NWT Open File 2015-02
Historical aeromagnetic surveys over the north shore of the East Arm, Great Slave Lake, NWT

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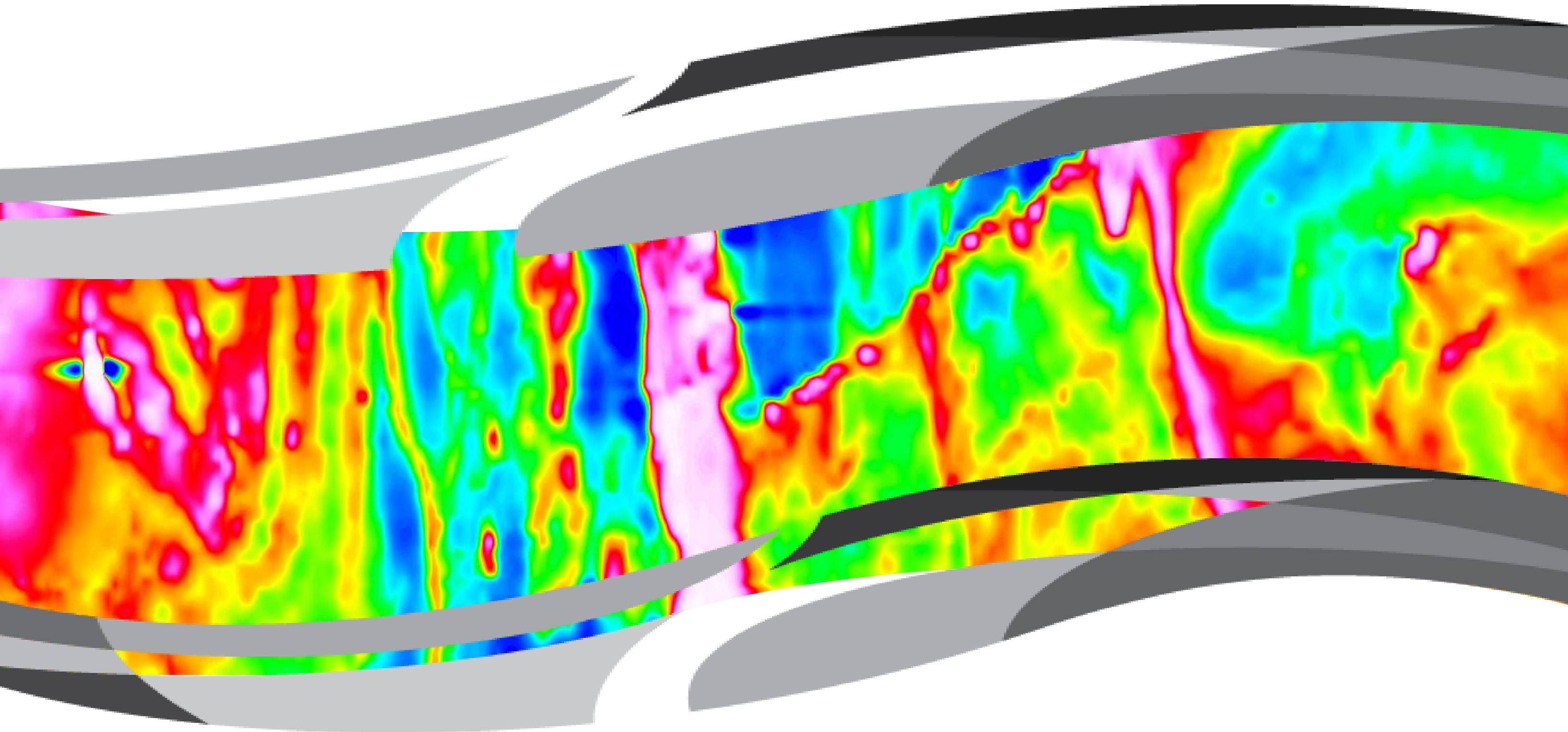

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NORTHWEST TERRITORIES
GEOLOGICAL SURVEY

Government of
Northwest Territories

NWT Open File 2015-02

HISTORICAL AEROMAGNETIC SURVEYS OVER THE NORTH SHORE OF THE EAST ARM, GREAT SLAVE LAKE, NWT

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BACKGROUND

During the middle to late 1990's, eleven fixed-wing aeromagnetic surveys were flown by Aeroquest Ltd. for Covello, Bryan and Associates, Ltd. (CBA, Ltd.; now Aurora Geosciences Ltd.) on behalf of a number of clients. The surveys covered various mineral properties on the north shore of the East Arm of Great Slave Lake, Northwest Territories (NWT; Fig. 1). The data from those surveys have been donated by Aurora Geosciences to the public, in care of the Northwest Territories Geological Survey (NTGS), and are herein released.

The 1990's were an exciting time for the mineral exploration industry in the Northwest Territories. The 1991 discovery of diamonds at Lac de Gras initiated the largest staking rush in Canada's history. During the following decade, an unprecedented amount of till sampling, airborne and ground geophysics, mapping, and drilling took place in the Slave Geological Province of the NWT (now NWT and Nunavut). All of this activity took place at the dawn of the digital era, when most people still did not even use email.

The airborne data presented here were acquired and processed digitally, but at that time within the mineral exploration sector, long-term archiving of digital datasets with appropriate metadata was an art in its infancy. As a consequence, this classic dataset is incomplete in some respects. We have endeavored to make the data as useful as possible despite this limitation.

DATA

The eleven aeromagnetic surveys donated by Aurora Geosciences comprise Storimin, Wiscan, NP_Tete, NP_MacKay, NP_Denis, NP_Barnston, MG_Misty, HF_West, HF_Northwest, HF_East and HF_Central. Survey footprints are shown on a geological background in Figure 2. For each of the surveys, one geosoft-format grid file (GRD) and one geosoft-format database (GDB) were donated. These data are provided largely as they were received from Aurora Geosciences, with the exception of some changes described below and the addition of whatever metadata could be deduced.

All database coordinates refer to a Universal Transverse Mercator projection for Zone 12N, based on North American Datum 1927 NWT-Sask (now known as NWT-Nunavut-Saskatchewan). All grid files use this projection as well.

This document (NWT Open File 2015-02.pdf) and the accompanying tables in Survey_Metadata.pdf provide as much information about the surveys as possible, including a narrative explanation of how data acquisition and processing was typically carried out by CBA Ltd. during those years, and therefore how it was probably carried out for these surveys. Minor alterations made to the data are detailed in the Survey_Metadata.pdf tables. The Explanation column in those tables contains a deduction of what the channel data represent, derived from available information and recollection of how things were done. It should be regarded as a best guess rather than irrefutable fact.

Database files (GDB format) were created by CBA Ltd. but have been modified for clarity. None of the databases appear to be the originals created by Aeroquest, nor are they the final, processed versions that would have been created by CBA Ltd. for their clients. Minor issues required

Figure 1. Location of the East Arm of Great Slave Lake in the Northwest Territories of Canada, on a background of colored topography (from lower to higher elevation: light green, yellow, dark green, orange, brown). Box shows location of Figures 2 and 3.

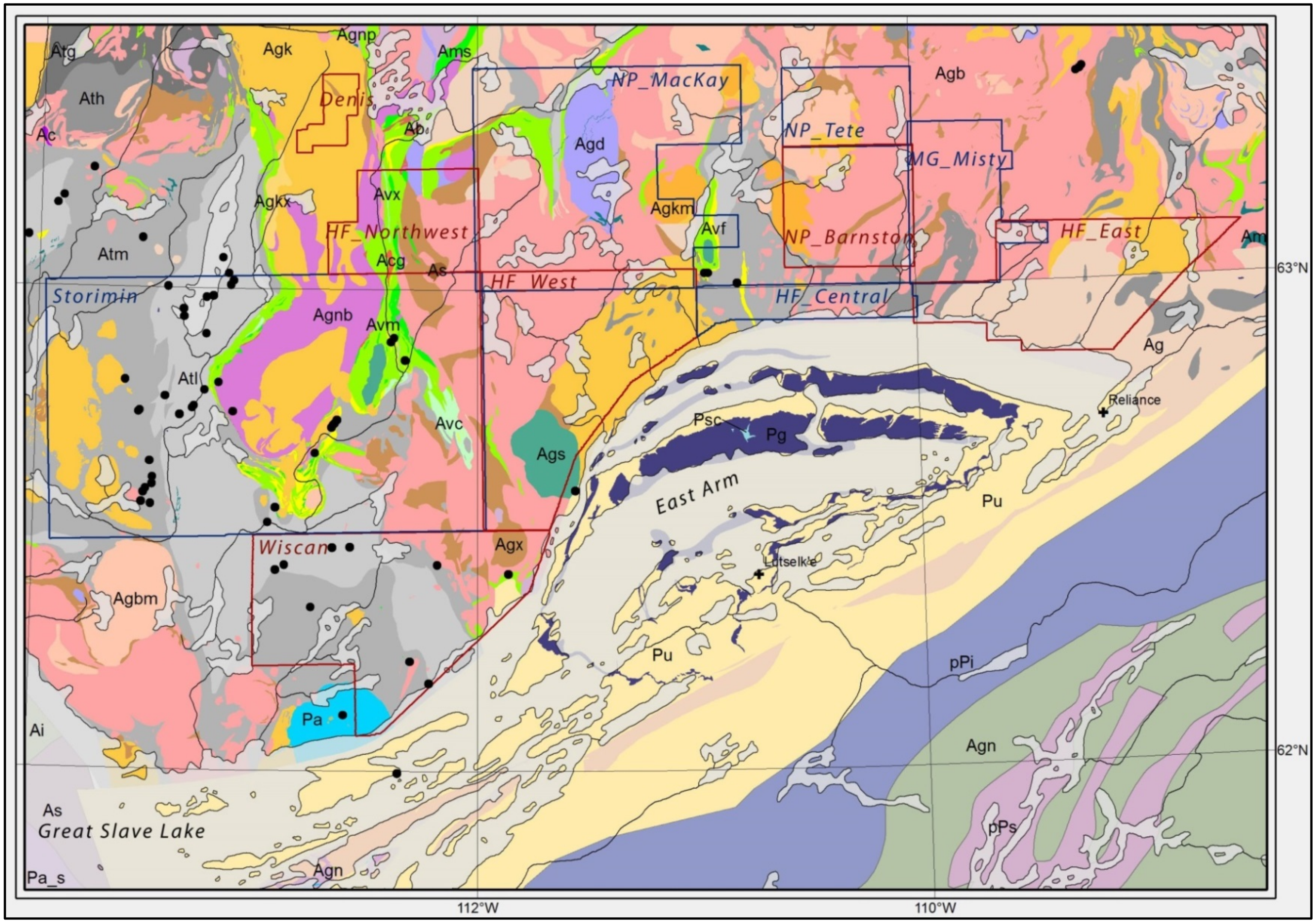

Figure 2. Footprints of aeromagnetic surveys on the north shore of East Arm, Great Slave Lake, on a bedrock geology background. Black dots are mineral deposits with development stage of Advanced Exploration, Producer, or Past Producer (NORMIN.DB definitions; see http://www.nwtgeoscience.ca/normin). Bedrock geology from NWT-NU Open File 2005-01 (Stubley, M.P., 2005. Slave Craton: Interpretive bedrock compilation NWT-NU; Northwest Territories Geoscience Office) and GSC Map 1860A (Wheeler, J.O., Hoffman, P.F., Card, K.D., Davidson, A., Sanford, B.V., Okulitch, A.V., Roest, W.R., 1996. Geological Map of Canada; Geological Survey of Canada). Legend on next page.

Legend for Figure 2.

cleaning in each of the databases: the results of various processing steps were missing, neither raw nor levelled data were consistently retained in every database, and tie-line data were missing from most of the surveys although tie lines were certainly flown for all of them. Channel descriptions were not archived with the databases and most of the headers are cryptic. The NP_MacKay and NP_Tete databases contained duplicate data for every line; these duplicates were removed by NTGS. The NP_MacKay and MG_Misty databases contained turn-around data that was trimmed from the ends of flight lines.

Grid files (GRD format) were created by CBA Ltd. and are provided with minor alterations by NTGS. The database channels used to generate the grids were not identified, nor was any subsequent grid-based filtering, although micro-levelling of some kind was clearly carried out on most of the grids. Levelling errors remain in many of the grids, however these will not affect most interpretations. There is commonly no overlap across adjoining surveys, which will complicate any future attempt to level the grids against each other. The NP_MacKay and MG_Misty grids were trimmed to remove false anomalies after the corresponding-database flight lines were trimmed to remove turn-around data. Some grids were clearly created from one of the database channels, as noted in the metadata tables, however other grids were apparently created by grid filtering and do not have a matching database channel. The grids are displayed together with topography in Figure 3.

In addition to the donated data, a number of files for each survey were generated by NTGS for the user's convenience:

- line data in ASCII XYZ format,
- grids in ASCII GXF format,
- flight paths in DXF and SHP (ESRI shapefile) formats,
- survey footprints as SHP and PLY (Geosoft vector polygon),
- georeferenced TIFF files exported at 400 dpi from grids displayed with a 2nT color interval, and
- a single georeferenced TIFF, AllSurveys_NthShoreEastArmMag.tif, generated from the collection of grids displayed together.

The folder structure is as follows:

```
|---Geotiff
|---GridData(GRD,GXF)
        |---GXF
|---LineData(GDB,XYZ)
        |---XYZ
|---SurveyBoundariesAndFlightPaths
        |---Boundaries(PLY)
        |---Boundaries(SHP)
        |---FlightPaths(DXF)
        |---FlightPaths(SHP)
```

An explanation of filename extensions (.gi, .tiff, etc.) is provided in Appendix I.

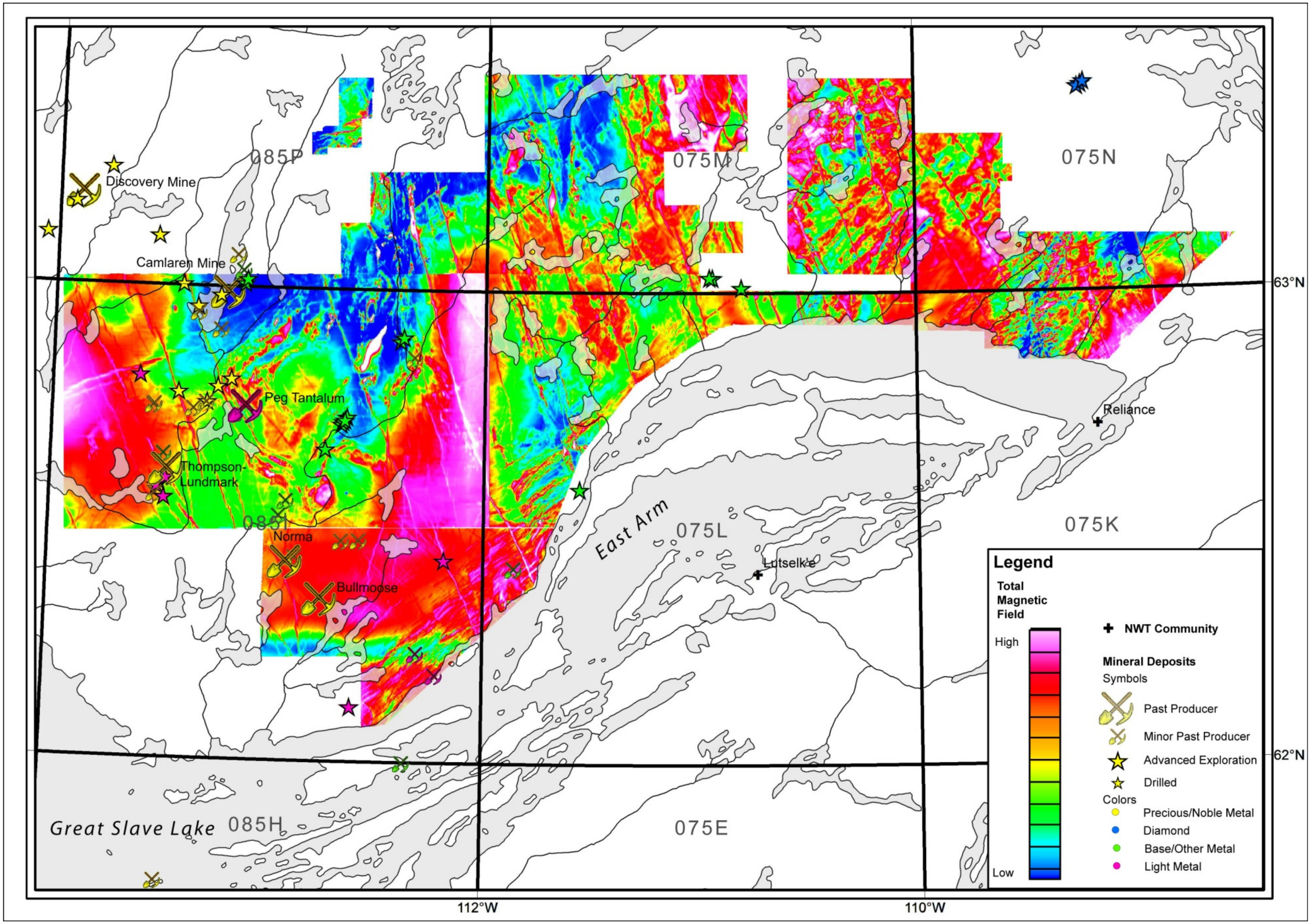

Figure 3. Gridded total magnetic field for 11 surveys on the north shore of East Arm, Great Slave Lake (see Fig. 2 for survey footprints). Surveys have ***not*** *been levelled against each other. Major mineral deposits are symbolized by their development stage and colored by major commodity group (from NORMIN.DB at http://www.nwtgeoscience.ca/normin).*

SURVEYING AND PROCESSING METHODS IN CONTEMPORANEOUS USE

Survey methodology and instrumentation

A Piper PA-31 Navajo twin-engine fixed-wing aircraft was equipped with a Geometrics G822A magnetometer with an optically pumped cesium-vapor sensor mounted in a tail stinger. All of the surveys were flown with east/west lines at a nominal 200-m line spacing. The original surveys probably included tie lines flown orthogonal to the flight lines. Tie lines were usually spaced 10 or 20 times the flight-line spacing (so for 200-m line spacing, tie-line spacing would be 2000 or 4000 m). The aircraft was flown a nominal height of 67 meters above the ground during surveying.

Direction and altitude during flight were maintained with the aid of radar and barometric altimeters and a real-time GPS (Global Positioning System). An intentional degradation of the signal, known as Selective Availability, was in effect at the time, reducing the accuracy of real-time GPS substantially, therefore data from a base GPS station were used post-flight to increase the accuracy of the recorded flight path.

The airborne magnetic data were acquired at a rate of 10 readings per second. Magnetic noise due to the aircraft motion and heading was compensated for by an RMS-manufactured real-time compensator in the aircraft. An RMS recorder captured the input from the compensator, and generated both digital and analog records.

A base-station magnetometer, probably an EDA OMNI IV proton-precession magnetometer with an accuracy of ±2 nT, recorded the diurnal magnetic field at a rate of one reading per second from a fixed location near the survey block . These data were examined daily to identify periods of rapidly fluctuating magnetic activity and to schedule re-acquisition of data obtained during those periods.

Additional technical specifications are given in Appendix II.

Data processing

Flight paths were corrected by using base-station GPS readings to differentially correct in-flight GPS readings to within 2 to 5 m accuracy. The compensated magnetic data were corrected for lag and heading errors, and spikes were removed. This pre-processed data was commonly identified in the final database as raw data. Although 10 readings per second were acquired, typically one per second was retrieved for processing, which resulted in an average 80 m along-line spacing between processed readings.

For most of the surveys, there is no indication of whether diurnal corrections were executed using base-station levelling, tie-line levelling, or both. In base-station levelling, the final base-station data provided the variation with time in the local magnetic field, which correction was subtracted from the raw airborne magnetic data. For small grids that did not extend far from the base station, this was deemed sufficient. Otherwise, or in some cases instead of base-station corrections, tie-line levelling was employed to remove the effect of diurnal variations in the magnetic field. The intersection errors (differences between tie-line and flight-line values at intersections) were minimized by iterative fitting of polynomial curves to those differences along tie lines then flight lines, and the resultant smoothly varying error was applied along lines.

Typically, the dataset that had been corrected for diurnal variations was then used to generate a grid, usually using a minimum-curvature algorithm. If necessary, de-corrugation filtering (microlevelling) was then applied to remove long-wavelength along-line and short-wavelength across-line errors. Standard office procedures for microlevelling evolved during the 1990's as follows:

1. initially, sequential steps of directional gridding were used to create a grid of errors that was sampled back into the database, where the final correction generated the final gridded channel;
2. later, the channel data were microlevelled by applying 1D Fast Fourier Transform (FFT) filters (typically a high-pass Butterworth followed by a directional cosine filter) to generate an error channel that was subtracted from the data channel to generate the final gridded channel; and
3. still later, the grid itself was micro-levelled using various 2D FFT filters, normally including Butterworth and directional cosine filters. Further noise reduction was accomplished with one pass of a 3x3 Hanning filter.

Not enough data/metadata are preserved to be able to tell which micro-levelling method was used for any particular survey, except NP_MacKay (described in Survey_Metadata.pdf). Preservation of the final errors (i.e., the corrections) or the final, micro-levelled data in a database channel does not necessarily mean that 1D FFT (channel filtering) methods were used to micro-level, since grids that were microlevelled using 2D FFT (grid) filters were often subsequently sampled to generate a channel of microlevelled line data in the database.

ACKNOWLEDGEMENTS

This product is a result of the public-minded spirit of data sharing shown by Aurora Geosciences. The authors gratefully acknowledge the time and expertise of Franz Dziuba and Doug Irwin, whose reviews provided us with the opportunity to enhance the final product. The authors would also like to acknowledge Mr. Wally Boyko, who, as president of Aeroquest during the 1990's diamond rush and through to 2005, oversaw numerous airborne geophysical surveys in the NWT.

APPENDIX I

Filename extension	Description of file
.dbf	Binary file in dBASE format containing attribute data for spatial features (shapes) described in the .shp file of the same name. Part of the collection of file types (.shp, .dbf, and .shx) that make up a shapefile, used in ESRI's ArcMap.
.dxf	ASCII text file in Drawing eXchange Format containing the information necessary to display map features, including geometric information (vertices for each point, line, and polygon feature), attribute information, and display attributes such as line weight and labelling options.
.gdb	Geosoft binary database file that organizes spatial information into Lines (for example, flight lines), channels (similar to columns in a spreadsheet), and elements (similar to cells in a spreadsheet).
.gi	Geosoft binary file containing projection information for a grid (.grd or .gxf) or TIFF (.tiff) of the same name.
.grd	Geosoft binary file containing grid data for use in montaj software. The grid is a rectangular array of points at which single values represent the parameter of interest (magnitude of the total magnetic field, in this case). Projection information is in a .gi file of the same name.
.gxf	ASCII text file in Grid eXchange Format of grid data with embedded projection information (older versions of the .gxf may not have projection information). Useful for transferring grids between proprietary formats.
.pdf	Binary file in Portable Document Format, and international standard ISO 32000, used for display of formatted text and figures independently of software, hardware, and operating system. Text, raster images, vector images, formatting information, and markup are embedded in the file. Formerly an Adobe proprietary format.
.ply	Geosoft ASCII text file for storing polygon coordinates.
.prj	ESRI ASCII text file containing projection information for a shapefile (.shp, .dbf, and .shx) or .dxf file of the same name.
.shp	ESRI binary file for use in ArcMap, containing spatial information as lists of vertices for points, lines, or polygons. Part of the collection of file types (.shp, .dbf, and .shx) that make up a shapefile.
.shx	ESRI binary index file containing the offset (from the beginning of the file) and length of each record in the .shp file. Part of the collection of file types (.shp, .dbf, and .shx) that make up a shapefile.
.tiff	Tagged Image File Format for storing raster graphics images, copyrighted by Adobe Systems whose most recent specification is TIFF 6.0. GeoTIFF is a TIFF 6.0-compliant, public domain metadata standard that allows projection, coordinate system, datum, and other georeferencing information to be embedded within a TIFF file.
.xyz	Geosoft ASCII text database file, in which columns represent various parameters related to a single point in space, for example, X coordinate, fiducial, raw magnetometer reading, etc. Line headers are used to separate data from different lines (eg. flight lines). This format was designed by Geosoft for exchange of line data between different formats.

APPENDIX II

The following description has been modified from:

> Sage (Fischer), B.J., 1996. Report on Airborne Magnetic and VLF-EM Survey, WM and COH Claim Groups, for A.C.A. Howe International Ltd., unpublished Assessment Report 083851, Northwest Territories Geoscience Office, Yellowknife, 32 p and 6 maps.

The description applies generally to all surveys carried out by Aeroquest Ltd. between about 1993 and 1997, including the East Arm surveys.

TECHNICAL SPECIFICATIONS

The survey platform was a modified Piper PA-31 Navajo twin-engine aircraft with auxiliary fuel tanks for extended range. Wing-tip pods held VLF sensors, which were not used during the East Arm surveys. A tail stinger held a high-sensitivity, cesium vapor sensor for the Geometries G822A magnetometer. Magnetic compensation was performed by an RMS-manufactured AADC II real-time compensator. A base-station magnetometer recorded the diurnal magnetic field in digital format.

The radar altimeter was manufactured by Terra Inc. Navigation was accomplished using a Magnavox MX 4200D GPS receiver in conjunction with Picodas PNav 2001 software with on-line pilot display. Data from a base-station GPS were used post-flight to differentially correct positional data, whose final accuracy was within 2 to 5 m. An ancillary color video camera was used for confirmation of flight path.

Magnetic-field intensity was sampled 10 times per second, translating roughly to a sample every 8 m. An RMS-manufactured DGR 33A recorder provided digital and analog records of the magnetic and altitude data. According to Aeroquest, the electrical noise of the operational system, as measured by the fourth difference, is less than ±0.3 nT, and the compensated Figure of Merit is less than 1.0 nT.

Nominal terrain clearance was 67 m. Line separation was client specified, with the most common requests being from 100 to 300 m.