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SUMMARY

During the period March 27th to April 5th, 1969, Seigel Associates Limited carried out a Turam Electromagnetic Survey on behalf of United States Smelting, Refining and Mining Company, in the Hurtubise Township, Ontario.

The survey on Grids 1A and 1B show numerous randomly distributed anomalies reflecting localized sources of relatively good conductivity. These anomalies likely reflect overburden conduction and hardly warrant further consideration.

A series of well developed parallel anomalies were outlined on Grid 2. These likely reflect a banded formational conductor. One exploratory diamond drill hole has been tentatively recommended to sample this zone.

REPORT ON A TURAM ELECTROMAGNETIC SURVEY
HURTUBISE TOWNSHIP, ONTARIO
ON BEHALF OF
UNITED STATES SMELTING, REFINING AND MINING COMPANY

INTRODUCTION

During the period March 27th to April 5th, 1969, Seigel Associates Limited carried out a Turam Electromagnetic Survey in HURTUBISE TOWNSHIP, Ontario, on behalf of United States Smelting, Refining and Mining Company. The survey crew was directed by Mr. Peter Sztuke.

The survey was conducted over three grids designated Grids 1A, 1B and 2 as shown on Plate 1. Access to the area is by bush plane or helicopter from Iroquois Falls. Traverse lines were oriented east-west in Grids 1A and 1B and north-west in Grid 2. They were spaced 400 ft. apart and picketed at 100 ft. intervals. Readings were taken over a total of 18 line miles.

The purpose of the present survey was to follow-up, on the ground, airborne electromagnetic anomalies which were obtained by Questor Surveys Ltd. using the Barringer Input System.

THE TURAM ELECTROMAGNETIC METHOD

A detailed description of the Turam method is given in Appendix "T" and in the accompanying paper entitled "Some Aspects of the Turam Electromagnetic Method".

The Turam results permit accurate determinations to be made of the conductivity thickness parameters, which form the basis of conductor discrimination. The turam method is not affected by topographic variations and it has a better potential depth penetration than other present day electromagnetic systems.

In this survey a Scintrex SE-700 three frequency solid state Turam unit was employed. A primary excitation frequency of 400 Hz was utilized over the Hurtubise grids. Readings were taken at 100 ft. intervals.

Primary loop dimensions and locations are shown on Plate 1.

PRESENTATION OF RESULTS

The results of the Turam electromagnetic survey are shown, in profile form, on Plates 2 and 3 on the scale of 1" = 200 ft. The observations are plotted at the midpoint between (receiving) coils. Field strength ratios and phase differences have vertical scales of 1" = 20% and 1" = 10° respectively. Whenever possible, the interpreted resistivity/thickness (r/d value) has been marked for the different anomalies as well as the depth to the current axis. The latter is located well below the upper part of the conductor and the values should be considered maximum depths.

Plate 2 refers to Grids 1A and 1B; Plate 3 refers to Grid 2.

DISCUSSION OF RESULTS

Grids 1A and 1B were laid out over a series of 2nd and 3rd channel input anomalies.

The Turam electromagnetic results show numerous anomalies in a random pattern, all of which indicate localized sources of relatively good conductivity. The general character of the response, their distribution and coincidence with river patterns in low ground suggests overburden conduction. They do not seem to warrant further consideration.

Plate 3 - Grid 2 - Hurtubise Township

Grid 2 was cut to cover a weak northeasterly trending Input anomaly. The Turam electromagnetic survey shows a series of parallel conductors (about 1500' south of the Base Line) striking across lines 8E to 16W inclusive, and possibly extending as far as Line 24E. The indicated conductivities are mostly excellent, particularly of the two strong anomalies on Lines 0 and 4W. ($r/d < 1$ ohm cm/m). The indicated depth of the current axis varies from 100 to 120 ft. The main conducting zone appears to correspond to the INPUT anomaly. It could represent a narrow, high conducting zone in a banded formational conductor. If this conductor occurs in a geologically favourable location, it would merit further work. It could be sampled by means of the following drill hole:

(1) Collar at 1250' on Line 4W. Drill grid south at 45° for a length of 200'.

CONCLUSIONS AND RECOMMENDATIONS

The Turam electromagnetic survey on Grids 1A and 1B Hurtubise Township show numerous randomly distributed anomalies reflecting localized sources of relatively good conductivity. These anomalies likely reflect overburden conduction and hardly warrant further consideration.

A series of well developed parallel anomalies were outlined on Grid 2, Hurtubise Township. These likely reflect a banded formational conductor. One exploratory diamond drill hole has been tentatively recommended to sample this zone.

Respectfully submitted,

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Toronto, Ontario.
May 27, 1969.

APPENDIX "T"

BRIEF DESCRIPTION OF THE TURAM ELECTROMAGNETIC SYSTEM

GENERAL

The Turam method can be classified as a fixed source compensation method. The primary or source field consists of a large energizing layout in the form of a long wire or a large loop laid out on the terrain, to which an audio frequency alternating current is fed by means of a motor generator. The resulting current pattern is investigated inductively, with two identical receiving coils connected to a bridge compensator which compares the signal received in each coil in relative phase and amplitude. When grounded cable is used, the energization is both galvanic and inductive; when the primary layout consists of a closed loop, the energization is purely inductive. Under most conditions the presence of galvanic current is undesirable and inductive energization is, as a rule, preferred.

Although the system allows the comparison of any two components of the resultant field, it is standard procedure in systematic surveys to measure the gradient of the vertical component.

The pattern for a typical Turam survey is shown in Fig. 1. A large rectangular loop is used as primary layout and the field gradients are measured with horizontal receiving coils along profiles perpendicular to a long side of the transmitting loop.

DATA REDUCTION

The relative strength of the undisturbed primary field is dependent on the loop dimensions and the location of the observation points, and can be determined by calculation. The measured field strength ratios are normalized through division by these calculated free space ratios.

The primary field causes eddy currents to flow in subsurface conductors. As a result the resultant field will be distorted in both amplitude and phase. The presence of conductors will thus be indicated by abnormal field strength ratios and phase differences.

PRESENTATION

The measuring results are usually presented in profile form, as (reduced) field strength ratio and phase difference curves, with the observed values plotted at the midpoint between coil positions.

Occasionally one of the two parameters is presented in contour form, but contour plans are generally inadequate to express the full significance of the data.

INTERPRETATION

Where field distortion occurs the curves indicate the location and the depth of burial of the main current flow. The "current axis" is well defined when the current is concentrated as, for instance, in thin, steeply dipping conductors. In wide, banded conductors, or in horizontal conductors such as, for instance, overburden, the current is usually more dispersed and the anomalies will yield less positive information.

As a rule the current axis is located right below the maximum field strength ratio deflection or the maximum negative phase shift. Its depth under the traverse is indicated by the shape of the anomaly.

The relative amplitudes of field strength and phase distortions are a measure of the conductivity of the conducting bodies, i.e. good conductors are characterized by field strength distortion combined with relatively little phase shifting, whereas poor conductors affect the phase, rather than the strength of the resultant field.

For an accurate grading the resistivity thickness (r/d) ratio of the individual conductors can be derived from the calculated in-phase and out-of-phase components, taking further into consideration the exciting frequency and the strike length of the conductor. The relations are shown in Fig. 2 and Fig. 3. The obtained r/d values are marked on the upper right side of the anomalies, in units of ohmcm/m. On the lower left side the depth of the current axis (ft.) is marked. It is normally located 30 - 40 ft. within the body and the indicated depth should be regarded as the maximum depth to the upper surface of the conductor.

To obtain the projection of the current pattern, the anomalies are connected between lines, whereby depth and r/d values, as well as other characteristics of the curves are used as criteria. The strike of the formations, if know, is also taken into consideration. Fig. 4 and Fig. 5 show a plan and section of a typical Turam survey and interpretation.

References: 1937 Hedstron, E.H. Phase Measurements in Electrical Prospecting. AIME Techn. Publ. 827.

1964 Bosschart, R.A. Analytical Interpretation of Fixed Source Electromagnetic Prospecting Data. Delft.

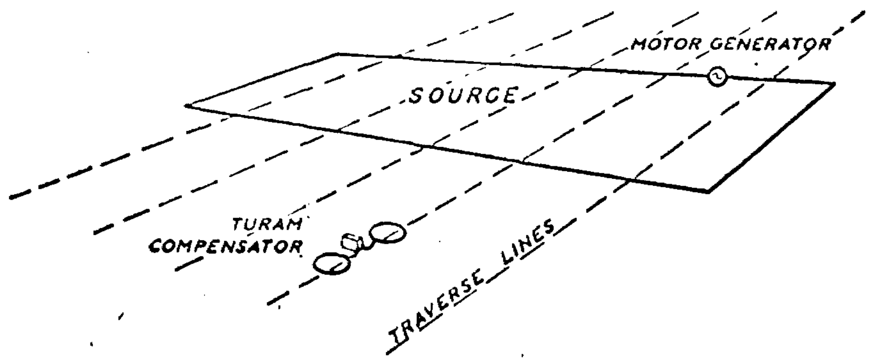

Fig. 1 The Turam method. General layout

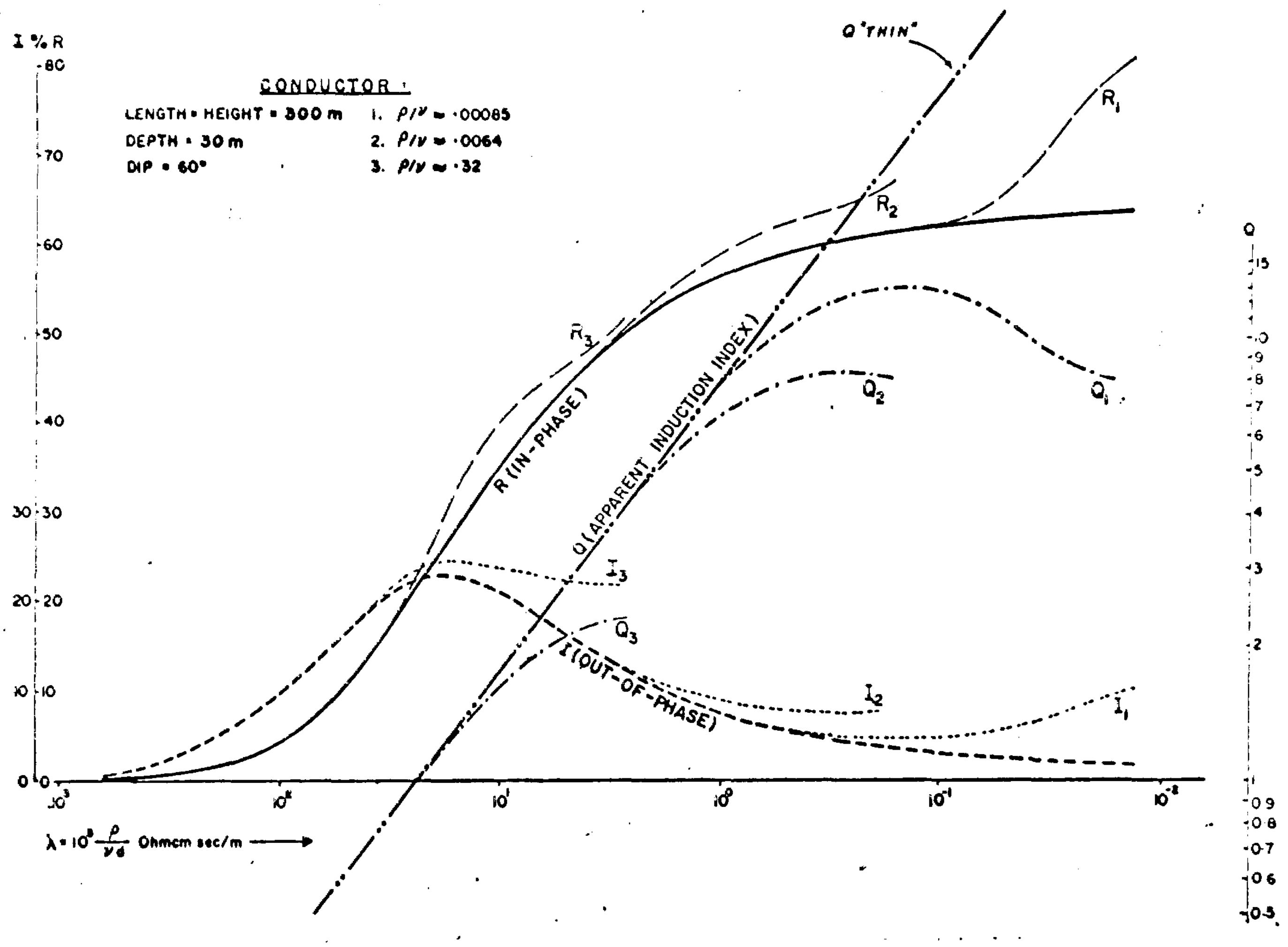

FIG. 2 RESPONSE OF A FINITE TABULAR CONDUCTOR.
(R.A. Bosschart 1964)

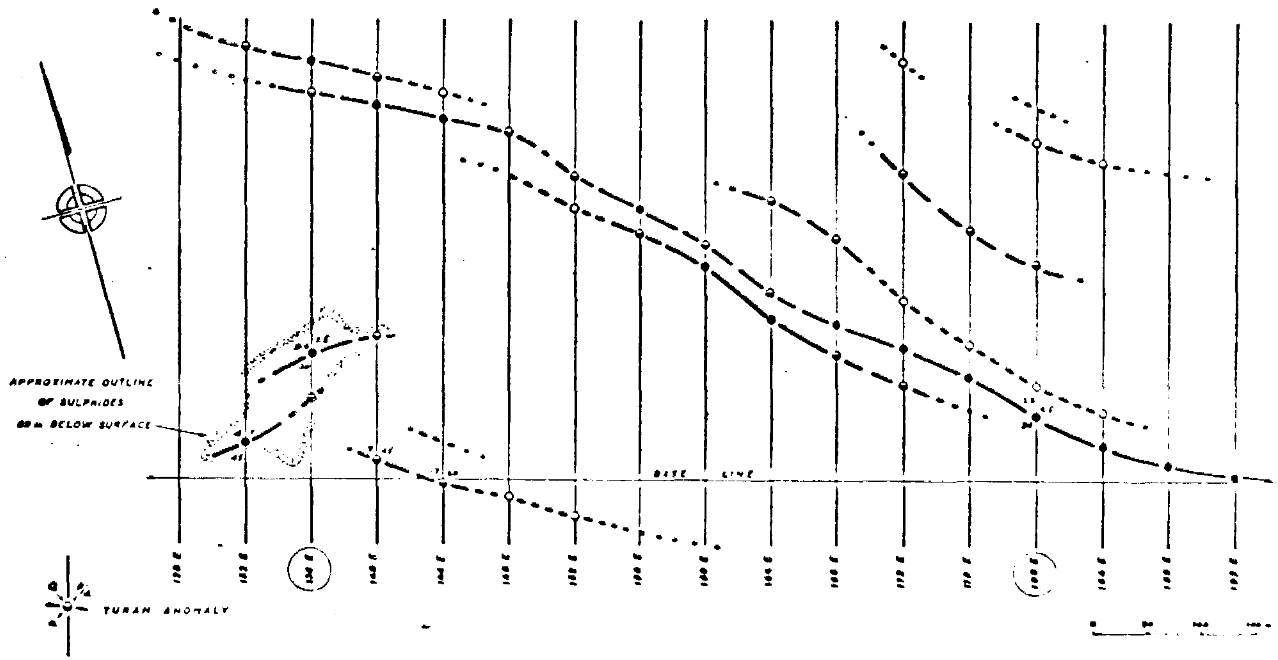

FIG. 3 RESPONSE DIAGRAM FOR CONDUCTORS OF VARYING STRIKE LENGTHS.

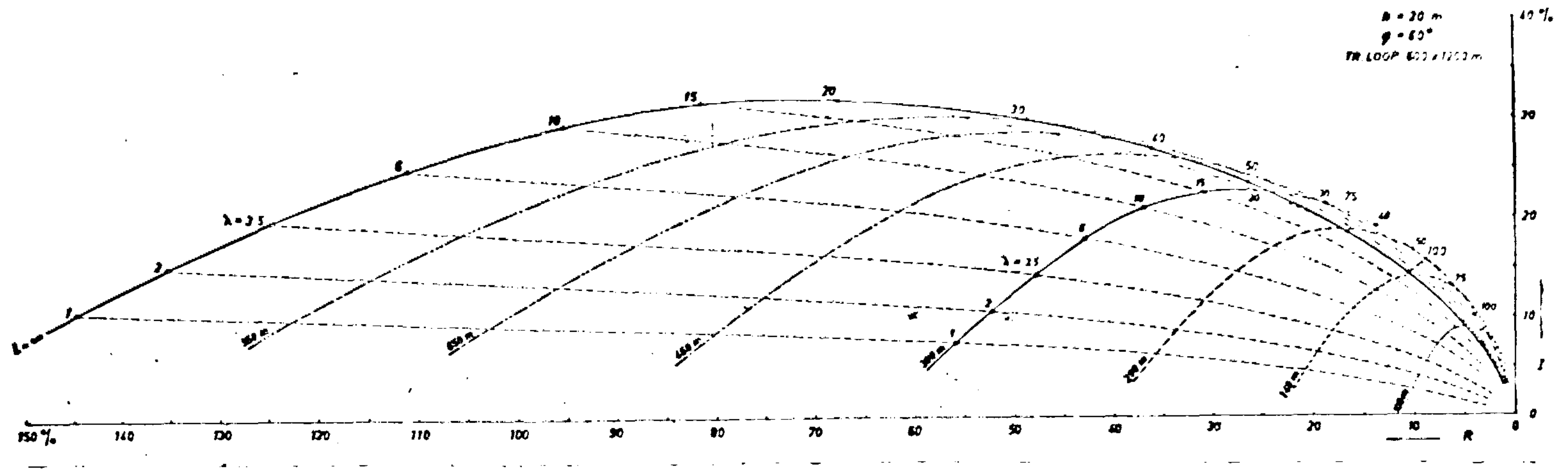

FIG. 4 TURAM SURVEY ON THE MURRAY GROUP, NEW-BRUNSWICK.
(R.A. Bosschart 1964)

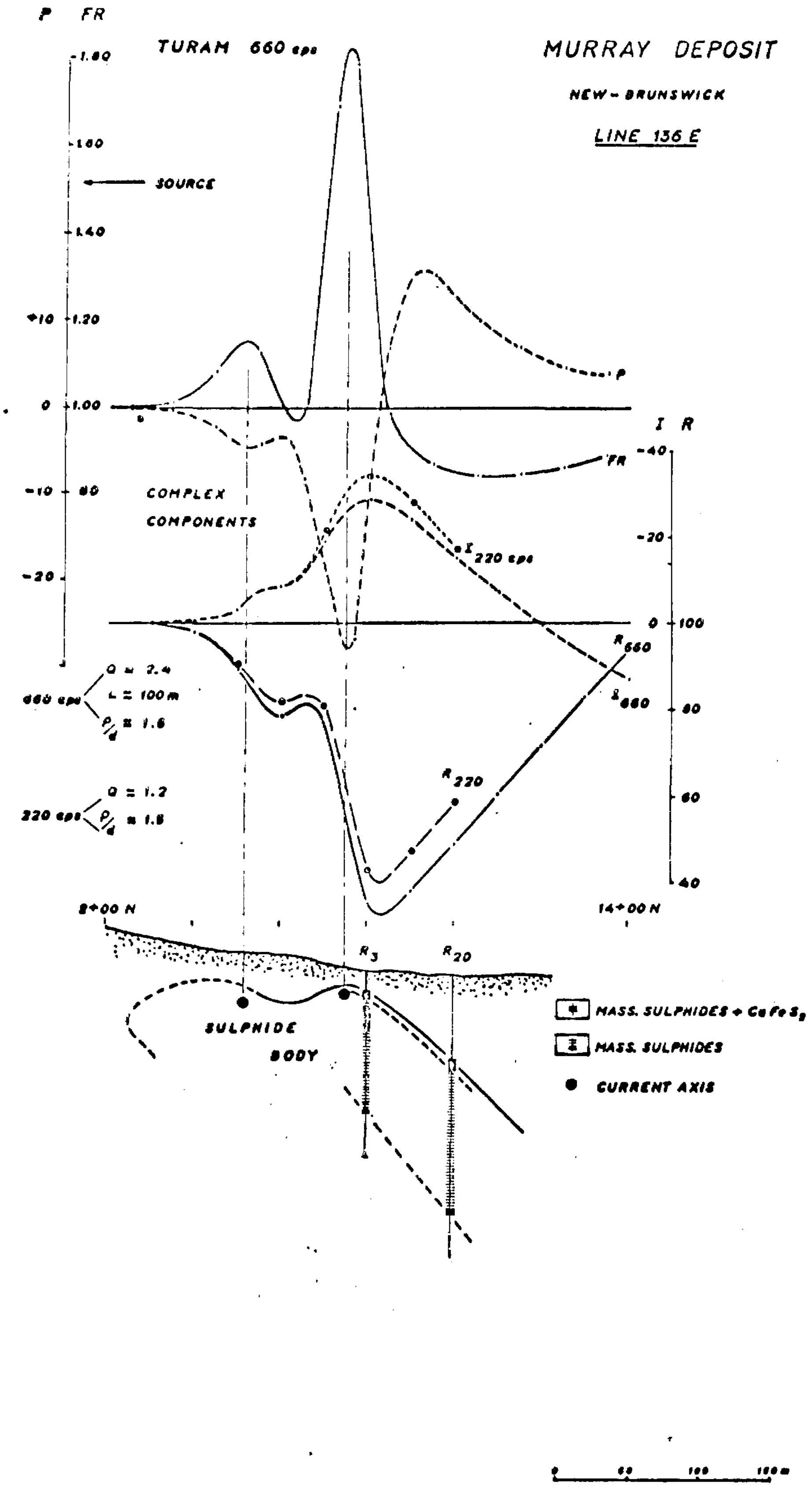

FIG. 5 TURAM SURVEY ON THE MURRAY GROUP, NEW BRUNSWICK.
INTERPRETATION OF A TYPICAL SECTION.
(R.A. Bosschart 1964)

Some Aspects of the Turam Electromagnetic Method

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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.

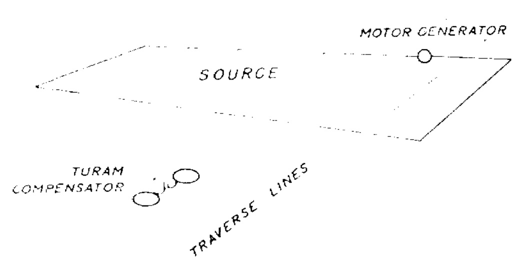

Figure 1.—General layout of the Turam method.

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*, = 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 diference) (*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 percent 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 Precambrian 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.,

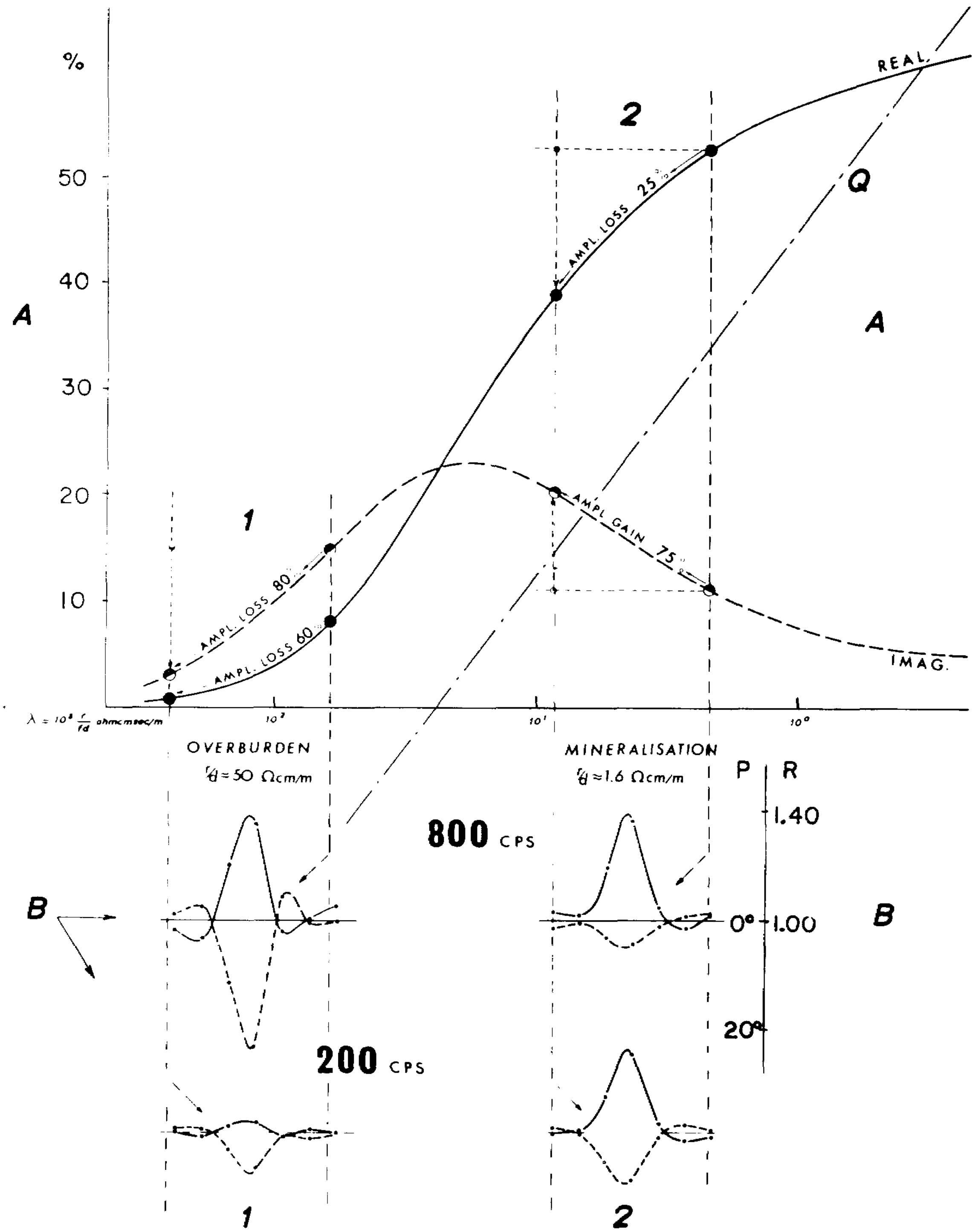

Figure 3.—Response of a thin, medium-size tabular conductor (1000-ft. strike length) in a fixed-source measuring configuration.

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 i ike length from 300 to 3,000 ft., the fixed-sour res-ponse increases from 6 per cent to 80 per cent, or

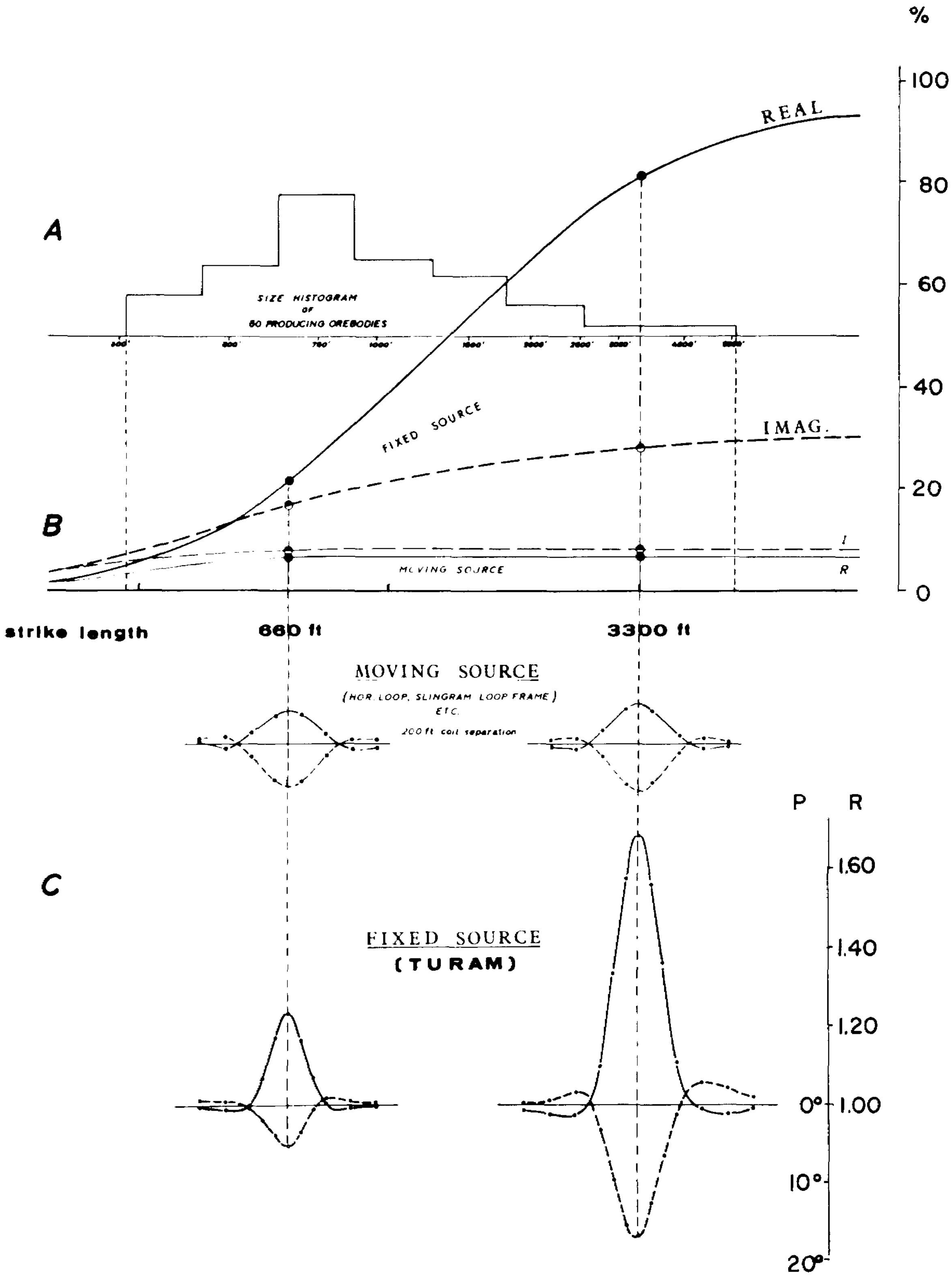

Figure 4.—A comparison of the response of conductors of varying size in moving-source and fixed-source measuring configurations.

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

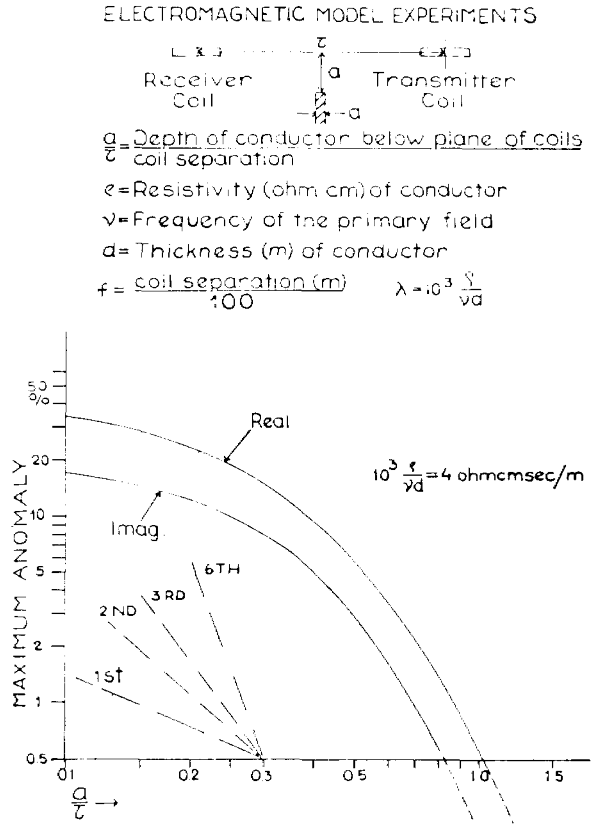

Figure 5.—Variation of the response with depth of a thin tabular conductor of infinite strike length in a moving source configuration. (Hedstrom and Parasnis, 1958).

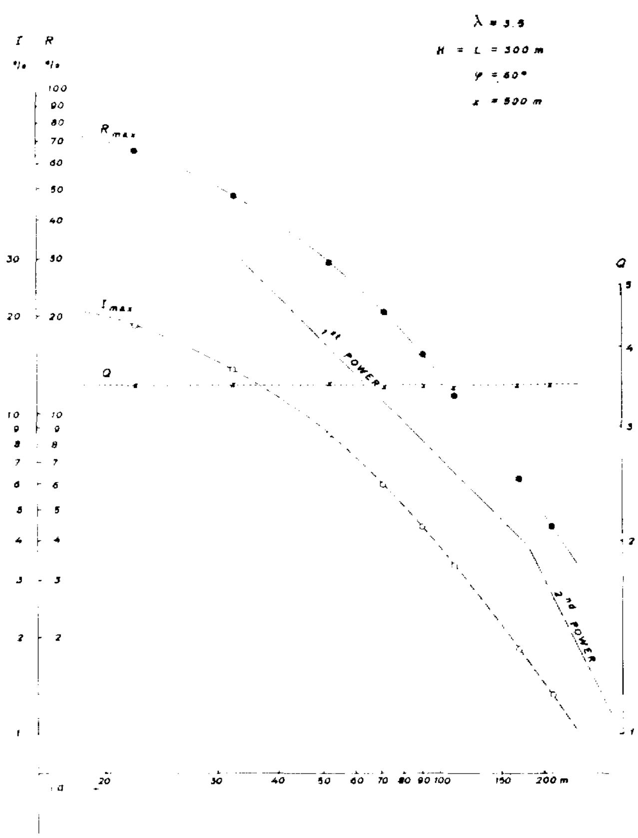

Figure 6.—Variation of the response with depth (a) of a thin tabular conductor of finite strike length (1000 ft.) in a fixed-source measuring configuration.

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 Precambrian 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.,

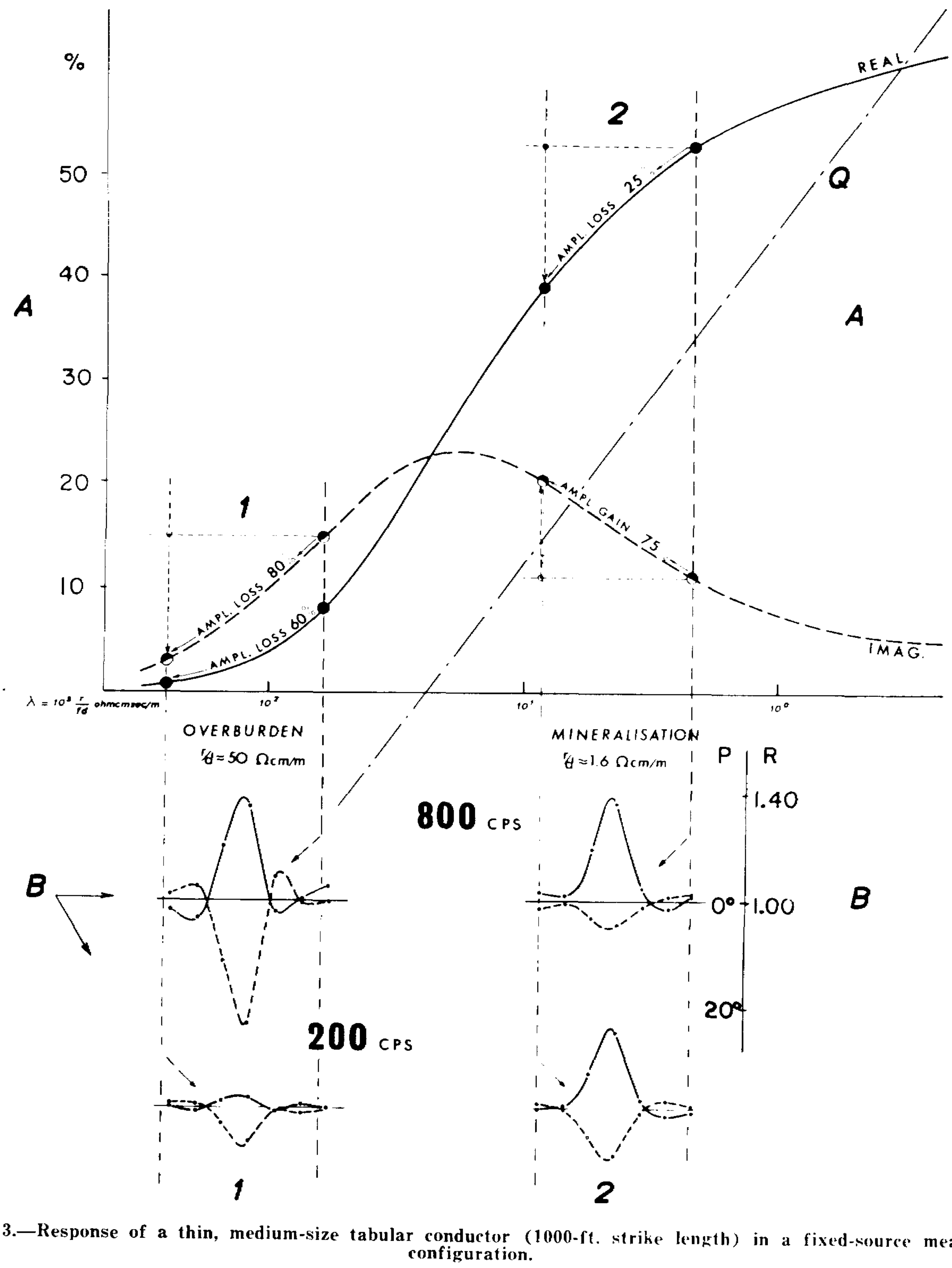

Figure 3.—Response of a thin, medium-size tabular conductor (1000-ft. strike length) in a fixed-source measuring configuration.

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$\lambda = 10^3 \frac{r}{fd}$, 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 λ = 2 to λ = 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 diference) (*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 percent out-of-phase (15 per cent field strength ratio, 5-degree phase difference), and it would stand out clearly from the reduced overburden response.

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 i· ·ike length from 300 to 3,000 ft., the fixed-sour· i·res-ponse increases from 6 per cent to 80 per cent, or

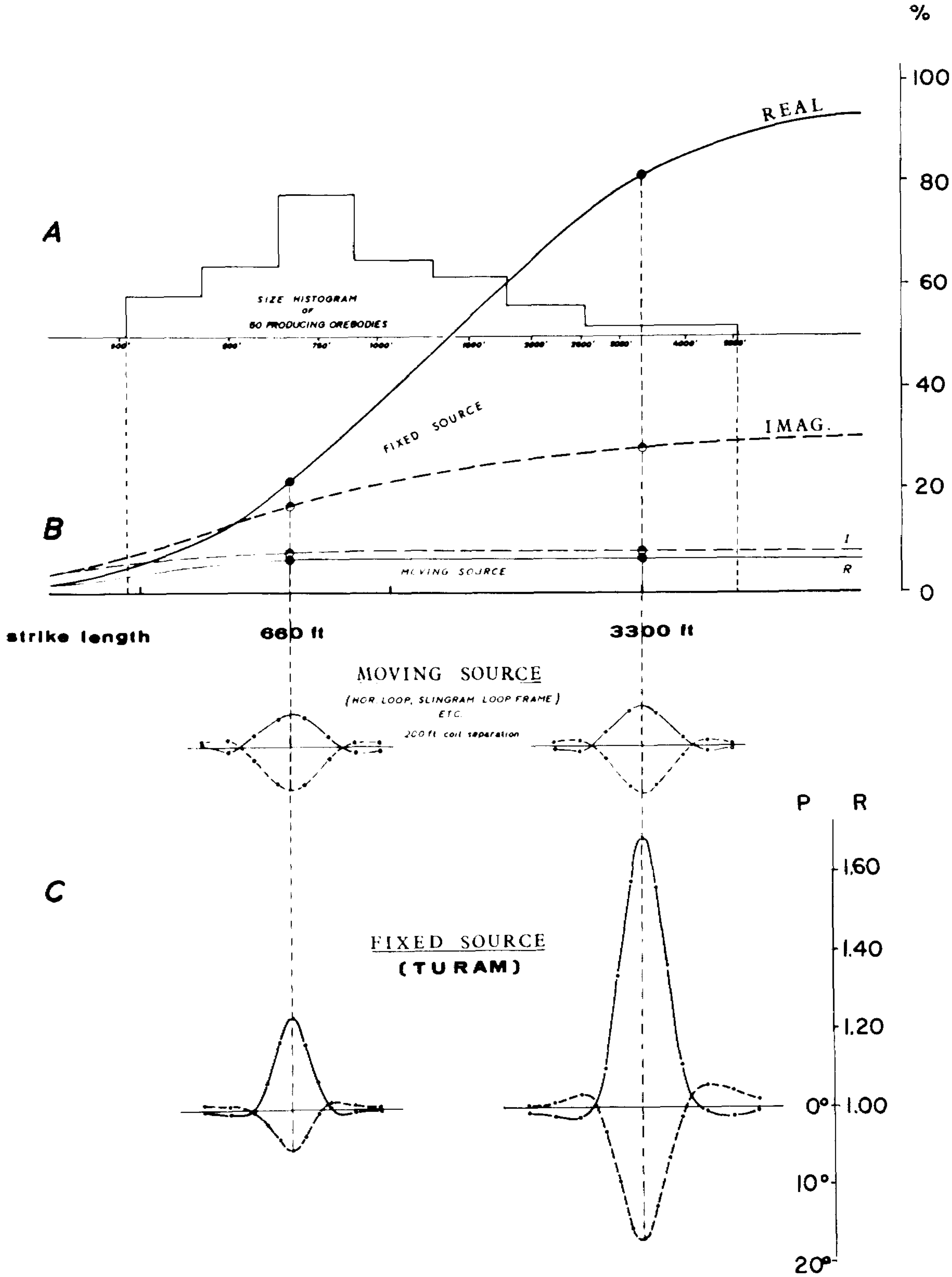

Figure 4.—A comparison of the response of conductors of varying size in moving-source and fixed-source measuring configurations.

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

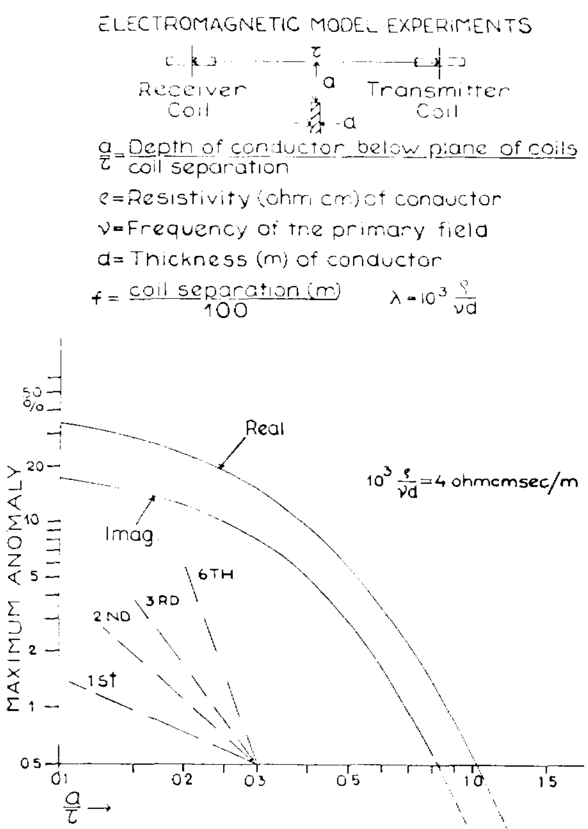

Figure 5.—Variation of the response with depth of a thin tabular conductor of infinite strike length in a moving source configuration.
(Hedstrom and Parasnis, 1958).

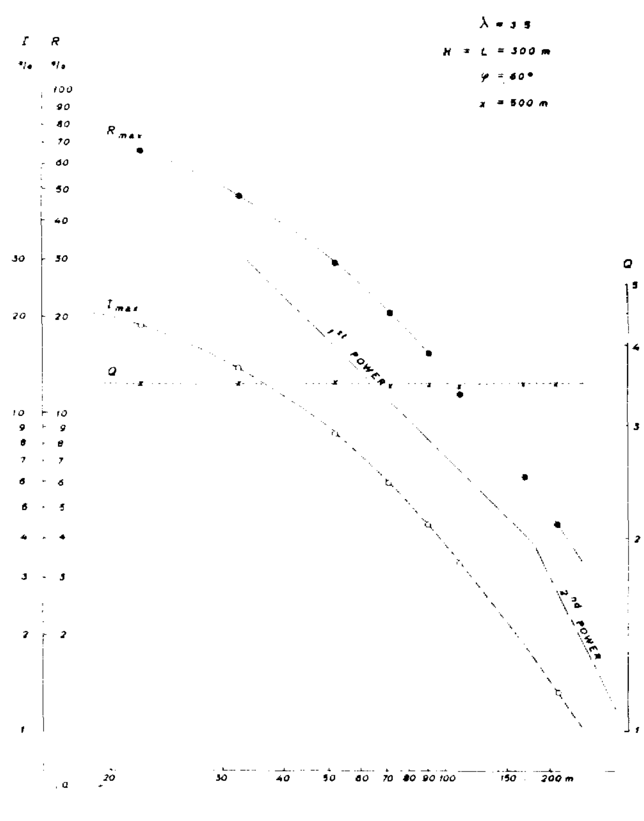

Figure 6.—Variation of the response with depth (a) of a thin tabular conductor of finite strike length (1000 ft.) in a fixed-source measuring configuration.

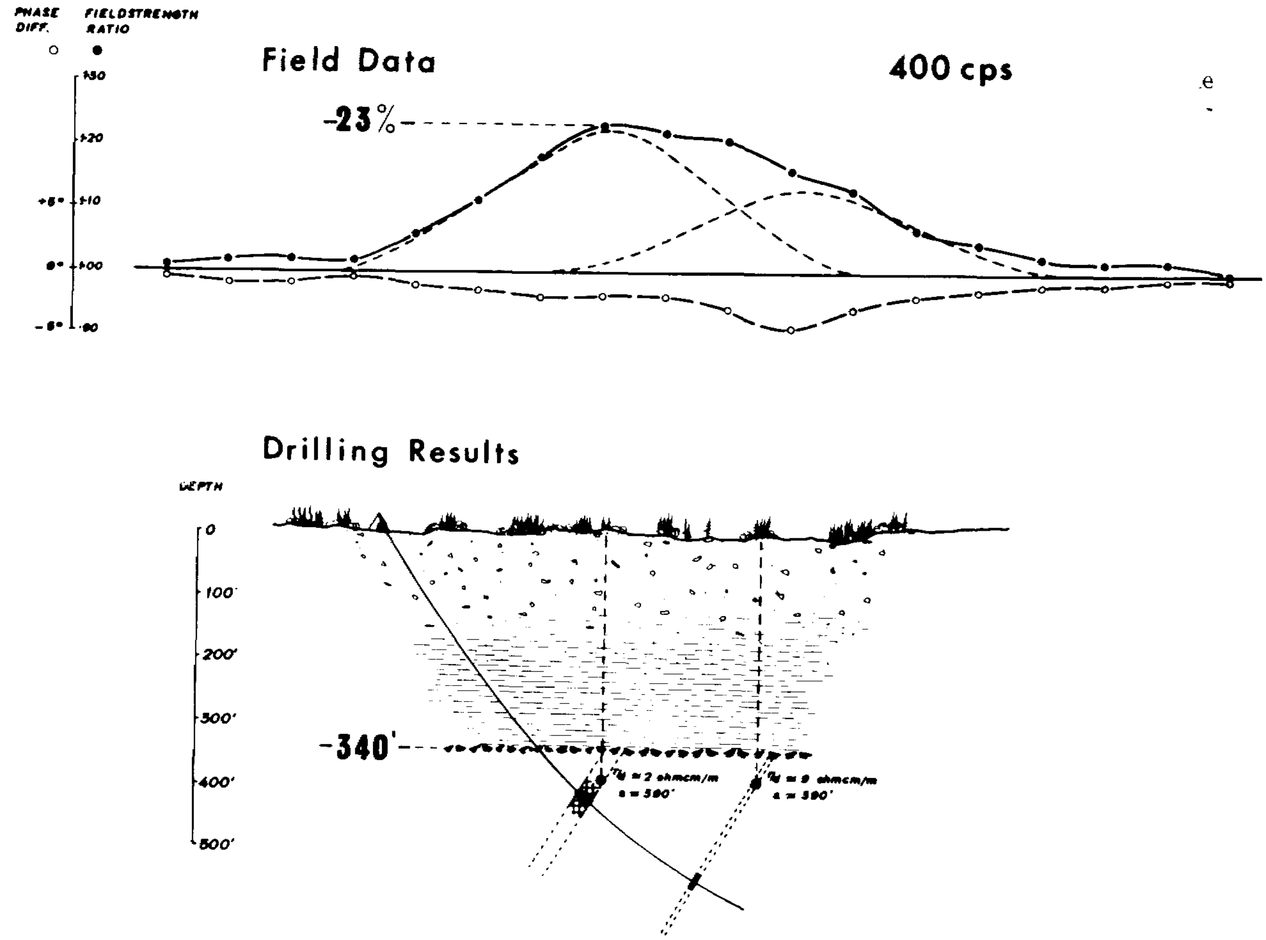

Figure 7.—Turam traverse over deeply buried conductors in the Timmins area.

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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Printed in Canada

HURTUBISE M-510

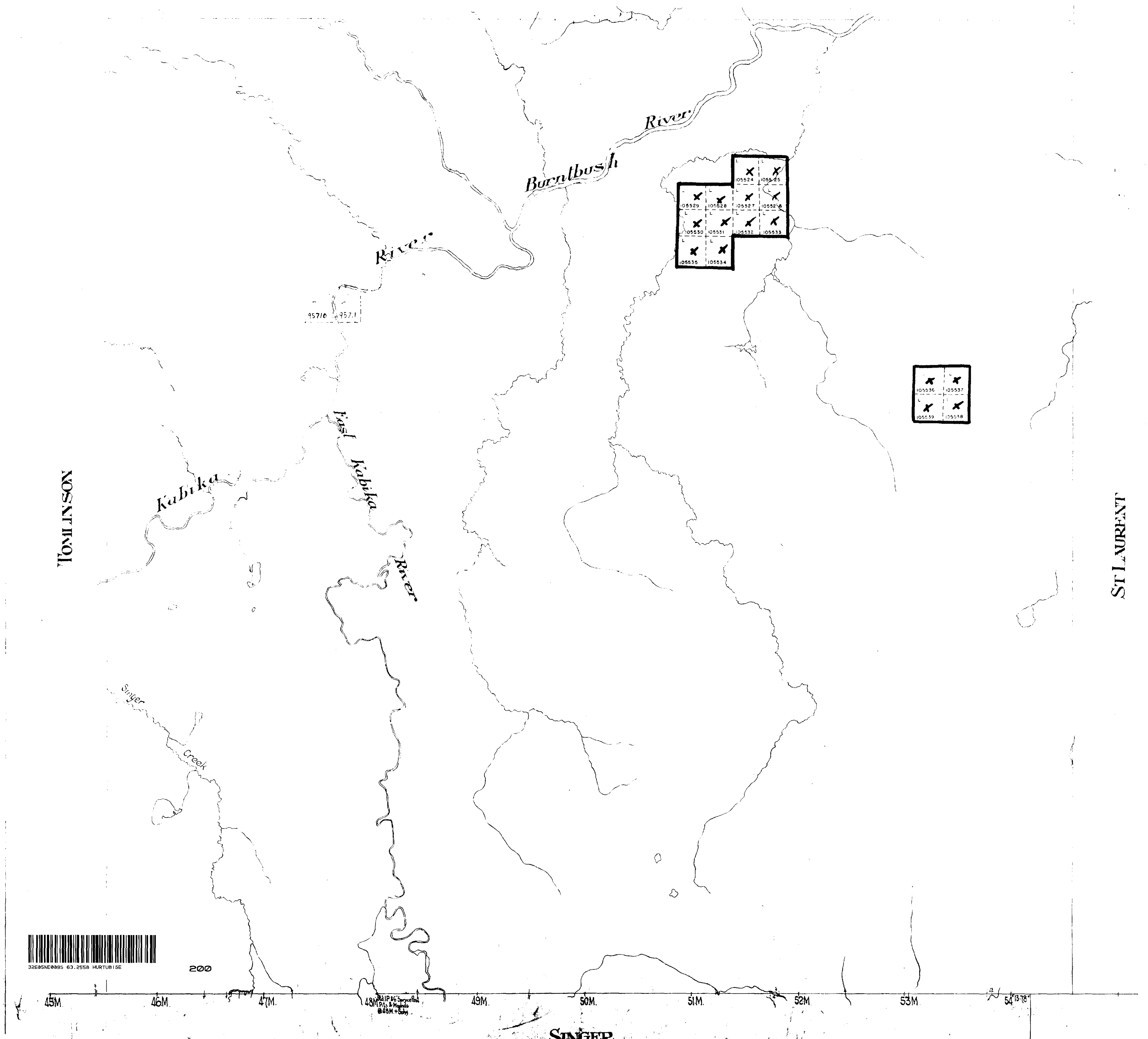
LARDER LAKE MINING DIVISION

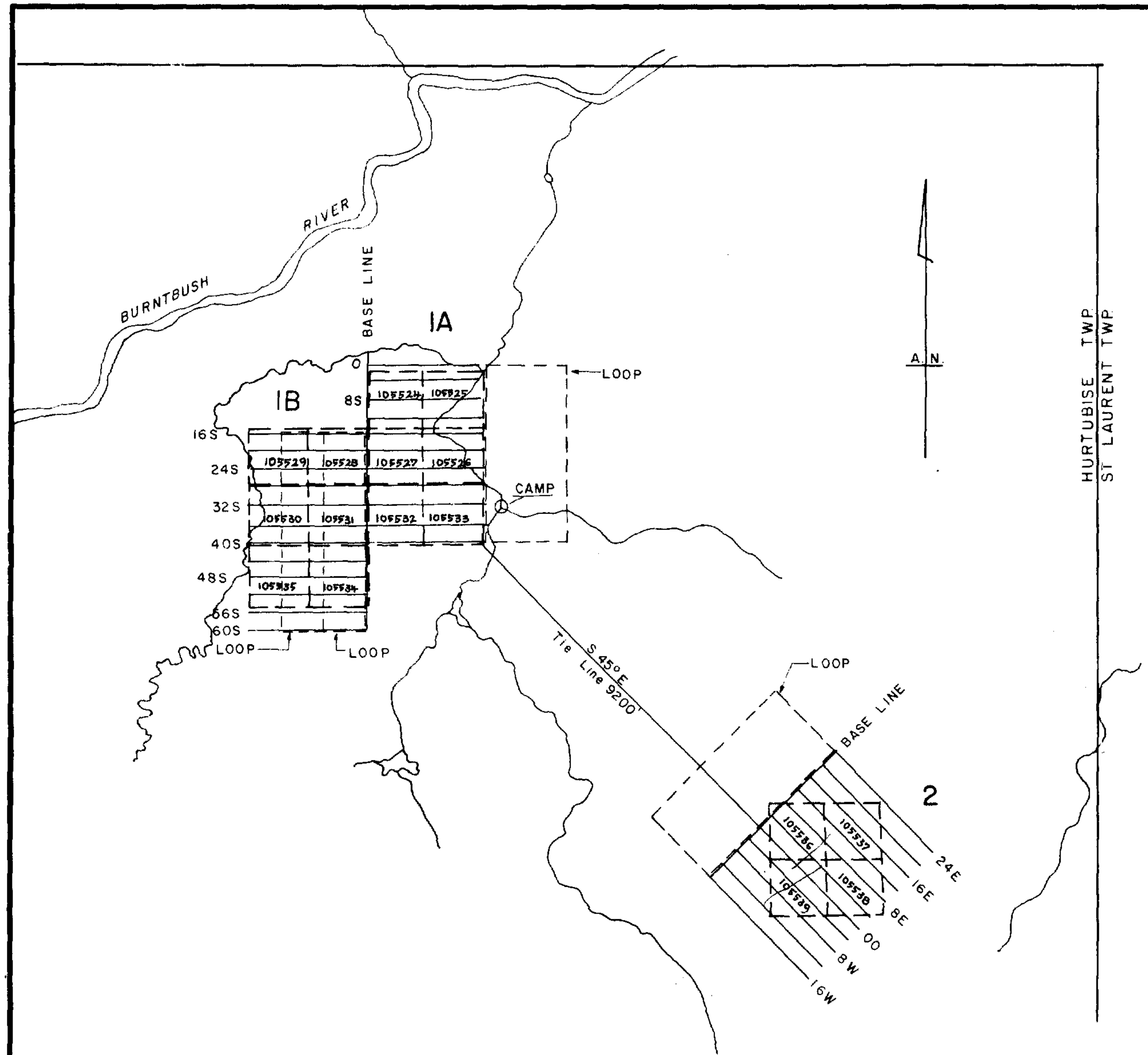
DISTRICT OF COCHRANE

Scale 40 Chains = 1 Inch.

NOTE

400' Surface Rights Reservation around all Lakes and Rivers.





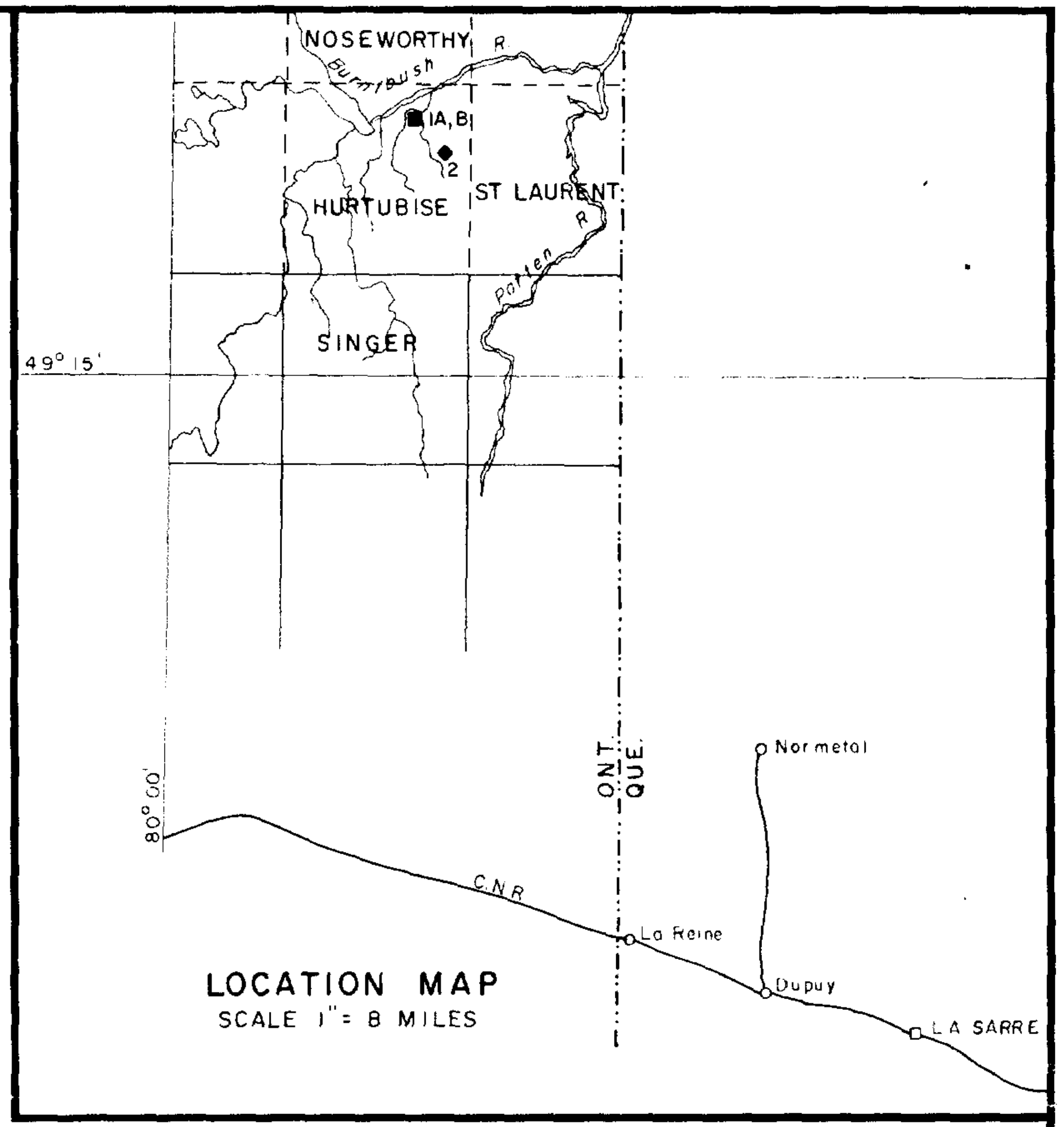


PLATE 1

UNITED STATES SMELTING REFINING AND MINING COMPANY

CANADIAN MINING EXPLORATION

HURTUBISE TWP. ONTARIO

LOCATION MAP OF TURAM ELECTROMAGNETIC SURVEY

SCALE 1" = 2640'

SURVEY BY SEIGEL ASSOCIATES LIMITED

MAR.-APR. 1969

32E05NE0095 63.2558 HURTUBISE

210

69-9142-01

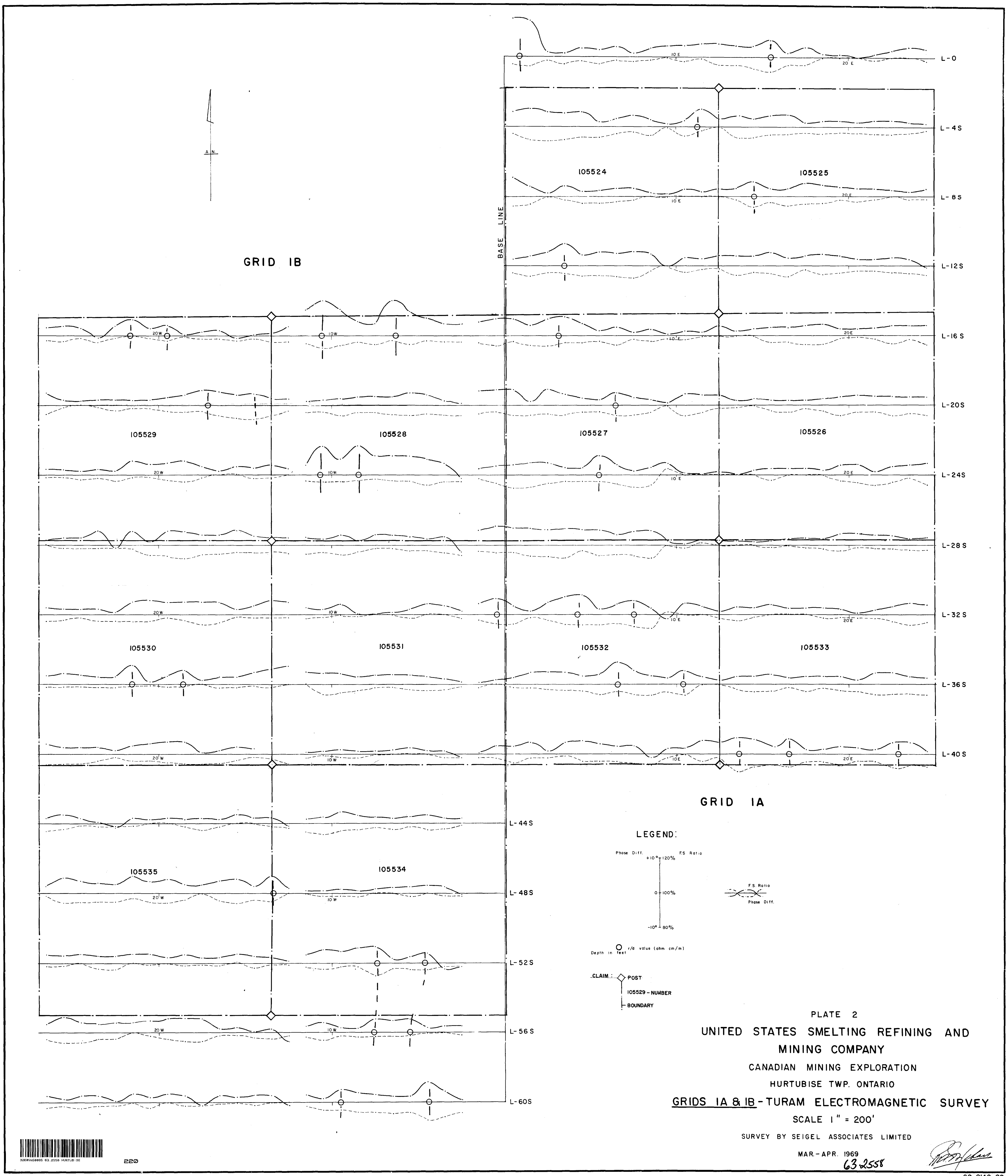


PLATE 2

UNITED STATES SMELTING REFINING AND MINING COMPANY

CANADIAN MINING EXPLORATION

HURTUBISE TWP. ONTARIO

GRIDS IA & IB - TURAM ELECTROMAGNETIC SURVEY

SCALE 1" = 200'

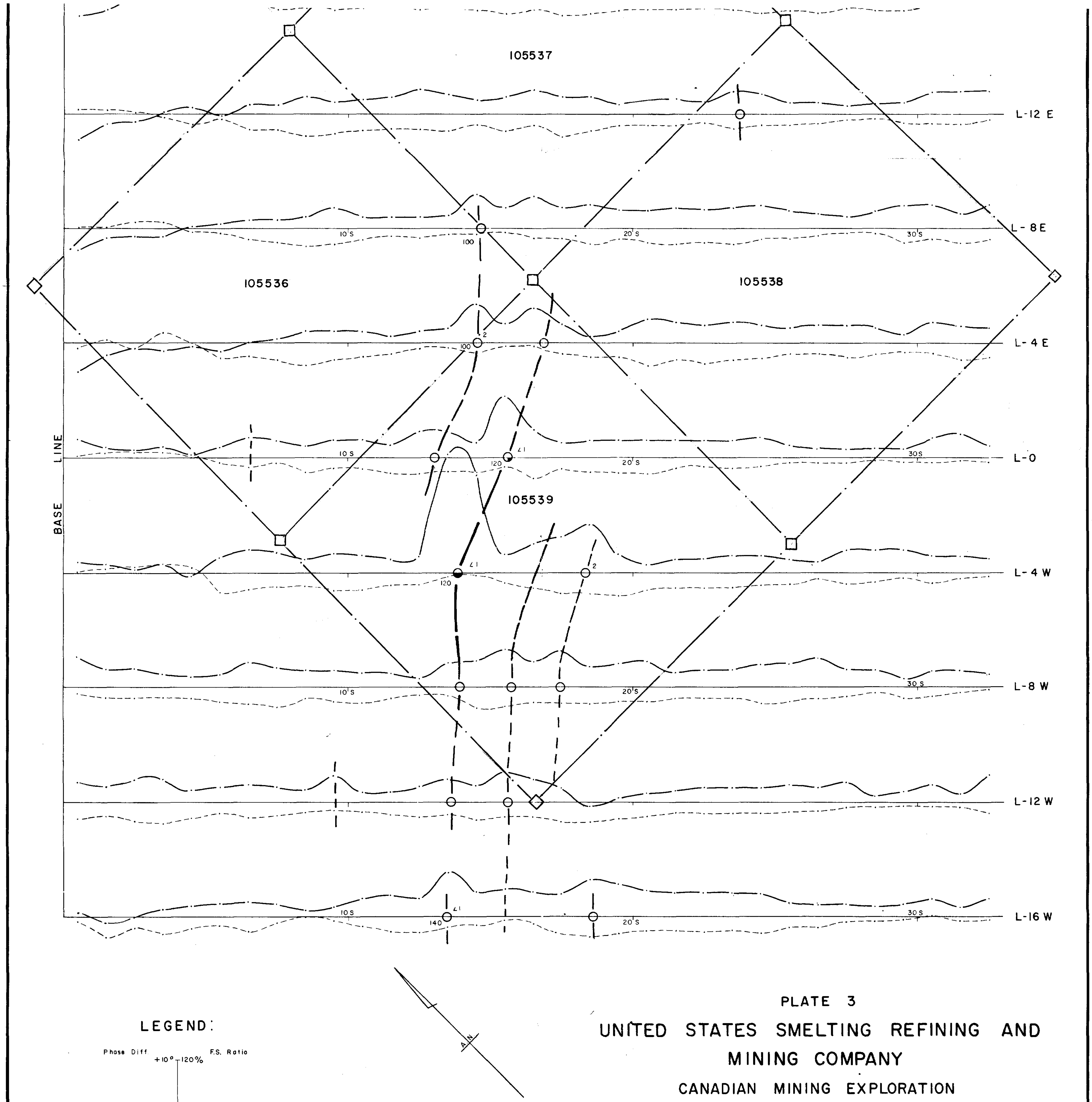
SURVEY BY SEIGEL ASSOCIATES LIMITED

MAR.-APR. 1969

63.2558

220

69-0142-02



LEGEND:

Phase Diff. +10° — 120% F.S. Ratio

0 — 100%

-10° — 80%

F.S. Ratio

Phase Diff.

Frequency: 400 Cycles

CLAIM: ◇ POST
105536 - NUMBER
BOUNDARY

○ r/d value (ohm cm/m)
Depth in feet.

PLATE 3

UNITED STATES SMELTING REFINING AND MINING COMPANY

CANADIAN MINING EXPLORATION

HURTUBISE TWP. ONTARIO

GRID 2 - TURAM ELECTROMAGNETIC SURVEY

SCALE 1" = 200'

SURVEY BY SEIGEL ASSOCIATES LIMITED

MAR. - APR. 1969

32E05NE0095 63.2558 HURTUBISE

230

69-9142-03