Ontario

KIRKLAND LAKE AREA

Ontario Airborne Magnetic and Electromagnetic Surveys

Geophysical Data Set 1022

Processed Data and Derived Products
Archean and Proterozoic "Greenstone" Belts

Ontario Geological Survey
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Report on Kirkland Lake Area Geophysical Survey

Geophysical Data Set 1022

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CREDITS

The overall project management, scientific authority and quality control was provided by Vinod K. Gupta, Ontario Geological Survey, Sudbury. The following is a list of the organisations that have participated in this project, and their various responsibilities:

Paterson, Grant & Watson Limited, Toronto - Prime contractor

-project management

-magnetic data processing

Geoterrex, a division of CGG Canada Ltd., Ottawa - Sub-contractor

-flight path correction

-electromagnetic data processing (time-domain surveys)

Dighem/I-Power, a division of CGG Canada Ltd., Mississauga - Sub-contractor

-flight path correction

-electromagnetic data processing (frequency-domain surveys)

CGI Controlled Geophysics Inc., Thornhill - Sub-contractor

- quality control of data
- data merging and preparation of final products

Geopak Systems, Toronto - Separate contractor

- developed viewing and geophysical data exporting Windows ™ "Centurion" software accompanying this CD-ROM

DISCLAIMER

Every possible effort has been made to ensure the accuracy of the information provided on this CD-ROM; 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 about the Archean and Proterozoic "greenstone belts" airborne geophysics digital data set may be quoted if credit is given. It is recommended that reference be made in the form shown in this example:

> Ontario Geological Survey 2003. Ontario airborne geophysical surveys, magnetic data, Kirkland Lake area; Ontario Geological Survey, Geophysical Data Set 1022.

1) INTRODUCTION

High resolution airborne magnetic and electromagnetic surveys, over major greenstone belts, were initiated in 1975 by the Ontario Department of Mines (currently known as the Ontario Geological Survey) to aid geological mapping and mineral exploration. Between the period 1975 to 1992, thirty-two airborne surveys were flown and processed by different survey contractors and subcontractors. The two earlier surveys, Matachewan and Bamaji-Fry Lakes, were acquired in analog form and the remaining thirty surveys were recorded digitally. The surveys were flown at a nominal flight line spacing of 200m with the exception of James Bay Cretaceous Basin survey, which was flown at a flight line spacing of 1000m. The flight directions for the surveys, including individual survey blocks, were chosen to transect the predominant regional structural trends of the underlying rocks. The result of the surveys were published on 1:20,000 semi-controlled photo mosaic paper maps, showing total magnetic field contours onto which picked electromagnetic conductor anomalies were superimposed in symbol form.

There are significant differences in quality of data acquisition, and original processing, of older and newer surveys. The surveys flown recently were designed and flown based on the state-of-the-art specifications, equipment and technology, while some of the older surveys, though conducted to the then industry prevailing standards, were poorly processed. In many cases, on older surveys, the local map coordinates were registered in map inches of uncontrolled to semi-controlled photo mosaics. The vast amount of digital data, collected by the survey contractors, was archived on 9-track tapes of different sizes and densities, in numerous incompatible data formats and file structures, many of which were difficult to access. For this reason the archival digital data largely remained inaccessible to the mining industry.

To alleviate many of these problems, and to bring the archival data set of all thirty-two airborne magnetic and electromagnetic (AMEM) surveys to modern data storage, digital processing and interpretation standards, the present recompilation and reprocessing project was initiated under

the Northern Ontario Development Agreement (NODA). This includes approximately 450 000 line-km of AMEM data, which was recompiled and reprocessed to correct any errors in the original data sets, to compute new derived products and to produce a revised electromagnetic anomaly database, using state-of-the-art geophysical data processing and imaging techniques. The major objectives of this project were to:

1) Provide a single, well-defined, common data format for all thirty-two AMEM survey data sets on CD-ROM, allowing easy access to the data on a PC platform.

2) Digitize survey data acquired in analog form, obtain missing or bad data from digital or paper archives, and check the validity of all data including units, conversion factors, etc.

3) Analyse and correct errors in the flight path to account for distortions in the photomosaics and provide a digital flight path referenced to Universal Transverse Mercator (UTM) coordinates.

4) Link and level all thirty-two surveys total magnetic field data to the Single Master Aeromagnetic Grid for Ontario, which was prepared from the Geological Survey of Canada's magnetic database under an earlier project.

5) Reprocess the magnetic data to provide image quality total magnetic field grids and profiles for each survey.

6) Create image quality second vertical derivative grids of the total magnetic field.

7) Compute image quality apparent resistivities from a selected single frequency of the frequency-domain electromagnetic data, which have been fully corrected for signal to noise enhancement and accurately levelled.

8) Compute image quality decay constant and resistivity values from the corrected and levelled data channels of time-domain electromagnetic data (INPUT, GEOTEM I and GEOTEM II systems). Provide de-herringboned (i.e. correct for directional effect) decay constant and resistivity grids for all time-domain surveys.

9) Re-pick electromagnetic anomalies from the surveys in a consistent manner, and store anomaly parameters, including a unique identifier, in a new digital anomaly database.

The resulting profile and grid data in digital form, along with the second vertical derivative of the total magnetic field, the apparent resistivity and decay constant values, and a comprehensive EM anomaly database, will become valuable tools for orebody detection, and enhanced lithological and structural mapping of the geology. The original profile data are also included in the profile database for reference. A full description of the digital databases are provided in Appendix B. In addition, MNDM has archived a number of interim processed channels, which can be made available to users on request.

2) FLIGHT PATH REPROCESSING

2.1) Flight Path Standards

The goals of the flight path processing were to satisfy the three criteria below:

1) The database coordinates of picked fiducial points corresponding to identifiable topographic features on the photo mosaic should match the position of these features on published topographic maps within 100 metres on average.

2) The appearance of the final levelled total magnetic field and apparent resistivity data is consistent with the above standard of accuracy, i.e. continuity of linear features on adjacent flight lines to within 100 metres on average.

3) Speed checks run on the profile data do not show discontinuities or improbable values for the survey aircraft flight speed.

2.2) Flight Path Reprocessing Methodology

The following steps were taken to ensure that the final flight path data is in correct UTM coordinates:

1) Determine, if necessary, a regional correction comprising scaling, rotation and translation based on position of flight path relative to identifiable topographic features on the uncontrolled photo-mosaics.

2) Apply any regional correction to the digital data.

3) Plot the digital flight path (with regional correction) at the 1:20,000 scale.

4) Pick visual control points from the published survey maps at identifiable topographic features. Transfer these pick points to a scale stable 1:20,000 scale topographic map (Ontario Base Map), or if not available, to a 1:50,000 scale topographic map (National Topographic System).

5) Identify the pick points on the digital flight path. Digitise the vectors joining the pick points on the digital flight path to the visual pick points on the topographic maps. These vectors represent the required corrections at each pick point.

6) Generate a polynomial surface through the corrections for each of the easting and northing components of the digitised vectors.

7) Correct the regionally accurate digital flight path for local distortions by adding the polynomial surfaces, which define the corrections, to the digital data.

8) Plot the final corrected flight path at 1:20,000 and confirm that all control points have been properly corrected.

9) Verify the flight path positioning by correlating the geophysical responses to any identifiable cultural features.

The error of the final flight path position is within the specification of less than 100m. The primary source of error is the visual picking of the control points. The final corrected flight path is provided in the archive.

3) ALTIMETER DATA REPROCESSING

The altimeter data has been checked for spikes, negative values, discontinuities, and other errors, in order to ensure a correct contribution to the computation of the apparent resistivity values (see Section 5 Electromagnetic Data Reprocessing).

The following steps were taken to correct any errors in the altimeter data:

1) The data set was checked to ensure that it represents the distance in metres from the ground to the EM system. In many surveys, the data set required a correction to account for the difference in elevation between the altimeter equipment and the EM equipment. Most surveys required a conversion from imperial to metric units of measurement.

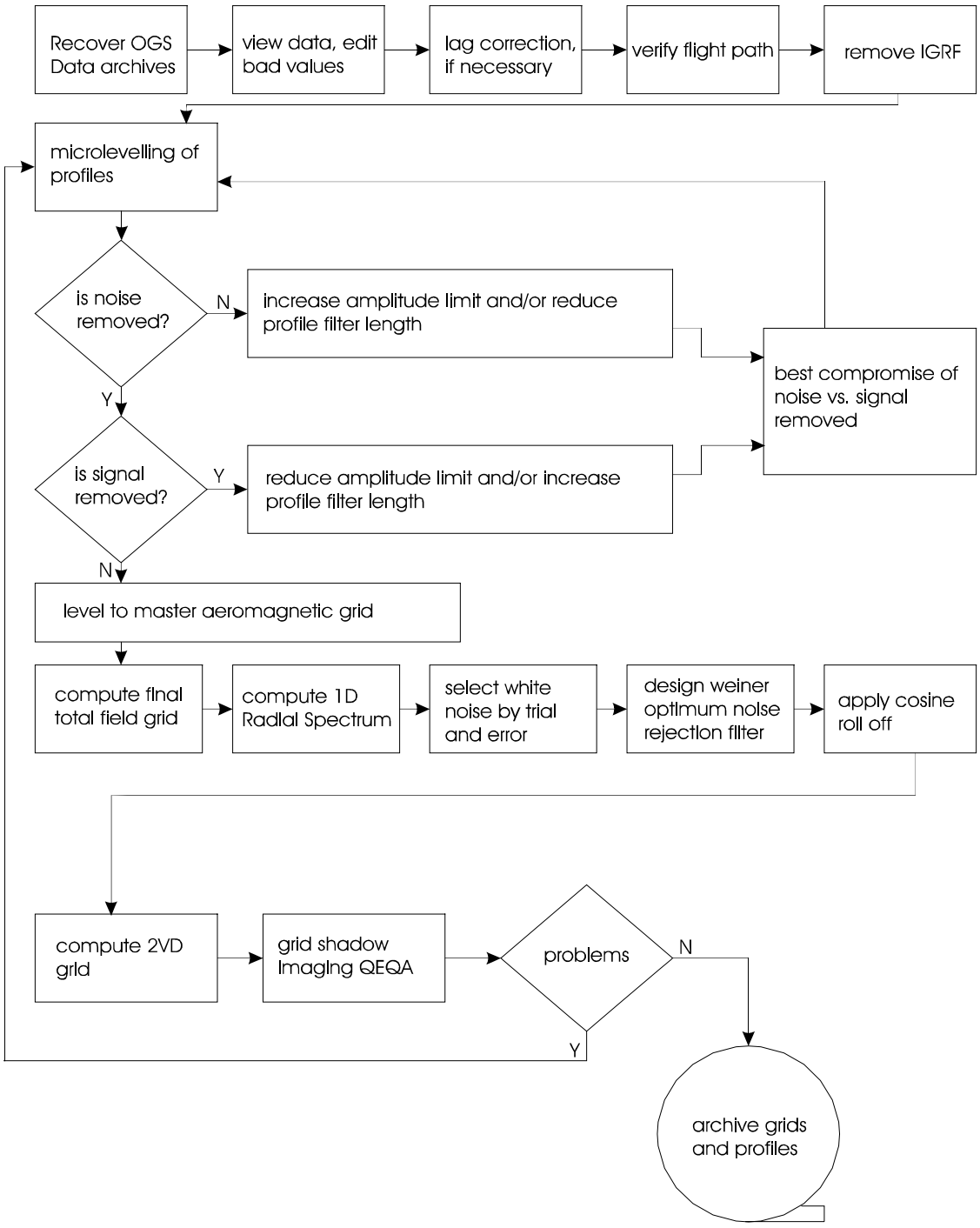
2) The data set was viewed on a line by line basis to check for errors using either a profile editor or digital profile maps.

3) Any spikes were replaced with default values. The default values were subsequently interpolated using a modified cubic spline (Akima, 1970).

4) MAGNETIC DATA REPROCESSING

The final magnetic data sets are image quality and conform to the criteria described below. All reprocessing corrections (Chart 4.1) are incorporated into the profile data as well as the final grids.

Chart 4.1: Flow Chart of Magnetic Data Reprocessing



4.1) Editing of Magnetic Data

The original magnetic profiles were viewed and edited for spikes, discontinuities, or other noise attributable to problems with the measuring and recording instruments and/or digitizing errors. The original and edited values are each retained in a separate column in the profile database.

4.2) IGRF Removal

An IGRF grid was calculated for the survey area and year based on coefficients supplied by the United States National Geophysical Data Center. The IGRF grid was calculated at 1 km cell size and then extracted to the profile data using cubic spline interpolation between grid points. The extracted IGRF values were then subtracted from the magnetic data values to give the IGRF corrected profile data. Both the IGRF values and the IGRF corrected survey data are stored in the magnetic profile database.

4.3) Micro-Levelling

Micro-levelling (Minty, 1991) was applied to remove low-amplitude flight line noise that remained in the magnetic data after tie line levelling by the original survey contractor. In this process a level correction channel is calculated and added to the profile database. This correction is then subtracted from the original data to give a set of levelled profiles, from which a levelled grid may then be generated. Micro-levelling has the advantage over standard methods of decorrugation that it better distinguishes flight line noise from geological signal, and thus can remove the noise without causing a loss in resolution of the data. Noise due to flight line level drift has been removed so that the background level of line noise visible in magnetically quiet areas is no more than: 1 nT for surveys flown from 1985-1991, 3 nT for 1978-1984 surveys, or 5 nT for 1975-1977 surveys, and similarly the background level of line noise in the second vertical derivative grids is no more than 0.001 nT/m^2 for any survey.

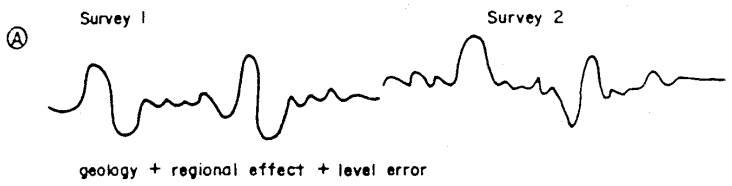
The micro-levelling process is described below. First the edited and IGRF-corrected profile data is gridded, with a cell size equal to 1/5 of the flight line spacing. Then a directional high-pass filter is applied in the Fourier-domain, to produce a grid known as the decorrugation noise grid, since it contains the noise to be removed from the data for decorrugation purposes. The decorrugation noise filter is a sixth-order high-pass Butterworth filter with a cutoff wavelength of four times the flight line spacing, combined with a directional filter. The directional filter coefficient as a function of angle is $F = \sin^2 a$, where a is the angle between the direction of propagation of a wave and the flight line direction (i.e. F=0 for a wave travelling along the flight lines, and F=1 for a wave travelling perpendicular to them). This is the opposite of what is usually called a decorrugation filter, since the intention here is to pass the noise only, rather than reject it.

The decorrugation noise grid will contain the line level drift component of the data, but it will also contain some residual high-frequency components of the geological signal. Flight line noise appears in the decorrugation noise grid as long stripes in the flight line direction, whereas anomalies due to geological sources appear as small spots and cross-cutting lineaments, generally with a higher amplitude than the flight line noise, but with a shorter wavelength in the flight line direction. The noise and the geological signal can be separated on the basis of these two criteria, i.e. amplitude and wavelength in the flight line direction. The operator examines the noise grid and estimates the maximum amplitude and minimum wavelength of the flight line noise. The noise grid is then extracted as a new channel in the database. Next, amplitude limiting is applied to this channel, such that any values exceeding the estimated maximum amplitude of the flight line noise are set to zero. Finally, the amplitude-limited noise channel is filtered with a Naudy non-linear low-pass filter (Naudy and Dreyer, 1968). The filter width is set so that any features narrower than half the estimated minimum wavelength of the flight line noise are eliminated. What remains at the end of all these filtering steps should be the component of line level drift only. This is then subtracted from the original data to give a better levelled set of profiles.

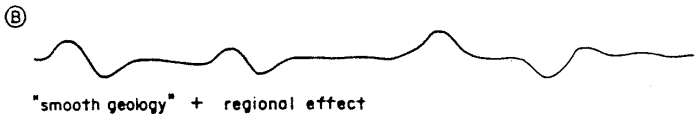
4.4) Levelling to Ontario Master Aeromagnetic Grid

The magnetic data is adjusted to the base level of the Ontario Master Aeromagnetic Grid, a linked and levelled magnetic reference grid at 200 m cell size and 300 m drape height for all of Ontario (Reford et al., 1990; Gupta et al. 1989). This has been done for the sake of consistency, so that adjacent surveys can be linked together seamlessly, and all of the survey data from this project can be conveniently linked with existing magnetic survey coverage in other areas. The base-level adjustment was applied as follows: The survey data was gridded at 200 m cell size and upward continued to 300 m observation height to match the Ontario grid. The difference of the two grids was computed, and then smoothed with a 15-km-wavelength low-pass filter. This low-frequency difference grid was then extracted to the profile database and subtracted from the original survey data values, to bring the survey to the same base level as the Ontario grid. Figure 4.1 shows how two adjacent surveys can be linked by adjusting them both to the base level of the master aeromagnetic grid. After the base shift has been applied, the reprocessed magnetic profiles and grids are still effectively at the same observation height as the original data, so that no resolution is lost.

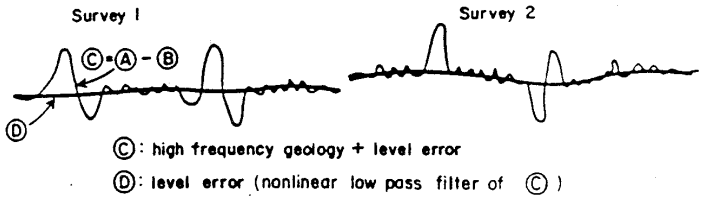
Figure 4.1: Levelling of aeromagnetic survey blocks together using an existing regional datum



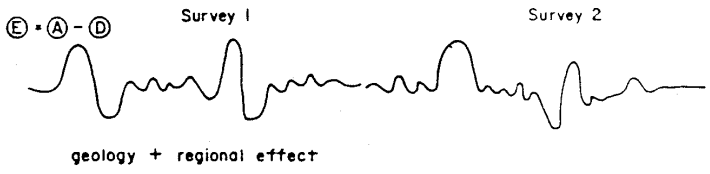
Unlevelled magnetic survey data (e.g. Wawa and Wawa-Michipicoten surveys)



Levelled regional magnetic datum (i.e. Ontario Master Aeromagnetic Grid)



Computation of the level error by differences and filtering



Magnetic survey data levelled to the regional magnetic datum

4.5) Gridding of Reprocessed Magnetic Data

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 data. However, sometimes this can cause narrow linear anomalies cutting across flight lines to appear as a series of isolated spots. Wherever this "bull's eye" effect was a problem, trend-enhanced gridding was applied (Keating, 1995).

Trend-enhanced gridding interpolates data values between flight lines so as to join up local maxima on adjacent lines, and similarly, to join local minima, so that geological trends are shown clearly. This has the great advantage over other methods of trend enhancement that it reinforces identifiable trends going in any direction, rather than merely in one single favoured direction. Similar to the conventional minimum-curvature gridding, trend-enhanced gridding also fits the profile data values within 1 nT for 99.98% of the data points. The only differences are in the values assigned to grid points between flight lines.

4.6) Second Vertical Derivative of the Total Magnetic Field

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 (Figure 4.2a). Secondly, an optimum Wiener filter (Figure 4.2b) was designed for the radially averaged power spectrum. Thirdly, a cosine-squared function was then applied to the optimum Wiener filter to remove the sharp roll-off at higher frequencies (Figure 4.2b).

Figure 4.2a: Radially averaged power spectrum of the magnetic field

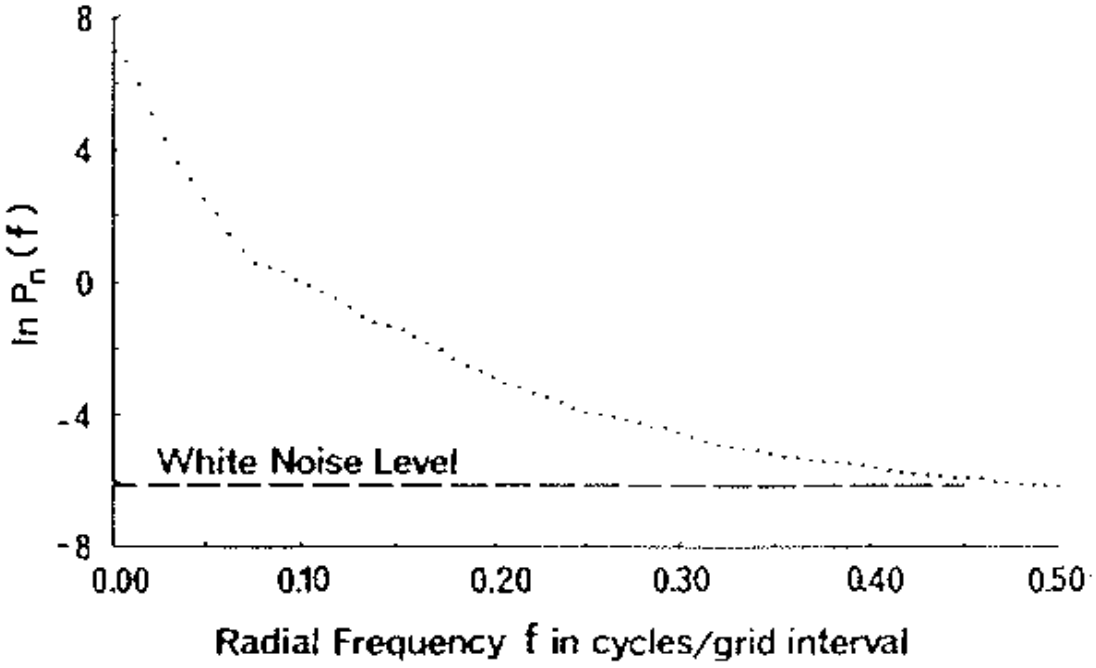
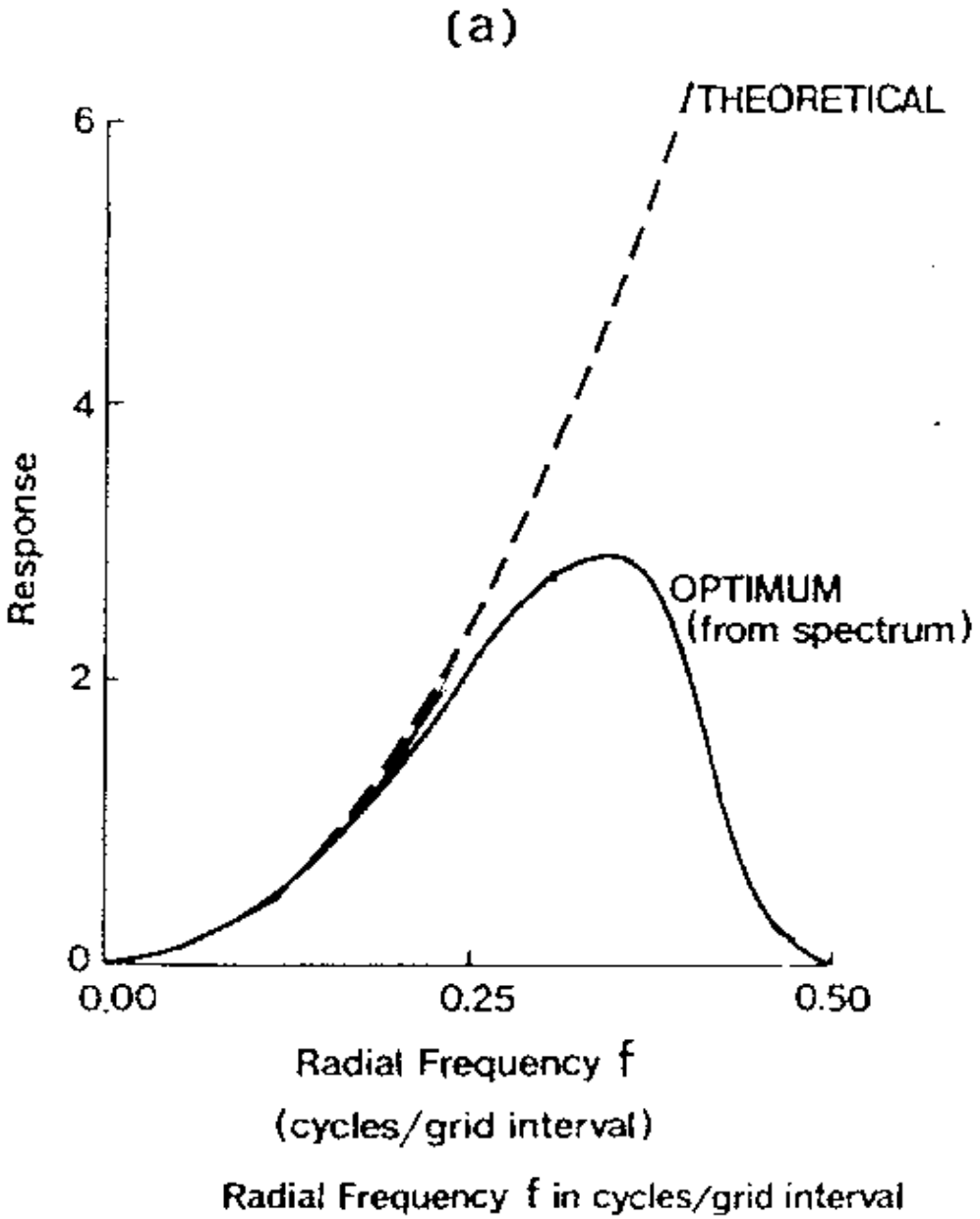


Figure 4.2b: Second vertical derivative filters



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

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

when, $x(f)$ is the logarithmic distance between the spectrum and the selected white noise. For each survey area, the shaded relief images of the second vertical derivative map were also used to identify and assess flight line noise contents of the micro-levelled total magnetic field grids.

4.7) 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 magnetized 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 : 40 m
Sensor height: 120 m
Magnetic inclination: 76.17^{o} N
Magnetic declination: 10.4^{o} W

Magnetization scale factor: 100

Maximum data range: 1 000 nT

Number of passes of smoothing filter: 0

Model window size: 15

Model window grid cell size

5) ELECTROMAGNETIC DATA REPROCESSING

5.1) Reprocessing Specifications and Tolerances

- EM filtering and processing techniques were applied to the data to reduce noise, improve base level estimates and increase the signal to noise ratio of selected EM profile data channels for the purpose of obtaining reliable and unambiguous resistivity and decay constant calculations;

- corrected amplitudes for those EM channels which were selected for resistivity calculations were to be near zero when no conductive or permeable source was present;

- due to high costs of removal, the cultural effects were to be left intact in the EM datasets;

- the EM data was to be checked and corrected for residual spheric and other identifiable noise events;

- for INPUT datasets, the EM channels were to be levelled to the following specifications:

  ± 200 ppm on channel 1,
  ± 50 ppm on channel 6 and pro-rated for in-between channels.
  for GEOTEM datasets, the EM channels were to be levelled to the following specifications:
  ± 75 ppm on channel 1;
  ± 25 ppm on channel 12;
  and pro-rated for in-between channels.

5.2) Electromagnetic Data Corrections

Correction for Spherics:

All recognizable artifacts caused by spheric activity were removed from the channel data by interpolation, utilizing a graphics screen.

Base Level Corrections:

Base levels for every channel were reviewed and adjusted when necessary by viewing the data in profile form on a graphic screen. Based on the resistive segments along each line (when noted), an appropriate combination of tilt and/or dc offset was applied to each channel baseline to set the mean value of the resistive sections of the data to zero. The accuracy of the resulting baseline values will still oscillate within the envelope of the original noise level for each channel, but these variations in the true amplitude level are taken into account during the calculation of the resistivity and decay constant values by appropriate application of thresholds and weighted fitting of the data (Figure 5.1).

Figure 5.1

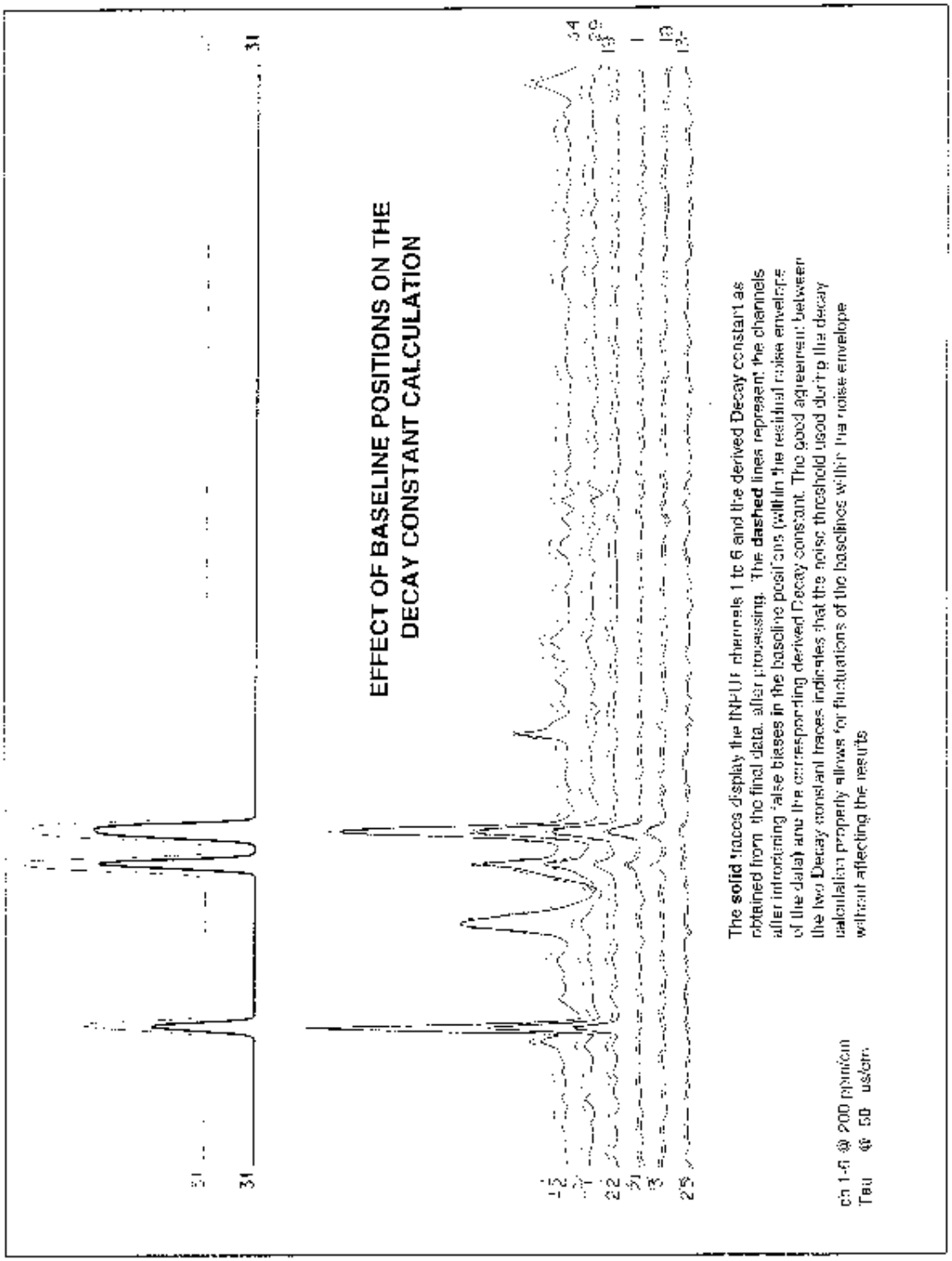
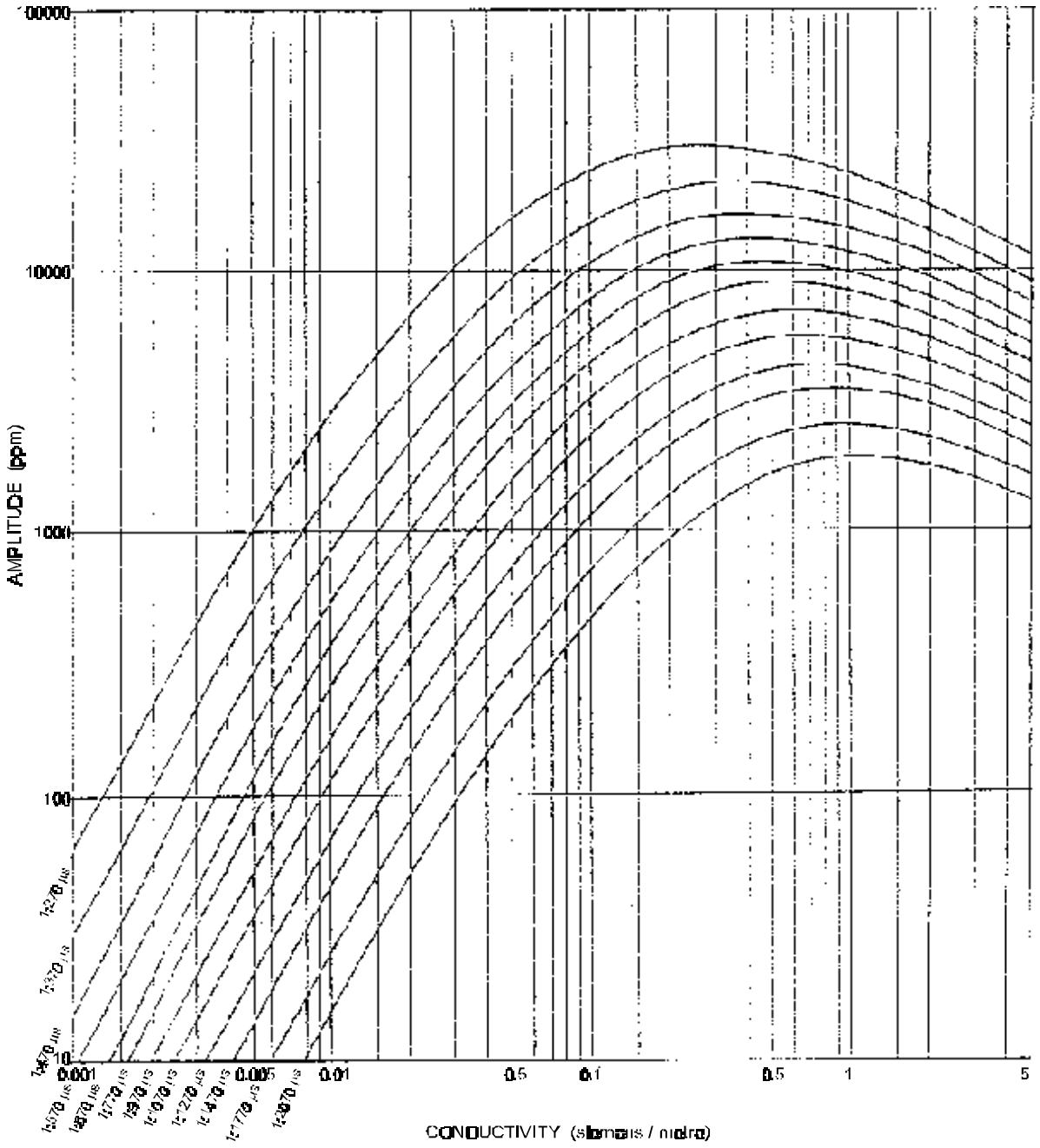

EFFECT OF BASELINE POSITIONS ON THE
DECAY CONSTANT CALCULATION
The solid traces display the INPUT channels 1 to 6 and the derived Decay constant as obtained from the final data, after processing. The dashed lines represent the channels after introducing false biases in the baseline positions (within the residual noise envelope of the data) and the corresponding derived Decay constant. The good agreement between the two Decay constant traces indicates that the noise threshold used during the decay calculation properly allows for fluctuations of the baselines within the noise envelope without affecting the results

Figure 5.2 illustrates the resulting decay constant traces from the channels before and after the adjustment of the baselines within the noise envelope thresholds, as specified in section 5.1. The good agreement between the two traces indicate that the application of the threshold and weighted fitting during the decay constant calculation can effectively compensate for residual baseline deviations which are within the noise envelope of the data.

Figure 5.2

HOMOGENEOUS HALF SPACE

NOMOGRAM



Filtering of the EM Channels:

Residual noise on the data was removed by applying a time domain adaptive filter which switches between a light and heavier filtering weight based on local gradient change. In areas of anomalous response, filtering was aimed at wavelengths of 1 Hz and higher; in the background, more resistive areas, the wavelength cut-off was set at 0.33 Hz and higher. Figures 5.3 and 5.4 provide an example of the effect of the filtering.

Figure 5.3

HORIZONTAL THIN SHEET

NOMOGRAM

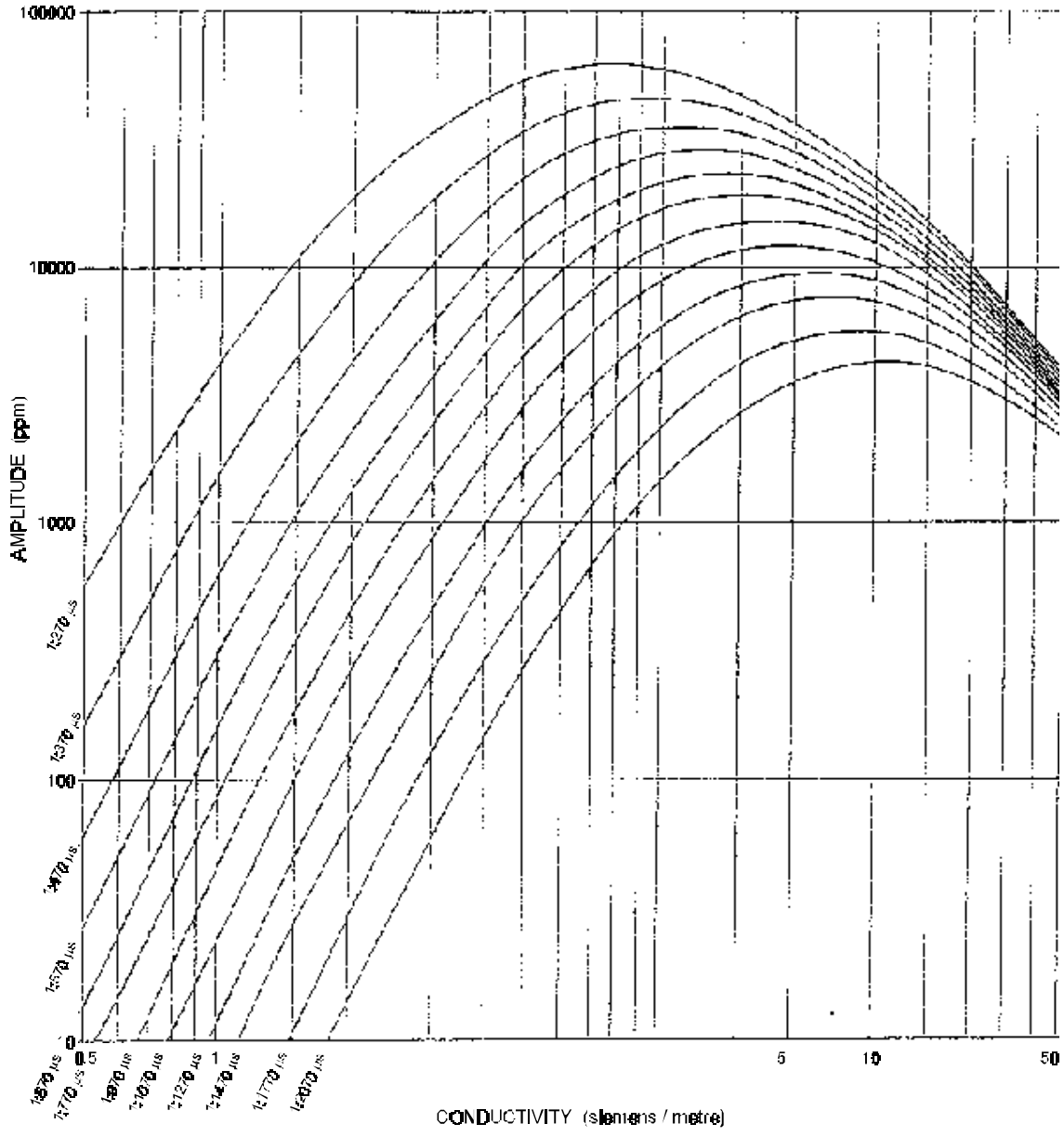
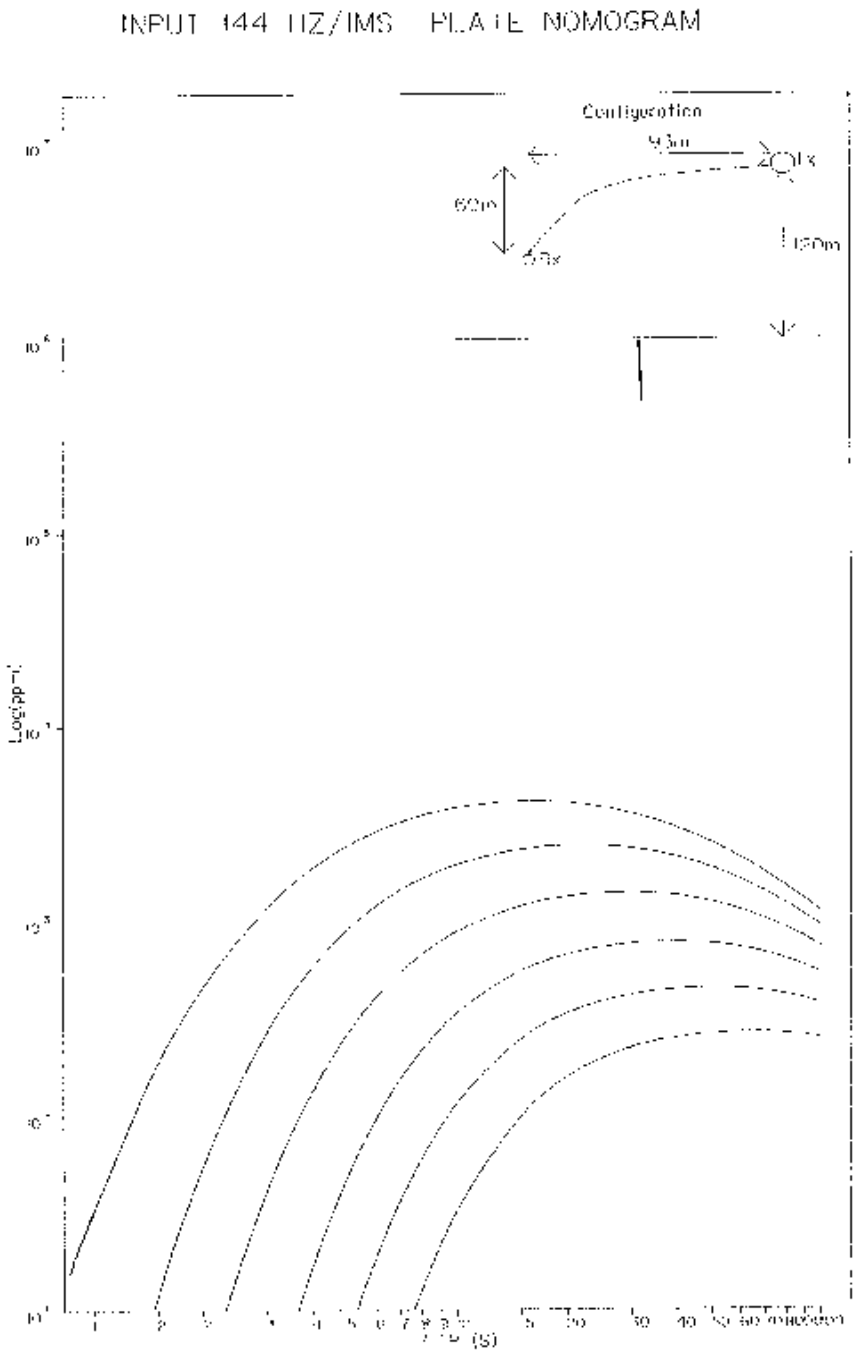


Figure 5.4


INPUT 144 HZ/IMS PLATE NOMOGRAM
Configuration
60m
150m
Log(pp-t)

Final Data Acceptance:

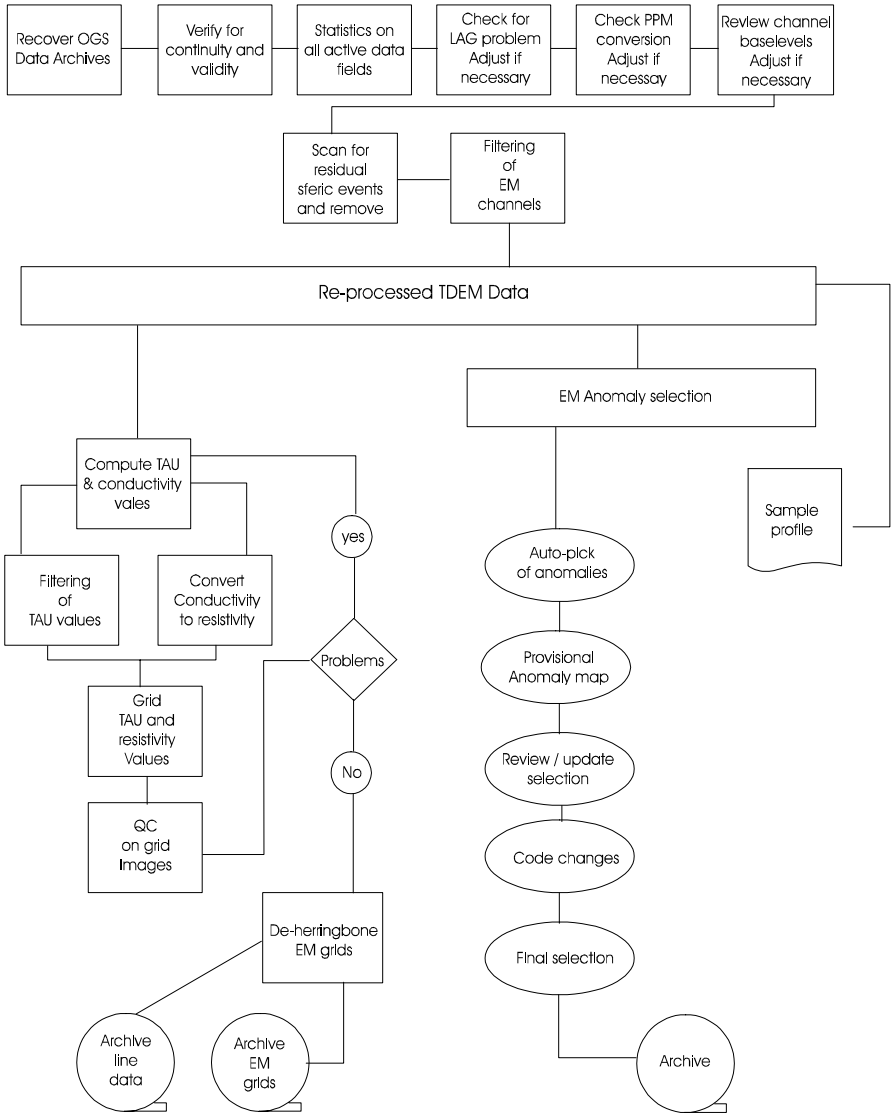
Interim digital archives of the raw and reprocessed data (in line form) and all the derived EM grids underwent initial quality control. The total effect of the reprocessing steps applied to the data (explained above) can be verified by creating difference traces between the original recovered data and the reprocessed data. Sample profile plots were also plotted as quality control measures to display the original recovered EM data and the reprocessed data.

5.3) Decay Constant Calculation

By definition, the INPUT system is a time domain system (TDEM) which measures the rate of decay of the received secondary field through the use of discrete time gates positioned during the off-time. The most direct representation of this information is by the decay constant (Vaughan, 1988) which is a measured value and thus independent of a model and theoretical response curves. Any other derived value such as conductivity or resistivity must be based on the corresponding response from a pre-selected model (i.e. homogeneous half-space, horizontal thin sheet, vertical plate). The derived conductivity/resistivity values are therefore only as good as the fit of the local geologic environment to the model selected. This trap is avoided by representing the TDEM data as decay constant values, which are independent of the geologic environment/model. The experience shows that after processing almost 170,000 line kilometres of GEOTEM data over the Ontario greenstone belts, that only a small percentage of the areas covered represented true homogenous half-space conductivity. As the surveys were generally defined to map greenstone belts in the search of base metal/gold, the EM signature is typically represented by resistive ground over granitic terrain, sometimes locally masked by weak surficial conductivity from glacial deposits or conductive muds in marsh areas, to confined conductors along contacts, shear zones and faults, representing the development of clay, graphite or mineralization. A flow chart of TDEM processing is shown in Chart 5.1

Chart 5.1

FLOWCHART OF TDEM PROCESSING



As a single parameter, the decay constant (TAU) provides more useful information than the amplitude of any given channel as it indicates not only the peak position of the response but also the relative strength of the conductor. It also often allows better discrimination of conductive axes within a broad formational group of conductors. The decay constant values are obtained by fitting the channel data, representing the decay transient, to a single exponential function. 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 conductivity. A slow rate of decay (high conductivity) will be represented by a gentle slope, yielding a high decay constant value and vice-versa. The actual fitting of the channel data to the exponential model uses a weighted function which will allow for minor offsets in the baseline values without affecting the calculation. Because of this, minor residual level/drift errors in the baseline values for the channels will not be reflected in the final computed decay constant values.

The calculation of the decay constant requires a certain minimum amount of signal to get a good fit to the exponential function used. This translates approximately to having response above the noise level in the first three channels. A grid of channel 2 was therefore produced as an interim quality control tool to evaluate the results of the decay constant calculation; i.e. all valid channel 2 responses should be matched by a decay constant value, and conversely, no decay constant values should exist where channel 2 falls below the noise level.

Users are cautioned that in fitting the channel data to the exponential function certain amount of minimum signal strength is required in order to ensure a reliable fit. For this, a weighted mean amplitude response is calculated at every sample point in the file; if this value is below a user defined threshold (25 ppm in this case), then no calculation is done and the TAU value is set to the reference background value of 33 microseconds. For the present dataset, this will be reflected in areas where less than three channels are deflected above the background noise.

On average, geological conductors in generally resistive terrain such as the greenstone belts of the shield, will yield decay constant values that range from approximately 100 microseconds to 400 or 500

microseconds. Values above this will reflect unusual anomaly decays, often associated with man-made conductors (culture effects).

Culture response (from power lines, pipelines, fences) can have a great variety of signatures on the TDEM channels, depending on the orientation of the feature relative to the flight line, the degree of grounding, the amount of current flow, etc. If the signature from a culture response is completely incoherent and does not follow a prescribed exponential decay pattern, it will be automatically sampled out by the decay constant calculation and therefore will not show up in the resulting values. On the other hand, if the signature from the culture response is coherent and follows a normal prescribed decay pattern, it will be treated as a valid conductor during the calculation and will be reflected in the resulting values.

5.4) Apparent Resistivity Calculation

The INPUT system was designed for the detection of massive sulphide conductors in the Canadian shield environment. At the time of system development, overburden and conductive ground was considered to be "geological noise" and of no interest. Thus the system was designed so that the overburden response would be small, only being detected on the early channels. The INPUT waveform is such that it is not possible to convert the individual channel amplitudes to an apparent resistivity directly. Figures 5.2 and 5.3 display the amplitude response over a homogeneous half-space and a horizontal thin sheet respectively. It becomes apparent that unique resistivity values cannot be derived from the amplitude of a single channel since the amplitude response rolls over as one crosses from lower to more conductive ground, yielding a dual solution. It is therefore necessary to analyse the relative amplitude changes from channel to channel (decay information) to properly isolate the conductivity/resistivity value.

As evident on the nomograms (figures 5.2 and 5.3), the decay rate of the off-time response increases (slows down) as conductivity increases. A set of pre-computed decays at a range of conductivities can

thus be used for converting the decay rate (TAU) to the conductivity or resistivity. Altitude variations are dealt with by generating decays at a range of aircraft flight heights and interpolating between these.

Now, since the method of calculating a resistivity value from TDEM data depends on being able to obtain an initial decay constant value (TAU), the lower limit of resolution is again controlled by the noise level and the amount of signal (as discussed in the section on decay constant calculation). Based on the theoretical response of the homogeneous half-space model and considering the general noise levels with the EM system, the upper limit of resistivity that can thus be defined from the off-time data is in the order of 0.001 to 0.002 S/m or 500 to 1000 ohm-m. In areas of greater resistivity, the signal strength in the off-time will be too low to allow a good calculation. For the present dataset, the homogeneous half-space model was used to translate the initial TAU values to apparent resistivity values. The data is stored in ohm-metres and was gridded along a 40 m cell size. Both profiles and grids of apparent resistivities are available in the database.

The apparent conductivity values were also derived, as these are strictly the inverse values of resistivity. These are stored in the profile database only, in units of millisiemens/metre.

5.5) Correction for Asymmetry (Deherringboning)

The inherent asymmetry of a TDEM system (separate transmitter loop and towed bird receiver arrangement) results in a pronounced directional effect noted along the edge of flat-lying conductive sheets when flying along alternating line directions. This aspect of TDEM data, although aesthetically unappealing, becomes a very diagnostic element as it allows the distinction between response from flat lying conductive sheets and vertical conductors which do not display the directional stagger. However, for imaging purposes, this directional effect, referred to as herringboning, can be corrected (de-herringboned) to produce a cosmetically more appealing image. This is done by obtaining a weighted average of the response from each pair of survey lines (from alternating flight directions), making sure to retain the maximum signal response from the appropriate line to maintain the original response amplitudes.

In some areas of extensive flat-lying conductive response (conductive overburden cover), severe coupling effects with alternating line direction were noted between the ground and receiver, resulting in pronounced linearity in the grids. This was evident even after the normal correction for asymmetry (de-herringboning). To improve the appearance of the final EM images, a directional grid filtering process was applied to the final corrected grids to better average the values from one line direction to another.

Since the herringbone patterns are geophysically diagnostic to distinguish between flat and near vertical bedrock conductors, regular and de-herringboned grids of the decay constant and the apparent resistivity values have both been supplied, including the de-herringboned directional grid filtered decay constant and resistivity grids.

5.6) Updated EM Anomaly Database

Historically, the OGS EM surveys were focused on base metal exploration in the greenstone belts. In order not to detract from this objective, the original contractors compiling the EM anomaly database, were requested not to display the EM response from surficial/overburden conductors on the EM anomaly maps. This resulted in criticism from the users of the published maps, since incomplete EM information on the maps led to sometimes inappropriate methods or survey specifications for ground follow-up and could also lead to missing a valid weak or deep conductor which could have been initially misinterpreted as a surficial source.

In the current project, from the revised and base level corrected electromagnetic channels, all anomalous EM responses have been picked. This has resulted in an increased number of anomalies than shown on the published OGS maps. The separation of bedrock from surficial response is both subjective and interpretive. The interpretation of the EM anomaly's significance is dependent upon the type of target sought, it's relationship to the geology, associated geochemical or magnetic responses, etc. The deletion

or even the classification of anomalies based upon the EM response alone is not only inappropriate but possibly misleading.

Therefore all anomalies have been represented in the database. Classification is interpretation which is best left to the user of the data; however, in the present case the sub-classifications of cultural, surficial, and normal (bedrock) responses has been done.

The University of Toronto Plate programme, with some modifications, is used to compute the theoretical secondary field response produced by various common geological models, relating amplitude and decay rate of the secondary field to the conductivity-thickness and depth of the causative body. For base metal exploration in greenstone belts, typically a vertical plate model (600 m strike length by 300 m depth extent) is used as the model for anomaly fitting. The anomaly selection routine scans the amplitude, width and decay of each anomaly simultaneously. Having located an anomaly (from its peak value), the routine computes the conductivity-thickness product and the depth to the top of the plate below surface. The nomogram shown in figure 5.4 illustrates the relationship of channel amplitudes to conductance (CTP). With reference to a provisional EM anomaly map, the selection is then studied on a graphic screen by an experienced geophysicist to ensure that all valid anomalies have been selected. Any errors in the automated anomaly selection are corrected directly via a graphic screen editing routine.

After reprocessing of the data, all anomalies (even if only affecting the 1st off-time channel) were identified with the following information (when applicable) stored in the anomaly database:

- Flight number;
- Line number;
- Line part number;
- Line heading;
- Anomaly type;
- Anomaly identifier;
- Fiducial position of conductor axis;

- Latitude;
- Longitude;
- UTM Easting;
- UTM Northing;
- Flying altitude above ground;
- Amplitude of initial picking channel (ppm);
- Amplitude of a later reference channel (ppm);
- Number of channels affected above background noise;
- Derived conductivity-thickness-product (siemens);
- Derived depth below surface to the top of the source;
- Computed decay constant value;
- Computer apparent resistivity value.

The information contained in the updated anomaly database was plotted and verified against the original published OGS maps to ensure that all the original anomaly information had been retained and to control the amount of new information being added.

6) QUALITY CONTROL AND QUALITY ASSURANCE

For each survey, the contractor was responsible for data merging, quality control and final archiving. All data has undergone quality control (QC) and quality assurance (QA) at least twice; once when data was submitted as an interim deliverable and again on the final deliverables prepared after any required additional adjustments and modifications were carried out. QA/QC was carried out both by the contractor and by the Ministry of Northern Development and Mines. Digital profiles, grids and EM anomalies were all included. At this stage the data was not edited in any way. The QA/QC procedures are summarized below.

Some deficiencies in the data fell within the reprocessing contract specifications and were not repaired. Others, such as original data acquisition problems, were beyond the control of the sub-contractors. For example, certain original flights may have been excessively noisy resulting in less than image quality derived products, e.g., resistivities. Any data deficiencies noted by the QA/QC officers that were not repaired are noted in section 7.5.

6.1) Flight Path

Overview scale plots of the flight path were generated for each survey and inspected in conjunction with gridded products to ensure that databases were complete.

6.2) Profile Data

Processed magnetic and electromagnetic data files were obtained in various formats from the processing contractors. An audit of each survey block was carried out to ensure that each magnetic record was present in the electromagnetic database. Missing data was noted and retrieved from the appropriate contractor.

The profile data sets were merged using both proprietary software and/or Geosoft Oasis montaj.

A post merge statistics file was produced to ensure that all input data were present.

Each survey block was prepared in both Geosoft ASCII .XYZ and Oasis montaj formats.

Using the Oasis montaj editor, each database was graphically inspected in a stacked profile format on a line-by-line and channel-by-channel basis. Instances of drift or mis-levelling, spherics, noise spikes, data drop-outs, and any other obvious processing artifacts were identified for adjustment by the appropriate magnetic or EM contractor. Concurrently, the data was also inspected by MNDM for independent QC.

In cases where data required repair, new archives were obtained and the steps above repeated.

Once data were approved by both the contractor and MNDM as meeting the contract specifications, the final corrected profile data were converted to the specified final formats and delivered on CD-ROM and magneto-optical disk.

6.3) Grid Data

The interim magnetic grids were supplied in Geosoft .GRD and .GXF formats, the latter to preserve the equivalent of 4-byte resolution. The interim frequency-domain electromagnetic grids were supplied in Geosoft .GRD and .GXF format. The interim time-domain electromagnetic grids were supplied in 4-byte binary format.

All interim grids were shadowed and reviewed on-screen using Geosoft MAPVIEW or Oasis montaj. Obvious deficiencies and/or disagreements with the profile database were noted. Once the final grids were created, the data were converted to the specified final format and delivered on CD-ROM and magneto-optical disk.

6.4) EM Anomaly Data

The re-picked ASCII EM anomaly database was converted to a Geosoft compatible ASCII format for and an Oasis montaj database for QC purposes. Selected portions of each survey were plotted and examined in conjunction with the published OGS total field and electromagnetic maps. The discrepancies between the published EM anomaly picks or suspect non-picks were brought to the attention of the appropriate contractor for further adjustment and/or re-picking. Once approved the re-picked anomalies were converted to the specified final format and delivered on CD-ROM and magneto-optical disk.

7) SURVEY SPECIFIC DETAILS - KIRKLAND LAKE SURVEY

7.1) Flight Path Reprocessing

Analysis of the flight path for 84 control points produced an average error of 72 m and a maximum error of 163 m. These results were not considered acceptable for the purposes of this project, and the flight path data were positioned using the procedure outlined in section 2.2.

The original maps published by the Ontario Geological Survey incorporated the survey block as a numerical identifier in the flightline number, as a single digit prefix (i.e. block A=1, ... block E=5). This prefix was dropped for preparation of the current dataset, so that the flightline originally labelled 15410 (i.e. line 5410 in Block A) is now labelled 5410 in the current dababase. The line numbering for all control lines remain unique after the prefix was dropped. However, this was not the case for the tie lines, which have now been renumbered starting with 9010 in block A, and incrementing by 10 through to 9150 in block E.

7.2) Altimeter Data Reprocessing

The digitizing and scaling of missing radar altimeter data is discussed in Section 7.4.

7.3) Magnetic Data Reprocessing

The sampling rate of the magnetic data was twice that of the electromagnetic data for Kirkland Lake area Consequently, every second record in the profile database contains dummy values for the magnetic channels.

Micro-levelling:

For Kirkland Land the noise amplitude limit was 100 nT, and the Naudy filter length was 1000 m (see Section 4.3).

Calculation of Reprocessed Total Magnetic Field Grids:

For the Kirkland Land area two types of total magnetic field grids were generated.

a) Total magnetic field grid (unsmoothed and unfiltered)

From the total field flight line XYZ data, which was edited, levelled, corrected for IGRF, micro-levelled, and levelled to the 200m Ontario Single Master Aeromagnetic grid, a 40m x 40 cell size grid was computed using the minimum curvature algorithm. During QC/QA of the total field image, it was noticed that at specific locations where adjacent flightlines touch or cross each other, minor level differences are apparent. To alleviate this problem and to provide high image quality grids, the offending section(s) of one of the touching or crossing flightlines, at each location, was dummied prior to re-gridding. The resultant grid is referred to as KLMAGONL.OMG in the database.

b) Smoothed total magnetic field grid:

A minor amount of flightline noise still remained in the total magnetic field grid, as produced in section (a) above, including a "spotty" appearance in the image in magnetically quiet areas. The noise could not be removed further unless strong micro-levelling filters were applied which would result in loss of data resolution and damping of real geological signal. To remove the remaining noise, and to improve the coherence of the geological signal, a deherringbone filter was applied. The herringbone noise appeared as a fringe on the edge of certain linear anomalies, with a wavelength of twice the flight line spacing (i.e. 2 x 200 m).

In order to remove this noise, a 400 m Naudy low-pass filter was applied perpendicular to the flightline direction of each block. This removed the herringbone noise without causing any loss of resolution in the flightline direction, so that the linear geological signal remained sharply defined. To improve the cosmetic appearance of the filtered grid, three passes of a Hanning smoothing filter were applied.

New magnetic values from the de-herringboned grid were extracted as an extra channel (FMAGGRDX) in the profile database, in order to give the user the option of working with a de-herringbone set of profiles. The smoothed total field grid is referred to as KLMAGOLS.OMG.

Three channels of magnetic data are provided in the profile dababase, all of which were reprocessed, microlevelled and levelled to the Ontario Master Aeromagnetic Grid. They are:

FMAGONTL - unsmoothed, no gaps, no corresponding grid;

FONLEDTC - unsmoothed, edited to remove sections of crossing or touching lines and remicro-levelled to produce optimal results, used to prepare the grid KLMAGONL.OMG; and

FMAGGRDX - no gaps, extracted from the smoothed grid KLMAGOLS.OMG.

Calculation of Second Vertical Derivative:

Due to the inherent noise problems in the total magnetic field flight data two different second vertical derivative grids, KLMAG2VD.OMG, and KL2VDS.OMG, were computed from the total magnetic field grid (unsmoothed and unfiltered KLMAGONL.OMG), and smoothed total magnetic field grid (KLMAGOLS.OMG), respectively.

The radially averaged power spectrum and the picked white noise levels are shown in Figure 7.1. The second vertical derivative optimum filter response is shown in Figure 7.2.

Figure 7.1: Kirkland Lake
Power Spectrum

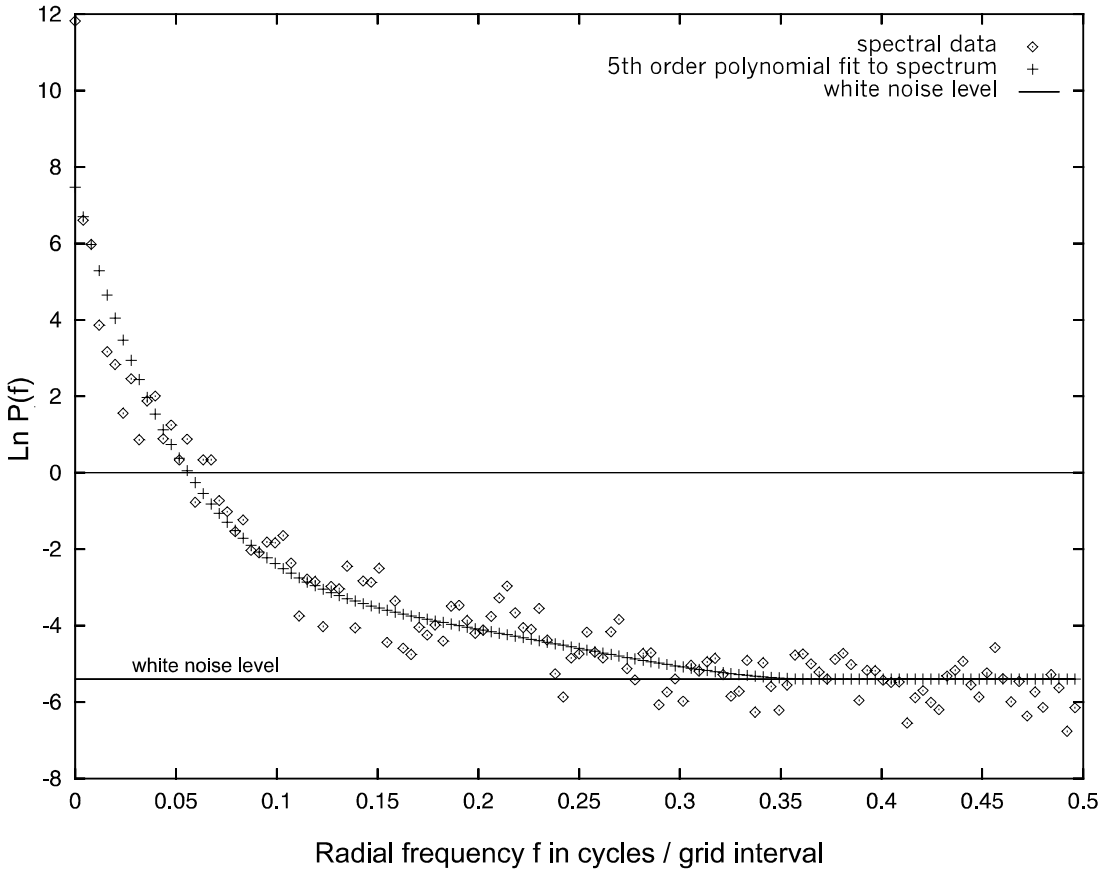
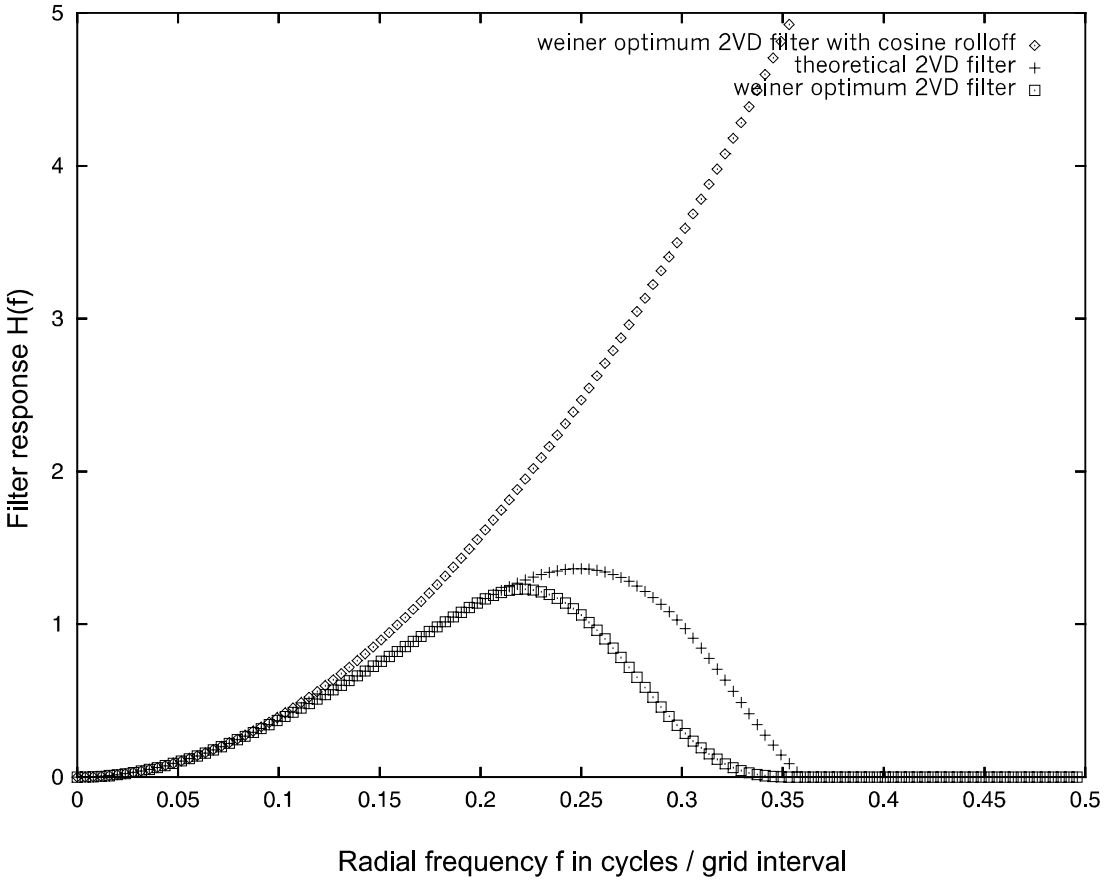


Figure 7.2: Kirkland Lake
Second Vertical Derivative (2VD) Filter



Cutoff for cosine rolloff filter: Start f = 0.22
End f = 0.36

7.4) Electromagnetic Data Reprocessing:

The following data was missing on the original OGS digital tapes and had to be recovered by digitizing the corresponding traces on the analogue records:

BLOCK	LINE	FIDUCIAL LIMITS	MISSING DATA
A	5330	8271500-8294100	Ch 5,6, Hz
	6570	2691450-end	Ch 1,2,3,4,5,6 Hz, radar
	6710	2981775-end	Ch 1,2,3,4,5,6, Hz, radar
	6720	2925425-end	Ch 1,2,3,4,5,6, Hz, radar
	6820	2190050-end	Ch 1,2,3,4,5,6, Hz, radar
	9021	5635300-5638800	Ch 1,2,3,4,5,6, Hz. radar
	6240	731100-741400	Radar
	6320	974500-989850	Ch 3,4,5,6, radar
	6260	783400-790050	Ch 1,2,3,4,5,6, Hz, radar
	6920	entire line	Ch 1,2,3,4,5,6, Hz, radar
	6690	entire line	Radar
	6730	entire line	Radar
	6740	entire line	Radar
	6750	entire line	Radar
	6760	entire line	Radar
	6780	entire line	Radar
	6790	entire line	Radar
	6800	entire line	Radar
	6830	entire line	Radar
	6840	entire line	Radar
	6850	entire line	Radar
	6860	entire line	Radar
	6870	entire line	Radar
	6880	entire line	Radar
	6890	entire line	Radar
	6900	entire line	Radar
	6910	entire line	Radar
B	820	208500 - 211500	Ch 1,2,3,4,5,6 Hz, radar
	1070	382800-end	Ch 1,2,3,4,5,6, Hz, radar
C	260	2662600-end	Ch 6

D	3784	start - 2432400	Ch 1,2,3,4,5,6, Hz, radar
	4420	start - 4757100	Ch 1,2,3,4,5,6, Hz, radar

Scaling of digitized radar data:

The radar trace was displayed at a vertical scale of 100 feet/cm, with the value of 400 feet located at 2.835 inches from the bottom of the chart, and increasing downward in a linear fashion.

So for X = 2835 digitizer units, Y = 400 ft.
X = 2639 digitizer units, Y = 450 ft.
X = 2443 digitizer units, Y = 500 ft.

This provides a linear regression function of Y = 1123 - 0.255X. Conversion of digitizer units to feet was then:

(value x -0.255) + 1123

Scaling of digitized Hz monitor to millivolts (?):

The Hz monitor trace is displayed on the analogue records at a vertical scale of 70 units/cm, increasing downward, with a base value of -70.

So for X = 5866 digitizer units, Y = -70
X = 5472 digitizer units, Y = 0
X = 4016 digitizer units, Y = 260

This provides a linear regression function of Y = 976 - 0.178 X
Conversion of digitizer units to millivolts (?) was then:

(value x -0.178) + 976

Scaling of INPUT channels to ppm:

The general formula used to convert raw INPUT signal (mv) to a ppm value is:

Calibration Signal x 10^6/1/2 of voltage at the bird = ppm for full gain

Calibration signal: standard used, normally 4 mv

Full gain deflection: 8 cm, as measured on the analogue records

Bird voltage: Unknown, typically would have ranged from 1.2 to 3.2 V, peak-to-peak.

Resulting scaling factors, based on varying voltage at the bird:

1/2 peak-to-peak voltage	Full gain (ppm)	scaling factor (ppm/cm)
0.6	6666	833
0.7	5714	714
0.8	5000	625
0.9	4444	556
1.0	4000	500
1.1	3636	455
1.2	3333	416
1.3	3076	385
1.4	2857	357
1.5	2666	333
1.6	2500	312

Check on analogue scaling factor by comparing Channel 2 amplitude as measured on the analogue record and posted on the original published anomaly maps, for selected anomalies:

BLOCK	LINE	FIDUCIAL	ANOMALY	CH2 ANALOGUE (cm)	CH2MA (ppm)	SCALING (ppm/cm)
D	4427	225065	C	6.25	3115	498
D	4346	72031	A	1.50	400	267
A	1574	922328	B	1.35	650	481
E	5323	27907	A	0.55	340	618

Average scaling factor = 354 ppm/cm

As quoted in the general literature = 500 ppm/cm

Closest corresponding scaling from estimates on varying the bird voltage = 357 ppm/cm for a voltage of 1.4 (2.8 peak to peak)

Scaling factor selected was 357 ppm/cm, based on best agreement between analogue charts, published anomaly maps, and estimate of voltage at the bird.

The digitized value of Channel 1 (in digitizer inches x 1000) baseline is 4235, with 0.15 inch offset between successive channels (equal to 136 ppm, assuming 357 ppm/cm) and anomaly peaks increasing downward.

So for X = 4235 digitizer units, Y = 0 ppm

X = 3684 digitizer units, Y = 500 ppm

X = 3283 digitizer units, Y = 1000 ppm

This provides a linear regression function of Y = 3840 - 0.907X.

Allowing for an offset of 136 ppm between channels, the conversion of digitizer units to ppm for Channels 1 to 6 becomes:

Channel 1 (value x -0.907) + 3840

Channel 2 (value x -0.907) + 3976

Channel 3	(value x -0.907) + 4112
Channel 4	(value x -0.907) + 4248
Channel 5	(value x -0.907) + 4384
Channel 6	(value x -0.907) + 4520

Conversion of the EM data from millivolts, as stored in the original OGS digital archives, to ppm:

The EM data, originally delivered in millivolts needed to be converted to ppm values. This step was done by applying the standard digital gain factors which are:

Channel 1	multiplied by 6.250
Channel 2	multiplied by 3.125
Channel 3	multiplied by 1.562
Channel 4	multiplied by 1.562
Channel 5	multiplied by 1.562
Channel 6	multiplied by 1.562

Lag Correction:

All the EM data (as recovered from the analogue records and as converted from the digital millivolts to ppm), were corrected for 4 samples (2 seconds) of system lag. The alignment of the data after correction was verified by producing a series of stacked profile plots.

Base level adjustments:

Difference traces were created for each of the channels, before and after the baseline levelling adjustments, and statistics run on these differences to quantify the adjustments made.

CHANNEL	BLOCK A	BLOCK B	BLOCK C	BLOCK D	BLOCK E
1. mean adjustment	+18	+53	+51	+45	+12
standard deviation	±84	±90	±106	±87	±87
2. mean adjustment	+9	+21	+32	+26	+7
standard deviation	±65	±50	±81	±59	±50
3. mean adjustment	-12	-24	+5	-13	-18
standard deviation	±69	±55	±85	±61	±38
4. mean adjustment	-2	-1	+10	+9	-10
standard deviation	±67	±36	±79	±55	±27
5. mean adjustment	-12	-8	+11	-1	-5
standard deviation	±69	±35	±86	±57	±26
6. mean adjustment	-10	-5	+4	+2	-11
standard deviation	±76	±40	±109	±62	±25

7.5) Known Data Bugs

As shown on the original published maps, the line spacing for the Kirkland Lake survey varied considerably from the nominal 200 m. Gaps in excess of 500 m, and locations where two or even three flightlines crisscross, are not uncommon. It is apparent from the magnetic data that this is due, in part, to poor recovery of the flight path. As a result, some flightline - related noise remains apparent in the image products.

The northern part of the Kirkland Lake survey area was reflown in 1992. Superior products for that portion are provided by the Blake River Syncline Area (ERLIS Dataset CD-ROM 1006).

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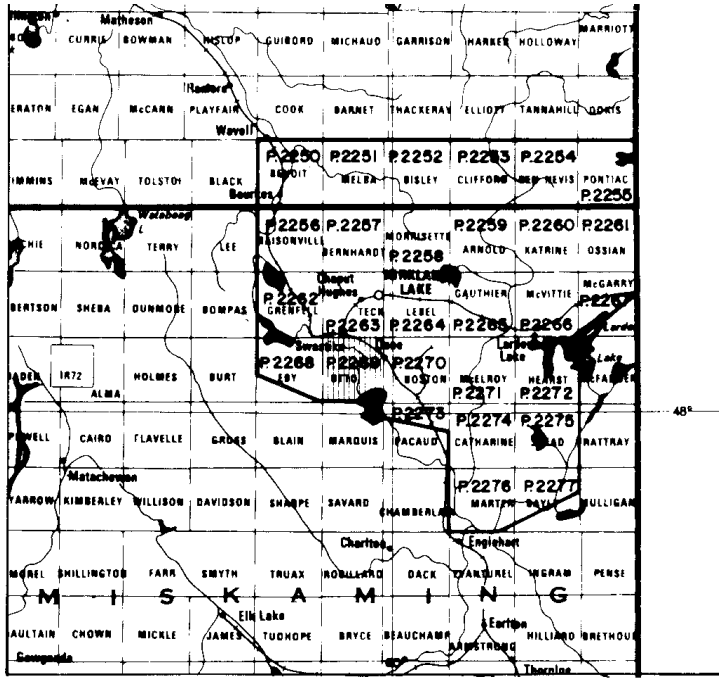
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APPENDIX A

SURVEY HISTORY

A1)	**Introduction:**	Contractor:	Questor Surveys Ltd.
		Type of Survey:	TDEM (INPUT)
		Size:	12,335 km
		Dates flown:	February to March, 1979
		Nominal terrain clearance:	122 m
		Flight grid:	Block A - 010^{o} heading at 200 m spacing Block B – 045^{o} heading at 200 m spacing Block C - 062^{o} heading at 200 m spacing Block D - 040^{o} heading at 200 m spacing Block E - 000^{o} heading at 200 m spacing
A2)	**Location:**	Nearest town:	Kirkland Lake
		Coordinates:	Latitude 47^{o}50' N to 48^{o}22' N. Longitude 79^{o} 30' W to 80^{o} 16' W
		OGS map numbers:	P.2250 to P.2277 inclusive

Figure A1: Kirkland Lake Survey Location Map



A3) Survey equipment on-board the aircraft:

- EM System

Model:	INPUT MK VI
Type:	TDEM
Coil orientation:	horizontal
Transmitter loop:	190 m^2
Frequency:	144 Hz

Pulse width:	1.05 ms
Off-time:	2.422 ms
Rx-Tx separation:	horizontal 93 m
	vertical 69 m
Sample interval:	0.5 second
Integration time constant:	1.25 sec
Number of channels:	6

Channel mid-positions from turn-off: 0.27, 0.45, 0.72, 1.08, 1.53, 2.07 ms

- Magnetometer

Model:	Sonotek 5010
Type:	Proton precession
Sensitivity:	1 nT
Sampling interval:	1 sec
Installation:	Nose boom

- Base station

Model:	Geometrics 823
Type:	Proton precession
Sensitivity:	1 nT
Sampling interval:	10 sec

SUMMARY OF EM DATA PROCESSING PARAMETERS USED

1. Lag Adjustment: 4 samples for EM channels, 4 samples for Hz monitor

2. Base level adjustments: interactively done via a graphic screen

3.	Digitizing of analogue traces:	EM channels recovered using a vertical scaling factor of 357 ppm/cm; Radar altimeter recovered using a vertical scaling factor of 100 feet/cm; Hz monitor recovered using a vertical scaling factor of 70 mv/cm
4.	Conversion of EM from mv to ppm:	Ch 1 x 6.250, Ch 2 x 3.125, Ch 3 x 1.562 Ch 4 x 1.562, Ch 5 x 1.562, Ch 6 x 1.562
5.	Editing of spherics:	removed by interpolation via a graphic screen
6.	EM channel filtering:	triangular adaptive filter used, minimum filter width of 3 points, maximum filter used of 11 points, local gradient threshold of 20 ppm
7.	TAU values:	channels 1 to 6 fitted to an exponential function, noise threshold of 20 ppm
8.	Filtering of TAU:	11 point bell filter
9.	Resistivity values:	translated from the TAU values, channels 1 to 6 used, noise threshold of 25 ppm, homogeneous-half-space model.
10.	Gridding of EM:	40 m cell size, linear interpolation
11.	Anomaly selection:	Vertical plate model used (600 m strike length by 300 m depth extent). Channels 1 to 6 used, noise threshold

in fitting 20 ppm. Minimum amplitude accepted for channels 1 to 6; 120, 85, 70, 55, 45, 35 ppm.

APPENDIX B

CONTENTS OF PROFILE, GRID, KEATING AND ELECTROMAGNETIC ANOMALY DATABASES

Kirkland Lake Area, Ontario - Profile Database Contents:

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

.csv - flat ASCII file

.gdb - Geosoft OASIS montaj binary database file (no compression)

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

LINE		Survey/Control line number
X_NAD27	metres	UTM Easting NAD27 Zone 17
Y_NAD27	metres	UTM Northing NAD27 Zone 17
X_NAD83	metres	UTM Easting NAD83 Zone 17
Y_NAD83	metres	UTM Northing NAD83 Zone 17
FID	seconds	Fiducial
LAT_NAD27	degrees	Latitude NAD27
LON_NAD27	degrees	Longitude NAD27
LAT_NAD83	degrees	Latitude NAD83
LON_NAD83	degrees	Longitude NAD83
FRADAR	metres	Final Radar Altimeter
O60HZMON	microvolts	Original Hydro Monitor
F60HZMON	microvolts	Final Hydro Monitor
OMAGLEV	nT	Original Magnetic Total Field
FMAGEDIT	nT	Final Edited Magnetic Field
FMAGIGRF	nT	Final IGRF Field
FMAGONTL	nT	Final Total Magnetic Field Levelled to Ontario Single Master Grid
FONLEDTC	nT	Final Total Magnetic Field Levelled to Ontario Single Master Grid. Touching or crossing lines data dummied
FMAGGRDX	nT extracted	Smoothed Final Total Magnetic Field from grid KLMAGOLS.OMG
REMCH01	ppm	Raw EM Channel 1

REMCH02	ppm	Raw EM Channel 2
REMCH03	ppm	Raw EM Channel 3
REMCH04	ppm	Raw EM Channel 4
REMCH05	ppm	Raw EM Channel 5
REMCH06	ppm	Raw EM Channel 6
RPEMCH01	ppm	Raw Processed EM Channel 1
RPEMCH02	ppm	Raw Processed EM Channel 2
RPEMCH03	ppm	Raw Processed EM Channel 3
RPEMCH04	ppm	Raw Processed EM Channel 4
RPEMCH05	ppm	Raw Processed EM Channel 5
RPEMCH06	ppm	Raw Processed EM Channel 6
FEMCH01	ppm	Final EM Channel 1
FEMCH02	ppm	Final EM Channel 2
FEMCH03	ppm	Final EM Channel 3
FEMCH04	ppm	Final EM Channel 4
FEMCH05	ppm	Final EM Channel 5
FEMCH06	ppm	Final EM Channel 6
DECAYCON	microseconds	Apparent Decay Constant
CONDTVTY	S/m	Apparent Halfspace Conductivity
RESIST	ohm-m	Apparent Halfspace Resistivity

Grids:

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

Grids are named so that the first two characters are the survey area initials followed by a standard set of grid type codes, e.g., KLDCDE is the Decay Constant De-herringboned for KIRKLAND LAKE Area (KL).

dc	microseconds	Decay Constant
dcde	microseconds	Decay Constant Deherringboned
dcdef	microseconds	Decay Constant Deherringboned and Filtered
res	ohm-m	Resistivity
resde	ohm-m	Resisitivity Deherringboned

resdef	ohm-m	Resisitivity Deherringboned and Filtered
magonl	nT	Total Magnetic Field levelled to Ontario Single Master Grid
mag2vd	nT/m^2	Second vertical derivative of the Total Magnetic Field
magols	nT	Bigrid and Hanning Filtered smoothed Total Magnetic Field levelled to Ontario Single Master Grid
2vds	nT/m^2	Smoothed Second vertical derivative of the Total Magnetic Field

Time domain Anomaly Database Contents:

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

.csv – ASCII comma-delimited format

.gdb – Geosoft OASIS montaj binary database file

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

ID	na	Unique Anomaly identifier (see Note 3)
DATAID	na	Dataset identifier
Flight	na	Flight number
Line	na	Line number
Let	na	Numeric Anomaly identifier for Line (see Note 4)
Fid	na	Fiducial value at anomaly peak
LON_NAD27	Dec. degrees	Longitude NAD27
LAT_NAD27	Dec. degrees	Latitude NAD27
LON_NAD83	Dec. degrees	Longitude NAD83
LAT_NAD83	Dec. degrees	Latitude NAD83
Cat	N,S,C,Q	Anomaly type (N=normal, S=surficial, C=cultural, Q=Undetermined)
Fradar	m	Aircraft terrain clearance
Decaycon	microseconds	Apparent decay constant
Resis	ohm-m	Apparent resistivity from half-space model
PCH	ppm	Amplitude of initial picking channel (Channel 03)
LCH	ppm	Amplitude of later reference channel (Channel 05)
NC	na	Number of channels deflected above background noise

CTP	S	Derived conductivity-thickness-product
DEP	m	Derived depth below surface to top of the source
Line_part	na	Line part number (Used to identify reflown lines)
Line_type	na	Line type (L=survey line T=tie line)
Azim	degree E of N	Average line heading
X_NAD27	m	UTM Easting NAD27 Zone 17
Y_NAD27	m	UTM Northing NAD27 Zone 17
X_NAD83	m	UTM Easting NAD83 Zone 17
Y_NAD83	m	UTM Northing NAD83 Zone 17

SYSTEM CONFIGURATION:	Pulse repetition rate	144 Hz
	Pulse width	1050 us
	Offtime	2422 us
	Receiver-transmitter horizontal separation	93 m
	Receiver-transmitter vertical separation	69 m
	Receiver axis orientation	Horizontal

MODEL USED IN FITTING:	Vertical plate model
	Length of 600 m
	Depth extent of 300 m
	Vertical dip
	Strike perpendicular to flight line

NOTE 1. Selections with 0 in the CTP and DEP columns reflect surficial or cultural selections, which were not fitted to the vertical plate model.

NOTE 2. Selections with a negative number shown in the DEP column indicate a normal selection (bedrock) where the vertical plate model used does not properly reflect the true conductor geometry.

NOTE 3. For non-cultural anomalies, the unique anomaly identifier 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 for that line padded with leading zeroes to three digits. For cultural anomalies, the leading numeral '1' and any line number padding zeroes are omitted so that cultural anomalies have a four to nine digit integer. For example, 1000101007 represents the seventh non-cultural anomaly on Line 101, 101005 represents the fifth cultural anomaly on Line 101, and 590101002 represents the second cultural anomaly on Line 590101.

NOTE 4. Numeric anomaly identifiers count up independently for cultural and non-cultural classifications.

Kimberlite Pipe Correlation Coefficients Database Contents:

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

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

Channel Name	Description	Units
x_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 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

A geographically referenced Keating colour image is provided in GeoTIFF format for use in GIS applications.

APPENDIX C

2002 DIGITAL ARCHIVE RE-FORMATTING NOTES

The changes made to the AMEM digital archives during the 2002 data re-formatting project are described below.

Coordinate Systems

The 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 Zone 17 UTM coordinate systems (NAD27_NTv2 and NAD83) as indicated by the codes “27” or “83” affixed to the file name.