GRAVITY OBSERVATIONS: CLIFTON-MORENCI AREA, GREENLEE COUNTY, SE ARIZONA

by

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INTRODUCTION

Seventy-one gravity stations were established in April 1979 near the towns of Clifton and Morenci in southeast Arizona. The survey area is generally bounded by latitudes 32°55′N to 33°05′N and longitudes 109°10′W to 109°25′W; however, the majority of new data were obtained within or near the areas labeled on Figure 1 as Clifton KGRA (Known Geothermal Resource Area) and Gillard Hot Springs KGRA. The data were obtained as part of the U.S. Geological Survey's program to evaluate geothermal resource areas. Previous available gravity data in the surrounding region from 32°45′ to 33°15′N and 107°00′ to 109°30′W has been incorporated into the new data set. This report presents the principal facts of this data[1/] with a residual bouguer anomaly map of the survey area.

[1/] Principal facts of previous data within the survey area (32°55′ to 33°05′N, 109°10′ to 109°25′W) are included for completeness; this data is extracted from a larger gravity collection compiled by J. C. Wynn's geophysical study of the Silver City Quadrangle (32°-33° N and 108°-110°W). His data includes U.S.G.S. data, DOD (U.S. Department of Defense) data, and private company data.

DATA ACQUISITION

Gravity observations were made using the LaCoste-Romberg geodetic gravity meter G-159[2/] All data are tied to the "Clifton" gravity base station (U.S. Department of Defense (DOD) Reference 3215-1) located at Greenlee County Airport about 10 miles south of Clifton. The DOD base station description on file at the U.S. Geological Survey (U.S.G.S) is not accurate in presenting the site characteristics found. A modified description for this base station showing the actual observation point is included as Appendix 1.1 to this report; it includes the 1971 International Gravity Standardization Net value (IGSN 71) of 979154.40 mgals which was used in this survey.

Gravity loops were started and closed daily by observations at either the Clifton base, referred to above, or at a supplemental base established at the benchmark "Gillard VABM" (referred to as Gillard base). Meter readings at these bases, corrected for earth tides, are plotted against observation time in Appendix 1.2. Characteristics of this repeat data are probably fair indicators of the uncertainties in the meter readings for all stations. The standard deviation of the mean value of the readings at each base is about 0.1 mgal in both cases. This is an upward limit on the uncertainty because some of the scatter in the repeat data is probably related to observer characteristics. This human effect is expected to be a consistent error that would be removed by the loop closures. Although three observers read data on various days during the survey, each

[2/] Use of brand names is for descriptive purposes and does not constitute endorsement by the U.S.G.S.

particular loop was carried out exclusively by a single observer. The mean value of the difference between repeat observations at Clifton and Gillard was used for establishing the tie to Gillard base. Referring to the standard deviations on the figures in Appendix 1.2, one assigns an uncertainty (one standard deviation) of ± 0.15 mgal to the relative value of the Gillard base.

Elevation control data and an elevation "uncertainty" are listed in Appendix 2. The "uncertainty" is a subjective estimate. Generally, this estimate is guided by the following: for elevations based on topographic map contours the uncertainty is assumed to be 1/2 the contour interval of 80 ft for topographic maps in the area; for elevations based on benchmarks or triangulation stations with vertical control the uncertainty is assumed to be 0.5 ft; for spot elevations and section corners with map elevations the uncertainty is assumed to be 3/10 of the contour interval, or about 25 ft. Many of the elevations were established in the field using a Hewlett-Packard Total Station Ranger[2/]. These elevations were established with ties to existing topographic survey benchmarks. An individual elevation difference obtained with the "Ranger" is generally accurate to within 0.1 foot for distances less than 7000 feet, (personal experience of the users) although finer accuracy is possible under optimum conditions. The uncertainty assigned to these elevations is 0.5 foot, the uncertainty of the benchmark elevation tie. These uncertainties are presented as rough estimates as a guide to data reliability. The elevation uncertainties translate to uncertainties (Δg) in simple bouguer values approximately as (Grant and West, 1965, p. 239):

$$\Delta g \approx (.094-0.13\rho)\Delta h \text{ mgal},$$

where Δh is the elevation uncertainty in feet and ρ is the density (gm/cm^3). When the density is taken as 2.67 gm/cm^3,

$$\Delta g \approx .06 \text{ mgal/foot elevation error.}$$

For the data in appendix 2, the worst case uncertainties (±40 ft) translate to less than ±3 mgal.

Horizontal control accuracy is a function of map scale. Topographic maps at 1:62,500 were used to locate points, and positions are believed to be known to at least ±250 feet. This would contribute a maximum uncertainty of about 0.06 mgal (Grant and West, 1965, p. 236).

The data observed in the present survey is augmented by previous data from the same general region extracted from USGS unpublished data [1/] (J. C. Wynn, written commun., 1979). Details of acquisition for the auxiliary data are not known. Observed gravity values at DOD stations which were reoccupied by the present survey (2 stations) agree to within ±.05 mgal. Comparison between private company observed gravity values and the present survey at two stations show that the company values are lower by approximately 1 mgal.

DATA REDUCTION

Computer programs existing on the U.S.G.S. Honeywell Multics [2/] computer system were used to obtain principal facts and terrain corrected gravity values and anomaly contour maps for this survey. Station coordinates were digitized from field maps and converted to geographic coordinates using program "digit" (R. E. Sweeney, unpub. program, 1978). Program "gravity_red" (D. A. Dansereau, unpub. program, 1978) calculated earth tide and linear meter-drift corrected observed gravity values using the 1967 geodetic reference system (International Union of Geodesy and

Geophysics, 1967) and the 1971 Potsdam gravity value (Morelli, 1971). The program also computes free-air and simple-bouguer anomaly values. Terrain corrections for the present observed data set were obtained by hand template through zone F (0.895 km) of the standard Hammer (1939) partitioning. Program "bouguer" (R. H. Godson, unpub. program, 1978) computed terrain corrections from 0.895 km out to 166.7 km using the method of Plouff (1977). The program uses mean elevation data on a 30 second grid for corrections from 0 to 5 km; 1 minute elevation data for corrections from 5 to 21 km, and 3 minute elevation data for corrections from 21 to 166.7 km. An assumed density of 2.67 gm/cm^3 is used for terrain corrections. "Bouguer" also calculated earth curvature corrections and complete (terrain corrected) bouguer anomaly values. For brevity, we refer to "bouguer anomaly" instead of "complete-bouguer anomaly".

The auxiliary data set was available only as observed gravity values. These values were reduced to bouguer anomaly values using program "bouguer" to calculate terrain corrections from the station to 166.7 km. (Spuriously large inner terrain corrections sometimes result from carrying computer corrections all the way in to the station; however, this was not the case for any of the stations of the auxiliary data set.) A grid based on the new and auxiliary bouguer anomaly values was formed with 2 km spacing between grid points using program "minc2" (M. W. Webring, unpub. program, 1977). "Minc2" forms a surface of minimum curvature (Briggs, 1974) through existing data points. Computer plotted contour maps of the gridded data were produced using program "contour" (R. H. Godson, unpub. program, 1977), which uses a linear interpolation technique

for positioning contours, with optional contour smoothing with splines under tension (Cline, 1974). The contour maps produced for this report make use of the smoothing option with a spline factor sigma = 3.

PRINCIPAL FACTS

The principal facts of the data within the present survey area are tabulated in Appendix 3. The data, including the earlier set acquired by J. C. Wynn, are shown contoured as a "regional" bouguer gravity map in Appendix 4. Station locations are shown as unlabelled X's; the two KGRA outlines are indicated.

Figure 2 shows a residual bouguer contour plot of the area of interest, obtained by removing a 2nd order polynomial surface from the regional complete bouguer grid (Appendix 4). Station locations are marked as X's and the two KGRA outlines are shown. For convenience, the regional field grid was constructed with borders on even 15 minutes of geographic coordinates. Because of this, the area of interest outlined on the regional map in appendix 4 is not exactly centered on the regional map, nor are the four boundaries of the area of interest equidistant from the boundaries of the regional map. This means the influence of edge effects on the residual map in figure 2 may be greater on the western edge of the map than in the other directions.

REFERENCES

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

Cline, A. K., 1974, Scalar and planar-valued curve fitting using spline under tension: Communications of the Association for Computing Machinery, v. 14, no. 4, p. 218-223.

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Hammer, S., 1939, Terrain corrections for gravimeter stations: Geophysics, v. 4, p. 184-194.

International Union of Geodesy and Geophysics, 1967, Resolution no. 1, XIV General Assembly: Bulletin Geodesique, v. 86, p. 367.

Morelli, C., 1971, The International Gravity Standardization Net 1971 (I.S.G.N. 71), International Association of Geodesy, Publication speciale no. 4.

Plouff, D., 1977, Preliminary documentation for a Fortran program to compute gravity terrain corrections based on topography digitized on a geographic grid: U.S. Geol. Survey Open-File Report 77-535, 45 p.

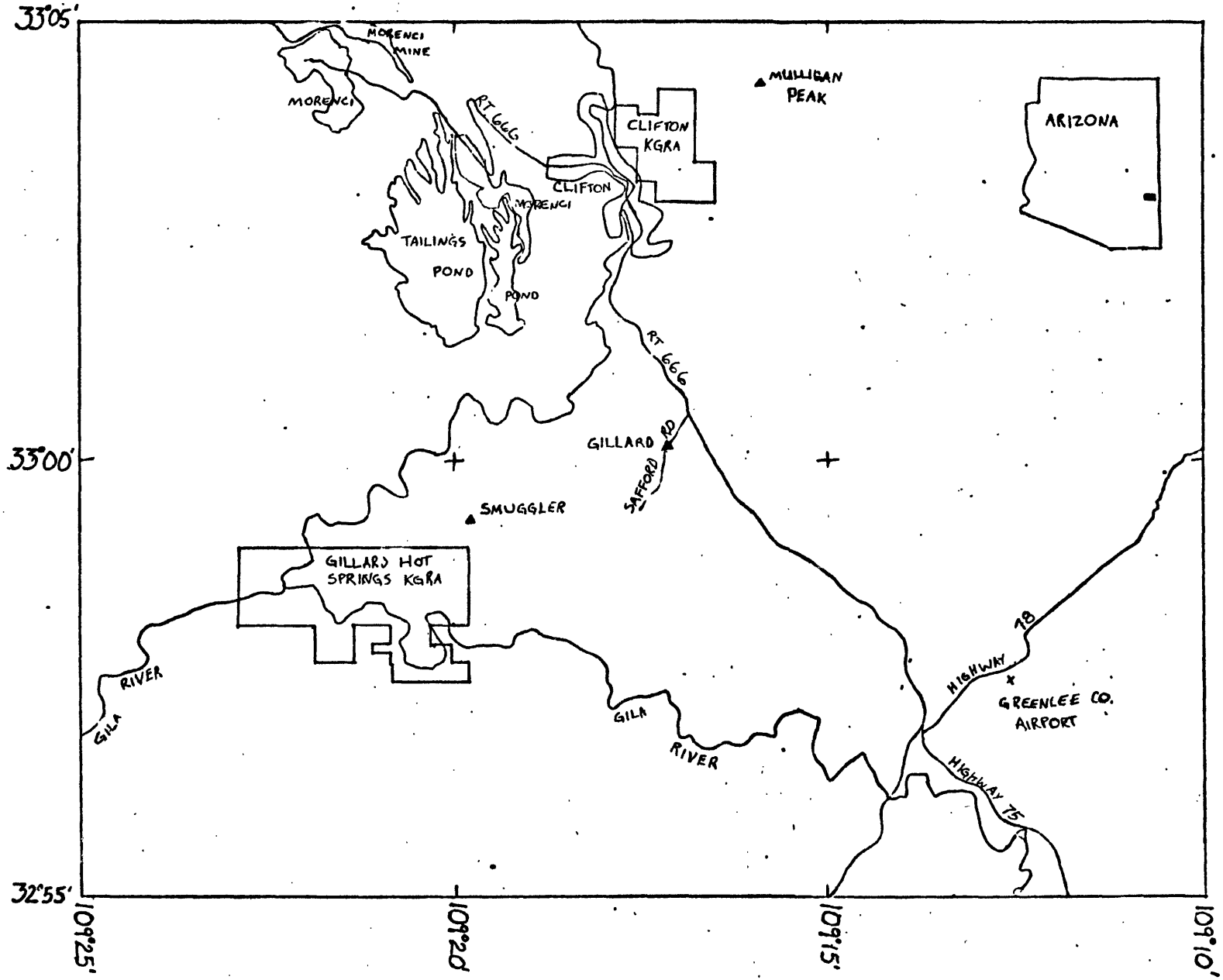


Fig. 1 Location map of the general region of gravity data and KGRA's.

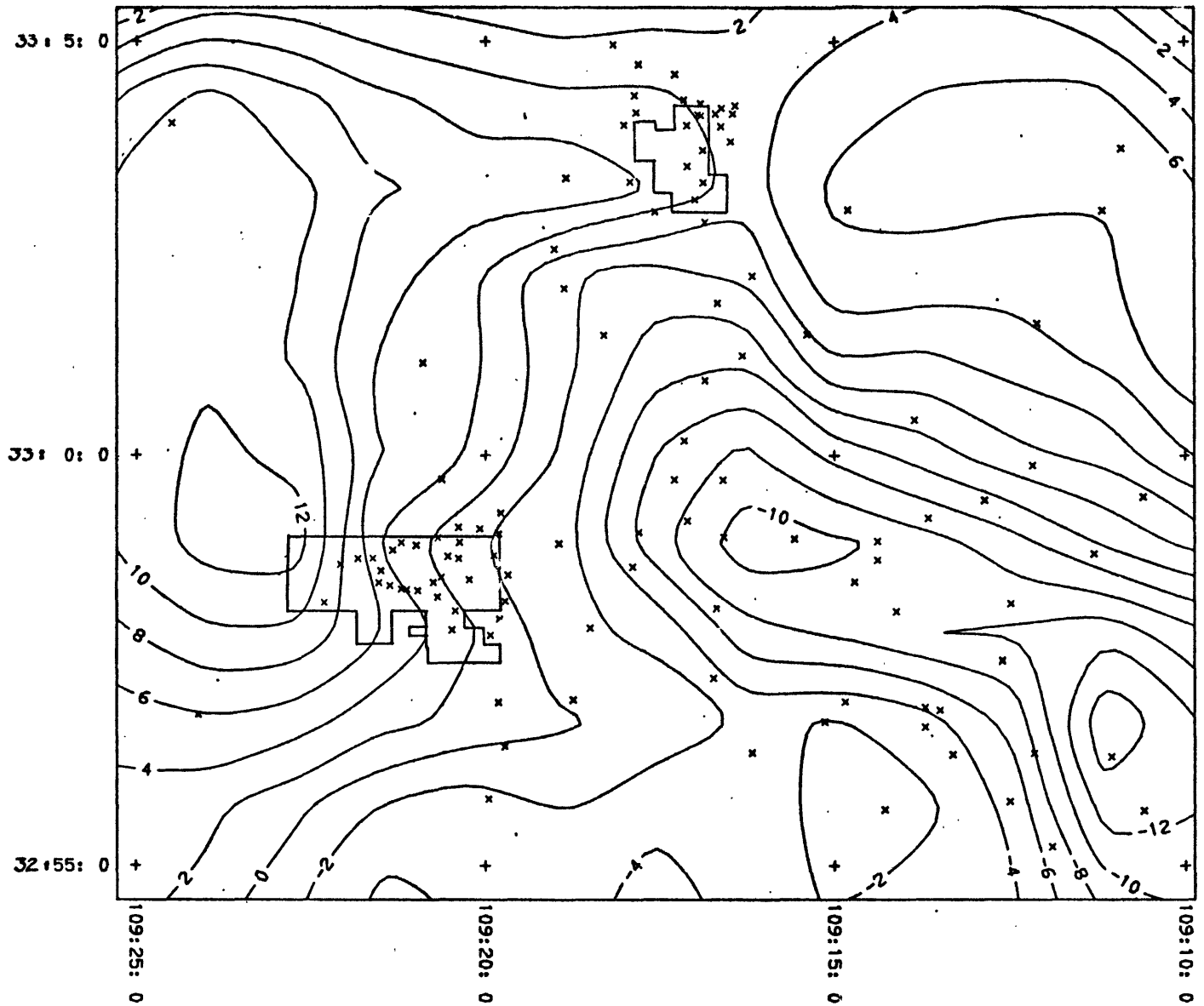


Fig. 2 Residual complete Bouguer anomaly contour map, derived by removing the second order polynomial fit from the regional field extending from 32°45' to 33°15'N latitude and 109°00' to 109°30' W longitude. Contour interval, 2 mgal. X, gravity station.

Appendix 1.1 Clifton Base Station Description

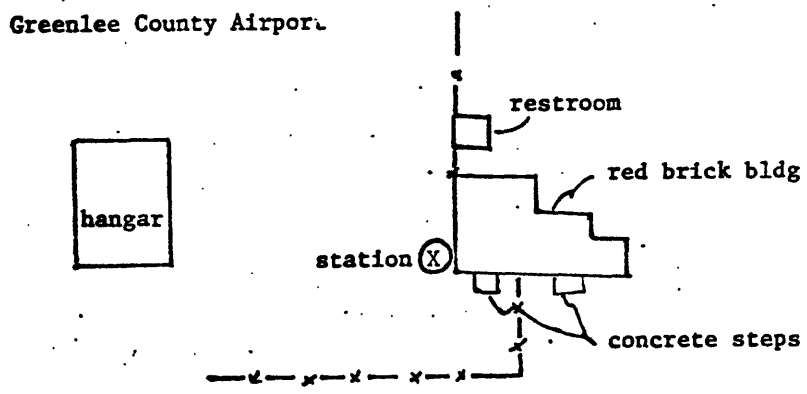
GRAVITY BASE STATION
U.S. GEOLOGICAL SURVEY

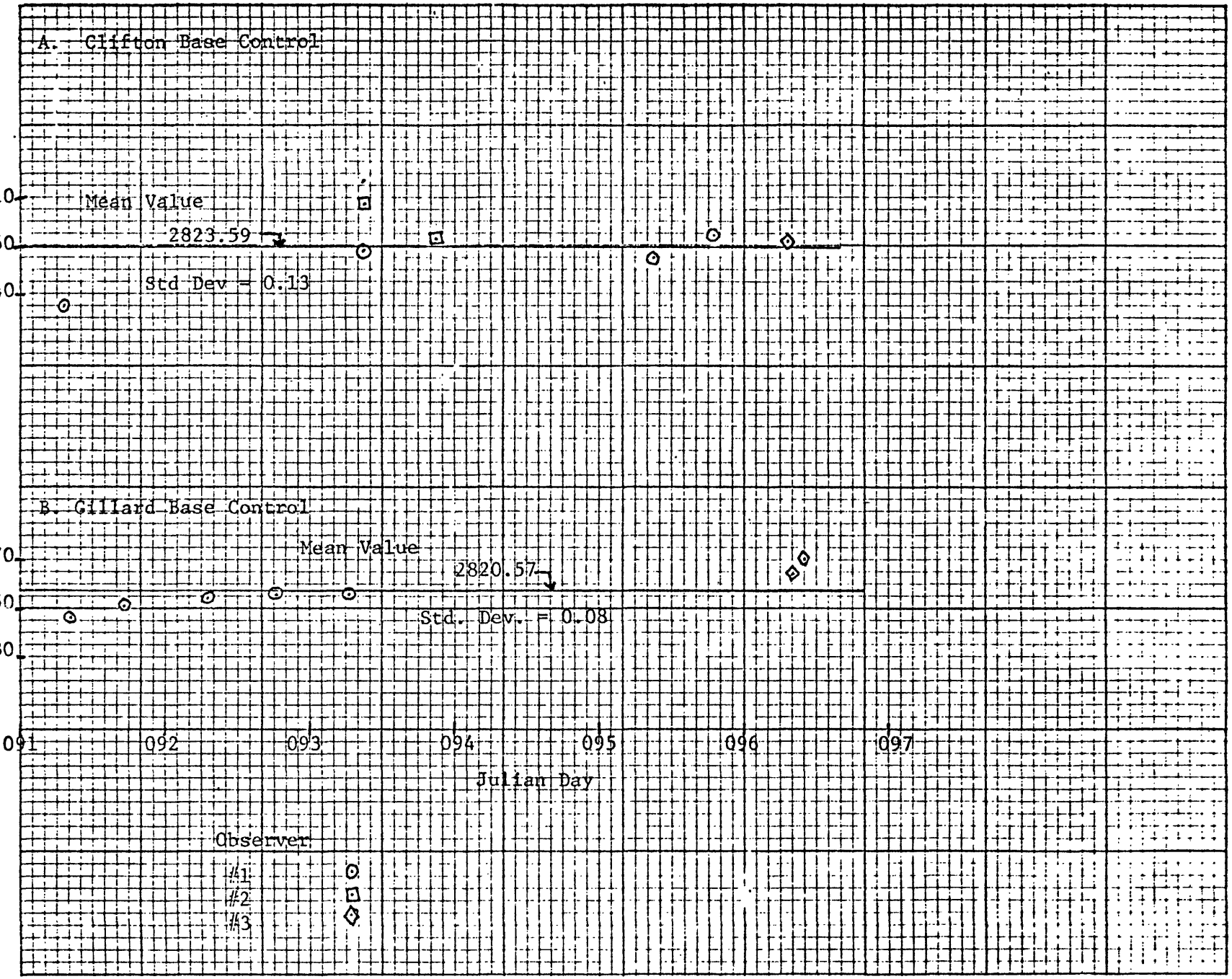
STATE/COUNTRY	STATION DESIGNATION	OBSERVED GRAVITY
Arizona	Clifton	979 154.40 mgals (1971)
NEAREST TOWN	**LONGITUDE**	**LATITUDE**
Clifton	109° 12.6' W	32° 57.48' N
ELEVATION	**TOPOGRAPHIC MAP(S)**	
1156.7 m	York Valley 15'	

DATE	OBSERVER	METER	REFERENCE STATION	REFERENCE VALUE

DESCRIPTION/SKETCH (Revised April, 1979, USGS Open File Report ____)

Station site is located at the Clifton Airport (Greenlee County Airport) at the southwest corner of red brick bouilding, under wall phone. The airport is approximately 10 miles south of Clifton.





Appendix 1.2 Base Control

Appendix 2: Tabulation of Elevation Control; Clifton and Gillard Hot Springs KGRAs

Station	Elevation (ft)	Elevation control from:
1	3794.9	international gravity net (Clifton AP)
2	3947 ±0.5	VABM (Gillard)
3	4051 ±0.5	triangulation pt (Smuggler)
4	3309.8 ±0.5	tie Smuggler
5	3875.2 ±0.5	tie Smuggler
6	3844.8 ±0.5	tie Smuggler
7	3560 ±40	topo map
8	3540 ±40	topo map
9	3674.5 ±0.5	tie Smuggler
10	3577.4 ±0.5	tie Smuggler
11	3507.2 ±0.5	tie Smuggler
12	3383.7 ±0.5	tie Smuggler
13	3288.2 ±0.5	tie Smuggler
14	3289.2 ±0.5	tie Smuggler
15	3814.7 ±0.5	BM
16	3720 ±40	topo map
17	3615.5 ±0.5	BM
18	3373 ±0.5	BM
19	3833.9 ±0.5	tie Smuggler
20	3951.7 ±0.5	tie Smuggler
21	3992.4 ±0.5	tie Smuggler
22	3818.6 ±0.5	tie Smuggler
23	3858.6 ±0.5	tie Smuggler
24	3918.9 ±0.5	tie Smuggler
25	3758.5 ±0.5	tie Smuggler
26	3587.8 ±0.5	tie Smuggler
27	3626.8 ±0.5	tie Smuggler
28	3499.5 ±0.5	tie Smuggler
29	3774.6 ±0.5	tie Smuggler
30	3602.4 ±0.5	tie Smuggler
31	3680 ±40	topo map
32	3735.2 ±0.5	tie Smuggler
33	3515.5 ±0.5	tie Smuggler

Appendix 2: Tabulation of Elevation Control; Clifton and Gillard Hot Springs KGRAs (Continued)

Station	Elevation (ft)	Elevation control from:
C1	4332.1 ±0.5	tie sewergate BM
C2	4634.5 ±0.5	tie sewergate BM
C3	4471.3 ±0.5	tie sewergate BM
C4	4430.2 ±0.5	tie sewergate BM
C5	4421.9 ±0.5	tie sewergate BM
C6	4209.0 ±0.5	tie sewergate BM
C7	4270 ±40	topo map
C8	4330 ±20	topo map
C9	4364 ±25	spot elevation
C10	4486.2 ±0.5	tie sewergate BM
C11	4511.9 ±0.5	tie sewergate BM
C12	4337.9 ±0.5	tie sewergate BM
C13	4244.6 ±0.5	tie sewergate BM
C14	4345.2 ±0.5	tie sewergate BM
C15	4505.8 ±0.5	tie sewergate BM
C16	4381.6 ±0.5	tie sewergate BM
C17	3930.0 ±0.5	tie sewergate BM
L2	**3504 ±0.5	sewergate BM (3506.2)
L4	3480 ±40	topo map
L5	3503 ±2	unrecovered BM
L6	3640 ±40	topo map
L7	3528.0 ±0.5	tie sewergate BM
L8	3465 ±2	unrecovered BM (old Clifton Post Office)
L9	3552 ±0.5	BM (bridge, Clifton)
L10	4094 ±25	spot elevation
L11	3942 ±5	unrecovered VABM
L12	3784 ±25	spot elevation
L13	3600 ±20	topo (water tower on contour line)
L14	3790 ±25	unrecovered BM
L15	4156.5 ±0.5	BM
L16	4287.7 ±0.5	BM
L17	4249 ±3	section corner
L18	4085 ±0.5	BM
D3	3720 ±0.5	BM
D4	4158 ±0.5	BM
D5	4352 ±40	topo map
D6	3898 ±40	topo map

*Stations with elevation control designated as "tie Smuggler" or "tie sewergate BM" were obtained with HP Total Station Ranger readings tied to the indicated elevations.

**Sewergate BM is a benchmark elevation painted on the side of a cement sewergate 3/4 mi no. of Clifton Jail Cave along the road going north out of Clifton. The benchmark was surveyed by the City of Clifton engineering department.

Appendix 3: Principal Facts of Gravity Data

Explanation of headings

identification

proj	Project name.
sta-id	Gravity identification.

location

latitude	North latitude in degrees, minutes, and hundredths of minutes.
longitude	West longitude in degrees, minutes and hundredths of minutes.
elev, f	Station elevation in feet.
st	State where location is located.
observed gravity	Observed gravity in milligals.
theoretical gravity	Theoretical gravity.

corrections

terrain	Terrain correction out to 166.7 Km in milligals.
bouguer	Elevation 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 densities.
spec fields	Not used.

Appendix 3.1: Principal facts of newly acquired data

Clifton,Gillard KGRAs
arizona gravity:april,1979
Meter ID: a-159 Date: 05/11/79

STATION IDENTIFICATION proj	sta-id	LOCATIONS LATITUDE deg	min	LONGITUDE deg	min	ELE (in ft)	ST	GRAVITY OBSERVED	THEORETICAL	CORRECTIONS TERRAIN	BOUGUER	CURV	SPECIAL	ANOMALIES FREE AIR	COMPLETE-BOUGUER d1=2.67	d2=2.50	SPEC FIELDS
KGRA :	clifton	32	57.48	-109	12.60	3794.9	AZ	979150.40	979561.90	0.45	-129.43	-1.22	0.00	-50.59	-180.80	-172.51	
KGRA :	gillard	33	0.18	-109	17.15	3947.0	AZ	979151.59	979565.61	0.74	-134.62	-1.25	0.00	-42.81	-177.94	-169.34	
KGRA :	3	32	59.29	-109	19.78	4051.0	AZ	979150.94	979564.38	3.65	-138.17	-1.27	0.00	-32.47	-168.25	-159.61	
KGRA :	4	32	58.35	-109	20.96	3309.8	AZ	979202.95	979563.09	2.39	-112.89	-1.12	0.00	-48.85	-160.46	-153.36	
KGRA :	6	32	58.84	-109	21.33	3844.8	AZ	979170.84	979563.77	1.89	-131.14	-1.23	0.00	-31.32	-161.80	-153.49	
KGRA :	7	32	58.74	-109	21.82	3560.0	AZ	979192.92	979563.63	1.47	-121.42	-1.17	0.00	-35.89	-157.01	-149.30	
KGRA :	8	32	58.67	-109	22.08	3640.0	AZ	979194.09	979563.53	2.18	-124.15	-1.19	0.00	-27.10	-150.26	-142.42	
KGRA :	9	32	58.78	-109	21.61	3674.5	AZ	979183.68	979563.63	1.97	-125.33	-1.20	0.00	-34.37	-158.92	-150.99	
KGRA :	10	32	58.59	-109	21.49	3577.4	AZ	979189.21	979563.42	1.60	-122.01	-1.18	0.00	-37.76	-159.35	-151.61	
KGRA :	11	32	58.48	-109	21.52	3507.2	AZ	979193.07	979563.22	1.41	-119.62	-1.16	0.00	-39.90	-159.27	-151.67	
KGRA :	12	32	58.41	-109	21.36	3383.7	AZ	979200.11	979563.17	1.85	-115.41	-1.13	0.00	-44.83	-159.52	-152.22	
KGRA :	13	32	58.37	-109	21.20	3288.2	AZ	979205.71	979563.12	2.46	-112.15	-1.11	0.00	-48.15	-158.95	-151.90	
KGRA :	14	32	58.36	-109	21.12	3289.2	AZ	979205.36	979563.11	2.39	-112.19	-1.11	0.00	-48.39	-159.30	-152.24	
KGRA :	15	32	59.70	-109	17.29	3814.7	AZ	979159.51	979564.95	0.49	-130.11	-1.22	0.00	-46.68	-177.52	-169.19	
KGRA :	16	32	59.06	-109	17.80	3720.0	AZ	979165.52	979564.07	0.47	-126.88	-1.21	0.00	-48.68	-176.30	-168.17	
KGRA :	17	32	58.64	-109	17.89	3615.5	AZ	979173.56	979563.49	0.68	-123.31	-1.18	0.00	-49.89	-173.71	-165.83	
KGRA :	18	32	57.89	-109	18.51	3373.0	AZ	979190.12	979562.46	0.89	-115.04	-1.13	0.00	-55.11	-170.39	-163.05	
KGRA :	19	32	58.78	-109	19.88	3833.9	AZ	979166.42	979563.68	0.82	-130.76	-1.23	0.00	-36.69	-167.86	-159.51	
KGRA :	20	32	59.10	-109	20.08	3951.7	AZ	979159.50	979564.13	2.02	-134.78	-1.25	0.00	-32.98	-166.99	-158.46	
KGRA :	21	32	59.12	-109	20.38	3992.4	AZ	979157.82	979564.15	2.04	-136.17	-1.26	0.00	-30.86	-166.25	-157.63	
KGRA :	22	32	58.99	-109	20.68	3818.6	AZ	979171.07	979563.97	1.63	-130.24	-1.23	0.00	-33.77	-163.61	-155.34	
KGRA :	23	32	58.90	-109	20.99	3858.6	AZ	979168.93	979563.85	2.38	-131.61	-1.23	0.00	-32.03	-162.49	-154.18	
KGRA :	5	32	58.93	-109	21.20	3875.2	AZ	979168.54	979563.89	3.13	-132.17	-1.24	0.00	-30.90	-161.18	-152.88	
KGRA :	24	32	58.94	-109	20.37	3918.9	AZ	979162.54	979563.91	1.69	-133.66	-1.24	0.00	-32.80	-166.02	-157.54	
KGRA :	25	32	58.74	-109	20.38	3758.5	AZ	979173.34	979563.63	1.43	-126.19	-1.21	0.00	-36.80	-164.78	-156.63	
KGRA :	26	32	57.87	-109	20.48	3587.8	AZ	979183.54	979562.43	2.14	-122.37	-1.18	0.00	-41.46	-162.85	-155.12	
KGRA :	27	32	58.10	-109	20.43	3626.8	AZ	979180.54	979562.75	2.97	-123.70	-1.19	0.00	-41.11	-163.03	-155.27	
KGRA :	28	32	58.27	-109	20.68	3499.5	AZ	979190.67	979562.98	1.14	-119.36	-1.16	0.00	-43.18	-162.56	-154.96	
KGRA :	29	32	58.48	-109	20.23	3774.6	AZ	979171.14	979563.27	2.23	-128.74	-1.22	0.00	-37.14	-164.66	-156.73	
KGRA :	30	32	58.22	-109	19.72	3602.4	AZ	979180.72	979562.91	1.17	-122.87	-1.18	0.00	-43.39	-166.27	-158.45	
KGRA :	31	32	58.54	-109	19.68	3680.0	AZ	979176.70	979563.35	1.18	-125.51	-1.20	0.00	-40.55	-166.08	-158.09	
KGRA :	32	32	58.77	-109	20.53	3735.2	AZ	979175.79	979563.67	1.17	-127.40	-1.21	0.00	-36.59	-164.03	-155.91	
KGRA :	33	32	58.51	-109	20.63	3515.5	AZ	979190.01	979563.31	0.93	-119.90	-1.16	0.00	-42.67	-162.81	-155.16	
KGRA :	C1	33	4.12	-109	16.95	4532.1	AZ	979140.38	979571.03	1.18	-147.75	-1.32	0.00	-23.24	-171.13	-161.72	
KGRA :	C2	33	4.13	-109	16.44	4471.3	AZ	979119.43	979571.05	2.34	-152.50	-1.34	0.00	-31.12	-182.62	-172.98	
KGRA :	C3	33	3.79	-109	16.48	4471.3	AZ	979131.14	979570.58	2.44	-152.50	-1.34	0.00	-18.94	-170.34	-160.70	
KGRA :	C4	33	3.98	-109	16.62	4430.2	AZ	979134.04	979570.80	0.86	-151.10	-1.33	0.00	-20.17	-171.74	-162.09	
KGRA :	C5	33	3.69	-109	16.88	4421.9	AZ	979134.49	979570.44	1.89	-150.82	-1.33	0.00	-20.09	-170.35	-160.79	
KGRA :	C6	33	3.50	-109	17.10	4209.0	AZ	979149.10	979570.18	2.16	-143.56	-1.30	0.00	-25.24	-167.93	-158.65	
KGRA :	C7	33	3.30	-109	16.87	4270.0	AZ	979142.10	979569.91	1.65	-145.64	-1.31	0.00	-26.23	-171.52	-162.27	

Appendix 3.1: Principal facts of newly acquired data (continued)

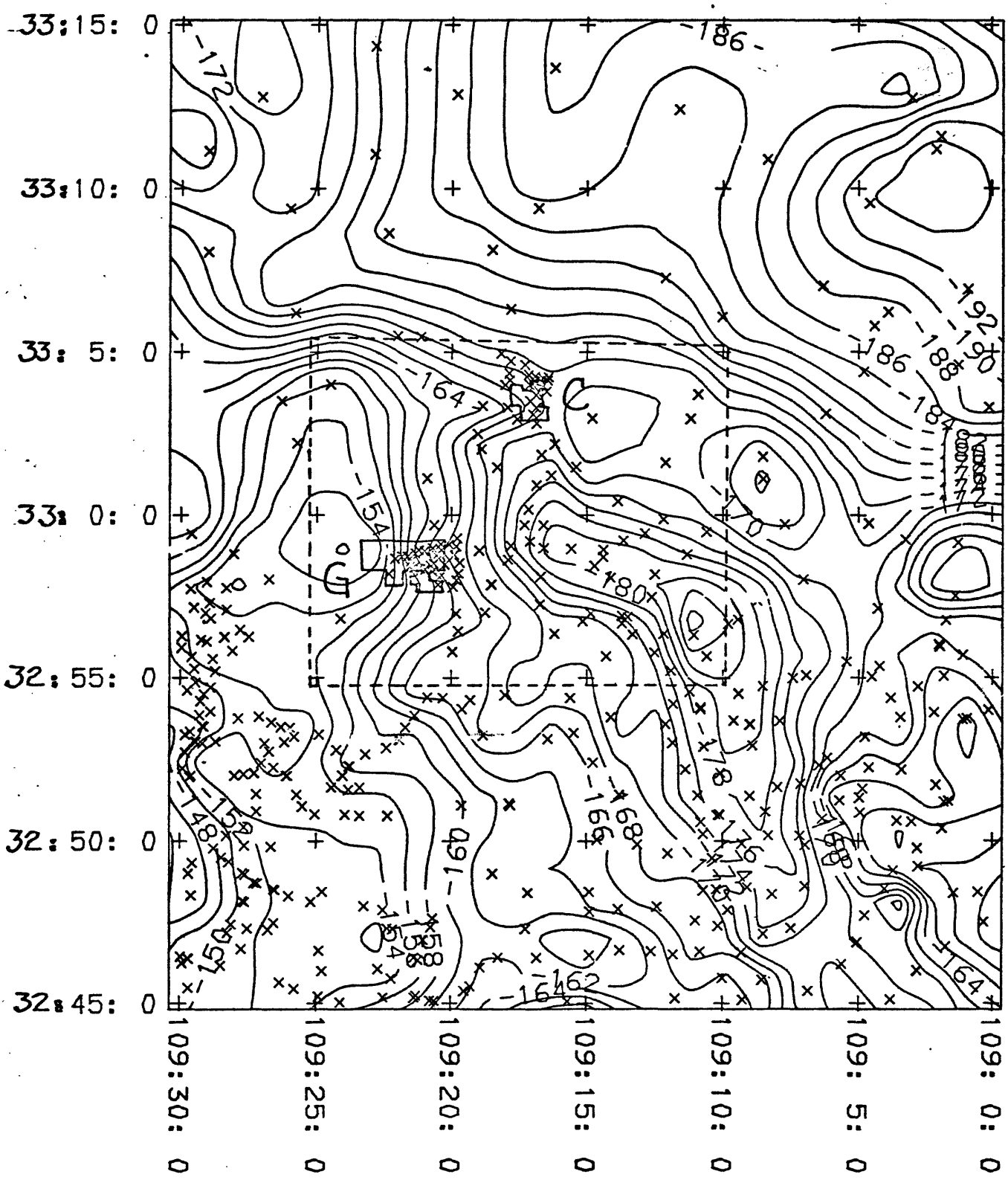
Clifton/Gillard KGRAs
Arizona gravity;April,1979
Meter ID: G-159 Date: 05/11/79

STATION IDENTIFICATION proj	sta-id	LOCATIONS LATITUDE deg	min	LONGTITUDE deg	min	ELE (in ft)	ST	GRAVITY OBSERVED	THEORETICAL	CORRECTIONS TERRAIN	BOUGUER	CURV	SPECIAL	ANOMALIES FREE AIR	COMPLETE-BOUGUER d1=2.67	d2=2.50	SPEC FIELDS
KGRA :	L8	33	3.09	-109	16.99	4330.0	AZ	979137.41	979569.62	3.56	-147.68	-1.32	0.00	-24.99	-170.43	-161.17	
KGRA :	C9	33	2.82	-109	16.85	4364.0	AZ	979135.56	979569.24	5.68	-148.84	-1.32	0.00	-23.27	-167.76	-158.56	
KGRA :	C10	33	4.20	-109	16.61	4486.2	AZ	979129.88	979571.14	1.99	-153.01	-1.34	0.00	-19.36	-171.73	-162.02	
KGRA :	C11	33	4.23	-109	16.41	4511.9	AZ	979127.96	979571.18	2.42	-153.89	-1.35	0.00	-18.91	-171.72	-161.99	
KGRA :	C12	33	4.13	-109	16.69	4337.9	AZ	979140.12	979571.05	1.98	-147.95	-1.32	0.00	-22.97	-170.27	-160.69	
KGRA :	C13	33	4.11	-109	16.90	4244.6	AZ	979146.09	979571.02	1.65	-144.77	-1.30	0.00	-25.79	-170.21	-161.02	
KGRA :	C14	33	3.99	-109	17.11	4345.2	AZ	979139.81	979570.85	2.22	-148.20	-1.32	0.00	-22.40	-169.70	-160.32	
KGRA :	C15	33	4.26	-109	16.91	4505.8	AZ	979127.59	979571.23	4.13	-153.68	-1.34	0.00	-19.89	-170.78	-161.18	
KGRA :	C16	33	4.30	-109	17.15	4381.6	AZ	979134.45	979571.28	5.05	-149.44	-1.33	0.00	-24.76	-170.50	-161.22	
KGRA :	C17	33	4.72	-109	17.81	3930.0	AZ	979165.11	979571.86	3.28	-134.04	-1.25	0.00	-37.15	-169.15	-160.75	
KGRA :	L2	33	3.99	-109	18.02	3504.0	AZ	979191.73	979570.85	2.15	-119.51	-1.16	0.00	-49.57	-168.09	-160.54	
KGRA :	L4	33	4.35	-109	17.86	3480.0	AZ	979191.91	979571.35	1.76	-118.69	-1.16	0.00	-52.14	-170.23	-162.71	
KGRA :	L5	33	4.96	-109	18.17	3503.0	AZ	979188.74	979572.19	2.53	-119.48	-1.16	0.00	-53.99	-172.10	-164.58	
KGRA :	L6	33	4.61	-109	17.28	3640.0	AZ	979181.62	979571.70	2.69	-124.15	-1.19	0.00	-47.75	-170.40	-162.59	
KGRA :	L7	33	4.14	-109	17.84	3528.0	AZ	979188.89	979571.06	2.59	-120.33	-1.17	0.00	-50.36	-169.27	-161.70	
KGRA :	L8	33	3.30	-109	17.93	3465.0	AZ	979194.16	979569.91	3.19	-118.18	-1.15	0.00	-49.86	-166.00	-158.60	
KGRA :	L9	33	3.35	-109	18.85	3552.0	AZ	979191.28	979569.97	2.90	-121.15	-1.17	0.00	-44.63	-164.05	-156.44	
KGRA :	L10	33	2.49	-109	19.02	4094.0	AZ	979154.69	979568.79	1.08	-139.63	-1.28	0.00	-29.08	-168.91	-160.00	
KGRA :	L11	33	2.02	-109	18.88	3942.0	AZ	979160.92	979568.14	1.01	-134.45	-1.25	0.00	-36.49	-171.17	-162.60	
KGRA :	L12	33	1.46	-109	18.31	3784.0	AZ	979166.66	979567.37	4.53	-129.06	-1.22	0.00	-44.83	-170.58	-162.57	
KGRA :	L13	33	2.99	-109	17.57	3600.0	AZ	979182.86	979569.41	2.25	-122.79	-1.18	0.00	-47.97	-169.69	-161.94	
KGRA :	L14	33	2.17	-109	16.17	3790.0	AZ	979166.10	979568.54	3.80	-129.27	-1.22	0.00	-45.80	-172.49	-164.42	
KGRA :	L15	33	1.47	-109	15.39	4156.5	AZ	979146.75	979567.38	3.80	-141.77	-1.29	0.00	-29.75	-169.00	-160.14	
KGRA :	L16	33	1.85	-109	16.67	4287.7	AZ	979135.34	979567.91	3.55	-146.24	-1.31	0.00	-29.33	-173.33	-164.16	
KGRA :	L17	33	1.21	-109	16.31	4249.6	AZ	979134.85	979567.02	2.83	-144.92	-1.30	0.00	-32.58	-175.97	-166.84	
KGRA :	L18	33	0.92	-109	16.85	4085.0	AZ	979144.88	979566.63	2.92	-139.33	-1.28	0.00	-37.56	-175.25	-166.48	
KGRA :	U3	32	57.02	-109	18.75	3720.0	AZ	979171.02	979561.27	2.48	-126.68	-1.21	0.00	-40.38	-165.98	-157.98	
KGRA :	U4	32	56.45	-109	19.73	4158.0	AZ	979145.53	979560.48	2.50	-141.82	-1.29	0.00	-23.91	-164.51	-155.56	
KGRA :	U5	32	55.81	-109	19.95	4352.0	AZ	979131.22	979559.60	0.96	-148.43	-1.32	0.00	-19.10	-167.89	-158.42	
KGRA :	U6	32	56.98	-109	19.82	3898.0	AZ	979163.82	979561.21	1.17	-132.95	-1.24	0.00	-30.79	-163.81	-155.34	

Appendix 3.2: Principal facts of auxiliary data in the region 32°55'-33°05'N and 109°10'-109°25'W

jeff wynn's silver city gravity data and DOD stations and private company data in the Clifton Gillard areas.
Meter ID: Date: 05/17/79

STATION IDENTIFICATION proj sta-id	LOCATIONS LATITUDE deg min	LONGITUDE deg min	ELE (in ft)	ST	GRAVITY OBSERVED	THEORETICAL	CORRECTIONS TERRAIN	BOUGUER	CURV	SPECIAL	ANOMALIES FREE AIR	COMPLETE-BOUGUER d1=2.67	d2=2.50	SPEC FIELDS
SILVER:DOD-2685	32 56.69	-109 13.69	3711.9	AZ	979165.57	979560.81	0.68	-126.60	-1.20	0.00	-46.14	-173.30	-165.21	2051
SILVER:GUI-12	32 56.83	-109 24.11	4604.0	AZ	979125.21	979561.00	3.93	-158.39	-1.36	0.00	0.94	-154.89	-144.96	0
SILVER:DOD-2700	32 56.89	-109 13.49	3600.1	AZ	979164.25	979561.09	0.55	-122.79	-1.18	0.00	-58.25	-181.67	-173.61	3097
SILVER:CLIFTON	32 57.48	-109 12.60	3795.0	AZ	979154.40	979561.90	0.55	-129.44	-1.22	0.00	-50.58	-180.69	-172.41	0
SILVER:GUI-7	32 57.80	-109 19.93	3360.0	AZ	979196.25	979562.34	2.01	-114.60	-1.13	0.00	-50.07	-163.79	-156.55	0
SILVER:GUI-5	32 59.20	-109 17.10	3816.0	AZ	979159.39	979564.26	0.51	-130.15	-1.22	0.00	-45.98	-176.85	-168.52	0
SILVER:DOD-2765	33 0.42	-109 13.84	4058.1	AZ	979148.12	979565.94	0.49	-138.41	-1.27	0.00	-36.18	-175.36	-166.50	3277
SILVER:DOD-2775	33 1.11	-109 20.86	3901.9	AZ	979169.37	979566.89	0.79	-133.08	-1.24	0.00	-30.56	-164.09	-155.59	3277
SILVER:DOD-2787	33 1.59	-109 12.09	4448.2	AZ	979130.68	979567.55	0.67	-151.71	-1.34	0.00	-18.55	-170.93	-161.22	3097
SILVER:DOD-2807	33 2.94	-109 14.80	4480.0	AZ	979133.70	979569.41	0.81	-152.80	-1.34	0.00	-14.39	-167.72	-157.96	3277
SILVER:GUI-25	32 56.37	-109 16.17	4495.0	AZ	979113.46	979560.37	8.38	-153.31	-1.34	0.00	-24.18	-170.46	-161.14	0
SILVER:GUI-40	32 56.75	-109 15.15	3414.0	AZ	979185.12	979560.89	1.32	-116.44	-1.14	0.00	-54.68	-170.95	-163.55	0
SILVER:YRK-30	32 56.92	-109 13.70	3635.0	AZ	979166.68	979561.13	0.51	-123.98	-1.19	0.00	-52.58	-177.23	-169.30	0
SILVER:YRK-31	32 58.19	-109 12.48	3815.0	AZ	979152.72	979562.88	0.51	-130.12	-1.22	0.00	-51.36	-182.19	-173.86	0
SILVER:GUI-23	32 58.20	-109 22.32	4569.0	AZ	979140.28	979562.88	7.75	-149.01	-1.32	0.00	-11.72	-154.31	-145.23	0
SILVER:YRK-29	32 58.45	-109 14.71	3710.0	AZ	979159.87	979563.23	0.52	-126.54	-1.20	0.00	-54.44	-181.66	-173.56	0
SILVER:YRK-20	32 59.88	-109 12.17	4058.0	AZ	979148.21	979565.20	0.61	-138.41	-1.27	0.00	-35.34	-174.41	-165.56	0
SILVER:COM-1804	32 55.68	-109 14.28	3720.0	AZ	979165.67	979559.42	0.59	-126.88	-1.21	0.00	-43.89	-171.58	-163.26	8
SILVER:COM-1815	32 55.79	-109 12.49	3500.0	AZ	979175.96	979559.56	0.96	-119.37	-1.16	0.00	-54.42	-174.00	-166.38	8
SILVER:COM-1810	32 56.35	-109 13.31	3500.0	AZ	979176.66	979560.34	0.94	-119.37	-1.16	0.00	-54.50	-174.10	-166.48	8
SILVER:COM-1814	32 56.37	-109 12.15	3579.9	AZ	979168.74	979560.37	0.69	-122.10	-1.18	0.00	-54.93	-177.52	-169.72	8
SILVER:COM-1803	32 56.99	-109 14.85	3600.0	AZ	979172.32	979561.22	0.63	-122.79	-1.18	0.00	-50.32	-173.66	-165.81	8
SILVER:COM-1754	32 57.27	-109 16.73	3600.0	AZ	979170.57	979561.61	0.71	-122.79	-1.18	0.00	-48.46	-171.72	-163.87	8
SILVER:COM-1746	32 58.00	-109 19.80	3535.0	AZ	979184.06	979562.61	0.84	-120.57	-1.17	0.00	-46.06	-166.98	-159.28	8
SILVER:COM-1802	32 58.09	-109 14.11	3700.0	AZ	979158.95	979562.73	0.51	-126.20	-1.20	0.00	-55.80	-182.69	-174.61	8
SILVER:COM-1757	32 58.13	-109 16.68	3680.0	AZ	979165.54	979562.79	0.50	-125.51	-1.20	0.00	-51.15	-177.36	-169.33	8
SILVER:COM-1745	32 58.45	-109 20.74	3470.0	AZ	979193.03	979563.23	1.18	-118.35	-1.15	0.00	-43.84	-162.17	-154.63	8
SILVER:COM-1763	32 58.72	-109 14.36	3650.0	AZ	979151.53	979563.60	0.51	-131.31	-1.23	0.00	-49.99	-182.02	-173.61	8
SILVER:COM-1626	32 58.92	-109 18.96	3579.9	AZ	979180.51	979563.88	0.64	-122.10	-1.18	0.00	-46.67	-169.31	-161.50	8
SILVER:COM-1801	32 58.95	-109 14.38	3785.0	AZ	979154.65	979563.91	0.47	-129.10	-1.22	0.00	-53.30	-183.14	-174.87	8
SILVER:COM-1759	32 58.98	-109 15.57	3740.0	AZ	979159.33	979563.96	0.47	-127.56	-1.21	0.00	-52.89	-181.19	-173.02	8
SILVER:COM-1756	32 59.00	-109 16.58	3780.0	AZ	979156.68	979563.98	0.43	-128.92	-1.22	0.00	-51.81	-181.52	-173.26	8
SILVER:COM-1747	32 59.04	-109 19.81	3820.0	AZ	979166.92	979564.04	0.60	-130.29	-1.23	0.00	-37.85	-168.77	-160.43	8
SILVER:COM-1808	32 59.23	-109 13.65	3935.0	AZ	979149.34	979564.30	0.59	-134.21	-1.25	0.00	-44.88	-179.75	-171.16	8
SILVER:COM-1811	32 59.45	-109 12.85	4020.0	AZ	979148.89	979564.60	0.58	-137.11	-1.26	0.00	-41.65	-179.44	-170.67	8
SILVER:COM-1743	32 59.70	-109 20.62	3340.0	AZ	979201.80	979564.95	2.40	-113.92	-1.12	0.00	-49.02	-161.66	-154.49	8
SILVER:COM-1757	32 59.70	-109 16.59	3781.0	AZ	979158.94	979564.95	0.52	-128.96	-1.22	0.00	-50.41	-180.07	-171.82	8
SILVER:COM-1800	32 59.93	-109 14.60	3960.0	AZ	979151.71	979565.27	0.45	-135.06	-1.25	0.00	-41.13	-177.00	-168.35	8



Regional complete Bouguer anomaly contour map, reduction density = 2.67 g/cm^3. Contour interval, 2 mgals. C, Clifton KGRA; G, Gillard KGRA; X, gravity station. The boxed area is presented in Fig. 2 of the text as a residual bouguer map.