Ontario

KIRKLAND LAKE AREA

Ontario Airborne Geophysical Surveys
Magnetic and Electromagnetic Data
Geophysical Data Set 1102 - Revised

Ontario Geological Survey
Ministry of Northern Development and Mines
Willet Green Miller Centre
933 Ramsey Lake Road
Sudbury, Ontario, P3E 6B5
Canada

TABLE OF CONTENTS

CREDITS 2

DISCLAIMER 2

CITATION 2

1) INTRODUCTION 3

2) SURVEY LOCATION AND SPECIFICATIONS 4

3) AIRCRAFT, EQUIPMENT AND PERSONNEL 6

4) DATA ACQUISITION 9

5) DATA COMPILATION AND PROCESSING 11

6) MICROLEVELLING AND GSC LEVELLING 19

7) FINAL PRODUCTS 30

8) QUALITY ASSURANCE AND QUALITY CONTROL 32

REFERENCES 38

APPENDIX A TESTING AND CALIBRATION 40

APPENDIX B PROFILE ARCHIVE DEFINITION 46

APPENDIX C ANOMALY ARCHIVE DEFINITION 52

APPENDIX D KEATING CORRELATION ARCHIVE DEFINITION 54

APPENDIX E GRID ARCHIVE DEFINITION 55

APPENDIX F GEOTIFF AND VECTOR ARCHIVE DEFINITION 56

APPENDIX G TDEM PARAMETER TABLE DEFINITION 57

APPENDIX H HALFWAVE ARCHIVE DEFINITION 65

CREDITS

This survey is part of the Operation Treasure Hunt geoscience initiative, funded by the Ontario Government.

List of accountabilities and responsibilities:

- Andy Fyon, Senior Manager, Precambrian Geoscience Section, Ontario Geological Survey (OGS), Ministry of Northern Development and Mines (MNDM) – accountable for the airborne geophysical survey projects, including contract management
- Stephen Reford, Vice President, Paterson, Grant & Watson Limited (PGW), Toronto, Ontario, OTH Geophysicist under contract to MNDM, responsible for the airborne geophysical survey project management, quality assurance (QA) and quality control (QC)
- Lori Churchill, Project and Results Management Coordinator, Precambrian Geoscience Section, Ontario Geological Survey, MNDM – manage the project-related milestone information
- Zoran Madon, OTH Data Manager, Precambrian Geoscience Section, Ontario Geological Survey, MNDM – manage the project-related digital and hard copy products
- Fugro Airborne Surveys, Geoterrex office, Ottawa, 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.

CITATION

Information from this publication may be quoted if credit is given. It is recommended that reference be made in the following form:

Ontario Geological Survey 2003. Ontario airborne geophysical surveys, magnetic and electromagnetic data, Kirkland Lake area; Ontario Geological Survey, Geophysical Data Set 1102 - Revised.

1) INTRODUCTION

Recognising the value of geoscience data in reducing private sector exploration risk and investment attraction, the Ontario Government embarked on "Operation Treasure Hunt" (OTH). The OTH initiative comprises a three-year, $29 million program that commenced April 1, 1999. It incorporates:

- airborne geophysics (high-resolution magnetic/electromagnetic surveys and some radiometric surveys)
- surficial geochemistry (lake sediments and indicator minerals)
- bedrock map compilation
- methods development (e.g. electro-geochemical modelling applied to exploration and 3-D geological/geophysical modelling)
- delivery of digital data products.

The OGS was charged with the responsibility to manage OTH. The OGS sought advice about the mineral industry needs and priorities from its OGS Advisory Board – a stakeholder board including representatives from the Ontario Mining Association, Ontario Prospectors Association, Prospectors and Developers Association, Aggregate Producers Association of Ontario, Chairs of Ontario University Geology Departments, Canadian Mining Industry Research Organisation and Geological Survey of Canada. The OGS Advisory Board mandated a Technical Committee to advise the OGS on geographic areas of interest within Ontario where collection of new data would make the greatest impact on reducing exploration risk.. Various criteria were assessed, including:

- commodities and deposit types sought
- prospectivity of the geology
- state of the local mining industry and infrastructure
- existing, available data
- mineral property status.

In late 1999, MNDM commenced an ambitious program of airborne magnetic and electromagnetic surveys as part of OTH geoscience initiative. The project involved four survey contractors, five different electromagnetic systems and more than 105,000 line-km of data acquisition.

The airborne survey contracts were awarded through a Request for Proposal and Contractor Selection process. The system and contractor selected for each survey area were judged on many criteria, including the following:

- applicability of the proposed system to the local geology and potential deposit types
- aircraft capabilities and safety plan
- experience with similar surveys
- QA/QC plan
- capacity to acquire the data and prepare final products in the allotted time
- price-performance.

In February 2002, PGW was retained by MNDM to microlevel and level to a common datum all OTH aeromagnetic surveys. Any OTH surveys adjacent to existing AMEM surveys were subsequently merged to form supergrids. PGW commenced this project in March 2002.

2) SURVEY LOCATION AND SPECIFICATIONS

The Kirkland Lake survey area is located in northeastern Ontario (Figure 1). It covers the the Archean Abitibi subprovince west and south of the Blake River Syncline, incorporating metavolcanic, metasedimentary and a range of granitic intrusive rocks, as well as Huronian sediments. Glacial overburden cover in the area is variable, from 0 to 35 m thickness, with extensive conductive clay in places. The commodities sought include gold, komatiite copper-nickel, intrusion-related copper-nickel-platinum group elements, volcanogenic massive sulphides, and potential diamond-bearing kimberlites. The Geotem III time-domain electromagnetic (30 Hz base frequency) and magnetic system, mounted on a fixed wing platform, was selected by MNDM to conduct the survey.

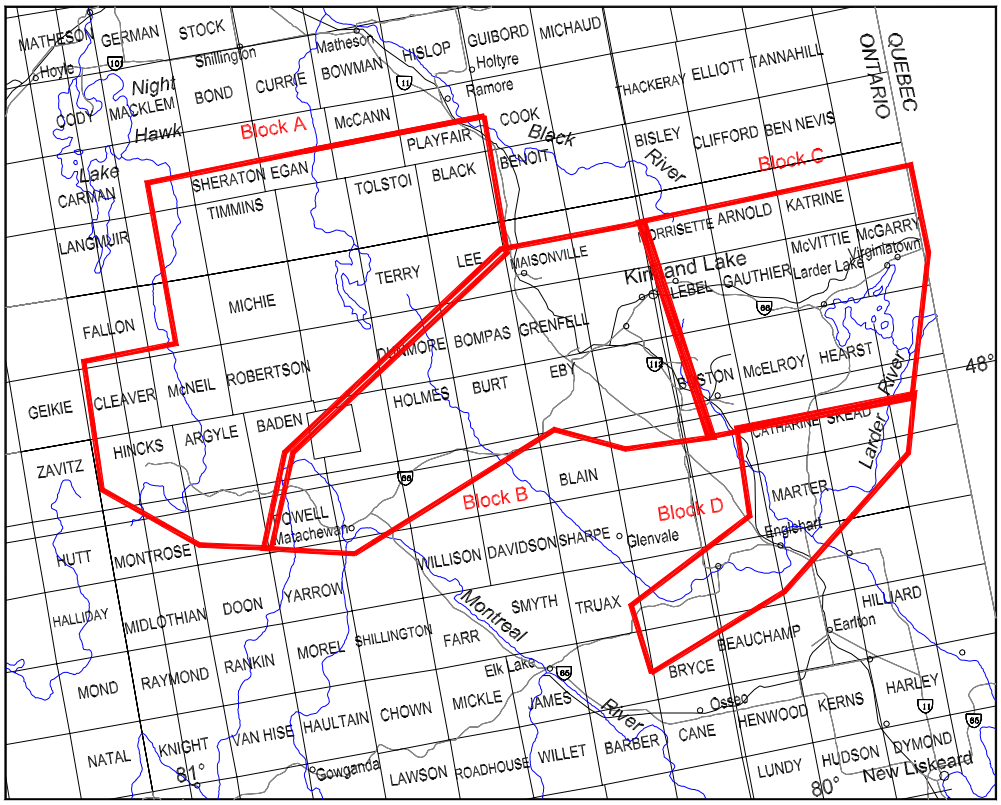


Figure 1: Kirkland Lake survey area (blocks A, B, C and D).

The airborne survey and noise specifications for the Kirkland Lake survey area were as follows:

a) traverse line spacing and direction
- flight line spacing was 200 m
- flight line direction for block A was 030°- 210° azimuth from true north.
- flight line direction for block B was 150°- 330° azimuth from true north.
- flight line direction for block C was 000°- 180° azimuth from true north.
- flight line direction for block D was 130°- 310° azimuth from true north.
- maximum deviation from the nominal traverse line location could not exceed 100 m over a distance greater than 3000 m
- minimum separation between two adjacent lines could be no smaller than 120 m or larger than 280 m

b) control line spacing and direction
- at a regular 1500 m interval, perpendicular to the flight line direction
- along each survey boundary (if not parallel to the flight line direction)
- maximum deviation from the nominal control line location could not exceed 100 m over a distance greater than 3000 m

c) terrain clearance of the EM receiver bird
- nominal terrain clearance was 70 m
- altitude tolerance limited to ±15 m over a long chord not to exceed 3000 m, except in areas of severe topography

d) aircraft speed
- nominal aircraft speed was 70 m/sec
- aircraft speed tolerance limited to ±10.0 m/sec, except in areas of severe topography

e) magnetic diurnal variation
- could not to exceed a maximum deviation of 2.5 nT peak-to-peak over a long chord equivalent to the control line spacing (1500 m)

f) magnetometer noise envelope
- in-flight noise envelope could not exceed 0.2 nT, for straight and level flight
- base station noise envelope could not exceed 0.2 nT

g) EM receiver noise envelope
- the noise envelope could not exceed:
  X-coil - ±3500 pV/m^2
  Z-coil - ±2000 pV/m^2
  over a distance exceeding 3000 m

3) AIRCRAFT, EQUIPMENT AND PERSONNEL

Aircraft and Geophysical On-Board Equipment

Aircrafts	CASA C-212 twin turbo-prop.
Operator	FUGRO AIRBORNE SURVEYS
Registrations	C-FDKM and C-GDPP
Survey Speed	125 knots/145 mph/65m/sec.
Magnetometer	Scintrex Cs-2 single cell cesium vapour, towed-bird installation, sensitivity of 0.01 nT, sampling rate = 0.1 sec., ambient range 20,000 to 100,000 nT. The general noise envelope was kept below 0.2 nT. Nominal sensor height of 73 metres above ground.
Electromagnetic system	GEOTEM multicoil system

System parameters

Transmitter: vertical axis loop of 231 m²,
number of turns : 6
nominal height above ground of 120 metres.
current of 502 amperes
dipole moment of 6.96×10^5 Am²

Receiver : multicoil system (x, y and z) with a final recording rate of 4 samples/second, for the recording of 20 channels of x, y and z-coil data; nominal height above ground of 70 metres, placed 131 m behind the centre of the transmitter loop

Base frequency:	30 Hz
Pulse width:	4080µs
Pulse delay:	130.2 µs
Off-time:	12486 µs
Point value:	43.4 µs

Window mean delay times in milliseconds from the end of the pulse

channel 1: -3.906	channel 11: 1.541
channel 2: -3.169	channel 12: 1.931
channel 3: -1.975	channel 13: 2.409
channel 4: -0.782	channel 14: 2.995
channel 5: -0.044	channel 15: 3.733
channel 6: 0.195	channel 16: 4.665

channel 7: 0.391	channel 17: 5.837
channel 8: 0.630	channel 18: 7.313
channel 9: 0.911	channel 19: 9.136
channel 10: 1.215	channel 20: 11.306

Digital Acquisition	FUGRO AIRBORNE SURVEYS GEODAS
Analogue Recorder	RMS GR-33, showing the total magnetic field at 2 vertical scales, the radar and barometric altimeters, the time-constant filtered traces of the x-coil channels 9 to 20 and the on-time channel 1, the raw traces of the x and z-coil channel 9 and 20, the EM primary field, the power line monitor, the 4th difference of the magnetics, the x-coil earth's field and fiducials
Barometric Altimeter	Rosemount 1241M, sensitivity 1 foot, 1 sec. Recording interval
Radar Altimeter	King, accuracy 2%, sensitivity one foot, range 0 to 2,500 feet, 1 sec. recording interval
Camera	Panasonic colour video, super VHS, model WV-CL302
Electronic Navigation	Sercel GPS receiver NR103, 1 sec. recording interval, with a resolution of 0.00001 degree and an accuracy of ±10 m. Real time differential correction was provided by Omnistar

Base Station Equipment

Magnetometer:	Scintrex Cs-2 single cell caesium vapour, mounted in a magnetically quiet area, measuring the total intensity of the earth's magnetic field in units of 0.01 nT at intervals of 1 second, within a noise envelope of 0.20 nT
GPS Receiver:	SERCEL NR103 V2.3, measuring all GPS channels, for up to 10 satellites
Computer:	Toshiba laptop, model T4600, 33 MHz, 486
Converter:	Picodas, model MEP710 3/10901 GTS 780008
Printer:	Kodak Diconix 150 plus Battery Backup

Field Office Equipment

Computers:	Dell Inspiron 3200 Pentium II laptop with 20 GB hard drive and an external 4 GB Hard drive
Plotter:	Tech Jet designer 720c Calcomp
Printer:	Hewlett Packard Deskjet 690C
DAT Tape Drive:	DDS-90 4 mm
Hard Drive:	Removable hard drive

Field Personnel

The following personnel were on-site during the acquisition program.

Rob Hattle	Aircraft engineer and acting crew chief
Darcy Wiens	Chief pilot
Al Capyck	Senior pilot
Michelle Millett	Senior pilot
Victor Easterbrook	Pilot
Scott Savage	Pilot
Martin Novak	Pilot (in training)
Paul Colleran	Pilot (in training)
Chris Lechner	Aircraft engineer
Dave Patzer	Electronics technician
Jerzy Wojciki	Electronics technician
Rick Williams	Senior geophysicist
Yuri Kroupoderov	Geophysicist
Andrew Marshall	Geophysicist
Clare O'Dowd	Junior geophysicist

The above personnel represents a double crew, responsible for the operation and data handling from two aircraft. All personnel are employees of Fugro Airborne Surveys.

The pre-survey calibrations and general start-up procedures were also monitored, on-site by the presence of the following personnel:

Jean Lemieux	Chief geophysicist and Project supervisor
Tom Payne	Manager of the Electronics Department
Dave O'Brien	Senior engineer.

4) DATA ACQUISITION

The town of Timmins, Ontario was selected as the base of operation. The survey was carried out from November 9th , 1999 to the January 18th, 2000. The area was covered by a total of 28,263 line kilometres of flying. The survey area was divided into four separate blocks, each one defined by a flight line direction selected to cross the mean direction of the local geological structures at right angle for optimum definition of the trends. A total of 1081 survey lines were flown over the four blocks with a separation of 200 metres. An additional 131 control lines were flown perpendicular to the traverse lines with a separation of 1500 metres, including some boundary control lines.

Division of flying between the two aircraft

C-FDKM

- Flying dates: November 9th to December 23rd, 1999
- Production flights : 3 to 44
- Survey coverage:
  Block A, lines 100 to 403, control lines 5001 to 5053
  Block B, lines 754 to 837, control lines 6001 to 6019 and 6021 to 6031

C-GDPP

- Flying dates: December 8th, 1999 to January 18th, 2000
- Production flights : 226 to 265
- Survey coverage:
  Block B, lines 501 to 753, control line 6020
  Block C, lines 901 to 1088, control lines 7001 to 7023
  Block D, lines 1092 to 1343, control lines 8001 to 8024

General statistics

Survey dates	November 9th, 1999 to January 18th, 2000
Total km	28,263 km
	Block A = 11,047 km
	Block B = 7,911 km
	Block C = 5,969 km
	Block D = 3,336 km
Total flying hours	271.1 hours
Production hours	247.8 hours
Number of production days	27 ½ days
Number of production flights	65 flights
Bad weather days	35 ½ days
Testing	2½ days

Equipment breakdown	4 days
Pilot training	none
Average production per flight	434.8 km
Average production per hour	114.1 km
Average production per day	1027.8 km

The following tests and calibrations were performed prior to the commencement of the survey flying:

- Magnetometer lag check.
- EM system lag check.
- GPS navigation lag and accuracy check.
- Altimeter calibration.
- Magnetometer heading (cloverleaf) check.

These tests were flown out of Timmins, as part of the start-up procedures.

Details of these tests and their results are given in Appendix A.

After each flight, all analogue records were examined as a preliminary assessment of the noise level of the recorded data. Altimeter deviations from the prescribed flying altitudes were also closely examined as well as the diurnal activity, as recorded on the base station.

All digital data were verified for validity and continuity. The data from the aircraft and base station were transferred to the PC's hard disk. Basic statistics were generated for each parameter recorded; these included the minimum, maximum and mean values, the standard deviation and any null values located. Editing of all recorded parameters for spikes or datum shifts was done, followed by final data verification via an interactive graphics screen with on-screen editing and interpolation routines. Any of the recorded parameters could be plotted back at a suitable scale on the field pen plotter.

The quality of the GPS navigation was controlled on a daily basis by recovering the flight path of the aircraft. The Trajecto correction procedure employs the raw ranges from the base station to create improved models of clock error, atmospheric error, satellite orbit, and selective availability. These models are used to improve the conversion of aircraft raw ranges to aircraft position. The Trajecto-corrected GPS was plotted back daily in the field on the pen plotter and checked for speed busts.

Checking all data for adherence to specifications was carried out in the field by the Fugro Airborne Surveys field geophysicists.

5) DATA COMPILATION AND PROCESSING

Personnel

The following personnel were involved in the compilation of data and creation of the final products:

Gord Roberts	Manager of the Processing section
Jean Lemieux	Project supervisor
Brenda Sharp	Senior geophysicist
Rick Williams	Senior geophysicist
Clare O'Dowd	Geophysicist
Andrew Marshall	Geophysicist
Jim Taggart	Senior processor and AUTOCAD technician
Don Skubiski	Senior processor

Base maps

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

Projection description

Datum:	NAD27 (NTv2)*
Ellipsoid:	Clarke 1866
Projection:	UTM (Zone 17N)
Central Meridian:	81° West
False Northing:	0 m
False Easting:	500,000 m
Scale factor:	0.9996

* The geophysical data was collected using the UTM NAD83 datum (WGS84 ellipsoid), then reprojected to the NAD27 datum (Manitoba, Ontario mean) and finally shifted 2.0 m east and 5.1 m south to best approximate the OBM topographic base.

Processing of Base Station data

The recorded magnetic diurnal base station data was reformatted and loaded into the OASIS database. After initial verification of the integrity of the data from statistical analysis, the appropriate portion of the data was selected to correspond to the exact start and end time of the flight. The data was then checked and corrected for spikes using a fourth difference editing routine. Following this, interactive editing of the data was done, via a graphic editing tool, to remove events caused by man-made disturbances. A small noise filter, such as a 5 point running average, was then applied if necessary. The final processing step consisted of extracting the long wavelength component of the diurnal signal, through low pass filtering, to be subtracted from the airborne magnetic data as a pre-leveling step.

Processing of the Positioning Data (GPS)

The raw GPS data from both the mobile (aircraft) and base station were recovered. Using TRAJECTOGRAPHY software (differential correction software, written by Sercel, maker of the GPS receiver used), positions were initially recalculated from the recorded raw range data in flight. Post-flight recalculation of the fixes from the raw ranges rather than using the fixes which are recorded directly in flight, improves on the final accuracy, as it eliminates possible time tag errors that can result during the real-time processing required to get from the range data to the fixes directly within the receiver. Differential corrections were then applied to the aircraft fixes using the recorded base station data. The resulting differentially corrected latitudes and longitudes were then converted from the WGS-84 spheroid to the local map projection and datum(Clarke 1866, NAD27) and to UTM metres. A point to point speed calculation was then done from the final X and Ys and reviewed as part of the quality control. The flight data was then cut-back to the proper survey line limits and a preliminary plot of the flight path was done and compared to the theoretical intended flight path to verify the navigation. The positioning data was then exported to the other processing files. A final adjustment was then made to account for the NTv2 local datum.

Processing of the Altimeter data

The altimeter data, which includes the radar altimeter, the barometric altimeter and the GPS elevation values, after differential corrections, were checked and corrected for spikes using a fourth difference editing routine. A small noise filter, such as a 5 point running average, was then applied to the data. During periods of poor satellite visibility which may affect the resolution of the GPS elevation values, the barometric altimeter data was available to bridge in over the bad segments. Following this, a digital terrain trace was computed by subtracting the radar altimeter values from the differentially corrected GPS elevation values. All resulting parameters were then checked, in profile form, for integrity and consistency, using a graphic viewing editor.

Processing of Magnetic data

The data was reformatted and loaded into the OASIS database. After initial verification of the data by statistical analysis, the values were adjusted for system lag. The data was then checked and corrected for any spikes using a fourth difference editing routine and inspected on the screen using a graphic profile display; interactive editing, if necessary, was done at this stage. Following this, a small noise filter, such as a 5 point running average, was applied to the data and the long wavelength component of the diurnal is subtracted from the data as a pre-leveling step. A preliminary grid of the values was then created and verified for obvious problems, such as errors in positioning or bad diurnal. Appropriate corrections were then applied to the data, as required.

Following this, the final leveling process was undertaken. This consists of calculating the positions of the control points (intersections of lines and tie lines), calculating the magnetic differences at the control points and applying a series of leveling corrections (combination of

movements and compensations) to reduce the misclosures to zero. A new grid of the values is then created and checked for residual errors. Any gross errors detected are corrected in the profile database and the leveling process repeated, otherwise residual errors are normally within the base contour interval and easily removed directly from the gridded values using a micro-leveling technique developed in-house. The micro-leveling corrections are then extracted from the final grid and stored back in the profile database as a second compensation field, along with the initial compensation values calculated by the line – tie line analysis. The International Geomagnetic Reference Field (IGRF) was then calculated from the 1995 model year extrapolated to 1999.96 at the survey elevation and removed from the corrected values.

Second Vertical Derivative of the Residual Magnetics

The final grid of the corrected total field values was then used as input to create the second vertical derivative. The calculation was done in the frequency domain by combining the transfer function of the 2nd vertical derivative and a small low pass filter (a 5 point triangular convolution having an effective width of 120 m) aimed at attenuating the high frequency signal enhanced by the 2nd derivative operator, without aliasing the geological signal.

Keating Correlation Coefficients

Possible kimberlite targets have been identified from the residual magnetic intensity data, based on the identification of roughly circular anomalies. This procedure was automated by using a known 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 gridded magnetic data. Only the results where the absolute value of the correlation coefficient is above a threshold of 75% were retained. 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. 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 cylinder model parameters are as follows:

Cylinder diameter: 200 m
Cylinder length: infinite
Overburden thickness: 35 m
Magnetic inclination: 74.67° N
Magnetic declination: 11.98° W
Magnetization scale factor: 100
Maximum data range: 21 194.5 nT
Number of passes of smoothing filter: 0
Model window size: 15
Model window grid cell size: 40 m

Processing of the Electromagnetic data

The data was reformatted and loaded into the OASIS database. After initial verification of the data by statistical analysis, the values were then adjusted for system lag. The next step was to check and correct each individual channel for system drift. This is done with the data in flight form, incorporating the pre and post flight high altitude background segments for zero signal reference. The response from each channel is viewed in profile form, using a graphic viewing tool, and the regions of background minimas checked against the high altitude background segments. Drift problems noted can be directly corrected using the interactive editing functions available from the graphic viewing tool. These corrections are either of a DC offset nature, a linear tilt or a gently varying (low order) polynomial function. Once corrected for drift, the baseline values for each individual channel will allow calculation of any derived product, such as the decay constant or the conductivity, free of errors. However, minor differences in the baseline level, of a magnitude less than the original noise level, may still exist in the data from one survey line to the next such that the EM channels, at this point, should not be considered to be of "image quality". To achieve this, final leveling of the individual channels on a line to line basis is required. This additional processing step is normally only applied to selected channels, if these are required as a final gridded image or map product. Such a requirement was not within the scope of the present project.

Following the correction for drift, spheric events in the data were isolated and removed through a decay analysis of each transient. Erroneous decays, not associated with power lines, are identified during this process and removed by interpolation.

A "pre-whitening" of the noise on each channel followed by the application of a small median filter, aimed at events of a 1 to 2 second period. The final low pass noise filtering was done using an adaptive filter with frequency cutoffs between 1.33 Hz and 0.25 Hz, as controlled by local gradients in the signal.

Calculation of the Decay Constant

Calculation of the Decay Constant (also known as tau) is done by fitting the data from the appropriate off-time channels (mapping the decay transient) 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. A semi-log plot of this exponential function will be displayed as a straight line, the slope of which will reflect the rate of decay and therefore the strength of the conductor. A slow rate of decay, reflecting high conductance, will be represented by a high decay constant value. For the present data set, the response from channels 8 to 18 (630 to 7313 μsec after turn-off) was used for the calculation. This was done from both the X and Z coil channels with the X coil results stored both in profile and gridded format but only in profile form for the Z coil results.

As a single parameter, the decay constant provides more useful information than the amplitude data of any given single channel, as it indicates not only the peak of the response but also the relative strength of the conductor. Also, unlike any quantitative value derived from the data, such as conductivity or resistivity, the decay constant is the expression of a simple mathematical

function which is model independent , such that it is a truer representation of the data. The only disadvantage of this parameter is that, in order to get a reliable fit of the data to the exponential function, a minimum amount of signal above the background is required to avoid introducing noise into the calculation. In essence, this means that the decay constant will effectively map features of a moderate to high conductance, but weaker, more resistive features will best be defined by the apparent conductivity or resistivity calculation.

Calculation of the Apparent Conductance

Both conductivity and resistivity values can be derived from TDEM data. However, since electromagnetic surveys, conducted for the purposes of base mineral exploration, have for their prime objective the definition of conductors, it is generally better to display the data as "conductivity" as opposed to "resistivity". Regions of high resistivity correspond to low conductive background of less significance than the resistivity lows which actually identify the conductors which are the targets. For this reason, preference was to provide the apparent conductivity or conductance .

The apparent conductivity or conductance values are derived from the full 20 channels (on-time and off-time) of the combined X and Z coil data, fitted to either a horizontal thin sheet or a homogeneous half-space model, as dictated by the geology. The introduction of the on-time data into the calculation extends the resolution of the system at the resistive limit by approximately 2 or 3 orders of magnitude, allowing conductivities to be mapped from 10^{-5} to 10^{3} siemens (100,000 to 0.001 ohm-metres). For the present data set, the horizontal thin sheet model was used in the fitting resulting in conductance values, stored in microsiemens.

The thickness of the layer used is infinite, as the calculated conductance is equal to the conductivity-thickness-product which is not unique. The ability to define the thickness of a conductive layer is related to the skin depth which itself is a function of the conductivity of the material and its thickness; e.g. 100 metres of 3 siemens/metre material will have the same conductance as 10 metres of 30 siemens/metre material. So, from the calculated conductance, the conductivity of a material can only be estimated if the thickness of the layer is known.

The EM Anomaly selection

EM anomalies are selected and stored in the database. An automatic routine locates all the anomaly peaks from a reference channel and fits the off-time channel data, above a pre-set noise background, to a vertical plate model, to derive the conductivity-thickness-product and the depth to the top of the conductor. The initial selection is then reviewed interactively by an experienced interpreter, using a graphic viewing / editing tool where the anomaly selections are checked against a multi channel profile display of the data. Corrections are made (erroneous selections are deleted and missing ones added) and selected anomalies are classified as to their possible source (surficial, bedrock or culture). The resulting anomaly selection is then checked with the magnetic signature and other derived EM parameters (decay constant and conductivity) for geological significance and a final revision made. Base map information and the flight video

tapes are also checked, during this process, to help in the final sorting between man-made responses and geological sources.

Note on the B-Field Data

One thing to note are the data units for the B-Field data, delivered in femtoteslas (fT) and how these compare to the regular dB/dt data, delivered in pT/s (picoteslas per second). After standard processing, the resolution (mean noise envelope) of the dB/dt data is approximately 1200 – 2000 pT/s. The corresponding resolution of the B-Field data, after regular processing is approximately 2500-4000 fT or 2.5 – 4.0 picoteslas. So the amplitude ratio, based on the residual noise levels after processing, of B-Field over dB/dt is approximately 2:1. This is an important factor when trying to image or display the data.

The introduction of the B-Field data stream, as part of the GEOTEM system, provides the explorationist with a more effective tool for exploration in a broader range of geological environments and for a larger class of target priorities. The advantage of the B-Field data compared with the normal voltage data (dB/dt) are as follows:

- A broader range of target conductances that the system is sensitive to. (The B-Field is sensitive to bodies with conductances as great as 100,000 siemens);
- Enhancement of the slowly decaying response of good conductors;
- Suppression of rapidly decaying response of less conductive overburden;
- Reduction in the effect of sferics on the data;
- An enhanced ability to interpret anomalies due to conductors below thick conductive overburden;
- Reduced dynamic range of the measured response (easier data processing and display).

Figures 2 and 3 display the calculated vertical plate response for the GEOTEM signal for the dB/dt and B-Field respectively. For the dB/dt response, you will note that the amplitude of the early channel peaks are about 25 siemens, and the late channel at about 250 siemens. As the conductance exceeds 1000 siemens the response curves quickly roll back into the noise level. For the B-Field response, the early channel amplitude peaks at about 80 siemens and the late channel at about 550 siemens. The projected extension of the graph in the direction if increasing conductance where the response would roll back into the noise level, would be close to 100,000 siemens. So , a strong conductor, having a conductance of several thousand siemens, would be difficult to interpret on the dB/dt data, since the response would be mixed in with the background noise. However, this strong conductor would stand out clearly on the B-Field data, although is would have an unusual character, being a moderate to high amplitude response, exhibiting almost no decay.

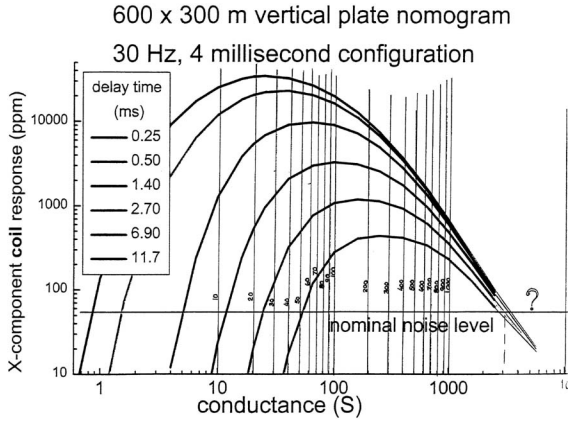


Figure 2.

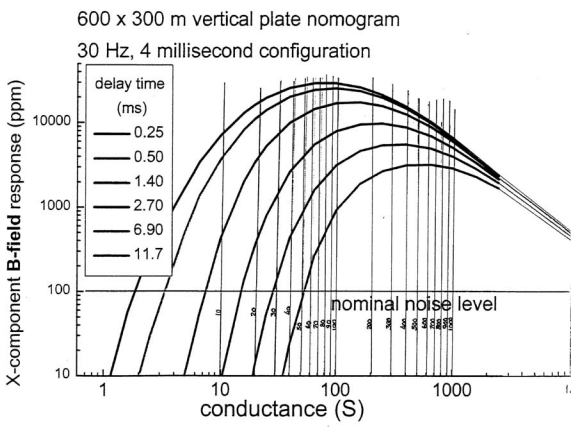


Figure 3.

In theory, the response from a super conductor (50,000 to 100,000 siemens) would be seen on the B-Field data as a low amplitude, non-decaying anomaly, not visible in the off-time channels of the dB/dt stream. Caution must be exercised here, as this signature can also reflect a residual noise event in the B-Field data. In this situation, careful examination of the dB/dt on-time (in-pulse) data is required to resolve the ambiguity. If the feature is strictly a noise event in the data, then being absent in the dB/dt off-time data stream would locate the response at the resistive limit and the mid in-pulse channel (normally identified as channel 3) would reflect little but background noise, or at best a weak negative peak. If, on the other hand, the feature does indeed reflect a superconductor, then this would locate the response at the inductive limit. In this situation, the on-time response of the dB/dt stream will mirror the transmitted pulse, giving rise to a large negative response on the mid in-pulse channel.

Discussion on filtering and gridding

The design of all filter parameters was controlled by power spectra analysis and by testing on selected portions of the data and graphically viewing the results pre and post filtering, to insure that the full resolution of the geological signal is preserved while minimising the non-geological signal.

Routinely two different gridding algorithms are used: a modified Akima spline routine for regular gridding and a Minimum Curvature routine, usually for under sampled data. The Minimum Curvature gridding was used on this project for the magnetic data to better represent small, single line features in the data which were not be adequately sampled by the 200 metre line spacing . The Akima spline routine was used for the gridding of the apparent conductance, the decay constant and the digital terrain model.

Gridding is normally done by interpolating the data at right angle to the line direction. Geological features which are orthogonal to the survey line direction will best represented in this manner, but features which trend at an oblique angle to the line direction will often be poorly represented, appearing as broken-up segments. This situation presented itself with the magnetic data which displayed the response of numerous dikes trending at shallow angles to the flight lines. To improve on the definition of these features, an in-house developed trending algorithm

was then used to locally re-interpolate the data along the direction of the trend. Versions of both the regular grid and the enhanced trended grid were prepared, with the trended grid used for the map presentation and creation of the second vertical derivative.

Fixed-wing TDEM systems exhibit an asymmetry in the response due to the system's geometry (i.e. physical separation between the transmitter loop and the receiver coils). The amount of asymmetry in the response also varies with the geometry of the conductor itself. A system lag correction is applied during the processing to align the responses, from one survey line to the next, over narrow vertical conductors, such that these will be displayed as straight axes. However, this will leave the edges of broad flat-lying conductors displaying a line-to-line oscillation or "herringbone" pattern. This, in itself, is a useful interpretation aid, as it helps to distinguish between vertical and flat-lying conductors but as a regional mapping presentation, it presents an unappealing image. This asymmetry, associated with the edges of flat-lying conductors, can be removed by applying a de-corrugation technique directly to the gridded values. This step is often referred to as "de-herringboning". All final EM grids were prepared in both the regular and "de-herringboned" versions, for comparison. The de-herringboned grids were used for the map presentation.

6) MICROLEVELLING AND GSC LEVELLING

Microlevelling

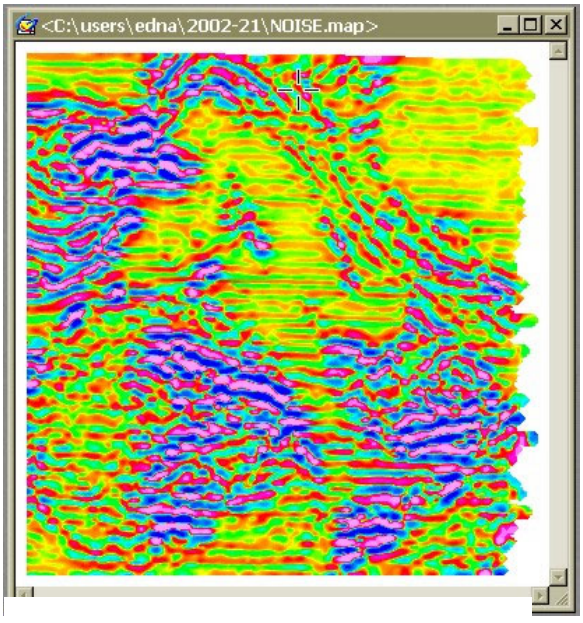
Microlevelling is the process of removing residual flightline noise that remains after conventional levelling using control lines. It has become increasingly important as the resolution of aeromagnetic surveys has improved and the requirement of interpreting subtle geophysical anomalies has increased. The frequency-domain filtering technique known as "decorrugation" has proven inadequate in most situations, as significant geological signal might be removed along with noise. In addition, the microlevelling correction is applied to the profile data, whereas decorrugation corrects only grids. The separation of noise from geological signal and the correction of the profiles, are the key strengths of the PGW's microlevelling procedure.

The PGW microlevelling technique resulted from a new application of filters used in the process of draping profile data onto a regional magnetic datum (Reford et al., 1990). It is similar to that published by Minty (1991).

Microlevelling is applied in two steps. The decorrugation steps are as follows:

- Grid the flightline data to a specified cell size using the minimum curvature gridding algorithm.
- Apply a decorrugation filter in the frequency-domain, using a sixth-order high pass Butterworth filter of specified cut-off wavelength (tuned to the flightline separation), together with a directional cosine filter, so that a grid of flightline-oriented noise is generated.
- Extract the noise from the grid to a new profile channel.

At this stage, the noise grid may be examined to ensure that the flightline noise has been isolated, and to determine what parameters will be required to separate the true residual flightline noise from the high-frequency geological signal incorporated in the filtering described above.

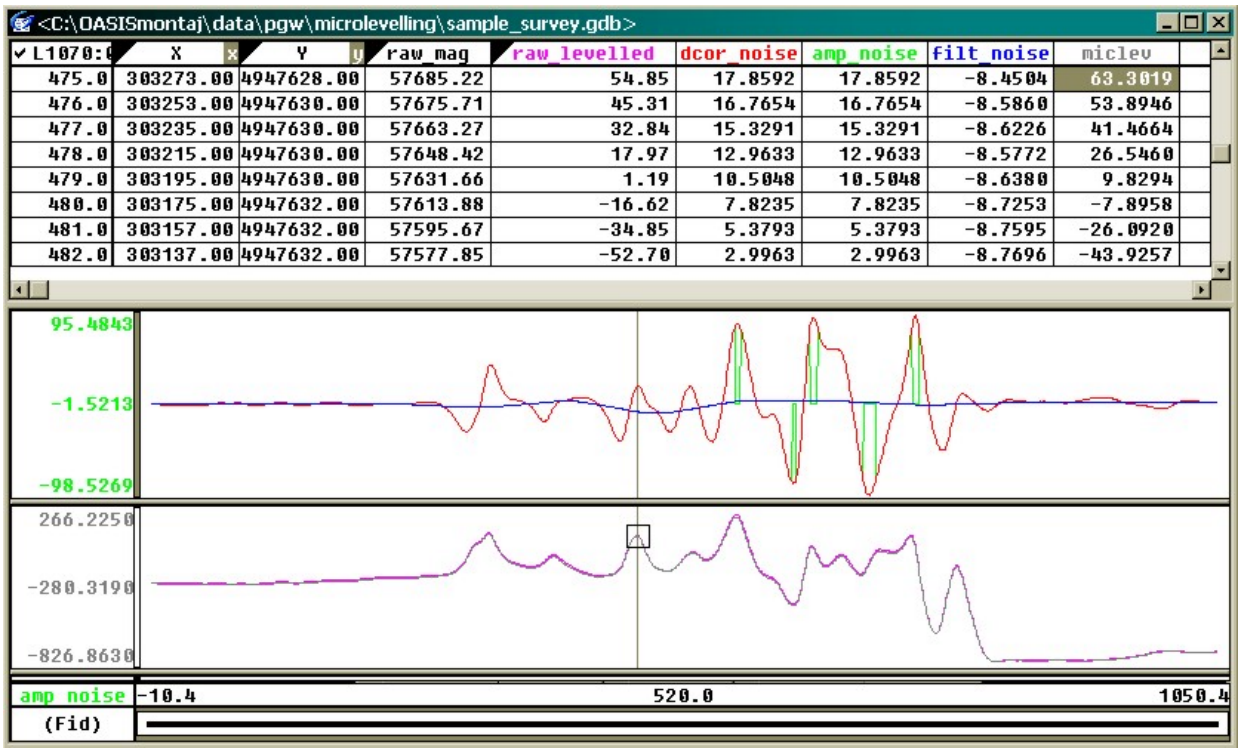


Decorrugation noise grid

The steps for the microlevelling procedure are as follows:

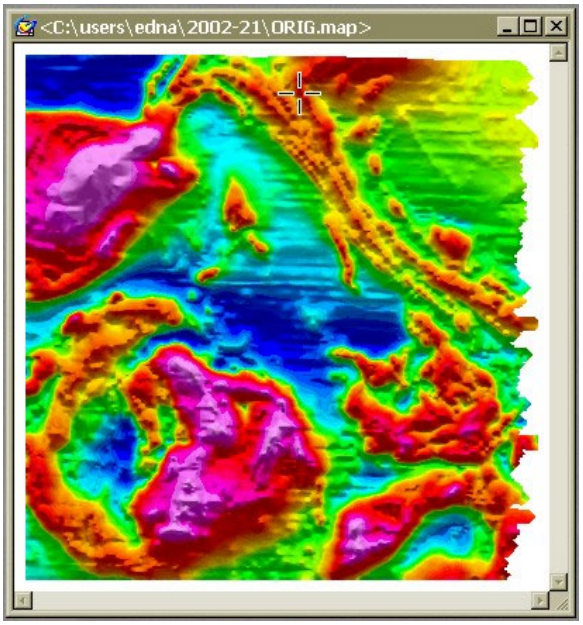
- Apply an amplitude limit to clip or zero high amplitude values in the noise channel, if desired.
- Apply a low pass non-linear filter (Naudy and Dreyer, 1968), so that only the longer wavelength flightline noise remains, forming the microlevel correction.
- Subtract the microlevel correction from the original data, resulting in the final, microlevelled profile channel.

In the example shown, the data are windowed from an airborne magnetic and electromagnetic survey flown in the Matachewan area of Ontario, over typical Archean granite-greenstone terrain (Ontario Geological Survey, 1997). Standard corrections (e.g. diurnal, IGRF, conventional tieline levelling) were applied to the magnetic data. However, a considerable component of residual flightline noise remains, due for example to inadequate diurnal monitoring or tieline levelling difficulties.

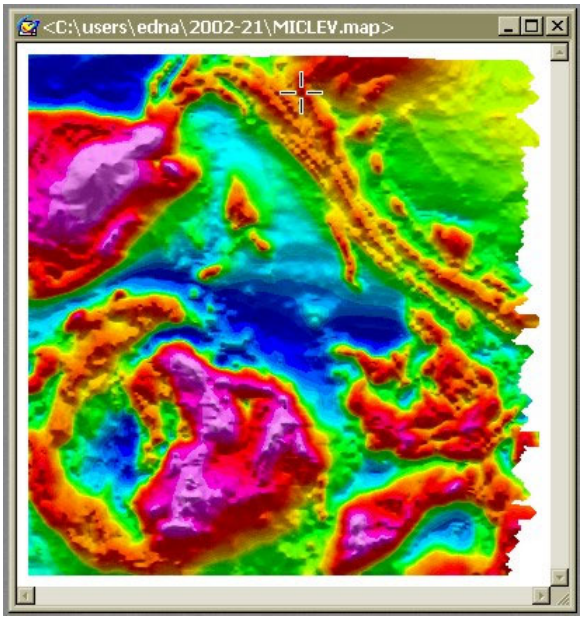


Middle panel: **red – decorrugated noise channel**
green – noise channel after zeroing high values
blue – non-linear filtered noise channel (=microlevel channel)
Lower panel: **magenta – original total magnetic field**
grey – microlevelled total magnetic field

The resultant microlevelled channel can then be gridded for comparison with the original data. In addition, it is useful to examine the intermediate noise channels in profile and grid form, to verify that the desired separation of residual flightline noise and geological signal has occurred.



Total magnetic field, before microlevelling.



Total magnetic field grid, after microlevelling.

Microlevelling can be applied selectively to deal with noise that varies in amplitude and/or wavelength across a survey area. It can also be applied to swaths of flightlines, where more regional level shifts are a problem due to inadequate levelling to the control lines. This can be particularly useful on older surveys where tieline data may no longer be available.

Microlevelling will not solve all problems of flightline noise. For example, positioning errors (e.g. poor lag correction) may result in some level shift that microlevelling will reduce. However, shorter wavelength anomalies will still remain mis-aligned. Line-to-line variations in survey height result in anomaly amplitude variations. Again, microlevelling will reduce long wavelength level shifts, but cannot compensate for localized amplitude changes.

Decorrugation Parameters

Decorrugation requires a database of geophysical data, oriented along roughly parallel survey lines. Surveys with more than one line orientation should be separated into blocks of consistent line direction. The profile channel to be microlevelled should have had all standard corrections, and conventional tieline levelling, already applied. Only traverse lines should be selected for microlevelling (i.e. no tie-lines).

Flight Line Spacing

The nominal flightline spacing is required to design the filter parameters. If a survey contains blocks flown at different line spacings, better results will likely be obtained if these blocks are microlevelled separately. If one is attempting to remove wider level shifts, across swaths of lines, then the average width of the swath should be specified instead.

Flight Line Direction
The nominal flightline direction is required so that the directional filtering incorporated in the decorrugation process has the correct orientation. Survey blocks flown with different line directions should be microlevelled separately.

Grid Cell Size for Gridding
The cell size chosen should be small enough so that the residual flightline noise represented in the grid of original data is well-defined on a survey line basis. Thus, a grid cell size of ¼ the line spacing or smaller is recommended. However, a cell size that is too small (i.e., less than 1/10 the line spacing) will not improve the microlevelling results, and will increase the processing time required.

Decorrugation cut-off wavelength
This parameter defines the cut-off wavelength of the sixth-order, high-pass Butterworth filter, that is combined with a directional cosine filter (power of 0.5) oriented perpendicular to the flightline direction, to extract the residual flightline noise component from the grid of the original data. A wavelength of four times the line spacing has typically proven to produce the best results. Setting this wavelength too small will not give the filter enough width to isolate the effect of each flightline. Setting it too large will extract more geological signal than necessary.

Microlevelling Parameters

Once decorrugation has been applied, it is recommended that the decorrugation grid be reviewed and compared to the original data. This is best done by shaded relief imaging. The purpose is to:

- Ensure that the parameters chosen when decorrugation was applied have properly isolated the residual flightline noise.
- Measure the amplitudes (e.g. determine the peak-to-trough amplitude variations between the survey lines) and wavelengths (in the flightline direction) of the residual flightline noise, from the decorrugation grid.

Amplitude limit value
The amplitude limit defines the value estimated by the user as the maximum amplitude of the residual flight line noise in a survey. If the absolute value of the decorrugation noise channel exceeds the specified amplitude for a given record, then it will be clipped to that value, or zeroed, depending on the mode chosen. This is one of the techniques employed to separate residual flightline noise from geological signal. It is assumed than any responses of higher amplitude reflect geology.

The user should also consider the sources of noise for the particular survey that is being microlevelled. When considering aeromagnetic data, the noise amplitudes produced by some sources (e.g. diurnal variation) are not affected by the geological signal of an area, whereas the noise amplitudes from others (e.g. height variations) are affected by the geology, particularly where the magnetic gradients are strong.

If the user does not want to apply an amplitude limit, than a large value, exceeding the dynamic range of the decorrugation noise channel, should be specified. This dynamic range can be determined from the channel statistics.

Amplitude Limit Mode
There are two choices for the amplitude limit mode:

Zero mode – This will set any value in the decorrugation noise channel, whose absolute value exceeds the specified amplitude limit value, to zero prior to application of the non-linear filter. This is suited to areas where the responses exhibit steep gradients (e.g. magnetic survey over near-surface igneous and metamorphic rocks). It has the effect of dividing a simple, high amplitude response into three parts: two flanks centred on a zeroed section, allowing a shorter non-linear filter wavelength to be applied, if appropriate. It also reduces the possibility of this filter distorting a response whose wavelength is close to the filter wavelength.

Clip Mode – This will set any value in the decorrugation noise channel, whose absolute value exceeds the specified amplitude limit value, to the amplitude limit value (with appropriate sign) prior to application of the non-linear filter. This is suited to areas where the magnetic responses exhibit shallow gradients (e.g. magnetic survey over sedimentary terrain). It is also applied where the wavelengths of the residual flightline noise in the line direction are clearly much greater than those of the geological signal in the decorrugation noise grid.

Naudy Filter Length
The Naudy non-linear low pass filter (Naudy and Dreyer, 1968) is used due to its superior qualities for either accepting or rejecting responses beyond the specified filter length. A linear filter, in contrast, would smear an undesirable, short wavelength response into the filtered data, rather than completely remove it. It is applied to the amplitude-limited noise channel, to remove any remaining geological signal. The filter length is set to half the length of the shortest linear noise segments visible in the decorrugation noise grid. In most situations, the lengths of these noise segments will still be considerably larger than the wavelengths of geological signal. The exception occurs where there is strong signal due to geology (e.g. magnetic dykes) that strike subparallel to the line direction. In such cases, it is wise to choose a fairly long filter length for the first pass of microlevelling, and then shorten the filter length for any subsequent microlevelling applied only to survey lines (or parts thereof) where problems remain.

Naudy Filter Tolerance
This parameter sets the amplitude below which the filter will not alter the data. For microlevelling, it is recommended that this value be set quite small (e.g. 0.001 nT for magnetic data) as otherwise, the filtered noise channel may contain low amplitude, high frequency chatter that will then be introduced into the microlevelled channel when the correction is applied.

Quality Control
Once the microlevelling process has been applied, it is instructive to study five parameters, both in profile and gridded form: original unmicrolevelled data, decorrugated noise, amplitude-limited noise, non-linear filtered noise (i.e. microlevel correction) and microlevelled data. This will allow the user to determine if separation of residual flightline noise from geological signal is satisfactory, and whether any levelling problems remain.

Shaded relief imaging of the total magnetic field and its residual component and/or $1^{st}/2^{nd}$ vertical derivatives will verify that the residual line noise has been minimised, and that new line noise has not been introduced. A grid of the microlevel correction will confirm that geological signal has not been removed.

GSC Levelling

In 1989, as part of the requirements for the contract with the Ontario Geological Survey (OGS) to compile and level all existing GSC aeromagnetic data (<1989) in Ontario, PGW developed a robust method to level the magnetic data of various base levels to a common datum provided by the Geological Survey of Canada (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 AMEM surveys flown by the OGS (Ontario Geological Survey, 1996).

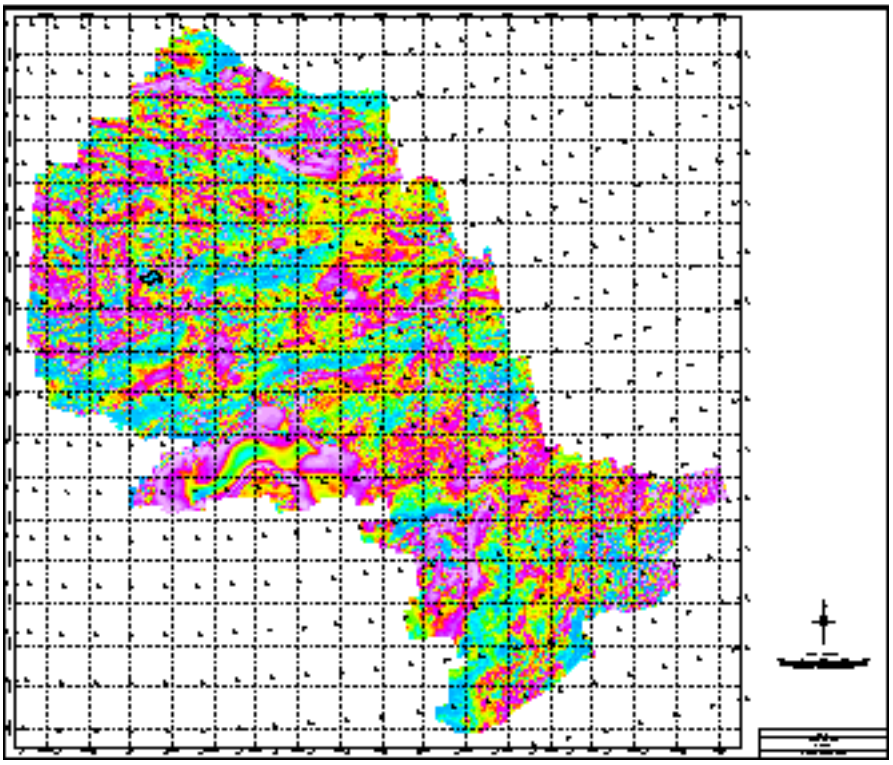
Terminology:

Master grid – refers to the 200 metre Ontario magnetic grid compiled and levelled to the 812.8 metre 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 – refer 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 levelling – refer 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 metre Ontario master grid, which was derived from all pre-1989 GSC magnetic data and adjusted, in turn, by the 812.8 metre GSC Canada wide grid.



Ontario Master Aeromagnetic Grid (Ontario Geological Survey, 1999). The outline for the sample dataset to be levelled (Vickers) is shown.

The GSC Levelling Methodology

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 is 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.

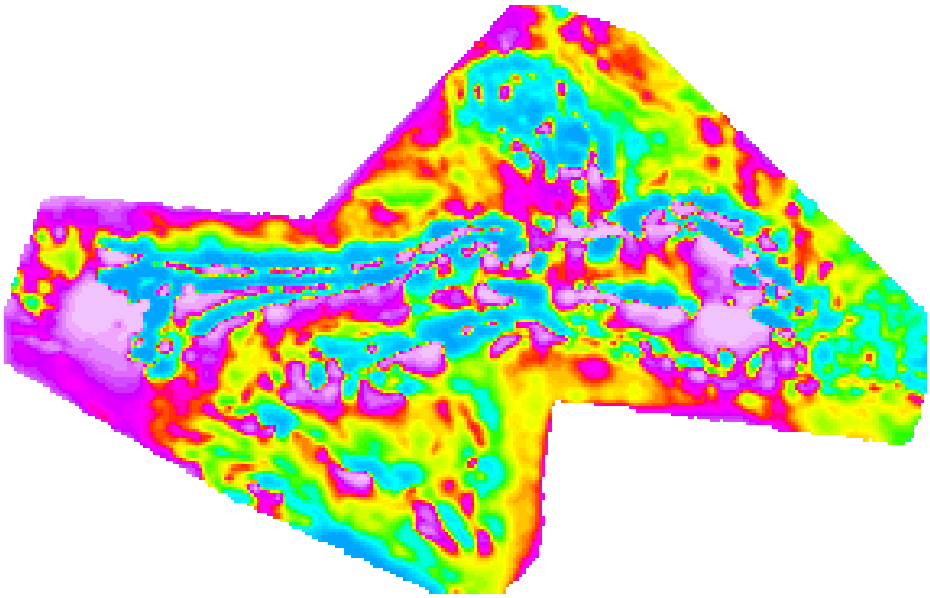
1.Create an upward continuation of the survey grid to 305m

Almost all recent surveys (1990 and later) to be compiled were flown at a nominal terrain clearance of 100 metres or less. The first step in the levelling method is to upward continue the survey grid to 305 metres, the nominal terrain clearance of the Ontario master grid. The grid cell size for the survey grids is set at 100 metres. Since the wavelengths of level corrections will be greater than 10 to 15 kilometres, working with 100 metre or even 200 metre 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 regridded to 1/5 of line spacing.

The unlevelled 100 metre 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.

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, regridded at 100 metres, is computed. The short wavelengths represent the higher resolution of the survey grid. The long wavelengths represent the level difference between the two grids.



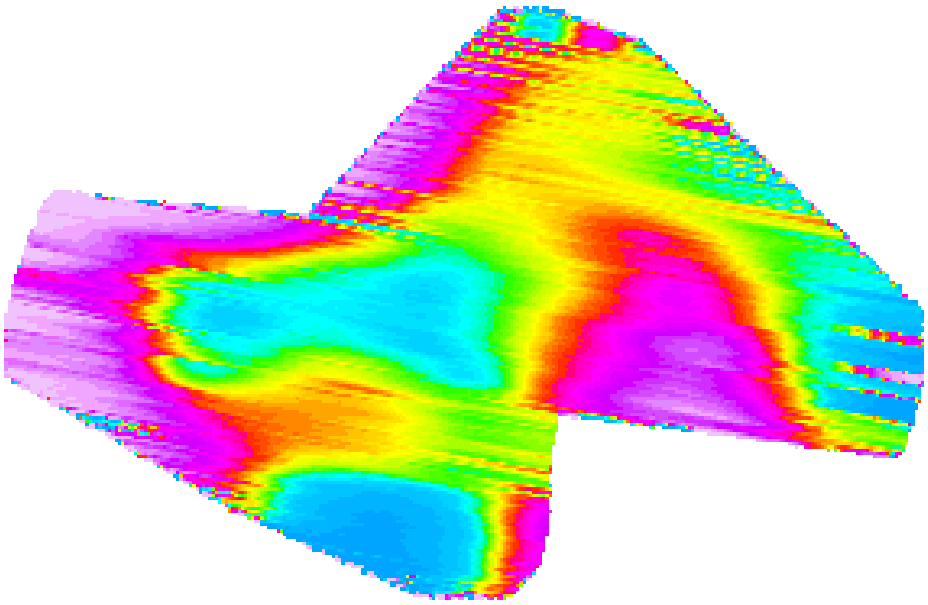
Difference grid (difference between survey grid and master grid), Vickers survey.

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

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

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

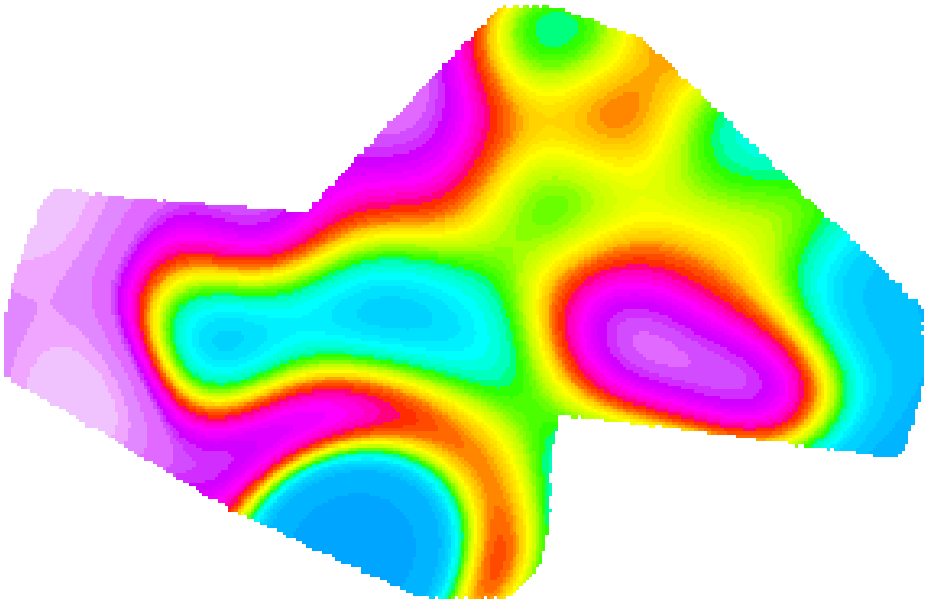
6. Rotate the filtered grid back to its original (true) orientation.



Difference grid after application on non-linear filtering, Vickers Survey.

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 kilometres.



Level correction grid, Vickers Survey.

8. Regrid to 1/5 line spacing and import level corrections into database.

9. Subtract the level correction channel from the unlevelled channel to obtain the level corrected channel.

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

Total Magnetic field and Second Vertical Derivative Grids

For most surveys the reprocessed total field magnetic grid was calculated from the final reprocessed profiles by a minimum curvature algorithm (Briggs, 1974). The accuracy standard for gridding is that the grid values fit the profile data to within 1 nT for 99.98% of the profile data points. The average gridding error is well below 0.1 nT.

Minimum curvature gridding provides the smoothest possible grid surface that also honours the profile line data. However, sometimes this can cause narrow linear anomalies cutting across flight lines to appear as a series of isolated spots.

The second vertical derivative of the total magnetic field was 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.

An optimum second vertical derivative filter was designed using Wiener filter theory and matched to the data (Gupta and Ramani, 1982) of individual survey areas. First, the radially averaged power spectrum of the total magnetic field was computed and a white noise power was chosen by trial and error. Second, an optimum Wiener filter was designed for the radially averaged power spectrum. Third, a cosine-squared function was then applied to the optimum Wiener filter to remove the sharp roll-off at higher frequencies.

The radial frequency response of the optimum second vertical derivative filter is given by:

$$H_{2VD}(f) = (2f*\pi)^2*(1-\exp(-x(f)))$$

Where x(f) is the logarithmic distance between the spectrum and the selected white noise.

Survey Specific Parameters

The following decorrugation and microlevelling parameters were used in the Kirkland Lake survey:

Block A

No microlevelling was required

Block B

Flight line spacing: 200 metres

Flight line direction: 150

Grid cell size: 40 metres
Decorrugation cut-off wavelength: 800 metres

Amplitude limit value: 20 nT
Amplitude limit mode: clip
Naudy filter length: 500 metres
Naudy filter tolerance: 0.001
Comments: none

Block C

Flight line spacing: 200 metres
Flight line direction: 0
Grid cell size: 40 metres
Decorrugation cut-off wavelength: 800 metres

Amplitude limit value: 20 nT
Amplitude limit mode: clip
Naudy filter length: 500 metres
Naudy filter tolerance: 0.001
Comments: none

Block D

Flight line spacing: 200 metres
Flight line direction: 130
Grid cell size: 40 metres
Decorrugation cut-off wavelength: 800 metres

Amplitude limit value: 30 nT
Amplitude limit mode: clip
Naudy filter length: 500 metres
Naudy filter tolerance: 0.001
Comments: none

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

Distance to upward continue: 230 metres
First pass non-linear filter length: 10000 metres
Second pass non-linear filter length: 2500 metres
Low pass filter cut-off wavelength: 15000 metres
Comments: none

7) FINAL PRODUCTS

Map products at 1/20,000

- Residual magnetic field contours, plotted with flight path and EM anomalies on a planimetric base.

Digital plot files at 1/50,000

- Residual magnetic field in colour with contours, presented with EM anomalies on a planimetric base.
- Shaded colour image of the 2nd vertical derivative of the magnetics, presented with the Keating Kimberlite coefficients, on a planimetric base.
- Colour EM decay constant with contours, presented with EM anomalies on a planimetric base.

Profile databases

- EM database at 4 samples/sec in both Geosoft GDB and ASCII format.
- Database for magnetics at 10 samples/sec in both Geosoft GDB and ASCII format.

EM Anomaly database

- EM Anomaly database in both Geosoft GDB and CSV format.

Kimberlite coefficient database

- Keating kimberlite coefficient database in both Geosoft GDB and CSV format.

Data grids

- Geosoft data grids, in both GRD and GXF formats, gridded from coordinates in both NAD27 and NAD83 datum of the following parameters:
  - Digital Terrain Model
  - Residual Magnetic Intensity (regular gridding)
  - Residual Magnetic Intensity (enhanced trended gridding)
  - GSC Levelled Magnetic Field
  - 2nd Vertical Derivative of Magnetics
  - 2nd Vertical Derivative of the GSC Levelled Magnetic Field
  - EM Decay Constant (regular grid)
  - EM Decay Constant (de-herringboned grid)
  - Apparent Conductance (regular grid)
  - Apparent Conductance (de-herringboned grid)

GeoTIFF images of the entire survey block

- Colour residual magnetics on a planimetric base.
- Colour shaded relief of 2nd vertical derivative of magnetics on a planimetric base.
- Colour de-herringboned EM decay constant on a planimetric base.

DXF vector files of the entire survey block

- Flight path.
- EM anomaly locations.
- Keating kimberlite coefficients.
- Residual magnetic field contours.
- De-herringboned EM decay constant contours.

Halfwave files

- These are raw binary files, covering one flight of data per file, delivered on separate DVDs. A DOS utility is included to convert these to a flat ASCII file. These files contain the 384 points of the TDEM waveform, stacked to 4Hz sampling, for the four components T, X, Y and Z.

Waveform parameter table files

- These are the TDEM reference waveform files delivered as a standard ASCII text file, one for each survey flight. These files provide information on the system geometry, the window (channel) positions , the conversion factors and the waveform itself.

Project report

- Provided in both WORD and PDF formats.

8) QUALITY ASSURANCE AND QUALITY CONTROL

Quality assurance and quality control (QA/QC) were undertaken by the survey contractor (Fugro Airborne Surveys), by PGW (as OTH Geophysicist), and by MNDM. Stringent QA/QC was emphasized throughout the project so that the optimal geological signal was measured, archived and presented.

Survey Contractor

Important checks were required during the data acquisition stage to insure that the data quality was kept within the survey specifications. The following lists in detail the standard data quality checks that were performed during the course of the survey.

Daily quality control

Navigation data

- The differentially corrected GPS flight track was recovered and matched against the theoretical flight path to ensure that any deviations were within the specifications (i.e. deviations not to exceed 50% of the nominal line spacing over a 3 km distance).

- All altimeter data (radar, barometric and GPS elevation) were checked for consistency and deviations in terrain clearance monitored closely. It is understood that the survey was to be flown in a smooth drape fashion maintaining a nominal terrain clearance of 120 metres, whenever possible. Altitude corrections were to be done in a smoothly controlled manner, rather than forcing the return to nominal, to avoid excessive motion of the towed-bird which would impact on the quality of the data. A digital elevation trace, calculated from the radar altimeter and the GPS elevation values, was also be generated to further control the quality of the altimeter data.

- The synchronicity of the GPS time and the acquired time of the geophysical data was checked by matching the recorded time fields.

- A final check on the navigation data was to compute a point-to-point speed from the final corrected UTM X and Y values. This should be free of erratic behavior showing a nominal ground speed of between 60 and 70 m/s with point-to-point variations of less than +/- 7 metres.

Magnetometer data

- The diurnal variation was examined for any deviations that exceeded the specification of 2.5 nT peak-to-peak over a chord equivalent to the control line interval of 1500 m (or approximately 25 seconds). Data was be re-flown when this condition was exceeded, with any re-flown line segment crossing a minimum of two control lines. A further quality control done on the diurnal variation is to examine the data for any man-made disturbances. When noted, these were graphically removed by a polynomial interpolation so that these artifacts will not be introduced into the final data when the diurnal values were subtracted from the recorded airborne data during the processing.

- The integrity of the airborne magnetometer data was checked through statistical analysis and graphically viewed in profile form to ensure that there were no gaps and the noise specification was met.

- A fourth difference editing routine was applied to the raw data to locate and correct any small steps and / or spikes in the data.

- Any effects of filtering applied to the data were examined by displaying in profile form the final processed results against the original raw data, via a graphic screen. This was done to ensure that any noise filtering applied has not compromised the resolution of the geological signal.

- On-going gridding and imaging of the data was also done to control the overall quality of the magnetic data.

Electromagnetic data

- The high altitude calibration sequences, recorded pre and post-flight, were closely examined. These background data segments, which are free of ground conductive response, were checked to ensure that the baseline positions for each channel were good, that the noise levels were within the specification and that the system had been well compensated for excessive motion of the towed-bird.

- The reference waveform, collected during the calibration sequence and used for the compensation of the primary field, was closely examined for consistency from flight to flight. Diagnostic parameters, such as the peak voltages for each coil set and the transmitter current were noted and entered in the daily processing log for future reference.

- All recorded EM channels were examined and adjusted for system drift. This was done by graphically displaying each channel data in profile for the entire flight as a continuous segment and checking the high altitude background segments and local minimas against a zero baseline value. This check also provides a good overall view of the response from each channel for any unusual behavior.

- Level of spheric activity was assessed during the processing, through a decay analysis. The percentage of bad decays detected, not associated with power lines, were tabulated and reported. Under normal conditions, this is kept to 1 % or less.

- The "streamed" data was checked for continuity and its integrity assessed by statistical analysis. A viewing tool was also used to display the transient / waveform response from each of the four measured components : Tx, Rx, Ry and Rz.

- After processing, the final results were displayed in profile form, via a graphic screen and compared with the raw data, to ensure that the data had not been over filtered. A multi channel profile display of the data, at this stage, also provided a visual check on the character of the decay information. This was followed by the calculation of the decay constant itself, which was gridded and imaged on an on-going basis throughout the survey, to further control the quality of the electromagnetic data.

Near-final field products

Near-final products of the navigation, magnetic and electromagnetic data were made available to the OTH Geophysicist during visits to the survey site, for review and approval, prior to demobilization.

Quality control in the office

Review of field processing of Magnetic & Electromagnetic data.

The general results of the field processing were reviewed in the profile database by producing a multi-channel stacked display of the data (raw and processed) for every line, using a graphic viewing tool. The magnetic and altimeter data were checked for spikes and residual noise. The electromagnetic channel data was checked for baseline positions, decay character and the effect of filtering.

Review of leveling of magnetics.

The results of the field leveling of the magnetics were reviewed, using imaging and shadowing techniques. Any residual errors noted were corrected and the final micro-leveling re-applied to the gridded values.

Creation of magnetic derivatives

The 2nd vertical derivative was created from the final gridded values of the total field magnetic data and checked for any residual errors using imaging and shadowing techniques.

Creation of final EM grids.

EM grids of the decay constant (Tau) and the apparent conductance values were created and reviewed for residual drift / leveling errors and necessary corrections applied, as required. At this stage, the option of using either the regular dB/dT coil data or the B-Field components, to generate the required parameter grids, was reviewed to insure the best definition of the targets sought. Necessary material was provided to the MNDM / OTH for this evaluation.

Correction of EM grids for asymmetry

The selected EM grids were corrected for asymmetry (de-herringboned) and checked against the original grids to insure that there was no loss or misrepresentation of geological features.

EM anomaly selection.

The automated EM anomaly selection was reviewed interactively against the profile data, via a graphic display tool and edited to insure that all valid anomalies were represented in the database. The final selection was then checked against the base maps (and in-flight videos, as required) to properly separate and label man-made responses from geological sources.

Interim products

Archive files containing the raw and processed profile data, the EM anomaly database and the final gridded parameters were provided to MNDM for review and approval.

Creation of 1/20,000 maps

After approval of the interim data, the 1/20,000 maps of the Total Field Magnetics with the EM anomalies and the base maps were created and verified for registration, labeling, dropping weights, general surround information, etc …

OTH Geophysicist

The OTH Geophysicist conducted on-site inspections during data acquisition, focusing initially on the data acquisition procedures, base station monitoring and instrument calibration. As data was collected, it was reviewed for adherence to the survey specifications and completeness. Any problems encountered during data acquisition were discussed and resolved.

The QA/QC checks included the following:

Navigation Data

- appropriate location of the GPS base station
- flight line and control line separations were maintained, and deviations along lines were minimized
- verified synchronicity of GPS navigation and flight video
- all boundary control lines were properly located
- terrain clearance specifications were maintained
- aircraft speed remained within the satisfactory range
- area flown covered the entire specified survey area
- differentially-corrected GPS data did not suffer from satellite-induced shifts or dropouts
- GPS height and radar/laser altimeter data were able to produce an image-quality DEM
- GPS and geophysical data acquisition systems were properly synchronized
- GPS data were adequately sampled

Magnetic Data

- appropriate location of the magnetic base station, and adequate sampling of the diurnal variations
- heading error and lag tests were satisfactory
- magnetometer noise levels were within specifications
- magnetic diurnal variations remained within specifications
- magnetometer drift was minimal once diurnal and IGRF corrections had been applied
- spikes and/or drop-outs were minimal to non-existent in the raw data
- filtering of the profile data was minimal to non-existent
- in-field leveling produced image-quality grids of total magnetic field and higher-order products (e.g. second vertical derivative)

Time-domain Electromagnetic Data

- selected receiver coil orientations, base frequency, primary field waveform and secondary field sampling were appropriate for the local geology
- raw "streaming" data were recorded and archived
- data behaved consistently between channels (i.e. consistent signal decay)
- noise levels were within specifications, and system noise was minimized
- bird swing and orientation noise was not evident
- sferics and other spikes were minimal (after editing)
- cultural (60 Hz) noise was not excessive
- regular tests were conducted to monitor the reference waveform and system drift, and ensure proper zero levels
- filtering of the profile data was minimal

- In-field processing produces image-quality images of apparent conductivity and decay constant (tau).

The OTH Geophysicist reviewed interim and final digital and map products throughout the data compilation phase, to ensure that noise was minimized and that the products adhered to the OTH specifications. This typically resulted in several iterations before all digital products were considered satisfactory. Considerable effort was devoted to specifying the data formats, and verifying that the data adhered to these formats.

MNDM

MNDM prepared all of the base map and map surround information required for the digital and hard copy maps. This ensured consistency and completeness for all of the OTH geophysical map products. For Temagami, the base map was constructed from digital files of the 1:20,000 OBM map series.

MNDM worked with the OTH Geophysicist to ensure that the digital files adhered to the specified ASCII and binary file formats, that the file names and channel names were consistent, and that all required data were delivered on schedule. The map products were carefully reviewed in digital and hard copy form to ensure legibility and completeness.

REFERENCES

Briggs, Ian, 1974, Machine contouring using minimum curvature, Geophysics, v.39, pp.39-48.

Fairhead, J. Derek, Misener, D. J., Green, C. M., Bainbridge, G. and Reford, S.W. 1997: Large Scale Compilation of Magnetic, Gravity, Radiometric and Electromagnetic Data: The New Exploration Strategy for the 90s; Proceedings of Exploration 97, ed. A. G. Gubins, p.805-816.

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, pp.244-250.

Gupta, V. and Ramani, N., 1982, Optimum second vertical derivatives in geological mapping and mineral exploration, Geophysics, v.47, pp. 1706-1715.

Gupta, V., Rudd, J. and Reford, S., 1998, Reprocessing of thirty-two airborne electromagnetic surveys in Ontario, Canada: Experience and recommendations, 68th Annual Meeting of the Society of Exploration Geophysicists, Extended Technical Abstracts, p.2032-2035.

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

Minty, B. R. S., 1991, Simple micro-levelling for aeromagnetic data, Exploration Geophysics, v. 22, pp. 591-592.

Naudy, H. and Dreyer, H., 1968, Essai de filtrage nonlinéaire appliqué aux profiles aeromagnétiques, Geophysical Prospecting, v. 16, pp.171-178.

Ontario Geological Survey, 1996, Ontario airborne magnetic and electromagnetic surveys, processed data and derived products: Archean and Proterozoic “greenstone” belts – Matachewan Area, ERLIS Data Set 1014.

Ontario Geological Survey, 1997, Ontario airborne magnetic and electromagnetic surveys, processed data and derived products: Archean and Proterozoic “greenstone” belts – Black River-Matheson Area, ERLIS Data Set 1001.

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

Palacky, G.J. and West, G.F. 1973. Quantitative interpretation of INPUT AEM measurements; Geophysics, v.38, p. 1145-1158.

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., pp.617-619.

Smith, R.S. and Annan, A.P. 1997. Advances in airborne time-domain EM technology; in Proceedings of Exploration 97: Fourth Decennial Conference in Mineral Exploration, p. 497-504.

Smith, R.S. and Annan, A.P. 1998. The use of B-Field measurements in an airborne time-domain system, Part I: Benefits of B-Field versus dB/dT data; Exploration Geophysics, v.29, p. 24-29.

Smith, R.S. and Keating, P.B. 1996. The usefulness of multicomponent time-domain airborne electromagnetic measurements; Geophysics, v.61, p. 74-81.

Wolfgram, P. and Thomson, S. 1998. The use of B-Field measurements in an airborne time-domain system, Part II: Examples in conductive regimes; Exploration Geophysics, v.29, p. 225-229.

APPENDIX A TESTING AND CALIBRATION

Pre-survey calibrations

EM calibration range

The new Reid and Mahaffy test range, representing approximately 100 km of flying, was flown along the coordinates provided by the MNDM. This included one line re-flown at several different elevations to provide a height attenuation calibration .This test was done to demonstrate the general functionality of all on-board systems (navigation, altimetry, magnetics and electromagnetics) and provide a comparison between different systems. Data from this test was made available to the OTH Geophysicist upon start-up of the program. These data were also used to generate a full suite of sample final products, which were made available for review .

Magnetometer & GPS Cloverleaf

A calibration site, selected to offer a good visual reference and a low magnetic gradient, was used to verify the heading errors of the magnetometer (basic cloverleaf test) and to verify the synchronicity between the GPS navigation and the video as well as the final accuracy of the GPS differentially corrected positions. Results of these tests were reviewed during the first field inspection by the OTH Geophysicist.

MAG CLOVERLEAF TEST

Flown over a cross-road, north of Nighthawk Lake, Ontario

C-FDKM, Flight # 01 November 8th, 1999

Line	Direction	Fiducial	Radar (ft)	TF Mag (nT)	Diurnal (nT)	Residual (nT)
1	East	62358.2	438	57763.41	57733.24	30.17
2	West	62541.7	401	57765.95	57737.01	28.94
3	East	62693.1	449	57765.18	57735.90	29.28
4	West	62850.8	425	57762.31	57733.82	28.49
5	North	62997.4	487	57764 74	57734.71	30.03
6	South	63131.7	427	57763.08	57734.80	28.28
7	North	63295.8	482	57760.28	57730.56	29.72
8	South	63436.7	431	57759.84	57732.04	27.80

Average East-West difference = 1.01 nT
Average North-South difference = 1.83 nT
Average E-W and N-S difference = 0.26 nT

C-GDPP, Flight # 201 November 11th, 1999

Line	Direction	Fiducial	Radar (ft)	Diurnal (nT)	TF Mag (nT)	Residual (nT)
1	South	73299.78	372	57671.76	57795.35	123.59
2	North	73438.86	366	57677.94	57801.24	123.30
3	South	73617.70	362	57684.45	57807.91	123.46
4	North	73740.12	379	57688.29	57812.26	123.97
5	West	73886.54	368	57690.83	57815.72	124.89
6	East	74031.44	381	57699.31	57824.92	125.61
7	West	74168.58	379	57702.69	57828.72	126.03
8	East	74314.06	361	57707.02	57831.86	124.84

Average East-West difference = 0.40 nT
Average North-South difference = 0.96 nT
Average E-W and N-S difference = 1.76 nT

GPS LAG / ACCURACY CHECK

C-FDKM, Flight # 03, November 9th, 1999

Flown over the VOR beacon at the Timmins Airport

Location (NAD27) …….Lat 48° 34' 19" N
Long 81° 22' 12" W
Resolution : 1 second = 31 m in Northing
21 m in Easting

LINE	DIRECTION	VIDEO	VOR Offset
1	West	59623.48	0
2	East	59759.32	2 m N
3	West	59926.42	3 m N
4	East	60047.26	5 m S
5	South	60184.58	3 m W
6	North	60303.62	4 m W
7	South	60411.04	0
8	North	60512.74	3 m W

GPS lag = 0.38 second
Error box = 6 x 7 metres
Mean position relative to VOR location = 28 metres to the NW

(Note : position of beacon from DOT information only given to nearest second reflecting a mean precision of only 25 metres).

C-GDPP, Flight # 201, November 11th, 1999

Flown over the same VOR beacon at the Timmins Airport

LINE	DIRECTION	VIDEO	VOR Offset
1	West	77462.20	0
2	East	77580.62	3.5 m N
3	West	77687.46	3.5 m S
4	East	77806.70	0.5 m N
5	South	77919.22	1.5 m E
6	North	78015.12	3.5 m W
7	South	78128.96	2 m E
8	North	78226.90	1 m W

GPS lag = 0.43 second
Error box = 2 x 4 metres
Mean position relative to VOR location = 28 metres to the NW

(Note : position of beacon from DOT information only given to nearest second reflecting a mean precision of only 25 metres).

Magnetometer and TDEM lag check

The system lag for the magnetometer and electromagnetic system was verified by flying several passes, in opposite directions, over a recognizable feature on the ground giving a sharp magnetic and electromagnetic response. Results of this test were made available to the OTH Geophysicist for the first field inspection.

Measured instrument lags were :

For C-FDKM

Magnetometer reading lag of 3.7 seconds or 37 recording samples

TDEM reading lag of 4.25 seconds or 17 recording samples.

For C-GDPP

Magnetometer reading lag of 3.9 seconds or 39 recording samples

TDEM reading lag of 4.4 seconds or 18 recording samples.

Pre and post-survey calibrations

Altimeter calibration

The accuracy and the relationship between the radar altimeter, the barometric altimeter and the GPS elevation values were verified, pre and post-survey, by flying a series of passes at designated altitudes over Nighthawk lake.

ALTIMETER CALIBRATION

C-FDKM, Flight # 03, November 11th, 1999

Flown over Nighthawk Lake, elevation ~ 896 feet a.s.l.

Nominal T.C. feet	**Nominal Elev.** feet	**Radar** feet	**Baro** feet	**GPS - Z** feet
300	1196	303	1170	1200
350	1246	352	1203	1253
400	1296	402	1231	1302
450	1346	458	1268	1368
500	1396	538	1312	1423
600	1496	627	1368	1509
800	1696	813	1487	1712

Linear regression analysis y = a + bx
1. Nominal (X) vs. Radar (Y) ……..… -4.7 + 1.037x , r = 0.997
2. Nominal (X) vs. Baro (Y) ……..……407 + 0.639x , r = 0.998
3. Nominal (x) VS. GPS - Z (Y) ……..…….-17.5 + 1.022x , r = 0.999
4. GPS - Z (X) vs. Baro (Y) ……..418 + 0.625x , r = 0.999
Barometric scalar correction : (value -418) / 0.625

C-GDPP, Flight # 201, November 11th, 1999

Flown over Nighthawk Lake, elevation ~ 896 feet a.s.l.

Nominal T.C. feet	**Nominal Elev.** feet	**Radar** feet	**Baro** feet	**GPS - Z** feet
300	1196	298	1369	1223
350	1246	345	1414	1271
400	1296	390	1462	1312
450	1346	434	1510	1355
500	1396	504	1590	1426
600	1496	589	1677	1515
800	1696	807	1914	1732

Linear regression analysis y = a + bx
1. Nominal (X) vs. Radar (Y) ……..… -14.4 + 1.020x , r = 0.999
2. Nominal (X) vs. Baro (Y) ……..…… 45.6 + 1.097x , r = 0.998
3. Nominal (x) VS. GPS - Z (Y) ……..……. -7.2 + 1.021x , r = 0.999
4. GPS - Z (X) vs. Baro (Y) …….. 53 + 1.074x , r = 0.999
Barometric scalar correction : (value - 53) / 1.074

Daily calibrations

Barometric altimeter drift check

The drift in the barometric altimeter and the general accuracy of the GPS elevation values were monitored daily by setting the barometric altimeter to the runway elevation prior to take-off on each flight and noting the readings upon landing. These values were recorded in the flight log.

Pre and post-flight TDEM calibration

TDEM systems must be compensated to remove all effects of the primary field on the received secondary signal. This primarily affects the on-time channels and the early off-time channels, close to the turn-off of the pulse. This compensation is done at altitude, sufficiently high to avoid contaminating the signal with ground conductive response. System backgrounds for all channels are collected and stacked over time to provide a statistically valid reference waveform for all components (Tx, Rx, Ry and Rz). This reference waveform is then used to subtract the effects of the primary field on the received signal. Changes in the current waveform, which take place during the survey, are used to deconvolve the X.Y and Z components and remove distortion from nominal waveform to first order. Following the compensation, the aircraft is also put through a series of pitches and rolls, while still at altitude, to verify the effectiveness of the compensation during excessive motion of the receiver bird, triggered by the aircraft maneuvers. This test is performed at the start of every flight and repeated at the end of the flight and is considered an integral part of the data. The reference waveform is also stored digitally and delivered as part of the final data.

APPENDIX B PROFILE ARCHIVE DEFINITION

Survey 1102 was carried out using the time-domain Geotem III electromagnetic and magnetic system, mounted on a fixed wing platform. A transmitter base frequency of 30 Hz was used.

Data File Layout

The files for the Kirkland Lake Geophysical Survey 1102 are archived as an 11 CD set with the file content divided as follows:

CD - 1102a

- ASCII (GXF) grids.
- EM Anomaly database (CSV format)
- Keating correlation (kimberlite) database (CSV format)
- DXF files of entire survey block at 1/50,000 for:
    - Flight path
    - EM anomalies
    - Keating correlation (kimberlite) anomalies
    - Total field magnetic contours
    - TAU contours
- GEOTIFF images (200 dpi) of the entire survey block at 1/50,000 for:
    - Total field colour magnetics with base map
    - Colour shaded relief of 2nd vertical derivative with base map
    - Colour TAU with base map.
- Project report (Word97 and PDF formats)

CD - 1102b

- Geosoft Binary (GRD) grids.
- EM Anomaly database (GDB format)
- Keating correlation (kimberlite) database (GDB format)
- DXF files of entire survey block at 1/50,000 for:
    - Flight path
    - EM anomalies
    - Keating correlation (kimberlite) anomalies
    - Total field magnetic contours
    - TAU contours
- GEOTIFF images (200 dpi) of the entire survey block at 1/50,000 for:
    - Total field colour magnetics with base map
    - Colour shaded relief of 2nd vertical derivative with base map
    - Colour TAU with base map.
- Project report (Word97 and PDF formats)

CD - 1102c

- Volume 1
  - Profile database of MAG (10 Hz sampling) in ASCII (XYZ) format. (complete coverage of blocks A, B, C and D).
- Volume 2
  - Profile database of EM (4 Hz sampling) in ASCII (XYZ) format for block A from lines 100 to 299.
- Volume 3
  - Profile database of EM (4 Hz sampling) in ASCII (XYZ) format for block A from lines 300 to 403 and control lines 5001 to 5053.
  - Profile database of EM (4 Hz sampling) in ASCII (XYZ) format for block D.
- Volume 4
  - Profile database of EM (4 HZ sampling) in ASCII (XYZ) format for block B.
- Volume 5
  - Profile database of EM (4 Hz sampling) in ASCII (XYZ) format for block C.
  - Parameter table files (PTAxxx.OUT) for each flight.
  - EM Anomaly database (CSV format).
  - Keating correlation (kimberlite) database (CSV format).
  - Project report (WORD97 and PDF formats).

CD - 1102d

- Volume 1
  - Profile database of MAG (10 Hz sampling) in Geosoft Montaj (GDB) format
  - Profile database of EM (4Hz sampling) in Geosoft Montaj (GDB) format for block A from lines 300 to 403 and control lines 5001 to 5053.
- Volume 2
  - Profile database of EM (4Hz sampling) in Geosoft Montaj (GDB) format for block A from lines 100 to 299.
  - Profile database of EM (4Hz sampling) in Geosoft Montaj (GDB) format for block D.
- Volume 3
  - Profile database of EM (4Hz sampling) in Geosoft Montaj (GDB) format for block B
- Volume 4
  - Profile database of EM (4Hz sampling) in Geosoft Montaj (GDB) format for block C.
  - Parameter table files (PTAxxx.OUT) for each flight
  - EM Anomaly database (GDB format)
  - Keating correlation (kimberlite) database (GDB format)
  - Project report (WORD97 and PDF formats)

The content of the ASCII and binary file types are identical. They are provided in both forms to suit the user's available software.

Coordinate Systems

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

Universal Transverse Mercator (UTM) projection, Zone 17N, NAD27 datum, NTV2 local datum;
Universal Transverse Mercator (UTM) projection, Zone 17N, NAD83 datum, North American local datum;
Latitude/longitude coordinates, NAD27 datum, NTV2 local datum; and
Latitude/longitude coordinates, NAD83 datum, North American local datum.

The gridded data are provided in the two UTM coordinate systems.

Line Numbering

The line numbering convention for survey 1102 are as follows:

Line number x 100 + part number

i.e.) Line 225 part 1 is identified as 22501

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

Block A is covered by lines 100 to 403 and control lines 5001 to 5053.
Block B is covered by lines 501 to 837 and control lines 6001 to 6031.
Block C is covered by lines 901 to 1088 and control lines 7001 to 7023.
Block D is covered by lines 1092 to 1343 and control lines 8001 to 8024.

Profile Data

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

thkirklandlake#.xyz - ASCII XYZ file, sampled at 4 Hz, divided into 5 files.

- thkirklandlake1.xyz includes the data from block A for lines 100 to 299.
- thkirklandlake2.xyz includes the data from block A for lines 300 to 403 and control lines 5001 to 5053.
- thkirklandlake3.xyz includes the data for block B, all lines.
- thkirklandlake4.xyz includes the data for block C, all lines.
- thkirklandlake5.xyz includes the data for block D, all lines.

thklmag.xyz - ASCII XYZ file, sampled at 10 Hz, for the complete survey coverage.

thkirklandlake#.gdb - Geosoft OASIS montaj binary database file (no compression) , sampled at 4 Hz, divided into 5 files.

- thkirklandlake1.gdb includes the data from block A for lines 100 to 299.
- thkirklandlake2.gdb includes the data from block A for lines 300 to 403 and control lines 5001 to 5053.
- thkirklandlake3.gdb includes the data from block B, all lines.
- thkirklandlake4.gdb includes the data from block C, all lines.
- thkirklandlake5.gdb includes the data from block D, all lines

thklmag.gdb - Geosoft OASIS montaj binary database file (no compression) , sampled at 10 Hz, for the complete survey coverage.

The files thkirklandlake.xyz/.gdb contain the bulk of the data, including the final magnetic channel, sampled at 4 Hz, the acquisition sampling rate of the electromagnetic data. The files thklmag.xyz/.gdb contain all of the magnetic and related data, sampled at 10 Hz, the acquisition sampling rate of the magnetic data.

The contents of thkirklandlake.xyz/.gdb (both file types contain the same set of data channels) are summarized as follows:

Channel Name	Description	Units
gps_x_raw	raw GPS X	degrees x 1 000 000
gps_y_raw	raw GPS Y	degrees x 1 000 000
gps_z_raw	raw GPS Z	metres
gps_x_final	differentially corrected GPS X (NAD83 datum)	decimal-degrees
gps_y_final	differentially corrected GPS Y (NAD83 datum)	decimal-degrees
gps_z_final	differentially corrected GPS Z (NAD83 datum)	metres above sea level
x_nad27	GPS X in UTM co-ordinates using NAD27 datum	metres
y_nad27	GPS Y in UTM co-ordinates using NAD27 datum	metres
x_nad83	GPS X in UTM co-ordinates using NAD83 datum	metres
y_nad83	GPS Y in UTM co-ordinates using NAD83 datum	metres
lon_nad27	longitude using NAD27 datum	decimal-degrees
lat_nad27	latitude using NAD27 datum	decimal-degrees
radar_raw	raw radar altimeter	metres above terrain
radar_final	corrected radar altimeter	metres above terrain
baro_raw	raw barometric altimeter	metres above sea level
baro_final	corrected barometric altimeter	metres above sea level
dem	digital elevation model	metres above sea level
fid	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
date	local date	YYYYMMDD
mag_final	IGRF-corrected magnetic field	nanoteslas
height_em	electromagnetic receiver height	metres above terrain
em_x_raw_on	raw (stacked) dB/dT, X-component, on-time (5 channels)	picoteslas per second
em_x_raw_off	raw (stacked) dB/dT, X-component, off-time (15 channels)	picoteslas per second
em_y_raw_on	raw (stacked) dB/dT, Y-component, on-time (5 channels)	picoteslas per second
em_y_raw_off	raw (stacked) dB/dT, Y-component, off-time (15 channels)	picoteslas per second
em_z_raw_on	raw (stacked) dB/dT, Z-component, on-time (5 channels)	picoteslas per second
em_z_raw_off	raw (stacked) dB/dT, Z-component, off-time (15 channels)	picoteslas per second
em_x_drift_on	drift-corrected dB/dT, X-component, on-time (5 channels)	picoteslas per second
em_x_drift_off	drift-corrected dB/dT, X-component, off-time (15 channels)	picoteslas per second
em_y_drift_on	drift-corrected dB/dT, Y-component, on-time (5 channels)	picoteslas per second
em_y_drift_off	drift-corrected dB/dT, Y-component, off-time (15 channels)	picoteslas per second
em_z_drift_on	drift-corrected dB/dT, Z-component, on-time (5 channels)	picoteslas per second
em_z_drift_off	drift-corrected dB/dT, Z-component, off-time (15 channels)	picoteslas per second
em_x_final_on	filtered dB/dT, X-component, on-time (5 channels)	picoteslas per second
em_x_final_off	filtered dB/dT, X-component, off-time (15 channels)	picoteslas per second
em_y_final_on	filtered dB/dT, Y-component, on-time (5 channels)	picoteslas per second
em_y_final_off	filtered dB/dT, Y-component, off-time (15 channels)	picoteslas per second
em_z_final_on	filtered dB/dT, Z-component, on-time (5 channels)	picoteslas per second
em_z_final_off	filtered dB/dT, Z-component, off-time (15 channels)	picoteslas per second
em_bx_raw_on	raw (stacked) B-field, X-component, on-time (5 channels)	femtoteslas
em_bx_raw_off	raw (stacked) B-field, X-component, off-time (15 channels)	femtoteslas
em_by_raw_on	raw (stacked) B-field, Y-component, on-time (5 channels)	femtoteslas
em_by_raw_off	raw (stacked) B-field, Y-component, off-time (15 channels)	femtoteslas
em_bz_raw_on	raw (stacked) B-field, Z-component, on-time (5 channels)	femtoteslas
em_bz_raw_off	raw (stacked) B-field, Z-component, off-time (15 channels)	femtoteslas
em_bx_drift_on	drift-corrected B-field, X-component, on-time (5 channels)	femtoteslas

em_bx_drift_off	drift-corrected B-field, X-component, off-time (15 channels)	femtoteslas
em_by_drift_on	drift-corrected B-field, Y-component, on-time (5 channels)	femtoteslas
em_by_drift_off	drift-corrected B-field, Y-component, off-time (15 channels)	femtoteslas
em_bz_drift_on	drift-corrected B-field, Z-component, on-time (5 channels)	femtoteslas
em_bz_drift_off	drift-corrected B-field, Z-component, off-time (15 channels)	femtoteslas
em_bx_final_on	filtered B-field, X-component, on-time (5 channels)	femtoteslas
em_bx_final_off	filtered B-field, X-component, off-time (15 channels)	femtoteslas
em_by_final_on	filtered B-field, Y-component, on-time (5 channels)	femtoteslas
em_by_final_off	filtered B-field, Y-component, off-time (15 channels)	femtoteslas
em_bz_final_on	filtered B-field, Z-component, on-time (5 channels)	femtoteslas
em_bz_final_off	filtered B-field, Z-component, off-time (15 channels)	femtoteslas
power	60 Hz power line monitor	microvolts
primary	electromagnetic primary field	microvolts
tau_x	decay constant (tau) for X-component	microseconds
tau_z	decay constant (tau) for Z-component	microseconds
conductance	apparent conductance	siemens

In thkirklandlake.xyz, the electromagnetic channel data are provided in individual channels with numerical indices (e.g. em_x_final_on[0] to em_x_final_on[4], and em_x_final_off[0] to em_x_final_off[14]). In thkirklandlake.gdb, the electromagnetic channel data are provided in array channels with five elements (on-time) or 15 elements (off-time).

The contents of thklmag.xyz/.gdb (both file types contain the same set of data channels) are summarized as follows:

Channel Name	Description	Units
gps_x_final	differentially corrected GPS X (NAD83 datum)	decimal-degrees
gps_y_final	differentially corrected GPS Y (NAD83 datum)	decimal-degrees
gps_z_final	differentially corrected GPS Z (NAD83 datum)	metres above sea level
x_nad27	GPS X in UTM co-ordinates using NAD27 datum	metres
y_nad27	GPS Y in UTM co-ordinates using NAD27 datum	metres
x_nad83	GPS X in UTM co-ordinates using NAD83 datum	metres
y_nad83	GPS Y in UTM co-ordinates using NAD83 datum	metres
lon_nad27	longitude using NAD27 datum	decimal-degrees
lat_nad27	latitude using NAD27 datum	decimal-degrees
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	
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
date	local date	YYYYMMDD
height_mag	magnetometer height	metres above terrain
mag_base_raw	raw magnetic base station data	nanoteslas
mag_base_final	corrected magnetic base station data	nanoteslas
mag_raw	raw magnetic field	nanoteslas
mag_edit	edited magnetic field	nanoteslas
mag_diurn	diurnally-corrected magnetic field	nanoteslas
igrf	local IGRF field	nanoteslas
mag_igrf	IGRF-corrected magnetic field	nanoteslas
mag_lev	levelled magnetic field	nanoteslas
mag_final	micro-levelled magnetic field	nanoteslas
mag_gsclev	GSC levelled magnetic field	nanoteslas

APPENDIX C ANOMALY ARCHIVE DEFINITION

Electromagnetic Anomaly Data

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

thklanomaly.csv – ASCII comma-delimited format

thklanomaly.gdb – Geosoft OASIS montaj binary database file

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

Channel Name	Description	Units
gps_x_final	differentially corrected GPS X (NAD83 datum)	decimal-degrees
gps_y_final	differentially corrected GPS Y (NAD83 datum)	decimal-degrees
x_nad27	GPS X in UTM co-ordinates using NAD27 datum	metres
y_nad27	GPS Y in UTM co-ordinates using NAD27 datum	metres
x_nad83	GPS X in UTM co-ordinates using NAD83 datum	metres
y_nad83	GPS Y in UTM co-ordinates using NAD83 datum	metres
lon_nad27	longitude using NAD27 datum	decimal-degrees
lat_nad27	latitude using NAD27 datum	decimal-degrees
dem	digital elevation model	metres above sea level
fid	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
time_local	local time	seconds
date	local date	YYYYMMDD
em_x_final_on	filtered dB/dT, X-component, on-time (5 channels)	picoteslas per second
em_x_final_off	filtered dB/dT, X-component, off-time (15 channels)	picoteslas per second
em_y_final_on	filtered dB/dT, Y-component, on-time (5 channels)	picoteslas per second
em_y_final_off	filtered dB/dT, Y-component, off-time (15 channels)	picoteslas per second
em_z_final_on	filtered dB/dT, Z-component, on-time (5 channels)	picoteslas per second
em_z_final_off	filtered dB/dT, Z-component, off-time (15 channels)	picoteslas per second
em_bx_final_on	filtered B-field, X-component, on-time (5 channels)	femtoteslas
em_bx_final_off	filtered B-field, X-component, off-time (15 channels)	femtoteslas
em_by_final_on	filtered B-field, Y-component, on-time (5 channels)	femtoteslas
em_by_final_off	filtered B-field, Y-component, off-time (15 channels)	femtoteslas
em_bz_final_on	filtered B-field, Z-component, on-time (5 channels)	femtoteslas
em_bz_final_off	filtered B-field, Z-component, off-time (15 channels)	femtoteslas
tau_x	decay constant (tau) for X-component	microseconds
tau_z	decay constant (tau) for Z-component	microseconds
conductance	apparent conductance	siemens
height_em	electromagnetic receiver height	metres above terrain

Channel Name	Description	Units
anomaly_no	nth anomaly along the survey line	
anomaly_id	unique anomaly identifier	
anomaly_type_letter	anomaly classification	
anomaly_type_no	anomaly classification number	
no_chan	number of off-time channels deflected	
conductance_vert	conductance of vertical plate model	siemens
depth	depth of vertical plate model	metres
heading	direction of flight	degrees
survey_number	survey number	

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. For example, 1000101007 represents the seventh 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.

The codes for anomaly_type and anomaly_type_number are as follows:

N	1	Normal response
N?	2	Normal response, questionable
S	3	Surficial response
S?	4	Surficial response, questionable
C	5	Man-made response
C?	6	Man-made response, questionable

The (?) does not question the existence of the anomaly, but denoted some uncertainty as to the possible origin of the source.

N: Bedrock (normal) - an anomaly whose response matches that of a bedrock conductor, but not thin and/or near vertical. This anomaly type might include other shapes of conductors: roughly pod-shaped, thick dykes, short strike length bodies, or conductors sub-parallel to the flight path.

S: Flat lying conductors - generally surficial. Typical geologic anomalies might be conductive overburden, swamps or clay layers. They would not appear to be conductive at depth.

C: Line current - an anomaly with the shape typical of line currents - typically cultural (human sources) such as power lines, train tracks, fences, etc.

APPENDIX D 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:

thklkc.csv – ASCII comma-delimited format

thklkc.gdb – Geosoft OASIS Montaj binary database file

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

Channel Name	Description	Units
gps_x_final	differentially corrected GPS X (NAD83 datum)	decimal-degrees
gps_y_final	differentially corrected GPS Y (NAD83 datum)	decimal-degrees
x_nad27	GPS X in UTM co-ordinates using NAD27 datum	metres
y_nad27	GPS Y in UTM co-ordinates using NAD27 datum	metres
x_nad83	GPS X in UTM co-ordinates using NAD83 datum	metres
y_nad83	GPS Y in UTM co-ordinates using NAD83 datum	metres
lon_nad27	longitude using NAD27 datum	decimal-degrees
lat_nad27	latitude using NAD27 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 E GRID ARCHIVE DEFINITION

Gridded Data

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

*.gxf - Geosoft ASCII Grid eXchange Format (revision 3.0)

*.grd - Geosoft OASIS montaj binary grid file (no compression)

The grids are summarized as follows:

thklmag27.grd/.gxf	IGRF-corrected magnetic field in nanoteslas (UTM coordinates, NAD27 datum)
thklmag83.grd/.gxf	IGRF-corrected magnetic field in nanoteslas (UTM coordinates, NAD83 datum)
thklmaggsc27.grd/.gxf	GSC levelled magnetic field in nanoteslas (UTM coordinates, NAD27 datum)
thklmaggsc83.grd/.gxf	GSC levelled magnetic field in nanoteslas (UTM coordinates, NAD83 datum)
thklmagtr27.grd/.gxf	IGRF-corrected magnetic field in nanoteslas (UTM coordinates, NAD27 datum), gridded with geological trend enhancement
thklmagtr83.grd/.gxf	IGRF-corrected magnetic field in nanoteslas (UTM coordinates, NAD83 datum), gridded with geological trend enhancement
thkl2vd27.grd/.gxf	second vertical derivative of the IGRF-corrected magnetic field in nanoteslas per metre-squared (UTM coordinates, NAD27 datum)
thkl2vd83.grd/.gxf	second vertical derivative of the IGRF-corrected magnetic field in nanoteslas per metre-squared (UTM coordinates, NAD83 datum)
thkl2vdgsc27.grd/.gxf	second vertical derivative of GSC levelled magnetic field in nanoteslas per metre-squared (UTM coordinates, NAD27 datum)
thkl2vdgsc83.grd/.gxf	second vertical derivative of the GSC levelled magnetic field in nanoteslas per metre-squared (UTM coordinates, NAD83 datum)
thkldem27.grd/.gxf	IGRF-corrected magnetic field in metres above sea level (UTM coordinates, NAD27 datum)
thkldem83.grd/.gxf	IGRF-corrected magnetic field in metres above sea level (UTM coordinates, NAD83 datum)
thklcon27.grd/.gxf	apparent conductance in siemens (UTM coordinates, NAD27 datum)
thklcon83.grd/.gxf	apparent conductance in siemens (UTM coordinates, NAD83 datum)
thklconde27.grd/.gxf	de-herringboned apparent conductance in siemens (UTM coordinates, NAD27 datum)
thklconde83.grd/.gxf	de-herringboned apparent conductance in siemens (UTM coordinates, NAD83 datum)
thkldc27.grd/.gxf	decay constant (tau) in microseconds (UTM coordinates, NAD27 datum)
thkldc83.grd/.gxf	decay constant (tau) in microseconds (UTM coordinates, NAD83 datum)
thkldcde27.grd/.gxf	de-herringboned decay constant (tau) in microseconds (UTM coordinates, NAD27 datum)
thkldcde83.grd/.gxf	de-herringboned decay constant (tau) in microseconds (UTM coordinates, NAD83 datum)

APPENDIX F GEOTIFF AND VECTOR ARCHIVE DEFINITION

GeoTIFF Images

Geographically referenced colour images are provided in GeoTIFF format for use in GIS applications.

The images are summarized as follows:

thklmag27.tif	IGRF-corrected magnetic field with planimetric base (UTM coordinates, NAD27 datum)
thkl2vd27.tif	shadowed second vertical derivative of the IGRF-corrected magnetic field with planimetric base (UTM coordinates, NAD27 datum)
thkldcde27.tif	X-coil decay constant, de-herringboned with planimetric base (UTM coordinates, NAD27 datum)

Vector Archives

Vector line work from the maps is provided in DXF ASCII format as follows:

thklem27.dxf	electromagnetic anomalies (UTM coordinates, NAD27 datum)
thklkc27.dxf	Keating correlation targets based on the IGRF-corrected magnetic field grid (UTM coordinates, NAD27 datum)
thklpath27.tif	flight path of the survey area (UTM coordinates, NAD27 datum)
thklmag27.dxf	contours of the IGRF-corrected magnetic field in nanoteslas (UTM coordinates, NAD27 datum)
thkldcde27.tif	contours of the X-coil decay constant, de-herringboned in microseconds (UTM coordinates, NAD27 datum)

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

APPENDIX G TDEM PARAMETER TABLE DEFINITION

A parameter table file exists for each survey flight. This file represents the TDEM reference waveform used by the system to compensate the received signal for the contribution by the primary field generated at the transmitter.

Each file is stored as "ptaxxx.out", where xxx identifies the corresponding flight number.

The files are archived as standard ASCII text files and contain the following information:

- System geometry / configuration.
- Window (channel) positions, given in samples along the waveform.
- Conversion factors from listed values to PPM.
- Each point of the waveform for the following 7 components:
  - Transmitter response in units of Am^2
  - dB/dT X-coil response in units of nT/s
  - dB/dT Y-coil response in units of nT/s
  - dB/dT Z-coil response in units of nT/s
  - B-Field X-coil response in units of pT
  - B-Field Y-coil response in units of pT
  - B-Field Z-coil response in units of pT

A sample of a parameter table follows

GEOTEM Calibration Data - Version 31 July 1998
'D0020403.002' = Name of original saved parameter table file
125.000000000000000 = Horizontal TX-RX separation in metres
50.000000000000000 = Vertical TX-RX separation in metres
30.000000000000000 = Base Frequency in Hertz
43.402777777777780 = Sample Interval in micro-seconds
20 Time Gates: First and Last Sample number, RMS chart position:

1	4	10	1
2	11	37	2
3	38	65	3
4	66	92	4
5	93	99	5
6	100	103	6
7	104	108	7
8	109	114	8
9	115	121	9
10	122	128	10
11	129	136	11
12	137	146	12
13	147	158	13
14	159	173	14
15	174	192	15
16	193	216	16
17	217	246	17
18	247	284	18

19	285	330	19					
20	331	384	20					
Component:	TX	dBx/dt	dBy/dt	dBz/dt	Bx	By	Bz	
IndivPPM:		54.05718	4037.497	50.27347	41.74842	3378.176	38.67785	
TotalPPM:		36.81221	36.81221	36.81221	28.37186	28.37186	28.37186	
SI_Units:		1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	
DataUnits:	A*m^2	nT/s	nT/s	nT/s	pT	pT	pT	
384 Samples:								
1	480.5162	1.215563	.5634664	5.528183	-43.75775	2.491147	-46.49867	
2	1279.624	3.964472	-2.355625	12.72398	-43.64533	2.452255	-46.10258	
3	3822.328	91.26800	-26.83435	374.1165	-41.57866	1.818792	-37.70760	
4	16029.49	1280.836	-23.99869	2800.135	-11.80210	.7156442	31.17806	
5	34170.60	5336.917	104.2937	8325.624	131.8123	2.458158	272.6225	
6	54242.76	10947.31	204.1042	14114.79	485.2027	9.150823	759.6107	
7	77146.08	15251.49	226.8098	17722.68	1053.753	18.50225	1450.528	
8	100937.0	17647.86	234.9995	19506.84	1767.715	28.52416	2258.460	
9	124555.6	18780.34	237.8629	20326.79	2558.257	38.78593	3122.906	
10	148001.8	19223.64	236.4763	20653.35	3382.997	49.07974	4012.232	
11	171174.6	19324.16	235.1403	20721.96	4219.537	59.31448	4910.133	
12	194083.0	19256.56	233.9544	20648.71	5056.793	69.49449	5807.934	
13	216683.5	19104.08	231.7175	20491.12	5889.272	79.60021	6700.726	
14	238957.6	18903.24	229.2193	20277.70	6714.084	89.60318	7585.466	
15	260871.6	18669.07	226.4244	20024.71	7529.455	99.49128	8460.084	
16	282422.3	18409.37	222.7214	19741.83	8334.109	109.2384	9323.073	
17	303586.7	18126.65	219.3419	19432.98	9126.991	118.8318	10173.22	
18	324322.5	17822.69	215.5308	19098.10	9907.142	128.2691	11009.40	
19	344622.3	17497.98	210.9233	18739.31	10673.65	137.5237	11830.52	
20	364469.8	17153.67	206.3201	18360.75	11425.64	146.5785	12635.65	
21	383789.7	16789.81	201.8370	17961.51	12162.26	155.4361	13423.89	
22	402577.3	16406.65	197.2591	17540.99	12882.67	164.0970	14194.34	
23	420805.6	16004.82	192.3465	17101.22	13586.04	172.5520	14946.13	
24	438511.6	15585.22	186.8746	16642.15	14271.59	180.7816	15678.40	
25	455622.2	15148.79	180.7640	16165.04	14938.56	188.7599	16390.37	
26	472163.7	14695.63	176.0963	15670.34	15586.23	196.5043	17081.24	
27	488115.0	14226.27	170.7549	15156.71	16213.87	204.0314	17750.23	
28	503435.6	13741.21	164.1767	14627.63	16820.80	211.2999	18396.59	
29	518084.9	13241.28	158.2274	14084.20	17406.36	218.2965	19019.68	
30	532134.8	12726.47	152.8196	13523.93	17969.90	225.0467	19618.81	
31	545505.3	12197.90	146.1884	12947.95	18510.79	231.5356	20193.29	
32	558174.2	11656.21	137.7266	12359.02	19028.46	237.6969	20742.48	
33	570117.9	11102.58	129.8745	11757.11	19522.36	243.5042	21265.84	
34	581398.2	10537.48	123.7303	11141.52	19991.98	249.0078	21762.77	
35	591940.9	9961.088	118.0949	10515.00	20436.82	254.2557	22232.75	
36	601743.2	9374.451	110.5512	9879.413	20856.43	259.2177	22675.33	
37	610803.5	8778.362	101.7860	9233.555	21250.37	263.8257	23090.11	
38	619119.3	8173.462	94.57332	8577.204	21618.25	268.0870	23476.63	
39	626670.7	7560.791	88.49695	7912.929	21959.71	272.0598	23834.49	
40	633440.1	6940.978	80.38290	7242.485	22274.41	275.7248	24163.38	
41	639440.8	6314.693	71.31604	6564.294	22562.08	279.0168	24463.01	
42	644663.9	5682.569	64.23908	5879.238	22822.44	281.9586	24733.05	
43	649118.8	5045.580	57.69310	5190.064	23055.25	284.6047	24973.27	
44	652811.6	4403.970	50.23255	4497.663	23260.32	286.9468	25183.51	
45	655739.9	3758.877	41.70074	3801.151	23437.47	288.9419	25363.60	
46	657845.6	3111.594	33.18136	3100.129	23586.57	290.5669	25513.37	
47	659191.5	2462.560	25.34648	2398.632	23707.53	291.8371	25632.70	
48	659763.8	1812.290	17.30351	1698.479	23800.30	292.7626	25721.61	
49	659533.4	1161.894	9.575081	996.4881	23864.85	293.3459	25780.10	

50	658532.2	511.1983	2.159673	293.5134	23901.16	293.6006	25808.09
51	656771.9	-138.4487	-5.876007	-406.5860	23909.24	293.5200	25805.64
52	654241.9	-785.6276	-14.01342	-1102.502	23889.19	293.0883	25772.89
53	650926.9	-1429.879	-21.62429	-1796.705	23841.11	292.3149	25709.97
54	646841.2	-2070.386	-29.99627	-2487.926	23765.15	291.1947	25616.99
55	642015.2	-2707.011	-37.69745	-3172.199	23661.47	289.7257	25494.16
56	636443.2	-3338.526	-44.28769	-3850.057	23530.28	287.9465	25341.77
57	630112.4	-3964.105	-51.64381	-4523.357	23371.80	285.8646	25160.05
58	623087.8	-4583.209	-60.04245	-5190.055	23186.31	283.4409	24949.26
59	615318.4	-5194.912	-68.00009	-5847.252	22974.11	280.6622	24709.73
60	606882.7	-5798.598	-74.45704	-6495.222	22735.54	277.5706	24441.88
61	597733.1	-6393.891	-81.51853	-7133.788	22470.95	274.1858	24146.11
62	587906.0	-6980.110	-89.28632	-7763.202	22180.71	270.4791	23822.83
63	577417.1	-7556.332	-96.58552	-8381.132	21865.25	266.4454	23472.47
64	566268.6	-8122.287	-102.9092	-8987.011	21525.00	262.1161	23095.56
65	554493.4	-8676.815	-109.4996	-9580.824	21160.44	257.5065	22692.61
66	542068.2	-9219.926	-116.7659	-10161.67	20772.05	252.5962	22264.17
67	529044.3	-9750.425	-123.2460	-10729.10	20360.37	247.3876	21810.82
68	515458.1	-10265.81	-128.2878	-11282.54	19925.99	241.9290	21333.13
69	501290.7	-10772.57	-134.0924	-11821.78	19469.43	236.2350	20831.74
70	486566.6	-11262.49	-141.0272	-12343.04	18991.24	230.2645	20307.33
71	471314.6	-11731.46	-146.8649	-12849.14	18492.24	224.0169	19760.62
72	455547.9	-12195.01	-151.9666	-13340.70	17973.00	217.5318	19192.27
73	439312.2	-12641.60	-156.7807	-13812.64	17434.01	210.8315	18603.00
74	422588.6	-13065.85	-161.3965	-14266.87	16876.12	203.9267	17993.64
75	405442.4	-13476.13	-166.8047	-14703.80	16300.13	196.8042	17364.93
76	387817.8	-13871.90	-172.6447	-15123.39	15706.63	189.4377	16717.64
77	369799.7	-14248.74	-177.0437	-15522.77	15096.38	181.8490	16052.58
78	351411.8	-14606.23	-180.8461	-15901.95	14470.18	174.0823	15370.62
79	332648.5	-14946.93	-185.5550	-16262.64	13828.84	166.1309	14672.60
80	313560.2	-15269.39	-188.5624	-16603.65	13173.10	158.0120	13959.36
81	294146.0	-15571.96	-191.6351	-16922.22	12503.80	149.7612	13231.80
82	274408.4	-15856.00	-195.6080	-17219.34	11821.77	141.3575	12490.88
83	254432.1	-16120.63	-198.4161	-17497.04	11127.84	132.8066	11737.48
84	234237.0	-16364.78	-200.7947	-17754.51	10422.86	124.1432	10972.48
85	213780.1	-16588.84	-203.4985	-17989.07	9707.718	115.3695	10196.79
86	193177.9	-16793.03	-206.1474	-18199.77	8983.285	106.4796	9411.443
87	172388.5	-16977.05	-208.9662	-18389.45	8250.428	97.47102	8617.406
88	151465.5	-17140.51	-210.4278	-18558.82	7510.029	88.36959	7815.577
89	130407.7	-17282.85	-211.7595	-18704.51	6762.994	79.20754	7006.911
90	109249.3	-17404.29	-212.8724	-18827.33	6010.235	69.99244	6192.418
91	88028.88	-17505.25	-213.7665	-18927.89	5252.650	60.73378	5373.078
92	66758.54	-17585.28	-214.9725	-19005.41	4491.136	51.42955	4549.873
93	45488.08	-17643.46	-215.6911	-19060.45	3726.624	42.08355	3723.790
94	24741.89	-17673.70	-223.4739	-19027.77	2960.192	32.55306	2897.223
95	9570.175	-17362.39	-257.4936	-18086.09	2199.861	22.11540	2091.801
96	2871.450	-15150.56	-198.0439	-14405.85	1494.284	12.22960	1386.681
97	-1047.734	-10331.35	-58.00745	-8719.416	941.2914	6.672931	884.8304
98	-2518.332	-5464.337	-4.647988	-4256.804	598.5032	5.313221	603.2284
99	-2194.390	-2453.016	-.7387698	-1963.443	426.6856	5.196321	468.2405
100	-1769.469	-1002.960	.2065757	-941.7551	351.6861	5.184772	405.1936
101	-1553.455	-399.8088	-.9692635	-494.8739	321.2441	5.168221	374.0168
102	-1444.229	-184.1177	-1.361392	-300.8394	308.5721	5.117642	356.7487
103	-1389.795	-122.2115	-1.942878	-218.0882	301.9243	5.045935	345.4872
104	-1361.409	-112.1995	-2.550455	-181.7662	296.8373	4.948423	336.8099
105	-1342.168	-115.4928	-1.525465	-164.0895	291.8960	4.859970	329.3043
106	-1347.528	-119.5813	-.7779249	-155.5543	286.7946	4.809983	322.3676

107	-1333.837	-121.3279	-.7179721	-150.2521	281.5665	4.777520	315.7312
108	-1322.557	-120.8412	-1.779489	-144.5302	276.3111	4.723322	309.3340
109	-1313.726	-118.2844	-2.392207	-138.8214	271.1218	4.632790	303.1849
110	-1313.190	-114.6643	-1.723622	-134.7324	266.0665	4.543471	297.2484
111	-1316.802	-111.0203	-1.647031	-130.9771	261.1688	4.470323	291.4821
112	-1304.167	-107.4917	-1.845901	-126.1830	256.4268	4.394522	285.9014
113	-1302.338	-103.4110	-.9564250	-121.4007	251.8499	4.333707	280.5285
114	-1292.910	-99.56857	-.9046596	-116.3590	247.4450	4.293319	275.3687
115	-1312.433	-96.45770	-1.053488	-112.4699	243.1909	4.250825	270.4028
116	-1314.607	-93.16880	-.7112125	-108.9140	239.0758	4.212528	265.5985
117	-1303.956	-89.83379	-1.517772	-103.7537	235.1044	4.164156	260.9833
118	-1306.555	-86.88269	-2.648480	-99.68216	231.2694	4.073743	256.5685
119	-1289.603	-84.20971	-2.377896	-98.32323	227.5564	3.964664	252.2715
120	-1293.907	-81.71333	-1.338374	-95.97935	223.9557	3.884015	248.0548
121	-1295.715	-79.59279	-.4947169	-92.12808	220.4551	3.844235	243.9726
122	-1302.262	-77.25868	-.6294900	-88.95735	217.0512	3.819838	240.0428
123	-1292.579	-74.40954	-1.384972	-86.57738	213.7598	3.776121	236.2335
124	-1289.979	-72.15148	-.8784191	-83.85363	210.5792	3.727003	232.5349
125	-1295.124	-70.14606	-.5855785E-01	-80.20129	207.4912	3.706669	228.9747
126	-1283.163	-67.68448	-.6985741	-77.80918	204.5000	3.690238	225.5456
127	-1288.098	-65.75870	-1.250724	-77.37740	201.6041	3.647936	222.1779
128	-1291.631	-64.78964	-.1742284	-75.24507	198.7711	3.617012	218.8658
129	-1296.858	-62.69235	-.4823076	-71.93860	196.0045	3.602764	215.6717
130	-1270.422	-60.66376	-.5979920	-69.95360	193.3275	3.579320	212.5924
131	-1286.520	-59.39385	-1.131908	-69.78829	190.7221	3.541779	209.5598
132	-1285.366	-57.45036	-2.665787	-68.64166	188.1864	3.459364	206.5557
133	-1290.457	-55.73547	-1.765994	-64.71267	185.7301	3.363188	203.6617
134	-1287.373	-54.78725	-.4529422	-61.34744	183.3316	3.315034	200.9260
135	-1270.608	-53.45405	-.8422062	-61.79933	180.9827	3.286928	198.2536
136	-1276.678	-52.06747	-.9323616	-61.82951	178.6927	3.248417	195.5707
137	-1276.936	-50.62012	-.6188368	-58.87620	176.4642	3.214754	192.9512
138	-1273.625	-49.52001	-1.090809	-56.64389	174.2910	3.177652	190.4442
139	-1280.644	-48.30315	-1.003786	-56.72475	172.1681	3.132196	187.9840
140	-1290.757	-47.20437	-.4143464	-56.53501	170.0955	3.101421	185.5261
141	-1275.000	-46.29657	-.1957834	-54.20094	168.0664	3.088180	183.1230
142	-1274.141	-45.29690	-.7308406	-50.85968	166.0787	3.068071	180.8430
143	-1266.373	-43.99260	-1.133610	-49.87436	164.1410	3.027610	178.6569
144	-1274.600	-42.58350	-1.961988	-50.21626	162.2622	2.960431	176.4848
145	-1276.970	-42.25753	-1.853904	-49.58237	160.4210	2.877621	174.3191
146	-1275.215	-40.91791	-2.896872	-48.02887	158.6160	2.774523	172.2008
147	-1276.510	-39.43304	-1.679297	-46.00315	156.8723	2.675214	170.1601
148	-1272.525	-39.73721	-.2160633	-43.65907	155.1541	2.634082	168.2143
149	-1276.414	-38.97220	-1.465506	-42.26031	153.4460	2.597589	166.3498
150	-1274.784	-37.56125	-1.384168	-42.39261	151.7852	2.535747	164.5127
151	-1260.105	-37.27805	-.2378934E-01	-42.12173	150.1610	2.505193	162.6786
152	-1283.133	-36.70847	-.9809297	-41.92348	148.5554	2.483389	160.8547
153	-1271.312	-35.57077	-2.002599	-41.67263	146.9869	2.418642	159.0406
154	-1267.331	-34.84400	-.4812094	-40.62331	145.4588	2.364740	157.2546
155	-1273.138	-34.50154	1.277074	-39.82766	143.9539	2.382012	155.5087
156	-1263.873	-33.98004	-.3081198	-38.89698	142.4677	2.403039	153.8003
157	-1280.272	-32.75883	-3.182051	-36.97049	141.0194	2.327298	152.1539
158	-1262.668	-32.19618	-1.872635	-35.06393	139.6098	2.217604	150.5906
159	-1259.648	-31.58495	1.025600	-34.68799	138.2257	2.199222	149.0769
160	-1271.678	-31.06763	.9103478	-35.78771	136.8660	2.241235	147.5475
161	-1271.644	-30.65333	-1.193882	-35.12759	135.5266	2.235082	146.0085
162	-1262.541	-29.79144	-1.325429	-34.41243	134.2148	2.180409	144.4994
163	-1264.284	-29.41677	.2022593	-33.86461	132.9299	2.156035	143.0177

164	-1266.601	-29.11685	.4792890	-32.99225	131.6597	2.170825	141.5668
165	-1274.173	-28.48848	-.6165693	-32.36612	130.4096	2.167846	140.1484
166	-1275.206	-27.59125	-.8714692	-31.55877	129.1926	2.135554	138.7612
167	-1260.861	-27.32994	.5148790	-29.93825	128.0007	2.127815	137.4266
168	-1259.357	-26.59234	.5851796	-29.10325	126.8305	2.151688	136.1453
169	-1253.571	-26.04604	-.3868446E-01	-29.56365	125.6882	2.163548	134.8722
170	-1265.576	-26.34385	-.3910750	-30.32570	124.5512	2.154221	133.5725
171	-1260.011	-25.96550	-.7083320	-29.35695	123.4161	2.130363	132.2773
172	-1258.661	-25.21025	-.3358688	-28.14722	122.3055	2.107702	131.0294
173	-1263.156	-24.49782	.3867895E-01	-27.51707	121.2267	2.101253	129.8214
174	-1269.692	-24.13623	-.6802542	-26.53861	120.1713	2.087330	128.6483
175	-1274.505	-23.79211	-1.166121	-24.86781	119.1312	2.047261	127.5327
176	-1257.802	-23.68281	-.3112130	-25.64482	118.1009	2.015200	126.4365
177	-1260.554	-23.50035	.3544274	-26.69444	117.0770	2.016138	125.3007
178	-1263.318	-22.84823	-.1615563	-25.54005	116.0712	2.020324	124.1671
179	-1249.665	-22.14244	-.9401112	-25.36924	115.0948	1.996416	123.0623
180	-1259.497	-22.06276	-.4030825	-25.28262	114.1355	1.967267	121.9631
181	-1255.143	-21.58456	-.5070254	-23.53664	113.1883	1.947516	120.9037
182	-1266.075	-21.20110	-.1498937	-22.74228	112.2598	1.933260	119.8993
183	-1260.469	-21.32333	-.6787660	-23.83480	111.3369	1.915277	118.8885
184	-1245.929	-20.85460	-1.486867	-24.19502	110.4216	1.868280	117.8462
185	-1252.732	-20.17981	-.9066823	-22.74697	109.5311	1.816337	116.8275
186	-1257.234	-19.90153	.1064023	-21.24323	108.6613	1.798969	115.8729
187	-1243.384	-19.77741	.4102520E-01	-21.45310	107.8002	1.802169	114.9463
188	-1258.994	-19.26252	-.7993864	-22.53864	106.9530	1.785711	113.9916
189	-1256.463	-18.73170	-1.206448	-21.60419	106.1285	1.742182	113.0337
190	-1252.411	-18.90749	-.6204522	-19.05928	105.3116	1.702536	112.1512
191	-1241.998	-19.35374	-.5235164	-18.85389	104.4813	1.677710	111.3284
192	-1253.402	-18.87034	-1.108154	-19.98162	103.6518	1.642300	110.4857
193	-1251.712	-17.88510	-.8519221	-19.81019	102.8541	1.599764	109.6221
194	-1250.836	-17.32593	.2826420	-19.78591	102.0900	1.587410	108.7628
195	-1250.261	-17.39624	-.3166705	-19.98792	101.3365	1.586671	107.8997
196	-1255.218	-17.29659	-.6912205	-19.84387	100.5836	1.564799	107.0353
197	-1248.976	-17.52413	-.3796901	-20.08838	99.82796	1.541559	106.1687
198	-1252.577	-17.31482	-.6093752	-19.66920	99.07191	1.520094	105.3059
199	-1250.809	-16.69829	-1.010681	-17.70417	98.33378	1.484937	104.4948
200	-1248.955	-16.14623	-.5987066E-01	-16.38547	97.62100	1.461705	103.7551
201	-1250.736	-16.02747	.7391445	-16.31240	96.92279	1.476446	103.0455
202	-1248.546	-15.82594	.4686632	-16.32689	96.23153	1.502657	102.3371
203	-1259.877	-15.50726	.3007474	-17.41591	95.55155	1.519354	101.6049
204	-1249.564	-15.22018	-.7429446	-17.75392	94.88472	1.509758	100.8416
205	-1250.596	-14.87669	-1.653896	-17.28919	94.23158	1.457743	100.0812
206	-1245.435	-15.03289	-1.248483	-16.75502	93.58250	1.394757	99.34236
207	-1245.229	-15.08348	-.9893286	-16.50885	92.92893	1.346194	98.62048
208	-1238.479	-15.05444	-.2541941	-16.84260	92.27490	1.319208	97.89671
209	-1259.475	-14.96318	.3087672	-16.28907	91.62348	1.320392	97.17771
210	-1236.007	-14.81530	.1035019	-16.18966	90.97724	1.329339	96.47288
211	-1253.945	-14.40398	-.4592561	-16.90369	90.34314	1.321618	95.75470
212	-1252.026	-13.88057	-.9515756	-15.34429	89.72933	1.291001	95.05488
213	-1250.201	-13.73286	-.9951738	-13.38160	89.13008	1.248754	94.43149
214	-1255.709	-13.66848	-1.031699	-13.87688	88.53543	1.204768	93.83994
215	-1246.791	-13.41491	-1.429526	-14.83679	87.94768	1.151356	93.21681
216	-1242.892	-13.02671	-.7125921	-13.39371	87.37386	1.104869	92.60417
217	-1242.660	-12.88722	.2414767	-13.60657	86.81150	1.094646	92.01823
218	-1238.371	-12.78035	-.2394563	-15.79497	86.25447	1.094689	91.38017
219	-1230.376	-12.88890	-.8249150	-14.88818	85.69742	1.071591	90.71431
220	-1243.145	-13.34744	-.6927674	-13.17021	85.12805	1.038655	90.10540

221	-1245.734	-13.42600	-.3137481	-14.07814	84.54703	1.016812	89.51407
222	-1236.268	-13.17039	-.6968421	-13.64209	83.96985	.9948812	88.91251
223	-1244.663	-12.64502	-.8367435	-12.99759	83.40962	.9616003	88.33439
224	-1240.466	-11.95874	-.4098827	-13.16370	82.87569	.9345467	87.76665
225	-1247.537	-12.24726	.1053597	-12.96351	82.35038	.9279382	87.19966
226	-1247.649	-12.09330	.6512576E-01	-12.78017	81.82216	.9316379	86.64098
227	-1244.225	-11.95878	-1.340627	-12.76167	81.30019	.9039578	86.08669
228	-1242.293	-12.16012	-1.473387	-12.52318	80.77678	.8428898	85.53797
229	-1234.767	-12.01413	-.3175545	-12.33583	80.25217	.8040239	84.99850
230	-1244.543	-11.40085	-.1239695E-01	-12.97904	79.74403	.7968634	84.44913
231	-1236.226	-11.22163	-.8183930	-12.61982	79.25309	.7788341	83.89360
232	-1246.016	-11.51239	-1.417319	-11.71671	78.75973	.7303161	83.36546
233	-1235.484	-11.06472	-.4396532	-11.95148	78.26977	.6900172	82.85183
234	-1251.174	-11.31609	.7825047	-12.18775	77.78408	.6974576	82.32797
235	-1243.204	-11.41800	-.4311408	-11.08134	77.29072	.7050827	81.82300
236	-1242.741	-11.09215	-1.596816	-10.14865	76.80222	.6610732	81.36228
237	-1232.762	-11.33984	-1.026303	-11.26619	76.31541	.6041479	80.89755
238	-1244.657	-11.00936	.1954746E-01	-11.42430	75.83040	.5822999	80.40514
239	-1240.295	-10.17204	.5520649	-10.48837	75.37074	.5947046	79.92960
240	-1229.955	-9.933452	-.2014041E-01	-11.05922	74.93442	.6062481	79.46199
241	-1241.321	-10.02049	.6427703E-01	-11.34958	74.50139	.6072060	78.97568
242	-1237.098	-9.887249	-.7344446	-11.19348	74.06937	.5926624	78.48647
243	-1240.031	-9.990455	-2.141503	-10.14080	73.63799	.5302503	78.02349
244	-1244.461	-9.700328	-1.671717	-9.345831	73.21068	.4474982	77.60060
245	-1244.932	-9.441468	-.3036637	-10.06511	72.79527	.4046297	77.17935
246	-1239.582	-9.343197	-.7548518	-9.656806	72.38762	.3816584	76.75136
247	-1246.644	-10.00870	-.7551514	-9.213914	71.96766	.3488892	76.34184
248	-1230.473	-11.32753	.6327625E-01	-9.324219	71.50463	.3338746	75.93954
249	-1228.048	-8.610706	.1781580	-9.920395	71.07194	.3391140	75.52190
250	-1245.989	-9.097253	-.4422290	-10.89545	70.68766	.3333833	75.07017
251	-1228.790	-11.18816	-1.216789	-9.729692	70.24743	.2973803	74.62258
252	-1236.526	-9.319866	-1.463167	-9.594446	69.80238	.2392216	74.20322
253	-1232.508	-8.243233	-1.111754	-11.14819	69.42124	.1833422	73.75307
254	-1232.951	-9.271472	-.8665116	-10.53463	69.04114	.1404111	73.28252
255	-1236.430	-9.343627	-1.161653	-9.699098	68.63717	.9639715E-01	72.84342
256	-1228.519	-8.565277	-1.493980	-10.06060	68.24852	.3876622E-01	72.41461
257	-1241.237	-8.143988	-.8538092	-9.218961	67.88591	-.1218407E-01	71.99622
258	-1238.047	-8.460127	-.3670517	-7.714831	67.52558	-.3867845E-01	71.62873
259	-1233.659	-8.886915	-.6368719	-8.291581	67.14912	-.6046498E-01	71.28137
260	-1235.381	-8.982089	-.8009963	-9.932605	66.76134	-.9166872E-01	70.88588
261	-1237.978	-8.741824	-.8345596	-9.174906	66.37671	-.1271626	70.47122
262	-1238.088	-8.365100	-.3150347	-8.259320	66.00546	-.1521103	70.09287
263	-1219.370	-8.035012	-.4296758	-9.050873	65.64956	-.1682716	69.71722
264	-1243.672	-7.879265	-.8999024	-9.232384	65.30419	-.1971253	69.32045
265	-1218.293	-7.872281	-1.309378	-8.763023	64.96236	-.2450698	68.92992
266	-1247.297	-7.722191	-.5309398	-8.041412	64.62394	-.2850072	68.56524
267	-1226.870	-7.678304	.1759276	-8.079221	64.28973	-.2927115	68.21540
268	-1236.788	-8.104294	-.2022468	-8.909127	63.94723	-.2932826	67.84673
269	-1242.236	-7.941270	-.2985246	-8.264694	63.59901	-.3041501	67.47403
270	-1248.284	-7.912342	-.1370905	-7.312865	63.25497	-.3136035	67.13598
271	-1221.116	-7.756525	-.5630125	-7.672553	62.91493	-.3287967	66.81078
272	-1229.011	-7.582969	-.6662094	-7.798904	62.58204	-.3554726	66.47502
273	-1235.262	-7.578905	-1.046308	-7.179069	62.25301	-.3926366	66.14998
274	-1240.555	-7.069460	-1.395608	-6.848136	61.93512	-.4456295	65.84557
275	-1226.301	-6.981314	-.9667468	-8.066109	61.63020	-.4968959	65.52191
276	-1224.312	-7.553744	.4243600	-7.958645	61.31477	-.5086665	65.17415
277	-1233.653	-7.417844	.7301787	-6.849954	60.98986	-.4836114	64.85278

278	-1245.818	-7.450869	-.5546522	-7.570212	60.66719	-.4798022	64.53985
279	-1224.213	-7.323213	-.5633751	-7.921566	60.34657	-.5040650	64.20365
280	-1235.857	-6.915716	.5013513	-7.353237	60.03757	-.5054110	63.87217
281	-1232.101	-6.798208	.7605377	-7.364423	59.73996	-.4780262	63.55278
282	-1233.044	-6.858937	-.4631431	-8.055018	59.44358	-.4715723	63.21815
283	-1228.667	-6.981395	-.9593683	-8.019136	59.14323	-.5024428	62.86932
284	-1219.155	-6.718142	-.4722495	-7.382765	58.84593	-.5335109	62.53508
285	-1236.335	-6.754923	-.2290471	-6.569574	58.55354	-.5487300	62.23229
286	-1221.890	-6.698779	-.4139061	-6.675289	58.26158	-.5626830	61.94486
287	-1231.472	-6.304317	-.2635258	-7.895643	57.97939	-.5773842	61.62865
288	-1219.883	-5.966845	-.9215854E-01	-7.077987	57.71309	-.5851030	61.30370
289	-1237.130	-6.300270	-.5930699	-5.525857	57.44688	-.5999735	61.03018
290	-1230.172	-6.366062	-1.049910	-6.074301	57.17200	-.6356284	60.77844
291	-1229.132	-6.228341	-1.543935	-7.124602	56.89869	-.6919184	60.49201
292	-1234.862	-6.353397	-.9840513	-7.632472	56.62564	-.7467792	60.17176
293	-1231.121	-7.324499	-.5886761	-5.656136	56.32881	-.7809096	59.88338
294	-1237.315	-6.003514	-.7005085E-01	-3.894228	56.03958	-.7952049	59.67612
295	-1221.633	-4.921720	.8264350E-01	-6.187842	55.80249	-.7949316	59.45733
296	-1233.959	-6.634798	-.2906725	-8.182875	55.55169	-.7994461	59.14546
297	-1225.902	-6.816263	-.2828843	-7.888471	55.25979	-.8118931	58.79669
298	-1229.506	-5.183618	.7615760E-01	-6.746113	54.99937	-.8163794	58.47910
299	-1223.745	-4.987698	-.5302547	-5.758256	54.77864	-.8262339	58.20774
300	-1218.897	-5.869637	-.3734265	-6.040138	54.54302	-.8458450	57.95170
301	-1230.618	-5.566281	.9107917E-01	-5.983759	54.29485	-.8519724	57.69076
302	-1220.173	-5.035721	-.5391868	-4.804485	54.06477	-.8616969	57.45664
303	-1235.566	-5.481694	-.9417763	-5.225454	53.83653	-.8938359	57.23898
304	-1226.468	-5.612366	-.1513387	-6.704617	53.59577	-.9175580	56.98008
305	-1235.096	-5.146244	-.1135796	-6.873712	53.36229	-.9233071	56.68541
306	-1220.688	-5.011396	-.8592947	-5.406124	53.14186	-.9444198	56.41892
307	-1227.148	-5.433739	-.8123748	-4.314807	52.91518	-.9806974	56.20796
308	-1232.127	-6.078244	.3728345	-5.409003	52.66536	-.9902360	55.99694
309	-1223.627	-6.205917	.5246490	-6.393283	52.39877	-.9707594	55.74082
310	-1213.824	-5.997473	-.5437170E-01	-6.030236	52.13394	-.9605537	55.47121
311	-1222.636	-5.762597	-.5085599	-5.556510	51.87873	-.9727701	55.21976
312	-1231.749	-5.985638	-1.063918	-6.525356	51.62378	-1.006895	54.95757
313	-1227.475	-5.703313	-.5789852	-6.790059	51.37011	-1.042548	54.66860
314	-1229.101	-5.270463	-.3158590	-6.265172	51.13197	-1.061968	54.38529
315	-1221.895	-5.173553	-.6551837	-5.798265	50.90532	-1.083041	54.12349
316	-1234.740	-5.384163	-.2951749	-5.408877	50.67620	-1.103665	53.88028
317	-1231.256	-5.273664	.5727626	-4.461604	50.44491	-1.097641	53.66608
318	-1226.182	-5.291283	.5206077	-4.302617	50.21564	-1.073913	53.47589
319	-1229.568	-5.768461	-.1690272	-5.307972	49.97563	-1.066283	53.26732
320	-1219.347	-5.842962	-.6820931	-6.274126	49.72364	-1.084754	53.01597
321	-1213.809	-5.393437	-.9006775E-01	-7.003778	49.47980	-1.101511	52.72783
322	-1233.314	-5.152554	.1876057	-6.528661	49.25093	-1.099394	52.43415
323	-1216.098	-5.072841	-.4400036	-5.058022	49.02903	-1.104871	52.18271
324	-1221.109	-5.083682	-.7638425	-4.154153	48.80862	-1.130997	51.98279
325	-1227.181	-4.865112	-.5689616	-4.984125	48.59272	-1.159920	51.78448
326	-1222.690	-4.391462	-.9157048	-5.768715	48.39183	-1.192140	51.55112
327	-1228.284	-5.265047	.3459089	-5.574243	48.18227	-1.204505	51.30497
328	-1233.995	-5.276792	.8537298	-5.290436	47.95350	-1.178471	51.06919
329	-1222.622	-4.078724	-1.071143	-5.642769	47.75047	-1.183189	50.83192
330	-1219.528	-4.465076	-1.845662	-5.427737	47.56506	-1.246488	50.59168
331	-1221.201	-5.081457	-.9725225	-4.150071	47.35789	-1.307647	50.38382
332	-1223.740	-4.954751	-.4472101E-01	-3.680992	47.14009	-1.329722	50.21388
333	-1228.412	-5.192944	-.2106569	-4.440061	46.91987	-1.335264	50.03764
334	-1224.768	-5.301581	-.1337789	-4.565200	46.69212	-1.342739	49.84221

335	-1229.513	-4.568606	.4997001	-4.436580	46.47793	-1.334798	49.64686
336	-1213.195	-4.344191	-.2652036	-5.111924	46.28451	-1.329709	49.43965
337	-1223.640	-4.898782	-2.145445	-6.142723	46.08392	-1.382023	49.19541
338	-1228.082	-4.978261	-2.040837	-5.613415	45.86958	-1.472872	48.94028
339	-1213.561	-4.831206	-.1864960	-4.814508	45.65670	-1.521208	48.71398
340	-1217.505	-4.831435	.1069366	-5.416822	45.44701	-1.522934	48.49195
341	-1227.307	-4.465014	.1996040	-5.899411	45.24526	-1.516282	48.24637
342	-1221.726	-4.051099	.6663067	-4.313669	45.06045	-1.497491	48.02473
343	-1206.624	-4.103019	-.6240872	-3.462809	44.88349	-1.496574	47.85597
344	-1224.603	-4.460080	-1.623854	-4.256103	44.69766	-1.545358	47.68846
345	-1213.534	-4.559427	-1.105402	-4.517284	44.50193	-1.604586	47.49807
346	-1217.851	-4.680243	-.6879951	-4.258183	44.30141	-1.643506	47.30763
347	-1214.297	-4.852104	-.2845796	-4.811328	44.09455	-1.664612	47.11080
348	-1220.493	-4.570615	-.5830670E-01	-4.684730	43.89006	-1.672053	46.90473
349	-1234.032	-4.404812	1.051311	-4.180095	43.69528	-1.650503	46.71235
350	-1225.756	-4.657457	1.141779	-5.109052	43.49862	-1.602910	46.51076
351	-1220.017	-4.362185	-1.099575	-6.135197	43.30288	-1.601994	46.26674
352	-1209.185	-4.121118	-2.613989	-4.986239	43.11878	-1.682584	46.02539
353	-1217.307	-4.058708	-.7975239	-3.336685	42.94127	-1.756618	45.84477
354	-1215.280	-4.350828	1.226104	-3.518532	42.75877	-1.747318	45.69601
355	-1207.546	-4.476606	-.1781616	-4.312852	42.56720	-1.724576	45.52606
356	-1221.233	-4.218021	-2.176956	-4.143879	42.37851	-1.775685	45.34253
357	-1226.066	-4.310445	-.7846774	-3.734693	42.19343	-1.839957	45.17156
358	-1211.425	-4.362894	1.304733	-4.695151	42.00521	-1.828671	44.98862
359	-1205.676	-3.925802	-.1680101	-5.954916	41.82533	-1.804002	44.75750
360	-1221.589	-3.777107	-1.385254	-5.495143	41.65817	-1.837710	44.50901
361	-1220.827	-4.105853	-.8421162	-3.620333	41.48710	-1.886047	44.31120
362	-1219.106	-3.799650	-.4441930	-2.607925	41.31554	-1.913962	44.17603
363	-1217.708	-3.535639	-.8076262E-01	-4.455669	41.15635	-1.925354	44.02274
364	-1212.537	-3.768093	-.3739848	-4.915640	40.99785	-1.935223	43.81937
365	-1222.404	-3.690374	-.5355436	-3.510801	40.83599	-1.954961	43.63651
366	-1214.412	-3.619439	-.4591502	-4.153373	40.67736	-1.976547	43.47018
367	-1219.468	-3.761034	-.6857985	-5.195395	40.51719	-2.001394	43.26730
368	-1221.625	-3.741489	-.9663598	-4.114048	40.35438	-2.037248	43.06528
369	-1214.591	-3.835768	-1.035248	-3.202938	40.18994	-2.080686	42.90649
370	-1212.366	-3.317115	-.6941394	-3.688523	40.03471	-2.118216	42.75693
371	-1216.179	-3.023706	-.7040349	-4.378768	39.89711	-2.148559	42.58186
372	-1216.961	-2.935308	-.8294372	-4.498296	39.76779	-2.181837	42.38922
373	-1219.419	-3.082494	-1.109802	-4.249371	39.63720	-2.223921	42.19938
374	-1223.800	-3.326306	-1.129328	-3.410337	39.49812	-2.272513	42.03315
375	-1219.221	-3.366346	-.5545418	-3.145079	39.35288	-2.309056	41.89089
376	-1230.951	-3.563950	-.6153397	-4.320667	39.20248	-2.334444	41.72887
377	-1217.511	-3.604406	-.8258539	-5.058240	39.04692	-2.365720	41.52534
378	-1212.239	-3.330562	.1705949	-4.433645	38.89642	-2.379940	41.31935
379	-1221.663	-3.512125	1.064198	-3.500472	38.74792	-2.353143	41.14717
380	-1214.766	-3.723648	.1559372	-3.629839	38.59089	-2.326664	40.99243
381	-1215.050	-3.043731	-1.400968	-3.896076	38.44403	-2.353683	40.82911
382	-1219.551	-3.080695	-.4457144	-3.924459	38.31112	-2.393759	40.65939
383	-1212.392	-3.647492	.5666208	-4.084128	38.16511	-2.391135	40.48560
384	-1203.388	-3.208490	-.8818409	-3.360447	37.94670	-2.417113	40.25111

APPENDIX H HALFWAVE ARCHIVE DEFINITION

Each ASCII file is a continuous data stream representing the acquisition for one complete flight. Each line of the ASCII file contains 1549 data values, namely the fiducial ***[F]***, and for each of the four components [T, X, Y, and Z], the primary electromagnetic field ***[PEM]***, the powerline monitor ***[PLM]***, the earth's field monitor (ambient electromagnetic noise) ***[EFM]*** and the 384 waveform points stored in that order. The four waveform components are:

T - PEM_T, PLM_T, EFM_T and the amplitude of the transmitted electromagnetic field $[T_1 \ldots T_{384}]$

X - PEM_X, PLM_X, EFM_X and the amplitude of the secondary electromagnetic field as seen by the X coil $[X_1 \ldots X_{384}]$

Y - PEM_Y, PLM_Y, EFM_Y and the amplitude of the secondary electromagnetic field as seen by the Y coil $[Y_1 \ldots Y_{384}]$

Z - PEM_Z, PLM_Z, EFM_Z and the amplitude of the secondary electromagnetic field as seen by the Z coil $[Z_1 \ldots Z_{384}]$

All data values are stored in scientific format (exponential notation), as volts. The format allows storage of the waveform as 384 points. Depending on the base frequency, if the waveform is not defined by the full 384 points, then the remaining points are simply filled with zeroes. At 30 Hz base frequency, the waveform is defined by 384 points. The halfwave sampling rate of 4 Hz is a fifteen-fold stack from the original sampling rate of 30 Hz.

The fiducials mark the number of seconds after midnight for the day of the flight. Each fiducial represents a 0.25 second sample. As such, although the fiducials repeat for four lines of data, they actually increment by 0.25 seconds. For example, the second occurrence of fiducial 74087 is actually 74087.25 seconds, the third is 74087.50 seconds and the fourth is 74087.75 seconds.

The following table illustrates the ASCII data structure:

column												
1	2	3	4	5		388	389	390	391	392		775
F	***PEM_T***	***PLM_T***	***EFM_T***	T_1	…	T_{384}	***PEM_X***	***PLM_X***	***EFM_X***	X_1	…	X_{384}
	volts											
74087	1.0012530E+00	9.7377970E-04	6.5032010E-04				9.9598440E-01	1.7564380E-03	-3.3043160E-03			
74087	1.0012400E+00	8.6172720E-05	7.1580250E-04				9.9651290E-01	1.7200990E-03	-6.0959600E-02			
74087	1.0012840E+00	8.7328300E-05	7.0525570E-04				9.9891420E-01	1.6912790E-03	-8.5706660E-02			
74087	1.0011300E+00	9.2401830E-05	7.4590280E-04				1.0005320E+00	2.5104030E-03	-4.9193540E-02			

column											
776	777	778	779		1162	1163	1164	1165	1166		1549
PEM_Y	***PLM_Y***	***EFM_Y***	Y_1	…	Y_{384}	***PEM_Z***	***PLM_Z***	***EFM_Z***	Z_1	…	Z_{384}
volts											
-1.4667880E+00	1.9064400E-03	1.9168430E-01				1.0075570E+00	1.3699210E-03	-6.2297300E-03			
-1.4890710E+00	4.5591580E-03	-2.0755340E-03				1.0058710E+00	1.4081860E-03	7.7472150E-03			
-1.3149210E+00	1.9930260E-03	-1.6909430E-01				1.0018460E+00	1.5687660E-03	9.7720830E-03			
-1.0673150E+00	1.8790290E-03	-1.8799610E-01				9.9887660E-01	1.7389310E-03	-5.1124900E-03			