KAPISKAU RIVER EAST AREA

Ontario Airborne Geophysical Surveys
Magnetic Data
Geophysical Data Set 1214 - Revised

Ontario Geological Survey
Ministry of Northern Development and Mines
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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.

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:

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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, including the purchase of proprietary data sets)
- 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.

The geophysical component of the OTH program involved:

- acquiring from the private sector existing proprietary airborne geophysical data that met Ontario Geological Survey (OGS) quality standards and objectives of Operation Treasure Hunt;
- flying new airborne magnetic and electromagnetic surveys over various greenstone belts;
- disseminating these geophysical data sets and their daughter products to clients in digital and hardcopy formats.

In August 1999, Paterson, Grant & Watson Limited (PGW) was retained by MNDM to provide Geophysicist Project Management and quality assurance (QA)/quality control (QC) inspection services for the airborne geophysical survey component of OTH. One of PGW's roles as the OTH Geophysicist was to seek out, and recommend for purchase by MNDM, proprietary airborne geophysical data that would complement the acquisition of new data being undertaken by OTH. PGW commenced the search process in September 1999.

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

- date of survey – recent surveys were favoured over older surveys because of improved acquisition technology, greater data density and improved final products.
- survey method – magnetometer surveys, without supplementary radiometrics or VLF, were given the lowest rating in this category; AEM and magnetometer were given the highest; the objective was to acquire data that complements what is already available in the public domain, with emphasis on exploration rather than mapping.
- location of area
  - highest value was accorded to data sets lying within areas identified by the Ontario Geological Survey Advisory Board as being of special commodity interest and worthy of airborne geophysical coverage (Figure 1),

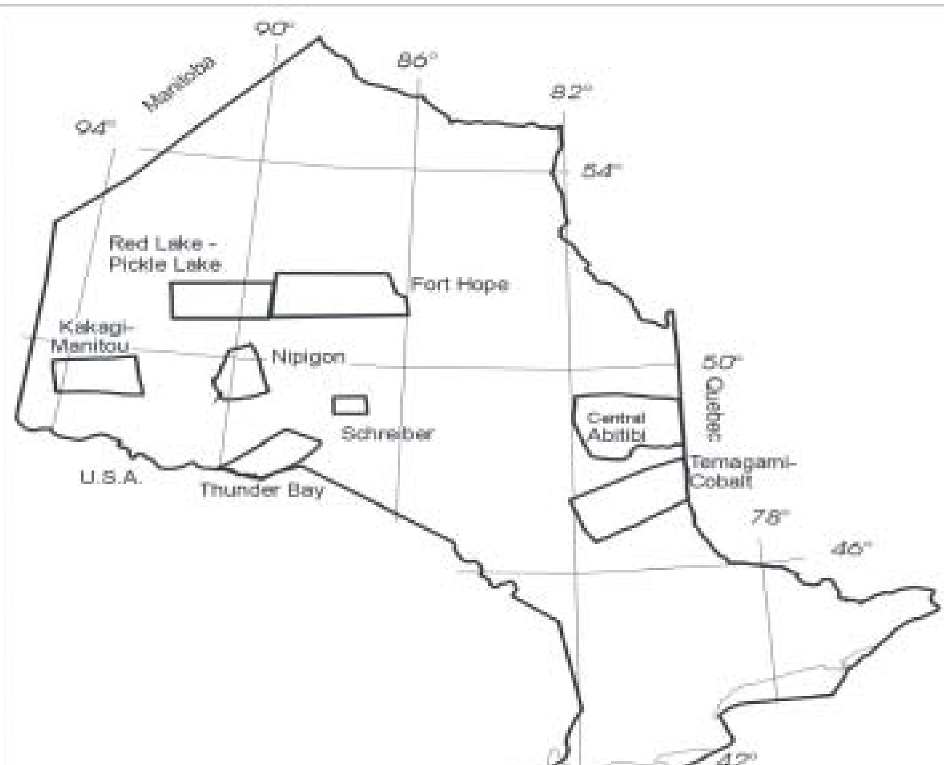


Figure 1

  - data sets occurring within areas already surveyed or scheduled for survey under Operation Treasure Hunt were only selected if they added significantly to the acquired data sets,
  - proximity or coincidence of the survey block with areas having restricted land use designations affected the value assigned to that survey,
  - consideration was given to data sets that were collected in remote areas where logistical costs are very high.

- line spacing - not normally a significant factor in the valuation of an airborne geophysical survey; however, in the case of OTH, points were assigned according to how well the line spacing met the desired exploration requirements; detailed surveys were normally accorded a higher rating than reconnaissance surveys.
- quality of data - data quality, processed products, and adherence to correct survey specifications had to be up to normal industry standards.
- survey size - data sets comprising less than 1000 line-km were selected only if they fell in very strategic locations.
- other criteria - factors such as apparent mineral significance, previous exploration activity and land availability were also considered in making the final selection.

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

An aeromagnetic survey was flown over the Kapiskau River East area, west of Attawapiskat, northern Ontario, on September 4th to16th, 2000, by Fugro Airborne Surveys on behalf of Navigator Exploration Corp. The purpose of the survey is to locate potential kimberlite bodies within the Precambrian basement and the overlying Paleozoic sediments. To achieve this goal, total magnetic field and calculated vertical gradient grids were produced from 10,026 line kilometres of data.

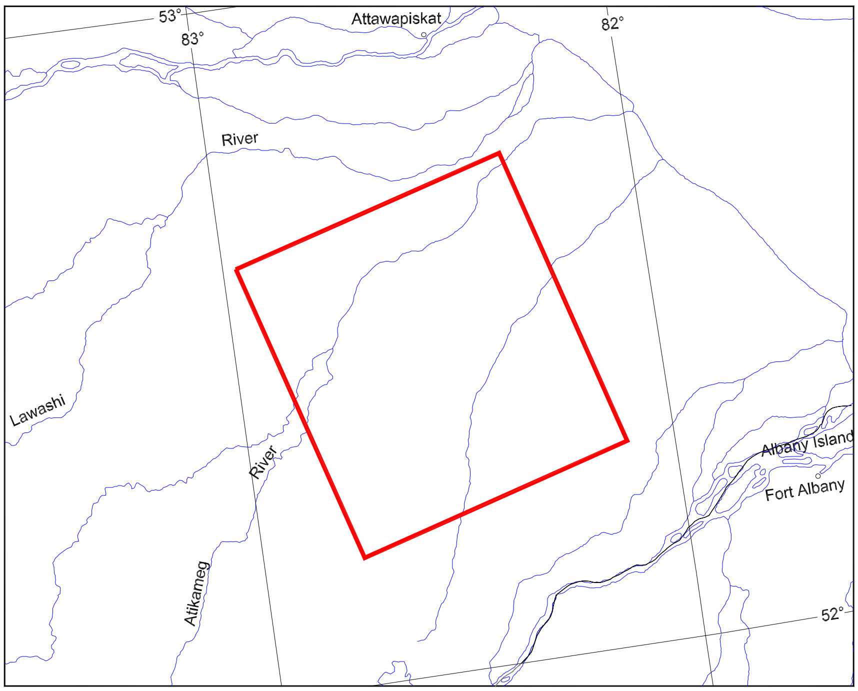


Figure 2: Kapiskau River East survey area.

The airborne survey specifications were as follows:

a) survey date
- September 4th to 16th, 2000
- 15 flights

b) traverse line spacing and direction
- flight line spacing was 250 metres
- flight line direction was 165° –345°

c) control line spacing and direction
- control line spacing was 5000 metres
- control line direction was 75° – 255°

d) terrain clearance of the geophysical sensors
  - clearance of the magnetic sensor was 100 metres
  - average sampling interval was 7.5 metres

3) AIRCRAFT, EQUIPMENT AND PERSONNEL

This section provides a brief description of the geophysical instruments used to acquire the survey data.

Aircraft

The survey was flown using a Cessna Caravan 208 single turbine fixed wing aircraft (registration number C-FZLK). The average air speed was 75 metres per second.

Magnetometer

A Scintrex CS-2 cesium vapour magnetometer was used during the survey. It has a 10 Hz sampling rate, 0.005 nanoteslas sensitivity, and a 0.001 nanoteslas resolution. The compensation was applied by an RMS AADC compensator using a 27 term polynomial.

Ancillary Systems

Base Station Magnetometer
A Scintrex CS-2 cesium vapour magnetometer was used as a base station magnetometer. It has a 2 Hz sampling rate, 0.005 nanoteslas sensitivity, and a 0.01 nanoteslas resolution. A Sercel NR-103 10-channel GPS receiver monitored the position of the base station.

The ground magnetometer was mounted in a magnetically quiet area; its clock was synchronized with the GPS time signal. The GPS data logger records all of the raw range data stream. The Trajecto differential correction software matches the output from the airborne GPS system and the ground GPS system during the data reduction process.

Altimeters
A TRT AVH-8 radar altimeter was used during the survey. It has a sampling rate of 10 Hz and an accuracy of ± 2%. Barometric altitude was monitored by a Rosemount 1241M altimeter with a sampling sate of 10Hz and an accuracy of ± 5 metres.

Tracking Camera
A video camera and video cassette recorder were used to record the flight path. The video camera was a Panasonic WVC 1302 and the video cassette recorder was a Panasonic AG2400 (NTSC format).

Navigation System
The GPS system used to monitor position was a Sercel NR103 10-channel receiver. In addition, a real time differential GPS system, an Omnistar 6300-A, was used.

Digital and Analog Recorders
The digital acquisition system, GeoDAS, was manufactured by Fugro Airborne Surveys. It is a Pentium computer based system that synchronizes and records data in real time. A digital backup was done by an Iomega 100 Mb removable Zip drive. Analog recordings were prepared by an RMS GR-33a-1 dot matrix printer.

Field Quality Control

Lines (or segments of lines crossing two control lines, or segments of control lines crossing several lines) were re-flown when any of the following tolerances were exceeded:

Navigation
- Nominal line spacing must not be exceeded by more than 25% for a distance of more than 1 km.
- No gaps may be > 500 m.

Flight Height
- Deviations from nominal must not exceed 15 metres for a distance of more than 1 km.

Magnetic Diurnal
- Deviations must not be greater than 5 nanoteslas from a 5 minute chord.
- The ground station magnetometer operated during all data acquisition, except for flight 13.

Airborne Magnetometer Noise
- "Maneuver" noise must not exceed an envelope of ± 0.1 nanoteslas. This was monitored on the analog chart with a fourth difference and high-pass filter.
- The absolute magnetic value was checked with a Bourget calibration.
- A standard Figure of Merit must be less than 1.5 nanoteslas.
- Heading errors must be within ± 1 nanotelsas.

To check the data for adherence to contract specifications and move the data closer to the final stage, the following procedures were followed for each survey flight:
- Downloading and verification of aircraft data
- Downloading and verification of GPS and magnetic base station data
- Post-processing of GPS data using Sercel Trajectography software
- Merging of navigation data with geophysical data including transformation of coordinates from WGS84 latitude/longitude to UTM x, y coordinates in the local spheroid.
- Creation of flight path plots and evaluation of compliance with contract specifications.
- Spike and null value location and removal from the magnetic and altimeter data
- Computing of terrain clearance quality control field for evaluation of compliance with the contact specifications
- Evaluation of diurnal data quality, and compliance with contract specifications.
- Correction of magnetic data for IGRF gradient.
- Backing up of all field data.

At regular intervals, the corrected magnetic data were levelled and gridded for quality inspection including real-time shade enhancement.

Personnel

Data and field procedures were checked by John Charlton, P. Eng., of AFAB Consultants.

Field Personnel

Name	Title	Project Position
Dave Dawson	Aircraft Maintenance Engineer	Aircraft Maintenance
Jeff Robb	Aircraft Maintenance Engineer	Aircraft Maintenance
Leo Denner	Electronics Technician	Electronics Operator
Jerzy Wojcicki	Electronics Technician	Electronics Operator
Clare O'Dowd	Operations Manager	Geophysicist, Processor, Logistics
Les Miake	Pilot	Survey Pilot
Darcy Wiens	Pilot	Survey Pilot
Mark Tapp	Pilot	Survey Pilot

4) DATA ACQUISITION, COMPILATION AND PROCESSING

Calibration and Test Results

GPS Base Station

To apply post-flight differential GPS corrections to the survey data, a GPS base station was installed near the crew's hotel. The location of the GPS base station antenna was determined by averaging positions over a 24 hour period. The location was 52°55'37.758" N latitude, 82° 25'44.782" W longitude, elevation 8.142 metres on the WGS spheroid.

Magnetic Lag Test

The camera on-board the aircraft records its position, A, relative to the ground, at time t_0. In fact the sensor will arrive over A at time t_1 ($>t_0$). Furthermore, because of electronic delays, the reading at time t1 will not be recorded until time t_2 ($>t_1$). The difference t_2-t_0 represents the lag between the actual aircraft position and the x y position tied to the magnetic reading on disk. A lag test was performed by flying the aircraft at survey altitude in opposite directions over a sharp magnetic feature. The position of the magnetic feature was referenced to a visible feature recorded by the video system, in this case a bridge, which was the anomaly source. By superimposing a plot of the east-west anomaly over the west-east anomaly, the video-picked position of the bridge can be transposed onto its counterpart; and one-half the difference between the two video-picked positions equals the magnetic system lag. The lag was 0.7 seconds, or 7 magnetic samples, for aircraft C-FZLK. These values were used to correct for magnetic system lag throughout the survey.

GPS Lag/Accuracy Test

A cloverleaf flown over the ground station was used to measure the lag in the GPS positioning, with regard to the video camera position. A value of 0.2 seconds resulted in a best fit with the video position. Once the lag is applied the cloverleaf intersection is used to test the accuracy of the GPS positioning.

Heading Test

A heading error is calculated as part of the Bourget calibration.

Bourget Calibration

Aircraft:	Cessna Caravan	Sampling Rate:	10 Hz
Registration:	C-FZLK	Date:	July 7, 2000
Magnetometer:	Cesium vapour	Location:	Bourget, Ontario
	Stinger mounted	Altitude:	250 ft MTC

Direction of flight across point	Time Survey aircraft was over point in fiducials	H	M	S	Total field value in nT recorded in aircraft over point (T1)	Radar value in feet	Blackburn observatory diurnal reading at previous minute (T2)	Blackburn observatory diurnal reading at subsequent minute (T3)	Interpolated diurnal reading at time over point. T4=T2+s*(T3-T2)/60	Calculated Bourget value. T5=T4-C	Error Value. T6=T1-T5
North	85998.43	23	53	18.4	55596.107	403	56165.11	56165.33	56165.18	55607.98	-11.87
South	85800.50	23	50	0.5	55593.875	423	56164.30	56164.34	56164.30	55607.10	-13.23
East	86085.90	23	54	45.9	55593.392	377	56165.33	56165.36	56165.35	55608.15	-14.76
West	85886.73	23	51	26.7	55592.762	384	56164.34	56164.68	56164.49	55607.29	-14.53
North	86356.88	23	59	16.9	55595.883	372	56165.05	56164.88	56165.00	55607.8	-11.92
South	86172.55	23	56	12.6	55594.646	398	56165.48	56165.65	56165.52	55608.32	-13.67
East	86443.75	23	54	45.9	55592.775	370	56165.33	56165.36	56165.35	55608.15	-15.38
West	86276.27	23	57	56.3	55593.644	360	56165.65	56165.45	56165.46	55608.26	-14.62
Totals	Average N-S heading error Average E-W heading error				T6N-T6S T6E-T6W		1.55 -0.19			Average	-13.75

C is the difference in the total field between the Blackburn observatory value(0) and the value B at the point about Bourget crossroads at a given height.
At 1000 ft, C = (0-B) = 550 nanoteslas. At 500 ft, C = 556 nanoteslas. At 400 feet, C=557.2 nanoteslas.

Figure of Merit

The figure of merit is the measurement of the ability of the compensation system to remove the effects of aircraft manoeuvres from the total field data. During the FOM test the aircraft is flown into a quiet magnetic area and put through a series of pitches (±5^o), rolls (±10^o) and yaws (±5^o) to examine the noise remaining in the signal after the 27 term automatic compensation algorithm has been applied to the data.

Heading	Manoeuvre	Value (nT)	Heading Total (nT)
North	Pitch	0.240	
	Roll	0.100	
	Yaw	0.120	0.460
East	Pitch	0.200	
	Roll	0.070	
	Yaw	0.140	0.410
South	Pitch	0.200	
	Roll	0.100	
	Yaw	0.080	0.380
West	Pitch	0.100	
	Roll	0.160	
	Yaw	0.160	0.420
		FOM value	1.210 nT
		Average Manoeuvre Noise (FOM/12)	0.101 nT

Altitude: 2000 ft mean terrain clearance.

Altimeter Calibration
The radar, barometric and GPS altimeters were compared by flying at 100 foot intervals from 200 to 1000 feet, over the airport at Attawapiskat. The results were acceptable.

Total Field Magnetics

Final data reduction was undertaken at the Fugro Airborne Surveys processing centre in Ottawa, Canada between November 2000, and January, 2001. In general, final processing consisted of the following operations:

- final levelling of the total field magnetic data
- image and 1:50,000 scale map analysis of the total field by a geophysicist for any residual levelling or positioning errors or gridding artefacts
- correction of errors
- final gridding and microlevelling
- calculation of the vertical gradient of the total magnetic field
- imaging and plotting of all final parameters
- archiving of final data

Final projection parameters used - Universal Transverse Mercator (UTM) on the Clarke 1866 spheroid using a false easting of 500,000 metres, false northing of 0 metres, a scale factor of 0.9996 and central meridians of 81^{o} West. The datum shift from WGS 84 to Clarke 1866 (NAD27) was x=8, y=-163, and z=-180 metres.

Noise Editing
An automatic editing routine, employing 4^{th} differences of the magnetic field removed nulls and spikes down to the noise level, and located abrupt level shifts.

Noise Filtering
No filtering was applied to the airborne magnetic data.

Diurnal Subtraction
Because of the distances between air and ground magnetic sensors, only the long period diurnal variations were subtracted from the air data, as they are more likely to correlate. Any miscorrelations were corrected by the levelling program. An average ground station value of 58,853 nanoteslas was added back in.

IGRF Correction
The IGRF regional value was calculated using the 1995 model updated to the mid-survey date, i.e., 2000.70, using the corrected GPS elevations. Using the actual elevations for IGRF correction has the added benefit of correcting for minor magnetic effect of altitude variations within the Earth’s primary field. The resulting magnetic field profiles were input to the levelling process.

Levelling
The lines (traverse lines) and tie-lines (control lines) of an aeromagnetic survey form a network, and the points where they cross are called intersections. At each intersection the magnetic values should be identical. In practice they differ as a result of:

- time variations of the magnetic field
- heading effects
- altitude differences
- position errors
- cultural or instrument noise

In the levelling process, it is assumed that most of the required level adjustments will vary smoothly along each line or tie-line. The network of line minus tie-line differences at the intersections is analyzed to produce a matrix of misclosures. These misclosures were reduced to zero through an iterative process of tilting the profile baselines and moving the intersection locations. Compensation values applied at adjacent tie-lines were not allowed to differ by more than 1 nanotesla. Intersection movements were restricted to about 50 metres. Less than 27 of the 2041 intersections needed manual corrections.

Gridding
Gridding was done by the Akima routine, with introduction of the tie line data. A gridding interval of 50 metres was used.

Grid Levelling
The final stage of levelling consisted of applying a grid-levelling routine to the gridded data to remove small residual errors that are not properly removed by conventional levelling of the line data (Minty, B. R. S., 1991: Simple micro-levelling for aeromagnetic data; Exploration Geophysics, v. 22, pp. 591-592).

Vertical Magnetic Gradients

The total magnetic intensity grid was input to the first and second vertical derivative calculation. This was done in the frequency domain together with a low pass filter which removed wavelengths below 225 metres.

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: 13.5 m
Magnetic inclination: 77.597° N
Magnetic declination: 12.071° W
Magnetization scale factor: 100
Maximum data range: 1 000 nT
Number of passes of smoothing filter: 0
Model window size: 12
Model window grid cell size: 50 m

5) MICROLEVELLING AND GSC LEVELLING

<u>Microlevelling</u>

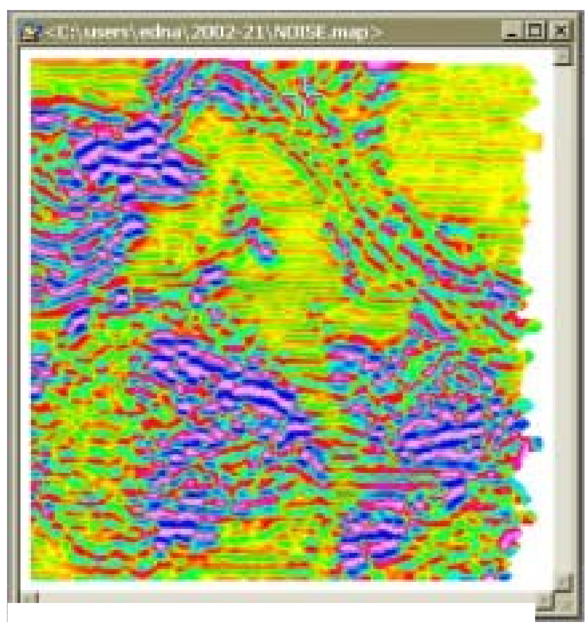
Microlevelling is the process of removing residual flightline noise that remains after conventional levelling using control lines. It has become increasingly important as the resolution of aeromagnetic surveys has improved and the requirement of interpreting subtle geophysical anomalies has increased. 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.

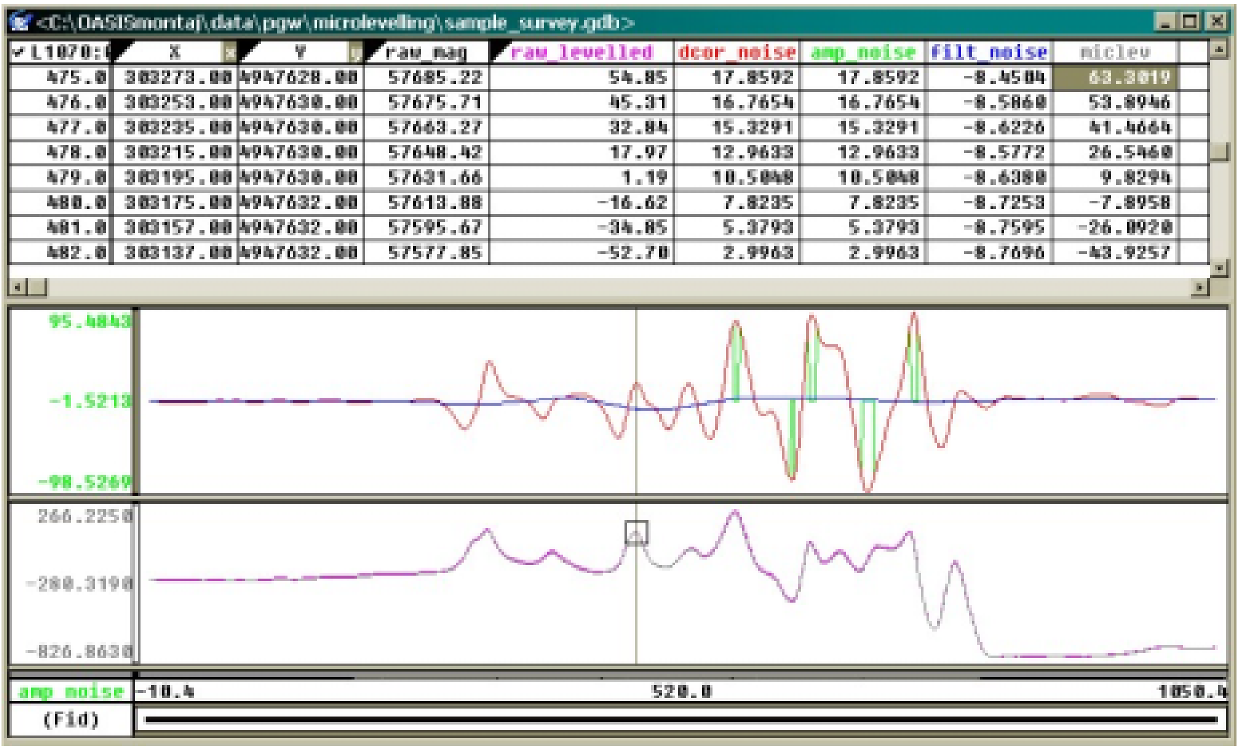


Decorrugation noise grid

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.

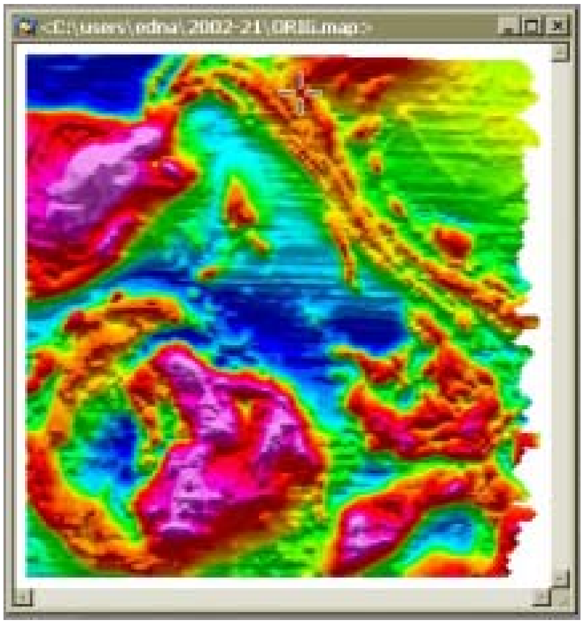
In the example shown, the data are windowed from an airborne magnetic and electromagnetic survey flown in the Matachewan area of Ontario, over typical Archean granite-greenstone terrain (Ontario Geological Survey, 1997). Standard corrections (e.g. diurnal, IGRF, conventional tieline levelling) were applied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



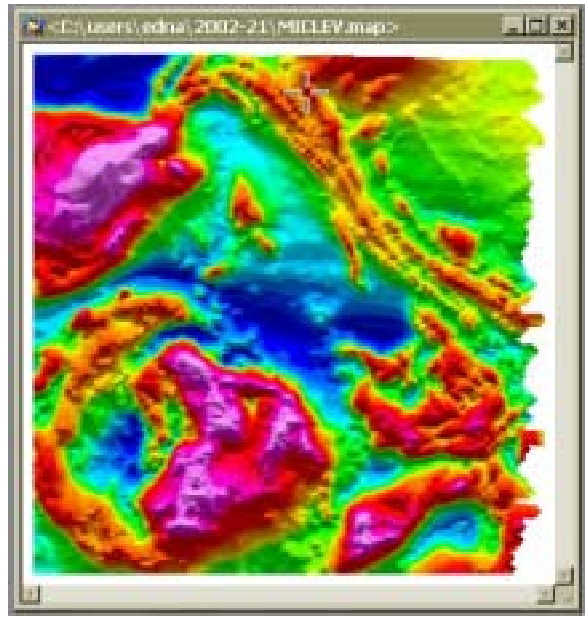
L1070:0	X	Y	raw_mag	raw_levelled	dcor_noise	amp_noise	filt_noise	miclev
475.0	303273.00	4947628.00	57685.22	54.85	17.8592	17.8592	-8.4504	63.3019
476.0	303253.00	4947630.00	57675.71	45.31	16.7654	16.7654	-8.5860	53.8946
477.0	303235.00	4947630.00	57663.27	32.84	15.3291	15.3291	-8.6226	41.4664
478.0	303215.00	4947630.00	57648.42	17.97	12.9633	12.9633	-8.5772	26.5460
479.0	303195.00	4947630.00	57631.66	1.19	10.5048	10.5048	-8.6380	9.8294
480.0	303175.00	4947632.00	57613.88	-16.62	7.8235	7.8235	-8.7253	-7.8958
481.0	303157.00	4947632.00	57595.67	-34.85	5.3793	5.3793	-8.7595	-26.0920
482.0	303137.00	4947632.00	57577.85	-52.70	2.9963	2.9963	-8.7696	-43.9257

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).

<u>Flight Line Spacing</u>
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 1st/2nd 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).

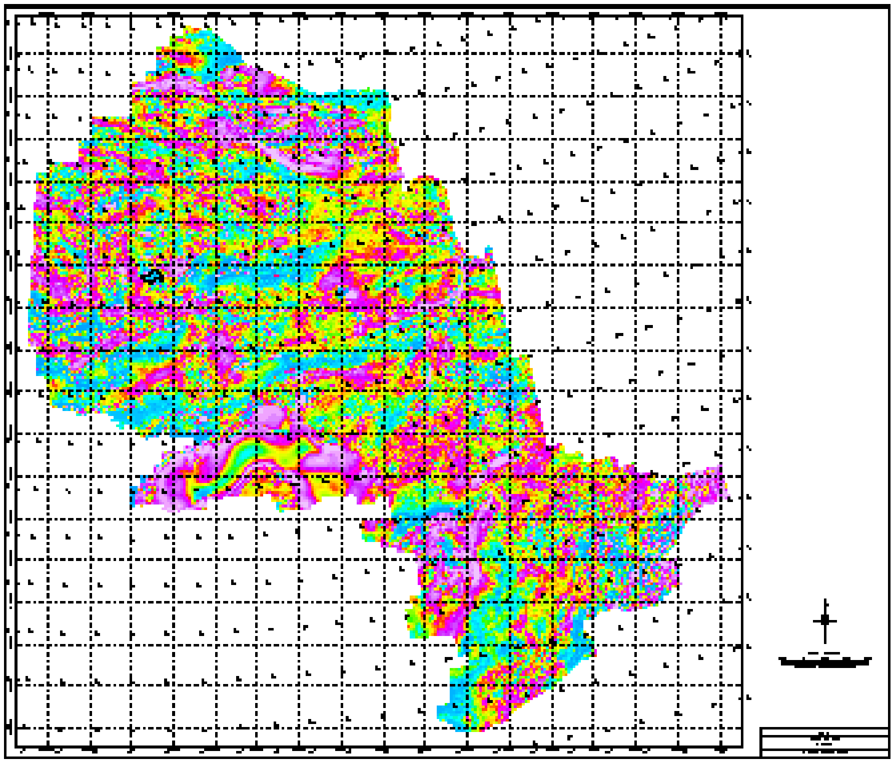
Terminology:

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.

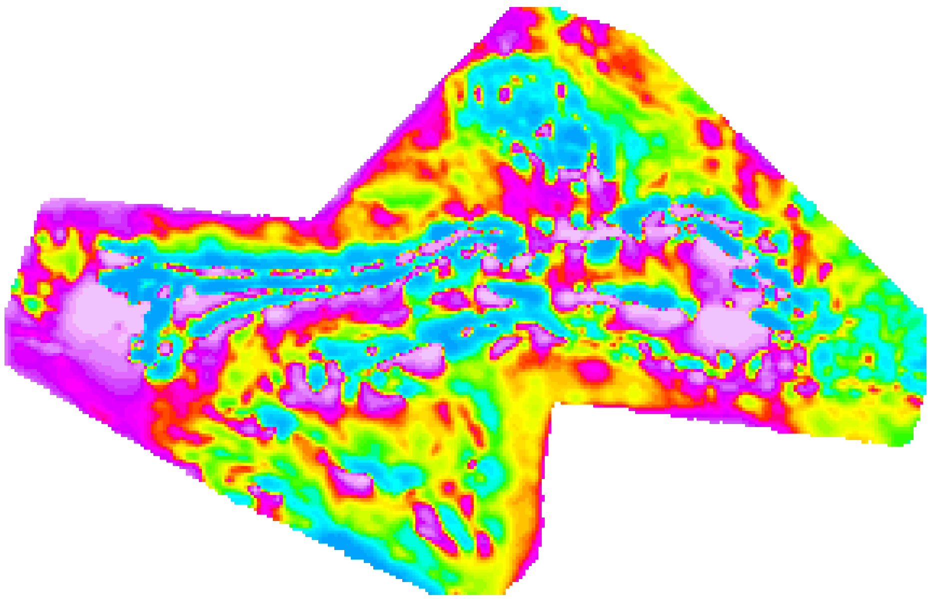
1.Create an upward continuation of the survey grid to 305m

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.



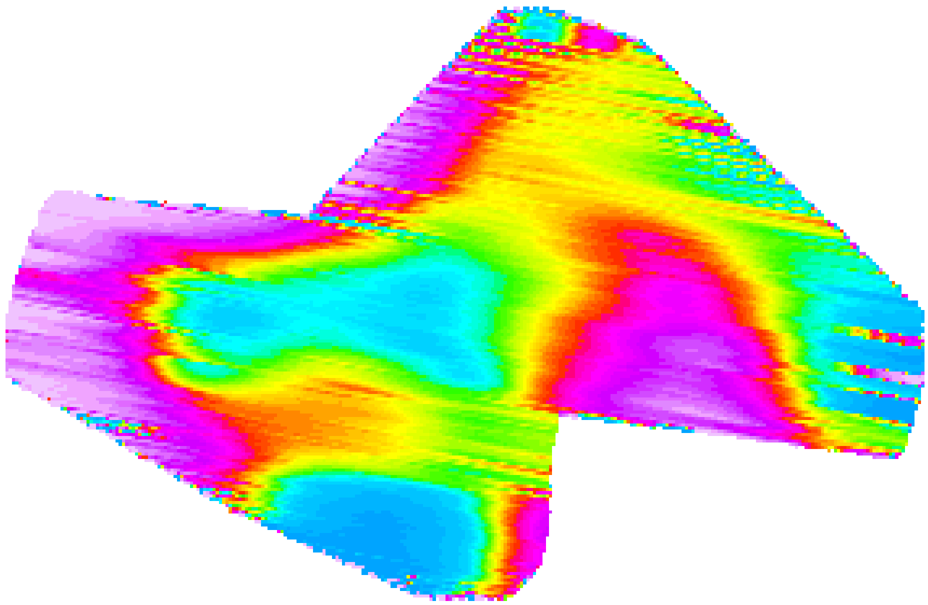
Difference grid (difference between survey grid and master grid), Vickers survey.

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.

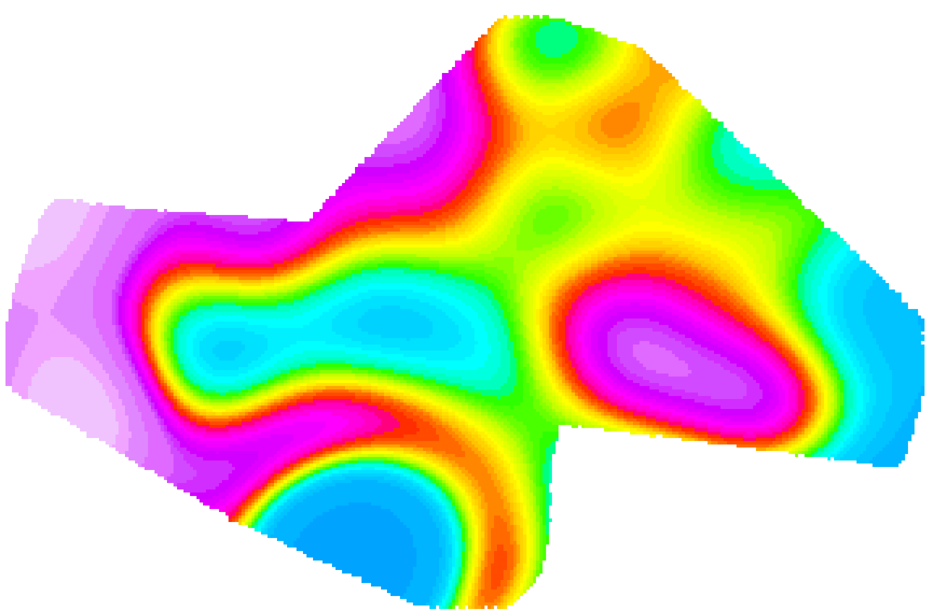
6. Rotate the filtered grid back to its original (true) orientation.



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 Kapiskau River East survey:

No microlevelling was required.

The following GSC levelling parameters were used in the Kapiskau River East survey:

Distance to upward continue: 205 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

6) FINAL PRODUCTS

Profile database

- Database for magnetics at 10 samples per second in both Geosoft GDB and ASCII format.

Keating Coefficient database

- Keating coefficients in Geosoft GDB format and ASCII 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:
  - Residual Magnetic Intensity
  - GSC Levelled Magnetic Field
  - 1st Vertical Derivative of the Residual Magnetic Intensity
  - 2nd Vertical Derivative of the Residual Magnetic Intensity
  - 2nd Vertical Derivative of the GSC Levelled Magnetic Field

Project report

- Provided in both WORD and PDF formats.

7) QUALITY ASSURANCE AND QUALITY CONTROL

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

OTH Geophysicist

On receipt of the purchased data, the OTH Geophysicist conducted a review for adherence to the survey specifications and completeness. Any problems encountered during this review were discussed and resolved.

The QA/QC checks included the following:

Navigation Data

- area flown covered the entire specified survey area

Magnetic Data

- magnetometer noise levels were 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

The OTH Geophysicist reviewed all digital products 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.

Where no databases were available, they were created from the original data files. The data was examined to verify that units were SI (metric measurement system) and contained no multipliers. If required, tie lines were renamed from an L prefix to a T prefix. The profile data was checked for unusually large spikes or gaps in the magnetic and EM channels.

If no grids were supplied with the profile data, they were created with a grid cell size of approximately 1/5th of the line spacing. Magnetic grids were produced using minimum curvature gridding and resistivity/conductivity grids were created using bi-directional gridding with a trend angle perpendicular to the flight line direction.

MNDM

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.

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APPENDIX A PROFILE ARCHIVE DEFINITION

Survey 1214 was carried out using the Scintrex magnetic system, mounted on a fixed-wing platform.

Data File Layout

The files for the Kapiskau River East survey are archived on Geophysical Data Set 1214 - Kapiskau River East Area. They are organized within six separate subdirectories, namely ASCII and binary files of the gridded, profile and Keating coefficient data. The content of the ASCII and binary file types is identical. They are provided in both forms to suit the user's available software.

Coordinate Systems

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

- Universal Transverse Mercator (UTM) projection, Zone 17N, NAD27 datum; Canada NTv2 (20 min) local datum
- Universal Transverse Mercator (UTM) projection, Zone 17N, NAD83 datum, North American local datum
- Latitude/longitude coordinates, NAD27 datum; Canada NTv2 (20 min) local datum
- Latitude/longitude coordinates, NAD83 datum, North American local datum.

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

- Universal Transverse Mercator (UTM) projection, Zone 17N, NAD27 datum, Canada NTv2 (20 min) local datum
- Universal Transverse Mercator (UTM) projection, Zone 17N, NAD83 datum, North American local datum

The original profile, electromagnetic and gridded data were compiled in UTM NAD27 projection. No documentation could be found that specified a local datum. A local datum of Canada NTv2 (20 min) was assumed and used to create the reprojected data in UTM NAD83, North American local datum.

Profile Data

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

- thkapiskaurivereast.xyz - flat ASCII file
- thkapiskaurivereast.gdb - Geosoft OASIS montaj binary database file (no compression)

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

Channel Name	Description	Units
x_nad27	easting in UTM co-ordinates using NAD27 datum	metres
y_nad27	northing in UTM co-ordinates using NAD27 datum	metres
x_nad83	easting in UTM co-ordinates using NAD83 datum	metres
y_nad83	northing 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
gps_z_raw	raw GPS Z	metres
radar_final	corrected radar altimeter	metres above terrain
baro_final	corrected barometric altimeter metres above sea level	metres above sea level
dem	digital elevation model	metres above sea level
fiducial	fiducial	
flight	flight number	
line	flightline number	
line_part	flightline part number	
time_local	time local	seconds after midnight
date	local date	YYYYMMDD
mag_base_raw	raw magnetic base station data	nanoteslas
mag_base_final	corrected magnetic base station data	nanoteslas
comp_long	compensation, longitudinal component	nanoteslas
comp_trans	compensation, transverse component	nanoteslas
comp_vert	compensation, vertical component	nanoteslas
mag_uncomp	uncompensated magnetics	nanoteslas
mag_raw	raw magnetic field	nanoteslas
mag_rawlong	raw magnetic field, longitudinal component	nanoteslas
igrf	local IGRF field	nanoteslas
mag_igrf	IGRF-corrected magnetic field	nanoteslas
mag_comp	compensated magnetics	nanoteslas
mag_lev	levelled magnetic field	nanoteslas
comp_final	final compensation	nanoteslas
mag_final	micro-levelled magnetic field	nanoteslas
mag_gsclev	GSC levelled magnetic field	nanoteslas

APPENDIX B GRID ARCHIVE DEFINITION

Gridded Data

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

- *.gxf - ASCII Grid eXchange Format (revision 3.0)
- *.grd - Geosoft OASIS montaj binary grid file (no compression)
- *.gi - binary file that defines the coordinate system for the *.grd file

The grids are summarized as follows:

thkremag27.grd/.gxf	Residual magnetic field in nanoteslas (UTM coordinates, NAD27 datum)
thkremag83.grd/.gxf	Residual magnetic field in nanoteslas (UTM coordinates, NAD83 datum)
thkremaggsc27.grd/.gxf	GSC levelled magnetic field in nanoteslas (UTM coordinates, NAD27 datum)
thkremaggsc83.grd/.gxf	GSC levelled magnetic field in nanoteslas (UTM coordinates, NAD83 datum)
thkre1vd27.grd/.gxf	Calculated first vertical derivative of residual magnetic field in nanoteslas per metre (UTM coordinates, NAD27 datum)
thkre1vd83.grd/.gxf	Calculated first vertical derivative of residual magnetic field in nanoteslas per metre (UTM coordinates, NAD83 datum)
thkre2vd27.grd/.gxf	Calculated second vertical derivative of residual magnetic field in nanoteslas per metre^2 (UTM coordinates, NAD27 datum)
thkre2vd83.grd/.gxf	Calculated second vertical derivative of residual magnetic field in nanoteslas per metre^2 (UTM coordinates, NAD83 datum)
thkre2vdgsc27.grd/.gxf	Calculated second vertical derivative of GSC levelled magnetic field in nanoteslas per metre^2 (UTM coordinates, NAD27 datum)
thkre2vdgsc83.grd/.gxf	Calculated second vertical derivative of GSC levelled magnetic field in nanoteslas per metre^2 (UTM coordinates, NAD83 datum)

APPENDIX C KEATING CORRELATION ARCHIVE DEFINITION

Kimberlite Pipe Correlation Coefficients

The Keating kimberlite pipe correlation coefficient data are provided in two formats, one ASCII and one binary:

- thkrekc.csv - ASCII comma-delimited format
- thkrekc.gdb - Geosoft OASIS Montaj binary database file

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

x_nad27	easting in UTM co-ordinates using NAD27 datum	metres
y_nad27	northing in UTM co-ordinates using NAD27 datum	metres
x_nad83	easting in UTM co-ordinates using NAD83 datum	metres
y_nad83	northing 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
corr_coeff	correlation coefficient	percent
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