U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Merged Aeromagnetic and Gravity Data for Montana: A Web Site for Distribution of Gridded Data and Plot Files

by

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Open-File Report 98-333

1998

Abstract

This report is a listing of the primary information pages in the following web site:

http://minerals.cr.usgs.gov/publications/ofr/98-333/mt.html

This web site describes the results of a USGS project to merge the best available aeromagnetic data into a consistent 500-m grid spanning the state of Montana. It also includes data from over 40,000 gravity stations, and Bouguer and isostatic gravity grids at 1 km. The website allows users to download (via FTP) data files in several formats. The anonymous FTP site is:

ftp://minerals.cr.usgs.gov/minerals/ofr/98-333/data.

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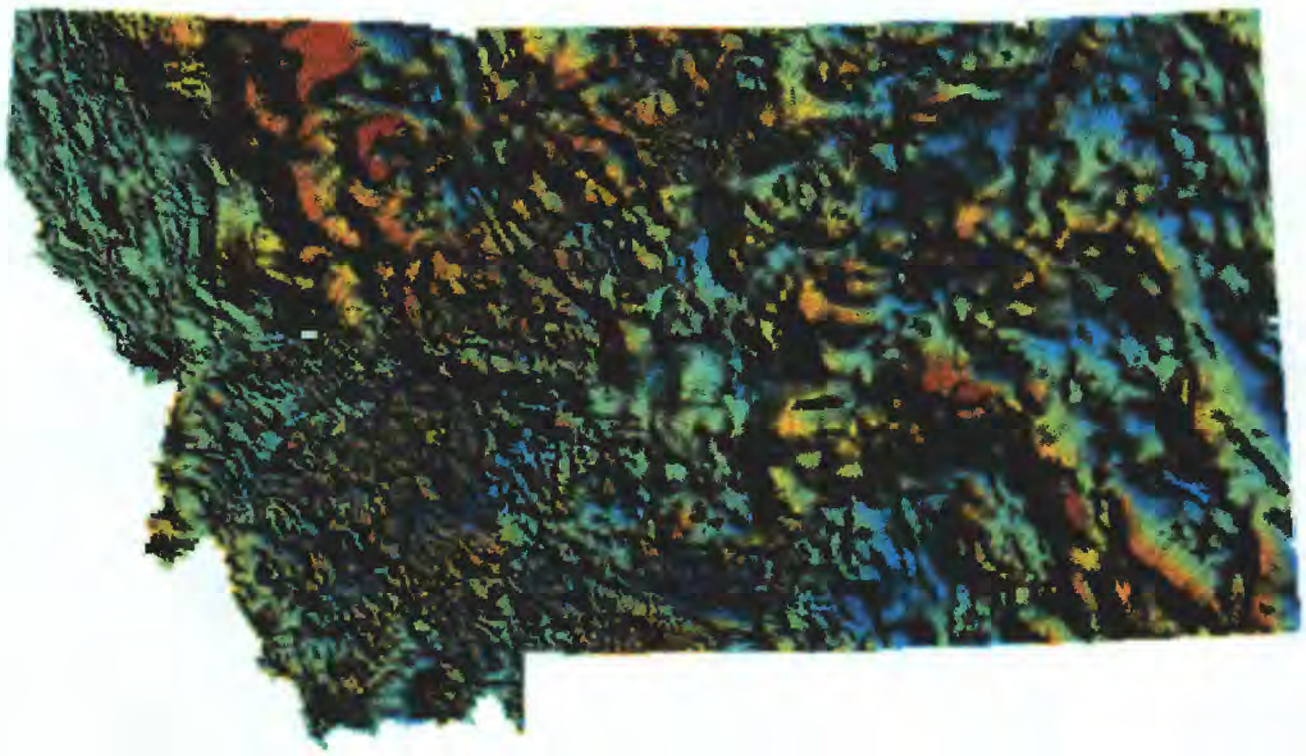
Montana Aeromagnetic and Gravity Maps and Data

Montana Aeromagnetic Anomaly Map



Get Map Info... | Get Processing Info... | Get Survey Info... | Bouguer Gravity Map... | Isostatic Gravity Map... | Get Data...

Non-graphical version of this page

URL: http://minerals.cr.usgs.gov/publications/ofr/98-333/mt.html
Maintainer: Anne McCafferty
Last modified: 16 Jun 1998

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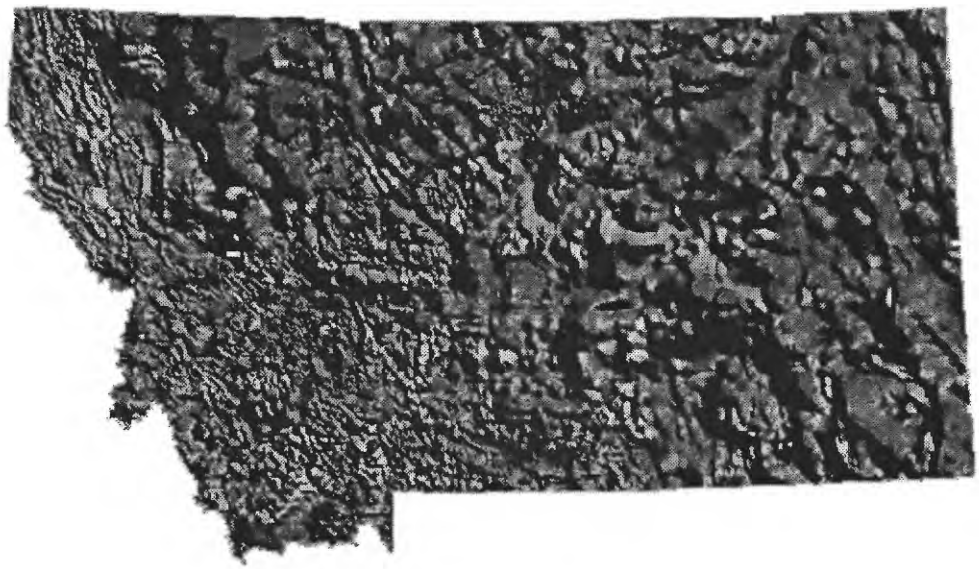
Montana Aeromagnetic and Gravity Maps and Data

This is a non-image-mapped page to access all the individual pages that make up the Montana Aeromagnetic and Gravity Web Site (USGS Open-file report 98-333) using older browsers. Pick a destination from the list below:

Read aeromagnetic map text
Read aeromagnetic project details
See the mag survey index map
See the mag survey index table
See the Bouguer gravity anomaly map
See the isostatic gravity anomly map
See reference list
Download gridded data via FTP

Montana Aeromagnetic Anomaly Map



URL: http://minerals.cr.usgs.gov/publications/ofr/98-333/mt_nograph.html
Maintainer: Anne McCafferty
Last Modified June 18, 1998 09:43 (MST)

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Montana Aeromagnetic Compilation

These maps show variations in the Earth's magnetic field caused primarily by the uneven distribution of the mineral magnetite in the rocks that make up the upper part of the Earth's crust. The features and patterns of the maps reveal details of subsurface geology including the locations of buried faults, the location of magnetite-bearing rocks, which include many kinds of rocks of interest to mineral exploration and environmental studies, and the thickness of surficial sedimentary rocks.

The map is constructed from grids that combine information collected in 65 separate aeromagnetic surveys conducted over the past 40 years. Data from these surveys are of varying quality. The design and specifications (terrain clearance, sampling rates, line spacing, and reduction procedures) varied from survey to survey depending on the purpose of the project and the technology of that time. An index plot gives an overview of the flightline spacing of the original surveys. A data table summarizes the detailed specifications of the surveys.

This project was supported by the Mineral Resource Program of the USGS.

Top || Montana Mag || Minerals || Geology || USGS

URL: http://minerals.cr.usgs.gov/publications/ofr/98-333/mt_desc.html
Maintainer: Anne McCafferty
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Montana Aeromagnetic Data Processing

The assembly of 65 individual aeromagnetic surveys and grids to build the Montana state-wide compilation was done in several steps.

DATA PROCESSING STEPS

1. Grids were constructed from the original aeromagnetic survey data with a cell size of between 1/3 and 1/5 of the flightline spacing of the survey, using a minimum curvature gridding algorithm when necessary due to wide flightline spacing. For digitized contour line data, the initial grid was constructed using a minimum curvature algorithm and a spacing appropriate for the scale of the digitized map.
2. Data quality problems were addressed.
3. The Definitive Geomagnetic Reference Field (DGRF) was applied for the date of the original survey (in some cases this required the determination and removal of the original reference field applied).
4. The survey grids were regridded, as necessary, to the final grid cell size of 500 m using a minimum curvature algorithm.
5. The datum levels of adjacent surveys were adjusted (by addition or subtraction of a constant value) to minimize differences at the boundaries.
6. The original survey grids were upward or downward continued and converted from level to drape as necessary to produce a consistent survey specification of 1000 ft above ground. Upward continuation of the NURE surveys was by standard 2D FFT filtering techniques. Downward continuation and level-to-drape was performed (Cordell and others, 1992).
7. The datum levels of the converted grids were then adjusted to minimize differences at the boundaries.
8. These adjusted grids were combined into a single merged grid.

GRID PROJECTION SPECIFICATIONS

- Projection = Lambert conformal conic
- Central meridian = 110 degrees W
- Base latitude = 0 degrees N
- Standard parallels = 33 and 45 degrees N
- Semi-major ellipsoid axis = 6378206.4 m
- Eccentricity squared = 0.0067686579973

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URL: http://minerals.cr.usgs.gov/publications/ofr/98-333/mt_proc.html
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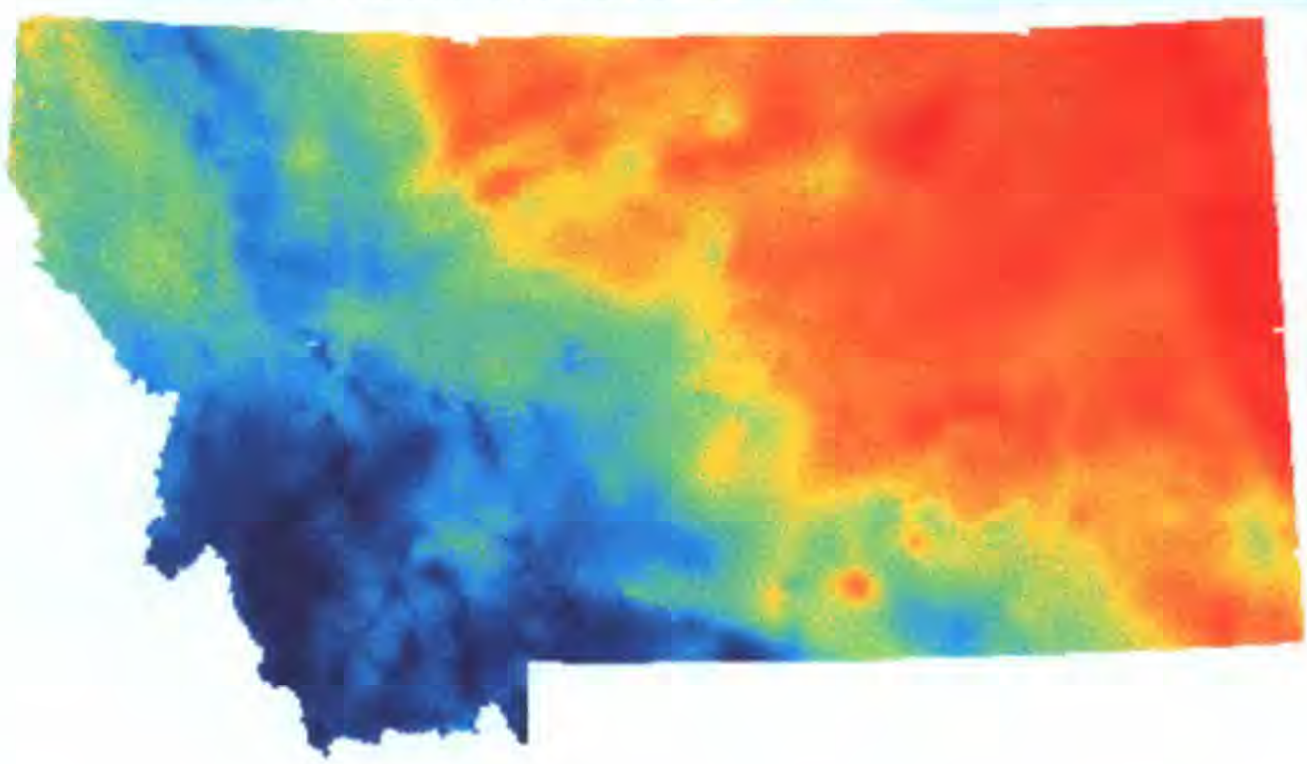
Montana Bouguer Gravity Anomaly Map



The complete-Bouguer gravity anomaly grid was compiled using data from over 35,000 gravity stations in and adjacent to the state of Montana. These data were extracted from the gravity data base maintained by the National Geophysical Data Center (from Department of Defense unclassified data) and augmented with data from the USGS and from several university theses and dissertations. Observed gravity relative to the IGSN-71 datum were reduced to the Bouguer anomaly using the 1967 gravity formula and a reduction density of 2.67 g/cc. Terrain corrections were calculated radially outward from each station to a distance of 167 km using a method developed by Plouff (USGS Open-file Report 77-535). The data were converted to a 1-km grid using minimum curvature techniques.

The gravity data are available as a compressed ASCII file for station data or as grids. This project was supported by the Mineral Resource Program of the USGS.

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URL: http://minerals.cr.usgs.gov/publications/ofr/98-333/mt_boug.html
Maintainer: Viki Bankey
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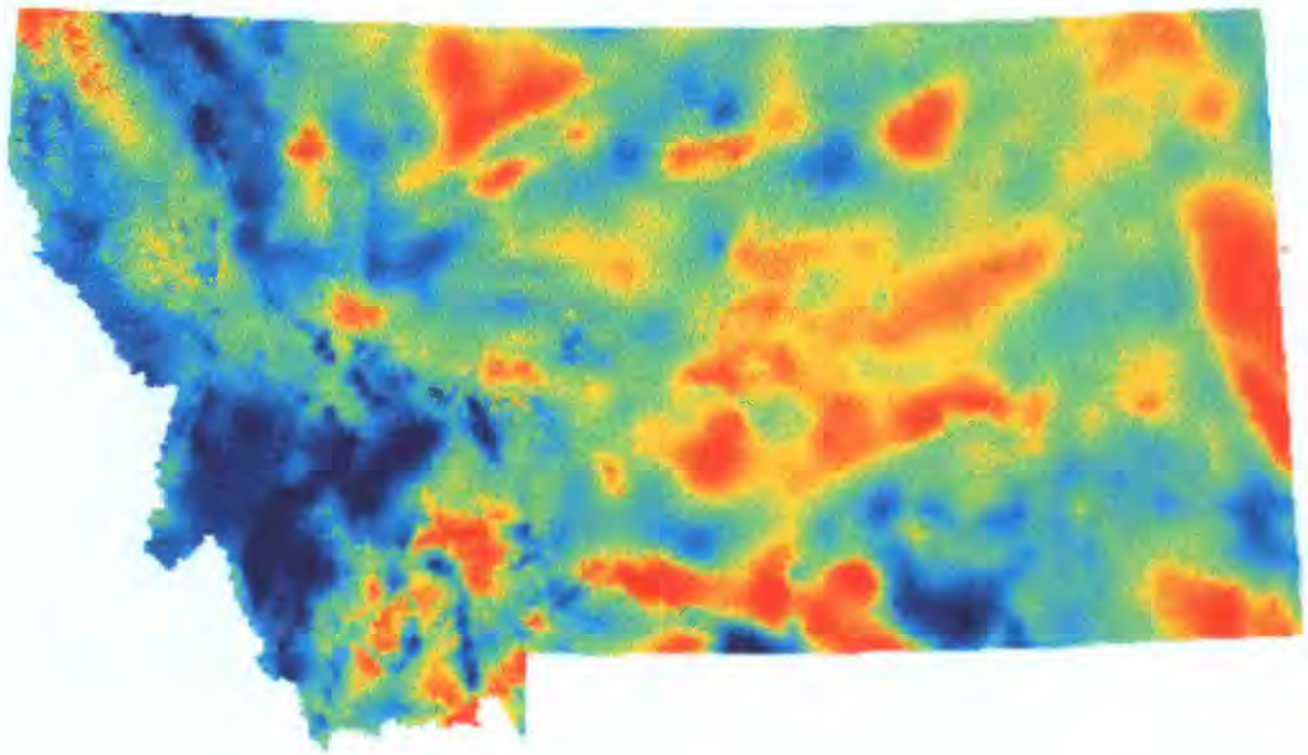
Montana Isostatic Gravity Anomaly Map



The colors on this isostatic gravity map reflect variations in the Earth's gravity field caused primarily by lateral variations in density in the rocks that make up the upper part of the Earth's crust. An isostatic gravity grid was derived from Bouguer and free-air gravity anomaly data. This grid was created by removing from the Bouguer gravity grid a model of the gravity expression caused by deficiencies in mass (compensating mass) that supports topographic loads. The calculation of the isostatic model used averaged digital topography, a crustal thickness of 30 km, a crustal density of 2.67 g/cc, and a density contrast between the crust and upper mantle of 0.35 g/cc. The features and patterns of the maps reveal details of subsurface geology including the location of buried faults, sedimentary basins, plutons, uplifted basement rocks, etc. Positive anomalies (red colors) delineate rocks denser than the surrounding rocks. Negative anomalies (blue colors) delineate rocks less dense than the surrounding rocks.

The gravity data are available as a compressed ASCII file for station data or as grids. This project was supported by the Mineral Resource Program of the USGS.

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URL: http://minerals.cr.usgs.gov/publications/ofr/98-333/mt_iso.html
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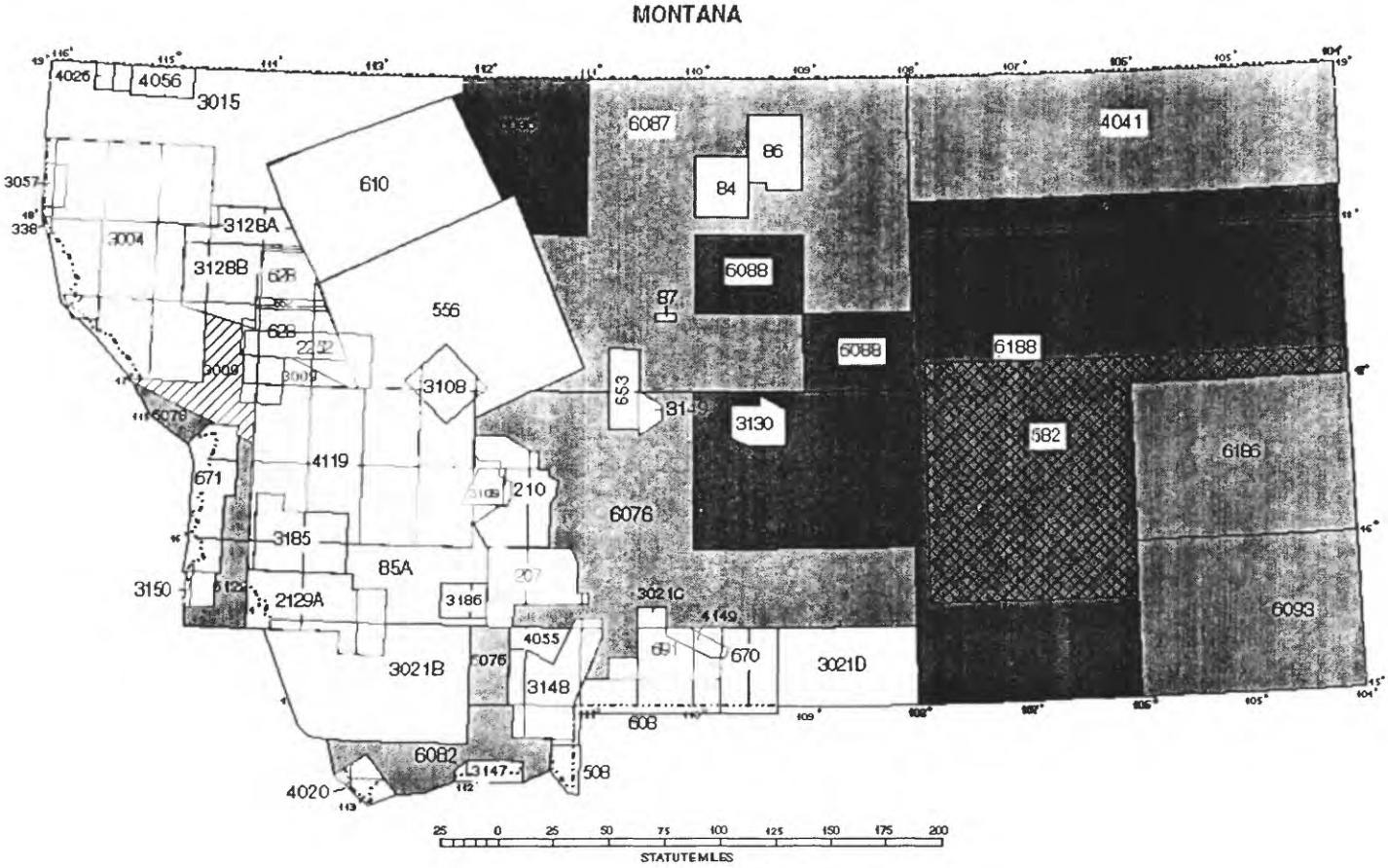
Montana Aeromagnetic Data Index Map



The Montana aeromagnetic compilation map contains data from 65 separate aeromagnetic surveys, digitized maps, and previous gridded compilations. This map is an index to the flightline spacing of the original surveys. A tabular index (see index) provides a summary of the data sources. The raw data for all these surveys are available from the National Geophysical Data Center (NGDC), Boulder, Colorado.

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URL: http://minerals.cr.usgs.gov/publications/ofr/98-333/mt_indmap.html
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Montana Aeromagnetic Compilation Index

Table of aeromagnetic surveys, specifications, and references.

No.[1]	Year Flown	Type[2]	Area Name	Line Spacing	Direction	Altitude (ft)[3]	Publication[4]
84	50	A	Bearpaw Mountains	0.5 mi.	var.	1000 AG	GP-150-153
85A	53	A	Boulder Batholith	2 mi.	E-W	10,500 B	GP-538
86	54	A	North Bearpaw	0.25 mi.	E-W	500 AG	GP-382-385
207	55	A	Bozeman	0.5 mi.	E-W	500 AG	GP-497,498
210	55	A	Townsend Valley	0.5 mi.	E-W	500 AG	GP-439,444,+
338B	59	A	Pend Oreille North-Central	1 mi.	E-W.	6000 B	P-646D
338C	59	A	Pend Oreille Central	0.5 mi.	E-W	6000 B	P-646D
508	62	A	Yellowstone '62	1 mi.	E-W	12,000 B	OF73-304
556	65	A	NW MT '65: Choteau	2 mi.	NE-SW	9000 B	P-726A
608	67	A	Northern Yellowstone '67	1 mi.	E-W	12,000 B	OF73-304
610	67	A	NW Montana '67	2 mi.	NE-SW	9000 B	OF69-289
628	67	A	Mission Range	1 mi.	E-W	9000 B	P-726A
652	68	A	Mission Range Fill-in	1 mi.	E-W	9000 B	P-726A
653	68	A	Little Belt Mountains	1 mi.	N-S	9000 B	GP-837
670A	69	A	Yellowstone Regional	1 mi.	N-S	13,000 B	OF73-304
670B	69	A	Yellowstone Regional	1 mi.	N-S	13,500 B	OF73-304
671	69	A	Selway-Bitterroot	1 mi.	N-S	11,000 B	GP-832

691	70	A	Beartooth	1 mi.	N-S	13,500 B	OF73-304
2252	79	D	Montana '79	0.5-1 mi.	E-W	8000 B	OF80-1127
3004	68	A	N.E. Idaho-W. Montana	1 mi.	E-W	7000 B	GP-682-691
3009	71	A	Missoula, MT., Lineament	1 mi.	N-S	7500 B	GP-934
3015A	72	A	Washington-Idaho-Montana	2 mi.	E-W	7000 B	OF73-293
3015B	72	A	Washington-Idaho-Montana	2 mi.	E-W	11,000 B	OF73-294
3021B	72	A	Central Idaho-SW Montana	2 mi.	E-W	12,000 B	OF75-655
3021C	72	A	North Absaraka Wilderness	1 mi.	E-W	12,000 B	B-1505
3021D	72	A	South-Central Montana	2 mi.	E-W	12,000 B	OF75-656
3108	77	D	Rogers Pass	0.75 mi.	NE-SW	7000 B	OF80-244
3109	77	D	Elkhorn Mountains	0.5 mi.	E-W	9000 B	OF78-325
3128	78	D	Wallace-Flathead	0.75-1 mi.	E-W	1000 AG	OF79-713
3129A	78	D	Dillon (Pioneer-Beaverhead Mts)	0.5 mi.	E-W	9000 B	OF79-758
3130	78	D	Big Snowy Mountains	1 mi.	N-S	9000 B	OF79-759
3147	79	D	Centennial	0.75 mi.	N-S	11,000 B	OF79-1443
3148	79	D	Gallatin	0.75 mi.	E-W	12,000 B	OF79-1648
3150	78	D	Blue Joint Area	0.75 mi	N-S	11000 B	OF79--1444
3185	81	D	Sapphire/Anaconda-Pintlar	0.5 mi.	E-W	1000 AG	OF81-1160
3186	80	D	Tobacco Roots	0.5 mi.	E-W	1000 AG	OF81-777
4020	81	D	Italian Peak	0.5 mi.	NE-SW	1000 AG	OF81-1162

4026	81	D	Mt. Henry	0.5 mi.	E-W	1000 AG	OF82-545
4041	80	D	Northeast Mt.-Western N.D.	3 mi.	E-W	4000 B	OF81-434
4055	81	D	Madison Range	0.75 mi.	E-W	12,000 B	OF82-946
4056	81	D	Ten Lakes	0.5 mi.	E-W	1000 AG	OF82-1084
4119	83	D	Butte	1 mi.	E-W	9000 B	OF84-278
4149	78	A	Stillwater '78	0.167 mi.	NE-SW	250 AG	OF84-799
6076	78	D	Southern Montana	3 mi.	E-W	400 AG	GJBX-081(79)+
6078	78	D	East Hamilton	3 mi.	E-W	400 AG	GJBX-119(79)
6082	78	D	Dubois-Ashton	3 mi.	E-W	400 AG	GJBX-106(79)+
6086	78	D	Northwest Montana NURE	6 mi.	E-W	400 AG	GJBX-126(79)
6087	78	D	North-central Montana	3 mi.	E-W	400 AG	GJBX-126(79)
6088	78	D	Lewistown NW-SE	6 mi.	E-W	400 AG	GJBX-126(79)
6093	78	D	Powder River II	3 mi.	E-W	400 AG	GJBX-082(79)
6122	79	D	Elk City	3 mi.	E-W	400 AG	GJBX-010(80)
6173	80	D	North-central Great Plains	6 mi.	E-W	400 AG	GJBX-068(81)+
6186	80	D	Miles City	3 mi.	E-W	400 AG	GJBX-180(81)
6188	80	D	Montana-North Dakota	6 mi.	E-W	400 AG	GJBX-179(81)+

1 Surveys refer to index map (USGS contract number) of magnetic surveys.

2 Data type: A, data exist in "analog" form only--subsequently, maps were digitized from published versions; D, data exist as original "digital" flight-line data.

3 Flight-altitude: AG, survey originally flown "above ground" in draped mode at a constant elevation above terrain; B, survey originally flown at constant "barometric" elevation.

4 Reference cited: References refer to published versions of the individual aeromagnetic surveys used in the compilation

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URL: http://minerals.cr.usgs.gov/publications/ofr/98-333/mt_indtab.html
Maintainer: Anne McCafferty
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Anne McCafferty
9 June 1998

README.TXT FILE FOR GRIDDED AND GRAVITY STATION DATA TRANSFER DIRECTORY

This directory contains ASCII and binary gridded files for
the Montana merged (mt*) aeromagnetic and gravity data.
Each data grid is available in four different data formats:

1. GeoSoft GXF format (an ASCII grid transfer format)
2. ER Mapper grid format (a two-part transfer format)
3. ARC/INFO grid export format (a binary format)
4. USGS ODDF grid format (a binary format)

Each of these formats is discussed briefly below.
If none of these formats are directly readable by software on your
system, then your best bet is to write a program to input
and translate the GXF format. Extensive description of this format
is given below.

The data grids in this directory have been compressed using the public-
domain "gzip" compression utility. Information on gzip is available at:

http://www.maths.lancs.ac.uk/~smithdm1/GNU/GNUWeb/gzip.html
(unix and PC DOS versions)

http://www.winzip.com/
(PC windows version)

http://www.1source.com/tools/compress.html
(contains link to download Mac gzip)

To avoid file name problems on older PC systems, we have replaced the
original "." in the filenames with an "_" (underscore) character.
For example:

original filename: mtmag.grd
changed to: mtmag_grd
compressed file name: mtmag_grd.gz

After you transfer and uncompress the files, you should rename them
to replace the "_" with a "." again.

COORDINATE SYSTEM DESCRIPTION

Projection	Lambert Conformal Conic		
Parameters:			
1st standard parallel(degrees, minutes, seconds)	33	0	0.000
2nd standard parallel(degrees, minutes, seconds)	45	0	0.000
central meridian(degrees, minutes, seconds)	-110	0	0.00
latitude of projection's origin(degrees, minutes, seconds)	0	0	0.000
false easting (meters)			0.00000
false northing (meters)			0.00000

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1. Grid eXchange Format (*.gxf)

GXF (Grid eXchange File) is a standard ASCII file format for exchanging
gridded data among different software systems. Software that supports the GXF

standard will be able to import properly formatted GXF files and export grids in GXF format.

Grid Description:
A grid is a rectangular array of points at which single data values define a two dimensional function. Grid point locations are related to a Grid Coordinate System (GCS), which is a right handed Cartesian system with X and Y axis defined by the bottom and left sides of a grid array. The grid point at the bottom, left corner of the array is the origin of the GCS. All distances are in meters.

GCS coordinates are related to a Base Coordinate System (BCS) through a plane translation and rotation. The origin of the GCS is located at point (x0,y0) in the BCS, and the X and Y grid indices are related to BCS units through the separation between points in the GCS X and Y directions.

Labeled Data Objects and Comments

A GXF file is an ASCII file made up of a number of labeled data objects and comments. Each labeled data object has a label line followed by one or more data lines. A label line is identified by a '#' character in the first column followed immediately by an upper-case label. The data associated with that label are found on one or more lines that follow the label.

Lines

All lines in a GXF file must be less than or equal to 80 characters in length. Any lines that are not part of a labeled data object are ignored and can be used to place comments within a GXF file. Programs that read GXF files will skip such comment lines while they search for the next GXF data object.

GXF Object Definitions

#TITLE
A one line descriptive title of the grid. Some grid formats include textual descriptions of the grid, and this information can be placed in a #TITLE object.
Default: blank title

#POINTS
The number of points in each grid row (horizontal or vertical as defined by the #SENSE object).
Default: no default - this object is required.

#ROWS
The number of rows in the grid. A grid row (or vector) is a collection of consecutive grid points that represent the grid values along a horizontal or vertical line in the grid. The complete grid is then defined by a consecutive sequence of grid rows.
Default: no default - this object is required.

#PTSEPARATION
The separation between points in the grid. This should be in Base Coordinate System units (ground units for geographically based grids).
Default: 1.0

#RWSEPARATION
The separation between rows in the grid. These should be in Base Coordinate System units (ground units for geographically based grids).
Default: 1.0

#XORIGIN
The X location of the bottom left corner of the grid in the Base Coordinate System.
Default: 0.0

#YORIGIN
The Y location of the bottom left corner of the grid in the Base Coordinate System.
Default: 0.0

#ROTATION
The rotation angle of the grid. This is the counter-clockwise angle of the bottom edge of the grid with respect to the Base Coordinate System X axis. Rotation only has meaning for Base Coordinate Systems that use the same units on the X and Y axis.
Default: 0.0

#SENSE
The first point of the first row of the stored grid can be at any corner of the grid rectangle, and the grid rows can be run vertically or horizontally. The SENSE object defines this storage sense as follows:

±1	first point at bottom left of grid
±2	first point at upper left of grid
±3	first point at upper right of grid
±4	first point at bottom right of grid

A positive SENSE stores rows in a right-handed sense; a negative SENSE stores rows in a left-handed sense. This means that if you were standing at the first grid point and looking into the grid, the first grid row would extend to your right for a right handed grid (positive sense), or to your left for a left handed sense (left-handed grid):
(All grids on this CD have SENSE=+1.)
Default: 1 (first point at bottom left, rows left to right)

#TRANSFORM
This keyword is followed by two numbers on the same line: SCALE and OFFSET, which are used to transform the grid data to desired units:
Z = G * SCALE + OFFSET
where

Z	grid value in the desired unit
G	are grid values as specified in the #GRID object

Default: SCALE = 1.0, OFFSET = 0.0

#DUMMY
The grid must be rectangular (every row must have the same number of points). The dummy value defined by this object is used to define blank areas of the grid. Any grids that include blank areas must define a dummy value.
Default: no dummy value.

#GRID
The grid data is listed point by point and row by row. The #GRID object and data is always the last object in a GXF file.
The first data point is at the location indicated by #SENSE, and is followed by successive points in that row of points (either horizontal or vertical), then the points in the next row, and so on. The points in a row can follow on to the next data line, although each new row must start on a new data line. A GXF reading program can expect #ROWS of #POINTS for a total of #ROWS times

#POINTS data values.
Default: none, must be included as the last object in a GXF file.

---

2. ER Mapper grid format (*.ers)

The ER Mapper grid format consists of two files: a binary data file (no file suffix) and a ASCII header file (*.ers). These files can be read directly by the ER Mapper software or by other packages such as ERDAS IMAGINE. Note that the header files refer to the projection called "L2MTEA". This is not a standard ER Mapper projection. To register the grid properly within ER Mapper you must create a projection entry that corresponds to the parameters listed above for the projection of these data. The files "project.dat" and "lamcon2.dat" include the correct projection information and format.

---

3. ARC/INFO Grid Export format (*.e00)

This format is readable by ARC/INFO, ERDAS IMAGINE, and other packages. When imported into ARC/INFO, this file will unpack into a directory containing all the components of the registered grid coverage.

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4. USGS ODDF binary grid format (*.gd)

This is a binary format with an included ASCII header. This format is used by the USGS Geophysics Group within the Minerals Program of the Geologic Division.

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5. ASCII Gravity Data File (gmtgrav.gz)

Description of the ASCII gravity station listing, named mtgrav.gz, a compressed file containing 40,671 stations within or adjacent to Montana.

The fields are listed in this order:

Station identification; 8 digit numbers are from the National Information Mapping Agency and the first four digits are their reference to individual surveys; other stations are USGS or other sources.

Longitude, negative west, in degrees, decimal degrees

Latitude, positive north, in degrees, decimal degrees

Free air gravity anomaly, in milligals (mGals)

Bouguer gravity anomaly, in milligals, reduction density 2.67 g/cc

Elevation, in feet

Inner terrain correction zone, from 0 to .895 km radial distance, mGals

Outer terrain correction zone, from .895 to 167 km radial distance, mGals (note: total terrain correction obtained by adding inner and outer zones)

Observed gravity minus 980,000. mGals, in mGals.

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Montana Aeromagnetic References

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- Aero Service Corp., 1979, Airborne gamma-ray spectrometer and magnetometer survey, Ashton Quadrangle, (Idaho, Montana, Wyoming): U.S. Department of Energy, Grand Junction Office Report GJBX-106(79), 2 volumes.

- Aero Service Corp., 1979, Airborne gamma-ray spectrometer and magnetometer survey, Dubois Quadrangle, (Idaho, Montana): U.S. Department of Energy, Grand Junction Office Report GJBX-155(79), 2 volumes.

- Balsley, J.R., Gilbert, F.P., and Mangan, G.B., 1957, Aeromagnetic map of the Shambo Quadrangle, Bearpaw Mountains, Montana: U.S. Geological Survey Geophysical Investigations Map GP-151, scale 1:31,680.

- Balsley, J.R., Gilbert, F.P., and Mangan, G.B., 1957, Aeromagnetic map of part of the Centennial Mountain Quadrangle, Bearpaw Mountains, Montana: U.S. Geological Survey Geophysical Investigations Map GP-152, scale 1:31,680.

- Balsley, J.R., Gilbert, F.P., and Mangan, G.B., 1957, Aeromagnetic map of part of the Warrick Quadrangle, Bearpaw Mountains, Montana: U.S. Geological Survey Geophysical Investigations Map GP-153, scale 1: 31,680.

- Blakely, R.J., 1984, Map showing aeromagnetic data over the Stillwater complex and vicinity, Montana: U.S. Geological Survey Open-File Report 84-799, 3 sheets, scale 1:24,000.

- Davis, W.E., Kinoshita, W.T., and Robinson, G.D., 1965, Bouguer gravity, aeromagnetic, and generalized geologic map of the western part of the Three Forks Basin, Jefferson, Broadwater, Madison and Gallatin counties, Montana: U.S. Geological Survey Geophysical Investigations Map GP-497, 2 sheets, scale 1:62,500.

- Davis, W.E., Kinoshita, W.T., and Robinson, G.D., 1965, Bouguer gravity, aeromagnetic, and generalized geologic map of the eastern part of the Three Forks Basin, Broadwater, Madison and Gallatin counties, Montana: U.S. Geological Survey Geophysical Investigations Map GP-49 8, 2 sheets, scale 1:62,500.

- Davis, W.E., Kinoshita, W.T., and Smedes, H.W., 1963, Bouguer gravity , aeromagnetic, and generalized geologic map of East Helena and Canyon Ferry quadrangles and part of the Diamond City Quadrangle, Lewis and Clark, Broadwater, and Jefferson counties, Montana: U.S. Geological Survey Geophysical Investigations Map GP-444, 2 sheets, scale 1:62,500.

- EG&G GeoMetrics, Inc., 1980, Aerial gamma ray and magnetic survey survey, Idaho project, Hailey, Idaho Falls, Elk City quadrangles, Idaho and Montana, and Boise Quadrangle, Oregon and Idaho: U.S. Department of Energy, Grand Junction Office Report GJBX-010(80), 5 volumes.

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