Report #1069

DIGHEM^{IV} SURVEY
FOR
CHAMPION BEAR RESOURCES LTD.
HELDER LAKE 1989, ONTARIO

NTS 52L/1, 2, 7, 8

DIGHEM SURVEYS & PROCESSING INC.
MISSISSAUGA, ONTARIO
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SUMMARY

This report describes the logistics and results of a DIGHEM^{IV} airborne geophysical survey carried out for Champion Bear Resources Ltd., over a property in the Helder Lake Area, Ontario.

The purpose of the survey was to detect zones of conductive mineralization and to provide information that could be used to map the geology and structure of the survey area. This was accomplished by using a DIGHEM^{IV} multi-coil, multi-frequency electromagnetic system, supplemented by a high sensitivity Cesium magnetometer and a two-channel VLF receiver. The information from these sensors was processed to produce maps which display the magnetic and conductive properties of the survey area. An electronic navigation system, operating in the UHF band, ensured accurate positioning of the geophysical data with respect to the base maps.

The EM survey detected many discrete bedrock conductors and numerous anomalies of possible bedrock origin. Some of these correlate with magnetic anomalies. Most of the inferred bedrock conductors appear to warrant further investigation using appropriate surface exploration techniques. Areas of interest may be assigned priorities on the basis of supporting geophysical, geochemical and/or

geological information. After initial investigations have been carried out, it may be necessary to re-evaluate the remaining anomalies based on information acquired from the follow-up program.

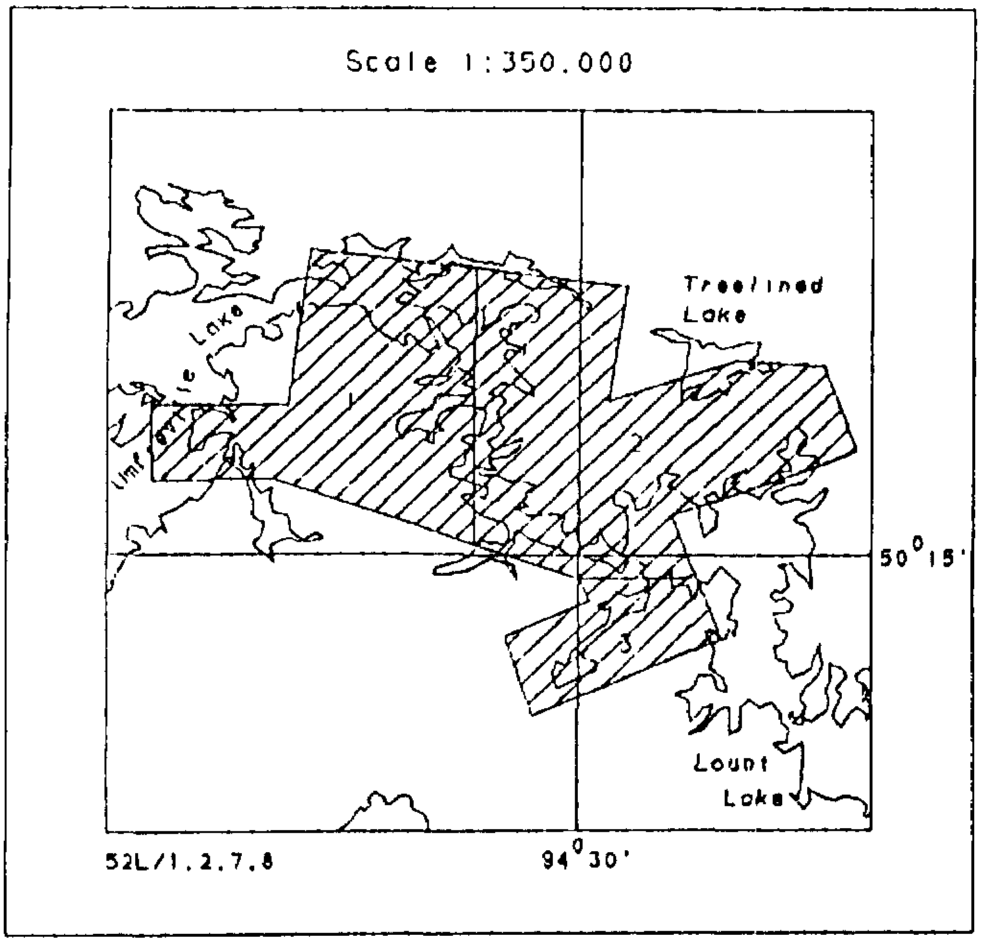

FIGURE 1

THE SURVEY AREA

CONTENTS

INTRODUCTION

A DIGHEM^{IV} electromagnetic/resistivity/magnetic/VLF survey was flown for Champion Bear Resources Ltd., from May 13 to May 15, 1989, over one survey block in the Helder Lake Area, Ontario. The survey area consists of 3 overlapping grids. This area is located on NTS map sheets 52L/1, 2, 7, 8. (See Figure 1).

Survey coverage consisted of approximately 1612 line-km. Flight lines were flown in an azimuthal direction of 158°/338° for the 10000 series lines, 12°/192° for the 20000 series lines, and 0°/180° for the 30000 series lines. The line separation for all grids was 200 metres.

The survey employed the DIGHEM^{IV} electromagnetic system. Ancillary equipment consisted of a magnetometer, radio altimeter, video camera, analog and digital recorders, a VLF receiver and an electronic navigation system. Details on the survey equipment are given in Section 2.

The instrumentation was installed in an Aerospatiale AS350B turbine helicopter which was provided by Questral Helicopters Ltd. The helicopter flew at an average airspeed of 122 km/hr with an EM bird height of approximately 30 m.

Section 2 also provides details on the data channels, their respective sensitivities, and the navigation/flight path recovery procedure. Noise levels of less than 2 ppm are generally maintained for wind speeds up to 35 km/h. Higher winds may cause the system to be grounded because excessive bird swinging produces difficulties in flying the helicopter. The swinging results from the 5 m^2 of area which is presented by the bird to broadside gusts.

SURVEY EQUIPMENT

This section provides a brief description of the geophysical instruments used to acquire the survey data:

Electromagnetic System

Model:	DIGHEM^{IV}
Type:	Towed bird, symmetric dipole configuration operated at a nominal survey altitude of 30 metres. Coil separation is 8 metres for the 900 Hz and 7200 Hz coil pairs; 6.3 metres for the 56,000 Hz.
Coil orientations/frequencies:	coaxial / 900 Hz coplanar/ 900 Hz coplanar/ 7,200 Hz coplanar/56,000 Hz
Channels recorded:	4 inphase channels 4 quadrature channels 3 monitor channels
Sensitivity:	0.2 ppm at 900 Hz 0.4 ppm at 7,200 Hz 1.0 ppm at 56,000 Hz
Sample rate:	10 per second

The electromagnetic system utilizes a multi-coil coaxial/coplanar technique to energize conductors in different directions. The coaxial transmitter coil is vertical with its axis in the flight direction. The coplanar coils are horizontal. The secondary fields are sensed simultaneously by means of receiver coils which are maximum coupled to their respective transmitter coils. The system yields an inphase and a quadrature channel from each transmitter-receiver coil-pair.

Magnetometer

Model:	Picodas 3000
Type:	Optically pumped Cesium vapour
Sensitivity:	0.01 nT
Sample rate:	10 per second

The magnetometer sensor is towed in a bird 15 m below the helicopter.

Magnetic Base Station

Model:	Scintrex IGS-2/MP-3
Type:	Digital recording proton precession
Sensitivity:	0.10 nT
Sample rate:	0.5 per second

A digital recorder is operated in conjunction with the base station magnetometer to record the diurnal variations of the earth's magnetic field. The clock of the base station is synchronized with that of the airborne system to permit subsequent removal of diurnal drift.

VLF System

Manufacturer: Herz Industries Ltd.

Type: Totem-2A

Sensitivity: 0.1%

Stations:	Annapolis, Maryland;	NSS, 21.4 kHz
	Cutler, Maine;	NAA, 24.0 kHz
	Seattle, Washington;	NLK, 24.8 kHz

The VLF receiver measures the total field and vertical quadrature components of the secondary VLF field. Signals from two separate transmitters can be measured simultaneously. The VLF sensor is towed in a bird 10 m below the helicopter.

Radio Altimeter

Manufacturer: Honeywell/Sperry

Type: AA 220

Sensitivity: 1 ft

The radio altimeter measures the vertical distance between the helicopter and the ground. This information is used in the processing algorithm which determines conductor depth.

Analog Recorder

Manufacturer: RMS Instruments

Type: GR33 dot-matrix graphics recorder

Resolution: 4x4 dots/mm

Speed: 1.5 mm/sec

The analog profiles were recorded on chart paper in the aircraft during the survey. Table 2-1 lists the geophysical data channels and the vertical scale of each profile.

Digital Data Acquisition System

Manufacturer: Scintrex

Type: CDI-6

Tape Deck: RMS TCR-12, 6400 bpi, tape cartridge recorder

The digital data were used to generate several computed parameters. Both measured and computed parameters were plotted as "digital profiles" during data processing. These parameters are shown in Table 2-2.

In Table 2-2, the log resistivity scale of 0.06 decade/mm means that the resistivity changes by an order of magnitude in 16.5 mm. The resistivities at 0, 33 and 67 mm up from the bottom of the digital profile are respectively 1, 100 and 10,000 ohm-m.

Table 2-1. The Analog Profiles

Channel Name	Parameter	Scale units/mm	Designation on digital profile
CX1I	coaxial inphase (900 Hz)	2.5 ppm	CXI (900 Hz)
CX1Q	coaxial quad (900 Hz)	2.5 ppm	CXQ (900 Hz)
CP2I	coplanar inphase (900 Hz)	2.5 ppm	CPI (900 Hz)
CP2Q	coplanar quad (900 Hz)	2.5 ppm	CPQ (900 Hz)
CP3I	coplanar inphase (7200 Hz)	5 ppm	CPI (7200 Hz)
CP3Q	coplanar quad (7200 Hz)	5 ppm	CPQ (7200 Hz)
CP4I	coplanar inphase(56000 Hz)	10 ppm	CPI (56 kHz)
CP4Q	coplanar quad (56000 Hz)	10 ppm	CPQ (56 kHz)
ALT	altimeter	3 m	ALT
VF1T	VLF-total: primary stn.	5%	
VF1Q	VLF-quad: primary stn.	5%	
VF2T	VLF-total: secondary stn.	5%	
VF2Q	VLF-quad: secondary stn.	5%	
CMGC	magnetics, coarse	25 nT	MAG
CMGF	magnetics, fine	2.5 nT	
CXSP	coaxial spherics monitor		CXS
CXPL	coaxial powerline monitor		CXPL
CPPL	coplanar powerline monitor		

Table 2-2. The Digital Profiles

Channel <u>Name (Freq)</u>	<u>Observed parameters</u>	Scale <u>units/mm</u>
MAG	magnetics	10 nT
ALT	bird height	6 m
CXI (900 Hz)	vertical coaxial coil-pair inphase	2 ppm
CXQ (900 Hz)	vertical coaxial coil-pair quadrature	2 ppm
CXS	ambient noise monitor (coaxial receiver)	
CXPL	coaxial 50/60 Hz powerline monitor	
CPI (900 Hz)	horizontal coplanar coil-pair inphase	2 ppm
CPQ (900 Hz)	horizontal coplanar coil-pair quadrature	2 ppm
CPI (7200 Hz)	horizontal coplanar coil-pair inphase	4 ppm
CPQ (7200 Hz)	horizontal coplanar coil-pair quadrature	4 ppm
CPI (56000 Hz)	horizontal coplanar coil-pair inphase	10 ppm
CPQ (56000 Hz)	horizontal coplanar coil-pair quadrature	10 ppm
	<u>Computed Parameters</u>	
DIFI (900 Hz)	difference function inphase from CXI and CPI	2 ppm
DIFQ (900 Hz)	difference function quadrature from CXQ and CPQ	2 ppm
CDT	conductance	1 grade
RES (900 Hz)	log resistivity	.06 decade
RES (7200 Hz)	log resistivity	.06 decade
RES (56000 Hz)	log resistivity	.06 decade
DP (900 Hz)	apparent depth	6 m
DP (7200 Hz)	apparent depth	6 m
DP (56000 Hz)	apparent depth	6 m

Tracking Camera

Type: Panasonic Video

Model: AG 2400/WVCD132

Fiducial numbers are recorded continuously and are displayed on the margin of each image. This procedure ensures accurate correlation of analog and digital data with respect to visible features on the ground.

Navigation System

Model: Del Norte 547

Type: UHF electronic positioning system

Sensitivity: 1 m

Sample rate: 0.5 per second

The navigation system uses ground based transponder stations which transmit distance information back to the helicopter. The ground stations are set up well away from the survey area and are positioned such that the signals cross the survey block at an angle between 30° and 150°. After site selection, a traverse line is flown at right angles to a base line drawn through the transmitter sites to establish an arbitrary coordinate system for the survey area. The onboard Central Processing Unit takes any two transponder distances and determines the helicopter position relative to these two ground stations in cartesian coordinates.

The cartesian coordinates are transformed to UTM coordinates during data processing. This is accomplished by correlating a number of prominent topographical locations with the navigational data points. The use of numerous visual tie points serves two purposes: to accurately relate the navigation data to the map sheet and to minimize location errors which might result from distortions in uncontrolled photomosaic base maps.

PRODUCTS AND PROCESSING TECHNIQUES

The following products are available from the survey data. Those which are not part of the survey contract may be acquired later. Refer to Table 3-1 for a summary of the maps which accompany this report, some of which may be sent under separate cover. Most parameters can be displayed as contours, profiles, or in colour.

Base Maps

Base maps of the survey area have been prepared from published topographic maps although photomosaics can also be used. Topographic maps provide an accurate, distortion-free base which facilitates correlation of the navigation data to the UTM grid. Photomosaics are useful for visual reference and for subsequent flight path recovery, but usually contain scale distortions. Orthophotos are ideal, but their cost and the time required to produce them, usually precludes their use as base maps.

Electromagnetic Anomalies

Anomalous electromagnetic responses are selected and analysed by computer to provide a preliminary electromagnetic anomaly map. This preliminary EM map is used, by the

Table 3-1 Products Available from the Survey

MAP	NO. OF SHEETS	ANOMALY MAP	PROFILES ON MAP	CONTOURS INK	CONTOURS COLOR	SHADOW MAP
Electromagnetic Anomalies	3	20,000	-	N/A	N/A	N/A
Probable Bedrock Conductors	-	-	N/A	N/A	N/A	N/A
Resistivity (900 Hz)	-	N/A	-	-	-	-
Resistivity (7,200 Hz)	3	N/A	-	20,000	-	-
Resistivity (56,000 Hz)	-	N/A	-	-	-	-
EM Magnetite	-	N/A	-	-	-	-
Total Field Magnetics	3	N/A	-	20,000	20,000	*
Enhanced Magnetics	3	N/A	-	20,000	-	-
Vertical Gradient Magnetics	-	N/A	-	-	-	-
2nd Vertical Derivative Magnetics	-	N/A	-	-	-	-
Magnetic Susceptibility	-	N/A	-	-	-	-
Filtered Total Field VLF	3	N/A	-	20,000	-	-
EM Profiles (900 Hz)	-	N/A	-	N/A	N/A	N/A
EM Profiles (7200 Hz)	-	N/A	-	N/A	N/A	N/A
EM Profiles (56,000 Hz)	-	N/A	-	N/A	N/A	N/A
Overburden Thickness	-	N/A	-	-	-	N/A
Digital Profiles		Worksheet profiles				20,000
		Interpreted profiles				-

N/A Not available
*** Highly recommended due to its overall information content
** Recommended
* Qualified recommendation, as it may be useful in local areas
- No recommendation
20,000 Scale of delivered map, i.e, 1:20,000

geophysicist, in conjunction with the computer-generated digital profiles, to produce the final interpreted EM anomaly map. This map includes bedrock, surficial and cultural conductors. A map containing only bedrock conductors can be generated, if desired.

Resistivity

The apparent resistivity in ohm-m may be generated from the inphase and quadrature EM components for any of the frequencies, using a pseudo-layer halfspace model. A resistivity map portrays all the EM information for that frequency over the entire survey area. This contrasts with the electromagnetic anomaly map which provides information only over interpreted conductors. The large dynamic range makes the resistivity parameter an excellent mapping tool.

EM Magnetite

The apparent percent magnetite by weight is computed wherever magnetite produces a negative inphase EM response.

Total Field Magnetics

The aeromagnetic data are corrected for diurnal variation using the magnetic base station data. The regional

IGRF gradient is removed from the data, if required under the terms of the contract.

Enhanced Magnetics

The total field magnetic data are subjected to a processing algorithm. This algorithm enhances the response of magnetic bodies in the upper 500 m and attenuates the response of deeper bodies. The resulting enhanced magnetic map provides better definition and resolution of near-surface magnetic units. It also identifies weak magnetic features which may not be evident on the total field magnetic map. However, regional magnetic variations, and magnetic lows caused by remanence, are better defined on the total field magnetic map. The technique is described in more detail in Section 5.

Magnetic Derivatives

The total field magnetic data may be subjected to a variety of filtering techniques to yield maps of the following:

- vertical gradient
- second vertical derivative
- magnetic susceptibility with reduction to the pole
- upward/downward continuations

All of these filtering techniques improve the recognition of near-surface magnetic bodies, with the exception of upward continuation. Any of these parameters can be produced on request. Dighem's proprietary enhanced magnetic technique is designed to provide a general "all-purpose" map, combining the more useful features of the above parameters.

VLF

The VLF data are digitally filtered to remove long wavelengths such as those caused by variations in the transmitted field strength.

Digital Profiles

Distance-based profiles of the digitally recorded geophysical data are generated and plotted by computer. These profiles also contain the calculated parameters which are used in the interpretation process. These are produced as worksheets prior to interpretation, and can also be presented in the final corrected form after interpretation. The profiles display electromagnetic anomalies with their respective interpretive symbols. The differences between the worksheets and the final corrected form occur only with respect to the EM anomaly identifier.

Contour, Colour and Shadow Map Displays

The geophysical data are interpolated onto a regular grid using a cubic spline technique. The resulting grid is suitable for generating contour maps of excellent quality.

Colour maps are produced by interpolating the grid down to the pixel size. The parameter is then incremented with respect to specific amplitude ranges to provide colour "contour" maps.

Monochromatic shadow maps are generated by employing an artificial sun to cast shadows on a surface defined by the geophysical grid. There are many variations in the shadowing technique which may be applied to total field or enhanced magnetic data, magnetic derivatives, VLF, resistivity, etc. Of the various magnetic products, the shadow of the enhanced magnetic parameter is particularly suited for defining geological structures with crisper images and improved resolution.

SURVEY RESULTS

GENERAL DISCUSSION

The survey results are presented on separate map sheets for each parameter at a scale of 1:20,000. Tables 4-1, 4-2 and 4-3 summarize the EM responses in the survey area, with respect to conductance grade and interpretation.

The anomalies shown on the electromagnetic anomaly maps are based on a near-vertical, half plane model. This model best reflects "discrete" bedrock conductors. Wide bedrock conductors or flat-lying conductive units, whether from surficial or bedrock sources, may give rise to very broad anomalous responses on the EM profiles. These may not appear on the electromagnetic anomaly maps if they have a regional character rather than a locally anomalous character. These broad conductors, which more closely approximate a half space model, will be maximum coupled to the horizontal (coplanar) coil-pair and should be more evident on the resistivity parameter. Resistivity maps, therefore, may be more valuable than the electromagnetic anomaly maps, in areas where broad or flat-lying conductors are considered to be of importance. Contoured resistivity maps, based on the 7200 Hz coplanar data, are included with this report.

TABLE 4-1

EM ANOMALY STATISTICS

HELDER LAKE (GRID A)

CONDUCTOR GRADE	CONDUCTANCE RANGE SEIMENS (MHOS)	NUMBER OF RESPONSES
7	> 100	44
6	50 - 100	58
5	20 - 50	112
4	10 - 20	99
3	5 - 10	87
2	1 - 5	245
1	< 1	289
*	INDETERMINATE	166
TOTAL		1100

CONDUCTOR MODEL	MOST LIKELY SOURCE	NUMBER OF RESPONSES
D	DISCRETE BEDROCK CONDUCTOR	342
B	DISCRETE BEDROCK CONDUCTOR	104
S	CONDUCTIVE COVER	599
H	ROCK UNIT OR THICK COVER	16
E	EDGE OF WIDE CONDUCTOR	39
TOTAL		1100

(SEE EM MAP LEGEND FOR EXPLANATIONS)

TABLE 4-2

EM ANOMALY STATISTICS

HELDER LAKE (GRID B)

CONDUCTOR GRADE	CONDUCTANCE RANGE SEIMENS (MHOS)	NUMBER OF RESPONSES
7	> 100	34
6	50 - 100	62
5	20 - 50	149
4	10 - 20	121
3	5 - 10	103
2	1 - 5	291
1	< 1	439
*	INDETERMINATE	211
TOTAL		1410

CONDUCTOR MODEL	MOST LIKELY SOURCE	NUMBER OF RESPONSES
D	DISCRETE BEDROCK CONDUCTOR	431
B	DISCRETE BEDROCK CONDUCTOR	198
S	CONDUCTIVE COVER	732
E	EDGE OF WIDE CONDUCTOR	49
TOTAL		1410

(SEE EM MAP LEGEND FOR EXPLANATIONS)

TABLE 4-3

EM ANOMALY STATISTICS

HELDER LAKE (GRID C)

CONDUCTOR GRADE	CONDUCTANCE RANGE SEIMENS (MHOS)	NUMBER OF RESPONSES
7	> 100	0
6	50 - 100	5
5	20 - 50	2
4	10 - 20	4
3	5 - 10	12
2	1 - 5	51
1	< 1	56
*	INDETERMINATE	34
TOTAL		164

CONDUCTOR MODEL	MOST LIKELY SOURCE	NUMBER OF RESPONSES
D	DISCRETE BEDROCK CONDUCTOR	11
B	DISCRETE BEDROCK CONDUCTOR	9
S	CONDUCTIVE COVER	139
E	EDGE OF WIDE CONDUCTOR	5
TOTAL		164

(SEE EM MAP LEGEND FOR EXPLANATIONS)

Excellent resolution and discrimination of conductors was accomplished by using a fast sampling rate of 0.1 sec and by employing a common frequency (900 Hz) on two orthogonal coil-pairs (coaxial and coplanar). The resulting "difference channel" parameters often permit differentiation of bedrock and surficial conductors, even though they may exhibit similar conductance values.

Anomalies which occur near the ends of the survey lines (i.e., outside the survey area), should be viewed with caution. Some of the weaker anomalies could be due to aerodynamic noise, i.e., bird bending, which is created by abnormal stresses to which the bird is subjected during the climb and turn of the aircraft between lines. Such aerodynamic noise is usually manifested by an anomaly on the coaxial inphase channel only, although severe stresses can affect the coplanar inphase channels as well.

Magnetics

A Scintrex IGS/MP-3 proton precession magnetometer was operated at the survey base to record diurnal variations of the earth's magnetic field. The clock of the base station was synchronized with that of the airborne system to permit subsequent removal of diurnal drift.

The background magnetic levels have been adjusted to the mean IGRF value for the survey area. However, the IGRF gradient across the survey block has not been removed.

The total field magnetic data have been presented as contours on the base maps using a contour interval of 10 nT where gradients permit. The maps show the magnetic properties of the rock units underlying the survey area.

There is ample evidence on the magnetic maps which suggests that the survey area has been subjected to deformation and/or alteration. These structural complexities are evident on the contour maps as variations in magnetic intensity, irregular patterns, and as offsets or changes in strike direction.

The geologic strike inferred from the magnetic data changes from approximately east/west to west-northwest/east-southeast in the western half of the area to approximately northeast/southwest in the east.

The magnetic values range from a background of approximately 59400 to over 67000 nT in the vicinity of fiducial 4170 on line 10180, and fiducial 300 on line 10460.

A highly magnetic feature, which is bounded by the 60000 nT contour is located on sheets 2 and 3. It contains the highest magnetic values in the survey area. The changes in strike direction within this feature, and the truncations in the contour patterns, suggest that this zone is structurally complex between lines 10460 and 20120. Many of the anomalies interpreted to be of bedrock origin are located within this complex feature or in close proximity to the contact of this zone with the surrounding, less magnetic material.

The western end of the survey area (sheet 1) also seems to be structurally complex. Several magnetic features near the north ends of lines 20330 to 20730 may have been subjected to some deformation or folding. They seem to be truncated in the east by a possible magnetic break extending from fiducial 2140 on line 20410 to the north end of line 20270.

If a specific magnetic intensity can be assigned to the rock type which is believed to host the target mineralization, it may be possible to select areas of higher priority on the basis of the total field magnetic maps. This is based on the assumption that the magnetite content of the host rocks will give rise to a limited range of contour values which will permit differentiation of various lithological units.

The total field magnetic data have been subjected to a processing algorithm to produce enhanced magnetic maps. This procedure enhances near-surface magnetic units and suppresses regional gradients. Maps of the first or second vertical magnetic derivative can also be prepared from existing survey data upon request.

The magnetic results, in conjunction with the other geophysical parameters, should provide valuable information which can be used to effectively map the geology and structure in the survey area.

Resistivity

Resistivity maps, which display the conductive properties of the survey area, were produced from the 7200 Hz coplanar data.

In areas where several conductors or conductive trends appear to be related to a common geological unit, these have been outlined as "zones" on the EM anomaly maps. These zone outlines usually approximate the limits of conductive units defined by the resistivity contours, but may also be related to possible contacts inferred from the magnetic data.

The zones may consist of a single conductive horizon, or may contain numerous banded or segmented conductors. They may show close correlation with magnetic units.

These zones are sometimes quite extensive and often reflect "formational" conductors which may be of minor interest as direct exploration targets. However, attention may be focused on areas where these zones appear to be faulted or folded or where anomaly characteristics differ along strike.

The resistivity patterns show a general agreement with the magnetic trends, although many of the resistivity lows outline the lakes and streams of the survey area. There are some bedrock anomalies in the survey area which are located in lakes and streams. These anomalies may not produce distinct resistivity lows on the 7200 Hz resistivity maps as they may be masked by the effects of conductive overburden.

Bedrock anomalies which occur in close proximity to magnetite-rich zones may also fail to produce distinct resistivity lows on the resistivity map.

VLF

The VLF method is quite sensitive to the angle of coupling between the conductor and the propogated EM field. Consequently, conductors which strike towards the VLF station will usually yield a stronger response than conductors which are nearly orthogonal to it.

The VLF parameter does not normally provide the same degree of resolution available from the EM data. Closely-spaced conductors, conductors of short strike length or conductors which are poorly coupled to the VLF field, may escape detection with this method. Erratic signals from the VLF transmitters can also give rise to strong, isolated anomalies which should be viewed with caution. The filtered total field VLF contours are presented on the base maps with a contour interval of one percent.

VLF results were obtained from the transmitting stations at Cutler, Maine (NAA - 24.0 kHz), Seattle, Washington (NLK-24.8 kHz), and Annapolis, Maryland (NSS - 21.4 kHz). The VLF maps show the contoured results of the filtered total field from Annapolis for all lines.

The general magnetic strike in the survey area, inferred from the magnetic data, changes from approximately east/west in the western half of the survey block to northeast/southwest in the east. The strike of the western half provides good coupling with the VLF signals from Cutler, while the eastern half provides moderate coupling.

In general, the VLF trends over the survey block are strong, and well defined. The general strike of the VLF data is east/west to northwest/southeast. These trends show good agreement with the trend of the lakes and streams in the area, and many of the VLF anomalies may be caused by conductive surficial material. Many VLF trends show good correlation with the bedrock conductors interpreted from the electromagnetic data.

Many of the structural features inferred from the magnetic data are evident as truncations in the contour patterns on the VLF maps.

Electromagnetics

The EM anomalies resulting from this survey appear to fall within one of three general categories. The first type consists of discrete, well-defined anomalies which yield marked inflections on the difference channels. These anomalies are usually attributed to conductive sulphides or graphite and are generally given a "B", "T" or "D" interpretive symbol, denoting a bedrock source.

The second class consists of moderately well-defined quadrature responses which coincide with low amplitude or negative polarity inphase responses. The positive quadrature is attributed to poorly conductive material which overlies, or is associated with, a magnetite-rich host. These anomalies often yield very weak conductance values but show moderate to strong magnetic correlation. Interpretive symbols may vary from "B?" to "S?".

The third class of anomalies comprises broad responses which exhibit the characteristics of a half space and do not yield well-defined inflections on the difference channels. Anomalies in this category are usually given an "S" or "H" interpretive symbol. The lack of a difference channel response usually implies a broad or flat-lying conductive source such as overburden.

The effects of conductive overburden are evident over most of the survey area. Although the difference channels (DIFI and DIFQ) are extremely valuable in detecting bedrock conductors which are partially masked by conductive overburden, sharp undulations in the bedrock/overburden interface can yield anomalies in the difference channels which may be interpreted as possible bedrock conductors. Such anomalies usually fall into the "S?" or "B?" classification but may also be given an "E" interpretive symbol, denoting a resistivity contrast at the edge of a conductive unit.

In areas where EM responses are evident primarily on the quadrature components, zones of poor conductivity are indicated. Where these responses are coincident with magnetic anomalies, it is possible that the inphase component amplitudes have been suppressed by the effects of magnetite. Most of these poorly-conductive magnetic features give rise to resistivity anomalies which are only slightly below background. If it is expected that poorly-conductive economic mineralization may be associated with magnetite-rich units, most of these weakly anomalous features will be of interest. In areas where magnetite causes the inphase components to become negative, the apparent conductance and depth of EM anomalies may be unreliable.

As economic mineralization within the area may be associated with massive to weakly disseminated sulphides, which may or may not be hosted by magnetite-rich rocks, it is difficult to assess the relative merits of EM anomalies on the basis of conductance. It is recommended that an attempt be made to compile a suite of geophysical "signatures" over areas of interest. Anomaly characteristics are clearly defined on the computer-processed geophysical data profiles which are supplied as one of the survey products.

Even weak conductors may be of economic significance in the survey area. A complete assessment and evaluation of the survey data should be carried out by one or more qualified professionals who have access to, and can provide a meaningful compilation of, all available geophysical, geological and geochemical data.

CONDUCTORS IN THE SURVEY AREA

The electromagnetic anomaly maps show the anomaly locations with the interpreted conductor type, dip, conductance and depth being indicated by symbols. Direct magnetic correlation is also shown if it exists. The strike direction and length of the conductors are indicated when anomalies can be correlated from line to line. When studying the map sheets, consult the anomaly listings appended to this report.

Many of the electromagnetic anomalies in the survey area seem to have some association with magnetic zones. Some anomalies are directly coincident with highly magnetic trends, while some are located at contacts between highly magnetic zones, and relatively non-magnetic zones. There are also some conductors attributed to bedrock sources that are located in the vicinity of apparent structural breaks.

The differences in magnetic signatures with respect to electromagnetic anomalies show that the conductors in the area are likely due to different causative sources. Strong magnetic conductors are commonly observed over pyrrhotite, while strong non-magnetic conductors often reflect graphitic zones.

Most of the stronger anomalies which have been attributed to bedrock sources, give rise to resistivity lows on the 7200 Hz resistivity map. Well-defined resistivity lows are not developed where the conductors are coincident with highly magnetic, magnetite-rich zones.

Not all anomalies can be described in this report. The following paragraphs, however, describe some of the more interesting geophysical targets in the survey area which are considered to warrant further investigation.

Sheet 1

Most of the conductive trends on sheet 1 that are of probable bedrock origin are associated with magnetic features. The magnetic data suggest that sheet 1 is structurally complex. The conductors therefore have a segmented appearance, and are mostly of limited strike length. Strike directions of the conductors are changeable, and are closely related to the changing magnetic strike direction on sheet 1.

Conductors 20210H-20340D, 20230E-20240F, 20290C-20400B, 20340A-20370B, 20340B-20360B, 20390B-20440A, 20440B-20610B, 20540B-20630A, 20570C-20590C, 20650A-20690B, 20700B-30040C and 20730A-30040B

These conductors are all related to a thin magnetic zone trending approximately west-northwest/east-southeast to east/west. This magnetic zone is complex. There are several places along strike where the magnetic contours seem to be truncated or offset. Dips have been determined for several of the conductors. There is evidence of a northerly dip for conductors 20440B-20610B, 20650A-20690B, 20700B-30440C. Southerly dips are exhibited by conductors 20210H-20340D, 20230E-20240F and 20290C-20400B. This suggests that some of the sources of these conductors may be overturned. Correlation with the magnetic data varies along strike of most of these conductors. Conductors 20290C-20400B, 20340B-20360B, 20390B-20440A, 20540B-20630A and 20700B-30040C coincide with the peaks of this magnetic zone, while the others seem to be related to magnetic contacts. Most of the conductors reflect thin bedrock sources. The highest conductance values of these trends are located between lines 20270 and 20350, 20530 and 20620, and 20730 and 30040. There is correlation of most of these trends with several strong VLF anomalies. These anomalies do not seem to be adversely affected by conductive overburden.

Conductors 20410B-20440D, 20420D-20450B, 20490B-20570F, 20490C-20500E, 20440E-20480C and 20400C-20490D

These conductors are also related to thin magnetic units trending west-northwest/east-southeast. Magnetic correlation varies along strike. Conductor 20490B-20570F reflects a very strong source. Dips vary along strike (north at anomalies 20510F and 20530B, and south at anomaly 20560C), suggesting that the source of this conductor is overturned at one or more locations. Closely-spaced parallel conductors 20410B-20440D and 20420D-20450B are moderately strong. Conductor 20410B-20440D dips to the south, while 20420D-20450B dips to the north. This suggests that the source of one is overturned with respect to the other.

Conductors 20450G-20470I, 20460H-20470H, 20480G-20500J and 20490F-20500I

These conductors are all associated with an east-northeast/west-southwest trending magnetic unit which seems to merge with a highly magnetic, semi-circular feature to the west. These conductors are moderately strong and of limited strike length. Conductor 20480G-20500J exhibits a dip to the north.

Conductors 20340M-20350K, 20340N-20350L, 20370L-20390N, 20370M-20410I and 20410H-20440L

These conductors are also associated with another east-northeast/west-southwest trending magnetic zone which merges with the same semi-circular feature to the west. These conductors are strong, and of limited strike length. Conductor 20410H-20440L exhibits a dip to the south.

Other conductors, such as conductors 20380Q-20390Q, 20410K-20420N, 20420O-20450J, and single line response 20410L are located near these conductive trends. The magnetic data suggest that this area is structurally complex. Several structural linear features can be inferred from the magnetic data.

Conductors 20730C-30030D, 20680C-30020C, 20670D-20680D, 20630B-20640C, 20630D-20650B, 20630E-20640E, 20600F-20610D, 20560F-20570I, 20530G-20540H, 20510L-20530H, 20460L-20470K and 20460M-20470L

These conductors are associated with the highly magnetic, semi-circular feature mentioned previously.

Conductors 20730C-30030D, 20680C-30020C, 20670D-20680D, 20630B-20640C, 20630D-20650B and 20630E-20640E seem to be related to the magnetic peaks of this feature. The others are situated in high gradient magnetics, suggesting that they are contact features.

Strikes of this group of conductors vary from east/west for the most westerly conductor, gradually changing to northeast/southwest for the eastern conductors.

Conductors 20590J-20640M, 20550I-20560H, 20550J-20560I, 20550K-20580H and 20460N-20480M

These conductors are of limited strike length, trending approximately east/west. All appear to be related to magnetic contacts at the northern edge of the same semi-circular magnetic feature as the previous group of conductors. These conductors exhibit northerly dips, except for 20460N-20480M, which dips to the south.

The magnetic data suggest that the area is complex in the vicinity of conductors 20460N-20480M, 20460L-20470K and 20460M-20470L. The strike directions of the conductors in this area are variable.

Conductors 20350V-20400O, 20360T-20370T, 20390AA-20410Q, 20400N-20460T, 20460S-20550O, 20360R-20430P, 20380U-20540M, 20380T-20390X, 20400I-20410N and 20450M-20460P

These conductors are related to two thin magnetic bands and a relatively non-magnetic zone. They are situated in an area which appears to have been subjected to some deformation or folding. Conductors 20350V-20400O, 20400N-20460T, 20460S-20550O and 20380U-20540M are coincident with the peaks of these thin magnetic bands. Most of these conductors reflect very strong, thin bedrock sources, although conductance values vary along strike. Dips vary within this area, suggesting that the sources of some conductors are overturned. Conductors 20400I-20410N and 20450M-20460P are of limited strike length. They occur within a magnetic low which is also located in this area of deformation. Conductor 20400I-20410N dips to the south.

These magnetic units are all truncated in the east by an apparent structural break which trends north-northeast/south-southwest from fiducial 2140 on line 20410 to the north end of line 20270.

Conductors 20680M-20720J, 20680N-20690L, 20690M-20700P, 20700O-20720L, 20710P-20730L and 20710R-20720M

These conductors are very strong and of limited strike length. They seem to be situated around a local magnetic high extending from fiducial 780 on line 20680 to fiducial 2295 on line 20720. All conductors seem to be related to the contact of this local magnetic high and the surrounding less magnetic units.

Conductors 20690I-20730G and 20690J-20730H

These very strong, parallel conductors are of limited strike length. Both are coincident with a local magnetic high extending from fiducial 1340 on line 20690 to fiducial 2853 on line 20730. A strong VLF anomaly is coincident with this magnetic feature.

Conductors 30180F-30190E and 30180G-30190F

These closely spaced, moderately weak conductors are of limited strike length. They show strong correlation with a magnetic high extending from fiducial 2190 on line 30150 to fiducial 1428 on line 30200. This magnetic unit is also coincident with a moderately strong VLF response. The VLF response, however, may be adversely affected by conductive overburden due to its proximity to the lake shore.

Conductors 30150A-30160B

This weak, probable bedrock conductor is of limited strike length. It is coincident with the peak of a highly magnetic circular feature extending over lines 30140 to 30180.

There are other weak conductive trends and single line responses on this sheet that should be subjected to further investigation to determine their importance.

Sheet 2

Most of the bedrock anomalies on sheet 2 are contained in 3 to 4 sub-parallel conductors trending east-northeast/ west-southwest. These conductors extend the length of sheet 2 through the central region of the map.

There is coincidence of these conductors with a complex, highly magnetic unit. Conductors 10010C-10020D, 10060A-10090C, 10110C-10290D, 10310E-10510K show the strongest magnetic correlation. These trends are coincident with a magnetite-rich zone within the magnetic unit. These trends do not give rise to well-defined resistivity lows on the 7200 Hz resistivity map.

Several conductors show correlation with other peaks within this magnetic zone, while some, such as 10050C-10110F, 10390H-10460T, 10460U-20080K and 20080J-20150G, seem to be related to the contact of this magnetic trend and the surrounding relatively non-magnetic material.

Most conductors reflect very strong, thin bedrock sources, although conductance values vary greatly along strike. Dip directions are difficult to determine when the EM responses exhibit the effects of magnetite, or when two or more conductors are closely spaced. At the eastern end of this conductive zone there is evidence of northerly dips. West of line 10630 the conductors exhibit a southerly dip. Two exceptions at the western end of this zone are north-dipping conductors 20090D-20100B and 20110C-20130B. The change in dip direction suggests some sources have been overturned. The magnetic zone is structurally complex, and several structural breaks can be inferred from the magnetic data. These structural linear features intersect the magnetic unit at steep angles. The magnetic zone is most complex between lines 10460 and 20180. Between these lines the zone appears to have been subjected to folding or deformation. Many of the structural breaks inferred from the magnetic data are situated between these lines.

West of line 10530, the magnetic trend seems to split into two magnetic units divided by a relative magnetic low. The conductive trends also seem to diverge, coinciding with the magnetic peaks of the zone.

The magnetic trends and the conductors seem to be truncated at the western end of sheet 2 by an apparent structural break trending approximately northwest from the southern end of line 20070 to fiducial 4200 on line 20200.

Zone A

Zone A contains two conductors of limited strike length and several single line responses. The approximate limit of this zone is the 1000 ohm-m contour. Most of the conductors in this zone reflect thin bedrock sources of moderate strength. There is some correlation of the conductors in this zone with local magnetic highs. Conductor 20050R-20060T exhibits a north dip.

Zone B

Zone B consists of four to five sub-parallel bedrock conductors. The conductors in this zone are associated with a highly complex magnetic unit. The zone is approximately outlined by the 59400 nT contour on the total field magnetic map. There is direct magnetic correlation of several conductors with some of the peaks in this zone. These include 10310Q-10380V and 10350L-10460X. Most conductors reflect very strong, thin bedrock sources, although conductance varies along strike.

Dips of closely-spaced conductors, such as those in Zone B, are difficult to determine. Conductors 10290N-10320Q and 10360Q-10380O exhibit a northerly dip, while conductor 10350L-10460X exhibits a dip to the south.

Zone C

The approximate limit of Zone C is the 1000 ohm-m contour on the 7200 Hz resistivity map. The conductors in Zone C reflect thin, strong bedrock sources. There is evidence of a northerly dip. There is direct correlation of this zone with a highly magnetic trend striking northwest/southeast. This magnetic feature seems to be intersected by two possible structural breaks inferred from the magnetic data. There is direct correlation of this zone with a strong VLF trend.

This VLF response may be a combination of the effects of conductive surficial material and bedrock sources as it is situated near a lake shore.

Conductor 10520W-20040I

This conductor is located west of Zone B. It seems to be coincident with part of the same magnetic trend as Zone B. This conductor reflects a thin bedrock source. There is evidence of a south dip.

Conductors 10150I-10230I, 10250I-10260K, 10270K-10310L, 10290J-10310K, 10330K-10340K, 10330J-10390K and 10340J-10420K

These conductors are situated in several weak magnetic features southeast of Zone B. Magnetic correlation varies along strike of all conductors. Conductor 10150I-10230I reflects a relatively weak, thin bedrock source with a probable dip to the north. No dips have been determined for the other conductors. Conductance values vary along strike of conductors 10330J-10390K and 10340J-10420K. The highest values are situated between lines 10340 and 10360.

Conductor 10130H-10140F

This conductor is a well-defined thin bedrock source of limited strike length. This conductor is associated with a local magnetic high. Anomaly 10130G is a strong single line response located in close proximity to this conductor. Both conductor 10130H-10140F and anomaly 10130G exhibit southerly dips.

Conductors 10460I-10510G, 10480G-10490E, 10490F-10510F and 10530F-10540E

These conductors are coincident with a highly magnetic unit, which is possibly related to the highly magnetic feature extending through the central region of the sheet.

Conductor 10460I-10510G is coincident with the peak of this magnetite-rich zone. This conductor reflects a thin, moderately strong bedrock source. It has a probable dip to the north. The other conductors reflect weak, probable bedrock conductors that appear to be related to the contacts of this zone with the surrounding, less magnetic material.

Conductors 20070L-20140H, 20110M-20220K, 20140G-20220H and 20200G-20210K

These conductors reflect thin, strong bedrock sources. Conductors 20110M-20220K and 20140G-20220H are coincident with two magnetic peaks of a magnetic zone extending over lines 20120-20220. Both conductors exhibit a probable south dip. These two conductors are coincident with very strong VLF trends.

Conductor 20070L-20140H is a moderately strong bedrock conductor which is located south of conductors 20110M-20220K and 20140G-20220H. There is no magnetic correlation with this trend.

Conductor 20010J-20070P

This conductor reflects a strong, thin bedrock source, although conductance varies along strike. There is evidence of a southerly dip. It is associated with a thin magnetic trend striking approximately east/west, although magnetic correlation also varies along strike. This conductor is coincident with a moderately strong VLF anomaly.

Conductors 20260Q-20270L and 20270M-20290O

These conductors reflect strong thin bedrock sources of limited strike length. There is direct correlation of these conductors with a local magnetic high, and a strong VLF anomaly.

Sheet 3

All of the anomalies interpreted to be of bedrock origin are situated within a highly complex magnetic zone defined by the 60000 nT contour. This zone may be related to the highly magnetic trend on sheet 2.

Several apparent structural breaks can be inferred from the magnetic data which seem to intersect this magnetic feature. This magnetic unit also appears to have been subjected to some deformation or folding.

Zone D

The conductors of Zone D reflect thin bedrock sources. Conductor 10460B-10500B is coincident with a peak of the magnetic zone above. Conductance values vary along strike of the conductors in this zone.

The limit of this zone is defined by the 1000 ohm-m contour on the 7200 Hz resistivity map.

Conductors 10530E-10540D, 10570D-10580D, 10610C-10620D

These conductors reflect probable bedrock sources. They are all located within the highly magnetic zone.

Single line responses 10610F, 10630J and 10660D may also be of interest. Anomaly 10660D is a very strong single line response which gives rise to a well-defined resistivity low. There is a probable dip to the north. All of these responses are located in high gradient magnetics, and may be related to contacts.

BACKGROUND INFORMATION

This section provides background information on parameters which are available from the survey data. Those which have not been supplied as survey products may be generated later from raw data on the digital archive tape.

ELECTROMAGNETICS

DIGHEM electromagnetic responses fall into two general classes, discrete and broad. The discrete class consists of sharp, well-defined anomalies from discrete conductors such as sulfide lenses and steeply dipping sheets of graphite and sulfides. The broad class consists of wide anomalies from conductors having a large horizontal surface such as flatly dipping graphite or sulfide sheets, saline water-saturated sedimentary formations, conductive overburden and rock, and geothermal zones. A vertical conductive slab with a width of 200 m would straddle these two classes.

The vertical sheet (half plane) is the most common model used for the analysis of discrete conductors. All anomalies plotted on the electromagnetic map are analyzed according to this model. The following section entitled **Discrete Conductor Analysis** describes this model in detail, including the effect of using it on anomalies caused by broad conductors such as conductive overburden.

The conductive earth (half space) model is suitable for broad conductors. Resistivity contour maps result from the use of this model. A later section entitled **Resistivity Mapping** describes the method further, including the effect of using it on anomalies caused by discrete conductors such as sulfide bodies.

Geometric interpretation

The geophysical interpreter attempts to determine the geometric shape and dip of the conductor. Figure 5-1 shows typical DIGHEM anomaly shapes which are used to guide the geometric interpretation.

Discrete conductor analysis

The EM anomalies appearing on the electromagnetic map are analyzed by computer to give the conductance (i.e., conductivity-thickness product) in siemens (mhos) of a vertical sheet model. This is done regardless of the interpreted geometric shape of the conductor. This is not an unreasonable procedure, because the computed conductance increases as the electrical quality of the conductor increases, regardless of its true shape. DIGHEM anomalies

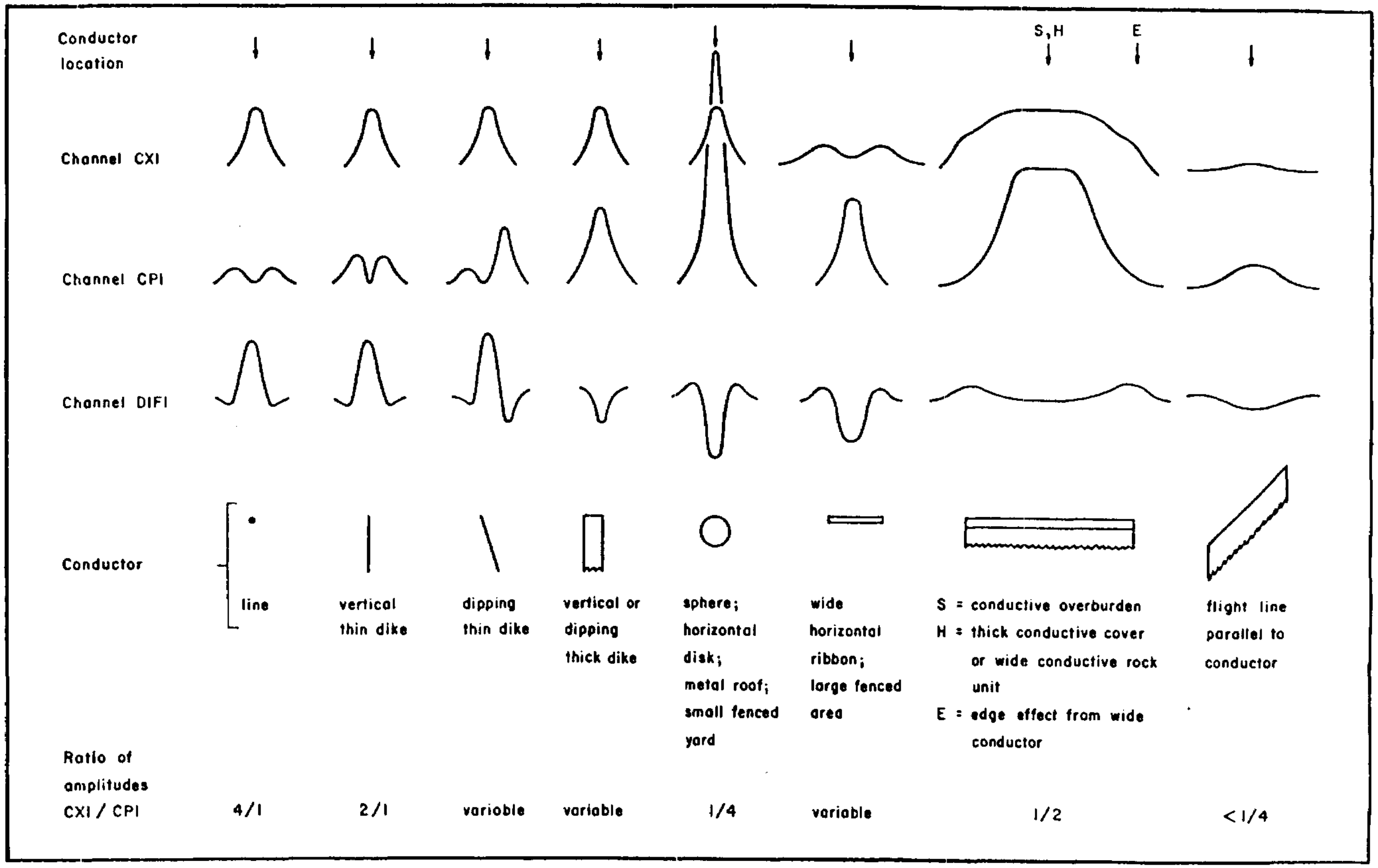

Fig. 5-1 Typical DIGHEM anomaly shapes

are divided into seven grades of conductance, as shown in Table 5-1 below. The conductance in siemens (mhos) is the reciprocal of resistance in ohms.

Table 5-1. EM Anomaly Grades

Anomaly Grade	siemens
7	> 100
6	50 - 100
5	20 - 50
4	10 - 20
3	5 - 10
2	1 - 5
1	< 1

The conductance value is a geological parameter because it is a characteristic of the conductor alone. It generally is independent of frequency, flying height or depth of burial, apart from the averaging over a greater portion of the conductor as height increases. Small anomalies from deeply buried strong conductors are not confused with small anomalies from shallow weak conductors because the former will have larger conductance values.

Conductive overburden generally produces broad EM responses which may not be shown as anomalies on the EM maps. However, patchy conductive overburden in otherwise resistive areas can yield discrete anomalies with a conductance grade (cf. Table 5-1) of 1, 2 or even 3 for conducting clays which have resistivities as low as 50 ohm-m. In areas where ground resistivities are below 10 ohm-m, anomalies caused by weathering variations and similar causes can have any conductance grade. The anomaly shapes from the multiple coils often allow such conductors to be recognized, and these are indicated by the letters S, H, and sometimes E on the electromagnetic anomaly map (see EM map legend).

For bedrock conductors, the higher anomaly grades indicate increasingly higher conductances. Examples: DIGHEM's New Insco copper discovery (Noranda, Canada) yielded a grade 5 anomaly, as did the neighbouring copper-zinc Magusi River ore body; Mattabi (copper-zinc, Sturgeon Lake, Canada) and Whistle (nickel, Sudbury, Canada) gave grade 6; and DIGHEM's Montcalm nickel-copper discovery (Timmins, Canada) yielded a grade 7 anomaly. Graphite and sulfides can span all grades but, in any particular survey area, field work may show that the different grades indicate different types of conductors.

Strong conductors (i.e., grades 6 and 7) are characteristic of massive sulfides or graphite. Moderate conductors (grades 4 and 5) typically reflect graphite or sulfides of a less massive character, while weak bedrock conductors (grades 1 to 3) can signify poorly connected graphite or heavily disseminated sulfides. Grades 1 and 2 conductors may not respond to ground EM equipment using frequencies less than 2000 Hz.

The presence of sphalerite or gangue can result in ore deposits having weak to moderate conductances. As an example, the three million ton lead-zinc deposit of Restigouche Mining Corporation near Bathurst, Canada, yielded a well-defined grade 2 conductor. The 10 percent by volume of sphalerite occurs as a coating around the fine grained massive pyrite, thereby inhibiting electrical conduction.

Faults, fractures and shear zones may produce anomalies which typically have low conductances (e.g., grades 1 to 3). Conductive rock formations can yield anomalies of any conductance grade. The conductive materials in such rock formations can be salt water, weathered products such as clays, original depositional clays, and carbonaceous material.

On the interpreted electromagnetic map, a letter identifier and an interpretive symbol are plotted beside the EM grade symbol. The horizontal rows of dots, under the interpretive symbol, indicate the anomaly amplitude on the flight record. The vertical column of dots, under the anomaly letter, gives the estimated depth. In areas where anomalies are crowded, the letter identifiers, interpretive symbols and dots may be obliterated. The EM grade symbols, however, will always be discernible, and the obliterated information can be obtained from the anomaly listing appended to this report.

The purpose of indicating the anomaly amplitude by dots is to provide an estimate of the reliability of the conductance calculation. Thus, a conductance value obtained from a large ppm anomaly (3 or 4 dots) will tend to be accurate whereas one obtained from a small ppm anomaly (no dots) could be quite inaccurate. The absence of amplitude dots indicates that the anomaly from the coaxial coil-pair is 5 ppm or less on both the inphase and quadrature channels. Such small anomalies could reflect a weak conductor at the surface or a stronger conductor at depth. The conductance grade and depth estimate illustrates which of these possibilities fits the recorded data best.

Flight line deviations occasionally yield cases where two anomalies, having similar conductance values but dramatically different depth estimates, occur close together on the same conductor. Such examples illustrate the reliability of the conductance measurement while showing that the depth estimate can be unreliable. There are a number of factors which can produce an error in the depth estimate, including the averaging of topographic variations by the altimeter, overlying conductive overburden, and the location and attitude of the conductor relative to the flight line. Conductor location and attitude can provide an erroneous depth estimate because the stronger part of the conductor may be deeper or to one side of the flight line, or because it has a shallow dip. A heavy tree cover can also produce errors in depth estimates. This is because the depth estimate is computed as the distance of bird from conductor, minus the altimeter reading. The altimeter can lock onto the top of a dense forest canopy. This situation yields an erroneously large depth estimate but does not affect the conductance estimate.

Dip symbols are used to indicate the direction of dip of conductors. These symbols are used only when the anomaly shapes are unambiguous, which usually requires a fairly resistive environment.

A further interpretation is presented on the EM map by means of the line-to-line correlation of anomalies, which is based on a comparison of anomaly shapes on adjacent lines. This provides conductor axes which may define the geological structure over portions of the survey area. The absence of conductor axes in an area implies that anomalies could not be correlated from line to line with reasonable confidence.

DIGHEM electromagnetic maps are designed to provide a correct impression of conductor quality by means of the conductance grade symbols. The symbols can stand alone with geology when planning a follow-up program. The actual conductance values are printed in the attached anomaly list for those who wish quantitative data. The anomaly ppm and depth are indicated by inconspicuous dots which should not distract from the conductor patterns, while being helpful to those who wish this information. The map provides an interpretation of conductors in terms of length, strike and dip, geometric shape, conductance, depth, and thickness. The accuracy is comparable to an interpretation from a high quality ground EM survey having the same line spacing.

The attached EM anomaly list provides a tabulation of anomalies in ppm, conductance, and depth for the vertical sheet model. The EM anomaly list also shows the conductance and depth for a thin horizontal sheet (whole plane) model, but only the vertical sheet parameters appear on the EM map. The horizontal sheet model is suitable for a flatly dipping thin bedrock conductor such as a sulfide sheet having a thickness less than 10 m. The list also shows the resistivity and depth for a conductive earth (half space) model, which is suitable for thicker slabs such as thick conductive overburden. In the EM anomaly list, a depth value of zero for the conductive earth model, in an area of thick cover, warns that the anomaly may be caused by conductive overburden.

Since discrete bodies normally are the targets of EM surveys, local base (or zero) levels are used to compute local anomaly amplitudes. This contrasts with the use of true zero levels which are used to compute true EM amplitudes. Local anomaly amplitudes are shown in the EM anomaly list and these are used to compute the vertical sheet parameters of conductance and depth. Not shown in the EM anomaly list are the true amplitudes which are used to compute the horizontal sheet and conductive earth parameters.

Questionable Anomalies

DIGHEM maps may contain EM responses which are displayed as asterisks (*). These responses denote weak anomalies of indeterminate conductance, which may reflect one of the following: a weak conductor near the surface, a strong conductor at depth (e.g., 100 to 120 m below surface) or to one side of the flight line, or aerodynamic noise. Those responses that have the appearance of valid bedrock anomalies on the flight profiles are indicated by appropriate interpretive symbols (see EM map legend). The others probably do not warrant further investigation unless their locations are of considerable geological interest.

The thickness parameter

DIGHEM can provide an indication of the thickness of a steeply dipping conductor. The amplitude of the coplanar anomaly (e.g., CPI channel on the digital profile) increases relative to the coaxial anomaly (e.g., CXI) as the apparent thickness increases, i.e., the thickness in the horizontal plane. (The thickness is equal to the conductor width if the conductor dips at 90 degrees and strikes at right angles to the flight line.) This report refers to a conductor as thin when the thickness is likely to be less than 3 m, and thick when in excess of 10 m. Thick conductors are indicated on the EM map by parentheses "( )". For base metal exploration in steeply dipping geology, thick conductors can be high priority targets because many massive sulfide ore bodies are thick, whereas non-economic bedrock conductors are often thin. The system cannot sense the thickness when the strike of the conductor is subparallel to the flight line, when the conductor has a shallow dip, when the anomaly amplitudes are small, or when the resistivity of the environment is below 100 ohm-m.

Resistivity mapping

Areas of widespread conductivity are commonly encountered during surveys. In such areas, anomalies can be generated by decreases of only 5 m in survey altitude as well as by increases in conductivity. The typical flight record in conductive areas is characterized by inphase and quadrature channels which are continuously active. Local EM peaks reflect either increases in conductivity of the earth or decreases in survey altitude. For such conductive areas, apparent resistivity profiles and contour maps are necessary for the correct interpretation of the airborne data. The advantage of the resistivity parameter is that anomalies caused by altitude changes are virtually eliminated, so the resistivity data reflect only those anomalies caused by conductivity changes. The resistivity analysis also helps the interpreter to differentiate between conductive trends in the bedrock and those patterns typical of conductive overburden. For example, discrete conductors will generally appear as narrow lows on the contour map and broad conductors (e.g., overburden) will appear as wide lows.

The resistivity profiles and the resistivity contour maps present the apparent resistivity using the so-called pseudo-layer (or buried) half space model defined by Fraser (1978)[1]. This model consists of a resistive layer overlying

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[1] Resistivity mapping with an airborne multicoil electromagnetic system: Geophysics, v. 43, p.144-172

a conductive half space. The depth channels give the apparent depth below surface of the conductive material. The apparent depth is simply the apparent thickness of the overlying resistive layer. The apparent depth (or thickness) parameter will be positive when the upper layer is more resistive than the underlying material, in which case the apparent depth may be quite close to the true depth.

The apparent depth will be negative when the upper layer is more conductive than the underlying material, and will be zero when a homogeneous half space exists. The apparent depth parameter must be interpreted cautiously because it will contain any errors which may exist in the measured altitude of the EM bird (e.g., as caused by a dense tree cover). The inputs to the resistivity algorithm are the inphase and quadrature components of the coplanar coil-pair. The outputs are the apparent resistivity of the conductive half space (the source) and the sensor-source distance. The flying height is not an input variable, and the output resistivity and sensor-source distance are independent of the flying height. The apparent depth, discussed above, is simply the sensor-source distance minus the measured altitude or flying height. Consequently, errors in the measured altitude will affect the apparent depth parameter but not the apparent resistivity parameter.

The apparent depth parameter is a useful indicator of simple layering in areas lacking a heavy tree cover. The DIGHEM system has been flown for purposes of permafrost mapping, where positive apparent depths were used as a measure of permafrost thickness. However, little quantitative use has been made of negative apparent depths because the absolute value of the negative depth is not a measure of the thickness of the conductive upper layer and, therefore, is not meaningful physically. Qualitatively, a negative apparent depth estimate usually shows that the EM anomaly is caused by conductive overburden. Consequently, the apparent depth channel can be of significant help in distinguishing between overburden and bedrock conductors.

The resistivity map often yields more useful information on conductivity distributions than the EM map. In comparing the EM and resistivity maps, keep in mind the following:

(a) The resistivity map portrays the absolute value of the earth's resistivity, where resistivity = 1/conductivity.

(b) The EM map portrays anomalies in the earth's resistivity. An anomaly by definition is a change from the norm and so the EM map displays anomalies, (i) over narrow, conductive bodies and (ii) over the boundary zone between two wide formations of differing conductivity.

The resistivity map might be likened to a total field map and the EM map to a horizontal gradient in the direction of flight[2]. Because gradient maps are usually more sensitive than total field maps, the EM map therefore is to be preferred in resistive areas. However, in conductive areas, the absolute character of the resistivity map usually causes it to be more useful than the EM map.

Interpretation in conductive environments

Environments having background resistivities below 30 ohm-m cause all airborne EM systems to yield very large responses from the conductive ground. This usually prohibits the recognition of discrete bedrock conductors. However, DIGHEM data processing techniques produce three parameters which contribute significantly to the recognition of bedrock conductors. These are the inphase and quadrature difference channels (DIFI and DIFQ), and the resistivity and depth channels (RES and DP) for each coplanar frequency.

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2 The gradient analogy is only valid with regard to the identification of anomalous locations.

The EM difference channels (DIFI and DIFQ) eliminate most of the responses from conductive ground, leaving responses from bedrock conductors, cultural features (e.g., telephone lines, fences, etc.) and edge effects. Edge effects often occur near the perimeter of broad conductive zones. This can be a source of geologic noise. While edge effects yield anomalies on the EM difference channels, they do not produce resistivity anomalies. Consequently, the resistivity channel aids in eliminating anomalies due to edge effects. On the other hand, resistivity anomalies will coincide with the most highly conductive sections of conductive ground, and this is another source of geologic noise. The recognition of a bedrock conductor in a conductive environment therefore is based on the anomalous responses of the two difference channels (DIFI and DIFQ) and the resistivity channels (RES). The most favourable situation is where anomalies coincide on all channels.

The DP channels, which give the apparent depth to the conductive material, also help to determine whether a conductive response arises from surficial material or from a conductive zone in the bedrock. When these channels ride above the zero level on the digital profiles (i.e., depth is negative), it implies that the EM and resistivity profiles are responding primarily to a conductive upper layer, i.e., conductive overburden. If the DP channels are below the zero level, it indicates that a resistive upper layer exists, and this usually implies the existence of a bedrock conductor. If the low frequency DP channel is below the zero level and the high frequency DP is above, this suggests that a bedrock conductor occurs beneath conductive cover.

The conductance channel CDT identifies discrete conductors which have been selected by computer for appraisal by the geophysicist. Some of these automatically selected anomalies on channel CDT are discarded by the geophysicist. The automatic selection algorithm is intentionally oversensitive to assure that no meaningful responses are missed. The interpreter then classifies the anomalies according to their source and eliminates those that are not substantiated by the data, such as those arising from geologic or aerodynamic noise.

Reduction of geologic noise

Geologic noise refers to unwanted geophysical responses. For purposes of airborne EM surveying, geologic noise refers to EM responses caused by conductive overburden and magnetic permeability. It was mentioned previously that the EM difference channels (i.e., channel DIFI for inphase and DIFQ for quadrature) tend to eliminate the response of conductive overburden. This marked a unique development in airborne EM technology, as DIGHEM is the only EM system which yields channels having an exceptionally high degree of immunity to conductive overburden.

Magnetite produces a form of geological noise on the inphase channels of all EM systems. Rocks containing less than 1% magnetite can yield negative inphase anomalies caused by magnetic permeability. When magnetite is widely distributed throughout a survey area, the inphase EM channels may continuously rise and fall, reflecting variations in the magnetite percentage, flying height, and overburden thickness. This can lead to difficulties in recognizing deeply buried bedrock conductors, particularly if conductive overburden also exists. However, the response of broadly distributed magnetite generally vanishes on the inphase difference channel DIFI. This feature can be a significant aid in the recognition of conductors which occur in rocks containing accessory magnetite.

EM magnetite mapping

The information content of DIGHEM data consists of a combination of conductive eddy current responses and magnetic permeability responses. The secondary field resulting from conductive eddy current flow is frequency-dependent and consists of both inphase and quadrature components, which are positive in sign. On the other hand, the secondary field resulting from magnetic permeability is independent of frequency and consists of only an inphase component which is negative in sign. When magnetic permeability manifests itself by decreasing the measured amount of positive inphase, its presence may be difficult to recognize. However, when it manifests itself by yielding a negative inphase anomaly (e.g., in the absence of eddy current flow), its presence is assured. In this latter case, the negative component can be used to estimate the percent magnetite content.

A magnetite mapping technique was developed for the coplanar coil-pair of DIGHEM. The technique yields a channel (designated FEO) which displays apparent weight percent magnetite according to a homogeneous half space model.[3] The method can be complementary to magnetometer mapping in certain cases. Compared to magnetometry, it is far less sensitive but is more able to resolve closely spaced magnetite zones, as well as providing an estimate of the amount of magnetite in the rock. The method is sensitive to 1/4% magnetite by weight when the EM sensor is at a height of 30 m above a magnetitic half space. It can individually resolve steep dipping narrow magnetite-rich bands which are

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3 Refer to Fraser, 1981, Magnetite mapping with a multi-coil airborne electromagnetic system: Geophysics, v. 46, p. 1579-1594.

separated by 60 m. Unlike magnetometry, the EM magnetite method is unaffected by remanent magnetism or magnetic latitude.

The EM magnetite mapping technique provides estimates of magnetite content which are usually correct within a factor of 2 when the magnetite is fairly uniformly distributed. EM magnetite maps can be generated when magnetic permeability is evident as negative inphase responses on the data profiles.

Like magnetometry, the EM magnetite method maps only bedrock features, provided that the overburden is characterized by a general lack of magnetite. This contrasts with resistivity mapping which portrays the combined effect of bedrock and overburden.

Recognition of culture

Cultural responses include all EM anomalies caused by man-made metallic objects. Such anomalies may be caused by inductive coupling or current gathering. The concern of the interpreter is to recognize when an EM response is due to culture. Points of consideration used by the interpreter, when coaxial and coplanar coil-pairs are operated at a common frequency, are as follows:

1. Channel CPS monitors 60 Hz radiation. An anomaly on this channel shows that the conductor is radiating power. Such an indication is normally a guarantee that the conductor is cultural. However, care must be taken to ensure that the conductor is not a geologic body which strikes across a power line, carrying leakage currents.

2. A flight which crosses a "line" (e.g., fence, telephone line, etc.) yields a center-peaked coaxial anomaly and an m-shaped coplanar anomaly.[4] When the flight crosses the cultural line at a high angle of intersection, the amplitude ratio of coaxial/coplanar response is 4. Such an EM anomaly can only be caused by a line. The geologic body which yields anomalies most closely resembling a line is the vertically dipping thin dike. Such a body, however, yields an amplitude ratio of 2 rather than 4. Consequently, an m-shaped coplanar anomaly with a CXI/CPI amplitude ratio of 4 is virtually a guarantee that the source is a cultural line.

3. A flight which crosses a sphere or horizontal disk yields center-peaked coaxial and coplanar anomalies with a CXI/CPI amplitude ratio (i.e., coaxial/coplanar) of

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[4] See Figure 5-1 presented earlier.

1/4. In the absence of geologic bodies of this geometry, the most likely conductor is a metal roof or small fenced yard.[5] Anomalies of this type are virtually certain to be cultural if they occur in an area of culture.

4. A flight which crosses a horizontal rectangular body or wide ribbon yields an m-shaped coaxial anomaly and a center-peaked coplanar anomaly. In the absence of geologic bodies of this geometry, the most likely conductor is a large fenced area.[5] Anomalies of this type are virtually certain to be cultural if they occur in an area of culture.

5. EM anomalies which coincide with culture, as seen on the camera film or video display, are usually caused by culture. However, care is taken with such coincidences because a geologic conductor could occur beneath a fence, for example. In this example, the fence would be expected to yield an m-shaped coplanar anomaly as in case #2 above. If, instead, a center-peaked coplanar anomaly occurred, there would be concern that a thick

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[5] It is a characteristic of EM that geometrically similar anomalies are obtained from: (1) a planar conductor, and (2) a wire which forms a loop having dimensions identical to the perimeter of the equivalent planar conductor.

geologic conductor coincided with the cultural line.

6. The above description of anomaly shapes is valid when the culture is not conductively coupled to the environment. In this case, the anomalies arise from inductive coupling to the EM transmitter. However, when the environment is quite conductive (e.g., less than 100 ohm-m at 900 Hz), the cultural conductor may be conductively coupled to the environment. In this latter case, the anomaly shapes tend to be governed by current gathering. Current gathering can completely distort the anomaly shapes, thereby complicating the identification of cultural anomalies. In such circumstances, the interpreter can only rely on the radiation channel CPS and on the camera film or video records.

MAGNETICS

The existence of a magnetic correlation with an EM anomaly is indicated directly on the EM map. In some geological environments, an EM anomaly with magnetic correlation has a greater likelihood of being produced by sulfides than one that is non-magnetic. However, sulfide ore bodies may be non-magnetic (e.g., the Kidd Creek deposit near Timmins, Canada) as well as magnetic (e.g., the Mattabi deposit near Sturgeon Lake, Canada).

The magnetometer data are digitally recorded in the aircraft to an accuracy of one nT (i.e., one gamma) for proton magnetometers, and 0.01 nT for cesium magnetometers. The digital tape is processed by computer to yield a total field magnetic contour map. When warranted, the magnetic data may also be treated mathematically to enhance the magnetic response of the near-surface geology, and an enhanced magnetic contour map is then produced. The response of the enhancement operator in the frequency domain is illustrated in Figure 5-2. This figure shows that the passband components of the airborne data are amplified 20 times by the enhancement operator. This means, for example, that a 100 nT anomaly on the enhanced map reflects a 5 nT anomaly for the passband components of the airborne data.

The enhanced map, which bears a resemblance to a downward continuation map, is produced by the digital bandpass filtering of the total field data. The enhancement is equivalent to continuing the field downward to a level (above the source) which is 1/20th of the actual sensor-source distance.

Because the enhanced magnetic map bears a resemblance to a ground magnetic map, it simplifies the recognition of trends in the rock strata and the interpretation of geological structure. It defines the near-surface local

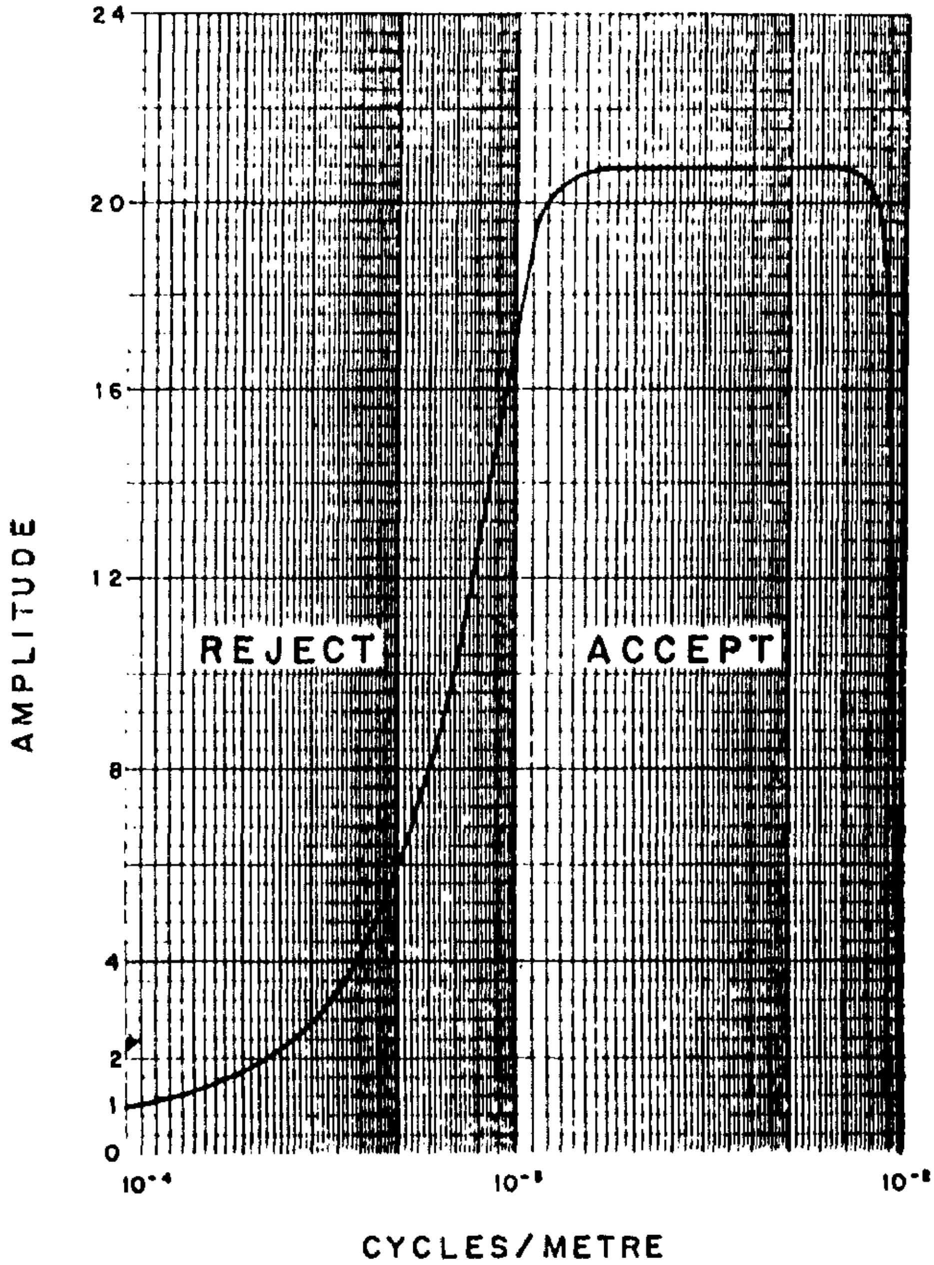

Fig. 5-2 Frequency response of magnetic enhancement operator for a sample interval of 50 m.

geology while de-emphasizing deep-seated regional features. It primarily has application when the magnetic rock units are steeply dipping and the earth's field dips in excess of 60 degrees.

Any of a number of filter operators may be applied to the magnetic data, to yield vertical derivatives, continuations, magnetic susceptibility, etc. These may be displayed in contour, colour or shadow.

VLF

VLF transmitters produce high frequency uniform electromagnetic fields. However, VLF anomalies are not EM anomalies in the conventional sense. EM anomalies primarily reflect eddy currents flowing in conductors which have been energized inductively by the primary field. In contrast, VLF anomalies primarily reflect current gathering, which is a non-inductive phenomenon. The primary field sets up currents which flow weakly in rock and overburden, and these tend to collect in low resistivity zones. Such zones may be due to massive sulfides, shears, river valleys and even unconformities.

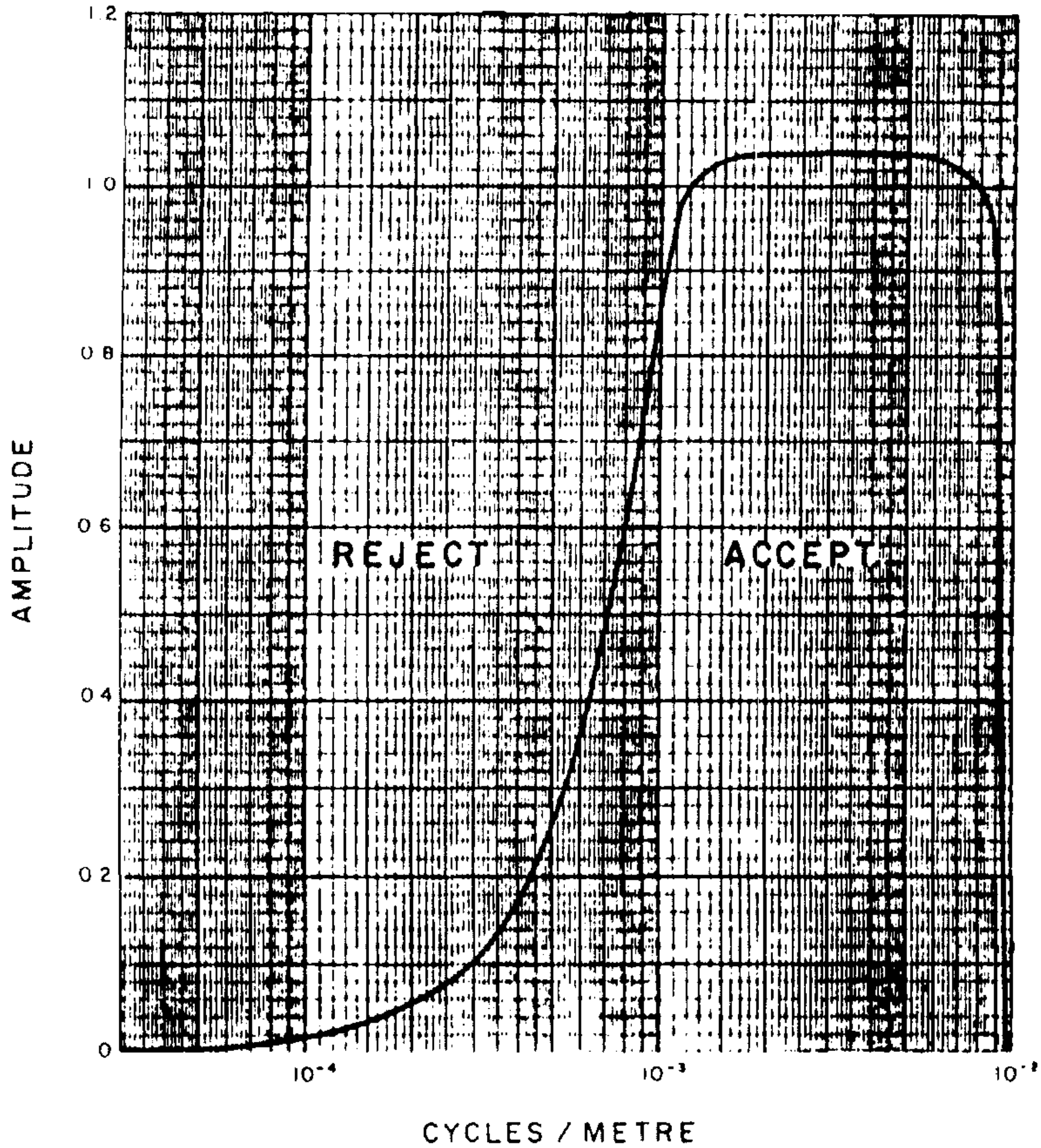

Fig. 5-3 Frequency response of VLF operator.

The VLF field is horizontal. Because of this, the method is quite sensitive to the angle of coupling between the conductor and the transmitted VLF field. Conductors which strike towards the VLF station will usually yield a stronger response than conductors which are nearly orthogonal to it.

The Herz Industries Ltd. Totem VLF-electromagnetometer measures the total field and vertical quadrature components. Both of these components are digitally recorded in the aircraft with a sensitivity of 0.1 percent. The total field yields peaks over VLF current concentrations whereas the quadrature component tends to yield crossovers. Both appear as traces on the profile records. The total field data are filtered digitally and displayed as contours to facilitate the recognition of trends in the rock strata and the interpretation of geologic structure.

The response of the VLF total field filter operator in the frequency domain (Figure 5-3) is basically similar to that used to produce the enhanced magnetic map (Figure 5-2). The two filters are identical along the abscissa but different along the ordinant. The VLF filter removes long wavelengths such as those which reflect regional and wave transmission variations. The filter sharpens short wavelength responses such as those which reflect local geological variations.

CONCLUSIONS AND RECOMMENDATIONS

This report provides a very brief description of the survey results and describes the equipment, procedures and logistics of the survey.

The survey was successful in locating many bedrock conductors and zones of interest. The various maps included with this report display the magnetic and conductive properties of the survey areas. It is recommended that the survey results be reviewed in detail, in conjunction with all available geophysical, geological and geochemical information. Particular reference should be made to the computer generated data profiles which clearly define the characteristics of the individual anomalies.

There are numerous anomalous responses in the survey area which are considered to be high priority targets.

The conductors detected by the survey show marked variations in magnetic correlation and conductance. These changes suggest that the conductive sources also vary in composition. Strike directions of the conductors vary throughout the survey area.

The magnetic data suggest that the area has been subject to deformation and/or alteration. There are many conductors which appear to be related to contacts between magnetically distinct units.

Other conductors, which are poorly defined, appear to transect the local geologic strike. In many areas, these trends may reflect faults or other structural features. Structural breaks, or deformation, are considered to be of particular interest as they may have influenced mineral deposition within the survey area.

The bedrock conductors defined by the survey should be subjected to further investigation, using appropriate surface exploration techniques. Anomalies which are currently considered to be of moderately low priority may require upgrading if follow-up results are favourable.

It is also recommended that additional processing of existing geophysical data be considered, in order to extract the maximum amount of information from the survey results. Colour maps and enhanced shadow maps often provide valuable information on structure and lithology, which may not be clearly evident on the contour maps. Current processing techniques can yield images which define subtle, but significant, structural details.

Respectfully submitted,

DIGHEM SURVEYS & PROCESSING INC.

R. Pritchard

Ruth A. Pritchard
Geophysicist

RAP/sdp

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APPENDIX A

LIST OF PERSONNEL

The following personnel were involved in the acquisition, processing, interpretation and presentation of data, relating to a $DIGHEM^{IV}$ airborne geophysical survey carried out for Champion Bear Resources Ltd., over a property in the Helder Lake Area, Ontario.

Kirby Mills	Survey Operations Manager
David E. Pritchard	Survey Operations Supervisor
Philip Miles	Geophysical Operator
David Miles	Second Geophysical Operator
Roger Morrow	Pilot (Questral Helicopters Ltd.)
Paul Bottomley	Computer Processor
Ruth A. Pritchard	Geophysicist/Interpreter
Gojko Mijac	Draftsperson
Susan Pothiah	Word Processing Operator

The survey consisted of 1612 km of coverage, flown from May 13 to May 15, 1989.

All personnel are employees of Dighem Surveys & Processing Inc., except for the pilot who is an employee of Questral Helicopters Ltd.

DIGHEM SURVEYS & PROCESSING INC.

R Pritchard

Ruth A. Pritchard
Geophysicist

RAP/sdp

Ref: Report #1069

A1069JUL.90R

APPENDIX B

STATEMENT OF COST

Date: July 11, 1989

IN ACCOUNT WITH
DIGHEM SURVEYS & PROCESSING INC.

To: Dighem flying of Agreement dated April 28, 1989 pertaining to an Airborne Geophysical Survey in the Helder Lake Area, Ontario

Survey Charges

Ferry and mobilization	$ 8,000.00
1586 km of flying	$ 91,988.00
	$ 99,988.00

Allocation of Costs

- Data Acquisition	(60%)
- Data Processing	(20%)
- Interpretation, Report and Maps	(20%)

DIGHEM SURVEYS & PROCESSING INC.

R Pritchard

Ruth A. Pritchard
Geophysicist

RAP/sdp

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APPENDIX C

STATEMENT OF QUALIFICATIONS

I, Ruth A. Pritchard of the City of Brampton, Province of Ontario, do hereby certify that:

1. I am a geophysicist, residing at 31 Barrington Crescent, Brampton, Ontario, L6Z 1N2.

2. I am a graduate of York University, Downsview, Ontario, with a Specialized Honours B.Sc. Earth Sciences - Geophysics (1986).

3. I have been actively engaged in geophysical exploration since 1986.

4. The statements made in this report represent my best opinion and judgement.

R. Pritchard

Ruth A. Pritchard
Geophysicist

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