UPGRADE OF THE GRAVITY DATABASE

MINNESOTA GEOLOGICAL SURVEY

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Every reasonable effort has been made to ensure the accuracy of the factual data on which this compilation is based; however, the Minnesota Geological Survey does not warrant or guarantee that there are no errors. Users may wish to verify critical information; sources include both the references listed here and information on file at the offices of the Minnesota Geological Survey in St. Paul. No claim is made that the data as shown are rigorously correct, however, and it should not be used to guide engineering-scale decisions without site-specific verification.

INTRODUCTION

The principal fact gravity database in Minnesota is comprised of over 59,000 measurements collected since 1950. It contains point location data, elevations, free-air and Bouguer anomaly values, field information and base U.S.G.S. quadrangle locations. Over the years gravity data in Minnesota has proven to be a useful resource for the Minnesota Geological Survey (MGS) in its mission of bedrock mapping, and it has provided mineral exploration companies with a significant supplement to exploration programs in Minnesota. Because much of the Precambrian bedrock in Minnesota lies beneath thick glacial deposits, gravity measurements, which are sensitive to density variations, are particularly helpful at inferring structures and rock types deep in the subsurface. The state-wide gravity data is most commonly used in conjunction with the high- resolution aeromagnetic data from Minnesota, which is highly sensitive to magnetic variations in the underlying Precambrian rocks. In 2003, the MGS released a state-wide gravity database with 57890 stations (gravity meter readings). In spite of its widespread utility, limitations of that data have become apparent with use. Most notably, the precision of gravity station locations were found to be mislocated by as much as 200 meters due to 0.10 minute of latitude or longitude rounding error upon initial data entry. This error, which can be even larger in the oldest data, was due to various technical limitations that existed throughout during the original surveying (1950's-1980's). While this precision was suitable for regional geologic mapping at scales of 1:250,000 or less, the error becomes quite noticeable at the now commonly used scales of 1:100,000 or 1:24,000. Beyond the annoyance of a poorly located data point, the displacement introduces a quantitative error into the reduced gravity values. For example, a north-south offset of 200 to 300 meters equates to an error of about 0.15 to 0.23 milligals, respectively. Although this level of error will not be significant where studies are concerned with anomalies of several milligals or larger, it will be a problem for investigating anomalies of 1 milligal or less, which can occur frequently when providing interpretations to support geologic mapping. In addition to addressing positional errors, the gravity data needed several other Improvements. Much of the data in the 2003 database lacks archival information, such as field number, date of acquisition, the specific instrument used, and the individual who did the readings. These omissions were usually made to accommodate the limited media formats and data storage that existed at the time. These bits of record can provide important information for evaluating the quality of the data and its suitability for a given application. Also, there has been a significant amount of gravity data collected in Minnesota since the release of the 2003 database, which can be added. .The MGS is particularly well-suited to carry out the task of updating the gravity data in the state. Most of the field notes and maps from previous gravity surveys are on-file at MGS, allowing for recovery of positional and archival data. In addition, the MGS has access to ArcGis software and Oasis-Montaj potential field software, providing a relatively straightforward means of re-positioning and re-reducing existing data, as well as incorporating new data. A project was initiated in 2009 to upgrade the MGS gravity data by (1) re-positioning the pre-existing stations and re-reducing these, (2) addition of the missing archival information to the pre-existing database, and (3) incorporating data that have become available since 2003. The resulting database contains 59,911 stations (Figure 1), and represents a significant improvement in size, completeness of information, and data quality. The database in its present form should serve the needs of the MGS and the broader geologic community for many years to come.

HISTORY OF GRAVITY SURVEYING IN MINNESOTA

The gravity database is compiled from many different gravity surveys beginning more than 50 years ago. Early systematic surveys were conducted in the mid-1950's, with a focus on the iron mining areas of Minnesota (Durfee, 1956 and Adams, 1957). Craddock and others (1970) compiled all of the gravity data available through the mid-1960's, and produced a state gravity map at 1:1,000,000 scale. The first efforts towards a comprehensive, state-wide surveying program were conducted between 1965 and 1969 by R, J, Ikola of MGS, who began acquiring stations at 1-2 mile (1.6-3.2 km) intervals along roads and trails that allowed motor vehicle access. Surveying of this scope continued through 1982 under the supervision of Professors L. D. McGinnis and C. P. Ervin of Northern Illinois University and into the late 1980's under supervision of V. W. Chandler of the MGS. This work culminated in the publication of a new state gravity map (Chandler and Schaap, 1991), with accompanying database and grids in a digital format. Gravity surveying by the MGS continued through 2002, usually in support of state- and federally-funded drilling and mapping programs throughout the state. These latter data were incorporated into the gravity database released in 2003.

Gravity surveying within the MGS since the 2003 database compilation, continued as part of new state- or federally-funded mapping projects where gravity data could support bedrock geologic mapping. Data acquired in 2003-2004 were conducted with support of the STATEMAP program of the U.S. Geological Survey (USGS), and were focused on areas along and inland from Lake Superior. These data filled several large coverage gaps over the Duluth Complex, most notably on Northshore Mining properties in the Mile Post 7 tailings area and along the railroad right-of-way between Babbitt and Silver Bay. In 2005 gravity surveying was conducted on the Hibtac property near Hibbing, Minnesota and in the Tower-Soudan area; the latter surveying was part of an evaluation for a Deep Underground Science and Engineering Laboratory (DUSEL) being considered by the National Science Foundation. Gravity surveying was conducted in the Bigfork area of north-central Minnesota in support of STATEMAP 100,000 scale map compilation, and surveying was conducted from 2006-2009 in support of the MGS County Geologic Atlas (CGA) Program in McLeod, Nicollet and Sibley Counties. Finally, gravity surveying was conducted in the Crane Lake area of northeastern Minnesota in support of another STATEMAP 100,000 scale bedrock geology compilation. The above projects yielded a total of 1145 new gravity stations.

In addition to newly acquired data, 879 closely-spaced (100-200 m) stations of pre-existing data were digitized and added to the database. These data were acquired along two profiles in west-central Minnesota, and were meant to supplement a seismic reflection study of crustal structure (Gibb and others, 1981 and Van de Voorde, 1980). Unfortunately, the positional accuracy of the original data was on the order of +/-200 meters, essentially negating the potential detail offered by the tight station spacing. These data were re-positioned and re-reduced as part of the Todd County Geologic Atlas. This part of the recovery relied primarily on the original field maps and surveyor's notes. The final task of compiling the missing archival information into the database was conducted during this project.

All re-positioning of stations was carried out within ArcGis, versions 9 and 10. Field notes and maps on-file at the MGS, were used to assist with locating the points on the digital maps. If no field notes or maps were available, the stations were re-positioned to what was judged to be their most likely position along nearby roads and trails. Typically these new positions corresponded to road intersections, bench marks or other features where spot elevations were available. If no such features were obvious, the station was moved the shortest visual distance to overlap a road or trail. The re-positioned data sets were imported into the Oasis-Montaj software system, and the data re-reduced to Free Air and Bouguer anomaly values. Individual datasets were merged into a single database that was in turn exported to an ESRI shapefile format as the final product.

. **DESCRIPTION OF THE UPGRADED DATABASE**

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 are made for earth curvature, but owing to the generally low topographic relief across most of Minnesota, no terrain corrections have been made. In their early compilation Chandler and Schaap (1991) estimated that reduced anomaly values typically had errors of 0.1-0.3 milligals, although some of the older stations could have errors of 0.3-0.5 milligals, possibly more. These errors will be decreased somewhat by the re-positioning and re-calculation that was part of the current upgrade. The reduction in error was estimated by comparing the Bouguer anomaly values of the pre-existing data set with those calculated after the re-positioning; the resultant distribution had a standard deviation of 0.16 milligal, so the error reduction was significant in some cases.

The principal fact gravity data are provided in an ESRI shapefile format named gravity_2011. The file can be accessed from the MGS web site home page, follow the Online services link, then click on the Gravity link under the Preview service heading of the table. From the application, it is possible to open the final report as a PDF document or download the shapefile from the MGS FTPS site.

Individual attributes associated with the data-table are described as follows:

UTME_N83 – UTM easting, NAD83 datum, Zone 15 N

UTMN_N83 – UTM northing, NAD83 datum, Zone 15 N

LAT_DD – Latitude in decimal degrees

LONG_DD – Longitude in decimal degrees

FIELD_NO – Station number, assigned in field

ELEV_FT – Station elevation in feet above mean sea level

METER – Gravity meter that was used for this station

OBSERVER – Name of individuals reading the gravity meter

ACQ_DATE – Date of acquisition, as available. Format is yyyymmdd

MGSQUAD – 7.5 minute quad station is located in, using MGS numbering system

QUAD_NAME – Name of 7.5 quad

QUAD_TILE – Another ID number for the quad

ABS-G – Absolute gravity value in milligals

FREE_AIR – Free air anomaly in milligals

BOUGUER – Bouguer anomaly in milligals

MAIN_BASE – Name of main base station, as available, usually part of a formal network.

FIELD_BASE – Name of field base, as available, usually tied to a major base and established as part of a local survey.

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Many individuals have contributed to the gravity database over the years. Space does not permit a full listing, but a fairly complete account for much of the work is given by Chandler and Schaap (1991). The authors are especially grateful to the Northshore Mining and Cleveland Cliffs companies for allowing access to their properties and for providing transportation in one case. Doug Halverson and Louie Larson of Northshore Mining were especially helpful in this regard. Rodney J. Ikola generously provided copies of field notes from some of the early surveying. During the summer of 2010 Roger Morrison lent valuable assistance during the early stages this compilation. Finally, the authors wish to give a special thanks to Jack Barland who worked on the project as a student during 2010-2011. Jack's efforts spanned data acquisition through GIS compilation, and his skills as a quick learner and a diligently consistent worker added much to the success of the program.

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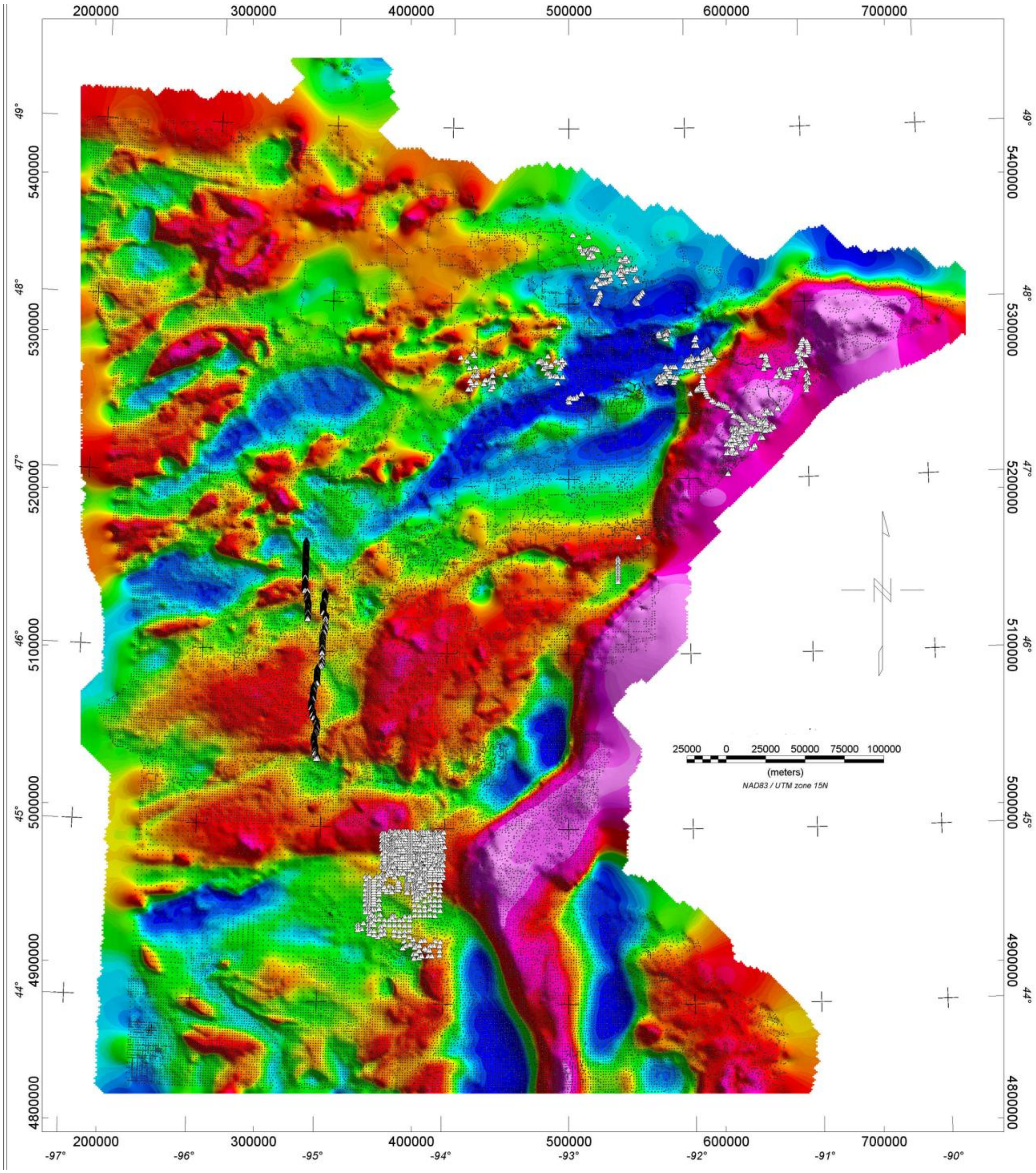
CAPTION

Figure 1. Upgraded gravity database. Station locations superimposed on a Bouguer Anomaly Map computed from the upgraded data. Black dots represent stations acquired before 2003, and white triangles represent stations acquired 2003-2010.



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