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PROJECT REPORT OF THE LITTLE CHENA RIVER HEADWATERS

by

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Mississauga, Ontario

April 1995

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WGM INC., DIGHEM SURVEY

OF

HEADWATERS LITTLE CHENA RIVER AREA

FOR

STATE OF ALASKA

DEPARTMENT OF NATURAL RESOURCES

DIVISION OF GEOLOGICAL & GEOPHYSICAL SURVEYS

Quadrangle; Circle: A-6

Mississauga, Ontario
January 30, 1995

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SUMMARY

This report describes the logistics and results of a DIGHEM^V airborne geophysical survey carried out under contract to WGM Inc., Mining and Geological Consultants, for The State of Alaska, Department of Natural Resources, Division of Geological & Geophysical Surveys over the Headwaters Little Chena River Area, Circle A-6 Quadrangle. Total coverage of the survey block amounted to 91 line miles (146 km). The survey was flown on August 20, 1994.

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 areas. This was accomplished by using a DIGHEM^V multi-coil, multi-frequency electromagnetic system, supplemented by a high sensitivity cesium magnetometer and a four-channel VLF receiver. The information from these sensors was processed to produce maps which display the magnetic and conductive properties of the survey area. A GPS electronic navigation system, utilizing a UHF link, ensured accurate positioning of the geophysical data with respect to the base maps. Visual flight path recovery techniques were used to confirm the location of the helicopter where visible topographic features could be identified on the ground.

Several bedrock conductors were identified in the survey area. These may warrant follow-up. Many structural breaks and contacts have been defined by the total field magnetics.

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.

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INTRODUCTION

A DIGHEM^V electromagnetic/resistivity/magnetic/VLF survey was flown under contract to WGM Inc., Mining and Geological Consultants, for The State of Alaska, Department of Natural resources, Division of Geological & Geophysical Survey over the Headwaters Little Chena River Area, Alaska.. The survey was flown on August 20, 1994. The survey area can be located on the Circle A-6 quadrangle (see figure 1-1).

The survey comprised 84 line-miles (135 line-km) of traverse lines and 7 line-miles (11 line-km) of tie lines. The traverse lines were flown at an azimuth of 0^0 with a line spacing of 1/4 mile (400 m).

The survey employed the DIGHEM^V electromagnetic system. Ancillary equipment consisted of a magnetometer, radar 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. Section 2 also provides details on the data channels, their respective sensitivities, and the navigation/flight path recovery procedure.

LOCATION INDEX

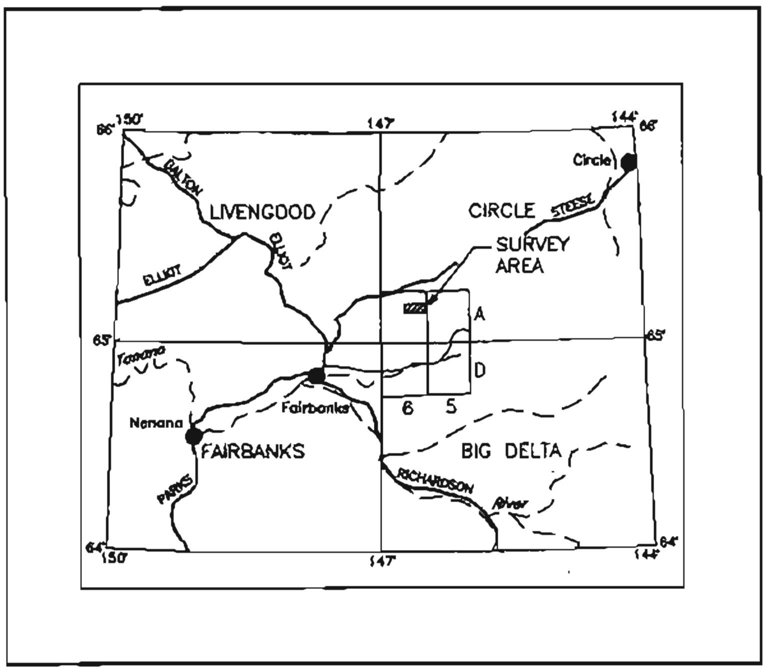

FIGURE 1-1

LOCATION MAP OF THE SURVEY AREA

SURVEY EQUIPMENT

The instrumentation was installed in an Aerospatiale AS350B turbine helicopter (Registration N162EH) which was provided by ERA Helicopters Ltd. The helicopter flew at an average airspeed of 70 mph (110 km/h) with an EM bird height of approximately 30 m.

Electromagnetic System

Model:	DIGHEM^{V}
Type:	Towed bird, symmetric dipole configuration operated at a nominal survey altitude of 30 metres. Coil separation is 8 metres for 900 Hz, 5000 Hz and 7200 Hz, and 6.3 metres for the 56,000 Hz coil-pair.
Coil orientations/frequencies:	coaxial / 900 Hz coplanar / 900 Hz coaxial / 5,000 Hz coplanar / 7,200 Hz coplanar / 56,000 Hz
Channels recorded:	5 inphase channels 5 quadrature channels 5 monitor channels
Sensitivity:	0.1 ppm at 900 Hz 0.2 ppm at 5,000 Hz 0.2 ppm at 7,200 Hz 0.5 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 coils are vertical with their axes 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.

The EM system was calibrated for phase at the beginning of each day of operation. Gain calibrations were made at the start of flying, and checked at the end of flying for each of the three blocks on which the EM system was utilized. Additional gain calibrations were made after any maintenance to the EM system.

The gain calibration was performed by inducing a 100 ppm signal into the system for each frequency using a calibrated coil, which was held externally to the EM bird. A corresponding reading in ppm was then obtained from the EM data acquisition system.

The phase calibration used a ferrite rod, which was held externally to the EM bird, that produced a negative deflection on the inphase electromagnetic parameter, but no deflection on the quadrature parameter. The phase was adjusted until no deflection was apparent on the quadrature EM parameter.

Magnetometer Sensor

Model:	Scintrex CS2
Type:	Optically pumped Cesium vapour
Sensitivity:	0.01 nT
Sample rate:	10 per second

The magnetometer sensor is towed in a bird 20 m below the helicopter.

Magnetic Base Station

Model:	Scintrex MP-3
Type:	Digital recording proton precession
Sensitivity:	0.10 nT
Sample rate:	0.2 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:	Seattle, Washington;	NLK,24.8 kHz
	Annapolis, Maryland;	NSS, 21.4 kHz
	Cutler, Maine;	NAA,24.0 kHz
	Lualualei, Hawaii;	NPM,23.4 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 housed in the same bird as the magnetic sensor, and is towed 20 m below the helicopter.

Radar Altimeter

Manufacturer:	Honeywell/Sperry
Type:	AA 220
Sensitivity:	1 ft

The radar 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:	DGR33 dot-matrix graphics recorder
Resolution:	4x4 dots/mm
Speed:	1.5 mm/sec

The analog profiles are 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:	RMS Instruments
Type:	DGR 33
Tape Deck:	RMS TCR-12, 6400 bpi, tape cartridge recorder

The digital data are used to generate several computed parameters. Both measured and computed parameters are plotted as "multi-channel stacked 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 16.6 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.

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 (RT-DGPS)

Model:	Sercel NR106, Real-time differential positioning
Type:	SPS (L1 band), 10-channel, C/A code, 1575.42 MHz.
Sensitivity:	-132 dBm, 0.5 second update
Accuracy:	$<$ 5 metres in differential mode, $\pm$ 50 metres in S/A (non differential) mode

The Global Positioning System (GPS) is a line of sight, satellite navigation system which utilizes time-coded signals from at least four of the twenty-four NAVSTAR satellites. In the differential mode, two GPS receivers are used. The base station unit is used as a reference which transmits real-time corrections to the mobile unit in the

Table 2-1. The Analog Profiles

Channel Name	Parameter	Scale units/mm	Designation on digital profile
1X9I	coaxial inphase (900 Hz)	2.5 ppm	CXI (900 Hz)
1X9Q	coaxial quad (900 Hz)	2.5 ppm	CXQ (900 Hz)
3P9I	coplanar inphase (900 Hz)	2.5 ppm	CPI (900 Hz)
3P9Q	coplanar quad (900 Hz)	2.5 ppm	CPQ (900 Hz)
2P7I	coplanar inphase (7200 Hz)	5 ppm	CPI (7200 Hz)
2P7Q	coplanar quad (7200 Hz)	5 ppm	CPQ (7200 Hz)
4X7I	coaxial inphase (5000 Hz)	5 ppm	CXI (5000 Hz)
4X7Q	coaxial quad (5000 Hz)	5 ppm	CXQ (5000 Hz)
5P5I	coplanar inphase(56000 Hz)	10 ppm	CPI (56 kHz)
5P5Q	coplanar quad (56000 Hz)	10 ppm	CPQ (56 kHz)
ALTR	altimeter	3 m	ALT
MAG1	magnetics, coarse	20 nT	MAG
CMGF	magnetics, fine	2.0 nT	
VF1T	VLF-total: primary stn.	2%	VLF1T
VF1Q	VLF-quad: primary stn.	2%	VLF1Q
VF2T	VLF-total: secondary stn.	2%	VLF2T
VF2Q	VLF-quad: secondary stn.	2%	VLF2Q
CXSP	coaxial sferics monitor		CXS
3XSP	coaxial sferics monitor		
3PSP	coplanar sferics monitor		
CXPL	coaxial powerline monitor		CXP
3PPL	coplanar powerline monitor		

Table 2-2. The Digital Profiles

Channel Name (Freq)		Observed parameters	Scale units/mm
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
CPI	(900 Hz)	horizontal coplanar coil-pair inphase	2 ppm
CPQ	(900 Hz)	horizontal coplanar coil-pair quadrature	2 ppm
CXI	(5000 Hz)	vertical coaxial coil-pair inphase	4 ppm
CXQ	(5000 Hz)	vertical coaxial coil-pair quadrature	4 ppm
CPI	(7200 Hz)	horizontal coplanar coil-pair inphase	4 ppm
CPQ	(7200 Hz)	horizontal coplanar coil-pair quadrature	4 ppm
CPI	(56 kHz)	horizontal coplanar coil-pair inphase	10 ppm
CPQ	(56 kHz)	horizontal coplanar coil-pair quadrature	10 ppm
CXS		coaxial sferics monitor	
CXP		coaxial powerline monitor	
		Computed Parameters	
DFI	(900 Hz)	difference function inphase from CXI and CPI	2 ppm
DFQ	(900 Hz)	difference function quadrature from CXQ and CPQ	2 ppm
RES	(900 Hz)	log resistivity	.06 decade
RES	(7200 Hz)	log resistivity	.06 decade
RES	(56 kHz)	log resistivity	.06 decade
DP	(900 Hz)	apparent depth	6 m
DP	(7200 Hz)	apparent depth	6 m
DP	(56 kHz)	apparent depth	6 m
CDT		conductance	1 grade

aircraft, via a UHF radio datalink. The on-board system calculates the flight path of the helicopter while providing real-time guidance. The raw XYZ data are recorded for both receivers, thereby permitting post-survey processing for accuracies of approximately 2 metres.

Although the base station receiver is able to calculate its own latitude and longitude, a higher degree of accuracy can be obtained if the reference unit is established on a known benchmark or triangulation point. The GPS records data relative to the WGS84 ellipsoid, which is the basis of the revised North American Datum (NAD83). Conversion software is used to transform the WGS84 coordinates to the system displayed on the base maps.

Field Workstation

Manufacturer:	Dighem
Model:	FWS: V2.41
Type:	80386 based P.C.

A portable PC-based field workstation is used at the survey base to verify data quality and completeness. Flight tapes are dumped to a hard drive to permit the creation of a database. This process allows the field operators to display both the positional (flight path) and geophysical data on a screen or printer.

PRODUCTS AND PROCESSING TECHNIQUES

The following products are available from the survey data. Products which are not part of the survey contract may be acquired later from WGM or Dighem. Refer to Table 3-1 for a summary of the maps which accompany this report. Most parameters can be displayed as contours, profiles, or in color.

Base Maps

Base maps of the survey area have been produced from published topographic maps. The maps used were quadrangles; Circle: A-5, 1952 and A-6, 1954.

Electromagnetic Anomalies

Anomalous electromagnetic responses were selected and analysed by computer to provide preliminary electromagnetic anomaly maps. These preliminary maps were used by the geophysicist, in conjunction with the computer-generated digital profiles, to produce the final interpreted EM anomalies, which appear on the "Total Field Magnetics and EM Anomalies" maps. These maps include bedrock, surficial and cultural conductors.

Table 3-1 Products which Accompany this Report

Maps at a scale of 1:31,680

Color Shadow Total Field Magnetics
Color Total Field Magnetics
Color 900 Hz resistivity
Color 7,200 Hz resistivity
900 Hz resistivity
7,200 Hz resistivity
Total Field Magnetics and EM anomalies

Other Products

XYZ and grid archive
Stacked profiles
All original materials including: flight logs, analog records, flight path videos and calibration records
I-POWER VISION Imaging Workstation software

Resistivity

Resistivity maps, which display the conductive properties of the survey areas, were produced from the 900 Hz and 7,200 Hz coplanar data. The maximum resistivity value, which is calculated for each frequency, is approximately 1.15 times the numerical value of the frequency. This cutoff eliminates the meaningless higher resistivities which would result from very small EM amplitudes.

Total Field Magnetics

The aeromagnetic data are corrected for diurnal variation using the magnetic base station data and by manually making corrections based on the tie line intercepts and visual analysis on the I-POWER VISION Imaging Workstation. The IGRF variation was removed from the data. The IGRF correction consisted of a 1st order polynomial surface which increased 2.9 nT along a 52^0 azimuth for a maximum difference of 36 nt from southwest to northeast.

The total field magnetic data have been presented as contours on the base maps using a contour interval of 5 nT where gradients permit. The maps show the magnetic properties of the rock units underlying the survey area.

VLF

VLF results were obtained from the transmitting stations at Cutler, Maine (NAA - 24.0 kHz) and Annapolis, Maryland (NSS - 21.4 kHz). The VLF data was not required as a deliverable under the terms of the survey agreement, but can be acquired later, if requested.

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

Multi-channel Stacked 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 are presented in the final corrected form after interpretation. The profiles are presented at a scale of 1:63,360.

Contour, Color and Shadow Map Displays

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

Color 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 color "contour" maps. Colour maps of the total magnetic field are particularly useful in defining the lithology of the survey area.

A monochromatic shadow map is generated by employing an artificial sun to cast shadows on a surface defined by the geophysical grid. This is combined with the color grid to produce the color shadowed total field magnetic map.

SURVEY RESULTS

GENERAL DISCUSSION

The survey results are presented on one separate map sheet at a scale of 1:31,680. Table 4-1 summarizes the EM responses in the survey area, with respect to conductance grade and interpretation.

The anomalies shown on the Total Tield Magnetics and Electromagnetic Anomalies" map 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 "Total Field Magnetics and EM Anomalies" map 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 anomalies, in areas where broad or flat-lying conductors are considered to be of importance. Contoured maps, based on the 900 Hz and 7,200 Hz coplanar data are included with this report.

Table 4-1

EM Anomaly Statistics

CONDUCTOR GRADE	CONDUCTANCE RANGE SIEMENS (MHOS)	NUMBER OF RESPONSES
7	>100	0
6	50 - 100	0
5	20 - 50	0
4	10 - 20	3
3	5 - 10	2
2	1 - 5	26
1	<1	20
*	INDETERMINATE	74
TOTAL		125

CONDUCTOR MODEL	MOST LIKELY SOURCE	NUMBER OF RESPONSES
D	DISCRETE BEDROCK CONDUCTOR	35
B	DISCRETE BEDROCK CONDUCTOR	17
H	ROCK UNIT OR THICK COVER	50
M	MAGNETITE	23
TOTAL		125

(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 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.

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.

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.

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 of anomalies comprises moderately 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. In Alaska, many of these anomalies may reflect conductive rock units or water saturated material beneath permafrost.

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. A triangular anomaly symbol with the letter "M" as an interpretive label is used to denote this fourth type of anomaly, where a weak quadrature response is associated with inphase driven negative by 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.

The effects of conductive overburden are evident over portions of the survey areas. Although the difference channels (DFI and DFQ) 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..

The "Total Field Magnetics and Electromagnetic Anomalies" maps at 1:31,680, 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 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 areas.

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 data. 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.

As economic mineralization within the areas 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.

This report is intended as a general overview only. Complete assessment and evaluation of the survey data should be carried out by qualified professionals who have access to, and can provide a meaningful compilation of, all available geophysical, geological and geochemical data in areas which are selected for follow-up.

DESCRIPTION OF SURVEY RESULTS

The following is a brief overview of geophysical responses in the survey areas. Figure 4-1 in the map pocket of this report shows a sketch which identifies features that are discussed in this report.

The inferred stratigraphic strike direction from the magnetics is east-west. Several narrow, magnetic, stratigraphic units are apparent on the total field magnetic contours. Where these are offset or abut northwest or northeast lineaments in the magnetics, faults have been inferred. The faults and magnetic trends have been indicated to a limited extent on the interpretation map.

There are numerous single-line responses and, in general, the gridded data shows numerous anomalies which do not correlate well from line-to-line. The low flying height (100 feet for the EM bird and 130 feet for the magnetometer sensor), coupled with the wide line spacing (¼ mile), results in over sampling along the line. The along-line detail has been preserved to the detriment of the aesthetic quality of the total field magnetic grid, but the validity of the data has not been affected.

In several parts of the survey area, surficial and/or bedrock resistivities were sufficiently high, and magnetite concentrations sufficiently high, that negative inphase EM magnetite responses could be identified. These have been indicated with triangular symbols on the Total Field Magnetics and Electromagnetic Anomalies map. These may be useful for lithological discrimination.

Some of the structural breaks are also apparent on the resistivity maps. For example, F1 is associated with a conductive region on the 7,200 Hz resistivity near its south end. This may result from structural control of conductive surficial (e.g., fluvial) material, or due to clay alteration or even conductive sulphide or graphite mineralization directly associated with the faulting.

In other locations, resistivity lows due to surficial and bedrock material appear to be truncated or offset by faulting. For example, the resistivity low associated with conductor axis EM6 on the interpretation map appears to be truncated at its east extreme by a northwest trending fault.

Conductor axes EM1 to EM7 reflect probable, narrow bedrock conductive sources such as graphite or sulphide-rich units. EM1, EM3, EM6 and EM7 are closely associated with magnetic anomalies which indicates that they have a higher probability of being due to sulphides such as pyrrhotite than do the non-magnetic conductors.

Where identifiable from the EM profiles, the conductive units appear to be consistently dipping to the south.

Further investigation of the bedrock conductors in this area to determine if they reflect sulphide bodies with economic mineralization is warranted. On-site checks for cultural sources should be made prior to further work; however, no obvious man-made objects were visible on the flight path videos.

There are many weak, broad conductors in the survey area which have been labelled as "H" or "H?" that may be of importance in exploration based on supporting geological, geochemical or ground geophysical data. In some cases such anomalies may not have been picked as anomalies at all due to their poorly defined profile shapes or low amplitudes. These will appear only as lows on the resistivity maps.

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 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.

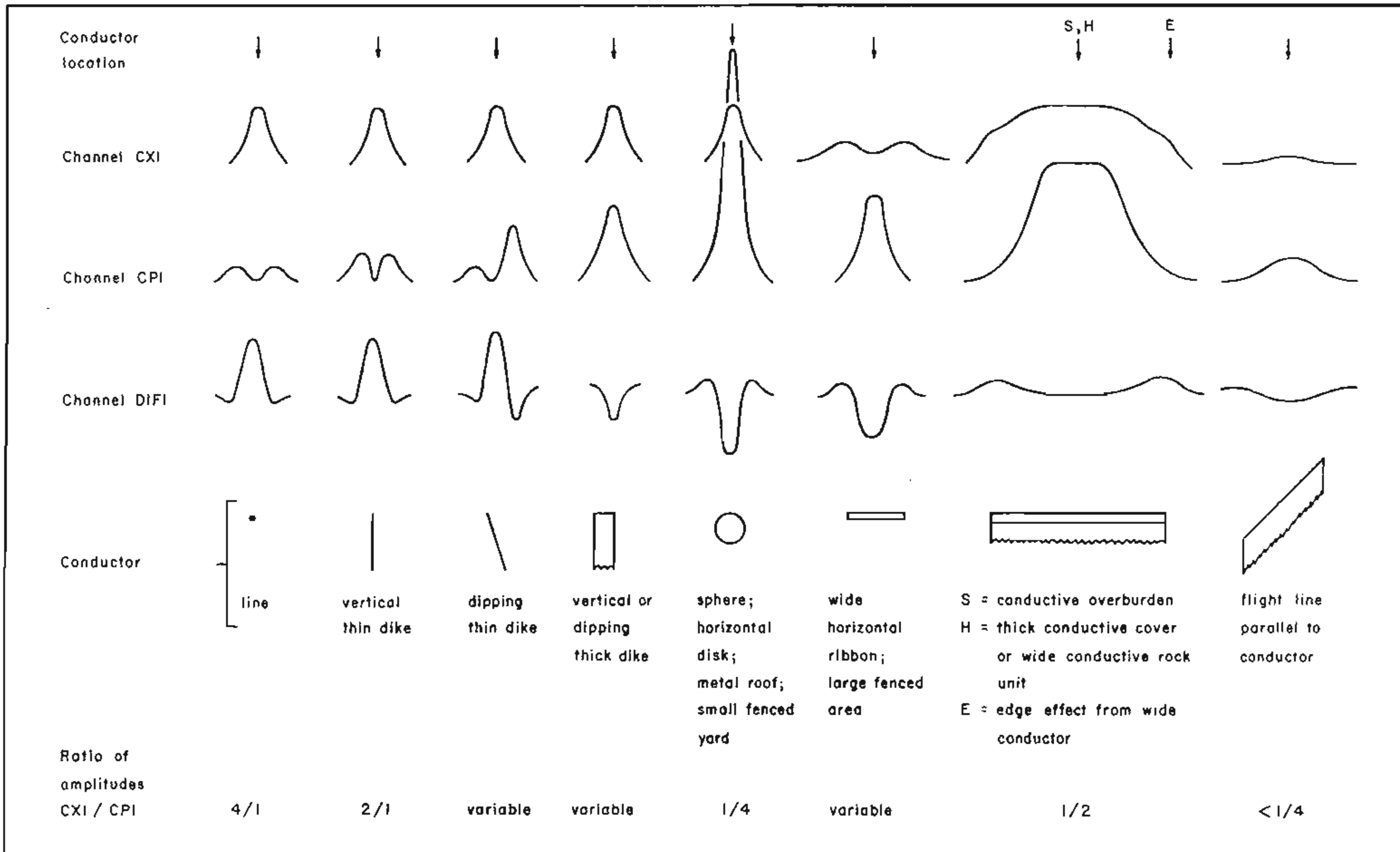

Fig. 5-1 Typical DIGHEM anomaly shapes

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 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.

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

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 apparent 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.

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

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 (DFI and DFQ), and the resistivity and depth channels (RES and DP) for each coplanar frequency.

The EM difference channels (DFI and DFQ) 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 (DFI and DFQ) 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 DFI for inphase and DFQ 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 DFI. 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 separated by 60 m. Unlike magnetometry, the EM magnetite method is unaffected by remanent magnetism or magnetic latitude.

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

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. Channels CXP and CPP monitor 60 Hz radiation. An anomaly on these channels 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 1/4. In the absence of geologic bodies of this geometry, the most likely conductor is

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[4] See Figure 5-1 presented earlier.

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 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

[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.

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 channels and on the camera film or video records.

MAGNETICS

Total field magnetics provides information on the magnetic properties of the earth materials in the survey area. The information can be used to locate magnetic bodies of direct interest for exploration, and for structural and lithological mapping.

The total field magnetic response reflects the abundance of magnetic material, in the source. Magnetite is the most common magnetic mineral. Other minerals such as ilmenite, pyrrhotite, franklinite, chromite, hematite, arsenopyrite, limonite and pyrite are also magnetic, but to a lesser extent than magnetite on average.

In some geological environments, an EM anomaly with magnetic correlation has a greater likelihood of being produced by sulphides than one that is non-magnetic. However, sulphide 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).

Iron ore deposits will be anomalously magnetic in comparison to surrounding rock due to the concentration of iron minerals such as magnetite, ilmenite and hematite.

Changes in magnetic susceptibility often allow rock units to be differentiated based on the total field magnetic response. Geophysical classifications may differ from geological classifications if various magnetite levels exist within one general geological classification. Geometric considerations of the source such as shape, dip and depth, inclination of the earth's field and remanent magnetization will complicate such an analysis.

In general, mafic lithologies contain more magnetite and are therefore more magnetic than many sediments which tend to be weakly magnetic. Metamorphism and alteration can also increase or decrease the magnetization of a rock unit.

Textural differences on a total field magnetic contour, colour or shadow map due to the frequency of activity of the magnetic parameter resulting from inhomogeneities in the distribution of magnetite within the rock, may define certain lithologies. For example, near surface volcanics may display highly complex contour patterns with little line-to-line correlation.

Rock units may be differentiated based on the plan shapes of their total field magnetic responses. Mafic intrusive plugs can appear as isolated "bulls-eye" anomalies. Granitic intrusives appear as sub-circular zones, and may have contrasting rings due to contact metamorphism. Generally, granitic terrain will lack a pronounced strike direction, although granite gneiss may display strike.

Linear north-south units are theoretically not well-defined on total field magnetic maps in equatorial regions due to the low inclination of the earth's magnetic field. However, most stratigraphic units will have variations in composition along strike which will cause the units to appear as a series of alternating magnetic highs and lows.

Faults and shear zones may be characterized by alteration that causes destruction of magnetite (e.g., weathering) which produces a contrast with surrounding rock. Structural breaks may be filled by magnetite-rich, fracture filling material as is the case with diabase dikes, or by non-magnetic felsic material.

Faulting can also be identified by patterns in the magnetic total field contours or colours. Faults and dikes tend to appear as lineaments and often have strike lengths of several kilometres. Offsets in narrow, magnetic, stratigraphic trends also delineate structure. Sharp contrasts in magnetic lithologies may arise due to large displacements along strike-slip or dip-slip faults.

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.

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 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 brief description of the survey results and describes the equipment, procedures and logistics of the survey.

There are several EM anomalies in the survey blocks which have been attributed to bedrock conductivity, which probably warrant ground follow-up. The survey was also successful in locating a few moderately weak or broad conductors which may warrant additional work.

The total field magnetic data will be useful for mapping structure and lithology. The interpretation sketch map that is included with this report identifies several faults and faulted contacts which were inferred from the magnetic data.

The resistivity products provide valuable information for general geological mapping purposes. Contacts, structures and conductive stratigraphic units are all apparent on the resistivity maps. The resistivity maps can also aid in follow-up planning as they show overburden covered 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.

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

Respectfully submitted,

DIGHEM

Doug McConnell

Douglas L. McConnell, P.Eng
Geophysicist

APPENDIX A

LIST OF PERSONNEL

The following personnel were involved in the acquisition, processing, interpretation and presentation of data, relating to a DIGHEM^{V} airborne geophysical survey carried out under contract to WGM Inc., for the State of Alaska, in the Headwaters Little Chena River Area, Circle A-6 quadrangle Alaska.

Robert Gordon	Survey Operations Supervisor
Dave Miles	Senior Geophysical Operator
Walt Greaves	Pilot (ERA Helicopters Ltd.)
Gordon Smith	Data Processing Supervisor
Dak Darbha	Computer Processor
Doug McConnell	Interpretation Geophysicist
Lyn Vanderstarren	Drafting Supervisor
Steve Mast	Draftsperson (CAD)
Susan Pothiah	Word Processing Operator
Albina Tonello	Secretary/Expeditor

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

APPENDIX B

EM ANOMALY LIST

ANOMALY/	FID/INTERP	COAXIAL 1094 HZ REAL PPM	COAXIAL 1094 HZ QUAD PPM	COPLANAR 883 HZ REAL PPM	COPLANAR 883 HZ QUAD PPM	COPLANAR 7253 HZ REAL PPM	COPLANAR 7253 HZ QUAD PPM	VERTICAL DIKE COND SIEMEN	VERTICAL DIKE DEPTH* M	HORIZONTAL SHEET COND SIEMEN	HORIZONTAL SHEET DEPTH M	CONDUCTIVE EARTH RESIS OHM-M	CONDUCTIVE EARTH DEPTH M	MAG CORR NT
LINE 40011	(FLIGHT 21)													
A	6947M	-1	0	-1	1	2	4	-	-	-	-	-	-	0
B	6951H	2	3	0	5	12	31	3.1	54	1	82	895	0	0
C	6991B?	-4	5	1	5	12	18	0.7	0	1	32	399	4	0
LINE 40021	(FLIGHT 21)													
A	6823B?	1	2	1	2	2	4	-	-	-	-	-	-	19
B	6795D?	1	2	1	2	2	4	-	-	-	-	-	-	0
C	6789M	1	1	1	0	1	0	-	-	-	-	-	-	130
D	6740D	1	3	2	6	12	39	1.3	45	1	63	334	17	0
E	6733H?	2	3	1	5	2	30	2.9	60	1	135	1015	0	0
LINE 40030	(FLIGHT 21)													
A	975M	0	1	0	1	2	4	-	-	-	-	-	-	110
B	980M	-2	4	1	8	17	38	0.4	1	1	61	784	0	0
C	982H	1	4	1	8	17	38	1.3	38	1	56	764	0	0
D	1040D?	1	2	1	2	2	4	-	-	-	-	-	-	0
E	1047D	-1	5	1	4	7	25	0.4	0	1	65	770	0	0
F	1054H	1	2	0	2	2	4	-	-	-	-	-	-	0
LINE 40040	(FLIGHT 21)													
A	1229D?	1	2	0	1	2	4	-	-	-	-	-	-	0
B	1223D?	0	2	1	2	2	4	-	-	-	-	-	-	0
C	1172D?	0	2	0	2	2	4	-	-	-	-	-	-	140
D	1126H?	1	2	1	2	2	4	-	-	-	-	-	-	0
E	1121D?	0	5	3	9	24	4	0.4	0	1	40	464	0	0
LINE 40051	(FLIGHT 21)													
A	6307H	-3	1	1	2	2	4	-	-	-	-	-	-	0
B	6292H	0	2	0	2	2	4	-	-	-	-	-	-	0
C	6249H	1	2	1	2	2	4	-	-	-	-	-	-	0
LINE 40061	(FLIGHT 21)													
A	6526H	-1	5	0	9	9	54	0.4	10	1	80	824	7	0
B	6553M	1	2	1	2	2	4	-	-	-	-	-	-	140
C	6562D	0	4	0	7	12	29	0.4	2	1	57	762	0	0
LINE 40070	(FLIGHT 21)													
A	1702H	1	2	1	2	2	4	-	-	-	-	-	-	0
B	1741B?	4	3	0	3	12	22	5.6	50	1	82	893	0	50
C	1754D	0	9	2	10	24	41	0.4	0	1	52	775	0	0
D	1810H	1	2	1	2	2	2	-	-	-	-	-	-	0

* ESTIMATED DEPTH MAY BE UNRELIABLE BECAUSE THE STRONGER PART OF THE CONDUCTOR MAY BE DEEPER OR TO ONE SIDE OF THE FLIGHT LINE, OR BECAUSE OF A SHALLOW DIP OR OVERBURDEN EFFECTS.

ANOMALY/ FID/INTERP		COAXIAL 1094 HZ REAL PPM	COAXIAL 1094 HZ QUAD PPM	COPLANAR 883 HZ REAL PPM	COPLANAR 883 HZ QUAD PPM	COPLANAR 7253 HZ REAL PPM	COPLANAR 7253 HZ QUAD PPM	VERTICAL DIKE COND SIEMEN	VERTICAL DIKE DEPTH* M	HORIZONTAL SHEET COND SIEMEN	HORIZONTAL SHEET DEPTH M	CONDUCTIVE EARTH RESIS OHM-M	CONDUCTIVE EARTH DEPTH M	MAG CORR NT
LINE 40080		(FLIGHT 21)												
A	1960H	-1	7	0	1	18	18	0.4	2	1	46	721	0	0
B	1901D	7	9	5	12	33	21	4.5	22	1	28	490	0	0
C	1873H	0	2	0	2	2	4	-	-	-	-	-	-	0
LINE 40090		(FLIGHT 21)												
A	2073H	1	0	0	2	2	4	-	-	-	-	-	-	0
B	2095H	-1	2	1	2	2	4	-	-	-	-	-	-	0
C	2111H	-1	3	1	5	10	22	0.4	0	1	40	469	12	0
D	2128H	1	1	0	2	2	4	-	-	-	-	-	-	0
LINE 40100		(FLIGHT 21)												
A	2400M	-3	1	-1	2	2	4	-	-	-	-	-	-	90
B	2389D?	1	2	0	2	2	4	-	-	-	-	-	-	0
C	2355M	-2	2	-2	2	2	3	-	-	-	-	-	-	0
D	2340M	1	1	-2	1	0	2	1.6	71	1	93	905	6	0
E	2322D?	1	2	1	0	1	4	-	-	-	-	-	-	0
F	2316D?	1	2	1	2	2	4	-	-	-	-	-	-	40
LINE 40110		(FLIGHT 21)												
A	2475D?	0	2	0	2	2	4	-	-	-	-	-	-	15
B	2483D?	1	2	0	2	2	4	-	-	-	-	-	-	10
C	2540B	3	7	9	18	48	35	1.7	23	1	34	266	0	0
D	2553M	1	4	-3	9	8	44	1.0	37	1	49	715	0	0
E	2576H	-1	2	0	2	2	4	-	-	-	-	-	-	0
LINE 40120		(FLIGHT 21)												
A	2763M	1	2	-2	2	2	4	-	-	-	-	-	-	12
B	2738H?	0	6	0	8	5	51	0.4	11	1	66	762	5	0
C	2692B?	1	2	1	1	2	4	-	-	-	-	-	-	0
D	2686B?	1	3	4	2	12	7	1.0	0	1	50	296	24	0
E	2672B?	4	2	2	1	19	20	16.9	77	1	49	402	8	0
F	2660M	1	1	-6	2	4	18	3.5	100	1	126	1015	0	0
LINE 40130		(FLIGHT 21)												
A	2825D?	0	2	-1	2	2	4	-	-	-	-	-	-	0
B	2841D	2	5	0	7	15	35	1.6	25	1	70	851	0	160
C	2884H?	1	2	1	2	2	4	-	-	-	-	-	-	0
D	2891D?	3	3	1	3	15	10	1.0	0	1	48	230	23	0
E	2913H	1	3	1	5	7	20	0.3	0	1	29	437	2	0
LINE 40140		(FLIGHT 21)												
A	3057B?	1	2	0	2	2	4	-	-	-	-	-	-	0

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ANOMALY/ FID/INTERP	COAXIAL 1094 HZ REAL PPM	QUAD PPM	COPLANAR 883 HZ REAL PPM	QUAD PPM	COPLANAR 7253 HZ REAL PPM	QUAD PPM	VERTICAL DIKE COND SIEMEN	DEPTH* M	HORIZONTAL SHEET COND SIEMEN	DEPTH M	CONDUCTIVE EARTH RESIS OHM-M	DEPTH M	MAG CORR NT
LINE 40140	(FLIGHT		21)										
B 3014H	-1	2	1	2	2	4	-	-	-	-	-	-	0
C 2995M	0	1	-4	2	2	4	-	-	-	-	-	-	40
D 2975B?	2	4	2	6	9	20	1.7	34	1	51	210	10	0
E 2969D	7	11	8	22	55	36	3.3	27	1	34	361	0	100
LINE 40150	(FLIGHT		21)										
A 3141H	1	2	0	2	2	4	-	-	-	-	-	-	0
B 3217H	1	2	1	2	2	4	-	-	-	-	-	-	0
C 3243D	1	2	1	2	2	4	-	-	-	-	-	-	0
D 3245D	6	20	12	45	117	104	1.7	10	1	25	284	0	0
LINE 40160	(FLIGHT		21)										
A 3324D	2	9	1	10	32	38	0.7	7	1	53	289	10	0
B 3300D	7	22	-2	27	89	104	2.0	13	1	15	414	0	0
LINE 40170	(FLIGHT		21)										
A 3468D?	1	1	0	2	2	4	-	-	-	-	-	-	0
B 3477D?	1	2	-1	2	2	4	-	-	-	-	-	-	0
C 3537B?	1	2	1	2	2	4	-	-	-	-	-	-	0
D 3548B	9	8	8	16	50	23	7.1	34	1	43	113	10	0
LINE 40180	(FLIGHT		21)										
A 3707H?	0	2	0	2	2	4	-	-	-	-	-	-	0
B 3703M	1	0	-1	0	2	4	-	-	-	-	-	-	50
C 3698H?	0	2	0	2	2	4	-	-	-	-	-	-	0
D 3648H	-2	6	-1	12	12	74	0.4	13	1	57	718	4	0
E 3645M	-2	2	-2	2	2	4	-	-	-	-	-	-	0
F 3640M	0	1	1	0	4	2	0.6	16	1	154	1015	0	0
G 3629D	2	6	2	5	18	19	1.2	26	1	64	786	0	0
H 3622H	1	6	0	11	13	63	0.4	9	1	48	712	0	0
LINE 40190	(FLIGHT		21)										
A 3791H	1	1	0	2	1	1	-	-	-	-	-	-	0
B 3814H	-1	3	0	5	13	29	0.4	1	1	70	815	0	0
C 3866D	2	5	-1	8	18	28	1.4	20	1	59	815	0	230
LINE 40200	(FLIGHT		21)										
B 4055H	1	5	0	7	16	48	1.0	32	1	52	725	0	0
C 4051M	1	2	-1	2	2	4	-	-	-	-	-	-	60
D 4021M	1	1	-3	2	-2	4	-	-	-	-	-	-	0
E 4003M	1	2	-2	2	2	4	-	-	-	-	-	-	160

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ANOMALY/ FID/INTERP	COAXIAL 1094 HZ REAL PPM	COAXIAL 1094 HZ QUAD PPM	COPLANAR 883 HZ REAL PPM	COPLANAR 883 HZ QUAD PPM	COPLANAR 7253 HZ REAL PPM	COPLANAR 7253 HZ QUAD PPM	VERTICAL DIKE COND SIEMEN	VERTICAL DIKE DEPTH* M	HORIZONTAL SHEET COND SIEMEN	HORIZONTAL SHEET DEPTH M	CONDUCTIVE EARTH RESIS OHM-M	CONDUCTIVE EARTH DEPTH M	MAG CORR NT
LINE 40200	(FLIGHT	21)											
F 3993D	4	9	3	12	40	31	2.5	21	1	45	743	0	0
G 3987M	1	3	-1	2	4	9	1.0	42	1	54	735	0	0
LINE 40210	(FLIGHT	21)											
A 4157H	3	3	1	10	24	52	3.2	59	1	40	535	0	0
B 4172H	1	1	0	0	1	1	-	-	-	-	-	-	40
C 4248H	0	3	0	5	12	25	0.4	0	1	68	858	0	0
LINE 40220	(FLIGHT	21)											
A 4407H	6	7	1	12	9	56	4.2	30	1	53	690	0	0
B 4382H	1	2	0	2	2	4	-	-	-	-	-	-	0
C 4335H	1	2	0	2	2	4	-	-	-	-	-	-	60
D 4309H	1	1	1	2	2	4	-	-	-	-	-	-	60
LINE 40230	(FLIGHT	21)											
A 4488D	1	2	1	2	2	4	-	-	-	-	-	-	0
B 4514D	1	2	0	2	2	4	-	-	-	-	-	-	0
C 4566H?	1	1	0	2	2	4	-	-	-	-	-	-	0
D 4572D?	1	2	1	2	2	4	-	-	-	-	-	-	180
LINE 40240	(FLIGHT	21)											
A 4701D	0	6	1	8	15	37	0.4	0	1	54	725	0	0
B 4652H?	1	2	0	1	2	4	-	-	-	-	-	-	0
C 4630D?	1	2	1	2	2	4	-	-	-	-	-	-	0
D 4626D	1	2	0	2	2	4	-	-	-	-	-	-	30
E 4620M	4	2	-2	6	13	38	15.6	73	1	82	878	0	0
F 4615M	4	2	-1	2	7	7	13.3	73	1	122	1015	0	0
LINE 40250	(FLIGHT	21)											
A 4804H	0	2	0	0	2	4	-	-	-	-	-	-	4
B 4837M	1	2	0	2	2	4	-	-	-	-	-	-	60
C 4853B?	1	2	0	2	2	4	-	-	-	-	-	-	0
D 4860B?	-1	2	1	2	2	4	-	-	-	-	-	-	0
E 4879H	1	2	-1	2	2	4	-	-	-	-	-	-	570
LINE 40260	(FLIGHT	21)											
A 5194H	-2	2	1	2	2	4	-	-	-	-	-	-	20
B 5150B	-5	2	1	2	2	4	-	-	-	-	-	-	0
C 5132B?	-3	2	1	1	2	4	-	-	-	-	-	-	0
LINE 40261	(FLIGHT	21)											
A 5739H	1	2	0	2	2	4	-	-	-	-	-	-	0

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	COAXIAL 1094 HZ		COPLANAR 883 HZ		COPLANAR 7253 HZ		VERTICAL DIKE		HORIZONTAL SHEET		CONDUCTIVE EARTH		MAG CORR
ANOMALY/ FID/INTERP	REAL PPM	QUAD PPM	REAL PPM	QUAD PPM	REAL PPM	QUAD PPM	COND SIEMEN	DEPTH* M	COND SIEMEN	DEPTH M	RESIS OHM-M	DEPTH M	NT
LINE 40261	(FLIGHT		21)										
B 5718H	-3	2	1	2	2	4	-	-	-	-	-	-	0
LINE 40270	(FLIGHT		21)										
A 5232H	-2	2	1	2	2	4	-	-	-	-	-	-	0
B 5275H	-5	2	0	2	2	4	-	-	-	-	-	-	0
C 5334B?	-4	6	1	6	4	35	0.4	5	1	42	591	0	0
D 5337M	1	2	1	2	2	4	-	-	-	-	-	-	0
LINE 40280	(FLIGHT		21)										
A 5498B?	2	5	1	7	20	30	1.7	32	1	60	612	0	0
B 5382H	1	3	0	3	2	18	1.7	50	1	129	1015	0	0
LINE 40290	(FLIGHT		21)										
A 5548H	1	2	1	5	14	27	1.5	60	1	78	791	0	0
B 5552H?	0	2	0	5	1	27	0.4	0	1	109	1015	0	0

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