MARSHALL LAKE AREA

Ontario Airborne Geophysical Surveys
Magnetic and Electromagnetic Data
Geophysical Data Set 1239

Ontario Geological Survey
Ministry of Northern Development and Mines
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CREDITS

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- Tom Watkins, Team Leader, Publication Services Section, Ontario Geological Survey, MNDM – managed the project-related hard copy products
- Desmond Rainsford, Geophysicist, Precambrian Geoscience Section, Ontario Geological Survey, MNDM – managed the project-related digital products
- Geotech Ltd, Aurora, Ontario - data acquisition and data compilation.

DISCLAIMER

To enable the rapid dissemination of information, this digital data has not received a technical edit. Every possible effort has been made to ensure the accuracy of the information provided; however, the Ontario Ministry of Northern Development and Mines does not assume any liability or responsibility for errors that may occur. Users may wish to verify critical information.

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Users of OGS products are encouraged to contact those Aboriginal communities whose traditional territories may be located in the mineral exploration area to discuss their project.

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1) INTRODUCTION

As part of an ongoing program to acquire high-quality, high-resolution airborne geophysical data across the Province of Ontario, the Ontario Ministry of Northern Development and Mines (MNDM) does, from time to time, issue Requests For Data (RFD) in order to purchase existing proprietary data held by mining companies. Purchase of existing data complements new surveys commissioned by the MNDM

The purchase of data is attractive because of the low cost of acquisition relative to flying new surveys.
The money used to purchase the data can be reinvested in exploration. The data are assessed for quality prior to purchase and are reprocessed to meet the common formats and standards of other Ontario geophysical data. Once reprocessed these data are then made public.

Ranking and valuation of submitted airborne geophysical survey data sets were based on the following criteria:

- date of survey – recent surveys were favoured over older surveys because of improved acquisition technology, greater data density and improved final products.
- survey method – magnetometer surveys, without supplementary radiometrics or very low frequency (VLF), were given the lowest rating in this category; airborne electromagnetic (AEM) and magnetometer were given the highest; the objective was to acquire data that complements what is already available in the public domain, with emphasis on exploration rather than mapping.
- location of area
  - data sets occurring within areas already surveyed or scheduled for survey were selected only if they added significantly to the acquired data sets,
  - proximity or coincidence of the survey block with areas having restricted land use designations affected the value assigned to that survey,
  - consideration was given to data sets that were collected in remote areas where logistical costs are very high.
- line spacing – detailed surveys were normally accorded a higher rating than reconnaissance surveys.
- quality of data – data quality, processed products, and adherence to correct survey specifications had to be up to normal industry standards.
- survey size – data sets comprising less than 1000 line-km were selected only if they fell in very strategic locations.
- other criteria – factors such as apparent mineral significance, previous exploration activity and land availability were also considered in making the final selection.

2) SURVEY LOCATION AND SPECIFICATIONS

The Marshall Lake area is located in north central Ontario (Figure 1) and was flown over an area of about 220 km^2, approximately 250 km northeast of Thunder Bay and 60 km northwest of Nakina.

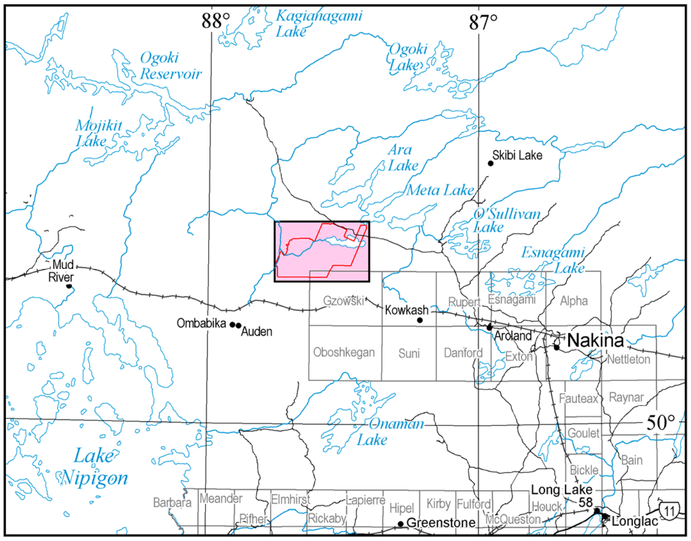


Figure 1: Marshall Lake survey area. Geotech Ltd. TDEM survey shown in red outline.

The survey was flown in two blocks (Figure 2), between February 25 to February 26, 2007 and September 20 to October 13, 2007. The surveys were originally flown for East West Resource Corp. The flight line spacing was 150 m in both surveys. The area was flown with varying line directions. The earlier survey was flown at 22^{o} and -39^{o} with an area of overlap of approximately 4 km^2. The later survey was flown at 22^{o} and -66^{o} with an area of overlap of approximately 12 km^2. Total survey coverage was 1615.6 line kilometres (1549.1 km traverse lines plus 66.5 km tie lines). To distinguish between the two surveys, databases were appended with 1 (earlier survey) or 2 (later survey), i.e., MARSHALL_1.gdb, MARSHALL_2.gdb, MLANOMALY_1.gdb, MLANOMALY_2.gdb, waveform_1.gdb and waveform_2.gdb.

Principal geophysical sensors included a time domain electromagnetic (VTEM) system and a high sensitivity cesium vapour magnetometer. Ancillary equipment included a GPS navigation system with GPS base station, a colour video tracking camera, radar altimeter, powerline monitor and a base station magnetometer.

The survey area is roughly 23 km east to west by 14 km north to south. It is located in the Summit Lake and Sollas Lake Areas in the District of Thunder Bay. The survey is located within National Topographic System (NTS) maps 042 L/05 and 042 L/06 . Prominent lakes within the survey area include Marshall, Little Marshall, Andy Thompson, Gripp, Summit, and Cecil. Topographically, the survey area exhibits a moderate relief, with elevation range from 310 m to 380 m above sea level. Swamp areas, lakes and rivers are observed in the survey area. The area is free of major roads or railroads. No power line activity was detected by the 60 Hz power line monitor.

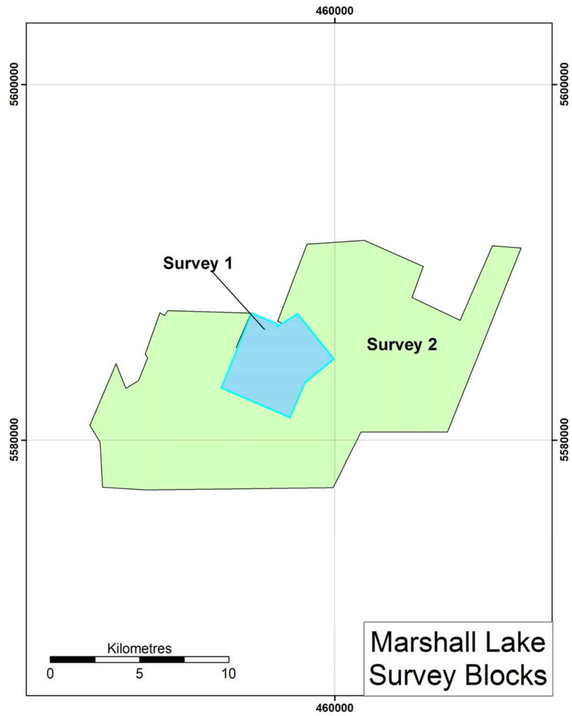


Figure 2: Marshall Lake survey block outlines

The area is centered at about 87° 35'W, 50° 25'N. For an elevation of 350 m and a 2007.8 date, the geomagnetic field had the following characteristics:

Total field :	57 999 nT
Inclination :	76.0°
Declination :	magnetic north is 5.7° west of geographic north

The airborne survey and noise specifications for the Marshall Lake survey area are as follows:

a) traverse line spacing and direction
- flight line spacing is 150 m
- Survey 1 was flown at 22 ° and -39 ° with an area of overlap of approximately 4 km^2. Survey 2 was flown at 22 ° and -66 ° with an area of overlap of approximately 12 km^2.

b) control line spacing and direction
- at regular 3000 m intervals, perpendicular to the flight line direction.

c) terrain clearance of the EM receiver bird
- nominal terrain clearance was 40 m for survey 1 and 35 m for survey 2.

d) terrain clearance of the magnetometer
- nominal terrain clearance was 65 m for survey 1 and 50 m for survey 2.

e) aircraft speed

- nominal aircraft speed was 80 km/hr for survey 1 and 75 km/hr for survey 2. This translates to a geophysical reading about every 2 m along flight track.

f) Data sampling rate
- EM : 0.1 seconds.
- Magnetometer : 0.1 seconds.
- Altimeter: 0.2 seconds.
- GPS : 0.2 seconds.

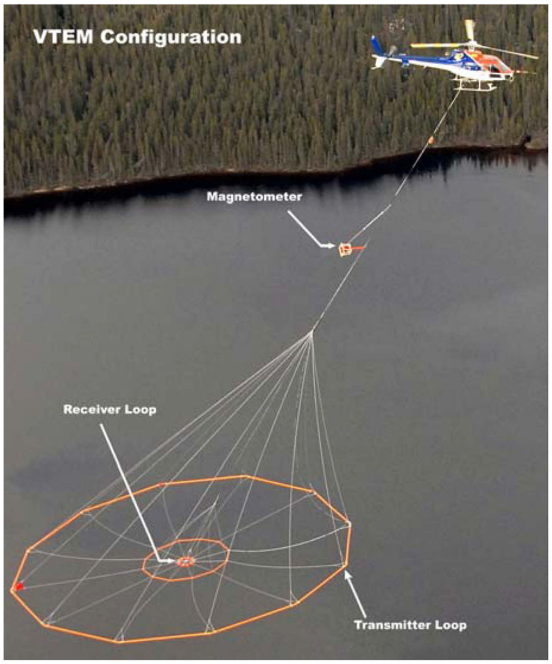
g) noise envelope
- EM noise levels are generally less than 1 ppm excluding sferics. Magnetometer noise levels are 0.1 nT or less.

3) AIRCRAFT, EQUIPMENT AND PERSONNEL

Survey 1

Aircraft and Geophysical On-Board Equipment

Aircraft:	Astar B2 helicopter
Operator:	Expedition Helicopters Ltd.
Registrations:	C-GWOW
Survey Speed:	80 km/hr
Magnetometer:	Geometrics optically pumped cesium vapour magnetic field sensor, mounted in a separate bird towed 15 m below the helicopter, as shown on figure 3. The sensitivity of the magnetic sensor is 0.02 nanoTesla (nT) at a sampling interval of 0.1 seconds. The magnetometer sends the measured magnetic field strength as nanoTeslas to the data acquisition system via the RS-232 port.
Electromagnetic system:	The electromagnetic system was a Geotech Versatile Time Domain EM (VTEM) system. The layout of the configuration used for this survey is as indicated in Figure 3 below.



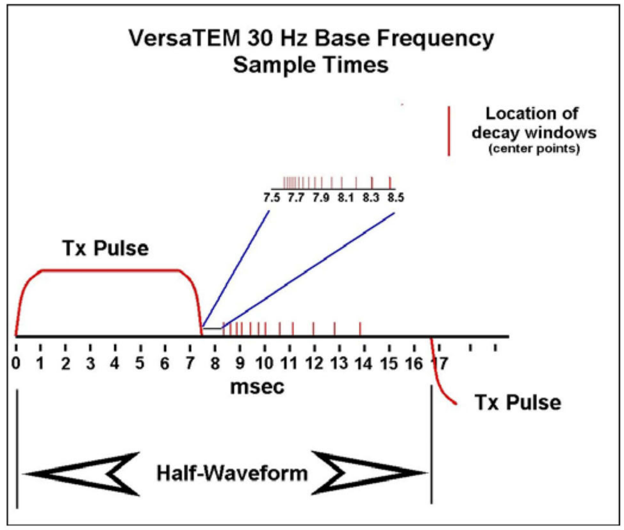


Figure 3. VTEM configuration

Figure 4. VTEM sample times

Receiver and transmitter coils are concentric and Z-direction oriented.

The receiver decay recording scheme is shown diagrammatically in Figure 4. Twenty-nine time gates were used in the range from 70 µs to 7540 µs, as shown in the following table.

VTEM Decay Sampling scheme (Microseconds)			
Time gate	**Start**	**End**	**Width**
70	60	80	20
90	80	100	20
110	100	120	20
130	120	140	20
150	140	160	20
170	160	180	20
190	180	205	25
220	205	240	35
260	240	280	40
300	280	325	45
350	325	380	55
410	380	445	65
480	445	525	80
570	525	625	100
680	625	745	120
810	745	885	140
960	885	1045	160
1130	1045	1235	190
1340	1235	1470	235

1600	1470	1750	280
1900	1750	2070	320
2240	2070	2450	380
2660	2450	2920	470
3180	2920	3480	560
3780	3480	4120	640
4460	4120	4880	760
5300	4880	5820	940
6340	5820	6860	1040
7540	6860	8220	1360

Table 1 - VTEM decay sampling scheme

Transmitter coil diameter was 26 m, the number of turns was 4.
Transmitter pulse repetition rate was 30 Hz.
Peak current was 212 Amp.
Pulse width was 7.2 ms
Duty cycle was 43%.
Peak dipole moment was 457 100 NIA.
Receiver coil diameter was 1.2 m, the number of turns was 100.
Receiver effective area was 113 m^2
Wave form – trapezoid.
Recording sampling rate was 10 samples per second.
The EM bird was towed 42 m below the helicopter.

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.

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

Digital Acquisition System: A Geotech data acquisition system recorded the digital survey data on an internal compact flash card. Data are displayed on an LCD screen as traces to allow the operator to monitor the integrity of the system. Contents and update rates were as follows:

DATA TYPE	SAMPLING
TDEM	0.1 sec
Magnetometer	0.1 sec

GPS Position	0.2 sec
Radar Altimeter	0.2 sec

Table 2 - Sampling Rates

Base Station Equipment

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

The base station magnetometer sensor was installed behind the motel where the crew was housed, away from electric transmission lines and moving ferrous objects such as motor vehicles.

The magnetometer base stations data was backed-up to the data processing computer at the end of each survey day.

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

Field Personnel

Crew Chief:	Les Moschuk
Operator:	Paul Taylor
Project Manager:	Shawn Grant

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

Pilot:	Alex Parra
Engineer:	Dave Luscombe

Office Personnel

Data Processing:	Andrei Bagrianski
Data Processing:	Nasreddine Bournas
Data Processing / Reporting:	Marta Orta

Data acquisition and processing phases were carried out under the supervision of Andrei Bagrianski, Surveys Manager. Overall management of the project was undertaken by Edward Morrison, President, Geotech Ltd.

Survey 2

Aircraft and Geophysical On-Board Equipment

Aircraft: Astar 350-B2 helicopter

Operator:	Abitibi Helicopters Ltd.
Registrations:	C-FXDM
Survey Speed:	75 km/hr
Magnetometer:	The magnetic sensor utilized for the survey was a Geometrics optically pumped cesium vapour magnetic field sensor, mounted in a separated bird, towed 15 m below the helicopter, as shown on Figure 5. The sensitivity of the magnetic sensor is 0.02 nT at a sampling interval of 0.1 seconds. The magnetometer sends the measured magnetic field strength in nanoTeslas (nT) to the data acquisition system via the RS-232 port.
Electromagnetic system:	The electromagnetic system was a Geotech Versatile Time Domain EM (VTEM) system. The configuration is as indicated in figure 5 below.

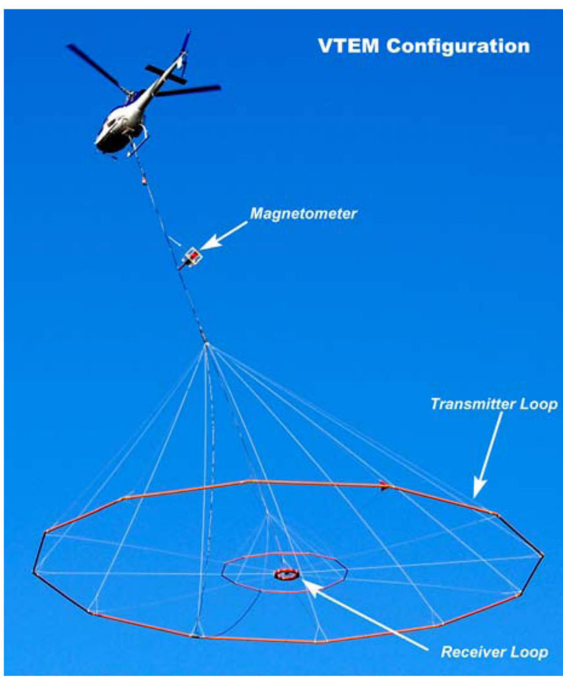


Figure 5. VTEM configuration

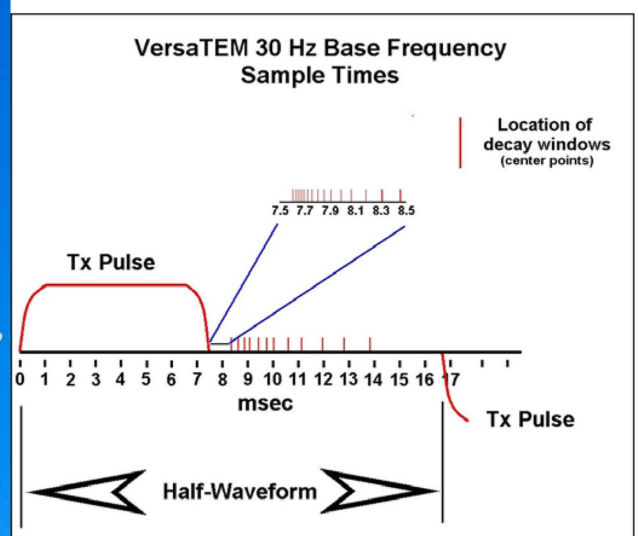


Figure 6. VTEM sample times

Receiver and transmitter coils are concentric and Z-direction oriented. The receiver decay recording scheme is shown in Figure 6.

Twenty-four measurement gates were used in the range from 120 µs to 6578 µs, as shown in Table 3.

VTEM Decay Sampling scheme (Microseconds)			
Time gate	**Start**	**End**	**Width**
120	110	131	21
141	131	154	24
167	154	183	29
198	183	216	34
234	216	258	42
281	258	310	53
339	310	373	63
406	373	445	73
484	445	529	84
573	529	628	99
682	628	750	123
818	750	896	146
974	896	1063	167
1151	1063	1261	198
1370	1261	1506	245
1641	1506	1797	292
1953	1797	2130	333
2307	2130	2526	396
2745	2526	3016	490
3286	3016	3599	583
3911	3599	4266	667
4620	4266	5058	792
5495	5058	6037	979
6578	6037	7203	1167

Table 3 - VTEM decay sampling scheme

Transmitter specifications:

- Loop diameter: 26 m
- Number of turns: 4
- Loop axis orientation: Z-axis
- Pulse frequency: 30 Hz
- Pulse width (on time): 7.4 ms
- Duty cycle: 44%.
- Dipole moment: 390 700 NIA.

Receiver specifications:

- Loop diameter: 1.2 m
- Number of turns: 100
- Receiver effective area: 113 m^2
- loop axis orientation: Z-axis
- Wave form: trapezoid.

Recording sampling rate was 10 samples per second.
A 60 Hz power line monitor data is also recorded.
EM measurements are recorded approximately 35 m above ground, according to flying conditions (cable length is 42 m).

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.

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

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DATA TYPE	SAMPLING
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Magnetometer	0.1 sec
GPS Position	0.2 sec
Radar Altimeter	0.2 sec

Table 4 - Sampling Rates

Base Station Equipment

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

The base station magnetometer sensor was installed where the crew was housed, away from electric transmission lines and moving ferrous objects such as motor vehicles.

The magnetometer base station's data was backed-up to the data processing computer at the end of each survey day.

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

Field Personnel

Field Operation Manager:	Les Moschuk
Crew Chief:	Collin Lennox
Operators:	Richard Samson

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

Pilots:	Joel Breton
Engineer:	Sebastian Bouchard

Office Personnel

QC Geophysicist:	Richard Yee
Data Processing / Reporting:	Marta Orta

Data acquisition and processing phases were carried out under the supervision of Andrei Bagrianski, Surveys Manager. Overall management of the project was undertaken by Edward Morrison, President, Geotech Ltd.

4) DATA COMPILATION AND PROCESSING

Base Maps

Base maps of the survey area were supplied by the Ontario Ministry of Northern Development and Mines.

Projection Description

Datum:	NAD83 (4m North America - Canada and USA)
Ellipsoid:	GRS80
Projection:	UTM (Zone 16N)
Central Meridian:	87° W
False Northing:	0 m
False Easting:	500 000 m
Scale factor:	0.9996

Flight Path

The flight path, recorded by the acquisition program as WGS84 latitude/longitude, was converted into the UTM 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 eastings (x) and UTM northings (y).

Processing of Magnetic Data

The processing of the magnetic data involved the correction for diurnal variations by using the digitally recorded ground base station magnetic values. The base station magnetometer data 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 the traverse lines. A micro-levelling procedure was then applied. This technique is designed to remove persistent low-amplitude components of flight-line noise remaining after tie line levelling.

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 30 m. The minimum curvature algorithm was used to interpolate values onto a rectangular regular spaced grid.

Each survey (1 and 2) had two different flight line directions and areas of overlap. The total magnetic intensity grid was calculated separately for each line direction with a minimum curvature algorithm and a grid cell size of 30 m. The grids from the two flight line directions were knitted together into one total magnetic intensity grid per survey using Geosoft's Oasis Montaj™ gridknit application. The "blend" method with no static shifts between the grids appeared to give the best result. The quality of the knitted grids was examined by observing any noticeable offsets in the total magnetic intensity grid or an evident suture line in the second vertical derivative of the total magnetic intensity. Finally, the total magnetic intensity grids of the two surveys were knitted together using the "blend" method and allowing for a static shift between the grids.

The total magnetic intensity grid was examined using sun shading from various angles to determine whether microlevelling was required. Also a second vertical derivative of the total magnetic intensity was calculated. In either case, no prominent linear anomalies were detected. Thus, it was concluded that microlevelling was not required.

GSC-levelling of the total magnetic intensity grid to the GSC magnetic datum is described in the following section. The levelling correction is calculated from the knitted total magnetic intensity grid described above. The correction is applied to the profile database and new residual grids are calculated and knitted together to create a GSC-levelled total magnetic intensity grid using the same grid knitting procedure described above.

Second Vertical Derivative Grid of the Total Magnetic Field

The second vertical derivative of the total magnetic field is computed to enhance small and weak near-surface anomalies and as an aid to delineate the contacts of the lithologies having contrasting susceptibilities. The location of contacts or boundaries is usually traced by the zero contour of the second vertical derivative map.

The second vertical derivative filter incorporated an 8^{th}-order low-pass Butterworth filter with a cut-off wavelength of 120 m. The purpose of the low-pass filter is to minimize grid aliasing effects in the total magnetic field, which are emphasized by the second vertical derivative.

Keating Correlation Coefficients

Possible kimberlite targets are identified from the residual magnetic intensity data, based on the identification of roughly circular anomalies. This procedure is automated by using an established pattern recognition technique (Keating 1995), which consists of computing, over a moving window, a first-order regression between a vertical cylinder model anomaly and the analytic signal of the gridded magnetic data. Only the results, where the absolute value of the correlation coefficient is above a threshold of 75%, were retained. On the magnetic maps, the results are depicted as circular symbols, scaled to reflect the correlation value. The most favourable targets are those that exhibit a cluster of high amplitude solutions. Correlation coefficients with a negative value correspond to reversely magnetised sources.

The technique was improved by using the analytic signal calculated from the gridded data and the analytic signal of the theoretical target anomaly. The method is easier to use at low magnetic latitudes and greatly reduces the effect of remanence since the analytic signal of the magnetic field is insensitive to the effects of magnetic field orientation and remanence (Keating 2001).

The Keating correlation coefficients were originally calculated using a model grid of the total magnetic field. Few correlations (only 120 solutions) were the result. Thus, the alternate approach using the analytic signal grid and model was used. This gave more solutions (729) and better selected targets. By definition, the analytic signal is always positive. Thus, there will only be positive correlations. Any negative correlations are erroneous.

The cylinder model parameters are as follows:

Cylinder diameter: 200 m
Cylinder length: infinite
Overburden thickness: 3.8 m
Magnetic inclination: 75.9°N
Magnetic declination: 5.7°W
Magnetization scale factor: 100
Model window size: 25 (750 by 750 m)
Model window grid cell size: 30 m

The model computed using these parameters is shown in Figure 7.

It is important to be aware that other magnetic sources may correlate well with the vertical cylinder model, whereas some kimberlite pipes of irregular geometry may not. The user should study the magnetic anomaly that corresponds with the Keating symbols, to determine whether it does resemble a kimberlite pipe signature, reflects some other type of source or even noise in the data e.g. boudinage (beading) effect of the minimum curvature gridding. All available geological information should be incorporated in kimberlite pipe target selection.

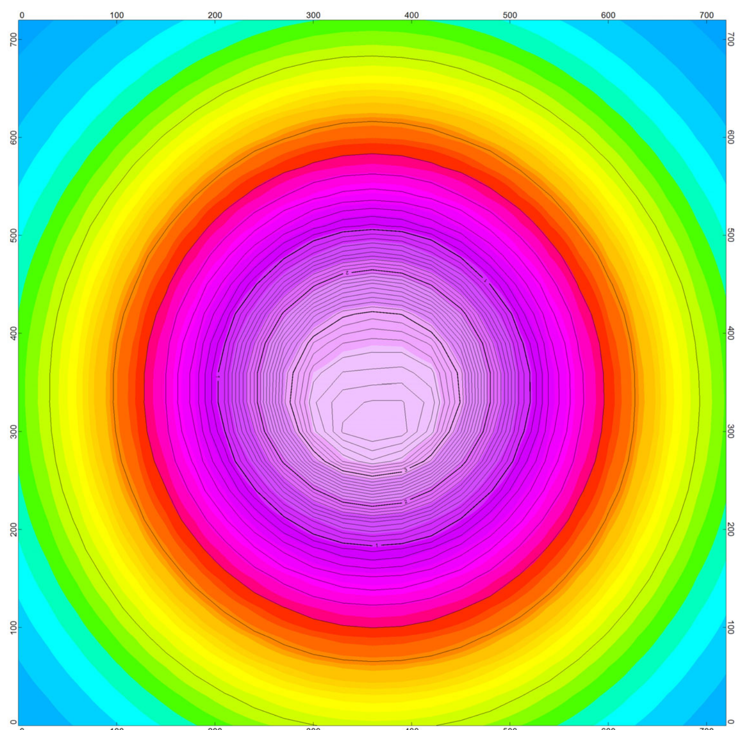


Figure 7: Analytic Signal of a vertical cylinder anomaly model used for Keating correlation on the Marshall Lake survey. Grid cell interval is 30 m and contour interval is 0.1 nT.

Processing of Electromagnetic Data

A three-stage digital filtering process was used to reject major sferic events and to reduce system noise. Local sferic activity can produce sharp, large amplitude events that cannot be removed by conventional filtering procedures. Smoothing or stacking will reduce their amplitude but leave a broader residual response that can be confused with geological phenomena. To avoid this possibility, a computer algorithm searches out and rejects the major sferic events. The filter used was a 16 point non-linear filter.

The signal to noise ratio was further improved by the application of a low pass linear digital filter. This filter has zero phase shift which prevents any lag or peak displacement from occurring, and it suppresses only variations with a wavelength less than about 1 second or 20 m. This filter is a symmetrical 1 sec linear filter.

The results are presented as stacked profiles of the time gates, plotted in linear–logarithmic scale.

Generalized modeling results of the VTEM system, written by Geophysicist Roger Barlow, are shown in Appendix F.

Graphical representation of the VTEM output voltage of the receiver coil is shown in Appendix G.

For each survey, the Z-component EM decay constant (tau) was calculated by fitting off-time channels to a single exponential function of the form:

$$Y = Ae^{-t/\tau}$$

where A = the amplitude at time zero, t = time is seconds and τ is the decay constant. The calculated decay constant is included in the profile databases.

Tau was calculated using a PGW application upon the" em_z_final" array channel. The output tau channel was filtered with a low pass Butterworth filter with a length of 30 m and degree = 8. The filtered tau channels from both surveys were gridded together using a minimum curvature algorithm with a grid cell size of 30 m. The grid was further filtered so that values less than zero (due to overshoots in the minimum curvature gridding algorithm) were clipped to zero. A De-herringbone filter was not applied, since it was not deemed necessary.

The EM Anomaly Selection

The main purpose of EM anomaly selection is to identify possible thin-sheet bedrock conductors. If the source conductance is not large, such anomalies may not appear on the apparent resistivity maps as a characteristic resistivity low.

The anomalies were picked based upon the location of stacked profiles of the "em_z_final" array channel. Bedrock conductors show a response in the early and late channels, while surficial conductors only have a response in the early channels. Bedrock conductors can be further divided into thin (N) and thick (K) conductors. The response expected from a vertical thin sheet conductor is an "M" shaped anomaly as shown in Appendix F. Thick vertical sheet conductors have a single peak response. If the EM anomaly was associated with a magnetic anomaly, it was classified as "anomaly_mag"=1. If there was no associated magnetic anomaly, then "anomaly_mag"=0.

The apparent surface conductance was calculated using Encom's EMFlow software. The two surveys had to be calculated separately since the VTEM sampling parameters differed. The surface conductance channel was gridded using a minimum curvature algorithm with a grid cell size of 30 m and sampled back to the locations of the EM anomalies. The EM anomalies were classified based upon the ranges of <3, 3 to 5, 5 to 8, 8 to 10, 10 to 15, and >15 Siemens.

The power line monitor channel "power" was gridded with a minimum curvature algorithm with a grid cell size of 30 m. No anomalies due to culture, i.e. power lines, etc. were noted. Thus, none of the EM anomalies were classified as culture.

5) GSC-LEVELLING OF THE MAGNETIC DATA

In 1989, as part of the requirements for the contract with the Ontario Geological Survey (OGS) to compile and level all existing Geological Survey of Canada (GSC) aeromagnetic data (flown prior to 1989) in Ontario, PGW developed a robust method to level the magnetic data of various base levels to a common datum provided by the GSC as 812.8 m grids. The essential theoretical aspects of the levelling methodology were fully discussed in Gupta et al. (1989), and Reford et al. (1990). The method was later applied to the remainder of the GSC data across Canada and the high-resolution airborne magnetic and electromagnetic (AMEM) surveys flown by the OGS (OGS 1999). It has since been applied to all newly acquired OGS aeromagnetic surveys.

Terminology

Master grid – refers to the 200 m Ontario magnetic grid compiled and levelled to the 812.8 m magnetic datum from the Geological Survey of Canada.

GSC-levelling – the process of levelling profile data to a master grid, first applied to GSC data.

Intra-survey levelling or microlevelling refers to the removal of residual line noise described earlier in this chapter; the wavelengths of the noise removed are usually shorter than tie line spacing.

Inter-survey levelling or GSC-levelling refers to the level adjustments applied to a block of data; the adjustments are the long wavelength (in the order of tens of kilometres) differences with respect to a common datum, in this case, the 200 m Ontario master grid, which was derived from all pre-1989 GSC magnetic data and adjusted, in turn, by the 812.8 m GSC Canada-wide grid.

The GSC-Levelling Methodology

The GSC-levelling methodology is described below, using the Vickers survey flown for OGS as an example (OGS 2002).

Several data processing procedures are assumed to be applied to the survey data prior to levelling, such as microlevelling, IGRF calculation and removal. The final levelled data are gridded at 1/5 of the line spacing. If a survey was flown as several distinct blocks with different flight directions, then each block is treated as an independent survey.

The steps in the GSC-levelling process are as follows:

1. Create an upward continuation of the survey grid to 305 m

Almost all recent surveys (1990 and later) to be compiled were flown at a nominal terrain clearance of 100 m or less. The first step in the levelling method is to upward continue the survey grid to 305 m, the nominal terrain clearance of the Ontario master grid (Figure 8). The grid cell size for the survey grids is set at 100 m. Since the wavelengths of level corrections will be greater than 10 to 15 km, working with 100 m or even 200 m grids at this stage will not affect the integrity of the levelling method. Only at the very end, when the level corrections are imported into the databases, will the level correction grids be re-gridded to 1/5 of line spacing.

The unlevelled 100 m grid is extended by at least 2 grid cells beyond the actual survey boundary, so that, in the subsequent processing, all data points are covered.

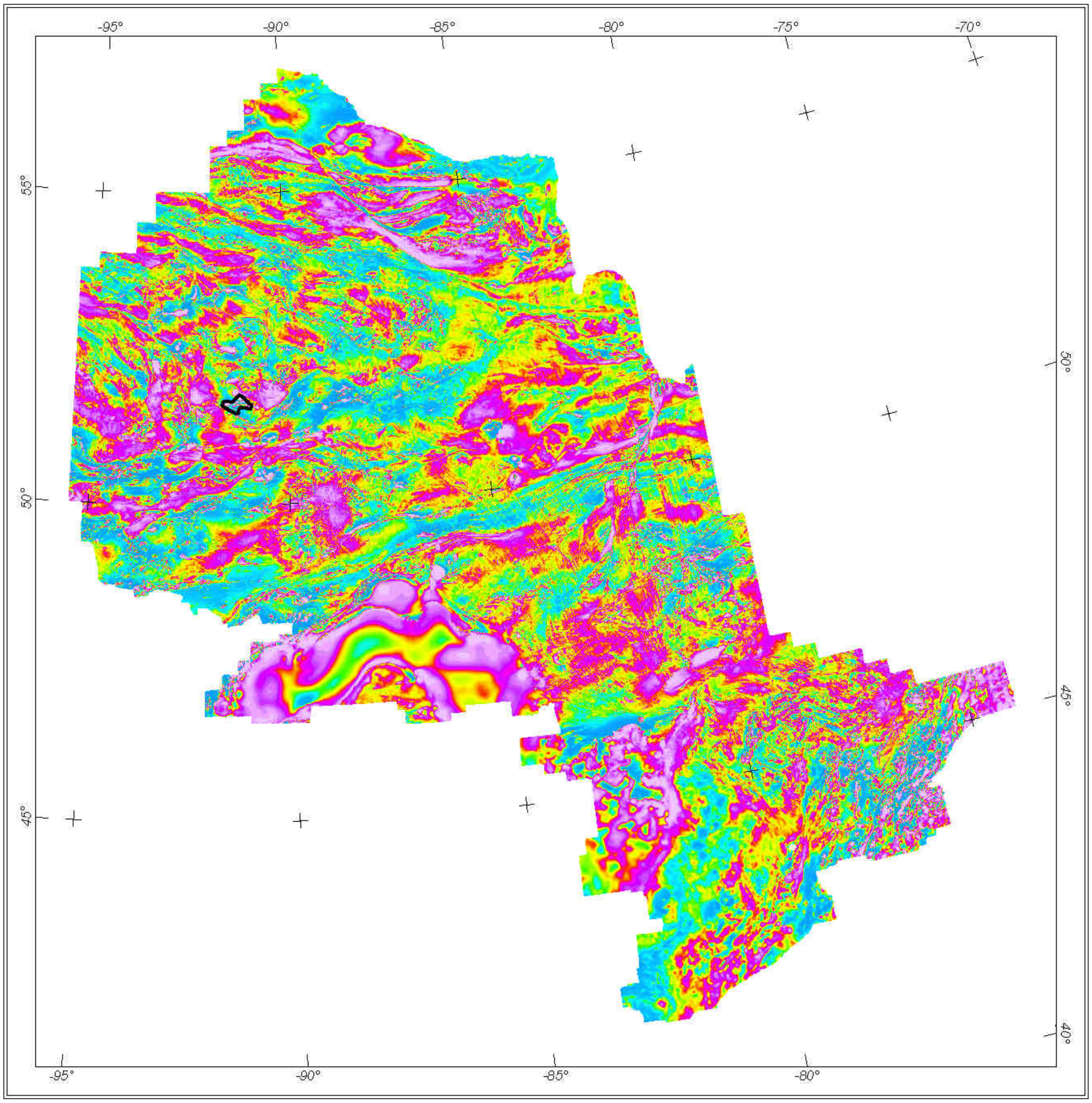


Figure 8: Ontario Master Aeromagnetic Grid (OGS 1999). The outline for the sample data set to be levelled (Vickers, OGS 2002) is shown.

2. Create a difference grid between the survey grid and the Ontario master grid

The difference between the upward continued survey grid and the Ontario master grid, re-gridded at 100 m, is computed (Figure 9). The short wavelengths represent the higher resolution of the survey grid. The long wavelengths represent the level difference between the two grids.

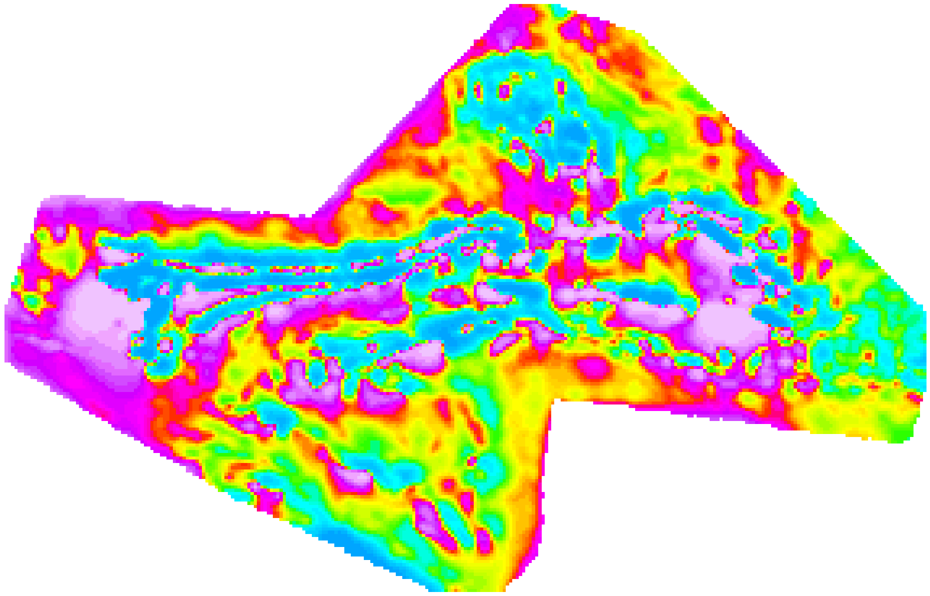


Figure 9: Difference grid (difference between survey grid and master grid), Vickers survey (OGS 2002).

3. Rotate difference grid so that flight line direction is parallel to grid column or row, if necessary.

4. Apply the first pass of a non-linear filter (Naudy and Dreyer 1968) of wavelength on the order of 15 to 20 km along the flight line direction. Reapply the same non-linear filter across the flight line direction.

5. Apply the second pass of a non-linear filter of wavelength on the order of 2000 to 5000 m along the flight line direction. Reapply the same non-linear filter across the flight line direction.

6. Rotate the filtered grid back to its original (true) orientation (Figure 10).

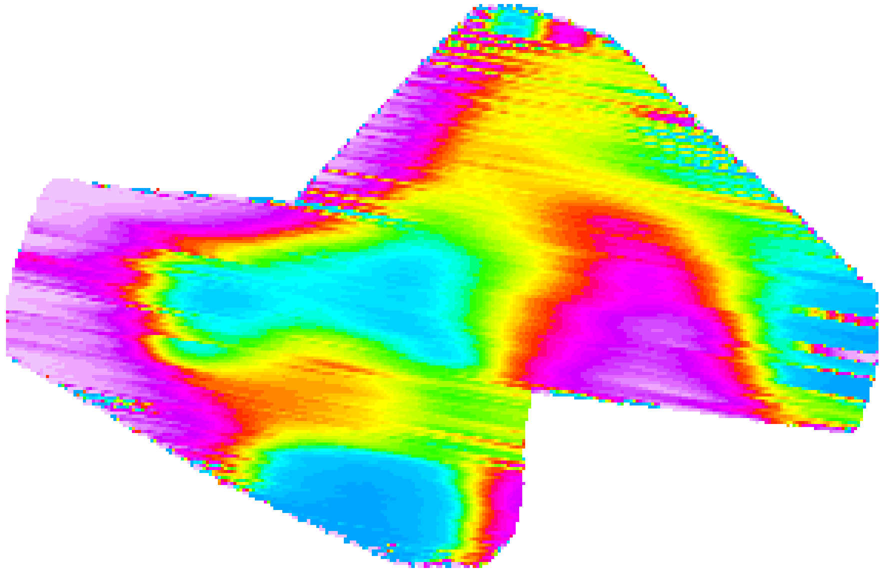


Figure 10: Difference grid after application of non-linear filtering and rotation, Vickers Survey (OGS 2002).

7. Apply a low pass filter to the non-linear filtered grid

Streaks may remain in the non-linear filtered grid, mostly caused by edge effects. They must be removed by a frequency-domain, low pass filter with the wavelengths in the order of 25 km (Figure 11).

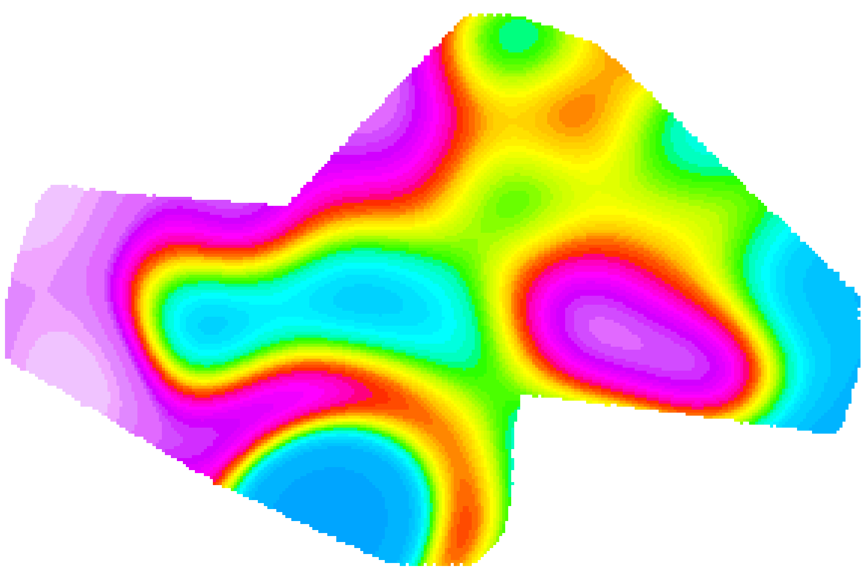


Figure 11: Level correction grid, Vickers survey (OGS 2002).

8. Re-grid to 1/5 line spacing and import level corrections into database.

9. Subtract the level correction channel from the un-levelled channel to obtain the level corrected channel.

10. Make final grid using the gridding algorithm of choice with grid cell size at 1/5 of line spacing.

Survey Specific Parameters

No microlevelling was performed on the Marshall Lake survey.

The following GSC-levelling parameters were used in the Marshall Lake survey:

Distance to upward continue: 245 m
First pass non-linear filter length: 10 000 m
Second pass non-linear filter length: 2500 m
Low pass filter cut-off wavelength: 15 000 m

6) FINAL PRODUCTS

The following products were delivered to MNDM:

Map products at 1:20 000

- Colour residual magnetic field grid with contours, plotted along with EM anomalies and flightlines on a planimetric base
- Shaded colour image of the second vertical derivative of the magnetics and Keating kimberlite coefficient anomalies on a planimetric base
- Colour-filled contours of Z-component decay constant (de-herringboned if applicable) with EM anomalies, flightlines and planimetric base

Profile databases

- Database with Magnetics and EM sampled at 10 samples per second in both Geosoft® GDB and ASCII format

EM anomaly database

EM anomaly database in both Geosoft® GDB and ASCII CSV format

Kimberlite coefficient database

Keating kimberlite coefficient anomaly database in both Geosoft® GDB and ASCII CSV format.

Data grids

Data grids, in both Geosoft® GRD and GXF formats, gridded from coordinates in UTM Zone 16N, NAD83 datum, of the following parameters:

- GSC-levelled magnetic field
- Second vertical derivative of the GSC-levelled magnetic field
- Z-component decay constant

GeoTIFF images of the total of all the 1:20,000 map sheets

- Colour residual magnetic field grid with contours, plotted along with EM anomalies on a planimetric base
- Shaded colour image of the second vertical derivative of the magnetics and Keating kimberlite coefficient anomalies on a planimetric base
- Colour-filled contours of Z-component decay constant with EM anomalies on a planimetric base.

DXF vector files of the entire survey

- Flight path

- EM anomaly locations
- Keating kimberlite coefficient anomalies
- Residual magnetic field contours
- Z-component decay constant contours

Project report

Provided as Microsoft® Word (*.doc*) and portable document format (*.pdf)* files.

REFERENCES

Gupta, V., Paterson, N., Reford, S., Kwan, K., Hatch, D., and Macleod, I. 1989. Single master aeromagnetic grid and magnetic colour maps for the province of Ontario; in Summary of Field Work and Other Activities 1989, Ontario Geological Survey Miscellaneous Paper 146, p.244-250.

Keating, P.B. 1995. A simple technique to identify magnetic anomalies due to kimberlite pipes, Exploration and Mining Geology, v.4, no.2, p.121-125.

——— 2001. Identification of kimberlite pipes from aeromagnetic surveys; Canadian Geophysical Union Annual Meeting, May 2001.

Naudy, H. and Dreyer, H. 1968. Essaie filtrage non-lineare appliqué aux profiles aeromagnetiques; Geophysical Prospecting, v.16, no.2, p.171-178

Ontario Geological Survey 2003. Ontario airborne magnetic and electromagnetic surveys, processed data and derived products: Archean and Proterozoic "greenstone" belts—Matachewan Area; Ontario Geological Survey, Geophysical Data Set 1014.

Ontario Geological Survey 2002. Ontario airborne geophysical surveys, magnetic and electromagnetic data, Vickers area; Ontario Geological Survey, Geophysical Data Set 1106—Revised.

Ontario Geological Survey 1999. Single master gravity and aeromagnetic data for Ontario; Ontario Geological Survey, Geophysical Data Set 1036.

Reford, S.W., Gupta, V.K., Paterson, N.R., Kwan, K.C.H., and Macleod, I.N. 1990. Ontario master aeromagnetic grid: A blueprint for detailed compilation of magnetic data on a regional scale; *in* Expanded Abstracts, Society of Exploration Geophysicists, 60th Annual International Meeting, San Francisco, v.1, p.617-619.

APPENDIX A PROFILE ARCHIVE DEFINITION

Survey 1239 was carried out using the time domain electromagnetic (VTEM) system and a high sensitivity cesium vapour magnetometer mounted on a helicopter platform.

Data File Layout

The files for the Marshall Lake Geophysical Survey 1239 are archived on a single DVD.
The content of the ASCII and Geosoft® binary file types are identical. They are provided in both forms to suit the user's available software. The survey data are divided as follows:

CD - 1239

- ASCII (GXF) grids
  - total (residual) field magnetics
  - second vertical derivative of the total field magnetics
  - Z-component decay constant
- EM anomaly database (ASCII CSV format)
- Keating correlation (kimberlite) database (ASCII CSV format)
- DXF files of entire survey block for:
  - flight path
  - EM anomalies
  - Keating correlation (kimberlite) anomalies
  - total field magnetic contours
  - Z-component decay constant contours
- GEOTIFF images (300 dpi) of the survey block
  - colour total field magnetics with base map
  - colour shaded relief of second vertical derivative with base map
  - colour Z-component decay constant with base map
- Geosoft® Binary (GRD) grids
  - total (residual) field magnetics
  - second vertical derivative of the total field magnetics
  - Z-component decay constant
- EM anomaly database (Geosoft® GDB format)
- Keating correlation (kimberlite) database (Geosoft® GDB format)
- ASCII Profile database of magnetic and electromagnetic data (10 Hz sampling) in ASCII (XYZ) format
- Binary Profile database of magnetic and electromagnetic data (10 Hz sampling) in Geosoft® GDB format
- Survey report (Microsoft® Word (*.doc*) and portable document format (*.pdf*) files)

Coordinate Systems

The profile, electromagnetic anomaly and Keating coefficient data are provided in two coordinate systems:

- Universal Transverse Mercator (UTM) projection, Zone 16N, NAD83 datum, Canada local datum
- Latitude/longitude coordinates, NAD83 datum, Canada local datum

The gridded data are provided in one UTM coordinate system:

- Universal Transverse Mercator (UTM) projection, Zone 16N, NAD83 datum, Canada local datum

Line Numbering

The line numbering convention for survey 1239 is as follows:

Line numbers are 5 digits with the last digit indicating part or revision number
i.e. Line 10010 is the first line of the survey followed by line 10020; should line 10010 be in two parts the first is 10010 and the second is 10011

The same convention is used for the labelling of the control lines.

Profile Data

The profile data are provided in two formats, one ASCII and one binary:

- ASCII (XYZ) file of magnetic and electromagnetic data, sampled at 10 Hz, one per survey
    - MARSHALL_1.XYZ and MARSHALL_2.XYZ

- Geosoft® OASIS Montaj™ binary database file (no compression) of magnetic and electromagnetic data, sampled at 10 Hz, one per survey
    - MARSHALL_1.gdb and MARSHALL_2.gdb

- Geosoft® OASIS Montaj™ binary database file (no compression) of TDEM reference waveform, one per survey
    - waveform_1.gdb and waveform _2.gdb

The contents of the MARSHALL_1.XYZ/gdb are summarized as follows:

Channel Name	Description	Units
x_nad83	easting in UTM co-ordinates using NAD83 datum	metres
y_nad83	northing in UTM co-ordinates using NAD83 datum	metres
gps_z_final	differentially corrected GPS Z (NAD83 datum)	metres above sea level
lon_nad83	longitude using NAD83 datum	decimal-degrees
lat_nad83	latitude using NAD83 datum	decimal-degrees
radar_final	corrected radar altimeter	metres above terrain
dem	digital elevation model	metres above sea level
fiducial	fiducial	
flight	flight number	
line_number	full flightline number (flightline and part numbers)	

line	flightline number	
line_part	flightline part number	
time_utc	UTC time	seconds
mag_base_final	corrected magnetic base station data	nanoteslas
mag_raw	raw magnetic field	nanoteslas
mag_diurnal	diurnal corrected magnetic field	nanoteslas
mag_lev	levelled magnetic field	nanoteslas
mag_gsclevel	GSC-levelled magnetic field	nanoteslas
em_z_final	final dB/dt time channel array	picovolts per ampere-metre^4
power	60 frequency power line monitor	millivolts
tau_z	Z-component decay constant	microseconds

Electromagnetic dB/dt data is found in array channel format between indexes 0 – 23.

The contents of the MARSHALL_2.XYZ/gdb are summarized as follows:

Channel Name	Description	Units
x_nad83	easting in UTM co-ordinates using NAD83 datum	metres
y_nad83	northing in UTM co-ordinates using NAD83 datum	metres
gps_z_final	differentially corrected GPS Z (NAD83 datum)	metres above sea level
lon_nad83	longitude using NAD83 datum	decimal-degrees
lat_nad83	latitude using NAD83 datum	decimal-degrees
radar_final	corrected radar altimeter	metres above terrain
dem	digital elevation model	metres above sea level
fiducial	fiducial	
flight	flight number	
line_number	full flightline number (flightline and part numbers)	
line	flightline number	
line_part	flightline part number	
time_utc	UTC time	seconds
mag_base_final	corrected magnetic base station data	nanoteslas
mag_raw	raw magnetic field	nanoteslas
mag_diurnal	diurnal corrected magnetic field	nanoteslas
mag_lev	levelled magnetic field	nanoteslas
mag_gsclevel	GSC-levelled magnetic field	nanoteslas
em_z_final	final dB/dt time channel array	picovolts per ampere-metre^4
em_z_B_final	final B-field time channel array	pV*ms/A/m^4
power	60 frequency power line monitor	millivolts
tau_z	Z-component decay constant	microseconds

Electromagnetic B-field and dB/dt data is found in array channel format between indexes 0 – 23.

The contents of the waveform_1.gdb are summarized as follows:

Channel Name	Description	Units
Volt	output voltage of the receiver coil	volts, sampling rate 20 microseconds

The contents of the waveform_2.gdb are summarized as follows:

Channel Name	Description	Units
Time	Sampling rate interval, 10.416 microseconds	microseconds
Voltage	output voltage of the receiver coil	volt

APPENDIX B ANOMALY ARCHIVE DEFINITION

Electromagnetic Anomaly Data

The electromagnetic anomaly data are provided in two formats, one ASCII and one binary:
MLANOMALY_1.csv and MLANOMALY_2.csv– ASCII comma-delimited Excel® format
MLANOMALY_1.gdb and MLANOMALY_2.gdb – Geosoft® OASIS Montaj™ binary database file

The contents of the MLANOMALY_1.csv/gdb are summarized as follows:

Channel Name	Description	Units
x_nad83	easting in UTM co-ordinates using NAD83 datum	metres
y_nad83	northing in UTM co-ordinates using NAD83 datum	metres
lon_nad83	longitude using NAD83 datum	decimal-degrees
lat_nad83	latitude using NAD83 datum	decimal-degrees
dem	digital elevation model	metres above sea level
fiducial	fiducial	
line_number	full flightline number (flightline and part numbers)	
line	flightline number	
line_part	flightline part number	
time_utc	UTC time	seconds
em_z_final	filtered dB/dT, Z-component	picovolts per ampere-metre^4
tau_z	decay constant (tau) for Z-component	microseconds
height_em	electromagnetic receiver height	metres above terrain
anomaly_no_letter	anomaly along the survey line (A,B,C …)	
anomaly_no	anomaly along the survey line (1,2,3 …)	
anomaly_id	unique anomaly identifier	
survey_number	MNDMF unique survey number	
anomaly_type_letter	anomaly classification	
anomaly_mag	anomaly association with magnetic anomaly	
anomaly_memo	anomaly description	
heading	direction of flight	degrees azimuth

The contents of the MLANOMALY_2.csv/gdb are summarized as follows:

Channel Name	Description	Units
x_nad83	easting in UTM co-ordinates using NAD83 datum	metres
y_nad83	northing in UTM co-ordinates using NAD83 datum	metres
lon_nad83	longitude using NAD83 datum	decimal-degrees
lat_nad83	latitude using NAD83 datum	decimal-degrees
dem	digital elevation model	metres above sea level
fiducial	fiducial	
line_number	full flightline number (flightline and part numbers)	
line	flightline number	
line_part	flightline part number	
time_utc	UTC time	seconds
em_z_final	filtered dB/dT, Z-component	picovolts per ampere-metre^4
em_z_B_field	processed off-time B field profile response	pV*ms/A/m^4
tau_z	decay constant (tau) for Z-component	microseconds
height_em	electromagnetic receiver height	metres above terrain
anomaly_no_letter	anomaly along the survey line (A,B,C …)	

anomaly_no	anomaly along the survey line (1,2,3 …)	
anomaly_id	unique anomaly identifier	
survey_number	MNDMF unique survey number	
anomaly_type_letter	anomaly classification	
anomaly_mag	anomaly association with magnetic anomaly	
anomaly_memo	anomaly description	
heading	direction of flight	degrees azimuth

The unique anomaly identifier (anomaly_id) is a ten digit integer in the format 1LLLLLLAAA where 'LLLLLL' holds the line number (and leading zeroes pad short line numbers to six digits). The 'AAA' represents the numeric anomaly identifier (anomaly_no) for that line padded with leading zeroes to three digits. The leading 1 indicates that the anomaly was identified as likely having a normal or surficial source. For example, 1000101007 represents the seventh anomaly on Line 101. Anomalies identified as likely having a cultural source do not include the leading 1, and take the format LLLLLLAAA. For example, 101007 represents the seventh cultural anomaly on Line 101. When combined with the survey number (survey_no), the anomaly identifier provides an electromagnetic anomaly number unique to all surveys archived by the Ontario Geological Survey.

APPENDIX C KEATING CORRELATION ARCHIVE DEFINITION

Kimberlite Pipe Correlation Coefficients

The Keating kimberlite pipe correlation coefficient data are provided in two formats, one ASCII and one binary:
MLKC.csv – ASCII comma-delimited Excel® format
MLKC.gdb – Geosoft® OASIS montaj binary database file

Both file types contain the same set of data channels, summarized as follows:

Channel Name	Description	Units
x_nad83	easting in UTM co-ordinates using NAD83 datum	metres
y_nad83	northing in UTM co-ordinates using NAD83 datum	metres
lon_nad83	longitude using NAD83 datum	decimal-degrees
lat_nad83	latitude using NAD83 datum	decimal-degrees
corr_coeff	correlation coefficient	percent x 10
pos_coeff	positive correlation coefficient	percent
neg_coeff	negative correlation coefficient	percent
norm_error	standard error normalized to amplitude	percent
amplitude	peak-to-peak anomaly amplitude within window	nanoteslas

APPENDIX D GRID ARCHIVE DEFINITION

Gridded Data

The gridded data are provided in two formats, one ASCII and one binary:
*.gxf - Geosoft® ASCII Grid eXchange Format (no compression)
*.grd - Geosoft® OASIS Montaj™ binary grid file (no compression)

The grids are summarized as follows:

- All grids are NAD83 UTM Zone 16 North, with a grid cell size of 30 m x 30 m.

MLMAG83.grd/.gxf – GSC-Levelled Residual Magnetic Intensity
ML2VD83.grd/.gxf – Second Vertical Derivative of GSC-Levelled Residual Magnetic Intensity
MLDCZ83.grd/.gxf – Z-component decay constant

APPENDIX E GEOTIFF AND VECTOR ARCHIVE DEFINITION

GeoTIFF Images

Geographically referenced colour images, incorporating a base map, are provided in GeoTIFF format for use in GIS applications:

MLMAG83.tif – colour-filled contours of the residual magnetic field with EM anomalies, flightlines and planimetric base
ML2VD83.tif –shaded colour image of the second vertical derivative of the residual magnetic field with Keating kimberlite pipe correlation coefficients and planimetric base
MLDCZ83.tif - colour-filled contours of Z-component decay constant with EM anomalies, flightlines and planimetric base

Vector Archives

Vector line work from the maps is provided in DXF (v12) ASCII format using the following naming convention:

MLPATH83.dxf – flight path of the survey area
MLEM83.dxf – electromagnetic anomalies
MLKC83.dxf – Keating correlation targets
MLMAG83.dxf – contours of the residual magnetic intensity in nanoteslas
MLDCZ83.dxf – contours of the Z-component decay constant in microseconds

The layers within the DXF files correspond to the various object types found therein and have intuitive names.

APPENDIX F MODELING VTEM DATA

Introduction

The VTEM system is based on a concentric or central loop design, whereby, the receiver is positioned at the centre of a 26.1 meters diameter transmitter loop that produces a dipole moment up to 625 000 NIA at peak current. The wave form is a bi-polar, modified square wave with a turn-on and turn-off at each end. With a base frequency of 30 Hz, the duration of each pulse is approximately 7.2 milliseconds followed by an off time where no primary field is present.

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

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

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

Variation of Plate Depth

Geometries represented by plates of different strike length, depth extent, dip, plunge and depth below surface can be varied along with characteristic parameters like conductance of the target, conductance of the host and conductivity/thickness and thickness of the overburden layer.

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

Variation of Plate Dip

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

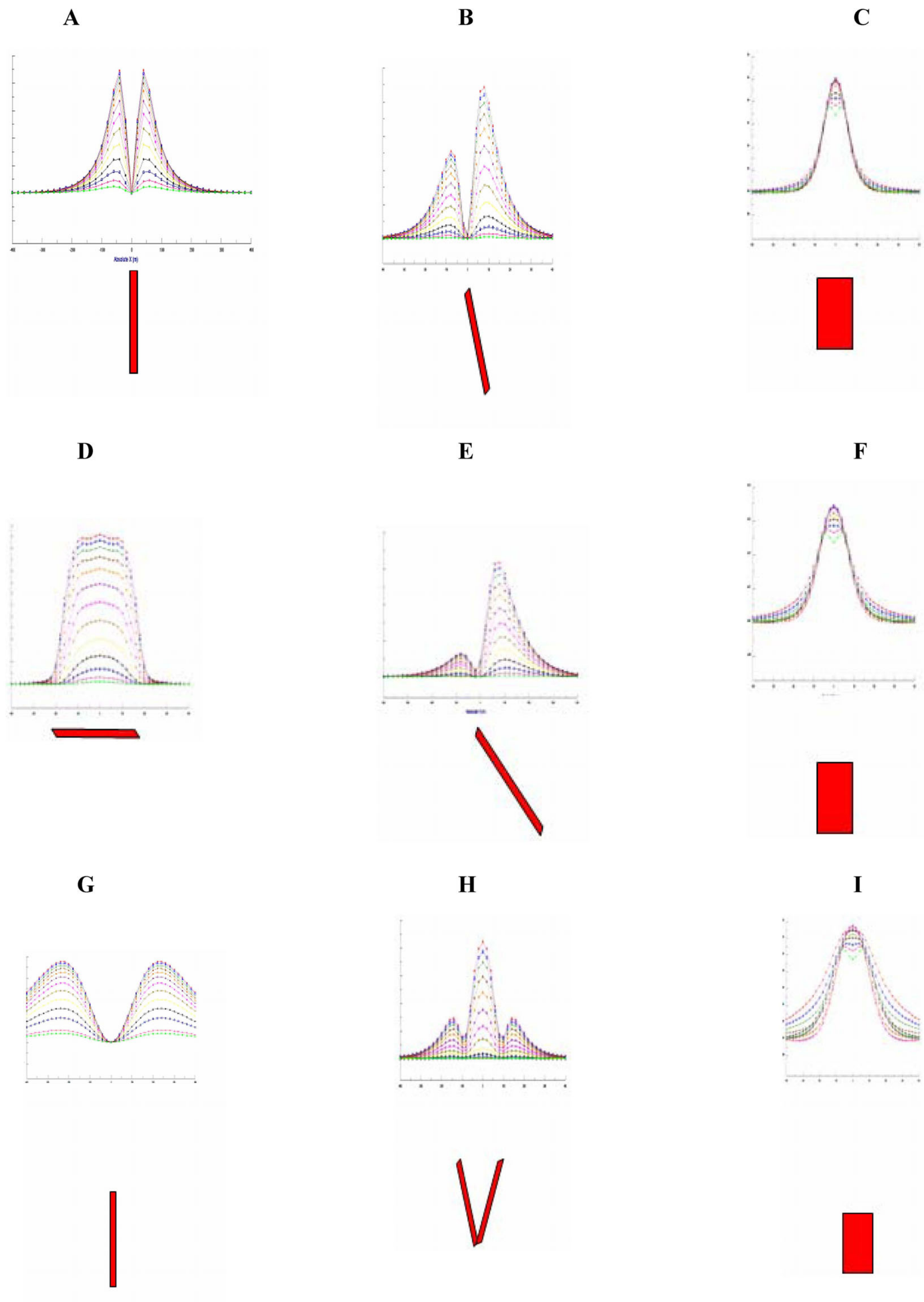
As the dip increases, the aspect ratio (Min/Max) decreases and this aspect ratio can be used as an empirical guide to dip angles from near 90º to about 30º. The method is not sensitive enough where dips are less than about 30º. Figure E shows a plate dipping 45º and, at this angle, the minimum shoulder starts to vanish. In Figure D, a flat lying plate is shown, relatively near surface. Note that the twin peak anomaly has been replaced by a symmetrical shape with large, bell shaped, channel amplitudes which decay relative to the conductance of the plate.

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

Variation of Prism Depth

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

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



Geotech Ltd.

General Modeling Concepts

A set of models has been produced for the Geotech VTEM system with explanation notes (see models A to I above). The reader is encouraged to review these models, so as to get a general understanding of the responses as they apply to survey results. While these models do not begin to cover all possibilities, they give a general perspective on the simple and most commonly encountered anomalies.

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

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

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

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

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

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

General Interpretation Principals

Magnetics

The total magnetic intensity responses reflect major changes in the magnetite and/or other magnetic minerals content in the underlying rocks and unconsolidated overburden. Precambrian rocks have often been subjected to intense heat and pressure during structural and metamorphic events in their history. Original signatures imprinted on these rocks at the time of formation have, it most cases, been modified, resulting in low magnetic susceptibility values.

The amplitude of magnetic anomalies, relative to the regional background, helps to assist in identifying specific magnetic and non-magnetic rock units (and conductors) related to, for example, mafic flows, mafic to ultramafic intrusives, felsic intrusives, felsic volcanics and/or sediments etc. Obviously, several geological sources can produce the same magnetic response. These ambiguities can be reduced considerably if basic geological information on the area is available to the geophysical interpreter.

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

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

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

Concentric Loop EM Systems

Concentric systems with horizontal transmitter and receiver antennae produce much larger responses for flat lying conductors as contrasted with vertical plate-like conductors. The amount of current developing on the flat upper surface of targets having a substantial area in this dimension, are the direct result of the effective coupling angle, between the primary magnetic field and the flat surface area. One therefore, must not compare the amplitude/conductance of responses generated from flat lying bodies with those derived from near vertical plates; their ratios will be quite different for similar conductances.

Determining dip angle is very accurate for plates with dip angles greater than 30º. For angles less than 30º to 0º, the sensitivity is low and dips can not be distinguished accurately in the presence of normal survey noise levels.

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

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

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

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

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

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

APPENDIX G VTEM WAVE FORM