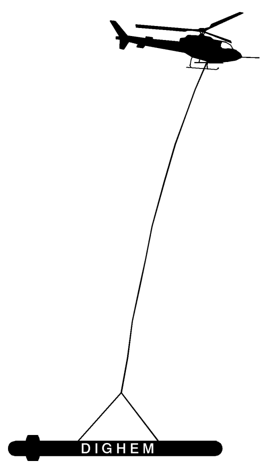
Report #4-309

DIGHEM^{VRES} SURVEY
FOR
CAMECO AUSTRALIA PTY. LTD.
JABIRU AREA
ARNHEM LAND, NT

REF: SD-53-5 “Mount Evelyn”
SD-53-6 “Mount Murumba”



Geoterrex-Dighem, a division of CGG Canada Ltd.
Mississauga, Ontario
November, 1998

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R391-jr.98

SUMMARY

This report describes the logistics and results of a DIGHEM^{VRES} airborne geophysical survey carried out for Cameco Australia Pty. Ltd., over four areas near Jabiru, NT, Australia. Total coverage of the survey blocks amounts to 1,657 km. The survey was flown from August 31 to September 8, 1998.

The purpose of the survey is to map the geophysical characteristics of the geology in the survey area in order to provide information that could be used to map the geology and structure and provide prospective targets for further exploration. This purpose was accomplished by using a DIGHEM^{VRES} multi-coil, multi-frequency electromagnetic system. The data have been processed to produce maps which display the conductive properties of the survey areas.

Arnhem Land (Jabiru) Area 1

One map sheet for the flight path and apparent resistivity at 1,400 Hz and 25,000 Hz are provided at a scale of 1:15,000. The following geophysical parameters are provided with this report as maps or as grids:

- 380 Hz coplanar apparent resistivity
- 1,400 Hz coplanar apparent resistivity
- 6,200 Hz coplanar apparent resistivity
- 25,000 Hz coplanar apparent resistivity
- 102,000 Hz coplanar apparent resistivity
- Sengpiel Sections (selected lines)

The apparent resistivity values range from 5 to over 20,000 Ohm metres with a resistive background of 5,000 to 10,000 Ohm-m. The resistivity patterns show good agreement with the geology in the survey area.

Arnhem Land (Jabiru) Area 2

One map sheet for the flight path and apparent resistivity at 1,400 Hz and 25,000 Hz are provided at a scale of 1:15,000. The following geophysical parameters are provided with this report as maps or as grids:

- 380 Hz coplanar apparent resistivity
- 1,400 Hz coplanar apparent resistivity
- 6,200 Hz coplanar apparent resistivity
- 25,000 Hz coplanar apparent resistivity
- 102,000 Hz coplanar apparent resistivity
- Sengpiel Sections (selected lines)

The apparent resistivity values range from less than 1 to over 20,000 Ohm metres with a resistive background of 10,000 to 20,000 Ohm-m. The resistivity patterns show good agreement with the geology in the survey area.

King River Area

One map sheet for the apparent resistivity computed from the 1,400 and 25,000 Hz EM data sets are provided at a scale of 1:15,000. The following geophysical parameters are provided with this report as maps or as grids:

- 380 Hz coplanar apparent resistivity
- 1,400 Hz coplanar apparent resistivity
- 6,200 Hz coplanar apparent resistivity
- 25,000 Hz coplanar apparent resistivity
- 102,000 Hz coplanar apparent resistivity
- Sengpiel Sections

The apparent resistivity values range from less than 1 to approximately 700 Ohm metres. The resistivity patterns show good agreement with the geology in the survey area.

Deaf Adder Test Area

Sengpiel sections for both of the test lines are provided at a scale of 1:15,000. The following geophysical parameters are provided with this report in digital form:

- 380 Hz coplanar apparent resistivity
- 1,400 Hz coplanar apparent resistivity
- 6,200 Hz coplanar apparent resistivity

- 25,000 Hz coplanar apparent resistivity
- 102,000 Hz coplanar apparent resistivity
- Sengpiel Sections

The apparent resistivity values range from 200 to over 20,000 Ohm metres. The target area shows as a relatively resistive feature on one of the lines and as a contact between relatively resistive and conductive units on the other.

CONTENTS

INTRODUCTION

A DIGHEM^{VRES} electromagnetic/resistivity survey was flown for Cameco Australia Pty. Limited from August 31 to September 8, 1998, over four areas near Jabiru in Arnhem Land, NT. The survey areas are presented in Figures 1a, 1b, 1c, and 1d and can be located on maps SD-53-5 “Mount Evelyn” and SD-53-6 “Mount Murumba”.

The purpose of the survey is to map the geophysical characteristics of the geology in the survey area in order to provide information that could be used to map the geology and structure.

The survey coverage consists of 1,657 line-km including the tie lines. Table 1 presents the details of the survey for each of the four areas. The tie lines were flown perpendicular to the survey lines.

Table 1.1 Survey Details

Area	Survey Line		Coverage (Line-km)
	Azimuth	Spacing	
Arnhem Land (Jabiru) Area 1	090°	100	610.0
Arnhem Land (Jabiru) Area 2	090°	100	913.3
King River Area	120°	200	125.4
Deaf Adder Test Area	000°/090°	-	8.3

The survey employs the DIGHEM^{VRES} electromagnetic system. Ancillary equipment consists of a magnetometer, radar altimeter, video camera, analog and digital recorders, and an electronic navigation system. The instrumentation is installed in an AS-350B2 turbine helicopter (Registration VH-XMR) provided by Jayrow Helicopters. The average airspeed of the helicopter is 138 km/h and the nominal EM sensor height is 30 m.

Section 2 gives a description of the survey equipment and specifications and an outline of the field procedures. Section 3 describes the processing techniques and lists the products which are delivered with this report. Descriptions of additional products which can be generated from the survey data sets are appended. Section 4 describes the results, and the conclusions and recommendations for further work are given in Section 5.

SURVEY EQUIPMENT and FIELD PROCEDURES

This section describes the geophysical instrumentation and the field procedures used in acquiring the survey data. Table 2.1 presents the specifications for each of the instruments used in the survey. Appendix A contains a list of the personnel involved with the project.

Table 2.1 Equipment Specifications

Equipment	Manufacturer	Model	Type	Accuracy	Sensitivity	Rate	Nominal Survey Altitude
Electromagnetic System	Geoterrex-Dighem	DIGHEM^{VRES}	Towed bird Symmetric dipole	_____	0.12 to 0.44 ppm	10 samples/s	30 m
Magnetometer Sensor	Scintrex	CS2	Optically pumped Cesium vapour	_____	0.01 nT	10 samples/s	45 m
Magnetometer Processor	Picodas	MEP 710	_____	_____	0.001 nT	10 samples/s	_____
Magnetometer Base Station	Geometrics	G856	Digital recording Proton precession	_____	0.10 nT	0.2 samples/s	_____
Radar Altimeter	Honeywell/ Sperry	AA220	4.3 GHz short pulse modulation	_____	0.3 m	10 samples/s	60 m
Analog Recorder	RMS Instruments	DGR33	Dot matrix graphics recorder	4x4 dots/mm	_____	1.5 mm/s	_____
Digital Data Acquisition System	RMS Instruments	DGR33	_____	_____	_____	Up to 9600 bytes/s	_____
Digital Recorder	IOmega	ZIP drive	1 Gb disks	_____	_____	_____	_____
Video System	Panasonic	AG 2400/ WVCD 132	VHS colour (NTSC)	_____	_____	Continuous	60 m
GPS Navigation	Ashtech Glonass with Omnistar Differential	GG24	SPS (L1 band) 24 channel C/A code 1575.42 MHz	<5 m in differential mode	-132 dBm	2 updates/s	60 m
Field Workstation	Geoterrex-Dighem	Dighem Processing System	PC processing system	_____	_____	_____	_____

Electromagnetic Survey

Table 2.2 presents the detailed configuration of the electromagnetic system for the current survey.

The secondary electromagnetic field is expressed in parts per million and has been defined as the ratio of the measured secondary field to the primary field as measured at the transmitter coil. This is a departure from previous DIGHEM surveys which have defined the ppm as the ratio of the secondary field to the primary as measured at the receiver coil with normalization to a coaxial coil configuration. The effect of this change is simply a multiplication of the coplanar EM amplitudes by a factor of 2. As a result, the ratio of coplanar to coaxial EM amplitudes over a halfspace with the same transmitted frequency is now 4:1.

Table 2.2 DIGHEM^{VRES} Electromagnetic System Survey Specifications

Coil-pair Name	Actual Frequency (Hz)	Coil Separation (m)	Sensitivity (ppm)	Sample Rate (seconds^{-1})	Channels Recorded	Nominal Altitude (m)
380 Hz coplanar	393	7.84	0.13	10	inphase/quadrature	30
1,400 Hz coplanar	1,550	7.84	0.13	10	inphase/quadrature	30
6,200 Hz coplanar	6,255	7.84	0.25	10	inphase/quadrature	30
25 kHz coplanar	25,760	7.84	0.44	10	inphase/quadrature	30
102 kHz coplanar	102,000	7.84	0.44	10	inphase/quadrature	30

The electromagnetic system utilizes a multi-coil coplanar technique to energize the geology at different depths. 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 DIGHEM^{VRES} calibration procedure involves four stages; primary field bucking, phase calibration, gain calibration, and zero adjust. At the beginning of the survey, the primary field at each receiver coil is canceled, or “bucked out”, by precise positioning of five bucking coils.

The phase calibration adjusts the phase angle of the receiver to match that of the transmitter. A ferrite bar, which produces a purely in-phase response, is positioned near each receiver coil. The bar is rotated from minimum to maximum field coupling and the responses for the in-phase and quadrature components for each coil pair/frequency are measured. The phase of the response is adjusted at the console to return an in-phase only response for each coil pair/frequency. Phase checks are performed on a daily basis.

The gain calibration uses extreme coils designed to produce an equal response on in-phase and quadrature components for each coil pair/frequency. The coil parameters and distances are designed to produce pre-determined responses at the receiver due to the current induced in the calibration coil by the transmitter when a switch closes the loop at the coil. The gain at the console is adjusted to yield a constant secondary response. The EM data are corrected to parts per million during the transfer to the field workstation PC. The gain calibrations are carried out at the beginning and the end of the survey.

The phase and gain calibrations each measure a relative change in the secondary field rather than an absolute value. This relative measurement removes any dependency of the calibration procedure on the secondary field due to the ground, except under circumstances of extreme ground conductivity.

During each survey flight, internal (Q-coil) calibration signals are generated to check system gain and to establish zero reference levels. These calibrations are carried out at intervals of approximately 20 minutes with the system out of ground effect. At a sensor height of more than 250 m, there is no measurable secondary field from the earth. The remaining residual is therefore established as the zero level of the system. Linear system drift is automatically removed by re-establishing zero levels between the Q-coil calibrations.

Four monitor channels are recorded to identify the occurrence of power line and sferic related noise. The power line monitor data were measured from the 1,400 Hz and 6,200 Hz receiver coils by extracting the 60 Hz data from the total response. The sferics monitor data are recorded from the same two coil pairs by rejecting the response from a frequency band encompassing the transmitted frequencies.

Total Magnetic Field Survey

One mobile and two base station magnetometer sensors are used in the survey. The mobile sensor is housed in a separate bird, 15 m below the helicopter. The base station sensors are situated within 40 km of the survey block in an area where the magnetic field is relatively inactive in order to minimize the effects of local variations in the diurnal field.

The data from the two base station magnetometers are used to record the diurnal variation of the earth's magnetic field. The clocks of the base stations are synchronized with that of the airborne system to permit diurnal correction.

Radar Altimeter

The radar altimeter is fixed to the helicopter and is positioned to measure the vertical distance between the helicopter and the ground.

Analog Recorder

The analog profiles are recorded on chart paper in the aircraft during the survey. Table 2-3 lists the geophysical data channels and the vertical scale of each profile.

Table 2-3. The Analog Profiles

Channel Name	Parameter	Scale units/mm	Designation on Digital Profile
380I	Coplanar inphase (380 Hz)	5 ppm	CPI (380 Hz)
380Q	Coplanar quad (380 Hz)	5 ppm	CPQ (380 Hz)
1K4I	Coplanar inphase (1440 Hz)	5 ppm	CPI (1400 Hz)
1K4Q	Coplanar quad (1440 Hz)	5 ppm	CPQ (1400 Hz)
6K2I	Coplanar inphase (6200 Hz)	10 ppm	CPI (6200 Hz)
6K2Q	Coplanar quad (6200 Hz)	10 ppm	CPQ (6200 Hz)
25KI	Coplanar inphase (25000 Hz)	20 ppm	CPI (25000 Hz)
25KQ	Coplanar quad (25000 Hz)	20 ppm	CPQ (25000 Hz)
102I	Coplanar inphase (102000 Hz)	20 ppm	CPI (102000 Hz)
102Q	Coplanar quad (102000 Hz)	20 ppm	CPQ (102000 Hz)
ALTR	Altimeter (radar)	3 m	ALTR
CMGC	Total magnetic field, coarse	20 nT	MAG
CMGF	Total magnetic field, fine	2 nT	
1SP	Sferics monitor (1400 Hz)		_1SP
2SP	Sferics monitor (6200 Hz)		_2SP
1PL	Powerline monitor (1400Hz)		_1PL
2PL	Powerline monitor (6200 Hz)		_2PL

Digital Data Acquisition System

The digital data are stored on a removable drive and are downloaded to the field workstation PC at the survey base for verification and backup of the survey results and for data processing and preparation of any in-field products.

Video Flight Path Recording System

The video camera is fixed to the helicopter and is positioned to record the image directly beneath the helicopter. 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 - Global Positioning System (GPS)

The Ashtech GG24 is a line of sight satellite navigation system which utilizes time-coded signals from at least four of forty-eight available satellites. Both Russian GLONASS and American NAVSTAR satellite constellations are used to calculate the position and to provide real time guidance to the helicopter. The Ashtech system is combined with an OMNISTAR differential receiver which further improves the accuracy of the flying and subsequent flight path recovery to better than 5 metres. The differential corrections, which are obtained from a network of virtual reference stations, are transmitted to the helicopter via a spot beam satellite. These virtual reference stations eliminate the need for a local GPS base station. The Ashtech and Omnistar receivers are coupled with a PNAV navigation system to provide real-time guidance to the pilot.

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 base station was located at latitude 13 degrees 19.993 minutes south, longitude 133 degrees 29.619 minutes east at an elevation of 613.17 m a.m.s.l. The GPS records data relative to the WGS84 ellipsoid. Conversion software is used to transform the WGS84 coordinates to the following coordinate system displayed on the base maps:

<u>Projection Description</u>:

Datum:	Australian Geodetic Datum 1966
Ellipsoid:	Australian National
Projection:	Universal Transverse Mercator Zone 53
Central Meridian:	135 East
False Northing:	10,000,000

False Easting: 500,000

Scale Factor: 0.9996

Field Workstation

A portable PC-based field workstation is used at the survey base to verify data quality and completeness. Flight data are transferred to the PC 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

This section describes the processing of the data and the presentation of the final delivered products. Table 3-1 lists the maps and other products which have been provided with this final report. Appendix D contains background information on each of the geophysical data sets. Please note that references to coaxial EM datasets and difference channels have no application to this survey. Other products which can be produced from the existing data sets are described in Appendix C.

A total of 3 map sheets for each of the plotted geophysical parameters are provided at a scale of 1:15,000. The geophysical data for the Arnhem Land (Jabiru) Area 1 and Area 2 and the King River area are presented in plan on a single map sheet for each area. Resistivity sections are provided for selected lines in all areas. The Deaf Adder Test Area is presented in section form only. Flight path plots are provided for all areas. The digital archive is provided on a CD-ROM disc. Appendix B contains a description of the contents of the digital archive.

Apparent Resistivity

Apparent resistivity is computed from the in-phase and quadrature EM components for all of the frequencies using a pseudo-layer halfspace model. The apparent resistivity maps are presented for the 1,400 and 25,000 Hz data sets. These portray the variation in apparent resistivity for the given frequency over the entire survey area. The large dynamic range afforded by the multiple frequencies in the DIGHEM^{VRES} system makes the apparent resistivity parameter an excellent mapping tool.

Preliminary apparent resistivity maps and images are carefully inspected to identify lines or line segments which may require base level adjustment. Subtle changes between in-flight calibrations of the system can result in line to line differences which are more

Table 3-1 Survey Products

1. Final Transparent Maps @ 1:15,000
   Flight Path
   Apparent resistivity – 1,400 Hz coplanar
   Apparent resistivity - 25,000 Hz coplanar

2. Colour Maps (2 sets) @ 1:15,000
   Apparent resistivity – 1,400 Hz
   Apparent resistivity - 25,000 Hz
   Sengpiel sections (selected lines only)

3. Digital Archive - on CD-ROM
   Grids in Geosoft and ERMapper binary format for the following parameters:
   - apparent resistivity - 380 Hz
   - apparent resistivity - 1,400 Hz
   - apparent resistivity - 6,200 Hz
   - apparent resistivity - 25,000 Hz
   - apparent resistivity - 102,000 Hz
   - Sengpiel sections (selected lines only)

   Located line data archive in Geosoft XYZ format
   Digital copy of final report
   DXF format plot files of Sengpiel section vector files

4. Additional Products
   Survey report (2 copies)
   Multi-channel stacked profiles (1 set)
   Analog chart records
   Flight path video cassettes

Note: Other products can be produced from the existing survey data, if requested (see Appendix C).

readily recognizable in resistive (low signal amplitude) areas. If required, manual leveling is carried out to eliminate or minimize resistivity differences which can be attributed in part to changes in operating temperature.

After the leveling process is complete, revised apparent resistivity grids are created. These grids are filtered using a 3 cell by 3 cell smoothing filter prior to the preparation of the final maps. This final filter will not degrade the apparent resistivity given the broad 'footprint' of the parameter and the assumption of a homogeneous half space inherent in the apparent resistivity computation.

The calculated apparent resistivity values are clipped at a maximum value of 1.15 times the operating frequency for each of the five EM data sets. These maxima eliminate the meaningless high apparent resistivity values which would result from very small EM amplitudes. A minimum apparent resistivity cutoff value of 1.7 X 10^{-5} times the frequency is applied in order to eliminate errors due to the lack of an absolute phase control for the EM data.

Contoured resistivity maps, based on the 1,400 Hz and 25,000 Hz coplanar data are included with this report. The calculated apparent resistivity for all five frequencies are included in the XYZ and grid archives. Values are in ohm-metres on all final products.

Sengpiel Resistivity Sections

Sengpiel resistivity sections are derived from the pseudo-layer halfspace model using all five of the apparent resistivity data sets. The method, developed by K.P.Sengpiel, can be described as an approximate inversion of the apparent resistivity data sets. It yields resistivity and depth values in the attempt to depict a smoothed approximation of the true resistivity distribution with depth.

Sengpiel sections are provided for the following lines:

Arnhem Land (Jabiru) Area 1: 11090, 11190, 11290, 11390, 11490, 11590, 11690, 19010, 19020, 19030

Arnhem Land (Jabiru) Area 2: 21050, 21150, 21250, 21350, 21420, 21450, 21550, 21650, 21750, 21850, 27010, 27020, 27030

King River Area: all lines

Deaf Adder Test Area: all lines

Monochrome Contour Map Displays

The final, corrected geophysical data sets are interpolated onto a regular grid using a modified Akima spline technique. The grid cell size is 50 m which is 25% of the nominal line spacing. In the detail areas, the grid cell size is set at 25 m to provide the higher resolution afforded by the 100 m line spacing. Contour vectors are generated from these gridded data sets.

SURVEY RESULTS AND DISCUSSION

This section presents a brief description of the results of the survey.

Apparent Resistivity

Arnhem Land (Jabiru) Area 1

The apparent resistivity values range from 5 to over 20,000 Ohm metres with a resistive background of 5,000 to 10,000 Ohm-m.

The resistivity patterns show good agreement with the geology in the survey area. The geology in the west central area is very resistive and the south, southeast and north central portions are the most conductive. These conductive portions of the survey area are interrupted by roughly circular resistive features several hundreds of metres in diameter. The northeastern quarter of the survey area has a more conductive background with values ranging from 1,000 to 5,000 ohm-m. The survey area is bifurcated with a south southeast trending structural feature defined on its east by a conductive unit. A conductive linear feature extending east northeast through the centre of the survey area is also indicative of structure.

Arnhem Land (Jabiru) Area 2

The apparent resistivity values range from less than 1 to over 20,000 Ohm metres with a resistive background of 10,000 to 20,000 Ohm-m.

The resistivity patterns show good agreement with the geology in the survey area. The background is resistive in the southern half and in the northwestern quadrant of the area. The northeastern quadrant is relatively conductive with values generally less than 1,000 ohm-m. A conductive unit extends from the south western corner northeast to the north central portion of the area. Structure is evident throughout the entire area. A structural break extends east across the area from approximately 8,560,500 mN. A second major structural feature extends east northeast through the centre of the survey area.

King River Area

The apparent resistivity values range from less than 1 to approximately 700 Ohm metres. The area has a relatively mottled texture in the apparent resistivity data sets. The southeast and northwest ends of the block are generally more conductive than the central portion. Several linear features extend northeast across the survey block although, in general, individual features are of limited strike extent.

Deaf Adder Test Area

The apparent resistivity values range from 200 to over 20,000 Ohm metres. The target area shows as a relatively resistive feature on one of the lines and as a contact between relatively resistive and conductive units on the other.

CONCLUSIONS AND RECOMMENDATIONS

This report describes the equipment, procedures and logistics of the survey and provides a brief description of the survey results. The survey was successful in defining the conductive properties and in extending the geologic knowledge of the survey area. The apparent resistivity data should be reviewed in light of the known geology in each of the areas to refine or extend the existing mapping. The Sengpiel sections can be used to discriminate shallow sources from features which extend to depth. The sections can also be used to determine the dip direction. Following this mapping, priority areas for ground follow up should be identified. Appropriate surface geophysical and/or geochemical survey should be completed prior to drill testing.

Respectfully submitted,

GEOTERREX-DIGHEM

Jonathan Rudd, P.Eng.
Geophysicist

JCR/sdp

R653JR.98

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 for Cameco Australia Pty. Limited, 150 km northeast of Calgary, NT.

Greg Paleolog	Manager, Helicopter Operations
Doug McConnell	Manager, Data Processing and Interpretation
Michael White	Geophysical Operator
Dwayne Griffith	Field Processing Geophysicist
Desmond Rose	Pilot (Jayrow Helicopters Limited)
Gordon Smith	Data Processing Supervisor
Stephen Harrison	Geophysicist - Processing
Jonathan Rudd	Geophysicist - Interpretation
Lyn Vanderstarren	Drafting Supervisor
Susan Pothiah	Word Processing Operator
Albina Tonello	Secretary/Expeditor

The survey consists of 1,657 line km of coverage, flown from August 31 to September 8, 1998.

All personnel are employees of Geoterrex-Dighem, except for the pilot who is an employee of Jayrow Helicopters Limited.

APPENDIX B

DIGITAL ARCHIVE DOCUMEMTATION

DIGITAL ARCHIVE DOCUMENTATION

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DIGHEM Reference: CCD01129
Disc 1 of 1
Volume Label: "391"
Archive Date: 1998-NOV-19

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This archive contains FINAL DATA ARCHIVES of an airborne geophysical
survey conducted by GEOTERREX-DIGHEM on behalf of Cameco Australia Pty
Ltd near Jabiru, Arnhem Land, Northern Territory, Australia during
August/September 1998.

DIGHEM Job # 391

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This archive comprises 27 files contained in 3 directories

******* Disc 1 of 1 *******

GRIDS\
      Grids in Geosoft binary (2-byte) and ERMapper format

   RES1400? - Apparent Resistivity 1400 Hz coplanar
   RES25K?  - Apparent Resistivity 25 000 Hz coplanar

      where ? = A for Arnhem Land (Jabiru) Area 1
      where ? = B for Arnhem Land (Jabiru) Area 2
      where ? = C for King River
      where ? = D for Deaf Adder Test Area (NO GRIDS)

LINEDATA\
   391A.XYZ   - ASCII line data archive in Geosoft XYZ format for area A
   391A.TXT   - ASCII text description file for the XYZ data archive
   391B.XYZ   - ASCII line data archive in Geosoft XYZ format for area B
   391B.TXT   - ASCII text description file for the XYZ data archive
   391C.XYZ   - ASCII line data archive in Geosoft XYZ format for area C
   391C.TXT   - ASCII text description file for the XYZ data archive
   391D.XYZ   - ASCII line data archive in Geosoft XYZ format for area D
   391D.TXT   - ASCII text description file for the XYZ data archive


REPORT\
   391.DOC    - Report document in MSWord v6.0 format

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The coordinate system for all grids and XYZ files is projected as
follows:

Datum                                AGD66
Spheroid                             Australian National
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Projection	UTM Zone 53S
Central meridian	135
False easting	500000
False northing	10000000
Scale factor	0.9996
Northern parallel	N/A
Base parallel	N/A
WGS84 to local conversion method	Molodensky
Delta X shift	+133
Delta Y shift	+48
Delta Z shift	-148

If you have any problems with this archive please contact

Processing Manager
Geoterrex-Dighem (A Division of CGG Canada Ltd.)
2270 Argentia Road, Unit 2
Mississauga, Ontario
Canada   L5N 6A6
Tel (905) 812-0212
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APPENDIX C

OPTIONAL PRODUCTS

OPTIONAL PRODUCTS

The following products have not been provided with the current report but can be produced from the survey data.

Optional Map Presentation

Monochromatic shadow maps and colour shadow maps can be 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 such as the angle and azimuth of incidence of the artificial sun. This mapping technique can be applied to virtually any geophysical parameter, however, shadowing is particularly well suited for the definition of geological structure in the total magnetic field data set.

Optional Electromagnetic Products

EM Anomalies

Discrete electromagnetic anomalies can be interpreted from the EM data sets. EM anomalies generally fall within one of 3 general interpreted categories. The first type consists of discrete, well-defined anomalies which yield marked inflections. 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. Anomalies in this category are given an "S" or "H" interpretive symbol. Some of these anomalies may reflect conductive rock units or zones of deep weathering.

The third class consists of cultural anomalies which are given the symbol "L" or "L?". The interpreted cultural responses correlate with power lines, pipe lines, buildings, and hydrocarbon wells. The effect on the electromagnetic data in the vicinity of power lines and other cultural features can vary from imperceptible to high amplitude noise over several hundred metres. As a result, any other interpreted conductors which are close to cultural sources should be confirmed as bedrock conductors prior to further exploration.

Conductivity-depth Sections

The apparent resistivity for all frequencies can be displayed simultaneously as coloured conductivity-depth sections. Usually, only the coplanar data are displayed given that the coaxial frequencies are close to those of the coplanar coils and add little information to what is offered by the coplanar coils. Furthermore, the coaxial data sets generally have a lower signal to noise ratio than the coplanar coils because of the differences in coupling with the coils are the ground. The sections can be plotted by "draping" the section over the digital terrain model surface. The digital terrain model is calculated from the GPS barometric altimeter and radar altimeter.

Conductivity-depth sections are best suited in areas where the geology is flat-lying and conductive, and may be unreliable in areas of moderate to high resistivity where signal amplitudes are weak. In areas where inphase responses have been suppressed by the effects of magnetite, the computed resistivities shown on the sections may be unreliable.

Conductivity-depth sections can be generated in three formats:

(1) Sengpiel resistivity sections, where the apparent resistivity for each frequency is plotted at the depth of the centroid of the inphase current flow[1]; and,

(2) Differential resistivity sections, where the differential resistivity is plotted at the differential depth[2].

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1 Approximate Inversion of Airborne EM Data from Multilayered Ground: Sengpiel, K.P., Geophysical Prospecting 36, 446-459, 1988.

(3) Inversion sections using the Occam[3] or Multi-layer[4] techniques.

Both the Sengpiel and differential methods are derived from the pseudo-layer halfspace model. Both yield a coloured conductivity-depth section which attempts to portray a smoothed approximation of the true resistivity distribution with depth. The differential resistivity technique, developed by Geoterrex Dighem, has a higher degree of sensitivity to changes in the earth's resistivity and it has greater depth sensitivity.

Both the Occam and Multi-layer inversions compute the layered earth resistivity model which would best match the measured EM data to within a specified tolerance. The Occam inversion uses a series of thin layers of fixed thickness (usually 20 layers of 5 m in thickness) and assigns resistivity values to each of the layers to fit the observed EM data. The multi-layer inversion computes the resistivity and thickness for each of a defined number of layers (typically 3-5 layers) to best fit the data.

EM Magnetite

The apparent percent magnetite by weight is computed wherever magnetite produces a negative inphase EM response. This calculation is more meaningful in resistive areas where positive responses due the conductive nature of the geology are minimal. Appendix C describes the EM magnetite effect in greater detail.

Optional Magnetic Products

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[2] The Differential Resistivity Method for Multi-frequency Airborne EM Sounding: Huang, H. and Fraser, D.C., presented at Intern. Airb. EM Workshop, Tucson, Ariz., 1993.

[3] Occam’s inversion: a practical algorithm for generating smooth models from electromagnetic sounding data: Geophysics, 52, 289-300.

Total Magnetic Field

Any spikes for which no cultural or other source can be discerned are removed through visual inspection. The aeromagnetic data are then corrected for diurnal variation using the magnetic base station data. Manual adjustments are applied to any lines that require leveling, as identified by shadowed images of the gridded total magnetic field data. The IGRF or IGRF gradient have not been removed from the corrected total field data for the current survey.

The final, leveled total magnetic field data are then gridded for presentation. The total magnetic field data can be presented as contours on maps using an appropriate contour interval.

Calculated Vertical Magnetic Gradient

The final corrected total magnetic field data are subjected to a fast Fourier transform processing algorithm which enhances the response of near-surface magnetic sources and attenuates the response from deeper bodies. The resulting vertical gradient map provides better definition and resolution of near-surface magnetic units and enhances weak magnetic features which may not be evident on the total field map. However, regional magnetic variations and changes in lithology may be better defined on the total magnetic field map.

Euler Deconvolution of the Total Magnetic Field

The final corrected total magnetic field data can be subjected to the Euler Deconvolution process. Euler Deconvolution is a computer assisted procedure for making depth estimates for solutions to a specific mathematical model with a correlating target geologic model. The primary parameters used in the process include a structural index which reflects the chosen model, and the window size which determines the depth to which the procedure will

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[4] Huang H., and Palacky, G.J., 1991, Dumped least-squares inversion of time domain airborne EM data based on singular value decomposition: Geophysical Prospecting, 39, 827-844.

investigate. The solutions are presented in plan as circles whose radii reflect the depth of the source.

Magnetic Derivatives

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

second vertical derivative
reduction to the pole/equator
apparent magnetic susceptibility
upward/downward continuation
analytic signal
enhanced magnetics

All of these filtering techniques with the exception of upward continuation enhance the recognition of near-surface magnetic sources. 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.

APPENDIX D

BACKGROUND INFORMATION

BACKGROUND INFORMATION

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 sulphide 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 sulphide 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 geophysical maps 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 sulphide bodies.

Geometric Interpretation

The geophysical interpreter attempts to determine the geometric shape and dip of the conductor. Figure D-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 D-1. The conductance in siemens (mhos) is the reciprocal of resistance in ohms.

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.

Table D-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

Conductive overburden generally produces broad EM responses which may not be shown as discrete anomalies on the geophysical maps. However, patchy conductive overburden in otherwise resistive areas can yield discrete anomalies with a conductance grade (cf. Table D-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 geophysical maps (see EM legend on maps).

For bedrock conductors, the higher anomaly grades indicate 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 2,000 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.

For each interpreted electromagnetic anomaly on the geophysical maps, 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.

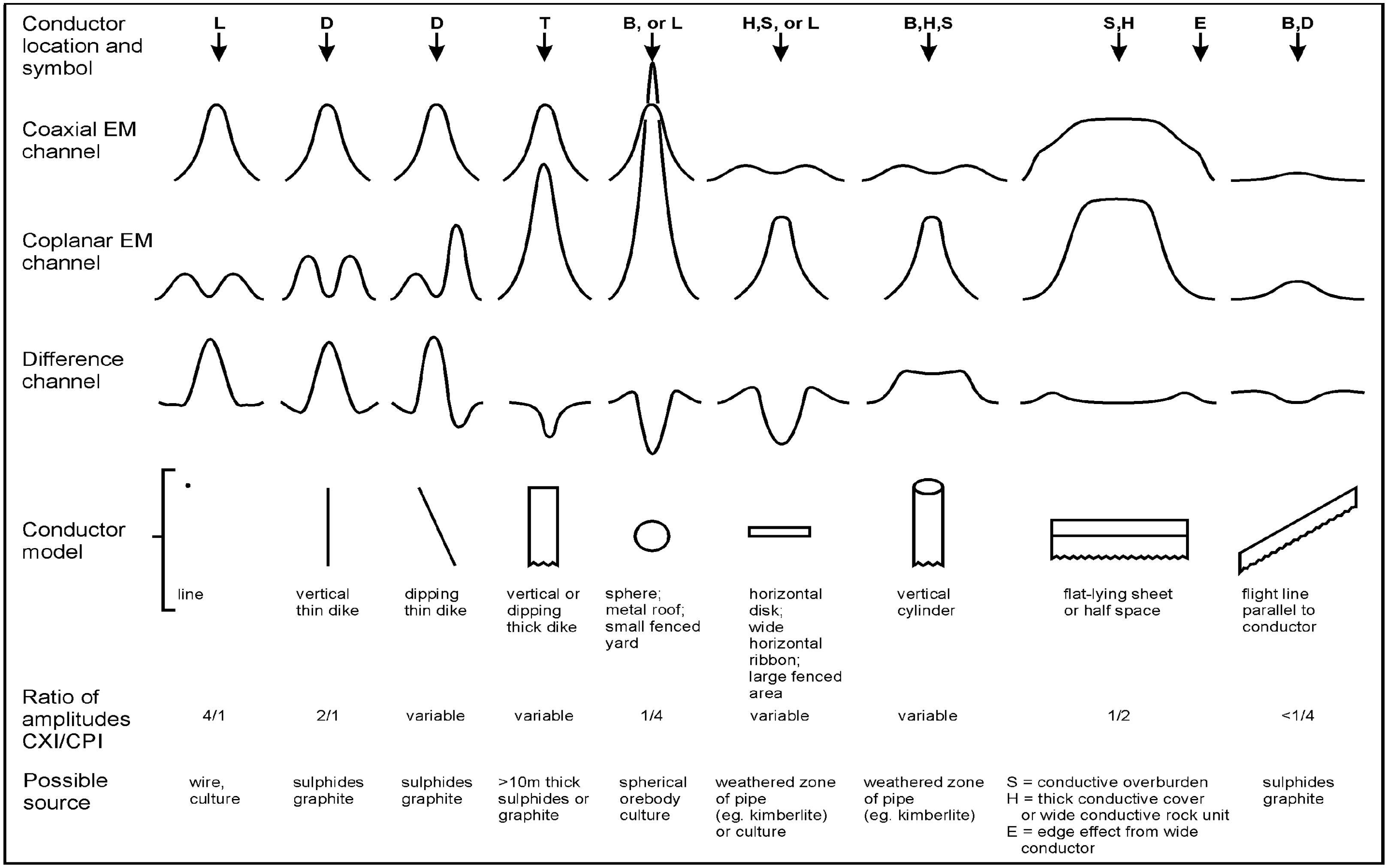
The vertical column of dots, under the anomaly letter, gives the estimated depth. In areas where anomalies are crowded, the letter identifiers, interpretive symbols and dots may be obliterated. The EM grade symbols, however, will always be discernible, and the obliterated information can be obtained 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.

The conductance measurement is considered more reliable than the depth estimate. 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 bedrock 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.



Typical DIGHEM anomaly shapes
Figure D-1

DIGHEM electromagnetic anomalies 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 require this information. The map provides an interpretation of conductors in terms of length, strike and dip, geometric shape, conductance, depth, and thickness.

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 sulphide 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 are normally 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 legend on maps). The others probably do not warrant further investigation unless their locations are of considerable geological interest.

The Thickness Parameter

DIGHEM surveys 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 sulphide 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 sub-parallel 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

Resistivity mapping is useful in areas where broad or flat lying conductive units are of interest. One example of this is the clay alteration that is associated with Carlin-type deposits in the south west United States. The Dighem system was able to identify the clay alteration zone over the Cove deposit. The alteration zone appeared as a strong resistivity low on the 900 Hz resistivity parameter. The 7,200 Hz and 56,000 Hz resistivities show more of the detail in the covering sediments, and delineate a range front fault. This is typical in many areas of the south west United States, where conductive near surface sediments, which may sometimes be alkalic, attenuate the higher frequencies.

Resistivity mapping has proven successful for locating diatremes in diamond exploration. Weathering products from relatively soft kimberlite pipes produce a resistivity contrast with the unaltered host rock. In many cases weathered kimberlite pipes were associated with thick conductive layers which contrasted with overlying or adjacent relatively thin layers of lake bottom sediments or overburden.

Areas of widespread conductivity are commonly encountered during surveys. These conductive zones may reflect alteration zones, shallow-dipping sulphide or graphite-rich units or conductive overburden. In such areas, anomalous amplitudes 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 bedrock and 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 apparent resistivity is calculated using the pseudo-layer (or buried) half space model defined by Fraser (1978)[5]. This model consists of a resistive layer overlying a conductive half space. The depth channels give the apparent depth below surface of the conductive

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

material. The apparent depth is simply the apparent thickness of the overlying resistive layer. The apparent depth (or thickness) parameter will be positive (ie. below surface) 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 when the conductivity of the measured material is sufficient to yield significant inphase as well as quadrature responses. 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.

Interpretation in Conductive Environments

Environments having low background resistivities (e.g., below 30 ohm-m for a 900 Hz system) 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 in conductive environments. These are the inphase and quadrature difference channels (DFI and DFQ, which are available only on systems with common frequencies on orthogonal coil pairs), 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 generally 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.

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 is present as well. 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 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.

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 magnetic surveys, 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 centre-peaked coaxial anomaly and an m-shaped coplanar anomaly.[6] 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 centre-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 a metal roof or small fenced yard.[7] Anomalies of this type are virtually certain to be cultural if they occur in an area of culture.

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[6] See Figure D-1 presented earlier.

[7] 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.

4. A flight which crosses a horizontal rectangular body or wide ribbon yields an m-shaped coaxial anomaly and a centre-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 centre-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 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 video records.

Magnetics

The total magnetic field 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 magnetic field 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 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 and dikes can also be identified in the total magnetic field as lineaments and offsets with strike lengths of up to 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.