# GRAVITY AND AEROMAGNETIC DATA GRIDS OF MINNESOTA

**By V. W. Chandler, R. S. Lively and T. E. Wahl**

## DESCRIPTION OF GRAVITY DATA GRIDS

### Data Collection and Compilation

The two gravity data grids included in this distribution are based on over 40 years of gravity surveying in the state of Minnesota. These grids and the accompanying principal fact gravity data (http://www.geo.umn.edu/mgs/gravity.htm#data) represent the first significant revision of the Minnesota gravity database since the compilation by Chandler and Schaap (1991). Since that compilation, approximately 2000 stations have been added as data collected in support a variety of projects related to bedrock mapping by the Minnesota Geological Survey (MGS). In addition, archival data not available for the earlier compilation are now included.

The post-1991 data includes profiles with gravity measurements collected at 0.25 mile (0.4 kilometers) intervals along selected corridors, to area surveys with stations spaced at 0.5 to 1.0 mile (0.8 to 1.6 kilometers) intervals along available roads and trails. Horizontal locations were usually determined by locating a point on 1:24,000 scale USGS topographic maps. These points were later digitized and combined into a database. Vertical control for the newer data was usually obtained from spot elevations shown on 1:24,000 scale USGS topographic maps. Occasionally, locations and elevations in areas of low relief were extrapolated from topographic contours. Small groups of locations and elevations were obtained by transit surveys tied into USGS benchmarks, and since 2000, Global Positioning System (GPS) readings have been used for point location with elevations determined from a built-in altimeter data. These stations therefore have horizontal accuracies +-50 meters down to +-10 meters or less. Station locations for some of the pre-1991 data may not be accurate to better than +/- 200 meters.

Most of the post-1991 measurements were taken with a Lacoste and Romberg gravity meter (#G-320) with a stated reading precision of 0.01 milligals. As a result of various error sources, gravity values are probably precise to +/- 0.10 milligals, although errors up to +/- 0.3 milligals may occur locally. All data have been reduced using the Geodetic Reference System 1967 (International Association of Geodesy, 1971), assuming a sea level datum and a Bouguer reduction density of 2.67 grams/cc. Corrections were made for earth curvature, but because of the generally low topographic relief across most of Minnesota, no terrain corrections have been made.

Description of Downloadable Grids

The gravity data were gridded and processed using the potential field software of the U. S. Geological Survey (Phillips, 1997). A minimum curvature program (program MINC) was used to create a grid of Bouguer gravity anomaly values; this grid has 463 rows, 404 columns, a grid spacing of 1500 meters, and a southwest origin at easting 170,500 meters and northing 4,790,000 meters (UTM coordinates, Zone 15, NAD27). In order to sharpen the gravity signature of sources at or near the bedrock surface, new grid values were obtained using the second vertical derivative data calculated from the original Bouguer anomaly grid. To eliminate the minor effects of noise, the derivative gravity data were slightly smoothed by upward continuation to a level of 2,000 meters above the surface. The Bouguer anomaly and the smoothed, second vertical derivative of gravity grids were re-projected to UTM, zone 15 (NAD83,) datum currently in use at MGS. These are posted as files ggd.zip and ggd2d2.zip, respectively. Each of these grids have 3074 rows, and 2680 columns, a grid spacing of 213.36 meters, and a southwestern origin located at an easting of 189,769.572 meters and northing of 4,816,380.742 (assume lower left cell corner for Arc-based applications). In using the gravity data grids the user must be aware that the data has been considerably over-gridded relative to actual data control. In most parts of the state the average spacing between gravity stations is actually 1.61 kilometers or wider. The tight grid interval is used here to create grids that register with the magnetic grids, which is useful for a variety of graphic and GIS applied studies that use both types of data. It is recommended that the original gravity station control be presented with any images or maps of the gravity grids; these locations can be obtained from the principal fact gravity data at http://www.geo.umn.edu/mgs/gravity.htm#data .

## DESCRIPTION OF AEROMAGNETIC DATA GRIDS

### History of Data Collection and Compilation

Aeromagnetic data grids include all of the high-resolution, total intensity, aeromagnetic data that were acquired in Minnesota by the Minnesota Geological Survey (MGS) and other organizations from 1979 to 1991 (Chandler, 1991). The impetus for a new statewide survey came from the late Matt Walton, who was director of the MGS from 1973 to 1986. Primary support for the survey was provided by the Minnesota Legislature as recommended by the Legislative Commission on Minnesota Resources (LCMR). Directors of LCMR during the time of the surveying were Robert Hanson (1979-1986) and John Velin (since 1988). Initially the chief application for the data collected by the program was its use for mineral exploration However, it quickly became obvious that the program would provide information for variety of geological information requirements in both the public and private sectors. It would also greatly assist the MGS in its own mission of geologic mapping and development of a geological framework for the state. Because the Precambrian rocks in Minnesota are almost completely covered by Pleistocene glacial deposits and Phanerozoic sedimentary rocks, studies of the Precambrian relies significantly on information provided by aeromagnetic and other geophysical surveys.

Organizations other than the MGS that have made significant contributions to collection of aeromagnetic data are shown in Fig. 1 and Tables 1-3 (see fig_tbls.pdf). Data covering north-central Minnesota were acquired and compiled between 1984 and 1991 by the U.S. Geological Survey (USGS), in cooperation with the MGS as part of the Conterminous United States Mineral Assessment Program. The Geological Survey of Canada conducted an aeromagnetic survey over the Lake of the Woods in 1985. The Minnesota part of this survey was incorporated into the present data grids. USX (U. S. Steel) Corporation donated aeromagnetic data acquired in 1979, for part of southwestern Minnesota. The metropolitan areas of Minneapolis and St. Paul were not included in the 1979-1991 data collection because of, flight restrictions over the cities and excessive amounts of cultural noise. Data from a 1961 survey by the USGS were used instead (Sims and Zietz, 1967).

The data for the various surveys differ somewhat in how they were acquired and compile, but several generalizations are possible. Most of the surveys that took place over land flew north-south lines with average terrain clearances of 91-213 meters (m). Flight-line spacing depended primarily on depth to magnetic basement and ranged between 380 to 1000 m apart. The Lake of the Woods data was collected from flights 300 m above the lake surface and a line spacing of 926 m. Most of the surveys also flew tie-lines, in east-west directions at spacings generally 5 to 10 times wider than flight-line spacing. In the MGS-LCMR surveys, data were not accepted if the diurnal variations exceeded 3 or 4 nanoTeslas (nT) across any 5-minute chord. Aircraft compensation, (for MGS-LCMR surveys), checked at the start, middle and end of each field season, was within 0.5 nT for all flight-line directions, and for $10^{o}$ of pitch, yaw and roll.

In general, flight-path recovery was accomplished photographically with spotted points every 2 to 5 kilometers (km) along line. Points were picked to achieve a horizontal accuracy plus or minus 50 m. Flight path recovery was also accomplished by electronic methods, including Global Positioning System in parts of Blocks 5, 6A and 7A, and ™Loran-C in parts of Block 8, and a portable radio positioning system in parts of Block 8 (Fig. 1). Corrections for diurnal variations were made by removal of a generalized or smoothed form of the diurnal monitor record, tie leveling, or a combination of the two. Correction for the regional (core-derived) field was based on the American World Charts-1975 model (Peddie and Fabiano, 1976), or the International Geomagnetic Reference Field and the Definitive Geomagnetic Reference Field models (Peddie, 1983; Inter. Assoc. of Geomagnetism and Aeronomy, 1988), updated to the approximate times of acquisition. In general, no attempts were made to remove cultural features. Recovered flight path data are available through The Department of Natural Resources at (http://deli.dnr.state.mn.us/ [follow the link to acquire data, select Minnesota Revised Aeromagnetic Data from the list of available layers]) All data within each survey block were gridded using minimum curvature (Briggs, 1974) or a similar method.

Data for individual survey blocks were composited into a master grid by Paterson Grant and Watson Ltd of Toronto, Ontario. All the MGS/LCMR data were gridded using

Universal Transverse Mercator (NAD27) coordinates and a common grid spacing of 213.36 meters. All other data were regridded to these parameters. An elevation of 150 meters above the mean land surface was designated as the flight altitude for the compilation. Grids derived from data at other flight elevations were continued to the 150 meter level. To lessen flight-line noise, sixth degree, low-pass Butterworth filters were applied to the data from Blocks 8 (1000 m cutoff), and 9 (1000 m cutoff). Other than base level shifts, no other adjustments were necessary to link the grids. In order to remove a negative bias that was caused by our use of the American World Charts Geomagnetic Field model, 375 nT were added to the composited data grid to approximate the base level of the International Geomagnetic Reference Field (IGRF) model, which is the preferred geomagnetic modelin use today. The final master grid was reprojected to a Lambert Conformal Projection (NAD27) with a central meridian of 93° W., a base latitude of 33° N. and southern and northern parallels of 33° and 45°, respectively.

Description of Downloadable Grids

The master magnetic anomaly grid was processed using the potential field software of the U. S. Geological Survey (Phillips, 1997). Due to grid size limitations of the processing software, the total field grid was divided into 4 overlapping quadrants (northeastern, northwestern, southwestern, and southeastern) prior to processing. In order to place anomalies more directly over their source, the aeromagnetic data from each grid quadrant were reduced to vertical polarization (reduced-to-pole). This was carried out assuming induced magnetization and an earth's field declination of 4.56°E and inclination of 74.16°. The declination /inclination values were derived from Program GEOMAG (National Oceanic and Atmospheric Administration, 1995), assuming the approximate midpoint of the state at 46.50°N/94.50°W) and an approximate mean date for all surveying of 1985.75. Assuming induced magnetization, the selected declination/inclination values should reduce the data in any given part of the state to within a few degrees of proper reduction-to-pole. Anyone needing greater precision, or who suspects the presence of a strong natural remanent magnetization oblique to the assumed declination/inclination values, may wish to re-process the data. In order to sharpen the magnetic signature of sources at or near the bedrock surface, first and second vertical derivatives were calculated from the reduced-to-pole data for each quadrent. Both first and second derivative grids were re-composited into a state-wide grid after the processing. The total field (the master magnetic anomaly grid), the first vertical derivative and the second derivative grids were reprojected to UTM (NAD83, zone 15) coordinates. These are posted as files mgd.zip, mgd1d.zip, and mgd2d.zip, respectively on the FTP site. Each of these grids have 3074 rows, and 2680 columns,a grid spacing of 213.36 meters, and a southwestern origin located at an easting of 189,769.572 meters and northing of 4,816,380.742 meters (assume lower left cell corner for Arc-based applications).

Acknowledgements

Most of the aeromagnetic surveying and the publication of related maps has been funded by the Minnesota Legislature as recommended by the Legislative Commission on Minnesota Resources. W. J. Hinze of Purdue University provided valuable advice during the early stages of the surveying program. Gratitude is expressed to the U.S. Geological Survey (USGS) and the Geological Survey of Canada for allowing their data to be included in this compilation. Robert Bracken and Robert Kuchs of the USGS helped prepare the original data grids for Lake of the Woods. The efforts of Mr. Cedric Iverson, who helped in the release of the USX data in southwestern Minnesota, are also greatly appreciated. The aeromagnetic data from the Twin Cities metropolitan area was digitized by Bryan D. Schaap of the MGS, using stable base copies of the original aeromagnetic map that were provided by Richard Godson of the USGS. Before 1982 gravity data acquisition in Minnesota was supervised by R. J. Ikola, L. D. McGinnis, and C. P. Ervin.

**Please reference the Minnesota Geological Survey if any of the above data is used in a publication or report.**

Suggested citation: Chandler, V. W., Lively, R. S., and Wahl, T. E., 2004, GRAVITY AND AEROMAGNETIC DATA GRIDS OF MINNESOTA, Minnesota Geological Survey Open File Data

## SELECTED BIBLIOGRAPHY

Briggs, I.C., 1974, Machine contouring using minimum curvature: Geophysics, v. 39, p. 39-48.

Chandler, V. W., 1991, Aeromagnetic anomaly map of Minnesota: Minnesota Geological Survey State Map Series S-17, scale 1:500,000.

International Association of Geomagnetism and Aeronomy, Division I, Working Group 1, 1988, International Geomagnetic Reference Field revision 1987: Geophysics v. 53, p. 576-578.

National Oceanic and Atmospheric Administration, 1995, Geomagnetic field models and synthesis software, Version 2.1, The National Geophysical Data Center, Boulder, Colorado.

Peddie, N. W., 1983, International Geomagnetic Reference Field- Its evolution and the difference in total field intensity between new and old models for 1965-1980: Geophysics, v. 48, p. 1691-1696.

Peddie, N. W., and Fabiano, E. B., 1976, A model of the Geomagnetic Filed for 1975: Journal of Geophysical Research, v. 81, p. 2539-2547.

Phillips, J. D. 1997 Phillips, J. D., 1997, U. S. Geological Survey Potential-Field Software Package, version 2.2 for the PC: United States Geological Survey Open File Report 97-725.

Sims, P. K., and Zietz, I., 1967, Aeromagnetic and inferred Precambrian paleogeological map of east-central Minnesota and part of Wisconsin: U. S. Geological Survey Geophysical Investigations Map GP-563, scale 1:250,000, section, text.