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# VECTOR PULSE ELECTROMAGNETOMETER SURVEYING

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Consulting Geophysicist
February 1979

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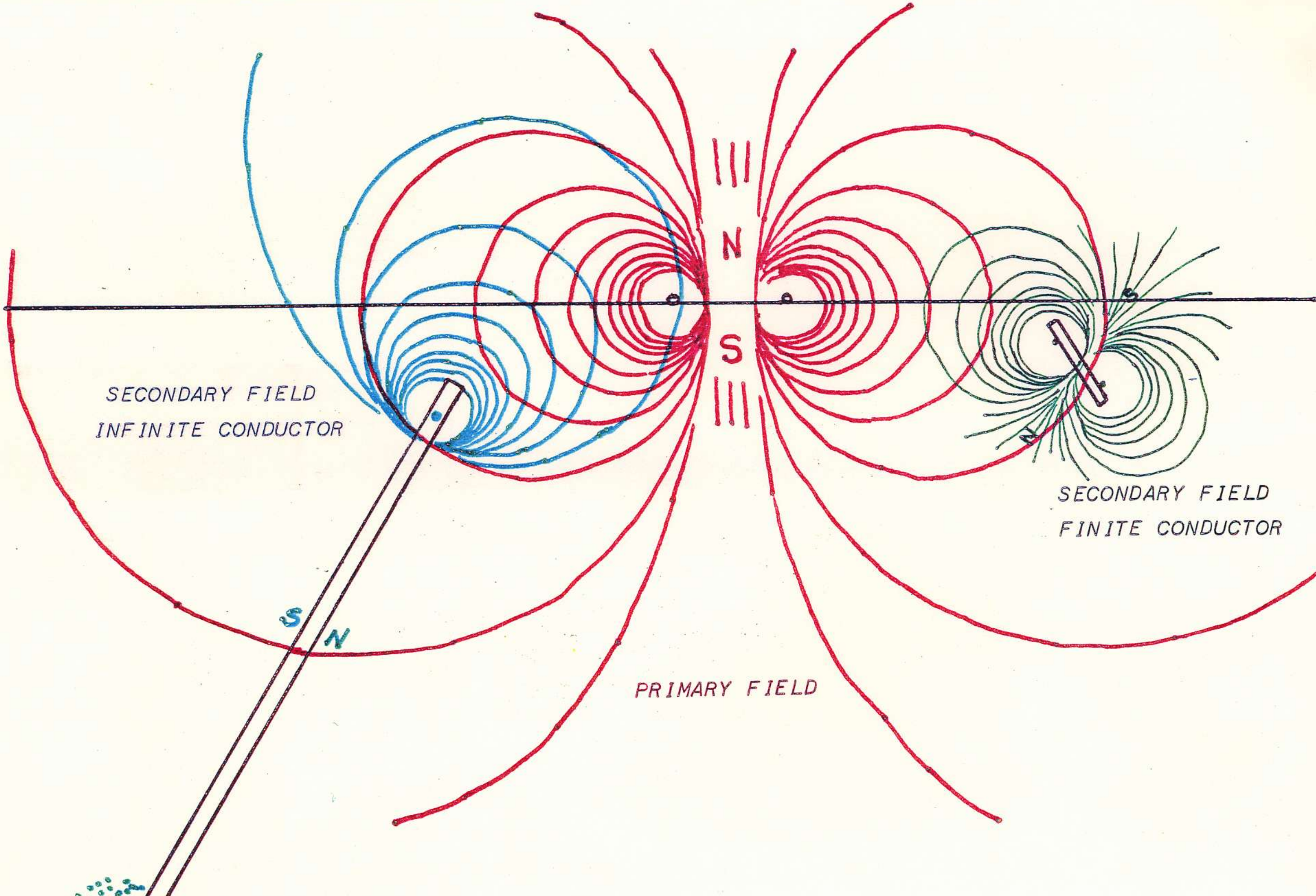
## INTRODUCTION

The purpose of this short paper is to give a general description of the vector pulse electromagnetometer method and its application and cost effectiveness to mineral exploration.

## INSTRUMENTATION

The VEM technique utilizes the Crone pulse electromagnetometer system and is comparable to the DEEPEM method described by Duncan Crone.

The pulse electromagnetometer system is a time domain electromagnetometer system which measures the secondary field directly rather than a resultant field reading. The primary current wave form through the transmitter loop is 10.8 ms on, 10.8 ms off with a 1.4 ms ramp shut-off. The current wave form pattern is transmitted to the receiver by radio ( or cable if required in horizontal loop surveys ) where eight delay time-windows or channels, of the secondary field are sampled after the current shut-off at 0.15, 0.30, 0.55, 0.90, 1.45, 2.40, 4.00 and 6.40 milliseconds to the center of the sample. This gives an approximate frequency equivalent range of 2000 cps to 20 cps. The sample amplitude is normalized




MODEL ELECTROMAGNETIC FIELDS

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by setting to 1000 a sample taken of the maximum shut-off voltage amplitude measured at the receiver. Thus, the pulse method is free of the geometrical restriction between the transmit and receive coil positions. This means that accurate surveys can be obtained in rugged and heavily timbered terrain.

## SURVEY TECHNIQUES

### Horizontal Loop Survey

The PEM system can be used as a regular horizontal loop electromagnetometer system with coil separations up to 150 m depending upon the primary transmit coil size. The normal coil is a multi-turn loop of wire 6 m in diameter laid out in a rough circle on the ground. Daily production varies from 50 - 120 readings depending upon terrain. Penetration is equivalent to the Max-Min system at ≁ 50% of the coil separation. Production by conventional systems such as the Max-Min system in flat terrain is greater than the PEM. However, where secant chaining is required or more than 3 freqnencies are taken, the PEM becomes the more cost-effective instrument. This is particularly apparent in the Cordilleran where many mineral zones are poor conductors and their responses equal that caused by topography with conventional systems. Thus, since the PEM reads only the secondary field response, it is relatively free of these geometrical restrictions. The availability of the eight channels allows for more precise interpretation of surficial conductors or changes in lithology.

## Vector Electromagnetic Surveying

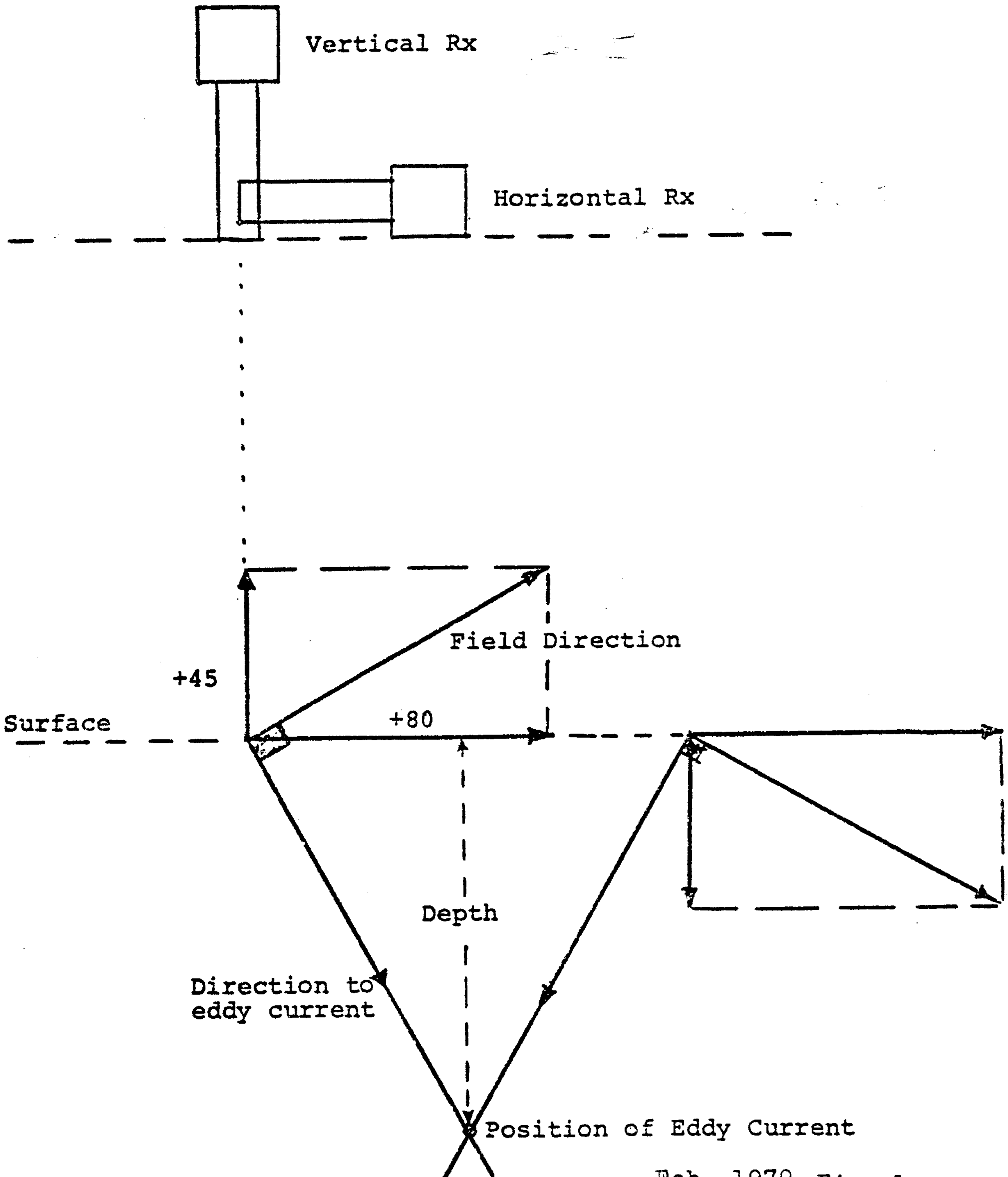
The vector pulse electromagnetometer system is a new survey technique which is giving deep penetration in the order of 200 - 300 m and is able to resolve complex finite source and infinite source conductor fields. This system is very cost-effective and has been successful in detecting narrow finite source conductors such as plunging lenses of massive sulphide mineralization and infinite source conductors such as those beneath the Athabasca sandstone in Saskatchewan. The vector pulse electromagnetometer system uses a transmit loop of 100 - 150 m / side which gives a powerful dipole magnetic moment. Thus, since only the secondary field is read, the receiver can be moved at intervals away from the transmit loop. An area of 600 x 800 m can be covered / side from one loop setup. At each station, X, Y and Z components can be obtained. Only the horizontal X and vertical

Z are read on a normal survey. The secondary field lines for samples ( Channels ) 1 and 2 are shown on Figures 1 and 2. The resultant field, from the X and Z component, is termed the scalar field. This field is important for finite conductors. The right angle to this resultant field is the VECTOR which for an infinite source model will point at an eddy current position. Thus, since 8 channels, equivalent to 8 frequencies, are obtained at each station. A considerable amount of information is available for interpretation of the source field and its host environment. Glen E. White Geophysical Consulting & Services Ltd. has developed computer plotting routines which plot the vector sections, horizontal components, vertical components and plan maps of the horizontal component data.

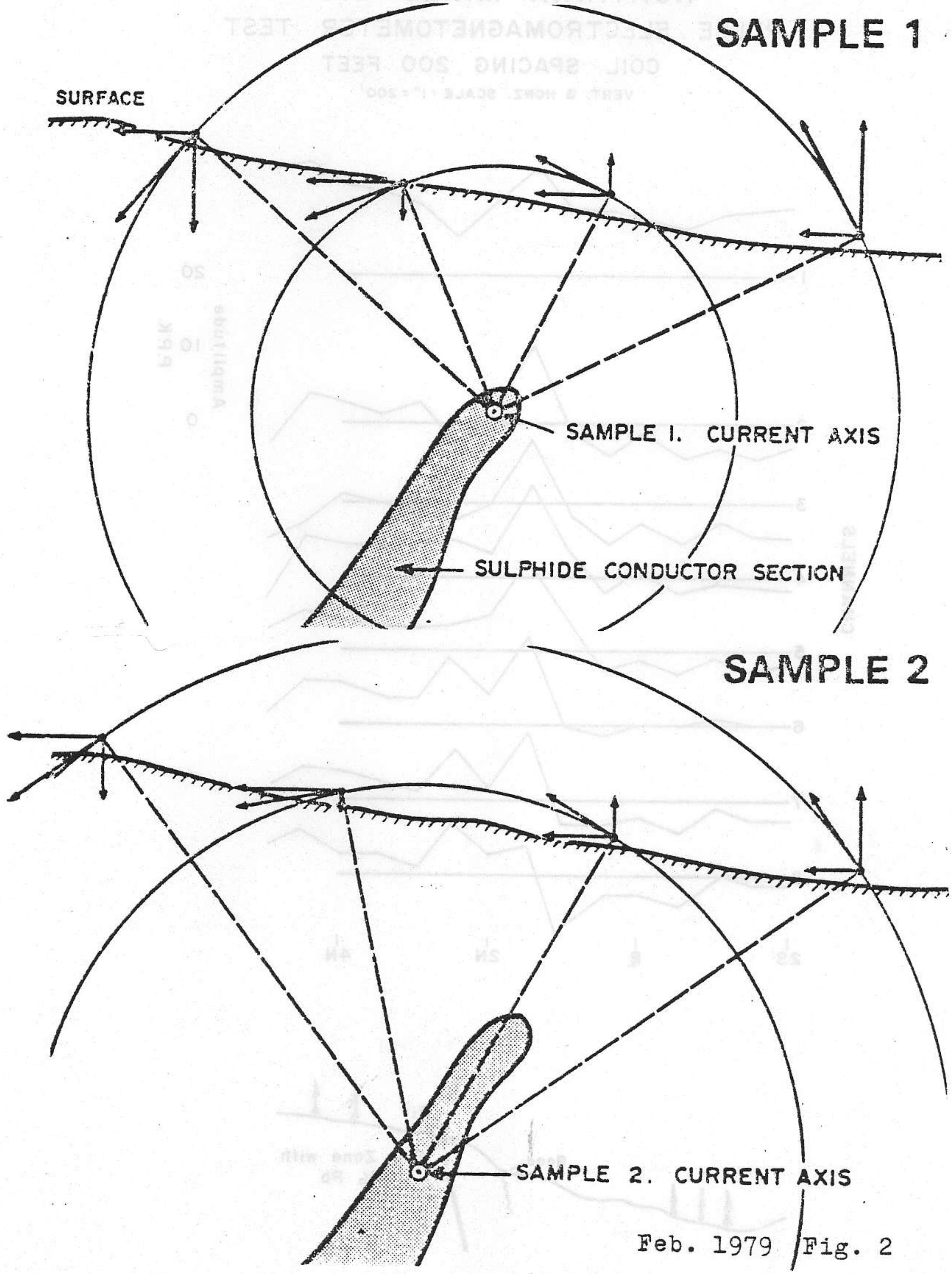
## SURVEY RESULTS

### Horizontal Loop Data

Figure 3 shows a low amplitude horizontal loop PEM anomaly. This example is from Northair Mines Ltd. a successfully producing gold mine near Squamish, B.C. The zone shown is the "Discovery" zone with some 4% Pb minor pyrite and chalcopyrite with precious metal values. The PEM in channels 1 - 3 detects a mineralized fault zone beneath the road. Channels 4 - 8



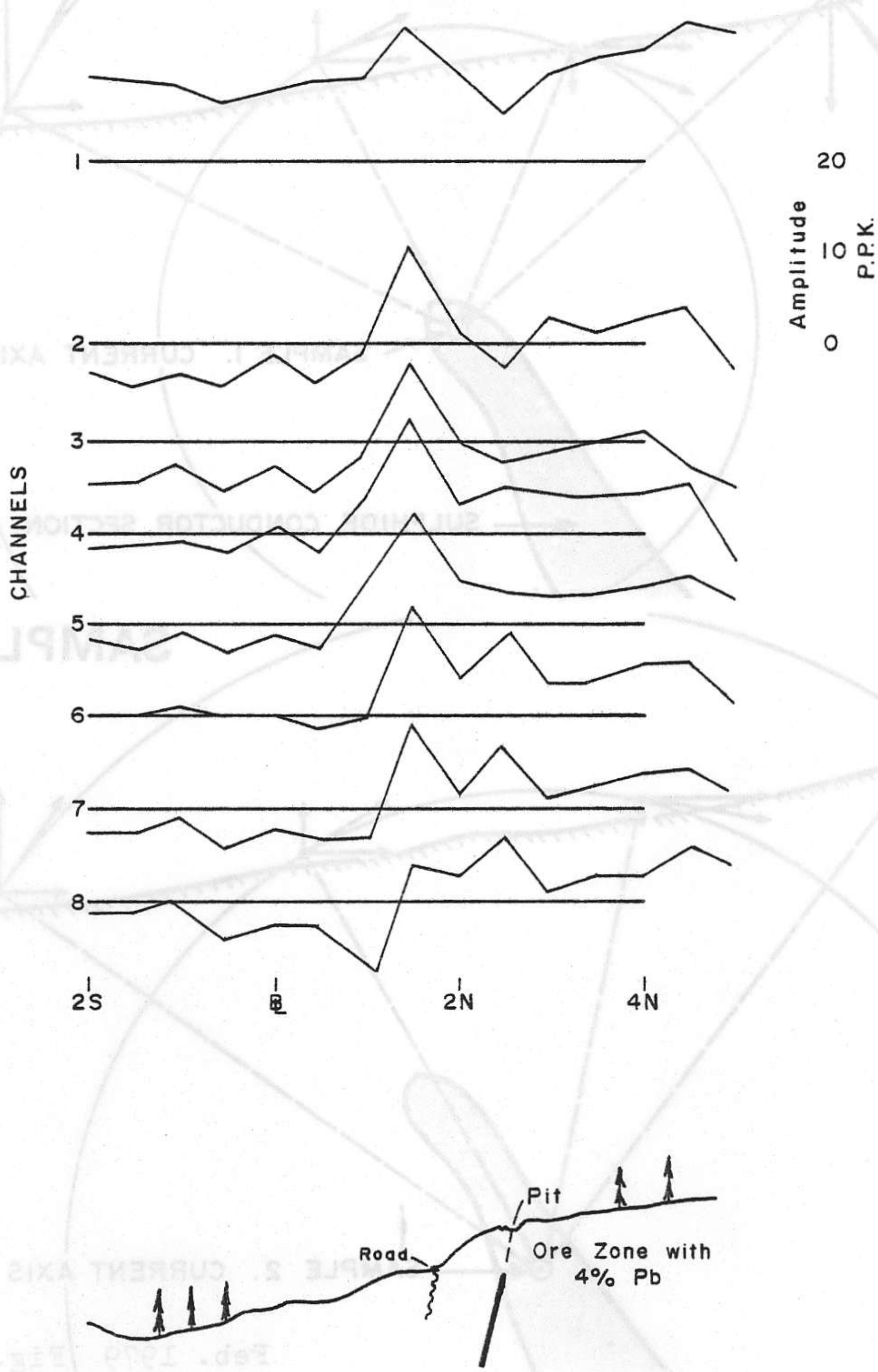

Feb. 1979 Fig. 1




Feb. 1979 Fig. 2

## Location of the Current Path in the Conductor

# NORTHAIR MINES LTD.
## PULSE ELECTROMAGNETOMETER TEST
### COIL SPACING 200 FEET
VERT. & HORZ. SCALE : 1" = 200'




Feb. 1979 Fig. 3

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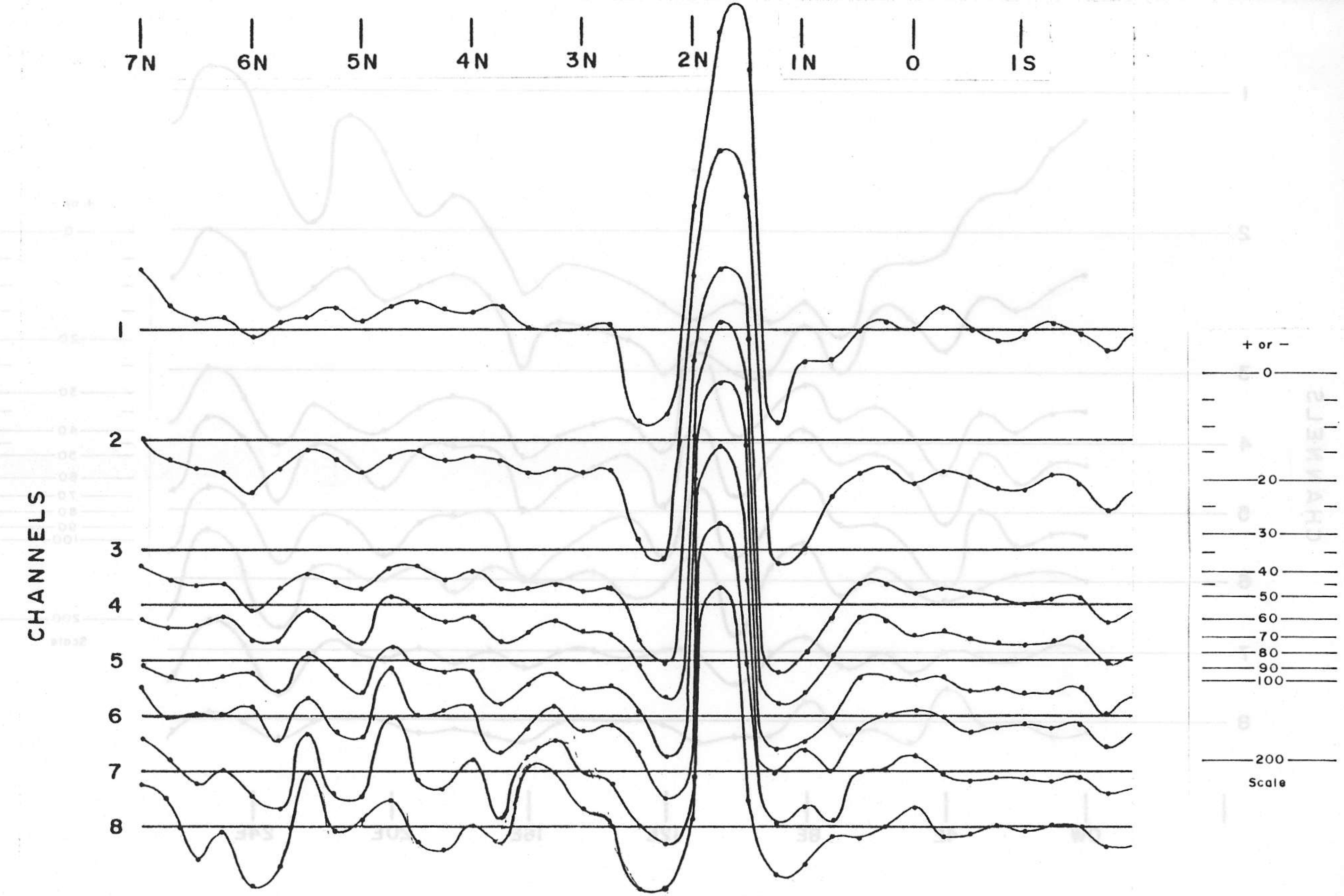


NARROW MASSIVE SULPHIDE CONDUCTOR

— HORIZONTAL LOOP P.E.M. —

SEPARATION 50M

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1cm = 50m

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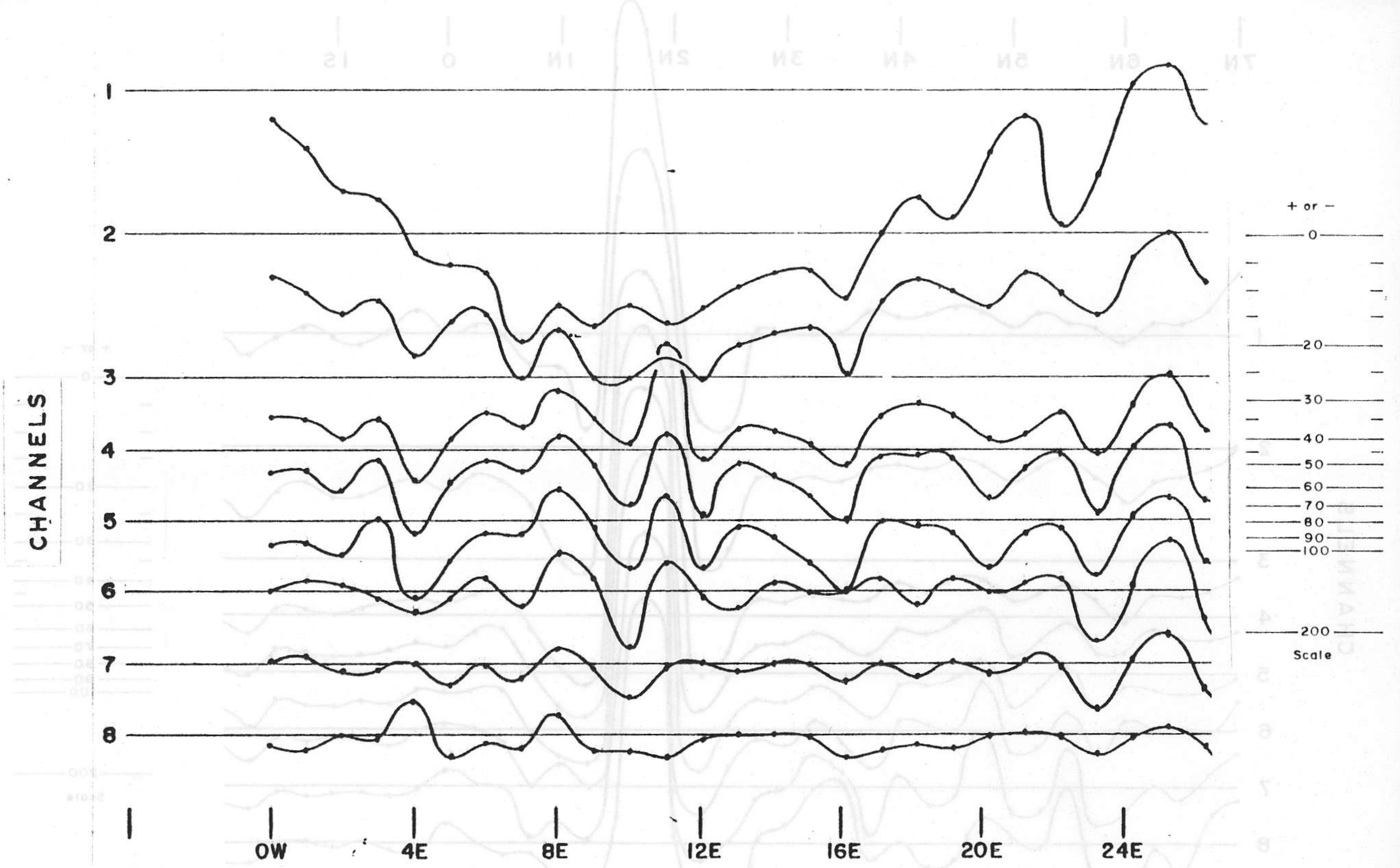
Fig. 4




SURFICIAL CONDUCTOR RESPONSE

— HORIZONTAL LOOP P.E.M. —

SEPARATION 200 FT.

*Glen E. White geophysical consulting & services ltd.*

½" = 200'

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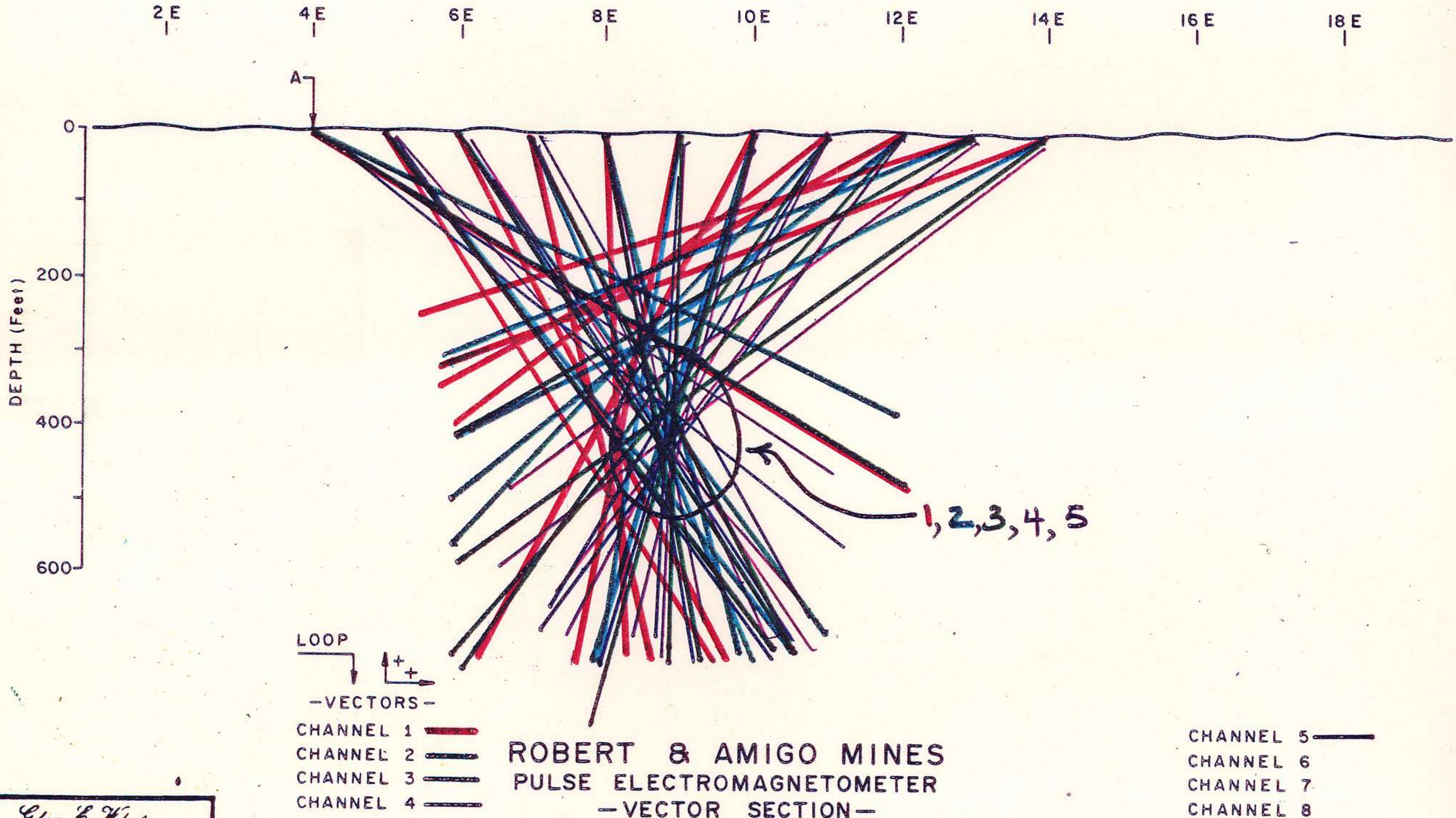
Fig 5




ROBERT & AMIGO MINES
PULSE ELECTROMAGNETOMETER
-VECTOR SECTION-
LINE 4+00 S
-INSTRUMENT: CRONE P.E.M.-

Scale: 1" = 200'

Fig 6

MAY, 1978
FIG. 34

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which are equivalent to decreasing frequencies, detect the ore zone at a depth of some 100 feet.

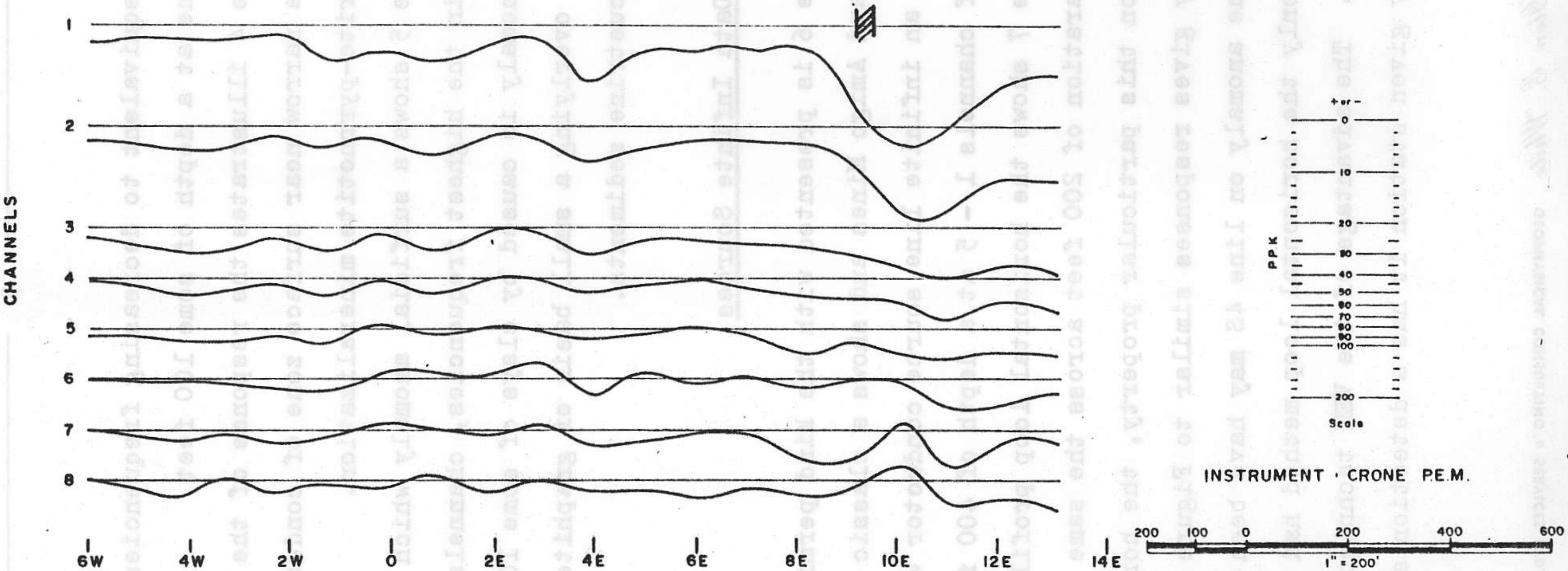
Figure 4 illustrates the response of the PEM system to a narrow near surface zone of conductive massive pyrite-pyrrhotite mineralization.

Figure 5 shows a surficial anomaly which is reflected in the highest frequencies, channels 1 and 2. This anomaly is caused by clays of some 10 - 50 ohm-meters overlying a small basin of graphite-bearing lacustrine sediments.

## Vector EM Data Infinte Sources

Figure 6 is presented with the kind permission of Robert and Amigo Mines and shows a classic vector section of an infinite line source conductor with focusing of channels 1 - 5 at a depth of 400 feet.

Figure 7 shows the horizontal loop profile with a separation of 200 feet across the same line. Elsewhere on this particular property, the horizontal loop survey gives responses similar to Figure 4. However, the anomaly on line 4S may have been overlooked if only the horizontal loop method had been undertaken. The advantage of the VEM technique is that at any given station it has a detection ability




N.T.S. 82 E/2

ROBERT & AMIGO MINES

GREENWOOD MINING DIVISION – B.C.

PULSE ELECTROMAGNETOMETER
SEPARATION 200 FT.
LINE 4+00 S

To Accompany Geophysical ...
Date ..........
By GLEN E. WHITE B.Sc. .......... GEOPHYSICIST

PROFESSIONAL ENGINEER — PROVINCE OF BRITISH COLUMBIA — GLEN E. WHITE

Glen E. White geophysical consulting & services ltd.

INTERPRETED BY: G.E.W.
DRAWN BY: T.M.
CHECKED BY:
DATE: MAY, 1978
FIG. No.: 15

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Fig 7

of some 300 m depending upon the conductivity thickness product of the source. Experience has shown that because of the large magnetic moment of the transmit loop, poor anomalies can be detected to a depth of some 100 - 200 m beyond the conductivity thickness product range of both the PEM and Max-Min systems.

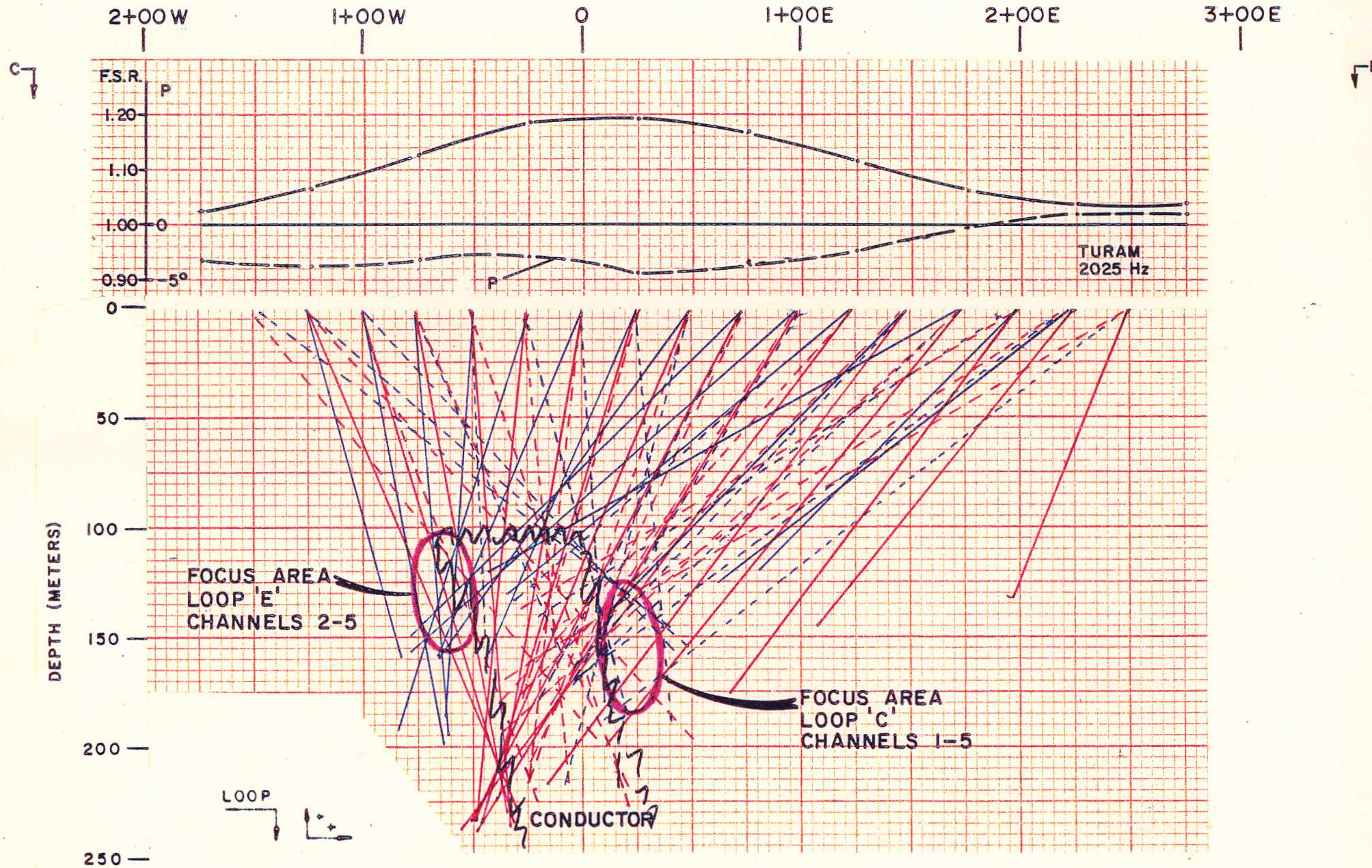
Figure 8 is published by the kind permission of Mr. Don Buchholz, P. Eng, Manager of Mining, Asamera Oil Corporation, who with his experience in time domain EM in Australia was willing to test our technique in Saskatchewan. This Figure is a composite of two loop setups and shows only the channels 1 and 2 data. A turam profile taken with an Androtex unit is shown for comparison. The vector data clearly defines both flanks of the conductor and gives a depth to top of some 100 m.

## Vector EM Data Finite Sources

Figures 9, 10 and 11 are illustrated with the kind permission of Nels Vollo of Craigmont Mines Ltd. and cover a line across a massive sulphide prospect near Kamloops, B. C. Figure 9 shows channels 1 and 2 plots of the secondary electromagnetic field data which indicates that the mineral zone is responding as a dipole magnet or as a finite electromagnetic source. The vectors on the dashed lines show a very shallow focus and can not be used in this model. The actual horizontal and vertical component plots are shown on Figures 10 and 11 where a conductor of good conductivity thickness product is easily interpreted.

Figure 12 illustrates an example where a conventional horizontal loop survey has insufficient magnetic moment to energize a plunging lense of poorly conductive sulphide mineralization. The center of this lense contains 10 feet of 3.5% copper. The vector technique on the other hand, with its large magnetic moment, energizes the complete crossectional area of the lense, and a weak secondary field is generated as is indicated by the channel 1 horizontal component data.

Figures 13 and 14 depict a more complex situation in an area of an old mine, where finite lenses of massive sulphide mineralization are located in a volcanic/sedimentary complex where there is a mixture of syngentic and fracture filling pyrite and irregular topography. They are used by kind permission but not of disclosure. Figure 13 shows a chargeability profile obtained with a 60 m Wenner array which gave two weakly anomalous peaks, one in an area of a resistivity low and the other in an area of high resistivity.




CHANNEL 1
CHANNEL 2
CHANNEL 3
CHANNEL 4

CHANNEL 5
CHANNEL 6
CHANNEL 7
CHANNEL 8

# ASAMERA OIL COMPANY LTD.

## PULSE ELECTROMAGNETOMETER
## —VECTOR SECTION—

1 cm = 25 m

—INSTRUMENT CRONE PEM—

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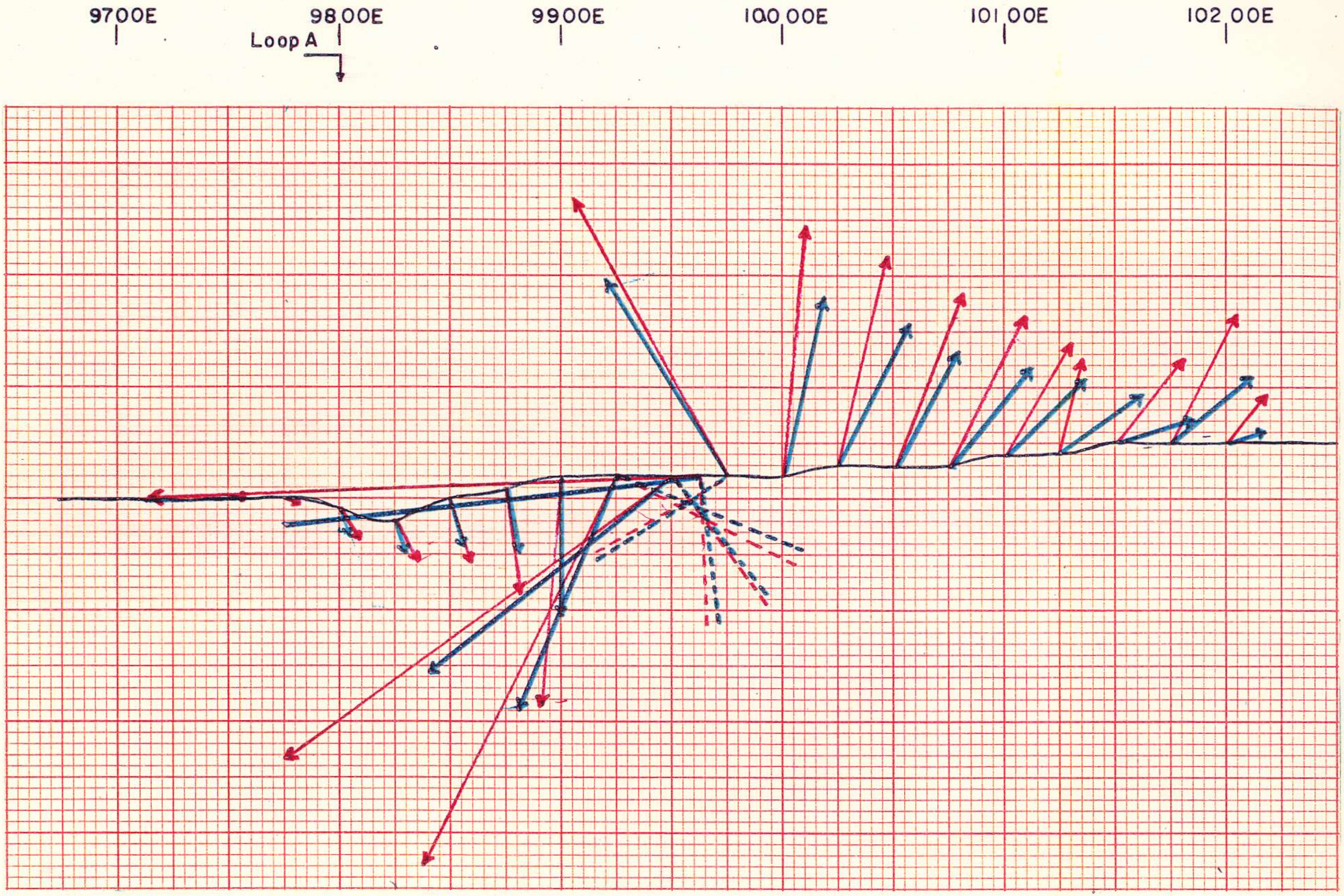
Fig. 8




CHANNEL 1
CHANNEL 2

# CRAIGMONT MINES LTD.

## CHU CHUA MOUNTAIN PROJECT

PULSE ELECTROMAGNETOMETER

RESULTANT SECONDARY FIELD

LINE 10000N

**Fig 9**

Scale: 1cm = 20 p.p.k.

1 cm = 25 Metres

— INSTRUMENT CRONE PEM —

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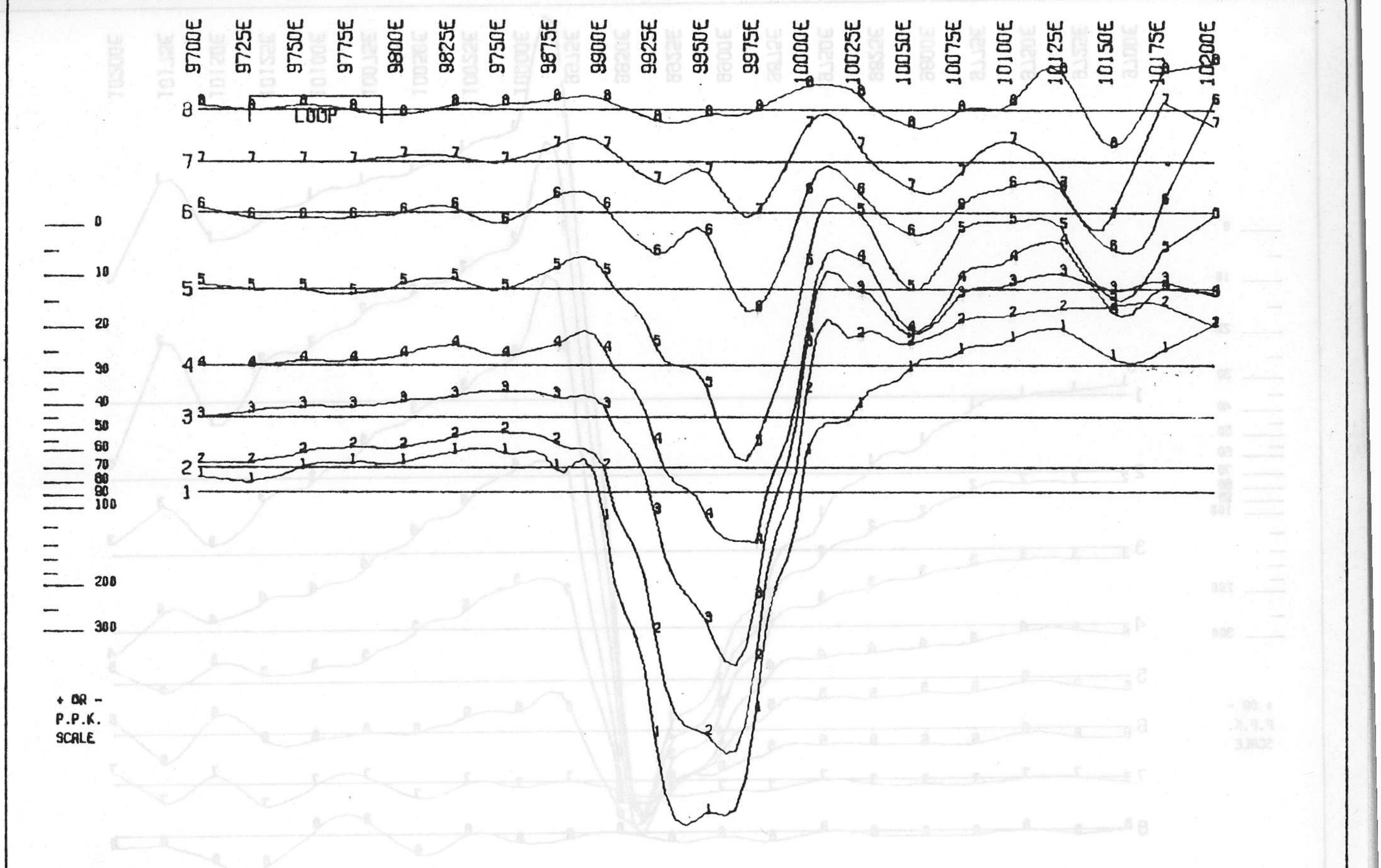
FIG. 18

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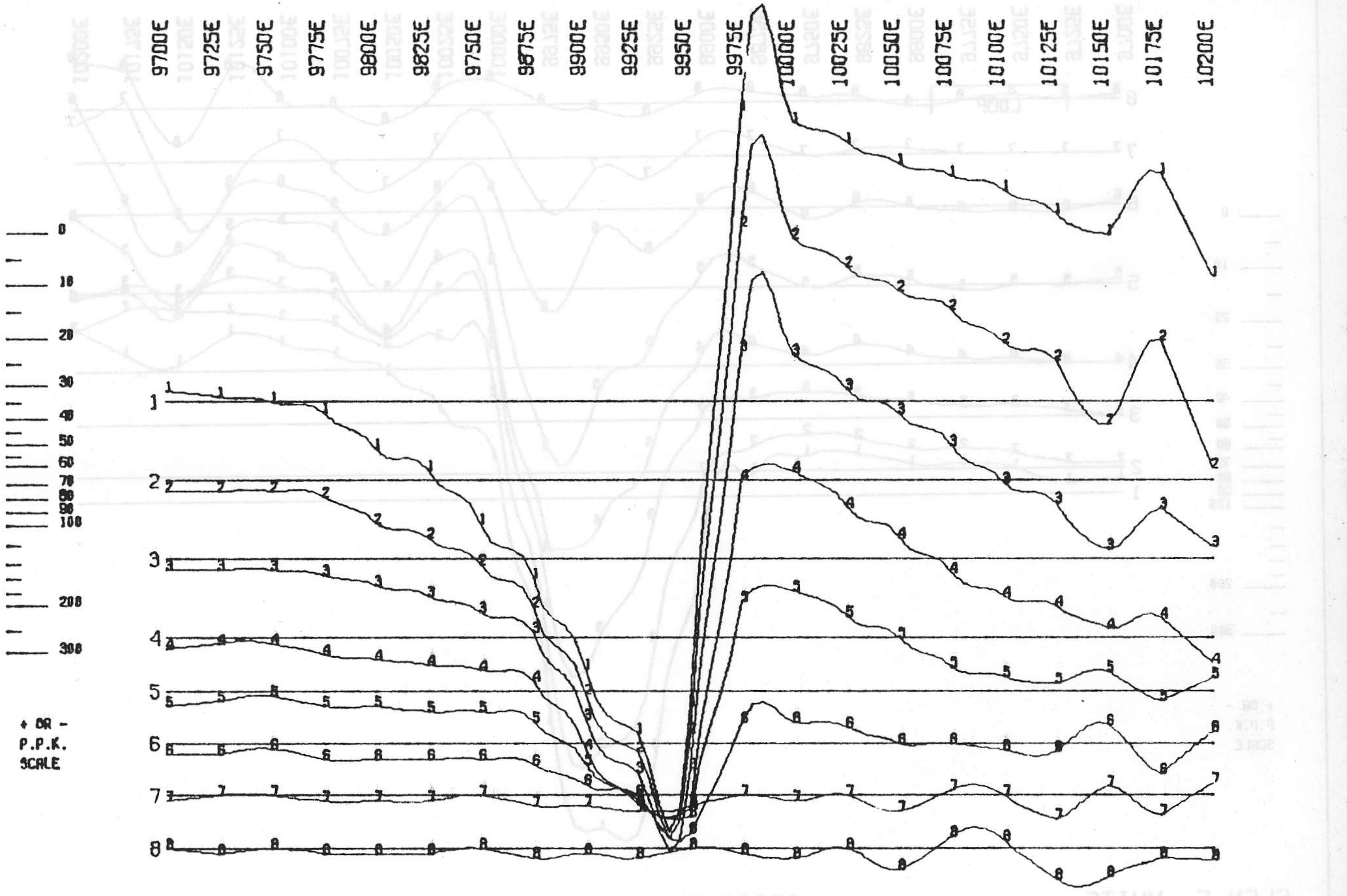
CRAIGMONT MINES LTD.
CHU CHUA MOUNTAIN PROJECT
LINE 10000 N LOOP A

1 CM = 25 METERS
PULSE ELECTROMAGNETOMETER
HORIZONTAL COMPONENT

Fig 10

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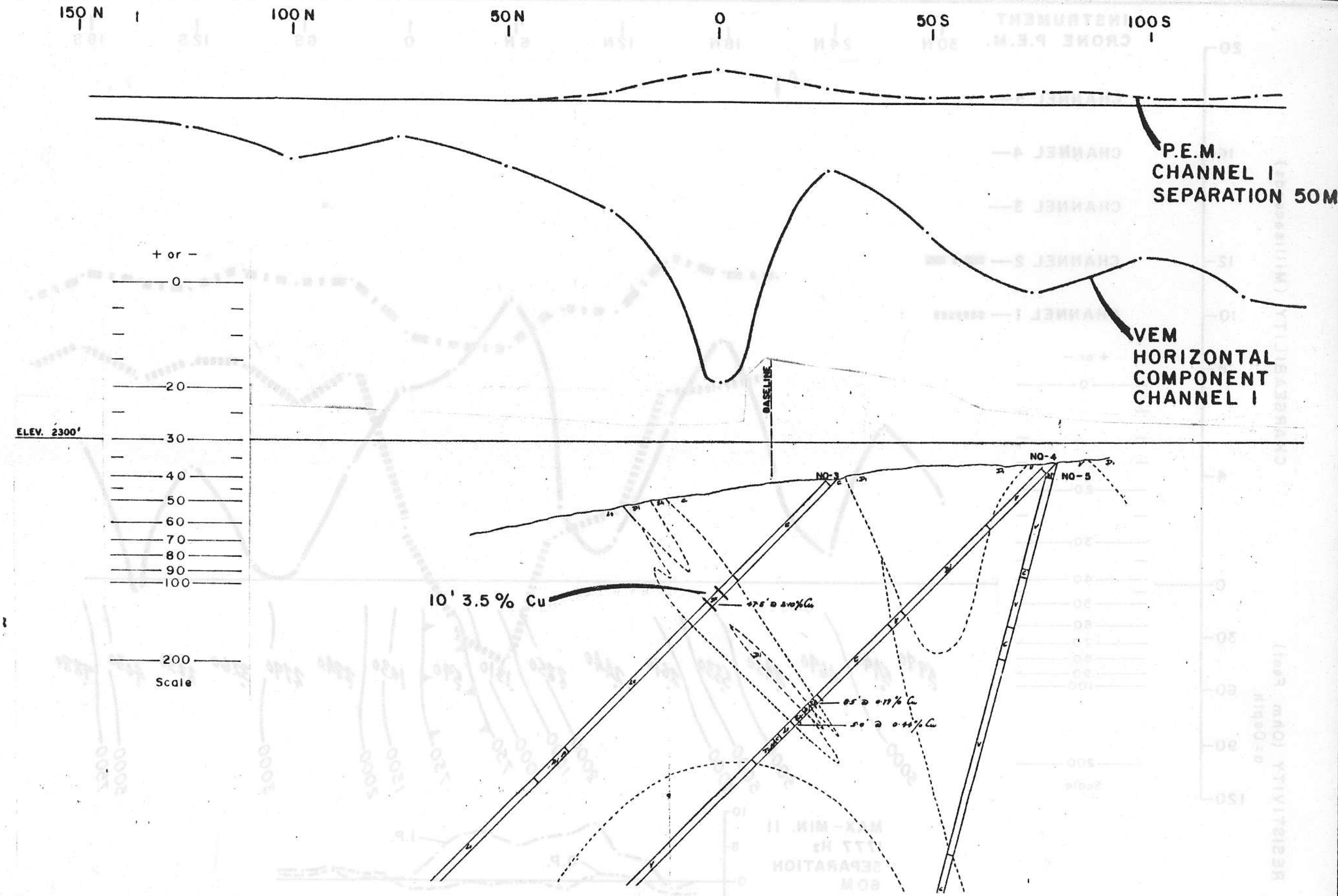
CRAIGMONT MINES LTD.
CHU CHUA MOUNTAIN PROJECT
LINE 10000 N LOOP A

1 CM = 25 METERS
PULSE ELECTROMAGNETOMETER
VERTICAL COMPONENT

Fig 11

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1" = 100'

# WESTMOUNT RESOURCES LTD.

## — KAR CLAIMS —

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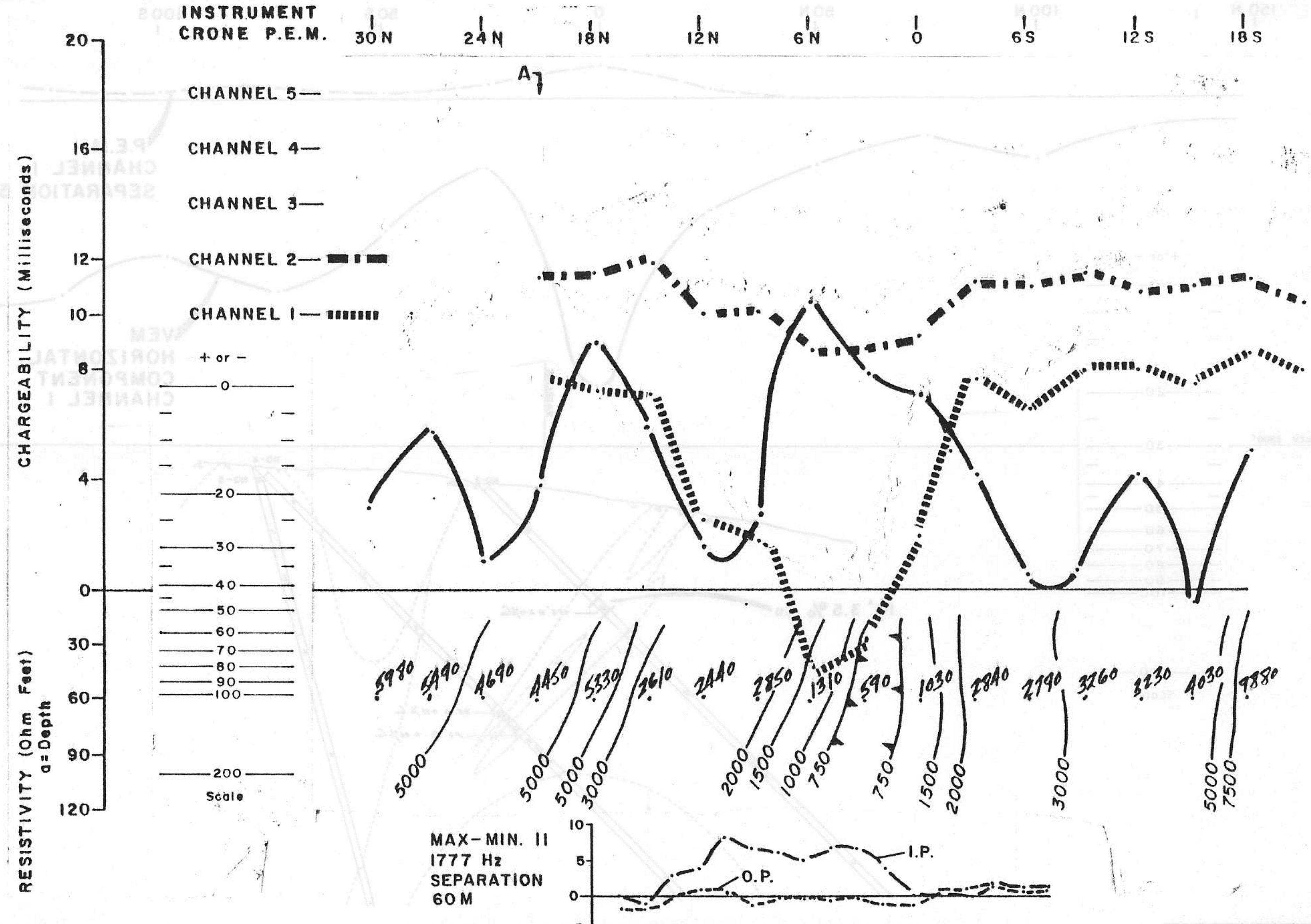
Fig. 12




INDUCED POLARIZATION PROFILES &
VECTOR PULSE ELECTROMAGNETOMETER
HORIZONTAL COMPONENT

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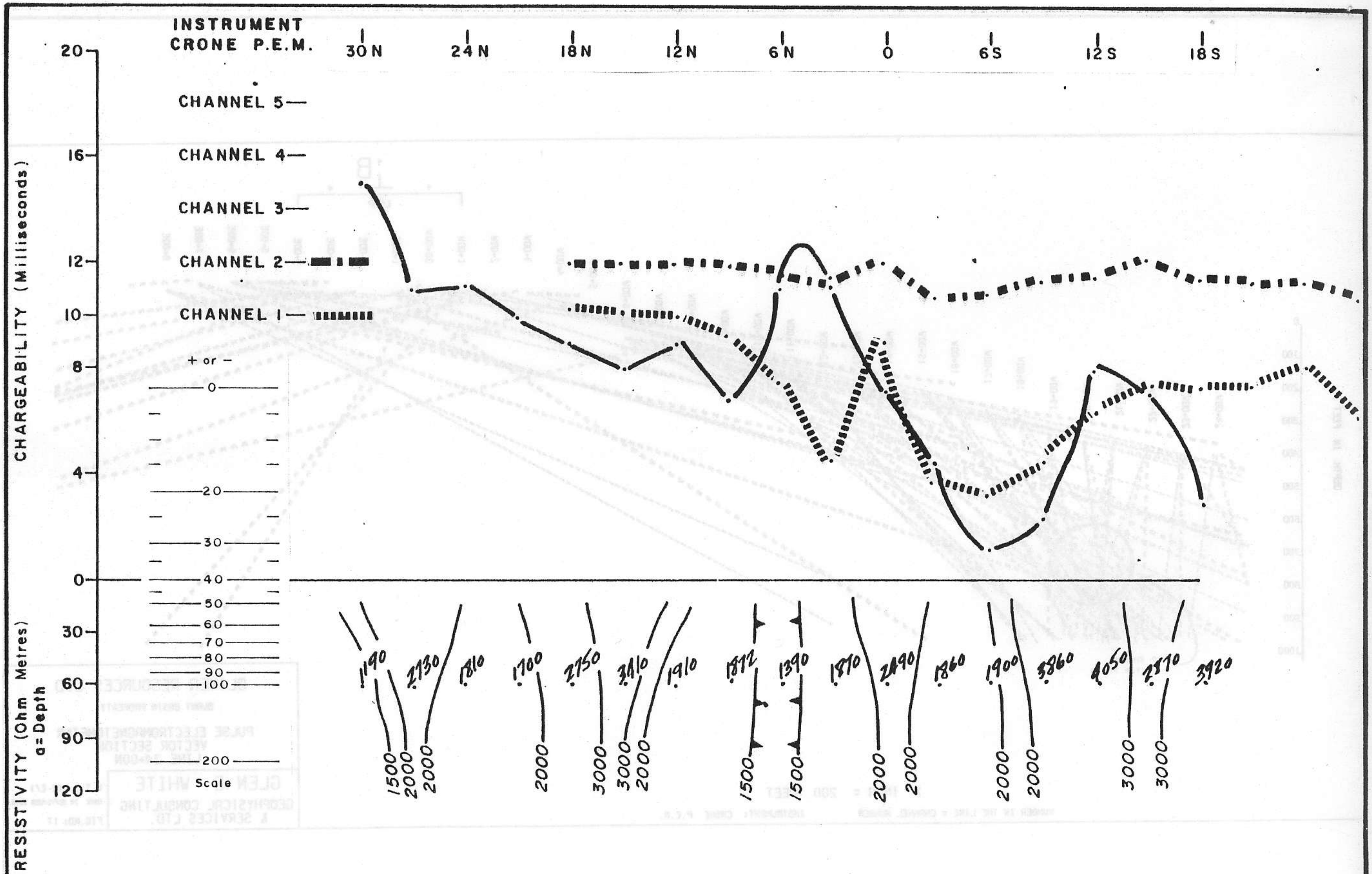
1cm = 30m

Feb. 1979
Fig. 13

The horizontal component vector data gives a definite channel 1 and 2 anomaly over the resistivity low. This zone is associated with a known ore zone at a depth of some 150 feet. The Max-Min conventional electromagnetic technique showed only topographic separation noise. Further to the east, Figure 14, the chargeability curve indicates a resistivity low associated anomaly at 6N. Here the vector horizontal component also indicates a conductor. This anomaly is caused by a narrow near surface zone containing some 10 feet of 3% copper. The large basin effect with the horizontal component at 6S reflects a known mineral zone at a depth of some 350 feet. There is no chargeability response over this zone and the resistivity values are moderately high. Increasing the separation does not help as the cross-sectional volume of the interesting zone decreases with respect to the volume of irregular pyrite zones being sampled.

Figures 15, 16 and 17 are published by the kind permission of Mr. L. Mayers, President Oliver Resources Ltd. The Burnt Basin property is a massive sulphide lead-zinc prospect with some chalcopyrite, in a complex of limey argillites which have been intruded by the Nelson Intrusives. This property contains both infinite and finite electromagnetic sources in a weakly conductive environment. Figure 15 shows a computer plot of a 2 channel vector focus at a depth of some 350 feet. Figure 16 illustrates the chargeability, apparent resistivity and horizontal component vector data. The chargeability readings show a broad high zone which reaches a value of some 46 ms. The high chargeability is caused by poorly connected graphite and pyrite disseminated throughout the argillite. The resistivity high to the east correlates with the Nelson Plutonic rocks. The horizontal component data clearly indicates the vector focus which is an infinite source response as well as delineating several other finite source conductors. Figure 17 completes this summation by illustrating the excellent crossovers obtained from the vertical component data.

The advantage of the vector EM technique is, that the scalar field, vector field, horizontal and vertical components can be utilized to evaluate a conductive source. The components are not always definitive, neither is the vector plot, particularly in cases of complex half-space responses and mixed infinite-finite conductor source models. Thus the ability to examine directly the secondary field and the galvanic-induction response of a conductive half-space environment makes the vector technique

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1cm = 30m

INDUCED POLARIZATION PROFILES
&
VECTOR PULSE ELECTROMAGNETOMETER
HORIZONTAL COMPONENT

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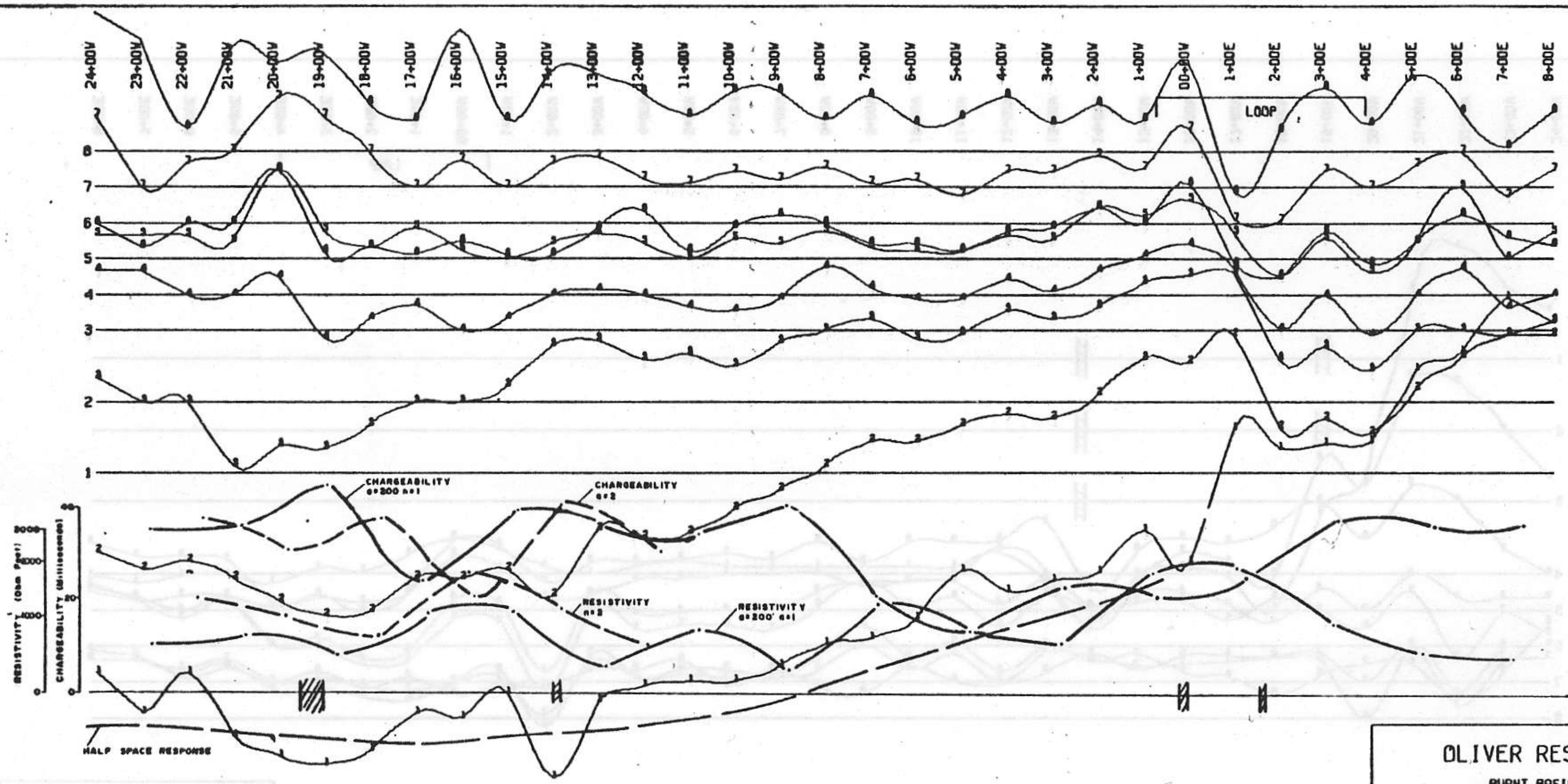
Fig. 14




# OLIVER RESOURCES LTD

BURNT BASIN PROPERTY

VECTOR PULSE ELECTROMAGNETOMETER
HORIZONTAL COMPONENT
LINE 24+00N LOOP B

STATION SPACING IS 100 FEET

NUMBER IN THE LINE = CHANNEL NUMBER

INSTRUMENT: CRONE P.E.M.

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FIG.NO: 4 9

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Fig 16

a powerful, cost effective geophysical tool which has increased the depth penetration for poor conductivity width targets to a depth of some 100 - 200 m and for good conductors, some 200 - 300 m.

Respectfully,

Glen E. White, B.Sc, P. Eng.
Consulting Geophysicist