84-#687 - 12705
$185

GEOPHYSICAL REPORT

ON THE

KING, KING #1 to KING #4, and MO

MINERAL CLAIMS

OSOYOOS MINING DIVISION B.C.

82E - 4E, 5E

(49°15', 119°41'W)

FOR

DRC RESOURCES CORPORATION

and

STRATA ENERGY CORPORATION

(OPERATORS)

BY

GRANT CROOKER, B.Sc.,

GEOLOGIST

OWNER - GRANT CROOKER

AUGUST, 1984

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ILLUSTRATIONS

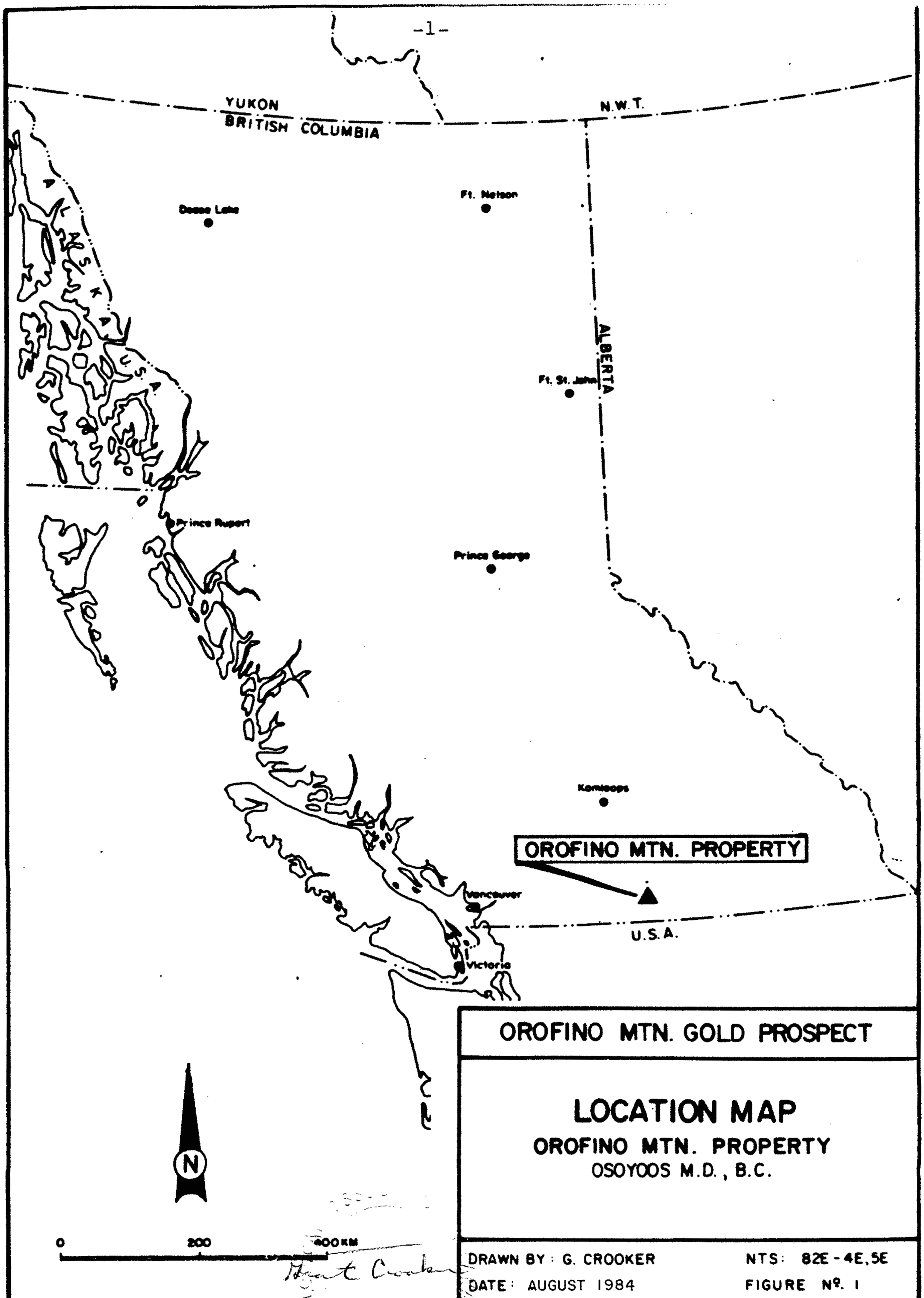
SUMMARY AND RECOMMENDATIONS

The Orofino Mountain property consists of the Mo, King, and King #1 through King #4 mineral claims covering 74 units in the Osoyoos Mining Division. The property is located about 20 kilometeres south of Penticton, British Columbia.

Mineralization on the property consists of quartz veins with related gold values. Enough significant gold values have been obtained in the past to justify additional work.

The 1984 program consisted of an orientation VLF-EM Survey over the area of known showings. A number of weak conductors appear to be associated with veining and shearing, and indicate extensions of zones.

Recommendations are to complete the VLF-EM Survey in the area of the showings, and carry out trenching to determine if the conductors are associated with the veining and shearing.



OROFINO MTN. GOLD PROSPECT

LOCATION MAP
OROFINO MTN. PROPERTY
OSOYOOS M.D., B.C.

DRAWN BY: G. CROOKER
DATE: AUGUST 1984
NTS: 82E-4E,5E
FIGURE Nº. 1

INTRODUCTION

General

Field work was carried out on the property by the author from July 8 to July 14, 1984.

An orientation VLF-EM Survey was carried out on the Mo and King mineral claims.

Location and Access

The property is located 7 kilometers southeast of Twin Lakes, on Orofino Mountain (figure 1) in southern B.C. The claims lie between $49^{\circ}14'$ and $49^{\circ}16'$ north latitude and $119^{\circ}39'$ and $119^{\circ}42'$ west longitude.

Access is via highway 3A turning onto a secondary road approximately 24 kilometers from Penticton. An all weather 2 wheel drive logging road leads to the claim area, with a network of logging roads and skid trails covering the entire claim area.

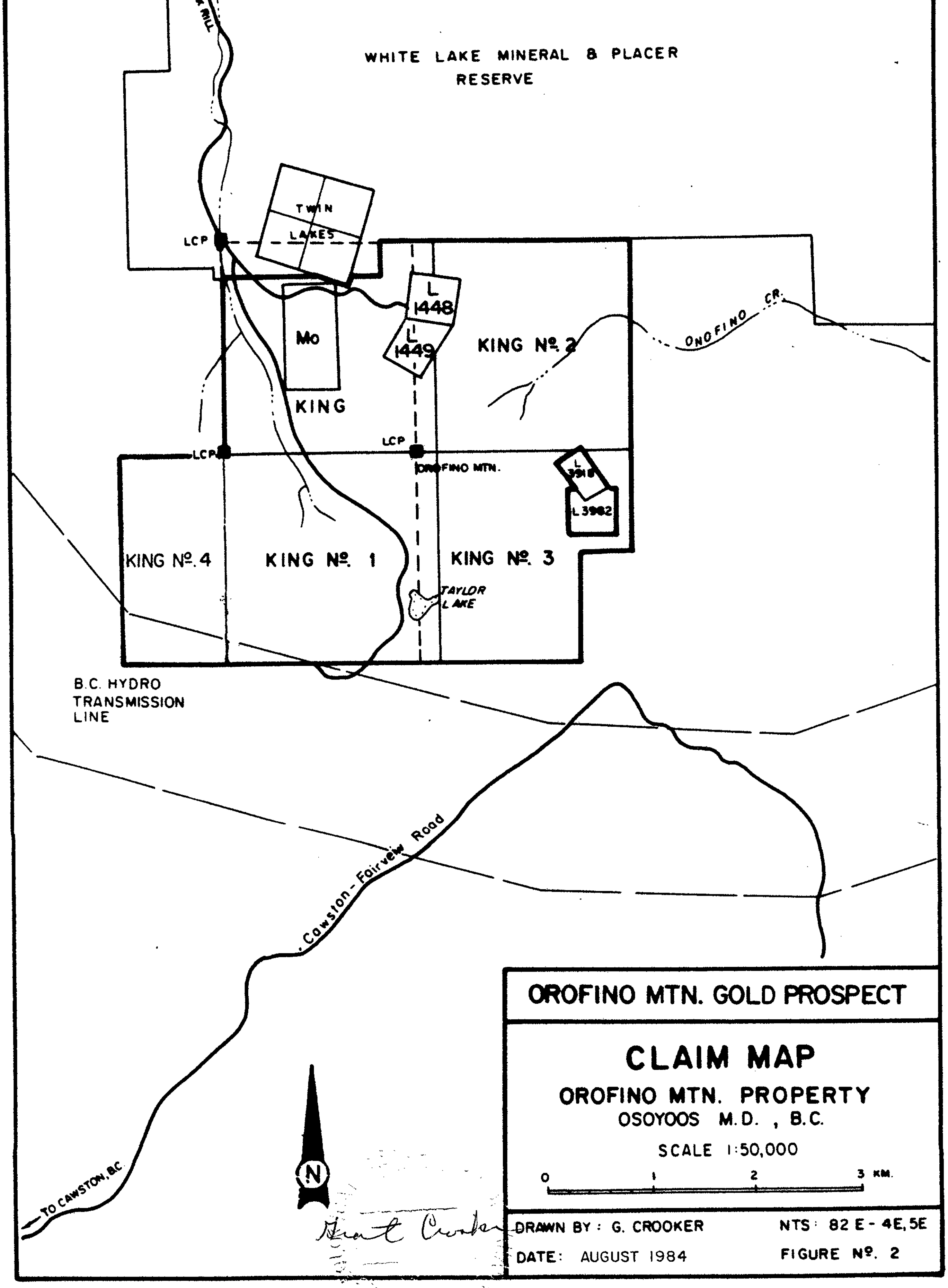
Physiography

The property is located in the Okanagan Highlands. Topography varies from rolling hills to steep slopes. Elevation varies from 1,000 meters to 1,600 meters above sea level.

Most areas are timbered with larch, spruce, fir, or pine. Bunch-grass and sagebrush cover the open areas.

Property and Claim Status

The Orofino Mountain Property consists of 6 mineral claims totalling 74 units and 2 Crown Grants (figure 2). The mineral claims are owned by Grant Crooker of Keremeos, B.C., with DRC Resources Corporation and Strata Energy Corporation,



WHITE LAKE MINERAL & PLACER RESERVE
TWIN LAKES
LCP
L 1448
L 1449
Mo
KING
KING No. 2
ONOFINO CR.
LCP
LCP
OROFINO MTN.
L 3918
L 3982
KING No. 4
KING No. 1
KING No. 3
TAYLOR LAKE
B.C. HYDRO TRANSMISSION LINE
Cawston - Fairview Road
TO CAWSTON, B.C.
N
OROFINO MTN. GOLD PROSPECT
CLAIM MAP
OROFINO MTN. PROPERTY
OSOYOOS M.D., B.C.
SCALE 1:50,000
0 1 2 3 KM.
Grant Crooker
DRAWN BY: G. CROOKER
NTS: 82 E - 4E, 5E
DATE: AUGUST 1984
FIGURE No. 2

#1250-800 West Pender Street, Vancouver, B.C. V6C 2V6 having an option on the property. The Crown Grants are also under option to DRC Resources and Strata Energy.

Claim	Units	Record No.	Expiry Date
MO	2	135	Oct. 15, 1989
King	16	1386	May 8, 1986
King #1	16	1398	June 5, 1985
King #2	16	1461	Aug. 31, 1984
King #3	16	1462	Aug. 31, 1985
King #4	8	1630	Nov. 12, 1985

Crown Grants	Lot Number
Orofino	1448
Independence	1449

History and Previous Work

The Orofino Mountain gold camp dates back to the late 1890's when the Fairview Camp was being developed. The Orofino Camp is only 7 kilometers from the Fairview Area, and has similiar geological conditions.

There are two properties covered by this report. These are the King and Grandoro (figure 3). Most of the activety in the camp was from 1930 to 1940.

At the Grandoro considerable underground development was carried out. This includes several adits, a tunnel, and a winze leading to a lower level. The workings are not accessable at this time. A limited amount of diamond drilling was carried out in the 1930's, but no records are available. Minister of Mines Reports indicate the following production from the Grandoro:

Year	Tonnage	Grade
1932	76	$20.00 per ton
1933	220	1.77 oz/ton gold
1935	10,000	0.50 oz/ton gold
1941	251	0.69 oz/ton gold

At the King only a small amount of work has been carried out. Two adits were driven, along with an winze. In the lower King adit some stoping was carried out, with production estimated at 2,000 tons. The grade is not known.

During 1981 and 1983 geological surveys were carried out on the property. This work included geological mapping, prospecting, sampling, and geochemical surveying.

EXPLORATION PROCEDURE

The 1984 program consisted of establishing a grid over the known showing on the property, and carrying out an orientation VLF-EM Survey.

A north-south baseline was established with a length of 900 meters. The baseline passed through the King showings. Eight crosslines were ran, and the lines were 100 meters apart. Length of the lines varied from 400 meters to 1,360 meters, and were ran over the showings as an orientation survey. Stations were established every 20 meters along the lines, and readings taken. A total of 7.5 line kilometers of VLF-EM surveying was carried out.

Grant Crooker, B.Sc. geologist carried out the survey using a Geonics EM-16 receiver. The VLF transmitter was NLK at 24.8 KHZ. This transmitter was used due to its good signal strength and orientation to the geological structures.

The EM-16 measures In-phase and Quadrature components of vertical magnetic field as a percentage of horizontal primary field. (That is tangent of the tiltangle and ellipticity.) Both values are given in percentages.

Field procedure requires to always face the same direction when taking readings. When approaching a conductor the readings will be positive, and when leaving a conductor the readings will be negative.

The EM-16 is rotated in the vertical plane until a minimum signal is obtained. This reading is the "In-phase" and gives the tiltangle in degrees and the tangent of the tilt-angle expressed as percent. Once this minimum signal is obtained, the "Quadrature" knob is rotated until the signal minimum is obtained. This reading is approximately the ratio of the quadrature component of the vertical secondary field to the horizontal primary field.

The VLF-EM can pick up conductors caused by electrolyte-filled fault or shear zones and porous horizons, graphite, carbonaceous sediments, lithological boundaries as well as sulphide bodies.

The In-phase and Quad-phase raw data were plotted as percentages on figure 4 at a scale of 1:2500.

The Fraser filter method was then applied to the In-phase data, and the results plotted at a scale of 1:2500 on figure 5.

GEOLOGY

Regional Geology

The gold showings in the Orofino Mountain area occur in an area about 4 square miles in extent. The area is underlain by irregular, easterly trending belts of greenstone, sedimentary rocks, and highly altered rocks of uncertain origin.

These rocks are intruded by bodies of diorite, granodiorite and granite. The Oliver Granite extends into the Fairview area. On the north and west Tertiary volcanics of considerable thickness are faulted against older rocks.

Claim Geology

The oldest rock underlying the Orofino Mountain gold prospect are quartzites of the Kobau Quartzite (Unit 0, figure 3) of Carboniferous age. The quartzites are generally massive and vary from grey to blue-grey in color.

Triassic quartzites of the Shoemaker Formation (Unit 1, figure 3) form two relatively narrow bands which strike west and northwest across the King and King #2 claims. The quartzites vary from massive to thinly bedded and are light grey in color.

Unit 2 consists of altered rocks of uncertain origin. This rock type varies from massive coarse grained hornblende gabbros and biotite diorite to finer grained biotite schists.

Unit 3 is generally a pinkish, medium grained diorite containing hornblende and biotite. This unit is often difficult to distinguish from Unit 2.

The granite of unit 4 is generally light grey, porphyritic and coarse grained. Biotite and hornblende are the main mafic constituents.

Unit 5 is a light grey granitic dike.

Unit 6 is a medium grained, grey granodiorite with hornblende predominating over biotite.

Weathered vesicular basalt of the Marron Formation of Eocene or Oligocene age form Unit 7. This unit is faulted against older rocks on the north and west sides of the claim block.

Mineralization

Mineralization on the Orofino Mountain property consists of quartz veins in which pyrite, galena and free gold occur. The mineralization is similiar to that which occurs in the Fairview gold camp to the south of the claim block.

The Upper King Adit (figure 3) exposes a quartz vein which varies from 10 centimeters up to 1.4 meters in width. The vein follows a shear zone in which some graphite was found.

The Lower King Adit also follows a vein and associated shear zone. Significant gold values have been found here.

From the descriptions given in Minister of Mines Reports, the Grandoro workings occur in an area which has been faulted and highly disturbed.

The quartz veins appear to be associated with shear zones in some cases.

VLF-EM SURVEY

The Fraser filter was applied to all In-phase readings to allow contouring of the data. The results were contoured at 10 percent intervals.

The highest readings of over 100% were obtained along L-5, at 1+20W and 0+40E. This anomaly occurs over a tailings pond, and would appear to be caused by sulphides in the tailings.

Anomaly A occurs near the Lower King Adit and associated workings. The conductor is weak, but appears to sub parallel the vein. The conductor is probably caused by a shear zone associated with the veining. If this is the case, the shear zone extends to the north and south of the known extent of the shear zone.

Anomaly B occurs near the Upper King Adit, and the conductor is weak. However the conductor parallels the direction of shearing within the adit. The vein occurs within a shear zone with graphite. The conductor again extends north and south from the area of showings, and thus the vein and shearing may extend in both directions.

Anomaly C is a weak to moderate conductor near the Grandoro Showings. The conductor sub parallels the northwest to southeast strike of the known veins. The conductor may again indicate shearing or faulting associated with the mineralization.

Several other conductors were found in the course of the survey, but no explanation is apparent for them. Shearing or fracturing would appear to be the most reasonable explanation.

CONCLUSIONS AND RECOMMENDATIONS

A number of quartz veins, with related gold values are found on the property. Shearing, sometimes with graphite is associated with some of the veining. An orientation VLF-EM survey was ran over the area of showings, to check the EM response, and located extensions of the mineralized zones.

Weak conductors appear to be associated with the veining and shearing, as the conductors are parallel or sub parallel to the strike of the veining and shearing. These areas may be extensions of the mineralized zones.

Recommendations are as follows:

1. The VLF-EM Survey be completed over the area of showings, and extended some distance beyond the showings.

2. Trenching be carried out to determine if the weak conductors are indicating extensions of the shearing and veining.

Respectfully submitted,

Grant Crooker

Grant Crooker, B.Sc.
Geologist

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CERTIFICATE OF QUALIFICATION

I, Grant F. Crooker, B.Sc., Geology of Upper Bench Road, Keremeos, in the Province of British Columbia, hereby certify as follows:

1. That I graduated from the University of British Columbia in 1972 with a Bachelor of Science degree in Geology.

2. That I have prospected and actively pursued geology prior to my graduation and have practiced my profession since 1972.

3. That I am a member of the Canadian Institute of Mining and Metallurgy.

4. That I am a Fellow of the Geological Association of Canada

5. That I am the sole owner of the MO, King, King #1, King #2, King #3 and King #4 mineral claims.

Dated at Vancouver, British Columbia this 30 th day of August, 1984.

Grant Crooker

Grant Crooker, B.Sc.
Geologist

COST STATEMENT

Wages	
1 Geologist, G. Crooker	
9 days @ $300.00 per day	$2,700.00
July 8-14, Aug. 7,8, 1984	
Accomodations	
1 Geologist, G. Crooker	
9 days @ $25.00 per day	225.00
July 8-14, Aug 7, 8, 1984	
Meals	
1 Geologist, G. Crooker	
9 days @ $25.00 per day	225.00
July 8-14, Aug. 7,8, 1984	
Transportation	
Vehicle Rental (Ford 3/4 ton 4x4)	
7 days @ $40.00 per day	280.00
July 8-14, 1984	
Gasoline	61.60
Supplies	
Hipchain thread, flagging, etc.	31.70
EM Rental	
Geonic EM-16	
8 days @ $18,00 per day	144.00
July 7-14, 1984	
Preparation of Report	
Secretarial, Draughting, Reproduction, etc.	500.00
TOTAL	$4,167.30

EM16 SPECIFICATIONS

MEASURED QUANTITY	In-phase and quad-phase components of vertical magnetic field as a percentage of horizontal primary field. (i.e. tangent of the tilt angle and ellipticity).
SENSITIVITY	In-phase : ±150% Quad-phase : ± 40%
RESOLUTION	±1%
OUTPUT	Nulling by audio tone. In-phase indication from mechanical inclinometer and quad-phase from a graduated dial.
OPERATING FREQUENCY	15-25 kHz VLF Radio Band. Station selection done by means of plug-in units.
OPERATOR CONTROLS	On/Off switch, battery test push button, station selector switch, audio volume control, quadrature dial, inclinometer.
POWER SUPPLY	6 disposable 'AA' cells.
DIMENSIONS	42 x 14 x 9cm
WEIGHT	Instrument: 1.6 kg Shipping : 4.5 kg

NOTES ON VLF TRANSMISSIONS

	STATION	LOCATION	FREQUENCY (kHz)	CO-ORDINATES
N.AMERICA	NAA	Cutler, Maine	~~17.8~~ 24.0	67W17-44N39
	NLK	Seattle, Washington	~~18.6~~ 24.8	121W55-48N12
	NSS	Annapolis, Maryland	21.4	76W27-38N59
EUROPE	GBR	Rugby, England	16.0	01W11-52N22
	FUO	Bordeaux, France	15.1	00W48-44N65
	JXZ	Helgeland, Norway	16.4	13E01-66N25
	UMS	Moscow, U.S.S.R.	17.1	37E01-55N49
PACIFIC	NWC	North West Cape Australia	22.3	114E09-21S47
	NDT	Yosami, Japan	17.4	137E01-34N58
	NPM	Lualualei, Hawaii	23.4	158W09-21N25

FIELD PROCEDURE

Orientation & Taking a Reading

The direction of the survey lines should be selected approximately along the lines of the primary magnetic field, at right angles to the direction to the station being used. Before starting the survey, the instrument can be used to orient oneself in that respect. By turning the instrument sideways, the signal is minimum when the instrument is pointing towards the station, thus indicating that the magnetic field is at right angles to the receiving coil inside the handle.(Fig.11).

To take a reading, first orient the reference coil (in the lower end of the handle) along the magnetic lines.(Fig.12) Swing the instrument back and forth for minimum sound intensity in the speaker. Use the volume control to set the sound level for comfortable listening. Then use your left hand to adjust the quadrature component dial on the front left corner of the instrument to further minimize the sound. After finding the minimum signal strength on both adjustments, read the inclinometer by looking into the small lens. Also, mark down the quadrature reading.

While travelling to the next location you can, if you wish, keep the instrument in operating position. If fast changes in the readings occur, you might take extra stations to pinpoint accurately the details of anomaly.

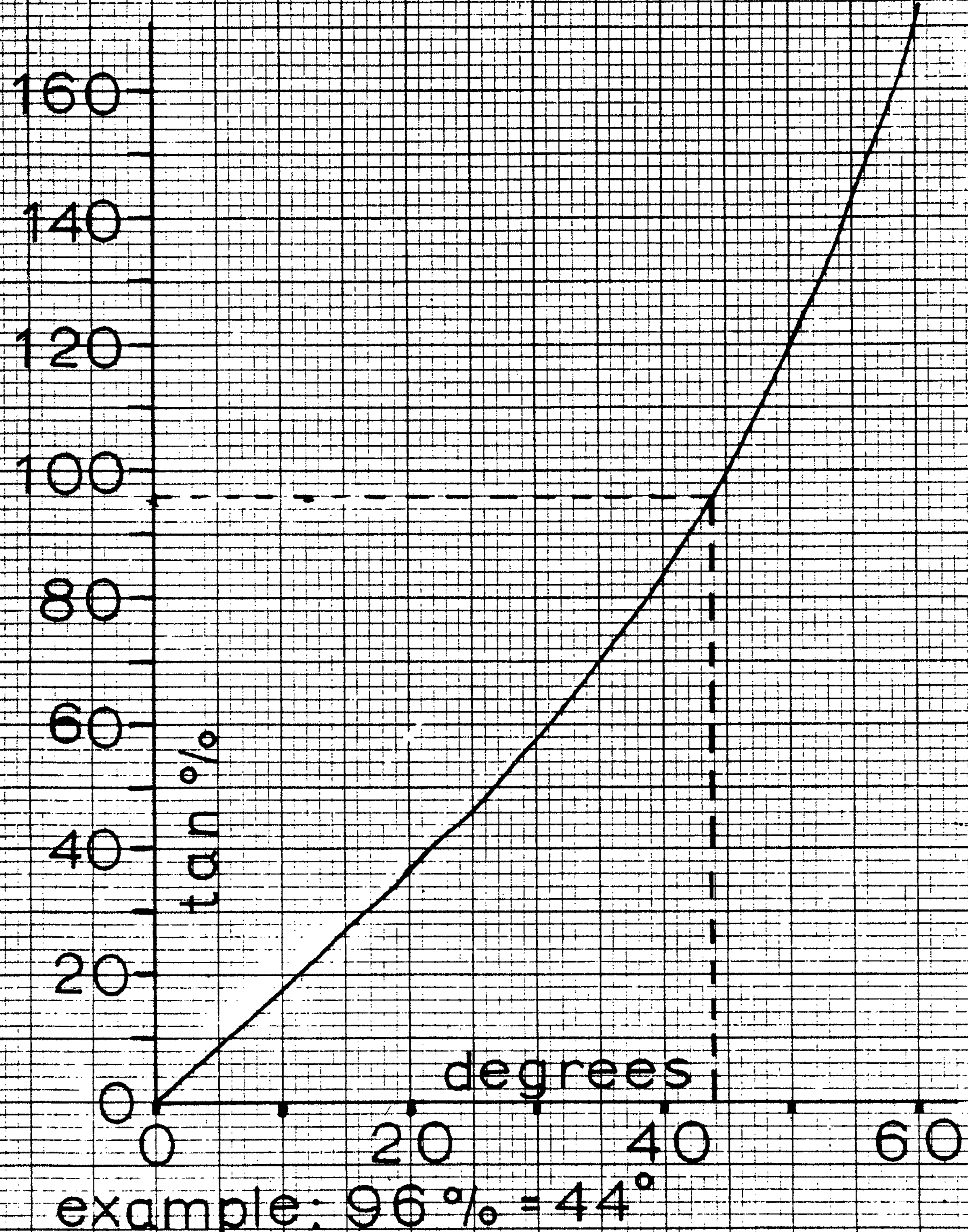
The dials inside the inclinometer are calibrated in positive and negative percentages. If the instrument is facing 180° from the original direction of travel, the polarities of the readings will be reversed. Therefore, in the same area take the readings always facing in the same direction even when travelling in opposite way along the lines.

The lower end of the handle, will as a rule, point towards the conductor. (Figs.13 & 14) The instrument is so calibrated that when approaching the conductor, the angles are positive in the in-phase component. Turn always in the same direction for readings and mark all this on your notes, maps, etc.

THE INCLINOMETER DIALS

The right-hand scale is the in-phase percentage(ie. Hs/Hp as a percentage). This percentage is in fact the tangent of the dip angle. To compute the dip angle simply take the arctangent of the percentage reading divided by 100. See the conversion graph on the following page.

The left-hand scale is the secant of the slope of the ground surface. You can use it to "calculate" your distance to the next station along the slope of the terrain.



EM16 in-phase, % to degrees

(1) Open both eyes.

(2) Aim the hairline along the slope to the next station to about your eye level height above ground.

(3) Read on the left scale directly the distance necessary to measure along the slope to advance 100 (ft) horizontally.

We feel that this will make your reconnaissance work easier. The outside scale on the inclinometer is calibrated in degrees just in case you have use for it.

PLOTTING THE RESULTS

For easy interpretation of the results, it is good practice to plot the actual curves directly on the survey line map using suitable scales for the percentage readings. (Fig.15) The horizontal scale should be the same as your other maps on the area for convenience.

A more convenient form of this data is easily achieved by transforming the zero-crossings into peaks by means of a simple numerical filtering technique. This technique is described by D.C. Fraser in his paper "Contouring of VLF-EM Data", Geophysics, Vol. 34, No. 6. (December 1969)pp958-967. A reprint of this paper is included in this manual for the convenience of the user.

This simple data manipulation procedure which can be implemented in the field produces VLF-EM data which can be contoured and as such provides a significant advantage in the evaluation of this data.

INTERPRETATION

The VLF primary field's magnetic component is horizontal. Local conductivity inhomogeneities will add vertical components. The total field is then tilted locally on both sides of a local conductor. This local vertical field is not always in the same phase as the primary field on the ground surface. The EM16 measures the in-phase and quadrature components of the vertical field.

When the primary field penetrates the conductive ground and rock, the wave length of the wave becomes very short, maybe only few tens of meters, depending on conductivity and frequency. At the same time the wave travels practically directly downwards. The amplitude of the field also decreases very fast, completely disappearing within one wavelength. The magnetic field remains, however, horizontal.

Figure 16 shows graphically the length and phase angle of the primary field penetrating into a conductive material.

The phase shift in radians per meter and the attenuation in nepers per meter (1/e) is:

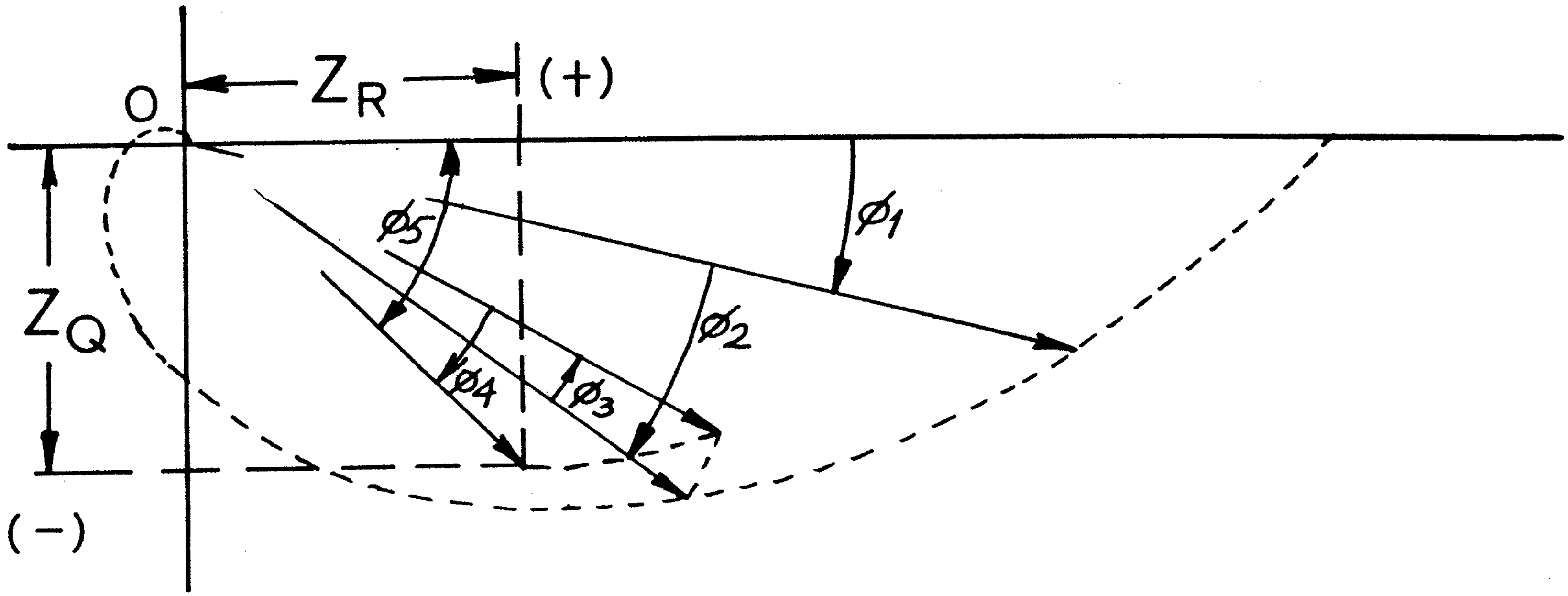
$$\beta = \alpha = \left[\frac{\omega \mu \sigma}{2}\right]^{\frac{1}{2}} \qquad \text{where} \qquad \begin{aligned} \omega &= 2 \pi f \\ \mu &= \mu_o \mu_r = 4\pi \times 10^{-7} \\ \sigma &= \text{conductivity} \\ &\quad\ \text{mho/m} \end{aligned}$$

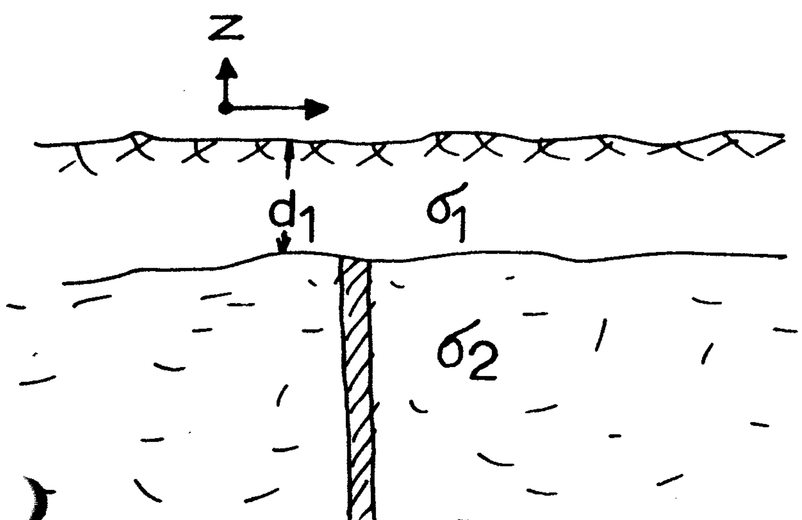
Figure 16 also reminds us of the fact that all secondary fields have a small (or large in poor conductors) positive phase shift in the target itself due to its resistive component, and that the secondary fields have another negative phase shift while penetrating back to surface from the upper edge of the target.

The targets are located somewhere in the depth scale (phase shift scale in this case). Suppose we have a semi-infinite vertical sheet target starting from the surface. Figure 17 shows that the total integrated primary field inphase and quadrature flux has a value of + 0.5 and - 0.5 respectively.

These two charts can be used to analyze the inphase and quadrature readings taken on both sides of the target. If one knows the actual conductivity of the overburden and the rock, the task is easier. Because of the many variables involved the precise analysis is usually impossible.

The most frequently encountered and easily solved problem is, however, the separation of surface conductors from the more interesting ones at depth. This is easily done by observing the negative quadrature signals compared to the usually positive or zero ones from the surface targets. See the sample profiles in Figures 18 and 19. This way we can often tell if we have a more interesting sulfide target under a swamp for example.





PHASE SHIFTS IN CONDUCTIVE MEDIUM

$\emptyset_1$ OVERBURDEN, DOWNWARD TRAVEL

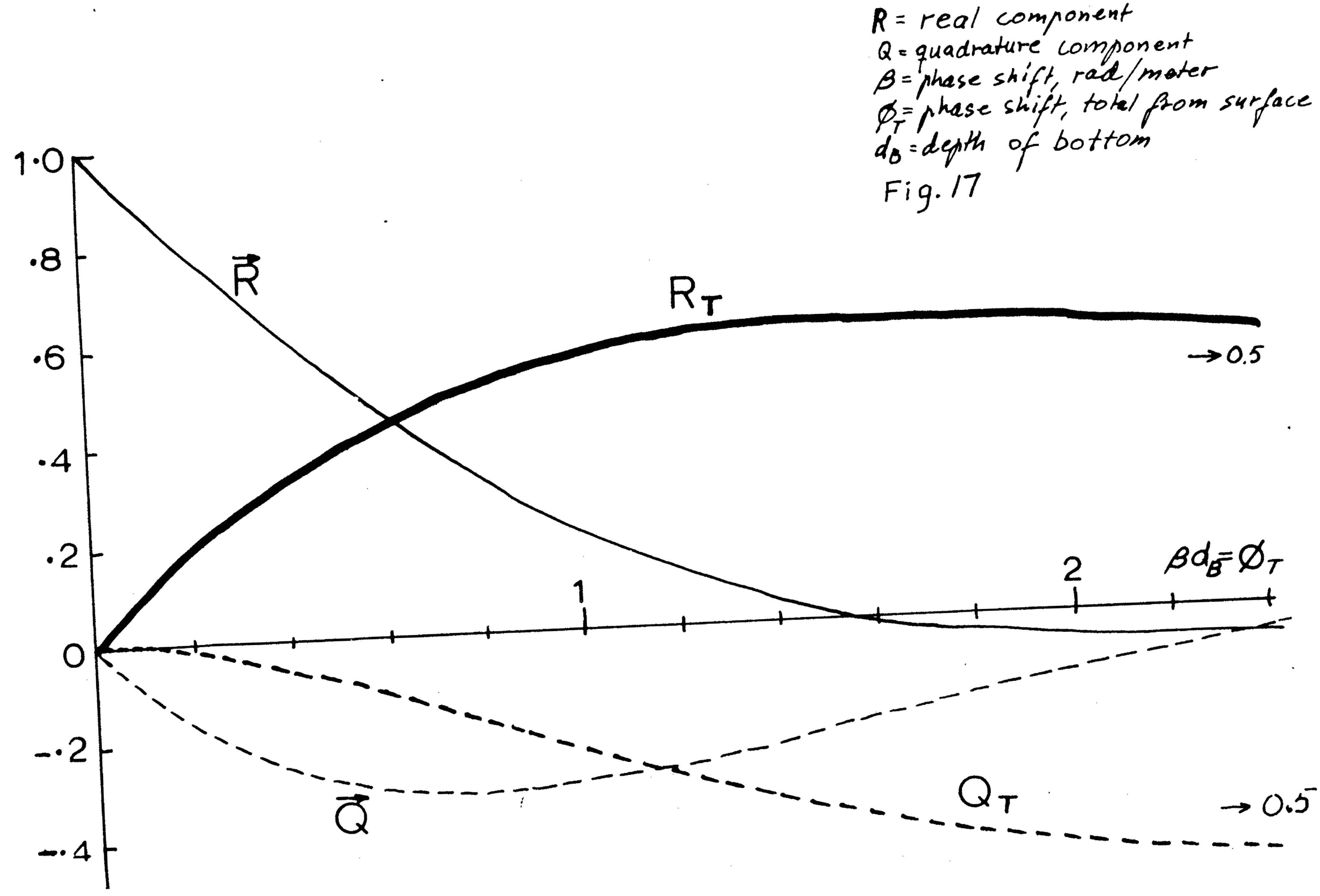
$\emptyset_2$ ROCK FROM OVERBURDEN TO THE CENTER OF TARGET

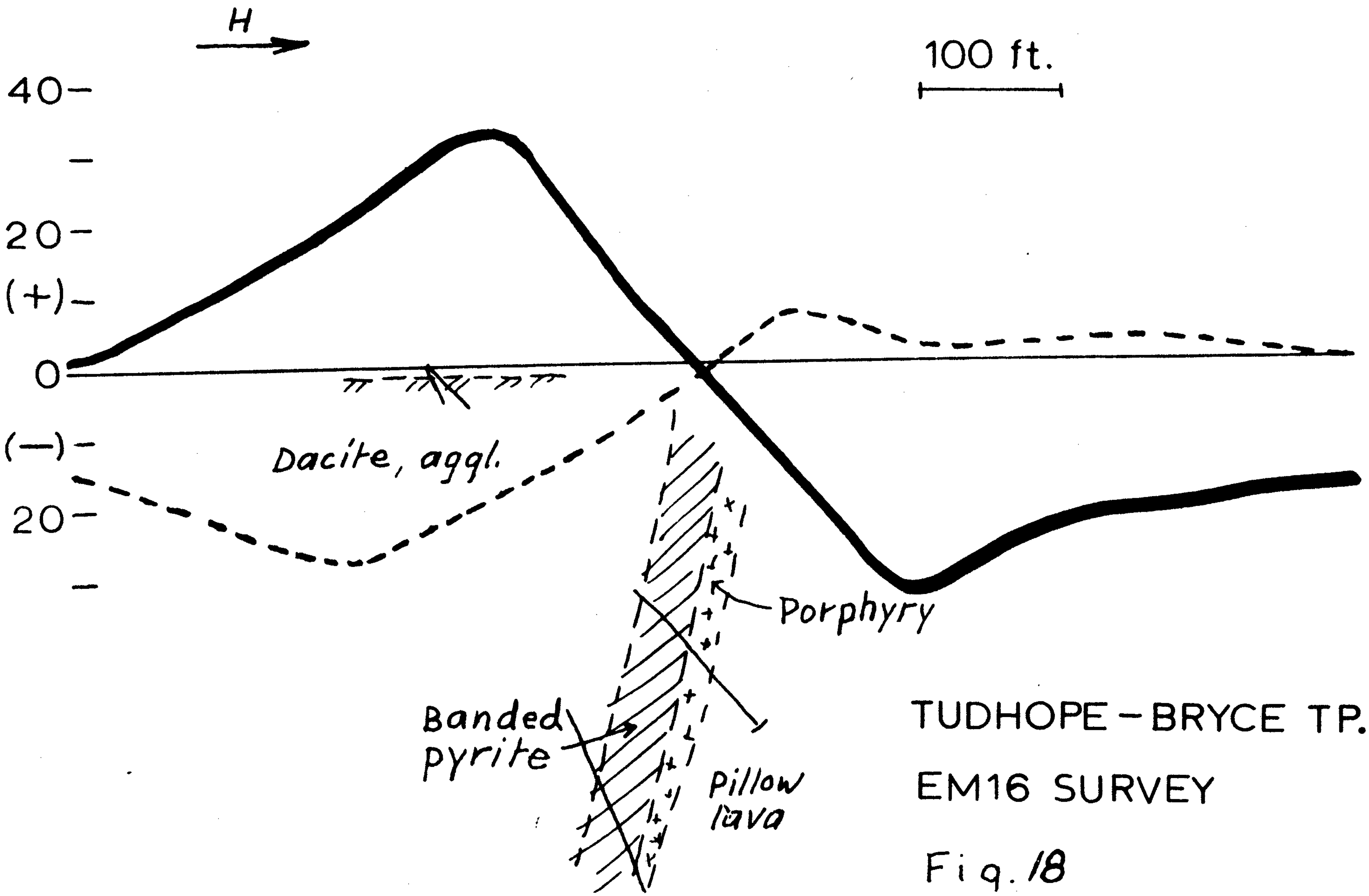
$\emptyset_3$ SHIFT IN TARGET, FINITE CONDUCTIVITY

$\emptyset_4$ SECONDARY FIELD IN OVERBURDEN AND SOME ROCK

$\emptyset_5$ TOTAL OF ALL $\emptyset_1$ TO $\emptyset_4$

Fig. 16


R = real component
Q = quadrature component
β = phase shift, rad/meter
ϕ_T = phase shift, total from surface
d_B = depth of bottom
1·0
·8
·6
·4
·2
0
-·2
-·4
$\vec{R}$
R_T
$\vec{Q}$
Q_T
→ 0.5
→ 0.5
1
2
$\beta d_B = \phi_T$
Fig. 17



TUDHOPE - BRYCE TP.
EM16 SURVEY
Fig. 18

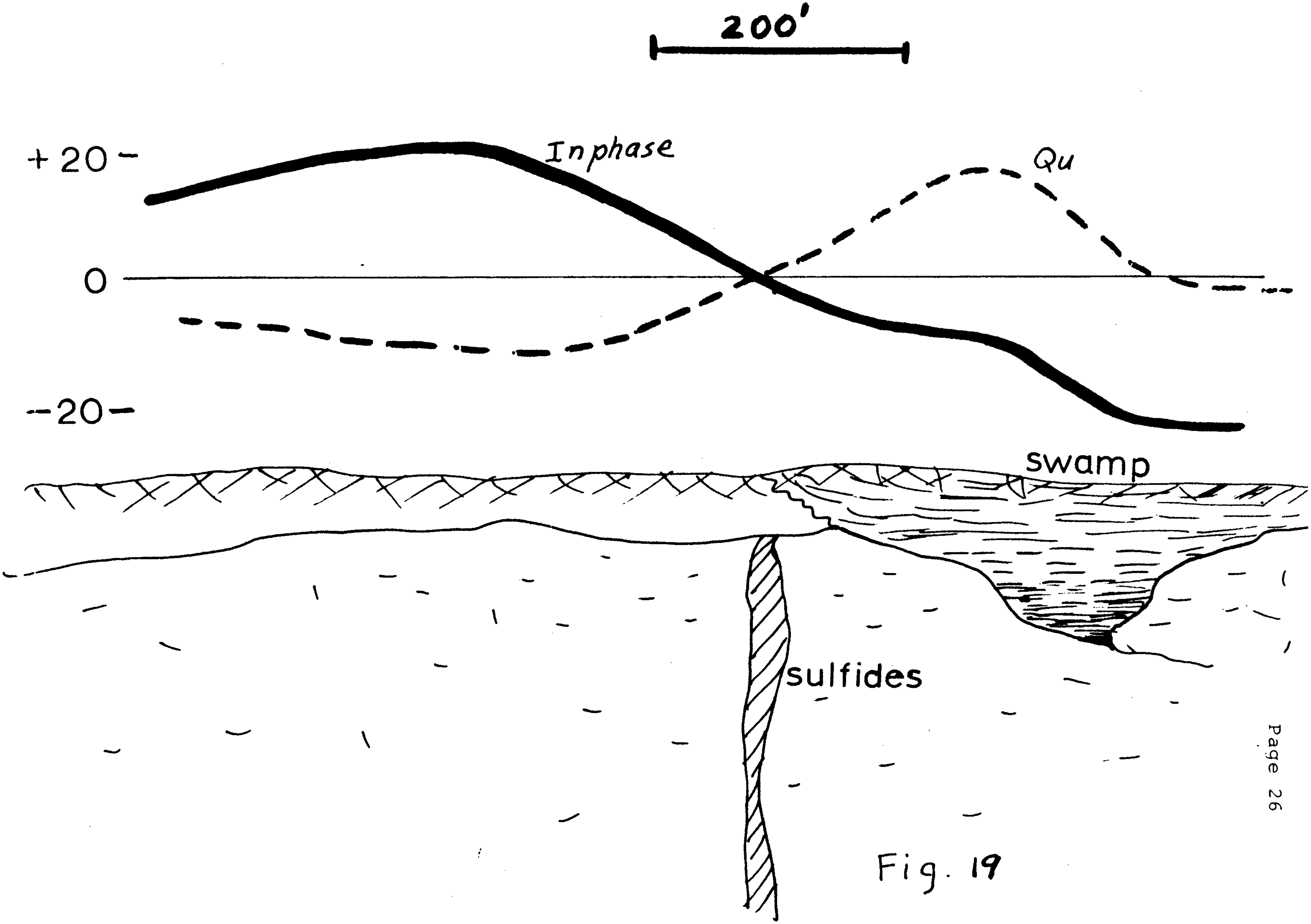


Fig. 19

Another use for the quadrature polarity is in the tracing of a fault or a shear zone. Normally these weak conductors give a fair amount of positive (the quadrature follows the in-phase polarity) quadrature. When we have a local sulfide concentration in these structures, we get a negative quadrature response.

All the interpretation is made easier by other indications of the depth to the target. The horizontal distance between the maximum positive and negative readings is about the same as the actual depth from the ground surface to the centre of the effective area of the conductive body. This point is not the centre of the body, but somewhat closer to the upper edge.

Theoretically, the depth 'h' of a spherical conductor with radius 'a' equals ΔX where ΔX is the horizontal distance between the maximum points of the vertical field H_z (Fig. 20a). The radius of the sphere is given by

$$a = 1.3\, h\, \sqrt[3]{H_z(\max)}.$$

For a cylindrical conductor the depth 'h' equals $0.86\Delta X$ and the radius of the cylinder is given by

$$a = 1.22\, h \quad H_z(\max).$$

In these equations $H_z = 1$ means 100% on the instrument dial.

The determination of the depth is generally more reliable than the estimation of the actual dimension a. The real component of H_z, which we should use in these calculations, decreases proportionally for a poorer conductor and with the depth in conductive material.

One can also draw some conclusions about the dip and shape of the upper area of the conductor by observing the smaller details of the profile. See the modelling curves.

A vertical sheet type conductor, if it comes close to the surface, gives a sharp gradient of large amplitude and slow roll-off on both sides. (Fig. 20b & 20c).

Horizontal sheets should give a single polarity on the edge of it, and again the opposite way on the other edge.(Fig.20f)

When looking at the plotted curves, one notices that two adjacent conductors may modify the shape of the anomalies for each one. In cases like this, one has to look for the steepest gradients of the vertical (plotted) field, rather than for the actual zero-crossings. Forget the word "crossover". Look for the centres of slopes on the in-phase for location of targets. See Figures 20d and 20e.

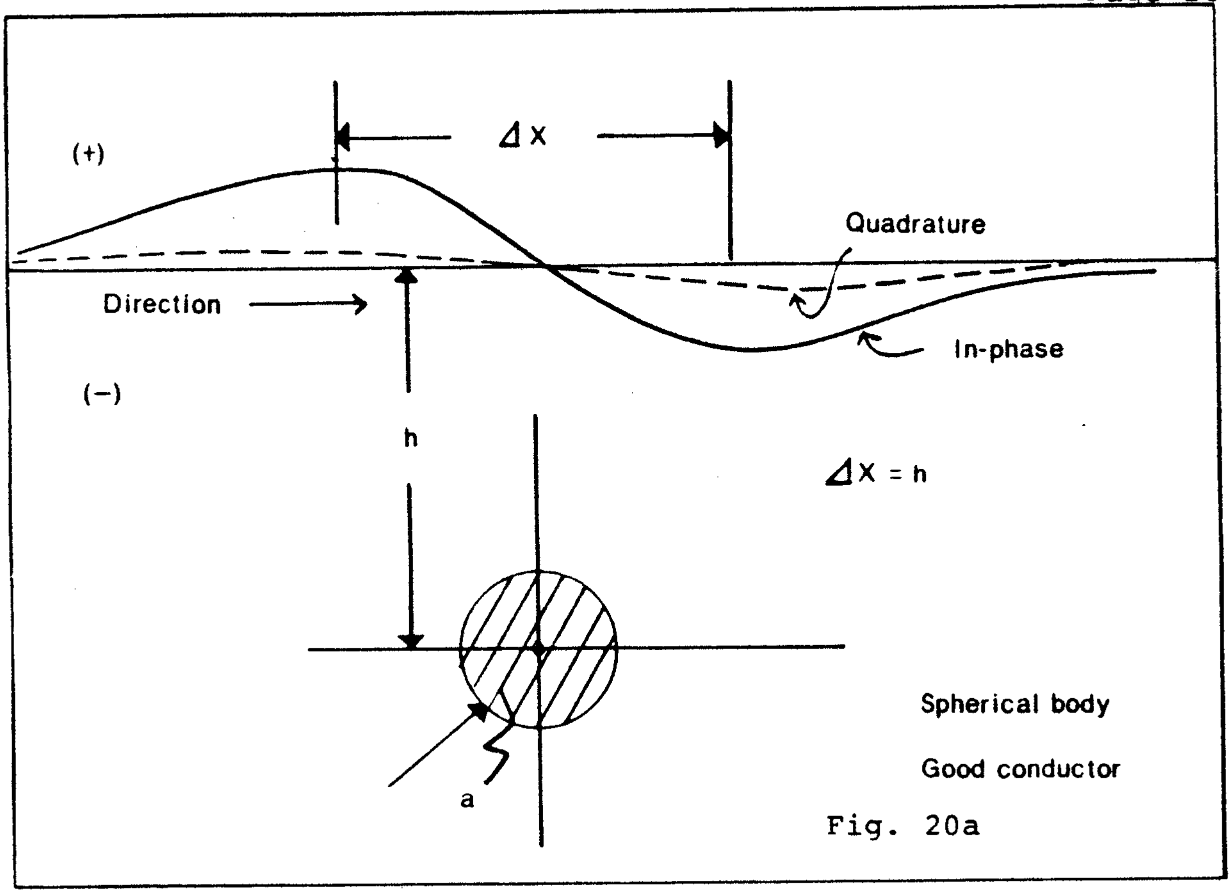


Fig. 20a

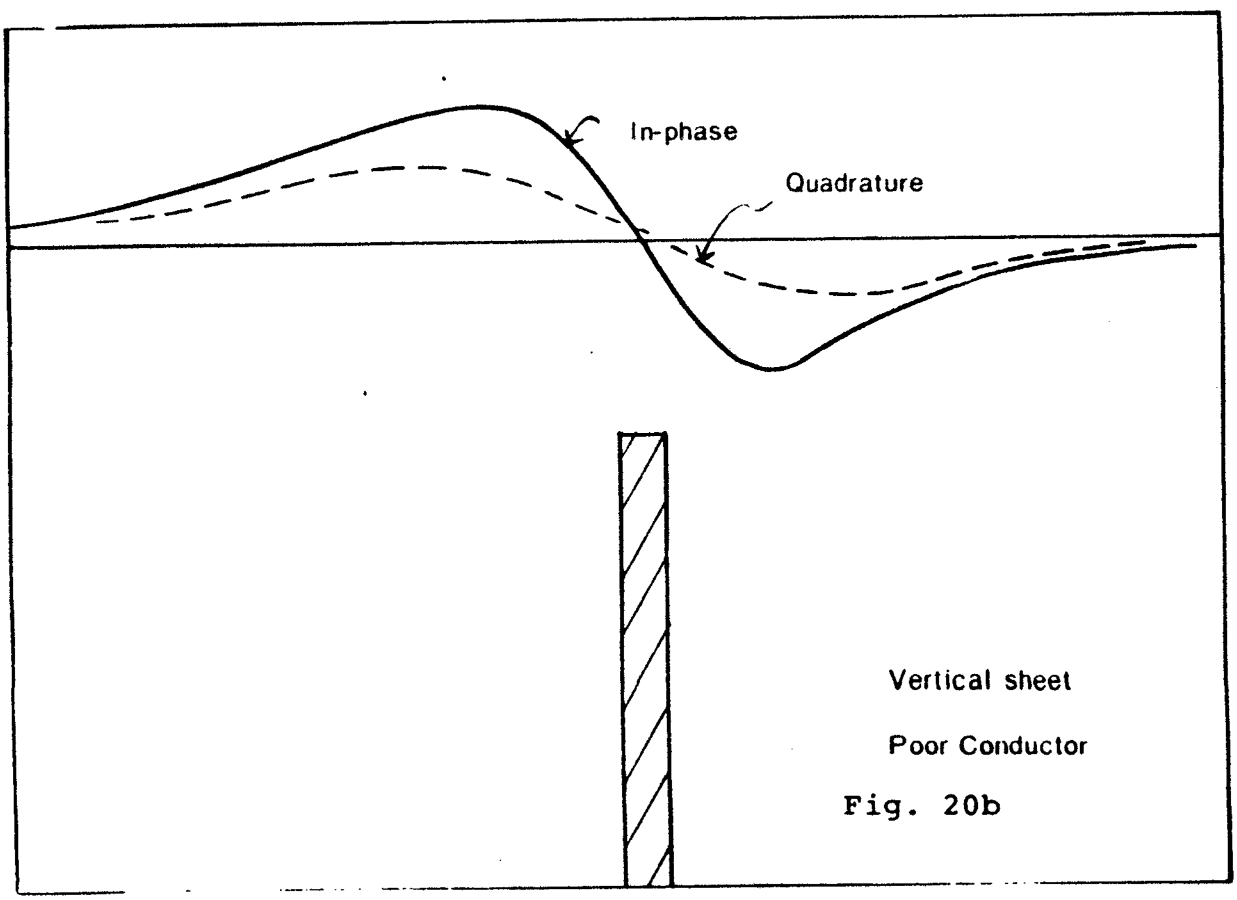
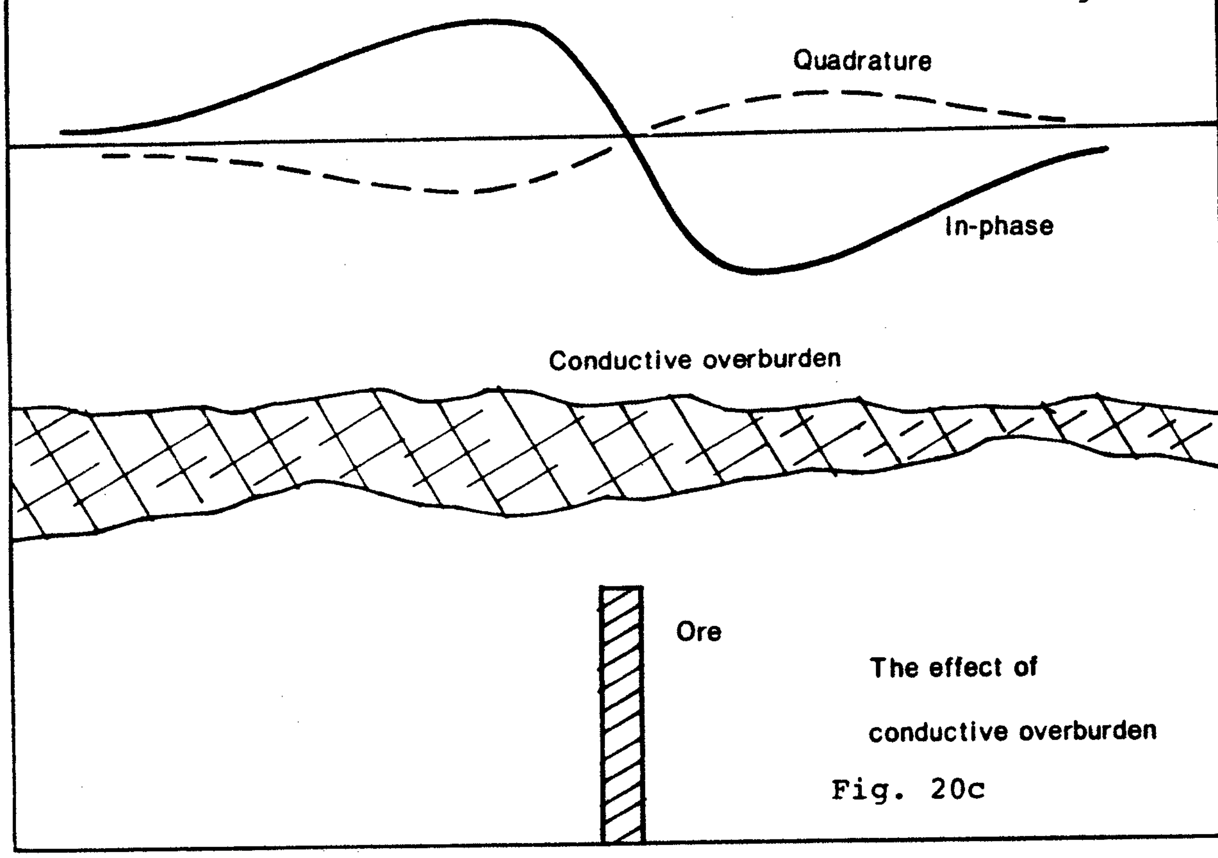


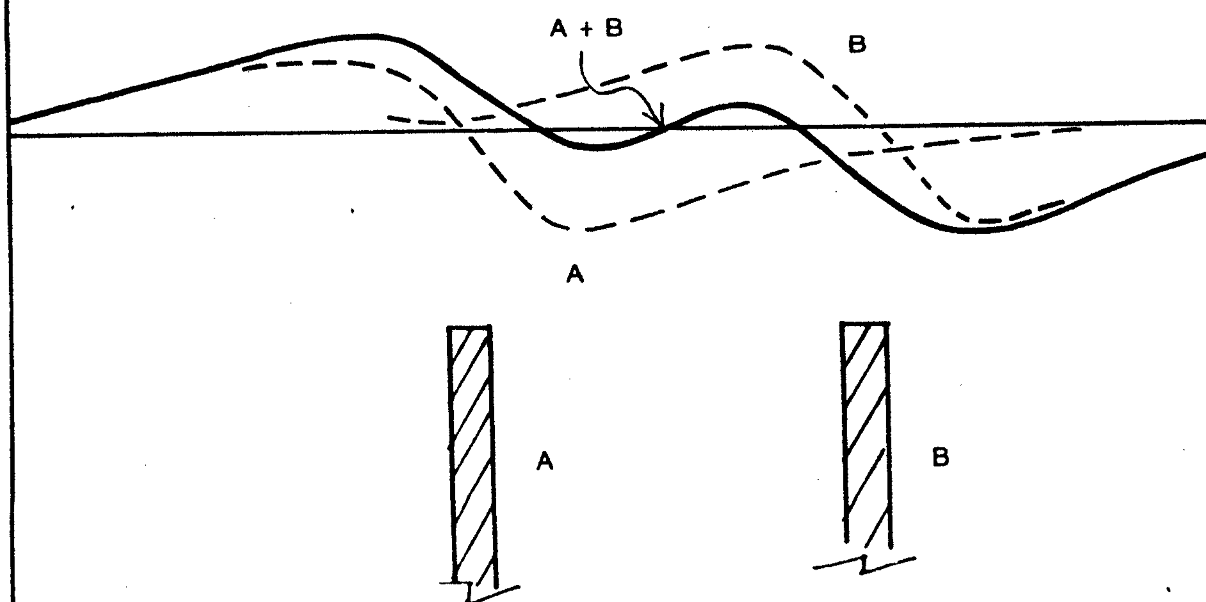
Fig. 20b



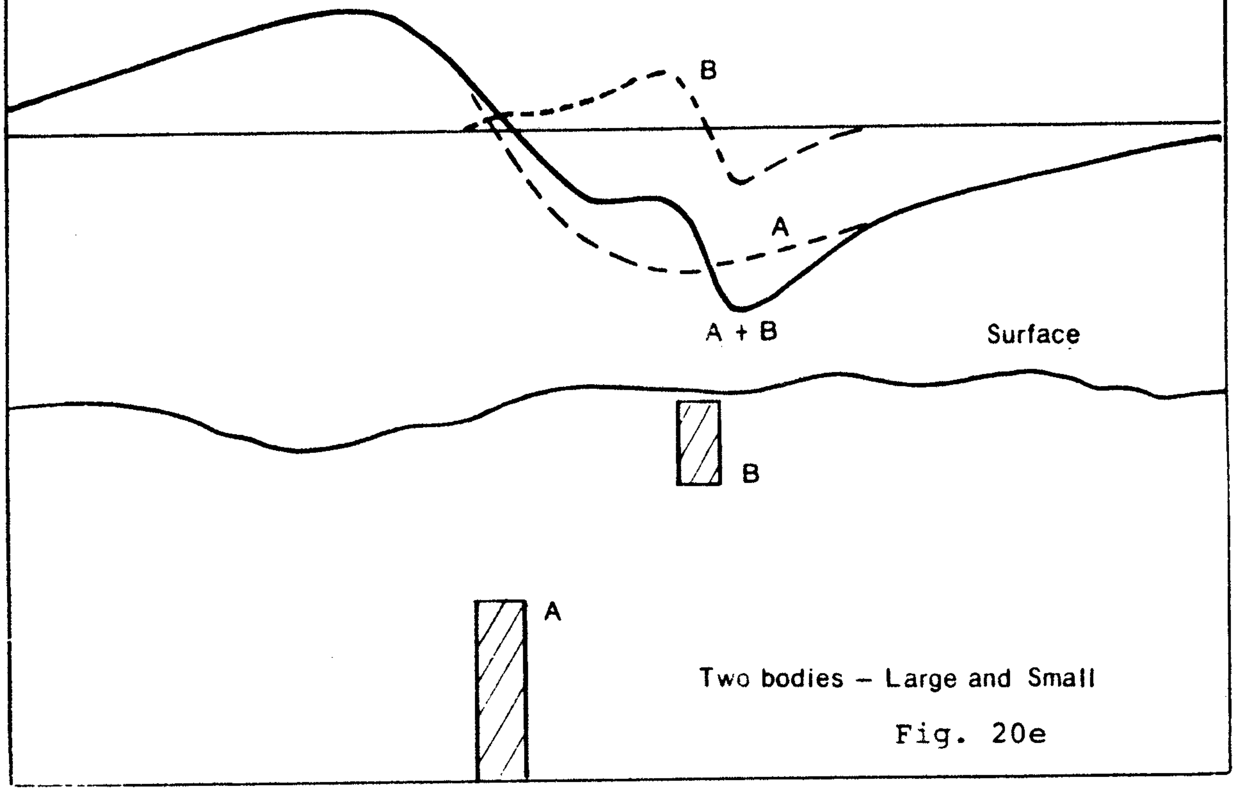
The effect of

conductive overburden

Fig. 20c

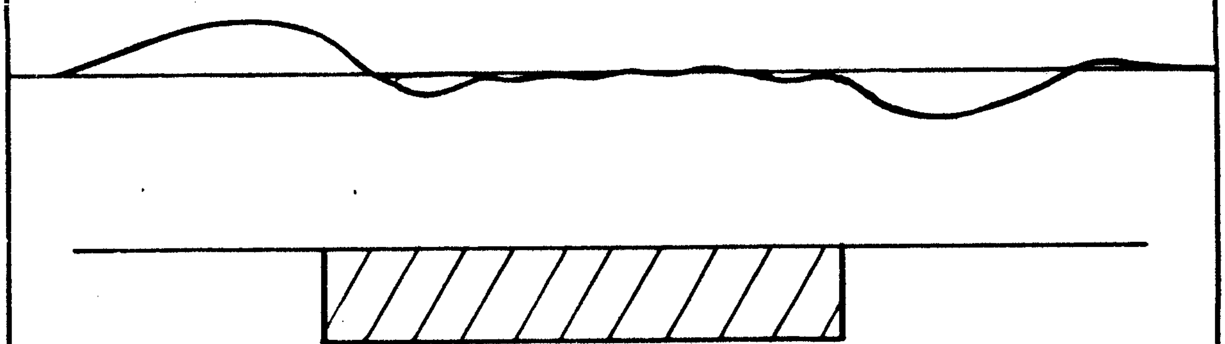


Two vertical bodies
Fig. 20d.



Two bodies – Large and Small

Fig. 20e



Horizontal slab

Fig. 20f

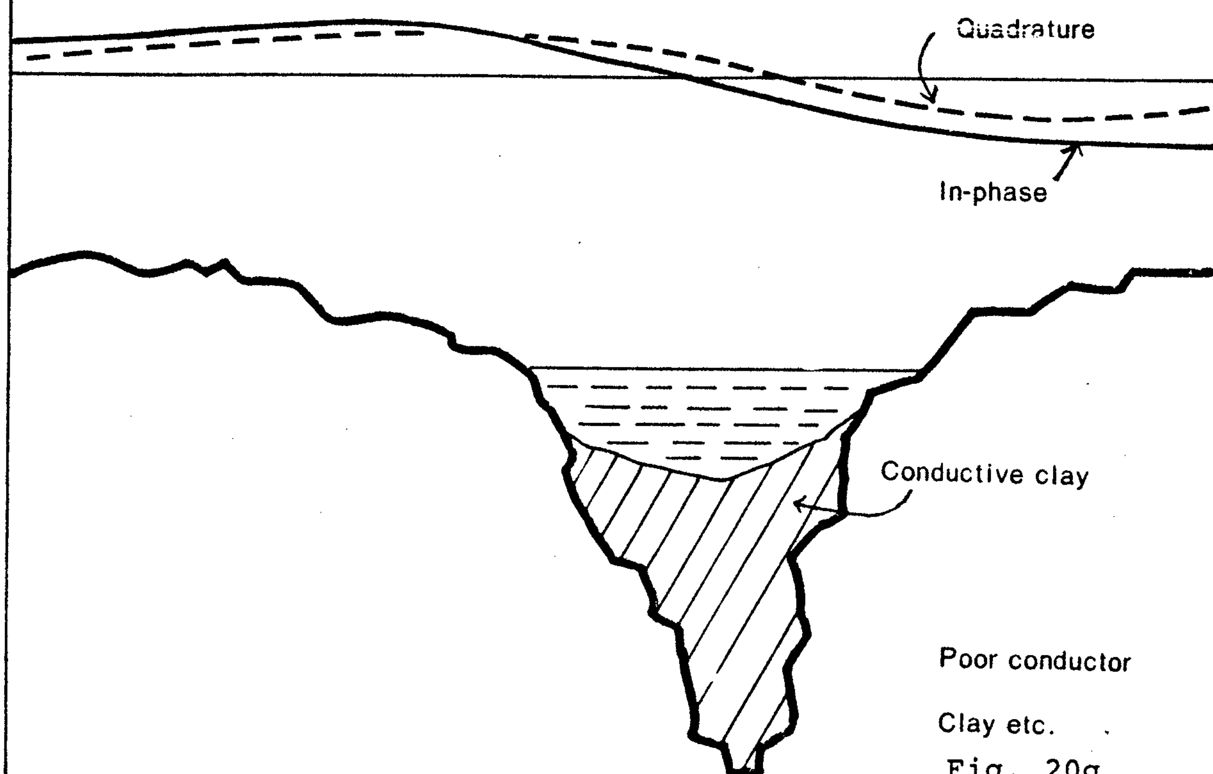


Fig. 20g

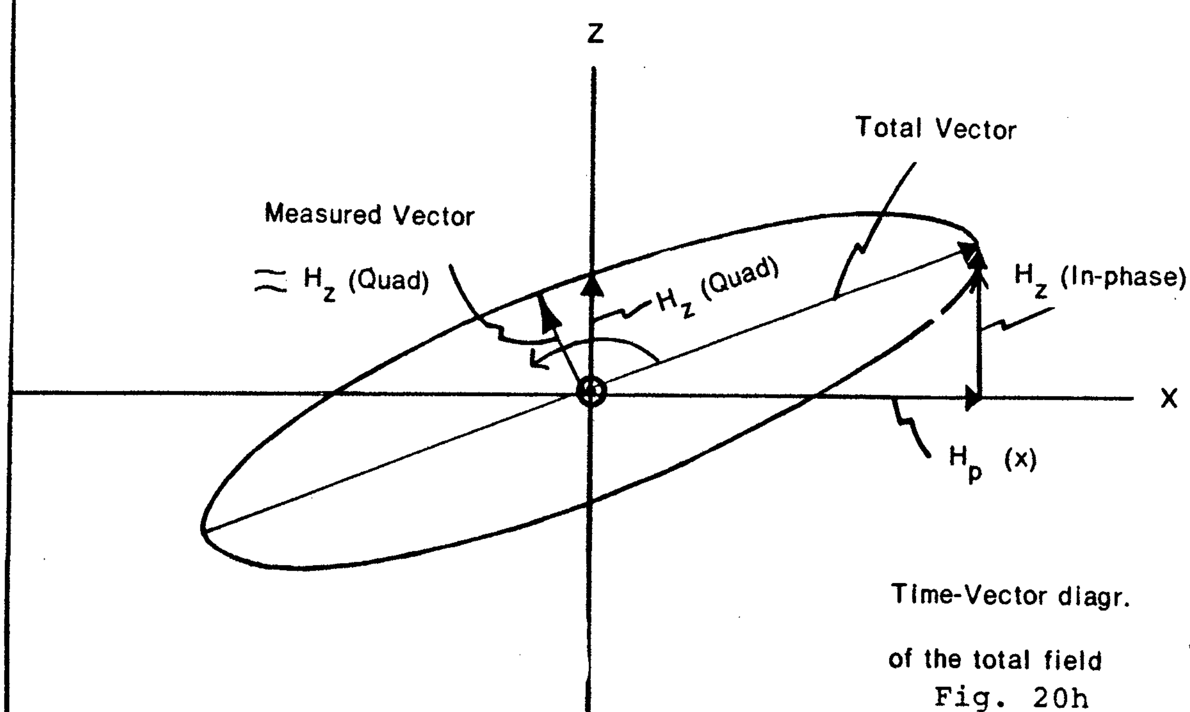


Fig. 20h

As with any EM, the largest and best conductors give the highest ratio of in-phase to quadrature components. In VLF however, the surrounding conductive material influences the results so much that it is almost an irrelevant statement except in a few cases. Also in practice most of the ore bodies are composed of different individual sections, and therefore one cannot use the in-phase/quadrature ratio as the sole indicator of the conductivity-size factor. In other words the characteristic response curves are flat, much flatter than with modelling.

MISCELLANEOUS NOTES

1) It has been shown in practice that this instrument can be used (in proper areas) also underground in mines. The rails and pipes may cause background variations. It was found in one mine even at 1400 foot level, that the signal strength was good. By taking readings at two directions at each station, one could obtain a very good indication about the location of the ore pockets in otherwise difficult geology.

2) On the other hand a thick layer of conductive clay can suppress the secondary field to a negligibly small value.

3) In mountainous areas one can expect a smooth rolling background variation. However, the actual sharper anomalies induced by conductive mineral zones can be usually easily recognized. Background variations can be effectively removed by standard numerical filtering procedures to emphasize local anomalies. +

4) Faults and shear-zones can give anomalies,* but not without a reason. There must be conductivity associated with them. Reverse quadrature may indicate sulfide deposits in these structures.

SERVICING

Changing the batteries is done by removing the cover and changing the penlight batteries one by one. Please notice the polarities marked on each individual cell. To test the condition of the batteries, turn the instrument on, press the push-button on the front panel. There should be a whistling sound in the loudspeaker if the batteries are in useable condition. If the sound is not heard, the battery voltage may be low, or the battery holders may be dirty or faulty.

* Telford, King and Becker, "VLF Mapping of Geological Structure".

\+ D.C. Fraser, "Contouring of VLF-EM Data".

It may be occasionally necessary to clean the contacts of the plug-in unit. For this, use a clean rag that is very slightly moistened with oil. The oily rag is good also for the battery terminals.

If any repairs are necessary, we recommend that the instrument be shipped to Geonics Limited for a thorough check-up and testing with proper measuring instruments.

GEONICS LIMITED
1745 Meyerside Drive, Unit 8, Mississauga, Ontario, Canada L5T 1C5 Tel. (416) 676-9580 Cables: Geonics

CONTOURING OF VLF-EM DATA

By

D. C. Fraser

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GEOPHYSICS, VOL. 34, NO. 6 (DECEMBER 1969), P. 958-967, 6 FIGS., 1 TABLE

CONTOURING OF VLF-EM DATA†

D. C. FRASER*

Prospecting for conductive deposits with ground VLF-EM instruments has received considerable impetus with the recent development of lightweight receivers. The large geologic noise component, which results from the relatively high-transmitted frequency, has caused some critics to avoid use of the technique. Those who routinely perform surveys with a VLF-EM unit find that, in some areas, a 5-degree peak-to-peak anomaly can be significant, whereas anomalies having amplitudes in excess of 100 degrees may occur as well. Consequently, there is a dynamic range problem when presenting the results as profiles plotted on a field map.

A data manipulation procedure is described which transforms noisy noncontourable data into less noisy contourable data, thereby eliminating the dynamic range problem and reducing the noise problem. The manipulation is the result of the application of a difference operator to transform zero-crossings into peaks, and a low-pass smoothing operator to reduce noise. Experience has shown that field personnel can routinely perform the calculations which simply involve additions and subtractions.

INTRODUCTION

VLF-EM data can be exceedingly difficult to interpret because a large geologic noise component can result from the relatively high-transmitted frequency of about 20,000 Hz. Routine surveys can yield useless data unless special care is taken both in survey procedure and in data presentation.

The purpose of this paper is to describe the survey procedure and the method of data presentation in use by the Keevil Mining Group and to illustrate the advantages of this approach.

VLF-EM GROUND SURVEY PROCEDURE AND DATA TREATMENT

The primary field

VLF-EM transmitter stations are located at several points around the globe. They broadcast at frequencies close to 20,000 Hz, which is low compared to the normal broadcast band. The purpose of these stations is to allow governmental communication with submarines, and the low frequency allows some penetration of the conductive ocean water. Skin depth is approximately $3.6\sqrt{P}$ meters, where P is the resistivity of a homogeneous halfspace in ohm-m, on the assumption that the frequency is 20,000 Hz and that the halfspace is magnetically nonpolarizable. Consequently, depth of exploration is severely restricted for overburden resistivities less than 200 ohm-m.

Since the area to be prospected normally is of considerable distance from the transmitter stations, the primary field is uniform in the area, allowing rather simple mathematics to be used in anomaly prediction and analysis.

Survey procedure and data treatment

The survey procedure first consists of selecting a transmitter station which provides a field approximately parallel to the traverse direction, i.e., approximately perpendicular to the expected strike of a conductor. The following points relate to the method of data treatment.

1. Readings should be taken every 50 ft, as will be shown below.
2. Transmitter stations should not be changed

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for a given block of ground, to avoid distortion in the contour presentation. Hence, fill-in lines should be run with the same transmitter station as other lines in the block. The field direction of this station should be shown on the data map.

3. List the dip angle[1] data in tabular form, as follows:
    a) list in the direction of north (top of paper) to south, or from west to east;
    b) designate south or east dips as negative; and
    c) perform calculations as shown in Table 1.

    Thus, the filtered output or contourable quantity simply consists of the sum of the observations at two consecutive data stations subtracted from the sum at the next two consecutive data stations. The theoretical basis for this procedure will be described below.
4. The right-hand column (filtered data) is suitable for contouring. Normally, negative values are not contoured since, being caused by dip angle flanks, they do not aid interpretation but only confuse the picture. The positive values generally are contoured at 10-unit intervals, and the zero contour is shown only when it brackets an anomaly. In quiet areas, 5-unit contours may be meaningful.

[1] This paper assumes that data is recorded as for the Crone Radem which defines a north-dipping field as a south "dip" on the instrument. This convention was chosen because a south reading is interpreted as arising from a conductor to the south.

Example

Figure 1 presents dip-angle data, according to the Crone convention, in the vicinity of the Temagami mine of Copperfields Mining Corporation Limited in Ontario. This figure illustrates that several conductors are present yielding large dip angles. A complex pattern has resulted which requires some thought to interpret properly.

Figure 2 presents the filtered data in contoured form where only the 0, 20, and 40 contours are shown for simplicity. The conductor pattern is immediately apparent, even to exploration personnel untrained in VLF-EM interpretation. The three anomalies correlate with a zone of nearly massive pyrite and two brecciated fault zones. Depth to bedrock is 15 ft.

In practice, all the data of Figures 1 and 2 are

Table 1. Example of calculations

Location	Measured dips	Apply sign and form the moving sum of pairs of entries		Take first differences of alternate entries	
3+00S	6S	−6	(−6)+(−7)=	−13	
3+50S	7S	−7	(−7)+(−8)=	−15	
4+00S	8S	−8		−23	(−23)−(−13)= −10
4+50S	15S	−15		−39	(−39)−(−15)= −24
					+7
5+00S	24S	−24		−16	+57
5+50S	8N	+8		+18	+38
6+00S	10N	+10		+22	+8
6+50S	12N	+12		+26	+6
7+00S	14N	+14		+28	(+34)−(+26)= +8
7+50S	14N	+14	(14)+(20)=	+34	
8+00S	20N	+20			

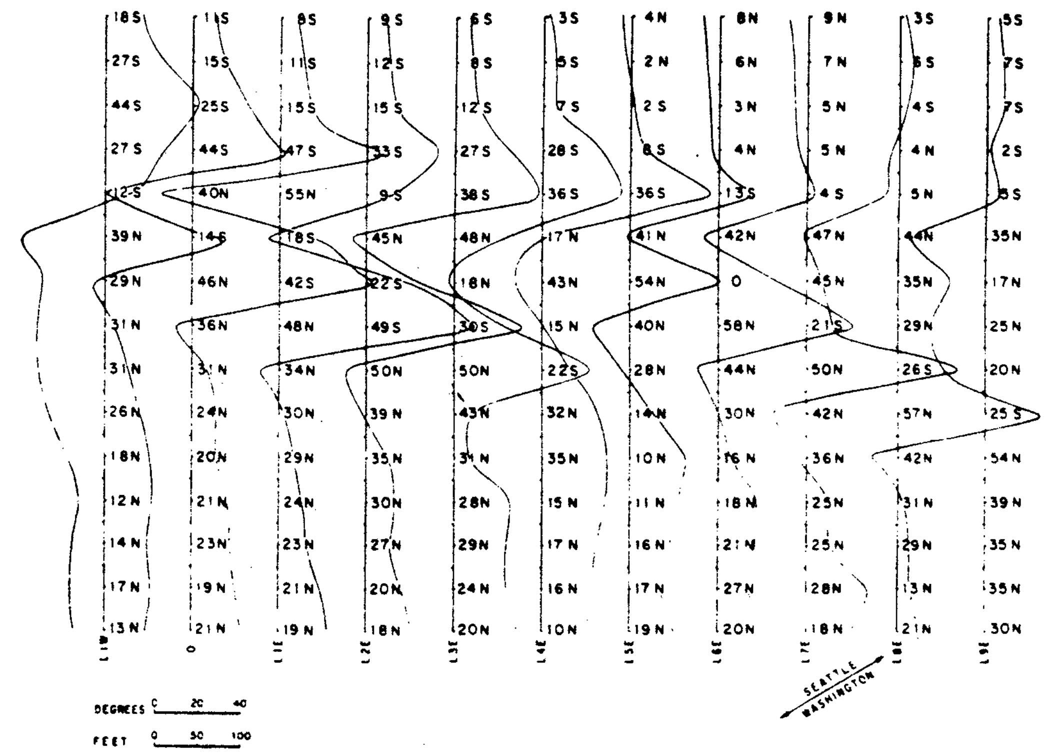

FIG. 1. Dip-angle data in the vicinity of the Temagami mine. The arrow defines the VLF-EM primary field direction from the transmitter at Seattle, Washington.

placed on a single map. The above example illustrates that this very simple one-dimensional filtering scheme yields a practical and effective approach to VLF-EM data handling.

The filter improves the resolution of anomalies, thereby making them easier to recognize. An inflection on the dip profile from a conductor subordinate to a larger one yields a positive peak, thereby emphasizing the presence of such a conductor. Figure 3 illustrates this effect where nine lines were run over an SP (self-potential) anomaly in the Temagami area. The dip-angle anomaly is very poorly resolved due to the regional south dips produced by an areally large conductor to the south of the map area. The contoured VLF-EM data yields a clearly defined anomaly which was located over the negative center of the SP.

THE FILTER AND ITS EFFECT ON ANOMALIES

The filter operator

The filter operator was designed to meet the following criteria:

1. It must phase shift the dip-angle data by 90 degrees so that crossovers and inflections will be transformed into peaks to yield contourable quantities.
2. It must completely remove dc and attenuate long spatial wavelengths to increase resolution of local anomalies.
3. It must not exaggerate the station-to-station random noise.
4. It must be simple to apply so that field personnel can make the calculations without difficulty.

The first two criteria are met by using a simple difference operator, i.e.

$$M_2 - M_1,$$

where M_1 and M_2 are any two consecutive data points.

The third criterion is met by applying a smoothing or low-pass operator to the differences, i.e.

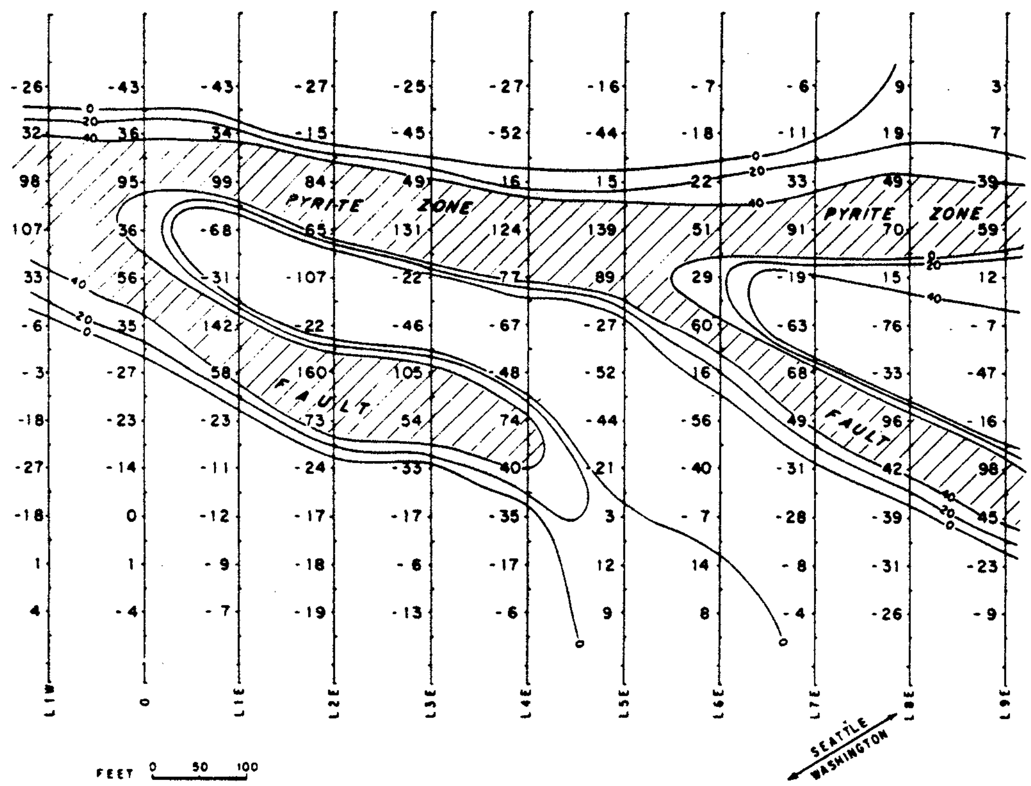

FIG. 2. Filtered data computed from the map of Figure 1.

$\frac{1}{4}(M_2 - M_1) + \frac{1}{2}(M_3 - M_2) + \frac{1}{4}(M_4 - M_3)$,

where M_1, M_2, M_3, and M_4 are any four consecutive data points. The filtered output then is

$$\frac{1}{4}(M_2 - M_1) + \frac{1}{2}(M_3 - M_2) + \frac{1}{4}(M_4 - M_3) = \frac{1}{4}[M_3 + M_4 - M_1 - M_2].$$

The final criterion is enhanced by eliminating the constant, so that the plotted function becomes

$$f_{2,3} = (M_3 + M_4) - (M_1 + M_2),$$

which is plotted midway between the M_2 and M_3 dip-angle stations.

This filter has its frequency (wavenumber) response displayed in Figure 4, for a station spacing of 50 ft. Its characteristics are as follows:

1. All frequencies are shifted by 90 degrees.
2. Noise having a wavelength equal to the station spacing and dc bias are completely removed.
3. Maximum amplitude occurs for wavelengths of 250 ft, or five times the station spacing.

The frequency (wavenumber) response of the filter is shown for a station spacing of 50 ft, because this is the most suitable spacing for defining sulfide bodies within a few hundred feet of surface. This will be demonstrated below.

The dike model

A conducting dike in a VLF-EM field will produce a secondary induction field from eddy currents maintained in it by the primary field. These eddy currents will tend to flow in such a manner as to form line sources concentrated near the outer edges of the dike since the field is uniform (Figure 5a). This dike may be replaced by a loop of wire of dimensions traced out by the main current concentration in the dike. The secondary field geometry of the loop and dike then will be practically identical, as has been shown by Fraser (1966), Parry (1966), and Parry et al (1965). This

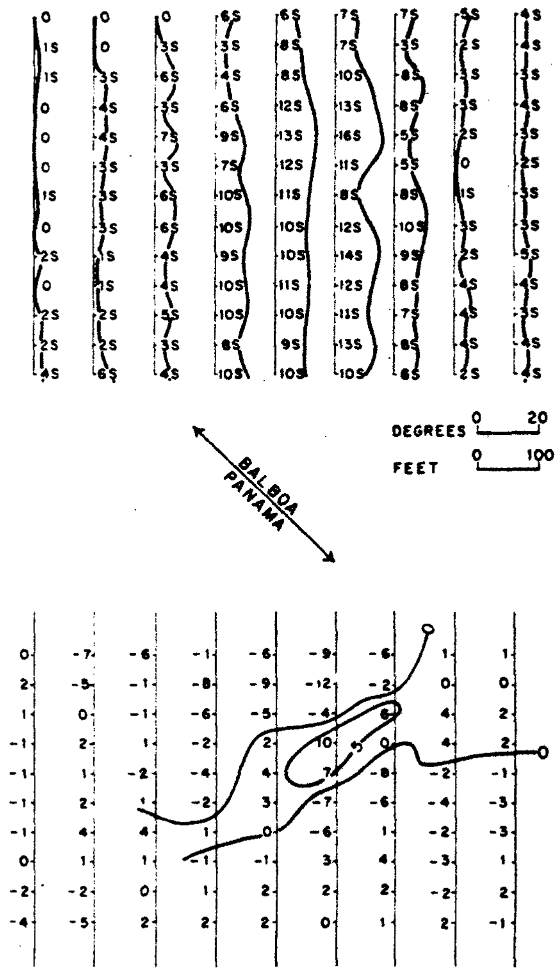

FIG. 3. Dip-angle (upper map) and filtered data (lower map) over a small grid in the Temagami area. The arrow defines the VLF-EM primary field direction from the transmitter at Balboa, Panama.

allows a mathematical model of a dike to be constructed because the field from a line source is known.

For brevity, only a dike which is large in depth extent and in length will be considered herein. Only the top line source of Figure 5a will contribute to the measured dip angles because the other current line sources are very far away.

The horizontal Hs_x and vertical Hs_z secondary fields are (Figure 5b)

$$Hs_x = kH_0 \frac{z}{x^2 + z^2}$$

$$Hs_z = kH_0 \frac{x}{x^2 + z^2},$$

where k is a positive constant having the dimension of length and is related to the conductivity and dimensions of the dike, and where H_0 is the primary VLF-EM strength at the dike. The measured dip angle is

$$\alpha = \tan^{-1}\left[\frac{H_{s_z}}{Hs_x + H_0}\right] = \tan^{-1}\left[\frac{kx}{kz + x^2 + z^2}\right]$$

Model dip profiles can be computed for various depths z only by assuming a value for k.

As a means of testing the effect of the filter operator, a single k value was chosen to yield a

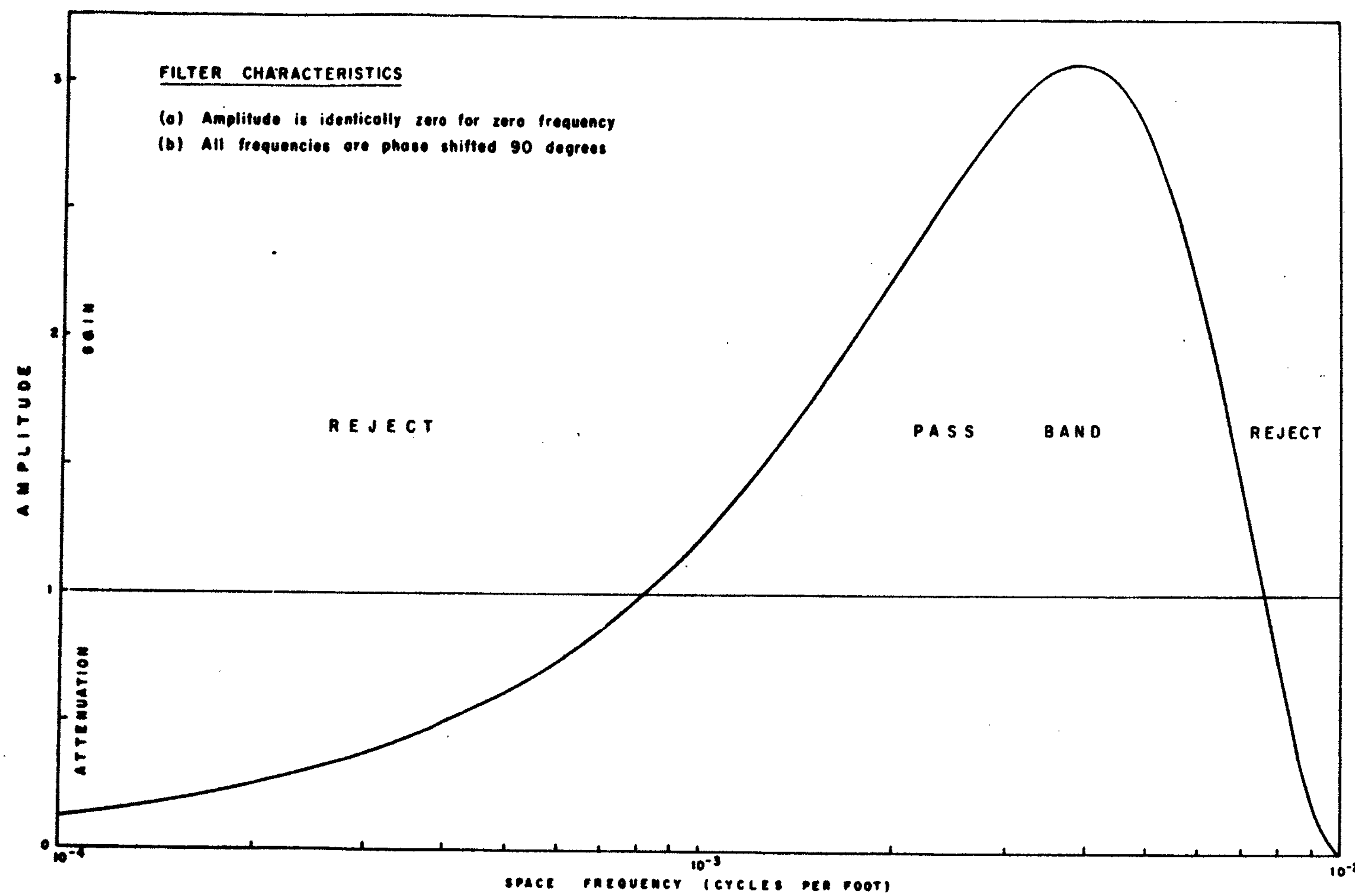

FIG. 4. Frequency response of filter operator for station spacing of 50 ft.

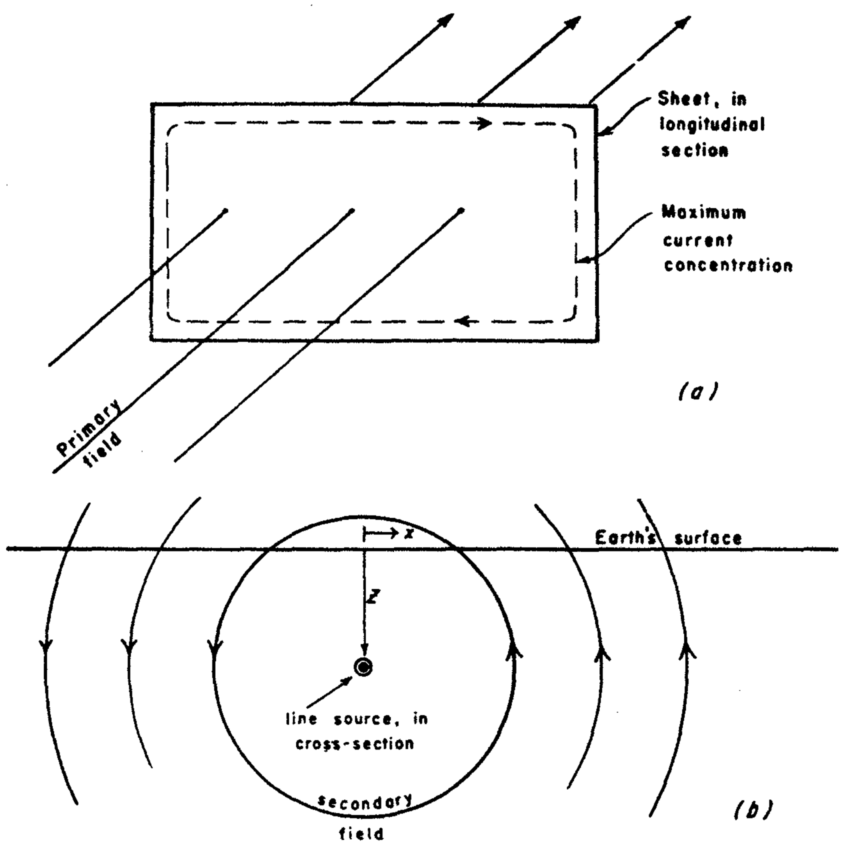

FIG. 5. (a) A sheet in a uniform primary field will have maximum current concentrated near its edges. (b) A line source, corresponding to the upper current concentration in (a), yields a secondary magnetic field of cylindrical shape.

maximum dip angle of 35 degrees when depth z to top of dike (or line source) was 100 ft. Figure 6 illustrates the dip angle and filtered profiles for this case for a station spacing of 50 ft and for several depth values.

The following are the main characteristics of these dike and filtered anomalies:

1. Peak-to-peak angles vary from 93 degrees for $z=50$ ft to 25 degrees for $z=500$ ft. Filtered peaks vary from 118 degrees for $z=50$ ft to 8 degrees for $z=500$ ft. Thus, the filter amplifies near-surface anomalies and attenuates deep-source anomalies. There is neither amplification nor attenuation when z is 100 ft.
2. On the basis of anomaly resolution and usual noise levels, dip angle data can detect dike-like conductors in a resistive medium to a depth of 500 ft, while filtered data can detect such bodies to a depth of 300 ft. Conductors in the upper 200 ft generally will be more easily recognized on the filtered data.

VLF-EM data commonly is measured at 100-ft intervals in Canada. A change in the sample interval from the 50 ft recommended herein to 100 ft causes the passband curve of Figure 4 to shift to the left, such that the peak is at 2×10^{-3} cpf rather than 4×10^{-3} cpf. Similarly, the anomaly curves of Figure 6 remain correct in shape provided all distance dimensions are doubled. Consequently, detection of conductors to a depth of 500 ft, when utilizing the filter operator, might appear facilitated by use of a 100-ft station interval rather than a 50-ft interval. However, anomalies from near-surface conductors will have poorly defined waveforms for a 100-ft

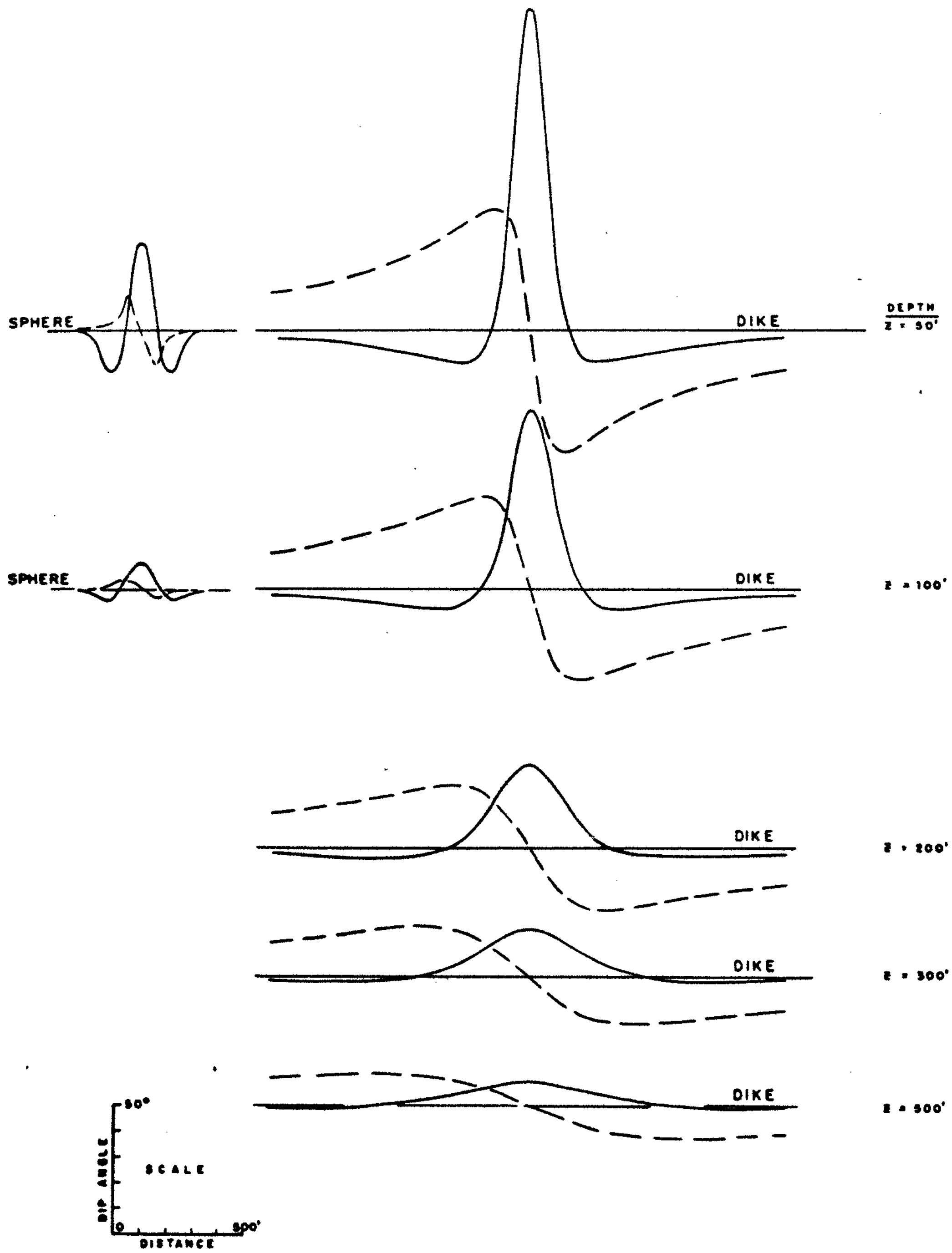

FIG. 6. Dip-angle (dashed) and filtered (solid) curves for model dike and sphere for several depths of burial, where z is depth to top of dike and to center of sphere.

data station interval, and will alias as deeper conductors. This "geologic noise" will somewhat confuse the contoured output. Generally, a comparison of the 50-ft data station dip angle profiles with the contoured filtered output suffices to indicate approximate depth to source and to allow recognition of sources deeper than 300 ft.

As an aside, some geophysicists have claimed that a reasonable dike model depth estimate can be obtained directly as half the distance between dip angle peaks, because the vertical field Hs_z peaks at $x = \pm z$. However, this formula is not applicable to dip-angle data, as can be seen by the dike curves of Figure 6. For this example, the formula provides erroneous depth estimates of 150, 200, 325, 425, and 625 for true depths of 50, 100, 200, 300, and 500 ft.

The sphere model

A conducting sphere in a VLF-EM field will produce an anomaly according to equations in Ward (1967). For a traverse directly over a sphere having its center at depth z, and run in the direction of the primary field H_0, the anomaly is,

$$Hs_x = kH_0 \frac{(2x^2 - z^2)}{(x^2 + z^2)^{5/2}}$$

$$Hs_z = kH_0 \frac{3xz}{(x^2 + z^2)^{5/2}},$$

where k is a positive constant which saturates at $R^3/2$, where R is the sphere radius, and where quadrature is ignored. The measured dip angle as a function of station location x is (where x is zero directly over the sphere center),

$$\alpha = \tan^{-1}\left(\frac{Hs_z}{Hs_x + H_0}\right)$$

$$= \tan^{-1}\left[\frac{3kxz}{k(2x^2 - z^2) + (x^2 + z^2)^{5/2}}\right].$$

Model dip profiles can be computed for various depths z only by assuming a value for k. The sphere curves of Figure 6 assume a saturated k-value for a sphere radius of 50 ft. Obviously, a sphere having its center at a depth of greater than twice its radius generally will not be detectable. However, the filter operator aids in the recognition of a spherical conductor because it amplifies the anomaly, for the small sphere sizes usually encountered in nature, assuming data spacing is 50 ft.

TOPOGRAPHIC EFFECT

Whittles (1969) recently described a topographic effect which may arise when surveying with VLF-EM in mountainous regions. The spatial wavelengths which result from the phenomenon he describes are greatly attenuated by the filter and generally do not appear on the contoured maps. Whittles advocates the use of first derivatives to remove the topographic effect. The filter operator described herein uses the first difference (i.e., the discrete first derivative) as one of its components.

ADDITIONAL APPLICATIONS

The simplicity of the calculations allows practical application of the filter to any form of ground geophysical data which yields zero-crossings over tragets, such as vertical loop EM and Afmag. However, it is difficult to justify the use of the filter on vertical loop EM data because neither dynamic range of anomalies nor geologic noise is large. In Afmag, utilization of the filter is not recommended because of the varying direction of the primary field.

Airborne VLF-EM systems, which measure parameters yielding zero-crossings over targets, are being marketed. If the data were collected on magnetic tape, a computer could be used to apply the filter, thereby allowing contouring of the data. However, in this situation more sophisticated filter operators should be employed.

If the filter is to be applied to data other than ground VLF-EM, the sample interval should be selected to ensure that the passband of the filter is correct relative to the frequency components of the anomalies sought.

CONCLUSIONS

A consideration of geologic noise and conductor shapes illustrates that VLF-EM data should be collected at 50-ft intervals, and that the described filter operator should be employed. The filtered data, when contoured, provides a data presentation which simplifies interpretation. The filter also amplifies anomalies from near-surface, highly conducting ore pods which is an important feature in several mining districts such as at Tribag and Temagami, both in Ontario, and in Louvicourt Township of Quebec.


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QUADRATURE (%)
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1cm = 25%
50%
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-50%
INSTRUMENT - GEONICS EM-16
TRANSMITTER - NLK-24.8 KHz, SEATTLE, WASHINGTON.
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GEOLOGICAL BRANCH
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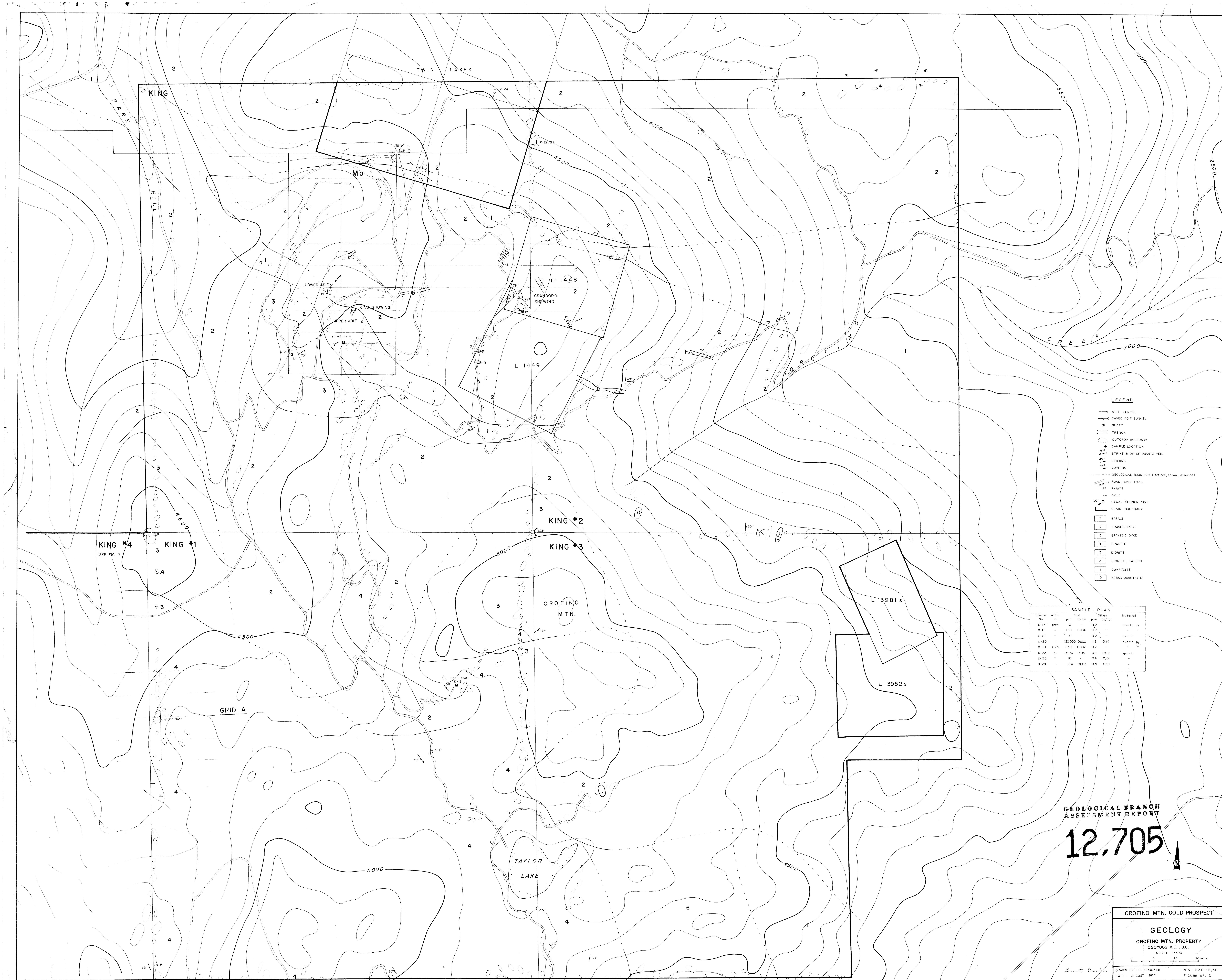
FIGURE Nº. : 4



SAMPLE PLAN

Sample No	Width m.	Gold ppb	Gold oz/ton	Silver ppm	Silver oz/ton	Material
K-17	grab	10	–	0.2	–	quartz, py
K-18	"	150	0.004	0.2	–	" "
K-19	"	10	–	0.2	–	quartz
K-20	"	>20,000	0.560	4.6	0.14	quartz, py
K-21	0.75	250	0.007	0.2	–	" "
K-22	0.4	1600	0.05	0.8	0.02	quartz
K-23	"	10	–	0.4	0.01	"
K-24	"	180	0.005	0.4	0.01	"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BASELINE
5+00E
10+00E
L.C.P. MO
L 6 N
L 5 N
TAILING POND
KING CLAIM
KING 2 CLAIM
MO CLAIM
L 2 N
L 1 N
L 0 N
L 1 S
L 2 S
Lower Adit
KING SHOWING
Upper Adit
ANOMALY A
ANOMALY B
ANOMALY C
GRANDORO SHOWING
LEGEND
VLF-EM STATIONS
ADIT
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SHAFT
LEGAL CORNER POST
CLAIM BOUNDARY
FAULT OR SHEAR ZONE
FRASER FILTER VALUE, %
QUARTZ VEIN
INSTRUMENT - GEONICS EM-16
TRANSMITTER - NLK-24.8 KHz, SEATTLE, WASHINGTON.
Seattle Washington
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GEOLOGICAL BRANCH ASSESSMENT REPORT
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OROFINO MTN. GOLD PROSPECT
VLF - EM SURVEY
FRASER FILTER DATA
OROFINO MTN. PROPERTY
OSOYOOS M.D., B.C.
SCALE 1:2500
0 50 100 200 METRES
DRAWN BY G. CROOKER
N.T.S. 82E-4E, 5E
DATE AUGUST 1984
FIGURE No. 5