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GEOPHYSIQUE DE L'OR/GEOPHYSICS FOR GOLD
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FOREWORD

CIM GEOPHYSICS FOR GOLD SYMPOSIUM
A GOLDEN OPPORTUNITY TO BRUSH UP ON YOUR KNOWHOW

WHY A SYMPOSIUM?

The practice of exploration is seldom if ever taught in universities and often it is difficult to communicate even among the personnel of a single company. Even when there is a success, the effectiveness of any exploration strategy is difficult to establish as there are so few mines found. For most discoveries, it is hard to separate the influence of "luck" from that of the exploration techniques used and from the influence of local conditions, showings already known, etc. Two other factors limit the transmission of knowhow: one is the "confidentiality" of much of the information and the other is simply misinformation as to circumstances surrounding actual discoveries. Geological Surveys should perhaps be involved or grants be made available to objectively reconstruct case histories of discoveries as mining companies seldom provide funds once a discovery is made.

Because of all these factors, the CIM Symposium on exploration for gold is a unique two-day occasion to compare our ideas with those of some 200 other geologists, geophysicists and geochemists. Some 24 speakers, a majority from senior mining companies, have accepted to relate some of their experiences. The other speakers are contractors, university and government scientists. Most of the speakers will relate case histories of gold discoveries and how geophysics contributed to their understanding and to the detection of ore deposits. The Symposium is organised so as to maximize questions to authors, exchange ideas and provoke discussions.

While listening to speakers, we should remember that when exploring for gold, geophysics and geochemistry are only two of several ways of gathering information on potential "ore bodies" hidden under the surface. They are sciences but also require knowhow to get reliable and repeatable results.

At times, all of us have to plan exploration programs to find gold deposits, often in the vicinity of some already known showings. For example, the common pitfall of not keeping at least half of our budget for immediate sampling (drilling) of wildcat anomalies, many difficult choices have to be made without much factual information. For example, we often have to decide whether we should use an expensive survey, theoretically capable of finding most targets, or should we be willing to accept a cheaper method to find only half of the "targets" but which could cover either a larger area or be used with a closely-spaced grid of lines capable of detecting smaller targets (big mines are frequently small targets).

The most important question to honestly answer is probably the following: do we expect ore bodies to directly react to any of the exploration tools, or are we really using geophysics to gain information on the geology? Properly used and accepted, geophysics is most useful even in its limited role.

As the volume of expanded abstracts already suggests, the Symposium will not give a unique set of answers or a magic formula on how to find gold. But after attending and learning how others use geophysics, we should all be able to take more knowledgeable decisions in the future. Indeed, geology varies and many approaches and different methods are being used successfully in the search for gold.

We hope that you will enjoy the Symposium and find many, but not too many mines thereafter. With the collaboration of the authors, we hope to publish a volume on the Symposium.

GEOPHYSICS OVER THE UPPER CANADA AND UPPER BEAVER GOLD MINES

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ABSTRACT

Queenston's Upper Canada and Upper Beaver Mines are located in Gauthier Township, Ontario, approximately 12 and 16 miles east of Kirland Lake.

The Upper Canada ore bodies occur within a zone of shearing and alteration of sediments, volcanics and pyroclastics. The Mine produced over 1.5 million ounces of gold from 1938 to 1971.

The Upper Beaver ore bodies occur in an unusual setting of quartz-calcite-magnetite-chalcopyrite-gold veins associated with interflow beds and basic volcanic flows. The Mine produced 0.5 million tons grading 0.25 oz/ton gold and 1.2% copper in several periods between 1938 and 1971.

Extensive geophysical surveys including airborne EM and magnetics, IP/resistivity, SP, various EM techniques (HLEM, VLEM, VLF, Turam), and magnetics have been conducted over the two deposits at various times during their productive life and afterwards in attempts to extend known ore zones and locate new mineralization.

The results of these surveys will be discussed in relation to the ability of each to contribute towars solving economic geological problems.

GEOPHYSICS OVER THE UPPER CANADA AND UPPER BEAVER GOLD MINES

This paper presents the results from various geophysical surveys over the former Upper Canada and Upper Beaver gold mines in Gauthier Township, 15 miles east of Kirkland Lake, Ontario. Both mines were originally discovered by prospecting in the 1920's with production ceasing at the end of 1971. The properties are now 100% owned by Queenston Gold Mines Limited. Most of the geophysical results presented are from surveys completed after the mines closed or from small-scale 'orientation' tests. No ore has yet been discovered on either property as a result of following up targets identified from geophysical data, although several previously unknown anomalous gold occurrences have been identified.

Upper Canada Mine

The Upper Canada produced 4.7 million tons of ore at a grade of 0.32 oz/ton gold from the 1920's to 1971. The ore bodies are located 4000 feet north of the Larder Lake-Cadillac Break on a subsidiary structure. This 'Upper Canada Fault' is subparallel to the major Larder Lake-Cadillac Break towards the west and divergent towards the east.

The ore occurs in nearly vertical shear zones. These shears are hosted by tuffaceous greywacke, tuff, conglomerate, trachyte and trachyte porphyry. The shears are strongly developed resulting in 'mud seams' being formed. There is significant sericite alteration and bleaching associated with gold bearing zones. Also associated with gold mineralization are narrow, bluish quartz veinlets and up to 5% cubic pyrite. The pyrite occurs as finely disseminated individual crystals up to 1 mm across and as 1-2 mm veinlets of fine-grained cubes. The average width of the ore bodies as mined is 7 feet. Strike extent is variable up to a maximum continous length of 1200 feet. There are numerous faulted offsets of up to 30 feet across strike and also parellel or en echelon ore zones. Down dip extent is also variable for individual zones but in total, ore is still strong below the 6100 level. Locally, gold values vary from nearly nil to 10 oz/ton.

Overburden cover varies from several hundred feet in the west near the Munro Esker to almost nil. Overburden composition is highly variable from sand to blue clays to tills. Generally the terrain is gently rolling with some swampy ground.

The geophysical results presented here are over the important 'L Zone' on Line 36W. These results were obtained subsequent to the closing of the mine and are part of a larger survey designed to explore for new ore zones. I am indebted to Garth Burton of Burton & Associates who conceived and supervised the actual programme. Survey methods consisted of magnetics, VLF-EM and reconnaissance, pole-dipole IP/resistivity with an a-spacing of 200 feet. Prospective areas were subsequently detailed with a dipole-dipole IP/resistivity survey using an a-spacing of 100 feet.

The VLF results primarlily reflect the overburden/bedrock inhomogeneities and topography with no apparent indication of the presence of the major shear structure. It is possible that since much of the 'L' is mined out that there is now enough electrical discontinuity to transform a 'conductive' zone into a 'resistive' one. However, this seems unlikely since the shearing is a major feature extending beyond the limits of the gold ore and indeed is wider than the stopes in most cases. Cross-faulting breaks all the zones up on approximately 200 to 500 foot intervals. This may account for the lack of a VLF anomaly, but despite this cross-faulting, one would have expected enough large-scale continuity to give a VLF anomaly.

The magnetic profile is also noteably devoid of character over the 'L'. This should not be surprising since the zone is not anomalous in magnetite. (Occasional minor concentrations of specularite are noted associated with the ore.)

The reconnaissance, large a-spacing (200-foot) IP survey indicated an anomaly over the 'L', but not of unique magnitude as can be seen when compared with the results over sedimentary/volcanic terrane centred at 10N. This should not be surprising since the ore zone is actually very narrow, i.e., less than 7 feet, and bulk effects from very low sulphide concentrations in the volcanics can overshadow small-scale IP targets. The effect of decreasing the a-spacing is fairly remarkable with a clearly anomalous response seen with a=100 ft and N=1. Again, with larger N's the anomaly is noticeably less obvious over the 'L'. It should be noted that the IP response amplitudes may be considerably reduced due to the fact that the main part of the orebody has been mined out beneath this traverse line.

I am not aware of any horizontal loop EM data over the Upper Canada orebodies; however, I would speculate that in specific places there may be enough pyrite to be a weak conductor.

Upper Beaver Mine

The Upper Beaver Mine produced 0.4 million tons grading 0.25 oz/ton gold and 1.28% copper in the period 1965 to 1971. The mine is located 4 miles north of the Larder Lake-Cadillac Break and 3.5 miles north-east of the Upper Canada Mine. The orebodies occur as a set of veins within mafic volcanics. The mafic volcanics and the gold bearing veins are bounded by a feldspar porphyry plug to the north and an andesite pyroclastic unit to the south.

The veins are generally oriented NE-SW with dips varying from vertical to 65° to the west. The veins are very discontinous due to post-ore faulting. Typically, veins are 100 feet along dip, 400 feet along strike and 2 feet thick. The mineralogy of the veins varies greatly amongst the following constituents: quartz, calcite, chalcopyrite, pyrite, molybdenite, specularite, magnetite and gold. Chalcopyrite and magnetite are important minerals from a geophysical point of view since they provide possible direct indicators of gold-bearing veins.

The only systematic geophysical surveying over the mine area has been Turam EM and magnetics. Results from these surveys and very limited orientation-type IP and HLEM are presented for Line 8N.

A large-scale EM survey, like Turam, probably is not well suited to exploration for limited dimension targets. Nevertheless, a weak, phase response is seen over the 'V-Vein'. The general background noise is very low on this survey making a 5 degree phase anomaly identifiable. Also there is an FSRatio and phase anomaly associated with the 'G' and 'H-Veins'. It is possible that some magnetic permeability effect is evident in this response.

Magnetics can be a powerful tool at Upper Beaver. Even from the limited results shown here, it is evident that the magnetite in the veins is sufficient to cause anomalies of from 1000 to 5000 gammas in areas with little overburden such as this. When looking for very narrow, sharply defined targets, very closely spaced readings will be important. This might also be a case where gradient magnetics could be very helpful.

The IP/resistivity survey array used was fittingly quite small scale (a=50 ft). Even so there is no clear frequency effect response although there is a clear resistivity low. Possibly modern IP equipment could deal better with identifying IP responses diagnostic of a complex mineralogy including such diverse target minerals as magnetite, pyrite, chalcopyrite and molybdenite.

The horizontal loop EM response on this line is difficult to interpret. It is possible that both interference from nearby conductors and permeability effects are creating the peculiar inphase response. There was insufficient continuous data collected to properly place the response in context for a good interpretation.

Concluding Comments

Although the geology of gold deposits can be highly variable, especially in detail, the principles of exploration should be the same as for any geophysical target:

- understand as much about the economic geology of potential targets as possible. In particular, get a clear framework for the interpretation of geophysical results. This includes the geometry and distribution of geophysically detectable minerals.
- carefully set survey specifications that will preferentially enhance the response from the geometry and mineralogy of the perceived target.
- do the field work and interpretation with excellence.

Acknowledgements

I wish to thank Queenston Gold Mines Limited for permitting me to present this paper. Also I owe debts to the geophysicists and geologists whose insights I have drawn heavily upon, namely Garth Burton, Michael Gray, Len Cunningham, Don Tully and Gordon Bragg. The conclusions drawn herein are, of course, my own.

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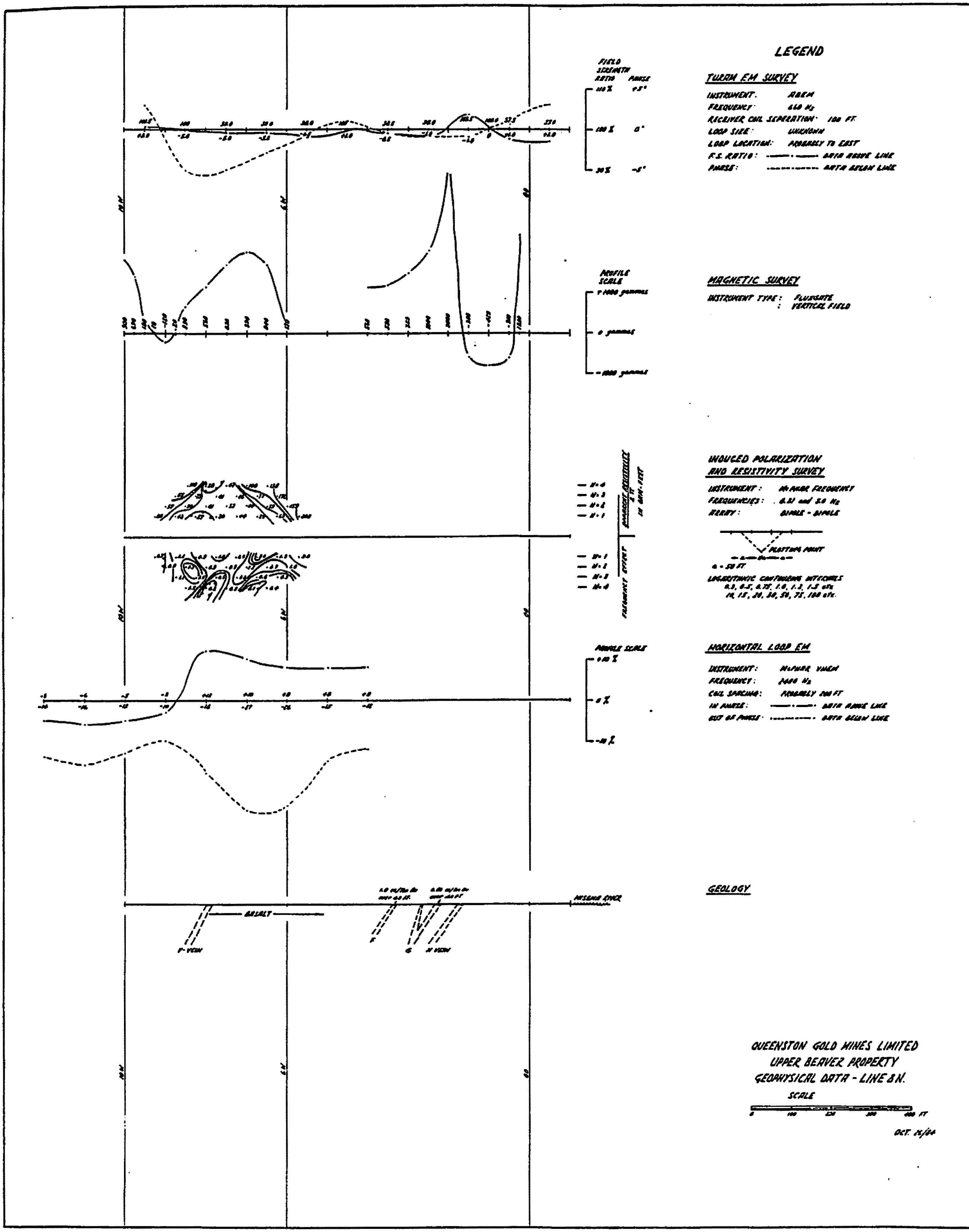
LEGEND
TURAM EM SURVEY
RECEIVER COIL SEPERATION: 100 FT.
LOOP SIZE: UNKNOWN
LOOP LOCATION: PROBABLY TO EAST
F.S. RATIO: DATA ABOVE LINE
PHASE: DATA BELOW LINE
MAGNETIC SURVEY
INSTRUMENT TYPE: FLUXGATE
: VERTICAL FIELD
INDUCED POLARIZATION
AND RESISTIVITY SURVEY
ARRAY: DIPOLE - DIPOLE
PLOTTING POINT
a = 50 FT
LOGARITHMIC CONTOURING INTERVALS
HORIZONTAL LOOP EM
GEOLOGY
BASALT
QUEENSTON GOLD MINES LIMITED
UPPER BEAVER PROPERTY
GEOPHYSICAL DATA - LINE 8 N.
SCALE
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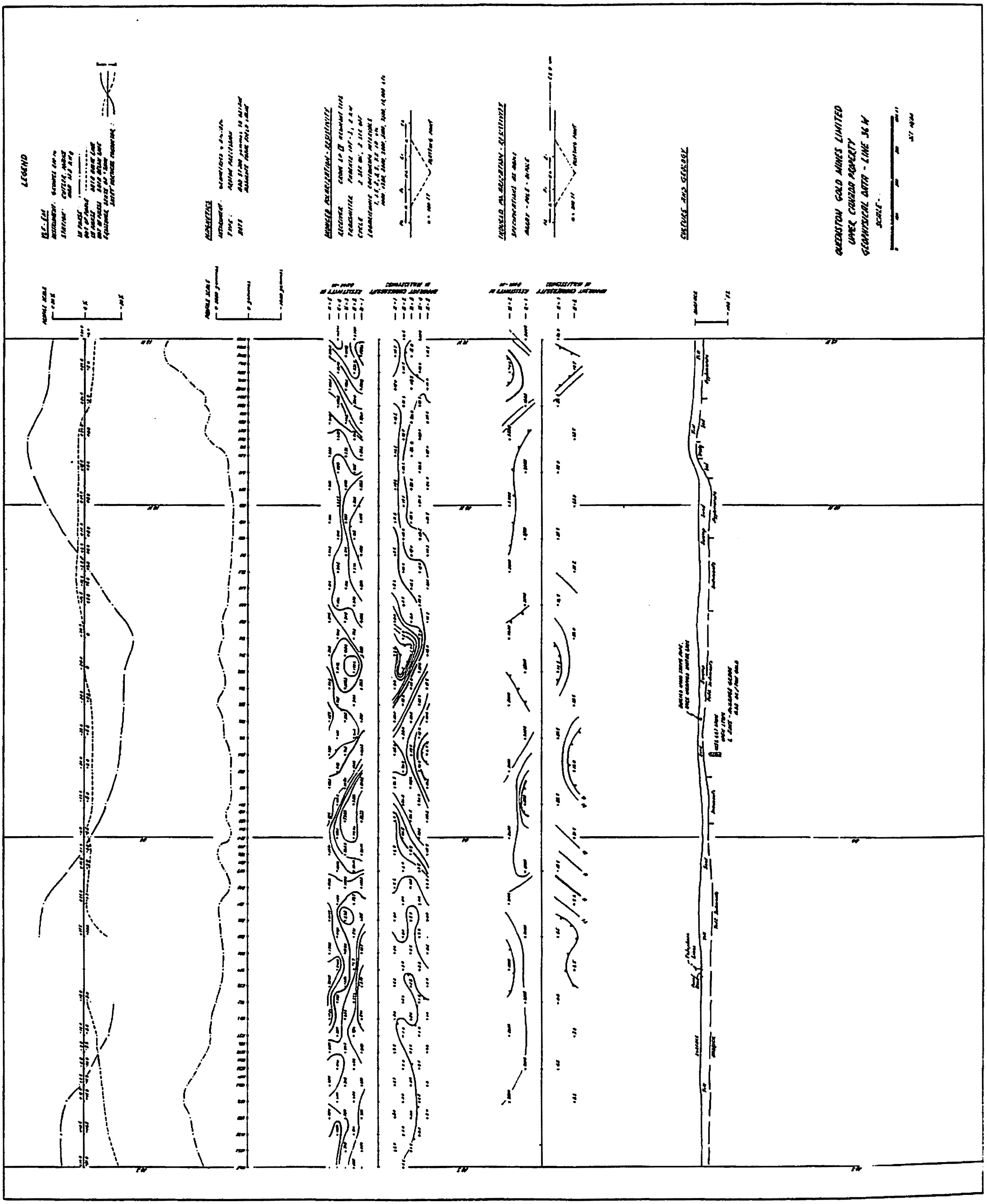
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QUEENSTON GOLD MINES LIMITED
UPPER CANADA PROPERTY
GEOPHYSICAL DATA - LINE 36 W
SCALE

THE ADVANTAGES OF VERTICAL GRADIENT MAGNETOMETER SURVEYING AND ITS APPLICATION TO GOLD EXPLORATION

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ABSTRACT

Total field magnetometer surveys have been successfully used for many years to infer geological information about partially mapped regions and/or areas overlain by a non-magnetic cover.

Interpretation involves a cycle of input and deduction until a satisfactory geological model is obtained. The process may involve the use of colour maps, characteristic curves, computer based interpretation methods and various filtering operations. The latter process, in a gold exploration context, is predominantly used to enhance near-surface features so that a plan map of the various lithologic units and structural events at the bedrock surface can be compiled.

The degree of useful information that can be economically extracted from the magnetic data is limited by two factors: the resolving power of the total field magnetic measurement and the ability to extract the near-surface responses without significantly degrading the data quality.

Over the last decade, the advent of more sensitive portable instruments now allows the vertical gradient of the total field to be accurately recorded. The technique has four main advantages that permit a more exact geological scenario to be extracted:

i) The data is very clean as diurnal and secular variations and magnetic storm noise are automatically removed.

ii) The regional gradient and the responses from deep-seated features are suppressed with the result that near surface sources are accentuated.

iii) Individual anomaly resolution is sharper. The delineation of geologic contacts is therefore more accurate.

iv) Closely spaced zones are individually resolved at smaller separations.

The advantage of using the vertical gradient of the total field for interpretation purposes in complex geologic environments is demonstrated in theoretical examples and a case history from a gold exploration programme in Canada. The instrument used was an EDA model PPM 500 in-line magnetic gradiometer which measures both the vertical gradient and the total magnetic field.

CONTRIBUTION DE LA POLARISATION PROVOQUEE A LA PROSPECTION POUR L'OR

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RESUME

La polarisation provoquée est un outil d'exploration géophysique permettant la détection directe de la minéralisation métallique disséminée. Dans la présente étude nous relevons les avantages et limitations de cette technique appliquée à la recherche de dépôts aurifères. Cette analyse est appuyée de plusieurs exemples de levés effectués sur des gîtes et indices minéralisés.

THE ROLE OF GEOPHYSICS IN THE EASTMAIN GOLD DISCOVERIES

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ABSTRACT

Unlike many a gold search, there has existed in the exploration undertaken at Eastmain a prominent geophysical comment throughout, it dating virtually from the programme's beginnings and continuing to the present development stage. Considering that the investigations there have passed through three distinct phases and through three corresponding scale changes, one leading in increasing degree of refinement to the next, this represents a significant achievement and one that is relatively unique in the history of gold exploration in the Canadian shield.

The three phases encompassed airborne surveying, ground detailing and borehole em. logging. Each in its turn gave direction to exploration, and to a very fair extent continues to do so.

THE ROLE OF GEOPHYSICS IN THE EASTMAIN GOLD DISCOVERIES

by

J. B. Boniwell, P. Kowalczyk, J. C. Gingerich

Unlike many a gold search, there has existed in the exploration undertaken at Eastmain a prominent geophysical component throughout, it dating virtually from the programme's beginnings and continuing to the present development stage. Considering that the investigations there have passed through three distinct phases and through three corresponding scale changes, one leading in increasing degree of refinement to the next, this represents a significant achievement and one that is relatively unique in the history of gold exploration in the Canadian shield.

The mineralization that sparked the quest for gold in the region had itself originally been discovered in a geophysical programme mounted 10 years earlier looking for copper/nickel sulphides around ultramafic occurrences along the Eastmain River immediately north of the Otish Mountains, some 315 kms NNE from Chibougamau, Quebec. In that older work, a fixed wing airborne em. and magnetic surveying had been extended to areas selected by surface geologic reconnaissance and followed up in a conventional way with appropriate ground methods on minimal grids prepared for the purpose. A particular airborne anomaly feature, dubbed A-9, short, isolated and involving correlating em. and magnetic signatures was so investigated, and upon its drilling proved to contain anomalous copper and gold in a narrow, semi-massive pyrrhotite band. It was an interesting intersection in a mafic volcanic domain but too clearly sub-economic for that time (1970) and in too remote an area to proceed with.

When the large rise in the price of bullion inspired a re-consideration of this prospect in 1981 by its original owners (Placer Development Ltd.), the fact that it had responded to geophysics in the first place became a fundamental about which new exploration programmes were designed. Following a stage of successful verification drilling, a second airborne coverage was carried out utilizing an up-to-date helicopter em. system (REXHEM II) to sense those similar short-strike conductors in the environment that might have been missed before. This hope was realized, and at least three new and separate events were added to the immediate on-strike setting of the A-9 sulphides. So situated, they promptly became top priority targets for ground geophysical screening.

From a large rectangular grid which incorporated all these airborne indications on the ground, extending from the known sulphides 1300 m to the south-east along the projected geologic strike, systematic surveying by V.L.F. (radio) em. and magnetics, and by horizontal loop em. (MaxMin II) was carried out. These coverages hearteningly elaborated the airborne responses and showed that if there were stratigraphic connections to be made between occurrences, there were also structural interventions which at the least were spatially of post-mineral importance but which potentially were in places of genetic consequence.

To refine targets for drilling, a limited and precisely directed second stage of horizontal loop em. surveying was completed at a second inter-coil spacing (50 m versus 200 m). These efforts resulted in the definition of what became known as the 'B' and 'C' Zones, the 'A' Zone appellation having been granted the A-9 sulphides by right of historical precedence.

Drilling based on the surface geophysics encountered additional sulphide mineralization carrying gold almost at once, but with an increasing number of holes probing to ever-increasing depths, it soon became evident that such sulphides formed pods of irregular outline and unpredictable extent. The need thus arose for extra insight into the in-depth probabilities as drill sampling proceeded within a context of rising costs and heightened uncertainty. This requirement fortunately geophysics was able to meet by down-hole (pulse) em. logging.

The first programme of such borehole em. surveying was mounted following the 1982 drilling. Working with large loop transmitter lay-outs encompassing in the first instance, all the collars of the holes put down on the 'A' and 'B' Zones, and in the second, the down-dip sulphide possibilities that lay beneath them in the plane of the ore, a set of results was acquired which allowed postulations of further sulphide occurrence to be made, either in extension of existing zones or as new incidences. Inevitably in this exercise, some assumptions had to be made, but with a fair appreciation of the operating empiricisms, together with a fortuitous freedom from source ambiguity in the geologic column, such predictions could be made with a growing confidence. The end-result was a successful drilling of projected sulphide occurrence at depths in excess of 300 m from surface.

With its effectiveness thus firmly established, geophysics can be reasonably expected to continue to provide a valuable guidance to exploration activities at Eastmain for the foreseeable future. Indeed, an on-going research is maintained to ensure that the past successful integration of geophysical inference and geologic interpretation continues.

QUALITATIVE AEROMAGNETIC INTERPRETATION METHODS WITH EXAMPLES FROM THE VAL D'OR AREA

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ABSTRACT

Many methods are now available for the qualitative analysis of aeromagnetic gradiometer and total field data which utilize colour display devices. These display methods are superior to the traditional contours and stacked profiles since the extra dimension of colour allows additional detail to be displayed. Colour intensity maps, shaded magnetic relief maps, stereo shaded magnetic relief maps and colour shaded relief maps are some examples of the methods available. A number of different maps were recently produced of the Val d'Or area from the data set used to produce the 1:1 million scale total field maps of Canada and from a detailed gradiometer survey flown in 1980 by the Geological Survey of Canada to demonstrate some of the available display techniques.

QUALITATIVE AEROMAGNETIC INTERPRETATION METHODS WITH EXAMPLES FROM VAL D'OR AREA

John Broome
(Geological Survey of Canada)

For many years total field aeromagnetic surveys have been a popular reconnaisance tool for mining exploration. Now that optical absorption magnometers have made high resolution gradiometer surveys a reality they have become accepted as an improvement over total field surveys. The Geological Survey of Canada has flown over 120,000 km of gradiometer surveying since 1975 and has proven that gradiometer surveys have a number of advantages for mining exploration. Gradiometer surveys allow near surface anomalies can be resolved in greater detail than total field surveys allow and in areas of steeply dipping contacts the zero gradient level approximates the position of the contact. In addition the regional field and diurnal variations are automatically removed from the data.

Unfortunately the application of aeromagnetic as well as other geophysical methods to gold exploration must be indirect since even in economic gold deposits the concentration of gold present does not directly affect the measured response of the host rock. In many cases however gold is associated with another lithological unit or specific mineralization which does have a measurable magnetic response. Even if this is not the case gold deposits are often structurally controlled and a good aeromagnetic survey can usually be of great assistance in structurally mapping an area. For example, hydrothermal gold deposits in quartz veins are often located in fault zone which can be detected on aeromagnetic maps by offsets in the data visible along the faults.

GRAPHICAL PRESENTATION TECHNIQUES

In order to fully utilize all the information contained in high resolution gradiometer and total field surveys the data must be displayed in a manner which allows it to be easily interpreted. The initial interpretation can then be used along with other geoscience data to define areas of interest for further qualitative analysis and possible quantitative analysis such as modelling.

Traditional methods of presenting aeromagnetic data include contours and stacked profiles however there is considerably more information in the data than can be displayed using these methods alone.

Alternate presentation methods have been developed which utilize colour display devices such as colour ink jet and electrostatic plotters and colour display terminals. The use of colour adds another dimension to the data presentation permitting more detail to be displayed. The simplest use of colour is in colour intensity maps which assign different colours to different intensity ranges in the data. For people not accustomed to reading contour maps this type of data presentation allows the variations in magnetic intensity to be more easily perceived. Although useful for general interpretation these maps have the disadvantage that small anomalies whose amplitude range falls entirely within one intensity level will be lost.

Another display method, shaded relief maps, does effectively display the low amplitude detail. This method treats the magnetic data, which can be either gradiometer or total field data, as a surface illuminated by an artificial light source.

The degree of illumination or reflectance at each point on the surface is calculated and the resulting image is plotted with different colours ranging from dark colours representing shaded surfaces to bright colours representing well illuminated surfaces. Since the location of the artificial light source is specified by the user, features striking in a particular direction can be emphasized relative to those striking in other directions. This is because anomalies striking perpendicular to the light source direction will exhibit more sharply contrasting reflectance than ones striking parallel to the light source direction and therefore be accentuated. This directionality is often useful since it permits the interpreter to emphasize features striking in a preferred direction. Variations in regional textures on a shaded relief map are also useful for recognizing areas with different lithologies, for example, magnetically homogeneous acid intrusives or sediments have a characteristically smooth texture.

The shaded relief method is useful for displaying fine detail, however regional amplitude information is lost with this technique. One interesting way of presenting the data so both the detail and regional amplitude can be seen is by producing stereo pairs of shaded magnetic relief images where the second image is an offset version of the first. This pair of images can be viewed using a stereo viewer in a manner similar to stereo pairs of aerial photographs to obtain a three dimensional perspective of the data. Alternately, the stereo pair can be plotted as an analglyph and viewed using filter glasses to obtain the three-dimensional effect.

Another method of displaying both the regional amplitude information and fine detail simultaneously is to modulate the colour intensities of each pixel of a colour intensity map based on the reflectance values calculated for a shaded relief map produced from the same data. This causes the colour intensity to darken in shaded areas and lighten in more brightly illuminated areas resulting in a coloured shaded relief map where the colour is defined by the amplitude of the field and the fine detail can be seen in the colour intensity variations.

These are only some of the possible methods, many others are available. Bandpass and directional filtering in the frequency domain can be applied to isolate anomalies with particular characteristics. The zero level from the vertical gradient, which approximates the geological contacts in steeply dipping structure, can be extracted and plotted on other data sets such as the total field data as a registration method. The choice of the methods to use is determined by the type of information required and the nature of the survey area.

APPLICATION TO THE VAL D'OR AREA

A number of different aeromagnetic data presentations were recently produced for the Val-d'Or mining area and were used by Aur Resources Inc. who are currently actively exploring claims in the Val d'Or area.

Two different data sets were used to produce these maps; the total field data which was digitized to produce the 1:1 million scale magnetic maps of Canada and the detailed gradiometer survey of the Val d'Or area flown in 1980 using the Geological Survey of Canada Beechcraft Queenair Aircraft. For the gradiometer survey the flight altitude was 150 metres and the North-South flight lines were flown at a line spacing of 300 metres. Two self-orienting single cell cesium vapour magnetometers with a vertical separation of 2.05 metres and .005 gamma resolution were used. The data was recorded at half second intervals resulting in a 35 metre sampling interval on the ground. The regional total field data was gridded at 800 m and 200 m to provide an overview of the main magnetic patterns and the much more detailed gradiometer survey data was gridded at 40 m and displayed using a number of techniques at a scale of 1:50,000.

After working with the different types of data presentation several of the methods were found useful for detecting structural features believed to be related to gold mineralization. Anomalies can be identified which are similar to others with known gold mineralization thus identifying possible drilling targets. For example, gold is often associated with diorite-granodiorite stocks such as at Lamaque and Sigma gold mines which have a characteristic small circular anomaly caused by the diorite (Hood et al, 1982).

Digital data enhancement method are relatively inexpensive relative to the costs of data acquisition and can extract additional information from data which would otherwise be lost.

The constantly shrinking costs for the required computers and plotting devices as well as the increasing availability of good interpretation software are making it increasingly attractive for more exploration companies to become involved in computer based interpretation of their geophysical data.

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LA MINE CHIMO

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RESUME

I.P. RESPONSE OF EPITHERMAL GOLD SYSTEMS IN THE SOUTH WESTERN UNITED STATES

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ABSTRACT

REPONSE GEOPHYSIQUE DU GISEMENT COOKE

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RESUME

La mine Cooke a produit entre 1976 et 1984 plus de 200,00 oz d'Au. La minéralisation connue à date est confinée à deux structures de cisaillement plus ou moins parallèles. La quantité de sulfures dans ces structures varie de 1% à 75% pour des largeurs variant de 6 pouces à 10 pieds.

Des tests géophysiques comprenant: levés magnétométrique, électromagnétique et de polarisation provoquée furent exécutés à l'extrémité Est du gisement. Toutes les méthodes, à l'exception de la polarisation provoquée, se sont avérées inaptes à déceler la zone minéralisée. Par contre, le levé de polarisation provoquée révèle une faible anomalie correspondant à la veine 7 E.S.

RÉSUMÉ

La mine Cooke a produit entre 1976 et 1984 plus de 200,000 oz d'Au. La minéralisation connue à date est confinée à deux structures de cisaillement plus ou moins parallèles. La quantité de sulfures dans ces structures varie de 1% à 75% pour des largeurs variant de 6 pouces à 10 pieds.

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INTRODUCTION

Le gisement Cooke exploité par la Corporation Falconbridge Copper dans la région de Chapais au Québec, a produit depuis le début de la production en 1976 plus de 1.2 millions de tonnes.

Le gisement fut découvert en 1968, lorsque le forage S-560 intersecta une valeur économique. Ce forage fut planifié afin de vérifier une faible anomalie Turam et la zone principale Chiboug-Copper.

En 1980, des tests géophysiques furent effectués sur la propriété afin de connaître la réponse du gisement aux diverses méthodes modernes.

GÉOLOGIE RÉGIONALE

Géologiquement, la propriété est située à l'extrémité Est de la ceinture volcano-sédimentaire de Chibougamau - Matagami (Fig. 1). La région de Chapais est caractérisée par un assemblage de roches archéennes du Groupe de Roy dans lesquelles s'est introduit le Pluton d'Opémiska. Le gisement Cooke qui nous intéresse particulièrement, se retrouve dans le filon couche de Bourbeau (Fig. 2), celui-ci représentant le dernier membre du complexe de cummings.

La minéralisation se retrouve confinée à deux structures de cisaillements orientées en moyenne à 120° avec un pendage de 65° à 85° vers le Nord-Ouest. Les veines #7 et #9 qui ont été exploitées jusqu'à date, ont produit 1,389,390 tonnes à une teneur de 0.80% Cu et de 0.165 oz/t Au.

Le minerai se présente en veines étroites de 6" à 10' de largeur dans une zone de cisaillement dont l'épaisseur varie de 1' à 15 pieds (localement 30 pieds); la largeur moyenne pour la veine #7 étant de 6 pieds et de 10 pieds pour la veine #9. Ces deux zones de cisaillements sont chloritisées et riches en carbonate, avec des occurences locales de quartz. La quantité de sulfure dans ces zones varie de moins de 1% jusqu'à 75% occasionnellement, la moyenne étant d'environ 10%. Les principaux sulfures sont la chalcopyrite, la pyrrhotine, l'arsénopyrite et la pyrite. Occasionnellement, on peut voir au contact une mince couche de graphite.

HISTORIQUE

Le gisement Cooke fut découvert en 1968. Le forage de découverte (S-560) intersecta 5 pieds à une teneur de 3.61% Cu, 1,600 oz/t Au et de 2.16 oz/t Ag. Ce forage fut exécuté afin de vérifier une faible anomalie Turam qui se situait dans l'extension de la zone explorée par la Compagnie Chiboug-Copper.

Ce forage fut prolongé et intersecta la veine #7, l'anomalie Turam correspondant à une zone contenant plus de 40% de pyrrhotine et entre 0.40% et 0.75% de cuivre, au contact de la pyroxénite et des volcaniques acides. Après une campagne de forage, il fut décidé de foncer une galerie de 5,000 pieds à partir du 8ième niveau du puits Robitaille. Les réserves lors du début de la production en 1976 étaient de 550,000 tonnes à une teneur de 1.44% Cu, de 0.230 oz/t Au et 0.46 oz/t Ag, après avoir alloué une dilution de 15%.

NATURE DU MORT TERRAIN

Le mort terrain recouvrant la mine Cooke est composé de sables fins (54%) et d'un Silt grossier (46%), c'est-à-dire que la taille des particules varie de 0.02 mm à 3 mm. Tout ce matériel est saturé en eau ce qui rend le mort terrain conducteur.

L'épaisseur moyenne de ce mort terrain est de 64 pieds avec localement des dépressions pouvant atteindrent près de 100 pieds.

LEVÉS GÉOPHYSIQUES

Il y a eu très peu de géophysique de fait sur la propriété. En 1968, une levé Turam fut à l'origine de la découverte. Cependant, l'anomalie forée se révéla non-économique, coïncidant avec le contact pyroxénite-Tuff rhyolitique (Fig. 3).

En 1980, des tests furent effectués sur la section 17,000 E. Cette section fut choisie pour éviter les infrastructures de surface. La minéralisation dans ce secteur est plus faible qu'au-dessus de la zone exploitée et la veine #9 n'a pas été recoupée au-dessus du 6ième niveau (900' sous la surface).

a) Test E.M.H. (Fig. 4,5 et 6)

Ce test fut fait avec un Max-Min II en utilisant un cable de 300 pieds. Les fréquences utilisées furent de 888 Hz et de 3555 Hz. Une anomalie fut décelée correspondant au contact pyroxénite-volcanique. Sur la fréquence 3555 Hz, on peut également noter une faible anomalie en quadrature correspondant possiblement avec la faille Chibougamau-Copper.

b) Levé V.L.F. (Fig. 7 et 8)

Ce levé fut exécuté en utilisant les stations N.S.S. (Annapolis) et N.L.K. (Washington). Les résultats obtenus se comparent avec ceux du levé E.M. à cadres horizontaux.

c) Levé magnétique (Fig. 9)

Ce levé fut exécuté avec un magnétomètre à protons. Le niveau de fond varie de 58,700 à 58,900 gammas. Trois pics de plus de 60,000 gammas furent décelés. Les deux qui sont le plus au Nord correspondent au contact pyroxénite - tuff rhyolitique, alors que le dernier peut soit coïncider avec le contact épidiorite - pyroxénite ou au tubage du trou CL-58, celui-ci ayant été laissé dans le trou.

d) Levé de polarisation provoquée (Fig. 10 et 11)

Ce levé fut exécuté en utilisant un transmetteur et un récepteur de la Compagnie Crone. Une configuration dipole-dipole fut utilisée avec une séparation de 100 pieds entre les électrodes.

On peut remarquer sur la pseudo-section une anomalie bien développée juste au contact pyroxénite - tuff rhyolitique. Autour de 5600 N, on remarque une faible indication d'anomalies sur les deux premières séparations, les deux autres se superposent avec la première anomalie. Le calcul du facteur métal pour la première séparation indique la présence de la seconde anomalie. Cette anomalie se superpose assez bien avec le seul indice minéralisé dans le secteur, c'est-à-dire la veine #7 E.S..

CONCLUSION

Le puits Cooke offre le cas typique d'un gisement difficile à repérer par la géophysique. Malgré une quantité de sulfure appréciable, les méthodes électromagnétiques et magnétiques ne se sont pas avérées efficaces. Par contre, la méthode de polarisation provoquée avec une faible séparation d'électrodes a permis de déceler une faible anomalie dans l'extension du gisement. Les nombreux désavantages tel que l'épaisseur du mort terrain, proximité d'un bon conducteur, rendent la plupart des méthodes géophysiques désuètes.

La recherche de minéralisations aurifères est toujours difficile et aucune méthode géophysique ne peut se vanter d'être infaillible, mais la méthode de polarisation provoquée n'apparait plus sécuritaire dans les cas où le mort terrain est conducteur et d'une épaisseur non-négligeable.

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LAVOIE, C., 1980, Levés électromagnétiques et magnétiques, Propriété Opémiska et test P.P. sur le gisement Cooke, Rapport non publié, 25 p.

WOODARD, J., 1968, Opemiska Copper Mines Turam Electromagnetic Survey Springer Lake Area, Unpub. Study, 3 p.

Legend

(Fig. 1)

- DIABASE
- GRANITIC ROCKS (UNDEFINED)
- GRANODIORITIC and TONALITIC INTRUSIONS
- MAFICS INTRUSIONS
- OPEMISKA GROUP
- CUMMINGS COMPLEX
- DORE LAKE COMPLEX
- ROY GROUP

(FROM)
A. GOBEIL
D. RACICOT 1983

KL. 5 0 5 10 KL.
SCALE 1 = 250 000

(TRACED)
S. LEHOUILLER
1984

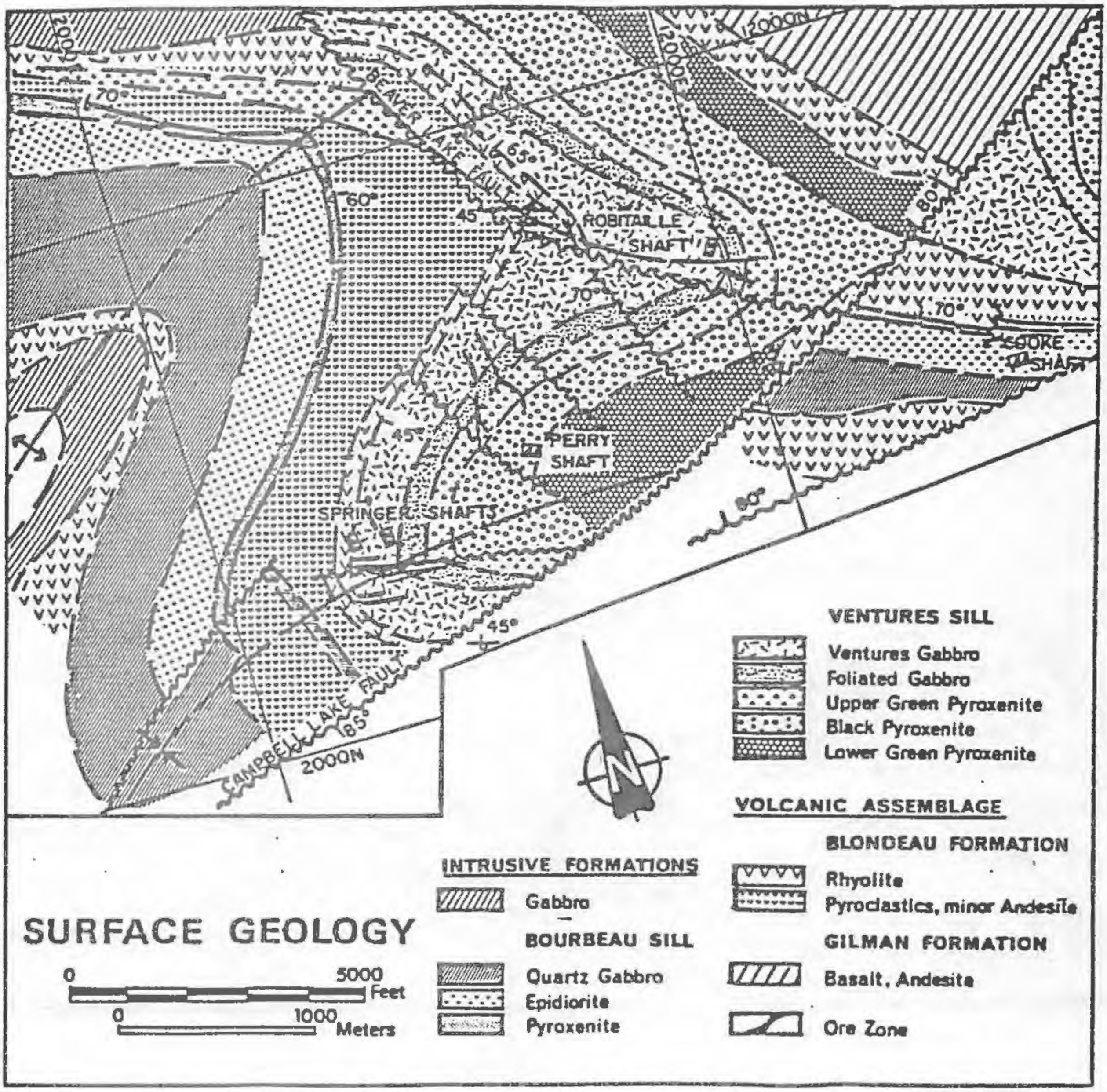

BEAVER LAKE FAULT
ROBITAILLE SHAFT
PERRY SHAFT
SPRINGER SHAFTS
COOKE SHAFT
CAMPBELL LAKE FAULT
2000N
SURFACE GEOLOGY
0
5000
Feet
0
1000
Meters
INTRUSIVE FORMATIONS
Gabbro
BOURBEAU SILL
Quartz Gabbro
Epidiorite
Pyroxenite
VENTURES SILL
Ventures Gabbro
Foliated Gabbro
Upper Green Pyroxenite
Black Pyroxenite
Lower Green Pyroxenite
VOLCANIC ASSEMBLAGE
BLONDEAU FORMATION
Rhyolite
Pyroclastics, minor Andesite
GILMAN FORMATION
Basalt, Andesite
Ore Zone

Fig.2

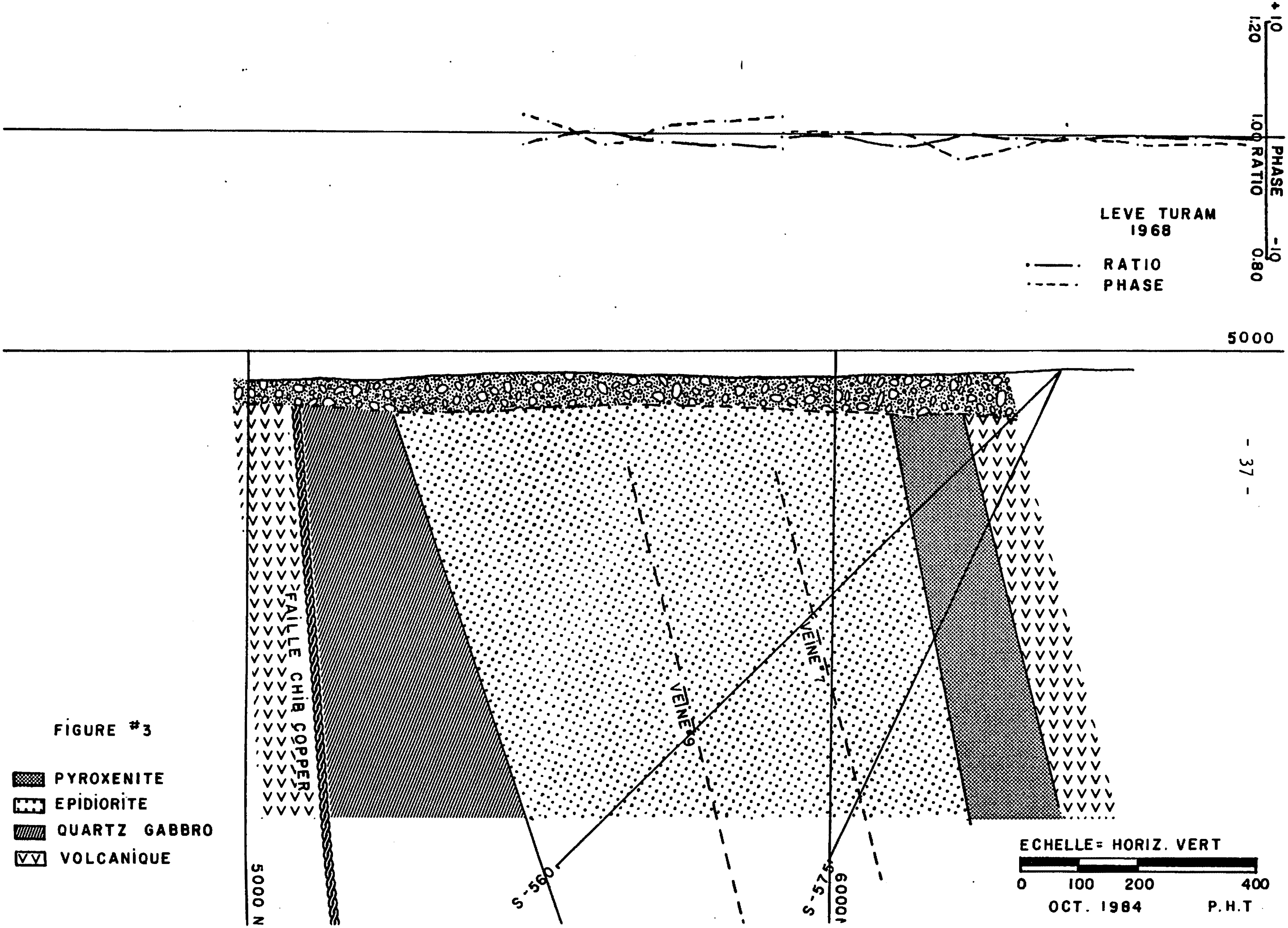

+10
1.20
PHASE
1.00 RATIO
-10
0.80
LEVE TURAM
1968
RATIO
PHASE
5000
5000 N
6000
FAILLE CHIB COPPER
VEINE 9
VEINE 7
S-560
S-575
PYROXENITE
EPIDIORITE
QUARTZ GABBRO
VOLCANIQUE
ECHELLE= HORIZ. VERT
0
100
200
400
OCT. 1984
P.H.T

FIGURE #3

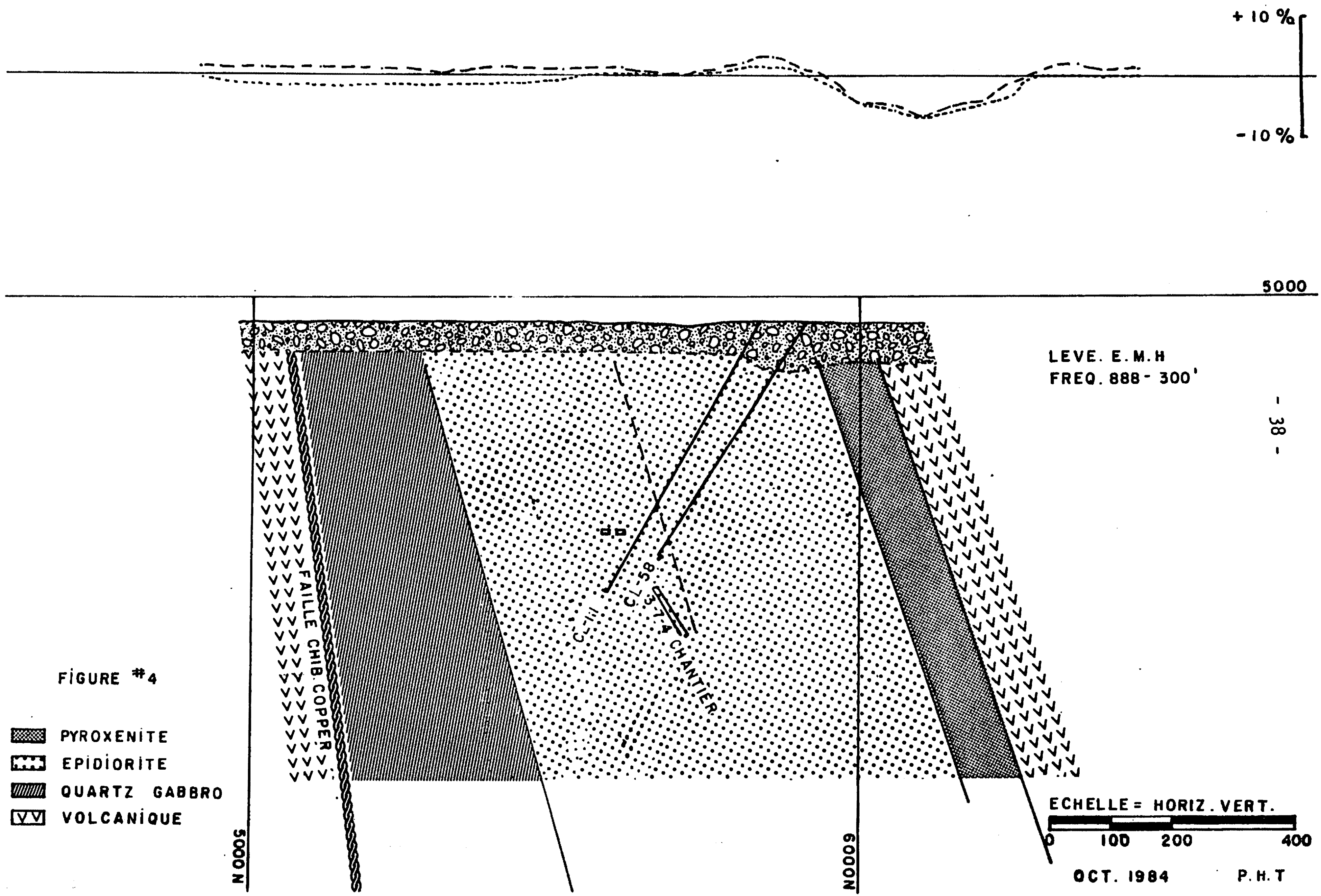

+ 10 %
- 10 %
5000
LEVE. E.M.H
FREQ. 888 - 300'
FAILLE CHIB. COPPER
CL-11
CL-58
37.4
CHANTIER
5000 N
6000N
PYROXENITE
EPIDIORITE
QUARTZ GABBRO
VOLCANIQUE
ECHELLE = HORIZ. VERT.
0 100 200 400
OCT. 1984
P.H.T

FIGURE #4

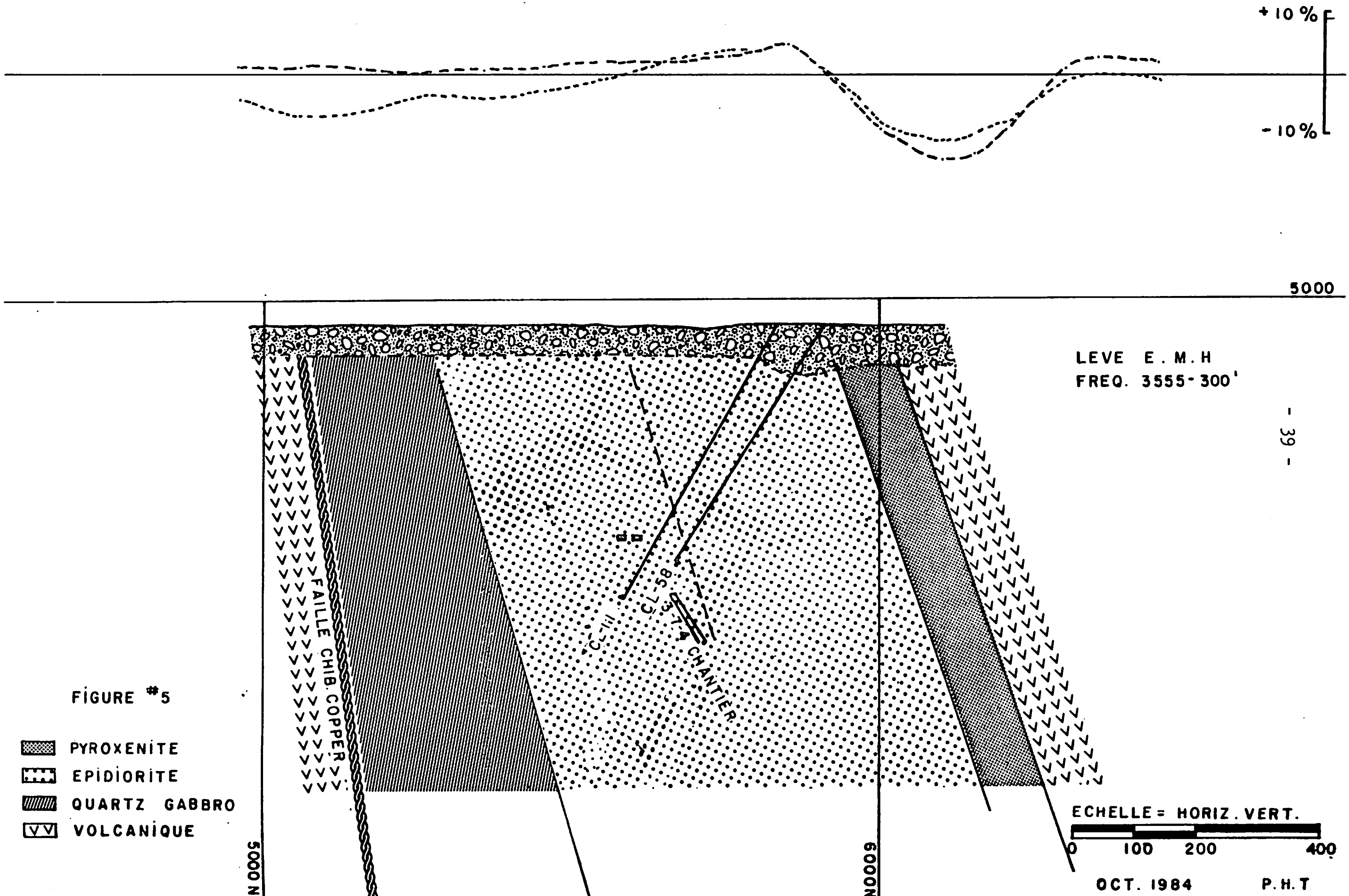


FIGURE #5

PYROXENITE
EPIDIORITE
QUARTZ GABBRO
VOLCANIQUE

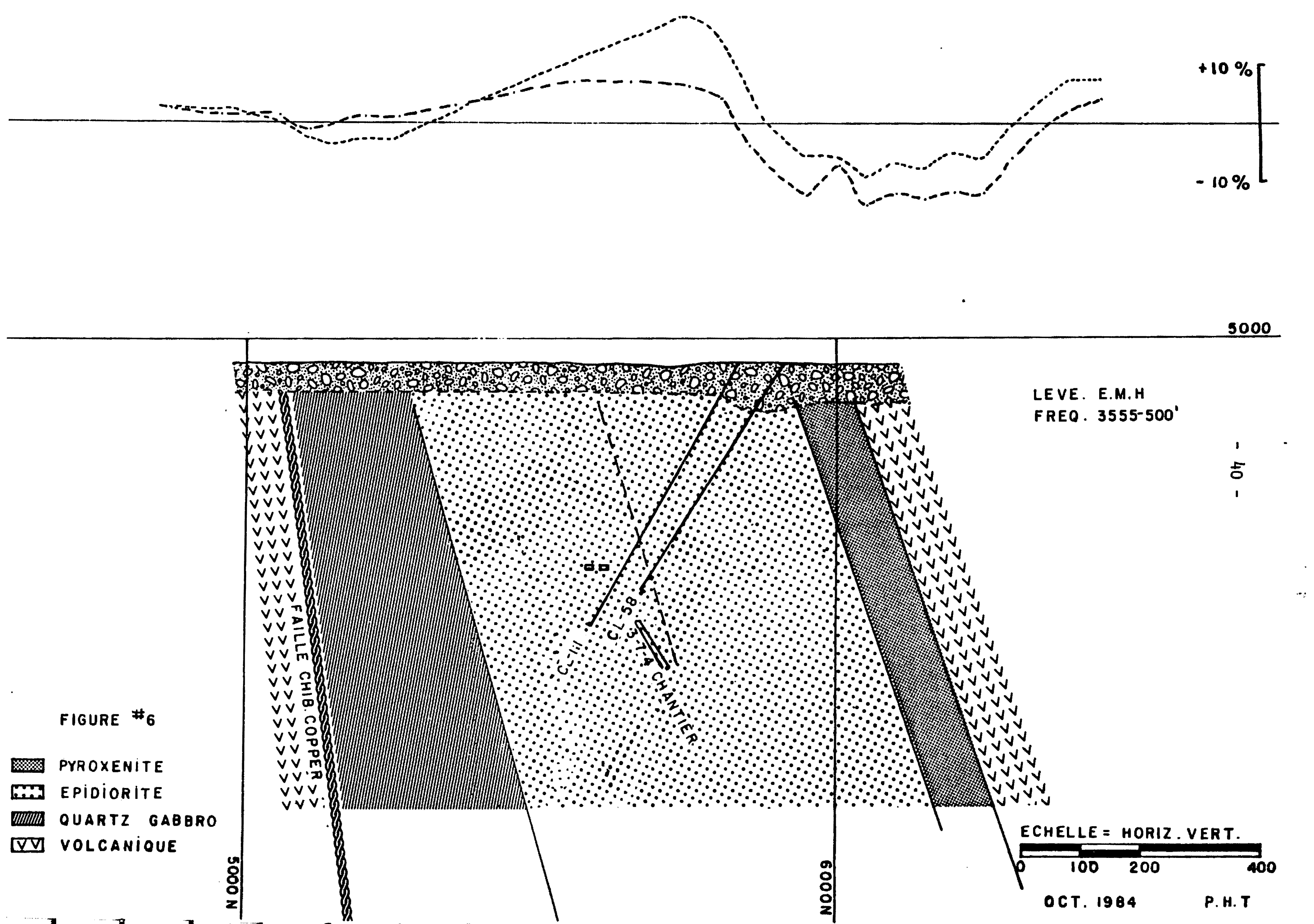


FIGURE #6

PYROXENITE
EPIDIORITE
QUARTZ GABBRO
VOLCANIQUE

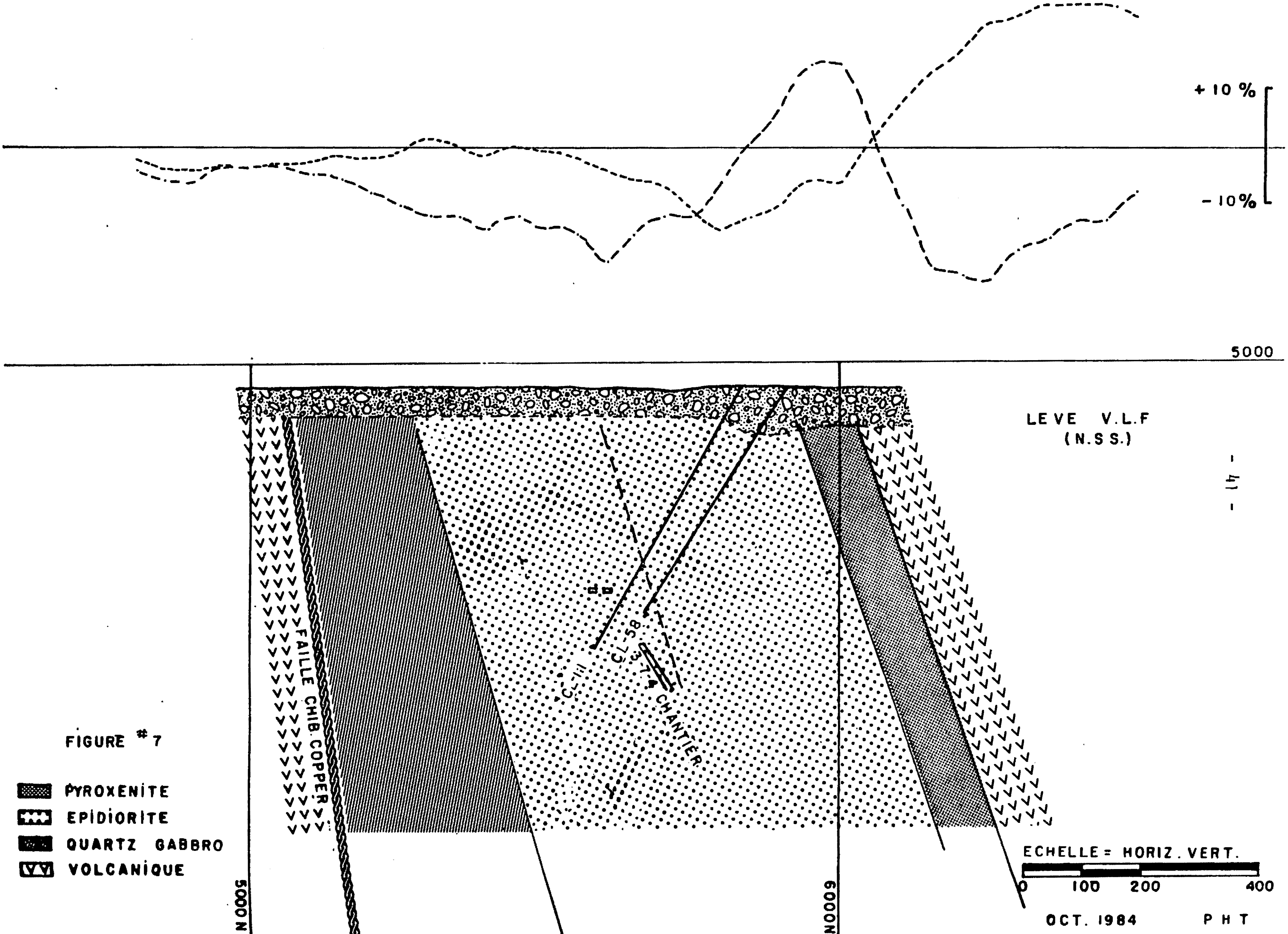

+10 %
-10%
5000
LEVE V.L.F
(N.S.S.)
FAILLE CHIB. COPPER
CL-111
CL-58
3-7-4
CHANTIER
5000 N
6000N
ECHELLE = HORIZ. VERT.
0 100 200 400
OCT. 1984
P H T
PYROXENITE
EPIDIORITE
QUARTZ GABBRO
VOLCANIQUE

FIGURE # 7

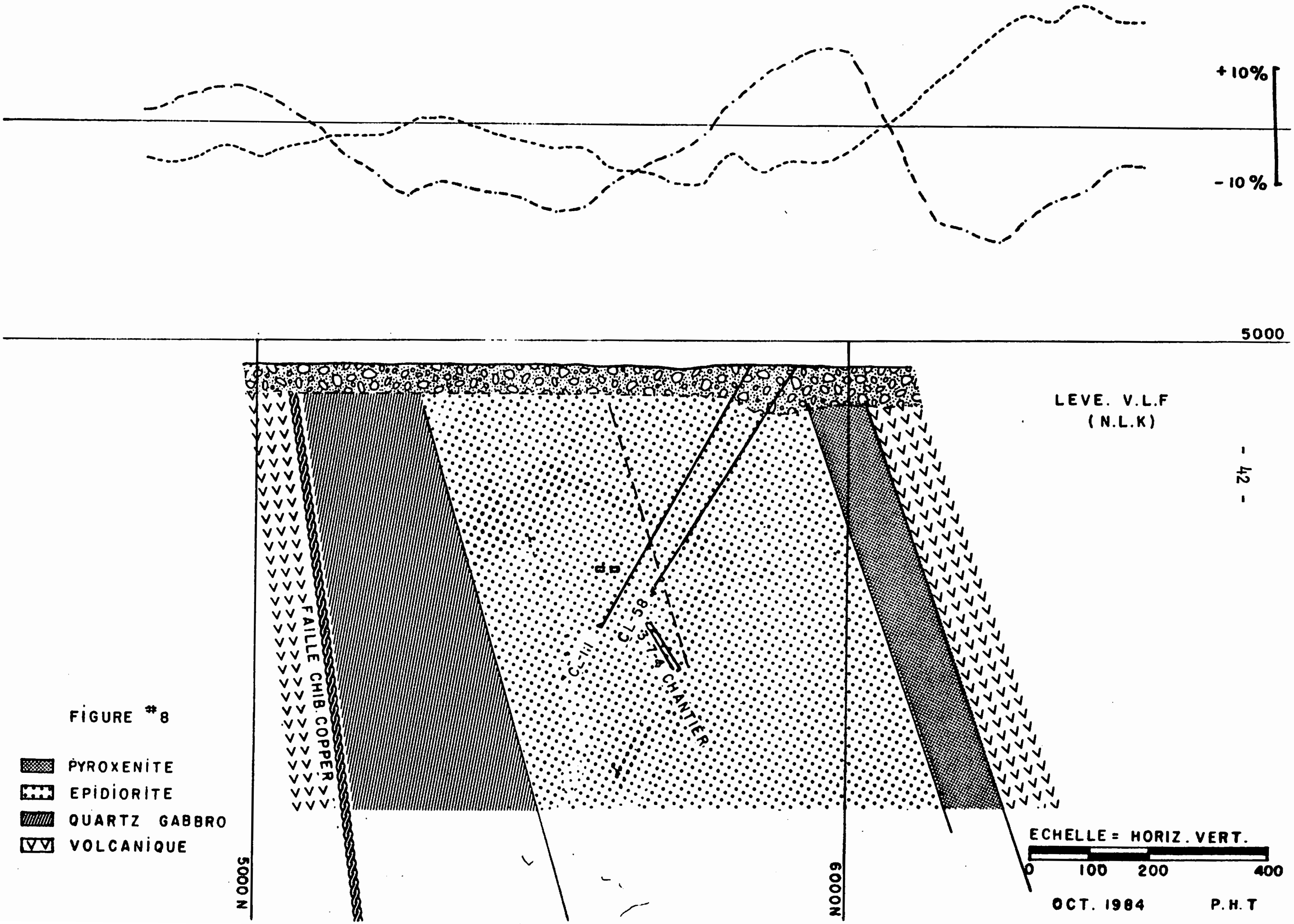

+10%
-10%
5000
LEVE. V.L.F
(N.L.K)
FAILLE CHIB. COPPER
CL-58
CL-111
37-4
CHANTIER
5000 N
6000N
ECHELLE = HORIZ. VERT.
0
100
200
400
OCT. 1984
P.H.T
PYROXENITE
EPIDIORITE
QUARTZ GABBRO
VOLCANIQUE

FIGURE #8

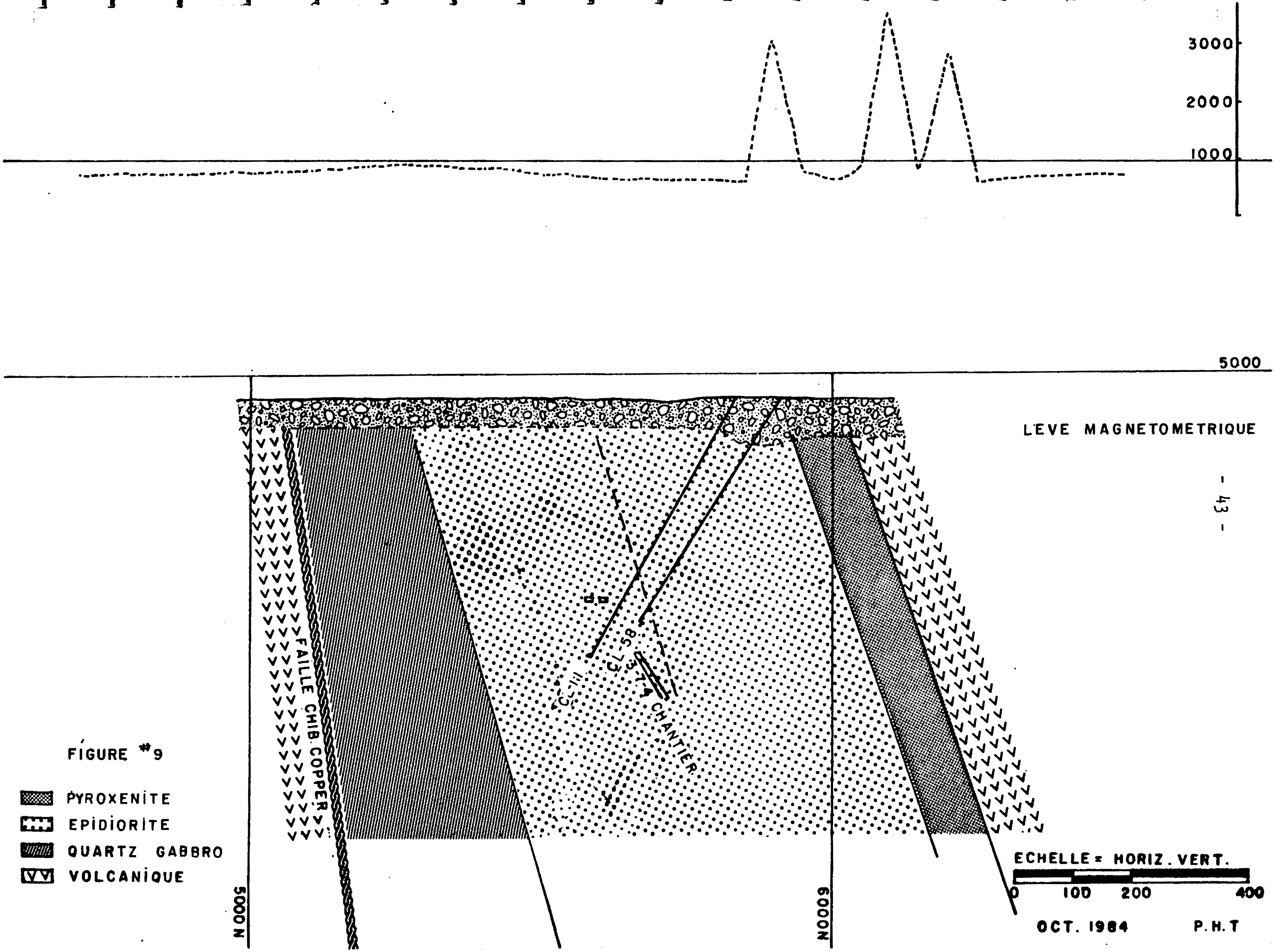

3000
2000
1000
5000
LEVE MAGNETOMETRIQUE
FAILLE CHIB. COPPER
CL-58
CL-111
37-4
CHANTIER
5000 N
6000 N
PYROXENITE
EPIDIORITE
QUARTZ GABBRO
VOLCANIQUE
ECHELLE = HORIZ. VERT.
0 100 200 400
OCT. 1984
P.H.T

FIGURE #9

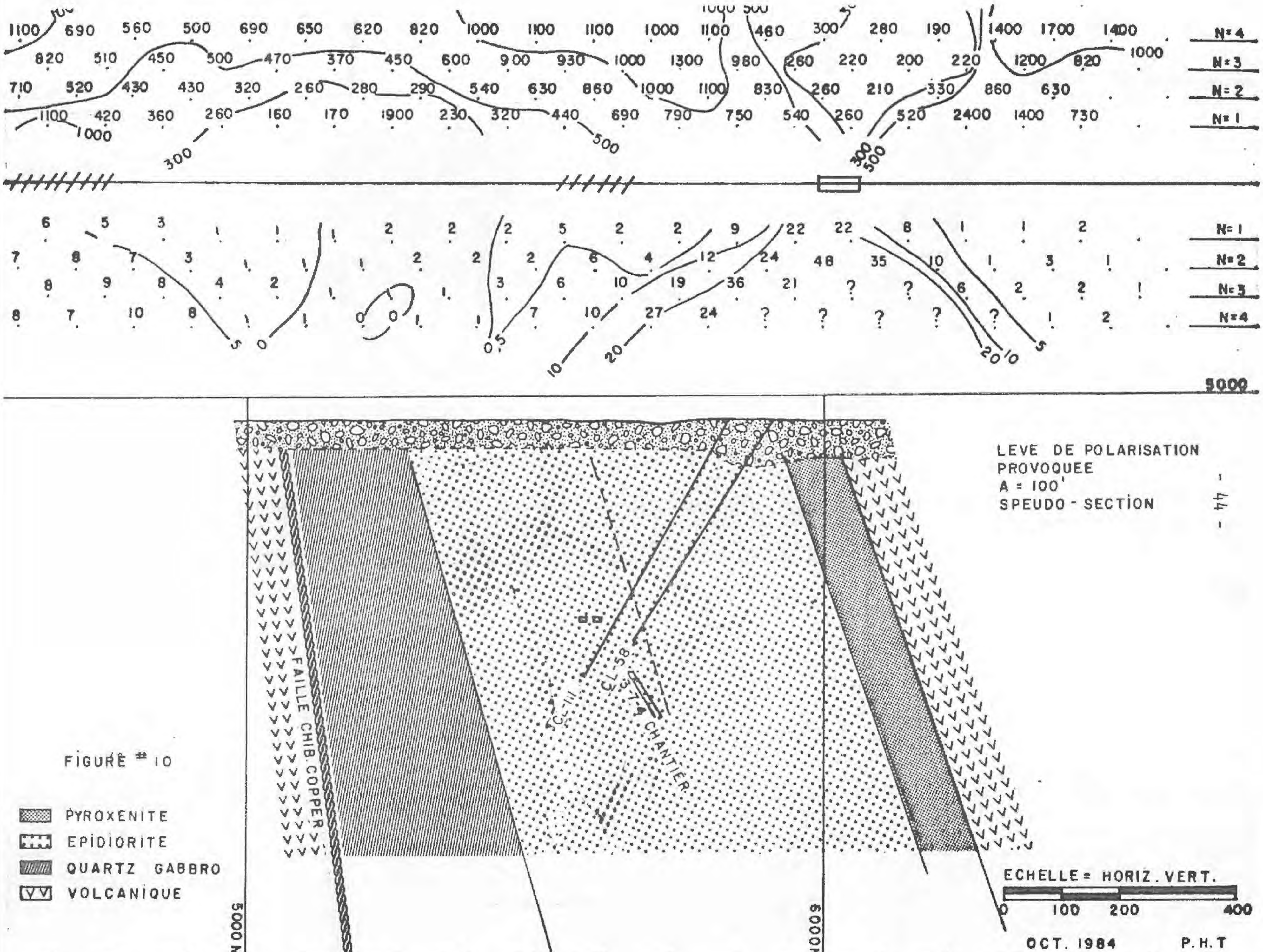
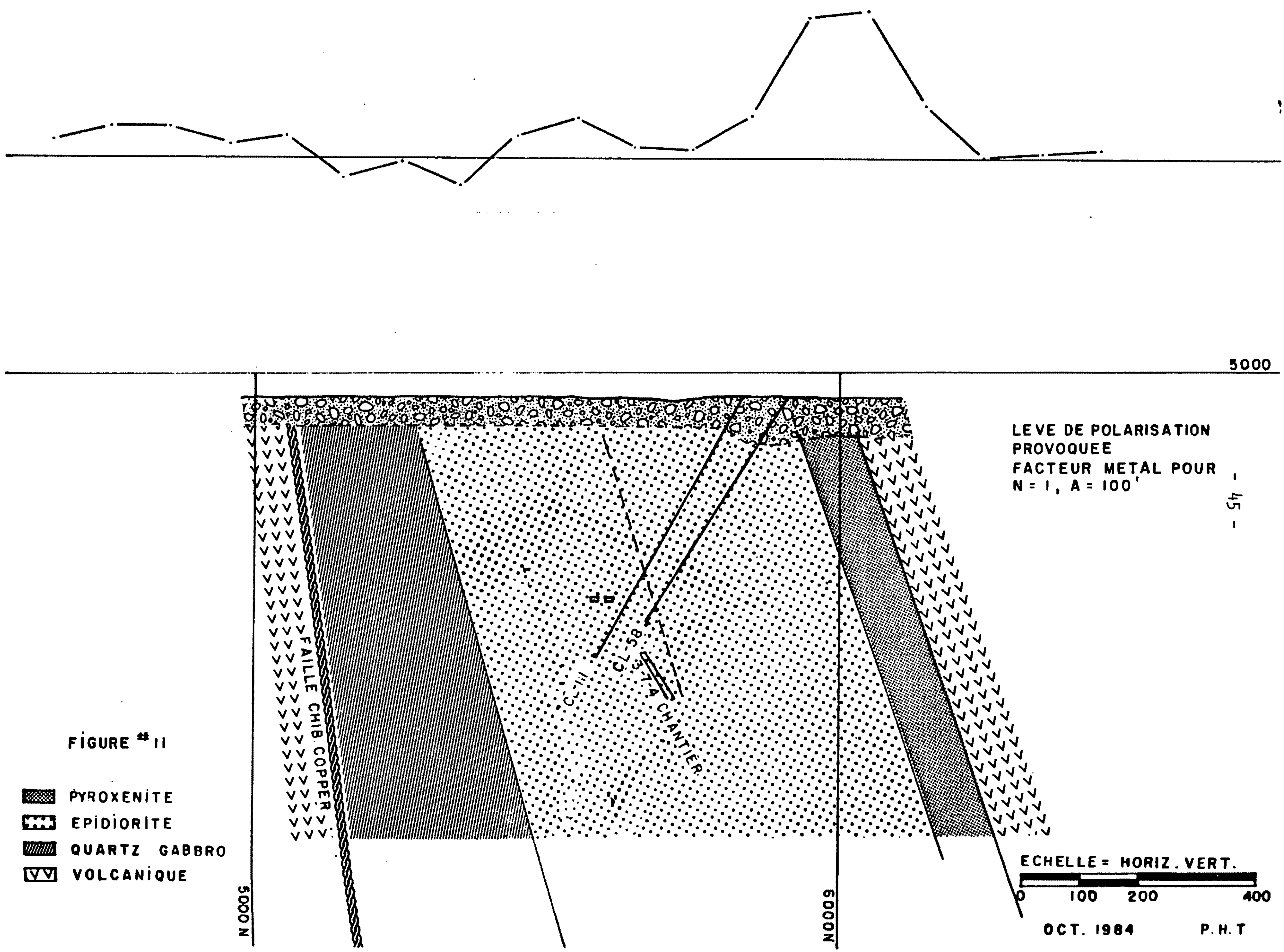


FIGURE # 10

PYROXENITE
EPIDIORITE
QUARTZ GABBRO
VOLCANIQUE


5000
LEVE DE POLARISATION
PROVOQUEE
FACTEUR METAL POUR
N = 1, A = 100'
FAILLE CHIB. COPPER
CL-11
CL-58
3-7-4
CHANTIER
5000 N
6000N
ECHELLE = HORIZ. VERT.
0
100
200
400
OCT. 1984
P.H.T
FIGURE # 11
PYROXENITE
EPIDIORITE
QUARTZ GABBRO
VOLCANIQUE

AMOCO'S DETOUR GOLD DISCOVERY
DETOUR LAKE AREA, N.E. ONTARIO

D.C. Crone
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Mississauga, Ontario

ABSTRACT

The project was originally conceived as a massive copper-zinc sulphide search, using the Input system to locate conductors.

Input anomaly #38 (the Detour mine), described as having good conductivity-thickness responses with a high magnetic correlation, was rated medium priority for follow-up.

In the normal course of events, it was ground-checked by Amoco geophysical crews and then tested by diamond core drilling.

Gold values were found to be centered on a 0.5 metre to four (4) metre wide cherty tuff horizon that was well mineralized with quartz, pyrrhotite bands, and lesser pyrite and chalcopyrite. The underlying serpentinized ultramafic and overlying basalts were similarly mineralized at a flexure in the east-west striking, north dipping sequence.

This gave a stratiform zone 600 metres long and ten to thirty metres wide with 10-15% sulphides, the majority pyrrhotite.

There appears to be little to distinguish the local geophysical response from non-gold bearing sulphide zones. A study of the regional aeromagnetics might show useful similarities to other productive gold camps in the Abitibi.

PAPER PRESENTED AT THE CIM - GEOPHYSICS FOR GOLD SYMPOSIUM

AMOCO'S DETOUR GOLD DISCOVERY, DETOUR LAKE AREA, N.E. ONTARIO

BY: J. DUNCAN CRONE, GEOPHYSICIST
CRONE GEOPHYSICS LIMITED

DATED: NOVEMBER 1984

HISTORY:

The Detour Lake Gold ore deposit was discovered in the fall of 1974 as a result of drilling a medium priority conductor (anomaly #38) detected by airborne and ground geophysics. The orebody was found primarily because the gold is closely associated with sulphides-pyrrhotite, chalcopyrite and minor pyrite. The volume of sulphides associated with the gold mineralization would average 10% to 15%, occassionally increasing to as high as 30%. The exploration program carried out by Amoco Canada Petroleum Company's Mineral Division was a routine search for massive sulphide, copper-zinc type deposits. The orebody was discovered not as a result of applying new exploration techniques but from a methodical testing of airborne anomalies supported with a drilling budget that would permit testing of second priority targets. Another important factor was the routine splitting and assaying of all core containing 5% sulphides or more - all samples were assayed for Pb, Zn, Cu, Ag and Au. The discovery drill hole cut 21m (68') of banded sulphide mineralization primarily pyrrhotite, with some chalcopyrite. There was no visible gold in the section. Only when the gold assays arrived averaging 5.5g/t (.16 oz/ton) over the entire mineralized width did Amoco realize they had discovered a potential orebody.

.../2

LOCATION AND GEOLOGY:

The deposit is located in a swamp covered area of Northern Ontario at the 50th parallel of latitude, 13 km from the Quebec border. The closest towns are Cochrane 225 km to the southwest and La Sarre the same distance to the southeast, (Figure 1 - Location map).

The main ore zones occur in a cherty tuff, felsic tuff horizon, underlain by an altered ultramafic, talc-carbonate zone (Figure 2 - Level plan of main ore zones), (Figure 3 - Geological column). Other rocks in the footwall sequence are gabbroic intrusives, mafic tuffs and felsic agglomerates. The hanging wall rocks are primarily basalt flows. Width of ore in the main zone averages 11m (36'), dip is approximately 70°N. The mineralization is believed to have been deposited with the cherty tuff sediments by the rising solutions that altered the ultramafics into talc-carbonates. The two ore sections occuring in the cherty tuff horizon, the main zone and the western zone occur along the nose of small flexures in the ultramafic unit (Figure 4 - Generalized geological cross-section). Both zones plunge westward at 45° (Figure 5 - Longitudinal section). Gold mineralization also occurs in the hanging wall basalt in the form of quartz veins with associated pyrrhotite and chalcopyrite. The quartz veins have a limited strike length - in the order of 60m to 90m (200' to 300') and also plunge 45° westward. They have been labelled the 150', 200', 300' and 900' veins according to their distance above the cherty tuff horizon. Width of the quartz ore vein is in the order of 3m to 6m (10' to 20'), dip 70°N. Three oreshoots also occur in the footwall talc carbonates unit. These oreshoots are much the same in size and structure as the hanging wall quartz vein shoots, but contain less quartz.

.../3

GEOPHYSICS:

The Detour Greenstone belt was flown for Amoco by Questor in January 1974. From this survey 43 groups of conductive zones were selected for ground follow-up. These were rated with low, medium or high priorities based on the relationship of the anomaly to known geology as well as the shape, length and apparent conductivity-thickness of the anomaly. Anomaly #38 (Figure 6 - Questor airborne plan map) was assigned a medium priority rating. It occured in a swamp covered area with little known geology. The airborne conductor was 3.2 km long with magnetic coincidence of 90 to 900 gammas. The western portion of the airborne conductor was very weak, conductivity-thickness of 1 to 2 mhos, the eastern half improving to within the range of 2 to 13 mhos. A north dip was indicated by the airborne profiles (Figure 7 - Questor airborne tapes of the two flight lines over the eastern portion of the conductor).

Ground geophysical coverage was by Amoco's own crews. The airborne anomaly was first pinned down in location by a VLF-EM pace and compass traverse. A baseline was then cut along the axis of the conductor and a pace and compass grid established. Shootback EM, VLF-EM, fluxgate magnetometer surveys were then completed on this grid. Geological mapping and soil sampling surveys followed after break-up. The speed and hence economy of this type of exploration coverage is illustrated by the Detour project. Flown in January 1974, all selected airborne anomalies on open ground were staked, grids established, followed by geophysical and geological surveys. Drill holes were then spotted and drilling commenced in October 1974.

The Shootback EM survey results (Figure 8 - Plan map of original grid) used the 1830-390Hz frequencies and a coil spacing of 90m (300'). The main ore zone, the eastern portion of the airborne conductor, is readily detected as well as several small flanking conductors. The flanking conductors are all small sulphide zones that are in most cases barren, but in some instances form the hanging wall and footwall gold veins.

The VLF-EM survey (Figure 9) using the Seattle Washington transmitter station also accurately outlined the main ore zone. The VLF survey coverage extended further westward than the Shootback EM survey and detected the western ore zone as a weak anomaly. Several small flanking conductors were also detected with the VLF although only one of these anomalies (L20W, 5+00N) is coincident with a hanging wall quartz-gold vein.

The ground magnetic survey (Figure 10) contains a 500γ to 4000γ anomaly primarily caused by the pyrrhotite mineralization within the cherty tuff horizon. The ultrabasic unit is not defined by the magnetic survey probably due to depletion of magnetite in the alteration process. This is unfortunate since mapping the extent and thickness of this unit would have helped to locate zones of possible gold mineralization within the overlying cherty tuff horizon. The gold ore is associated with minor flexures in the ultrabasic unit, as illustrated previously (Figure 4).

Subsequent I.P. surveys by Geoterrex, using time domain equipment and equi-spaced three electrode arrays easily detected the main ore zones (Figure 11 - I.P. profile). The profile shown picks up the main ore zone at 201+50N. A talc carbonate footwall gold ore zone on this line is also detected as a weak one station anomaly on the 100' electrode spacing survey. The hanging and footwall subsidiary ore zones are again not readily detected by this geophysical method due to their small strike length.

A geophysical survey method that proved to be useful in the drilling development stage of this discovery was what might be called the "old-fashioned", high powered, fixed transmitter vertical loop EM method. This method has the advantage of being able to selectively energize a near vertical conductor by placing the transmitter loop directly above it. This survey accurately traced out the cherty tuff horizon over a strike length of 4.6 km (15,000'), (Figure 12 - Plan map of a portion of the Vertical Loop EM survey). The weak conductor axis south of the main cherty tuff zone anomaly corresponds to the footwall contact of the ultramafic unit - other conductors are barren sulphide zones.

CONCLUSIONS:

The Detour Lake main orebody was readily detected by standard geophysical methods due to the sulphide content of the gold bearing formations being above 10%. Gold content within the cherty tuff horizon generally increased as sulphide content increased. The subsidiary hanging wall and footwall gold ore lenses containing similar mineralization were only marginally anomalous or failed to be detected by geophysics due to their small strike length of 100 meters or less at surface. Continuity of the sulphides in these lenses was not as continuous as in the sedimentary tuff horizons.

.../6

Determination of structures favourable to gold mineralization in the Detour camp would first require outlining the cherty tuff horizon, secondly determining the presence and thickness of the footwall altered ultramafic formation in order to identify flexures in this unit. The magnetic survey in the vicinity of the Detour orebody did not produce an anomaly that could be identified as the ultramafic unit. The high powered vertical loop survey was the most effective geophysical method used to trace out these geological formations. It could only be put to effective use, however, after the favourable formations had been identified by drilling.

REFERENCES:

Jackson, A., 1976, Geological Report Detour Lake Gold Prospect, Ontario, Canada; Internal Report, Amoco Canada Petroleum Co. Limited.

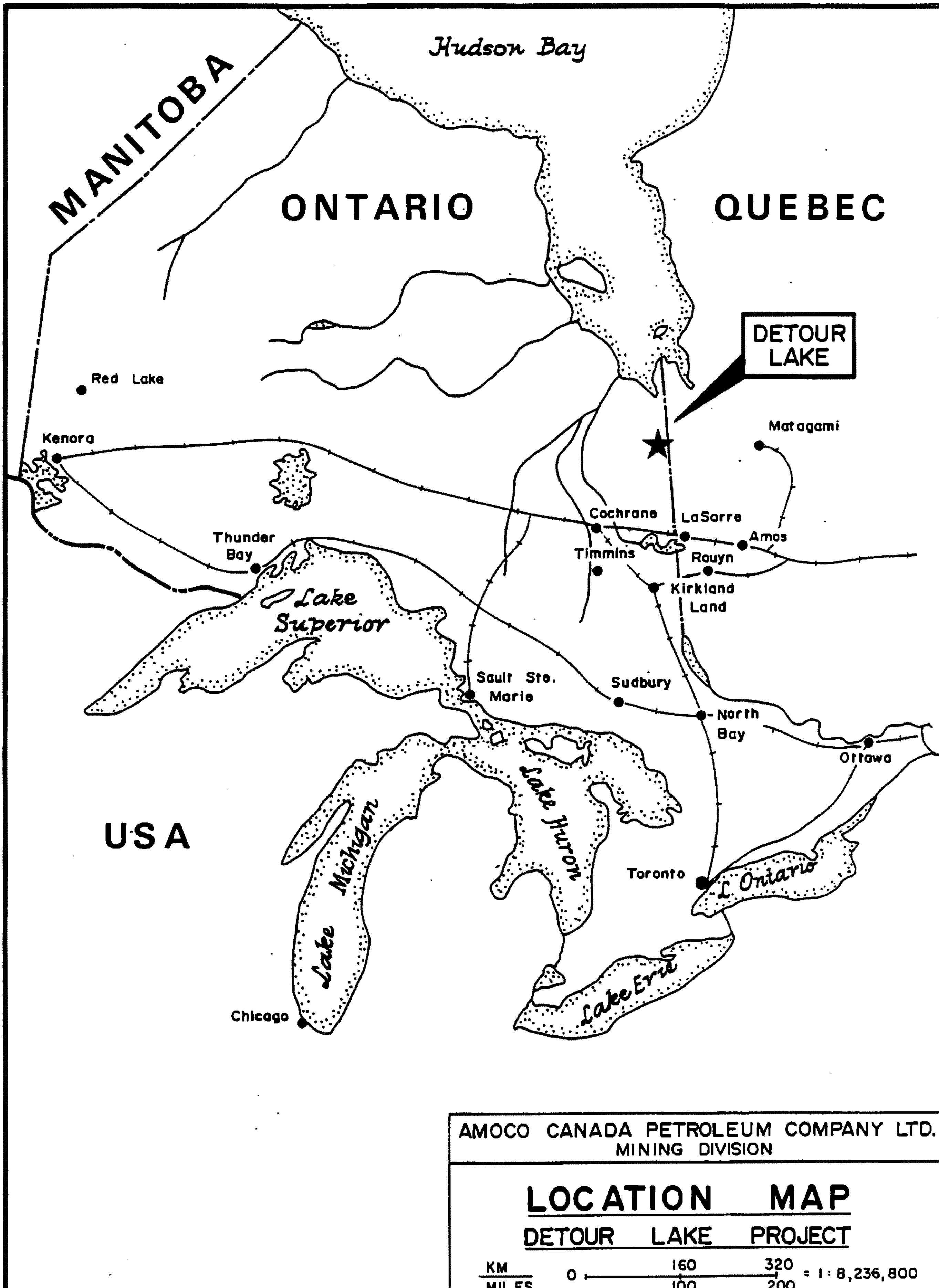

Hudson Bay
MANITOBA
ONTARIO
QUEBEC
DETOUR LAKE
Red Lake
Kenora
Matagami
Cochrane
LaSarre
Amos
Thunder Bay
Timmins
Rouyn
Kirkland Land
Lake Superior
Sault Ste. Marie
Sudbury
North Bay
Ottawa
USA
Lake Michigan
Lake Huron
Toronto
L Ontario
Lake Erie
Chicago
AMOCO CANADA PETROLEUM COMPANY LTD.
MINING DIVISION
LOCATION MAP
DETOUR LAKE PROJECT
KM
MILES
0
160
320
100
200
= 1 : 8,236,800

FIGURE 1

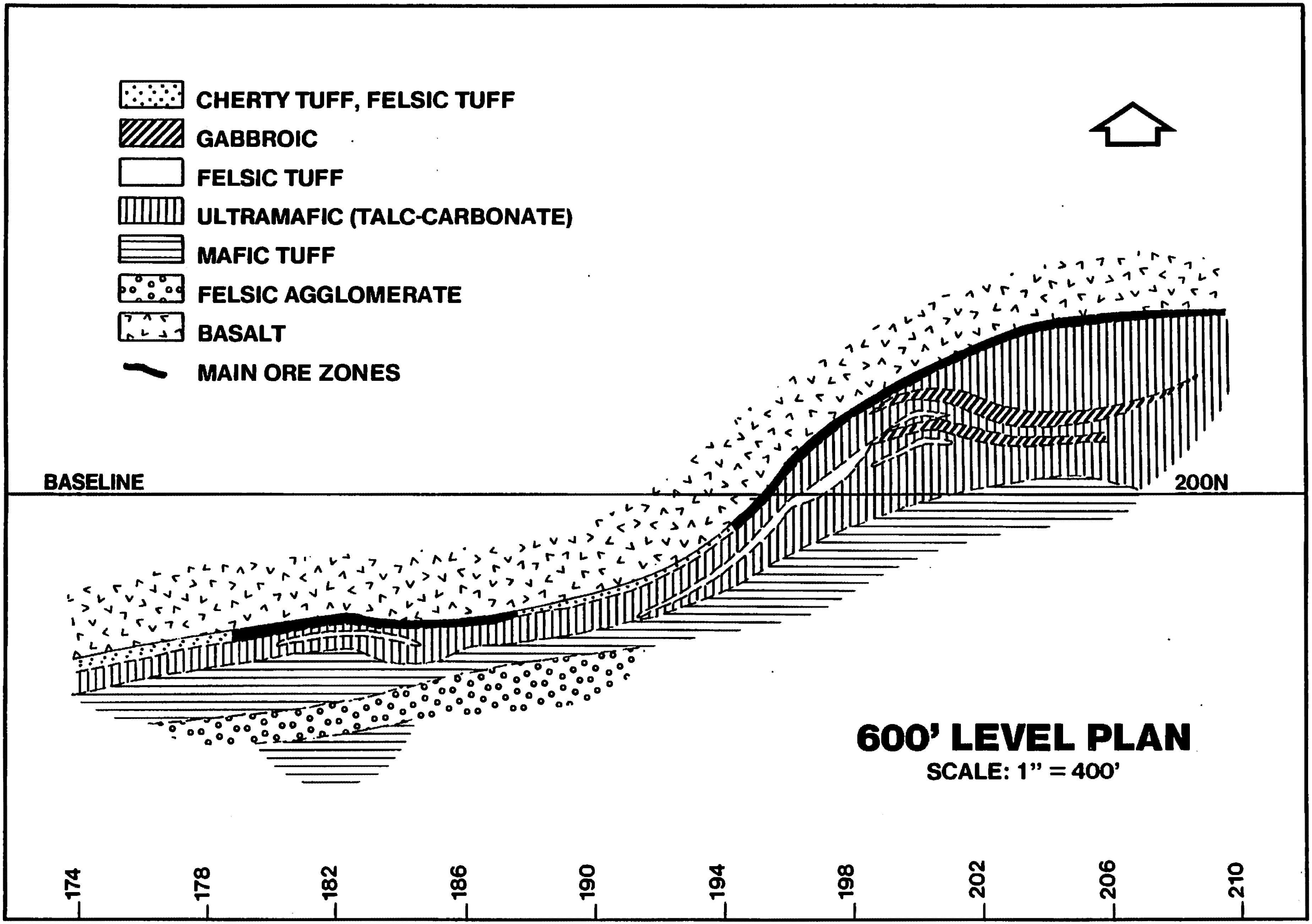
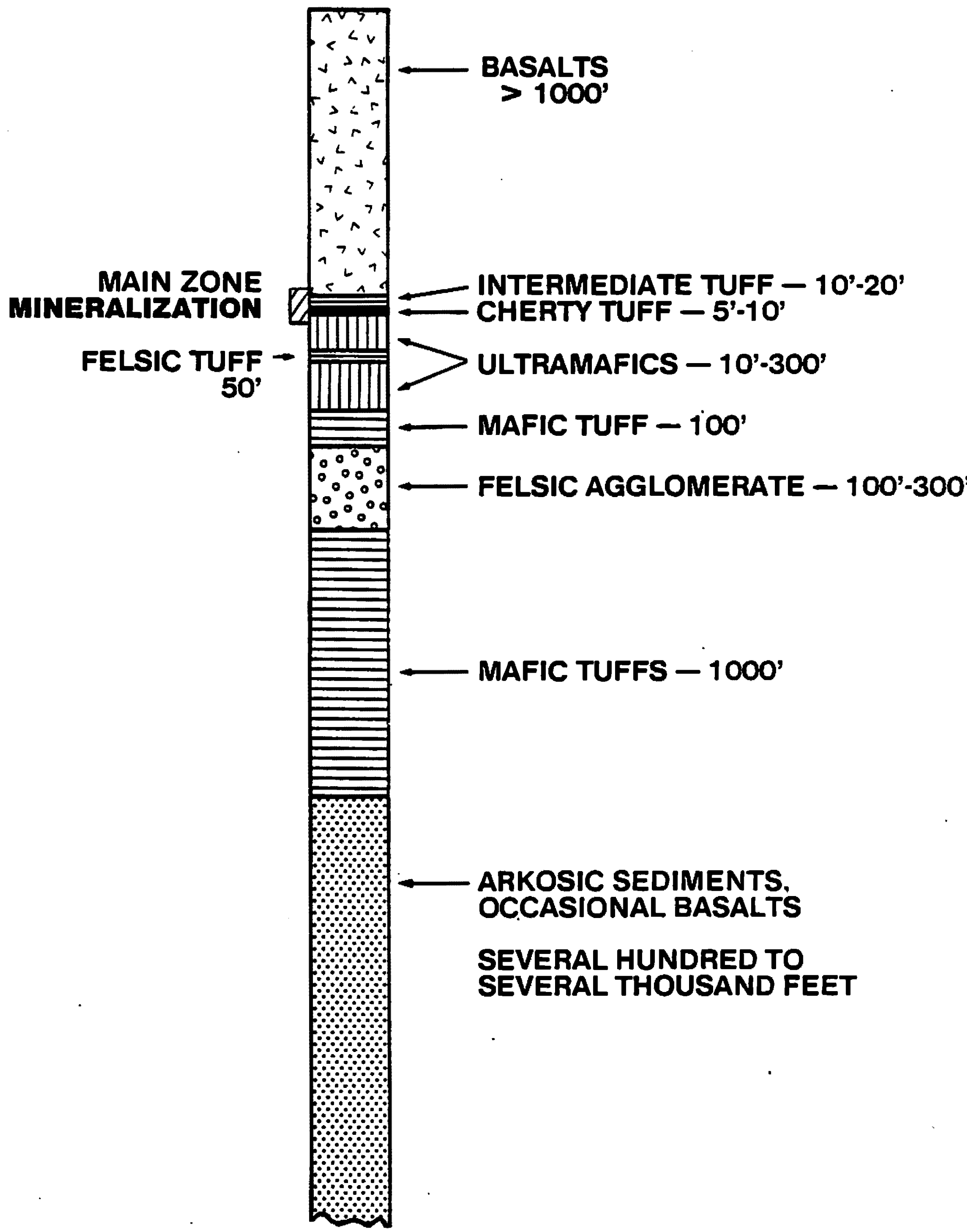

CHERTY TUFF, FELSIC TUFF
GABBROIC
FELSIC TUFF
ULTRAMAFIC (TALC-CARBONATE)
MAFIC TUFF
FELSIC AGGLOMERATE
BASALT
MAIN ORE ZONES
BASELINE
200N
600' LEVEL PLAN
SCALE: 1" = 400'
174
178
182
186
190
194
198
202
206
210

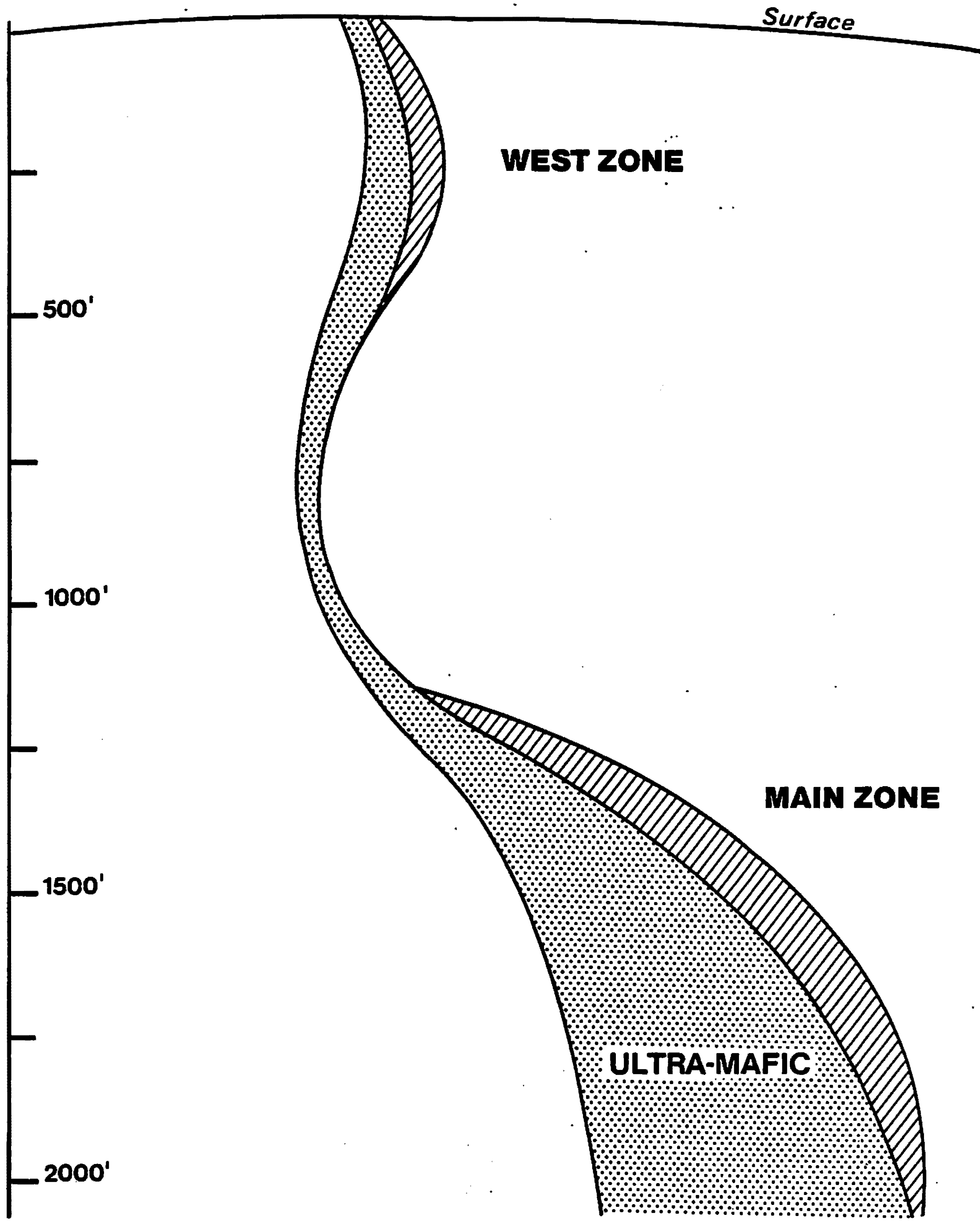
FIGURE 2



GENERALIZED GEOLOGICAL COLUMN

SCALE: 1" = 600'

FIGURE 3



GENERALIZED GEOLOGICAL SECTION
LOOKING WEST
APPROX. SCALE: 1" = 250'

FIGURE 4

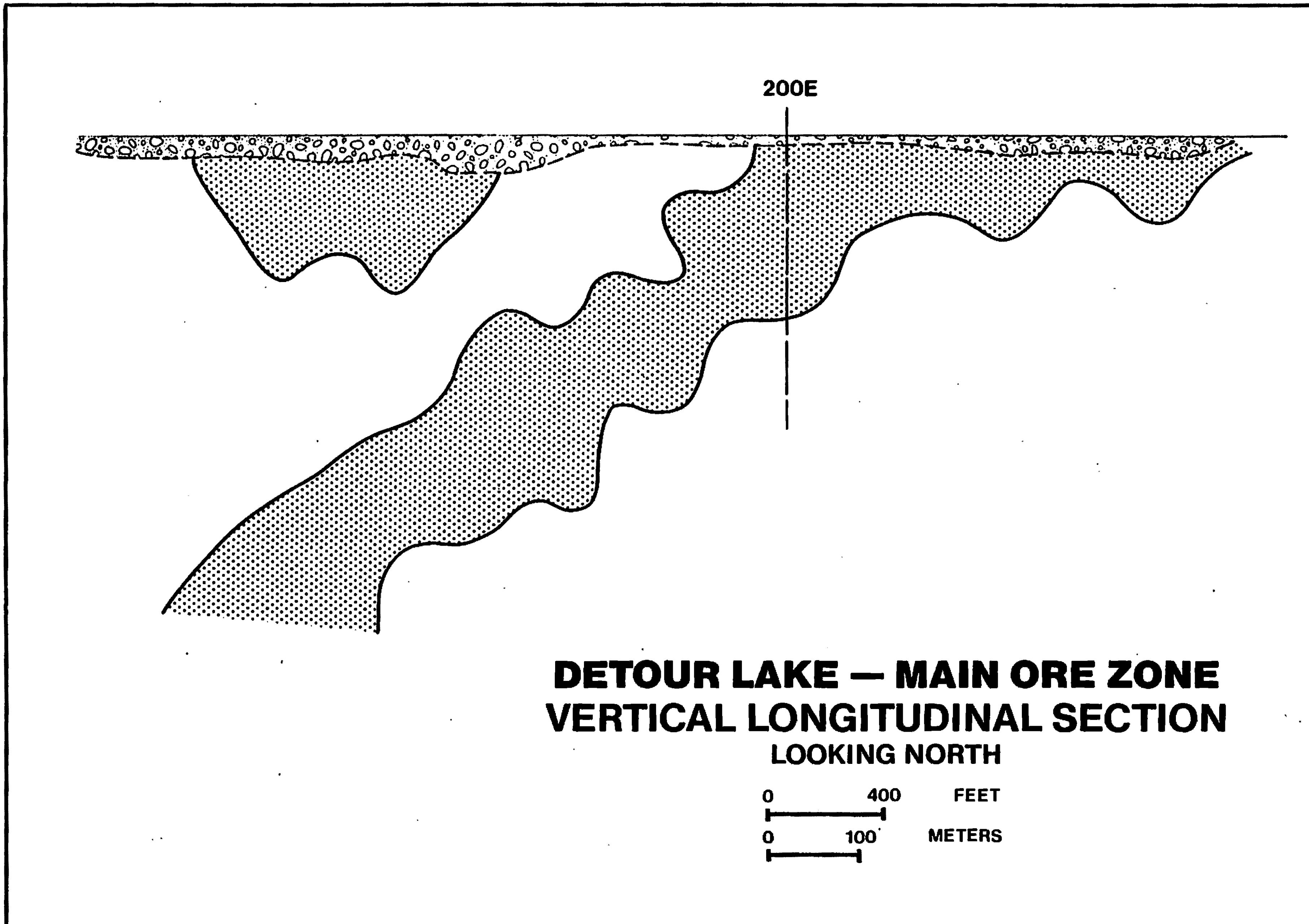
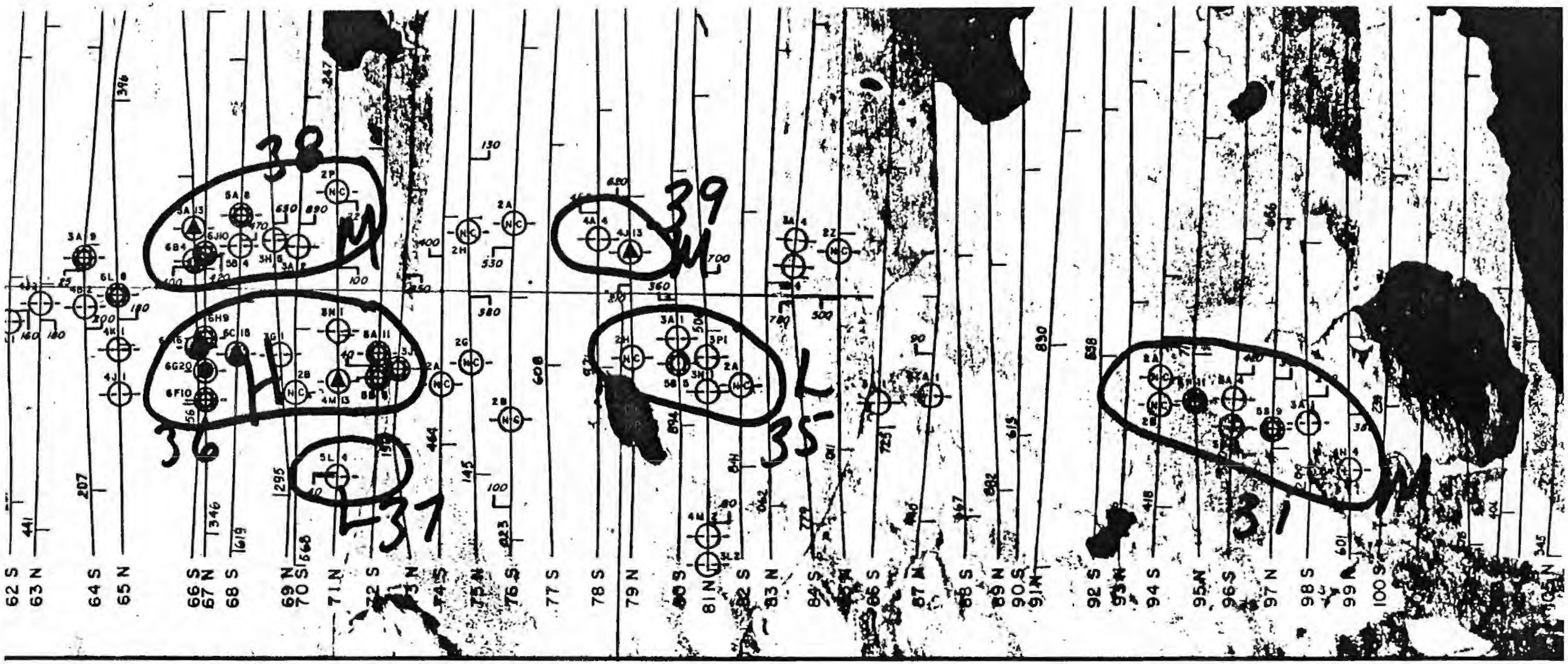

200E
DETOUR LAKE — MAIN ORE ZONE
VERTICAL LONGITUDINAL SECTION
LOOKING NORTH
0 400 FEET
0 100 METERS

FIGURE 5



H — HIGH PRIORITY TARGET
M — MEDIUM PRIORITY TARGET
L — LOW PRIORITY TARGET
XXX — MAIN ORE ZONES FROM SUBSEQUENT DRILLING

QUESTOR SURVEYS LIMITED
AIRBORNE Mk VI INPUT SURVEY

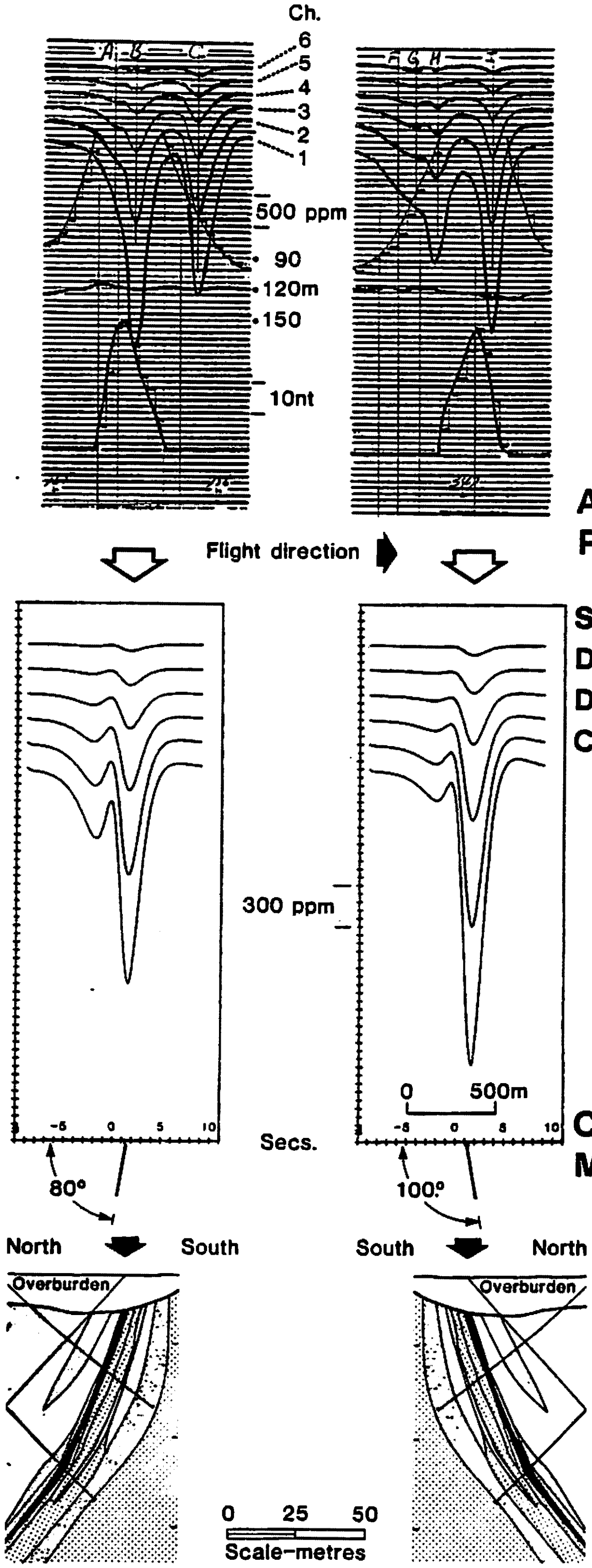
DETOUR RIVER AREA

FIGURE 6

Questor Surveys Limited

Fixed Wing MK VI INPUT®

DETOUR LAKE
GOLD DEPOSIT
Amoco



ANALOG PROFILES

STRIKE LENGTH	• 600m
DEPTH EXTENT	• 300m
DEPTH	• 10m
CONDUCTANCE	• 13s

COMPUTER MODELLING

GEOLOGICAL SECTION

FIGURE 7

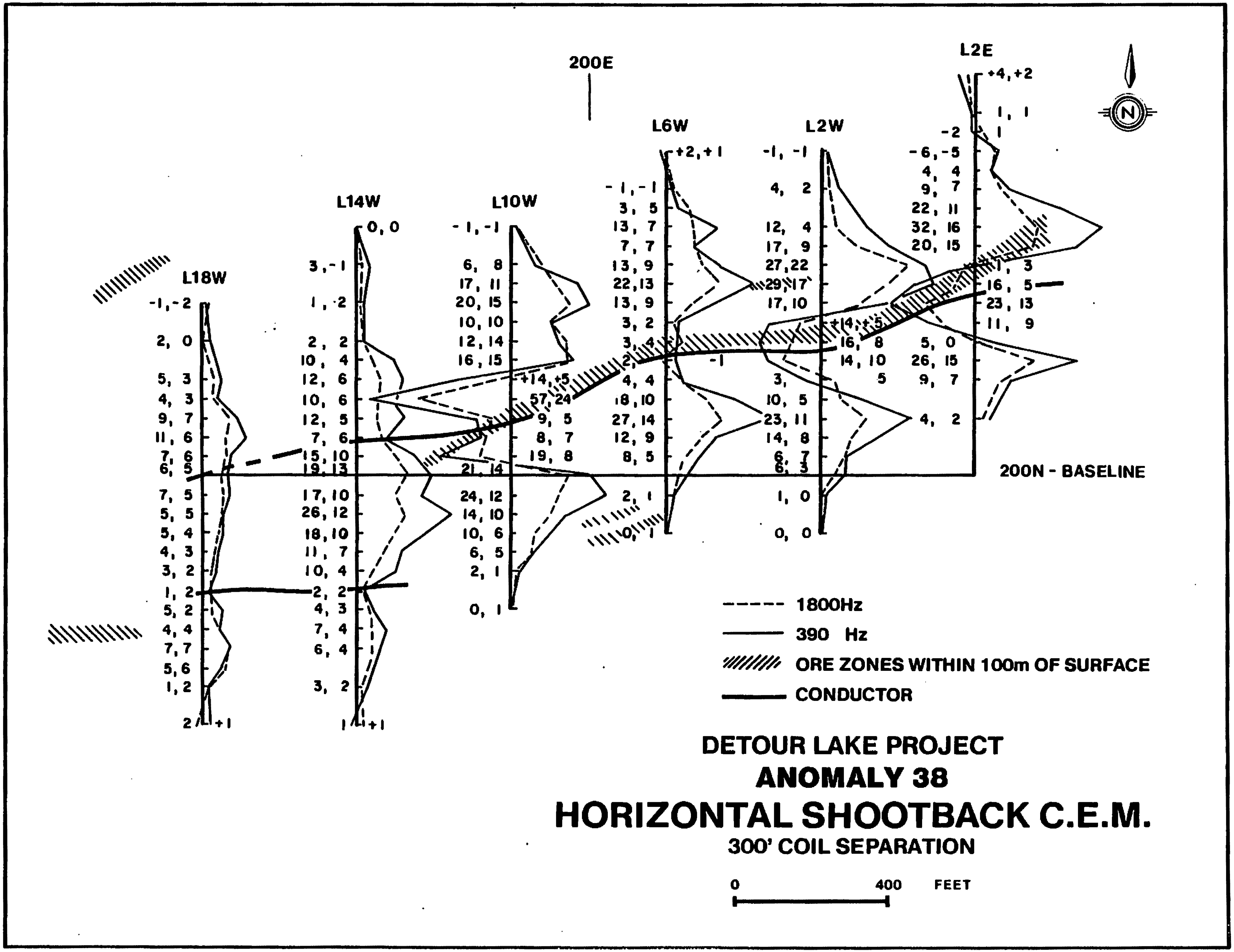

L18W
L14W
L10W
200E
L6W
L2W
L2E
200N - BASELINE
1800Hz
390 Hz
ORE ZONES WITHIN 100m OF SURFACE
CONDUCTOR
DETOUR LAKE PROJECT
ANOMALY 38
HORIZONTAL SHOOTBACK C.E.M.
300' COIL SEPARATION
0
400
FEET

FIGURE 8

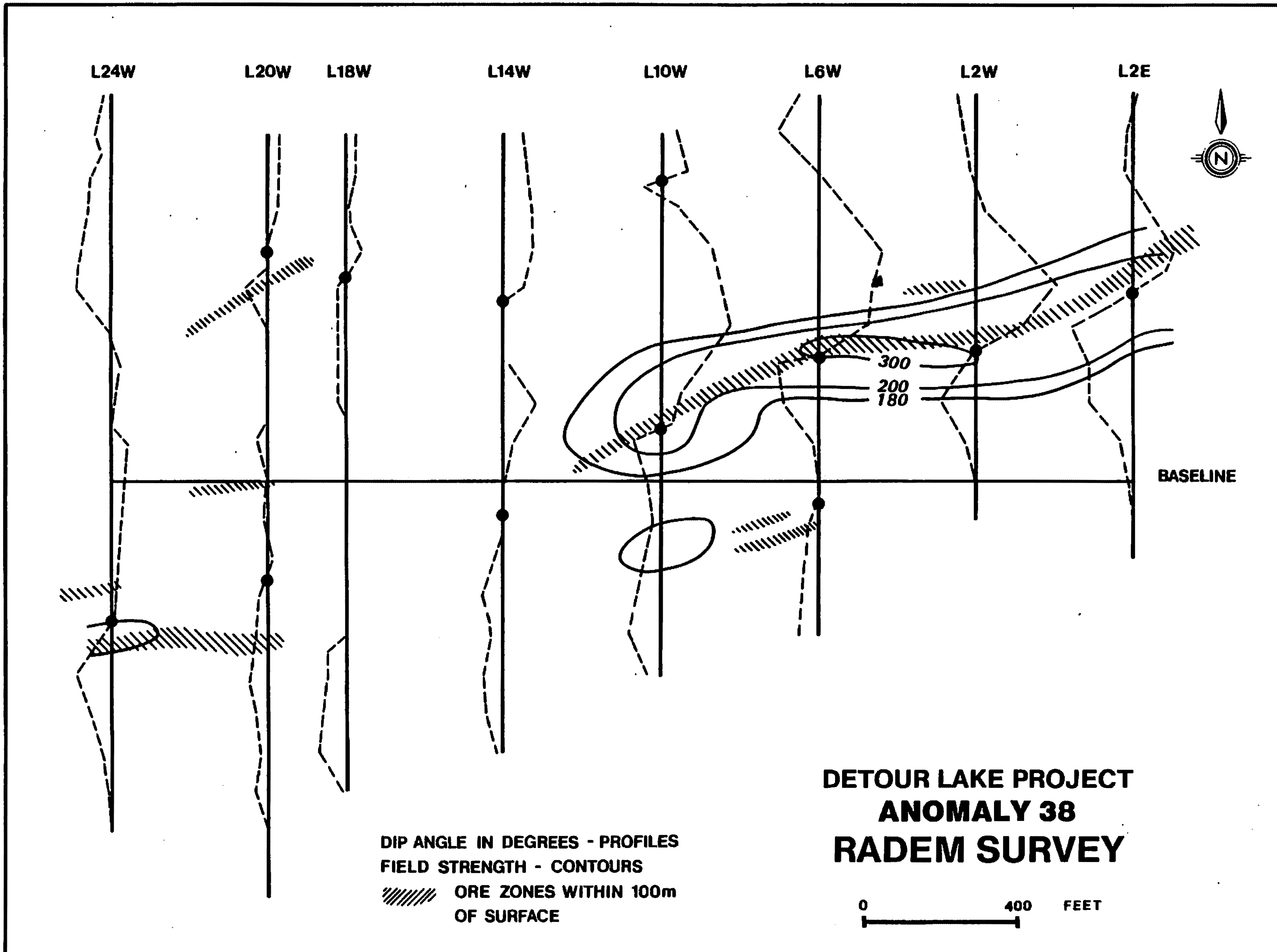
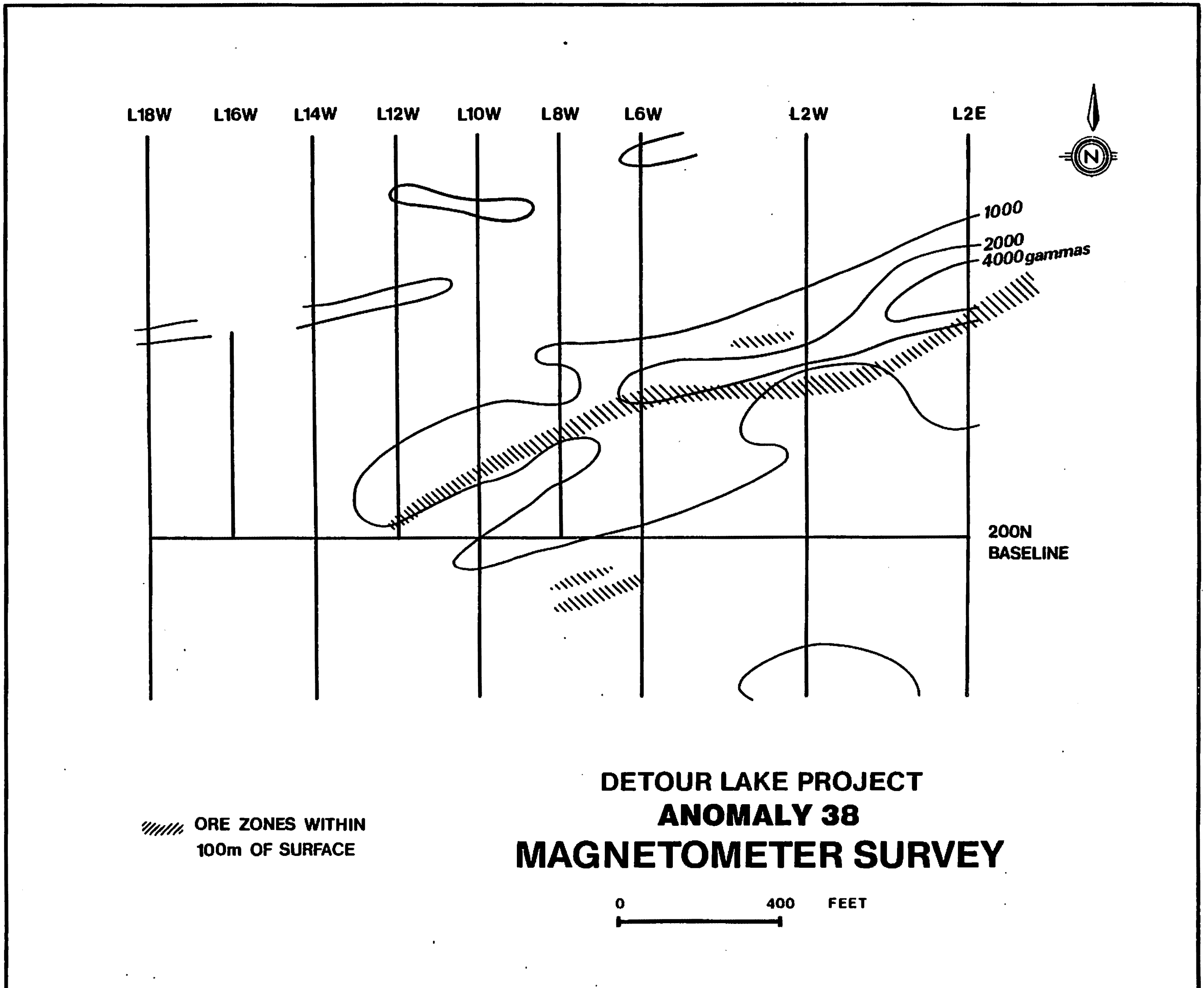
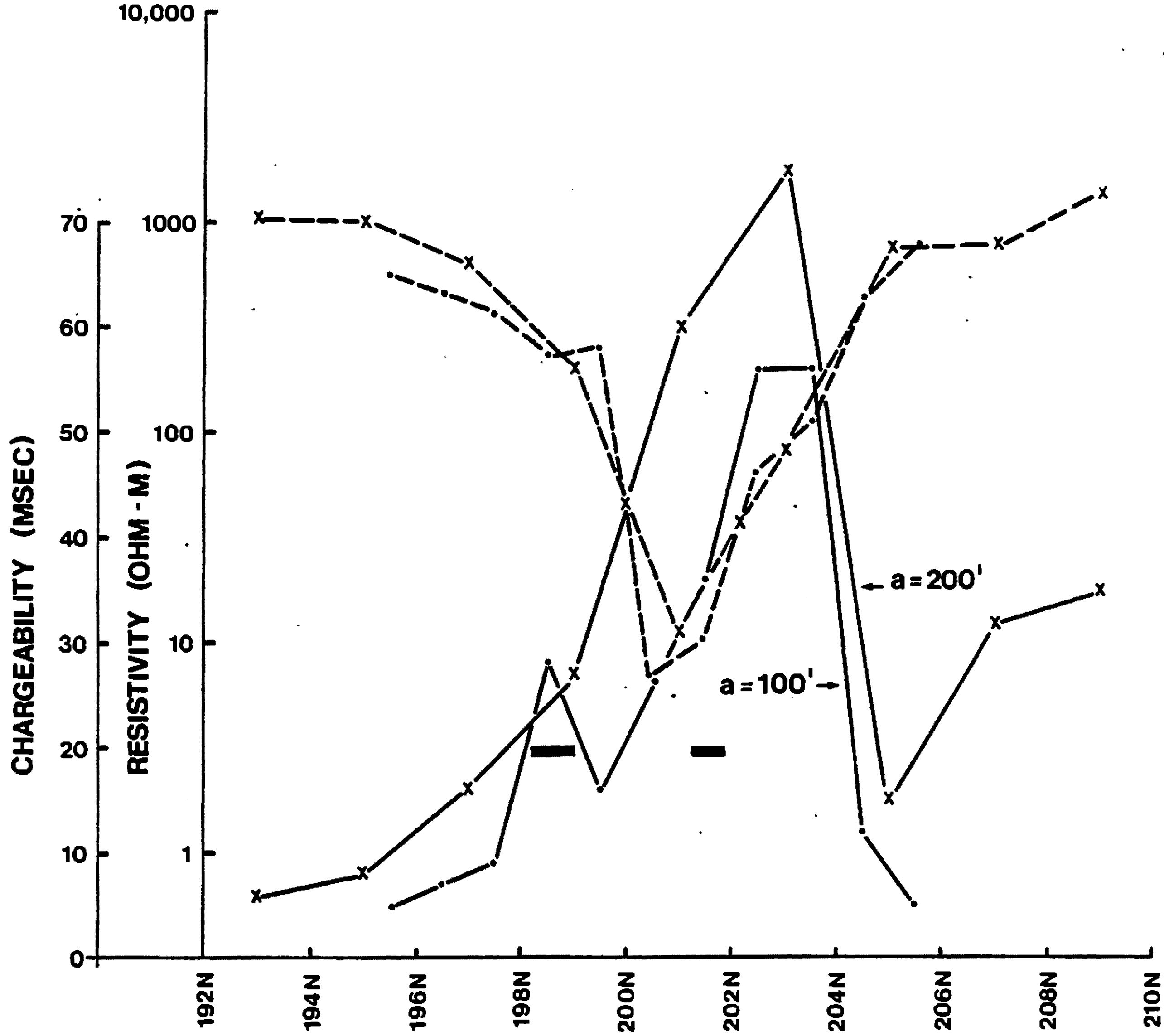

L24W
L20W
L18W
L14W
L10W
L6W
L2W
L2E
N
300
200
180
BASELINE
DETOUR LAKE PROJECT
ANOMALY 38
RADEM SURVEY
DIP ANGLE IN DEGREES - PROFILES
FIELD STRENGTH - CONTOURS
ORE ZONES WITHIN 100m
OF SURFACE
0
400
FEET

FIGURE 9



L18W
L16W
L14W
L12W
L10W
L8W
L6W
L2W
L2E
N
1000
2000
4000 gammas
200N
BASELINE
ORE ZONES WITHIN
100m OF SURFACE
DETOUR LAKE PROJECT
ANOMALY 38
MAGNETOMETER SURVEY
0
400
FEET

FIGURE 10



DETOUR LAKE PROJECT
INDUCED POLARIZATION SURVEY
LINE 198E (L10W OLD GRID)

THREE ELECTRODE ARRAY

C P1 P2 — a = 100' •——•

C P1 P2 — a = 200' x——x

CHARGEABILITY — MILLISECONDS

RESISTIVITY — OHM – METERS

ORE ZONES

FIGURE 11

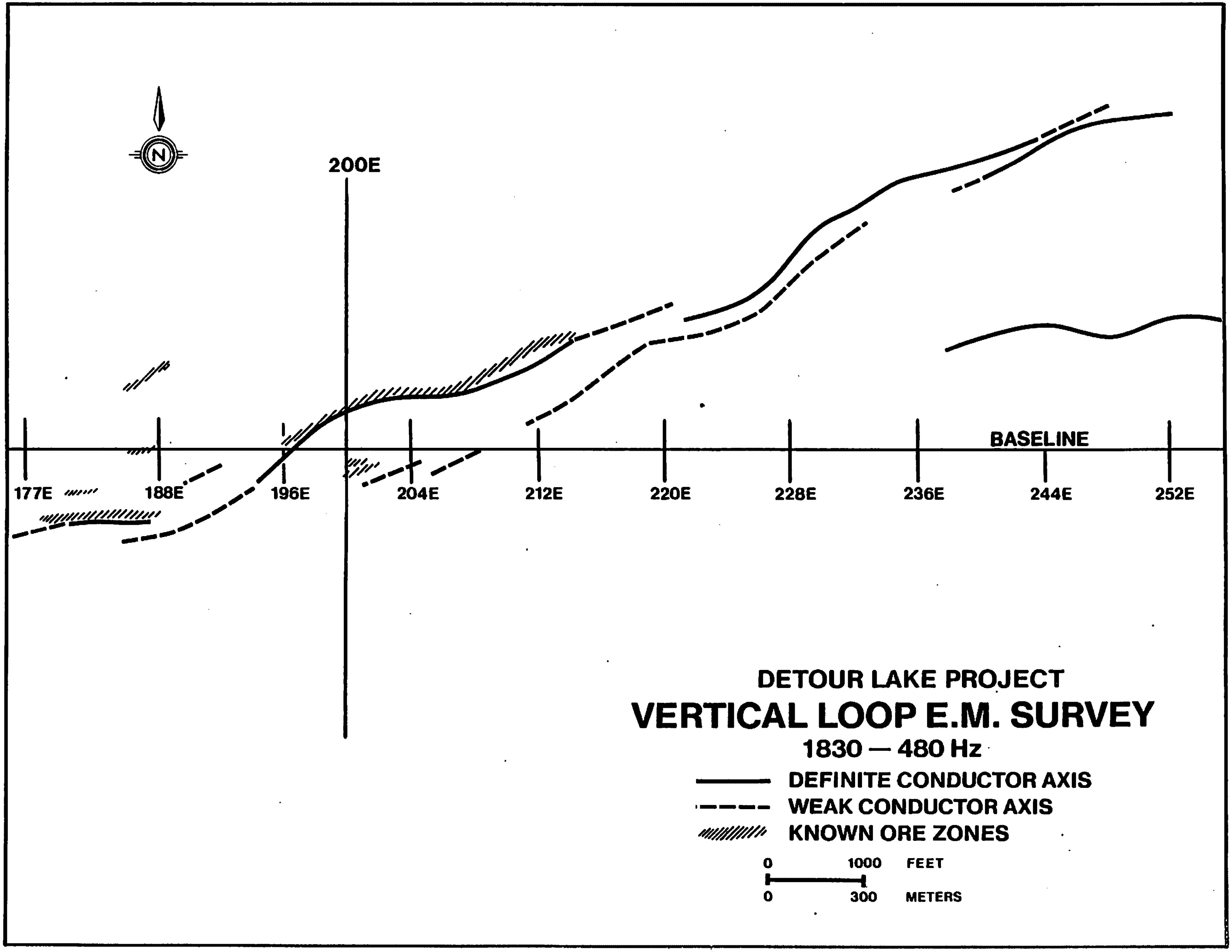

N
200E
BASELINE
177E
188E
196E
204E
212E
220E
228E
236E
244E
252E
DETOUR LAKE PROJECT
VERTICAL LOOP E.M. SURVEY
1830 — 480 Hz
DEFINITE CONDUCTOR AXIS
WEAK CONDUCTOR AXIS
KNOWN ORE ZONES
0 1000 FEET
0 300 METERS

FIGURE 12

GEOPHYSICS OF THE CASA BERARDI AREA

J.S. Dowsett and B.R. Krause
Canadian Nickel Co. Ltd.
Copper Cliff, Ontario

ABSTRACT

The Casa Berardi gold mineralization was found by following up an Inco airborne electromagnetic conductor on the flank of a strong airmag anomaly. The mineralization occurs in the northwest corner of Casa Berardi Township, approximatley 80 km north of La Sarre. The discovery was made near two small ponds dubbed Golden Pond by our geologists.

The gold mineralization occurs in two geological environments: gold occurring in fine grained graphitic clastic sediments and gold associated with 5 to 10% pyrite and arsenopyrite in agglomerates. The gold bearing zones occur under 50 metres of clay, sand and till and thus would not have been found without the use of geophysical or geochemical techniques.

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by J. S. Dowsett and B. R. Krause

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The gold mineralization occurs in two geological environments; gold occurring in fine grained graphitic clastic sediments and gold associated with 5 to 10% pyrite and arsenopyrite in agglomerates. The gold bearing zones occur under 50 metres of clay, sand and till and thus would not have been found without the use of geophysical or geochemical techniques.

Fig. 1 shows the location of Golden Pond, and the claim group held by the Inco - Dome - Golden Knight Joint Venture. In total the Joint Venture holds 882 claims, covering a 42 km strike length.

Inco was first attracted to the greenstones of northerwestern Quebec for their base metal potential and surveying with Inco's airborne electromagnetic and magnetic equipment was carried out over the Casa Berardi area in the late 1960's and early 1970's. Fig. 2 shows the airmag anomaly and AEM conductor locations over 160 sq. km including Casa Berardi Twp. The magnetic anomaly southwest of Golden Pond is caused by Iron Formation. Note that the AEM results in the vicinity of Golden Pond indicate that two conductors exist. The black outline shows the area covered by Fig. 5 which will show the type of ground geophysical coverage that we have given to the area.

Fig. 3 is an airborne profile across the Golden Pond area. The EM signal trace definitely shows the existance of two conductors which are both reasonably high priority exploration targets as the phase responses are lower in amplitude than the signal response indicating good conductivity. Note the negative anomaly on the EM signal trace coinciding with the magnetic anomaly.

Ground follow up on the airborne conductor in June 1974 revealed two medium strength vertical loop EM conductors in a non-magnetic area between two magnetic anomalies as seen in Fig. 4. The two small ponds referred to as Golden Pond can be seen on the slide. Three attempts were made in March 1975 to drill the southern conductor from the north with a light drill but all three holes had to be abandoned in overburden. In October 1981, a larger machine was brought in and a hole from the south intersected 12.6 gms/metric ton over 6.7 metres under 57 metres of overburden. Undercut and bracket holes failed to find similar mineralization but subsequent drilling under the northern conductor found gold mineralization over a considerable strike length.

Subsequent ground geophysics revealed the picture shown in Fig. 5. The lines are spaced at 100 metre intervals and magnetic and electromagnetic readings were taken at 25 metre stations. A pole-dipole array was used for the induced polarization survey with a 75 metre electrode interval and readings taken at N=1 and N=2.

The most prominent features on the slide are the magnetic anomalies which are caused by iron formation. In the vicinity of Golden Pond the northern conductor is caused by a graphite bearing fault. The southern conductor is caused by a concentration of graphite in mudstones which closely traces a conglomerate - sediment contact throughout part of its length.

In the Golden Pond area the IP anomalies are caused by graphite in mudstones and sulphides in the agglomerates. Note that the IP anomaly starting at the magnetic anomaly just east of Golden Pond splits into two towards the east. The southern branch is caused by graphite in sediments and the northern branch is underlain by sulphides in agglomerates with which gold is associated.

Geology at bedrock surface as defined by drilling in a smaller area around Golden Pond is shown in Fig. 6. From the bottom of the figure the formations consist of conglomerate, mudstones and siltstones which are locally graphitic, agglomerate, tuff, iron formation, and finally non graphite bearing sediments, mostly sandstones. The gold occurs in the central graphitic sediments and in the agglomerates.

Fig. 7 shows geophysical results and a selection of drill holes over the same area as in Fig. 6. The conductors found on the original anomaly investigation are the two long conductors traversing the figure. The discovery hole is borehole 40670.

Fig. 8 shows the geology on section 119E. Minor gold mineralization was intersected in graphitic mudstones in two holes on this section but the agglomerates are devoid of sulphides and gold.

Fig. 9 shows geophysics on the same section. The southern conductor is caused by graphites in mudstones while the northern conductor is caused by graphite in the fault zone. The IP and resistivity results accurately located the sediments indicating that the sediments carry graphitic zones throughout their whole width on section 119E. Note the one to one correlation between the chargeability anomaly and the resistivity low. This is a common feature for IP and resistivity results over the mudstones and siltstones but the one to one correlation does not always exist on results obtained over the agglomerates. (See below).

In general the geology on section 124E (Fig. 10) is similar to the northern part of the geology on the previous section. The significance of the volcanic flow which did not appear on section 119E is not yet known. On this section we see gold mineralization occurring in both the sediments and the agglomerates.

Fig. 11 shows the geophysical results on the same section. Again the northern conductor is caused by graphite in the fault zone.

The southern IP response does not extend across the full width of the sediments indicating that the sediments on section 124E do not all carry graphite to the same extent. In the case of this southern IP response, again note the one to one correlation between the IP anomaly and the resistivity low.

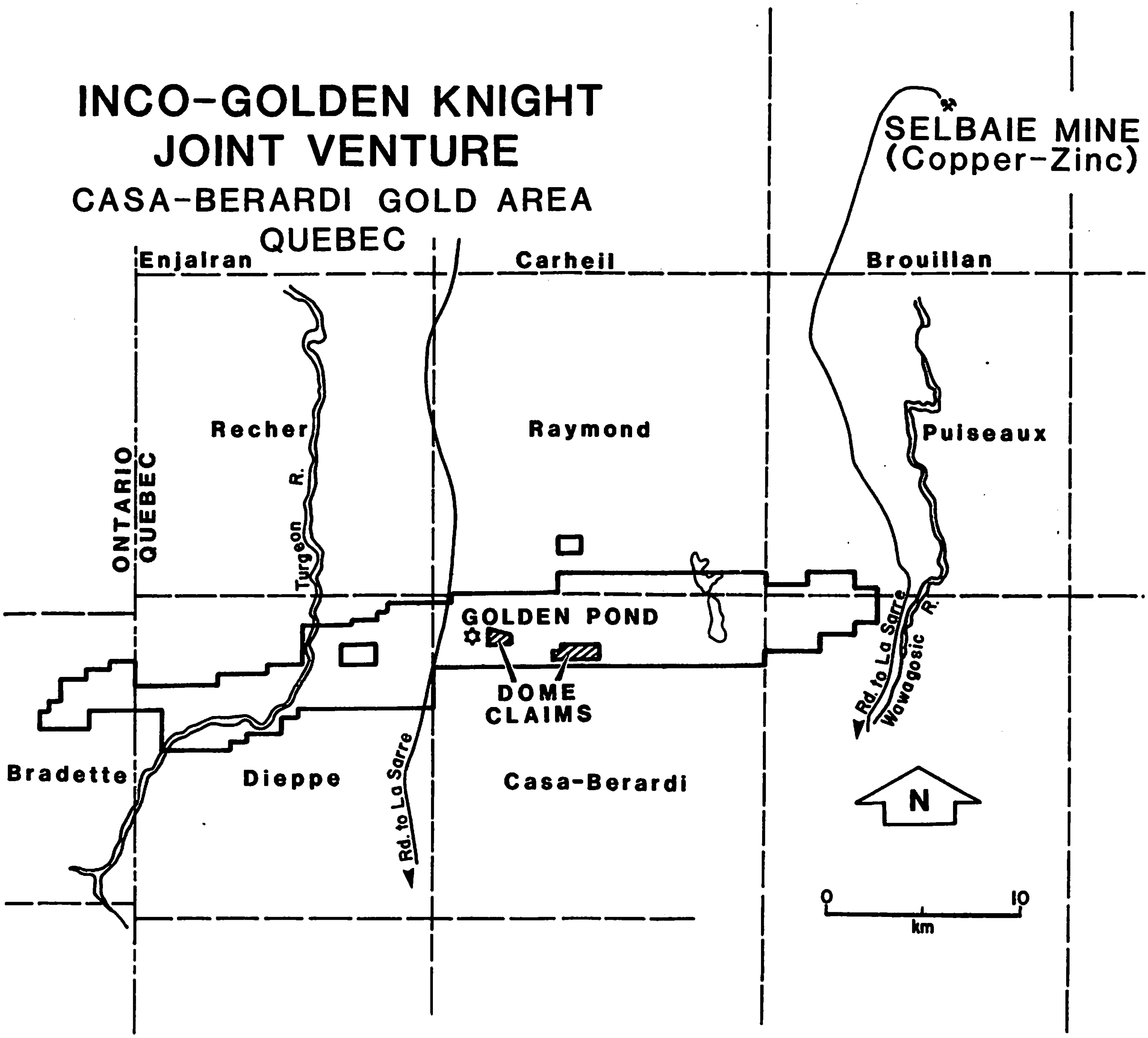
On the northern IP response we do not see a direct one to one correlation between the chargeability and the resistivity. The southern and stronger part of the IP response does coincide with a resistivity low and is caused by graphite in the mudstones with which the gold is associated. The northern and weaker part of the IP response is not associated with a resistivity low. However, it is not associated with an abnormally high resistivity either. This part of the IP anomaly is caused by sulphides in the agglomerates with which the gold is associated.

Fig. 12 shows a compilation of the geology and geophysics in the Golden Pond area. Note that the southern conductor indicates the general trend of the conglomerate/sediment contact. Also the northern conductor follows the fault throughout its length and is very close to the sediment/agglomerate contact. Thus EM has been very useful in tracing lithology. Note also that some part of all the zones of gold mineralization is located under an IP response. Thus the induced polarization results were a great aid in spotting drill holes, particularly in the agglomerates where the IP anomalies are indicative of the presence of sulphides with which gold is often associated.

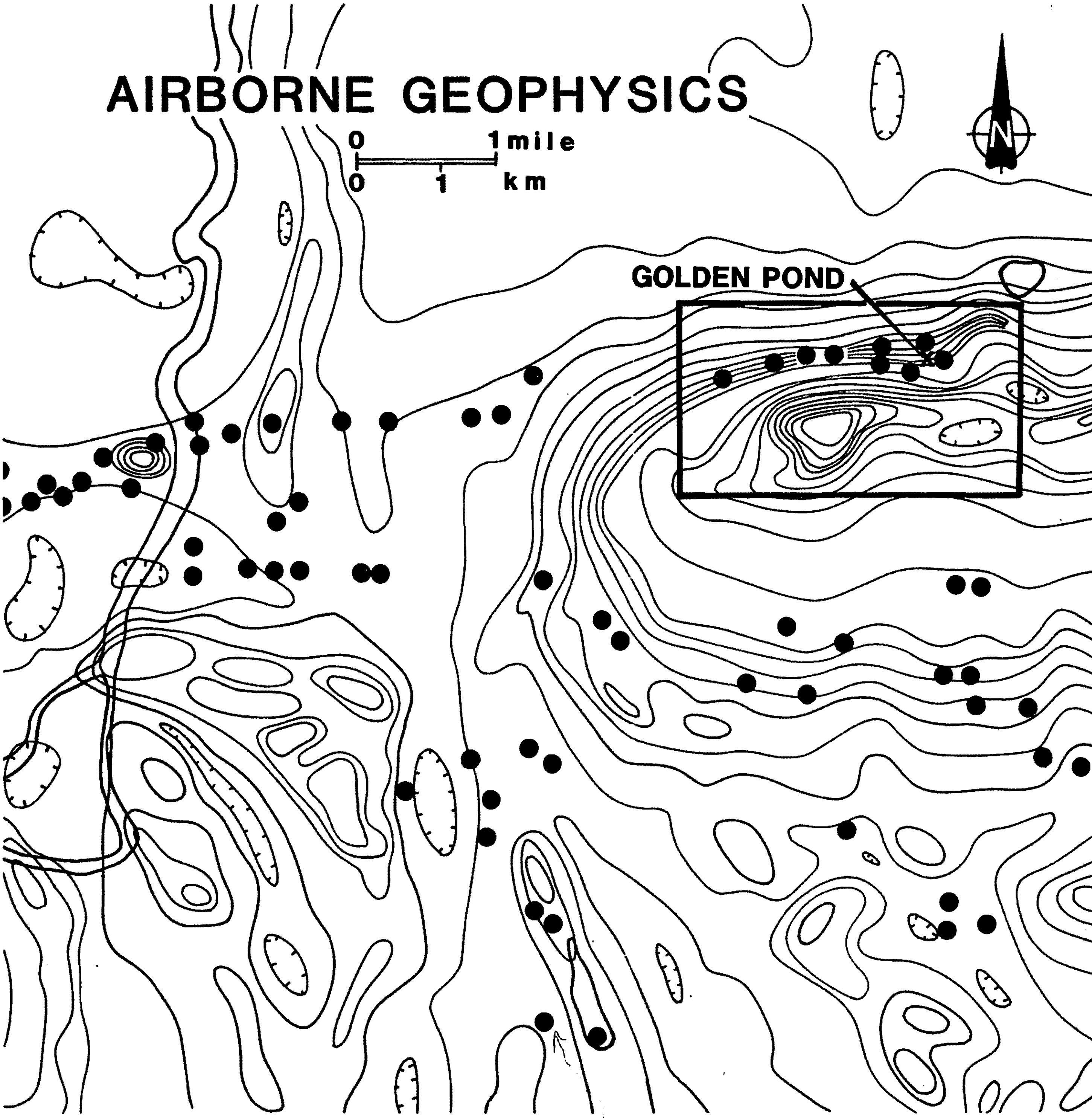
In summary, Geophysics has made a significant contribution to exploration at Casa Berardi. An airborne electromagnetic and magnetic survey initially led us to the area. The ground electromagnetic work was a great help in mapping lithology and the induced polarization results helped indicate where gold may occur within the prospective geological units.

In conclusion I would like to thank Inco Limited, Dome Mines Limited, and Golden Knight Resources for permission to use the information and Barry Krause and Inco's exploration staff for collecting the data and in helping to prepare this paper.

END


INCO-GOLDEN KNIGHT
JOINT VENTURE
CASA-BERARDI GOLD AREA
QUEBEC
SELBAIE MINE
(Copper-Zinc)
Enjalran
Carheil
Brouillan
Recher
Raymond
Puiseaux
ONTARIO
QUEBEC
Turgeon R.
GOLDEN POND
DOME
CLAIMS
Rd. to La Sarre
Wawagosic R.
Bradette
Dieppe
Casa-Berardi
N
0
10
km

FIGURE



Airborne contours & AEM conductor locations

FIGURE 2

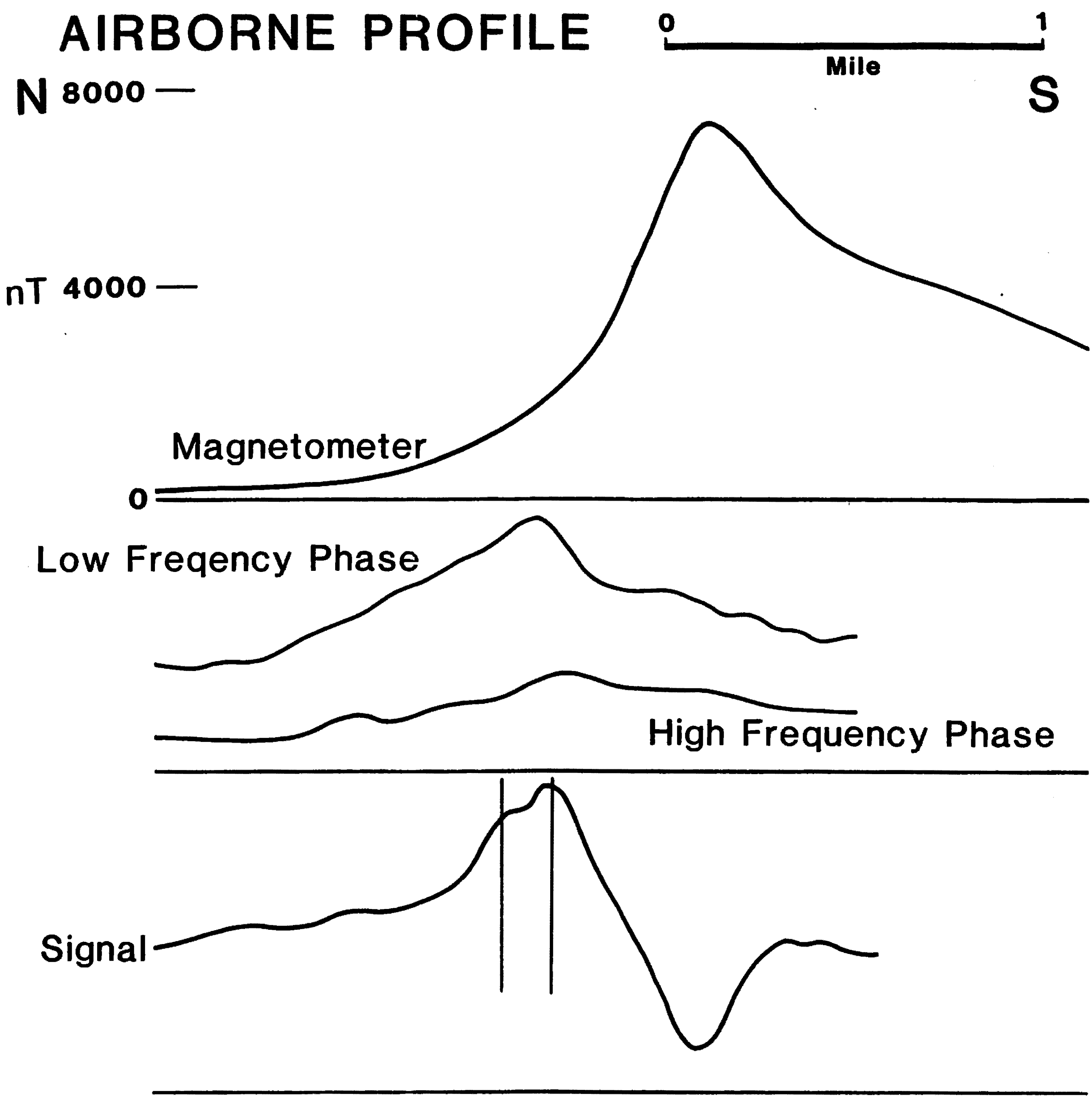

AIRBORNE PROFILE
0
1
Mile
N
S
8000
nT 4000
0
Magnetometer
Low Freqency Phase
High Frequency Phase
Signal

FIGURE 3

ANOMALY INVESTIGATION

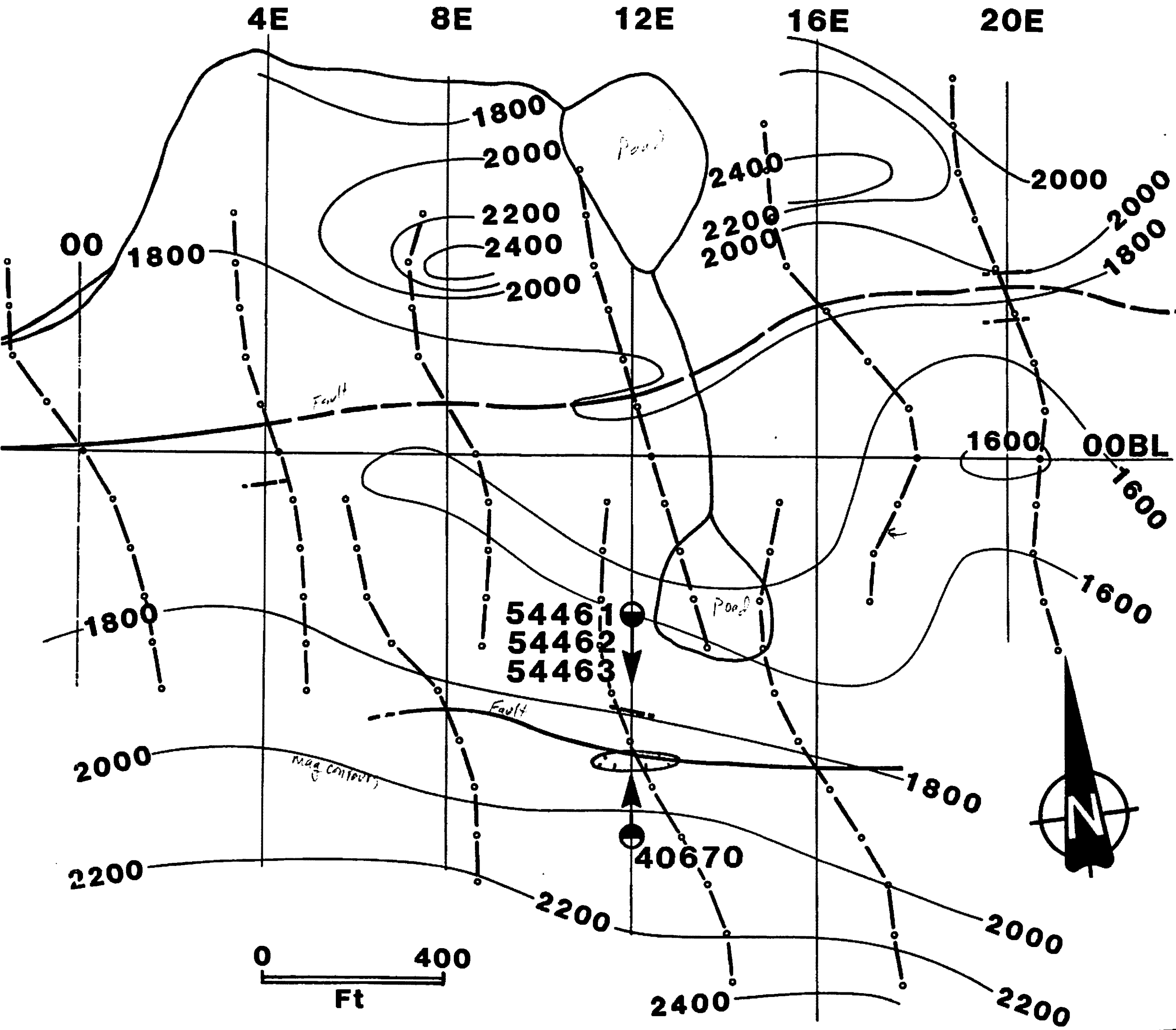


FIGURE 4

GROUND GEOPHYSICS

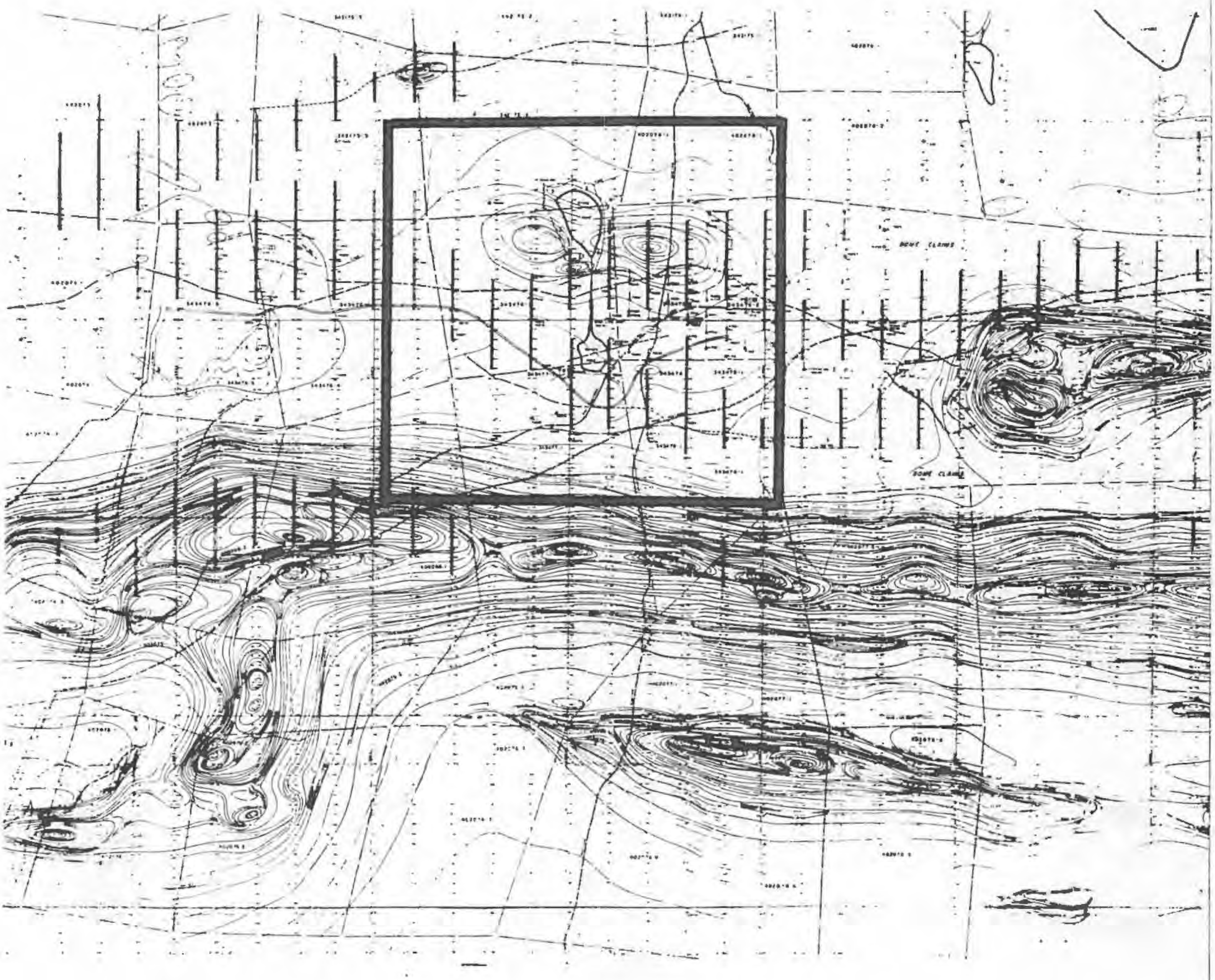


FIGURE 5

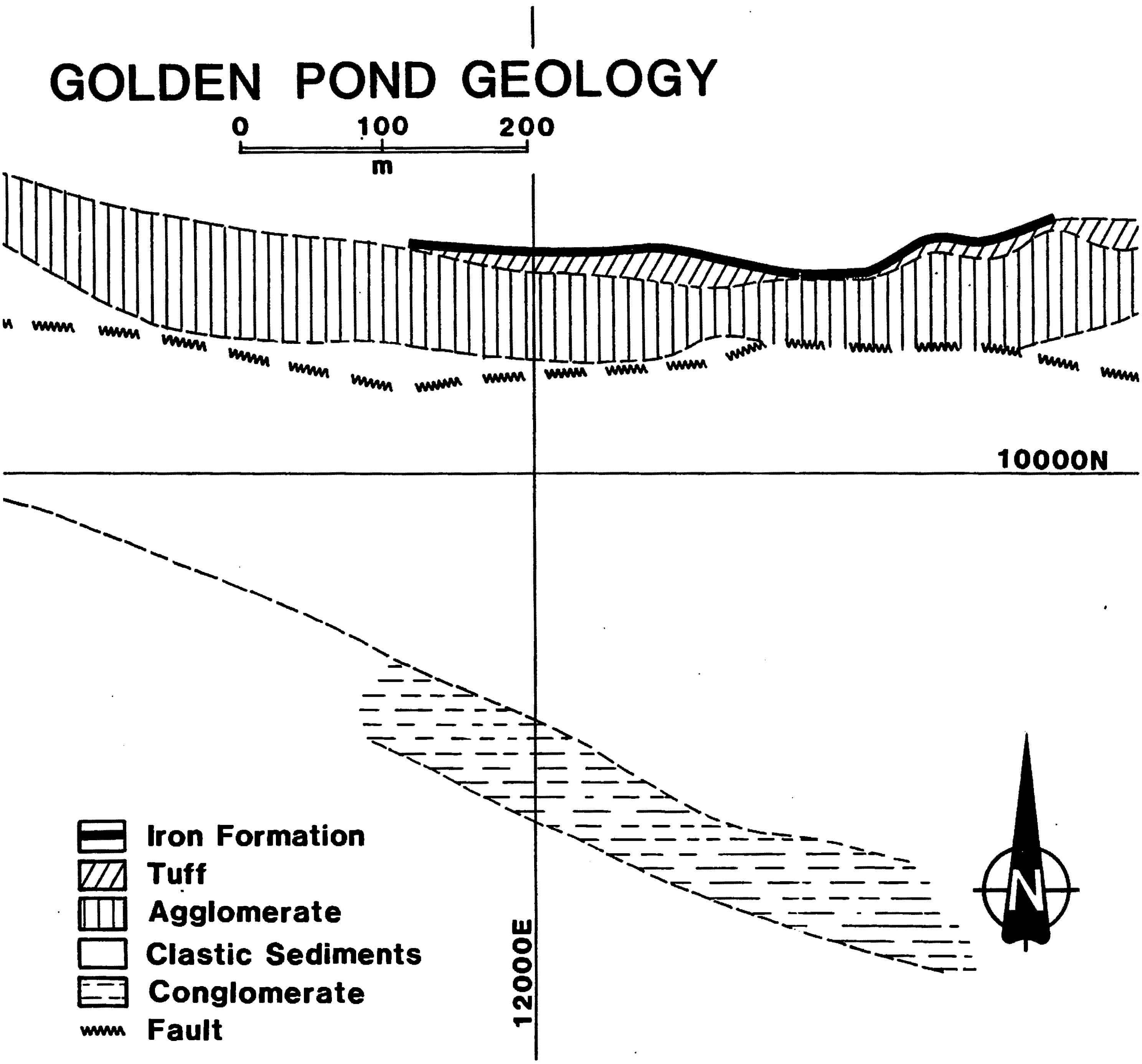

GOLDEN POND GEOLOGY
0
100
200
m
10000N
12000E
Iron Formation
Tuff
Agglomerate
Clastic Sediments
Conglomerate
Fault
N

FIGURE 6

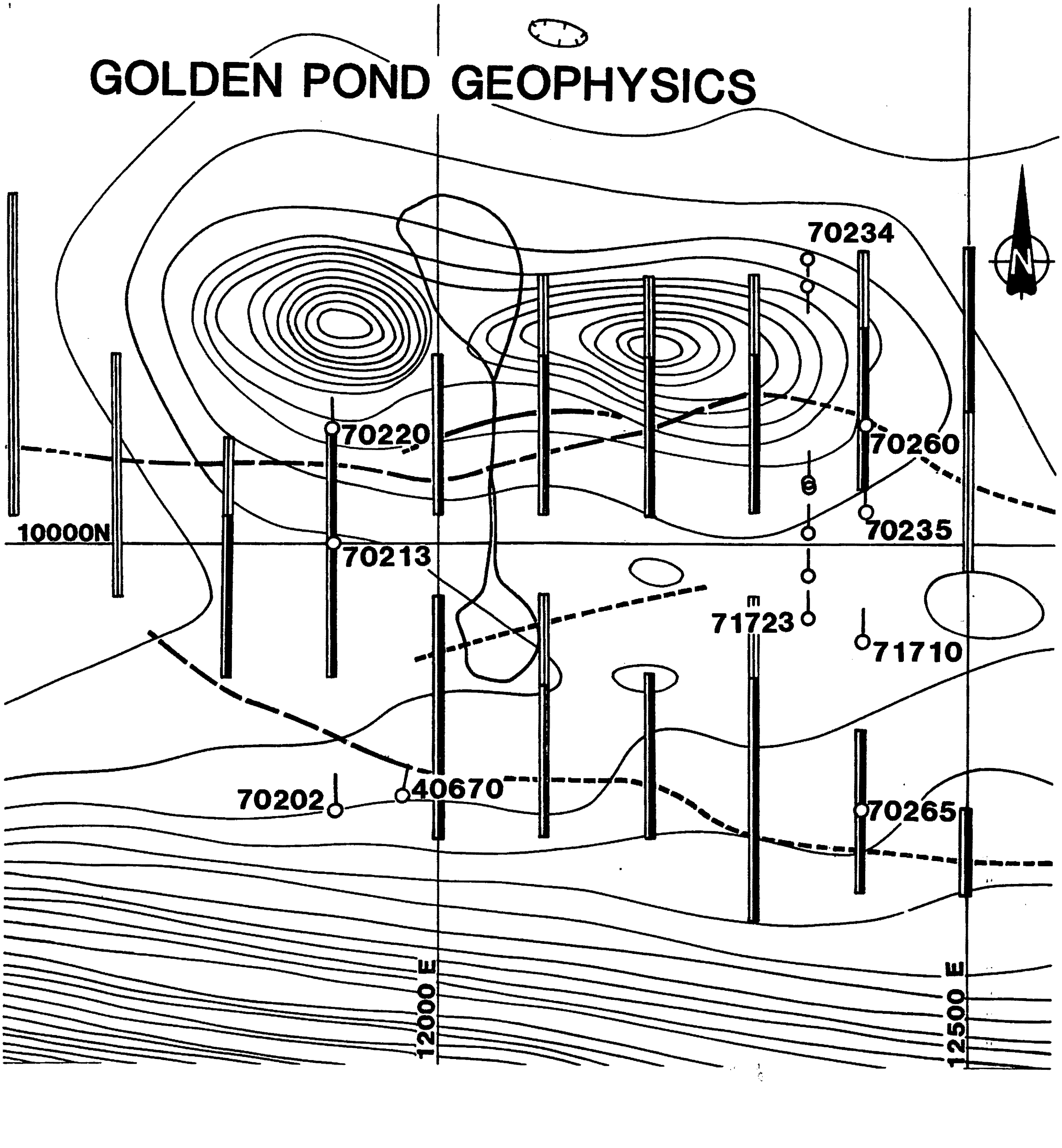
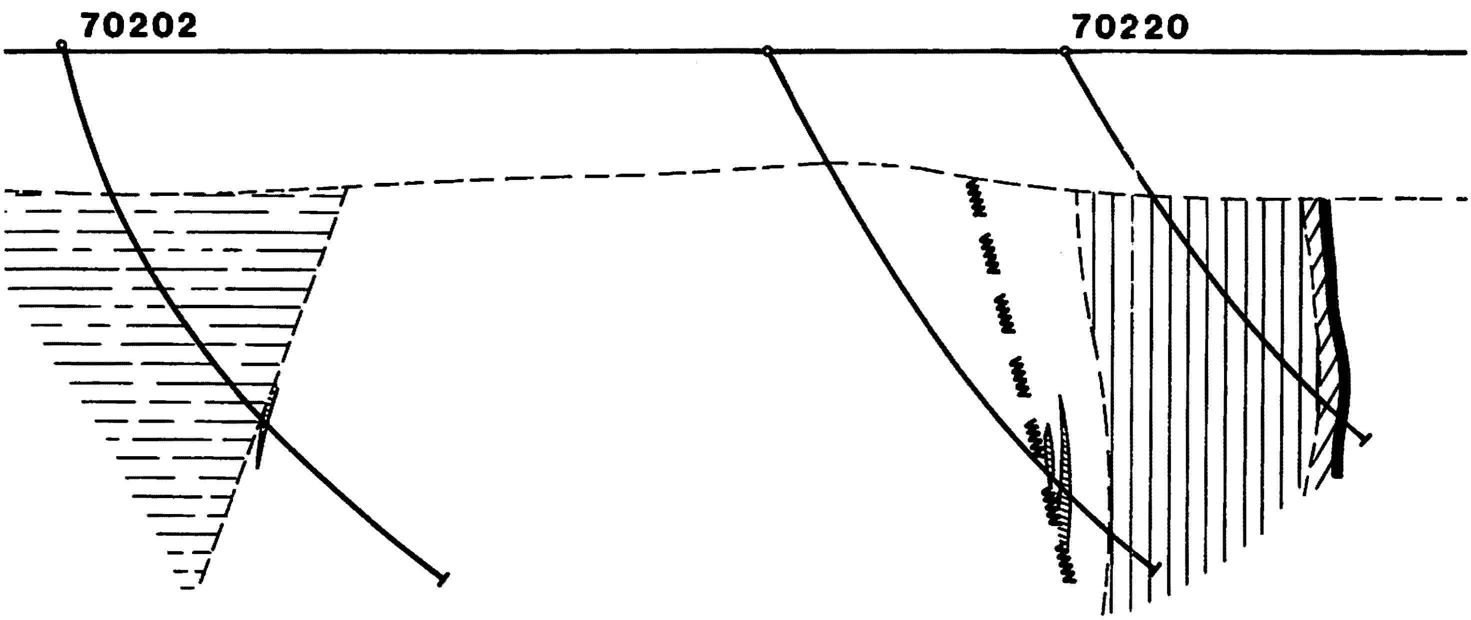

GOLDEN POND GEOPHYSICS
70234
N
70220
70260
70235
10000N
70213
71723
71710
70202
40670
70265
12000 E
12500 E

FIGURE 7

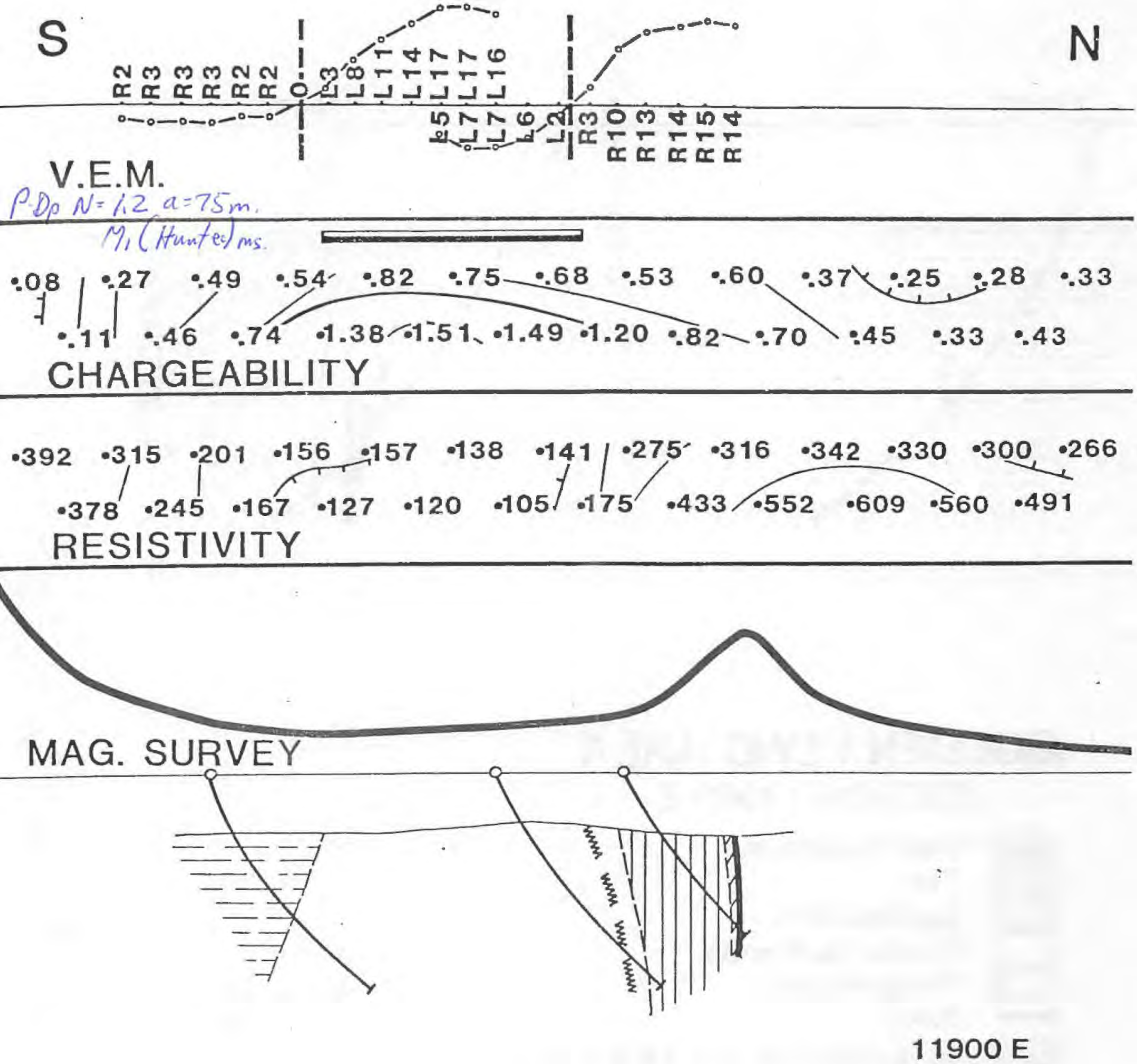


GOLDEN POND AREA
SECTION 11900 E

- Iron Formation
- Tuff
- Agglomerate
- Clastic Sediments
- Conglomerate
- Fault
- Mineralization (> 2.75 g/t Au)

0 100
m

FIGURE 8


S
N
R2 R3 R3 R3 R2 R2 0 L3 L8 L11 L14 L17 L17 L16
L5 L7 L7 L6 L2 R3 R10 R13 R14 R15 R14
V.E.M.
P.Dp N=1,2 a=75m.
M1 (Huntec) ms.
.08 .27 .49 .54 .82 .75 .68 .53 .60 .37 .25 .28 .33
.11 .46 .74 1.38 1.51 1.49 1.20 .82 .70 .45 .33 .43
CHARGEABILITY
392 315 201 156 157 138 141 275 316 342 330 300 266
378 245 167 127 120 105 175 433 552 609 560 491
RESISTIVITY
MAG. SURVEY
11900 E

FIGURE

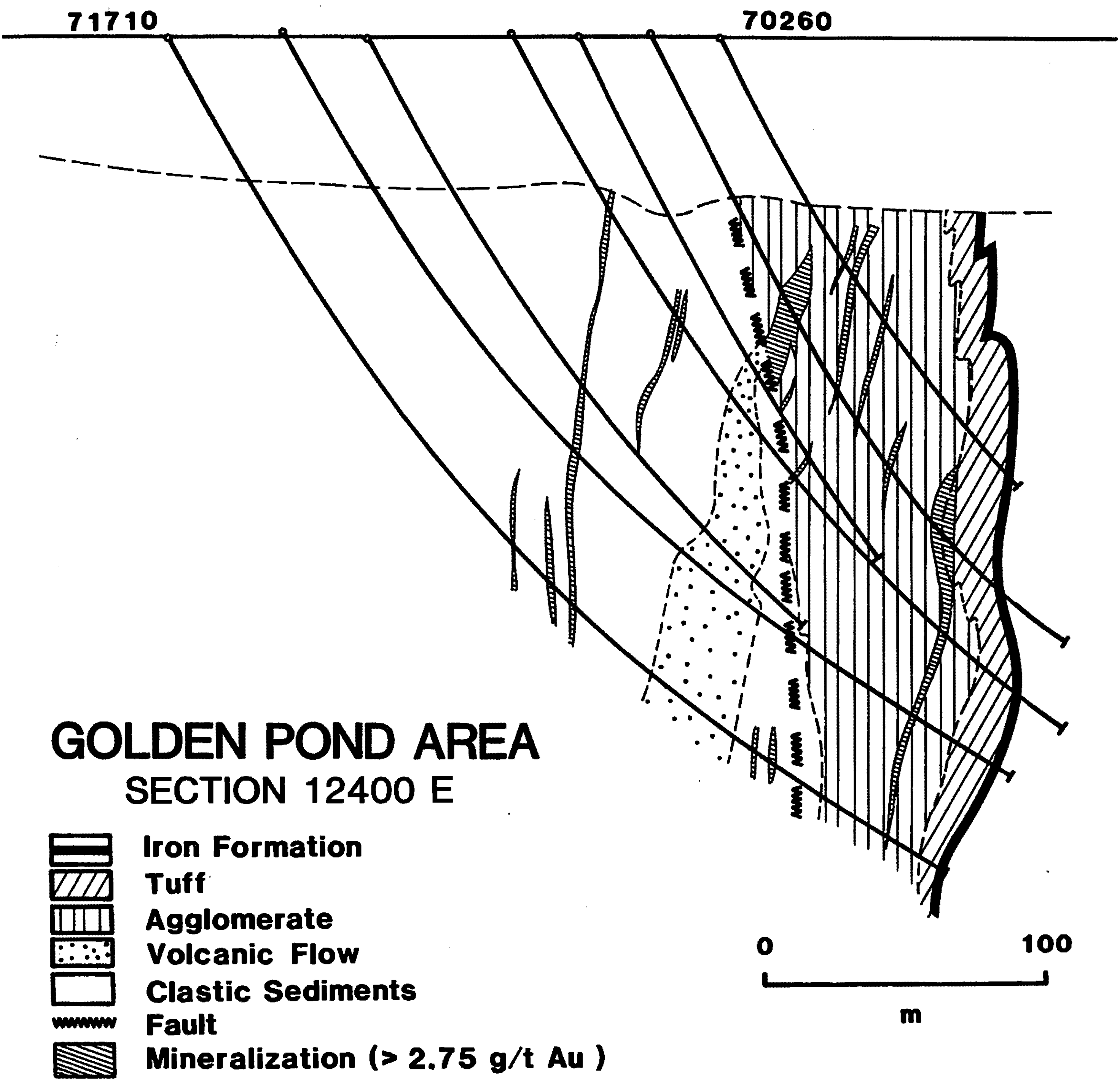

71710
70260
GOLDEN POND AREA
SECTION 12400 E
Iron Formation
Tuff
Agglomerate
Volcanic Flow
Clastic Sediments
Fault
Mineralization (> 2.75 g/t Au)
0
100
m

FIGURE 10

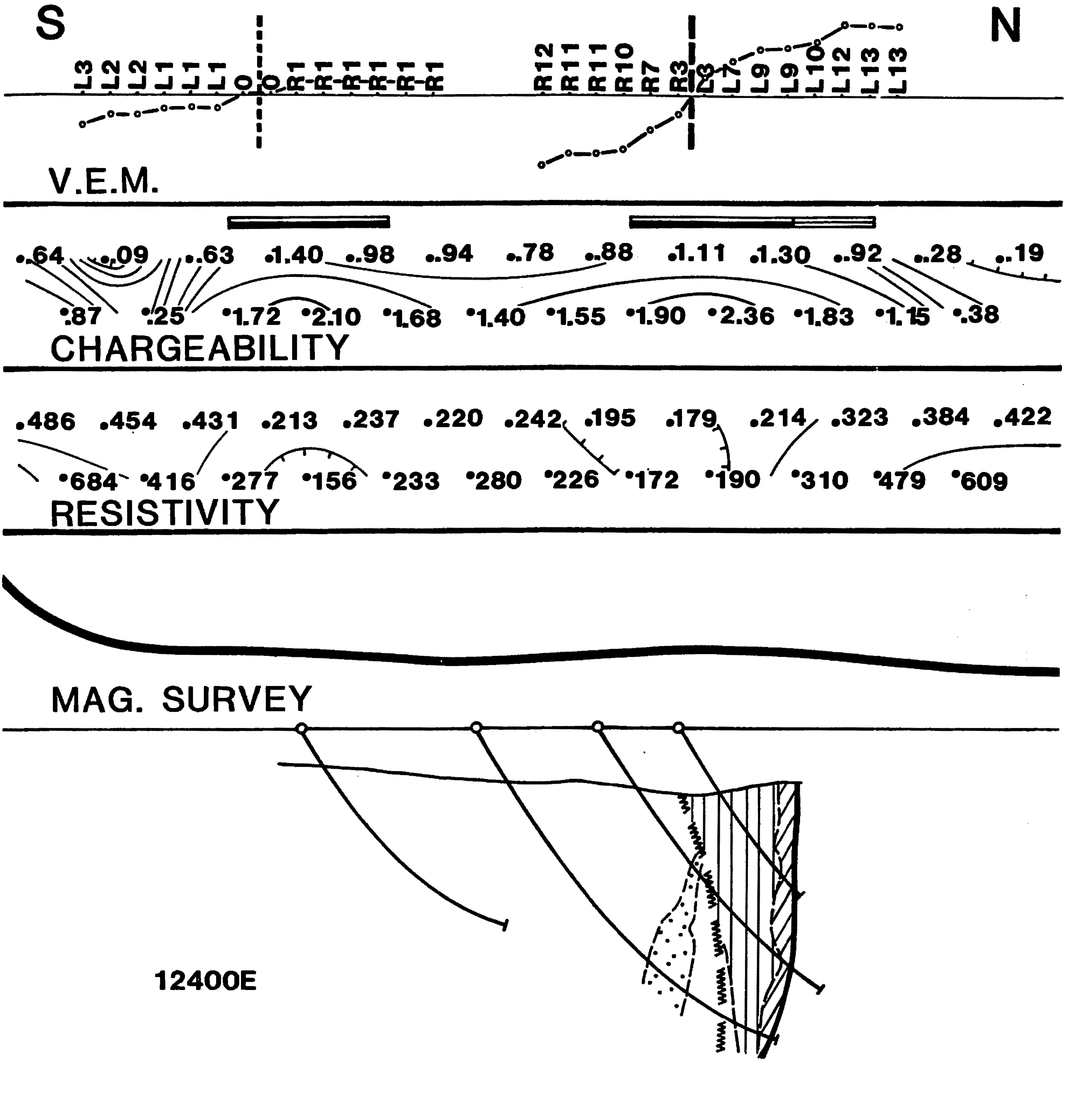

S
N
L3 L2 L2 L1 L1 L1 0 0 R1 R1 R1 R1 R1 R1
R12 R11 R11 R10 R7 R3 L3 L7 L9 L9 L10 L12 L13 L13
V.E.M.
.64 .09 .63 .1.40 .98 .94 .78 .88 .1.11 .1.30 .92 .28 .19
.87 .25 .1.72 .2.10 .1.68 .1.40 .1.55 .1.90 .2.36 .1.83 .1.15 .38
CHARGEABILITY
.486 .454 .431 .213 .237 .220 .242 .195 .179 .214 .323 .384 .422
.684 .416 .277 .156 .233 .280 .226 .172 .190 .310 .479 .609
RESISTIVITY
MAG. SURVEY
12400E

FIGURE 11

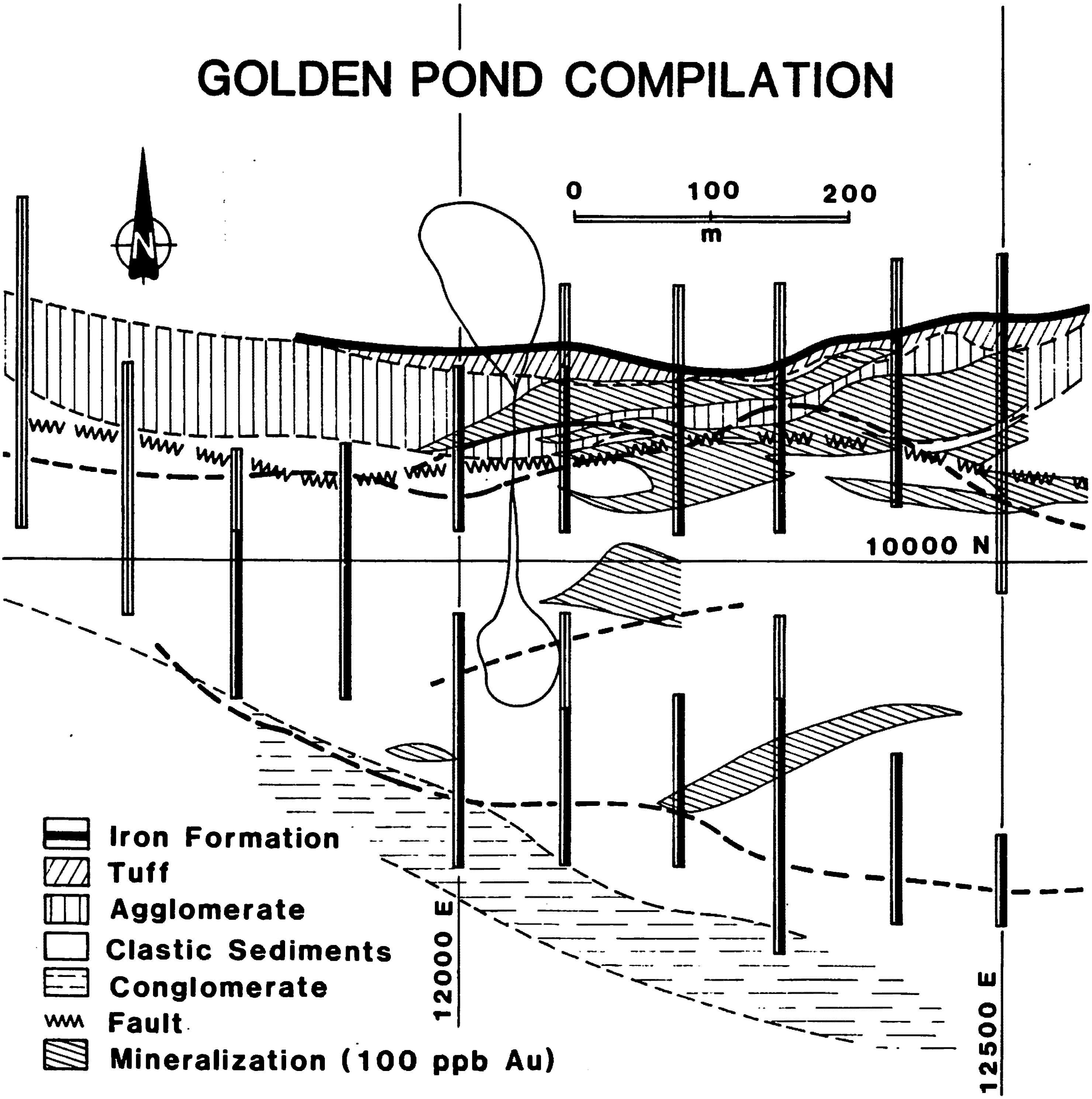

GOLDEN POND COMPILATION
N
0
100
200
m
10000 N
12000 E
12500 E
Iron Formation
Tuff
Agglomerate
Clastic Sediments
Conglomerate
Fault
Mineralization (100 ppb Au)

FIGURE 12

MARINE SEISMIC METHODS IN MINERAL EXPLORATION

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Goldak Exploration Technology Ltd.
Langham, Saskatchewan

ABSTRACT

Marine seismic techniques have been used in ocean sciences and oil exploration for several decades. It has only been the last fifteen years that high resolution marine seismic techniques have made a really significant contribution to mineral exploration. The most extensive application was the Lake Athabasca Project which from 1974 to 1980, conducted more than 2,000 km of marine seismic, and was a proving ground for the development of techniques and instrumentation. The Golden Marlin Program, recently begun in 1984, will also involve several thousand kilometers of marine seismic work in the Yellowknife Volcanic Belt. In addition, contract surveys have been done in Lake Athabasca, and in Tazin and Martin Lakes in Saskatchewan, and Lake Chibougamau in Quebec betwen 1970 and 1983.

The Precambrian Shield contains a large fraction of water, and much of this water area is related to topographic lows which are often controlled by preglacially eroded fault and shear zone structures. Since many ore deposits are fault related, on the average, underwater areas may be somewhat more favorable than land areas. High resolution marine seismic procedures can provide a determination of depth of water, and thickness and kind of surficial sediments. Detailed surveys, carefully done, can easily define faults and shear zones. To a considerable extent the bedrock type can be inferred with the proper type of survey and competent interpretation.

Mining explorationists might assume that the costs of underwater exploration would be prohibitive and that the technical difficulties of exploration would be severe. In fact, the opposite is

often true; underwater exploration can be less difficult and less expensive. As will be shown later, high resolution seismic can provide a great deal of valuable data, at reasonable cost, that simply cannot be obtained in overburden-covered areas. This paper describes some of the techniques of marine seismic mineral exploration together with illustrative field results and comparative exploration costs.

THE USE OF THE INDUCED POLARIZATION METHOD TO LOCATE GOLD-BEARING SULPHIDE MINERALIZATION

P.G. Hallof and M. Yamashita
Phoenix Geophysics Limited
Willowdale, Ontario

ABSTRACT

Many, perhaps even most, of the gold deposits discovered in Canada in recent years are associated with metallic sulphide mineralization. This is certainly true of the new ore zones located in the Hemlo Area of Ontario and the Val d'Or Area of Quebec. The metallic mineral zone itself will almost always have a true IP effect. It is possible that no IP effect will be detectable, if intense, late silicification has taken place. The detectability of such a zone by surface induced polarization and resistivity measurements is determined by the following factors:

i) The width and lateral extent of the Zone.
ii) The thickness and resistivity of the covering layer.
iii) The resistivity of the surrounding rocks.
iv) The background IP effect in the surrounding rocks.
v) The electrode configuration and the electrode interval employed for the survey.

THE USE OF THE INDUCED POLARIZATION METHOD TO LOCATE GOLD-BEARING SULPHIDE MINERALIZATION

BY

Philip G. Hallof, Ph.D.

And

Mitsuru Yamashita, M.Sc.

EXTENDED ABSTRACT

Many, perhaps even most, of the gold deposits discovered in Canada in recent years are associated with metallic sulphide mineralization. This is certainly true of the new gold orebodies located in the Hemlo Area of Ontario and the Val D'Or Area of Quebec. The metallic mineral zone itself, will almost always have a true IP effect. In rare cases it is possible that no IP effect will be detectable, if intense, late silicification has made the zone completely non-porous. The detectability by induced polarization and resistivity measurements of a more normal mineralized zone, that has an IP effect, is determined by the following factors:

i) The width and lateral extent of the Zone.
ii) The thickness and resistivity of the covering layer.
iii) The resistivity and background IP effect in the surrounding rocks.
iv) The electrode configuration and the electrode interval employed for the survey.

In our recent work in gold exploration, we have used the phase IP technique almost exclusively. We find the greater sensitivity and faster survey progress of the phase IP Method (when compared to the variable frequency method or the time-domain method) to be a significant improvement.

If it is possible to make test measurements to determine the IP effect within a typical mineralized zone of the type being sought, this is always desirable. The spectral IP plot shown on Figure I (X = 1.0 meter) gives the usual phase vs. frequency plot for a typical pyrite-bearing schist zone in the Hemlo Area of Ontario. The pyrite gives a moderate time-constant (τ_1); this signifies to us that the grain-size of the pyrite mineralization is moderate.

These results indicate that the frequency range (0.11 Hz to 9.0 Hz) of the Phoenix IPV-2, Phase IP System is well suited to detect the source. If the metallic minerals present had a very large grain-size (perhaps veinlets) the critical frequency would be much lower; in this situation the phase IP effects in the vicinity of 1.0 Hz would be much lower in magnitude. In the same manner, the critical frequency would be much higher, if the metallic mineral grain-size were extremely small (perhaps colloidal).

We use the dipole-dipole electrode configuration in our work, since the second derivative nature of the measurement makes it very sensitive to small lateral variations in the earth's electrical parameters. The rate of progress, and therefore the cost, of a dipole-dipole induced polarization survey is directly dependent upon the electrode interval (X) that is used (assuming that n = 1,2,3,4,5 is kept standard). But cost is not the only consideration; choice of electrode interval has a powerful influence on the character and amplitude of the anomalies detected.

As shown in Figure IIa, it is possible to choose a large interval for (X), in order to speed a reconnaissance survey, and detect little, or no, anomaly from the target zone. For X = 75 meters, the apparent effects measured are only slightly above background. If X = 75 meters were to be used, it would be necessary to check a great many narrow, weak, shallow anomalies.

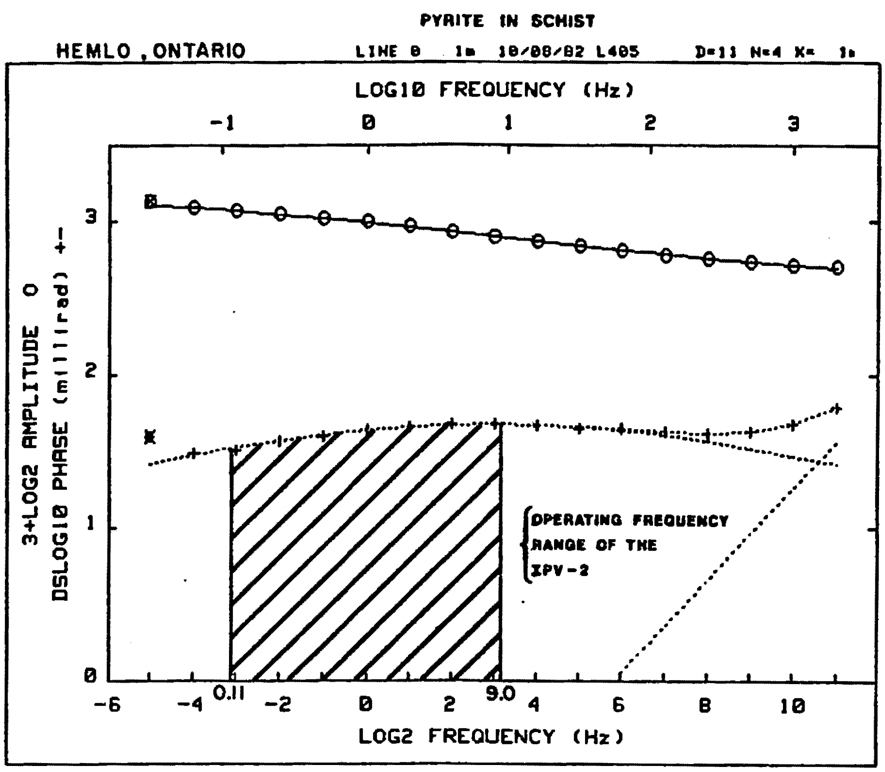
The results shown on Figure IIb indicate that the anomaly detected using X = = 15 meters is more definite, but an electrode interval of X = 15 meters is quite small, and therefore costly, to use for a reconnaissance survey. However, it is clearly desirable to use detailed measurements, with X = 15 meters, to evaluate the importance of the reconnaissance anomalies for the source modelled by the computer in the forward problem solution.

These problems in interpretation are encountered repeatedly in the field. The results shown on Figure III were measured, using a compromise value of X = 50 meters, over the up-dip end of the mineralized zone containing the Golden Sceptre Orebody in the Hemlo Area of Ontario. The narrow zone contains low concentrations of pyrite, and gold near surface; however, at a depth of a few tens of meters to a hundred meters it contains a world-class gold orebody. If larger electrode intervals (say X = 75 meters) were used for the reconnaissance survey, the anomaly might not be interpretable.

The data shown on Figure IV located a narrow, gold-bearing sulphide zone in the Hemlo Area. The reconnaissance anomaly (X = 50 meters) at 1+50S to 1+00S was not immediately chosen for detailed measurements. Later drilling in the general area confirmed the possible geologic importance of any mineralization that might be present.

A re-interpretation of the reconnaissance results resulted in the specification of Zone VI. The detailed measurements with X = 25 meters confirmed the fact that a significant, narrow source was present. After further detailed measurements on closely spaced, parallel lines, a short drill hole was completed to test the source.

The results from the Hemlo Area demonstrate the importance of the factors listed above in planning an induced polarization and resistivity survey to detect narrow, weakly mineralized zones that may contain ore-grade gold values. Our experience has shown that the same considerations are important in exploration in other areas such as Val D'Or, Quebec and Larder Lake, Ontario.



CRL: Number of dispersions= 2
M2=1 C2=1 fixed

Iter	Lambda	Rchsq	R0	M1	T1	C1	T2
0	1.E-02	.00019	1.153	.339	4.2E-02	.288	3.4E-06
1	1.E-02	.00004	1.152	.336	4.2E-02	.291	2.9E-06
2	1.E-03	.00004	1.153	.339	4.2E-02	.288	2.8E-06
3	1.E-04	.00004	1.153	.339	4.2E-02	.288	2.8E-06
Pct Std Deviations			.3	1.2	4.1	1.7	3.2

Correlation Matrix	1.000				
	.839	1.000			
	.287	-.007	1.000		
	-.809	-.956	.029	1.000	
	-.475	-.706	.385	.649	1.000

Apparent Resistivity Measured at 1 Hz is 1473

Apparent Resistivity Calculated from Inductive Coupling is 2.139

FIGURE I

COMPUTER-GENERATED FORWARD PROBLEM SOLUTIONS

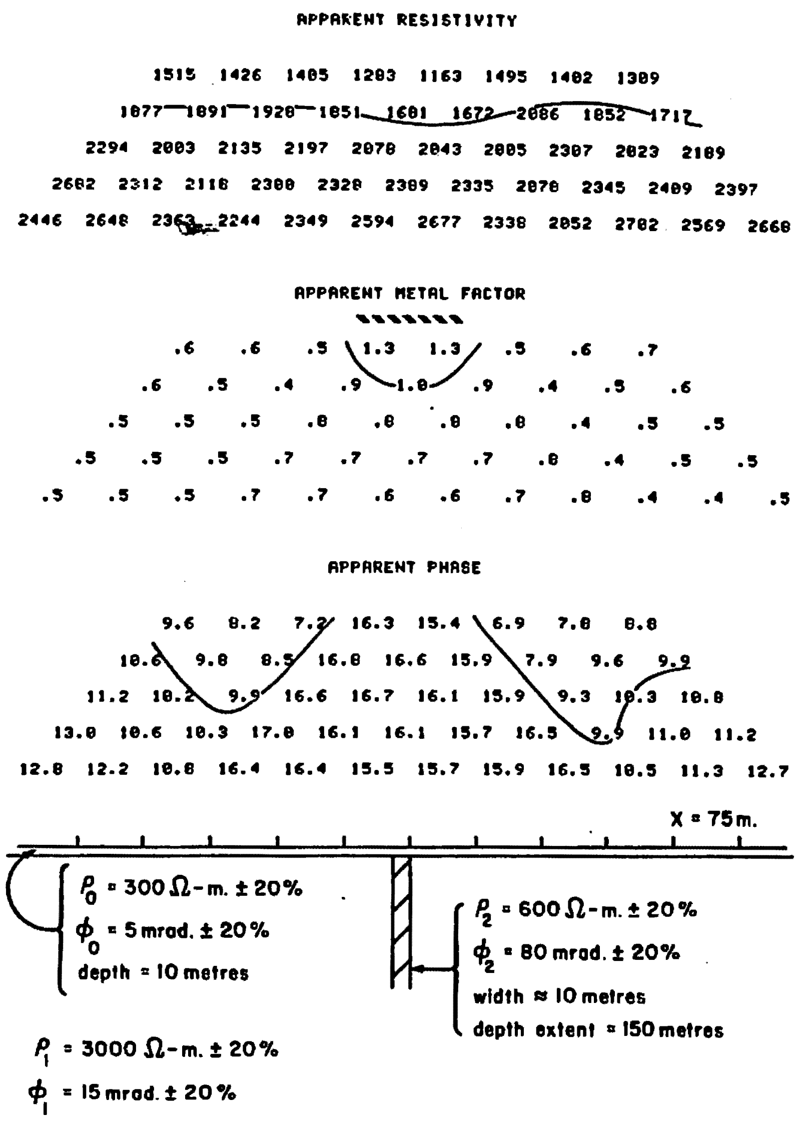


FIGURE IIa

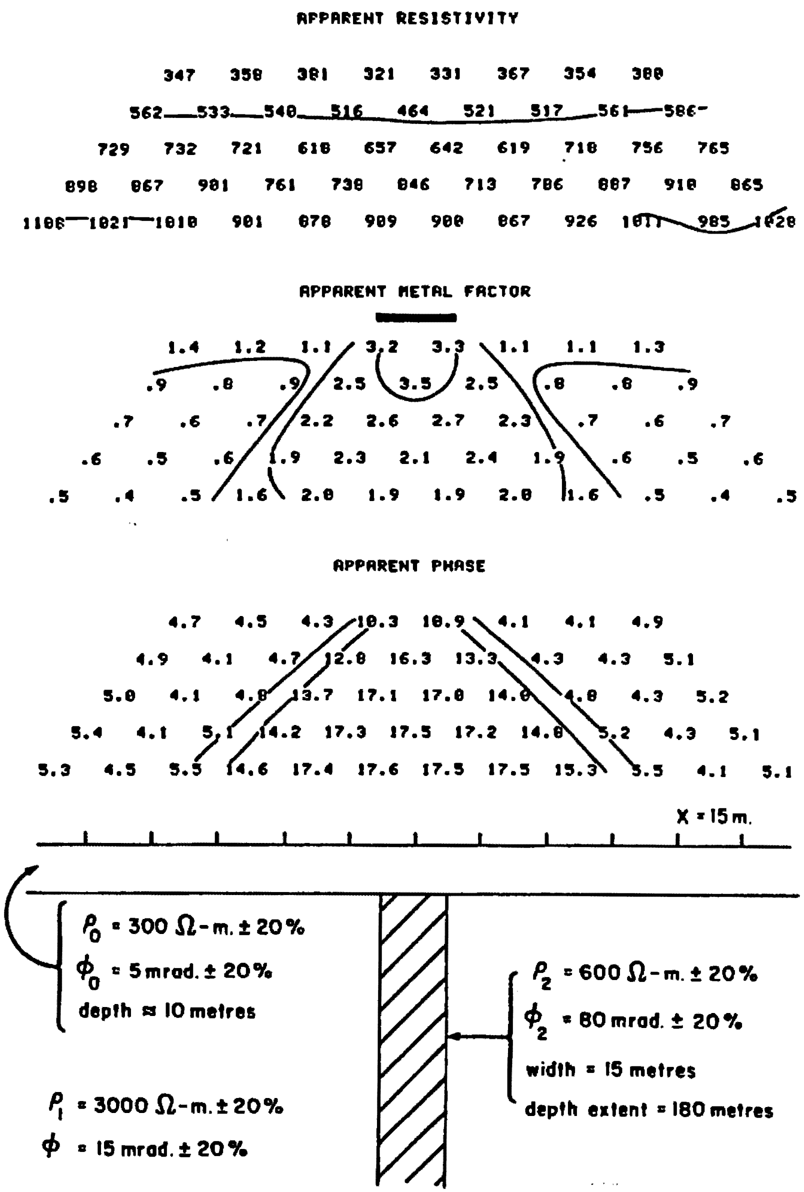
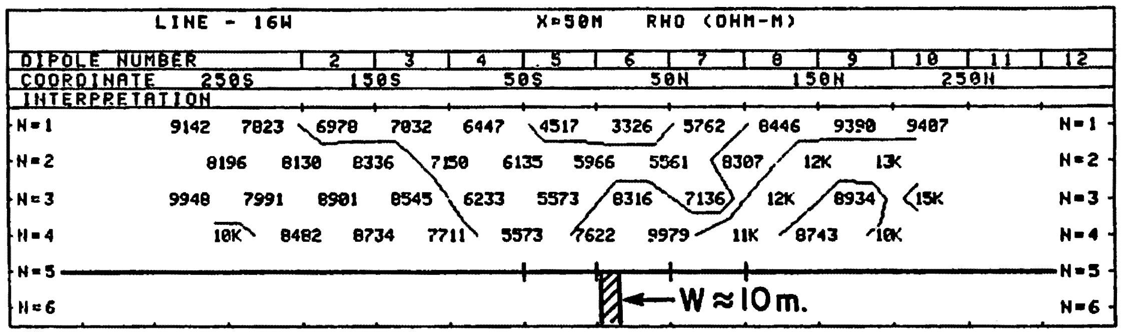
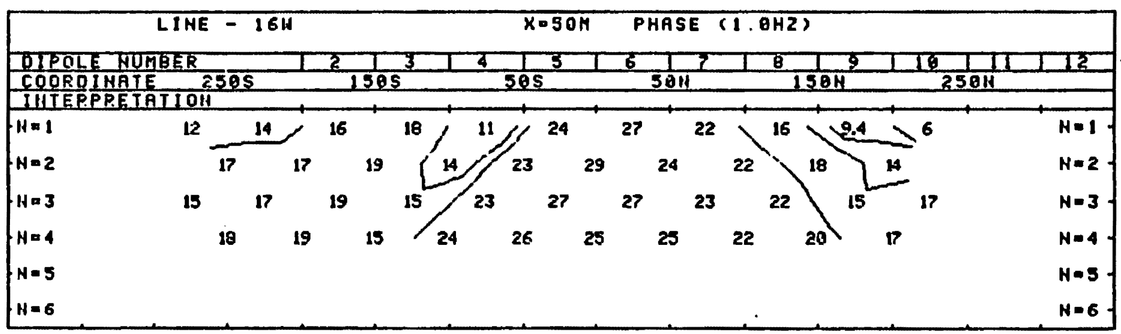


FIGURE IIb

IP ANOMALY OVER UP-DIP END OF MINERALIZED ZONE CONTAINING GOLDEN SCEPTRE OREZONE





ZONE II

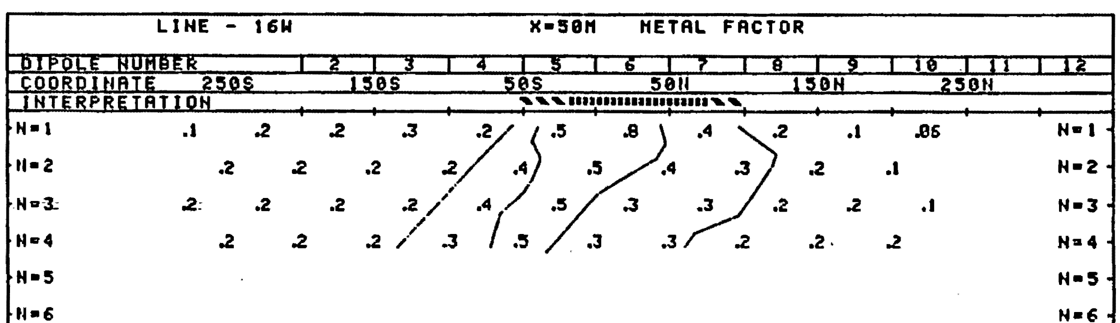


FIGURE III

IF SOURCE IS NARROW, RECONNAISSANCE MEASUREMENTS WITH LARGE ELECTRODE INTERVALS MAY GIVE ONLY WEAK ANOMALY

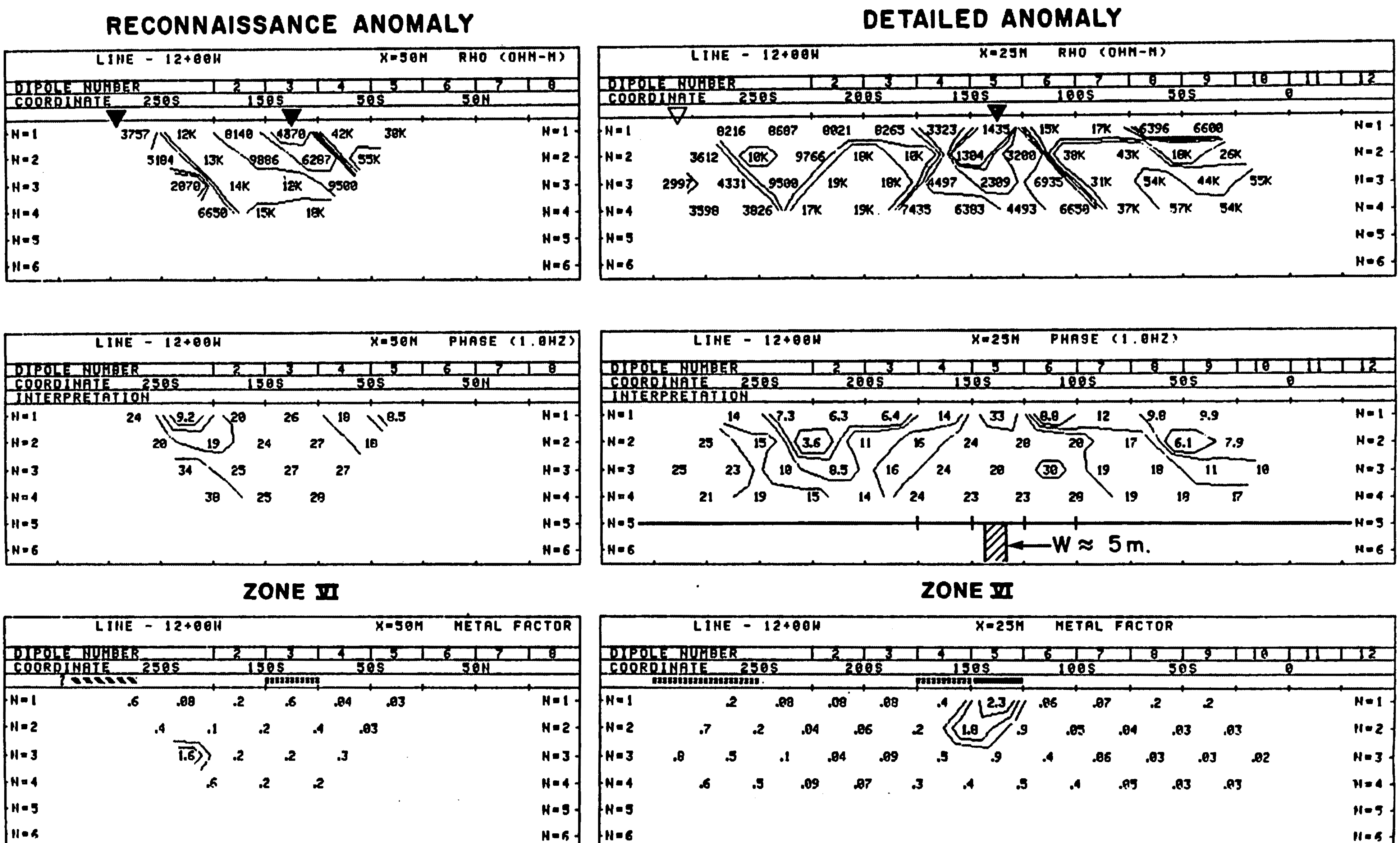


FIGURE IV

Title: The Use of the Induced Polarization Method To Locate Gold-Bearing Sulphide Mineralization

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and

Mitsuru Yamashita*, M.Sc., P.Eng.

Abstract:

Many, perhaps even most, of the gold deposits discovered in Canada in recent years are associated with metallic sulphide mineralization. This is certainly true of the new ore zones located in the Hemlo Area of Ontario and the Val D'Or Area of Quebec. The metallic mineral zone itself, will almost always have a true IP effect. Upon rare occassions, it is possible that no IP effect will be detectable, if intense, late silicification has taken place. The detectability of a zone that is anomalous, by surface induced polarization and resistivity measurements is determined by the following factors:

i) The width and lateral extent of the Zone.

ii) The thickness and resistivity of the covering layer.

iii) The resistivity of the surrounding rocks.

iv) The background IP effect in the surrounding rocks.

v) The electrode configuration and the electrode interval employed for the survey.

INTRODUCTION

Many, perhaps even most, of the gold deposits discovered in Canada in recent years are associated with metallic sulphide mineralization. This is certainly true of the new orebodies located in the Hemlo Area of Ontario. It is also true for many of the more traditional types of gold deposits such as those in quartz veins or those contained within swarms of quartz veinlets.

* Phoenix Geophysics Limited

S.V. 15-10-84

The metallic sulphide mineral is often pyrite or frequently arsenopyrite. However, sometimes chalcopyrite and/or other base metal sulphide minerals are also present. It is the presence of the sulfide minerals that usually result in a true IP effect within the gold ore zone. If free gold is present, it is of course metallic and contributes to the IP effect. However, even in the richest ore zone the gold concentrations are too small to make a significant contribution to the IP effect.

Once in a great while, we have encountered a gold-bearing sulphide zone (usually a quartz vein) in which a late surge of intense silicification has completely eliminated all porosity within the mineralized zone. In this situation the mineralized zone will have an extremely high true resistivity and there will be no true IP effect within the zone. There can be no IP effect, if there are no ionic-metallic interfaces.

However, these situations are rare and it can usually be assumed that a sulphide zone (with or without gold) will have a true IP effect. If the parameters of an induced polarization and resistivity survey are properly determined, such a mineralized zone of significant width and relatively shallow depth can usually, but not always, be detected by surface IP methods.

In this paper we shall try to make clear the considerations that determine the type of IP and resistivity anomaly to be expected from a narrow, weakly anomalous, mineralized zone. It is also very necessary to understand the differences between a reconnaissance survey and a detailed survey. We shall use actual field data, primarily from the Hemlo Area, to demonstrate actual IP anomalies from known mineralized zones, with gold present. We will then employ computer generated, forward problem solutions to demonstrate the variations in the apparent IP anomalies that can be expected with different geologic conditions. It is hoped that from this presentation the field geophysicist will be able to isolate the problems to be expected in using the induced polarization and resistivity techniques, in any given gold exploration problem.

TRUE IP EFFECT WITHIN ZONE

In recent years we have made considerable progress in our understanding of the induced polarization phenomena (Pelton, et al 1978; Hallof and Klein, 1982; Hallof, 1983). We can now make rough predictions as to the magnitude of the IP effect, and more importantly the shape of the phase vs frequency curve, for a well documented zone of metallic mineralization. We know that the concentrations of metallic minerals present, and also the texture of the mineralization, determine the induced polarization response.

The induced polarization and resistivity response from within a potentially gold-bearing zone of mineralization will be little affected by the presence, or absence, of gold. As mentioned previously, there is a true IP effect within almost all gold-bearing sulphide zones; the difficulty encountered in the detection of some zones of ore-grade mineralization, in some geologic environments, is a direct result of the high value mankind has placed upon the noble metal.

I can think of no other exploration problem in which a steeply dipping mineralized zone with a width of two to three meters, a sulphide content of two to four percent pyrite, under twenty meters of glacial till, would be considered an important target. Yet, in the Hemlo Area of Ontario some of the newly discovered ore zones have exactly this description; they also contain 0.25 to 0.35 oz. of gold per ton. Much of the ore at Hemlo is present in greater widths, and contains greater concentrations of pyrite. However, it is also true that in places the favourable quartz-sericite schist host rock is a poorer geophysical target than this, particularly if little or no gold is present.

The fact that makes geophysical exploration for gold such a tricky enterprise is the high value of gold itself. A zone ten meters in width and containing ten percent pyrite may contain no gold, or one-half ounce of gold per ton; in neither case will the gold be visible. Such a zone could be one to two meters in width and still be of immense geologic and economic interest.

Such a small, weakly mineralized zone is rarely of interest in exploration for a massive, volcanogenic sulphide deposit. Some "porphyry copper" deposits may contain only a few percent sulphide mineralization; however, in order to be of possible geologic or economic interest they must have a considerable lateral extent. It is only in exploration for gold-bearing sulphide orebodies, that very small zones of very weak metallic mineralization can be ore!

Due to the relatively small size of these sources, it is not often possible to measure the true electrical parameters of the source, even with very short electrode intervals. It is usually necessary to measure the apparent anomaly from a known source and then to determine the true effects necessary in a narrow source to create an anomaly of the measured magnitude. Regardless of how it is accomplished, it is always desirable to gather as much information as possible concerning the true IP effect, and other parameters, for the type of target being sought.

The results shown on Figure 1 are the spectral IP data, in pseudo-section format, measured with one meter electrode intervals over the up-dip end of the Corona Orebody at Hemlo, Ontario.

The highest apparent resistivities measured were from the quartzites in the hanging wall and the footwall. The apparent resistivities within the schist host rock are somewhat lower in magnitude, and quite variable.

The apparent IP effects from the pyrite mineralization in the schist are 50 to 80 milliradians; these are fairly typical for the ore mineralization in the Hemlo Area. The anomalous pattern is broad, and nearly uniform; under these conditions the apparent effects measured must be nearly equal to the true effects within the source.

It is of some interest that the time-constant (τ_1) appears to be larger at the eastern edge of the schist rock unit. This is the position of gold values within the pyritic schist. The indication of larger grain-size (larger τ_1) (see Hallof, 1983) for the pyrite with gold present, agrees with petrographic work carried out by the Ontario Geologic Survey. (Springer, J; 1983).

The spectral plot shown on Figure 2 is typical of those from within the anomaly. (see Hallof, 1983). They suggest a relatively small grain-size (τ_1). The spectral plot indicates that exploration using phase-IP measurements with the frequency in the vicinity of 1.0 Hz would be optimum.

The data shown on Figure 3 and Figure 4 demonstrate the use of computer generated, forward problem solutions to obtain an estimate of the electrical parameters of the source of an IP anomaly. The field data (Figure 3) was measured using X = 50 meters over the up-dip edge of the mineralized zone at the Golden Sceptre property at Hemlo, Ontario. At surface on Line 16W, the favourable schist is weakly pyritized and only low gold values are present. However, an ore-grade zone of gold-bearing sulphide mineralization begins at a depth of a few tens to a hundred meters. The IP anomaly measured using X = 50 meters is low in magnitude.

The weakly mineralized rock unit is about ten meters thick at Line 16W. Therefore, it is possible to use a forward problem solution to obtain an estimate of the electrical parameters of the source. (Figure 4). The electrical parameters necessary in a source with a width of ten meters are much the same as those measured using X = 1.0 meters over the outcrop of the Corona Orebody.

The computer generated, forward problem solution shown on Figure 4 is typical of those that will be employed in interpretational solutions and problems throughout this paper. The finite element matrix solution is for a two-dimensional geometry, with the survey line perpendicular to the strike of the earth geometry. Although we shall present only dipole-dipole electrode configuration data in this paper, the results for any electrode configuration may be calculated. Because a finite element matrix solution is employed, the subsurface modelled may have any number of rock types (electrical parameter variations) with any shape.

A recent improvement in the software permits a random error to be added to the parameter values for each finite element. For the solution on Figure 4, the maximum random error was ± 20%; however, any error magnitude may be used. The use of this software formulation results in pseudo-sections which are somewhat irregular; therefore, they are more easily identified with actual field data.

ELECTRODE INTERVAL (X) vs. SOURCE WIDTH (W)

In all of our exploration work to locate gold-bearing sulphide zones, we have used the dipole-dipole electrode configuration. The electrode interval (X) has varied from X = 100 meters to X = 3.0 meters; the electrode separation (n) has varied from n = 1,2 to n = 1,2,3,4,5,6. We employ the dipole-dipole electrode configuration, because of the second lateral derivative nature of the measurement. The apparent effects measured from a small, local source are larger in magnitude than for other electrode configurations.

For any given survey, planned for any purpose, the choice of the electrode interval (X) is one of the most critical that the geophysicist must make. A larger value of (X) will result in a faster rate of progress (and therefore a lower cost) for the work planned. All things being equal, a larger value of (X) should also result in a greater depth of detection for the survey.

However, in an exploration program to locate the narrow, weak sources described above, there are additional factors that must be taken in account:

a) First and foremost is the fact that measurements with large electrode intervals average a large volume of the subsurface into each measurement. If the anomalous source is small, it will have a small effect on the apparent value measured. It is entirely possible that if the electrode interval is too large, no detectable anomaly will be measured from a small source, regardless of its depth.

b) The exact location of a small source between two widely spaced electrodes cannot be determined. If X = 100 meters is used to locate a source with a width equal to 10 meters, the minimum uncertainty in locating the source is 100 meters; the maximum uncertainty may be 200 meters.

c) In any situation in which the electrode interval is appreciably greater than the width of the source, there is a general ambiguity regarding the parameters of the source. For the situation above, the anomaly from a source 10 meters in width and containing 5% to 6% sulphide mineralization will look very much like the anomaly from a rock unit that is 60 meters in width and containing a much lower concentration of metallic minerals.

The usual result of the factors outlined above is that if a reconnaissance IP and resistivity survey is planned using very large electrode intervals, two things will happen! There will be some small sources that will not be detected by the survey, even if they are at zero depth. Secondly, there will be a great many one-station and two-station anomalies that could be due to a narrow, shallow, weak source of the type being sought. Detailed measurements with shorter electrode intervals will, of course, help to sort out the problem.

However, the detailed measurements will require survey time and therefore add to the cost of the survey. Some of the cost benefit arising from the use of the large electrode interval will be lost in the requirement for a greater amount of detailed survey time needed to completely evaluate, and better locate, the sources of all of the reconnaissance anomalies.

The cost of not detecting a few very small, very weak sources can, of course, not be evaluated since they may never be tested. This latter concern can be very real, once the geophysicist and the geologist realize that the weak, narrow anomaly shown on Figure 3 and Figure 4 is all that we can expect to detect from a narrow band of mineralized quartz-sericite schist that contains the up-dip end of a previously unknown zone of gold-bearing sulphide mineralization at a depth of less than 100 meters. As we shall see, if X = 100 meters, or even X = 75 meters, were used for the reconnaissance survey, the resulting apparent anomaly might not be interpretable.

Even if the conditions are fairly ideal for the application of the IP method, a reconnaissance survey using large electrode intervals may not definitely detect the source that is the target of the survey. The theoretical results shown on Figure 5 are those that would be measured, from a fairly typical source, using X = 75 meters.

In these cases, as in all further cases, the source parameters are set at fairly typical values for the zones at Hemlo, Ontario or for sulphide bearing quartz veins. These parameters of the source are then held constant while the parameters of the survey, or the parameters of the other rocks present, are varied. It is obviously possible in each case to make the reconnaissance anomaly more definite by altering the parameters of the source. However, that is not the point we are trying to make. What we are attempting to demonstrate is how easy it can be to miss a possibly important bedrock source, by a careless choice of survey parameters.

A further, unwelcome conclusion will be that for any given earth geometry there may very well be narrow, weakly mineralized sources at depth that cannot be detected by IP measurements, no matter how carefully the parameters of the survey are chosen.

The maximum random error for the example shown on Figure 5 has been set at ± 35%. For X = 75 meters the anomalous magnitudes are less than twice background. This poorly interpretable anomaly does point out one distinct advantage of the pseudo-section format for plotting dipole-dipole measurements made with multiple (n) values. A low magnitude, anomalous measurement that conforms to a recognizable anomalous pattern, can often be considered to be significant, even if it is not several times background in magnitude.

The results measured for X = 25 meters are shown on Figure 6. In this situation, the anomalous magnitude, as well as the anomalous pattern, can be considered to be anomalous. It should be further noted that the uncertainty of location of the source has been reduced from about 100 to 150 meters to the much smaller distance of 25 meters.

These problems of interpretation are encountered continuously in the field. The results shown on Figure 7 (reconnaissance, X = 50 meters) and on Figure 8 (detail, X = 25 meters) located a pyrite-bearing schist band in the Hemlo Area of Ontario. The zone was five meters in width; it contained a few percent pyrite and a few low gold values. The zone is not ore, but it is of extreme geologic importance. However, the reconnaissance anomaly is not significant enough to have been chosen for detail at the time of the first interpretation; it was chosen for detail during a review of the reconnaissance data several months later.

THICKNESS AND CONDUCTIVITY OF COVERING LAYER

Even for detailed measurements with a small electrode interval, the geologic environment, and the electrical parameters of that environment have a profound effect upon the IP anomaly to be detected from a small zone of weak mineralization. We will first examine the influence of the thickness, and the conductivity of the material that lies between the top of the anomalous zone and the surface on which the measurements are made.

In these forward problem solutions we have used X = 25 meters and used a width of the source of W = 7.5 meters. The electrical parameters of the source, and the country rock have been chosen to approximate those in the Hemlo Area. In order to approximate the "real earth" situation, we have introduced a maximum random error of ± 35%.

The data on Figure 9 is that for the case in which the source is at a depth of 19 meters. The overlying layer has a lower resistivity, similar to that for glacial overburden. Even with the introduction of the random errors, the anomalous pattern has a recognizable shape. The maximum apparent phase shift is less than twice background. However, it is important to notice that the anomalous magnitude is 4.0 to 6.0 milliradians above background. This can be achieved.

If we increase the thickness of the overburden to 25 meters (Figure 10), we have altered the non-polarizable conduction path that lies in parallel with the conducting paths that are influenced by the polarizable source. We have also reduced the resistivity of the overburden layer from 300 ohm-meters to 150 ohm-meters. This value is still fairly typical for Canadian Shield glacial overburden. Without delving into the usefulness, or even the validity, of the M.F. (Metal Factor) or M.C.F. (Metallic Conduction Factor) parameter, it should be noted that its magnitude does not change very much. As seen on Figure 10, the $(M.F.)_a$ pseudo-section is much the same. However, since the apparent resistivities must be lower, the anomalous apparent phase shifts measured are also lower in magnitude.

The apparent phase-shift and apparent M.F. anomalous patterns are still fairly definite. However, there is one difference from Figure 9. In order to clearly outline the anomaly, the accuracy in the measurements of the apparent phase-shift must now be 1.0 to 3.0 milliradians. This is considerably more difficult to achieve consistently.

It is this need for extreme accuracy, and sensitivity, that has led us to use the phase IP technique for reconnaissance and detailed surveys in regions such as the Hemlo Area. A system such as the Phoenix IPV-2 Phase IP Prospecting system can use coherent filtering (signal stacking) and extremely accurate crystal clocks to achieve an accuracy of 2.0 to 3.0 milliradians of phase shift, at 1.0 Hz. This is just about an order of magnitude better than previous variable frequency or time-domain IP systems.

The same result can be expected in exploration for Hemlo-type, gold-bearing sulphide zones in geologic regions of thicker, more conductive overburden. The problems of exploration and the need for greater accuracy would be even greater in a geologic environment of deep weathering, which would form a very conductive overburden layer. In this regard, the Hemlo Area of Ontario is just about ideal for the use of IP. There is a thin layer of glacial overburden almost everywhere; this cover confounds the geologist and makes the preparation of electrodes relatively easy. At the same time, the overburden layer is usually thin enough, and has a high enough resistivity, so that the measurement difficulties are not great.

BACKGROUND IP EFFECTS

Another advantage we have found to exploration in the Hemlo Area is that the relatively non-porous, high resistivity, metamorphic rocks that form the host rocks are usually devoid of metallic mineralization. Therefore, the background IP effects measured in reconnaissance surveys are usually low in magnitude and a weak, low magnitude IP anomaly can be interpreted in the data, if it is present.

The results (X = 25 meters) shown on Figure 11 show a weak, narrow, shallow anomaly that might just be interpretable due to the fact that the anomalous pattern is regular, and easily recognized. However, any interpretation of a narrow, shallow, weak anomaly becomes even more difficult as the background values are made more complex and a greater variability is added (Figure 12). The apparent parameters shown in Figure 12 are variable and complex enough, that the presence of an anomaly may be impossible to interpret.

It is clear from this simple example, that the search for small, weakly mineralized zones, that might contain gold, would be more difficult in a different geologic environment.

ELECTRODE INTERVAL (X) AND MULTIPLE SOURCES

In a reconnaissance induced polarization and resistivity survey with large electrode intervals, a very large volume of rock is averaged into each measurement. Since the potentials must satisfy LaPlace's equation, the apparent effects measured must be very smooth. For X = 75 meters, n = 1, the outside electrodes are 225 meters apart. It is not surprising that very little detail concerning the internal character of a bedrock source can be interpreted from a reconnaissance anomaly.

The results shown on Figure 13 are those measured with X = 75 meters over two sources that have a width of 10 meters and a separation of 45 meters. The pseudo-section indicates only a single, simple anomalous pattern, centered at station 0+00. The results are almost exactly like those shown on Figure 4 or Figure 9, from a single source.

There are several comments that should be made concerning the difficulties that might be encountered in determining the nature of the source of the anomaly outlined on Figure 13.

1) A vertical drill hole spotted near the center of the anomalous pattern (i.e., near station 0+00) would not intersect either source.

2) An angled drill hole spotted to either side of the anomaly, would intersect one of the sources but would probably be stopped before it intersected the second source.
3) A trench to bedrock (a depth of 5.0 meters) that was 50 to 60 meters in length, and centered near station 0+00, might expose one source or the other, or just possibly both.

If X = 15 meters are used for the survey (Figure 14) the sources still appear to be shallow (i.e. anomalous for n = 1), since the depth of cover is only 6.0 meters. This electrode interval is appreciably less than the separation of the sources. In these results, the presence of two distinct sources can clearly be interpreted from the pseudo-section.

The problem of missing multiple sources is a continuing problem in interpreting reconnaissance IP data. It is a particular problem in exploration for gold-bearing sulphide zones. Several narrow zones of weak pyritic mineralization may be present; however, while the mineralized zones may all look the same, one may contain significant gold values. If the anomalous zones have been located in a region of geologic interest, there is no way to determine which of the sources may be of the greatest economic importance; they must all be tested. In order to accomplish the testing in an effective manner, it is almost always necessary to make detailed measurements.

The X = 50 meter reconnaissance induced polarization and resistivity data shown on Figure 15 is also from the Hemlo Area. On this pseudo-section, it is possible to interpret three weak, narrow, shallow IP anomalies. The anomaly centered at 1+00S to 0+50S was somewhat more definite and it was detailed first.

The results shown on Figure 16 were measured using X = 10 meters. The anomaly centered at 0+95S is the source of the interpreted reconnaissance anomaly. This source is indicated to have some width. The shallow source centered at 0+35S to 0+25S cannot be interpreted from the reconnaissance results; it is indicated to be quite narrow.

All of the anomalous sources located by the IP results shown on Figure 15 and Figure 16 have been investigated by trenching. All four anomalies are due to pyritic mineralization within the favourable metamorphic rocks. The three sources located by the reconnaissance data (Figure 15) do not contain significant gold values. The narrow source centered at 0+35S to 0+25S, detected only by the detailed, X = 10 meter measurements, does in fact contain some gold values.

CONCLUSIONS

With very few exceptions, the zones of weak to moderate concentrations of sulphide mineralization, that sometimes contain gold, can be expected to have a significant true induced polarization effect. The amount of gold present does not appear to be related to the sulphide concentration in the zone. Therefore, a zone can be a few meters in width, contain a few percent sulphide mineralization and be an extremely rich orebody because it also contains a third of an ounce of gold per ton. Much of the ore in the orebodies recently discovered in the Hemlo Area of Ontario has this general description.

In order to specify an induced polarization and resistivity survey to detect this type of mineralized zone, it is necessary to choose the parameters of the survey so that the apparent effects measured at the surface will be interpreted as being anomalous. It is not satisfactory to merely choose a large electrode interval so that the progress of the survey will be rapid and the cost of the survey will be reduced.

A number of factors must be considered in planning a survey for typical gold-bearing sulphide zones. These factors include:

i) The true IP effect and resistivity within the sources that are the the target of the exploration program
ii) The electrode configuration to be used for the IP Survey
iii) The electrode interval to be used relative to the expected source width
iv) Thickness and Conductivity of the Surface Layer
v) Background IP Effects and their Variability
vi) The necessity to detect multiple sources

From a practical point of view, it is usually necessary to execute a reconnaissance survey using as large an electrode interval as is practical. Then, it is necessary to check a large number of weak, narrow, shallow reconnaissance anomalies using detailed measurements with shorter electrode intervals. These detailed measurements will confirm the presence of a definite, narrow source, more definitely locate the position of the source and more fully evaluate the nature of the mineralization that is the source of the anomaly.

None of the above will enable the geologist and geophysicist to predict whether significant gold values are present. However, the detail measurements will ensure that only a short drill hole is necessary to confirm that no gold is present.

Acknowledgement:

It is obvious that this paper could not have been prepared for presentation without the help and permission of the following companies. We owe them our thanks.

Bachelor Lake Gold Mines Ltd.
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Kellar Lake Gold Mines Ltd.
Orequest Consultants Ltd.
Noranda Exploration Co. Ltd.
Teck Corporation

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HEMLO AREA, ONTARIO

SPECTRAL IP RESULTS

ANOMALY OVER CORONA ORE ZONE AT ZERO DEPTH

LINE - O DIPOLE - DIPOLE ELECTRODE CONFIGURATION X = ONE METER

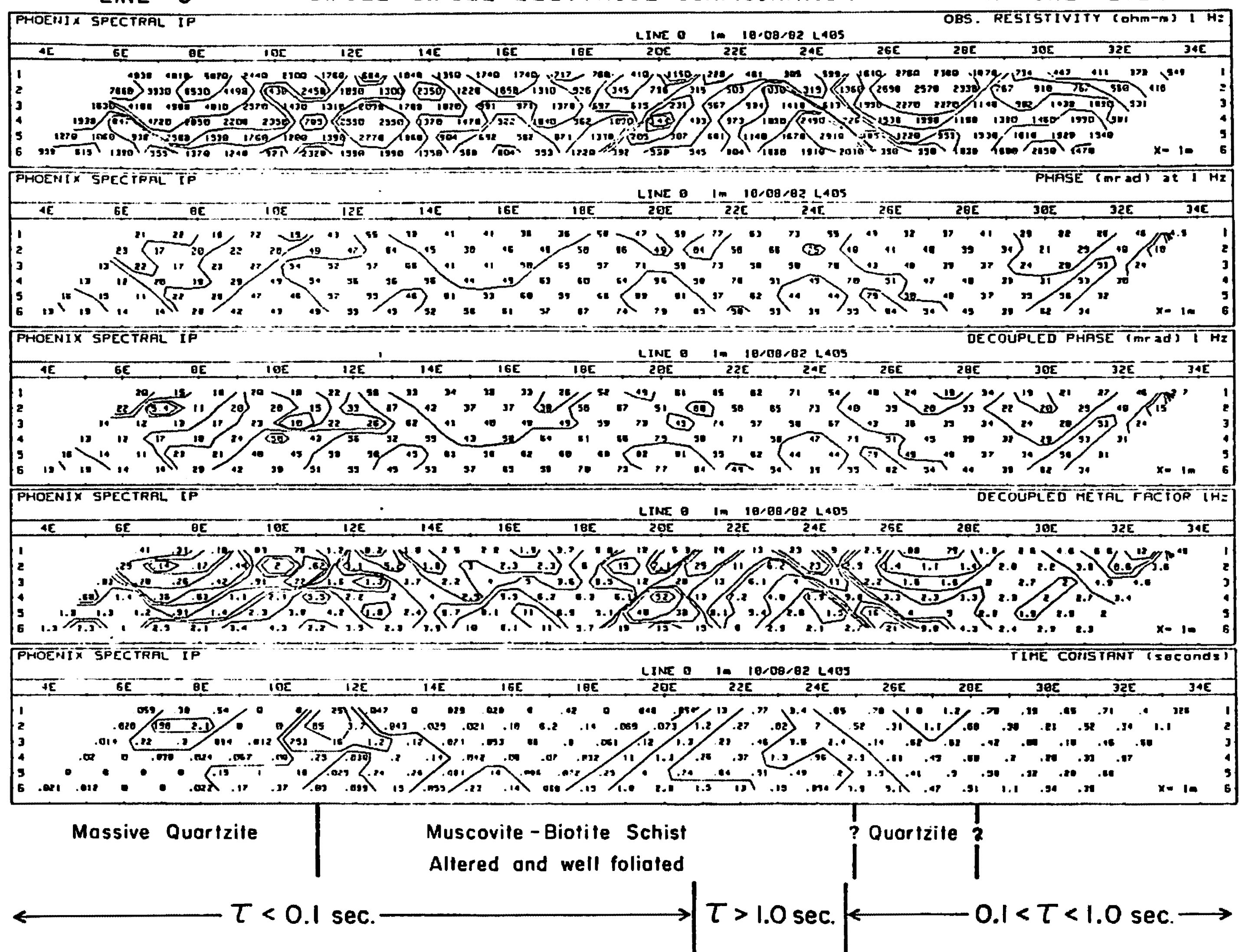
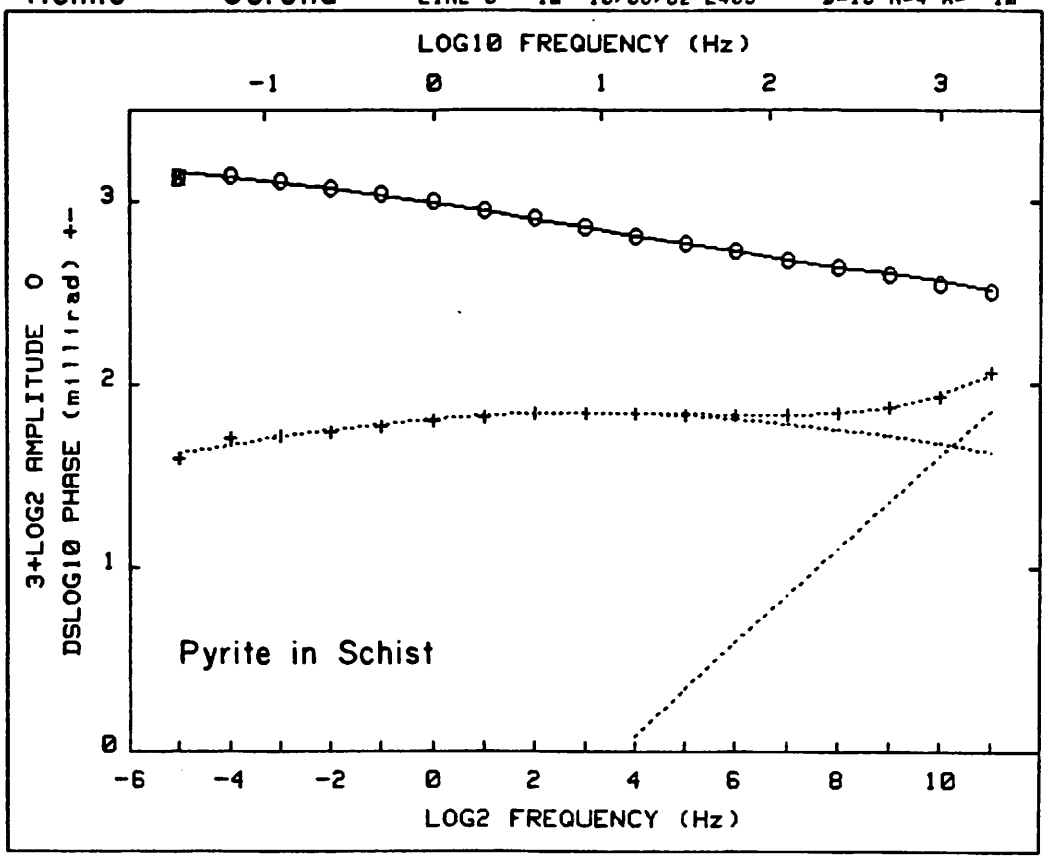


FIGURE 1

SPECTRAL IP PLOT

Hemlo Corona LINE 0 1m 10/08/82 L405 D=13 N=4 X= 1m



CRL: Number of dispersions= 2 PHOENIX GEOPHYSICS LIMITED

Iter	Lambda	Rchsq	R0	M1	T1	C1	M2	T2	C2
0	1.E-02	.00020	1.253	.446	1.0E-01	.288	.555	5.9E-06	.650
1	1.E-02	.00017	1.259	.458	9.4E-02	.281	.573	5.9E-06	.696
2	1.E-03	.00016	1.268	.483	7.5E-02	.265	.608	5.9E-06	.797
3	1.E-04	.00015	1.270	.488	7.1E-02	.262	.573	7.2E-06	.839
4	1.E-04	.00015	1.270	.489	7.0E-02	.262	.491	9.0E-06	.852
Pct Std Deviations			1.2	5.7	23.7	6.9	633.7	1658.7	25.0

Correlation Matrix

1.000						
.899	1.000					
-.556	-.848	1.000				
-.925	-.981	.769	1.000			
-.471	-.614	.651	.541	1.000		
.483	.635	-.673	-.558	-.999	1.000	
.657	.854	-.871	-.773	-.882	.901	1.000

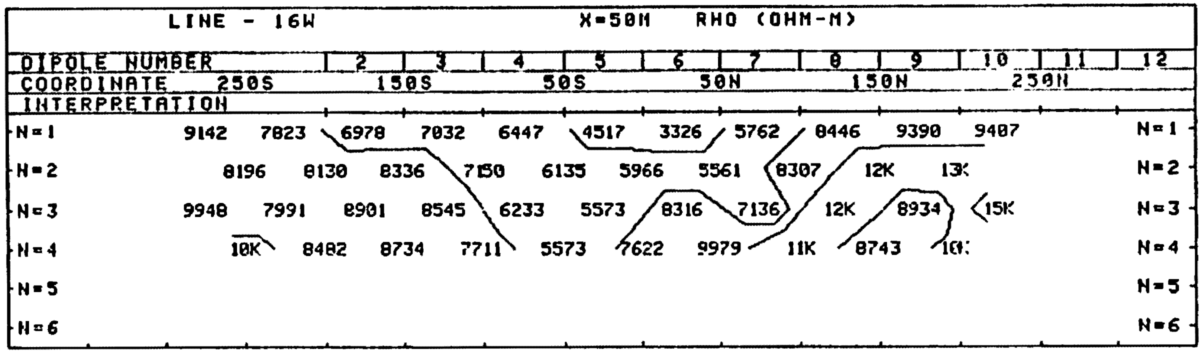
Apparent Resistivity Measured at 1 Hz is 1045

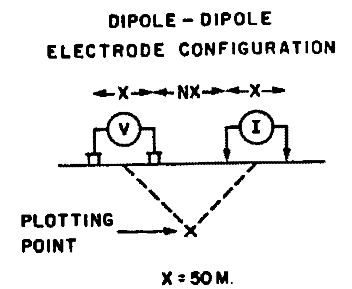
Apparent Resistivity Calculated from Inductive Coupling is .816

FIGURE 2

HEMLO AREA, ONTARIO

IP ANOMALY OVER UP-DIP END OF MINERALIZED ZONE CONTAINING GOLDEN SCEPTRE GOLD ZONE





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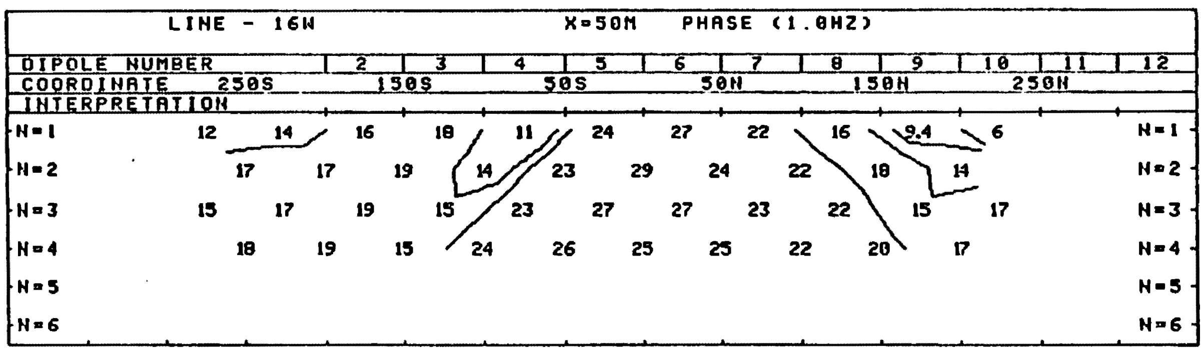


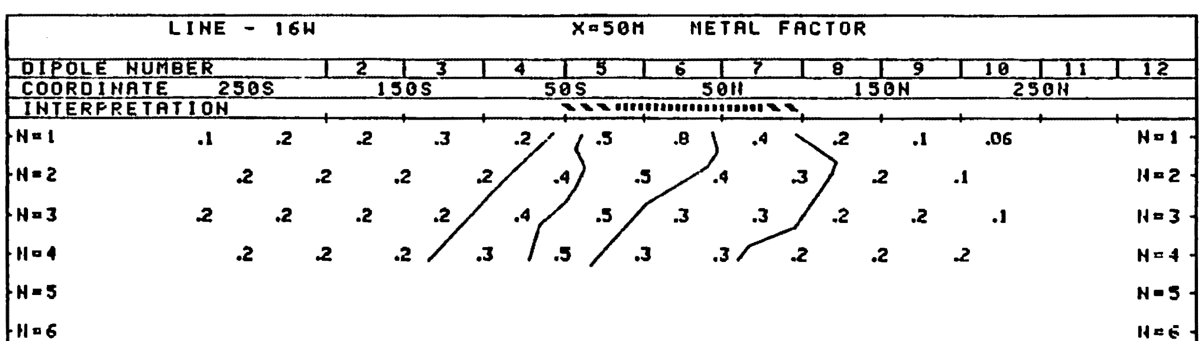
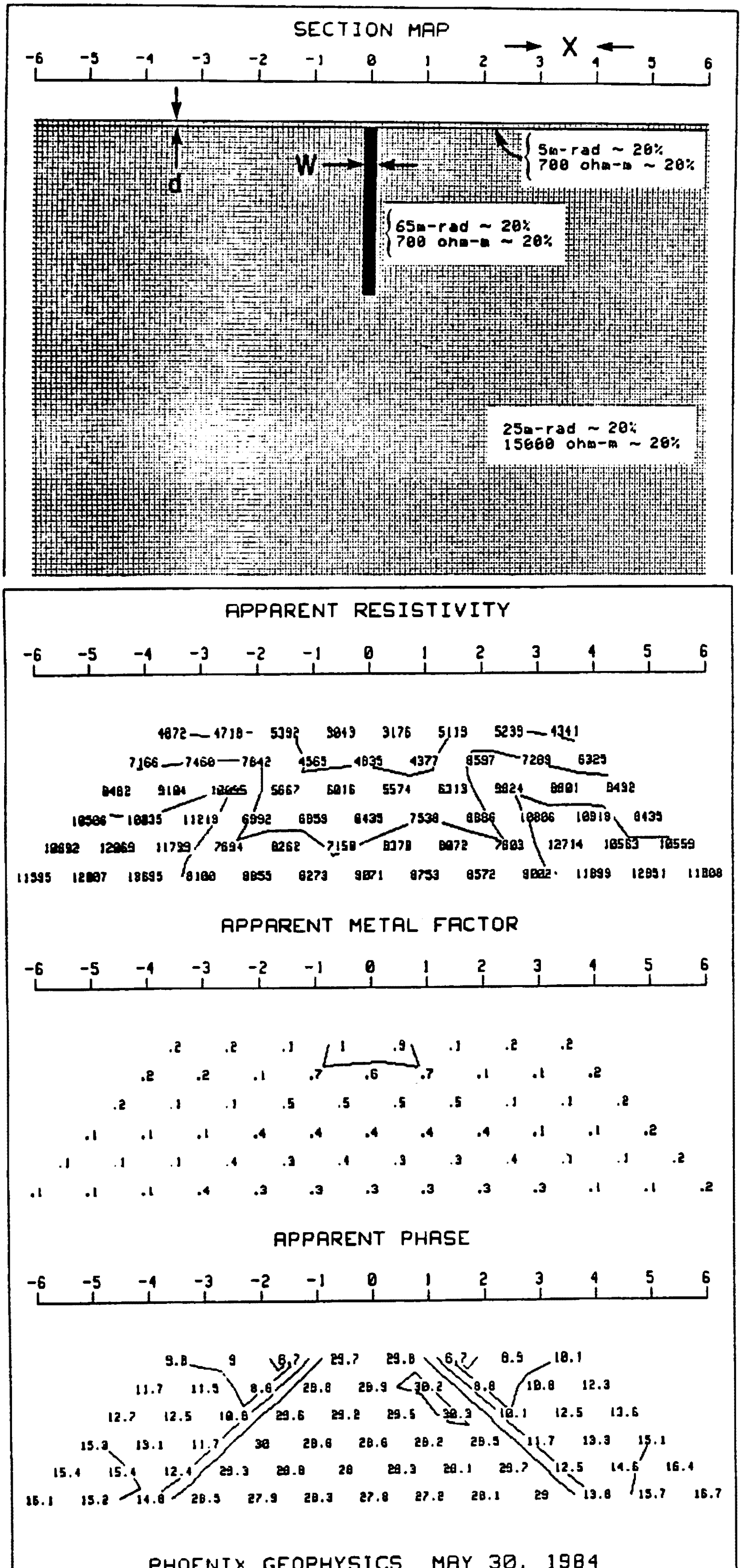


FIGURE 3



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FORWARD PROBLEM SOLUTION

X = 50 meters

W = 10 meters

d = 5.0 meters

DIPOLE - DIPOLE ELECTRODE CONFIGURATION

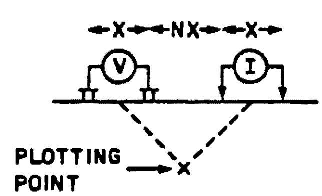
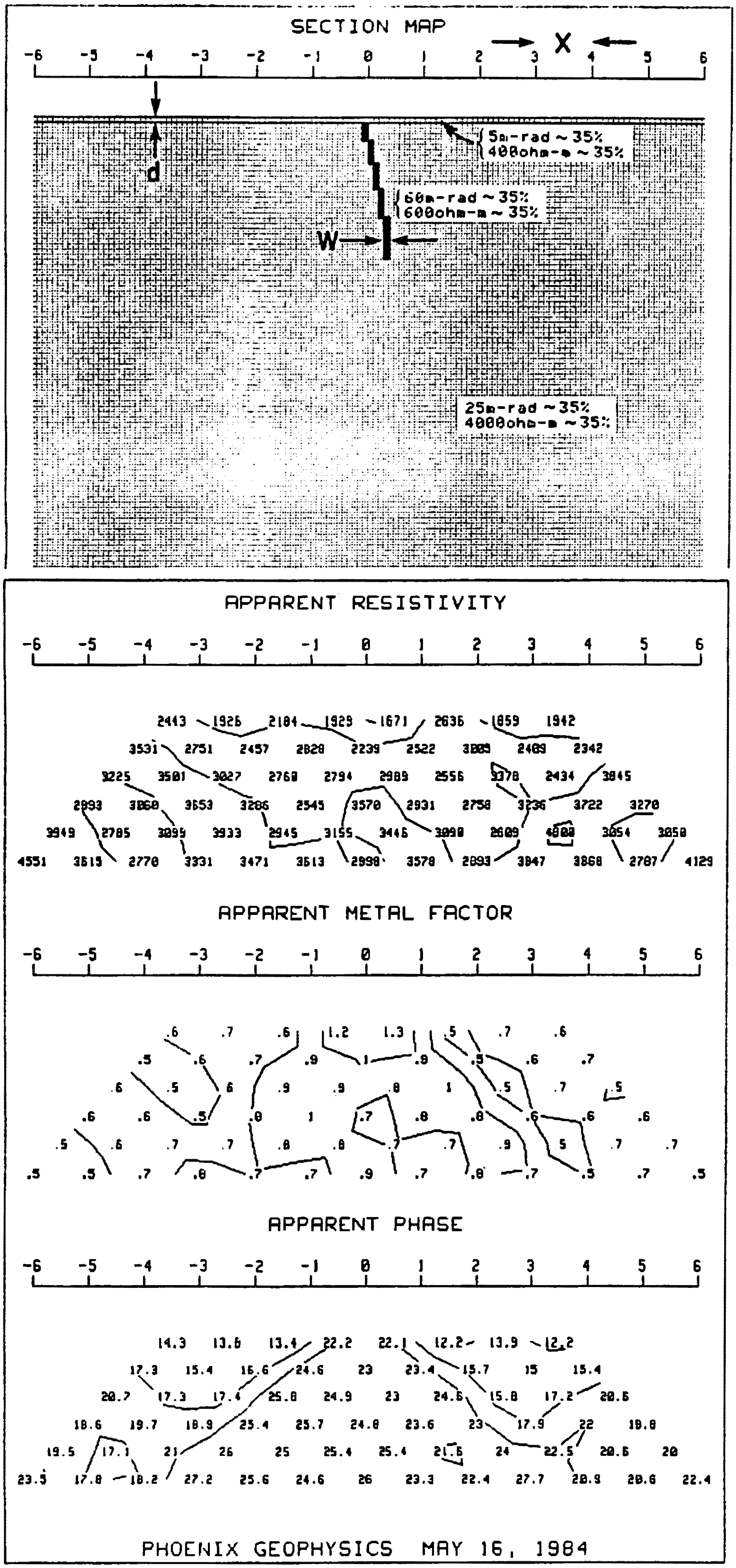


FIGURE 4



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FORWARD PROBLEM SOLUTION

X = 75 meters

W = 7.5 meters

d = 7.5 meters

DIPOLE – DIPOLE ELECTRODE CONFIGURATION

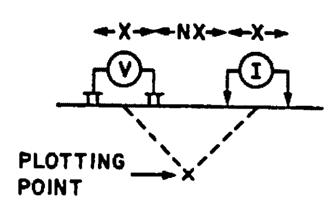
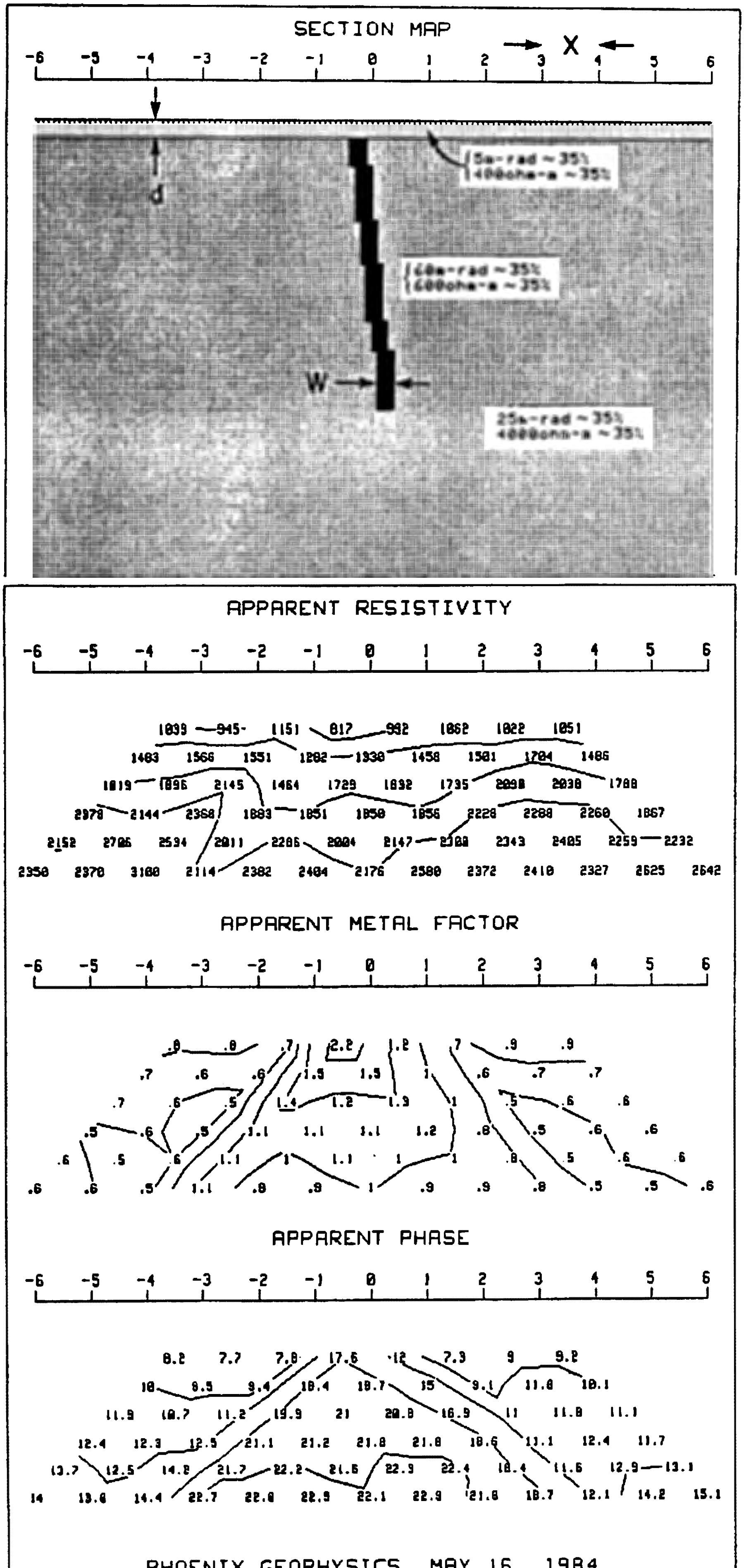


FIGURE 5



PHOENIX GEOPHYSICS LIMITED

FORWARD PROBLEM SOLUTION

X = 25 meters

W = 7.5 meters

d = 7.5 meters

DIPOLE – DIPOLE ELECTRODE CONFIGURATION

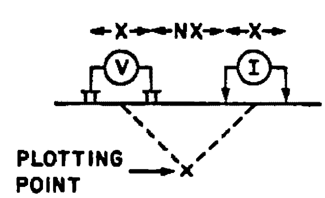
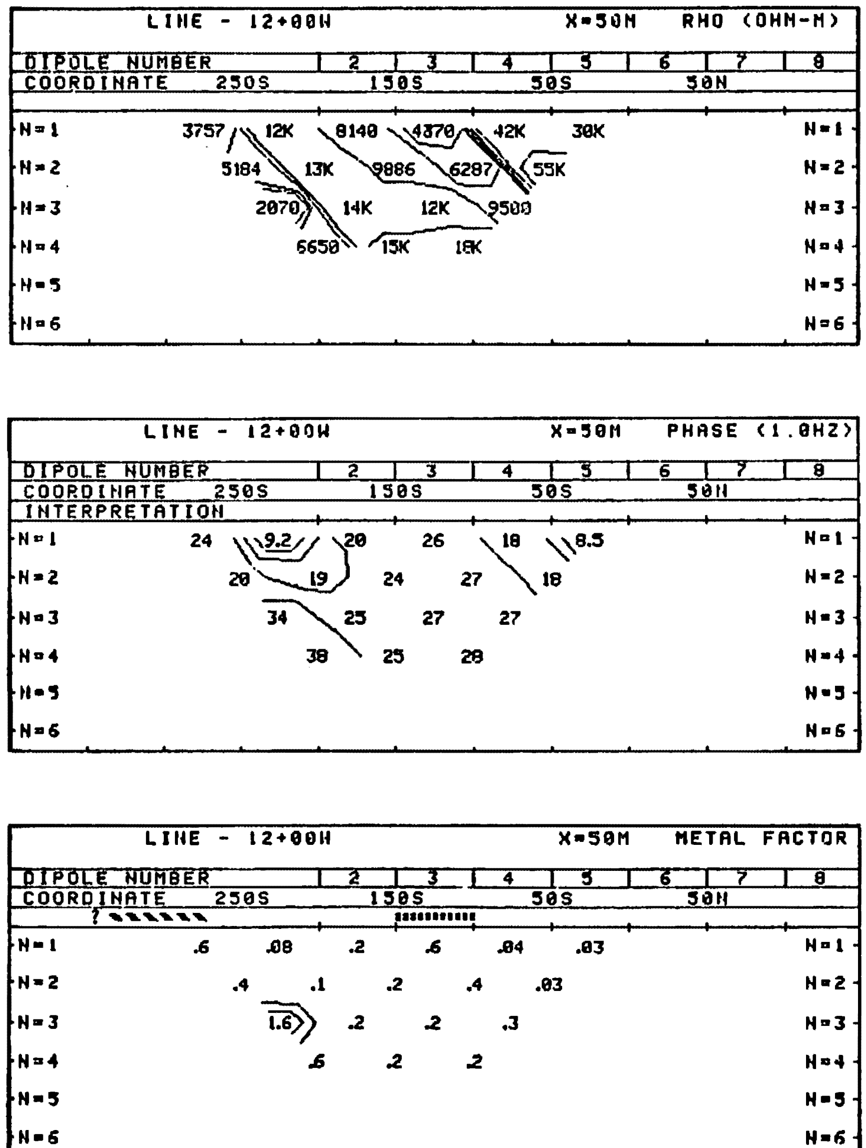


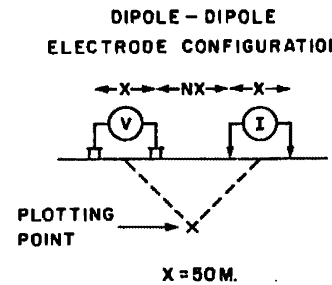
FIGURE 6

HEMLO AREA , ONTARIO

IP and RESISTIVITY SURVEY

RECONNAISSANCE ANOMALY





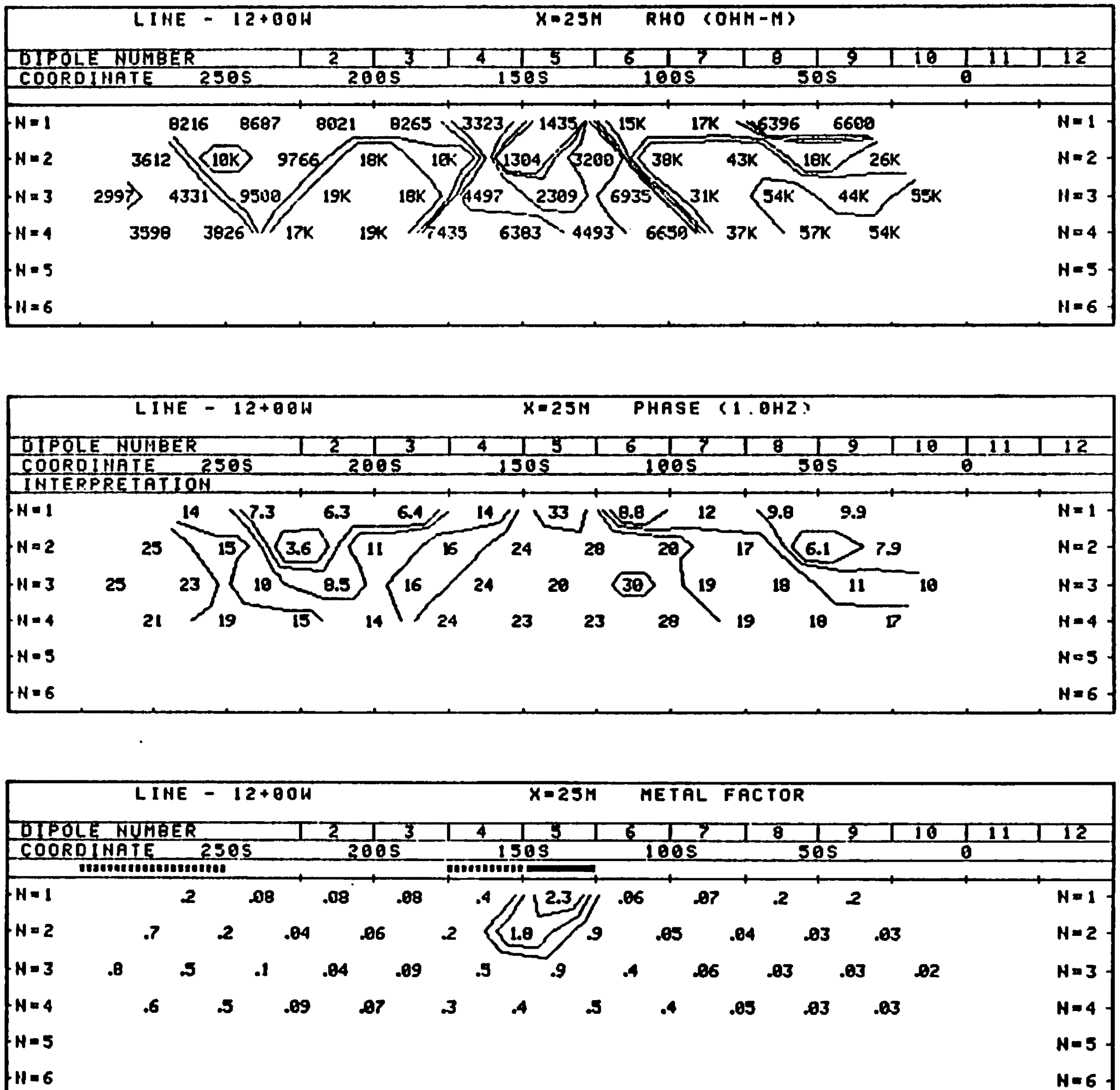
PHOENIX GEOPHYSICS LIMITED

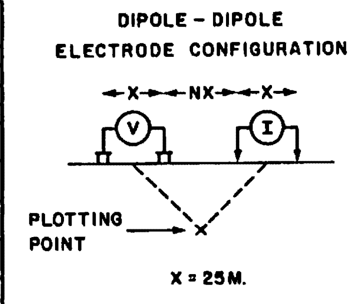
FIGURE 7

HEMLO AREA , ONTARIO

IP and RESISTIVITY SURVEY

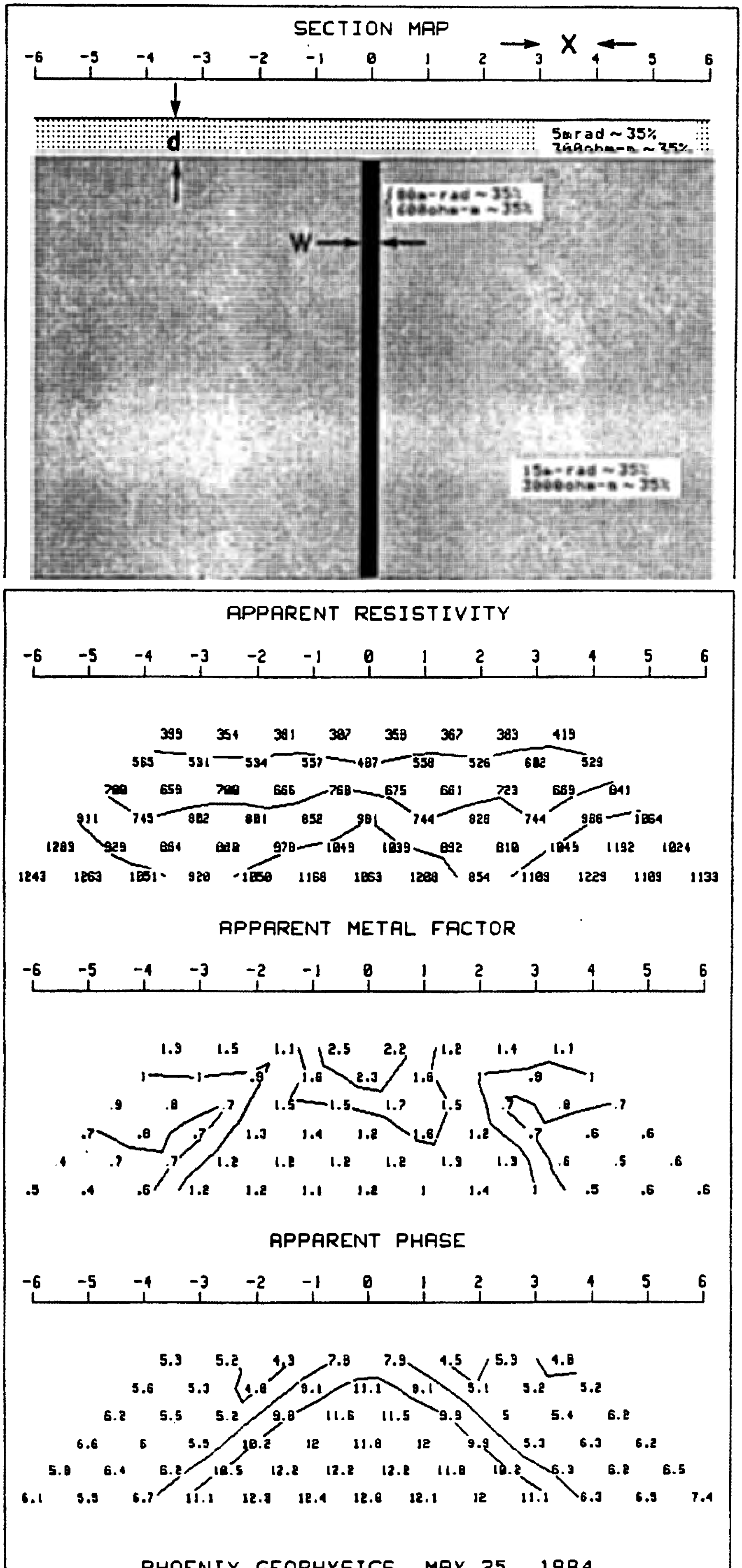
DETAILED ANOMALY





PHOENIX GEOPHYSICS LIMITED

FIGURE 8



PHOENIX GEOPHYSICS LIMITED

FORWARD PROBLEM SOLUTION

X = 25 meters

W = 7.5 meters

d = 19 meters

DIPOLE - DIPOLE ELECTRODE CONFIGURATION

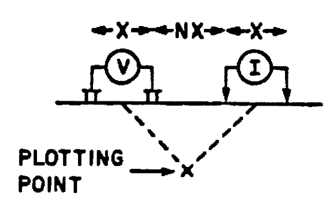
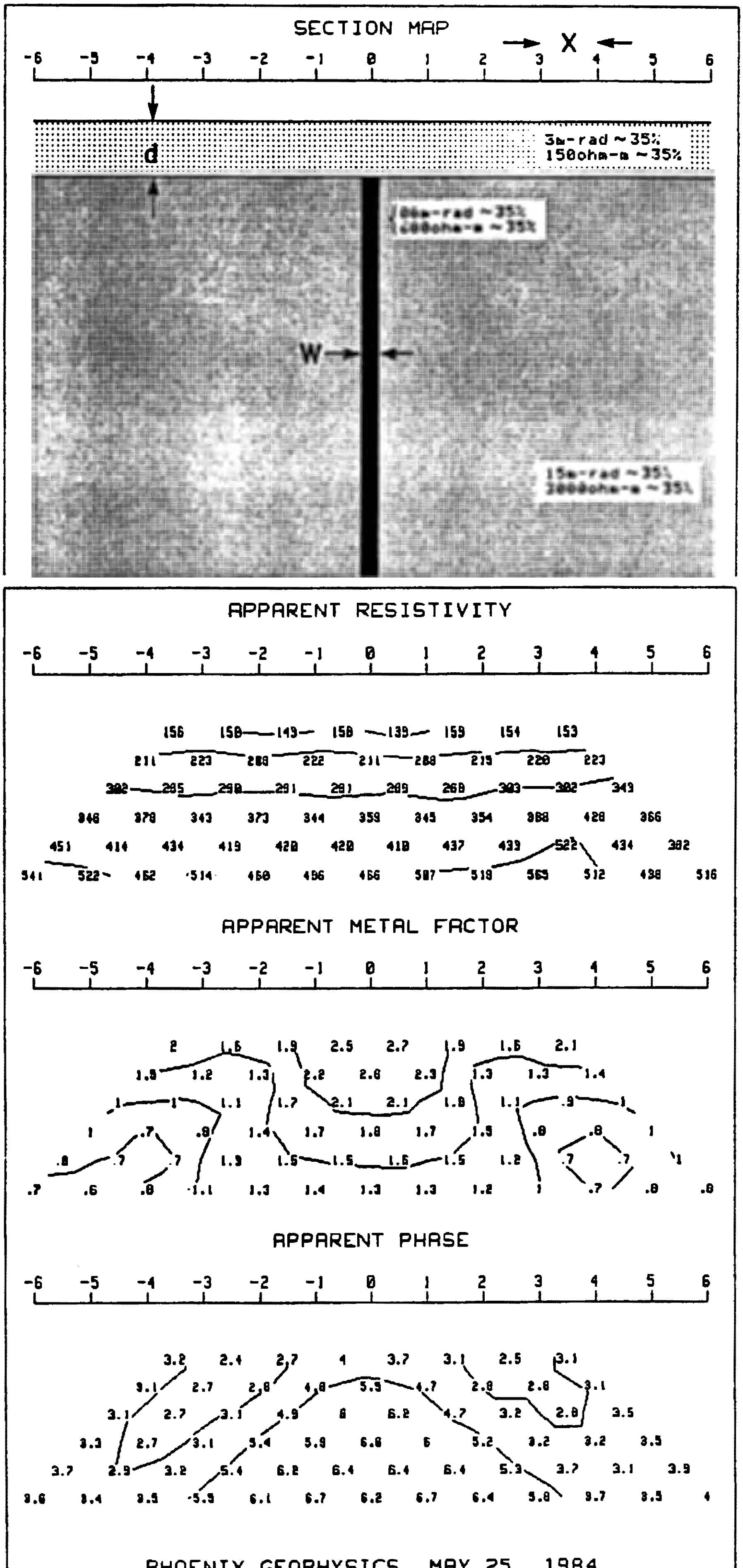


FIGURE 9



PHOENIX GEOPHYSICS LIMITED

FORWARD PROBLEM SOLUTION

X = 25 meters

W = 7.5 meters

d = 25 meters

DIPOLE – DIPOLE ELECTRODE CONFIGURATION

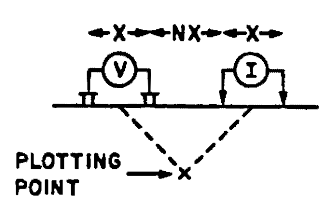
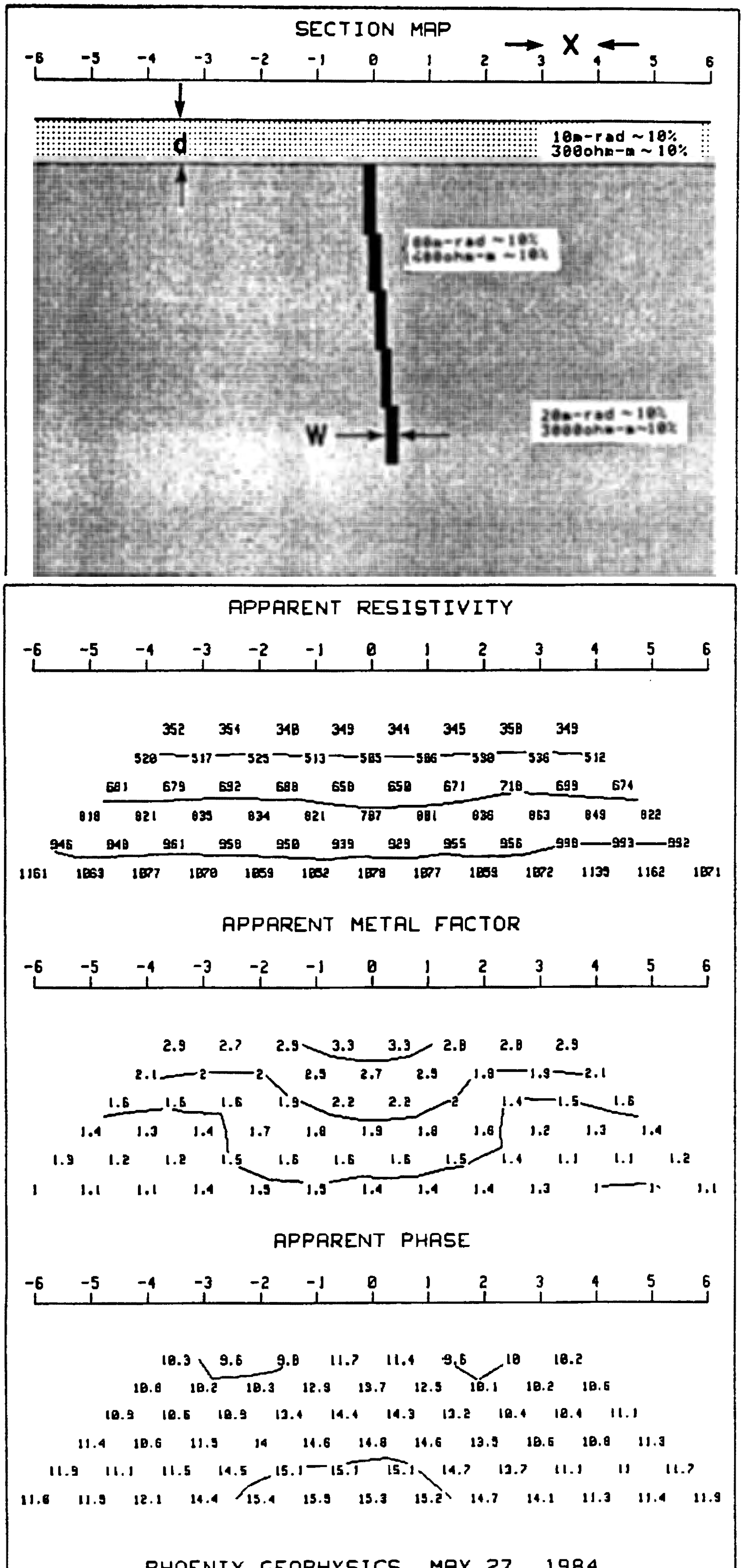


FIGURE 10

PHOENIX GEOPHYSICS LIMITED



FORWARD PROBLEM SOLUTION

X = 25 meters

W = 5.0 meters

d = 19 meters

DIPOLE - DIPOLE ELECTRODE CONFIGURATION

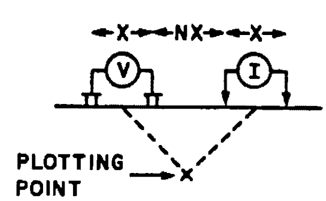
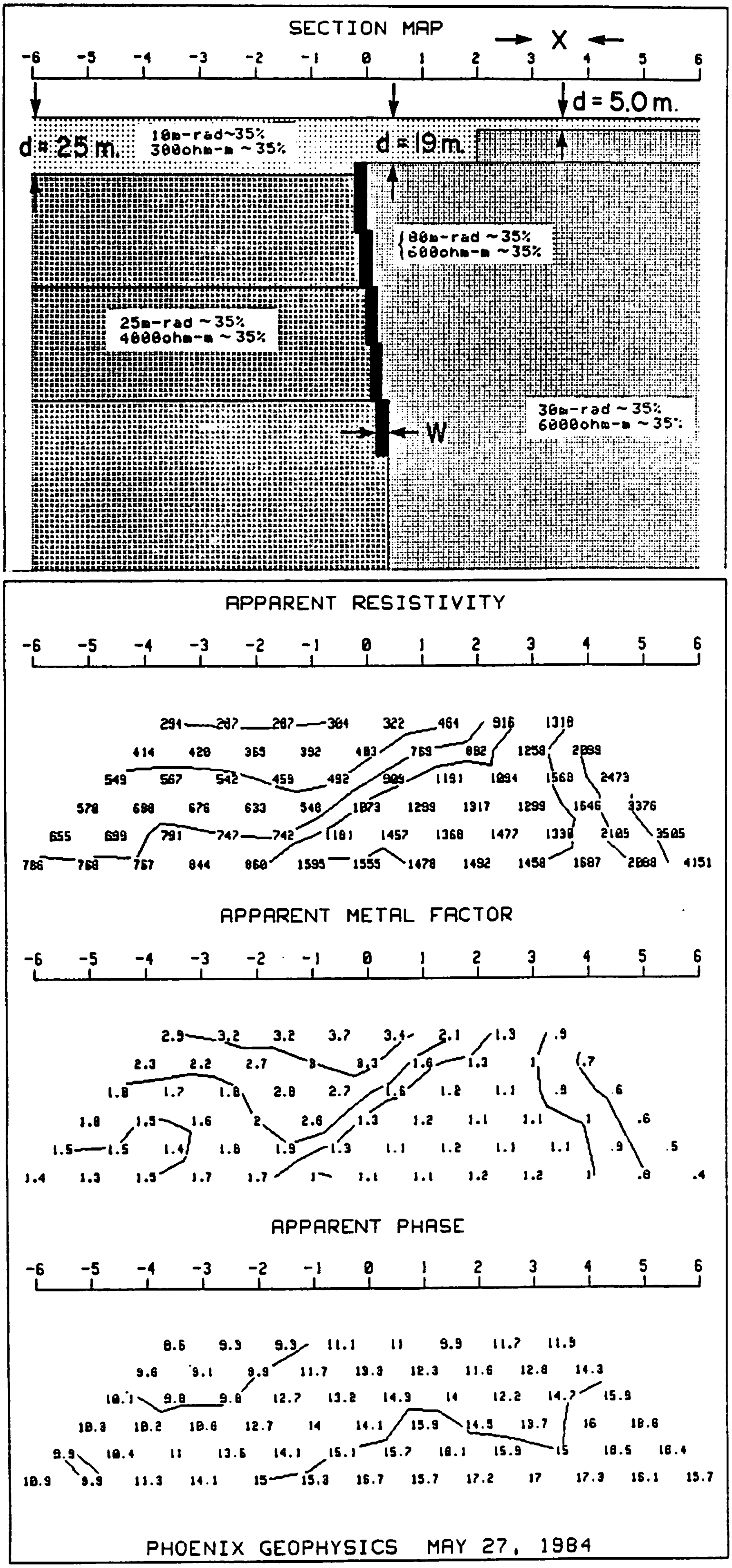


FIGURE 11



PHOENIX GEOPHYSICS LIMITED

FORWARD PROBLEM SOLUTION

X = 25 meters

W = 5.0 meters

DIPOLE - DIPOLE ELECTRODE CONFIGURATION

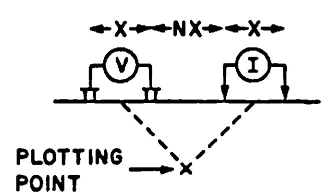
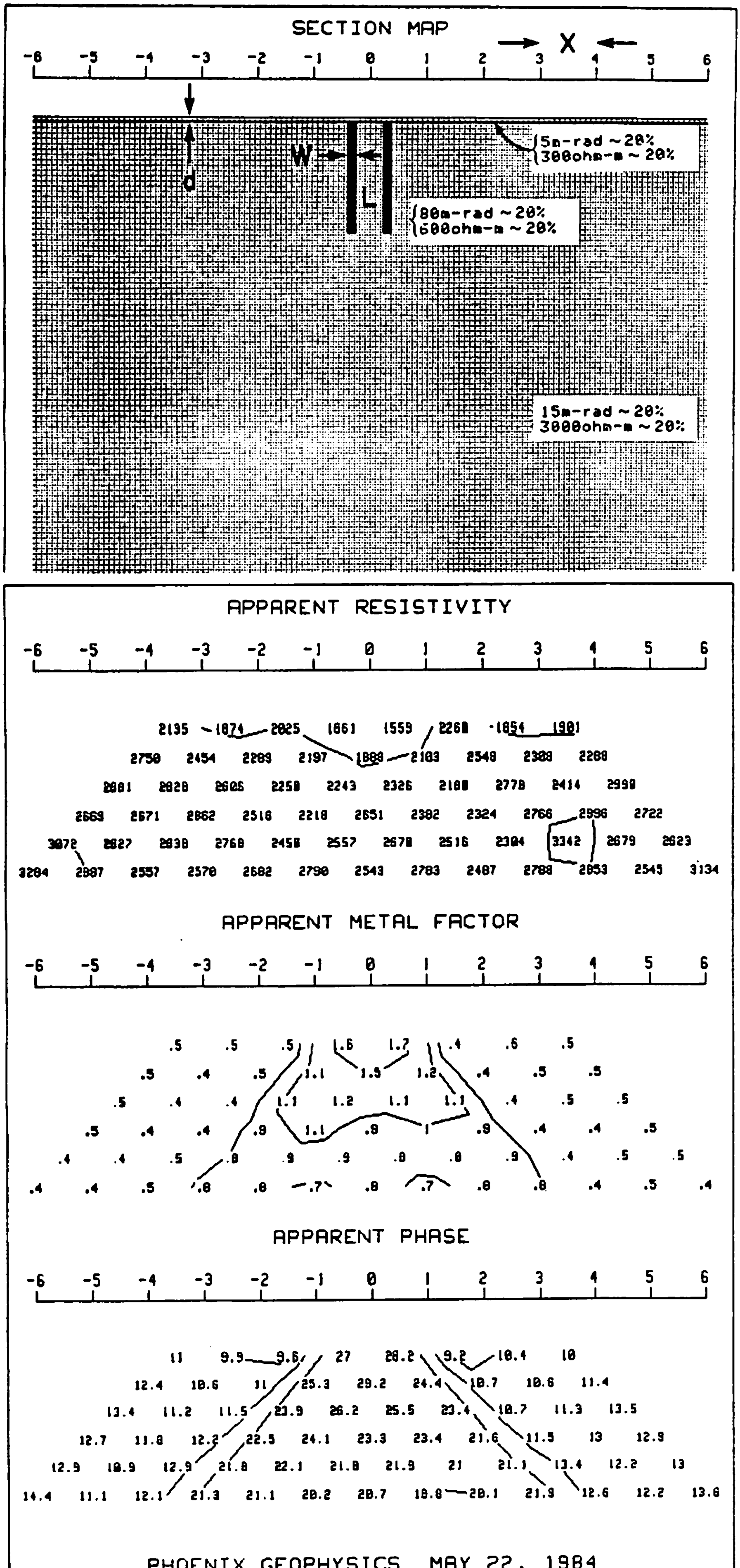


FIGURE 12



PHOENIX GEOPHYSICS LIMITED

FORWARD PROBLEM SOLUTION

X = 75 meters

W = 10 meters

d = 5.0 meters

L = 45 meters

Two Identical Sources

DIPOLE - DIPOLE ELECTRODE CONFIGURATION

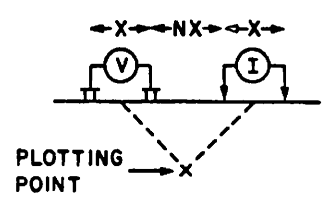
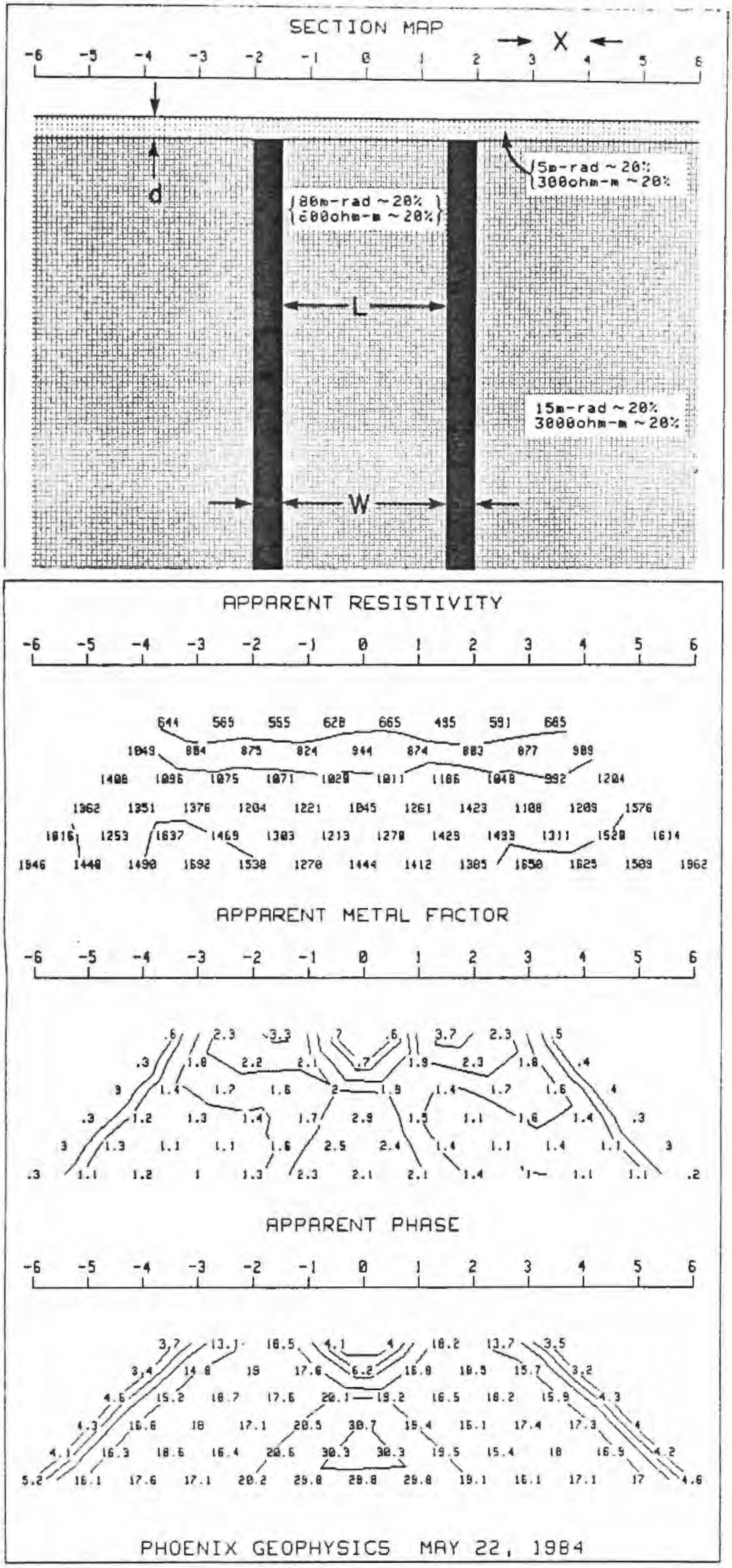


FIGURE 13



PHOENIX GEOPHYSICS LIMITED

FORWARD PROBLEM SOLUTION

X = 15 meters

W = 10 meters

d = 6.0 meters

L = 45 meters

Two Identical Sources

DIPOLE - DIPOLE ELECTRODE CONFIGURATION

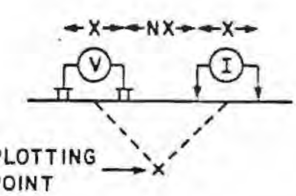
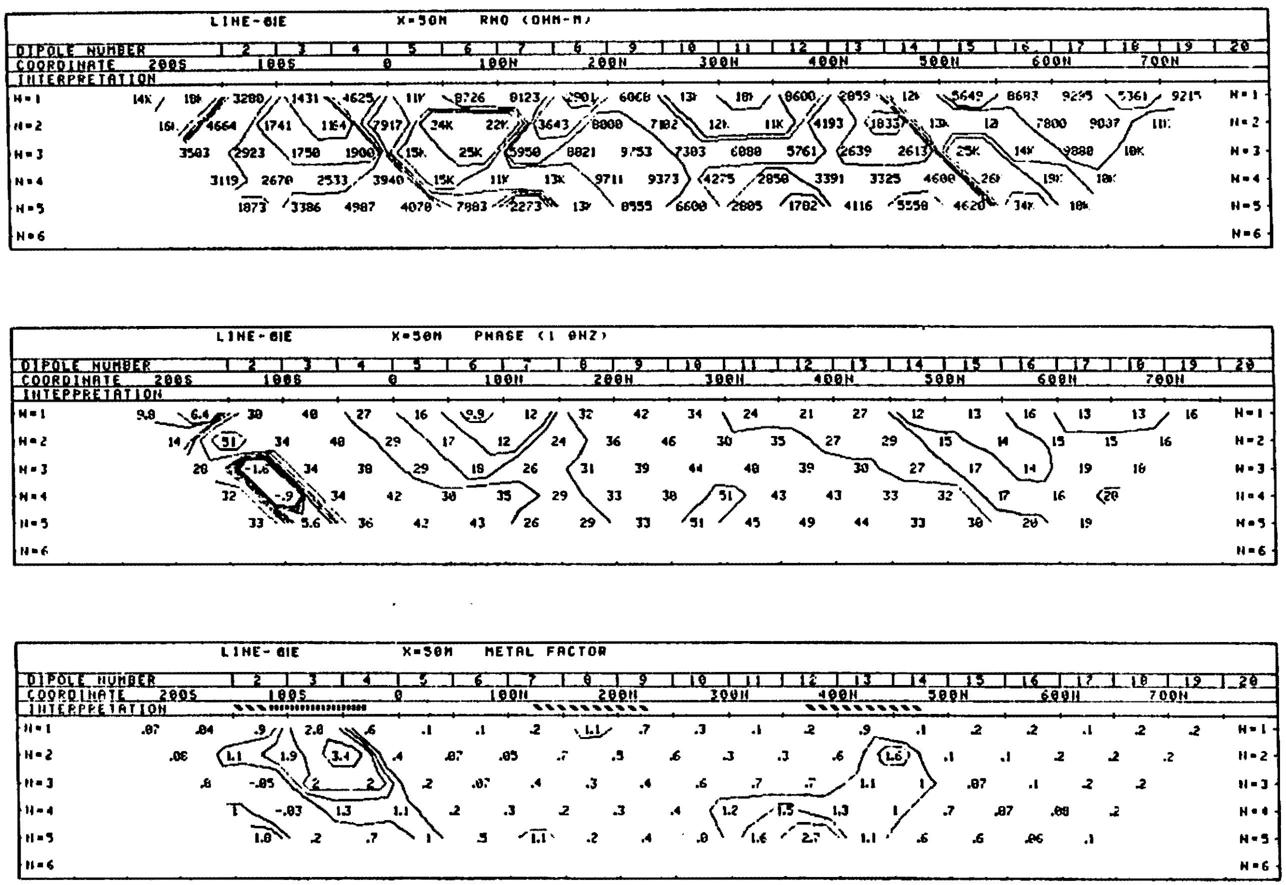


FIGURE 14

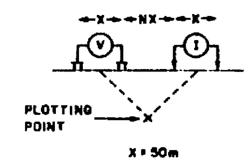


INDUCED POLARIZATION
and
RESISTIVITY RESULTS

HEMLO AREA , ONTARIO

LINE NO.- 6IE

DIPOLE - DIPOLE
ELECTRODE CONFIGURATION

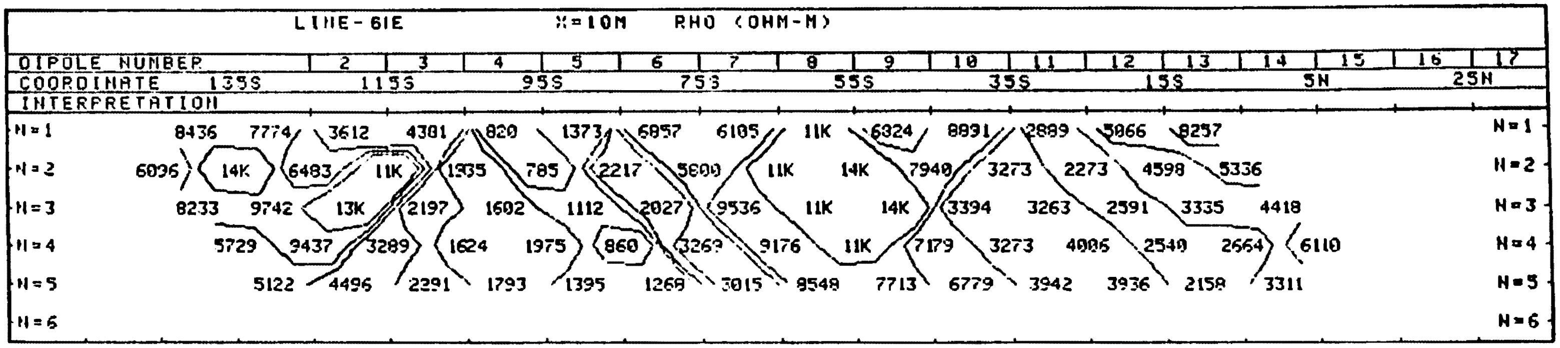


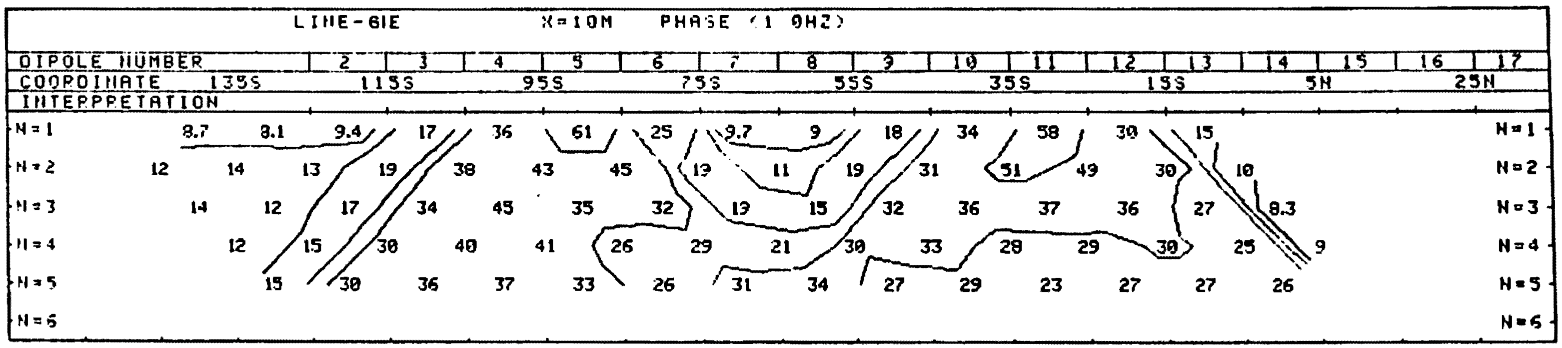
FREQUENCY - 1.0 HZ.

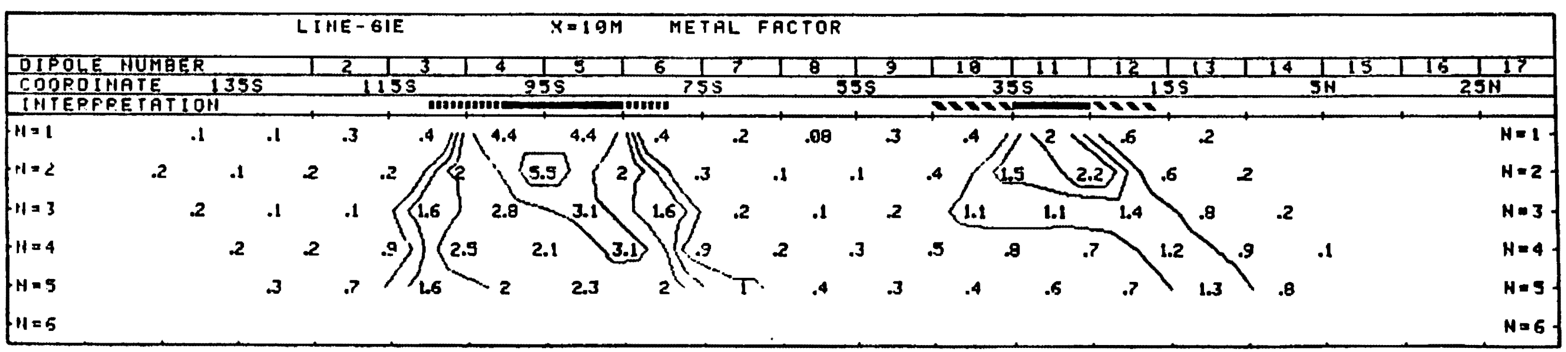
NOTE - CONTOURS AT
LOGARITHMIC INTERVALS
1,-1.5,-2,-3,-5,-7.5,-10

PHOENIX GEOPHYSICS LIMITED

FIGURE 15





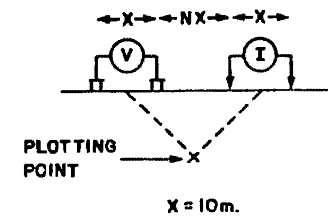


INDUCED POLARIZATION and RESISTIVITY RESULTS

HEMLO AREA, ONTARIO

LINE NO.- 6IE

DIPOLE - DIPOLE ELECTRODE CONFIGURATION



FREQUENCY - 1·0 HZ.

NOTE - CONTOURS AT LOGARITHMIC INTERVALS
1,-1.5,-2,-3,-5,-7.5,-10

PHOENIX GEOPHYSICS LIMITED

FIGURE 16

LA DECOUVERTE DU GITE DE ROUEZ

T. Huyghes Despointes
Société Elf Aquitaine, France

RESUME

Le corps de sulfure massif de Rouez (France) est un énorme amas pyriteux (environ 100 millions T) à basses teneurs en métaux de base et précieux (Zn: 1,5%, Cu: 0.6%, PB: 0,3%, AG: 21 G/T, Au 1,5 G/T). Il ne constitue un gisement d'or, malheureusement très petit, que dans sa partie sommitale - épaisse de 15 à 20 mètres. Elle forme la zone oxydée de l'amas et représente environ 150 000 à 200 000 tonnes de minerai enrichi à 10 G/T d'or et 150 G/T d'argent.

La géophysique est intervenue à deux stages, tout aussi essentiels:

- Le premier est celui de la découverte de l'amas en 1975 par le système électromagnétique aéroporté Input.

- Le second stage, complété par les sondages et les travaux miniers, est celui de la définition géométrique de l'amas et de son chapeau-de-fer par des méthodes à pouvoirs d'investigation et de discrimination divers: polarisation spontanée, magnétométrie, électromagnétisme, mise-à-la-masse, résistivité, polarisation provoquée, magnétotellurique et gravimétrie.

Les facilités d'extraction et de traitement de la zone oxydée vont permettre sa mise en exploitation sur trois années, au rythme de 200 T/j après investissements de l'ordre de 3 millions US$.

L'ART DES ANCIENNES METHODES GEOPHYSIQUES ENCORE LES MEILLEURES POUR TROUVER DE L'OR

C. Lavoie et S. Hamel
Géola Ltée, Val d'Or, Qué.

RESUME

Que l'or soit déposé par sédimentation, par sources hydrothermales, par diffusion dans des sédiments, des volcaniques ou des intrusions, chaque géologue trouve des caractéristiques particulières aux gisements aurifères.

La structure géologique revient souvent dans leur description du gisement.

Géophysiquement, nous présentons la méthode qui semble la plus propice à déceler ces structures. C'est une ancienne méthode qui peut être faite de nos jours avec plus de précision, plus facilement et plus rapidement. Malheureusement, elle est si commune que peu de gens prennent le temps de bien la planifier et encore moins de bien l'interpréter.

Quoi de plus vieux que la méthode magnétique, mais elle demeure encore la meilleure. A vous d'en profiter si vous l'utilisez bien.

VLF RESISTIVITY SURVEYS ON SHASTA'S TOODOGGONE AREA PROPERTY, B.C.

H. Limion and B.W. Downing
Newmont Exploration of Canada Ltd.
Toronto, Ontario

ABSTRACT

Shasta's gold-silver property is located in the Toodoggone region of North central British Columbia. It is an epithermal vein type deposit in the Jurassic Toodoggone volcanics, specifically within an orange weathering, quartz-eye, feldspar, crystal tuff. Mineralization consists of pyrite, electrum, acanthite, and native silver with minor amounts of chalcopyrite, galena, and sphalerite in chalcedony and quartz, which form fracture fillings as stockwork veins and as a matrix within breccia zones.

The better grades of mineralization occur at the junction of intersecting fractures and faults. Silicification, which accompanies the mineralization, is believed to reduce the porosity of the rocks and cause an increase in rock resistivities.

The VLFR method is used to map apparent resistivity. The resistivity map becomes the main guide to the alteration/silicification patterns, and the higher resistivity areas are the near surface drill targets. The mineralized and altered rocks are exclusively in the high resistivity areas.

The VLF resistivity method is well suited to map resistivity changes of the expected type and order. Other surveys - Mag, VLF dip angle, and Induced Polarization - do eke out the information, but those surveys are not as efficient or as discriminating. While the method has been proven empirically, the electrical/geological system can be investigated in more detail.

GEOPHYSICAL CHARACTERISTICS OF THE MONTAUBAN GOLD DEPOSITS MONTAUBAN-LES-MINES, QUEBEC

John Mc Adam
Muscocho Explorations Ltd.
Toronto, Ontario

ABSTRACT

The Montauban North Gold Zone, currently being mined by Muscocho Explorations Ltd., is locatd 80 kilometers west of Quebec City. The mine has been in production since mid 1983 at a rate of approximately 300 metric tons per day and has been a profitable venture from the beginning. A production decision was based on an ore reserve status of 300,000 tons of 0.2 ounce of gold per ton. It is felt that the opportunities for increasing reserves are excellent in the immediate mine area and, in fact, work towards that end is currently under way. The exploration potential for additional gold ore zones elsewhere on the property is excellent as well.

This gold mine is unique in North America in that it is hosted by highly metamorphosed and deformed rocks of the Grenville Structural Province of the Canadian Shield. The geological aspects of these deposits and particularily thoughts as to its orogenesis are becoming more widely known. Their geophysical signature, however, is less well known and it is felt that a presentation of the geophysical characteristics and responses of the Montauban Gold Deposits would be an aid to others involved in the search for Montauban-type gold deposits in highly metamorphosed terrains.

INTRODUCTION

The Montauban North Gold Zone, currently being mined by Muscocho Explorations Ltd., is located 80 kilometers west of Quebec City. The mine has been in production since mid 1983 at a rate of approximately 300 metric tons per day and has been a profitable venture from the beginning. A production decision was based on an ore reserve status of 300000 tons of 0.2 ounce of gold per ton. It is felt that the opportunities for increasing reserves are excellent in the immediate mine area and, in fact, work towards that end is currently under way. The exploration potential for additional gold ore zones elsewhere on the property is excellent as well.

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GEOLOGICAL CHARACTER OF THE MONTAUBAN DEPOSITS

The Montauban area lies within the Grenville Structural Province of the Canadian Shield. The bedrock consists predominantly of quartz - biotite - hornblende gneisses, quartzites, amphibolites and minor lenses of calc-silicate rocks. These Grenville Group rocks are cut by numerous intrusive bodies ranging in composition from granite to peridotite. In the map area, intrusive rocks undelie approximately one half of the total area.

Structurally, the lithologies generally trend northerly and dip to the east, however complex folding, a result of at least two generations of folding, is noted in several areas.

Regional metamorphism is of amphibolite facies, however many clues as to the proto-liths have been recorded. Remnant pillow structures in amphibolites, as well as, distintive geochemical signatures strongly suggest that the local suite of rocks were mafic volcanics, felsic pyroclastics and related volcano- sedimentary and sedimentary rocks.

At Montauban, the ore is contained within a thick sequence of quartzo-feldspathic gneisses with minor thin amphibolite members. The southern portion of the ore horizon which hosts the main Anacon zinc-lead deposits is comprised of a distinctive calcsilicate assemblage of tremolite and diopside with some quartz and coarse dolomite and calcite. On strike to the north, the unit changes character and is referred to as a cordierite-anthophyllite gneiss. To date, the ore horizon is known over a strike length of 8500 feet and is open on both ends. It ranges in width from a few feet to 200 feet. The ore horizon strikes northerly and has an average dip of 50 degrees to the east.

The ore zones are of two types: 1) a base metal assemblage of which over 2.5 million tons of 4.5% zinc, 1.5% lead, 0.02 ounce per ton gold and 2.5 ounce per ton silver were mined and 2) the gold ore zones which contain less than 10 % sulphide, a significant portion, of which, is non-conductive sphalerite with lesser quantities of galena, chalcopyrite, pyrrhotite, and pyrite. Other sulphide minerals are present in minor quantities.

GEOPHYSICAL ASPECTS OF THE MONTAUBAN DEPOSITS

The mine property has been subjected to numerous geophysical surveys and it is the essence of this paper to review the various geophysical signatures of the ore horizon. Both airborne and ground surveys have been performed and, as in the typical exploration sequence, airborne results will be reviewed and then, the ground results will be examined.

It is noteworthy that the Montauban area is a settled area and geophysical surveys must always be scrutinized for cultural influences. Furthermore, the area was submerged by marine waters at the end of the last glacial period and while the area was inundated, a conductive marine clay was deposited. This clay responds to VLF frequencies, as well as, to frequencies in the upper HLEM range.

AIRBORNE SURVEYS

Two private airborne surveys have been flow over the mine property: the first by Questor in 1976 and the second by Aerodat in 1979.

QUESTOR SURVEY - A total of 1024 line miles of INPUT and magnetic survey were performed with the use of a Skyvan aircraft. Terrain clearance was maintained at an elevation of 400 feet and the E.M. bird at approximately 150 feet. Survey lines were spaced at 1000 feet.

The INPUT survey was performed using a Barringer/Questor Mark IV (R) System. INPUT is not a conventional E.M. system in that it is a time domain system. A pulsed primary electromagnetic field induces currents in the ground which in turn generate a secondary electromagnetic field. The receiving coil towed behind the aircraft measures the decay of the secondary field after termination of the primary pulse. Measurements are made in six time windows or channels. Simply put, the secondary field produced from a conductive body will take a relatively long time to die and hence, a response over a conductive body will be recorded on more channels than that over a weaker conductor.

The ore horizon did not respond to the INPUT system, although numerous other anomalies were detected in the Montauban area. Of note, a 5 channel anomaly was detected on strike with the known ore zones, to the north of the mine area, on ground currently held by Muscocho. This anomaly is located on the Montauban North Group.

A Geometrics G 803 proton precession magnetometer was used to perform the aeromagnetic survey.

Results of the survey indicate that that the ore horizon is contained within a wide (2000 to 3000 foot) northerly trending magnetic depression. The rocks adjacent to the ore bodies are in the order of 20 to 30 gammas less magnetic than the surronding rocks. The magnetic response over the ore bodies is not unique as the Montauban area offers numerous other similiar environments.

AERODAT SURVEY-A total of 1865 kilometers of E.M., VLF-EM and magnetic survey were helicopter flown in the Montauban area. Terrain clearance of the aircraft was 220 feet while the bird ground clearance was approximately 120 feet. Flight line spacing was 1/8 of a mile.

The E.M. survey was performed using a Geonics E.M.-33 system which uses a frequency of 914 hertz and a coil spacing of 19.5 feet. Both, in phase and quadrature components of the secondary field were recorded.

A weak, but obvious, response from the ore zone was detected over a strike length of 800 meters. The amplitude of the inphase response was in the order of 1 or 2 ppm of the primary field. Disappointing, however, is the fact many other anomalies were detected as well. Conductive lake bottom sediments, conductive overburden and cultural noise produced responses equivalent or stronger than that of the known ore zones.

The 5 channel INPUT anomaly detected by Questor on the Montauban North Group gave a 2 ppm inphase response.

Instrumentation for the VLF-EM survey was a Hertz Totem 1A-VLF. The VLF receiver was located midway between the aircraft and the bird. The survey in the mine area was performed using the Annapolis, Maryland naval station transmitter which broadcasts a signal at a frequency of 21.4 kHz. Coupling of the transmitted field lines and the general ore trend is reasonably good as Annapolis is in a direction SSW from the mine.

Profiles of the filtered vertical component quadrature response along the flight lines and profiles of the total VLF field indicate that the VLF survey detected the ore zone, however the response was not appreciably different from very many other areas where the VLF field was strongly disturbed.

Magnetic readings were taken with a Barringer AM-104 proton precession magnetometer.

The survey results were not materially different from those produced in the Questor survey.

GROUND SURVEYS

Numerous ground geophysical surveys have been performed over the mine area including VLF-EM surveys, various EM surveys, some magnetic coverage and a few lines of gravity testwork since Muscocho acquired the Montauban property

VLF SURVEY-The North Gold Zone portion of the ore bearing horizon was covered by a VLF survey in 1975 using a Crone Radem. This survey was conducted reading signals from the now defunct Balboa, Panama station which transmitted at a frequency of 24 kHz. Readings, taken at 50 foot intervals, revealed a very strong well defined conductor whose axis overlies the gold zone.

Although the survey area was relatively restricted in areal extent, ie. over the North Gold Zone only, no other anomalies of comparable strength were detected. The following points are noteworthy:

1) The strongest response was recorded in the northern portion of the survey area where dip angles changed from 32 degrees west to 32 degrees east in the matter of 100 feet. The maximum Fraser Filter Unit overlying the zone was 110 Units.

2) The weakest response was recorded in the southern portion of the grid area where dip angles changed from 22 degrees west to 12 degrees east over à distance of 300 feet. The lowest Fraser Filter Unit value recorded over the zone was 29 Units.

It is noteworthy that the secondary field generated by the ore zone disturbed the VLF field at a distance of, at least, 500 feet from the zone. An easterly dip to the conductive horizon was easily ascertained from the dip angle profiles.

In 1977 Muscocho extended the grid coverage of the above survey; both to the north and to the south. Due to change in strike of the rocks, as well as, the fact that the Balboa transmitting station was no longer in operation, Annapolis, Maryland was read to the north. The survey traced the conductive zone a few hundred meters to the north, although the anomaly was weaker. Adjacent lines produced Fraser Filter Units of 71 from the Balboa survey and Filter Units of 30 from the Annapolis survey.

In the south, where Culter was used as the transmitting station, the conductive zone was traced a couple hundred meters south of the Anacon Number Three shaft. Fraser Filter Units of up to 62 were recorded nearest the shaft and decreased southerly.

To the north of the mine area, on the Montauban North Group, VLF coverage , in 1980, using a Geonics EM-16 and the Annapolis transmitting configuration detected a lengthy and strong conductor which in part corresponds to the airborne EM anomalies detected by both the Questor and Aerodat surveys. A Fraser Filter Unit of 110 was recorded over the approximate location of the airborne EM anomaly. Note however, the survey on the North Group was performed using a Geonics EM-16 which measures dip angles in per cent as opposed to the Crone Radem which measures dip angles in degrees. As a very crude approximation, a degree is twice as large as a per cent and so the Filter Unit if halved would be roughly equivalent to Filter Units derived from Radem surveys.

ELECTROMAGNETIC SURVEYS-A survey, using an Geonics EM-17, was performed on a portion of the grid area over which the Balboa VLF survey had been conducted. The EM-17 employs a frequency of 1600 Hz. and for this survey a coil spacing of 300 feet was used. Inphase and quadrature components of the secondary field were measured using a coplanar horizontal loop configuration.

The survey revealed a weak but consistent quadrature response coincident with the axis of the VLF conductor. Inphase response was varied and often offset from the axis of the quadrature and VLF anomaly.

On the northern portion of the grid, where the VLF response was most accentuated, the EM-17 inphase did not respond. Further south, where VLF Fraser Filter Units in the range of 30 to 40 were encountered, a well defined EM-17 inphase response was recorded, although it tended to be offset to the east of the VLF anomaly.

The anomaly profiles are characterized by positive inphase values of up to 13 % but more usually in the order of 5 % and negative values over the conductor of up - 6 % but generally less than - 3 %. Quadrature profiles exhibit a weak but consistent reponse from the southern to the northern limit of the grid. Quadrature anomalies exhibit very weak to nonexistant positive shoulders adjacent to the ore zone and negative values of up to -6 % though usually less over the zone itself.

An unequivocal dip direction from profiles alone could not be determined.

In 1977 a max-min horizontal loop EM survey was performed over select lines on the property. A coplanar coil arrangement with a coil separation of 100 meters was used to read frequencies of 1777 and 444 hz. Inphase and quadrature components of the secondary field were recorded.

A test line run over the ore zone revealed a very well defined quadrature anomaly on both frequencies. The high frequency response was stronger, as expected, and gave a clear indication of conductor dip. Amplitude range was in the order of ± 10 %. The lower frequency gave quadrature reponse of up to -5 % but no dip indications.

Inphase readings deviated from nil but did not clearly indicate a conductive zone.

For comparison purposes, the Balboa VLF survey over the ore zone rendered Fraser Filter values of 103 Units.

Elsewhere on the property, but not over the North Gold Zone, test lines were run over relatively weak VLF (Annapolis) anomalies which had Fraser Filter Filter Units of up to 33 Units. The max-min responses were restricted to the quadrature scale and were, at best, poorly defined, even on the higher frequency.

Further detail work, over the ore zone, using the max-min was undertaken in 1980. The line with the weakest VLF response over the North Gold Zone (Fraser Filter Unit values ranged up to 29 Units) was chosen to evaluate the response at 100 and 150 meter coil separations at three frequencies: 3555, 1777 and 444 hertz. The VLF

The following can be stated concerning the results:

1) The anomaly was defined largely by the quadrature profiles although at the higher frequencies the inphase reacted as well.

2) The response was best defined at the higher frequencies and almost indiscernable on the 444 hertz profiles. The maximum range of readings was from + 17 % to - 13 % on the 3555 hertz frequency and the 150 meter coil spacing.

3) The anomaly amplitude increased marginally at the greater coil separation for a given frequency.

MAGNETIC SURVEY- The mine property has been magnetically surveyed but on a piecemeal basis. Little will be said, other than it has been reported that the zone does not have a distinct signature.

GRAVITY SURVEY- In 1980 four test lines were run over the ore zones using a Lacoste and Romberg model G No. 166 gravimeter. Readings were taken at 50 and 100 feet.

The survey did not clearly define the zone. Total Bouger anomaly relief was less than one millligal and remained in that order of magnitude even after topographic corrections were made.

DISCUSSION

The Montauban deposits have been subjected to a number of electromagnetic surveys and tests over a wide range of frequencies. More specifically, the conductor response has been studied over the frequency range of 444 hz to 24 khz.

The ore zones are poor conductors in the realm of the absolute.

From an airborne point of view, the weakly conductive nature of the ore zones present problems. The primary problem encountered with the Montauban airborne HLEM data, let alone the VLF data, was the proliferation of anomalies. Many could be attributed to cultural sources and still many others are likely caused by the very conductive overburden deposited by the influx of marine waters near the end of the last glacial period. It would be expected that these unusual circumstances at Montauban are unlikely to be present in most other target areas. Nonetheless, in most areas there will likely be a large number of weakly conductive situations that must be distinguished from potential orebodies.

The horizontal loop E.M. (HLEM) anomalies are defined consistently by the quadrature component of the secondary field whereas the inphase component is often lacking or offset from the quadrature anomaly. An offset of the two responses can be attributed to: 1) significant topographical relief across the ore zones resulting in inconsistant coil spacing and coil configuration, 2) the inphase responding to known base metal mineralization down dip from the gold zone or 3) a combination of the above.

Nonetheless, HLEM, particularily at higher frequencies, is effective in detecting the Montauban ore zones.

More dramatic, however, is the response of the ore zones at VLF frequencies. Unfortunately, the main ore horizons have only been surveyed using the now defunct transmitter at Balboa, Panama (24 khz). There is no known ground coverage of the main gold ore zone using either the Annapolis or Cutler transmitting stations which transmit at lower frequencies; 21.4 and 17.8 khz respectively. It is the intent to resurvey some of the Balboa read lines using the other two frequencies in the near future. This would allow better comparisons of the ore zone response with anomalies on adjacent ground detected using either the Annapolis or Cutler stations.

Magnetic surveys have not been tremendously useful in detecting the ore zones largely due to the lack of magnetic differeniation between the ore zone and the host rocks as well as the unsuitability of the method in detecting a sometimes very narrow target. Despite the above, magnetic surveys still have great value as a mapping tool and are recommended as a routine part of an exploration program.

A general problem which applies to geophysical surveying Grenville hosted targets is the difficulty maintaining good coupling with the targets when the host rocks are notorious for complex folding. Little can be done other than performing multidirectional surveying.

CONCLUSIONS

It has been the experience at Montauban that electromagnetic remote sensing techniques have yielded the best results in terms of tracing the known ore zones. As noted above, other geophysical methods have been tried but none with as much success as the EM methods. Therefore, a geophysical search program for Montauban-type mineralization should be strongly oriented towards electromagnetic surveying.

Initially, a prospective area for Montauban type gold is likely to be selected on the basis of favourable geologic environment. As the next step, however, a regional airborne survey of the prospective area should be flown with three instruments: a magnetometer, a VLF EM system and a HLEM system. The VLF survey would employ whatever transmitting station(s) give the most appropriate coupling with the expected target orientation. A frequency in the order of 1000 to 2000 hertz would be recommended for the HLEM survey.

As with all airborne surveys, anomalies are screened and priority ranked. Coincidence with favourable geology and conformity with local geologic strike are probably the single most powerful criteria at this stage. At Montauban, the gold ore is in a mineralized unit with imposing strike length and so, long targets are favourable.

From the experience at Montauban, further screening of anomalies at this stage is almost certainly to involve ground follow up. There is little substitute for a well conceived, methodical program of anomaly verification. Recommended is a VLF instrument, and a good geologist disposed towards collecting plenty of samples.

A Montauban EM anomaly pales in comparison to a typical response over a massive sulphide deposit or a pyritic graphite horizon. In fact, were a Montauban-type EM anomaly located in a typical greenstone terrain it could very well be overlooked. This underlines the point that big beautiful anomalies are not prerequisite to finding ore bodies.

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GEOPHYSICAL AND GEOCHEMICAL TECHNIQUES FOR GOLD EXPLORATION IN THE TIMMINS AREA, ONTARIO A CASE HISTORY

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ABSTRACT

Geophysical and geochemical survey techniques were used in Hoyle Township, near Timmins, Ontario, to delineate stratigraphy, structures and carbonate alteration known to be ssociated with gold mineralization. Initially, major element rock analysis was used to verify the selection of the area as being within similar stratigraphy known to host gold mineralization within the Porcupine Gold Camp. Subsequently, geophysical surveys were used to project more accurately geological interpretations beyond sparce outcrop exposure in the area, and to interpret geology in areas of overburden cover.

A time domain induced polarization survey was used to map zones characterized by high chargeability and high resistivity values, related to the presence of disseminated sulphides and pervasive carbonate alteration. A detailed magnetometer survey was used to outline structural trends and further identify carbonate alteration zones. Ferromagnetic minerals in basalts are destroyed by carbonatization resulting in areas of low magnetic gradient. An electromagnetic survey was used to trace highly conductive graphitic horizons which mark lithologic boundaries and further delineate fold structures and faults.

In order to test the interpreted carbonatized zones for auriferous mineralization a "basal" till sampling program was conducted along and down ice

from the geophysical targets. Overburden drill sites were selected to accumulate the greatest amount of geological information at the least cost. Anomalous gold values found in the till and bedrock samples were further delineated by a second overburden drilling program. Heavy mineral concentrates from the till samples were analyzed for gold, with zinc and arsenic used as additional pathfinder elements.

The application of these integrated exploration techniques in Hoyle Township resulted in the discovery of three gold bearing zones. Two of these auriferous quartz vein occurrences have been partially explored by diamond drilling, and the third zone is currently being explored underground. These techniques can be directly applied to gold exploration in other regions of Canada.

INTRODUCTION

This paper is a case history from the Porcupine Gold Camp at Timmins, Ontario, and illustrates how integrated geophysical and geochemical methods can be used together to delineate gold bearing geological environments beneath moderate overburden cover. This combined method can be used for gold exploration in other parts of the world, if modified to suit the specific geology (Middleton & Campbell, 1979).

Geochemical techniques, using major and trace element analyses can be used to focus on favourable sections of stratigraphy, and to define alteration zones. Basal till sampling utilizing dual tube reverse circulation equipment (Skinner 1972) followed by analyses of the contained heavy minerals has proven to be a valuable process for prospecting and/or classifying geophysical anomalies , (Gleeson & Cormier, 1971).

The reverse of this procedure has also been true, with geophysical methods used to locate source areas of anomalous gold values found in the glacial materials. Three areas of gold mineralization were discovered in Hoyle Township, near Timmins, as a result of a combined geochemical - geophysical search technique. One of these discoveries is currently being evaluated for exploitation, and the other two are active exploration targets.

STUDY AREA

The study area discussed in this paper is located in southwestern Hoyle Township, approximately 8 miles northeast of Timmins. This area comprises approximately one half of the lands currently held jointly by Canamax Resources Inc. (Rosario Resources Canada Ltd.) and Du Pont of Canada Exploration Ltd. Figure 1 shows the location of the subject area in relation to other gold deposits, whether past, active or potential producers.

REGIONAL STRATIGRAPHY AND CHEMISTRY OF THE MATAVOLCANIC ROCKS

The geology of the Timmins area and the gold deposits has been presented by Davies (1977), Ferguson et al (1968), Fyon and Crocket (1981), Karvinen (1978), and Pyke (1975, 1982). A generalized table of formations is given in Table 1. Except for diabase dykes, all of the bedrock is of Archean age. The Deloro Group has a minimum age of 2725 $\pm$ 2 Ma. and the overlying Tisdale Group has a minimum age of 2703 $\pm$ 2 Ma (Nunes & Pyke, 1980) which is in accordance with earlier stratigraphic studies (Ferguson et al, 1968).

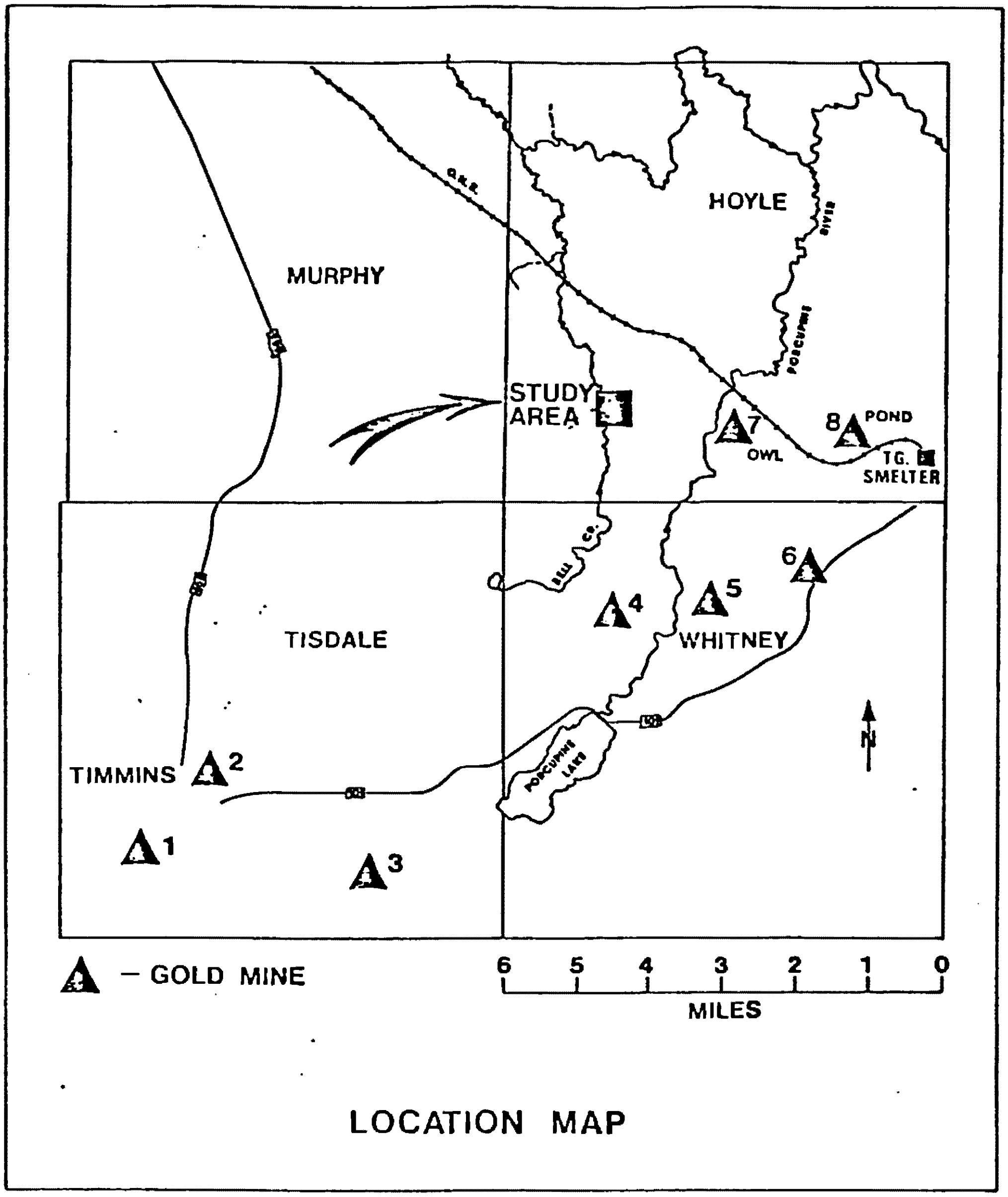

Figure 1 - Location Map - Gold deposits shown are:
1. Hollinger, 2. McIntyre, 3. Dome, 4. Broulan Reef,
5. Hallnor, 6. Pamour #1, 7. Owl Creek, 8. Pond Zone.

Table 1 Generalized Table of formatins, Timmins Area

(after Pyke, 1982)

	Lithology
Porcupine Group	
Upper Formation	- submarine alluvial and fluvial arenites
Lower Formation	- arenites, turbidite, rudites
Tisdale Group (4000 m)	
VI Upper Metavolcanic Formation	- felsic pyroclastic rocks
V Middle Metavolcanic Formation	- iron tholeiite, minor ultramafic metavolcanic rocks
IV Lower Mètavolcanic Formation	- ultramafic metavolcanic rock and magnesium tholeiites, basaltic komattiies.
Deloro Group (5000 m)	
III Upper Metavolcanic Formation	- intermediate to felsic pyroclastic rocks, oxide and sulphide facies iron formations
II Middle Metavolcanic Formation	- andesite, basalt, tuff
I Lower Metavolcanic Formation	- ultramafic metavolcanic rock

Volcanic lithologic subdivisions are based upon both field appearances and whole rock chemistry. The Deloro Group is largely calc-alkalic in composition (Pyke 1982) exclusive of Formation I (Lower Metavolcanic Fm). The Tisdale Group is a more primitive volcanic cycle (Shegelski 1982) exhibiting ultramafic, magnesium tholeiite and iron tholeiite compositions, except for the calc-alkalic felsic pyroclastic rocks of Formation VI (upper Metavolcanic Fm). The Porcupine Group metasediments are considered to have been deposited laterally and locally contemporaneously with the upper part of the Deloro Group and the entire Tisdale Group.

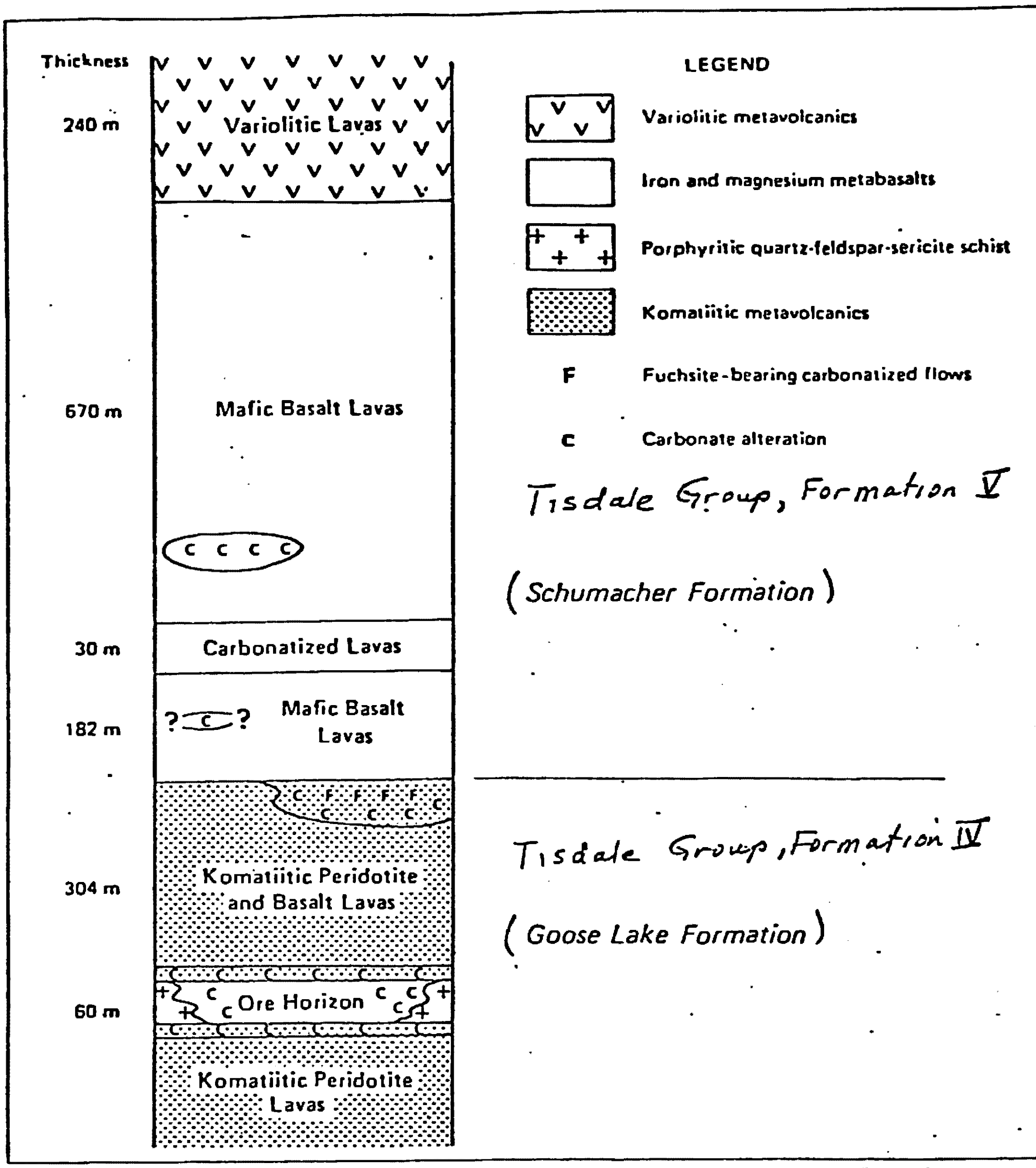

Figure 2 - Generalized stratigraphic section in area of major gold deposits, from Fyon & Karvinen (1978).

The stratigraphic section in the immediate area of the economic deposits has been studied by Fyon and Karvinen (1978), and is given in Figure 2. This section focuses on Formations IV and V of the Tisdale Group, and emphasizes the stratigraphic control of alteration assemblages. This concept recognized major carbonate alteration horizons coincident with major gold deposits. Thus the presence of large zones of carbonate alteration within lithologies dominated by komatiites, magnesium and iron tholeiites, and ultramafic rocks characterized areas suitable for intense exploration.

Regional folding in the Timmins area has been interpreted as a multiphase process, and has been described by Ferguson et al (1968), Pyke (1975), Davies (1977), Roberts et al (1978), and Roberts (1980). The resultant fold pattern consists of the northeast trending Porcupine Syncline flanked to the north and south by paired anticlines and synclines. While structural data and attendant stratigraphic knowledge did not extend to the north of Tisdale Township, it was considered possible that the known fold patterns would allow Tisdale Group lithologies to occur in the southern portions of Murphy and Hoyle Townships.

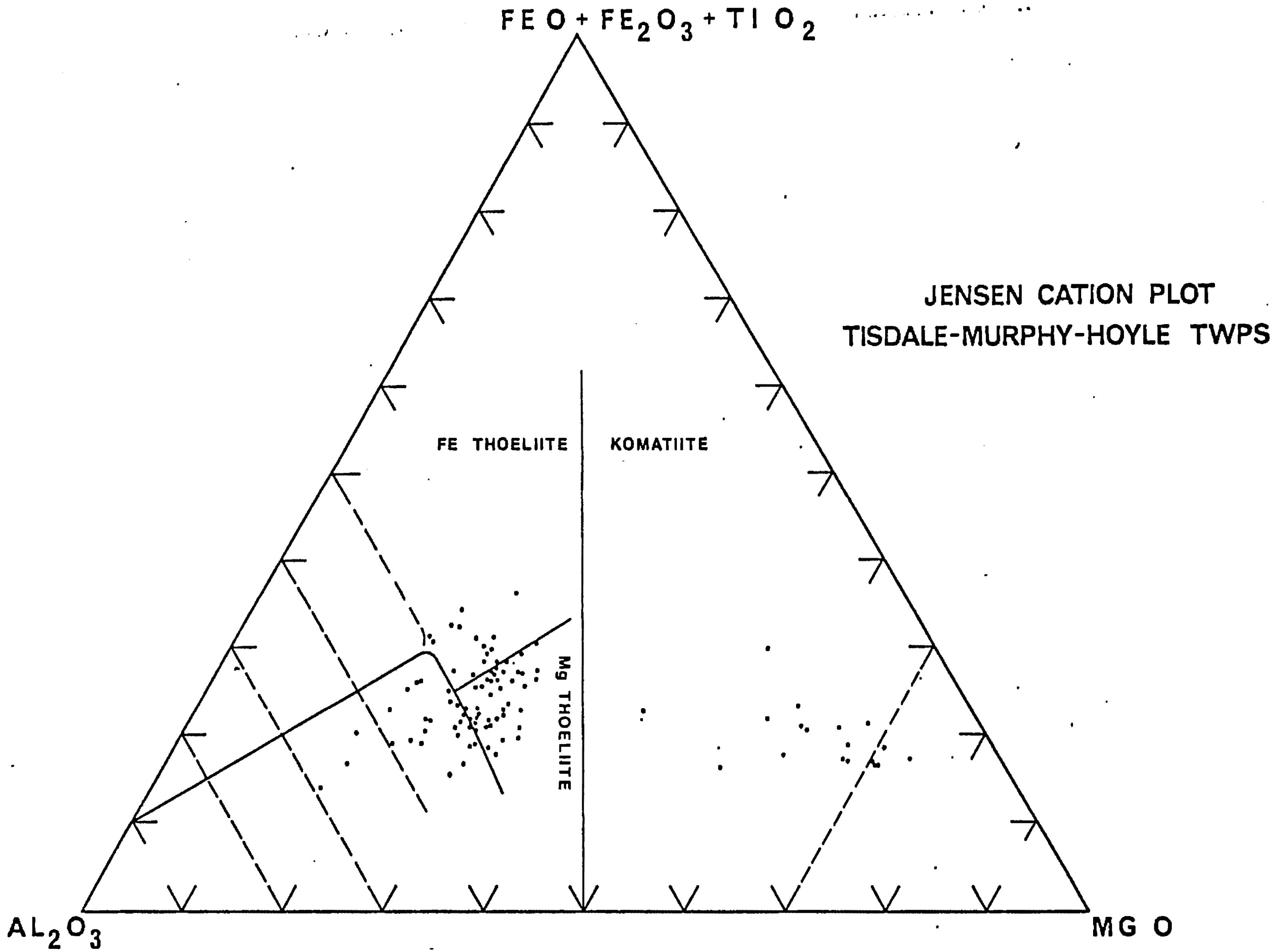

Figure 3 - Jensen Cation Plot of 97 core and outcrop samples in study area.

WHOLE ROCK GEOCHEMICAL PROGRAM

Based on the possibility that Tisdale Group rocks, especially Formations IV and V could occur in the study area, and with knowledge of the alteration assemblage related to gold deposits, a lithogeochemical program was undertaken. The derived major element data for 97 samples was plotted on the cation ternary diagram of Jensen (1976). The resulting pattern, (Figure 3) shows the presence of komatiitic and tholeiitic rocks, analogous to the stratigraphic section shown in Figure 2. Rocks plotting in the calc-alkaline field are those exhibiting significant carbonatization - sericitization and silicification.

Analyses for CO_2 by standard methods were performed in order to measure the extent of carbonatization in these same rocks. The results showed values of 6-10% CO_2 over wide widths (~300 ft) in Hoyle Township, and in narow zones (~ 30 ft) in southeastern Murphy Township, suggesting Hoyle Township as the preferred target for further exploration. Subsequent to this work, Whitehead et al (1980) has documented CO_2 values in excess of 6% enveloping the major gold deposits in the Timmins Gold Camp, confirming our empirical data. In a more comprehensive discussion of CO_2 or an ore guide, Davies et al (1982) suggest that CO_2 /CaO is a more rigorous measure of carbonate alteration in basaltic rocks.

Analyses for gold by neutron activation methods (detection limit 1-2 ppb) were carried out on the rocks from the study area. In addition, a large number of samples from carbonatized and mineralized, or quartz veined rocks from various localities in the Timmins Gold Camp were analyzed and compiled for comparative purposes. This phase of the study indicated that anomalous (threshold) values were greater than 30 ppb Au, and values in excess of 100 ppb were suggestive of "close proximity" to gold mineralization of possible economic significance. Subsequent work by Fyon and Crocket (1979, 1981) suggest that values in excess of 5 ppb (threshold) in magnesium tholeiites and komatiitic are significant.

EXPLORATION TECHNIQUES

As the study area was essentially devoid of outcrops, exploration by ground geophysical methods, and overburden drilling were deemed appropriate. Prior to the first overburden drilling campaign magnetometer and horizontal loop electromagnetic surveys were conducted to define the gross stratigraphy and structure of the area. Thus overburden drill sites could be selected to optimize geological and geochemical data at the least cost. Anomalous gold values from the till samples, and carbonatized bedrock chips from the overburden drilling prompted an induced polarization/resistivity survey. These surveys outlined carbonatized zones permissive for the occurrence of gold deposits, and were in turn subjected to a second overburden drilling program. The bedrock samples verified the geophysical interpretation, and suggested other areas for intensive exploration.

Overburden Drilling and Field Procedures

The first phase of overburden drilling consisted of 29 holes spaced 800 to 1200 feet apart on east-west lines, approximately normal to the glacial transport direction. The dual tube reverse circulation equipment used has been previously described (Skinner, 1972) and others.

It consisted of a Longyear 38 drill, a 125 cfm air compressor, pressure pump, 18" cyclone, and a 300 gallon water recovery tank. Water, or a mixture of water and air were injected into the outer tube to the face of the tricone button bit. The sample returned up the inner tube, through the cyclone and into a 10 gallon plastic pail fitted with a 10 mesh Tyler screen. The lithology of the overburden was logged at this point, and samples of -10 mesh size were collected in 5 foot segments. Where possible a 2 or 3 foot section of bedrock was penetrated at the bottom of each hole.

A second overburden program consisting of 12 holes to verify the carbonatized zone interpreted from the induced polarization/resistivity survey utilized a unique drill system capable of coring bedrock as well as collecting till samples.

The drill system consisted of a skid mounted Inspiration #3 drill, pressure pump, cyclone and water retrieval tank. The drill string consisted of outer NW size casing pipe fitted with a casing shoe, and inner AW size casing pipe fitted with a tricone bit which protruded 1/2 inch beyond the crown of the NW casing shoe. Water was injected between the two casings and the sample returned up the inner tube, through a cyclone and into 30 gallon pails fitted with 10 mesh Tyler screens. Lithologic logging and sampling of the -10 mesh size material in 5 foot segments occurred at this point. Upon reaching bedrock, the inner drill string was replaced with BQ rods and core drilling of the bedrock for an average of 10 feet was completed.

A third program of 23 overburden holes utilizing the dual tube system were required to complete the assessment of the carbonatized zones outlined by the induced polarization/resistivity anomaly.

LABORATORY PROCEDURES

The samples from all three till sampling programs were processed by Overburden Drilling Management of Ottawa, and details of the procedures are given in Skinner (1972) and others. Briefly, the -10 mesh portion of the sample was treated to recover the heavy minerals with a specific gravity in excess of 3.28, with the magnetic minerals and drill steel removed. Three quarters of this concentrate was geochemically analyzed, and the remainder archieved. During the processing the number of gold grains, if present, and their morphology were noted.

The non-magnetic heavy mineral concentrates were analyzed for gold by neutron activation analyses, while zinc and arsenic were analyzed by atomic absorption methods. Bedrock chip samples and cores were analyzed for gold, chrome, and nickel by atomic absorption methods. Rock types and alteration assemblages were determined visually and by major element analyses.

OVERBURDEN DRILL RESULTS

Typically the till sections encountered were clay-gravel tills 15 to 20 feet thick, and total overburden depths varied from 7 to 129 feet.

The range of gold values in the heavy mineral concentrates was to 0 to 7110 ppb with a mean of 50 ppb. A cumulative frequency plot of the data, Figure 4, indicated a population skewed towards the low end of the range and a threshold value of 2000 ppb.

Distribution of gold in till is in part a function of the distance from the source as well as glacial transport direction and the number of stages of ice movements. A plot of gold present in the total till section shown in Figure 5, indicates an anomalous gold train approximately 3/4 mile long from the source area. A plot of gold values residing only in lower most till samples shown in Figure 6 indicates a more restricted anomalous gold train, in the order of 2000 feet. The explanation of this phenomenon is related to bedrock topography. Figure 7 is a N-S longitudinal section through the till anomaly which shows the relationship of gold values to bedrock topography. It can be seen that the highest values occur close to bedrock source and decrease in magnitude down ice. These values also rise in the till section and are interrupted by the bedrock ridge near station 30N.

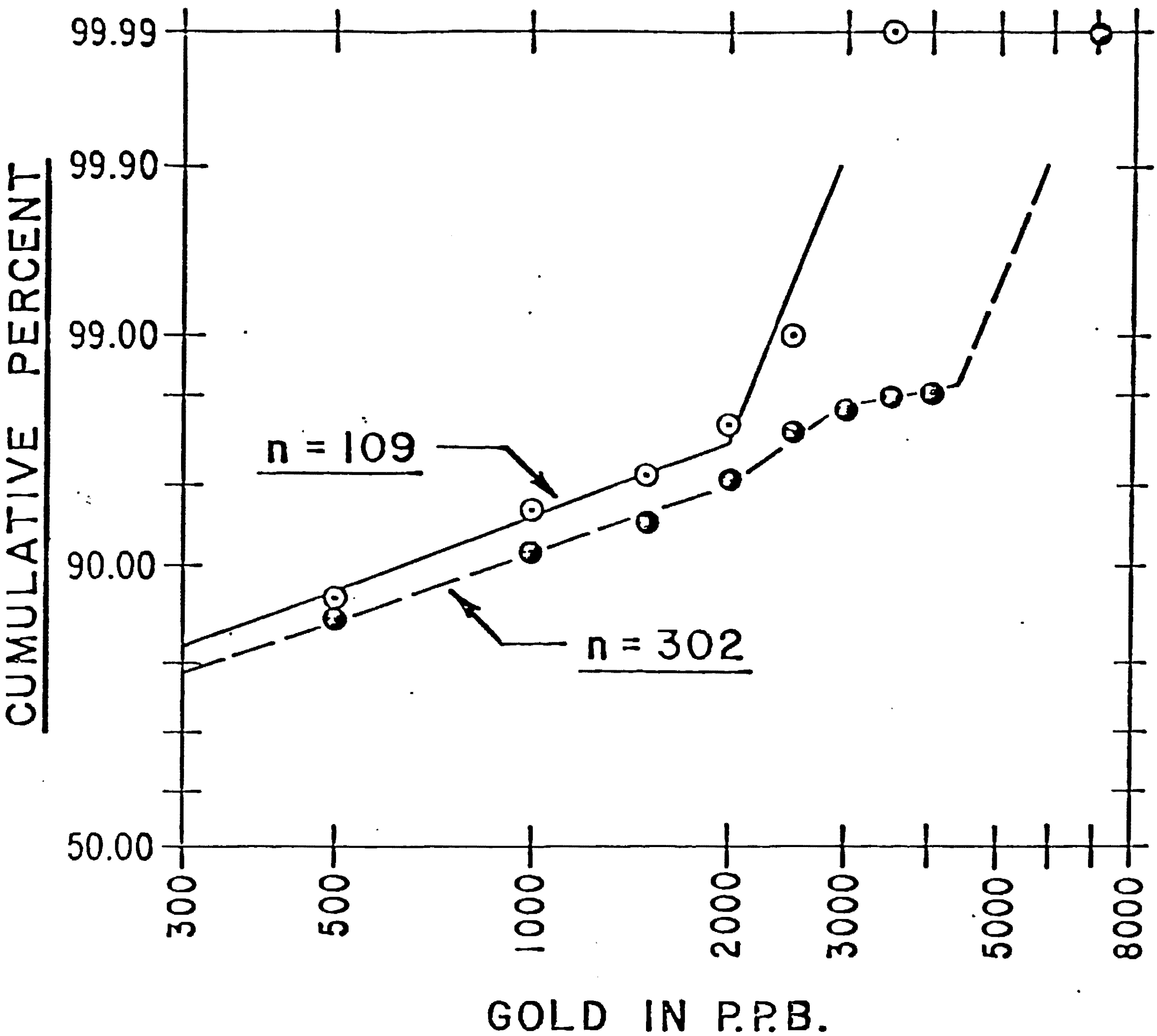

Figure 4 - Cumulative Frequency Plot of gold (ppb) in heavy mineral concentrates. First 29 sample sites produced 109 samples, 90 sample sites yielded 302 samples.

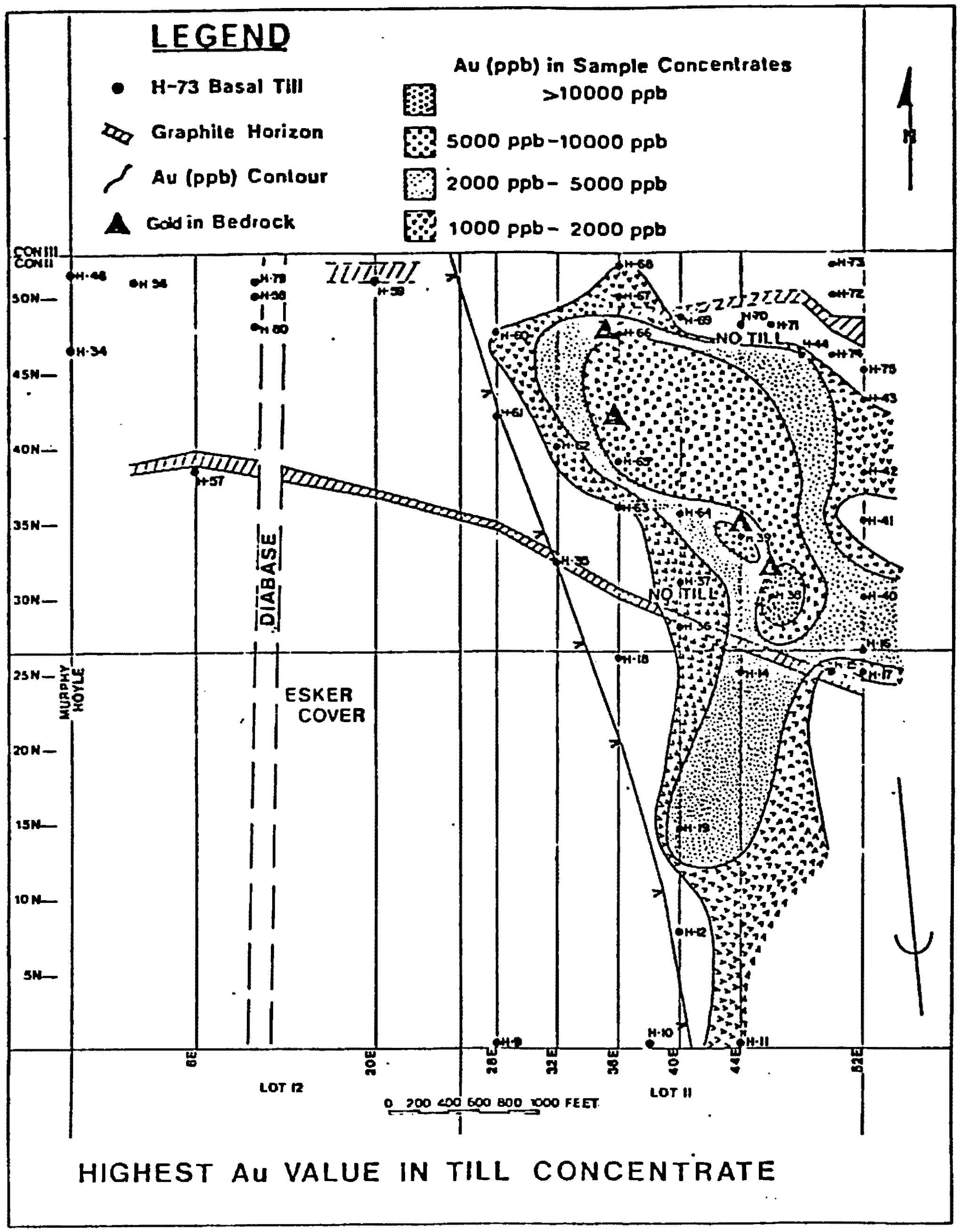

Figure 5 - Plot of highest gold values (ppb) in heavy mineral concentrates located in entire till section.

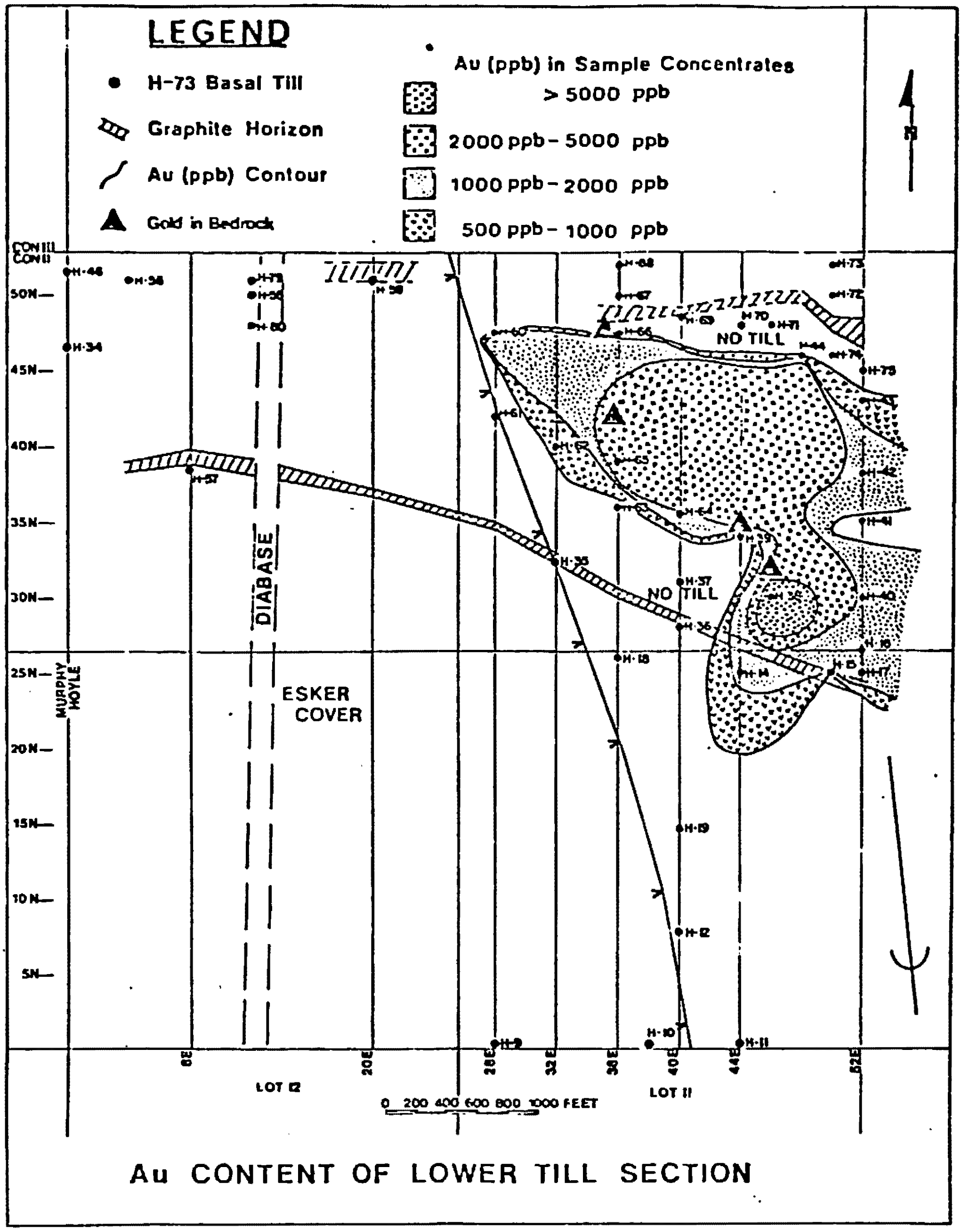

Figure 6 - Plot of gold values (ppb) in heavy mineral concentrates located in "basal" till.

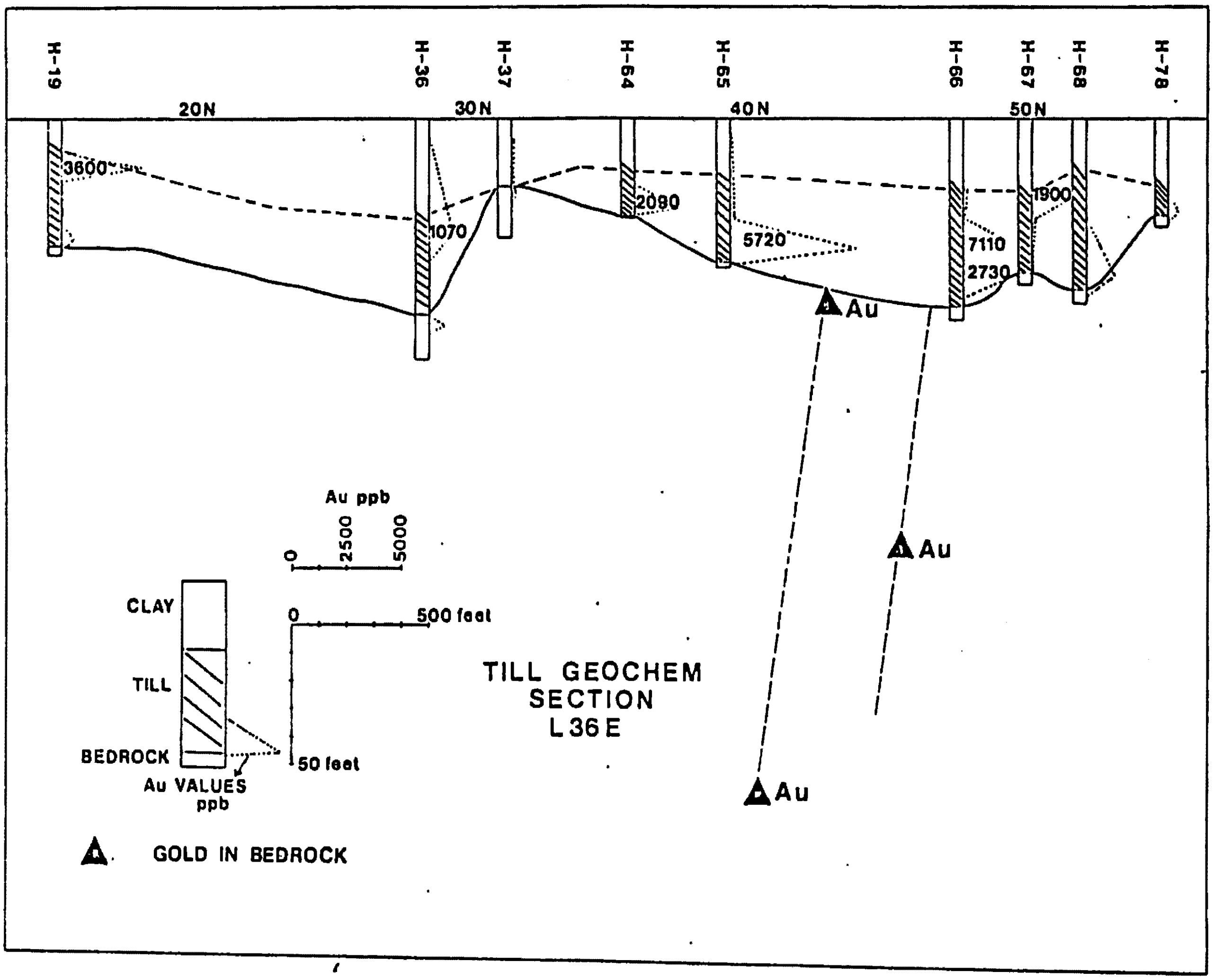

Figure 7 - North-south longitudinal section through geochemical anomaly showing the effect of bedrock topography.

It should also be noted that bedrock chips in the vicinity of the mineralization shown in Figures 5 & 6 were characterized by extensive carbonate-sericite-quartz-pyrite alteration, and contained values up to 300 ppb gold.

Arsenic values in the till usually did not correlate with the highest gold values, however, values in excess of 500 ppm As did generally occur in the anomalous gold train. Zinc values also exhibited poor correlation with gold values, and were of little value in defining gold mineralization. Thus, gold in till gave the best definition of bedrock sources, whereas other pathfinder elements such as As and Zn have erratic patterns and values.

The presence of till is necessary for this technique to be effective, and other surficial materials, such as the esker shown on Figures 5 and 6, limit the utility of the exploration method. Therefore, geophysical surveys are necessary to explore such areas.

MAGNETIC SURVEYS

The study area was completely covered with a proton procession magnetometer survey, and outlined three areas of low magnetic values (below 59,500 gammas) within the volcanic rocks, as shown on Figure 8. One of these areas known as S zone (#1 on Figure 8) occurred in the northwest part of the survey area and was the subject of the overburden drilling discussed earlier. A second magnetic low area occurred in the east central region (#2 on Figure 8) in the vicinity of an outcropping gold showing previously explored by Broulan Reef Mines Ltd. The third area occurred in the south central part of the survey (#3 on Figure 8), which contains the Bell Creek and North Zone gold deposits.

These magnetic lows reflect areas of carbonate alteration as noted in outcrops, overburden drill chips, and drill cores. The reason for the low magnetic signature is due to the fact that magnetic minerals in the mafic volcanic rocks are oxidized during the carbonatization process, and in many cases are converted to ankerite, leucoxene and hematite, with the result that the magnetic suseptibility is reduced. The higher magnetic values on Figure 8 are associated with relatively unaltered mafic volcanic rocks and north trending diabase dykes. The recognition of these associations can be used in generating a geological map for this overburden covered terrane.

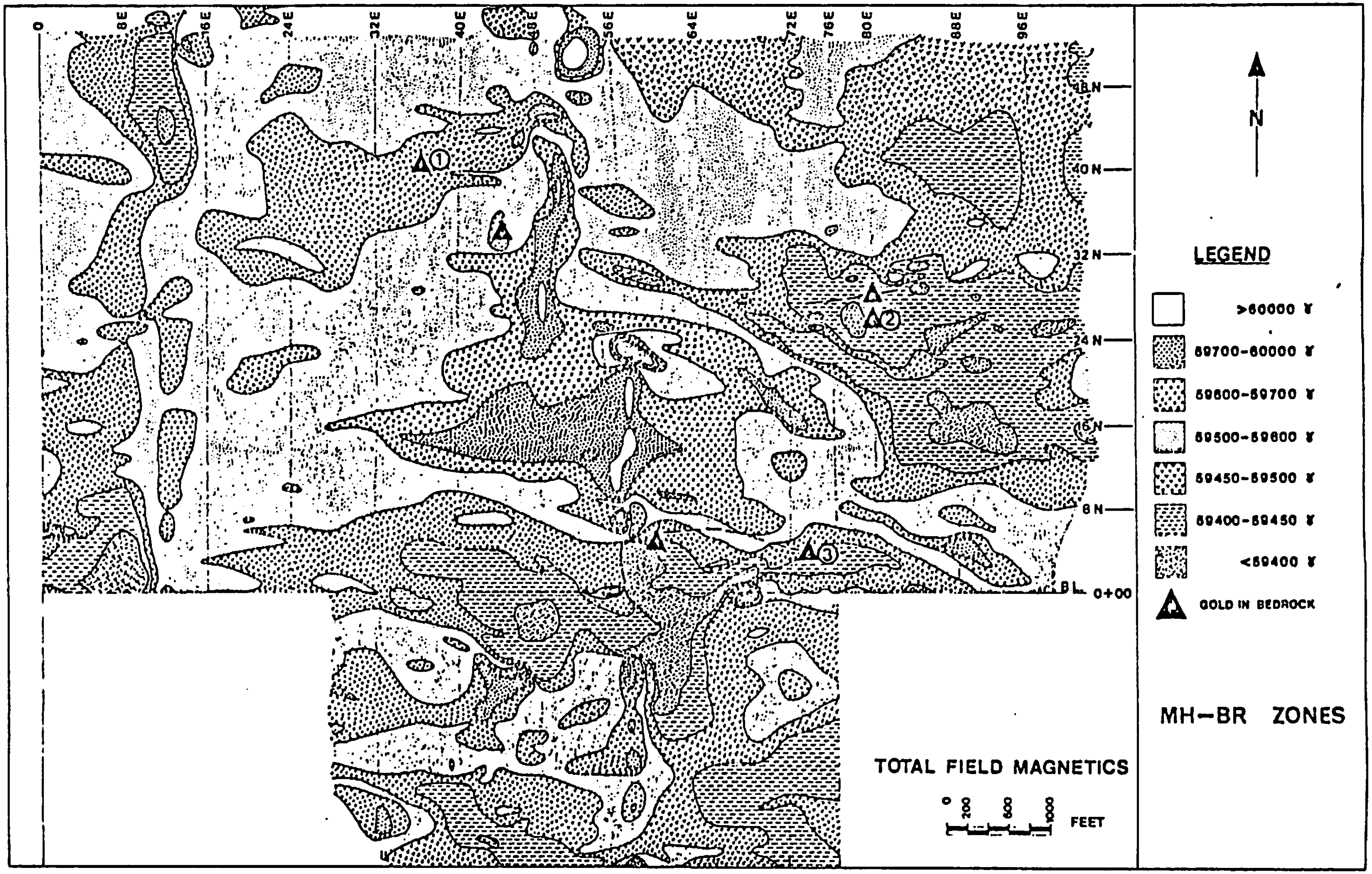

Figure 8 - Total Field Ground Magnetic Map of study area. Anomalies shown are: 1. S Zone, 2. Broulan Reef M.L. showing, 3. Bell Creek and North Zones.

However, not all magnetically low areas reflect carbonatized volcanic rocks. The magnetically subdued area in the northeast corner of the survey area is underlain by sedimentary rocks, as noted in drill cores. Thus, other methods of verifying bedrock are necessary to refine the magnetic interpretation, such as induced polarizaton and resistivity surveys.

INDUCED POLARIZATION - RESISTIVITY SURVEYS

Induced polarization and resistivity surveys were conducted using a pole-dipole array, with an "a" spacing of 200 feet and "n" = 2. This array was chosen to survey bedrock at all overburden depths (7 to 129 feet) and to outline large areas of carbonatization in the bedrock on a reconnaissance basis. A Scintrex IPR-8 receiver was used with a 2.5 Kw IPC-7 transmitter. Current values were carefully measured to give more precise resistivity values. Three chargeability readings were observed after the shut off of the 2 second square wave pulse, in order to observe electromagnetic coupling effects, such as those present in the vicinity of highly conductive graphite zones.

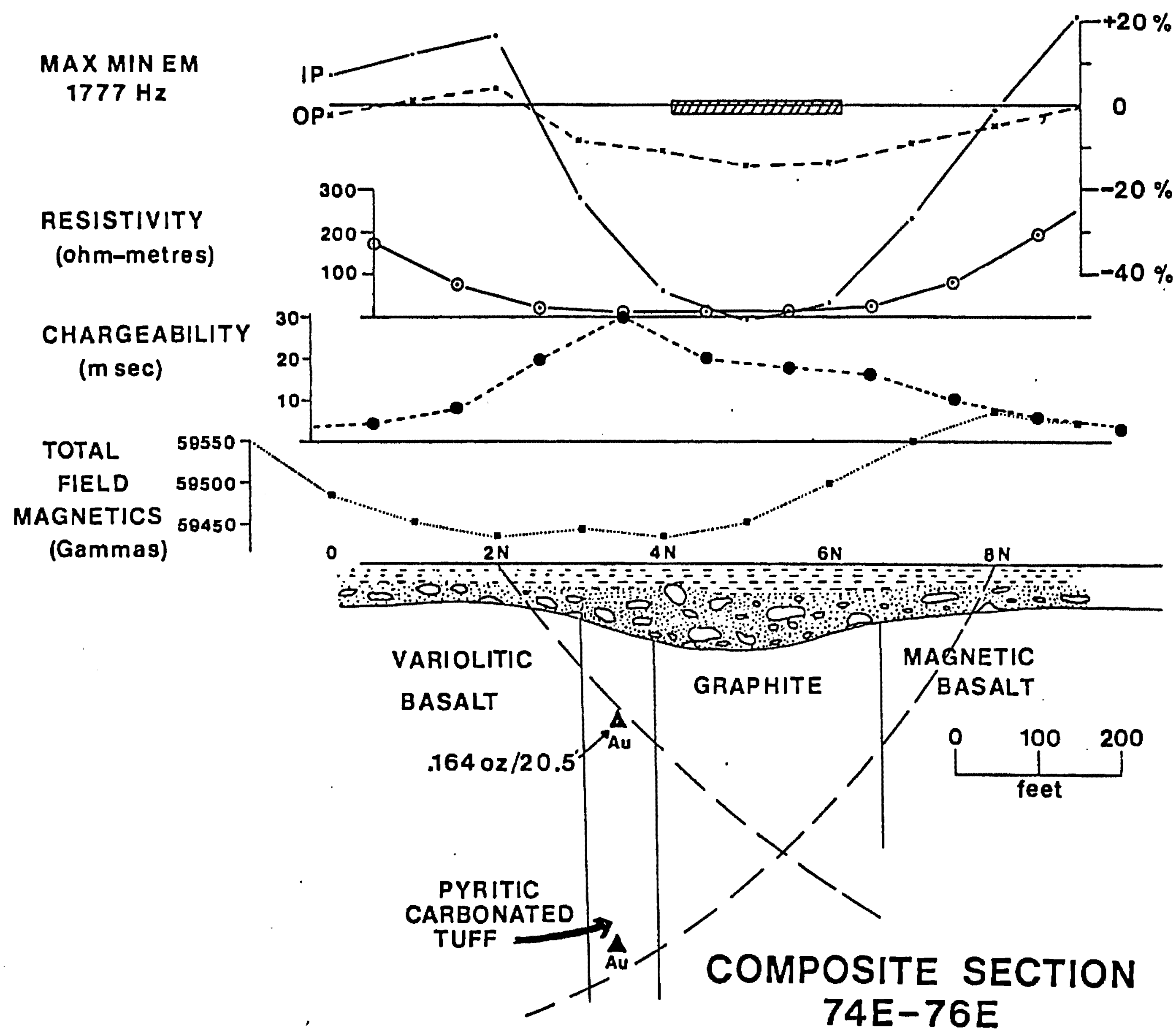

Figure 13 - Composite Section through Eastern End of Bell Creek Zone, showing relationship of the geophysical surveys and geology.

The association of enhanced resistivity and carbonatized rock is related to the alteration process. The introduction of carbonate mineral forming hydrothermal solutions into rocks causes a partial recrystallization and a corresponding reduction of pore space, resulting in an increase in resistivity. Enhanced chargeability values in carbonatized rocks is related to the presence of abundant disseminated pyrite, particularly adjacent to quartz veins, which is part of the gold mineralization process in the study area.

Figure 9 portrays the resistivity survey conducted over the S zone, discovered by overburden drilling techniques, see Figures 5 & 6). In this area bedrock chips had indicated carbonatized bedrock east of an esker. This survey represented a cost effective technique of delineating the zone westward beneath the esker. Subsequent diamond drilling has confirmed that the carbonatized zone does pinch out west of the diabase dyke, as shown by the survey.

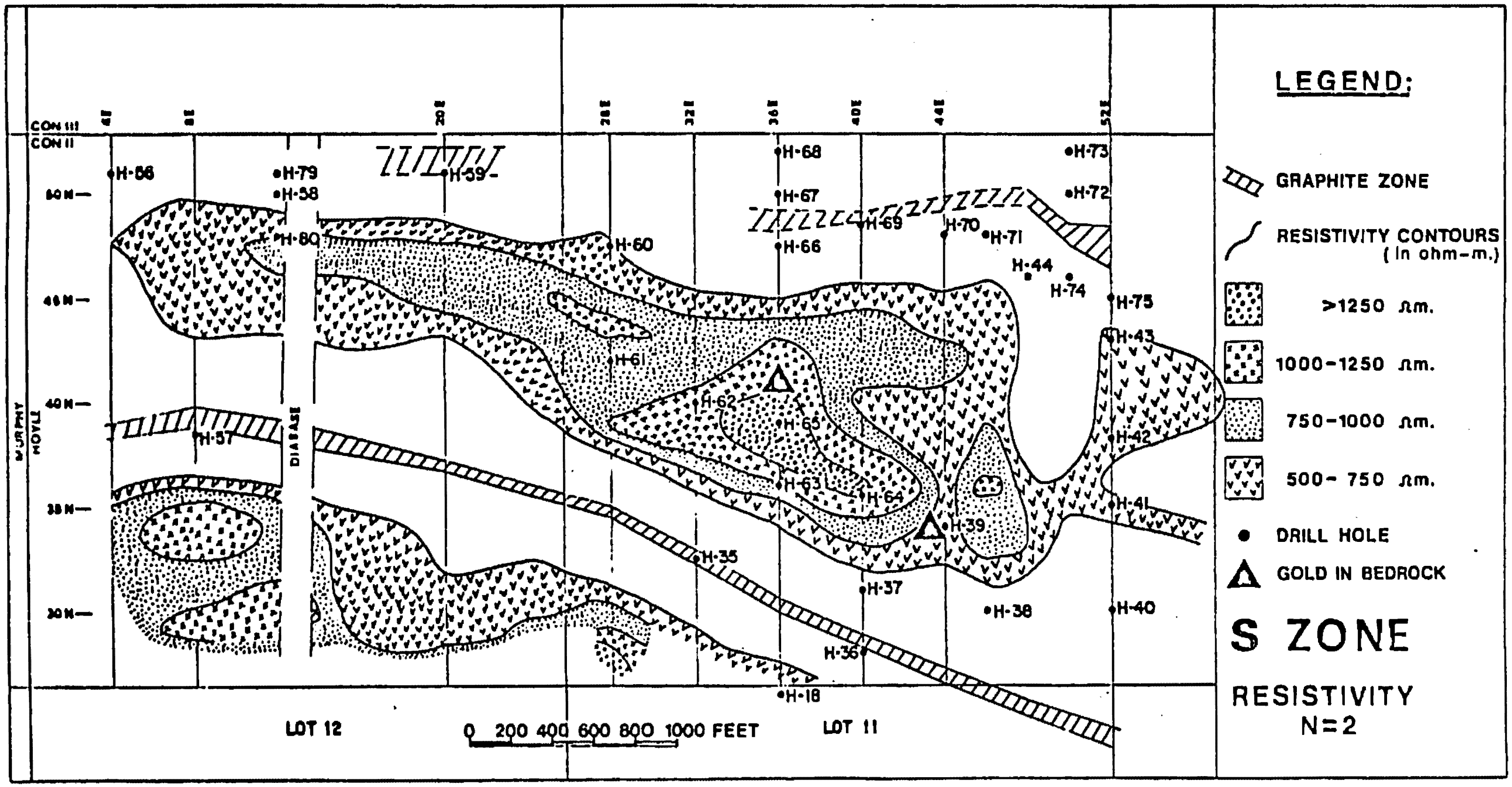

Figure 9 - Resistivity Survey of S Zone (#1 of Figure 8), using pole-dipole array with "a" = 200 ft., and plotting n = 2.

Figure 10 illustrates the chargeability response from the S zone (see figure 4, 5). The anomaly has a smaller areal extent than the resistivity anomaly of Figure 9. Subsequent diamond drilling has confirmed that higher gold values are generally restricted to the area of the chargeability anomaly.

As previously suggested, the carbonatized zones inferred from the magnetometer survey could be verified with electrical methods. Figure 11 shows the resistivity survey over the previously defined magnetic low areas and illustrates two points.

High resistivity values in excess of 100 ohm-metres correspond to the three magnetic low areas presented in Figure 8, confirming the carbonate alteration in the mafic volcanic rocks. It is also apparent that the magnetic low area in the northeast corner of the survey area corresponds to a resistivity low and corroborates the underlying sedimentary rocks. Graphitic horizons with their attendant high conductivities are clearly defined in the data, and were previously known from drill cores and horizontal loop electromagnetic surveys.

The chargeability survey of the same area is shown in Figure 12 and exhibits a very good correlation with the resistivity anomalies and the magnetic low areas. The east central anomaly (#2 on Figure 8) characterized by a magnetic

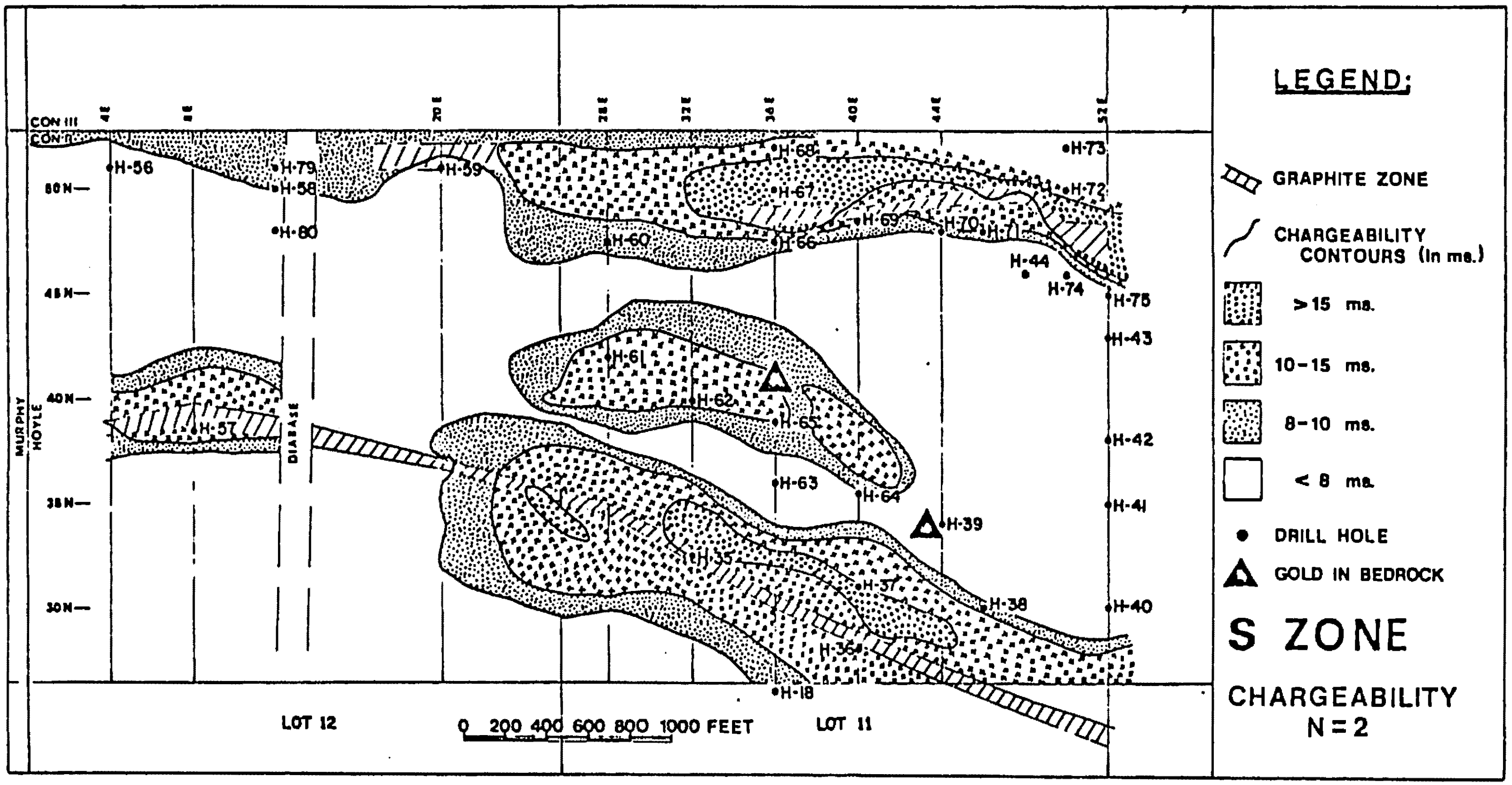

Figure 10 - Chargeability Survey of S Zone (#1 of Figure 8), using pole-dipole array with "a" = 200 ft. and plotting n = 2.

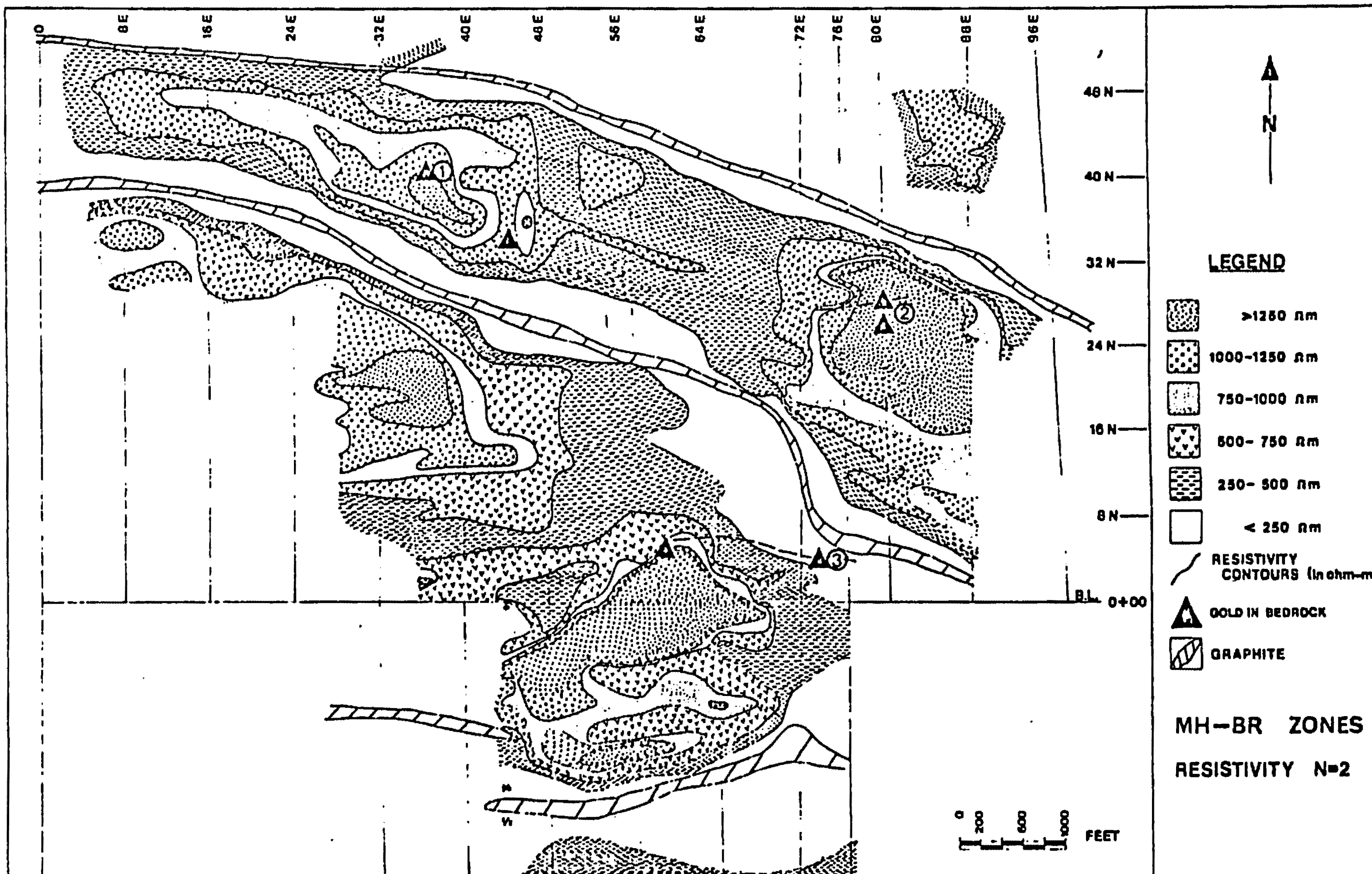

Figure 11 - Resistivity Survey of Study Area using pole-dipole array, with "a" = 200 ft, plotting n = 2. Locations shown are: 1. S Zone, 2. Broulan Reef M.L. showing, 3. Bell Creek and North Zone.

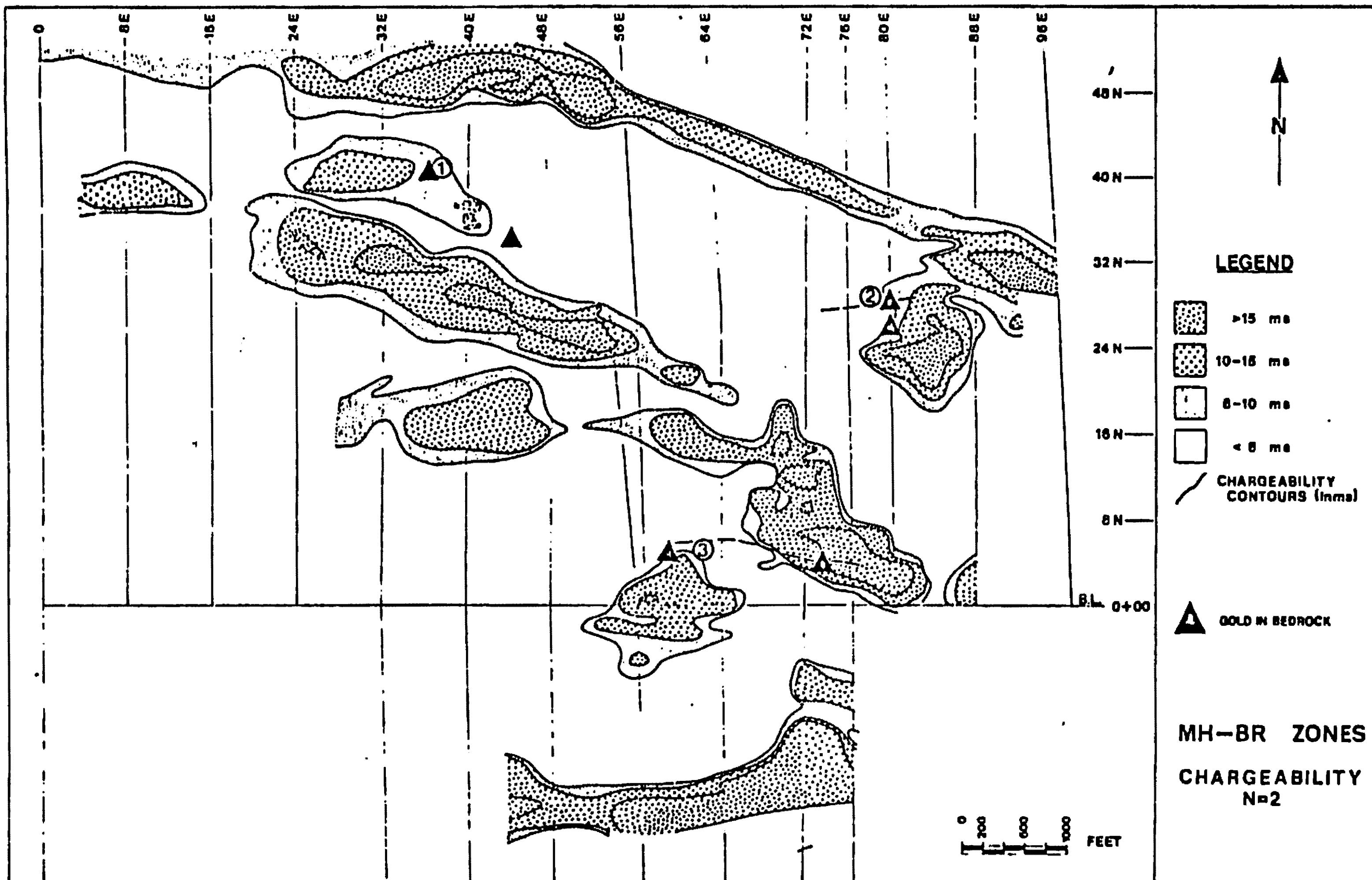

Figure 12 - Chargeability Survey of Study Area using pole-dipole array, with "a" = 200 ft, plotting n = 2. Locations shown are: 1. S Zone, 2. Broulan Reef M.L. showing, 3. Bell Creek and North Zone.

low area, with resistivity and chargeability anomalies occurs in an area of shallow overburden. Stripping and trenching have revealed several auriferous quartz veins with disseminated pyrite in the wall rocks, hosted in carbonated mafic volcanic rocks. Further exploration in this area may reveal an economic deposit.

In the south central area (#3 on Figure 8) outcrops of carbonatized mafic and ultramafic rocks correspond to the chargeability and resistivity anomalies located in a magnetically subdued area. Diamond drilling in the area has outlined a pyritic tuff horizon known as the Bell Creek Zone, located under overburden along the north margin of the outcrops. Geological reserves in this zone are currently estimated at 300,000 tons grading 0.14 oz/t gold. Approximately 600 feet to the north is the North Zone, a pyritic ~~shear~~ -pyrrhotite, sheared zone with a central quartz vein hosted in carbonatized mafic volcanic rocks containing a drill indicated reserve of ~~550,000~~ 600,000 tons grading 0.2 oz/t gold.

Figure 13 is a composite section through the east end of the Bell Creek Zone illustrating several features of the geophysical signature associated with gold bearing carbonatized volcanic rocks. Graphite horizons correspond to chargeability highs, which in turn are also magnetically subdued. These could be confused with carbonatized zones if it were not for the fact that graphitic horizons are associated with resistivity lows, (or EM conductors). Therefore, it is necessary to screen the chargeability anomalies against their conductivities and magnetic character for a reasonable interpretation.

Interpretation of the carbonatization zone boundaries is difficult where these alteration zones occur adjacent to graphitic horizons. With a wide "a" and "n" spacing, the conductive (low resistivity) graphitic material is averaged into the volume of rock being measured. If overburden depths permit, closer "a" spacings could be used to define such contacts accurately.

Integration of all of the geophysical and overburden drilling data resulted in generating a first approximation geological map of the area, as shown in Figure 14. Overlays of the various data sets are necessary to complete the interpretation. A complete synthesis of all the data allows an interpretation of the stratigraphy, cross cutting and stratiform alteration zones, and geochemically anomalous till and bedrock leading to sites that are permissive for the occurrence of gold deposits.

ACKNOWLEDGEMENTS

The writers wish to acknowledge Canamax Resources Inc., (and predecessor companies) and Du Pont of Canada Exploration Ltd., (and successor companies) for their continued support in financing the exploration program described in this paper. The efforts by these companies illustrates the persistence that is required in gold exploration.

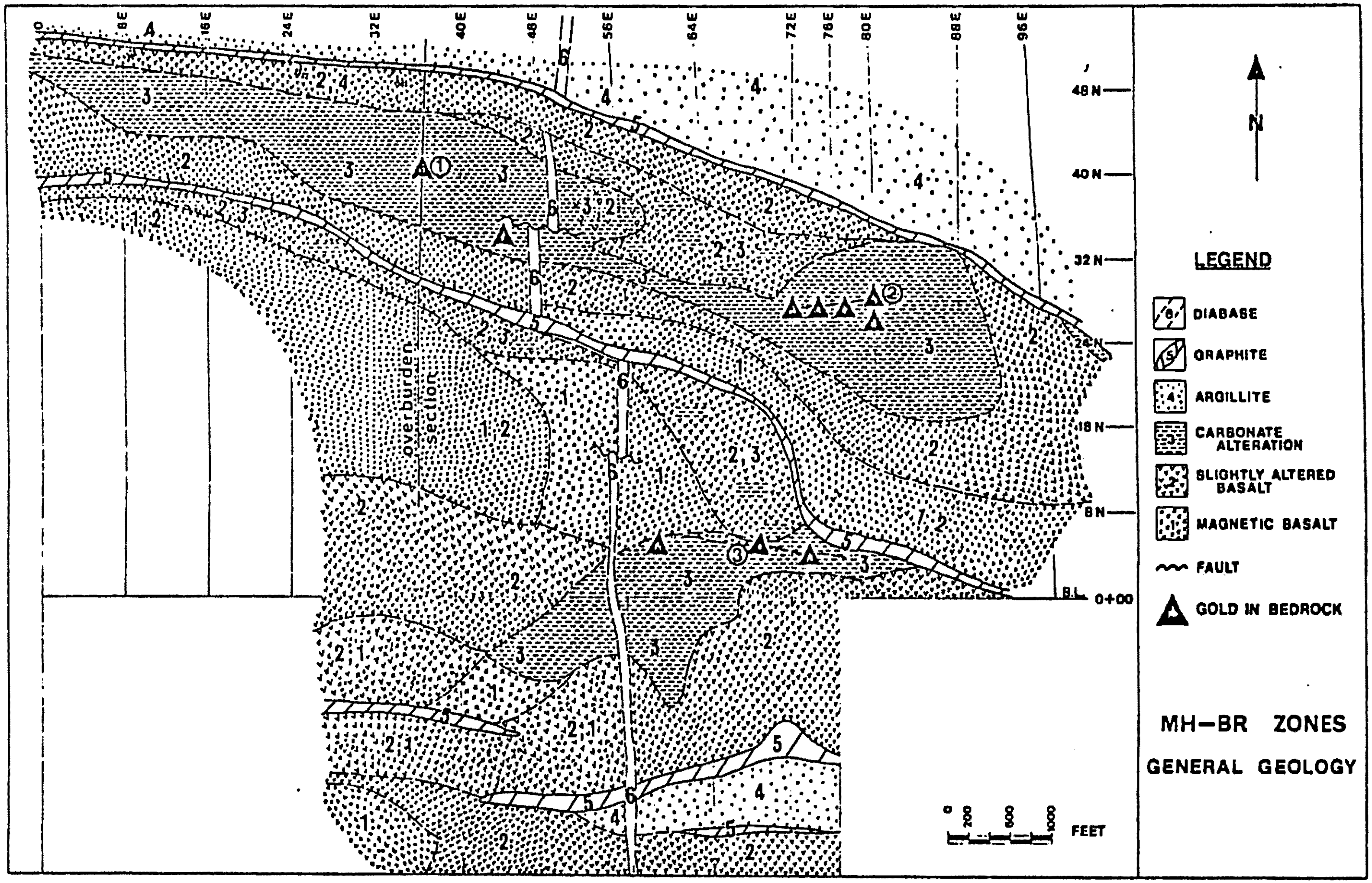

Figure 14 - Synthesized Geology Map of Study Area based on combined geophysical surveys, overburden drill hole, diamond drill, and outcrop data. Locations shown are: 1. S Zone, 2. Broulan Reef M.L. showing, 3. Bell Creek and North Zone.

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AN APPLICATION OF THE MISE-A-LA-MASSE METHOD TO THE MAPPING OF GOLD-BEARING ALTERATION ZONES

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ABSTRACT

Recent application of borehole geophysics to gold exploration have indicated that significant geophysical anomalies may be observed in gold-bearing horizons. The single-hole geophysical logging methods that give promising results with respect to outlining gold-bearing alteration zones include gamma ray spectrometry, IP and resistivity (Mwenifumbo, et al, 1983, Urbancic and Mwenifumbo, 1984). These single-hole geophysical logging techniques, however, provide information on the changes in the physical properties of the rock mass in the immediate vicinity of the drill hole. Geophysical anomalies observed in a number of holes are often difficult to correlate from hole to hole. This is mainly due to lack of characteristic signatures. To provide information on the nature of the rock mass between holes and to determine whether anomalous features continue from hole to hole, techniques such as the mise-a-la-masse method are employed. The mise-a-la-masse method is a cross-hole or hole-to-furface electrical technique used for determining the orientation and extension of a conductive mineralization or structure.

In this paper, we present an example of the application of the mise-a-la-masse method to mapping gold-bearing alteration zones. The study was carried out on the Hoyle Pond Gold Prospect in Timmins, Ontario. Alteration zones in the area are termed "grey zones" because of their distinctive steely blue-black colour (Downes, et al, 1983). They are carbonate alteration zones within a uniform sequence of magnesium-rich tholeiitic basalts. They vary in width from 5 to 30 metres and contain 1 to 3 percent fine-grained disseminated pyrite. The zones are structurally controlled and are characterized by in situ brecciation and a strong

schistosity in their centres. Their attitude is usually nearly vertical. Gold is present in quartz veins, 1 cm to 1 m wide, within the grey zones and is also associated with the fine-grained disseminated pyrite. A number of these grey zones are intersected in drillholes and hole to hole correlation of these zones is, in a number of cases, ambiguous. The drillhole IP, resistivity and mise-a-la-masse measurements were carried out to outline the zones and to determine their correlation between holes. Most of the measurements were conducted in two holes; H80-14 and HP82-04 on the Holye Pond Gold Prospect.

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INTRODUCTION

Recent applications of borehole geophysics to gold exploration have indicated that significant geophysical anomalies may be observed in gold bearing horizons. The single-hole geophysical logging methods that give promising results with respect to outlining gold bearing alteration zones include gamma ray spectrometry, IP and resistivity (Mwenifumbo, et al, 1983, Urbancic and Mwenifumbo, 1984). These single-hole geophysical logging techniques, however, provide information on the changes in the physical properties of the rock mass in the immediate vicinity of the drillhole. Geophysical anomalies observed in a number of holes are often difficult to correlate from hole to hole. This is mainly due to lack of characteristic signatures. To provide information on the nature of the rock mass between holes and to determine whether anomalous features continue from hole to hole, techniques such as the mise-a-la-masse method are employed. The mise-a-la-masse method is a cross-hole or hole-to-surface electrical technique used for determining the orientation and extension of a conductive mineralization or structure.

In this paper we present an example of the application of the mise-a-la-masse method to mapping gold-bearing alteration zones. The study was carried out on the Hoyle Pond Gold Prospect in Timmins, Ontario. Alteration zones in the area are termed 'grey zones' because of their distinctive steely blue-black colour (Downes, et al, 1983). They are carbonate alteration zones within a uniform sequence of magnesium-rich tholeiitic basalts. They vary in width from 5 to 30 metres and contain 1 to 3 percent fine-grained disseminated pyrite. The zones are structurally controlled and are characterized by in-situ brecciation and a strong schistosity in their centres. Their attitude is usually nearly vertical. Gold is present in quartz veins, 1 cm to 1 m wide, within the grey zones and is also associated with the fine-grained disseminated pyrite. A number of these grey zones are intersected in drillholes and hole to hole correlation of these zones is, in a number of cases, ambiguous. The drillhole IP, resistivity and mise-a-la-masse measurements were carried out to outline the zones and to determine their correlation between holes. Most of the measurements were conducted in two holes; H80-14 and HP82-04 on the Hoyle Pond Gold Prospect.

DRILL HOLE RESISTIVITY LOGGING

Drillhole IP and resistivity data were obtained with the lateral (pole-dipole) array. The potential dipole spacing (MN) was 0.4 m and the distance between the current electrode and the potential dipole centre was 2.8 m. The electrodes consisted of gold-plated brass cylinders, 4 cm in diameter. The surface electrode was located at approximately 500 metres from the drillholes being logged. The measurements were carried out with the GSC R&D time domain IP/resistivity logging system (Bristow, 1984). The transmitter on this system is capable of supplying currents up to 250 mA. There are 4 selectable cycle times (periods) for the current waveform; 1, 2, 4 and 8 seconds. Complete IP waveforms are recorded on a 9 track magnetic tape. The resistivity logs were obtained using a 1 second period. The logging speed was 3 m/minute with measurements taken every second (equivalent to a sample depth interval of 5 cm).

Figure 1 is a vertical section showing the location of the two holes logged with the resistivity logs displayed along the holes. The locations of the grey zones and the current electrode positions used in the mise-a-la-masse measurements are also indicated in the figure. There is a good correlation between the grey zones and low resistivity zones. Due to the asymmetric nature of the response from the lateral resistivity logs, the resistivity lows are not exactly coincident with the true location of the conductors. There are a few low resistivity zones which do not correspond to any of the mapped grey zones especially along drillhole H80-14. They may correspond to grey zones narrowly missed by the drill hole. It should be remembered that the drill core represents only a very small sample volume along the drill hole. The conductivity contrast (as indicated by the resistivity logs) between the grey zones and the unaltered basalts is well suited to the mise-a-la-masse method.

DRILL HOLE MISE-A-LA-MASSE MEASUREMENTS

The mise-a-la-masse measurements were done with the same equipment used in the resistivity logging. The measurements were accomplished by placing a current electrode directly in a conductive zone in one hole and then the potentials were measured in another hole. The in-hole current electrode consisted of a 1 metre long copper tube about 4 cm in diameter attached to an insulated copper wire to lower it into the selected drillhole. The lateral resistivity logs and the geologic logs were used to locate the conductive zones where the current electrode was to be emplaced. The surface current electrode was placed approximately 500 metres away from the drillholes (effectively at infinity). The in-hole potential measuring electrode was a gold-plated brass cylinder, 4 cm in length. The other potential electrode (reference electrode) was placed on the surface approximately

100 metres away from the drillhole. Logging speeds varied from 3 m/minute to 9 m/minute. The mise-a-la-masse potential gradients presented in the results are derived from the potential measurements by means of a Kaiser derivative operator (Kaiser and Reed, 1977).

For an electrically homogeneous and isotropic medium, the equipotential surfaces resulting from a buried current source are concentric about the source, governed by the equation, $V=\rho I/4\pi R$. In this situation, mise-a-la-masse data will indicate maximum potential amplitudes or zero gradients (inflection point in the gradient data) at a point in the measurement hole which is closest to the source. When a current electrode is placed in a conductor, current tends to be channelled along the conductor and observations in a hole that intersects the energized conductor will show a flat potential maximum or zero gradients across the intersection. The intersection is not necessarily the shortest distance from the source.

A) Measurements in H80-14 - Current Electrodes in HP82-04

Figure 2 shows mise-a-la-masse measurements in drillhole H80-14 with the current electrode implanted at three different low resistivity zones in drillhole HP82-04. The lateral resistivity logs are displayed in the figure as well as the location of the grey zones. Both potential and potential gradient logs are presented. The dominant current flow direction from hole-to-hole is indicated by arrows and this is determined from the maximum amplitudes in the potential logs and the inflection point in the gradient logs. The log depths shown are downhole-lengths, not true vertical depths. C1-LOG, C2-LOG and C3-LOG represent mise-a-la-masse data obtained with the current electrode at C1, C2 and C3 respectively in hole HP82-04. The C1-LOG shows maximum potential amplitudes and an inflection point in the gradient at approximately 110 m in drillhole H80-14 indicating that electrical continuity exists between the location of C1 in HP82-04 and the location at 110 m in H80-14. In the gradient data conductive zones which are not in electrical continuity with the energized conductor show up as low gradient regions at approximately 80 - 86 m and at 140 - 150 m and correlate with the low resistivity zones on the lateral resistivity log.

The C2-LOG exhibits high mise-a-la-masse potentials at approximately 140 - 150 m. This coincides with the location of a grey zone. It is interesting to note that the rate of change of the potentials is gradual on the downhole side and rapid on the uphole side. This trend is more evident in the gradient data. This potential pattern suggests that the conductive structure from C2 intersects H80-14 at a fairly low angle or that another branch of this conductor passes close to the hole. The main current axis is located at approximately 145 metres (inflection point in the gradient data with maximum peak to peak amplitude).

The C3-LOG indicates that the conductive grey zone at C3 intersects H80-14 at approximately 350 m. It is interesting to note the abrupt step-like change in potentials at approximately 315 m, above which the potentials are fairly low and flat (almost zero gradients). The conductive zone at 350 is well isolated from the conductive grey zone above, contrary to the interpretation inferred from the drill core log. The zero gradients between 255 and 315 correlate well with the grey zone and correspond to low resistivities on the lateral log.

Figure 3 shows mise-a-la-masse data along drillhole H80-14 with current electrodes placed at two locations in HP82-04. The grey zones and the lateral resistivity logs obtained along the two drillholes are also displayed in the figure.

The C4-LOG represents mise-a-la-masse data with the current electrode located at C4 in the lower part of the same grey zone measured with the C2 electrode. A very broad zone (from approximately 140 to 190 m) of high potentials is observed. The lateral resistivity log, however, indicates that there is a zone of high resistivity between the conductive grey zones at 145 m and that at 190 m. As noted earlier, the resistivity log only provides information on the resistivity variations in the immediate vicinity of the drillhole. The mise-a-la-masse data indicates that the conductive zone intersected at C4 in HP82-04 splits into two zones; one intersecting H80-14 at approximately 145 m and the other one at approximately 187 m. The data suggest that the lower conductive zone passes close to H80-14 but not close enough to be detected by the lateral resistivity log.

The C5-LOG represents mise-a-la-masse data along H80-14 with current electrode at C5 in HP82-04. Again we see a broad potential high from approximately 190 m to 295 m. The diffuse nature of the response indicates that the conductor at C5 is not in electrical continuity with any of the conductive zones along H80-14. This will be more evident in the data to follow. The gradient data shows the location of maximum current flow at approximately 226 - 250 metres which does not coincide with any of the low resistivity zones on the lateral log. However, the potential as well as the gradient data indicate that there is a conductive zone between the holes which appears to be located between 185 and 295 along H80-14.

B) Measurements in HP82-04 - Current Electrodes in H80-14

Figure 4 shows mise-a-la-masse data obtained in drillhole HP82-04 with current electrodes emplaced at C6 and C7 respectively in H80-14. It is interesting to note the similarities in the observed potentials for the two current electrode positions. The gradients are almost identical. For both of the current electrode positions, the current axes are observed at 125 m, 97 m and 77 m, suggesting that these two conductive zones converge and intersect hole HP82-04 at the same locations. They also suggest that the two conductive zones in hole HP82-04, at 78 and 95 metres are isolated from each other by a resistive zone. The location of the maximum potential at approximately 120 m in HP82-04 does not coincide with any mapped grey zones. The conductor from C7 and C6 to 120 m in HP82-04 is a good conductor. The data indicate that there is strong current channelling along this conductor over a distance of 160 metres between the holes.

The overall interpretation of all the mise-a-la-masse observations and the lateral resistivity logs carried out between the two drillholes (HP82-04 and H80-14) are presented in figure 5. This is a qualitative interpretation of the conductive structure between the two holes. The thicknesses of the conductive zones between the holes are speculative at the present time. Theoretical modelling of the structure may provide some realistic thicknesses. It appears that there are two sets of conductive structures. The majority are nearly vertical or dip steeply to the south. The other conductive structure from C7 to C4 dips steeply to the north and crosscuts the southerly dipping structures. These may represent two stages of fracturing and alteration.

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FIGURE CAPTIONS

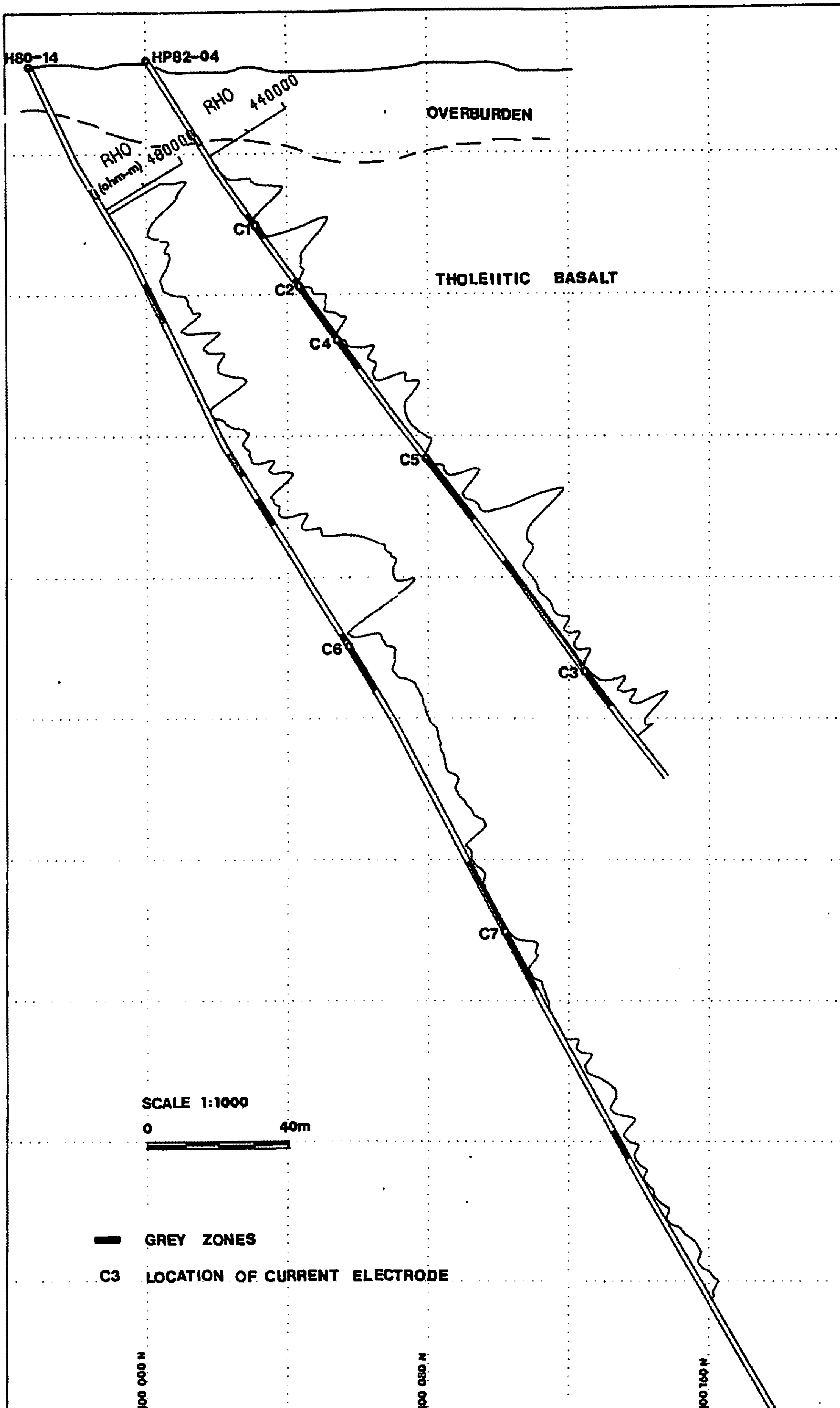
Fig. 1 Vertical section showing the orientation of the two drillholes. The lateral resistivity logs are displayed along the holes.

Fig. 2 Mise-a-la-masse potential and gradient measurements obtained in drillhole H80-14 with the current electrodes in drillhole HP82-04. The C1-LOG, C2-LOG and C3-LOG represent measurements with the current electrodes located at C1, C2 and C3 respeetively. P--potential log; G--gradient log. The hatched columns indicate the locations of grey zones: screen hatch--grey zones, slant hatch--prominent quartz veins, horizontal hatch--strong in-situ brecciation. The lateral resistivity logs for the two holes are displayed along with the grey zone information. The arrows represent the direction of dominant current flow.

Fig. 3 Mise-a-la-masse potential and gradient measurements obtained in drillhole H80-14 with the current electrodes in drillhole HP82-04. The C4-LOG and C5-LOG represent measurements with the current electrodes located at C4 and C5 respectively. Notations and shading patterns same as for figure 2.

Fig. 4 Mise-a-la-masse potential and gradient measurements obtained in drillhole HP82-04 with the current electrodes in drillhole H80-14. The C6-LOG and C7-LOG represent measurements with the current electrodes located at C6 and C7 respectively. Notations and shading patterns same as for figure 2.

Fig. 5 Conductivity structures between holes HP82-04 and H80-14 as inferred from the mise-a-la-masse and lateral resistivity logs.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HP82-04
RHO 440000
OVERBURDEN
RHO (ohm-m) 480000
C1
C2
THOLEIITIC BASALT
C4
C5
C6
C3
C7
SCALE 1:1000
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GREY ZONES
C3 LOCATION OF CURRENT ELECTRODE
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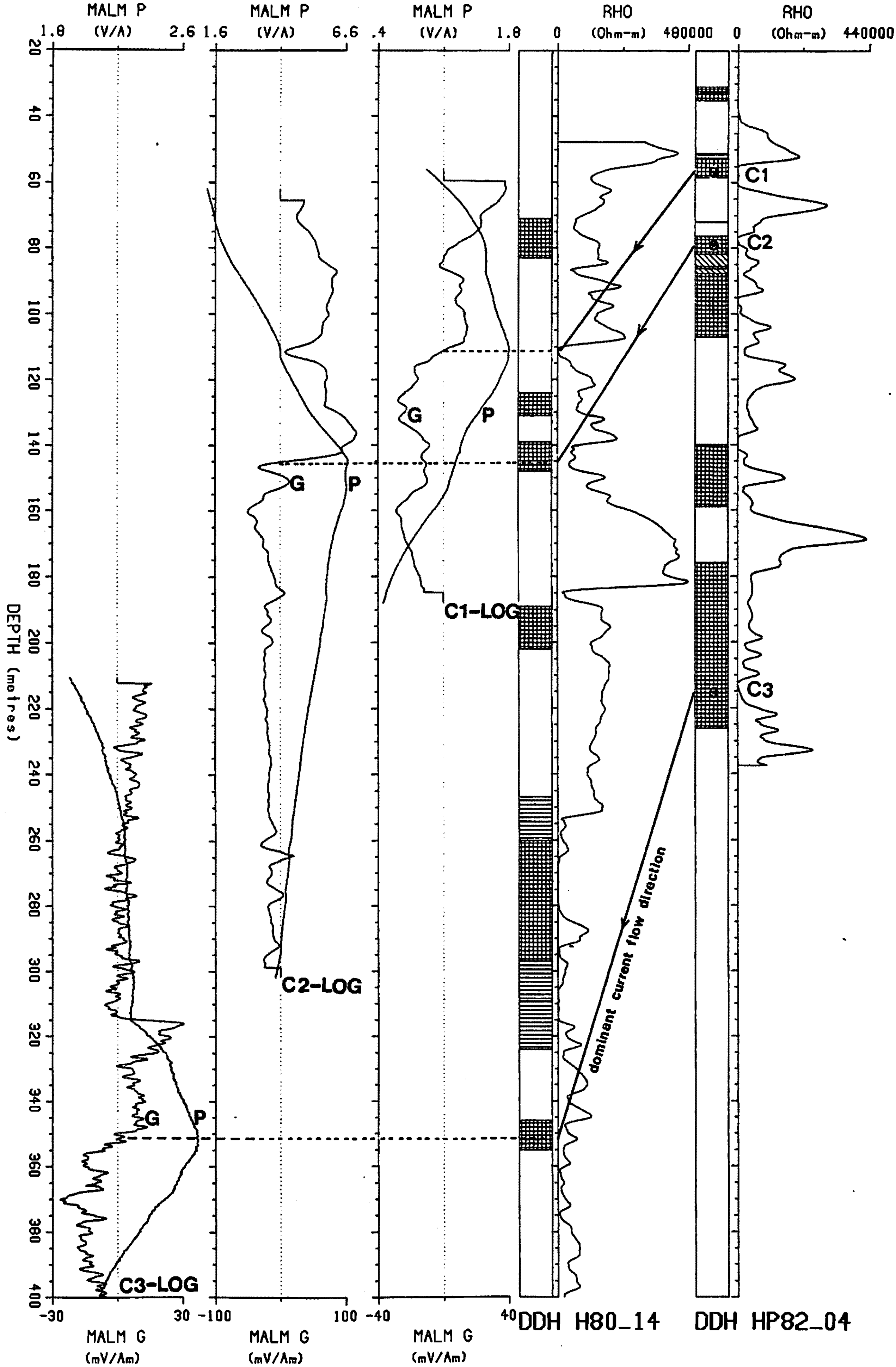
100 050 N
100 100 N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(V/A)
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2.6
MALM P
(V/A)
1.6
6.6
MALM P
(V/A)
.4
1.8
RHO
(Ohm-m)
0
480000
RHO
(Ohm-m)
0
440000
DEPTH (metres)
G
P
C1-LOG
C2-LOG
C3-LOG
C1
C2
C3
dominant current flow direction
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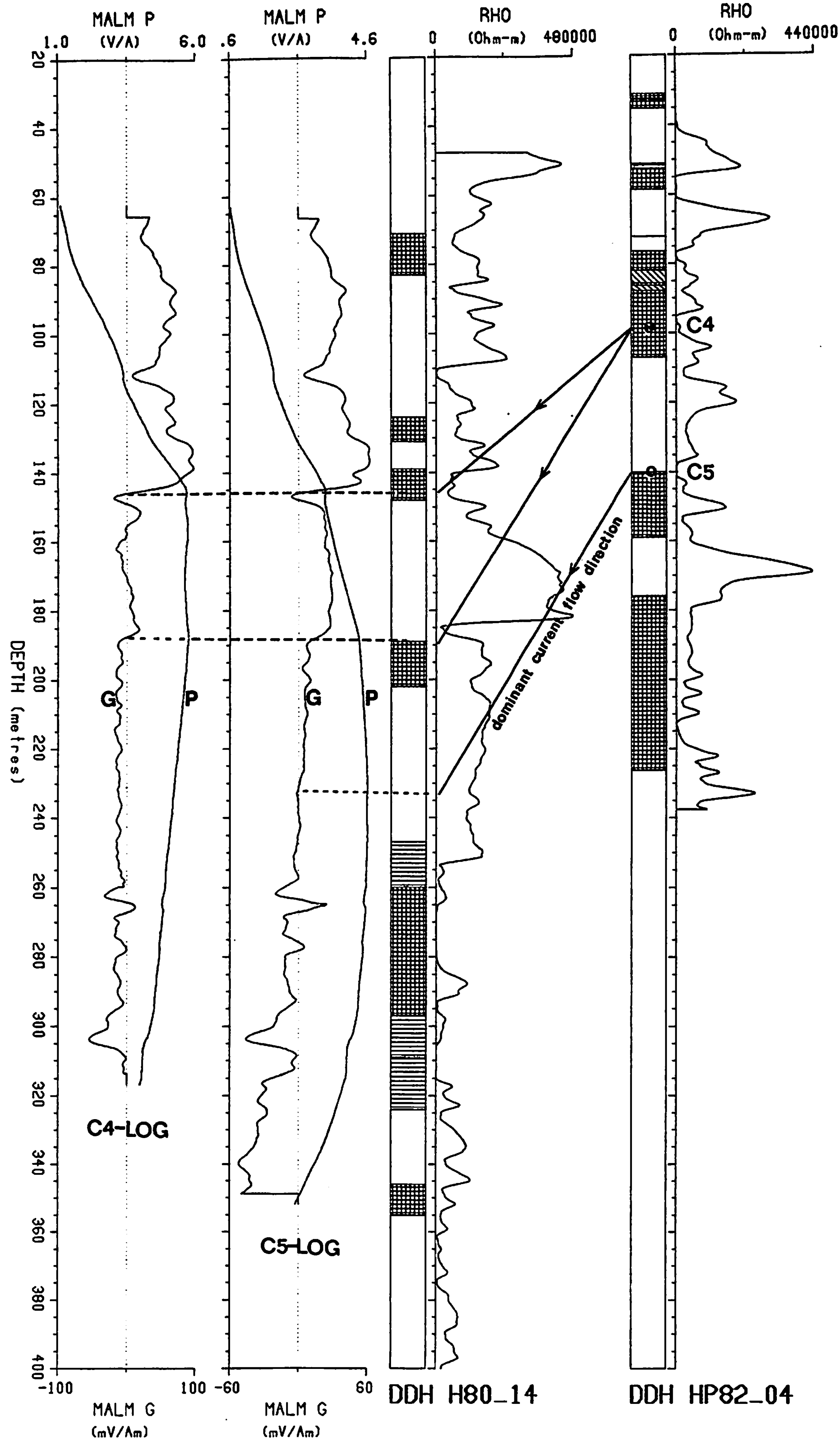
(mV/Am)
-30
30
-100
100
-40
40
DDH H80_14
DDH HP82_04



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(V/A)
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6.0
MALM P
(V/A)
.6
4.6
RHO
(Ohm-m)
0
480000
RHO
(Ohm-m)
0
440000
DEPTH (metres)
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
G
P
G
P
C4
C5
dominant current flow direction
C4-LOG
C5-LOG
-100
100
-60
60
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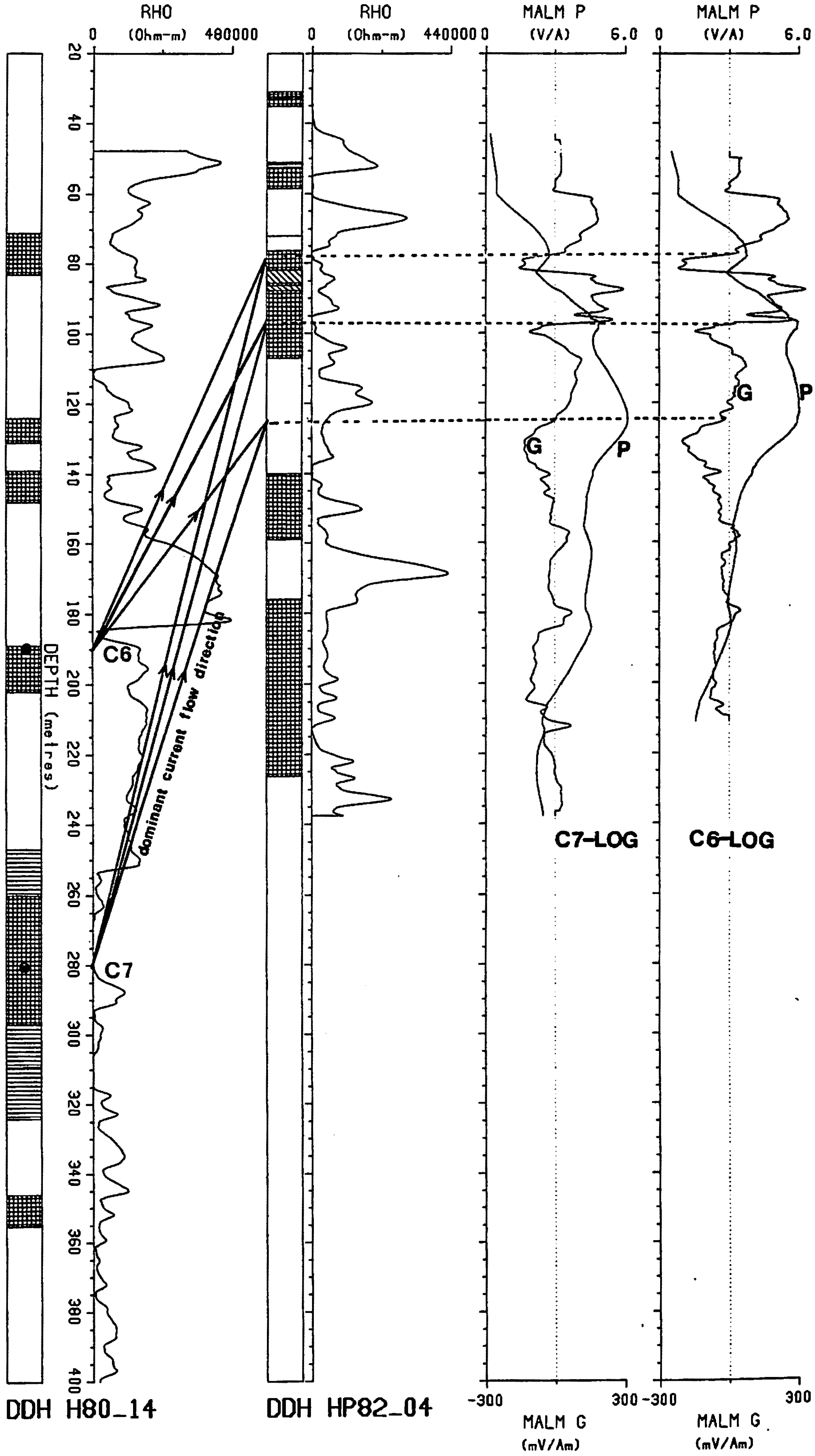
(mV/Am)
MALM G
(mV/Am)
DDH H80_14
DDH HP82_04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(V/A)
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6.0
DEPTH (metres)
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
C6
C7
dominant current flow direction
G
P
G
P
C7-LOG
C6-LOG
DDH H80_14
DDH HP82_04
-300
300
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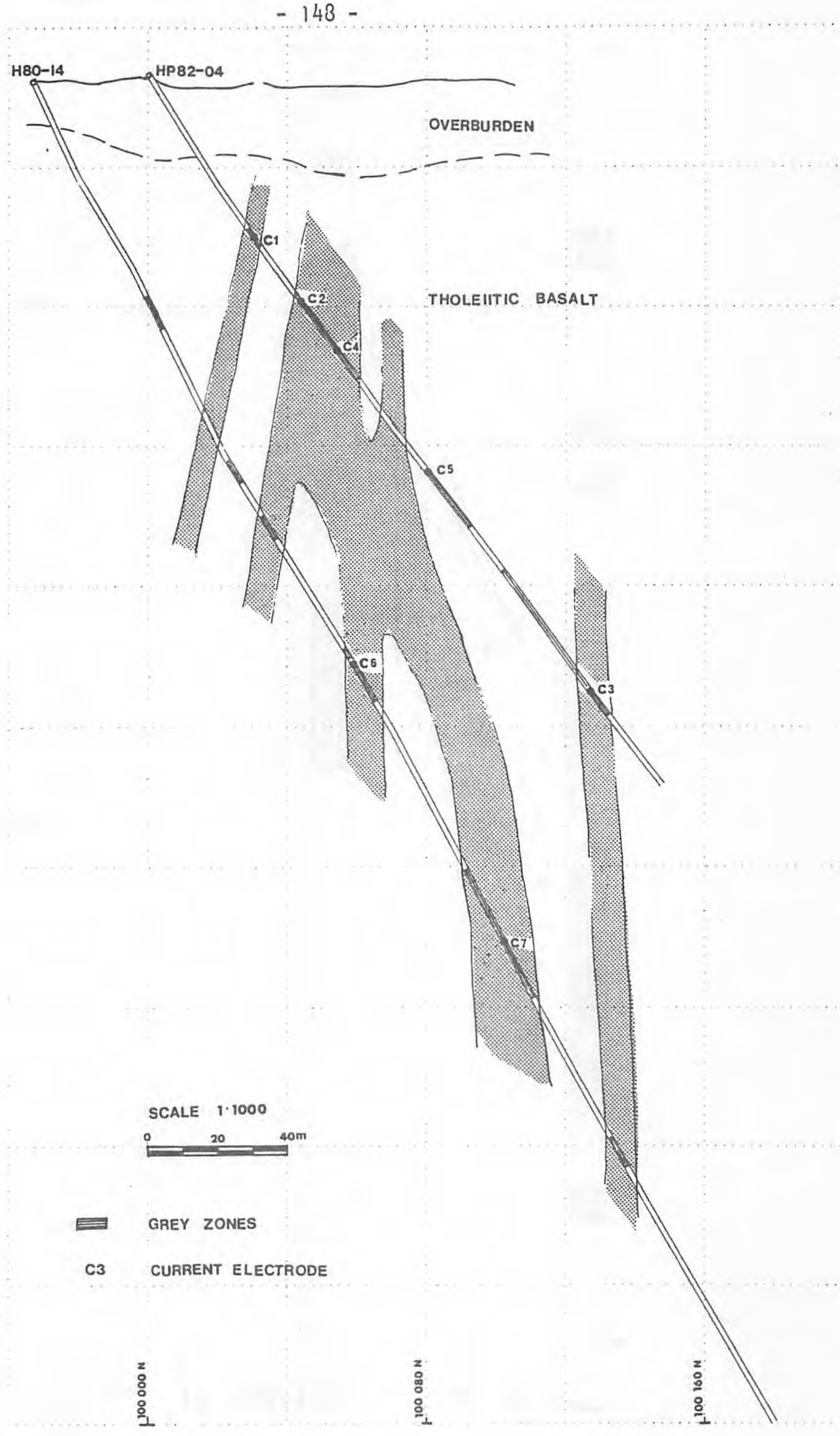
MALM G
(mV/Am)
MALM G
(mV/Am)


H80-14
HP82-04
OVERBURDEN
THOLEIITIC BASALT
C1
C2
C4
C5
C6
C3
C7
SCALE 1:1000
0
20
40m
GREY ZONES
C3
CURRENT ELECTRODE
100 000 N
100 080 N
100 160 N

APPLICATION OF GEOPHYSICAL METHODS TO GOLD EXPLORATION

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ABSTRACT

Although we have not found a practical geophysical survey method for the direct detection of gold, there are a number of indirect methods that have been used very successfully. To plan an effective geophysical approach, a geological model for the gold mineralization and its environment must first be formulated. Second, the geophysical characteristics of the model need to be identified. Finally, the background responses of adjacent rocks and soils must be taken into consideration.

The successful application of geophysical methods is illustrated by thumbnail case-histories of twelve mineralized areas. In all cases, the cause of the geophysical response and its relation to the gold mineralization are identified.

1 veins - stockworks lodes in volcanics / volcanics
2 skarns
3 ms v sulphides
4 granitoids
5 dis in vol - igneous - sed. beds
6 Pebble congl.
7 placers

ENVIRONMENTS AND MODELS

I have often said that it is a great help when one is exploring for minerals to know what one is looking for. Though many mines have been found by applying the wrong technique in the wrong place, this would seem to be a poor basis for carrying out systematic exploration.

The sequence commonly followed in designing, implementing and interpreting a geophysical program can be simplified as follows:

1. Develop model of favourable geological environment.
2. Develop orebody model.
3. List geophysical characteristics of environment and model.
4. Assess ability to recognise these characteristics in presence of geologic/topographic noise.
5. Design and implement survey program.
6. Compare results qualitatively and quantitatively with the environment/orebody models.

In the case of exploration for massive sulphides, for example, the above sequence is relatively straightforward and usually focuses on item 4 - namely the detectability of a given orebody of a particular size and depth in a given environment. In the case of gold, however, the process is much more difficult.

Without presuming to know more about gold deposits than the average person who probably has only 2-3 hours per week to spend on reading current literature, it would seem possible to classify gold deposits into the following seven major categories.

TABLE 1

Types of Gold Deposits

1. VEINS, STOCKWORKS, LODES in: volcanics/volcanoclastics; sediments and chemically favourable beds; igneous rocks; combinations of above.
2. SKARNS.
3. AURIFEROUS VOLCANOGENIC SULPHIDES.
4. AURIFEROUS GRANITOIDS.
5. DISSEMINATED AU-AG IN IGNEOUS, VOLCANIC AND SEDIMENTARY BEDS.
6. PEBBLE CONGLOMERATES: QUARTZITES.
7. PLACERS.

Of the above categories, I have probably taken the greatest liberty with the first. Lumping deposits in volcanic rocks with those in sediments and igneous intrusives may be an unpardonable offence from a geological point of view. It does, however, make some sense geophysically. In the following seven tables I have attemped to list deposit types for each of the main geological characteristics that would appear to have a measurable geophysical signature. Beside each characteristic I have indicated one or more geophysical methods that might be used in its identification and/or measurement. Characteristics, such as the actual mineral assemblage and distribution that do not appear to have a recognisable geophysical signature, are not included.

At the bottom of each table I have included a partial list of typical mineral deposits or mining camps. In some cases geophysics has played a significant or even important part in the discovery process. Often, satellite bodies to the main mineral deposits have been located with the aid of geophysics. In other cases I believe that geophysics could have made a contribution to either discovery or development had there been sufficient awareness of the advantages to be gained.

I.F. = Iron Formation

1. Veins, Stockworks, Lodes

Geol. Characteristic	Geoph. Method
Typical hosts: greenstones, slates, tuffs, I.F., cut by granitoids, gabbros.	Magnetics, gravity, gamma-ray spectrometry.
Faulting, fracturing, shearing important.	Magnetics, VLF, resistivity.
Granitization frequent, metamorphic grade important locally.	Magnetics, gamma-ray spectrometry.
Qtz, py, calcite typical gangue; graphite frequent.	IP, resistivity, VLF, piezo-electricity (?).
Alteration (eg. chlorite, calcite, pyrite etc.) widespread.	IP, resistivity, magnetics, VLF.

Examples:
Yellowknife, N.W.T.
Squall Lake, Man.
Campbell Red Lake, Ontario
Kerr-Addison, Ontario
East Malartic, P.Q.
Senator, Rouyn, P.Q.
Kalgoorlie, Australia

2. Skarn Deposits

Geol. Characteristics	Geoph. Method
High-grade metamorphism, granitization, injection of granite.	Magnetics, resistivity (?).
Usually near granitoid contacts carbonates and metacarbonates.	Magnetics, gamma-ray spectrometry, gravity.
Characteristic alteration: Ca-Mg-Fe silicates, magnetite, hematite.	Magnetics, gamma-ray spectrometry.
Py, arsenopyrite usually abundant; bodies large and irregular.	IP/resistivity.

Examples: Headley, B.C.
Battle Mt., Nev.
Rosita and La Luz, Nicaragua
Calumet, Ontario
Mengapur, Malaysia

3. Auriferous Volcanogenic Sulphides

Geol. Characteristic	Geoph. Method
Usually associated with felsic facies of volcanic pile.	Magnetics, gravity.
I.F., graphite common.	Magnetics, EM.
Sulphide host usually massive, lens-like.	EM (airborne-ground).
Disseminated or stringer zones less common.	IP.
Majority of Cu-Py-Au bodies carry Fe_3O_4 (minor).	Magnetics (with EM).

Examples: Horne Mine, Noranda, P.Q.
Detour Lake, Ontario
Sudbury, Ontario

4. Auriferous Granitoids

Geol. Characteristics	Geoph. Method
Usually felsic, coarse-grained, discordant.	Magnetics, gamma-ray spectrometry.
Ore associated with shattering, brecciation.	VLF, resistivity.

Examples: Silver Peak, Nevada
Natas, S.W. Africa
Dartmoor, U.K.
Canadian Malartic, P.Q.

5. Disseminated Au-Ag Deposits

Geol. Characteristics	Geoph. Method
Typically strata-bound in felsic intrusives, tuffs, I.F.	Magnetics, gravity, VLF.
In igneous rocks fracturing, shattering important.	VLF, resistivity.
In tuffs, I.F., drag-folding, faulting usual.	Magnetics, VLF, resistivity.
In chemically favourable rocks carbonates preferred.	Magnetics, resistivity, AMT.
Generally large tonnage, with widespread py, arsenopyrite, often graphite (with I.F.)	IP, VLF.
Sometimes associated with massive sulphide bands in I.F.	EM, VLF.

Examples: Camflo, Malartic, P.Q.
Lamaque, P.Q.
Madsen, Red Lake, Ontario
Homestake, S. Dak.
Carlin, Nev.

6. Pebble Conglomerates; Quartzites

Geol. Characteristics	Geoph. Method
Cg. deposits in erosional unconformities on old Precambrian rocks.	Magnetics, seismics, gravity, EM/resistivity sounding.
Sometimes associated with py or po (especially quartzites).	IP.
Sometimess associated with magnetite-hematite.	Magnetics.
Sometimes associated with U or Th.	Gamma-ray spectrometry.

7. Placers

Geol. Characteristics	Geoph. Method
All associated with alluvial, eluvial or beach deposits of coarse sediments.	Seismics, resistivity.
Often controlled by bedrock topography.	Seismics, resistivity, magnetics.
Sometimes associated with magnetite.	Magnetics.
Alluvial deposits affected by stream dynamics.	Seismics.

Examples: Quadrilàtero Ferrífero, Brazil
Luzon, Phillippines
Hargraves, Lucknow etc., N.S.W.
Kuranakh, U.S.S.R.
Fraser River, Cariboo, B.C.
Lena Basin, Siberia
Klondike, Yukon

The following examples are intended as illustrations of the geophysical signatures listed in the above tables. Each one, by itself, is only a fragment of the tapestry that constitutes the complete signature or thumbprint of the mineral deposit to which it is related. Sometimes it is the important fragment. Generally, however, like a jigsaw puzzle, many more fragments are needed before the tapestry can be fully appreciated.

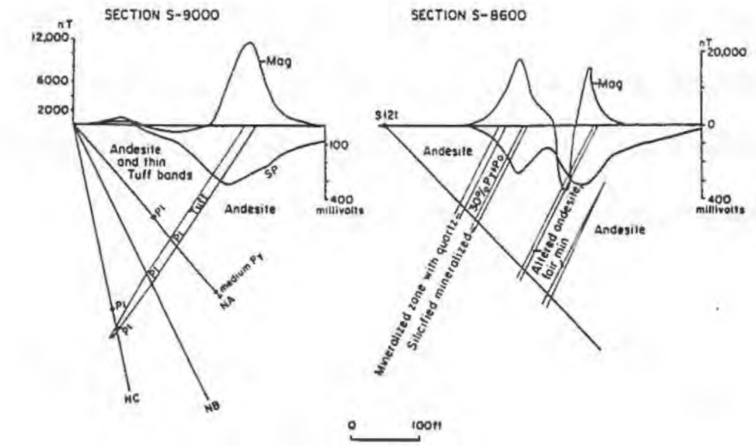
The analogy can be carried further. Viewed at the start, looking for a gold deposit is as complex and uncertain as weaving a tapestry or solving a jigsaw puzzle. After discovery, the whole process looks trivial and straightforward.

The lesson is simple. The key to solving a puzzle effectively is to use all of the available parts in a logical and systematic sequence. In the case of exploration, the difference is simply one of scale. There are infinitely more parts and the logic is more complicated. But to attempt to explore for gold without considering the use of geophysics and geochemistry, is equivalent to solving a jigsaw puzzle with only one third of the pieces.

CASE-HISTORIES

Madsen Red Lake, Ontario

Figure 1 shows magnetometer and SP profiles over two sections of the Madsen orebody. In both cases the mineralization occurs as disseminations, with pyrite and pyrrhotite, in tuffaceous, andesitic beds in a predominately mafic volcanic sequence. Magnetite is probably present also. The beds are clearly defined by both their magnetic and SP responses. In plan form the magnetic and SP contours closely delineate the surface traces of the gold-bearing beds.



MAGNETOMETER AND S.P. PROFILES OVER AU-BEARING TUFF HORIZONS, MADSEN MINE, RED LAKE, ONTARIO

Figure 1

Elsewhere on the Madsen property it was found that the magnetic anomalies could not be separated from the background response of the country rocks. Here, VLF resistivity methods were used effectively to detect the mineralized beds which, in this area, were altered in such a way as to significantly lower their resistivity.
IP didn't work to well due to wide spread pyrite in country rocks

Jerome Mine, Ontario

This deposit, in Osway Township, produced gold from 1939 to 1943 from a shear-controlled vein along the contact between granodiorite porphyry and Timiskaming age metasediments.

Ground geophysical methods were used in 1979-80 to assist in guiding a surface exploration program prior to further underground development.

Figure 2 shows magnetic, VLF and IP/resistivity data on a profile centrally across the main ore zone. At this location the zone is approximately 30 feet wide and occurs as a strongly hematized shear zone in the hanging wall of the contact between the porphyry and a sequence of mainly conglomerates, arkoses and greywakes.

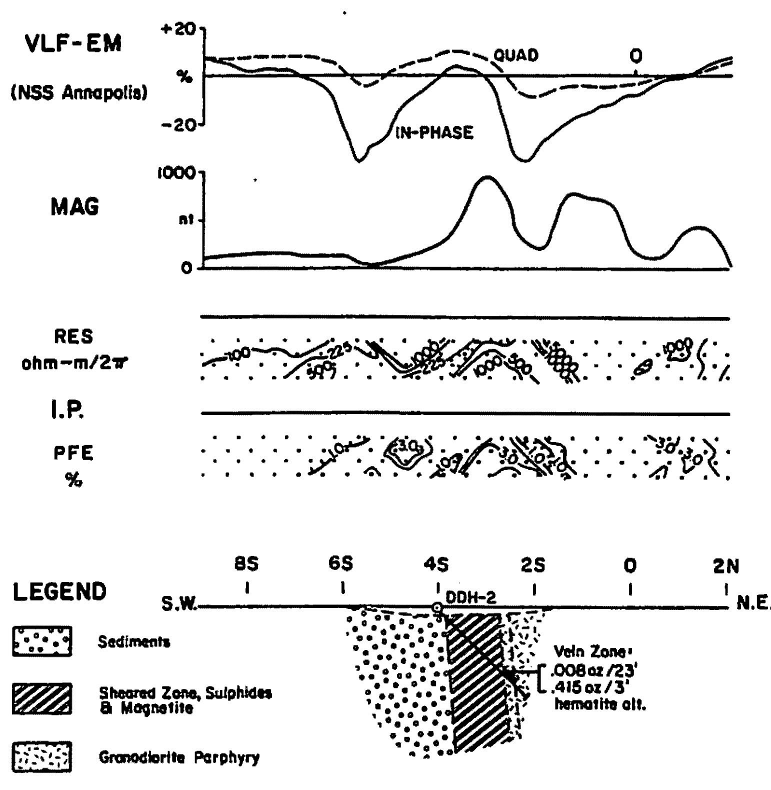


Figure 2
I.P., VLF-EM and Magnetometer Profiles
Jerome Mine, Osway Twp., Ont.

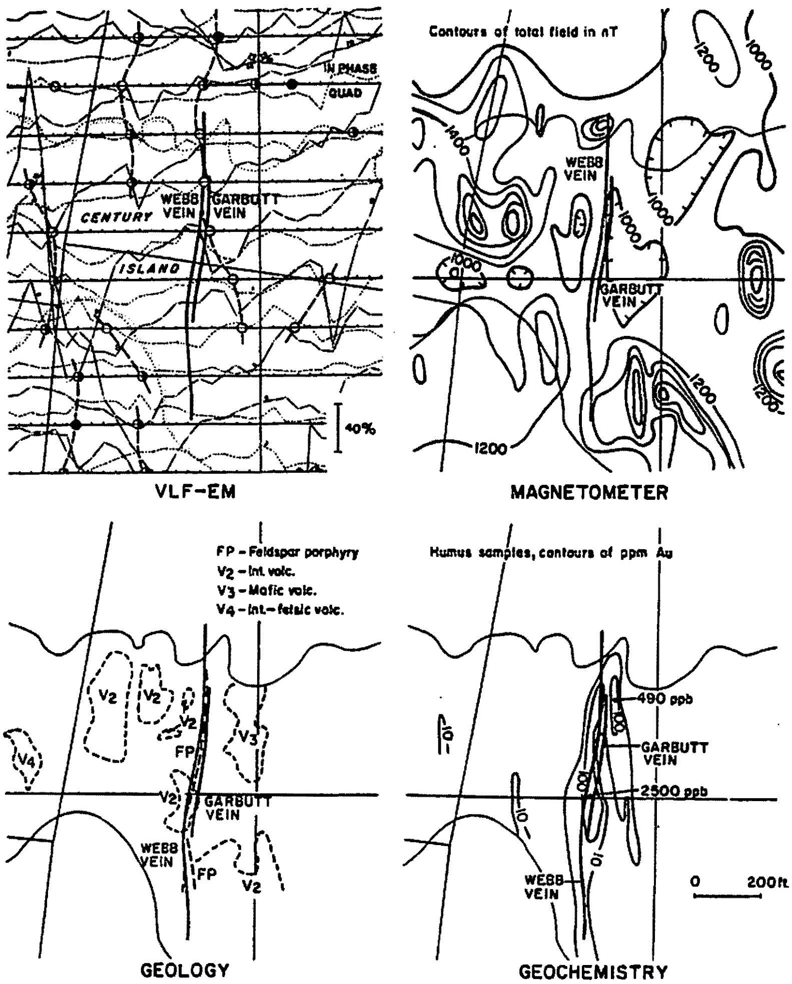
It is evident that the strong geophysical responses are centered not over the ore zone but over a wide band of sulphides with magnetite, occuring in the footwall of the contact. The ore zone itself is marked by a consistent magnetic low, corresponding to the hematization.

Systematic surveys at close spacings on lines 200 feet apart were used to delineate the hematized porphyry, which was nearly everywhere flanked by a similar band of sulphides. Three exploration holes encountered gold in the hanging wall of this prominent structure.

Elbow Lake, Manitoba

Ground geophysical surveys and geochemical soil sampling were carried out for Ram Petroleums Limited in 1980. The investigations centered on the Webb and Garbutt veins, comprising the main ore zone of the old Century Mine, on which development work was carried out in 1936. The veins are in sheared mafic volcanics adjacent to a feldspar porphyry dyke. The dyke is generally altered and brecciated, and carries both quartz and sulphides locally.

As illustrated in Figure 3, the magnetometer survey showed a picture characteristic of sheared metavolcanics, with little or no expression of the dyke or the associated shear zones. The VLF EM survey, however, produced fairly discrete anomalies which subsequently have been found to be associated with shearing. The brecciation and alteration of the quartz feldspar dyke may also contribute.



GEOPHYSICAL-GEOCHEMICAL SIGNATURES,
CENTURY MINE, ELBOW LAKE, MANITOBA

Figure 3

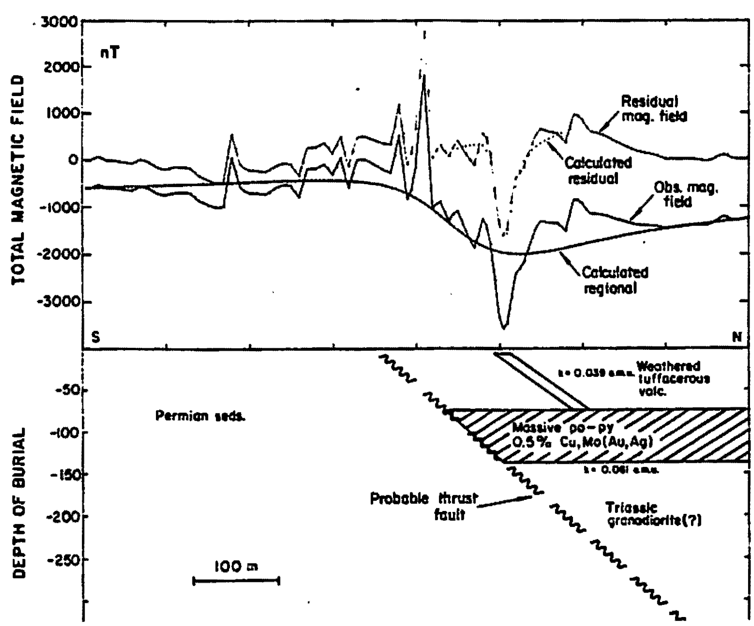
Nuclear activation analyses of humus samples taken at 25-ft centers showed gold concentrations of up to 2500 ppb over the veins, against a background concentration of generally less than 10 ppb.

Further exploration in the area concentrated on coincident VLF EM and geochemical anomalies. Some of these were found to be related to the Vanderberg showings, approximately 2 km northwest of the Century Mine.

Mengapur, Malaysia

The Mengapur deposit is essentially a large pyrrhotite-pyrite-magnetite skarn adjacent to Triassic granodiorite in Permian sediments and tuffaceous volcanics. The drilled area is in excess of 16 km^2 and the body is understood to average more than 200 m in thickness. The sulphides carry about 0.5 percent Cu-Mo, as well as a roughly equal value in Au-Ag.

The deposit was found as a result of a geochemical soil survey in the vicinity of a prominent aeromagnetic anomaly. Ground magnetic traverses were carried out, as illustrated in Figure 4.



OBSERVED AND FITTED MAGNETIC ANOMALIES
MENGAPUR AREA, MALAYSIA

Figure 4

The computer modelling results shown in the illustration indicate a highly magnetic zone (equivalent to 24% Fe_3O_4 by volume) lying beneath about 75 m of non-magnetic cover. Within the cover there are numerous narrow bodies, each dipping about 45° northward.

Available geological information confirms the approximate location and dimensions of the body and the existence of bands of magnetite-rich mineralization in the overlying weathered volcanics.

Opawica Lake, P.Q.

A seismic survey was carried out in 1980 on the Opawica Explorations Option of Falconbridge Nickel Mines Limited in Gand Township, P.Q. The purpose was primarily engineering: to map the bedrock topography and to detect the presence of bedrock faulting. As a by-product, however, it was found that a prominent fault zone in the hanging wall of the orebody produced a distinct anomaly in the seismic velocity map.

Figure 5 shows a typical seismic interpretation section over the main zone of mineralization. The gold-bearing syenite occurs on the contact between diorite and andesite. Seismically it appears as a zone of velocity 7200 m/sec within andesitic and dioritic country rocks whose velocities average 5400 m/sec. Furthermore, a zone 10-15 m wide of very low seismic velocity was found in the hanging wall side of the contact. This has been interpreted as a shear zone.

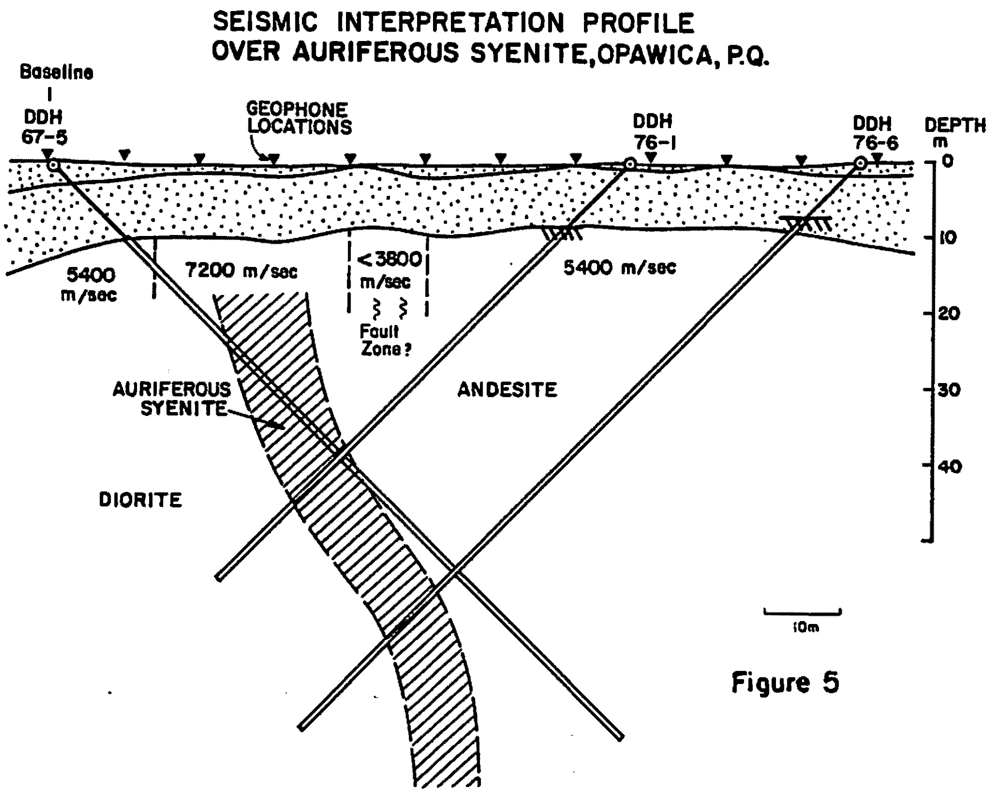


Figure 5

Zones of similar velocity characteristics were mapped elsewhere on the property and have been recommended as targets for further exploration.

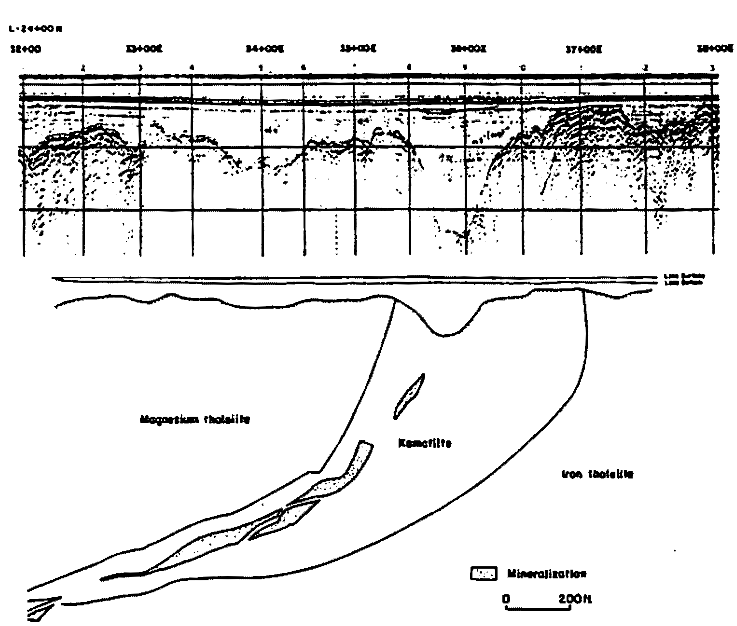
Kiena Mine, Val d'Or, P.Q.

A marine seismic survey was carried out in 1982 over a portion of Lac de Montigney in the Malartic area, Northwest Quebec. The main purpose was to locate and map the bedrock surface underlying lake-bottom sediments, as part of crown pillar studies of the Kiena Mine underground workings. The survey was extended to explore other holdings of Kiena Gold Mines Limited for the purpose of assisting exploration work and locating faults or shear zones in the bedrock.

The continuous reflection seismic profiling system consisted of a mechanical "boomer" and a single hydrophone receiver, both towed behind a 26-foot steel boat. The survey was controlled by an electronic range-range positioning system.

Good sub-bottom reflections were obtained over most of the area and bedrock was mapped reliably except in localised areas of thick organic sediments.

Figure 6 shows a typical profile over the S-50 zone which follows closely a prominent bedrock depression. This could be the result of differential erosion and/or faulting. The seismic reflection method provides no information on bedrock velocity.



Seismic Cross-section
over Kiena Mine
Quebec

Figure 6

Other prominent bedrock depressions were mapped elsewhere under the lake and have been used as a guide for further exploration.

CONCLUSIONS

The above examples illustrate how geophysical methods are able to recognise several of the geological features associated with commonly occuring gold deposits. Specifically, we have seen the following important relationship:

1. VLF EM anomalies over shear zones enclosing or adjacent to gold-quartz veins.
2. Magnetic and SP anomalies over gold-pyrite disseminations in tuffaceous beds in volcanic rocks.
3. Magnetic and IP anomalies over sulphide- and magnetite-rich shear zones adjacent to gold-quartz vein in granodiorite.
4. Magnetically inactive zones over hematized, gold-bearing zones in granodiorite porphyry.
5. Low seismic velocities associated with a shear zone adjacent to a mineralized syenite porphyry. High velocity over the syenite itself.
6. Buried bedrock depressions over a preferentially weathered ore zone under lake-bottom sediments.
7. An unusual magnetic anomaly over a Cu-Mo-Au-Ag skarn zone adjacent to a granodiorite intrusive.

The major limiting factor to the successful application of geophysics to gold exploration is the lack of uniqueness of geophysical signatures. For example, a non-mineraliaed shear zone may not be recognisable from a mineralized one. A skarn zone with gold may look exactly like a skarn zone without gold. There may be no solutions to such problems other than to drill a lot of holes.

In some cases, as we saw at Elbow Lake, Manitoba, a secondary method such as geochemistry, will reduce the ambiguity. Where the mineralization carries both sulphides and magnetite an IP survey may provide the necessary degree of uniqueness. To select the appropriate complementary method, one should know as much as possible about the model that one is looking for. If one does not have a known model to work from one should develop a detailed conceptual model. It may turn out to be a false one, but it is always hard to get from A to B without going down a few blind alleys.

The second most serious limitation to the use of geophysics is the difficulty of recognising weak signatures in the presence of strong background variations. As we saw at Elbow Lake, it was impossible to recognise the weak magnetic low associated with a narrow porphyry dyke in the presence of strong linear anomalies from the adjacent mafic volcanics. Likewise, the weakly magnetic tuffaceous beds on the Madsen property were not distinguishable in areas underlain by other magnetic rocks. In such cases the use of several geophysical techniques is sometimes successful, even when one does not have a very clear idea of what kind of background geophysical responses will be obtained.

Orientation surveys over both mineral showings and unmineralized country rocks can help establish both the signatures of interest and the ones that have to be dealt out.

A word of caution: signatures of country rocks differ widely from place to place even on a property scale. It is a mistake to rule out a method, such as magnetics, because country rocks in one part of an area show a high background response. This condition may not prevail everywhere and, besides, variations in the character of the response is often revealing of the metamorphic and/or tectonic history of the terrain.

A final word concerning signatures. The geophysicist should be alert for geophysical signatures that do not match the prevailing model of the mapped or inferred geology. Too often we tend to explain away differences in location or differences in apparent lithology on the basis of limitations in the state of the art. It is when the geophysics does not fit the geology that the geophysicist should become most interested. A famous geophysicist once said that his interpretation of a particular survey was complicated because of the abundance of geological information. His was not a unique situation. Most of us are faced daily with such problems and it is essential to remember that the physical properties that we measure are seldom related directly to the mineral assemblages which form the basis for the geological classification. The geophysicist is seeing something different, and that difference could be the all important factor in distinguishing between an ore-bearing environment and one that is just plain rock.

Hemlo.

75MT - 19m oz

Au in transitional stratigraphy
- entire volcaniclastic is anomalous in Au

fine diss. free Au in sulphide sed.

Moore Lk   Selwyn - fine grained py.

Surface c's - variable, OB thickness and composition

o/c - 1K - 20K Ω-m

swamp 500 Ω-m

E & W of main cap 100 Ω-m in clay OB

- They bought Aerodat's package (16K l.km)

Done to mag. { Red to pole. / down cont / R. calculation / dyke suppression - lots of dykes.

good. mag response over ore zone.

TF + Grad - grad did see several anomalies not apparent in TF.

IP best is small "a", ie 100' better than 200'

Golden Sceptre

6 - 7% PFE effect

3K - 7K Ω-m ore - 9 - 26K bg

Zone 250 m wide

20 IP anomalies most barren

combine VLF &

GSC Logging density anomaly corr to 10% barite content

Halloff

- comments on grad IP - too insensitive for gold work.

price ~ $40K

- new receiver - sugg both IP and mag field or EM & E field
- Spectral study - doing rock property measurements to go with Alan's study. he said rocks show a lot of variability - much more than what appeared in Imaspring results

NOV 12

Horizontal Mag gradient

Patterson said measurements need to be made
in two directions or ∥ to earth's field

- what ~ station density - 25m / 12.5m / 6.25m

Kidd TEM

- Prefer in-loop to get away from ring current effects
  600m × 300m loops common
- found new coil is much faster but runs out of memory.
- use XT clocks - good for UG but heavy - looking fwd to new rec -
- like 3 comp cause they don't often know geol strike - blind prospect

Casa Berardi

- BK said IP good but lots of anomalies are ∅
- did a big play on using reprocessing, ie Rapp, column plots etc & nothing really new showed up. - he sugg it is a presentation tool not interp

J. Mwenifumbo

- Patterson R tool can rundown if not switched off properly.
- with other coils, range of ea which can be measured can be varied
- considerable drift, sometimes non-linear apparent particularly notable at low R values
- at Kemb, highest values of sulphides ~10 Ω-m
- Lumina dhole has only 200' cable; still have problems of sorts
- their Kemb δ data is a bit suspect re processing due to low count rate -

J. Corbett - (personal comment) NOV 12.

problems with grad in low mag latitudes; anomalies but what do they mean! - Dave Jones comment appropriate - you have to have a good idea of what you are looking for before grad makes any sense!

NOV 13 Eastmain - ~~Au~~ sulphides 10-30%
mag lows - abatements - lows along mag highs

Beniawell's talk
OMNR data shows mag second least common (schedule is last) ← Py ~80% ~same as qtz.
- hematization or destruction of mag is common in deposits
mentioned McCool TWP discovery

F400 dual oop (McPhar)
Aerodat

3 zones
VLF / Max-Min / DEEPEM.
- downhole PEM used and quite useful.

one result this year showed in hole response with one loop and a off hole response with another loop

- sulphides not much but well interconnected - ccp ass with gold

A. L. VLF EM16R - 12.5m Δs.

- zones greater 2000 m-m outlined.

Seattle results sort of broken up, ~~Hawaii~~ likely due to strike of A being poor

- Effects of topo

- Hawaii results smoother but s/n was weak.

- 50m dp-dp. ρ results picked up some zones but others too narrow ie showed up on EM16R but not IP. chang broad but not specific enough.