SINGLE MASTER GRAVITY AND AEROMAGNETIC DATA FOR ONTARIO

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ERLIS Dataset CD-ROM # 1035 (ASCII Format) and # 1036 (Geosoft Format)
Issued July 12, 1999

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1. BOUGUER GRAVITY AND VERTICAL GRAVITY GRADIENT OF ONTARIO

1.1 INTRODUCTION

The systematic regional gravity mapping of Ontario was initiated in 1947, by the Dominion Observatory of Canada (Innes, 1960). By 1964, uniform survey coverage of most of the province had been achieved, at a relatively coarse station spacing of 10 to 15 km, and the resulting Bouguer anomaly maps published at a scale of 1:500,000. Later surveys by the Earth Physics Branch of Energy, Mines and Resources, Canada, increased the density of coverage in certain areas of the province.

The metavolcanic-metasedimentary belts of Ontario are perceived to be regions of high economic mineral potential. Prospecting and geological mapping in these regions are hampered by inaccessibility, difficult terrain, and extensive areas of thick glacial overburden. The importance of gravity data as a reconnaissance tool in such areas led the Ontario Division of Mines, in 1970, to initiate systematic, detailed gravity surveys of these belts. The results of the surveys have been used to outline areas warranting detailed follow-up exploration (Gupta and Sutcliffe, 1990), and have proved an effective aid to geological mapping (Gupta and Ramani, 1982).

These systematic detailed gravity surveys have helped to outline the deeper geological and geophysical characteristics of the Precambrian Shield of Ontario (Gupta and Ramani, 1980; Gupta and Grant, 1985). Gravity interpretation and modelling have constrained the third dimension of the metavolcanic-metasedimentary belts, and have contributed to a better understanding of their evolution and associated mineral deposits (Gupta et al., 1982). Examples of these early detailed surveys include those by Middleton (1976), Barlow et al. (1976), Gupta and Wadge (1978), and Gupta (1981).

1.2 GRAVITY DATA PROCESSING

1.2.1 Editing

The gravity data used in the compilation of the Bouguer Gravity of Ontario were obtained from the digital files of Geomatics Canada and the Ontario Geological Survey. A data file containing the station latitudes, longitudes and Bouguer gravity values in mGal, referred to as the XYZ file, was first converted to the Lambert Conformal Conic Projection. Using a minimum curvature gridding algorithm, the gravity data were then gridded to 2000 m cell size for editing purposes (Briggs, 1974). At the location of each recorded gravity value in the XYZ file a corresponding interpolated gravity value was extracted from the gridded file. The difference between the corresponding values were entered into a third data set, known as the difference data set, which was also gridded to a 2000 m cell size using the minimum curvature algorithm with a tolerance of fit 0.2 mGal. Using an imaging workstation, colour images of the gridded difference set and the plot of gravity station locations were displayed concurrently in order to locate suspect values in the data set. This helped to identify areas of poor fit to the original recorded Bouguer gravity values. The poor fit resulted from either the coarse station spacing or from errors in the original recorded Bouguer gravity values.

Areas of large Bouguer gravity difference (>1 mGal) between the original and gridded data sets were evaluated using Bouguer gravity maps published by the Dominion Observatory of Canada and the Ontario Geological Survey. These areas were subsequently attributed to unsubstantiated, anomalous single-point values that create extreme localized gradients, and incorrect station elevations in the reduction calculations. The editing process resulted in the deletion of a total of 177 questionable stations, mostly in Hudson Bay, from the XYZ file.

1.2.2 Gridding

a) **The Bouguer Gravity Grid:**

Due to a large variation in the spacing of the gravity stations (0.3 to 15 km), four test areas were examined to obtain the optimum gridding parameters. Each selected test area contained a mix of detailed and regional surveys. In addition, one of the areas also contained shipborne and iceborne gravity stations.

The four test areas were gridded at three different grid intervals (400 m, 1000 m, and 2000 m) using the minimum curvature algorithm with tolerance of fit to 0.01 mGal. Colour images of the gridded Bouguer gravity field were displayed on the workstation to check anomaly resolution, grid smoothness, and to verify that the integrity of the recorded Bouguer gravity values was maintained during the gridding process. It was found that the 1000 m grid cell size fit the data well within acquisition accuracy, and exhibited the maximum resolution.

The edited XYZ file of Bouguer gravity data was used to create the final 1000 m x 1000 m cell-size grid, using the minimum curvature method. This method interpolates each grid cell from a minimum curvature surface that passes through all the data points. The final 1000 m by 1000 m cell-size (i.e., x cell-size = 0.012°, y cell-size=0.00925°) Single Master Gravity Grid for Ontario consists of 2303 columns by 1867 rows (Also see Gupta, 1991a). The Bouguer gravity values range from -99.98 mGal to 36 mGal.

b) **The Vertical Gravity Gradient Grid:**

The rationale for computing vertical gravity gradient, or a second vertical derivative, is that anomalously dense rocks occurring near the ground surface produce much stronger gradient effects than those which lie at great depths (Gupta and Sutcliffe, 1990; Gupta and Grant, 1985; Gupta and Ramani, 1982). However, it should be noted that the amplitudes of the Bouguer gravity anomalies that are caused by shallow and weak sources may be considerably smaller than those due to larger, deeply buried sources. The vertical derivative map thus enhances the weak, near-surface anomalies.

The vertical gradient (1000 m by 1000 m cell-size grid) of the Bouguer gravity field was computed by applying a first vertical derivative filter to the Fourier transform of the Bouguer gravity field grid. A fourth degree, low-pass, cosine roll-off filter, with roll-off wavelengths commencing at seven km and ending at five km, was applied to remove the sharp roll-off at the high frequency end of the filter. The first vertical derivative in the space domain was then obtained by taking the inverse Fourier transform of the filtered, frequency domain map. The final 1000 m x 1000 m cell-size gravity gradient grid ranges from -0.0056 mGal/km to 0.00787 mGal/km.

The vertical derivative map (see Gupta, 1992) is used primarily to locate vertical to subvertical boundaries between rock units of contrasting densities. The zero contour of the vertical derivative anomalies helps to outline approximate boundaries of the anomalous gravity sources. In general, the vertical gradient is therefore useful for mapping near-surface structures, such as faults and folds.

1.2.3 Grid Projection

The 1000 m x 1000 m cell-size grid referred to as the Single Master Gravity Grid for Ontario was compiled using the Lambert Conformal Conic Projection with standard parallels 49° N and 77° N and central meridian of 92° W. The grid origin was chosen at 0° N (equator) and 92° W. A false Easting of 1,000,000 was applied. The Lambert projection grids were then converted to Latitude-Longitude projection grids. The projection used the North American Datum 1927 (NAD 27), Canada (Manitoba; Ontario local datum).

1.3 DATA SPECIFICATIONS

The Bouguer Gravity grid of Ontario was compiled from approximately 55,639 gravity stations retrieved from the National Gravity Data Base at the Geological Survey of Canada. The Ontario Geological Survey has contributed over 23,000 gravity stations to this database. The remaining 32,639 stations were measured by the Dominion Observatory of Canada and its successor the Earth Physics Branch of Energy, Mines Resources, Canada. The Gravity measurements used in the compilation of this map are consistent with the standards set forth by the international Gravity Standardization Net 1971 (IGSN71) and the Geodetic Reference System 1967 (GRS67; see Woollard, 1979). Bouguer anomalies were calculated using a vertical gravity gradient of 0.3086 mGal/m and a crustal density of 2.67 g/cm^3. The data were not terrain-corrected except for those from 40 stations near Sudbury and 54 stations near Cornwall. In the current data base, the accuracy of the anomalies varies generally from about ±0.5 mGal for detailed surveys carried out by the Ontario Geological Survey, to about ±2 mGal for regional surveys, and to about ±5 mGal for shipborne surveys.

2. TOTAL MAGNETIC FIELD AND VERTICAL MAGNETIC GRADIENT OF ONTARIO

2.1 INTRODUCTION

Aeromagnetic surveys have been conducted in Ontario since 1947, when the first survey was carried out in Northern Ontario by the Gulf Research and Development Company. In 1948, systematic survey coverage of Ontario was initiated by the Geological Survey of Canada (GSC) and the Ontario Department of Mines, through federal-provincial agreements. Between 1947 and 1979, data from 32 aeromagnetic surveys were acquired in analog form. Flight directions for these surveys were chosen to transect the predominant regional structural trends of the underlying rocks. Therefore, most of these surveys were nominally flown in a north-south direction, with a flight line spacing of 0.5 mile (805 m) and a mean terrain clearance of 1000 feet (305 m). A few of the surveys were flown in an east-west direction at a mean terrain clearance of 500 feet (150 m). Between 1984 and 1987, nine digitally recorded surveys were flown by the GSC in north-south, and to a lesser extent east-west, directions at a flight line spacing of 1000 m and a mean terrain clearance of 300 m. Aeromagnetic contour maps are available from the GSC at scales of either 1:63,360 (1 inch to 1 mile) and 1:253,440 (1 inch to 4 miles), or 1:50,000 and 1:250,000.

In the early 1980s, the GSC initiated a program to create a digital aeromagnetic database by digitizing existing maps. The digital data set for each survey was gridded at 812.8 m by the GSC and then levelled at survey boundaries (Dods et al., 1985).

The total magnetic field intensity colour images and computer-enhanced products created from the GSC grid are useful for regional mapping purposes. However, the 812.8 m grid spacing is too coarse for these images to be used as an aid in mineral exploration. Therefore, all the aeromagnetic data for Ontario were recompiled into a contiguous grid of total magnetic field intensity at a smaller grid cell size. A unique method, utilizing the existing GSC 812.8 m grid data base, was applied to level the 41 surveys together and create a Single Master Aeromagnetic Grid for the province of Ontario at a chosen uniform grid cell size 200 x 200 m (Gupta et al., 1989).

2.2 MAGNETIC DATA PROCESSING

2.2.1 Editing

The digitized magnetic survey data were first sorted into contiguous original survey blocks. This was done by digitizing the boundaries of the various surveys and placing each in the correct location. Both the digitized and digitally recorded total field data were gridded to a 200 m cell size, using a bi-directional gridding algorithm. The digitized data were gridded with the Akima spline (Akima, 1970) in both directions. The digitally recorded data were first interpolated linearly along flight lines, due to the higher density of data, and then with the Akima spline perpendicular to the flight lines. A contiguous grid for each of the surveys was thus created. Using an imaging workstation, colour total field grid images and profiles of the magnetic data along flight lines were displayed concurrently in order to locate and correct location and digitization errors in the data sets.

To bring the entire data set to a common 300 m altitude, data from the six surveys which were acquired at a 500-foot (150 m) mean terrain clearance were continued upward to a common altitude of 300 m above ground.

2.2.2 Levelling

The levelling of the magnetic survey data was carried out using the existing GSC 812.8 m grid as a reference grid, onto which the unleveled survey grids were draped to produce a levelled grid (Reford et al., 1990)

The original unleveled magnetic grids (200 m cell size) contain signals arising from three sources: i) geological sources of short and medium wavelengths, ii) the regional field, and iii) levelling error. Since the GSC reference grid has been produced from the same data set, its signal contains two of the above sources, the geological sources of short and medium wavelengths and the regional field.

By subtracting the reference grid from the unleveled grid, the signals due to the geological sources of medium wavelengths and the regional field were removed. This left the signals due to geological sources of short wavelengths and the levelling error intact in the unlevelled magnetic grid. A low-pass nonlinear filter in the flight line direction was applied to remove the signal due to geological sources of short wavelengths, leaving a grid containing levelling error only. The grid of levelling error was then subtracted from the original unleveled grid to produce a leveled grid, which contains only the desired signal, that due to geological sources of short and medium wavelengths and the regional field. The removal of levelling error between surveys resulted in a seamless fit at mutual boundaries.

2.2.3 Gridding

a) **The Total Magnetic Field Grid:**

For the digitized magnetic surveys, profile data were extracted from the levelled grid by interpolation, using a bicubic spline over a 6 by 6 window of 200 m x 200 m grid cells. Similarly, the levelling corrections for the digitally recorded surveys were extracted from the correction grid and were then applied to the profile data. Levelled profile data were used to create the final master 200 m x 200 m cell-size (i.e., x cell-size = 0.002401°, y cell-size = 0.001851°) grid using the minimum curvature method (Briggs, 1974). This method interpolates each grid cell from a minimum curvature surface that passes through all the data points. The final 200 m x 200 m cell-size Single Master Aeromagnetic Grid for Ontario consists of 8455 rows and 9013 columns and the IGRF-corrected magnetic field values range from -6,232.7 nT to 30,418.2 nT.

b) **The Vertical Magnetic Gradient Grid:**

The rationale for computing a vertical magnetic gradient grid is that anomalously magnetic rocks occurring near the ground surface produce much stronger gradient effects than those that lie at great depths. However, it should be noted that the amplitudes of the total magnetic field anomalies that are caused by shallow and weak sources may be considerably smaller than those due to larger, deeply buried sources. The vertical derivative map thus enhances the weak near-surface anomalies.

The vertical gradient of the magnetic field was computed by applying a first vertical derivative filter to the Fourier transform of the total magnetic field grid (see Gupta, 1991b). A sixth-degree Butterworth low-pass filter with a cut-off wavelength of one km was applied to minimize high frequency flight line and gridding noise. The vertical magnetic gradient map (Gupta, 1991c) in the space domain was then obtained by taking the inverse Fourier transform of the filtered, frequency domain map. The final 200 m x 200 m cell-size vertical magnetic gradient grid has a range varying from -12.063 nT/m to 48.6401 nT/m.

2.2.4 Grid projection

The 200 m x 200 m grid referred to as the Single Master Aeromagnetic Grid of Ontario was compiled using the Lambert Conformal Conic Projection with standard parallels of 49° N and 77° N and central meridian of 92° W. The grid origin was chosen at 0° N (equator) and 92° W. A false Easting of 1,000,000 was applied. The projection used the North American Datum 1927 (NAD 27), Canada (Manitoba; Ontario local datum).

3. ADDITIONAL DATA PROCESSING

3.1 INTRODUCTION

The three geophysical data sets were converted to flat ASCII and Geosoft formats by Controlled Geophysics. To preserve the integrity of the data, no data values were deleted or modified in any way. The parameters in the data set and the grids are described in Appendix A.

3.2 GRAVITY DATA

The gravity station data have been provided in Geosoft oasis montaj, flat ASCII text, Microsoft Access™, and Microsoft Excel™ formats. The Bouguer gravity and vertical gravity gradient grids were prepared in Geosoft binary .GRD and ASCII .GXF formats.

3.3 DIGITIZED MAGNETIC DATA

The ERLIS # 1 data CD-ROM contains the digitized magnetic profile data, organized as one file per NTS sheet. There are 54,395 survey line segments in the provincial digitized magnetic database. Line numbers had been assigned arbitrarily during digitizing. A specialized routine was applied to link lines that were broken during the original map digitizing.

Each new line comprised of linked segments was assigned a unique line number derived from a combination of the NTS sheet value and a line number counter. The new line numbers have the format XXYYYYY, where XX is the NTS sheet number and YYYYY is the linked line number counter.

Each of the eleven NTS data files was linked individually, and then all NTS sheets were combined into a single, master profile data file. Note that crossing survey lines made it impossible to achieve perfect linking. A number of digitized points that had been assigned to the wrong line number in the original data archive, were not corrected.

The profile data set was prepared in Geosoft oasis montaj and flat ASCII text formats. The total magnetic field and vertical magnetic gradient grids were prepared in Geosoft binary and ASCII GXF formats.

3.4 DIGITALLY RECORDED MAGNETIC DATA

The ERLIS # 1 CD-ROM contains magnetic profile data organized as one file for each of nine detailed survey areas. Line numbers are re-used from one area to another. To store all nine data sets in a single file, each area was assigned a two-digit code, which was added to the existing line number as a prefix. The new line numbers have the format XXYYYYY, where XX is the two-digit code number and YYYYY is the original line number. The two-digit codes are:

BORDER 11	HURON 14	ST CLAIR............17
ERIE.....................12	ONTARIO...........15	SUPERIOR 18
GEORGIAN.........13	SIMCOE 16	WATERLOO 19

The profile data set was prepared in Geosoft oasis montaj and flat ASCII text formats.

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CREDITS

Project management and supervision by V.K. Gupta, Ontario Geological Survey.

Processing and grid generation was carried out, under contract, by Paterson, Grant and Watson, Ltd., Toronto.

Conversion of all data to Geosoft format and linking of fragmented digitized magnetic flight line segments was carried out, under contract, by CGI Controlled Geophysics Inc., Thornhill, Ontario.

SOURCES OF INFORMATION

Digital gravity data were provided by Geodetic Survey Division, Geomatics Canada, Natural Resources Canada and Ontario Geological Survey.

Digitally recorded and digitized aeromagnetic survey data, including the 812.8 m aeromagnetic grid for Ontario, were provided by the Geological Survey of Canada.

APPENDIX A - CONTENTS OF PROFILE AND GRID DATA FILES

Note: i) ERLIS CD-ROM # 1035 contains gravity and magnetic point data (XYZ) in ASCII .TXT format and grid data in ASCII .GXF format. In addition, gravity point data (XYZ) are also provided in Microsoft ACCESS™ and EXCEL™ formats.

ii) ERLIS CD-ROM # 1036 contains gravity and magnetic point data (XYZ) in Geosoft oasis montaj .GDB format and grid data in Geosoft .GRD format.

ONTARIO BOUGUER GRAVITY STATION XYZ VALUES
(ASCII format file name: ONGRAVTY.TXT)
(Geosoft oasis montaj format file name: ONGRAVTY.GDB)

Parameter	Unit	Description
LX	metres	Lambert Conformal Easting
LY	metres	Lambert Conformal Northing
LAT	degrees	Latitude
LONG	degrees	Longitude
BOUGUER	mgal	Bouguer Gravity

ONTARIO AEROMAGNETIC XYZ VALUES DIGITIZED FROM CONTOUR MAPS
(ASCII format file name: ONDTZMAG.TXT)
(Geosoft oasis montaj format file name: ONDTZMAG.GDB)

Parameter	Unit	Description
LINE	na	Line Number
LX	metres	Lambert Conformal Easting
LY	metres	Lambert Conformal Northing
LAT	degrees	Latitude
LONG	degrees	Longitude
EDITMAG	nT	Edited Digitized Total Magnetic Field
LEVMAG	nT	Levelled Digitized Total Magnetic Field
RAWMAG	nT	Original Digitized Total Magnetic Field
OLDLINE	na	Original Digitizing Line Number

ONTARIO AEROMAGNETIC XYZ DATA RECORDED DIGITALLY OVER NINE SURVEY AREAS

(ASCII format file name: ONDIGMAG.TXT)

(Geosoft oasis montaj format file name: ONDIGMAG.GDB)

Parameter	**Unit**	**Description**
LINE	na	Line Number
LX	metres	Lambert Conformal Easting
LY	metres	Lambert Conformal Northing
LAT	degrees	Latitude
LONG	degrees	Longitude
RAWMAG	nT	Original Magnetic Total Field
LEVMAG	nT	Final Levelled Magnetic Total Field
OLDLINE	na	Original Contractor Line Number

The line numbers (LINE) have the format XXYYYYY, where XX is a two-digit code for each survey area and YYYYY is the original line number (OLDLINE). The two-digit codes are:

BORDER 11	HURON 14	ST CLAIR............17
ERIE.....................12	ONTARIO...........15	SUPERIOR 18
GEORGIAN.........13	SIMCOE 16	WATERLOO 19

ONTARIO SINGLE MASTER MAGNETIC AND GRAVITY GRIDS

Grids are named so that the first two characters represent the name of the survey area followed by a standard set of grid type codes, e.g., ONGRV1VD is the first vertical derivative of gravity in Ontario. All Geosoft binary grids are provided in Real*4 precision. All ASCII grids are Geosoft GXF format.

ONGRAVTY.GXF	mgal	Bouguer gravity grid (1000m x 1000 m) Geosoft ASCII format
ONGRV1VD.GXF	mgal/km	Vertical gravity gradient grid (1000 m x 1000 m) Geosoft ASCII format
ONMAGONL.GXF	nT	Total magnetic field grid (200 m x 200 m) Geosoft ASCII format
ONMAG1VD.GXF	nT/m	Vertical magnetic gradient grid (200 m x 200 m) Geosoft ASCII format
ONGRAVTY.GRD	mgal	Bouguer gravity grid (1000m x 1000 m) Geosoft binary format
ONGRV1VD.GRD	mgal/km	Vertical gravity gradient grid (1000 m x 1000 m) Geosoft binary format
ONMAGONL.GRD	nT	Total magnetic field grid (200 m x 200 m) Geosoft binary format
ONMAG1VD.GRD	nT/m	Vertical magnetic gradient grid (200 m x 200 m) Geosoft binary format