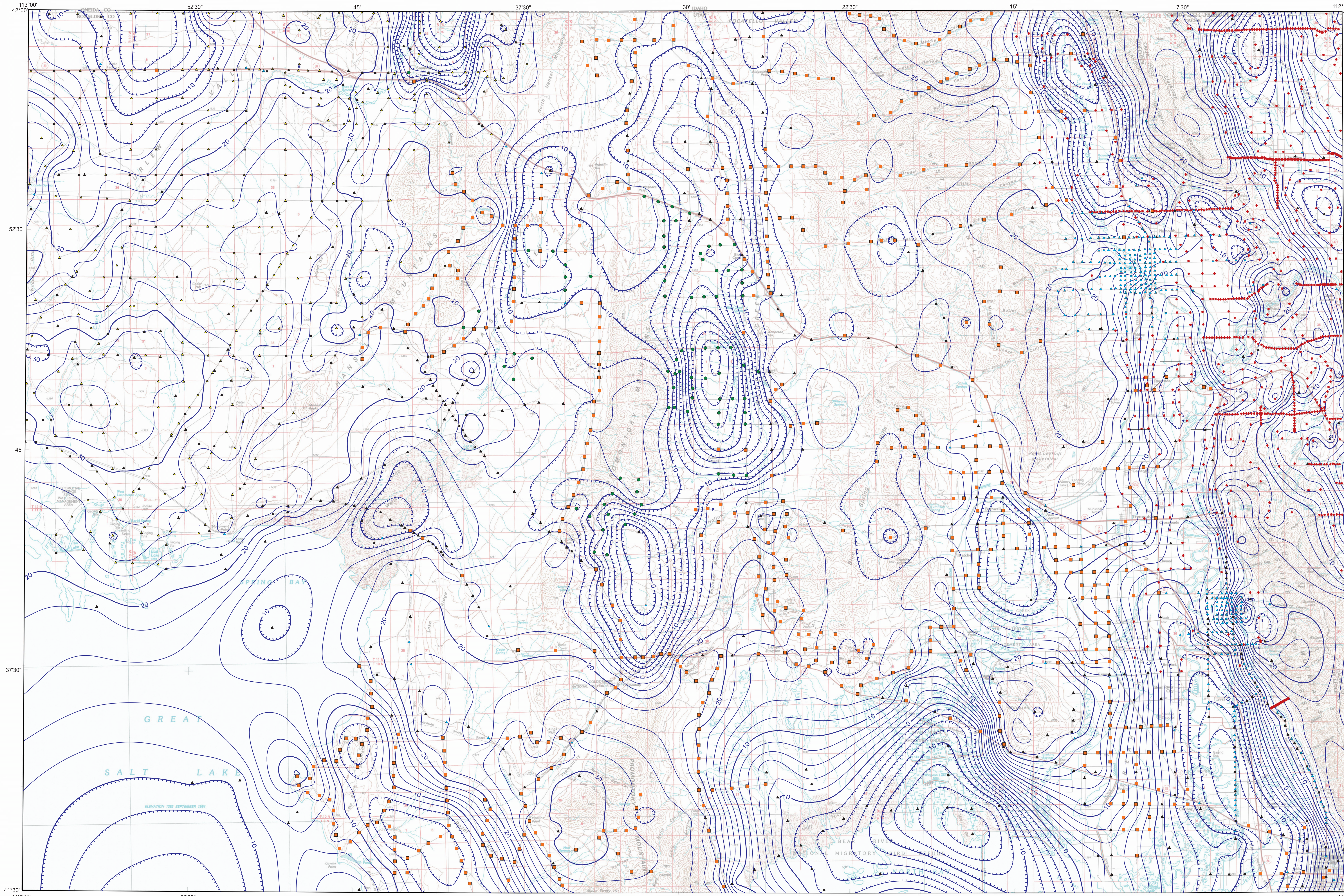
Utah Geological Survey
a division of
Utah Department of Natural Resources
in cooperation with
U.S. Department of the Interior
U.S. Geological Survey



Topographic base from U.S. Geological Survey 1:100,000 Tremonton quadrangle.
Projection, Universal Transverse Mercator. 1927 North American Datum.

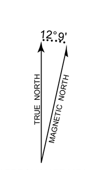
ISBN 978-1557918925

SCALE 1:100,000

2 0 2 4 6 Miles

2 0 2 4 6 Kilometers

Topographic contour interval 50 meters



APPROXIMATE MEAN DECLINATION, 2014

PRELIMINARY ISOSTATIC RESIDUAL GRAVITY MAP OF THE TREMONTON 30' x 60' QUADRANGLE, BOX ELDER AND CACHE COUNTIES, UTAH, AND FRANKLIN AND ONEIDA COUNTIES, IDAHO

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2014

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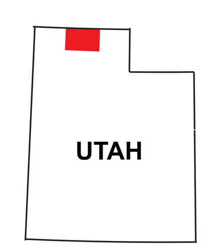
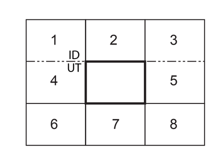


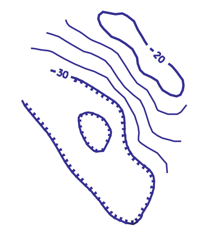
STUDY AREA



1. Oakley
2. Malad City
3. Preston
4. Grouse Creek
5. Logan
6. Newfoundland Mountains
7. Promontory Point
8. Ogden

ADJOINING 30' X 60' QUADRANGLE NAMES

EXPLANATION



Gravity anomaly contours. Contour interval, 2 mGal. Hachures indicate gravity low. Contours were computer-generated based on a 400-m grid using the principle of minimum-curvature (Briggs, 1974). Although the data have been edited, caution should be exercised when interpreting anomalies controlled by only a single gravity station.

MEASUREMENT LOCATIONS

- Older data (Bankey and others, 1998)
- Pan American Center for Earth and Environmental Sciences (2010)
- Utah State University (Goessel, 1999)
- Utah Geological Survey (Hurlow and Burk, 2008)
- Utah Geological Survey 2011-2012
- U.S. Geological Survey 2011-2012

ABSTRACT

This isostatic residual gravity map is part of an effort to map the three-dimensional geology in northwest Utah. This map will serve as a basis for modeling the shape of basins and for determining the location and geometry of faults within the area. The map presents gravity anomalies contoured at an interval of 2 milliGals (mGal) on a topographic base at a scale of 1:100,000. Figure 1 shows contours with a color ramp applied to 2 mGal intervals, at a scale of approximately 1:400,000. Local spatial variations in the Earth's gravity field, after accounting for variations caused by elevation, terrain, and deep crustal structure, reflect the distribution of densities in the mid- to upper crust. Densities often can be related to rock type, and abrupt spatial changes in density commonly mark lithologic or structural boundaries.

Higher density pre-Cenozoic rocks exposed within the mountain ranges in the quadrangle are comprised of a sedimentary sequence that ranges from Cambrian to Permian in age. These rocks define basement for gravity interpretations. Alluvial sediments, usually located in the valleys, and Tertiary sedimentary rocks are characterized by low densities. However, with increasing depth of burial and age, the densities of these rocks may become indistinguishable from those of basement rocks. Tertiary volcanic rocks are characterized by a wide range of densities, but are less dense, on average, than the pre-Cenozoic basement rocks. Basalt exposed in Curlew Valley, the north Hansel Mountains and east of the Great Salt Lake, is as dense as crystalline basement, but is probably thin (less than 300 m thick), as indicated by the thickness of basalt encountered in drill holes in the Great Salt Lake 5 km south of the quadrangle boundary (Bortz, 2002).

Isostatic residual gravity values within the map area range from about -17 mGal over North Bay to nearly +35 mGal over the southern part of Curlew Valley. Steep linear gravity gradients bound the Wellsville, Clarkston, and Promontory Mountains, as well as Little Mountain, West Hills, and the eastern margin of the North Promontory Mountains. These gradients result from juxtaposing dense basement rocks against thick Cenozoic sedimentary rocks and have been inferred to mark basin-bounding faults in northwest Utah (Cook and others, 1964).

DATA SOURCES, REDUCTIONS, AND ACCURACIES

The isostatic residual gravity map was created from 2698 gravity stations. Previously published data are from a regional compilation by (Bankey and others, 1998) and the Pan American Center for Earth and Environmental Sciences (2010). Other sources include data collected in Curlew Valley for a hydrogeologic study (Hurlow and Burk, 2008), data collected by Bob Oaks and his students at Utah State University (Goessel, 1999), and efforts in 2011-2012 by the Utah and U.S. Geological Surveys. Gravity stations are non-uniformly distributed in the region, mostly along roads. Station spacing is on average 1 station per 2 km^2, although the station spacing is as low as 1 station per 50 km^2 within remote parts of the quadrangle, such as the Great Salt Lake and Wellsville Mountains.

The datum of observed gravity for this map is the International Gravity Standardization Net of 1971 (IGSN 71) as described by Morelli (1974); the reference ellipsoid is the Geodetic Reference System of 1967 (GRS67; International Union of Geodesy and Geophysics, 1971). The observed gravity data were reduced to free-air anomalies using standard formulas (for example, Telford and others, 1990). Bouguer, curvature, and terrain adjustments to a radial distance of 166.7 km were applied to the free-air anomaly at each station to determine the complete Bouguer anomalies at a standard reduction density of 2670 kg/m^3 (Plouff, 1977). An isostatic adjustment was then applied to remove the long-wavelength effect of deep crustal and/or upper mantle masses that isostatically support regional topography. The isostatic adjustment assumes an Airy-Heiskanen model of isostatic compensation (Heiskanen and Vening-Meinesz, 1958). Compensation is achieved by varying the depth of the model crust-mantle interface, using the following parameters: a crustal thickness of 25 km for topography at sea level, a crust-mantle density contrast of 400 kg/m^3, and a crustal density of 2670 kg/m^3 for the topographic load. These parameters were used because (1) they were consistent with model parameters used for isostatic corrections computed for nearby Nevada (Ponce, 1997), and (2) changing the model parameters did not significantly affect the resulting isostatic anomaly (Jachens and Griscom, 1985). The computer program ISOCOMP (Jachens and Roberts, 1981) directly calculates the attraction of an Airy-Heiskanen root by summing the attraction of individual mass prisms making up the root and thus calculating the isostatic adjustment. The resulting isostatic residual gravity values should reflect lateral variations of density within the mid- to upper crust. Higher gravity values in Curlew Valley may be caused by thick basalt flows (Hurlow and Burk, 2008), although equivalent values over Paleozoic limestone suggest that the highs are also produced in part by deeper crustal density variations and/or crustal thinning in this area.

Accuracy of the data used to create this map is estimated to be on the order of ±0.1 to ±0.5 mGal based on comparison of observed gravity values at duplicate measurements from different data sources and expected uncertainty resulting from the total terrain correction and station elevation. Note that some of the older data were located using a 1:250,000-scale quadrangle and plot parallel to roads. In a few cases when the elevation of the data point could be correlated to a benchmark elevation on a road, the data point was relocated and anomalies and terrain corrections recalculated. Total terrain corrections for the measurements collected for this study ranged from 0.18 to 17.36 mGal, with an average of 1.16 mGal. If the uncertainty from the terrain correction is considered to be 5 to 10% of the terrain correction, the largest uncertainty expected for the data is 1.7 mGal. However, the likely uncertainty due to the terrain correction is small (less than 0.1 mGal) for most of the stations. The elevations are known to ±1 m or better for most of the measurements, yielding an uncertainty due to elevation in the anomaly value of <0.2 mGal.

ACKNOWLEDGMENTS

We thank Darcy McPhee, Jared Peacock, Don Clark, and Grant Willis for their reviews of the map. We thank various landowners for granting access. The study was supported by U.S. Geological Survey National Cooperative Geologic Mapping Program and the Utah Geological Survey.

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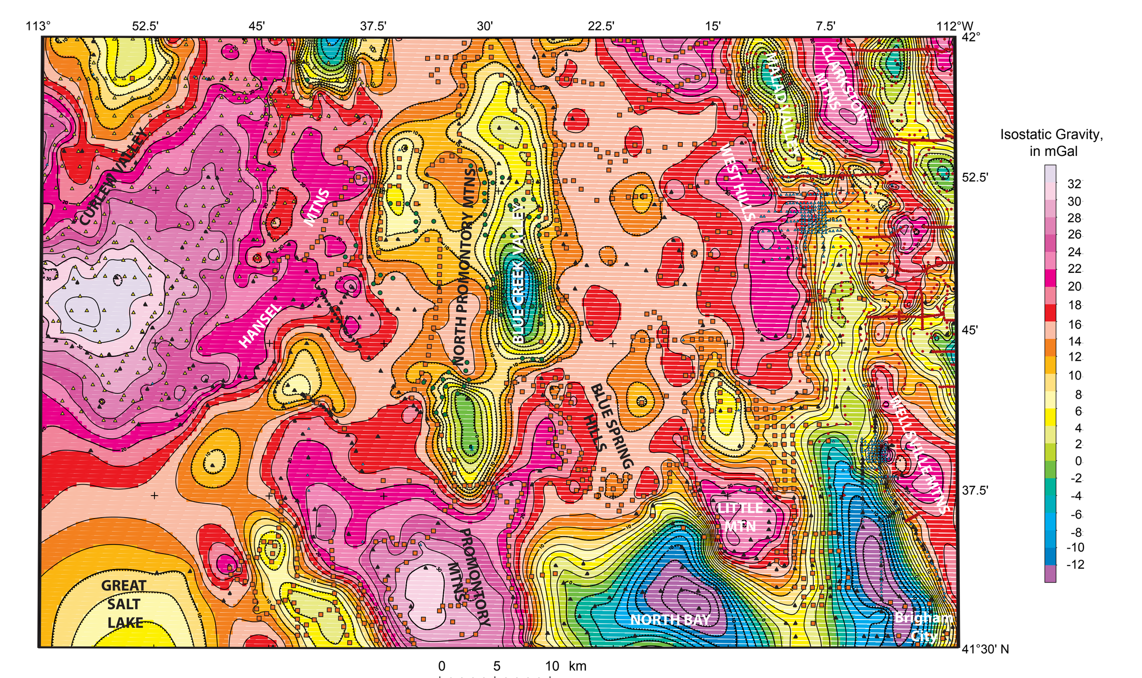

Figure 1. Colored isostatic residual gravity map. Symbols are gravity measurements shown with same shape and color as in main map, but smaller.

Preliminary Isostatic Residual Gravity Map of the Tremonton 30′ x 60′ Quadrangle, Box Elder and Cache Counties, Utah, and Franklin and Oneida Counties, Idaho

by V.E. Langenheim, R.Q. Oaks, H. Willis, A.I. Hiscock, B.A. Chuchel, J. Rosario, and C.L. Hardwick

2014

Utah Geological Survey Miscellaneous Publication 14-2

ABSTRACT

A new isostatic residual gravity map of the Tremonton 30′ x 60′ quadrangle of Utah is based on compilation of preexisting data and new data collected by the Utah and U.S. Geological Surveys. Pronounced gravity lows occur over North Bay, northwest of Brigham City, and Malad and Blue Creek Valleys, indicating significant thickness of low-density Tertiary sedimentary rocks and deposits. Gravity highs coincide with exposures of dense pre-Cenozoic rocks in the Promontory, Clarkston, and Wellsville Mountains. The highest gravity values are located in southern Curlew Valley and may be produced in part by deeper crustal density variations or crustal thinning. Steep, linear gravity gradients coincide with Quaternary faults bounding the Wellsville and Clarkston Mountains. Steep gradients also coincide with the margins of the Promontory Mountains, Little Mountain, West Hills, and the eastern margin of the North Promontory Mountains and may define concealed basin-bounding faults.

CITATION

Langenheim, V.E., Oaks, R.Q., Willis, H., Hiscock, A.I., Chuchel, B.A, Rosario, J., and Hardwick, C.L., 2014, Preliminary Isostatic Residual Gravity Map of the Tremonton 30′ x 60′ Quadrangle, Box Elder and Cache Counties, Utah, and Franklin and Oneida Counties, Idaho: Utah Geological Miscellaneous Publication 14-2, 1 plate, scale 1:100,000.

NOTICES

This project was funded by the Utah Geological Survey and the U.S. Geological Survey, National Cooperative Geologic Mapping Program. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

GRAVITY DATA CONTENTS

The six data files included in Utah Geological Survey Miscellaneous Publication 14-2 are given as ascii data files and as Excel files on this CD, and are online at geology.utah.gov/maps/geophysmap/index.htm.

The format of the data files are described below.

The horizontal and vertical locations for the stations are on the North American Datum 1927 (NAD27) and the North American Vertical Datum 1929 (NAVD29), respectively.

The gravity measurements are separated into six files according to source. old-iso.txt contains previously collected measurements (see Bankey and others, 1998). Some of these data were located on 1:250,000-scale quadrangles and do not plot on, but are offset from roads. Where the elevation of a measurement could be correlated to a benchmark elevation along the road, the data point was relocated and the resulting terrain corrections and anomalies recalculated (these measurements have a tc code of M). For other measurements, they were left as is (tc code of f). oaks-iso.txt contains data collected by Robert Q. Oaks and his students at Utah State University. paces-iso.txt contains data downloaded from the Pan-American Center for Environmental and Earth Science (http://research.utep.edu/Default.aspx?tabid=37229 [last accessed September 23, 2010]). curlew-iso.txt contains data from Hurlow and Burk (2008). Terrain corrections were recalculated for these data using 10- and 30-m digital elevation models out to a distance of 2000 m (code M). ugs-iso.txt and usgs-iso.txt are data collected in 2011–2012 by the Utah Geological Survey and the U. S. Geological Survey, respectively. Elevation control was from postprocessing of Trimble handheld GPS devices and accuracy is estimated to be 1 meter or less. Data were tied to the base station at Snowville, Utah. Terrain corrections were calculated using 10- and 30-m digital elevation models out to a distance of 2000 m (code M).

The data were referenced to the International Gravity Standardization Net 1971 (IGSN71) datum and the reference ellipsoid is the Geodetic Reference System 1967 (GRS67). The free-air anomalies were calculated using a modified version of formulas from Swick (1942). The complete Bouguer anomalies were calculated from the free-air anomalies using the Bouguer correction, terrain corrections, a curvature correction, and a reduction density of 2670 kg/m3. Isostatic corrections were calculated using an Airy-Heiskanen model of isostatic compensation. The depth of the crust-mantle boundary was controlled using the following parameters: a crustal thickness at sea level of 25 km, a density contrast of 400 kg/m3 between the crust and mantle, and a crustal density of 2670 kg/m3.

EXPLANATION OF PRINCIPAL FACT FORMAT FOR GRAVITY MEASUREMENTS

Files old-iso.txt, oaks-iso.txt, paces-iso.txt, curlew-iso.txt, ugs-iso.txt, and usgs-iso.txt are fixed format. Format is as follows:

ITEM	**EXPLANATION**
STATION NAME:	An alphanumeric combination of up to 8 characters used for station identification. Columns 0–8
LATD:	Degree latitude. Columns 9–11
LATM:	Minute latitude. Columns 12–17
LOND:	Degree longitude. Columns 18–21
LONM:	Minute latitude. Columns 22–27
ELEV:	Elevation. Columns 28–35
OG:	Observed gravity. Columns 36–45
FAA:	Free-air anomaly. Columns 46–58
SBA:	Simple Bouguer anomaly. Columns 59–66

ITC:	Inner terrain correction out to a radius of various distances (see TC CODE) from the station, for a density of 2.67 g/cc. Columns 67–73
TC:	Total terrain correction from the station to 166.7 km for a density of 2.67 g/cc. Columns 74–80
TC CODE:	Letter denoting the extent of the inner-zone correction, according to the Hayford-Bowie and Hammer templates (f=895 meters; M=2000 meters). See Spielman and Ponce (1984) for additional explanation. Column 82
CBA:	Complete Bouguer anomaly reduced for a density of 2.67 g/cc. Columns 83–90
ISO:	Isostatic residual anomaly values. Columns 91–98.

Example of format for gravity file

```
BE001    41. 42.60 112. 12.01  4318.0 79898.71       -17.29 -164.56   0.00   0.22 M -165.65   15.87
```

STATION NAME:	BE001
LATD:	41 degrees North
LATM:	42.60 minutes
LOND:	112 degrees West
LONM:	12.01 minutes
ELEV:	4318.0 feet
OG:	979898.71 mGal
FAA:	-17.29 mGal
SBA:	-164.56 mGal
ITC:	0.00 mGal
TC:	0.22 mGal
TC_CODE:	M (2000 m)
CBA:	-165.65 mGal
ISO:	15.87 mGal

REFERENCES

Bankey, V., Grauch, V.J.S., and Kucks, R.P., 1998, Utah aeromagnetic and gravity maps and data: A web site for distribution of data: U.S. Geological Survey Open-File Report 98-0761: Online, http://pubs.usgs.gov/of/1998/ofr-98-0761/, last accessed December 26, 2012.

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