REPORT ON A HELICOPTER-BORNE Z-AXIS TIPPER ELECTROMAGNETIC (ZTEM) AND AEROMAGNETIC GEOPHYSICAL SURVEY

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Lac des Iles Mine, Ontario

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REPORT ON A HELICOPTER-BORNE Z-AXIS, TIPPER ELECTROMAGNETIC (ZTEM) AND AEROMAGNETIC GEOPHYSICAL SURVEY

Shelby
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Executive Summary

During November 4th to 21st 2014 Geotech Ltd. carried out a helicopter-borne geophysical survey for Lac de Iles Mines Ltd over the Shelby survey situated near Lac des Iles Mine, Ontario.

Principal geophysical sensors included a Z-Axis Tipper electromagnetic (ZTEM) system, and a caesium magnetometer. Ancillary equipment included a GPS navigation system and a radar altimeter. A total of 575 line-kilometres of geophysical data were acquired during the survey.

The survey operations were based out of Lac des Iles Mine, Ontario. 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
- Digital Elevation Model
- 3D View of In-Phase Total Divergence versus Skin Depth
- In-Phase Total Divergence (45Hz, 180Hz, and 720Hz)
- Tzx In-line In-Phase & Quadrature Profiles over 90Hz Phase Rotated Grid
- Tzy Cross-line In-Phase & Quadrature Profiles over 90Hz Phase Rotated Grid

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

These services are the result of the Agreement made between Geotech Ltd. and Lac De Iles Mines Ltd to perform a helicopter-borne geophysical survey over the Survey located near Lac des Iles Mine, Ontario (Figure 1).

Robert Stewart represented Lac De Iles Mines Ltd during the data acquisition and data processing phases of this project.

The geophysical surveys consisted of helicopter borne AFMAG Z-axis Tipper electromagnetic (ZTEM) system and aero magnetics using a caesium magnetometer. A total of 575 line kilometres of geophysical data were acquired during the survey. The survey area is shown in Figure 2.

In a ZTEM survey, a single vertical-dipole air-core receiver coil is flown over the survey area in a grid pattern, similar to regional airborne EM surveys. Two orthogonal, air-core horizontal axis coils are placed close to the survey site to measure the horizontal EM reference fields. Data from the three coils are used to obtain the Tzx and Tzy Tipper (Vozoff, 1972) components at six frequencies in the 30 to 720 Hz band. The ZTEM is useful in mapping geology using resistivity contrasts and magnetometer data provides additional information on geology using magnetic susceptibility contrasts.

Figure 1: Property Location

The crew was based out of Lac des Iles Mine, Ontario for the acquisition phase of the survey. Survey flying started on November 4th and finished on November 21st 2014.

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 reporting, data presentation and archiving were completed from the Aurora office of Geotech Ltd. in December, 2014.

1.2 Survey Location

The Block is located near Thunder Bay, Ontario as shown in Figure 2.

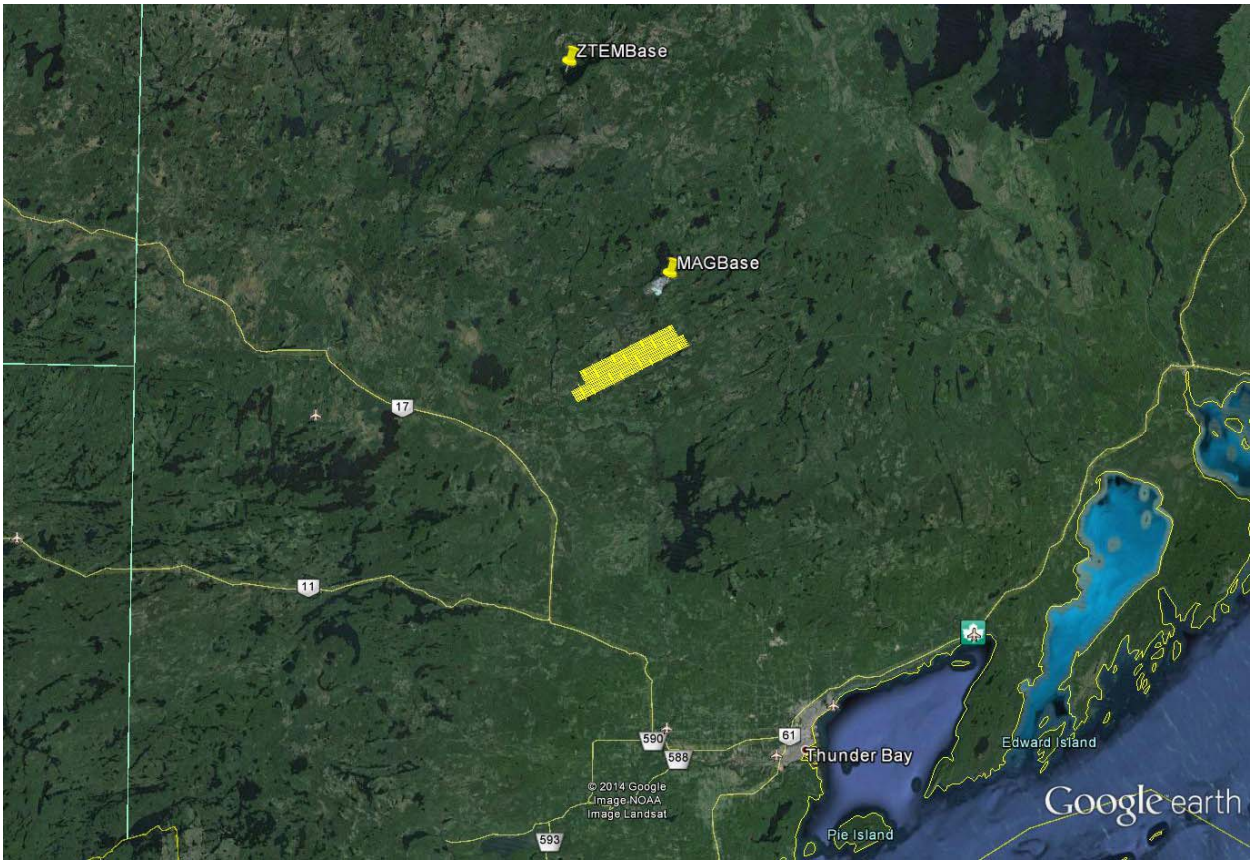

Figure 2: The Block, with ZTEM and Magnetic Base Station Locations

The block was flown in an east to west (N 65° E azimuth) direction, with a flight line spacing of 200 metres, as depicted in Figure 3. Tie lines were flown perpendicular to the traverse lines at a spacing of 2000 metres, in a north to south (N 155° E azimuth) direction. For more detailed information on the flight spacing and direction see Table 1.

1.3 Topographic Relief and Cultural Features

Topographically, the block exhibits a shallow relief with an elevation ranging from 436 to 495 metres above mean sea level over an area of 103 square kilometres (Figure 3).

The survey area has various rivers and streams running throughout which connects various lakes and wetlands. There are visible signs of culture such as roads throughout the survey.

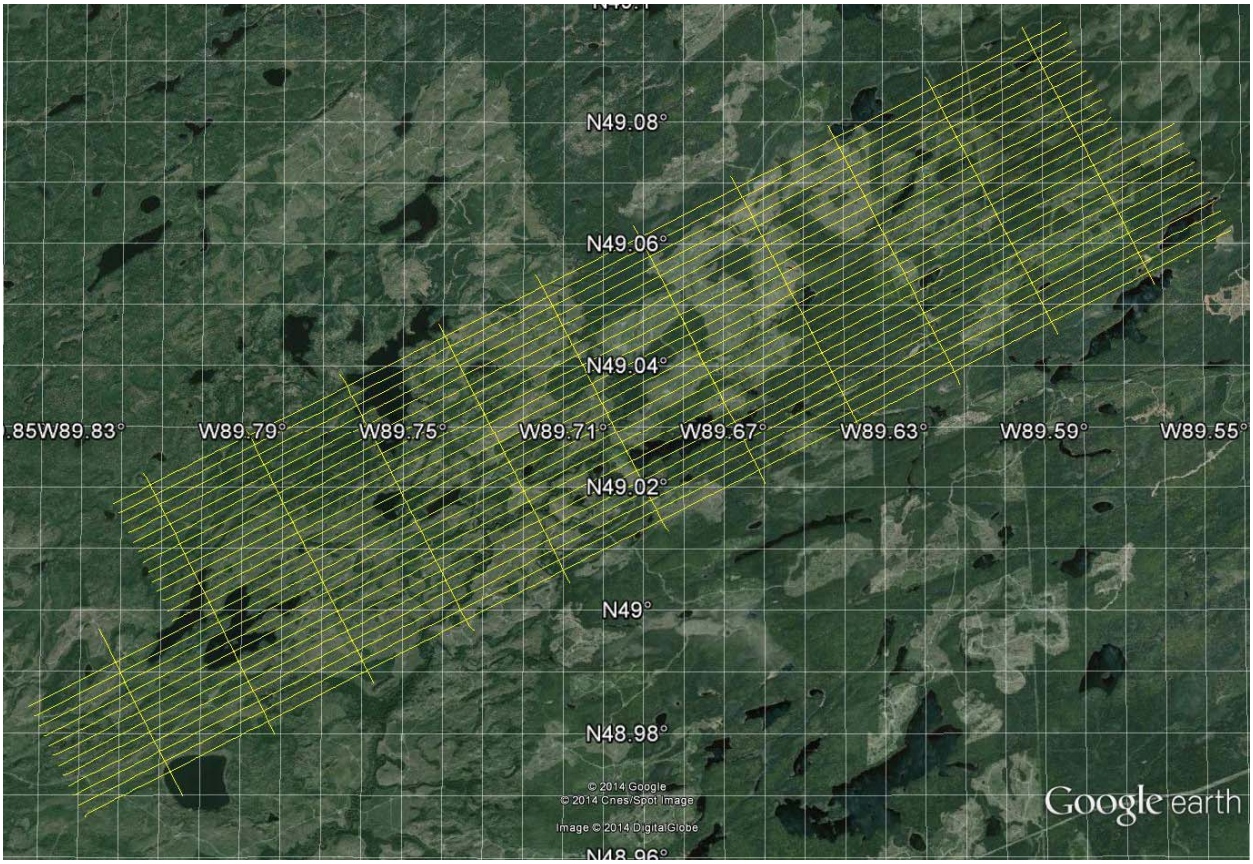

Figure 3: Google Earth image of the survey

The block 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 052A13 and 052H04.

2. DATA ACQUISITION

2.1 Survey Area

The survey block (see Location map in Appendix A and Figure 2) and general flight specifications are as follows:

Table 1: Survey Specifications

Survey block	Traverse Line spacing (m)	Area (Km^2)	Planned Line-km	Actual[1] Line-km	Flight direction	Line numbers
Block	Traverse: 200	103	524	535	N 65° E / N 245° E	L1000 – L1240
	Tie: 2000		51	56	N 155° E / N 335° E	T2000 – T2100
TOTAL		**103**	**575**	**591**		

Survey block boundaries co-ordinates are provided in Appendix B.

2.2 Survey Operations

Survey operations were based out of Lac des Iles Ontario on November 4th, 2014 until November 21st, 2014. The following table shows the timing of the flying.

Table 2: Survey Schedule

Date	Flight #	Flown km	Block	Crew location	Comments
4-Nov-2014				Lac des Iles Mine, Ontario	Mobilization
5-Nov-2014				Lac des Iles Mine, Ontario	Mobilization
6-Nov-2014				Lac des Iles Mine, Ontario	Crew arrived
7-Nov-2014				Lac des Iles Mine, Ontario	System assembly
8-Nov-2014				Lac des Iles Mine, Ontario	System assembly
9-Nov-2014				Lac des Iles Mine, Ontario	System assembly & testing
10-Nov-2014				Lac des Iles Mine, Ontario	Testing
11-Nov-2014				Lac des Iles Mine, Ontario	Testing limited due to weather
12-Nov-2014				Lac des Iles Mine, Ontario	No Testing due to weather & fuel issues
13-Nov-2014				Lac des Iles Mine, Ontario	No Testing due to weather & fuel issues
14-Nov-2014				Lac des Iles Mine, Ontario	No Testing due to weather & contaminated fuel
15-Nov-2014				Lac des Iles Mine, Ontario	Testing
16-Nov-2014				Lac des Iles Mine, Ontario	Testing
17-Nov-2014				Lac des Iles Mine, Ontario	No Testing due to weather
18-Nov-2014	1,2	199	Shelby	Lac des Iles Mine, Ontario	199km flown
19-Nov-2014				Lac des Iles Mine, Ontario	No production due to weather
20-Nov-2014				Lac des Iles Mine, Ontario	No production due to technical issues
21-Nov-2014	3,4	377	Shelby	Lac des Iles Mine, Ontario	Remaining kms were flown – flying complete

[1] Actual line-km represents the total line-km contained in the final databases. These line-km normally exceed the Planned line-km's, as indicated in the survey NAV file.

2.3 Flight Specifications

During the survey the helicopter was maintained at a mean height of 152 metres above the ground with a nominal survey speed of 80 km/hour for the survey block. This allowed for a nominal EM sensor terrain clearance of 82 metres and a magnetic sensor clearance of 97 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 feature.

On return of the aircrew to the base camp the survey data were 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 trained personnel.

2.4 Aircraft and Equipment

2.4.1 Survey Aircraft

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

2.4.2 Airborne Receiver

The airborne ZTEM receiver coil measures the vertical component (Z) of the EM field. The receiver coil is a Geotech Z-Axis Tipper (ZTEM) loop sensor which is isolated from most vibrations by a patented suspension system and is encased in a fibreglass shell. It is towed from the helicopter using an 85 metre long cable as shown in Figure 4. The cable is also used to transmit the measured EM signals back to the data acquisition system.

The coil has a 7.4 metre diameter with an orientation to the Vertical Dipole. The digitizing rate of the receiver is 2000 Hz. Attitudinal positioning of the receiver coil is enabled using 3 GPS antennas mounted on the coil. The output sampling rate is 0.4 seconds (see Section 2.4.7)

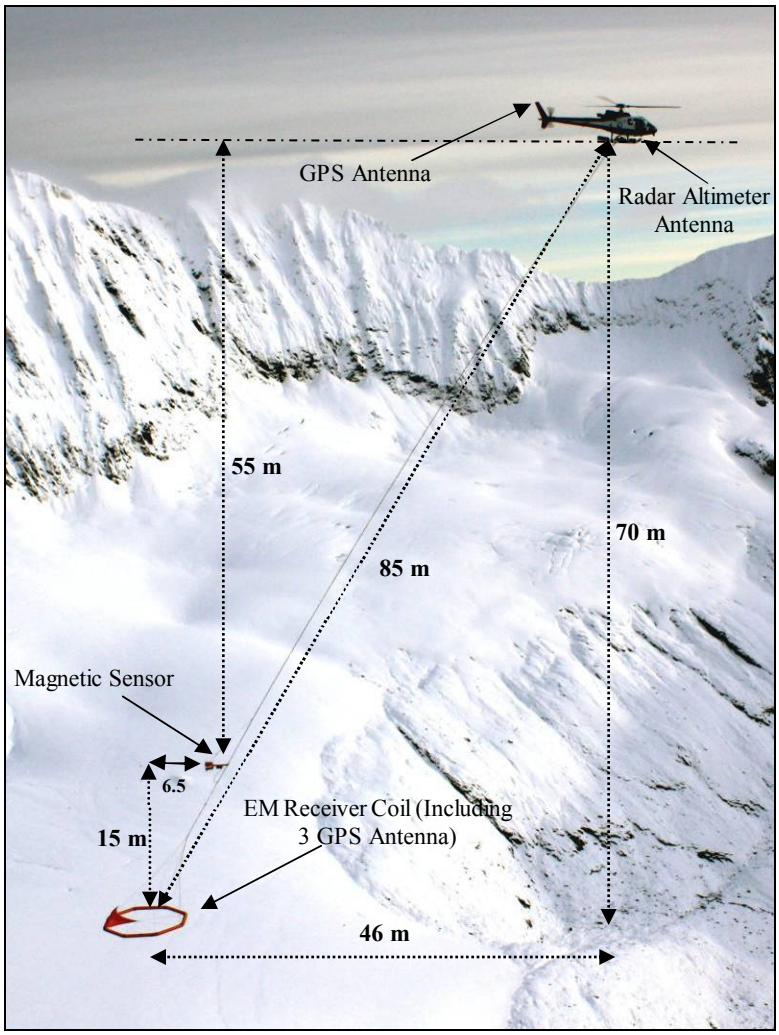

Figure 4: ZTEM System Configuration

2.4.3 Base Station Receiver

The Geotech ZTEM base station deployed on this survey was consisted of three orthogonal coils as shown in Figure 5. The measured field by these coils provide horizontal X and Y components of the EM reference field which is further used with the airborne coil data to calculate the in-line and cross-line component of the Tzx and Tzy field. One side of each coil is 3.04 metres.

The base station for the survey was installed in a rock field on the northeast corner of the block (49°31'10"N, 89°51'36"W) away from any cultural sources. The azimuth of the reference coil was N208°E (named as A) and for the orthogonal component it was N298°E (named as B). Angles A and B are taken into account together with the survey lines azimuth to calculate the in-line (Tzx) and cross-line (Tzy) field utilizing a proprietary software.

Figure 5: ZTEM base station receiver coils.

2.4.4 Airborne magnetometer

The magnetic sensor utilized for the survey was a Geometrics split-beam optically pumped caesium vapour magnetic field sensor, mounted in a separate bird, and towed on a cable at a mean distance of 55 metres below the helicopter (Figure 4). The sensitivity of the magnetic sensor is 0.02 nanoTesla (nT) at a sampling interval of 0.1 seconds. The magnetometer will perform continuously in areas of high magnetic gradient with the ambient range of the sensor approximately 20k-100k nT. The Aerodynamic magnetometer noise is specified to be less than 0.5 nT. The magnetometer sends the measured magnetic field strength as nanoTesla to the data acquisition system via the RS-232 port.

2.4.5 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.

2.4.6 GPS Navigation System

The navigation system used was a Geotech PC104 based navigation system utilizing a NovAtel WAAS(Wide Area Augmentation System) enabled OEM4-G2-3151W GPS receiver, Geotech navigation 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 5). 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.

2.4.7 Digital Acquisition System

The power supply and the data acquisition system are mounted on an equipment rack which is installed into the helicopter. Signal and power wires are run through the helicopter to connect on to the tow cable outside. The tow cable supports the ZTEM and magnetometer birds during flight via a safety shear pin connected to the helicopter hook. The major power and data cables have a quick disconnect safety feature as well. The installation was undertaken by the Geotech Ltd. crew and was certified before surveying.

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 3.

Table 3: Acquisition and Processing Sampling Rates

DATA TYPE	ACQUISITION SAMPLING	PROCESSING SAMPLING
ZTEM Receiver	0.0005 sec	0.4 sec
Magnetometer	0.1 sec	0.4 sec
GPS Position	0.2 sec	0.4 sec
Radar Altimeter	0.2 sec	0.4 sec
ZTEM Base station	0.0005 sec	– –

2.4.8 Mag Base Station

A combined magnetometer/GPS base station was utilized on this project. A Geometrics Caesium split-beam 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 sensors for the block were installed at the back of a building (49° 09'0" N, 89° 36'0" W) 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.

Field:

Project Manager:	Darren Tuck (Office)
Data QC:	Nick Venter (Office)
Crew chief:	Les Moschuk
Operator:	Ben Bruder

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

Pilot:	Tyson Murphy Bruno Prieur
Mechanical Engineer:	n/a

Office:

Preliminary Data Processing:	Nick Venter
Final Data Processing:	Geoffrey Plastow
Final Data QC:	Geoffrey Plastow
2D Inversions:	Shengkai Zhao
Reporting/Mapping:	Wendy Acorn

Data acquisition phase was carried out under the supervision of Andrei Bagrianski, P. Geo, Chief Operating Officer. Processing and 2D Inversions phases were carried out under the supervision of Geoff Plastow P. Geo Data Processing Manager and Jean Legault, P. Geo, P. Eng, Chief Geophysicist (Interpretation). The overall contract management and customer relations were by Mandy Long.

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, UTM Zone 16 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 In-field Processing and Quality Control

In-Field data processing and quality control are done on a flight by flight basis by a qualified data processor (see Section 3.0). Processing steps and check-up procedures are designed to assure the best possible final quality of ZTEM survey data. A general overview of those steps is presented in the following paragraphs.

The In-Field quality control can be separated into several phases:

a. GPS Processing Phase: GPS Data are first examined and evaluated during the GrafMov processing.
b. Raw data, ZTEM viewer phase:

   Data can be viewed, examined for consistency, individual channel spectra examined and overall noise estimated in the viewer provided by the ZTEM proprietary software, on the raw flight data and raw base station data separately, on the merged data, and finally on the data that have undergone ZTEM processing.
c. Field Geosoft phase:

   Magnetic data, Radar altimeter data, GPS positioning data are re-examined and processed in this phase. Prior to splitting the lines EM data are examined flight by flight and the effectiveness of applying the attitude correction evaluated. After splitting the lines, a set of grids are generate for each parameter and their consistency evaluated. Data profiles are also re-evaluated on a line to line basis. A power line monitor channel is available in order to identify power line noise.

4.3 GPS Processing

Three GPS sensor (mounted on the airborne receiving loop) measurements were differentially corrected using the Waypoint GrafMov^{TM} software in order to yield attitude corrections to recorded EM data.

4.4 ZTEM Electromagnetic Data

The ZTEM data were processed using proprietary software. Processing steps consist of the following preliminary and final processing steps:

4.4.1 Preliminary Processing

a. Airborne EM, Mag, radar altimeter and GPS data are first merged with EM base station data into one file.
b. Merged data are viewed and examined for consistency in an incorporated viewer
c. In the next, processing phase, the following entities are taken into account:
   - the Base station coils orientation with respect to the Magnetic North,
   - the Local declination of the magnetic field,
   - Suggested direction of the X coordinate (North or line direction),
   - Sensitivity coefficient that compensates for the difference in geometry between the base station and airborne coils.
   - Rejection filters for the 60 Hz and helicopter generated frequencies.
d. Six frequencies (30, 45, 90, 180, 360, and 720 Hz) are extracted from the airborne EM time-series coil response using windows of 0.4 seconds and the base station coils using windows of 1.0 seconds.
e. The real (In-Phase) and imaginary (Quadrature) parts of the tipper transfer functions are derived from the In-line (X or Tzx) and Cross-line (Y or Tzy) components.
f. Such processed EM data are then merged with the GPS data, magnetic base station data and exported into a Geosoft xyz file.

4.4.2 Geosoft Processing

Next stage of the preliminary data processing is done in a Geosoft ™ environment, using the following steps:

a. Import the output xyz file from the AFMAG processing, as well as the base Mag data into one database.
b. Split lines according to the recorded line channel,
c. GPS processing, flight path recovery (correcting, filtering, calculating Bird GPS coordinates, line splitting)
d. Radar altimeter processing, yielding the altitude values in metres.
e. Magnetic spike removal, filtering (applied to both airborne and base station data). Calculation of a base station corrected mag.
f. Apply preliminary attitude corrections to EM data (In phase and Quadrature), filter and make preliminary grids and profiles of all channels.

4.4.3 Final Processing

Final data processing and quality control were undertaken by Geotech Ltd headquarters in Aurora, Ontario by qualified senior data processing personnel.

A quality control step consisted of re-examining all data in order to validate the preliminary data processing and to allow for final adjustments to the data.

Attitude corrections were re-evaluated, and re-applied, on component by component, flight by flight, and frequency by frequency bases. Any remaining line to line system noise was removed by applying a mild additional levelling correction.

4.4.4 ZTEM Profile Sign Convention

Tzx and Tzy tipper components do not exhibit maxima or minima above conductors, resistors or at contacts; in fact they produce cross-over type anomalies (Ward, 1959; Vozoff, 1972; Labson, 1985). The sign of the cross-over (positive-to-negative or neg-to-pos) or its polarity (normal or reversed) depends on the line direction and follows a well-defined convention. The crossover polarity sign convention for ZTEM is according to the right hand Cartesian rule (Z positive –up) that is commonly used for multi-component transient electromagnetic methods.

For the north east to southwest lines of the block the sign convention for the In-phase Tzx in-line component crossover is positive-negative pointing N 65°E for tabular conductors' perpendicular to the profile (Figure 6-right). The corresponding Tzy component in-phase cross-over polarity is positive-negative pointing N 335°E (90 degrees counter clockwise to Tzx) according to the right hand Cartesian rule.

For the northwest to southeast tie-lines of the block the sign convention for the In-phase Tzx in-line component crossover is positive-negative pointing N 155°E for tabular conductors' perpendicular to the profile (Figure 6-left). The corresponding Tzy component in-phase cross-over polarity is positive-negative pointing N 65°E (90 degrees counter clockwise to Tzx) according to the right hand Cartesian rule.

Conversely, tabular resistive bodies produce In-Phase cross-overs for the In-line Tzx and Cross-line Tzy components that are opposite in sign to conductors, i.e., negative to positive cross-overs.

On the other hand, the Quadrature part of the tipper transfer function can produce cross-overs in Tzx and Tzy that are of either polarity over a conductor or resistor. For this reason, the ZTEM profile sign convention only applies to the In-phase part of the tipper response. A brief discussion of ZTEM and AFMAG, along with selected forward model responses is presented in Appendix D.

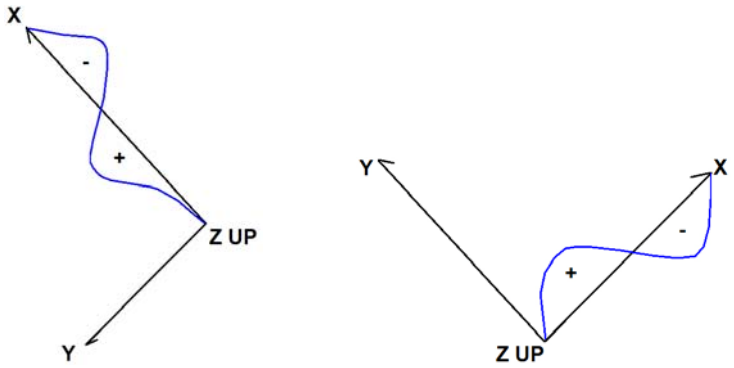

Figure 6: ZTEM Crossover Polarity Convention for Tzx and Tzy for tie-lines (Left) and survey lines (Right)

4.4.5 ZTEM Quadrature Sign Dependence

One important note regarding the sign of the ZTEM Quadrature, relative to the In-Phase component, particularly with regards to computer modeling and inversion.

The sign of the magnetotelluric Quadrature relative to the In-Phase tipper transfer function component pertains to the Fourier transformation of the time series to give frequency domain spectra. There are two widely used conventions for time dependence in the transformations, **exp(+iωt)** and **exp(-iωt).** That which is implemented largely is a matter of personal preference and precedent. The importance of the In-Phase and Quadrature sign convention is not critical, provided that it is known and documented.

In ZTEM, the data processing code used for the Fourier transformation the time-series data to frequency domain spectra adopts a **exp(-iωt)** time dependence (J. Dodds, Geo Equipment Manufacturing, pers. comm., Nov-2009). Whereas in the forward modeling and inversion program Zvert2d, the sign of the Quadrature relative to the In-Phase transfer function assumes an **exp(+iωt)** dependence[2].

As a result, for users interested in computer modeling and inversion of ZTEM data, the sign of the Quadrature will need to be reversed, relative to the In-Phase component, in order to provide a proper result (Figure 7). Indeed this reverse Quadrature polarity convention is assumed in all forward modeling and inversion of ZTEM data, as described in Figures 5-7 in Appendix D.

[2] Phillip E. Wannamaker (2009): Two-dimensional Inversion of ZTEM data: Synthetic Model Study and Test Profile Images, Internal Geotech technical report by Emblem Exploration Services Inc., January 22, 2009, 32 pp.

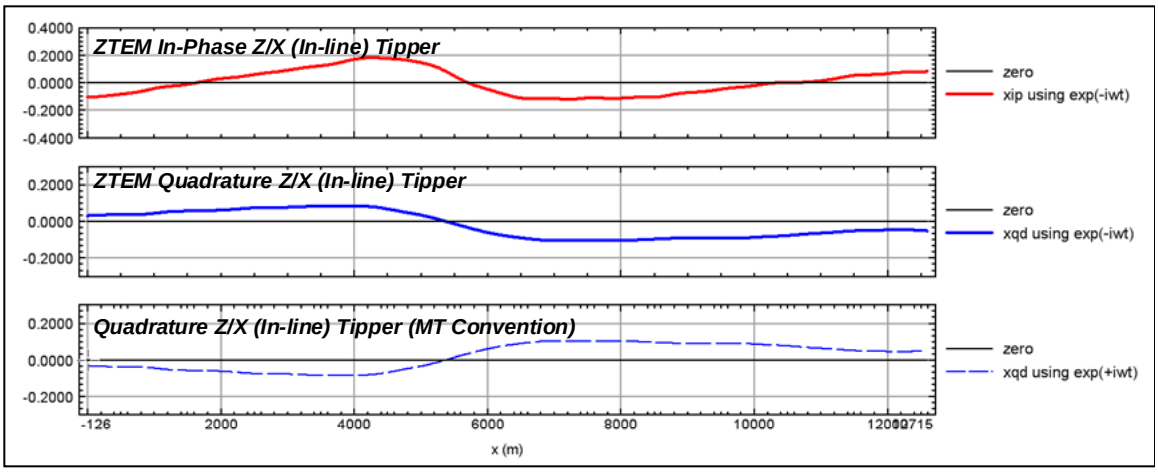

Figure 7: Illustration of ZTEM In-Phase & Quadrature Tipper transfer function polarity convention (e-iωt) relative to equivalent MT Tipper Quadrature polarity convention (e+iωt) for a graphitic conductor in Athabasca Basin, SK.

4.4.6 Total Divergence and Phase Rotation Processing

In a final processing step DT (Total Divergence) and PR (Phase Rotation) processing are applied to the multi-frequency In-phase and Quadrature ZTEM data. This is due to the crossover nature of the Tipper Responses; these additional processing steps are applied to convert them into local maxima for easier interpretation.

To present the data from both tipper components into one image, the Total Divergence parameter, termed the DT is calculated from the horizontal derivatives of the Tzx and Tzy tippers (Lo and Zang, 2008). It is analogous to the "Peaker" parameter in VLF (Pedersen, 1998).

Total Divergence DT:	***DT = DIV (Tzx, Tzy)*** ***= d(Tzx)/dx+d(Tzy)/dy***

This DT parameter was introduced by Petr Kuzmin (Milicevic, 2007, p. 13) and is derived for each of the In Phase and Quadrature components at individual frequencies. These in turn allow for minima over conductors and maxima over resistive zones. DT grids for each of the extracted frequencies were generated accordingly, using a reverse colour scheme with warm colours over conductors and cool colours over resistors.

The DT gives a clearer image of conductor's location and shape but, as a derivative, it does not preserve some of the long wavelength information and is also sensitive to noise.

As an alternative, a 90 degree Phase Rotation (PR) technique is also applied to the grids of each individual component (Tzx and Tzy). It transforms bipolar (cross over) anomalies into single pole anomalies with a maximum over conductors, while preserving long wavelength information (Lo et al., 2009). The two orthogonal grids are then usually added to obtain a Total Phase Rotated (TPR) grid for the In-Phase and Quadrature.

Total Phase-Rotation TPR:	***= PR (Tzx) + PR (Tzy)***

A presentation of the ZTEM test survey results over unconformity uranium deposits that illustrates DT and TPR examples, as documented by Lo et al. (2009) is provided in Appendix E.

4.4.7 2D EM Inversion

2d inversions of the ZTEM results were performed over selected lines using the Geotech Av2dtopo software developed by Phil Wannamaker, U. of Utah, for Geotech Ltd. The inversion algorithm is based on the 2D inversion code with Jacobians of de Lugao and Wannamaker (1996), the 2D forward code of Wannamaker et al (1987), and the Gauss-Newton parameter step equations of Tarantola (1987). Av2dtopo has been developed/modified for use with our ZTEM platform by taking into account the ground topography and the air-layer between the receiver bird and the ground surface. It also implements a depth-of-investigation (DOI) index, using the 1.5x MT maximum skin depth and integrated 1D conductance method of Spies (1989). This is shown using a dashed DOI line and opaque coloring in the 2d inversion section of Appendix F.

The 2D code only considers the In-Line (Tzx) data and assumes that the strike lengths of bodies are infinite and orthogonal to the profile. The code is designed to account for the ZTEM vertical coil receiver and fixed base station reference measurements. The inversion uses a model-mesh consisting of 440 cells laterally and 112 cells vertically. Typically the ZTEM data are de-sampled to 192 pts, in order to allow the inversion to run in 20 minutes or less. Typically, between 1-2% errors are added to the In-line in-phase (XIP) and Quadrature (XQD) data obtained at 30,45,90,180,360 & 720Hz. Errors are adjusted until numerical convergence (<1.0 rms) is attained in 5 iterations or less. All inversions are based on an apriori homogeneous starting half-space model, usually between 100 – 1000ohm metres, as determined by the interpreter, based on model testing, as described in Appendix F.

4.5 Magnetic Data

The processing of the total magnetic field intensity (TMI) data involved the correction for diurnal variations by using the digitally recorded ground base station magnetic values. The base station magnetometer data were edited and merged into the Geosoft GDB database on a daily basis. The aeromagnetic data were 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 micro-levelling procedure was applied to remove persistent low-amplitude components of flight-line noise remaining in the data.

The final total magnetic field intensity data (TMI_IGRF) channel was obtained by removing the regional IGRF (International Geophysical Reference Field) magnetic field from the final levelled TMI data using the IGRF GX in Geosoft Oasis Montaj™.

The corrected magnetic data were interpolated between survey lines using a random point gridding method to yield x-y grid values for a standard grid cell size of 40 metres. 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 1:20,000. The coordinate/projection system used was NAD83, UTM Zone 16 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 profile plans for the EM data that were generated for individual real (In-Phase) and imaginary parts (Quadrature) of the Tzx and Tzy components. Colour contour maps of the corresponding DT (Total Divergence) or TPR (Total Phase Rotated) grids for three of the six frequencies, (30, 45, 90, 180, 360 and 720Hz), as well as for corresponding Phase Rotated Grids for individual components.

3D views have been constructed by plotting the either DT or TPR grids at their respective penetration depths using a 1000 ohm-m half space, using the Bostick skin depth rule (Bostick, 1977) see Appendix D.

Final maps were chosen, in consultation with the client, to represent all collected data, are listed in Section 5.3.

Sample maps of the related 3D view, Magnetic and Total Divergence are included in this report and presented in Appendix C.

Digital Data

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

- DVD structure.

  There are two (2) main directories;

Data	contains databases and grids, 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 4.

Table 4: Geosoft GDB Data Format

Column	Description
X_NAD83	UTM Easting NAD83 Zone 16N, (Centre of the ZTEM loop) (metres)
Y_NAD83	UTM Northing NAD83 Zone 16N, (Centre of the ZTEM loop) (metres)
Longitude	Longitude – WGS84 (Centre of the ZTEM loop) (Decimal degree)
Latitude	Latitude – WGS84 (Centre of the ZTEM loop) (Decimal degree)
Z	Elevation- WGS84 (Centre of the ZTEM loop) (metres)
Radar	Helicopter terrain clearance from radar altimeter (metres - AGL)
Alt_B:	Calculated ZTEM Bird terrain clearance (metres)
DEM	Digital Elevation Model (above mean sea level, metres)
Gtime	UTC Time (seconds of the day)
basemag	Magnetic base station data, nT
Mag1	Measured total magnetic field, nT
Mag2	Diurnally-corrected total magnetic field, nT
TMI	total magnetic field, nT
TMI_IGRF	IGRF corrected TMI, nT
IGRF	International Geomagnetic Reference Field, nT
INC	Magnetic Inclination
DEC	Magnetic Declination
xIp_030Hz	Tzx In-Phase 30 Hz final corrected
xIp_045Hz	Tzx In-Phase 45 Hz final corrected
xIp_090Hz	Tzx In-Phase 90 Hz final corrected
xIp_180Hz	Tzx In-Phase 180 Hz final corrected
xIp_360Hz	Tzx In-Phase 360 Hz final corrected
xIp_720Hz	Tzx In-Phase 720 Hz final corrected
xQd_030Hz	Tzx Quadrature 30 Hz final corrected
xQd_045Hz	Tzx Quadrature 45 Hz final corrected
xQd_090Hz	Tzx Quadrature 90 Hz final corrected
xQd_180Hz	Tzx Quadrature 180 Hz final corrected
xQd_360Hz	Tzx Quadrature 360 Hz final corrected
xQd_720Hz	Tzx Quadrature 720 Hz final corrected
yIp_030Hz	Tzy In-Phase 30 Hz final corrected
yIp_045Hz	Tzy In-Phase 45 Hz final corrected
yIp_090Hz	Tzy In-Phase 90 Hz final corrected
yIp_180Hz	Tzy In-Phase 180 Hz final corrected
yIp_360Hz	Tzy In-Phase 360 Hz final corrected
yIp_720Hz	Tzy In-Phase 720 Hz final corrected
yQd_030Hz	Tzy Quadrature 30 Hz final corrected
yQd_045Hz	Tzy Quadrature 45 Hz final corrected
yQd_090Hz	Tzy Quadrature 90 Hz final corrected
yQd_180Hz	Tzy Quadrature 180 Hz final corrected
yQd_360Hz	Tzy Quadrature 360 Hz final corrected
yQd_720Hz	Tzy Quadrature 720 Hz final corrected
PLM	Power Line Monitor (60Hz)

- Grids in Geosoft GRD format, as follows:

TMI:	Total Magnetic Intensity (TMI)
TMI_CVG:	Calculated Vertical Derivative
TMI_IRGF:	IGRF corrected TMI
DEM:	Digital Elevation Model
PLM:	Power Line Monitor
XIP_xxxHz:	Tzx (in-line) In-Phase Component of Tipper at xxx hertz (ratio)
XQd_xxxHz:	Tzx (in-line) Quadrature Component of Tipper at xxx hertz (ratio)
YIP_xxxHz:	Tzy (cross-line) In-Phase Component of Tipper at xxx hertz (ratio)
YQd_xxxHz:	Tzy (cross-line) Quadrature Component of Tipper at xxx hertz (ratio)
XIP_xxxHz_PR:	Tzx (in-line) In-Phase Component Phase Rotated Tipper grid at xxx hertz (ratio)
XQd_xxxHz_PR:	Tzx (in-line) Quadrature Component Phase Rotated Tipper grid at xx hertz (ratio)
YIP_xxxHz_PR:	Tzy (cross-line) In-Phase Component Phase Rotated Tipper grid at xxx hertz (ratio)
YQd_xxxHz_PR:	Tzy (cross-line) Quadrature Component Phase Rotated Tipper grid at xxx hertz (ratio)
IP_xxxHz_TPR:	Total Phase Rotated (TPR) Tzx + Tzy grid from In-phase components at xxx Hz (ratio)
QD_xxxHz_TPR:	Total Phase Rotated (TPR) Tzx + Tzy grid from Quadrature components at xxx Hz (ratio)
IP_xxxHz_DT:	Total Divergence (DT) of Tzx + Tzy Tipper grid from In-phase components at xxx Hz (1000*ratio/m)
QD_xxxHz_DT:	Total Divergence (DT) of Tzx + Tzy Tipper grid from Quadrature components at xxx Hz (1000*ratio/m)

(Where xxx = 30, 45, 90, 180, 360 and 720Hz, yyyy = line number, zzzz = depth (m)

A Geosoft .GRD file has a .GI metadata file associated with it, containing grid projection information. A grid cell size of 40 metres was used.

- Maps at 1:20,000 scale in Geosoft MAP format, as follows:

GL140367_20K_3D_IP_DT:	3D view of In-Phase Total Divergence versus Skin Depth (30-720Hz)
GL140367_20K_TMI:	Total Magnetic Intensity (TMI)
GL140367_20K_45Hz_IP_DT:	45Hz In-Phase Total Divergence Grid
GL140367_20K_180Hz_IP_DT:	180Hz In-Phase Total Divergence Grid
GL140367_20K_720Hz_IP_DT:	720Hz In-Phase Total Divergence Grid
GL140367_20K_XIP_profiles_XIP_PR:	Tzx (In-line) In-Phase Profiles over 90Hz Phase Rotated In-Phase Grid
GL140367_20K_XQD_profiles_XQD_PR:	Tzx (In-line) Quadrature Profiles over a 90Hz Phase Rotated Quadrature Grid.
GL140367_20K_YIP_profiles_YIP_PR:	Tzy (Cross-line) In-Phase Profiles over 90Hz Phase Rotated In-Phase Grid
GL140367_20K_YQD_profiles_YQD_PR:	Tzy (Cross-line) Quadrature Profiles over 90Hz Phase Rotated Quadrature Grid.

- Maps are also presented in PDF format.

- The topographic data base was derived from 1:50000 NRC (Natural Resources Canada) NTDB data (www.geogratis.ca).

- Background shading is derived from NASA SRTM (Shuttle Radar Topography Mission) data.

- A Google Earth file “GL140367_FP.kml” is included, showing the flight path of each block. Free versions of Google Earth software from: http://earth.google.com/download-earth.html

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

A helicopter-borne ZTEM and aeromagnetic geophysical survey has been completed over the Shelby survey area located near Lac des Iles Mine, Ontario.

The total area coverage is 103 km^2. Total survey line coverage is 575 line kilometres. The principal sensors included a Z-Axis Tipper electromagnetic (ZTEM) system and a caesium magnetometer. Results have been presented as stacked profiles and contour colour images at a scale of 1:20,000.

6.2 Recommendations

Based on the geophysical results obtained, a number of interesting conductive structures were identified across the property. The magnetic results also contain worthwhile information in support of exploration targets of interest. We therefore recommend a more detailed interpretation of the available geophysical data, including the 2D ZTEM inversion for all survey lines, 3D magnetic inversion, 3D ZTEM inversion and structural interpretation in conjunction with the geology, prior to ground follow up and drill testing.

Respectfully submitted[3],

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December 2014

[3]Final data processing of the EM and magnetic data were carried out by Nick Venter and Geoffrey Plastow. from the office of Geotech Ltd. in Aurora, Ontario, under the supervision of Geoffrey Plastow, P.Geo., Data Processing Manager and Jean Legault, P. Geo, P. Eng, Chief Geophysicist (Interpretation).

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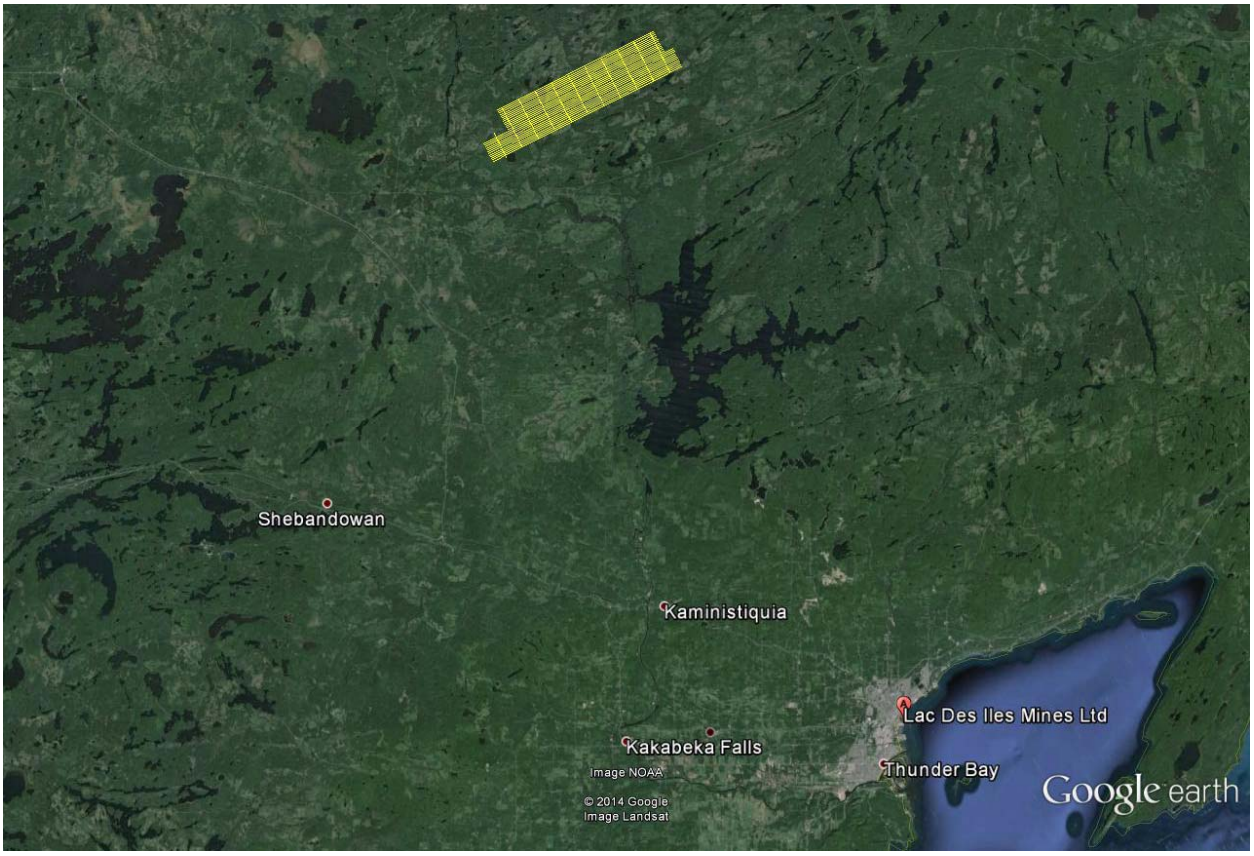
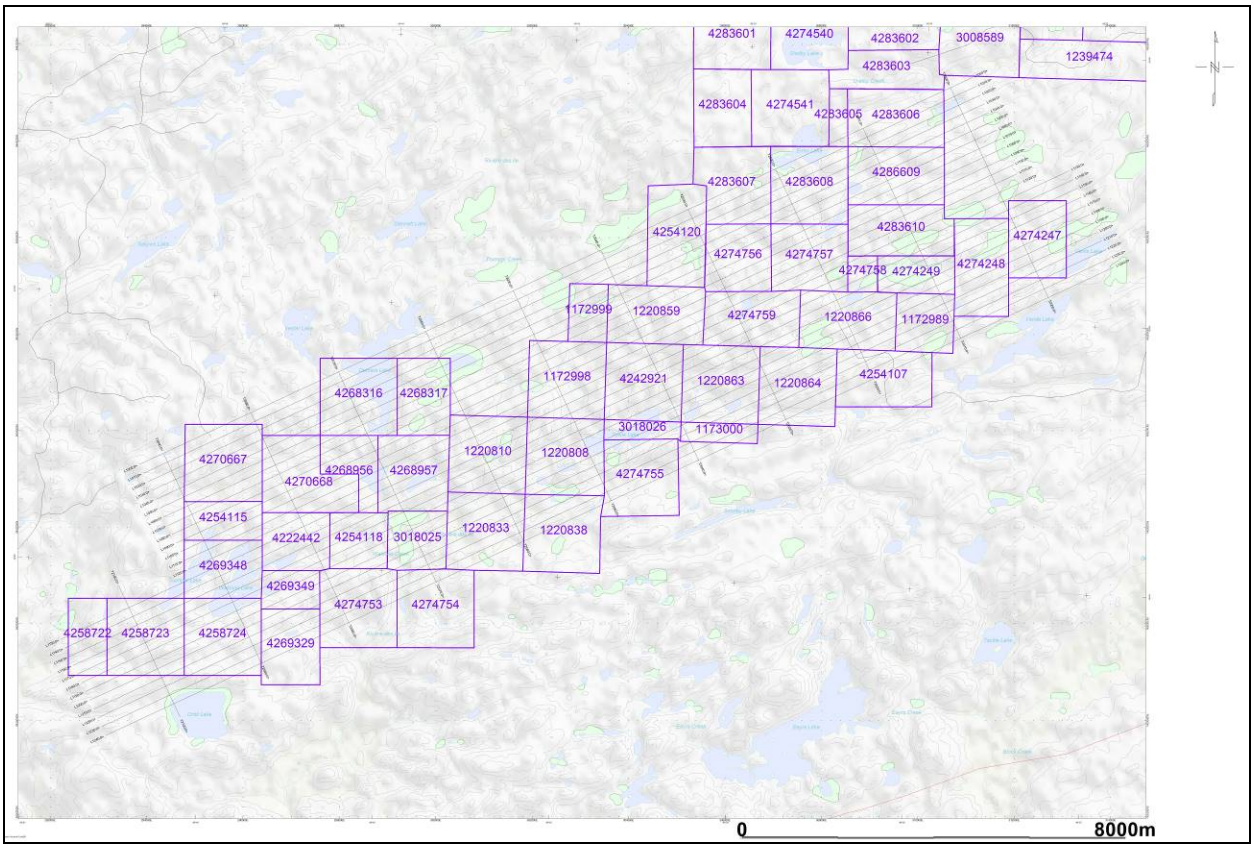
APPENDIX A

SURVEY AREA LOCATION MAP



Survey Overview Location Map



Mining Claims

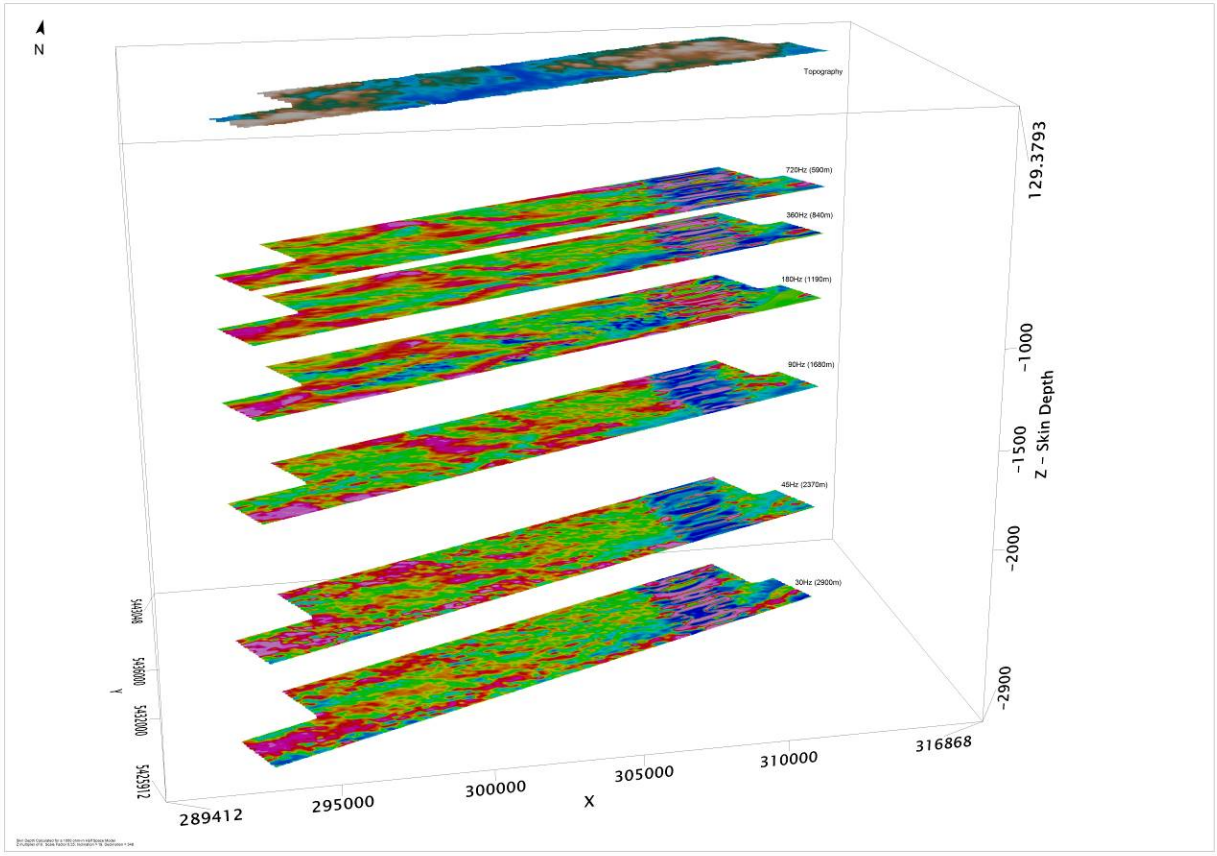
APPENDIX B

SURVEY BLOCK COORDINATES

(WGS84 Zone 16N)

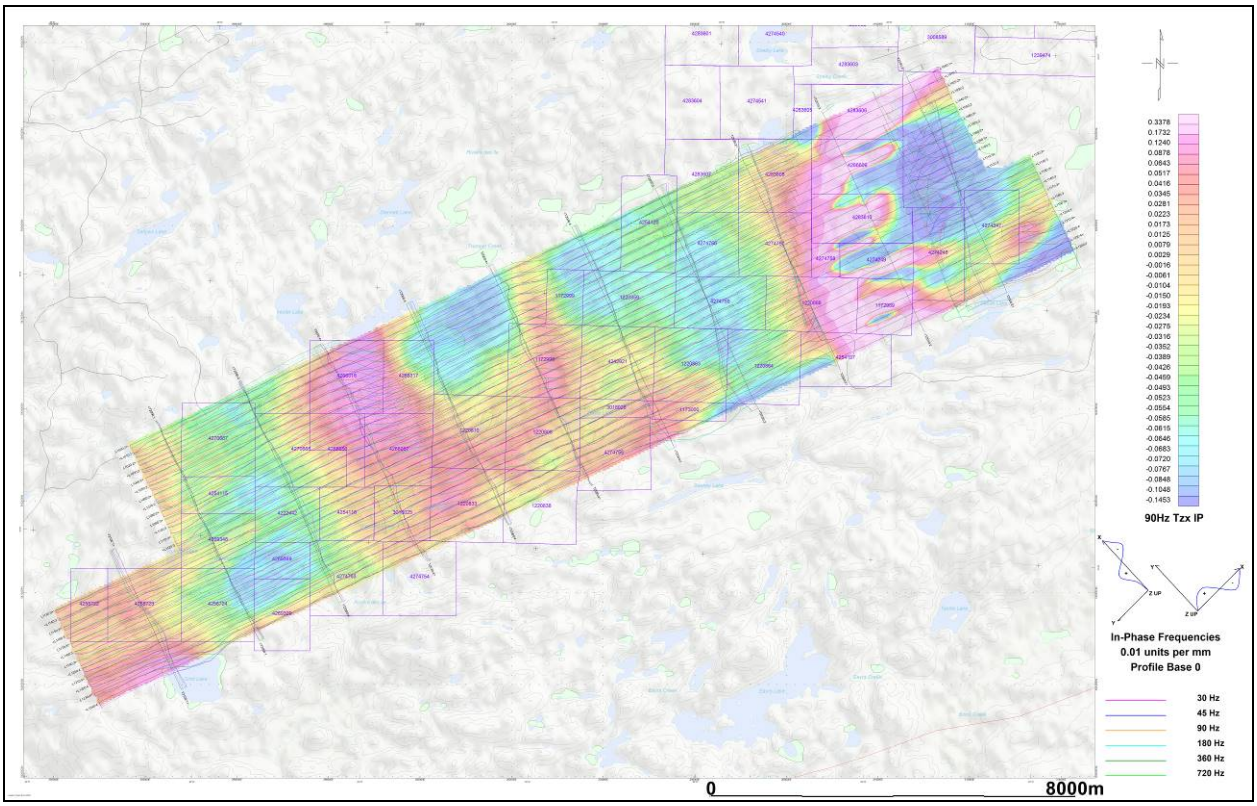
X	Y
293160	5427680
292140	5429855
294870	5431125
293850	5433300
311130	5441315
312150	5439140
313060	5439560
314075	5437385
293160	5427680

APPENDIX C
GEOPHYSICAL MAPS[1]

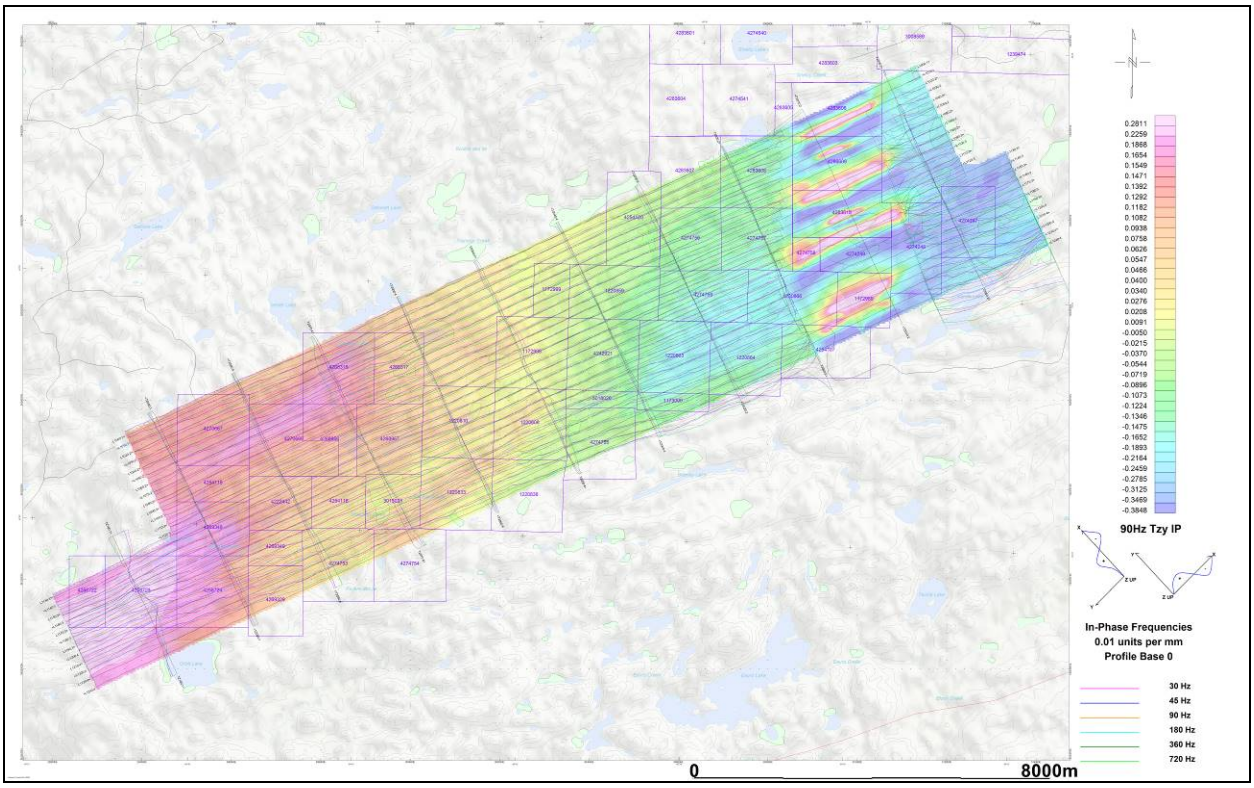


3D View of In-Phase, Total Divergence (DT) grids versus Skin Depth (30Hz–720Hz)

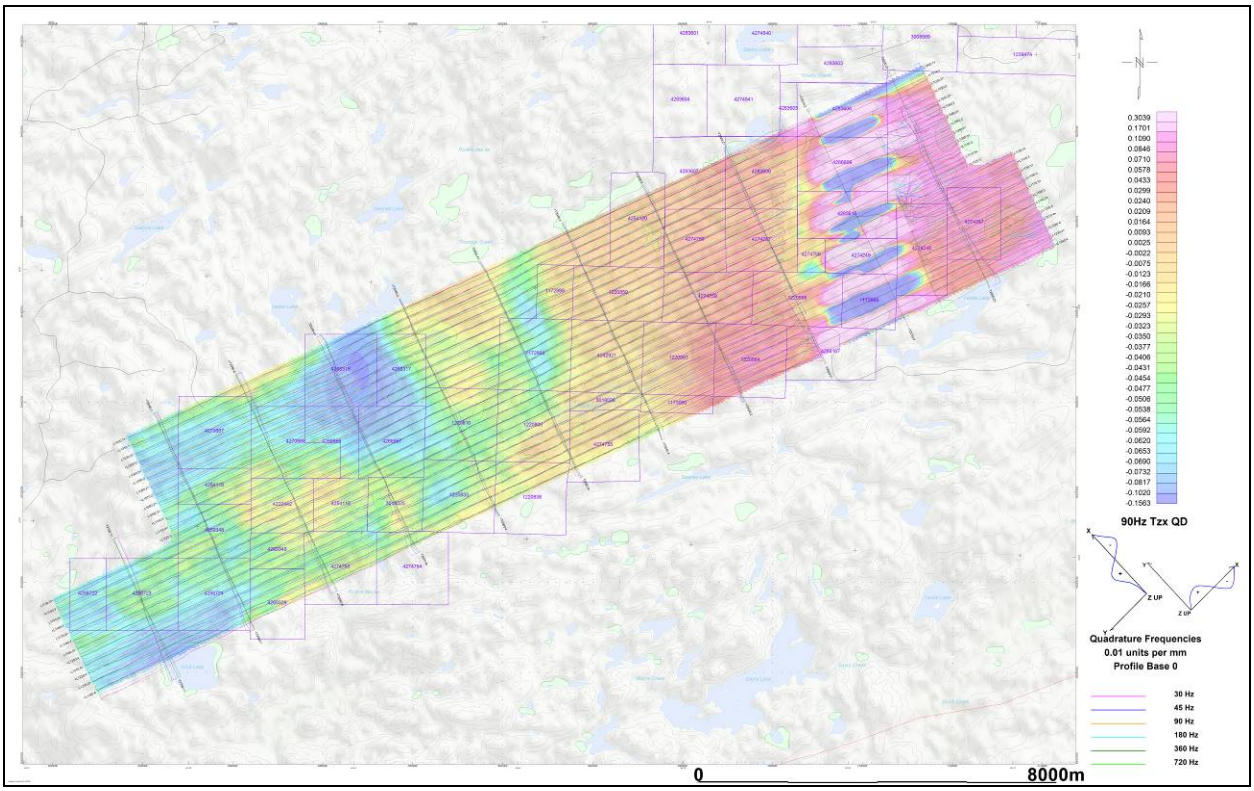
[1] Full size geophysical maps are also available in PDF format on the final DVD



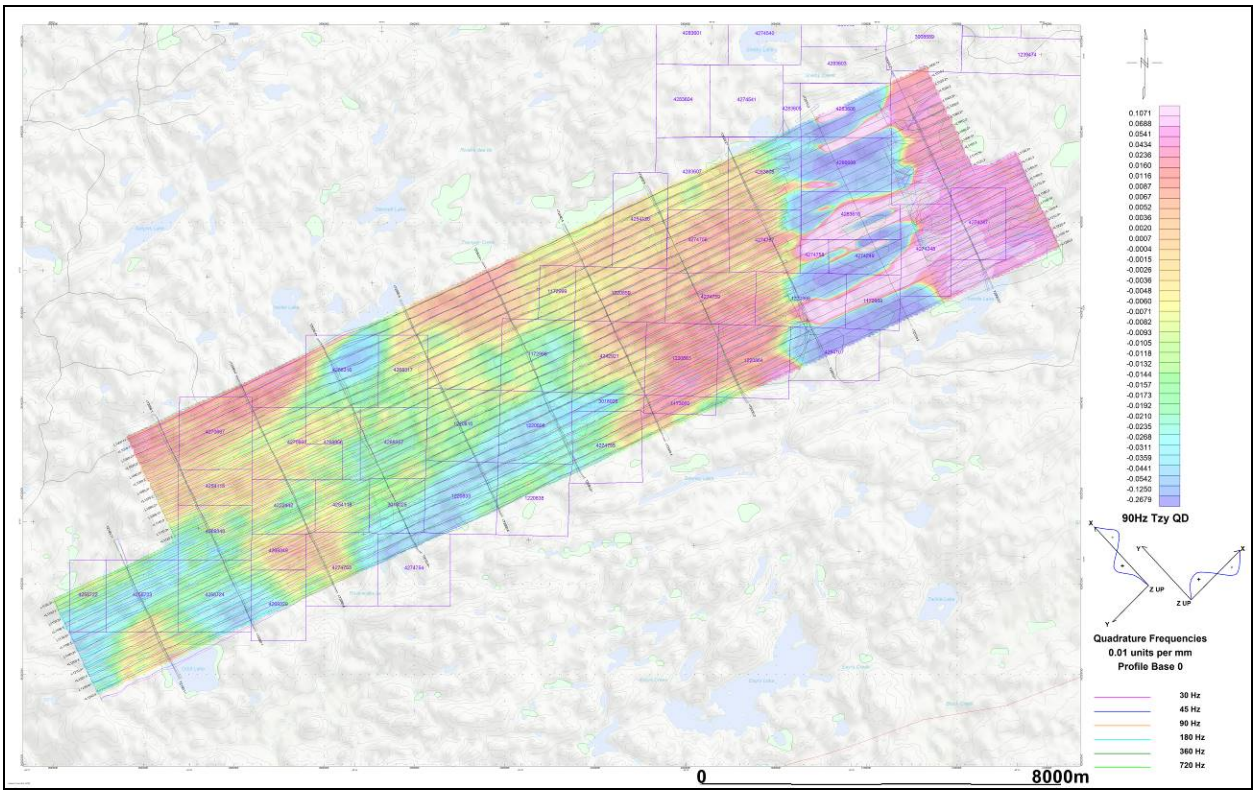
Tzx (In-line) In-Phase Profiles over 90Hz Rotated Tzx In-Phase Grid



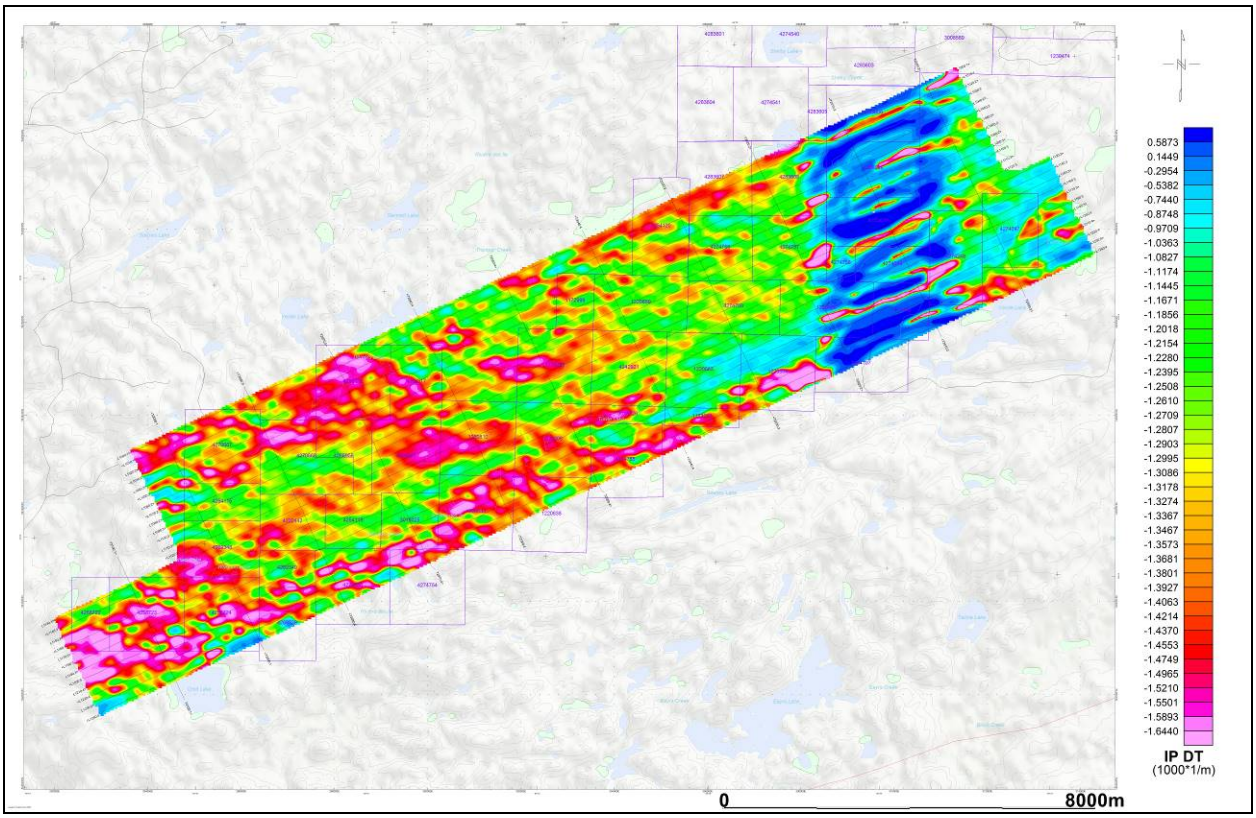
Tzy (Cross-line) In-Phase Profiles over 90Hz Rotated Tzy In-Phase Grid



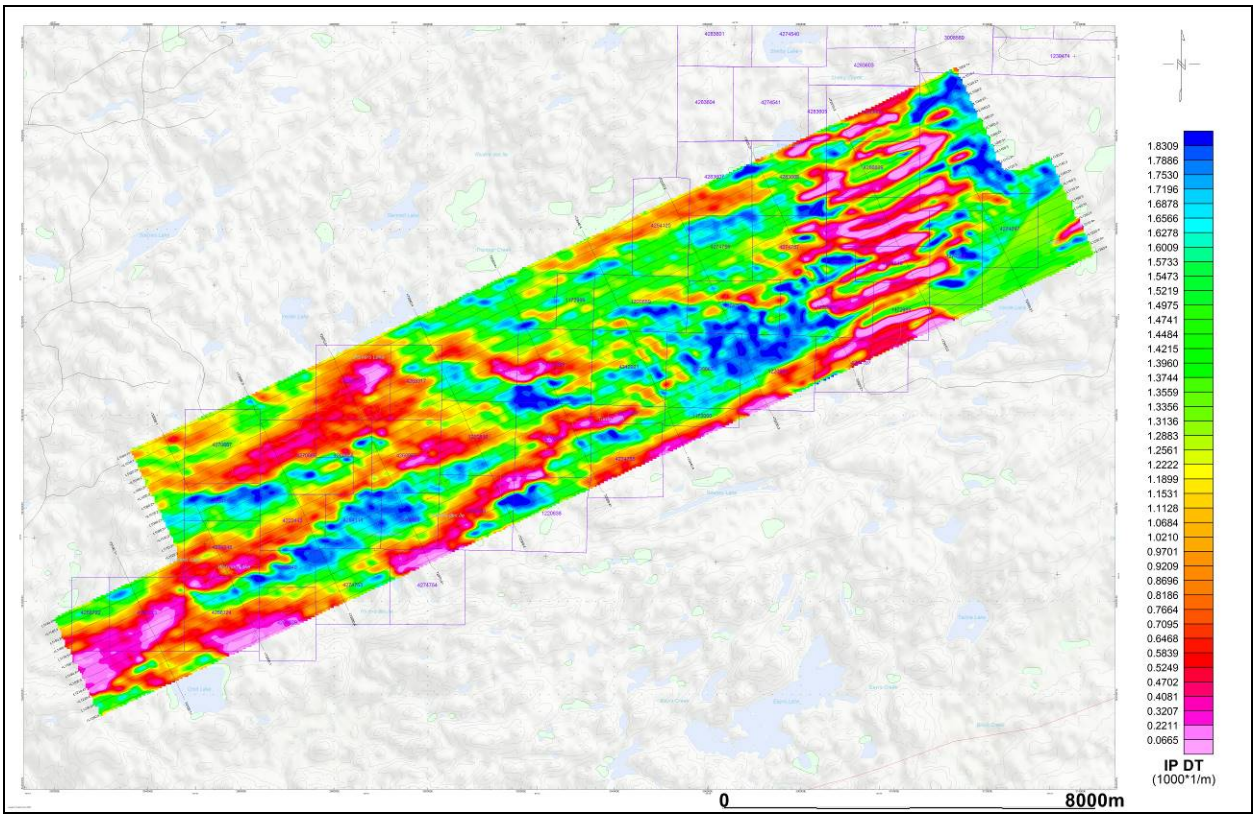
Tzx (In-line) Quadrature Profiles over 90Hz Rotated Tzx Quadrature Grid



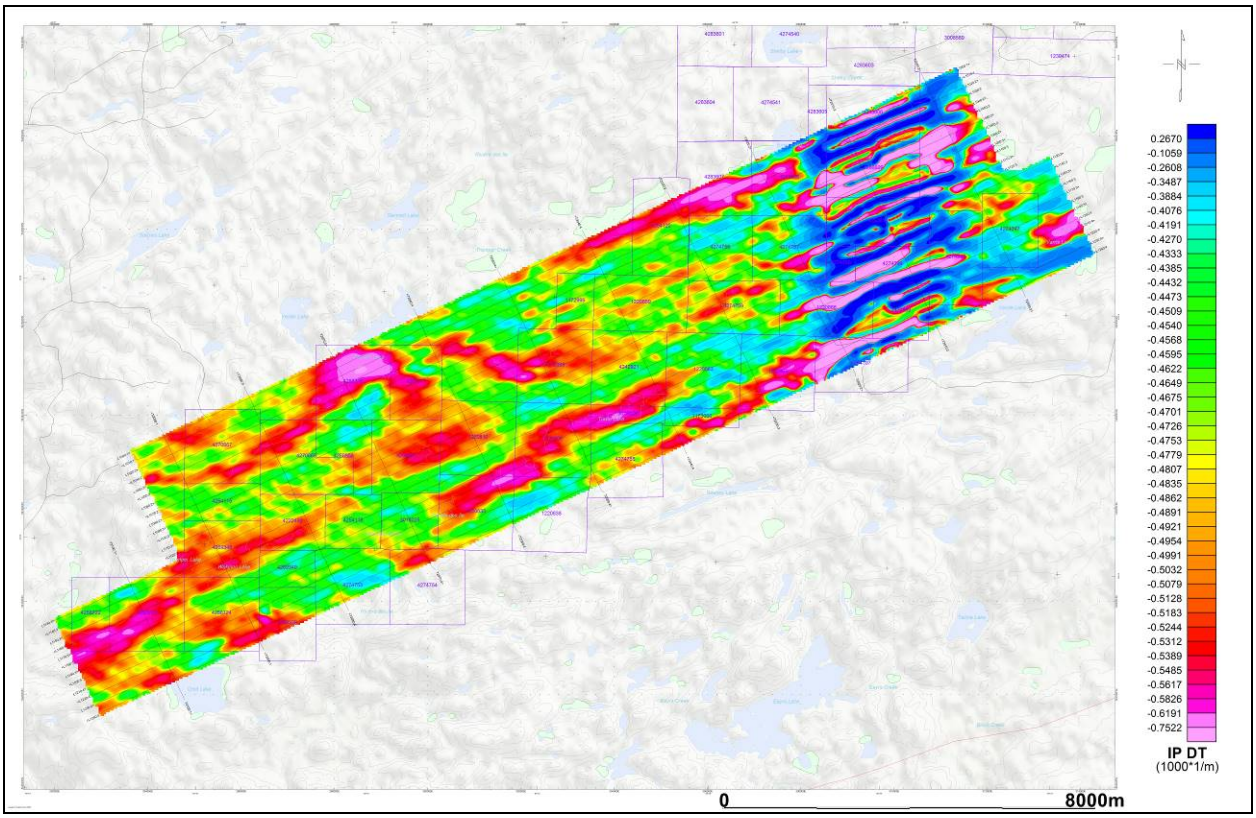
Tzy (Cross-line) Quadrature Profiles over 90Hz Rotated Tzy Quadrature Grid



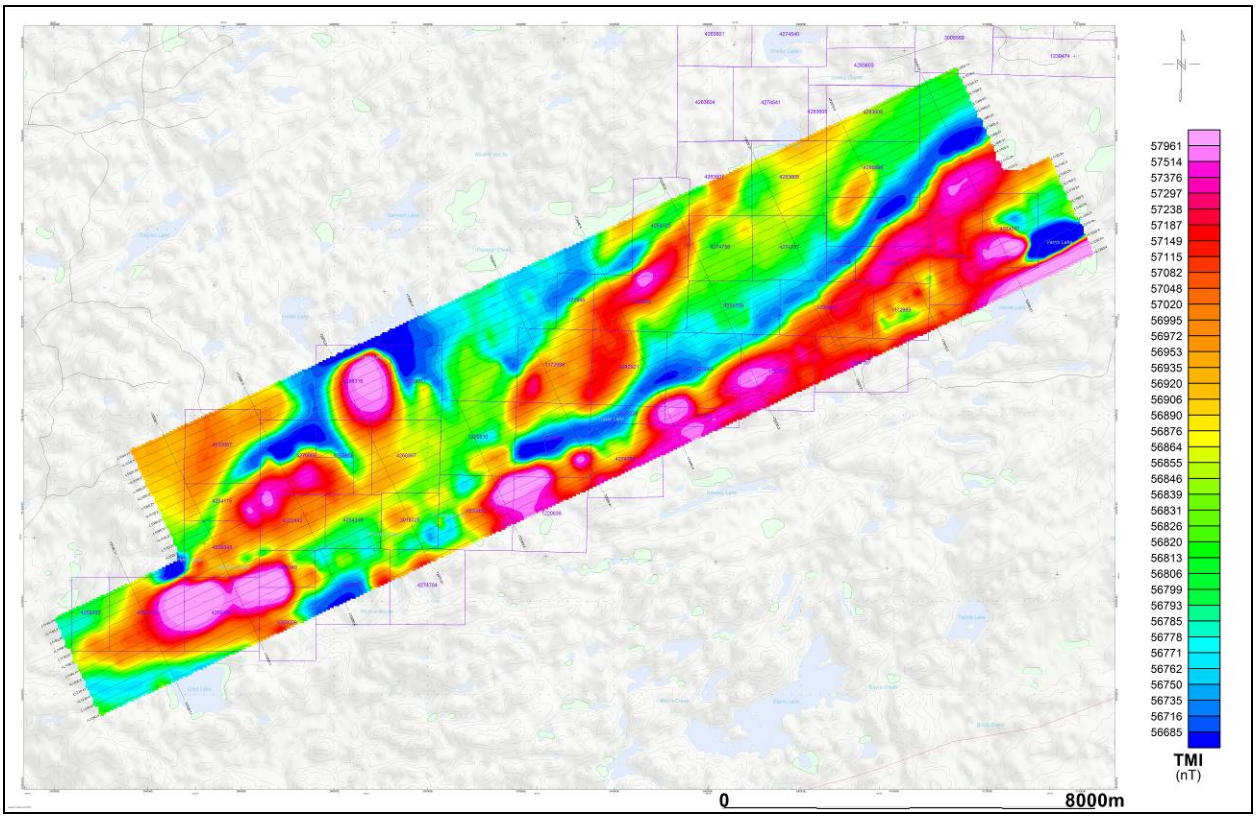
45Hz Total Divergence In-Phase (DT) Grid



180Hz Total Divergence In-Phase (DT) Grid



720Hz Total Divergence In-Phase (DT) Grid



Total Magnetic Intensity (TMI)

APPENDIX D

ZTEM THEORETICAL CONSIDERATIONS

A brief section on the theory behind the AFMAG technique is provided for completeness and a more comprehensive development of the theory can be found in standard texts. The natural EM field is normally horizontally polarized. Subsurface lateral variations of conductivity generate a vertical component, which is linearly related to the horizontal field. Although the fields look like random signals, they may be treated as the sum of sinusoids. At each frequency the field can be expressed as a complex number with magnitude and argument equal to the amplitude and phase of the sinusoid. The relation between the field components can then be expressed by a linear complex equation with two complex coefficients at any one frequency. These coefficients are dependent upon the subsurface and not upon the horizontal field present at any particular time and are appropriate parameters to measure (Vozoff, 1972).

$$\mathbf{Hz(f) = Tx(f)\ Hx(f) + Ty(f)\ Hy(f),} \qquad \mathbf{(1)}$$

Where

Hx(f), Hy(f) and Hz(f) are x, y and z components of the field,

Tx(f) and Ty(f) are the “tipper” coefficients.

In the case of a horizontally homogeneous environment, Tx and Ty are equal to zero because Hz =0. They show certain anomalies only by the presence of changes in subsurface conductivity in the horizontal direction. The real parts of the coefficients correspond to tangents of tilt angles measured with a controlled source. The complex tensor [Tx, Ty] known as the “tipper” defines the vertical response to horizontal fields in the x and y directions respectively.

Tx and Ty are two unknown coefficients in one equation, and we therefore must combine two or more sets of measurements to solve them. To reduce effects of noise, multiple sets of measurements can be made, and the coefficients, which minimize the squared error in predicting the measured Z from X and Y, can be found. This leads to next formulas for estimating the coefficients.

$$\mathbf{Tx = ([HzHx^*]\ [HyHy^*] - [HzHy^*]\ [HyHx^*])\ /\ ([HxHx^*]\ [HyHy^*] - [HxHy^*]\ [HyHx^*]),} \qquad \mathbf{(2)}$$

and

$$\mathbf{Ty = ([HzHy^*]\ [HxHx^*] - [HzHx^*]\ [HxHy^*])\ /\ ([HxHx^*]\ [HyHy^*] - [HxHy^*]\ [HyHx^*]\ .} \qquad \mathbf{(3)}$$

Where

[HxHy*] (For example) denotes a sum of the product of Hx with the complex conjugate of Hy.

In practical processing algorithms, all numbers Hx, Hy and Hz can be obtained by applying the same digital band-pass filters to three incoming parallel data signals. FFT algorithms are also applicable. All sums like [HxHy*] can be calculated on the basis of a discrete time interval in the range from 0.1 to 1 sec or on a sliding time base.

Using platform attitude data in the EM data processing can be done at different stages of the signal processing. The most obvious idea is to transform parallel data from local coordinates of the platform into absolute geographical coordinates before the main signal processing procedure. Unfortunately, the proper algorithms of attitude data obtained, often require some post-processing algorithms such as using post-calculated accelerations based on GPS data etc. That is why it is preferable to treat x-y-z coordinates in formulas above in the local coordinate system of the platform and to recalculate resulting local tilt angles into a geographical or global coordinate system later, during the data post processing.

In weak field conditions where the level of the signal is comparable with input noise levels in preamplifiers, the bias in the estimated values of Tx and Ty caused by noise in the horizontal signals become substantial and cannot be reduced by any averaging. This bias can be removed by the use of separate reference signals containing noise uncorrelated with noise in signals Hx and Hy. (Anav et al., 1976).

$$Tx = ([HzRx^*]\,[HyRy^*] - [HzRy^*]\,[HyRx^*]) / ([HxRx^*]\,[HyRy^*] - [HxRy^*]\,[HyRx^*]), \quad (4)$$

and

$$Ty = ([HzRy^*]\,[HxRx^*] - [HzRx^*]\,[HxRy^*]) / ([HxRx^*]\,[HyRy^*] - [HxRy^*]\,[HyRx^*]). \quad (5)$$

Where:

Rx is the reference field x component,
Ry is the reference field y component.

An additional two electromagnetic sensors, providing these reference signals can be placed at some distance away from the main x, y and z sensors. Currently, though, no additional remote-reference processing are applied to ZTEM data.

Numerical Modelling

In order to understand the airborne AFMAG responses to conductors for a variety of geological environments, EMIGMA™ modelling code from PetRos EiKon (Toronto, ON) was obtained to conduct the formulated model studies.

Below are some of the modelling results from their study.

Modelling assumption:

The assumptions for the modelling are that:
3 components of the magnetic field are measured and they are processed according to:

$$Hz(f) = Tx(f)\,Hx(f) + Ty(f)\,Hy(f)$$

The vector (Tx,Ty) is usually referred to as the 'tipper' vector and is determined in the frequency domain through processing. This is normally done by determining transfer functions from an extended time series.

For the modelling exercise, the 3 components of the magnetic vector (Hx,Hy,and Hz) are modelled twice for 2 orthogonal polarizations of a plane wave source field and then the tipper is calculated from a matrix calculation using the results of the 2 source polarizations' models. For the 2D forward modelling results, the tipper vectors are shown as a function of frequency

Basic Model Response

For the initial models, we assume a thin plate-like model. The model is perpendicular to the flight direction. Initially, we will assume very long strike directions. From this quasi-2D model, there are 2 basic responses. The so-called TE response and the so-called TM response.

For the initial models, we will assume the strike is in the y (North) directions and the flight is in the x (East) direction Sensor heights are 30m above ground.

TE Mode: For the TE response, the electric field excitation flows along strike (current channelling) and the horizontal H field (Hx) flows perpendicular to strike thus causing induction through Faraday's law. The Hz response is generated both from channelling and induction.

TM Mode: For this response, the electric field excitation flows perpendicular to strike generating quasi-static charges on faces and the horizontal H field (Hx) flows parallel to strike. Since, the XZ face is very small for this model, little current is induced. The charges on the faces have a small dipole moment due to the thinness of the model.

For the rest of the models unless otherwise noted, the parameters used are:

Strike Length: 1km
Depth Extent: 1km
Conductance: 100S
Depth to Top: 10m
Background: Thin-overburden (10m), Resistive Basement (1000 Ohm-m)

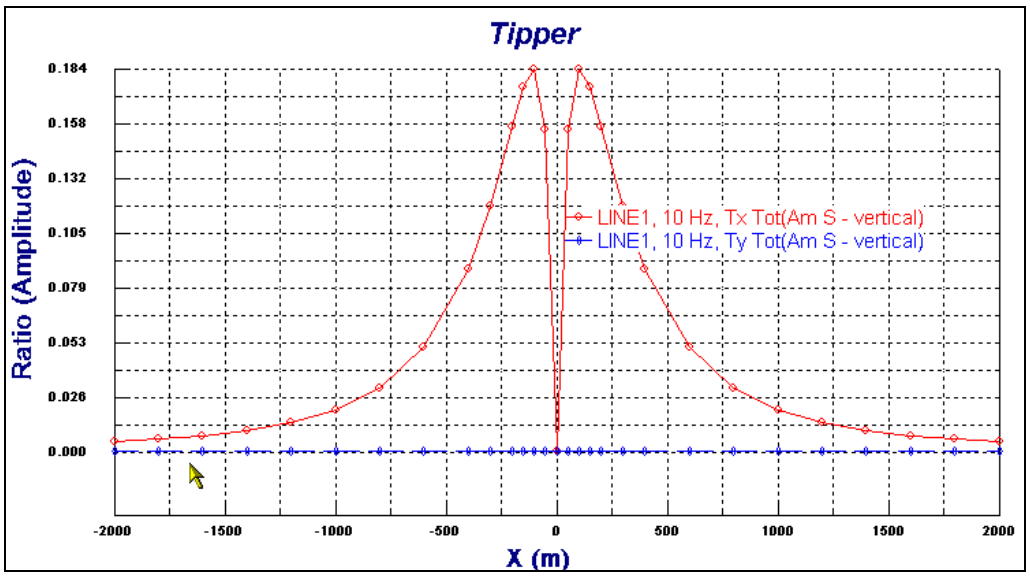


Figure D-1 – Calculated Tipper components at 10 Hz for above model parameters.

Figure D1 shows the Tipper (Tx,Ty) Amplitudes at 10Hz using a10Ωm overburden. Note small Ty (ie quasi-TM response)

Amplitude Response

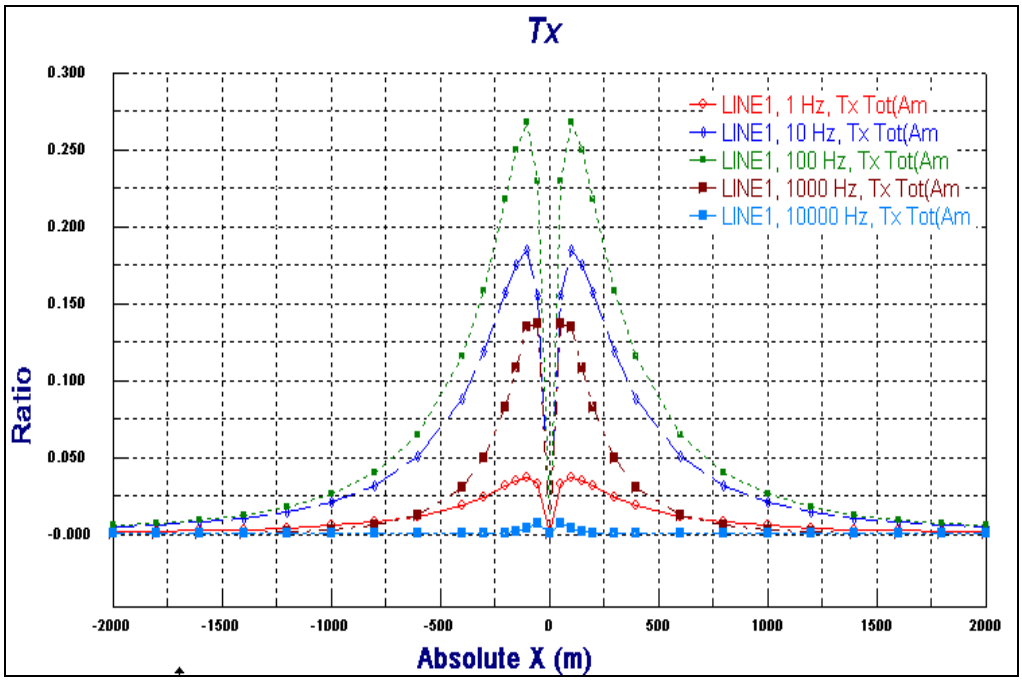


Figure D-2 – Calculated Tx component of the Tipper at various frequencies

The (Tx) response amplitude at 1,10,100,1000,10000 Hx. Peak amplitude at 100Hz

Inphase and Quadrature Response

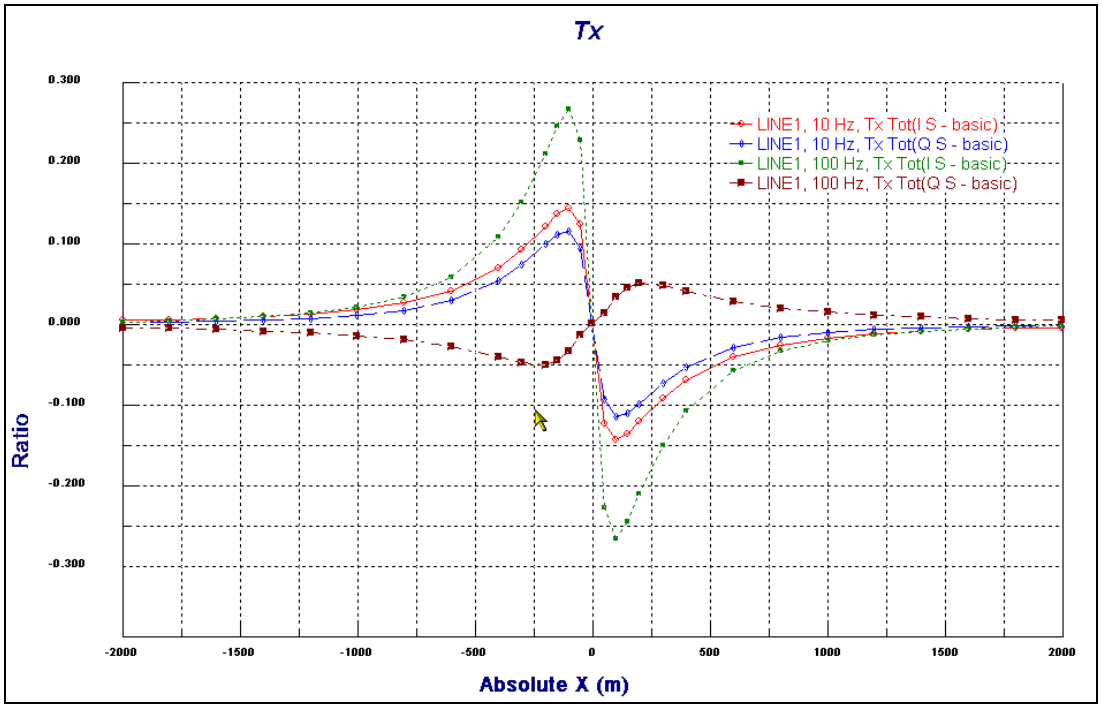


Figure D-3 – Calculated In-phase and Quadrature of the Tx component at various frequencies

Figure D-3 shows the In-phase and Quadrature response at 10 and 100Hz. Note the crossovers in the In-phase and Quadrature, and the phase reversal in the Quadrature responses from low to high frequencies.

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Geotech Ltd.
September, 2007

AFMAG Source Fields and ZTEM method[1]

AFMAG uses naturally occurring audio frequency magnetic fields as the source of the primary field signal, and therefore requires no transmitter (Ward, 1959). The primary fields resemble those from VLF except that they are lower frequency (tens & hundreds of Hz versus tens of kHz) and are usually not as strongly directionally polarized (Labson et al., 1985). These EM fields used in AFMAG are derived from worldwide atmospheric thunderstorm activity, have the unique characteristic of being uniform, planar and horizontal, and also propagate vertically into the earth – to great depth, up to several km, as determined by the magnetotelluric (MT) skin depth (Vozoff, 1972), which is directly proportional to the ratio of the bedrock resistivity to the frequency (Figure D4).

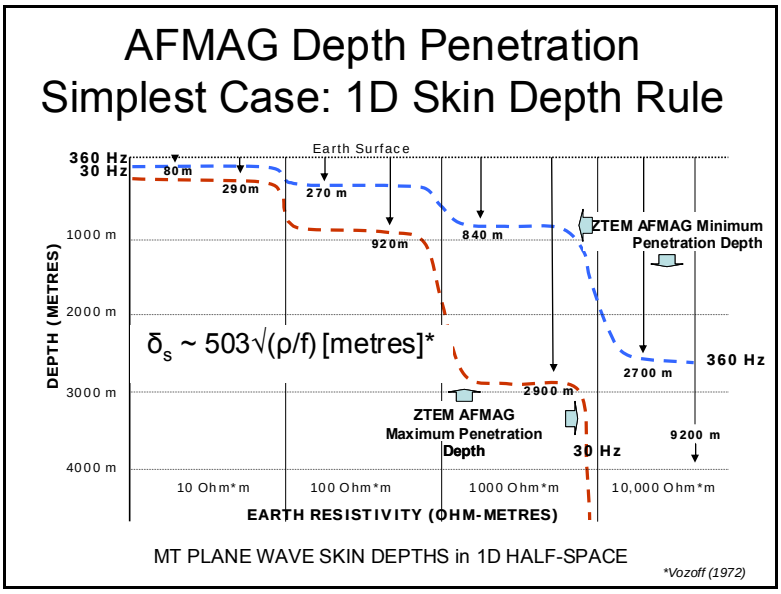

Figure D4: MT Skin Depth Penetrations for ZTEM in 30-360Hz and 10-1000 ohm resistivity

At the frequencies used for ZTEM, the penetration depths likely range between approx. 600m to 2km in this region (approx. 1k ohm-m avg. resistivity assumed), according to the following equation for the Bostick skin depth $\delta_B = 356 * \sqrt{(\rho / f)}$ metres (Bostick, 1977), which is considered appropriate as a rule of thumb equivalent depth estimate.

The other unique aspect of AFMAG fields is that they react to relative contrasts in the resistivity, and therefore do not depend on the absolute conductance, as measured using inductive EM systems, such as VTEM. Hence poorly, conductive targets, such as alteration zones and fault zones can be mapped, as well as higher conductance features, like graphitic units. Conversely, resistive targets can also be detected using AFMAG– provided they are of a sufficient size and contrast to produce a vertical field anomaly. Indeed resistors produce reversed anomalies relative to conductive features. Hence AFMAG can be effective as an all-round resistivity mapping tool, making it unique among airborne EM

[1] From: Legault, J.M., Kumar, H., and Milicevic, B. (2009): ZTEM tipper AFMAG and 2D inversion results over an unconformity uranium target in northern Saskatchewan, Expanded Abstract submitted to Society of Exploration Geophysics SEG conference, Houston, Tx, Nov-2009, 5 pp.

methods. A series of 2D synthetic models that illustrate these aspects have been created using the 2D forward MT modelling code of Wannamaker et al. (1987) and are presented in figures D5-D7.

The tipper from a single site contains information on the dimensionality of the subsurface (Pedersen, 1998), for example, in a horizontally stratified or 1D earth, $\boldsymbol{T}$=0 and as such H_Z is absent. For a 2D earth with the y-axis along strike, T_Y=0 and $H_Z = T_X * H_X$. In 3D earths, both T_X and T_Y will be non-zero. H_Z is therefore only present, as a secondary field, due to a lateral resistivity contrast, whereas the horizontal H_X and H_Y fields are a mixture of secondary and primary fields (Stodt et al., 1981). But, as an approximation, as in the telluric-magnetotelluric method (T-MT; Hermance and Thayer, 1975) used by distributed MT acquisition systems, the horizontal fields are assumed to be practically uniform, which is particularly useful for rapid reconnaissance mapping purposes. By measuring the vertical magnetic field H_X, using a mobile receiver and the orthogonal horizontal H_X and H_Y fields at a fixed base station reference site, ZTEM is a direct adaptation of this technique for airborne AFMAG surveying.

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Geotech Ltd.

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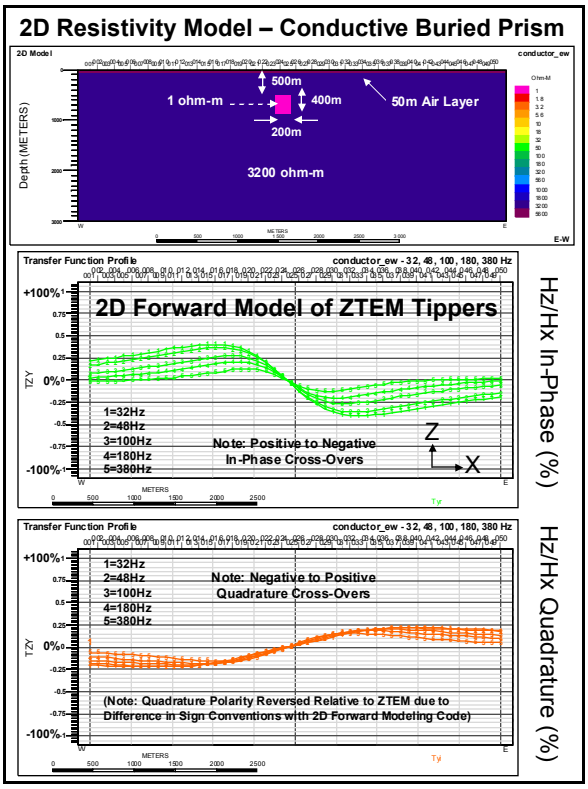

Figure D5: 2D synthetic forward model Tipper responses (Tzy) for conductive brick model.

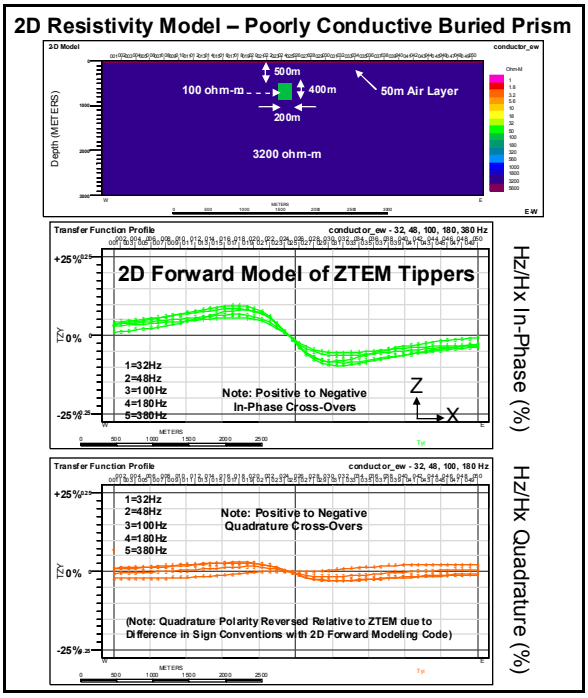

Figure D6: 2D synthetic forward model Tipper response (Tzx) for poorly conductive brick model.

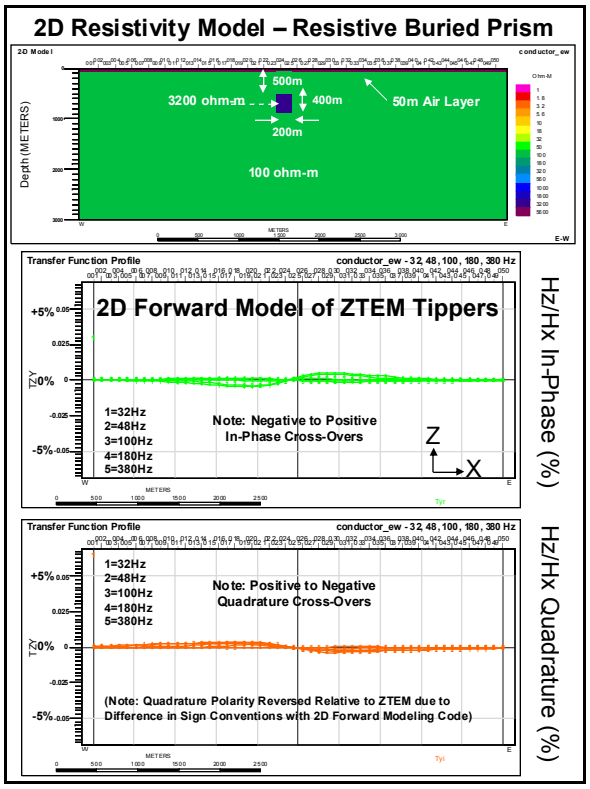

Figure D7: 2D synthetic forward model Tipper response (Tzx) for resistive brick model.

APPENDIX E

ZTEM (AIRBORNE AFMAG) TESTS OVER UNCONFORMITY URANIUM DEPOSITS[6]

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Key Words: ZTEM, AFMAG, electromagnetic, airborne, uranium, Athabasca.

INTRODUCTION

A series of demonstration tests were conducted using the ZTEM, airborne AFMAG system over deep targets in the Athabasca Basin of Saskatchewan, Canada. These tests were conducted in mid-2008 and were flown to test ZTEM's ability to detect large conductive targets at depth; deeper than conventional airborne EM methods. Data are presented over areas where the conductors are located 450-600 metres beneath the surface. As well, a case of ZTEM following the plunge of a conductor to over 800 metres depth is shown.

BACKGROUND

The ZTEM system is the latest implementation of an airborne AFMAG system first commercialized in late 2006. ZTEM uses a large, 8 metre diameter airborne air core coil, slung from a helicopter, to measure the vertical component of the AFMAG signal. Two 4 metre square coils are deployed on the ground to measure the horizontal field. The ZTEM system has flown successful demonstration surveys over porphyry copper deposits in the southwest USA (Zang et al., 2008).

ZTEM was tested in the Athabasca Basin in Canada in May of 2008 to determine its depth of investigation and to determine its suitability for mapping deep conductors in the crystalline basement. Over 30% of the world's U3O8 is mined in the Athabasca Basin from unconformity uranium deposits. Unconformity uranium deposits of the Athabasca Basin are often associated with conductors located in the crystalline basement. The search for economic uranium deposits is moving to areas of the basin which are deeper and beyond the detection limits of modern airborne instrumentation. This creates the requirement for a system which can detect conductivity past the detection limits of modern traditional EM systems. This was the motivation behind the field trials of the ZTEM system in the Athabasca Basin. Several areas where known deep conductors (450-600m+) were located were flown. Also, a test survey block in the northern part of the basin was able to trace a deep and plunging conductor to depths that no other airborne EM system has been able to achieve.

ATHABASCA BASIN GEOLOGY

The high-grade uranium deposits within the Athabasca Basin are associated with the unconformity between the essentially flat-lying Proterozoic Athabasca Group sandstones and the underlying Archean-Paleoproterozoic metamorphic and igneous basement rocks. The deposits occupy a range of positions from wholly basement-hosted to wholly sediment-hosted, at structurally favourable sites in the interface between the deeply weathered basement and overlying sediments

[6] Extended abstract submitted to 20TH ASEG International Geophysical Conference & Exhibition, Adelaide, AU, 22-26 Feb, 2009.

of the Athabasca Basin (Ruzicka, 1997). The locations of These deposits are lithologically and structurally controlled by the sub-Athabasca unconformity and basement faults and fracture zones, which are localized in graphitic pelitic gneisses that may flank structurally competent Archean granitoid domes (Quirt, 1989).

In general, most of the known important deposits tend to occur within a few tens to a few hundred metres of the unconformity and within 500 m of the current ground surface. This may be more of a limitation of exploration techniques. There is no reason to believe that the distribution of the deposits is dependent on the modern day depth of burial.
Empirically, the geophysical exploration for unconformity type uranium targets have been to search for large basement structures which post date the sandstone deposition of the basement (Matthews et. al, 1997). All the deposits located so far are associated with fault structures associated with a graphitic conductive basement. An alteration zone of clay silicification and enrichment around the deposits probably leads to magnetite destruction causing the magnetic low observed around the deposits. The clay alteration should give rise to a resistivity low signature about the deposits. The low conductivity of the clay alteration makes it a difficult target for airborne EM if it is buried at significant depth.

ZTEM INSTRUMENTATION AND PRESENTATION

ZTEM is an airborne AFMAG system introduced by Geotech Ltd. of Canada in early 2007 (Lo et al., 2008). In a ZTEM survey, a single vertical dipole air-core coil is flown over the survey area in a grid pattern similar to other airborne electromagnetic surveys. Two orthogonal, air-core, horizontal axis coils placed close to the survey site measures the horizontal EM fields for reference. A GPS array on the airborne coil monitors its attitude for post-flight corrections.

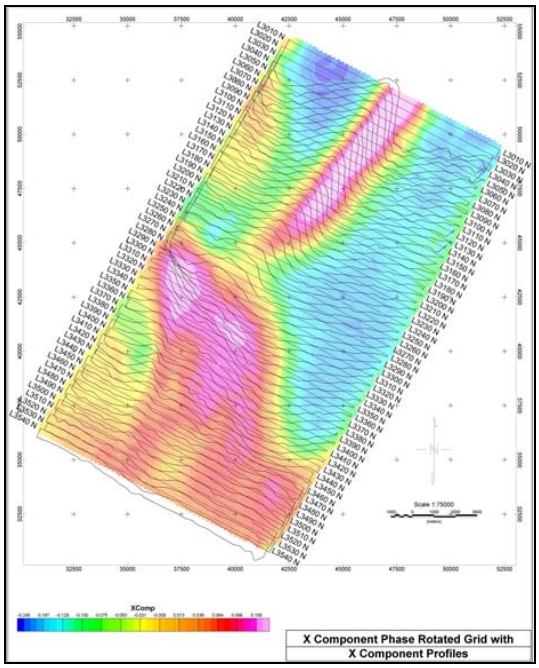

Figure 1 – Stacked profiles of the x-component Tipper over the gridded values of the phase rotated

x-component data. Note that the cross-overs in the profiles are now peaks on the image.

As the source field is assumed to be far away, the excitation of the ground is more or less uniform. For large structures, the signal fall-off will be much slower than from a dipole source, such as those energized by traditional airborne systems. With the ZTEM system being less susceptible to terrain clearance, the planned ground clearance height is higher and the terrain drape is looser as compared to standard helicopter EM surveys.

The two Tippers obtained from the relationship between the vertical airborne coil and the two ground coils have a cross-over over a steeply dipping, plate-like body. The cross-overs can be made into local maxima via a 90 degree phase rotation which allows for easier interpretation of the gridded values. Figure 1 is an example of this transformation.

To present the data of both Tippers as one image, we calculate a parameter termed the DT which is the horizontal divergence of the two Tippers, much in the same manner as the "peaker" parameter in VLF (Pedersen, 1998). The DT is typically plotted with an inverted colour bar as it is negative over a steeply dipping thin body.

ZTEM RESULTS – NORTHERN ATHABASCA BASIN

Figure 2 shows gridded values from a number of ZTEM lines over an area where the sedimentary cover is approximately 450-600 metres thick. A number of traditional EM systems have also been flown over this block. While they were able to detect conductors, the resolution of the conductive features is not nearly as detailed as the information provided by ZTEM.

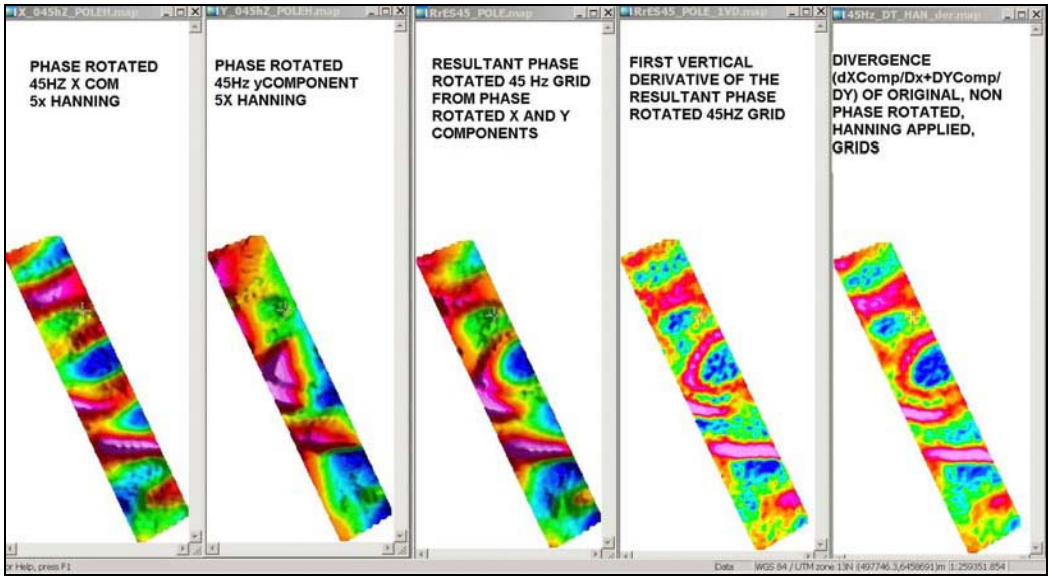

Figure 2 – ZTEM results over an area of 450-600 metre thick sedimentary cover.

Figure 3, from another area, shows the data from one of the larger blocks that was flown. It is a 3D composite image of the DT at various frequencies plotted at the equivalent skin depth assuming a 1,000 ohm-m average resistivity.

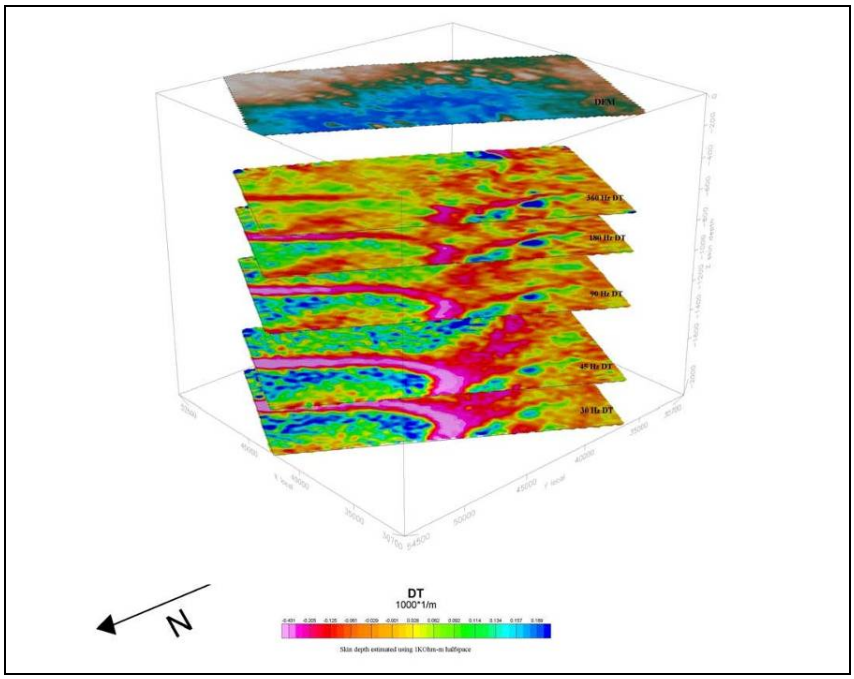

Figure 3 - Perspective view of DT's of different frequencies plotted at the skin depth (using a 1,000 ohm-m Earth.

The data in Figure 3 come from a survey over the north rim of the Athabasca Basin. The sandstone cover is about 500m on the left hand side of the image, and progressively getting deeper to the right. It is about 700m in the middle part of the image and over 800 metres thick on the right middle portion where exploration drilling is concentrated. Starting in the middle left and trending to the right of the image, there is a known graphitic shear.

In the uppermost (600m) "depth slice", Figure 3 shows a linear conductive feature that progressively weakens as one moves to the right until it is no longer seen. This is interpreted to be due to the graphitic shear conductor plunging deeper past the depth of investigation of the 360 Hz data. The lower frequencies penetrate more into the sedimentary cover that is deeper towards the right. DT's of decreasing frequency show the linear conductive feature extending more and more to the right. The feature also strengthens/sharpens into a synformal shape with lower frequencies. This fits with what the known geology of a plunging conductor at depth is doing.

At the nose of the fold, in the right third of the images, we also see another, broader anomalous zone that trends towards the back of the image. At this location, two radioactive springs are situated. These spring waters which are anomalously high in uranium and radon may reflect the upward migration of deep waters along faults, suggesting structural targets in areas where basinal waters may have tapped a radioactive source. This broad DT trend might be the plunge of the fold axis that is aligned away from the front of the image. An anomaly along this trend, at the highest frequency, that steadily grows with each decreasing frequency can be seen. This might represent an alteration zone in the sandstone that is detected at the shallowest depth. By about the 90Hz DT depth slice or so, we are possibly in the deeper basement and into a basement graphitic unit.

CONCLUSIONS

A number of successful ZTEM tests were conducted over the Athabasca Basin. The tests demonstrated that ZTEM can easily detect conductivity to 800 metres beneath relatively resistive sedimentary cover. Assuming a 1,000 ohm-metre resistivity, the skin depth of the 30 Hz data is approximately 2,000 metres. The 30 Hz data presented have good signal to noise ratios indicating a deep depth of exploration. The observation that ZTEM may be detecting the clay alteration above the crystalline basement is a significant advantage for exploration of unconformity uranium deposits.

More demonstration surveys are planned in the Athabasca Basin later this year. And more target types for testing are also planned.

ACKNOWLEDGEMENTS

The authors thank Geotech Ltd. for allowing them to publish this work and for providing the support required to write this abstract and to present this paper.

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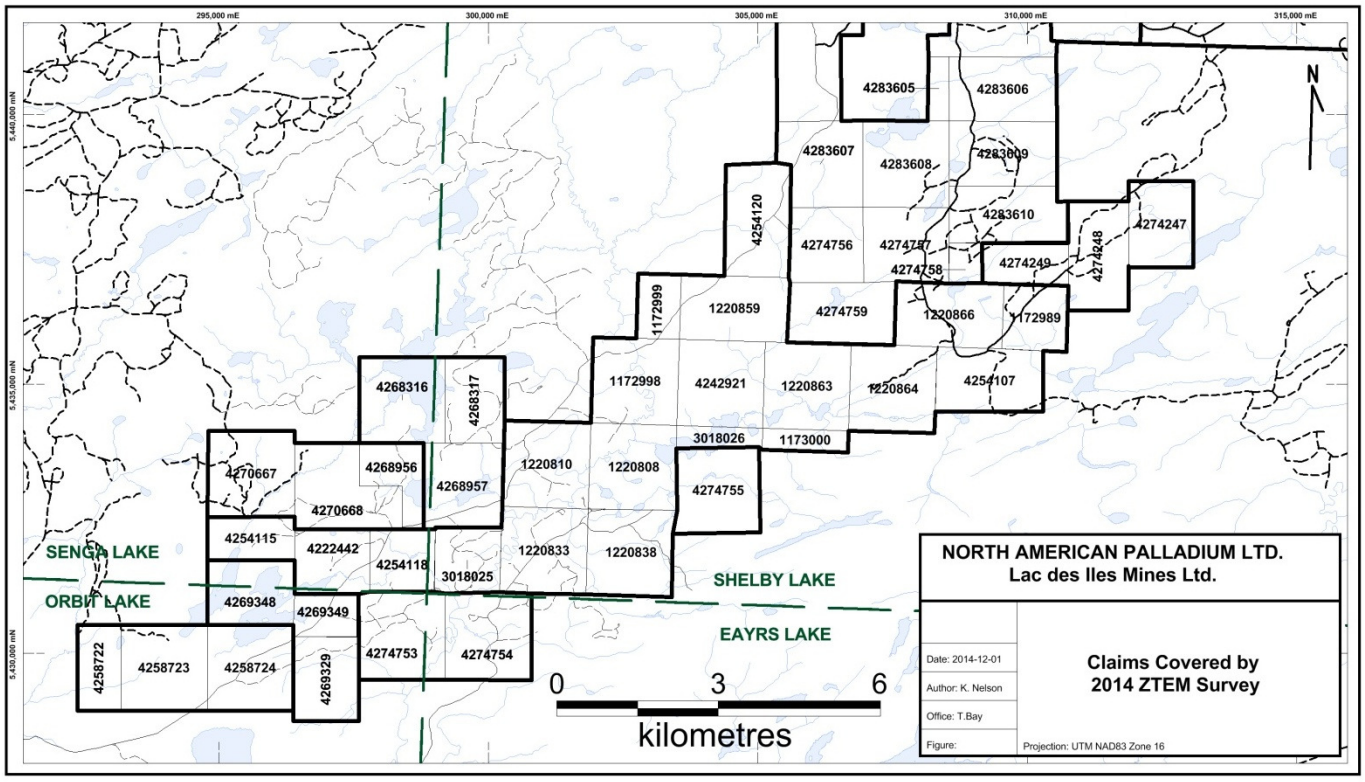
Claims Ownership List

Claims Ownership

The 2014 Shelby ZTEM survey was flown over 48 staked mining claims (603 claim units) in the Senga Lake, Shelby Lake, Orbit Lake and Eayrs Lake map areas in the Thunder Bay Mining Division. The centre of the property is located at approximately 302,651 Easting and 5,434,689 Northing (UTM Nad 83 Zone 16).



The 48 claims are primarily held by Lac des Iles Mines Ltd (217699), twenty of which are under option from Platinum Group Metals (392741). Three of the 48 claims are under an option agreement from Ken Fenwick (300118) and Karl Bjorkman (108755).

The complete claims list with recorded holders is shown below.

Claim Holder	Township/Area	Recording Date	Claim Units	Approximate Area (ha)
Lac des Iles Mines Ltd	SHELBY LAKE AREA	2012-Mar-01	16	255.1
Lac des Iles Mines Ltd	SHELBY LAKE AREA	2012-Mar-01	12	175.0
Lac des Iles Mines Ltd	SHELBY LAKE AREA	2012-Mar-01	16	229.7
Lac des Iles Mines Ltd (PTM Option)	SHELBY LAKE AREA	2000-Mar-06	12	145.2
Lac des Iles Mines Ltd (PTM Option)	SHELBY LAKE AREA	2000-Mar-06	12	253.5
Lac des Iles Mines Ltd (PTM Option)	SHELBY LAKE AREA	2000-Mar-06	6	95.9
Lac des Iles Mines Ltd (PTM Option)	SHELBY LAKE AREA	2000-Mar-13	4	63.4
Lac des Iles Mines Ltd (PTM Option)	SHELBY LAKE AREA	2000-Mar-06	16	256.1
Lac des Iles Mines Ltd (PTM Option)	SHELBY LAKE AREA	2000-Mar-06	16	255.2
Lac des Iles Mines Ltd (PTM Option)	SHELBY LAKE AREA	2000-Mar-06	16	254.9
Lac des Iles Mines Ltd (PTM Option)	SHELBY LAKE AREA	2000-Mar-06	16	254.4

Lac des Iles Mines Ltd (PTM Option)	SHELBY LAKE AREA	1999-Dec-10	15	240.4
Lac des Iles Mines Ltd (PTM Option)	SHELBY LAKE AREA	1999-Dec-10	16	255.9
Lac des Iles Mines Ltd (PTM Option)	SHELBY LAKE AREA	1999-Dec-10	16	256.7
Lac des Iles Mines Ltd (PTM Option)	SHELBY LAKE AREA	1999-Dec-10	15	237.9
Lac des Iles Mines Ltd (PTM Option)	SHELBY LAKE AREA	2008-Jun-04	9	148.1
Lac des Iles Mines Ltd (PTM Option)	SHELBY LAKE AREA	2008-Jun-04	4	61.6
Lac des Iles Mines Ltd (PTM Option)	SENGA LAKE AREA	2010-Feb-19	8	166.9
Lac des Iles Mines Ltd (PTM Option)	SHELBY LAKE AREA	2009-Jun-15	16	254.5
Lac des Iles Mines Ltd (PTM Option)	SHELBY LAKE AREA	2010-Feb-25	15	230.5
Lac des Iles Mines Ltd (PTM Option)	SENGA LAKE AREA	2010-Feb-19	8	129.5
Lac des Iles Mines Ltd (PTM Option)	SENGA LAKE AREA	2010-Feb-19	9	138.6
Lac des Iles Mines Ltd (PTM Option)	SHELBY LAKE AREA	2010-Feb-19	12	253.2
Lac des Iles Mines Ltd	SHELBY LAKE AREA	2014-Oct-16	16	260.3
Lac des Iles Mines Ltd	SHELBY LAKE AREA	2014-Oct-16	16	257.9
Lac des Iles Mines Ltd	SHELBY LAKE AREA	2014-Oct-16	16	244.9
Lac des Iles Mines Ltd	SHELBY LAKE AREA	2014-Oct-16	11	190.7
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Lac des Iles Mines Ltd	SHELBY LAKE AREA	2014-Oct-16	15	238.6
Lac des Iles Mines Ltd	SHELBY LAKE AREA	2014-Oct-16	16	234.7
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Lac des Iles Mines Ltd	SHELBY LAKE AREA	2014-Oct-16	15	227.0
Lac des Iles Mines Ltd	SHELBY LAKE AREA	2013-Apr-25	12	191.4
Lac des Iles Mines Ltd	SHELBY LAKE AREA	2013-Apr-25	15	226.6
Lac des Iles Mines Ltd	SHELBY LAKE AREA	2013-Apr-25	8	124.2
K. Fenwick & K. Bjorkman Option	ORBIT LAKE AREA	2011-May-31	8	128.2
K. Fenwick & K. Bjorkman Option	ORBIT LAKE AREA	2011-May-31	16	255.5
K. Fenwick & K. Bjorkman Option	ORBIT LAKE AREA	2011-May-31	16	255.4
Lac des Iles Mines Ltd	SENGA LAKE AREA	2012-Mar-01	8	127.6
Lac des Iles Mines Ltd	ORBIT LAKE AREA	2012-Apr-02	12	190.0
Lac des Iles Mines Ltd	SENGA LAKE AREA	2012-Apr-02	12	193.4
Lac des Iles Mines Ltd	ORBIT LAKE AREA	2012-Apr-02	6	95.5
Lac des Iles Mines Ltd	SENGA LAKE AREA	2012-Jun-27	16	257.1
Lac des Iles Mines Ltd	SENGA LAKE AREA	2012-Jun-27	16	255.1

Krista Nelson
Sr. Exploration Geologist
North American Palladium
Lac des Iles Mines Ltd.

ATTRIBUTE DATA

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Krista Nelson-Authorized Agent for
Lac des Iles Mines Ltd
Client Number 217699
Phone Number: 807-623-8005
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Technical Report
Report Title: Report on a Helicopter-Borne Z-Axis Tipper Electromagnetic (ZTEM) and Aeromagnetic Geophysical Survey, Shelby.
Report Completed: December 2014
Number of Pages (inc title page, table of contents, etc): 51
Report Authors: Nick Venter, Jean Legault, Geoff Plastow
Work Performed For: Lac des Iles Mines Ltd.
Digital File Name: GL140367_Report.pdf

Appendix C: Maps

GL140367_20K_3D_IP_DT.pdf, '3D View of In-Phase, Total Divergence (DT) grids versus Skin Depth (30Hz–720Hz)', Geotech

GL140367_20K_45Hz_IP_DT.pdf, '45Hz In-Phase Total Divergence(DT)', Geotech, 1:20,000

GL140367_20K_180Hz_IP_DT.pdf, '180Hz In-Phase Total Divergence (DT)', Geotech, 1:20,000

GL140367_20K_720Hz_IP_DT.pdf, '720Hz In-Phase Total Divergence (DT)', Geotech, 1:20,000

GL140367_20K_TMI.pdf, 'Total Magnetic Intensity (TMI)', Geotech, 1:20,000

GL140367_20K_XIP_profiles_XIP_PR.pdf, 'Tzx (In-line) In-Phase Profiles over 90Hz Phase Rotated In-Phase Grid', Geotech, 1:20,000

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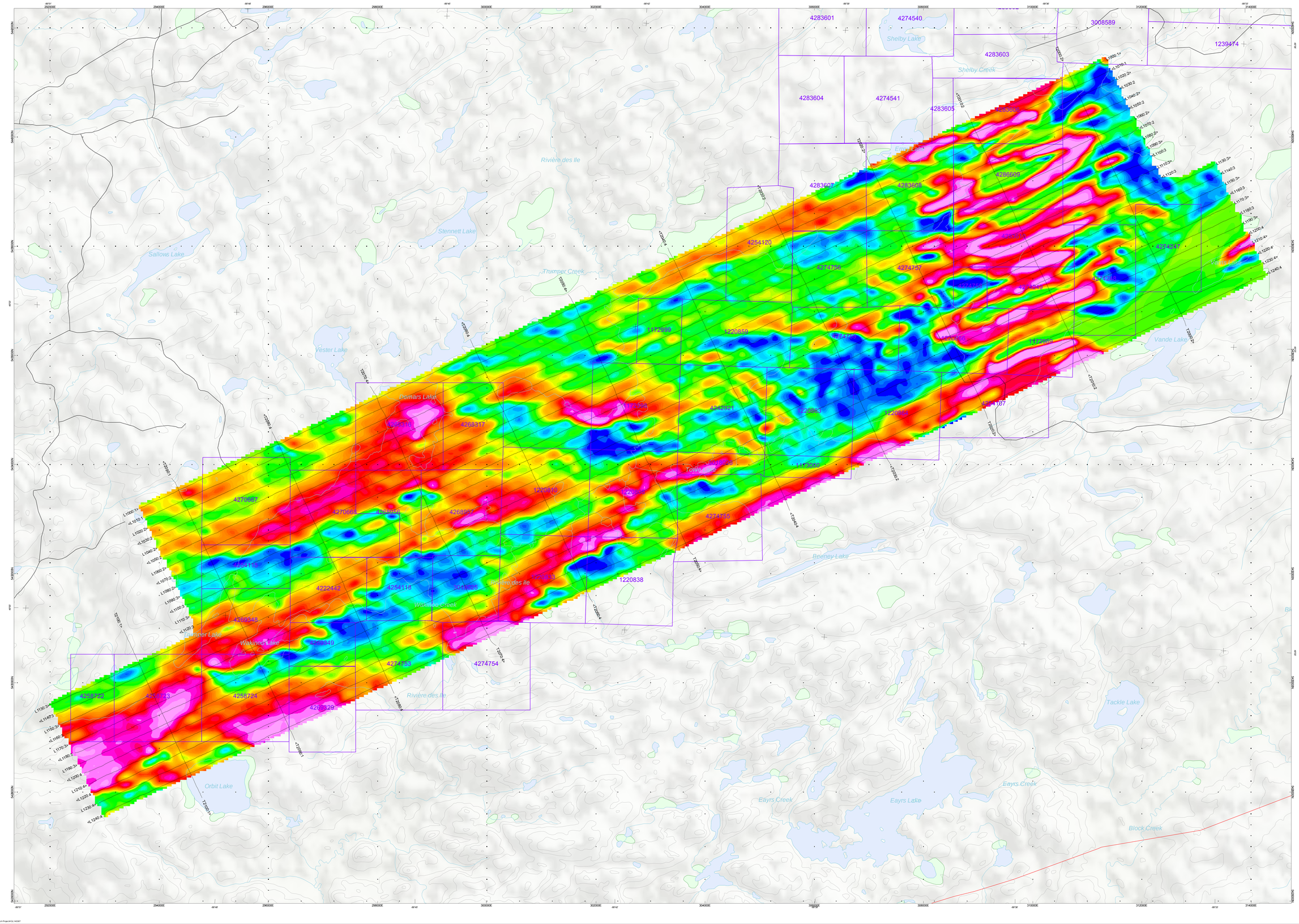
GL140367_20K_YIP_profiles_YIP_PR.pdf, 'Tzy (Cross-line) In-Phase Profiles over 90Hz Phase Rotated In-Phase Grid', Geotech, 1:20,000

GL140367_20K_YQD_profiles_YQD_PR.pdf, 'Tzy (Cross-line) Quadrature Profiles over 90Hz Phase Rotated Quadrature Grid', Geotech, 1:20,000

Supplement: Claims Ownership List



GEOTECH LTD.

Scale 1:10,000,000

SURVEY SPECIFICATIONS:

Survey Flying Date: November 4th to 21st 2014
Survey Operations Base: Lac des Iles Mines, Ontario
Survey Line Spacing: 200 Meters
Survey Line Direction: N 65° E / N 245° E
Survey Tie Line Spacing: 2000 Meters
Survey Tie Line Direction: N 155° E / N 335° E
Helicopter Mean Terrain Clearance: 152 metres
Mean Ground Air Speed: 25 metres/sec
ZTEM airborne coil: towed at a mean distance of 70 m below the helicopter
Airborne Magnetometer bird: towed at a mean distance of 55 m below the helicopter

HELICOPTER SPECIFICATIONS

Helicopter Type: Aerospatiale A-Star 350 B3 (C-FVTM)

AIRBORNE INSTRUMENTATION

Survey Type: Helicopter Z-Axis Tipper Electromagnetic (ZTEM), Magnetic towed Bird
GPS Receivers (4): NovAtel CDGPS enabled Propak V3-RT20
GPS Receivers Location: One on the helicopter, three on EM coil
Radar Altimeter: Terra TRA 3000TRI 40
Navigation: GEONAV-3

AIRBORNE ELECTROMAGNETIC SYSTEM

Electromagnetic System: Geotech Z-Axis Tipper (ZTEM)
Coil dimensions: 7.4 metres diameter
Coil orientation: Vertical Dipole
Digitizing rate: 2000Hz

AIRBORNE MAGNETOMETER

Magnetometer: GEOMETRICS
Magnetometer Sensitivity: +/- 0.02 nT
Sampling Rate: 0.2 Hz

GROUND INSTRUMENTATION

MAGNETIC BASE STATION

Magnetometer: GEOMETRICS
Base Station Location: (49°09' 0" N, 89°36'0" W)

EM BASE STATION

Three orthogonal square coils
Coil dimensions: 3.04 metres each side
Coil orientation: Horizontal Dipole
Base Station Location: (49°31'10" N, 89°51'36" W)
Azimuth: AxA = N 239° E AzB = N 298° E

PROCESSING SUMMARY

MAGNETICS:

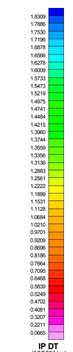
Diurnal Subtraction, microlevelling

ZTEM:

Frequencies extracted: 30, 45, 90, 180, 360, 720Hz.
Sampling rate: 0.4 sec.
Rotation of the inphase part of the inline and orthogonal components (ZXXoc and ZYXoc)on to UTM Eastings and Northings.
Attitude correction applied, (calculated from 3 GPS recievers installed on aiborne coil).
DIV(Tilt) calculated: dX(compl)dX+dY(compl)Y for all 6 frequencies.
Phase Rotated Grids (90 deg) calculated from each individual X and Y component grids, for each individual frequency.

MAP PROJECTION

Datum NAD83
Projection: Universal Transverse Mercator
Central Meridian: 87°W (Zone 16N)
Central Scale Factor: 0.9996
False Easting/Northing: 500,000mV0m
Major Axis: 6378137.0
Inverse Flattening: 298.25722
NTS: 052A13 & 052H04



TOPOGRAPHIC LEGEND:

Roads
Pipelines
Streams / Rivers
Contours
Lakes / Ponds
Wetlands
Mining Claims

Scale 1:20000

250 0 250 500 750 1000
(meters)
NAD83 / UTM zone 16N

The topographic database was derived from 1:50000 NRC (Natural Resources Canada) NTDB data
Background shading is derived from NASA SRTM Shuttle Radar Topography Mission data
Inset data derived from Geocommunities 1:250,000 Canadian National Topographic database
Mining Claims are derived from the Ontario Ministry of Northern Development and Mines
(www.geocomm.com)(www.geogratis.ca)(http://www.mndm.gov.on.ca)

Lac des Iles Mines Ltd
Shelby
Lac de Iles Region, Ontario
NTS: 052H04

Geotech ZTEM System
180Hz In-Phase Total Divergence
(DT)

Flown and processed by Geotech Ltd.
245 Industrial Parkway North,
Aurora, Ontario, Canada L4G 4C4
www.geotech.ca

December 2014

N

Topography

720Hz (590m)

360Hz (840m)

180Hz (1190m)

90Hz (1680m)

45Hz (2370m)

30Hz (2900m)

129.3793

-1000

-1500

-2000

-2900

Z – Skin Depth

5443948

5436000

5432000

5425912

Y

289412

295000

300000

305000

310000

316868

X

Skin Depth Calculated for a 1000 ohm-m Half Space Model
Z multiplier of 8, Scale Factor 0.25, Inclination = 19, Declination = 348

GEOTECH LTD.

SURVEY SPECIFICATIONS:

- Survey Flying Date: November 4th to 21st 2014
- Survey Operations Base: Lac des Iles Mines, Ontario
- Survey Line Spacing: 200 Meters
- Survey Line Direction: N 65° E / N 245° E
- Survey Tie Line Spacing: 2000 Meters
- Survey Tie Line Direction: N 155° E / N 335° E
- Helicopter Mean Terrain Clearance: 152 metres
- Mean Ground Air Speed: 25 metres/sec
- ZTEM airborne coil: towed at a mean distance of 70 m below the helicopter
- Airborne Magnetometer bird: towed at a mean distance of 55 m below the helicopter

HELICOPTER SPECIFICATIONS

- Helicopter Type: Aerospatiale A-Star 350 B3 (C-FVTM)

AIRBORNE INSTRUMENTATION

- Survey Type: Helicopter Z-Axis Tipper Electromagnetic (ZTEM), Magnetic towed Bird
- GPS Receivers (4): NovAtel CDGPS enabled Propak V3-RT2D
- GPS Receivers Location: One on the helicopter, three on EM coil
- Radar Altimeter: Terra TRA 3000/TRI 40
- Navigation: GEONAV-3
- AIRBORNE ELECTROMAGNETIC SYSTEM
- Electromagnetic System: Geotech Z-Axis Tipper (ZTEM)
- Coil dimensions: 7.4 metres diameter
- Coil orientation: Vertical Dipole
- Digitizing rate: 2000Hz
- AIRBORNE MAGNETOMETER
- Magnetometer: GEOMETRICS
- Magnetometer Sensitivity: +/- 0.02 nT
- Sampling Rate: 0.2 Hz

GROUND INSTRUMENTATION

- MAGNETIC BASE STATION
- Magnetometer: GEOMETRICS
- Base Station Location: (49°09' 0" N, 89°36'0" W)
- EM BASE STATION
- Three orthogonal square coils
- Coil dimensions: 3.04 metres each side
- Coil orientation: Horizontal Dipole
- Base Station Location: (49°31'10" N, 89°51'39" W)
- Azimuth : AzA = N 208° E AzB = N 298° E

PROCESSING SUMMARY

- MAGNETICS
- Diurnal Subtraction, microlevelling.
- ZTEM:
- Frequencies extracted: 30, 45, 90, 180, 360, 720Hz.
- Sampling rate: 0.4 sec.
- Rotation of the inphase part of the inline and orthogonal components (Z1Xoc and Z1Yocon to UTM Eastings and Northings.
- Attitude correction applied, (calculated from 3 GPS recievers installed on airborne coil).
- DIV(Tilt) calculated: d/dx(comp)/dX+d/dy(comp)/dY for all 6 frequencies.
- Phase Rotated Grids (90 deg) calculated from each individual X and Y component grids, for each individual frequency.

MAP PROJECTION

- Datum NAD83
- Projection: Universal Transverse Mercator
- Central Meridian: 87°W (Zone 16N)
- Central Scale Factor: 0.9996
- False Easting/Northing: 500,000mN/m
- Major Axis: 6378137.0
- Inverse Flattening: 298.25722
- NTS: 052A13 & 052H04

Inset data derived from Geocommunities 1:250,000 Canadian National Topographic database (www.geocomm.com)

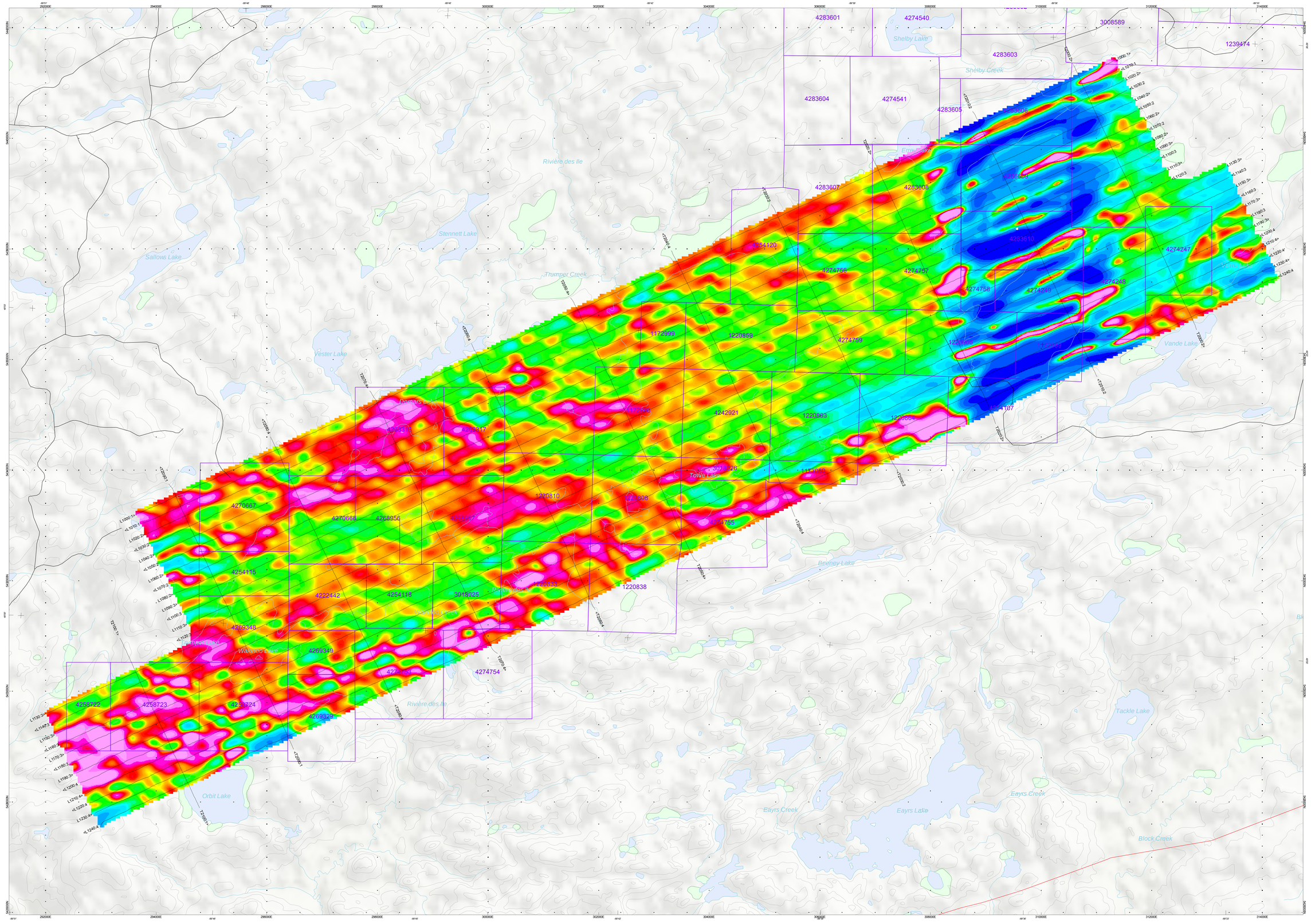
Lac des Iles Mines Ltd
Shelby
Lac de Iles Region, Ontario
NTS: 052H04

Geotech ZTEM System
3D view of In-Phase Total Divergence versus Skin Depth (30-720Hz)

Flown and processed by Geotech Ltd.
245 Industrial Parkway North,
Aurora, Ontario, Canada L4G 4C4
www.geotech.ca

December 2014

Geotech Project # 13_141007



GEOTECH LTD.

SURVEY SPECIFICATIONS:

Survey Flying Date: November 4th to 21st 2014
Survey Operations Base: Lac des Iles Mines, Ontario
Survey Line Spacing: 200 Meters
Survey Line Direction: N 65° E / N 245° E
Survey Tie Line Spacing: 2000 Meters
Survey Tie Line Direction: N 155° E / N 335° E
Helicopter Mean Terrain Clearance: 152 metres
Mean Ground Air Speed: 25 metres/sec
ZTEM airborne coil: towed at a mean distance of 70 m below the helicopter
Airborne Magnetometer bird: towed at a mean distance of 55 m below the helicopter

HELICOPTER SPECIFICATIONS

Helicopter Type: Aerospatiale A-Star 350 B3 (C-FVTM)

AIRBORNE INSTRUMENTATION

Survey Type: Helicopter Z-Axis Topper Electromagnetic (ZTEM), Magnetic towed Bird
GPS Receivers (4): NovAtel CDGPS enabled Propak V3-RT20
GPS Receivers Location: One on the helicopter, three on EM coil
Radar Altimeter: Terra TRA 3000/TRI 40
Navigation: GEONAV-3

AIRBORNE ELECTROMAGNETIC SYSTEM

Electromagnetic System: Geotech Z-Axis Topper (ZTEM)
Coil dimensions: 7.4 metres diameter
Coil orientation: Vertical Dipole
Digitizing rate: 2000Hz

AIRBORNE MAGNETOMETER

Magnetometer: GEOMETRICS
Magnetometer Sensitivity: +/- 0.02 nT
Sampling Rate: 0.2 Hz

GROUND INSTRUMENTATION

MAGNETIC BASE STATION

Magnetometer: GEOMETRICS
Base Station Location: (49°09' 0" N, 89°36'0" W)

EM BASE STATION

Three orthogonal square coils
Coil dimensions: 3.04 metres each side
Coil orientation: Horizontal Dipole
Base Station Location: (49°31'10" N, 89°51'36" W)
Azimuth: AzA = N 209° E AzB = N 298° E

PROCESSING SUMMARY

MAGNETICS:

Diurnal Subtraction, microlevelling

ZTEM:

Frequencies extracted: 30, 45, 90, 180, 360, 720Hz.
Sampling rate: 0.4 sec.
Rotation of the inphase part of the inline and orthogonal components (Z/Xloc and Z/Yloc)on to UTM Eastings and Northings.
Attitude correction applied, (calculated from 3 GPS recievers installed on airborne coil).
DIV(TIR) calculated: dX/compr/dX+dY/compr/dY for all 6 frequencies.
Phase Rotated Grids (90 deg) calculated from each individual X and Y component grids, for each individual frequency.

MAP PROJECTION

Datum: NAD83
Projection: Universal Transverse Mercator
Central Meridian: 87°W (Zone 16N)
Central Scale Factor: 0.9996
False Easting/Northing: 500,000m/0m
Major Axis: 6378137.0
Inverse Flattening: 298.25722
NTS: 052A13 & 052H04

TOPOGRAPHIC LEGEND:

Roads
Pipelines
Streams / Rivers
Contours
Lakes / Ponds
Wetlands
Mining Claims

Scale 1:20000

250 0 250 500 750 1000
(meters)
NAD83 / UTM zone 16N

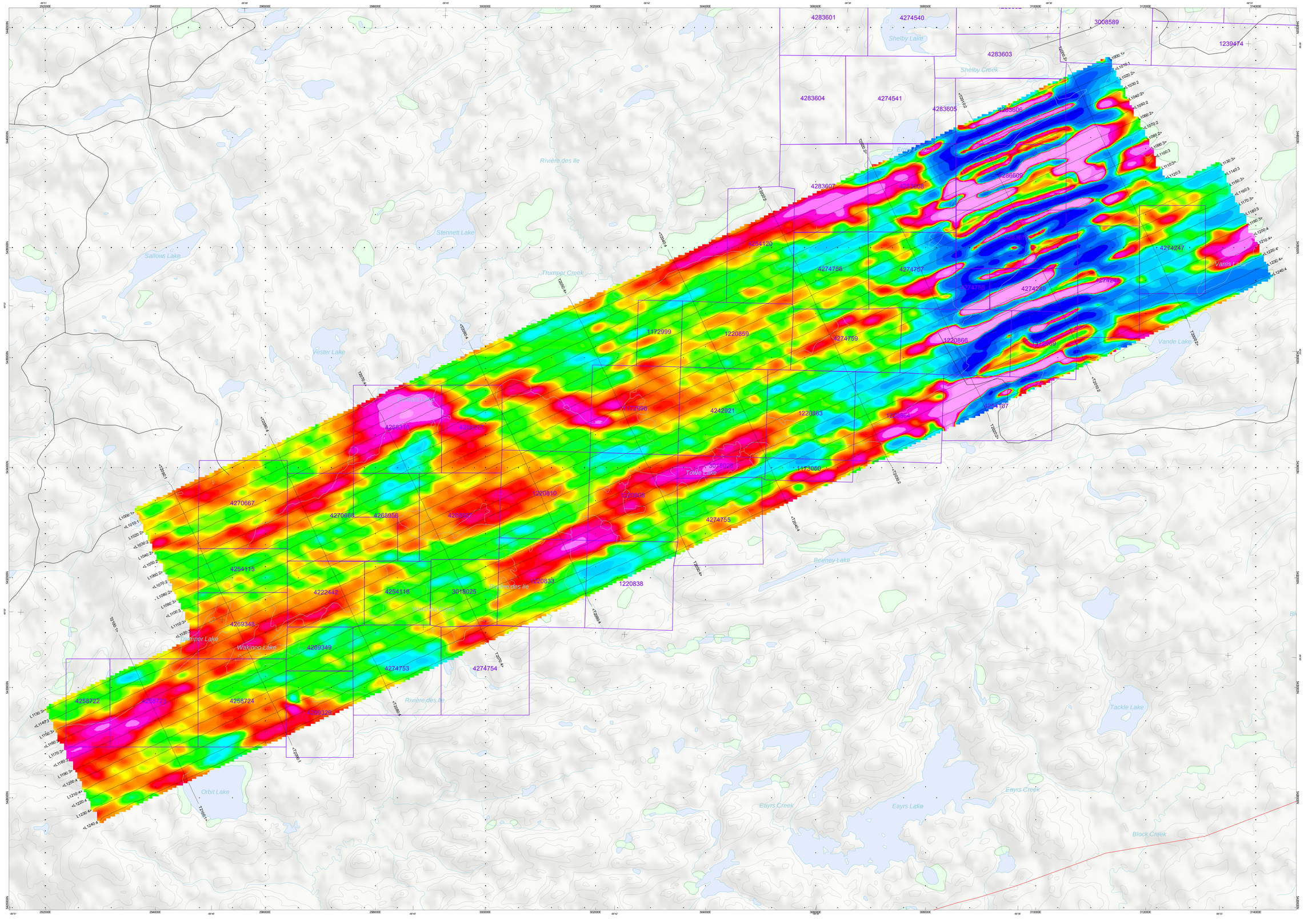
The topographic data base was derived from 1:50000 NRC/Natural Resources Canada) NTDB data
Background shading is derived from NASA SRTM/Shuttle Radar Topography Mission/data
Inset data derived from Geocommunities 1:250,000 Canadian National Topographic database
Mining Claims are derived from the Ontario Ministry of Northern Development and Mines
(www.geocomm.com)(www.geogratis.ca)(http://www.mndm.gov.on.ca)

Lac des Iles Mines Ltd
Shelby
Lac de Iles Region, Ontario
NTS: 052H04

Geotech ZTEM System
45Hz In-Phase Total Divergence
(DT)

Flown and processed by Geotech Ltd.
245 Industrial Parkway North,
Aurora, Ontario, Canada L4G 4C4
www.geotech.ca

December 2014



GEOTECH LTD.

Scale 1:10,000,000

SURVEY SPECIFICATIONS:

Survey Flying Date: November 4th to 21st 2014
Survey Operations Base: Lac des Iles Mines, Ontario
Survey Line Spacing: 200 Meters
Survey Line Direction: N 65° E / N 245° E
Survey Tie Line Spacing: 2000 Meters
Survey Tie Line Direction: N 155° E / N 335° E
Helicopter Mean Terrain Clearance: 152 metres
Mean Ground Air Speed: 25 metres/sec
ZTEM airborne coil: towed at a mean distance of 70 m below the helicopter
Airborne Magnetometer bird: towed at a mean distance of 55 m below the helicopter

HELICOPTER SPECIFICATIONS

Helicopter Type: Aerospatiale A-Star 350 B3 (C-FVTM)

AIRBORNE INSTRUMENTATION

Survey Type: Helicopter Z-Axis Tipper Electromagnetic (ZTEM), Magnetic towed Bird
GPS Receivers (4): NovAtel CDGPS enabled Propak V3-RT20
GPS Receivers Location: One on the helicopter, three on EM coil
Radar Altimeter: Terra TRA 3000/TRI 40
Navigation: GEONAV-3

AIRBORNE ELECTROMAGNETIC SYSTEM

Electromagnetic System: Geotech Z-Axis Tipper (ZTEM)
Coil dimensions: 7.4 metres diameter
Coil orientation: Vertical Dipole
Digitizing rate: 2000Hz

AIRBORNE MAGNETOMETER

Magnetometer: GEOMETRICS
Magnetometer Sensitivity: +/- 0.02 nT
Sampling Rate: 0.2 Hz

GROUND INSTRUMENTATION

MAGNETIC BASE STATION

Magnetometer: GEOMETRICS
Base Station Location: (49°09' 0" N, 89°36'0" W)

EM BASE STATION

Three orthogonal square coils
Coil dimensions: 3.04 metres each side
Coil orientation: Horizontal Dipole
Base Station Location: (49°31'10" N, 89°51'36" W)
Azimuth: AzA = N 208° E AzB = N 298° E

PROCESSING SUMMARY

MAGNETICS:

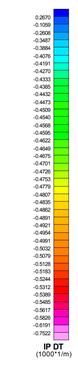
Diurnal Subtraction, microlevelling

ZTEM:

Frequencies extracted: 30, 45, 90, 180, 360, 720Hz.
Sampling rate: 0.4 sec.
Rotation of the inphase part of the inline and orthogonal components (Z/X0oc and Z/Yloc)on to UTM Eastings and Northings.
Attitude correction applied, (calculated from 3 GPS recievers installed on airborne coil).
DIV(Tilt) calculated: d/dcomp/dX+d/dcomp/dY for all 6 frequencies.
Phase Rotated Grids (90 deg) calculated from each individual X and Y component grids, for each individual frequency.

MAP PROJECTION

Datum NAD83
Projection: Universal Transverse Mercator
Central Meridian: 87°W (Zone 16N)
Central Scale Factor: 0.9996
False Easting/Northing: 500,000m/0m
Major Axis: 6378137.0
Inverse Flattening: 298.25722
NTS: 052A13 & 052H04



TOPOGRAPHIC LEGEND:

Roads
Pipelines
Streams / Rivers
Contours
Lakes / Ponds
Wetlands
Mining Claims

Scale 1:20000

250 0 250 500 750 1000
(meters)
NAD83 / UTM zone 26N

The topographic data base was derived from 1:50000 NRC(Natural Resources Canada) NTDB data
Background shading is derived from NASA SRTM/Shuttle Radar Topography Mission data
Inset data derived from Geocommunities 1:250,000 Canadian National Topographic database
Mining Claims are derived from the Ontario Ministry of Northern Development and Mines
(www.geocomm.com)(www.geogratis.ca)(http://www.mndm.gov.on.ca)

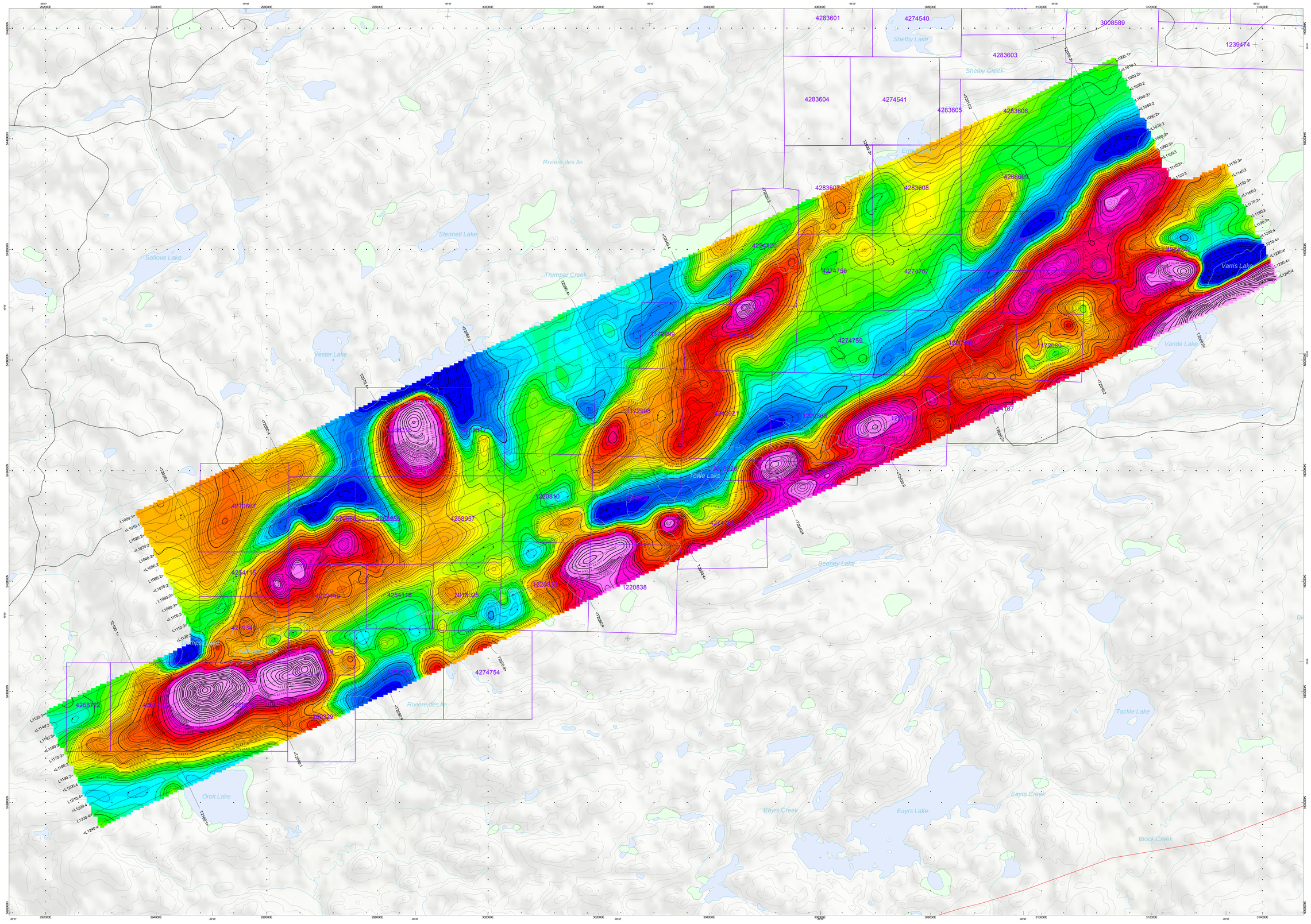
Lac des Iles Mines Ltd
Shelby
Lac de Iles Region, Ontario
NTS: 052H04

Geotech ZTEM System
720Hz In-Phase Total Divergence (DT)

Flown and processed by Geotech Ltd.
245 Industrial Parkway North,
Aurora, Ontario, Canada L4G 4C4
www.geotech.ca

December 2014

Geotech Project # GL140367



GEOTECH LTD.

Scale 1:10,000,000

SURVEY SPECIFICATIONS:

Survey Flying Date: November 4th to 21st 2014
Survey Operations Base: Lac des Iles Mines, Ontario
Survey Line Spacing: 200 Meters
Survey Line Direction: N 65° E / N 245° E
Survey Tie Line Spacing: 2000 Meters
Survey Tie Line Direction: N 155° E / N 335° E
Helicopter Mean Terrain Clearance: 152 metres
Mean Ground Air Speed: 25 metres/sec
ZTEM airborne coil: towed at a mean distance of 70 m below the helicopter
Airborne Magnetometer bird: towed at a mean distance of 55 m below the helicopter

HELICOPTER SPECIFICATIONS

Helicopter Type: Aerospatiale A-Star 350 B3 (C-FVTM)

AIRBORNE INSTRUMENTATION

Survey Type: Helicopter Z-Axis Tipper Electromagnetic (ZTEM), Magnetic towed Bird
GPS Receivers (4): NovAtel CDGPS enabled Propak V3-RT20
GPS Receivers Location: One on the helicopter, three on EM coil
Radar Altimeter: Terra TRA 3000/TRI 40
Navigation: GEONAV-3

AIRBORNE ELECTROMAGNETIC SYSTEM

Electromagnetic System: Geotech Z-Axis Tipper (ZTEM)
Coil dimensions: 7.4 metres diameter
Coil orientation: Vertical Dipole
Digitizing rate: 2000Hz

AIRBORNE MAGNETOMETER

Magnetometer: GEOMETRICS
Magnetometer Sensitivity: +/- 0.02 nT
Sampling Rate: 0.2 Hz

GROUND INSTRUMENTATION

MAGNETIC BASE STATION

Magnetometer: GEOMETRICS
Base Station Location: (49°09' 0" N, 89°36'0" W)

EM BASE STATION

Three orthogonal square coils
Coil dimensions: 3.04 metres each side
Coil orientation: Horizontal Dipole
Base Station Location: (49°31'10" N, 89°51'36" W)
Azimuth: AzA = N 208° E AzB = N 298° E

PROCESSING SUMMARY

MAGNETICS:

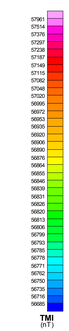
Diurnal Subtraction, microlevelling

ZTEM:

Frequencies extracted: 30, 45, 90, 180, 360, 720Hz.
Sampling rate: 0.4 sec.
Rotation of the inphase part of the inline and orthogonal components (ZX0oc and ZY0oc)on to UTM Eastings and Northings.
Attitude correction applied, (calculated from 3 GPS recievers installed on airborne coil).
DIV(Tilt) calculated: dX/comp/dX+dY/comp/dY for all 6 frequencies.
Phase Rotated Grids (90 deg) calculated from each individual X and Y component grids, for each individual frequency.

MAP PROJECTION

Datum NAD83
Projection: Universal Transverse Mercator
Central Meridian: 87°W (Zone 16N)
Central Scale Factor: 0.9996
False Easting/Northing: 500,000m/0m
Major Axis: 6378137.0
Inverse Flattening: 298.25722
NTS: 052A13 & 052H04



TMI Contour Intervals:

10 nT
50 nT
250 nT

TOPOGRAPHIC LEGEND:

Roads
Pipelines
Streams / Rivers
Contours
Lakes / Ponds
Wetlands
Mining Claims

Scale 1:20000

250 0 250 500 750 1000
(meters)
NAD83 / UTM zone 28N

The topographic database was derived from 1:50000 NRC (Natural Resources Canada) NTDB data
Background shading is derived from NASA SRTM/Shuttle Radar Topography Mission data
Inset data derived from Geocommunities 1:250,000 Canadian National Topographic database
Mining Claims are derived from the Ontario Ministry of Northern Development and Mines
(www.geocomm.com)(www.geogratis.ca)(http://www.mndm.gov.on.ca)

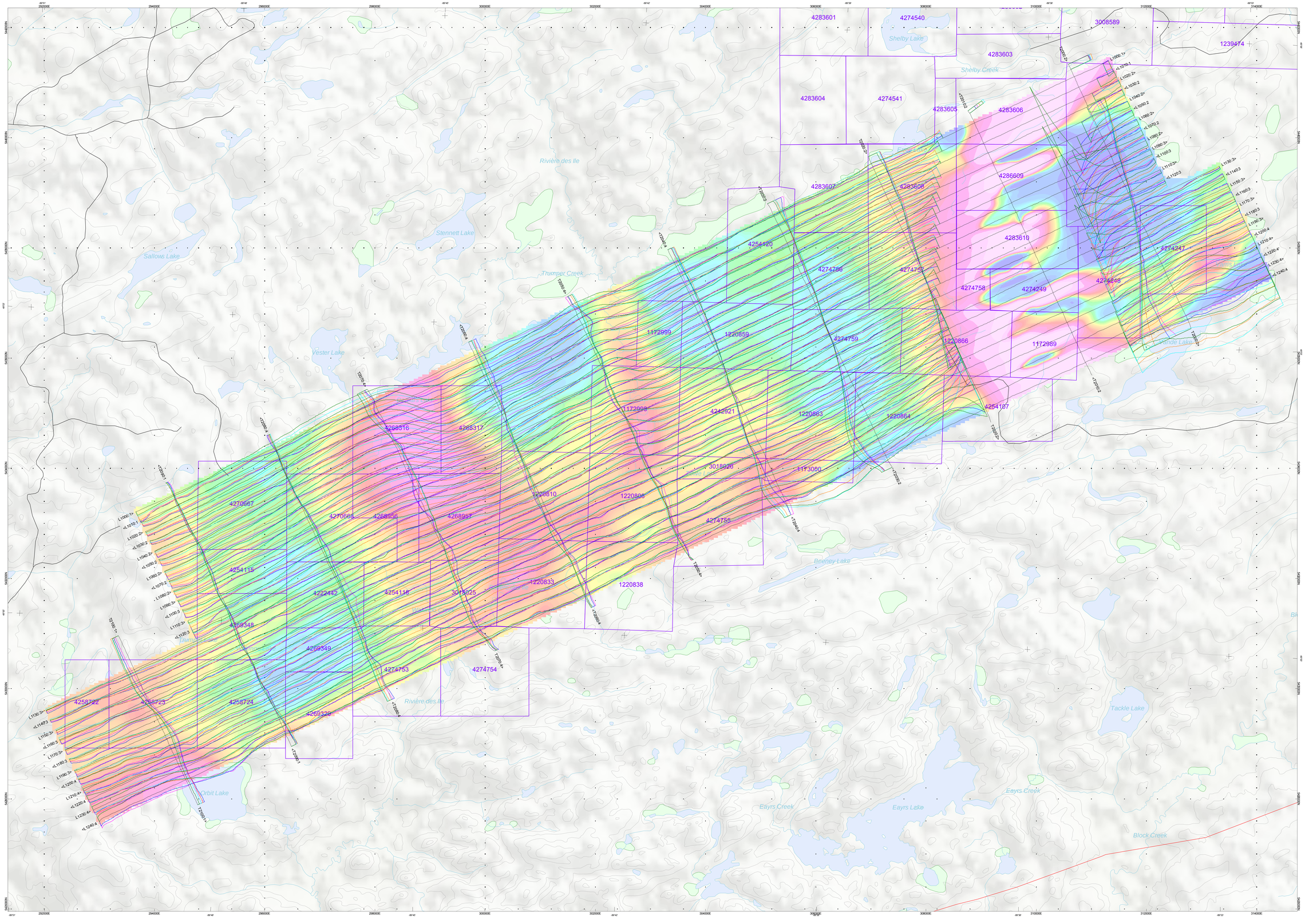
Lac des Iles Mines Ltd
Shelby
Lac de Iles Region, Ontario
NTS: 052H04

Geotech ZTEM System
Total Magnetic Intensity (TMI)

Flown and processed by Geotech Ltd.
245 Industrial Parkway North,
Aurora, Ontario, Canada L4G 4C4
www.geotech.ca

December 2014

Geotech Project # 01-140367



GEOTECH LTD.

Scale 1:10,000,000

SURVEY SPECIFICATIONS:

Survey Flying Date: November 4th to 21st 2014
Survey Operations Base: Lac des Iles Mines, Ontario
Survey Line Spacing: 200 Meters
Survey Line Direction: N 65° E / N 245° E
Survey Tie Line Spacing: 2000 Meters
Survey Tie Line Direction: N 155° E / N 335° E
Helicopter Mean Terrain Clearance: 152 metres
Mean Ground Air Speed: 25 metres/sec
ZTEM airborne coil: towed at a mean distance of 70 m below the helicopter
Airborne Magnetometer bird: towed at a mean distance of 55 m below the helicopter

HELICOPTER SPECIFICATIONS

Helicopter Type: Aerospatiale A-Star 350 B3 (C-FVTM)

AIRBORNE INSTRUMENTATION

Survey Type: Helicopter Z-Axis Tipper Electromagnetic (ZTEM), Magnetic towed Bird
GPS Receivers (4): NovAtel CDGPS enabled Propak V3-RT20
GPS Receivers Location: One on the helicopter, three on EM coil
Radar Altimeter: Terra TRA 3000/TRI 40
Navigation: GEONAV-3

AIRBORNE ELECTROMAGNETIC SYSTEM

Electromagnetic System: Geotech Z-Axis Tipper (ZTEM)
Coil dimensions: 7.4 metres diameter
Coil orientation: Vertical Dipole
Digitizing rate: 2000Hz

AIRBORNE MAGNETOMETER

Magnetometer: GEOMETRICS
Magnetometer Sensitivity: +/- 0.02 nT
Sampling Rate: 0.2 Hz

GROUND INSTRUMENTATION

MAGNETIC BASE STATION

Magnetometer: GEOMETRICS
Base Station Location: (49°09' 0" N, 89°36'0" W)

EM BASE STATION

Three orthogonal square coils
Coil dimensions: 3.04 metres each side
Coil orientation: Horizontal Dipole
Base Station Location: (49°31'10" N, 89°51'36" W)
Azimuth: AzA = N 208° E AzB = N 298° E

PROCESSING SUMMARY

MAGNETICS:

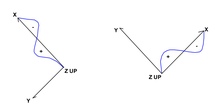
Diurnal Subtraction, microlevelling

ZTEM:

Frequencies extracted: 30, 45, 90, 180, 360, 720Hz.
Sampling rate: 0.4 sec.
Rotation of the inphase part of the inline and orthogonal components (ZX0oc and ZY0ocion to UTM Eastings and Northings.
Attitude correction applied, (calculated from 3 GPS recievers installed on aiborne coil).
DIV(Tilt) calculated: dX/compt/dX+dY/compt/dY for all 6 frequencies.
Phase Rotated Grids (90 deg.) calculated from each individual X and Y component grids, for each individual frequency.

MAP PROJECTION

Datum NAD83
Projection: Universal Transverse Mercator
Central Meridian: 87°W (Zone 16N)
Central Scale Factor: 0.9996
False Easting/Northing: 500,000m/0m
Major Axis: 6378137.0
Inverse Flattening: 298.25722
NTS: 052A13 & 052H04



In-Phase Frequencies
0.01 units per mm
Profile Base 0

30 Hz
45 Hz
90 Hz
180 Hz
360 Hz
720 Hz

TOPOGRAPHIC LEGEND:

Roads
Pipelines
Streams / Rivers
Contours
Lakes / Ponds
Wetlands
Mining Claims

90Hz Tzx IP

Scale 1:20000

250 0 250 500 750 1000
(meters)
NAD83 / UTM zone 26N

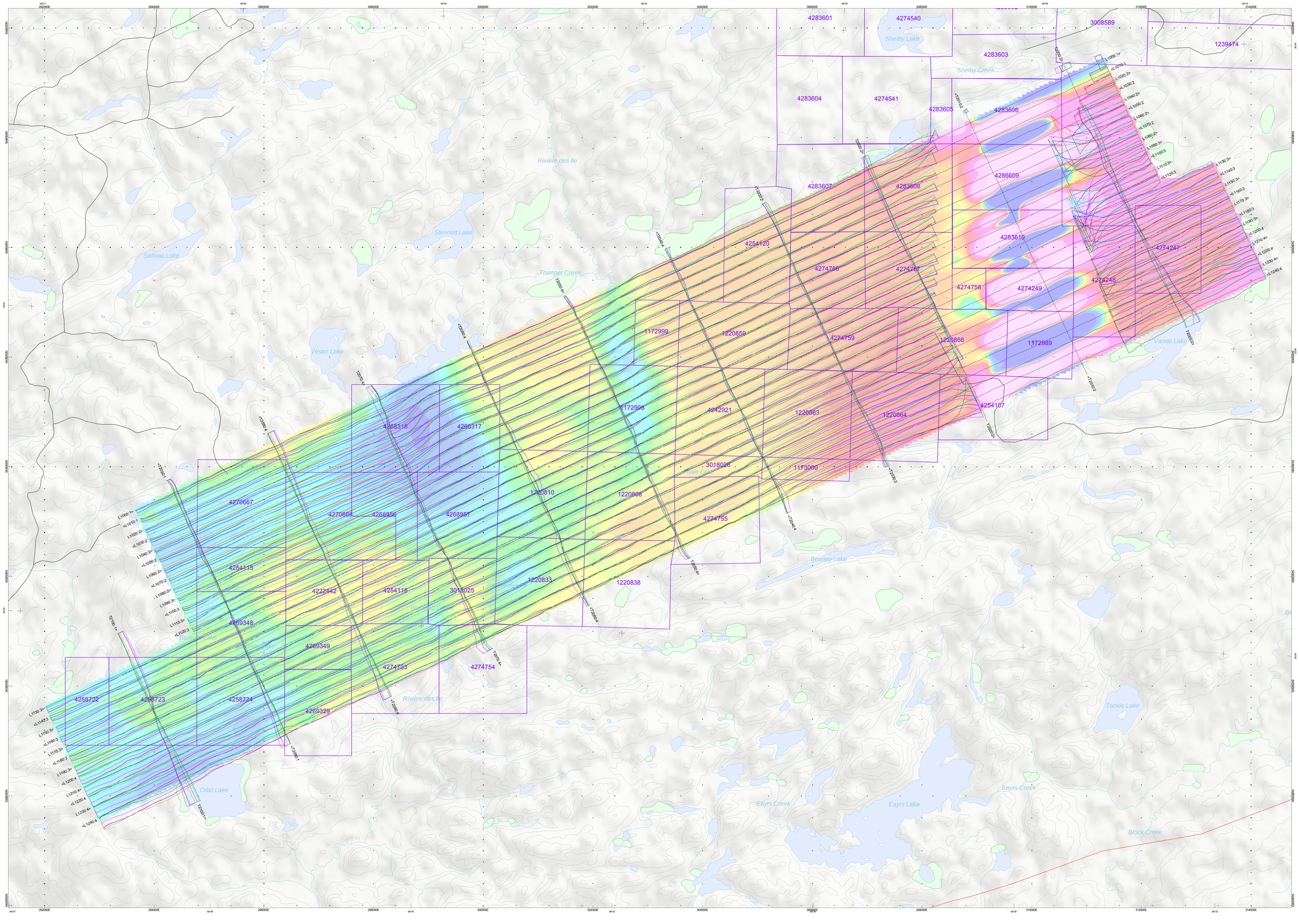
The topographic database was derived from 1:50000 NRC (Natural Resources Canada) NTDB data
Background shading is derived from NASA SRTM/Shuttle Radar Topography Mission/data
Insert data derived from Geocommunities 1:250,000 Canadian National Topographic database
Mining Claims are derived from the Ontario Ministry of Northern Development and Mines
(www.geocomm.com)(www.geogratis.ca)(http://www.mndm.gov.on.ca)

Lac des Iles Mines Ltd
Shelby
Lac de Iles Region, Ontario
NTS: 052H04

Geotech ZTEM System
Tzx (In-line) In-Phase Profiles over
90Hz Phase Rotated In-Phase Grid

Flown and processed by Geotech Ltd.
245 Industrial Parkway North,
Aurora, Ontario, Canada L4G 4C4
www.geotech.ca

December 2014



SURVEY SPECIFICATIONS:

Survey Flying Date: November 4th to 21st 2014
Survey Operations Base: Lac des Iles Mines, Ontario
Survey Line Spacing: 200 Meters
Survey Line Direction: N 65° E / N 245° E
Survey Tie Line Spacing: 2000 Meters
Survey Tie Line Direction: N 155° E / N 335° E
Helicopter Mean Terrain Clearance: 152 metres
Mean Ground Air Speed: 25 metres/sec
ZTEM airborne coil: towed at a mean distance of 70 m below the helicopter
Airborne Magnetometer bird: towed at a mean distance of 55 m below the helicopter

HELICOPTER SPECIFICATIONS

Helicopter Type: Aerospatiale A-Star 350 B3 (C-FVTM)

AIRBORNE INSTRUMENTATION

Survey Type: Helicopter Z-Axis Tipper Electromagnetic (ZTEM), Magnetic towed Bird
GPS Receivers (4): NovAtel CDGPS enabled Propak V3-RT20
GPS Receivers Location: One on the helicopter, three on EM coil
Radar Altimeter: Terra TRA 3000/TRI 40
Navigation: GEONAV-3

AIRBORNE ELECTROMAGNETIC SYSTEM

Electromagnetic System: Geotech Z-Axis Tipper (ZTEM)
Coil dimensions: 7.4 metres diameter
Coil orientation: Vertical Dipole
Digitizing rate: 200Hz

AIRBORNE MAGNETOMETER

Magnetometer: GEOMETRICS
Magnetometer Sensitivity: +/- 0.02 nT
Sampling Rate: 0.2 Hz

GROUND INSTRUMENTATION

MAGNETIC BASE STATION

Magnetometer: GEOMETRICS
Base Station Location: (49°09' 0" N, 89°36'0" W)

EM BASE STATION

Three orthogonal square coils
Coil dimensions: 3.04 metres each side
Coil orientation: Horizontal Dipole
Base Station Location: (49°31'10" N, 89°51'36" W)
Azimuth: AzA = N 208° E AzB = N 298° E

PROCESSING SUMMARY

MAGNETICS:

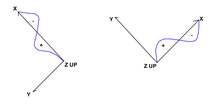
Diurnal Subtraction, microleveling

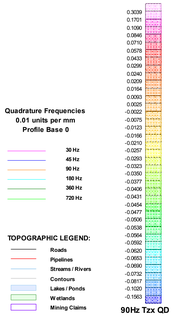
ZTEM:

Frequencies extracted: 30, 45, 90, 180, 360, 720Hz.
Sampling rate: 0.4 sec.
Rotation of the inphase part of the inline and orthogonal components (ZXXoc and ZYXoc)on to UTM Eastings and Northings.
Attitude correction applied. (calculated from 3 GPS recievers installed on aborne coil).
DIV(TIR) calculated: dXcomp/dX+dYcomp/dY for all 6 frequencies.
Phase Rotated Grids (90 deg) calculated from each individual X and Y component grids, for each individual frequency.

MAP PROJECTION

Datum NAD83
Projection: Universal Transverse Mercator
Central Meridian: 87°W (Zone 16N)
Central Scale Factor: 0.9996
False Easting/Northing: 500,000m/0m
Major Axis: 6378137.0
Inverse Flattening: 298.25722
NTS: 052A13 & 052H04





Scale 1:20000

250 0 250 500 750 1000
(meters)
NAD83 / UTM zone 16N

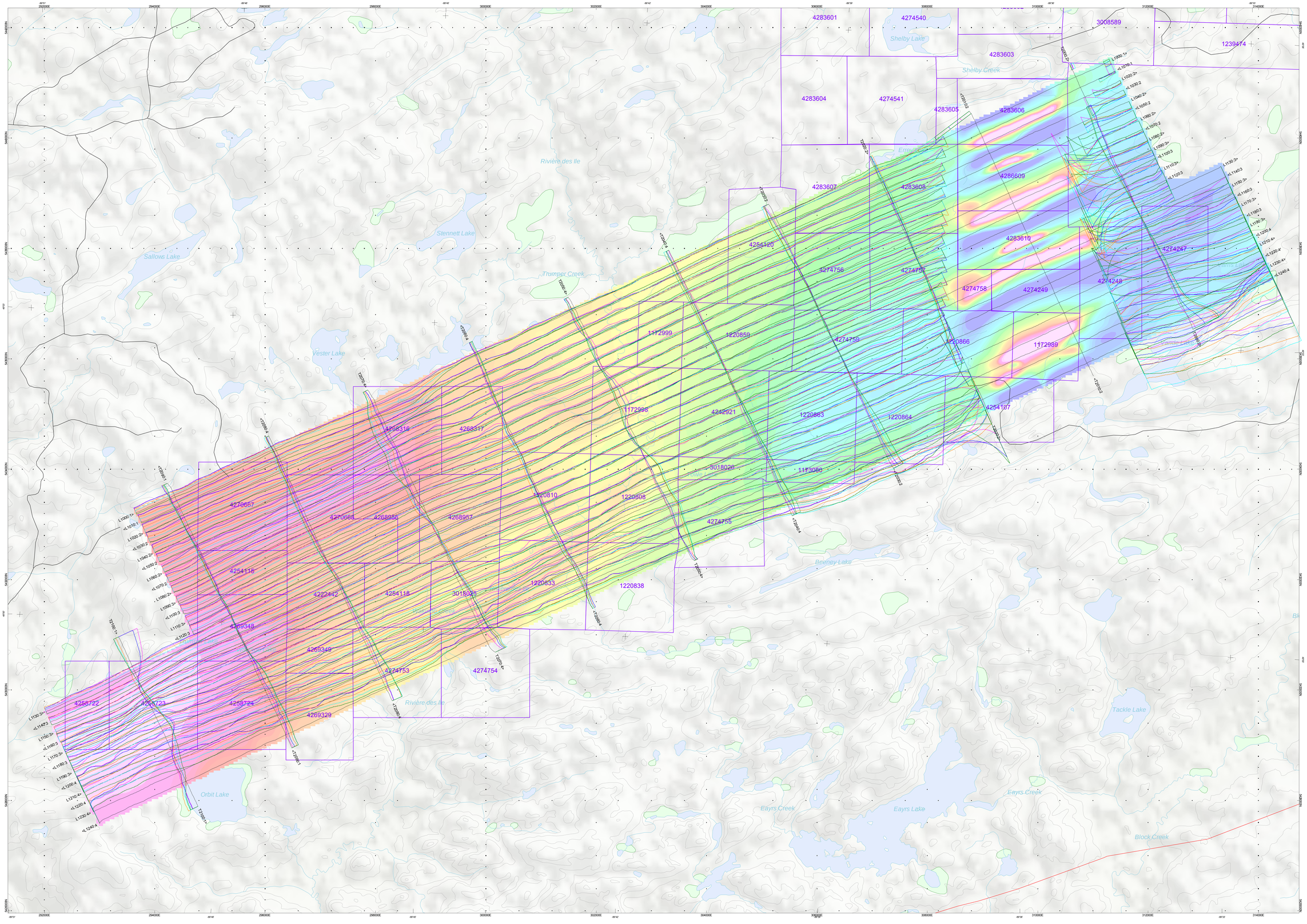
The topographic data base was derived from 1:50000 NRC (Natural Resources Canada) NTDB data
Background shading is derived from NASA SRTM (Shuttle Radar Topography Mission) data
Inset data derived from Geocommunities 1:250,000 Canadian National Topographic database
Mining Claims are derived from the Ontario Ministry of Northern Development and Mines
(www.geocomm.com)(www.geogratis.ca)(http://www.mndm.gov.on.ca)

Lac des Iles Mines Ltd
Shelby
Lac de Iles Region, Ontario
NTS: 052H04

Geotech ZTEM System
Tzx (In-line) Quadrature Profiles over
90Hz Phase Rotated Quadrature Grid

Flown and processed by Geotech Ltd.
245 Industrial Parkway North,
Aurora, Ontario, Canada L4G 4C4
www.geotech.ca

December 2014



GEOTECH LTD.

Scale 1:10,000,000

SURVEY SPECIFICATIONS:

Survey Flying Date: November 4th to 21st 2014
Survey Operations Base: Lac des Iles Mines, Ontario
Survey Line Spacing: 200 Meters
Survey Line Direction: N 65° E / N 245° E
Survey Tie Line Spacing: 2000 Meters
Survey Tie Line Direction: N 155° E / N 335° E
Helicopter Mean Terrain Clearance: 152 metres
Mean Ground Air Speed: 25 metres/sec
ZTEM airborne coil: towed at a mean distance of 70 m below the helicopter
Airborne Magnetometer bird: towed at a mean distance of 55 m below the helicopter

HELICOPTER SPECIFICATIONS

Helicopter Type: Aerospatiale A-Star 350 B3 (C-FVTM)

AIRBORNE INSTRUMENTATION

Survey Type: Helicopter Z-Axis Tipper Electromagnetic (ZTEM), Magnetic towed Bird
GPS Receivers (4): NovAtel CDGPS enabled Propak V3-RT20
GPS Receivers Location: One on the helicopter, three on EM coil
Radar Altimeter: Terra TRA 3000/TRI 40
Navigation: GEONAV-3

AIRBORNE ELECTROMAGNETIC SYSTEM

Electromagnetic System: Geotech Z-Axis Tipper (ZTEM)
Coil dimensions: 7.4 metres diameter
Coil orientation: Vertical Dipole
Digitizing rate: 2000Hz

AIRBORNE MAGNETOMETER

Magnetometer: GEOMETRICS
Magnetometer Sensitivity: +/- 0.02 nT
Sampling Rate: 0.2 Hz

GROUND INSTRUMENTATION

MAGNETIC BASE STATION

Magnetometer: GEOMETRICS
Base Station Location: (49°09' 0" N, 89°36'0" W)

EM BASE STATION

Three orthogonal square coils
Coil dimensions: 3.04 metres each side
Coil orientation: Horizontal Dipole
Base Station Location: (49°31'10" N, 89°51'36" W)
Azimuth: AzA = N 295° E AzB = N 296° E

PROCESSING SUMMARY

MAGNETICS:

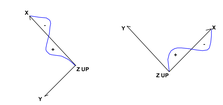
Diurnal Subtraction, microlevelling

ZTEM:

Frequencies extracted: 30, 45, 90, 180, 360, 720Hz.
Sampling rate: 0.4 sec.
Rotation of the inphase part of the inline and orthogonal components (Z/Xloc and Z/Yloc)on to UTM Eastings and Northings.
Attitude correction applied, (calculated from 3 GPS recievers installed on airborne coil).
DIV(Tilt) calculated: dX/comp/dX+dY/comp/dY for all 6 frequencies.
Phase Rotated Grids (90 deg) calculated from each individual X and Y component grids, for each individual frequency.

MAP PROJECTION

Datum: NAD83
Projection: Universal Transverse Mercator
Central Meridian: 87°W (Zone 16N)
Central Scale Factor: 0.9996
False Easting/Northing: 500,000m/0m
Major Axis: 6378137.0
Inverse Flattening: 298.25722
NTS: 052A13 & 052H04



In-Phase Frequencies
0.01 units per mm
Profile Base 0

30 Hz
45 Hz
90 Hz
180 Hz
360 Hz
720 Hz

TOPOGRAPHIC LEGEND:

Roads
Pipelines
Streams / Rivers
Contours
Lakes / Ponds
Wetlands
Mining Claims

90Hz Tzy IP

Scale 1:20000

250 0 250 500 750 1000
(meters)
NAD83 / UTM zone 16N

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Inset data derived from Geocommunities 1:250,000 Canadian National Topographic database
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(www.geocomm.com)(www.geogratis.ca)(http://www.mndm.gov.on.ca)

Lac des Iles Mines Ltd
Shelby
Lac de Iles Region, Ontario
NTS: 052H04

Geotech ZTEM System
Tzy (Cross-line) In-Phase Profiles over
90Hz Phase Rotated In-Phase Grid

Flown and processed by Geotech Ltd.
245 Industrial Parkway North,
Aurora, Ontario, Canada L4G 4C4
www.geotech.ca

December 2014

GEOTECH LTD.

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AIRBORNE ELECTROMAGNETIC SYSTEM

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- Digitizing rate: 2000Hz

AIRBORNE MAGNETOMETER

- Magnetometer: GEOMETRICS
- Magnetometer Sensitivity: +/- 0.02 nT
- Sampling Rate: 0.2 Hz

GROUND INSTRUMENTATION

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- Magnetometer: GEOMETRICS
- Base Station Location: (49°09' 0" N, 89°36'0" W)

EM BASE STATION

- Three orthogonal square coils
- Coil dimensions: 3.04 metres each side
- Coil orientation: Horizontal Dipole
- Base Station Location: (49°31'10" N, 89°51'39" W)
- Azimuth: AzA = N 208° E AzB = N 298° E

PROCESSING SUMMARY

MAGNETICS

- Diurnal Subtraction, microlevelling

ZTEM

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- DX(Tilt) calculated: dXcomp(dX+dYcomp)dY for all 6 frequencies.
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- Datum: NAD83
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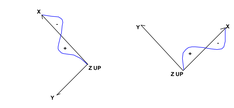

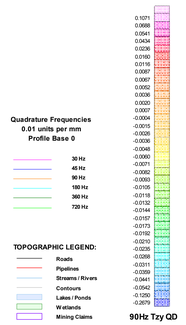

Quadrature Frequencies
0.01 units per mm
Profile Base 0

- 30 Hz
- 45 Hz
- 90 Hz
- 180 Hz
- 360 Hz
- 720 Hz

TOPOGRAPHIC LEGEND:

- Roads
- Pipelines
- Streams / Rivers
- Contours
- Lakes / Ponds
- Wetlands
- Mining Claims

90Hz Tzy QD

The topographic data base was derived from 1:50000 NRC-Natural Resources Canada) NTDB data
Background shading is derived from NASA SRTM30Ultra Radar Topography Mission)data
Road data derived from Geocommunities 1:250,000 Canadian National Topographic database
Mining Claims are derived from the Ontario Ministry of Northern Development and Mines
(www.geocomm.com)(www.geogratis.ca)(http://www.mndm.gov.on.ca)

Lac des Iles Mines Ltd
Shelby
Lac de Iles Region, Ontario
NTS: 052H04

Geotech ZTEM System

Tzy (Cross-line) Quadrature Profiles over 90Hz Phase Rotated Quadrature Grid

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Aurora, Ontario, Canada L4G 4C4
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December 2014

Geotech Project # 05-14/3927