REPORT ON A HELICOPTER-BORNE

VERSATILE TIME DOMAIN ELECTROMAGNETIC (VTEM) AND AEROMAGNETIC GEOPHYSICAL SURVEY

Colby Mines Project

BC Geological Survey

Assessment Report

33197b

Sicamous, British Columbia

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Survey flown during March 2012

Project 11219

April, 2012

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REPORT ON A HELICOPTER-BORNE VERSATILE TIME DOMAIN ELECTROMAGNETIC (VTEM) and AEROMAGNETIC SURVEY

Colby Mines Project Sicamous, British Columbia

Executive Summary

During March 6th, 2012 to March 7th, 2012 Geotech Ltd. carried out a helicopter-borne geophysical survey over the Colby Mines Project located 19 kilometres southeast of Sicamous, British Columbia, Canada.

Principal geophysical sensors included a versatile time domain electromagnetic (VTEM) system, and a caesium magnetometer. Ancillary equipment included a GPS navigation system and a radar altimeter. A total of 205.3 line-kilometres of geophysical data were acquired.

In-field data quality assurance and preliminary processing were carried out on a daily basis during the acquisition phase. Preliminary and final data processing, including generation of final digital data and map products were undertaken from the office of Geotech Ltd. in Aurora, Ontario.

The processed survey results are presented as the following maps:

- Total Magnetic Intensity
- B-Field Z Component Channel 36, Time Gate 2.021 ms colour grid
- Calculated Time Constant (TAU)
- Electromagnetic stacked profiles of the B-field Z component
- Electromagnetic stacked profiles of the dB/dt Z component

Digital data includes all electromagnetic and magnetic products, ancillary data and the VTEM waveform.

The survey report describes the procedures for data acquisition, processing, final image presentation and the specifications for the digital data set.



1. INTRODUCTION

1.1 General Considerations

Geotech Ltd. performed a helicopter-borne geophysical survey over the Colby Mines Project located 19 kilometres southeast of Sicamous, British Columbia, Canada (Figure 1 & Figure 2).

Robert Coltura represented Inexco Mining Corp. during the data acquisition and data processing phases of this project.

The geophysical surveys consisted of helicopter borne EM using the versatile time-domain electromagnetic (VTEM) system with Z component measurements and aeromagnetics using a caesium magnetometer. A total of 205.3 line-km of geophysical data were acquired during the survey.

The crew was based out of Sicamous, British Columbia for the acquisition phase of the survey. Survey flying started on March 6th, 2012 and was completed on March 7th, 2012.

Data quality control and quality assurance, and preliminary data processing were carried out on a daily basis during the acquisition phase of the project. Final data processing followed immediately after the end of the survey. Final reporting, data presentation and archiving were completed from the Aurora office of Geotech Ltd. in April, 2012.



Figure 1: Property Location.



1.2 Survey and System Specifications

The Colby Mines Project is located 19 kilometres southeast of Sicamous, British Columbia, Canada (Figure 2).



Figure 2: Survey area location on Google Earth.

The project was flown in a northwest to southeast (N 145° E azimuth) direction with traverse line spacing of 100 metres as depicted in Figure 3. Tie lines were flown perpendicular to the traverse lines at a spacing of 1000 metres (N 55° E azimuth).

For more detailed information on the flight spacing and direction see Table 1.



1.3 Topographic Relief and Cultural Features

Topographically, the block exhibit a highly rugged relief with elevations ranging from 568 to 1344 metres above mean sea level over an area of 22 square kilometres (Figure 3).

There are various rivers and streams running through the survey area which connect various lakes and wetlands. There are visible signs of culture such as roads and a power line which run along the survey property.



Figure 3: Colby Mines Project flight path over a Google Earth Image.

The survey area is covered by numerous mining claims, which are shown in Appendix A, and are plotted on all maps. The survey area is covered by NTS (National Topographic Survey) of Canada sheets 082L10 and 082L15.



2. DATA ACQUISITION

2.1 Survey Area

The survey blocks (see Figure 3 and Appendix A) and general flight specifications are as follows:

Survey block	Traverse Line spacing (m)	Area (Km²)	Planned ¹ Line-km	Actual Line- km	Flight direction	Line numbers
Colby Mines	Traverse: 100	22	205.3	199.7	N 145° E / N 325° E	L1000 - L1550
	Tie: 1000			25.3	N 55° E / N 235° E	T1800 - T1830
TOTAL		22	205.3	225		

Table 1: Survey	Specifications.
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Survey block boundaries co-ordinates are provided in Appendix B.

2.2 Survey Operations

Survey operations were based out of Sicamous, British Columbia from March 3rd, 2012 to March 7th, 2012. The following table shows the timing of the flying.

Date	Flight #	Flown km	Block	Crew location	Comments
03-Mar-2011				Sicamous, BC	Crew mobilized
04-Mar-2011				Sicamous, BC	Crew arrived
05-Mar-2011				Sicamous, BC	System assembly
06-Mar-2011	1	146	Colby Mines	Sicamous, BC	146km flown
07-Mar-2011	2	59	Colby Mines	Sicamous, BC	Remaining kms were flown – flying complete

Table	2 :	Survey	schedule.
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¹ Note: Actual Line kilometres represent the total line kilometres in the final database. These line-km normally exceed the Planned line-km, as indicated in the survey NAV files.



2.3 Flight Specifications

During the survey the helicopter was maintained at a mean altitude of 95 metres above the ground with an average survey speed of 80 km/hour. This allowed for an average EM bird terrain clearance of 61 metres and a magnetic sensor clearance of 82 metres.

The on board operator was responsible for monitoring the system integrity. He also maintained a detailed flight log during the survey, tracking the times of the flight as well as any unusual geophysical or topographic features.

On return of the aircrew to the base camp the survey data was transferred from a compact flash card (PCMCIA) to the data processing computer. The data were then uploaded via ftp to the Geotech office in Aurora for daily quality assurance and quality control by qualified personnel.

2.4 Aircraft and Equipment

2.4.1 Survey Aircraft

The survey was flown using a Eurocopter Aerospatiale (Astar) 350 B3 helicopter, registration C-GTEQ. The helicopter is owned and operated by Geotech Aviation. Installation of the geophysical and ancillary equipment was carried out by a Geotech Ltd crew.

2.4.2 Electromagnetic System

The electromagnetic system was a Geotech Time Domain EM (VTEM) system. VTEM, with the serial number 17 had been used for the survey. The configuration is as indicated in Figure 5.

The VTEM Receiver and transmitter coils were in concentric-coplanar and Z-direction oriented configuration. The EM bird was towed at a mean distance of 35 metres below the aircraft as shown in Figure 5 and Figure 6. The receiver decay recording scheme is shown diagrammatically in Figure 4.







Figure 5: VTEM Configuration, with magnetometer.



The VTEM decay sampling scheme is shown in Table 3 below. Thirty-two time measurement gates were used for the final data processing in the range from 0.096 to 7.036 msec.

VTEM Decay Sampling Scheme							
Index Middle Start End							
Milliseconds							
14	0.096	0.090	0.103				
15	0.110	0.103	0.118				
16	0.126	0.118	0.136				
17	0.145	0.136	0.156				
18	0.167	0.156	0.179				
19	0.192	0.179	0.206				
20	0.220	0.206	0.236				
21	0.253	0.236	0.271				
22	0.290	0.271	0.312				
23	0.333	0.312	0.358				
24	0.383	0.358	0.411				
25	0.440	0.411	0.472				
26	0.505	0.472	0.543				
27	0.580	0.543	0.623				
28	0.667	0.623	0.716				
29	0.766	0.716	0.823				
30	0.880	0.823	0.945				
31	1.010	0.945	1.086				
32	1.161	1.086	1.247				
33	1.333	1.247	1.432				
34	1.531	1.432	1.646				
35	1.760	1.646	1.891				
36	2.021	1.891	2.172				
37	2.323	2.172	2.495				
38	2.667	2.495	2.865				
39	3.063	2.865	3.292				
40	3.521	3.292	3.781				
41	4.042	3.781	4.341				
42	4.641	4.341	4.987				
43	5.333	4.987	5.729				
44	6.125	5.729	6.581				
45	7.036	6.581	7.560				

Table 3 [.]	Off-Time	Decay	Sampling	Scheme
Table J.		Decay	Sampling	ouneme.

Z Component: 14-45 time gates



VTEM system specification:

Transmitter

- Transmitter coil diameter: 17.6 m
- Number of turns: 4
- Effective coil area: 973 m²
- Transmitter base frequency: 30 Hz
- Peak current: 255 A
- Pulse width: 3.41 ms
- Wave form shape: Bi-polar trapezoid
- Peak dipole moment: 248,151 nIA
- Actual average EM Bird terrain clearance: 61 metres above the ground

<u>Receiver</u>

- Z-Coil coil diameter: 1.2 m
- Number of turns: 100
- Effective coil area: 113.04 m²



Figure 6: VTEM System Configuration.

2.4.3 Airborne magnetometer

The magnetic sensor utilized for the survey was Geometrics optically pumped caesium vapour magnetic field sensor mounted 13 metres below the helicopter, as shown in Figure 6. The sensitivity of the magnetic sensor is 0.02 nanoTesla (nT) at a sampling interval of 0.1 seconds.

2.4.4 Radar Altimeter

A Terra TRA 3000/TRI 40 radar altimeter was used to record terrain clearance. The antenna was mounted beneath the bubble of the helicopter cockpit (Figure 6).

2.4.5 GPS Navigation System

The navigation system used was a Geotech PC104 based navigation system utilizing a NovAtel's WAAS (Wide Area Augmentation System) enabled GPS receiver, Geotech navigate software, a full screen display with controls in front of the pilot to direct the flight and a NovAtel GPS antenna mounted on the helicopter tail (Figure 6). As many as 11 GPS and two WAAS satellites may be monitored at any one time. The positional accuracy or circular error probability (CEP) is 1.8 m, with WAAS active, it is 1.0 m. The co-ordinates of the block were set-up prior to the survey and the information was fed into the airborne navigation system.

2.4.6 Digital Acquisition System

A Geotech data acquisition system recorded the digital survey data on an internal compact flash card. Data is displayed on an LCD screen as traces to allow the operator to monitor the integrity of the system. The data type and sampling interval as provided in Table 4.

Data Type	Sampling
TDEM	0.1 sec
Magnetometer	0.1 sec
GPS Position	0.2 sec
Radar Altimeter	0.2 sec

Tahla	٨.	Aca	uicition	Sampli	na	Rates
i apie	4:	ACQ	uisition	Sampi	ng	Rales.

2.5 Base Station

A combined magnetometer/GPS base station was utilized on this project. A Geometrics Caesium vapour magnetometer was used as a magnetic sensor with a sensitivity of 0.001 nT. The base station was recording the magnetic field together with the GPS time at 1 Hz on a base station computer.

The base station magnetometer sensor was installed (118° 57.2481' W, 50° 50.6504' N); away from electric transmission lines and moving ferrous objects such as motor vehicles. The base station data were backed-up to the data processing computer at the end of each survey day.



3. PERSONNEL

The following Geotech Ltd. personnel were involved in the project.

<u>Field</u> :	
Project Manager:	Adrian Sarmasag (Office)
Data QC:	Nick Venter (Office)
Crew chief:	Paul Taylor
Operator:	Yves Larouche Ioan Serbu

The survey pilot and the mechanical engineer were employed directly by the helicopter operator – Geotech Aviation.

Pilot:	Guy Poirier
Mechanical Engineer:	Dylan Pike
<u>Office</u> :	
Preliminary Data Processing:	Nick Venter
Final Data Processing:	Marta Orta
Final Data QA/QC:	Alexander Prikhodko
Reporting/Mapping:	Liz Mathew

Data acquisition phase was carried out under the supervision of Andrei Bagrianski, P. Geo, Chief Operations Officer. The processing and interpretation phase was under the supervision of Alexander Prikhodko, P. Geo, Ph.D. The overall contract management and customer relations were by Blair Walker.



4. DATA PROCESSING AND PRESENTATION

Data compilation and processing were carried out by the application of Geosoft OASIS Montaj and programs proprietary to Geotech Ltd.

4.1 Flight Path

The flight path, recorded by the acquisition program as WGS 84 latitude/longitude, was converted into the NAD83 Datum, UTM Zone 11 North coordinate system in Oasis Montaj.

The flight path was drawn using linear interpolation between x, y positions from the navigation system. Positions are updated every second and expressed as UTM easting's (x) and UTM northing's (y).

4.2 Electromagnetic Data

A three stage digital filtering process was used to reject major sferic events and to reduce system noise. Local sferic activity can produce sharp, large amplitude events that cannot be removed by conventional filtering procedures. Smoothing or stacking will reduce their amplitude but leave a broader residual response that can be confused with geological phenomena. To avoid this possibility, a computer algorithm searches out and rejects the major sferic events.

The signal to noise ratio was further improved by the application of a low pass linear digital filter. This filter has zero phase shift which prevents any lag or peak displacement from occurring, and it suppresses only variations with a wavelength less than about 1 second or 15 metres. This filter is a symmetrical 1 sec linear filter.

The results are presented as stacked profiles of EM voltages for the time gates, in linear - logarithmic scale for the B-field Z component and dB/dt responses in the Z. B-field Z component time channel recorded at 2.021 milliseconds after the termination of the impulse is also presented as a color image. Calculated Time Constant (TAU) with anomaly contours of Calculated Vertical Derivative of TMI is presented in Appendix C and E. Tau was calculated for B-Field and dB/dt. Resistivity Depth Image (RDI) is also presented in Appendix C and F.

VTEM receiver coil orientation Z-axis coil is oriented parallel to the transmitter coil axis and is horizontal to the ground. Generalized modeling results of VTEM data, are shown in Appendix D.

Z component data produce double peak type anomalies for "thin" sub vertical targets and single peak for "thick" targets.

The limits and change-over of "thin-thick" depends on dimensions of a TEM system the system's height and depth of a target. For example see Appendix D, Fig.D-16.



4.3 Magnetic Data

The processing of the magnetic data involved the correction for diurnal variations by using the digitally recorded ground base station magnetic values. The base station magnetometer data was edited and merged into the Geosoft GDB database on a daily basis. The aeromagnetic data was corrected for diurnal variations by subtracting the observed magnetic base station deviations.

Tie line levelling was carried out by adjusting intersection points along traverse lines. A microlevelling procedure was applied to remove persistent low-amplitude components of flight-line noise remaining in the data.

The corrected magnetic data was interpolated between survey lines using a random point gridding method to yield x-y grid values for a standard grid cell size of approximately 25 metres at the mapping scale. The Minimum Curvature algorithm was used to interpolate values onto a rectangular regular spaced grid.



5. DELIVERABLES

5.1 Survey Report

The survey report describes the data acquisition, processing, and final presentation of the survey results. The survey report is provided in two paper copies and digitally in PDF format.

5.2 Maps

Final maps were produced at scale of 1:10,000 for best representation of the survey size and line spacing. The coordinate/projection system used was NAD83 Datum, UTM Zone 11 North. All maps show the mining claims, flight path trace and topographic data; latitude and longitude are also noted on maps.

The preliminary and final results of the survey are presented as EM profiles, a late-time gate gridded EM channel, and a color magnetic TMI contour map. The following maps are presented on paper;

- VTEM dB/dt profiles Z Component, Time Gates 0.220 7.036 ms in linear logarithmic scale.
- VTEM B-Field profiles Z Component, Time Gates 0.220 7.036 ms in linear logarithmic scale.
- VTEM B-Field late time Z Component Channel 36, Time Gate 2.021 ms colour image.
- Total Magnetic Intensity (TMI) colour image and contours.
- VTEM dB/dt Calculated Time Constant (TAU) with contours of anomaly areas of the Calculated Vertical Derivative of TMI

5.3 Digital Data

- Two copies of the data and maps on DVD were prepared to accompany the report. Each DVD contains a digital file of the line data in GDB Geosoft Montaj format as well as the maps in Geosoft Montaj Map and PDF format.
- DVD structure.

Data	contains databases, grids and maps, as described below.
Report	contains a copy of the report and appendices in PDF format.

Databases in Geosoft GDB format, containing the channels listed in Table 5.



Channel name	Units	Description
X:	metres	UTM Easting NAD83 Zone 11 North
Y:	metres	UTM Northing NAD83 Zone 11 North
Z:	metres	GPS antenna elevation (above Geoid)
Longitude:	Decimal Degrees	WGS 84 Longitude data
Latitude:	Decimal Degrees	WGS 84 Latitude data
Radar:	metres	helicopter terrain clearance from radar altimeter
Radarb:	metres	Calculated EM bird terrain clearance from radar altimeter
DEM:	metres	Digital Elevation Model
Gtime:	Seconds of the day	GPS time
Mag1:	nT	Raw Total Magnetic field data
Basemag:	nT	Magnetic diurnal variation data
Mag2:	nT	Diurnal corrected Total Magnetic field data
Mag3:	nT	Levelled Total Magnetic field data
SFz[14]:	pV/(A*m ⁴)	Z dB/dt 0.096 millisecond time channel
SFz[15]:	pV/(A*m ⁴)	Z dB/dt 0.110 millisecond time channel
SFz[16]:	pV/(A*m ⁴)	Z dB/dt 0.126 millisecond time channel
SFz[17]:	pV/(A*m ⁴)	Z dB/dt 0.145 millisecond time channel
SFz[18]:	pV/(A*m ⁴)	Z dB/dt 0.167 millisecond time channel
SFz[19]:	pV/(A*m ⁴)	Z dB/dt 0.192 millisecond time channel
SFz[20]:	pV/(A*m ⁴)	Z dB/dt 0.220 millisecond time channel
SFz[21]:	pV/(A*m ⁴)	Z dB/dt 0.253 millisecond time channel
SFz[22]:	pV/(A*m ⁴)	Z dB/dt 0.290 millisecond time channel
SFz[23]:	pV/(A*m ⁴)	Z dB/dt 0.333 millisecond time channel
SFz[24]:	pV/(A*m ⁴)	Z dB/dt 0.383 millisecond time channel
SFz[25]:	pV/(A*m ⁴)	Z dB/dt 0.440 millisecond time channel
SFz[26]:	pV/(A*m ⁴)	Z dB/dt 0.505 millisecond time channel
SFz[27]:	pV/(A*m⁴)	Z dB/dt 0.580 millisecond time channel
SFz[28]:	pV/(A*m⁴)	Z dB/dt 0.667 millisecond time channel
SFz[29]:	pV/(A*m ⁴)	Z dB/dt 0.766 millisecond time channel
SFz[30]:	pV/(A*m*)	Z dB/dt 0.880 millisecond time channel
SFz[31]:	pV/(A*m*)	Z dB/dt 1.010 millisecond time channel
SFz[32]:	pV/(A*m ⁻)	Z dB/dt 1.161 millisecond time channel
SFz[33]:	pV/(A*m ⁺)	Z dB/dt 1.333 millisecond time channel
SFz[34]:	$pV/(A^*m^2)$	Z dB/dt 1.531 millisecond time channel
SFZ[35]:	$pV/(A^m)$	
SFZ[36]:	$pV/(A^m)$	
SFZ[37]:	$pV/(A^m)$	Z dB/dt 2.323 millisecond time channel
SFZ[38]:	$pv/(A^{*}m)$	
SFZ[39]:	$pV/(A^m)$	
SFZ[40]:	$pV/(A^m)$	Z dB/dt 3.521 millisecond time channel
SF2[41].	pv/(A m)	Z dB/dt 4.641 millisscond time channel
SF2[42].	pv/(A m)	Z dB/dt 4.041 millisecond time channel
SFZ[43]:	$pV/(A^{*}m)$	Z dB/dt 5.333 millisecond time channel
SF2[44].	pv/(A III)	Z uD/ut 0.120 millisecond time channel
<u>ər2[45]:</u>	$pv/(A^{m})$	Z uD/ut 7.000 minisecond time channel
	(pv ms)/(A*m)	2 D-FIELU UALA IUI LIME CHAMMELS 14 10 45
	nT/m	Calculated Magnetic Vertical Credient
	millicocondo	Calculated Magnetic Vertical Gradient
	milliseconds	Time Constant (Tau) calculated from R-Field data
Nchan RF		Last channel where the Tau algorithm stops calculation R-Field data
Nchan SF		Last channel where the Tau algorithm stops calculation, B Hold data

Table 5: Geosoft GDB Data Format.



Electromagnetic B-field and dB/dt Z component data is found in array channel format between indexes 14 - 45.

• Database of the VTEM Waveform "11219_waveform_final.gdb" in Geosoft GDB format, containing the following channels:

Time:	Sampling rate interval, 5.2083 microseconds
Rx_Volt:	Output voltage of the receiver coil (Volt)
Tx_Current:	Output current of the transmitter (Amp)

• Grids in Geosoft GRD format, as follows:

TMI:	Total Magnetic Intensity (nT)
BFz36:	B-Field Z Component Channel 36 (Time Gate 2.021 ms)
TauSF:	dB/dt Calculated Time Constant (TAU)
TauBF:	B-Field Calculated Time Constant (TAU)
CVG:	Calculated Vertical Derivative of TMI (CVG)
PLM:	60 Hz Power Line Monitor

A Geosoft .GRD file has a .GI metadata file associated with it, containing grid projection information. A grid cell size of 25 metres was used.

• Maps at 1:10,000 in Geosoft MAP format, as follows:

11219_10K_dBdtz:	dB/dt profiles Z Component, Time Gates 0.220 - 7.036 ms in linear - logarithmic scale.
11219_10K_Bfieldz:	B-field profiles Z Component, Time Gates 0.220 - 7.036 ms in linear - logarithmic scale.
11219_10K_BFz36:	B-Field late time Z Component Channel 36, Time Gate 2.021 ms colour image.
11219_10K_TMI:	Total Magnetic Intensity (TMI) colour image and contours.
11219_10K_TauSF:	dB/dt Calculated Time Constant (TAU) with contours of anomaly areas of the Calculated Vertical Derivative of TMI

Maps are also presented in PDF format.

- 1:50,000 topographic vectors were taken from the NRCAN Geogratis database at; <u>http://geogratis.gc.ca/geogratis/en/index.html</u>.
- A Google Earth file 11219_Colby Mines_FP.kml showing the flight path of the block is included. Free versions of Google Earth software from: <u>http://earth.google.com/download-earth.html</u>



6. CONCLUSIONS AND RECOMMENDATIONS

A helicopter-borne versatile time domain electromagnetic (VTEM) geophysical survey has been completed over the Colby Mines Project located 19 kilometres southeast of Sicamous, British Columbia, Canada.

The total area coverage is 22 km². Total survey line coverage is 225 line kilometres. The principal sensors included a Time Domain EM system and a magnetometer. Results have been presented as stacked profiles, and contour color images at a scale of 1:10,000. A formal Interpretation has not been included or requested.

Based on the geophysical results obtained, a number of TEM anomalies are identified across the property. In general these conductive zones and EM anomalies correspond to lithological broad objects and local targets strongly associated with magnetic dyke similar anomalies as observed in the Time-constant (Tau) image presented with the calculated vertical magnetic gradient (CVG) contours (see Appendix C).

The local conductive targets are presented in RDIs of L1340 and L1371 (Appendix C). The approximate depth to the tops of the targets is around 50 meters.

One of the lithological conductors is presented in RDI section for L1170 (Appendix C).

A power line is identified toward the south-eastern part of the property. Caution is recommended during further interpretation; as such cultural components might affect the geological response inherent in the data.

We recommend a detailed interpretation of the available geophysical data, in conjunction with the geology. It will include resistivity depth imaging of more surveyed lines and Maxwell modeling for the local conductors prior to ground follow up and more drill testing.

Respectfully submitted⁶,

Nick Venter Geotech Ltd.

Marta Orta Geotech Ltd.

Alexander Prikhodko, P. Geo Geotech Ltd. April 2012

⁶Final data processing of the EM and magnetic data were carried out by Marta Orta, from the office of Geotech Ltd. in Aurora, Ontario, under the supervision of Alexander Prikhodko, P.Geo., PhD, Senior Geophysicist, VTEM Interpretation Supervisor.



APPENDIX A

SURVEY BLOCK LOCATION MAP



Survey overview of the property





Mining Claims - Colby Mines Project

APPENDIX B

SURVEY BLOCK COORDINATES

(WGS 84, UTM Zone 11 North)

Colby Mines Project

X	Y
378796.2	5624349.8
374699.9	5622572.3
373980.0	5622070.4
375732.0	5619572.8
378155.5	5620252.4
380517.0	5621892.3
382533.2	5621846.0
380812.4	5624303.4



APPENDIX C

GEOPHYSICAL MAPS¹



VTEM B-Field Z Component Profiles, Time Gates 0.220 to 7.036 ms over Total Magnetic Intensity

¹ Full size geophysical maps are also available in PDF format on the final DVD



VTEM dB/dt Z Component Profiles, Time Gates 0.220 to 7.036 ms over Geology



VTEM B-Field Z Component Channel 36, Time Gate 2.021 ms





Total Magnetic Intensity





VTEM dB/dt Calculated Time Constant (TAU) with contours of anomaly areas of the Calculated Vertical Derivative of TMI

Resistivity Depth Image (RDI) MAPS

3D Resistivity-Depth Image (RDI)

















APPENDIX D

GENERALIZED MODELING RESULTS OF THE VTEM SYSTEM

Introduction

The VTEM system is based on a concentric or central loop design, whereby, the receiver is positioned at the centre of a transmitter loop that produces a primary field. The wave form is a bipolar, modified square wave with a turn-on and turn-off at each end.

During turn-on and turn-off, a time varying field is produced (dB/dt) and an electro-motive force (emf) is created as a finite impulse response. A current ring around the transmitter loop moves outward and downward as time progresses. When conductive rocks and mineralization are encountered, a secondary field is created by mutual induction and measured by the receiver at the centre of the transmitter loop.

Efficient modeling of the results can be carried out on regularly shaped geometries, thus yielding close approximations to the parameters of the measured targets. The following is a description of a series of common models made for the purpose of promoting a general understanding of the measured results.

A set of models has been produced for the Geotech VTEM® system dB/dT Z and X components (see models D1 to D15). The Maxwell [™] modeling program (EMIT Technology Pty. Ltd. Midland, WA, AU) used to generate the following responses assumes a resistive half-space. The reader is encouraged to review these models, so as to get a general understanding of the responses as they apply to survey results. While these models do not begin to cover all possibilities, they give a general perspective on the simple and most commonly encountered anomalies.

As the plate dips and departs from the vertical position, the peaks become asymmetrical.

As the dip increases, the aspect ratio (Min/Max) decreases and this aspect ratio can be used as an empirical guide to dip angles from near 90° to about 30°. The method is not sensitive enough where dips are less than about 30°.















The same type of target but with different thickness, for example, creates different form of the response:

Figure D-16: Conductive vertical plate, depth 50 m, strike length 200 m, depth extends 150 m.

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September 2010



APPENDIX E

EM TIME CONSTANT (TAU) ANALYSIS

Estimation of time constant parameter¹ in transient electromagnetic method is one of the steps toward the extraction of the information about conductances beneath the surface from TEM measurements.

The most reliable method to discriminate or rank conductors from overburden, background or one and other is by calculating the EM field decay time constant (TAU parameter), which directly depends on conductance despite their depth and accordingly amplitude of the response.

Theory

As established in electromagnetic theory, the magnitude of the electro-motive force (emf) induced is proportional to the time rate of change of primary magnetic field at the conductor. This emf causes eddy currents to flow in the conductor with a characteristic transient decay, whose Time Constant (Tau) is a function of the conductance of the survey target or conductivity and geometry (including dimensions) of the target. The decaying currents generate a proportional secondary magnetic field, the time rate of change of which is measured by the receiver coil as induced voltage during the Off time.

The receiver coil output voltage (e_0) is proportional to the time rate of change of the secondary magnetic field and has the form,

$$e_0 \alpha (1 / \tau) e^{-(t / \tau)}$$

Where, $\tau = L/R$ is the characteristic time constant of the target (TAU) R = resistance L = inductance

From the expression, conductive targets that have small value of resistance and hence large value of τ yield signals with small initial amplitude that decays relatively slowly with progress of time. Conversely, signals from poorly conducting targets that have large resistance value and small τ , have high initial amplitude but decay rapidly with time¹ (Figure E-1).



Figure E-1: Left – presence of good conductor, right – poor conductor.

¹ McNeill, JD, 1980, "Applications of Transient Electromagnetic Techniques", Technical Note TN-7 page 5, Geonics Limited, Mississauga, Ontario.

EM Time Constant (Tau) Calculation

The EM Time-Constant (TAU) is a general measure of the speed of decay of the electromagnetic response and indicates the presence of eddy currents in conductive sources as well as reflecting the "conductance quality" of a source. Although TAU can be calculated using either the measured dB/dt decay or the calculated B-field decay, dB/dt is commonly preferred due to better stability (S/N) relating to signal noise. Generally, TAU calculated on base of early time response reflects both near surface overburden and poor conductors whereas, in the late ranges of time, deep and more conductive sources, respectively. For example early time TAU distribution in an area that indicates conductive overburden is shown in Figure 2.



Figure E-2: Map of early time TAU Area with overburden conductive layer and local sources.



Figure E-3: Map of full time range TAU with EM anomaly due to deep highly conductive target.

There are many advantages of TAU maps:

- TAU depends only on one parameter (conductance) in contrast to response magnitude;
- TAU is integral parameter, which covers time range and all conductive zones and targets are displayed independently of their depth and conductivity on a single map.
- Very good differential resolution in complex conductive places with many sources with different conductivity.
- Signs of the presence of good conductive targets are amplified and emphasized independently of their depth and level of response accordingly.

In the example shown in Figure 4 and 5, three local targets are defined, each of them with a different depth of burial, as indicated on the resistivity depth image (RDI). All are very good conductors but the deeper target (number 2) has a relatively weak dB/dt signal yet also features the strongest total TAU (Figure 4). This example highlights the benefit of TAU analysis in terms of an additional target discrimination tool.



Figure E-4: dB/dt profile and RDI with different depths of targets.



The EM Time Constants for dB/dt and B-field were calculated using the "sliding Tau" in-house program developed at Geotech2. The principle of the calculation is based on using of time window (4 time channels) which is sliding along the curve decay and looking for latest time channels which have a response above the level of noise and decay. The EM decays are obtained from all available decay channels, starting at the latest channel. Time constants are taken from a least square fit of a straight-line (log/linear space) over the last 4 gates above a pre-set signal threshold level (Figure E-6). Threshold settings are pointed in the "label" property of TAU database channels. The sliding Tau method determines that, as the amplitudes increase, the time-constant is taken at progressively later times in the EM decay. If the maximum signal amplitude falls below the threshold, or becomes negative for any of the 4 time gates, then Tau is not calculated and is assigned a value of "dummy" by default.



Figure E-6: Typical dB/dt decays of VTEM data

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² by A.Prikhodko

APPENDIX F

TEM RESISTIVITY DEPTH IMAGING (RDI)

Resistivity depth imaging (RDI) is technique used to rapidly convert EM profile decay data into an equivalent resistivity versus depth cross-section, by deconvolving the measured TEM data. The used RDI algorithm of Resistivity-Depth transformation is based on scheme of the apparent resistivity transform of Maxwell A.Meju (1998)¹ and TEM response from conductive half-space. The program is developed by Alexander Prikhodko and depth calibrated based on forward plate modeling for VTEM system configuration (Fig. 1-10).

RDIs provide reasonable indications of conductor relative depth and vertical extent, as well as accurate 1D layered-earth apparent conductivity/resistivity structure across VTEM flight lines. Approximate depth of investigation of a TEM system, image of secondary field distribution in half space, effective resistivity, initial geometry and position of conductive targets is the information obtained on base of the RDIs.

Maxwell forward modeling with RDI sections from the synthetic responses (VTEM system)

Figure F-1: Maxwell plate model and RDI from the calculated response for conductive "thin" plate (depth 50 m, dip 65 degree, depth extend 100 m).

¹ Maxwell A.Meju, 1998, Short Note: A simple method of transient electromagnetic data analysis, Geophysics, **63**, 405–410.





Figure F-2: Maxwell plate model and RDI from the calculated response for "thick" plate 18 m thickness, depth 50 m, depth extend 200 m).



Figure F-3: Maxwell plate model and RDI from the calculated response for bulk ("thick") 100 m length, 40 m depth extend, 30 m thickness



Figure F-4: Maxwell plate model and RDI from the calculated response for "thick" vertical target (depth 100 m, depth extend 100 m). 19-44 chan.



Figure F-5: Maxwell plate model and RDI from the calculated response for horizontal thin plate (depth 50 m, dim 50x100 m). 15-44 chan.





Figure F-6: Maxwell plate model and RDI from the calculated response for horizontal thick (20m) plate – less conductive (on the top), more conductive (below)



Figure G-7: Maxwell plate model and RDI from the calculated response for inclined thick (50m) plate. Depth extends 150 m, depth to the target 50 m.



Figure F-8: Maxwell plate model and RDI from the calculated response for the long, wide and deep subhorizontal plate (depth 140 m, dim 25x500x800 m) with conductive overburden.



Figure F-9: Maxwell plate models and RDIs from the calculated response for "thick" dipping plates (35, 50, 75 m thickness), depth 50 m, conductivity 2.5 S/m.



Figure F-10: Maxwell plate models and RDIs from the calculated response for "thick" (35 m thickness) dipping plate on different depth (50, 100, 150 m), conductivity 2.5 S/m.



Figure F-11: RDI section for the real horizontal and slightly dipping conductive layers





Presentation of series of lines



3d presentation of RDIs





Apparent Resistivity Depth Slices plans:



3d views of apparent resistivity depth slices:



Real base metal targets in comparison with RDIs:

RDI section of the line over Caber deposit ("thin" subvertical plate target and conductive overburden).



3d RDI voxels with base metals ore bodies (Middle East):







Alexander Prikhodko, PhD, P.Geo **Geotech Ltd.** April 2011







Colby Mines Project



111	601	Hz power line monitor ale = 5 units
		1300 (m) 1200 l 1100 l 1000 l
		800 700 600 Wieles
		Elevat
23000 56232	50 50	400 Q 523500

RDI SECTION PLOT LINE #: L1340 Colby Mines Project



Colby Mines Project









- EM Transmitter Loop: Towed at an average terrain clearance of 35 meters below the helicopter Magnetic Sensor: Towed at an average terrain clearance of 13 meters below the helicopter

April 2012



- EM Transmitter Loop: Towed at an average terrain clearance of 35 meters below the helicopter Magnetic Sensor: Towed at an average terrain clearance of 13 meters below the helicopter

	0.220 ms
	0.253 ms
	0.290 ms
	0.333 ms
	0.383 ms
	0.440 ms
	0.505 ms
	0.580 ms
	0.667 ms
	0.766 ms
	0.880 ms
	1.010 ms
	1.161 ms
	1.333 ms
	1.531 ms
	1.760 ms
	2.021 ms
	2.323 ms
	2.667 ms
	3.063 ms
	3.521 ms
	4.042 ms
	4.641 ms
	5.333 ms
	6.125 ms
	7 036 ms

- Magnetic Sensor: Towed at an average terrain clearance of 13 meters below the helicopter

April 2012