UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

# Gravity survey data of the Terry Badlands, Antelope Creek, and Cow Creek BLM study areas, Blaine, Phillips, and Prairie Counties, Montana

by

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Open-File Report 86-590

1986

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## Studies related to Wilderness

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine the mineral values, if any, that may be present. Results must be made available to the public and be submitted to the President and the Congress. This report presents the data from a gravity survey of the Terry Badlands, Cow Creek, and Antelope Creek Wilderness Study Areas and vicinity, Montana.

## Introduction

This report presents part of the work undertaken by the U.S. Geological Survey to evaluate the mineral resource potential of the Terry Badlands, Cow Creek and Antelope Creek areas. During the summer field season of 1985, 61 new gravity stations were established in these areas. The Terry Badlands (MT-024-684) covers 29,020 acres; Antelope Creek (MT-065-266) covers 9,600 acres; and Cow Creek (MT-066-256) covers 21,590 acres (fig. 1). The acreages given here are those for which the Bureau of Land Management requested surveys, and throughout this report are referred to as the "wilderness study area" or "area". The Antelope Creek and Cow Creek areas are located in Blaine and Phillips Counties, south of the Fort Belnap Indian Reservation and north of the Charles M. Russell National Wildlife Range. The Terry Badlands area is located 28 mi northwest of Miles City. This report presents the principal facts for these data.

## Data Collection

Gravity observations were made using LaCoste-Romberg gravity meter G-550. The gravity stations were referenced to the U.S. Department of Defense (DOD) base at Glendive or Malta, Montana (appendices A and B), which are part of the International Gravity Standardization Net, 1971, (Morelli, 1974). Gravity loops were started and closed daily by making repeat observations at the primary or secondary bases. Access was by vehicle along highways and secondary roads outside or between the wilderness study areas.

## Elevation Control

Station elevations were obtained from benchmarks, spot elevations, and section corners on 1:24,000-scale and 1:62,500-scale USGS topographic maps. The uncertainty of elevations based on benchmarks is assumed to be 0.5 ft (0.15 m). For spot elevations and section corners, on 1:24,000-scale maps with a 40-ft contour interval, the uncertainty is assumed to be one-third the contour interval, or thirteen ft. At a density of 2.67 $g/cm^3$, this elevation uncertainty translates to a maximum uncertainty in the Bouguer anomaly value of 0.74 mGals.

## Data Reduction

Computer programs existing on the USGS Digital Equipment Corporation VAX 11-750 computer system were used to obtain principal facts and terrain-corrected gravity values. A program written by M. W. Webring, D. A. Dansereau, and R. R. Wahl (USGS, unpub. program, 1983) was used to reduce

gravity meter-readings to observed-gravity values by calculating and correcting for earth tide and linear meter-drift. The theoretical gravity value was calculated using the 1967 formula of the Geodetic Reference System (International Association of Geodesy, 1971). Mathematical equations are given in Cordell and others (1982).

Terrain corrections were computed using a program by R. H. Godson (USGS, unpub. program, 1978), correcting for the gravity effects of terrain from each station to a radial distance of 166.7 km (103.4 mi) using a modification of the method of Plouff (1977). Godson's program also calculates earth-curvature corrections and complete (terrain-corrected) Bouguer gravity anomaly values. These computed terrain corrections use mean-elevation data digitized on a 15-second grid for corrections from 0 to 5 km (3.1 mi), 1-minute terrain data for corrections from 5 to 21 km (13.0 mi), and 3-minute terrain data for corrections from 21 to 166.7 km (103.4 mi). A density of 2.67 $g/cm^3$ was used to calculate terrain corrections, giving the corrections and gravity anomaly values listed in Appendix C.

## References


Briggs, I. C., 1974, Machine contouring using minimum curvature: Geophysics, v. 39, no. 1, p. 39-48.

Cordell, Lindrith, Keller, G. R., and Hildenbrand, T. G., 1982, Bouguer gravity map of the Rio Grande Rift, Colorado, New Mexico, and Texas: U.S. Geological Survey Geophysical Investigations Series, Map GP-949, scale 1:1,000,000.

Defense Mapping Agency, 1974, World Relative Gravity Reference Network, North America, Part 2: St. Louis, Missouri, Aerospace Center, DMAAC Reference Publication 25, with supplement updating gravity values to the International Gravity Standardization Net 1971, 1635 p.

International Association of Geodesy, 1971, Geodetic Reference System, 1967: International Association of Geodesy Special Publication No. 3, 116 p.

Morelli, Carlo, ed., 1974, The International Gravity Standardization Net 1971: International Association of Geodesy Special Publication No. 4, 194 p.

Plouff, Donald, 1977, Preliminary documentation for a FORTRAN program to compute gravity terrain corrections based on topography digitized on a geographic grid: U.S. Geological Survey Open-File Report 77-535, 43 p.

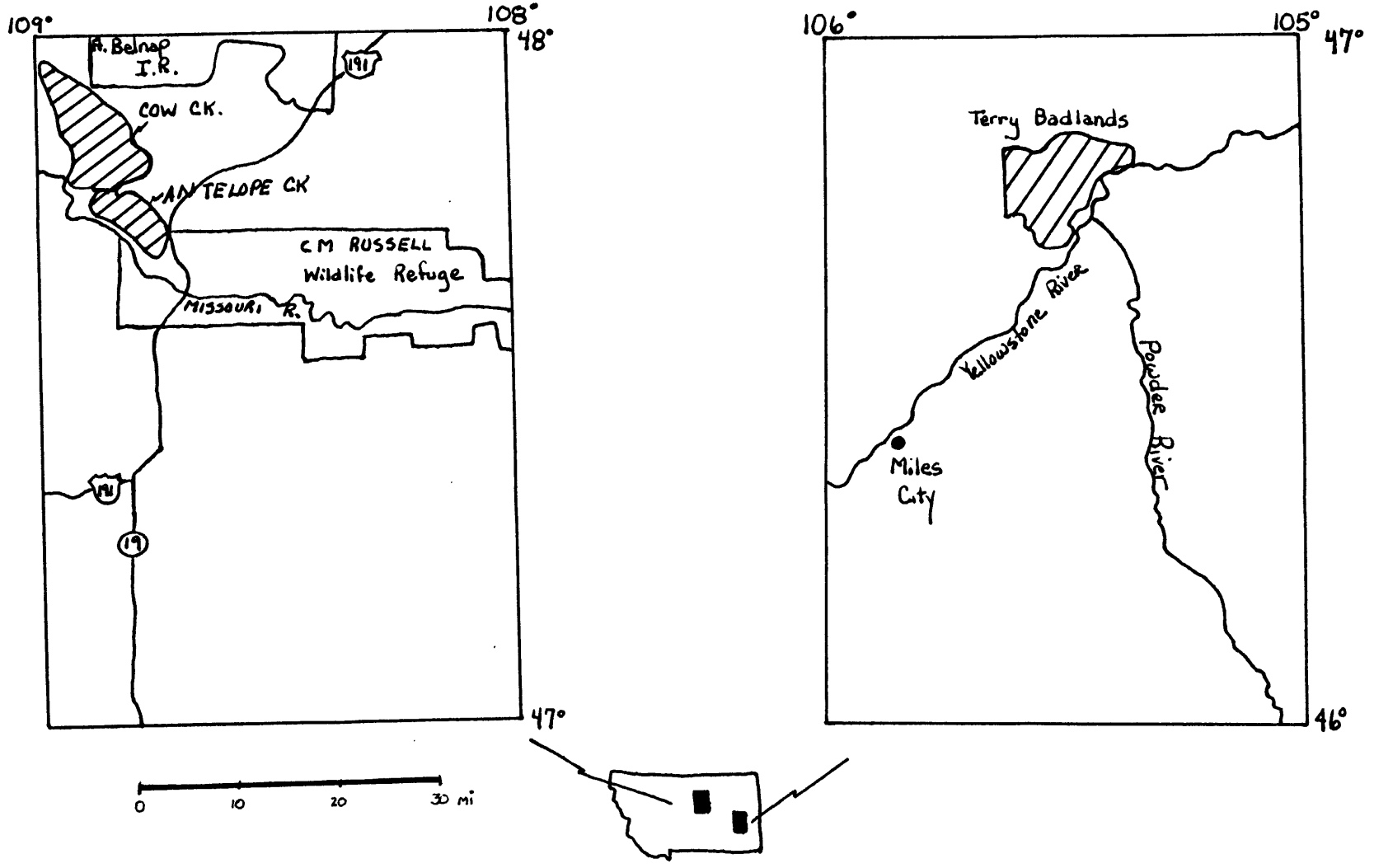



Figure 1--Map showing the location of the wilderness study areas

Appendix A

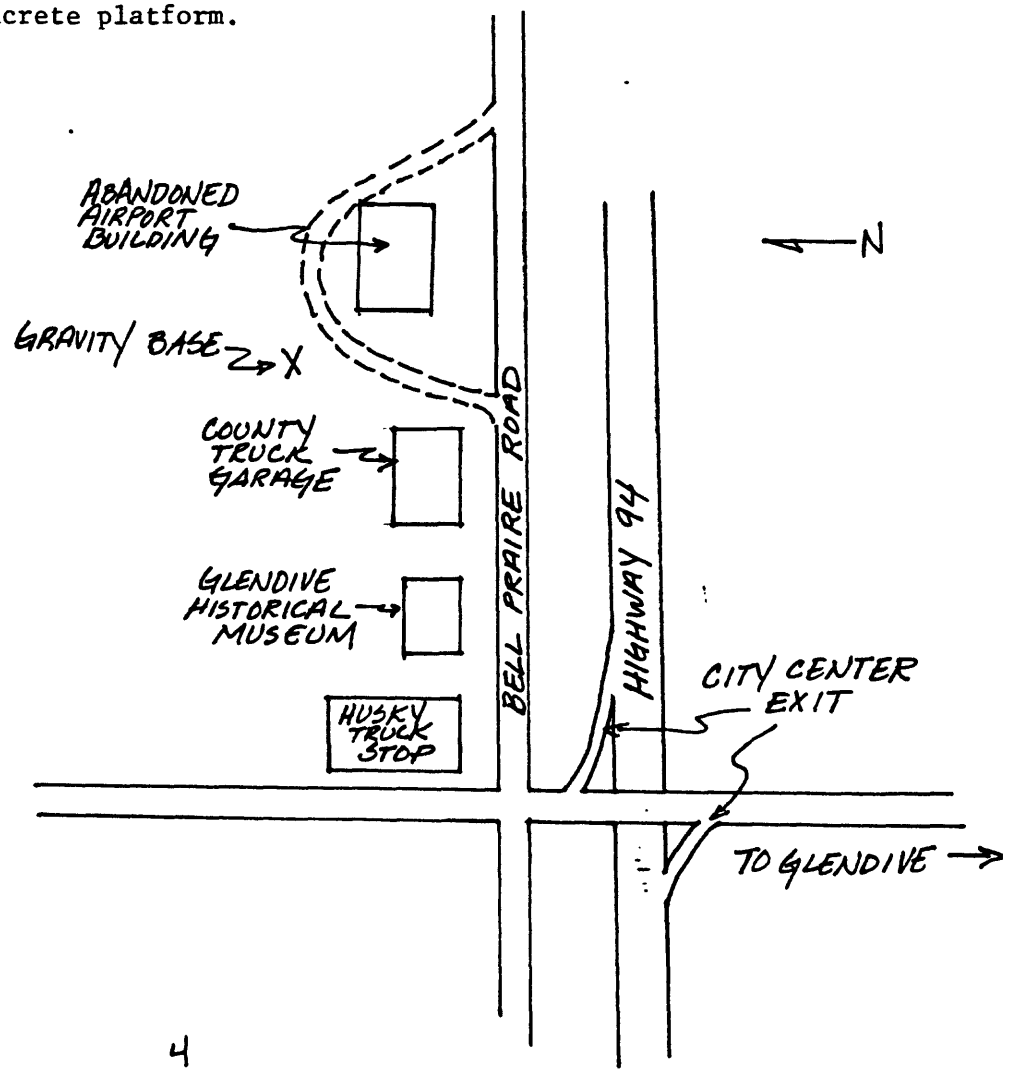
GRAVITY BASE STATION
U.S. GEOLOGICAL SURVEY

| STATE/COUNTRY | STATION DESIGNATION | OBSERVED GRAVITY |
|---|---|---|
| Montana/USA | Glendive | 980 622.44 |
| **NEAREST TOWN** | **LONGITUDE** | **LATITUDE** |
| Glendive | 104 41'.23 | 47 7'.02 |
| **ELEVATION** | **TOPOGRAPHIC MAP(S)** | |
| 2130' (648.6m.) | Stipek 1:24,000 Glendive 1:250,000 | |

| DATE | OBSERVER | METER | REFERENCE STATION | REFERENCE VALUE |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |

DESCRIPTION/SKETCH

Station is located at the abandoned airport north of Glendive. The base is located on Belle Praire Road west of the abandoned airport building on the concrete platform.

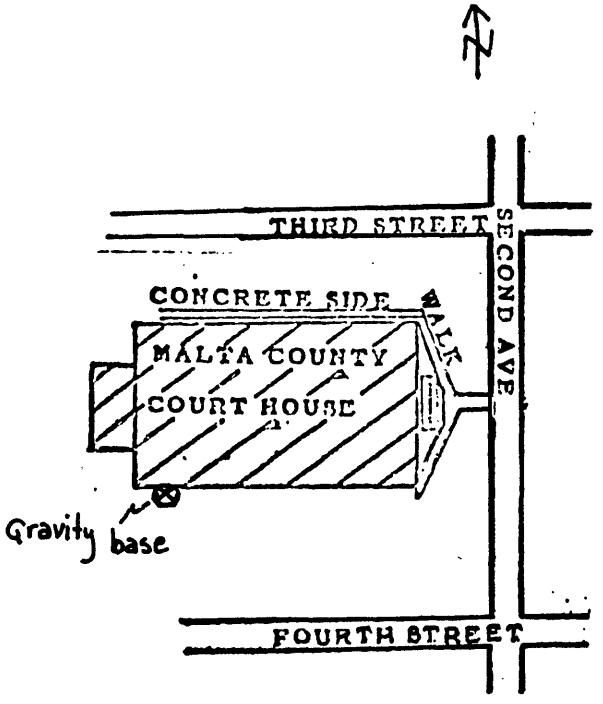


Appendix B: GRAVITY BASE STATION

| | |
|---|---|
| LATITUDE: 48° 21.50' N (1) | STATION DESIGNATION: MALTA |
| LONGITUDE: 107° 52.00' W (1) | |
| ELEVATION: 686.98 METERS (1) | COUNTRY/STATE: USA/Montana |
| REFERENCE CODE NUMBERS: ACIC 1221-O; IGC 15587B | ADOPTED GRAVITY VALUE: g= 980 706.43 mgals |
| | ESTIMATED ACCURACY: ± 0.1 mgals; DATE: MONTH/YEAR 1971 |

DESCRIPTION AND/OR SKETCH

Station is located in Malta, Mont., at the Phillips County Court House, directly over USC&GS EM X39. The EM is located at the county court house, 3.3 foot east of the SW corner of the foundation, and against the south face. The standard disk, stamped "2253.850 x 39 1931" is set in the top of a concrete post about flush with the ground. (1)




REFERENCE SOURCE

(1) 01355 (2) 05100



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## Appendix C: Principal Facts of Gravity Data

Explanation of headings

| | |
|---|---|
| **Identification** | |
| sta-id | Gravity station identification number. |
| **Location** | |
| latitude | North latitude in degrees, decimal minutes. |
| longitude | West longitude in degrees, decimal minutes. |
| ele | Station elevation in feet. |
| st | State where station is located. |
| **Gravity** | |
| observed | Observed gravity in milliGals. |
| theoretical | Theoretical gravity in milliGals. |
| **Corrections** | |
| Terrain | Terrain correction, 166.7 km radius, in milliGals. |
| Bouguer | Simple Bouguer slab correction in milliGals. |
| curv | Curvature correction in milliGals. |
| special | Not used. |
| **Anomalies** | |
| free-air | Free-air anomaly in milliGals. |
| complete-Bouguer | Complete Bouguer anomaly in milliGals for designated density d1. |

Antelope and Cow Creek Bouger Gravity Data
V. Bankey, Anne McCafferty, 1985
2g-550 elev=f gu=.01 srt=tme a-f g-x Date: 20-SEP-1985 09:36:47.23

| STATION IDENTIFICATION | | LOCATIONS | | | | | GRAVITY | | CORRECTIONS | | | | ANOMALIES | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | LATITUDE | | LONGITUDE | | ELE | ST | OBSERVED | THEORETICAL | TERRAIN | BOUGUER | CURV | SPECIAL | FREE | COMPLETE-BOUGUER | | SPEC |
| proj | sta-id | deg | min | deg | min | (in ft) | | | | (d1=2.67) | | | | AIR | d1=2.67 | d2=2.72 | FIELDS |
| | :malta | 48 | 21.44 | -107 | 52.65 | 2254.00 | mt | 980706.43 | 980922.30 | -0.09 | -76.88 | -0.84 | 0.00 | -3.95 | -81.75 | -83.21 | |
| | :ac1 | 47 | 45.69 | -108 | 41.67 | 3065.00 | mt | 980590.03 | 980868.66 | 0.36 | -104.54 | -1.06 | 0.00 | 9.54 | -95.69 | -97.66 | |
| | :ac2 | 47 | 49.22 | -108 | 38.20 | 3286.00 | mt | 980578.30 | 980873.96 | 0.36 | -112.08 | -1.11 | 0.00 | 13.28 | -99.55 | -101.66 | |
| | :ac3 | 47 | 48.76 | -108 | 39.69 | 3219.00 | mt | 980583.56 | 980873.27 | 0.31 | -109.79 | -1.10 | 0.00 | 12.93 | -97.64 | -99.72 | |
| | :ac4 | 47 | 48.71 | -108 | 40.34 | 3200.00 | mt | 980586.81 | 980873.20 | 0.31 | -109.14 | -1.09 | 0.00 | 14.47 | -95.45 | -97.51 | |
| | :ac5 | 47 | 48.78 | -108 | 41.63 | 3222.00 | mt | 980584.19 | 980873.30 | 0.32 | -109.89 | -1.10 | 0.00 | 13.82 | -96.85 | -98.93 | |
| | :ac6 | 47 | 48.77 | -108 | 42.34 | 3225.00 | mt | 980584.48 | 980873.28 | 0.29 | -110.00 | -1.10 | 0.00 | 14.40 | -96.40 | -98.48 | |
| | :ac7 | 47 | 48.70 | -108 | 43.82 | 3195.00 | mt | 980586.19 | 980873.18 | 0.29 | -108.97 | -1.09 | 0.00 | 13.40 | -96.38 | -98.43 | |
| | :ac8 | 47 | 48.53 | -108 | 44.57 | 3221.00 | mt | 980584.17 | 980872.92 | 0.28 | -109.86 | -1.10 | 0.00 | 14.08 | -96.59 | -98.67 | |
| | :ac9 | 47 | 48.80 | -108 | 45.14 | 3230.00 | mt | 980582.07 | 980873.33 | 0.43 | -110.17 | -1.10 | 0.00 | 12.42 | -98.41 | -100.49 | |
| | :ac10 | 47 | 47.82 | -108 | 45.81 | 3189.00 | mt | 980585.10 | 980871.86 | 0.22 | -108.77 | -1.09 | 0.00 | 13.07 | -96.57 | -98.62 | |
| | :ac11 | 47 | 47.56 | -108 | 46.74 | 3204.00 | mt | 980583.44 | 980871.47 | 0.27 | -109.28 | -1.09 | 0.00 | 13.20 | -96.90 | -98.96 | |
| | :ac12 | 47 | 46.25 | -108 | 46.18 | 3129.00 | mt | 980587.49 | 980869.50 | 0.23 | -106.72 | -1.07 | 0.00 | 12.18 | -95.39 | -97.40 | |
| | :ac13 | 47 | 45.12 | -108 | 46.10 | 3095.00 | mt | 980588.63 | 980867.60 | 0.50 | -105.56 | -1.07 | 0.00 | 11.82 | -94.31 | -96.30 | |
| | :ac14 | 47 | 47.04 | -108 | 49.32 | 3175.00 | mt | 980585.36 | 980870.69 | 0.70 | -108.29 | -1.09 | 0.00 | 13.18 | -95.50 | -97.53 | |
| | :ac15 | 47 | 46.80 | -108 | 50.17 | 3194.00 | mt | 980583.54 | 980870.33 | 0.70 | -108.94 | -1.09 | 0.00 | 13.50 | -95.82 | -97.87 | |
| | :ac16 | 47 | 46.30 | -108 | 51.12 | 3131.00 | mt | 980587.50 | 980869.58 | 0.48 | -106.79 | -1.08 | 0.00 | 12.29 | -95.09 | -97.10 | |
| | :ac17 | 47 | 46.16 | -108 | 52.36 | 3010.00 | mt | 980595.11 | 980869.37 | 0.72 | -102.66 | -1.05 | 0.00 | 8.74 | -94.25 | -96.18 | |
| | :ac18 | 47 | 44.47 | -108 | 52.87 | 2360.00 | mt | 980636.53 | 980866.83 | 0.71 | -80.49 | -0.87 | 0.00 | -8.40 | -89.05 | -90.56 | |
| | :ac19 | 47 | 44.31 | -108 | 53.54 | 2360.00 | mt | 980638.33 | 980866.59 | 0.48 | -80.49 | -0.87 | 0.00 | -6.36 | -87.24 | -88.76 | |
| | :ac20 | 47 | 44.36 | -108 | 54.49 | 2319.00 | mt | 980639.40 | 980866.66 | 0.58 | -79.09 | -0.86 | 0.00 | -9.22 | -88.60 | -90.08 | |
| | :ac21 | 47 | 44.17 | -108 | 55.87 | 2313.00 | mt | 980639.97 | 980866.38 | 0.71 | -78.89 | -0.86 | 0.00 | -8.93 | -87.96 | -89.44 | |
| | :ac22 | 47 | 43.86 | -108 | 56.13 | 2294.00 | mt | 980641.09 | 980865.91 | 0.67 | -78.24 | -0.85 | 0.00 | -9.12 | -87.54 | -89.01 | |
| | :ac8 | 47 | 48.53 | -108 | 44.57 | 3221.00 | mt | 980584.15 | 980872.92 | 0.28 | -109.86 | -1.10 | 0.00 | 14.06 | -96.62 | -98.69 | |
| | :ac23 | 47 | 52.86 | -108 | 39.87 | 3688.00 | mt | 980564.29 | 980879.43 | 1.31 | -125.79 | -1.20 | 0.00 | 31.59 | -94.09 | -96.44 | |
| | :ac24 | 47 | 54.55 | -108 | 42.64 | 3981.00 | mt | 980545.59 | 980881.96 | 1.23 | -135.78 | -1.26 | 0.00 | 37.90 | -97.91 | -100.45 | |
| | :ac25 | 47 | 57.12 | -108 | 43.07 | 3967.00 | mt | 980549.65 | 980885.82 | 1.05 | -135.30 | -1.25 | 0.00 | 36.78 | -98.73 | -101.27 | |
| | :ac26 | 47 | 56.66 | -108 | 46.63 | 3652.00 | mt | 980563.99 | 980885.13 | 0.56 | -124.56 | -1.19 | 0.00 | 22.20 | -102.99 | -105.33 | |
| | :ac27 | 47 | 56.65 | -108 | 47.81 | 3652.00 | mt | 980569.31 | 980885.12 | 0.71 | -124.56 | -1.19 | 0.00 | 27.54 | -97.50 | -99.85 | |
| | :ac28 | 47 | 56.01 | -108 | 49.20 | 3526.00 | mt | 980571.23 | 980884.16 | 0.44 | -120.26 | -1.17 | 0.00 | 18.57 | -102.42 | -104.68 | |
| | :ac29 | 47 | 56.28 | -108 | 50.51 | 3482.00 | mt | 980574.69 | 980884.56 | 0.40 | -118.76 | -1.16 | 0.00 | 17.49 | -102.03 | -104.27 | |
| | :malta | 48 | 21.44 | -107 | 52.65 | 2254.00 | mt | 980706.43 | 980922.30 | -0.09 | -76.88 | -0.84 | 0.00 | -3.95 | -81.75 | -83.21 | |

Terry Badlands Bouguer Gravity Data
V. Bankey, Anne McCafferty, 1985
2g-550 elev=f gu=.01 srt=tme a-f g-x Date: 13-SEP-1985 12:57:22.63

| STATION IDENTIFICATION proj | sta-id | LOCATIONS LATITUDE deg | min | LONGITUDE deg | min | ELE (in ft) | ST | GRAVITY OBSERVED | THEORETICAL | CORRECTIONS TERRAIN (d1=2.67) | BOUGUER | CURV | SPECIAL | ANOMALIES FREE AIR | COMPLETE-BOUGUER d1=2.67 | d2=2.72 | SPEC FIELDS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | :glend | 47 | 7.52 | -104 | 41.23 | 2125.00 | mt | 980622.44 | 980811.27 | -0.05 | -72.48 | -0.80 | 0.00 | 10.98 | -62.35 | -63.72 | |
| | :te1 | 46 | 47.36 | -105 | 19.89 | 2255.00 | mt | 980571.13 | 980780.92 | -0.09 | -76.91 | -0.84 | 0.00 | 2.24 | -75.60 | -77.06 | |
| | :te2 | 46 | 46.60 | -105 | 21.24 | 2309.00 | mt | 980566.60 | 980779.77 | -0.08 | -78.75 | -0.86 | 0.00 | 3.94 | -75.75 | -77.25 | |
| | :te3 | 46 | 45.83 | -105 | 20.90 | 2346.00 | mt | 980562.49 | 980778.62 | -0.04 | -80.02 | -0.87 | 0.00 | 4.46 | -76.46 | -77.98 | |
| | :te4 | 46 | 44.94 | -105 | 24.87 | 2236.00 | mt | 980569.07 | 980777.27 | -0.02 | -76.26 | -0.83 | 0.00 | 2.04 | -75.08 | -76.52 | |
| | :te5 | 46 | 44.38 | -105 | 25.47 | 2223.00 | mt | 980568.98 | 980776.43 | -0.07 | -75.82 | -0.83 | 0.00 | 1.57 | -75.15 | -76.59 | |
| | :te6 | 46 | 42.86 | -105 | 26.79 | 2257.00 | mt | 980564.09 | 980774.14 | -0.06 | -76.98 | -0.84 | 0.00 | 2.17 | -75.71 | -77.17 | |
| | :te7 | 46 | 41.60 | -105 | 27.90 | 2256.00 | mt | 980561.90 | 980772.24 | -0.07 | -76.95 | -0.84 | 0.00 | 1.78 | -76.07 | -77.53 | |
| | :te8 | 46 | 40.76 | -105 | 28.75 | 2249.00 | mt | 980560.82 | 980770.98 | -0.04 | -76.71 | -0.84 | 0.00 | 1.31 | -76.27 | -77.73 | |
| | :te9 | 46 | 40.06 | -105 | 29.51 | 2259.00 | mt | 980558.97 | 980769.92 | -0.04 | -77.05 | -0.84 | 0.00 | 1.45 | -76.47 | -77.93 | |
| | :te10 | 46 | 47.65 | -105 | 18.11 | 2244.00 | mt | 980572.69 | 980781.35 | -0.07 | -76.54 | -0.84 | 0.00 | 2.33 | -75.11 | -76.56 | |
| | :te11 | 46 | 49.17 | -105 | 17.73 | 2333.00 | mt | 980568.62 | 980783.64 | -0.05 | -79.57 | -0.86 | 0.00 | 4.34 | -76.14 | -77.65 | |
| | :te12 | 46 | 50.85 | -105 | 19.55 | 2316.00 | mt | 980570.10 | 980786.17 | 0.09 | -78.99 | -0.86 | 0.00 | 1.69 | -78.07 | -79.56 | |
| | :te13 | 46 | 51.69 | -105 | 20.62 | 2352.00 | mt | 980569.35 | 980787.44 | 0.09 | -80.22 | -0.87 | 0.00 | 3.06 | -77.93 | -79.45 | |
| | :te14 | 46 | 52.70 | -105 | 21.99 | 2419.00 | mt | 980565.39 | 980788.96 | -0.01 | -82.51 | -0.89 | 0.00 | 3.88 | -79.53 | -81.09 | |
| | :te15 | 46 | 53.42 | -105 | 28.32 | 2559.00 | mt | 980557.39 | 980790.05 | 0.04 | -87.28 | -0.93 | 0.00 | 7.95 | -80.21 | -81.87 | |
| | :te16 | 46 | 53.41 | -105 | 29.88 | 2571.00 | mt | 980556.97 | 980790.03 | 0.01 | -87.69 | -0.93 | 0.00 | 8.67 | -79.94 | -81.59 | |
| | :te17 | 46 | 53.86 | -105 | 31.93 | 2592.00 | mt | 980556.57 | 980790.70 | 0.04 | -88.41 | -0.94 | 0.00 | 9.58 | -79.72 | -81.40 | |
| | :te18 | 46 | 53.84 | -105 | 33.43 | 2644.00 | mt | 980553.10 | 980790.68 | 0.08 | -90.18 | -0.95 | 0.00 | 11.02 | -80.03 | -81.73 | |
| | :te19 | 46 | 53.85 | -105 | 35.91 | 2661.00 | mt | 980550.79 | 980790.69 | 0.11 | -90.76 | -0.95 | 0.00 | 10.30 | -81.31 | -83.02 | |
| | :te20 | 46 | 53.42 | -105 | 37.27 | 2688.00 | mt | 980547.47 | 980790.05 | 0.05 | -91.68 | -0.96 | 0.00 | 10.16 | -82.43 | -84.17 | |
| | :te21 | 46 | 53.31 | -105 | 39.48 | 2744.00 | mt | 980542.69 | 980789.88 | 0.08 | -93.59 | -0.98 | 0.00 | 10.81 | -83.67 | -85.44 | |
| | :te22 | 46 | 51.68 | -105 | 40.58 | 2812.00 | mt | 980535.43 | 980787.42 | 0.08 | -95.91 | -1.00 | 0.00 | 12.40 | -84.42 | -86.24 | |
| | :te23 | 46 | 50.78 | -105 | 40.14 | 2926.00 | mt | 980526.29 | 980786.07 | 0.24 | -99.80 | -1.02 | 0.00 | 15.33 | -85.25 | -87.14 | |
| | :te24 | 46 | 49.95 | -105 | 39.88 | 2937.00 | mt | 980524.30 | 980784.82 | 0.30 | -100.17 | -1.03 | 0.00 | 15.62 | -85.28 | -87.17 | |
| | :te25 | 46 | 48.62 | -105 | 39.17 | 2732.00 | mt | 980537.03 | 980782.81 | 0.08 | -93.18 | -0.97 | 0.00 | 11.09 | -82.98 | -84.75 | |
| | :te26 | 46 | 47.61 | -105 | 38.55 | 2715.00 | mt | 980536.71 | 980781.30 | 0.06 | -92.60 | -0.97 | 0.00 | 10.69 | -82.82 | -84.57 | |
| | :te27 | 46 | 46.46 | -105 | 38.92 | 2662.00 | mt | 980538.47 | 980779.56 | 0.04 | -90.79 | -0.96 | 0.00 | 9.20 | -82.51 | -84.23 | |
| | :te28 | 46 | 45.10 | -105 | 38.77 | 2546.00 | mt | 980544.12 | 980777.52 | -0.02 | -86.84 | -0.92 | 0.00 | 5.99 | -81.79 | -83.43 | |
| | :te29 | 46 | 44.23 | -105 | 36.37 | 2461.00 | mt | 980549.91 | 980776.20 | 0.05 | -83.94 | -0.90 | 0.00 | 5.10 | -79.69 | -81.27 | |
| | :te30 | 46 | 43.28 | -105 | 34.79 | 2425.00 | mt | 980551.94 | 980774.77 | -0.02 | -82.71 | -0.89 | 0.00 | 5.18 | -78.44 | -80.01 | |
| | :te31 | 46 | 42.05 | -105 | 33.29 | 2362.00 | mt | 980553.79 | 980772.92 | -0.03 | -80.56 | -0.87 | 0.00 | 2.96 | -78.50 | -80.03 | |
| | :te32 | 46 | 41.22 | -105 | 32.92 | 2416.00 | mt | 980549.35 | 980771.67 | -0.04 | -82.40 | -0.89 | 0.00 | 4.85 | -78.48 | -80.04 | |
| | :glend | 47 | 7.52 | -104 | 41.23 | 2125.00 | mt | 980622.44 | 980811.27 | -0.05 | -72.48 | -0.80 | 0.00 | 10.98 | -62.35 | -63.72 | |