

STATE OF SOUTH DAKOTA

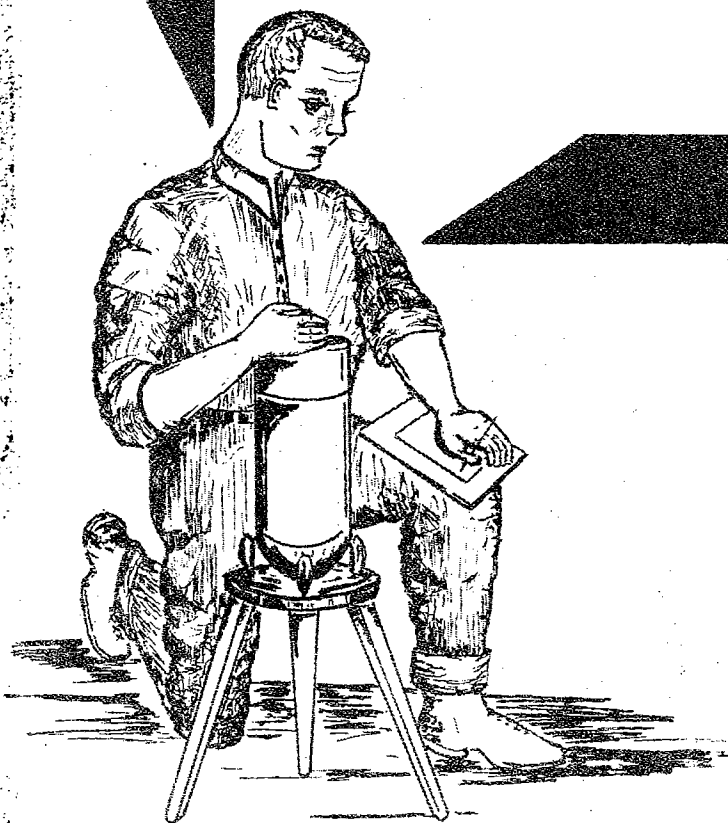
Archie Gubbrud, Governor

Report of Investigations No. 94

GRAVITY SURVEY OF SOUTHWESTERN SOUTH DAKOTA

by Edward L. Tullis

Chairman, Department of Geology and Geological Engineering
South Dakota School of Mines and Technology



SOUTH DAKOTA STATE

GEOLOGICAL SURVEY

Duncan J. McGregor

State Geologist

*Science Center, University
Vermillion, South Dakota
December, 1963*

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ABSTRACT

Gravity observations in central southwest South Dakota were made in 1960 by the State Geological Survey as the second part of a research project supported by the National Science Foundation. Data from 709 stations covering 3400 square miles were calculated to make a simple Bouguer anomaly map.

The gravity trends established by Lum in his study of 1959 continue southward into the area discussed here. Between eastern Custer County and Wanblee the negative Bouguer anomaly increases to the south.

Certain of the Bouguer anomalies are influenced by the lack of terrain corrections and, along the valleys, by the use of too large a value for rock density. It is desirable to be able to interpret the gravity results in terms of the configuration of the surface of the Precambrian.

INTRODUCTION

The gravity survey reported here was conducted during nearly three months of the Summer of 1960 by the South Dakota State Geological Survey, supported by the National Science Foundation. This is the second part of a regional gravity study in western South Dakota (fig. 1). The first regional map and a traverse from east to west across the State were completed in 1959 and reported on by Daniel Lum (1961). In 1960, observations were made in a strip 4 to 6 townships wide, north-south, and 23 townships long, east-west, including more than 3,400 square miles. The town of Draper is near the eastern end of the area and Fairburn is at the western end (pls. 1, 2).

The purpose of the work was to determine basic data from which interpretations of regional geologic structure may be made. Only general comments are made in this report. Additional interpretation, either directly or by any secondary methods (Dobrin, 1960, p. 171-178, 227-262) believed effective, may be made from the Bouguer anomaly map (pls. 1, 2) and Lum's map. The station density is too low to justify detailed interpretation.

The ten base stations (Appendix A) which have been tied to the national gravity network (Woollard, 1958) may be used for more detailed work in the area.

Under the general supervision of the writer, the field observations in 1960 were made by Robert Benson assisted by LeRoy Johnson. Using a computer, Dr. Judson Mead, of the Department of Geology at Indiana University, kindly reduced the field data in the Fall of 1961. During the Winter and Spring of 1963, Roger Wilde, a student at the South Dakota School of Mines and Technology, plotted the data and drew a preliminary Bouguer anomaly map. He also assisted the writer in making a field check of apparent discrepancies in the data. Two other students at the South Dakota School of Mines and Technology, Wallace Bertrand and Bryan Ramsey, calculated the values of theoretical gravity, and recalculated certain apparent discrepancies in the Bouguer values, respectively.

ACKNOWLEDGMENTS

The work was supported by the National Science Foundation under Grant No. 7606. The writer particularly acknowledges the counsel and patience of Dr. Allen F. Agnew, State Geologist, during the course of the field work and the preparation of map and report.

FIELD OBSERVATIONS

A Worden gravity meter having a scale constant of 0.1072 milligals was used by Benson and Johnson. The constant was checked twice by an airplane trip between the Rapid City and Hot Springs airport stations of Woollard (1958). All base stations were tied to the Rapid City Airport station or to other base stations by "looping" (Nettleton, 1940, p. 38-39). The bases are from 12 to 34 miles apart.

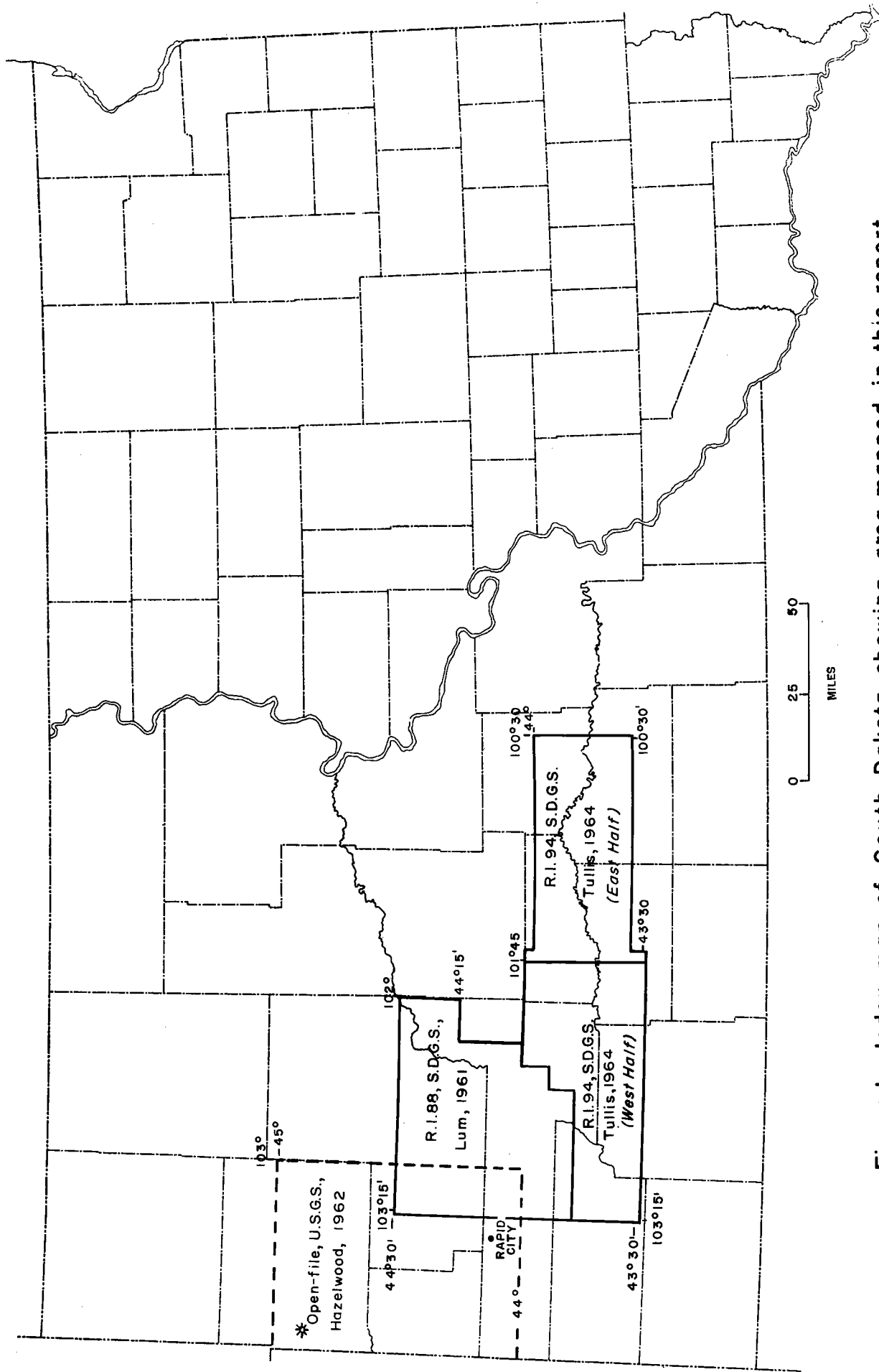


Figure 1. Index map of South Dakota showing area mapped in this report, and that of Lum, 1961.

* Released February 5, 1964

Plate 1

See pocket in back of report

Plate 2

See pocket in back of report

A Worden gravity meter having a scale constant of 0.1561 milligals was used by Tullis and Wilde to make the field check in the Spring of 1963. Reobservations were tied to the nearest field base.

The value of gravity at the Rapid City Airport primary base station is 980.2510, Potsdam datum. Because the gravity meter can be read to 0.01 milligal, the primary base value was assumed as 980.25100.

The area is covered by U. S. Geological Survey $7\frac{1}{2}$ -minute topographic quadrangles. The locations of all stations can be recovered by using the latitude and longitude, measured to the nearest 0.01 foot, and the elevations at benchmarks are accurate to within 0.5 foot because the elevations used in the calculations are to the nearest foot. Elevations at other points, such as road intersections, are accurate to within two feet.

Drift corrections were made after reoccupying a base station as frequently as feasible during the day. In the badlands areas of rough terrain and poor accessibility it was often not practicable to occupy a base station oftener than every four hours, but the regularity of the drift curves indicates that drift corrections probably were made with acceptable accuracy.

REDUCTION OF DATA

An excellent general paper concerning gravity determinations by Woollard (1952) lays the foundation for understanding the reduction and interpretation of gravity-meter observations. More specific descriptions of techniques are given in textbooks by Nettleton (1940) and by Dobrin (1960).

Values of the simple Bouguer anomalies, plotted with isogals* in Plates 1 and 2, are obtained by subtracting theoretical gravity from observed gravity.

*For use of the term "isogal", compare Nettleton, 1940, p. 163, and Heiland, 1940, pp. 11 and 18.

The simple Bouguer anomalies usually are negative in areas of the continents which indicates rocks of lesser density.

The theoretical value γ_0 , that gravity would have at sea level at any latitude, ϕ , is given by the International Formula, $\gamma_0 = 978.0490 (1 + 0.0052884 \sin^2 \phi - 0.0000059 \sin^2 2\phi)$. The value that gravity has at sea level at the equator is 978.0490. Lum (1961, p. 10) used the formula $\gamma_0 = 980.63227192 - 2.58615717 \cos 2\phi + 0.0028852446 \cos 4\phi$, which may be easier for calculations. These equations correct for the rotation and ellipsoidal shape of the earth.

The elevation correction is subtracted from the theoretical value of gravity at sea level at the latitude of any gravity meter station. The elevation correction consists of two parts, the free-air correction and the Bouguer correction. The free-air correction, which is -0.094 milligals per foot, allows for the elevation of the station above sea level. The Bouguer correction, $+0.034$ milligals per foot, allows for the attraction of the column of rock between sea level and the station, assuming a rock density of 2.67. The difference between -0.094 and $+0.034$ is -0.060 , and is used for all elevation corrections.

Theoretical gravity, corrected as described above, is subtracted from observed gravity to obtain the simple Bouguer anomaly. As pointed out by Swick (1942, p. 65), some workers apply the corrections to observed gravity before calculating the Bouguer anomaly. The result is the same but the signs of the corrections change.

The values of theoretical gravity in Appendix A were obtained by adding corrections given in a table prepared by Judson Mead to the value at latitude 43 degrees 30 minutes. It appears from Lum's tables (1961, p. 11-26) that he used 980.49404 for theoretical gravity at latitude 43 degrees 30 minutes; so that value is used in this report.

Terrain corrections also may be applied to the simple Bouguer anomalies. Hills rising above a station, or valleys below a station, reduce the value of observed gravity. Therefore a terrain correction can be added to observed gravity. This reduces the magnitudes of the Bouguer anomalies if the anomalies are negative, as in this area.

Lum (1961, p. 4) concluded that for regional interpretation no terrain corrections were needed outside the Black Hills, as all corrections that he had made (except one) were less than 0.8 milligal. The same procedure of not making terrain corrections was followed in the present work. However, more of the present study was made in the White River Badlands than in the case of Lum's work. Many benchmarks are also triangulation points and near the edges of badlands tables. Therefore, significant terrain corrections might be made.

BOUGUER ANOMALY RESULTS

Along the northern border of the area studied, between Fairburn and Wall, Plate 1 shows the isogals extending beyond the margin of station control. This is the area of junction with Lum's work. His stations were plotted in joining the isogals of the two areas, but to avoid confusion, his gravity values are not shown.

Because terrain corrections were not made, Station 16, with a Bouguer anomaly of -89.0 , in the northwestern part of T. 41 N., R. 47 W., was chosen as an example of the possible importance of corrections. It is at the top of a steep slope on the eastern margin of Red Shirt Table, overlooking Cedar Creek. A rough calculation of the terrain correction, using Hammer's (1939) method through Zone K with a radius of more than 6 miles, gives a correction of about 1 milligal. Changing the value of the station by this much would shift the -88 isogal about 0.4 mile south, which would not affect the regional picture.

However, in some cases a considerable change in the shape and position of the isogals would result. Station 383, with Bouguer anomaly of -87.6, is in the southern part of T. 43 N., R. 44 W., at the south end of Sheep Mountain Table. The terrain correction here would amount to well over 1 milligal and would remove the loop in the isogals. A similar condition exists at Station 391, Bouguer anomaly -78.0, in the southwestern part of T. 3 S., R. 13 E., near the south end of Hart Table.

Many of the minor irregularities in the isogals would be removed by terrain corrections. This is possible for anyone interested, because the basic data are available in Appendix A and on the U.S.G.S. $7\frac{1}{2}$ minute topographic quadrangles (basic data sheets).

Lum (1961, p. 8) noted high gravity values along the major rivers. If these effects were purely from uncorrected topography, observed gravity would have a relatively low value and give a greater negative Bouguer anomaly. However, Lum recognized that the positive anomalies along the rivers resulted from using 2.67 for the density instead of the actual rock density. Calculations from data given by Pesonen, Tullis and Zinner (1949) indicate densities for the Pierre Shale ranging between 2.06 and 1.72. These correspond to Bouguer and elevation corrections of 0.026 and 0.068; 0.022 and 0.072 respectively.

Along the Belle Fourche River where Lum's map (1961, pl. 1) shows gravity values in the valley bottom about 2.5 milligals higher than on the uplands, the elevation of the flood plain may be assumed to be 2,150 feet and the upland 2,450 feet. The elevation corrections from sea level would serve to lower the gravity values in the flood plain as compared with those on the upland by 2.4 milligals using a rock density of 2.06, and by 3.6 milligals using a rock density of 1.72. In other words, the present relatively positive anomalies along the rivers would be reduced to zero or even become relatively slightly negative.

The results of the present study show similar effects along the White River, and there are local modifications of the large gravity high that extends along the Cheyenne River. However, not all of the local gravity features along this high can be attributed to the use of 2.67--for example, the small high centered about 4 miles southeast of Creston (Lum, 1961, pl. 1).

As stated by Lum (1961, p. 2) "The studies were undertaken with the hope that gravity observations might aid in understanding some of the regional geological structures and structural trends." He described all of the major gravity highs and lows as found by his cross-state traverse and by his regional mapping. All of the major highs that he found extend into the area of the present study, and additional major and minor features have been found.

The gravity high that Lum found in his traverse east of Murdo extends S. 30 degrees E. beyond the limits of the present map. The gravity low to the west of Murdo extends south at least as far as the town of White River. The large high west of Wall on Lum's profile extends north to and possibly beyond Pedro in the area that he studied and southwest up the Cheyenne River beyond the Custer County line, a length of about 85 miles.

The large low centered southeast of Rapid City extends discontinuously southward to a point about nine miles south of Fairburn, where it is lost in the northern part of an east-west gravity low that lies to the south of the area.

This east-west low extends for 75 miles from the west edge of the map to Wanblee on the east. It is interrupted for about 20 miles in the longitude of Rockyford by a poorly defined gravity high that extends northward to merge with the one along the Cheyenne River.

Extending southeastward from the gravity high that lies west of Wall are two smaller areas in which the isogals close. One is southeast of Wall, the other is southwest of Weta Station.

Thus, the Bouguer anomaly results can be described, but can they be interpreted in terms of regional geology as a geologist understands the term?

CONCLUSIONS

Lum (1961) interpreted nearly all of the major features of his Bouguer anomaly map in terms of a change in the nature of the Precambrian basement. His reasons for such interpretations are the relief and the extent of the anomalies. For lack of better interpretation, and because of the limitation placed by our knowledge of the geology of the region, the writer cannot disagree. Lum believes that the major regional minimum found along his traverse results from a thickening of the granitic layer. All such interpretations are of value in other geophysical attacks on the area, but they are of little solace to the geologist who hopes to find some clue to the regional structure expressed in the configuration of the Precambrian surface as revealed by the gravitational field.

As a geologist the writer must disagree with Lum's two more direct geological conclusions. He tentatively suggested that the major gravity low west of Rapid City and its abrupt western termination "are related to steep folding or possibly faulting" (1961, p. 7). In the well-exposed Paleozoic and Mesozoic rocks along the eastern flank of the Black Hills, there is no evidence of such a structure. Farther south, where he found an elongated gravity high across the trend of the major low, no anticline is known. The closed isogal is along the valley of Battle Creek and probably results from using 2.67.

The geologist might hope that in the increase in magnitude of the Bouguer anomalies he is seeing the southward slope of the surface of the basement rocks into the Kennedy basin, south of a line from the Cheyenne River at the Custer-Shannon County line eastward to the Weta Station. He must admit that the gravity gradients probably are too high--but is there not some clue here? He can also accept the reality of some inhomogeneity in the crustal rocks that can be represented by an equivalent cylinder (Lum, 1961, p. 7) at a depth of 11.5 miles, about 15 miles east of Murdo. On the other hand he is tempted to think that possibly the gravity minimum about 4 miles west of Murdo and extending southward to the town of White River is related to a low in the surface of the Precambrian (Steece, 1961), although he must admit that the data on Steece's map indicate that the low in the Precambrian surface probably is about 30 miles to the west.

If terrain corrections and realistic values of density were used, what would happen to the small marginal gravity highs like those south-east of Wall and southwest of Weta Station? Would they disappear and others appear? Perhaps we should find out, but that is beyond the scope of this investigation.

REFERENCES

- Dobrin, Milton B., 1960, Introduction to geophysics: McGraw-Hill Book Co., Inc., New York, p. 169-262.
- Hammer, Sigmund, 1939, Terrain corrections for gravimeter stations: Geophysics, v. 4, p. 184-194.
- * Heiland, C. A., 1940, Geophysical exploration: Prentice-Hall, Inc., New York, p. 67-292.
- Lum, Daniel, 1961, Gravity measurements east of the Black Hills and along a line from Rapid City to Sioux Falls, South Dakota: S. Dak. Geol. Survey, Rept. Invest. 88, 26 p.
- Nettleton, L. L., 1940, Geophysical prospecting for oil: McGraw-Hill Book Co., Inc., New York p. 11-154.
- Pesonen, Paul E., Edward L. Tullis, and Paul Zinner, 1949, Missouri Valley Manganese deposits, South Dakota: U. S. Bur. Mines, Rept. Invest. 4375, p. 22.
- Steece, Fred V., 1961, Preliminary map of the Precambrian surface of South Dakota: S. Dak. Geol. Survey, Min. Res. Invest., Map No. 2.
- Swick, Clarence H., 1942, Pendulum gravity measurements and isostatic reductions: U. S. Coast and Geodetic Survey, Spec. Publ. No. 232, p. 65.
- Woollard, George Prior, 1952, The Earth's gravitational field and its exploitation: Advances in geophysics, v. 1, p. 281-311, Academic Press, Inc., New York.
- _____, 1958, Results for a gravity control network at airports in the United States: Geophysics, v. 23, p. 520-535.
- *Hazelwood, Robert M., 1962, Simple Bouguer gravity map of the northern part of the Black Hills, South Dakota: U. S. Geol. Survey open-file report (released February 5, 1964).

APPENDIX A

GRAVITY STATIONS

Principal Facts

Base Station: Rapid City Municipal Airport, Entrance to terminal lobby
from the field, g-980.2510 gal., referred to Commerce
building base, Washington, D. C., g-980.1190 gal.

Theoretical Gravity: International gravity formula = $978.0490 (1 + 0.0052884 \sin^2 \phi - 0.0000059 \sin^2 2\phi)$.

Assumed density for Bouguer anomaly: 2.67 g/cc

B = Bench Mark

* = Tied by looping

Station	Latitude	Longitude	Elev. in feet	Observed Gravity	Theoret. Gravity	2.67
BASE STATIONS						
Rapid City	44°02.55'N	103°03.55'W	3164	980.25100	980.54296	-102.12
1. USGS	00.57	103°10.81	3331B	.23862	.53998	-101.52
2. Fairburn	43°42.56	103°14.37	3338B	.21566	.51291	- 96.98
3. Wall	59.64	102°14.50	2817B	.29615	.53858	- 73.43
4. Interior	43.64	101°58.80	2378B	.29222	.51453	- 79.65
5. Scenic	46.26	102°33.42	2809B	.27509	.51847	- 74.85
6. Potato Creek	33.28	101°54.02	2846B	.23564	.49897	- 92.58
7. Cottonwood	57.93	51.62	2374B	.30981	.53601	- 83.77
8. Kadoka	50.17	30.21	2451B	.28187	.52435	- 95.43
9. Belvidere	49.99	15.77	2320B	.28296	.52408	-101.94
10. Murdo	49.89	100°42.06	2213B	.27733	.52393	-113.83
OTHER STATIONS						
1.	39.95	103°09.52	3186B	.22209	.50899	- 95.75
2.	38.18	08.44	3189	.21963	.50633	- 95.38
3.	37.22	08.01	3298B	.21180	.50489	- 95.22
4.	35.78	08.62	3331	.20797	.50272	- 94.90
5.	35.68	10.76	3413B	.20170	.50257	- 96.10
6.	36.76	12.38	3479B	.19925	.50420	- 96.22
7.	38.64	13.00	3582B	.19615	.50702	- 95.95
8.	39.95	13.13	3399	.20960	.50899	- 95.46
9.	41.16	13.02	3312B	.21642	.51081	- 95.68
10.	44.25	102°56.35	2934	.25598	.51560	- 83.60

Appendix A.--Gravity stations--Continued

Station	Latitude	Longitude	Elev. in feet	Observed Gravity	Theoret. Gravity	2.67
11.	43° 42.35' N	102° 53.82' W	2965B	980.25545	980.51260	- 79.25
12.	38.23	53.58	2948	.25153	.50640	- 78.01
13.	37.66	53.29	2976B	.24745	.50555	- 79.56
14.	37.45	55.15	2974B	.24632	.50523	- 80.49
15.	35.62	53.55	3103B	.23268	.50248	- 83.64
16.	33.81	53.22	3204B	.21857	.49976	- 88.95
17.	32.02	52.99	3305B	.20277	.49707	- 96.02
18.	30.69	53.62	3148B	.20987	.49508	- 96.34
19.	30.23	55.90	3176B	.20713	.49439	- 96.69
20.	30.33	58.34	3302B	.19883	.49454	- 97.60
21.	30.35	103° 00.69	3164B	.20705	.49457	- 97.69
22.	33.85	14.52	3337	.20843	.49982	- 91.18
23.	30.40	09.83	3188B	.20464	.49464	- 98.74
24.	30.37	11.62	3091	.21122	.49460	- 97.93
25.	32.11	12.21	3187	.21136	.49721	- 94.64
26.	33.84	12.21	3241	.21277	.49981	- 92.60
27.	32.09	07.52	3021B	.22253	.49718	- 93.41
28.	32.08	09.83	3098	.21739	.49716	- 93.91
29.	33.84	07.54	3118B	.22047	.49981	- 92.27
30.	33.84	09.82	3129	.21934	.49981	- 92.75
31.	42.56	10.04	3254B	.22126	.51291	- 96.43
32.	42.82	08.55	3154B	.22729	.51330	- 96.79
33.	30.35	07.44	3044B	.21439	.49457	- 97.56
34.	30.35	05.14	2978B	.21901	.49457	- 96.90
35.	30.42	02.64	3110B	.20983	.49467	- 98.26
36.	32.09	02.95	2802	.23796	.49718	- 91.12
37.	34.76	01.53	2965B	.23605	.50119	- 87.26
38.	32.96	01.52	3012	.22827	.49849	- 89.51
39.	31.44	01.53	3043B	.21963	.49620	- 94.01
40.	32.10	05.10	2972	.22624	.49719	- 92.65

Appendix A.--Gravity stations--Continued

Station	Latitude	Longitude	Elev. in feet	Observed Gravity	Theoret. Gravity	2.67
41.	43°33.83'N	103°05.11'W	2959	980.23201	980.49979	- 90.26
42.	38.17	102°59.12	2928B	.24526	.50631	- 85.39
43.	36.76	103°00.61	2787B	.25150	.50420	- 85.49
44.	35.75	102°57.93	2888	.25006	.50568	- 82.36
45.	39.51	58.76	2818	.25431	.50833	- 84.96
46.	40.82	58.77	3053	.24036	.51030	- 86.77
47.	40.38	57.28	3040	.24271	.50963	- 84.54
48.	39.51	103°00.14	2867	.24900	.50833	- 87.32
49.	39.28	02.27	2960	.24035	.50798	- 90.05
50.	40.94	04.74	3036	.23529	.51048	- 93.04
51.	42.21	05.15	3078B	.23354	.51238	- 94.18
52.	44.43	07.13	3238B	.22478	.51572	- 96.67
53.	44.29	05.25	3245B	.22572	.51551	- 95.11
54.	44.28	03.54	3164B	.23264	.51550	- 93.09
55.	39.29	04.75	3068	.23192	.50800	- 92.01
56.	37.73	06.22	3228	.21866	.50565	- 93.33
57.	39.44	07.14	3138	.22561	.50822	- 94.35
58.	43.43	13.12	3320	.21709	.51422	- 97.94
59.	39.99	102°52.22	2671B	.27253	.50905	- 76.27
60.	42.96	56.35	2992	.25090	.51351	- 83.11
61.	41.88	56.08	3099B	.24210	.51189	- 83.87
62.	43.42	58.75	3075	.24261	.51420	- 87.11
63.	44.29	103°01.12	3144	.23611	.51551	- 90.77
64.	43.64	102°54.50	2830B	.26498	.51453	- 79.77
65.	42.80	52.47	2774B	.26990	.51327	- 76.94
66.	44.27	51.57	3085B	.25133	.51548	- 79.07
67.	43.61	50.53	3084	.25087	.51449	- 78.60
68.	44.56	49.79	3128B	.24900	.51592	- 79.25
69.	52.75	101°42.01	2477B	.29517	.52823	- 84.45
70.	52.75	44.45	2434B	.29928	.52823	- 82.92

Appendix A.--Gravity stations--Continued

Station	Latitude	Longitude	Elev. in feet	Observed Gravity	Theoret. Gravity	2.67
71.	43° 52.76' N	101° 39.63' W	2428B	980.29609	980.52824	- 86.48
72.	53.63	39.65	2405B	.29901	.52955	- 86.26
73.	54.50	40.84	2514	.29371	.53086	- 86.32
74.	54.50	43.24	2479	.29784	.53086	- 84.29
75.	56.23	40.84	2528	.29289	.53346	- 88.91
76.	56.23	43.25	2581	.29144	.53346	- 87.17
77.	55.42	38.47	2410B	.29941	.53224	- 88.25
78.	57.13	38.47	2475B	.29549	.53481	- 90.83
79.	58.79	38.48	2449B	.29879	.53731	- 91.59
80.	59.70	38.80	2428B	.30231	.53867	- 90.70
81.	57.86	40.79	2372	.30346	.53591	- 90.15
82.	59.71	41.85	2302	.31162	.53869	- 88.97
83.	57.94	43.23	2493	.29762	.53604	- 88.86
84.	51.01	39.65	2466	.28993	.52561	- 87.73
85.	50.14	42.05	2512	.28814	.52430	- 85.46
86.	50.95	44.44	2446B	.29579	.52552	- 82.98
87.	51.01	42.05	2483	.29132	.52561	- 85.32
88.	49.31	44.45	2530B	.28916	.52306	- 82.11
89.	45.80	44.45	2300	.29911	.51778	- 80.69
90.	44.94	43.26	2277B	.29908	.51649	- 80.80
91.	43.76	43.26	2330	.29473	.51471	- 80.20
92.	41.85	43.31	2226	.29920	.51184	- 79.10
93.	46.67	43.25	2304	.29918	.51909	- 81.68
94.	46.66	41.29	2324B	.29600	.51910	- 83.65
95.	47.53	42.05	2334	.29726	.52038	- 83.09
96.	46.70	39.65	2332B	.29382	.51913	- 85.40
97.	46.67	37.88	2281	.29534	.51909	- 86.90
98.	47.65	38.46	2356B	.29188	.52055	- 87.32
99.	50.14	38.48	2455B	.28796	.52430	- 89.06
100.	45.02	39.66	2252	.29745	.51661	- 84.05

Appendix A.--Gravity stations--Continued

Station	Latitude	Longitude	Elev. in feet	Observed Gravity	Theoret. Gravity	2.67
101.	43° 42.66' N	101° 40.89' W	2336	980.29110	980.51306	- 81.82
102.	43.78	39.67	2236	.29736	.51474	- 83.24
103.	44.94	40.88	2260B	.29800	.51649	- 82.90
104.	32.92	40.87	2760	.24040	.49843	- 92.44
105.	32.92	42.67	2700	.24392	.49843	- 92.52
106.	32.92	44.43	2707B	.24274	.49843	- 93.28
107.	33.83	44.64	2640B	.24981	.49979	- 91.59
108.	31.95	44.45	2726B	.23903	.49697	- 94.39
109.	30.32	44.44	2803B	.23059	.49452	- 95.76
110.	30.32	42.05	2728B	.23799	.49452	- 92.86
111.	30.33	39.70	2855B	.22962	.49454	- 93.63
112.	30.32	37.84	2812B	.23276	.49452	- 93.05
113.	31.63	39.67	2800	.23607	.49649	- 92.43
114.	40.74	57.60	2473	.28005	.51018	- 81.77
115.	41.60	59.99	2465	.28255	.51147	- 81.03
116.	39.87	102° 00.00	2645B	.26647	.50887	- 83.71
117.	38.13	101° 59.98	2687B	.26051	.50625	- 84.52
118.	37.62	58.53	2654	.26223	.50549	- 84.03
119.	36.68	57.12	2870B	.24513	.50408	- 86.76
120.	38.99	44.44	2422B	.27931	.50755	- 82.94
121.	37.63	44.05	2709B	.25511	.50550	- 87.87
122.	35.53	44.14	2779B	.24491	.50235	- 90.72
123.	35.50	42.09	2759B	.24665	.50230	- 90.13
124.	34.65	41.55	2750	.24527	.50103	- 90.77
125.	31.63	42.06	2721	.24075	.49649	- 92.50
126.	32.93	38.44	2748	.24063	.49844	- 92.95
127.	35.50	54.01	2837B	.24391	.50230	- 88.19
128.	34.11	54.02	2789B	.24217	.50021	- 90.71
129.	32.81	56.68	3098B	.22372	.49826	- 88.67
130.	35.52	56.42	2864	.24219	.50233	- 88.31

Appendix A.--Gravity stations--Continued

Station	Latitude	Longitude	Elev. in feet	Observed Gravity	Theoret. Gravity	2.67
131.	43 ^o 39.00'N	101 ^o 54.02'W	2595B	980.26810	980.50756	- 83.78
132.	40.74	52.84	2424	.28311	.51018	- 81.64
133.	40.74	55.20	2443B	.28185	.51018	- 81.77
134.	39.90	46.20	2335B	.28709	.50891	- 81.74
135.	40.38	44.88	2386	.28517	.50963	- 81.32
136.	39.36	47.97	2576B	.26922	.50810	- 84.34
137.	38.55	48.74	2565B	.26790	.50689	- 85.10
138.	41.55	46.76	2372	.28856	.51139	- 80.53
139.	40.72	49.24	2425	.28237	.51015	- 82.29
140.	40.73	51.05	2419	.28343	.51016	- 81.60
141.	38.99	51.75	2593B	.26738	.50755	- 84.60
142.	37.58	50.62	2504	.26994	.50543	- 85.27
143.	44.10	50.78	2321B	.29492	.51523	- 81.05
144.	42.85	50.18	2315	.29512	.51335	- 79.35
145.	43.22	52.97	2371B	.29139	.51390	- 80.27
146.	42.32	54.04	2352B	.29127	.51255	- 80.18
147.	43.54	56.40	2371B	.29191	.51438	- 80.23
148.	42.08	56.07	2304	.29392	.51219	- 80.05
149.	42.40	58.33	2353	.29155	.51267	- 79.96
150.	30.32	51.88	2693B	.23750	.49452	- 95.45
151.	30.32	49.38	2609B	.24101	.49452	- 96.98
152.	34.17	49.90	2752	.24276	.50030	- 92.44
153.	32.49	49.90	2792	.23415	.49778	- 96.13
154.	33.78	46.87	2792	.23824	.49972	- 93.98
155.	35.38	48.75	2406	.26942	.50212	- 88.36
156.	32.11	47.48	2501	.25176	.49721	- 94.87
157.	32.23	52.23	2906	.22708	.49739	- 95.97
158.	31.10	54.28	2856	.22938	.49569	- 94.96
159.	30.33	53.15	2788	.23206	.49454	- 95.21
160.	30.33	55.20	2763	.23492	.49454	- 93.85

Appendix A.--Gravity stations--Continued

Station	Latitude	Longitude	Elev. in feet	Observed Gravity	Theoret. Gravity	2.67
161.	43 ^o 30.33'N	101 ^o 58.53'W	2850B	980.22847	980.49454	- 95.08
162.	31.20	57.68	2959	.22280	.49584	- 95.52
163.	34.66	57.60	2908B	.23737	.50104	- 89.20
164.	37.27	52.83	2740	.25463	.50496	- 85.95
165.	30.35	102 ^o 00.83	3020B	.21666	.49457	- 96.72
166.	32.08	00.10	2751	.23966	.49716	- 92.45
167.	32.06	02.36	2948	.22731	.49713	- 92.96
168.	30.97	04.45	3151B	.20913	.49550	- 97.32
169.	31.51	06.43	2932B	.22620	.49631	- 94.20
170.	32.59	05.35	3022B	.22283	.49793	- 93.79
171.	35.96	05.94	2902B	.24212	.50299	- 86.77
172.	34.17	05.95	3059B	.22559	.50030	- 91.19
173.	35.64	02.50	2788	.24916	.50251	- 86.09
174.	33.80	04.12	2023	.22772	.49975	- 90.66
175.	42.52	01.12	2339	.29297	.51285	- 79.55
176.	43.88	02.32	2380B	.29254	.51489	- 79.56
177.	42.54	02.85	2387	.28976	.51288	- 79.92
178.	42.51	04.70	2390	.28965	.51284	- 79.80
179.	43.98	04.71	2430	.28990	.51504	- 79.36
180.	42.87	06.49	2428	.28796	.51338	- 79.75
181.	42.77	08.29	2419B	.28860	.51323	- 79.50
182.	42.73	10.71	2426	.28769	.51317	- 79.93
183.	44.91	11.88	2501	.28641	.51644	- 79.98
184.	44.03	14.27	2492	.28541	.51512	- 80.21
185.	42.26	14.27	2483	.28291	.51246	- 80.59
186.	40.98	14.31	2474B	.28200	.51054	- 80.11
187.	38.90	14.27	2574B	.27128	.50741	- 81.71
188.	40.30	12.40	2425B	.28370	.50951	- 80.33
189.	41.43	12.01	2428	.28519	.51121	- 80.36
190.	38.15	02.35	2716B	.25853	.50628	- 84.81

Appendix A.--Gravity stations--Continued

Station	Latitude	Longitude	Elev. in feet	Observed Gravity	Theoret. Gravity	2.67
191.	43° 38.13'N	102° 04.74'W	2693B	980.26109	980.50625	- 83.60
192.	38.15	06.54	2740	.25789	.50628	- 84.01
193.	39.80	07.24	2697	.26398	.50876	- 82.98
194.	38.14	07.72	2775B	.25544	.50627	- 84.34
195.	38.14	09.26	2700B	.26103	.50627	- 83.26
196.	39.02	09.51	2673B	.26460	.50759	- 82.63
197.	40.72	09.50	2553B	.27570	.51015	- 81.27
198.	39.99	02.98	2557	.27323	.50905	- 82.42
199.	33.49	11.95	3090B	.21953	.49928	- 94.36
200.	30.40	12.48	2864B	.23470	.49464	- 88.12
201.	30.68	13.89	2736B	.24414	.49506	- 86.78
202.	30.34	15.44	2867	.23546	.49455	- 87.09
203.	31.74	08.60	3017B	.22126	.49665	- 94.39
204.	32.36	13.79	2659B	.24914	.49759	- 88.92
205.	33.81	14.63	2599B	.25534	.49976	- 88.50
206.	35.18	15.55	2573B	.26038	.50182	- 87.07
207.	36.55	16.35	2495B	.26884	.50388	- 85.35
208.	37.22	14.95	2475B	.27264	.50489	- 83.77
209.	31.61	09.89	3106B	.21562	.49646	- 94.49
210.	33.75	10.01	2992	.22696	.49967	- 93.21
211.	56.22	101° 51.62	2480B	.30297	.53344	- 81.69
212.	54.91	51.59	2459	.30321	.53147	- 80.74
213.	53.61	51.97	2438	.30316	.52952	- 80.09
214.	53.61	49.71	2442	.30189	.52952	- 81.12
215.	53.61	46.79	2446	.30082	.52952	- 81.95
216.	55.35	49.18	2380	.30763	.53213	- 81.72
217.	55.77	46.79	2354	.30847	.53277	- 83.06
218.	58.14	46.00	2266B	.31453	.53633	- 85.85
219.	57.76	48.60	2477B	.30096	.53576	- 86.19
220.	59.68	49.18	2374	.30885	.53864	- 87.37

Appendix A.--Gravity stations--Continued

Station	Latitude	Longitude	Elev. in feet	Observed Gravity	Theoret. Gravity	2.67
221.	43° 59.62' N	101° 47.00' W	2312	980.31255	980.53855	- 87.30
222.	59.69	53.20	2436	.30757	.53866	- 84.93
223.	57.82	53.93	2405B	.30995	.53585	- 81.61
224.	58.14	56.34	2446B	.30899	.53633	- 80.59
225.	59.67	56.35	2538B	.30427	.53863	- 82.09
226.	56.21	56.35	2599	.29806	.53343	- 79.44
227.	59.51	58.69	2466	.31060	.53839	- 79.85
228.	58.37	58.77	2482B	.30873	.53667	- 79.04
229.	57.08	58.75	2539	.30410	.53473	- 78.31
230.	55.26	58.74	2592B	.29884	.53200	- 77.66
231.	53.60	58.75	2536	.29979	.52950	- 77.57
232.	53.60	56.35	2491	.30197	.52950	- 78.09
233.	53.61	52.80	2521	.29781	.52952	- 80.46
234.	54.67	53.94	2439	.30534	.53111	- 79.44
235.	56.21	53.94	2510	.30204	.53343	- 80.80
236.	44.07	46.35	2364B	.29388	.51518	- 79.47
237.	44.12	48.67	2335B	.29503	.51526	- 80.14
238.	50.16	47.98	2529B	.28974	.52433	- 82.87
239.	51.01	46.80	2526	.29132	.52561	- 82.74
240.	51.88	45.65	2447	.29778	.52692	- 82.34
241.	48.40	49.47	2548	.28435	.52169	- 84.47
242.	50.12	52.33	2468B	.29447	.52427	- 81.73
243.	58.04	102° 14.33	2882B	.28897	.53618	- 74.30
244.	56.20	14.30	2929	.28296	.53341	- 74.72
245.	53.59	14.30	3018	.27175	.52949	- 76.68
246.	51.91	13.57	3063B	.26394	.52696	- 79.25
247.	50.62	12.27	2646B	.28943	.52502	- 76.86
248.	48.37	11.96	2569B	.28810	.52164	- 79.42
249.	48.38	14.90	2567B	.28907	.52165	- 78.58
250.	45.78	11.89	2516	.28705	.51775	- 79.76

Appendix A.--Gravity stations--Continued

Station	Latitude	Longitude	Elev. in feet	Observed Gravity	Theoret. Gravity	2.67
251.	43°46.21'N	102°13.08'W	2516B	980.28788	980.51840	- 79.57
252.	45.91	08.54	2492B	.28810	.51795	- 80.34
253.	47.99	07.63	2711	.27604	.52107	- 82.39
254.	49.24	09.43	2765	.27717	.52295	- 79.89
255.	50.90	09.49	2726	.28508	.52545	- 76.82
256.	52.73	10.48	2660	.29354	.52820	- 75.07
257.	54.73	09.48	2654	.29809	.53120	- 73.89
258.	59.24	11.90	2704	.30158	.53798	- 74.17
259.	59.66	09.38	2651	.30349	.53861	- 76.07
260.	57.93	08.28	2622	.30372	.53601	- 74.99
261.	57.93	10.00	2663	.30195	.53601	- 74.30
262.	56.19	09.49	2697	.29777	.53340	- 73.83
263.	52.95	11.72	2703	.29140	.52853	- 74.96
264.	59.19	07.42	2611	.30486	.53791	- 76.40
265.	59.67	05.93	2636	.30260	.53863	- 77.88
266.	59.67	04.02	2542	.30822	.53863	- 77.91
267.	44°00.00	02.35	2504	.31065	.53912	- 78.25
268.	43°58.38	01.12	2499	.30901	.53669	- 77.76
269.	57.50	03.53	2584B	.30352	.53537	- 76.81
270.	55.33	03.53	2628	.29838	.53210	- 76.06
271.	52.72	03.53	2575	.29795	.52818	- 75.75
272.	57.93	07.13	2621	.30317	.53601	- 75.60
273.	56.24	07.15	2671B	.29867	.53347	- 74.56
274.	52.73	01.12	2550	.29864	.52820	- 76.57
275.	54.42	07.15	2641	.29818	.53074	- 74.10
276.	58.93	16.85	2754	.30094	.53752	- 71.35
277.	56.38	16.11	2813	.29198	.53368	- 72.94
278.	57.51	16.65	2864	.29112	.53538	- 72.44
279.	57.39	19.04	2888	.29092	.53520	- 71.02
280.	58.90	20.26	2906	.29338	.53747	- 69.75

Appendix A.--Gravity stations--Continued

Station	Latitude	Longitude	Elev. in feet	Observed Gravity	Theoret. Gravity	2.67
281.	43° 57.79' N	102° 22.09' W	2889B	980.29281	980.53580	- 69.67
282.	59.25	22.07	2826	.30024	.53800	- 68.21
283.	56.22	21.84	2950B	.28495	.53344	- 71.50
284.	56.21	19.67	2934	.28533	.53343	- 72.07
285.	54.37	21.97	2731B	.29382	.53066	- 73.00
286.	54.20	19.68	2968	.27709	.53041	- 75.25
287.	52.80	19.07	2669B	.29156	.52830	- 76.62
288.	52.17	20.14	2677	.29005	.52735	- 76.70
289.	55.32	16.55	2924	.28285	.53209	- 73.81
290.	54.03	17.47	2961B	.27649	.53015	- 76.02
291.	52.73	15.43	3089B	.26431	.52820	- 78.56
292.	50.13	101° 50.37	2496	.29171	.52429	- 82.83
293.	51.00	49.18	2490	.29432	.52560	- 81.88
294.	51.86	51.59	2452	.29915	.52689	- 80.63
295.	50.12	53.94	2507	.29282	.52427	- 81.04
296.	52.30	53.95	2551	.29392	.52755	- 80.58
297.	50.99	55.29	2561	.29166	.52558	- 80.28
298.	51.85	57.56	2587	.29292	.52687	- 78.75
299.	51.00	59.95	2575B	.29335	.52560	- 77.76
300.	50.55	57.91	2619	.28897	.52492	- 78.82
301.	49.58	56.35	2588	.28831	.52346	- 79.89
302.	48.17	56.34	2532	.28869	.52134	- 80.75
303.	48.40	54.08	2560B	.28544	.52169	- 82.66
304.	46.28	55.13	2611B	.27946	.51850	- 82.40
305.	45.64	56.22	2661	.27536	.51754	- 82.54
306.	44.47	59.94	2399	.29234	.51578	- 79.51
307.	47.98	59.90	2726B	.27618	.52106	- 81.34
308.	49.24	102° 00.18	2764B	.27643	.52295	- 80.69
309.	45.98	02.49	2455B	.29076	.51805	- 80.00
310.	48.08	03.48	2701B	.27825	.52121	- 80.91

Appendix A.--Gravity stations--Continued

Station	Latitude	Longitude	Elev. in feet	Observed Gravity	Theoret. Gravity	2.67
311.	43 ^o 49.24'N	102 ^o 03.52'W	2630	980.28632	980.52295	- 78.85
312.	50.97	03.52	2578B	.29437	.52555	- 76.52
313.	50.98	07.17	2679B	.28831	.52557	- 76.53
314.	50.98	01.90	2559	.29527	.52557	- 76.77
315.	49.24	06.53	2643	.28541	.52295	- 78.98
316.	47.57	04.73	2679B	.27834	.52044	- 81.37
317.	48.31	16.69	2605B	.28651	.52155	- 78.76
318.	46.64	16.68	2596B	.28386	.51904	- 79.44
319.	45.78	16.66	2564B	.28405	.51775	- 79.87
320.	45.70	19.31	2595B	.28255	.51763	- 79.39
321.	45.31	06.11	2466	.28893	.51704	- 80.17
322.	50.60	29.81	2882	.27630	.52499	- 75.78
323.	51.90	29.80	2856	.28054	.52695	- 75.07
324.	51.01	27.34	2762	.28401	.52561	- 75.89
325.	52.33	27.43	2866	.28024	.52759	- 75.41
326.	49.29	29.81	2923	.27173	.52303	- 75.93
327.	49.29	27.42	2869	.27416	.52303	- 76.74
328.	49.12	25.20	2766	.27954	.52277	- 77.28
329.	48.30	23.55	2771B	.27709	.52154	- 78.21
330.	47.69	27.42	2962	.26469	.52062	- 78.22
331.	47.55	29.20	2950	.26622	.52041	- 77.21
332.	42.11	16.12	2509	.28124	.51223	- 80.46
333.	42.98	16.09	2529	.28121	.51354	- 80.60
334.	42.97	17.89	2546	.28038	.51353	- 80.40
335.	42.97	19.31	2586B	.27822	.51353	- 80.16
336.	39.66	17.19	2656	.26693	.50855	- 82.28
337.	41.25	18.10	2697	.26743	.51094	- 81.71
338.	42.88	21.50	2595	.27841	.51339	- 79.30
339.	41.52	21.62	2579	.27701	.51135	- 79.61
340.	38.15	21.39	2675	.26176	.50628	- 84.04

Appendix A.--Gravity stations--Continued

Station	Latitude	Longitude	Elev. in feet	Observed Gravity	Theoret. Gravity	2.67
341.	43 ^o 36.37' N	102 ^o 21.52' W	2555B	980.26606	980.50361	- 84.26
342.	36.42	19.34	2502B	.26847	.50368	- 85.11
343.	39.26	22.47	2650B	.26696	.50795	- 82.01
344.	39.63	20.05	2685	.26633	.50851	- 81.09
345.	38.58	17.18	2629	.26610	.50693	- 83.11
346.	32.15	29.15	2701B	.25002	.49727	- 85.21
347.	30.36	29.73	2696B	.25031	.49458	- 82.52
348.	33.50	29.41	2645B	.25393	.49930	- 86.68
349.	32.96	27.36	2691	.25104	.49849	- 86.01
350.	34.70	27.35	2672	.25492	.50110	- 85.88
351.	35.56	24.95	2632	.26090	.50239	- 83.59
352.	36.42	27.35	2847	.24751	.50368	- 85.37
353.	37.31	28.40	2946B	.24243	.50502	- 85.85
354.	32.75	31.41	2896B	.23824	.49817	- 86.19
355.	31.69	32.11	2697	.25186	.49658	- 82.91
356.	30.08	32.52	2706	.24942	.49416	- 82.40
357.	35.17	30.33	2760B	.24784	.50181	- 88.38
358.	37.02	32.45	2799B	.24852	.50459	- 88.14
359.	36.96	30.18	2737B	.25474	.50450	- 85.56
360.	38.73	30.19	2848	.25243	.50716	- 83.86
361.	40.01	30.65	2774B	.26085	.50908	- 81.81
362.	41.74	31.27	2800B	.26412	.51168	- 79.58
363.	43.26	31.54	2816B	.26698	.51396	- 78.04
364.	44.74	33.92	2834	.27044	.51619	- 75.72
365.	43.19	34.13	2888	.26282	.51386	- 77.77
366.	44.79	32.40	2830B	.27052	.51626	- 75.97
367.	31.69	26.40	2647B	.25300	.49658	- 84.77
368.	32.61	24.35	2589B	.25848	.49796	- 84.16
369.	31.18	27.28	2667B	.25153	.49581	- 84.28
370.	43.94	37.56	2702B	.27488	.51498	- 78.00

Appendix A.--Gravity stations--Continued

Station	Latitude	Longitude	Elev. in feet	Observed Gravity	Theoret. Gravity	2.67
371.	43°40.72'N	102°28.55'W	2845	980.25826	980.51015	- 81.19
372.	39.55	28.43	2809	.25759	.50839	- 82.28
373.	37.30	25.57	2772B	.25480	.50501	- 83.90
374.	39.90	24.96	2734	.26296	.50891	- 81.93
375.	41.68	24.73	2742	.26654	.51159	- 80.54
376.	37.94	33.88	2775B	.25129	.50597	- 88.19
377.	38.45	35.93	2775B	.25280	.50673	- 87.45
378.	39.41	36.63	2796B	.25460	.50818	- 85.84
379.	41.25	37.46	2782B	.26208	.51094	- 81.96
380.	42.65	38.10	2711B	.27057	.51305	- 79.83
381.	43.87	38.67	2667	.27664	.51488	- 78.24
382.	44.84	39.75	2625	.28136	.51634	- 77.49
383.	40.13	34.10	3259	.22616	.50926	- 87.58
384.	42.10	34.83	3152	.24096	.51222	- 82.16
385.	43.81	22.65	2620B	.27882	.51479	- 78.78
386.	43.10	23.68	2616B	.27771	.51372	- 79.07
387.	43.98	26.23	2664	.27715	.51504	- 78.07
388.	45.40	26.21	2688	.27812	.51718	- 77.80
389.	45.83	27.14	2703	.27831	.51782	- 77.35
390.	44.70	29.45	2738	.27514	.51613	- 76.73
391.	44.70	35.78	3055B	.25484	.51613	- 78.00
392.	30.38	37.66	3154B	.21642	.49461	- 88.96
393.	31.25	39.25	3154B	.21657	.49592	- 90.12
394.	32.99	42.24	3204	.21353	.49853	- 92.77
395.	34.56	41.65	3200	.21774	.50089	- 91.17
396.	35.50	41.62	3222B	.21667	.50230	- 92.33
397.	32.48	40.43	3188	.21625	.49777	- 90.25
398.	32.20	36.31	3151	.21943	.49734	- 88.87
399.	32.54	38.09	3187	.21950	.49786	- 87.15
400.	31.25	42.22	3240B	.20694	.49592	- 94.60

Appendix A.--Gravity stations--Continued

Station	Latitude	Longitude	Elev. in feet	Observed Gravity	Theoret. Gravity	2.67
401.	43° 30.88'N	102° 44.45'W	3221B	980.20600	980.49536	- 96.11
402.	32.12	44.02	3222	.20845	.49722	- 95.47
403.	32.12	46.42	3237	.20632	.49722	- 96.70
404.	31.25	47.00	3257B	.20333	.49592	- 97.18
405.	30.39	47.98	3220	.20400	.49463	- 97.45
406.	32.12	48.20	3249	.20510	.49722	- 97.20
407.	33.41	48.66	3271B	.20629	.49916	- 96.63
408.	51.89	101° 31.34	2441	.28748	.52693	- 93.00
409.	51.89	33.98	2356	.29438	.52693	- 91.21
410.	51.87	37.29	2451	.29039	.52690	- 89.47
411.	50.67	36.09	2414	.28891	.52510	- 91.36
412.	49.28	36.69	2441	.28575	.52301	- 90.82
413.	48.84	34.88	2408	.28526	.52235	- 92.63
414.	47.58	34.23	2345B	.28706	.52046	- 92.72
415.	46.89	35.63	2336	.28864	.51942	- 90.63
416.	45.20	35.98	2184B	.29781	.51688	- 88.05
417.	45.82	33.67	2303	.28751	.51781	- 92.14
418.	49.60	33.13	2386	.28645	.52349	- 93.90
419.	48.41	31.31	2447B	.27908	.52170	- 95.82
420.	47.67	32.01	2369B	.28337	.52059	- 95.09
421.	45.41	31.94	2374B	.28103	.51719	- 93.74
422.	44.23	30.41	2134B	.29626	.51542	- 91.13
423.	44.13	32.15	2291B	.28658	.51527	- 91.24
424.	42.07	32.50	2491B	.27227	.51217	- 90.46
425.	41.63	30.64	2482	.27103	.51151	- 91.58
426.	40.56	32.26	2597B	.26267	.50991	- 91.43
427.	39.39	30.72	2375B	.27525	.50815	- 90.41
428.	37.72	30.03	2395B	.27178	.50564	- 90.17
429.	39.67	32.10	2664B	.25604	.50857	- 92.70
430.	43.36	34.28	2355	.28324	.51411	- 89.59

Appendix A.--Gravity stations--Continued

Station	Latitude	Longitude	Elev. in feet	Observed Gravity	Theoret. Gravity	2.67
431.	43 ^o 43.23'N	101 ^o 36.66'W	2359	980.28561	980.51392	- 86.79
432.	44.60	27.67	2257B	.28650	.51598	- 94.07
433.	44.45	25.86	2354B	.27887	.51575	- 95.66
434.	45.85	26.44	2231	.28843	.51786	- 95.58
435.	45.11	24.18	2394B	.27506	.51674	- 98.06
436.	46.84	22.82	2223B	.28791	.51934	- 98.06
437.	43.36	24.04	2462B	.26975	.51411	- 96.65
438.	41.17	23.73	2566B	.26010	.51082	- 96.78
439.	42.50	25.73	2483	.26875	.51282	- 95.11
440.	43.36	28.70	2365	.27973	.51411	- 92.49
441.	41.61	28.26	2213	.28812	.51148	- 90.60
442.	38.15	28.77	2346B	.27433	.50628	- 91.21
443.	38.14	26.45	2405B	.26797	.50627	- 94.01
444.	39.90	27.65	2332	.27630	.50891	- 92.70
445.	49.19	22.63	2378B	.28203	.52287	- 98.18
446.	51.02	22.98	2366B	.28551	.52563	- 98.17
447.	52.31	22.97	2352	.28813	.52756	- 98.33
448.	52.32	25.32	2326	.29262	.52758	- 95.41
449.	51.88	26.53	2344	.29143	.52692	- 94.86
450.	50.65	26.49	2388B	.28541	.52507	- 96.40
451.	51.88	28.93	2457	.28462	.52692	- 94.89
452.	50.20	29.38	2475B	.27984	.52439	- 96.06
453.	48.41	26.65	2344	.28326	.52170	- 97.81
454.	49.71	27.99	2362	.28562	.52366	- 96.33
455.	48.91	29.39	2352	.28560	.52245	- 95.75
456.	48.11	28.28	2393	.28070	.52125	- 96.99
457.	46.67	28.92	2273	.28711	.51909	- 95.61
458.	51.87	100 ^o 32.77	2074	.29943	.52690	-103.04
459.	51.01	30.38	2093B	.29775	.52561	-102.29
460.	51.00	35.14	2134	.29116	.52560	-106.41

Appendix A.--Gravity stations--Continued

Station	Latitude	Longitude	Elev. in feet	Observed Gravity	Theoret. Gravity	2.67
461.	43° 51.88' N	100° 36.35' W	2257	980.28409	980.52692	-107.43
462.	51.26	37.55	2184	.28666	.52599	-108.30
463.	50.13	32.77	2066	.29557	.52429	-104.78
464.	48.40	32.77	2009	.29412	.52169	-107.04
465.	48.40	30.37	1991	.29748	.52169	-104.77
466.	49.26	34.56	2194	.28267	.52298	-108.68
467.	46.23	32.75	2117	.28186	.51843	-109.57
468.	45.42	30.72	1888B	.29723	.51721	-106.72
469.	46.17	35.11	1795B	.30134	.51834	-109.31
470.	47.51	35.90	1970	.29248	.52035	-109.69
471.	49.27	36.94	2120	.28579	.52300	-110.02
472.	45.83	36.80	1779B	.30033	.51782	-110.78
473.	48.32	41.44	2168B	.27695	.52157	-114.56
474.	46.61	40.70	2092B	.27861	.51900	-114.89
475.	46.21	43.52	2156	.27386	.51840	-115.19
476.	44.87	38.92	1807B	.29395	.51638	-114.03
477.	43.24	43.62	1802	.29137	.51393	-114.46
478.	44.62	44.93	1872	.28947	.51601	-114.24
479.	43.54	43.32	1793	.29251	.51438	-114.31
480.	45.15	38.31	1771	.29744	.51680	-113.12
481.	46.42	37.54	2066B	.28220	.51871	-112.57
482.	47.50	37.58	2109B	.28154	.52033	-112.28
483.	48.66	38.44	2157B	.28037	.52208	-112.31
484.	50.09	38.75	2124B	.28630	.52423	-110.51
485.	51.90	39.97	2230	.28310	.52695	-110.07
486.	51.90	42.93	2245	.27987	.52695	-112.39
487.	51.98	44.74	2227B	.28073	.52693	-112.60
488.	43.16	38.77	1802B	.29094	.51381	-114.77
489.	43.48	36.61	1983B	.28080	.51429	-114.54
490.	43.48	34.87	1959	.28388	.51429	-112.89

Appendix A.--Gravity stations--Continued

Station	Latitude	Longitude	Elev. in feet	Observed Gravity	Theoret. Gravity	2.67
491.	43 ^o 41.30 'N	100 ^o 36.60 'W	2098B	980.26910	980.51102	-116.06
492.	41.32	32.97	2073	.27501	.51105	-111.68
493.	42.40	31.79	2043	.27980	.51237	-110.01
494.	43.80	31.37	1730	.30368	.51477	-107.31
495.	40.88	30.58	2064B	.27740	.51039	-109.17
496.	39.58	30.58	2161	.26854	.50843	-110.25
497.	38.28	30.57	2105B	.26969	.50648	-110.51
498.	40.00	34.17	2085	.27040	.50906	-113.58
499.	38.28	32.97	2108	.26745	.50648	-112.57
500.	38.27	35.39	2208B	.25927	.50646	-114.73
501.	39.13	36.57	2168B	.26126	.50776	-116.43
502.	38.77	36.58	2126	.26449	.50588	-113.85
503.	37.82	39.71	2116B	.26136	.50579	-117.49
504.	37.72	40.91	1886B	.27505	.50564	-117.45
505.	39.84	39.52	1857	.28065	.50882	-116.76
506.	40.66	38.28	1856B	.28248	.51006	-116.24
507.	41.73	39.26	1986	.27604	.51166	-116.49
508.	40.85	41.38	2117	.26509	.51034	-118.25
509.	40.05	42.55	2232	.25574	.50914	-119.49
510.	38.23	44.98	2247B	.25228	.50640	-119.32
511.	39.48	44.93	2056B	.26673	.50828	-118.21
512.	41.72	42.61	2003	.27474	.51165	-116.75
513.	41.68	44.99	1844B	.28531	.51159	-115.66
514.	37.79	46.78	2234	.25373	.50574	-117.99
515.	39.53	46.78	2175	.25971	.50836	-118.16
516.	41.04	47.38	1981	.27586	.51063	-115.92
517.	42.55	48.57	2173	.26612	.51290	-116.42
518.	44.72	49.76	2036B	.28067	.51616	-113.35
519.	43.71	50.98	2203	.26789	.51464	-114.59
520.	42.55	51.59	2269	.26094	.51290	-115.83

Appendix A.--Gravity stations--Continued

Station	Latitude	Longitude	Elev. in feet	Observed Gravity	Theoret. Gravity	2.67
521.	43°40.81'N	100°49.14'W	2128	980.26557	980.51028	-117.05
522.	40.81	52.17	2197B	.26206	.51028	-116.42
523.	39.08	51.58	2214B	.25771	.50768	-117.15
524.	38.00	51.59	2128B	.26172	.50606	-116.68
525.	38.32	49.30	1993	.27107	.50654	-115.91
526.	39.52	49.15	1971	.27411	.50834	-116.00
527.	44.09	46.84	1839B	.29119	.51521	-113.70
528.	46.25	45.92	2213B	.27041	.51846	-115.29
529.	46.21	47.66	1997	.28450	.51840	-114.09
530.	47.57	48.31	2031	.28560	.52044	-113.00
531.	48.37	45.91	2146B	.27903	.52164	-113.87
532.	50.57	45.91	2149B	.28311	.52495	-112.92
533.	51.90	46.51	2208	.28223	.52695	-112.26
534.	51.89	48.30	2279	.27726	.52693	-112.95
535.	50.16	48.31	2268	.27457	.52433	-113.70
536.	51.84	50.68	2304	.27589	.52686	-112.75
537.	50.15	50.69	2250	.27615	.52432	-113.18
538.	48.37	50.85	2205	.27652	.52164	-112.84
539.	46.51	50.09	2045	.28291	.51885	-113.25
540.	49.03	53.21	2079	.28620	.52263	-111.71
541.	50.17	53.27	2116B	.28587	.52435	-111.54
542.	51.71	53.08	2209B	.28244	.52666	-111.71
543.	51.89	55.47	2179	.28545	.52693	-110.76
544.	49.60	55.12	1889	.30042	.52349	-109.75
545.	50.16	56.67	2085	.28917	.52433	-110.08
546.	51.90	57.87	2196	.28502	.52695	-110.19
547.	50.68	58.83	1921	.30135	.52511	-108.53
548.	52.37	59.27	2315	.27828	.52765	-110.50
549.	51.26	00.25	1985B	.29852	.52599	-108.39
550.	51.79	101°02.45	1960	.30155	.52678	-107.65

Appendix A.--Gravity stations--Continued

Station	Latitude	Longitude	Elev. in feet	Observed Gravity	Theoret. Gravity	2.67
551.	43°50.14'N	101°01.31'W	2115B	980.28795	980.52430	-109.48
552.	48.57	01.18	2237B	.27747	.52194	-110.27
553.	46.83	01.18	2249B	.27312	.51933	-111.29
554.	52.35	04.17	2133	.29167	.52762	-108.00
555.	48.56	100°58.80	2216	.27872	.52193	-110.27
556.	47.26	56.09	2221	.27581	.51997	-110.92
557.	48.57	56.43	2077	.28738	.52194	-109.96
558.	48.43	54.64	1898B	.29777	.52173	-110.11
559.	47.38	55.17	2153	.27977	.52015	-111.23
560.	46.89	53.37	2090B	.28257	.51942	-111.46
561.	45.35	53.35	1961B	.28869	.51710	-110.78
562.	45.15	52.46	2188B	.27292	.51680	-112.63
563.	45.44	55.76	2325B	.26430	.51724	-113.46
564.	45.07	57.60	2350B	.26419	.51668	-111.51
565.	45.96	101°00.00	2328B	.26595	.51802	-112.41
566.	45.95	02.83	2389B	.26206	.51801	-112.62
567.	45.96	05.99	2398B	.26216	.51802	-112.00
568.	47.58	06.01	2311B	.27087	.52046	-110.95
569.	44.22	100°58.79	2402	.25750	.51541	-113.80
570.	43.03	56.90	2267	.26339	.51362	-114.23
571.	41.62	59.38	2394	.25287	.51150	-115.01
572.	41.70	56.42	2247	.26183	.51162	-114.99
573.	40.82	55.75	2321	.25518	.51030	-115.88
574.	41.69	53.36	2242B	.26126	.51160	-115.84
575.	43.42	53.36	2256	.26452	.51420	-114.34
576.	39.98	53.36	2317	.25289	.50903	-117.14
577.	38.22	54.76	2190	.25915	.50639	-115.86
578.	39.01	56.42	2304	.25365	.50758	-115.70
579.	39.01	58.79	2311	.25459	.50758	-114.35
580.	37.74	59.38	2281	.25545	.50567	-113.38

Appendix A.--Gravity stations--Continued

Station	Latitude	Longitude	Elev. in feet	Observed Gravity	Theoret. Gravity	2.67
581.	43°37.75'N	101°01.19'W	2307	980.25509	980.50568	-112.19
582.	39.01	01.20	2320B	.25602	.50758	-112.37
583.	40.75	01.20	2355B	.25527	.51019	-113.63
584.	42.44	01.20	2400B	.25422	.51273	-114.53
585.	44.22	01.18	2367B	.25993	.51541	-113.47
586.	42.49	04.79	2324	.26169	.51281	-111.69
587.	44.22	04.80	2336	.26325	.51541	-112.02
588.	40.75	04.78	2422	.25397	.51019	-110.91
589.	39.00	04.78	2393	.25433	.50756	-109.68
590.	37.57	06.43	2498B	.24605	.50541	-109.50
591.	39.14	07.17	2464B	.25070	.50777	-109.25
592.	40.73	07.24	2481B	.25217	.51016	-109.15
593.	42.46	07.19	2334B	.26304	.51276	-109.69
594.	44.50	08.76	2533	.25269	.51583	-111.17
595.	44.78	10.78	2280B	.27335	.51625	-106.12
596.	44.86	07.32	2281B	.26931	.51637	-110.21
597.	42.47	08.38	2301	.26717	.51278	-107.56
598.	41.17	08.13	2478	.25382	.51082	-108.34
599.	42.09	10.18	2272	.27052	.51220	-105.39
600.	42.92	13.15	2298	.27247	.51345	-103.13
601.	44.09	12.18	2288	.27425	.51521	-103.71
602.	44.96	13.53	2106B	.28874	.51652	-101.43
603.	40.66	11.96	2280	.26773	.51006	-105.55
604.	39.71	11.29	2327	.26301	.50863	-106.01
605.	38.13	11.96	2287	.26420	.50625	-104.85
606.	37.85	13.67	2300B	.26431	.50583	-103.55
607.	39.01	13.67	2336B	.26329	.50758	-104.14
608.	40.40	13.66	2276B	.26883	.50966	-104.29
609.	41.27	14.98	2306B	.26900	.51097	-103.62
610.	42.50	16.32	2348B	.26922	.51282	-102.74

Appendix A.--Gravity stations--Continued

Station	Latitude	Longitude	Elev. in feet	Observed Gravity	Theoret. Gravity	2.67
611.	43° 43.95' N	101° 16.17' W	2378B	980.26998	980.51500	-102.36
612.	40.76	16.78	2363	.26612	.51021	-102.33
613.	42.06	19.24	2355	.26874	.51216	-102.14
614.	44.23	18.40	2375	.27143	.51542	-101.52
615.	45.08	18.67	2358	.27403	.51670	-101.21
616.	46.62	19.27	2080	.29550	.51901	- 98.72
617.	46.72	21.62	2096	.29544	.51916	- 97.98
618.	45.53	21.12	2370B	.27523	.51737	- 99.96
619.	44.24	20.46	2388	.27157	.51544	-100.61
620.	45.09	17.33	2358B	.27372	.51671	-101.53
621.	45.50	15.57	2339B	.27565	.51733	-101.36
622.	46.83	15.57	2183	.28857	.51933	- 99.80
623.	39.02	15.57	2289	.26842	.50759	-101.84
624.	37.63	17.23	2435B	.25895	.50550	-100.48
625.	38.40	18.90	2379B	.26477	.50666	- 99.16
626.	39.89	19.25	2313	.27189	.50890	- 98.25
627.	40.76	21.66	2323	.27500	.51021	- 95.85
628.	38.83	22.47	2404B	.26665	.50731	- 96.43
629.	37.78	23.93	2485B	.26216	.50723	- 95.99
630.	50.10	04.39	2127	.28787	.52424	-108.77
631.	48.56	03.58	2262	.27593	.52193	-110.30
632.	47.22	03.58	2315	.26970	.51991	-111.33
633.	48.56	06.33	2269B	.27618	.52193	-109.63
634.	50.28	07.31	1978B	.29932	.52451	-106.53
635.	49.11	11.50	2044	.29557	.52275	-104.56
636.	50.69	12.92	2286B	.28342	.52513	-104.57
637.	51.90	12.19	2243	.28727	.52695	-105.12
638.	51.90	09.63	2343B	.27895	.52695	-107.44
639.	51.87	07.40	2309B	.28032	.52690	-108.06
640.	49.93	08.64	1989	.29839	.52399	-106.28

Appendix A.--Gravity stations--Continued

Station	Latitude	Longitude	Elev. in feet	Observed Gravity	Theoret. Gravity	2.67
641.	43 ^o 51.89'N	101 ^o 14.58'W	2295B	980.28551	980.52693	-103.74
642.	48.65	14.47	2226B	.28651	.52206	-102.02
643.	47.37	13.15	2021B	.29690	.52014	-102.00
644.	45.94	10.31	2354	.26863	.51799	-108.14
645.	46.82	08.38	2332	.26980	.51931	-109.61
646.	48.09	08.62	2278	.27539	.52122	-109.17
647.	47.98	10.77	2023	.29400	.52106	-105.69
648.	51.89	15.78	2320	.28454	.52693	-103.21
649.	48.85	16.68	2345	.28114	.52236	-100.54
650.	48.85	19.07	2364	.28111	.52236	- 99.43
651.	50.17	19.37	2359	.28278	.52435	-100.05
652.	48.28	21.92	2302	.28478	.52151	- 98.62
653.	50.10	20.57	2415	.27988	.52424	- 99.47
654.	51.95	20.58	2500B	.27513	.52706	-101.92
655.	51.89	18.14	2390	.28127	.52693	-102.28
656.	35.09	38.44	2683	.24930	.50169	- 91.42
657.	36.83	38.61	2439B	.27139	.50430	- 86.58
658.	38.65	39.36	2337B	.28293	.50704	- 83.90
659.	40.17	40.18	2262B	.29258	.50932	- 81.04
660.	41.38	39.94	2338B	.28926	.51114	- 81.61
661.	37.97	42.30	2353	.28026	.50601	- 84.59
662.	40.82	34.86	2301	.28567	.51030	- 86.58
663.	39.00	34.88	2332	.28197	.50756	- 85.69
664.	41.62	37.42	2262	.29109	.51150	- 84.70
665.	47.54	45.64	2355	.29753	.52039	- 81.58
666.	46.29	46.30	2383	.29371	.51852	- 81.83
667.	45.82	49.36	2403	.29075	.51781	- 82.89
668.	57.07	102 ^o 11.90	2710	.29846	.53472	- 73.67
669.	52.72	05.44	2609	.29636	.52818	- 75.29
670.	30.33	17.82	3071	.22209	.49454	- 88.20

Appendix A.--Gravity stations--Continued

Station	Latitude	Longitude	Elev. in feet	Observed Gravity	Theoret. Gravity	2.67
671.	43°32.02'N	102°17.81'W	3063	980.22371	980.49707	- 89.60
672.	30.71	18.91	3131	.21811	.49511	- 89.16
673.	43.99	08.66	2452B	.28839	.51506	- 79.57
674.	35.84	103°07.11	3519B	.19495	.50281	- 96.74
675.	30.37	13.37	3233	.20144	.49460	- 99.20
676.	32.12	14.53	3188	.21135	.49722	- 94.61
677.	35.58	14.52	3427	.20392	.50242	- 92.90
678.	37.33	14.51	3571	.19493	.50505	- 95.88
679.	44.30	14.37	3443B	.21055	.51553	- 98.41
680.	44.30	11.72	3323B	.21732	.51553	- 98.84
681.	37.82	102°51.57	3073	.24007	.50579	- 81.35
682.	36.53	50.90	3165	.23003	.50385	- 83.94
683.	39.25	49.47	2656	.27095	.50794	- 77.64
684.	37.83	47.28	2716	.25990	.50580	- 82.95
685.	36.82	46.57	2756	.25286	.50429	- 86.08
686.	40.04	54.14	2694	.26985	.50912	- 77.65
687.	41.34	103°01.15	3103B	.23447	.51108	- 90.44
688.	42.98	01.74	3121	.23514	.51354	- 91.16
689.	37.71	03.16	3272B	.21704	.50562	- 92.27
690.	44.69	102°43.72	2890B	.26474	.51611	- 77.99
691.	43.65	45.95	2592	.28259	.51455	- 76.46
692.	42.78	47.34	2597	.28178	.51324	- 75.65
693.	44.90	22.64	2634B	.27980	.51643	- 78.60
694.	42.40	26.83	2812	.26412	.51269	- 79.85
695.	42.50	28.90	2855	.26131	.51282	- 80.23
696.	32.95	23.24	2575B	.25995	.49847	- 84.04
697.	32.95	21.42	2596	.25870	.49847	- 84.03
698.	34.98	21.84	2542B	.26505	.50152	- 83.97
699.	33.85	34.49	2731	.25076	.49982	- 85.22