REPORT ON A HELICOPTER-BORNE GEOTECH VTEM TIME DOMAIN ELECTROMAGNETIC / MAGNETIC GEOPHYSICAL SURVEY

Trill, Foy, Wisner, Parkin, Skynner, Frost, and NC Blocks Survey
Sudbury, Ontario, Canada

for
Wallbridge Mining Company Ltd.

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Survey flown from October, 2005 through February, 2006

Project 568
December, 2006
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REPORT ON A HELICOPTER-BORNE GEOTECH VTEM
TIME DOMAIN ELECTROMAGNETIC / MAGNETIC SURVEY

INTRODUCTION

This report describes the helicopter-borne geophysical survey carried out on behalf of Wallbridge Mining Company Ltd. by Geotech Ltd. under an agreement dated September, 2005. Principal geophysical sensors included a time domain electromagnetic system and a cesium magnetometer. Ancillary equipment included a GPS navigation system and a radar altimeter.

Seven blocks, named Trill, Foy, Wisner, Parkin, Skynner, Frost, and NC, were surveyed. To best map known geological structures orthogonally, the blocks vary in survey line direction. The Skynner and Frost blocks partially overlap. The blocks are located between 27 and 40 km away from Sudbury, Ontario at or outside the northern edge of the Sudbury Basin. The coordinates of the centre of the cluster of blocks are: 81° 10’ W, 46° 40’ N. The total line kilometres flown and processed was 2,701 km. Data acquisition was carried out in two stages: from October 8th to 26th, 2005 and from January 9th to February 10th, 2006.

This report describes the survey, the data processing and presentation, and final products.
SURVEY AREA

The survey area is shown in figure 1.

Figure 1 - Location Map
The survey specifications are summarised in the following table:

<table>
<thead>
<tr>
<th>Block Number</th>
<th>Line Km</th>
<th>Line Spacing m</th>
<th>Line Direction</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>NC</td>
<td>20.2</td>
<td>variable</td>
<td>160°/340° - Lines</td>
<td>NA - Ties</td>
</tr>
</tbody>
</table>

Table 1 - Survey Blocks
SURVEY OPERATIONS

Survey operations were based out of Sudbury, Ontario. The following table shows the timing of the flying indicated by the first and last production flights.

<table>
<thead>
<tr>
<th>Date</th>
<th>Flight #</th>
<th>Block flown</th>
<th>Flown, km</th>
<th>Stand-by reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>24/10/05</td>
<td>28-29</td>
<td>Trill, NC, Foy, Wisner</td>
<td>188.8</td>
<td></td>
</tr>
</tbody>
</table>

Table 2 - Survey Schedule

The nominal EM sensor terrain clearance was 30 m (EM bird height above ground, i.e., the helicopter is maintained 65 m above ground). Nominal survey speed was 80 km/hour. The data-recording rates of the data acquisition was: 0.1 second for electromagnetics and magnetometer, 0.2 second for altimeter and GPS. This translates to a geophysical reading about every 2 metres along flight track. Navigation was assisted by a GPS receiver and data acquisition system, which reports GPS co-ordinates as latitude/longitude and directs the pilot over a pre-programmed survey grid.

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

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.
AIRCRAFT AND EQUIPMENT

2 Aircraft

An Astar 350 BA+ helicopter, registration C-GHSM - owned and operated by Abitibi Helicopters was used for the survey. Installation of the geophysical and ancillary equipment was carried out by Geotech Ltd.

3 Electromagnetic System

The electromagnetic system was a Geotech Time Domain EM system. The layout is as indicated in Figures 2 below.

Receiver and transmitter coils were concentric and Z-direction oriented. Transmitter coil diameter was 26 metres, the number of turns was 4. Receiver coil diameter was 1.2 metre, the number of turns was 100. Transmitter pulse repetition rate was 30 Hz.
Peak current was 145 A.
Duty cycle was 40%.
Peak dipole moment was 307900 NIA.
Wave form – trapezoid.
Twenty-six measurement gates were used in the range from 130 µs to 7540 µs.
The transmitter waveform and the receiver decay recording scheme is shown diagrammatically in Figure 3.
Recording sampling rate was 10 samples per second.
The EM bird was towed 50 m below the helicopter.

4  Airborne magnetometer

The magnetic sensor utilized for the survey was a Geometrics optically pumped cesium vapor magnetic field sensor, mounted in a separate bird towed 15 m below the helicopter. The sensitivity of the magnetic sensor is 0.02 nanoTesla (nT) at a sampling interval of 0.1 seconds. The magnetometer sends the measured magnetic field strength as nanoTeslas to the data acquisition system via the RS-232 port.

5  Ancillary Systems

5.1 Radar Altimeter

A Terra TRA 3000/TRI 30 radar altimeter was used to record terrain clearance. The antenna was mounted beneath the bubble of the helicopter cockpit.

5.2 GPS Navigation System

The navigation system used was a Geotech PC based navigation system utilizing a NovAtel’s WAAS enable OEM4-G2-3151W GPS receiver, Geotech navigate software, a full screen display with controls in front of the pilot to direct the flight and an NovAtel GPS antenna mounted on the helicopter tail. The co-ordinates of the blocks were set-up prior to the survey and the information was fed into the airborne navigation system.

5.3 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. Contents and update rates were as follows:
<table>
<thead>
<tr>
<th>DATA TYPE</th>
<th>SAMPLING</th>
</tr>
</thead>
<tbody>
<tr>
<td>TDEM</td>
<td>0.1 sec</td>
</tr>
<tr>
<td>Magnetometer</td>
<td>0.1 sec</td>
</tr>
<tr>
<td>GPS Position</td>
<td>0.2 sec</td>
</tr>
<tr>
<td>Radar Altimeter</td>
<td>0.2 sec</td>
</tr>
</tbody>
</table>

Table 3 - Sampling Rates

6 Base Station

A combine magnetometer/GPS base station was utilized on this project. A Scintrex CS-2 Cesium 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 in Yellowknife away from electric transmission lines and moving ferrous objects such as motor vehicles. The magnetometer base station's data was backed-up to the data processing computer at the end of each survey day.
PERSONNEL

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

Field Geophysicists: -
Crew Chief: Chris Kahue
Data Processors: Neil Fiset / Chris Vaughan
Operators: Vlad / Alex Dumyn / Brian Davis

Office
Data Processing/Reporting: Andrei Bagrianski

The survey pilot and the mechanic were employed directly by the helicopter operator – Abitibi Helicopters.

Pilot: Michel Frigon / Richard Berube
Mechanic: Marco Blais / Eric Desilets

Overall management of the survey was carried out from the Aurora offices of Geotech Ltd. by Edward Morrison, President.
DATA PROCESSING AND PRESENTATION

Flight Path and Digital Elevation Model

The flight path, recorded by the acquisition program as WGS 84 latitude/longitude, was converted into the UTM co-ordinate 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 eastings (x) and UTM northings (y).

The helicopter radar altimeter terrain clearance was subtracted from the GPS elevation to yield a digital elevation model (DEM). The difference in radar altimeter and GPS antenna sensor heights was accounted for. Any lines exhibiting differences from a global low-resolution DEM were adjusted with a DC shift until a coherent DEM was obtained. Finally, the DEM was micro-levelled to remove line-direction noise. The corrected DEM line data from the survey 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 0.2 cm at the mapping scale. The Minimum Curvature algorithm was used to interpolate values onto a rectangular regular spaced grid. The NC Block lines were insufficiently dense to permit gridding.

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 filter used was a 16 point non-linear filter.

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 20 metres. This filter is a symmetrical 1 sec linear filter. The results are presented as stacked profiles of EM voltages for the gate times in both linear scale and log-linear scale formats.
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. The corrected magnetic line data from the survey 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 0.2 cm at the mapping scale. The Minimum Curvature algorithm was used to interpolate values onto a rectangular regular spaced grid. The NC Block lines were insufficiently dense to permit gridding.
DELIVERABLES

The survey is described in a report, which is provided in two copies. The final maps were produced at a scale of 1:10,000 using one sheet per block, except for Trill, which required separate north and south sheets.

MAPS

The final results of the survey are presented in a colour magnetic contour map and an EM profiles map at a linear-logarithmic scale. The coordinate/projection system used was NAD83, Universal Transverse Mercator, zone 17N. For reference, the NAD83 latitude and longitude are also noted on the maps. All EM maps show the helicopter flight path trace.

The map products are as follows:

Standard maps (digital map file names in brackets, where "*" is substituted by the block name):

1. Total Magnetic Intensity contoured colour image and digitized topo base, on paper in two copies (*TMI),
2. VTEM Plan Profiles Map at a linear scale of the early time gates (190 – 680 μs) on the GPS flight path and digitized topo base, on paper in two copies (*EM_early),
3. VTEM Plan Profiles Map at a linear scale of the late time gates (810 – 3180 μs) on the GPS flight path and digitized topo base, on paper in two copies (*EM_late), and
4. VTEM Plan Profiles Map at a linear-logarithmic scale of the twenty one gates times (220 – 6340 μs) on the GPS flight path and digitized topo base, on paper in two copies (*EM_log).

DIGITAL DATA on CD-ROM

Two copies of CD-ROMs were prepared to accompany the report. Each CD-ROM contains a digital file of the line data in GDB Geosoft Montaj format in addition to the maps in Geosoft Montaj Map format and data grids and scanned topo image in Geosoft binary grid format.

A readme.txt file may be found on the CD-ROM that describes the contents in more detail.

CONCLUSIONS
A time domain electromagnetic helicopter-borne geophysical survey has been completed over seven blocks in the Sudbury Area, Ontario, Canada. Total survey line coverage is 2,701 line kilometres. The principal sensors included a Geotech VTEM Time Domain EM system and a magnetometer. EM and magnetic results have been presented on four colour maps, each at a scale of 1:10,000.

Respectfully submitted,

Chris Vaughan,
Geotech Ltd.
APPENDIX A - 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 26.1 meters diameter transmitter loop that produces a dipole moment up to 456,000 NIA at peak current. The wave form is a bi-polar, modified square wave with a turn-on and turn-off at each end. With a base frequency of 30 Hz, the duration of each pulse is approximately 7.5 milliseconds followed by an off time where no primary field is present.

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.

Measurements are made during the off-time, when only the secondary field (representing the conductive targets encountered in the ground) is present.

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.

Variation of Plate Depth

The most common anomaly encountered during surveys over Precambrian Shield geology is the “plate” model. Geometries represented by plates of different strike length, depth extent, dip, plunge and depth below surface can be varied with characteristic parameters like conductance of the target, conductance of the host and conductivity/thickness and thickness of the overburden layer.

Diagrammatic models for a vertical plate are shown in figures A and G at two different depths, all other parameters remaining constant. With this transmitter-receiver geometry, the classic M shaped response is generated. Figure A shows a plate where the top is near surface. Here, amplitudes of the duel peaks are higher and symmetrical with the zero centre positioned directly above the plate. Most important is the separation distance of the peaks. This distance is small when the plate is near surface and widens with a linear relationship as the plate (depth to top) increases. Figure G shows a much deeper plate where the separation distance of the peaks is much wider and the amplitudes of the channels have decreased.
Variation of Plate Dip

As the plate dips and departs from the vertical position, the peaks become asymmetrical. Figure B shows a near surface plate dipping 80°. Note that the direction of dip is toward the high shoulder of the response and the top of the plate remains under the centre minimum.

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°. Figure E shows a plate dipping 45° and, at this angle, the minimum shoulder starts to vanish. In Figure D, a flat lying plate is shown, relatively near surface. Note that the twin peak anomaly has been replaced by a symmetrical shape with large, bell shaped, channel amplitudes which decay relative to the conductance of the plate.

Figure H shows a special case where two plates are positioned to represent a synclinal structure. Note that the main characteristic to remember is the centre amplitudes are higher (approximately double) compared to the high shoulder of a single plate. This model is very representative of tightly folded formations where the conductors were once flat lying.

Variation of Prism Depth

Finally, with prism models, another algorithm is required to represent current on the plate. A plate model is considered to be infinitely thin with respect to thickness and incapable of representing the current in the thickness dimension. A prism model is constructed to deal with this problem, thereby, representing the thickness of the body more accurately.

Figures C, F and I show the same prism at increasing depths. Aside from an expected decrease in amplitude, the side lobes of the anomaly show a widening with deeper prism depths of the bell shaped early time channels.
General Modeling Concepts

A set of models has been produced for the Geotech VTEM® system with explanation notes (see models A to I above). 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.

When producing these models, a few key points were observed and are worth noting as follows:

- For near vertical and vertical plate models, the top of the conductor is always located directly under the centre low point between the two shoulders in the classic M shaped response.

- As the plate is positioned at an increasing depth to the top, the shoulders of the M shaped response, have a greater separation distance.

- When faced with choosing between a flat lying plate and a prism model to represent the target (broad response) some ambiguity is present and caution should be exercised.

- With the concentric loop system and Z-component receiver coil, virtually all types of conductors and most geometries are most always well coupled and a response is generated (see model H). Only concentric loop systems can map this type of target.

The modelling program used to generate the responses was prepared by PetRos Eikon Inc. and is one of a very few that can model a wide range of targets in a conductive half space.

General Interpretation Principals

Magnetics

The total magnetic intensity responses reflect major changes in the magnetite and/or other magnetic minerals content in the underlying rocks and unconsolidated overburden. Precambrian rocks have often been subjected to intense heat and pressure during structural and metamorphic events in their history. Original signatures imprinted on these rocks at the time of formation have, in most cases, been modified, resulting in low magnetic susceptibility values.
The amplitude of magnetic anomalies, relative to the regional background, helps to assist in identifying specific magnetic and non-magnetic rock units (and conductors) related to, for example, mafic flows, mafic to ultramafic intrusives, felsic intrusives, felsic volcanics and/or sediments etc. Obviously, several geological sources can produce the same magnetic response. These ambiguities can be reduced considerably if basic geological information on the area is available to the geophysical interpreter.

In addition to simple amplitude variations, the shape of the response expressed in the wavelength and the symmetry or asymmetry, is used to estimate the depth, geometric parameters and magnetization of the anomaly. For example, long narrow magnetic linears usually reflect mafic flows or intrusive dyke features. Large areas with complex magnetic patterns may be produced by intrusive bodies with significant magnetization, flat lying magnetic sills or sedimentary iron formation. Local isolated circular magnetic patterns often represent plug-like igneous intrusives such as kimberlites, pegmatites or volcanic vent areas.

Because the total magnetic intensity (TMI) responses may represent two or more closely spaced bodies within a response, the second derivative of the TMI response may be helpful for distinguishing these complexities. The second derivative is most useful in mapping near surface linears and other subtle magnetic structures that are partially masked by nearby higher amplitude magnetic features. The broad zones of higher magnetic amplitude, however, are severely attenuated in the vertical derivative results. These higher amplitude zones reflect rock units having strong magnetic susceptibility signatures. For this reason, both the TMI and the second derivative maps should be evaluated together.

Theoretically, the second derivative, zero contour or colour delineates the contacts or limits of large sources with near vertical dip and shallow depth to the top. The vertical gradient map also aids in determining contact zones between rocks with a susceptibility contrast, however, different, more complicated rules of thumb apply.

**Concentric Loop EM Systems**

Concentric systems with horizontal transmitter and receiver antennae produce much larger responses for flat lying conductors as contrasted with vertical plate-like conductors. The amount of current developing on the flat upper surface of targets having a substantial area in this dimension, are the direct result of the effective coupling angle, between the primary magnetic field and the flat surface area. One therefore, must not compare the amplitude/conductance of responses generated from flat lying bodies with those derived from near vertical plates; their ratios will be quite different for similar conductances.
Determining dip angle is very accurate for plates with dip angles greater than 30°. For angles less than 30° to 0°, the sensitivity is low and dips cannot be distinguished accurately in the presence of normal survey noise levels.

A plate like body that has near vertical position will display a two shoulder, classic M shaped response with a distinctive separation distance between peaks for a given depth to top.

It is sometimes difficult to distinguish between responses associated with the edge effects of flat lying conductors and poorly conductive bedrock conductors. Poorly conductive bedrock conductors having low dip angles will also exhibit responses that may be interpreted as surficial overburden conductors. In some situations, the conductive response has line to line continuity and some magnetic correlation providing possible evidence that the response is related to an actual bedrock source.

The EM interpretation process used, places considerable emphasis on determining an understanding of the general conductive patterns in the area of interest. Each area has different characteristics and these can effectively guide the detailed process used.

The first stage is to determine which time gates are most descriptive of the overall conductance patterns. Maps of the time gates that represent the range of responses can be very informative.

Next, stacking the relevant channels as profiles on the flight path together with the second vertical derivative of the TMI is very helpful in revealing correlations between the EM and Magnetics.

Next, key lines can be profiled as single lines to emphasize specific characteristics of a conductor or the relationship of one conductor to another on the same line. Resistivity Depth sections can be constructed to show the relationship of conductive overburden or conductive bedrock with the conductive anomaly.