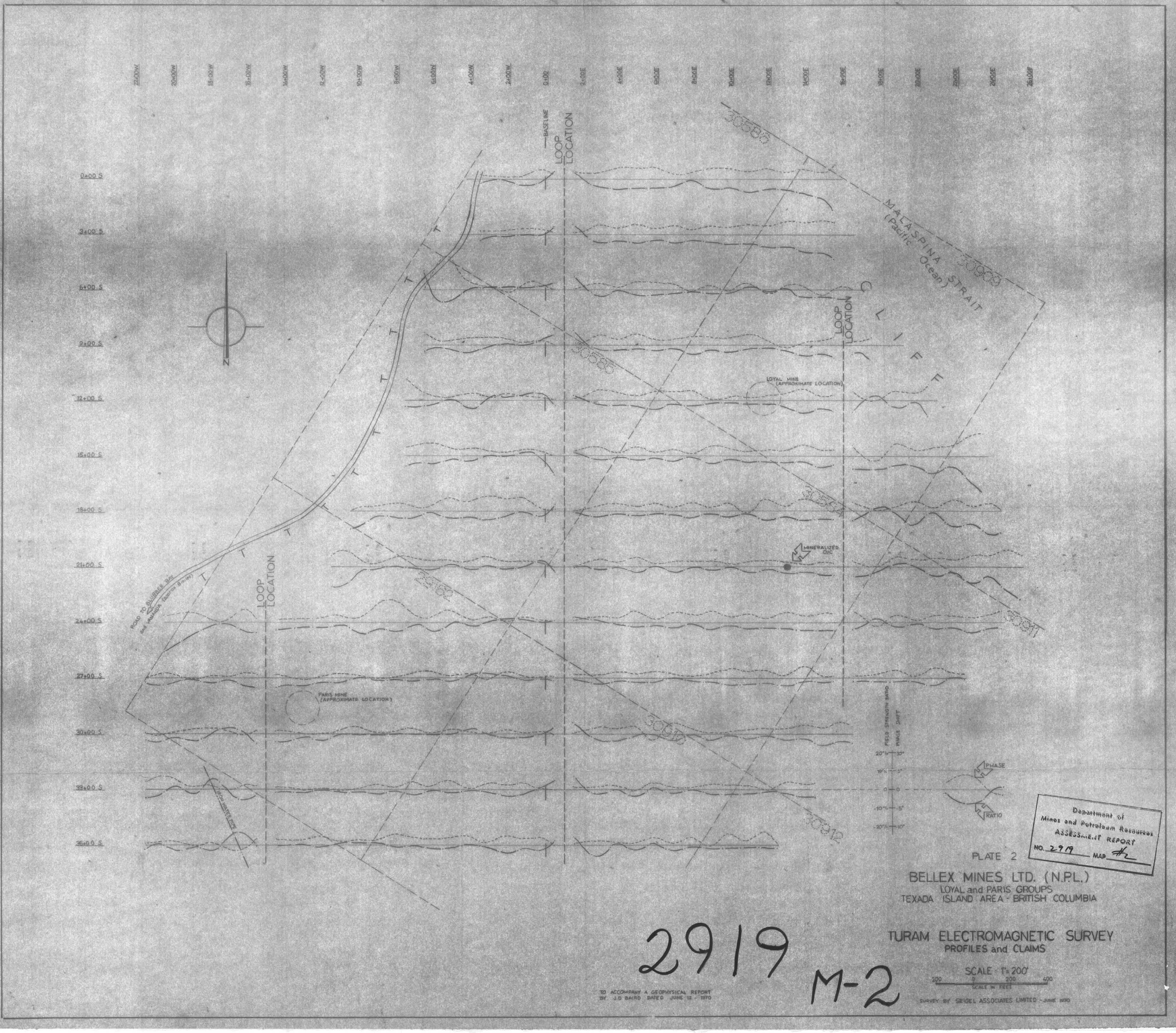
TURAM ELECTROMAGNETIC SURVEY

TEXADA ISLAND AREA - BRITISH COLUMBIA

5 0 5 miles

Survey by
SEIGEL ASSOCIATES LIMITED
June 1970

PLATE 1



MALASPINA STRAIT
(Pacific Ocean)
CLIFF
BASELINE
LOOP LOCATION
LOYAL MINE (APPROXIMATE LOCATION)
PARIS MINE (APPROXIMATE LOCATION)
MINERALIZED O/C
FIELD STRENGTH RATIO
PHASE SHIFT
PHASE
RATIO
0+00 S
3+00 S
6+00 S
9+00 S
12+00 S
15+00 S
18+00 S
21+00 S
24+00 S
27+00 S
30+00 S
33+00 S
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30586
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Department of
Mines and Petroleum Resources
ASSESSMENT REPORT
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PLATE 2
BELLEX MINES LTD. (N.P.L.)
LOYAL and PARIS GROUPS
TEXADA ISLAND AREA - BRITISH COLUMBIA
TURAM ELECTROMAGNETIC SURVEY
PROFILES and CLAIMS
SCALE: 1" = 200'
SCALE IN FEET
SURVEY BY SEIGEL ASSOCIATES LIMITED - JUNE 1970
TO ACCOMPANY A GEOPHYSICAL REPORT
BY J.G. BAIRD DATED JUNE 12 - 1970
2919
M-2