NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY

A GRAVITY SURVEY OF THE RIO GRANDE VALLEY NEAR SOCORRO, NEW MEXICO

BY

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ACKNOWLEDGMENT

The work described in this paper was done under the direction of Dr. Marvin H. Wilkening of the New Mexico Institute of Mining and Technology. I am indebted to many members of the various departments and divisions of the New Mexico Institute of Mining and Technology for helpful information and suggestions concerning this problem. Special thanks are due to Mr. Hartmut Winkler, who made the facilities of the Geophysical Laboratory of the Research and Development Division available to me, and who made many valuable sugges- tions throughout the course of this work. Mr. Howard Sylvester, of the Humanities Department, reviewed the paper during its preparation and suggested many corrections to its form. Mr. Roger Torres, of the Geophysical Laboratory, helped make the elevation and location surveys, and did considerably more service than his job required. My wife helped me in the field on several occasions, and did all the typing.

ABSTRACT

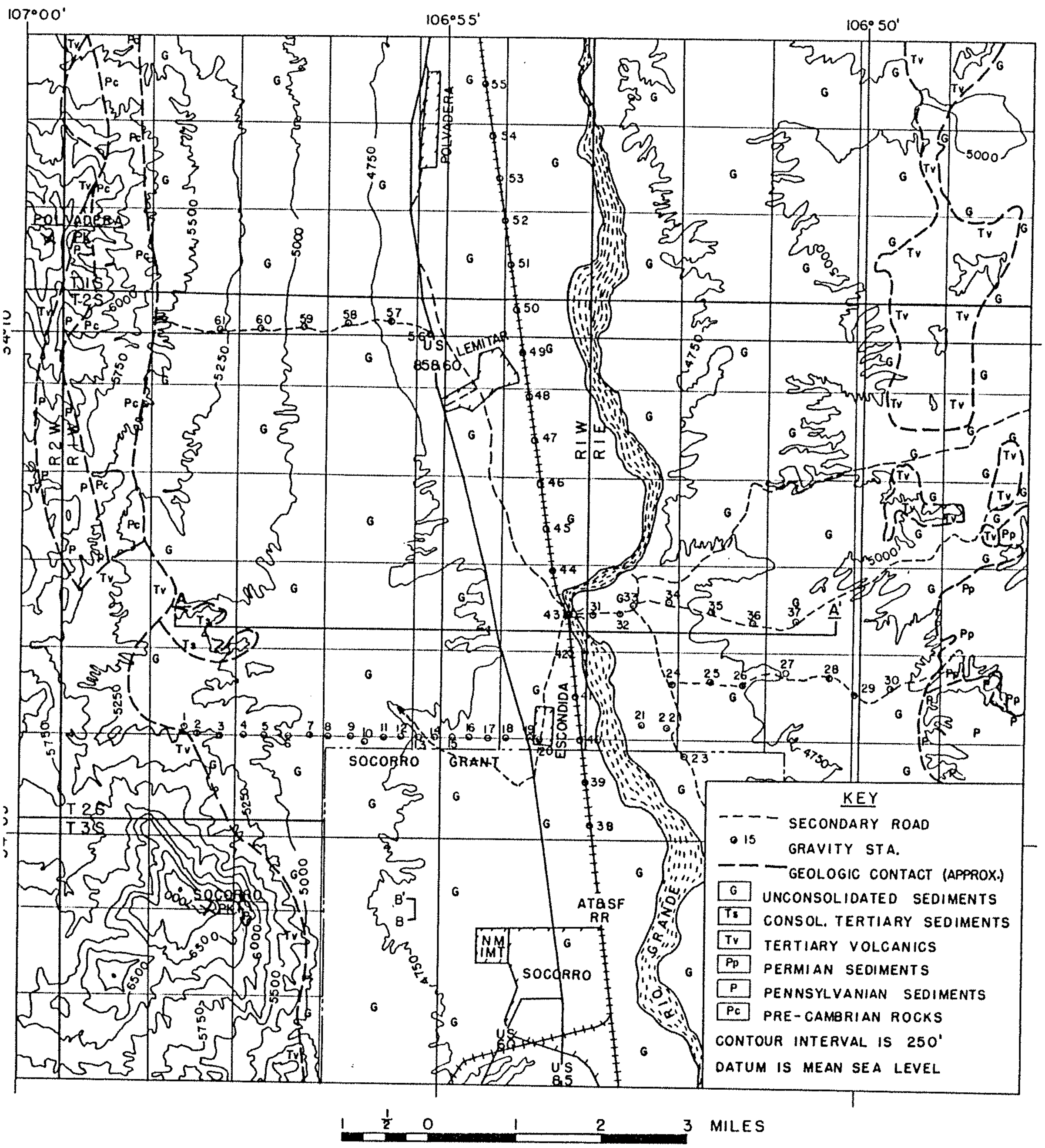
A gravity survey involving 61 stations was made in the vicinity of Socorro, New Mexico. The anomaly obtained was such that a two dimensional type of analysis could be used to determine the form of the Rio Grande trough in this area. One problem considered was that of determining a suitable datum for use in calculating the forms of anomaly-producing structures which closely approach or cut the surface along which the gravity values were obtained. Analysis of the data was based on two assumptions: (1) that the Tertiary rocks were, principally, unconsolidated sediments with exception of intrusives and (2) that the Tertiary rocks were, principally, consolidated sediments and volcanics. The two analyses gave limiting values of 2100 feet and 5800 feet, respectively, for the greatest thickness of Tertiary rocks.

A GRAVITY SURVEY OF THE RIO GRANDE VALLEY NEAR SOCORRO, NEW MEXICO

INTRODUCTION

In the early 18th century, Bouguer and others used pendulums to study the variation of gravity over the earth's surface. However, it was not until 1916 that the gravity methods were used for prospecting. At that time, the Eötvös torsion balance was used to make a very successful survey of the Egbell oil field in Czechoslovakia. In 1922, the first torsion balances were introduced into the United States, and were used extensively, following the discovery of the Nash salt dome in Texas in 1924. Pendulum equipment was also used, to a limited extent, in the succeeding years. The development of the gravimeter, in the early 1930's, brought about a renewed interest in gravity prospecting. A gravimeter party could survey many times more rapidly than a torsion balance party, although the information on the horizontal gradients of gravity had to be sacrificed. The survey described in this paper was made with an astatic type gravimeter.

The usual gravity survey, in search of prospective petroleum bearing structures, ordinarily is made in an area of moderate topographic relief, and the structures sought are generally very deep compared to their vertical extent. In contrast, the survey described in this paper was made in the Rio Grande Valley (Fig. 1), where the topography is quite rugged along the edges. More important, the anomaly-producing structure is a large trough, one edge of which outcrops in the surveyed area. Such a structure has rarely been surveyed by the gravity method, and introduces a rather unique problem of determining a suitable reference datum from which the anomaly-producing structure may be calculated. The survey described in this paper had, for its objective, the determination of the general shape of the Rio Grande trough in this area, and the determination of limiting values for the thickness of the Tertiary rocks.



Base map is USGS Socorro Quadrangle Sheet
Edition of Sept. 1906

Geology east of the Rio Grande is from USGS "Oil and Gas Investigations Map OM 121" entitled "Geology of the Region From Socorro and San Antonio East to Chupadera Mesa, Socorro County, New Mexico" by R.H.Wilpolt and A.A.Wanek

Geology west of the Rio Grande is from an unpublished thesis by John F. Waldron and from field observation.

MAP SHOWING LOCATION OF GRAVITY STATIONS AND SECTIONS

AND GENERALIZED GEOLOGY NEAR SOCORRO, NEW MEXICO

FIG. 1

GEOLOGY AND DENSITY RELATIONS

The Rio Grande trough, in this region, is a large graben structure. On the east side of the river, the Permian Abo and Yeso formations, Pennsylvanian limestones, and Tertiary volcanics comprise the solid outcrops as shown in Fig. 1. West of the river there are considerable quantities of Pennsylvanian limestones and Pre-Cambrian rocks exposed in and near Polvadera Mountain, where they are not covered by Tertiary volcanics. The general structure is apparently a trough, highly faulted along the edges, composed of Pre-Cambrian and Paleozoic rocks filled in partly with Tertiary volcanics and arid lake sediments but primarily with Tertiary gravels and some Quaternary alluvium in the arroyos and Rio Grande channel.

The property of the rocks of particular interest in a gravity survey is, of course, density. Table 1 is a tabulation of density samples taken in this area. This tabulation includes only consolidated rocks. The values of density for the Pennsylvanian and Permian rocks fall within a quite narrow range, so their averages were considered reliable. The Pre-Cambrian rocks show a rather wide range of density, but the average value of 2.7 g/cc is probably accurate

Table 1. Tabulation of Density Samples of Consolidated Rocks

Geologic Age	Rock Type	Sample No.	Density (g/cc)	Estimated per cent of Exposed Rock of Same Geologic Period in Vicinity Similar to Sample	Average or Weighted Average Density (g/cc)
Tertiary	Vesicular Basalt	1	2.55	60%	2.4
	"	32	2.30		
	"	33	2.44		
	"	34	2.54		
	Rhyolite	5	2.38	20%	
	"	6	2.47		
	Tuff	2	2.34	10%	
	"	3	2.05		
	"	4	2.05		
	Siltstone	35	2.35	10%	
	"	36	2.42		
	"	37	2.39		
	Conglomerate	19	2.42		
	Sandstone	20	2.04		
Permian	San Andres Limestone	7	2.56		2.6
	"	8	2.71		
	"	9	2.53		
	"	10	2.60		
	Yeso Formation	15	2.51		
	"	16	2.52		
	"	17	2.56		
	"	18	2.56		
	Abo Formation	11	2.66		
	"	12	2.63		
	"	13	2.63		
	"	14	2.70		

Table 1- cont. Tabulation of Density Samples of Consolidated Rocks

Geologic Age	Rock Type	Sample No.	Density (g/cc)	Estimated per cent of Exposed Rock of Same Geologic Period in Vicinity Similar to Sample	Average or Weighted Average Density (g/cc)
Pre-Cambrian	Granite	22	2.48	50%	
"		23	2.92	20%	
"		24	3.05	neg.	2.7
"	Granite	26	2.70	10%	
"		29	2.91	20%	
Pennsylvanian	Limestone	27	2.69		
	"	28	2.70		
	"	30	2.70		2.7
	"	31	2.70		

to ± 0.1 g/cc. Only the limiting values of density can be derived from the data on the Tertiary rocks. It should also be noted that the density values for basalt are much lower than normal owing to the vesicular character of the samples. If thick flows are present in the valley fill, the density of the constituent basalt may very well reach 3.0 g/cc.

A very critical problem in this kind of survey is the determination of a good average value for the density of the gravels. Physical sampling, unless done on a tremendous scale, can not be expected to give satisfactory results. Therefore, a method suggested by Nettleton[1] was used. A gravity survey was made across an arroyo which was considered free from local anomaly. See section B-B', Fig. 1. Section B-B' was selected because it is approximately perpendicular to the major east-west regional gravity gradient and because it is far from any known volcanics. Fig. 2-A shows the topography and the gravity values after all corrections except the elevation correction were made. Note that the gravity values mirror the topography, since the value of gravity increases with a decrease in elevation. In Fig. 2-B the results of correcting the gravity values for various assumed values of gravel density are shown. Ideally, after correcting the gravity data with the elevation correction for the proper density, we should have a straight line or smooth curve, representing the regional gradient of gravity along the survey

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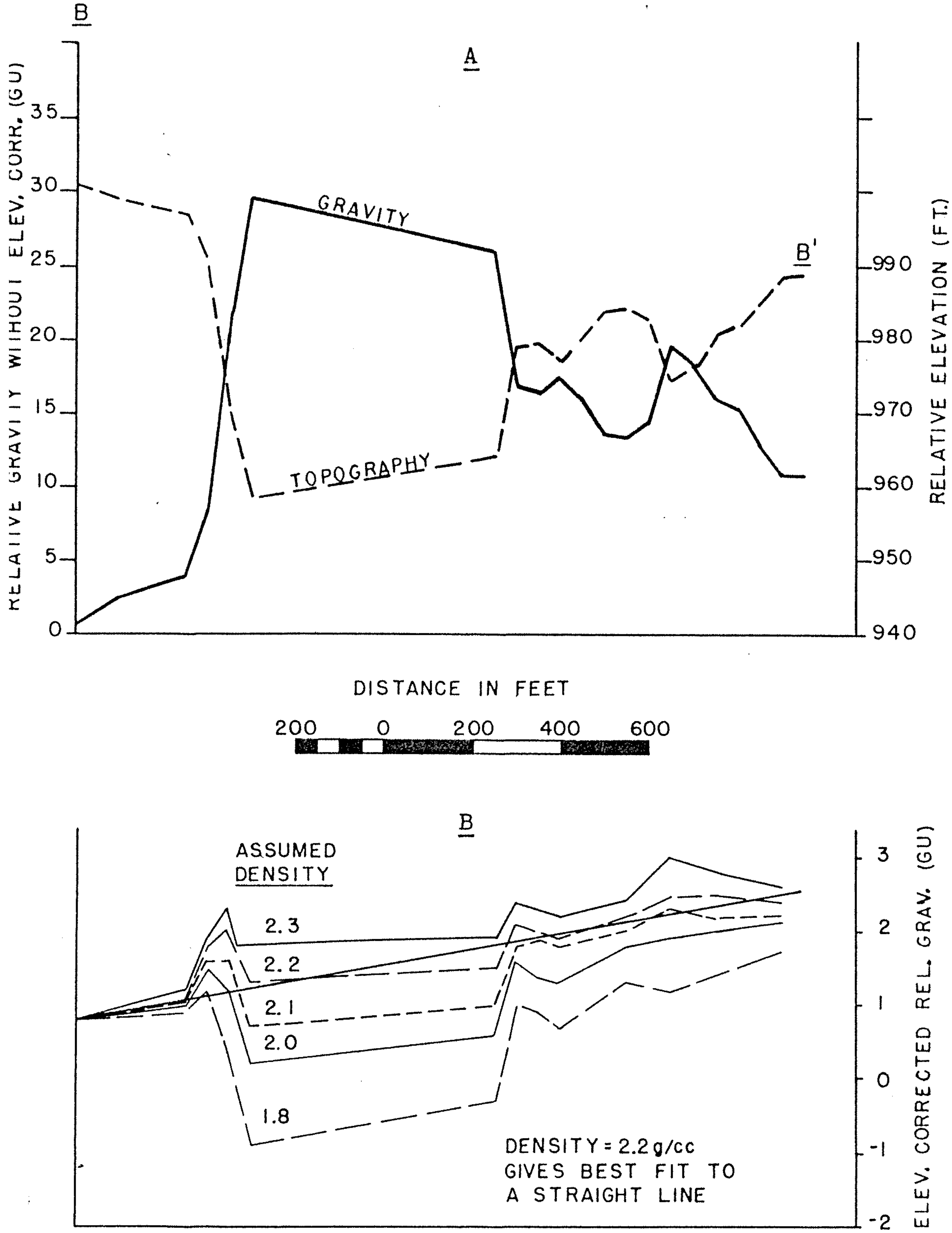
[1]Nettleton, L. L., Geophysical Prospecting for Oil, 1st ed. (New York, 1940), pp. 57-58.



NETTLETON'S METHOD TO DETERMINE DENSITY
OF NEAR SURFACE SEDIMENTS

A Topography and Gravity Without Elevation Correction
B Corrected Gravity for Various Assumed Values of Surface Sediment Density

FIG. 2

line. Our example is, unfortunately, not ideal since we have an obvious anomalous low in the valley; nevertheless, the gravity versus distance curve for a value of density = 2.2 g/cc clearly gives the best approximation to a straight line.

As another check on the reasonableness of the value of density for the gravels obtained by Nettleton's method, we have Fig. 3 which is a plot of bulk density of unconsolidated sediments versus pore space. It was assumed that the mean density of the rocks from which the gravels were derived is 2.6 g/cc. Actual sampling of the top foot of the gravels in the valley gave porosities of about 35% and dry bulk densities of 1.6 g/cc to 1.7 g/cc which check well with the assumed values in Fig. 3. The limiting values for porosity of the gravels in Fig. 3 were obtained from Jakosky[2]. In this part of the valley, the water table in the gravels is nearly everywhere within 200 feet of the surface and generally much closer. Therefore, the water saturated condition should give the most reasonable results. From Fig. 3, it is seen that the most probable value for the density of the gravels lies between 2.0 g/cc and 2.5 g/cc. The figure, of 2.2 g/cc obtained above, lies well within this range.

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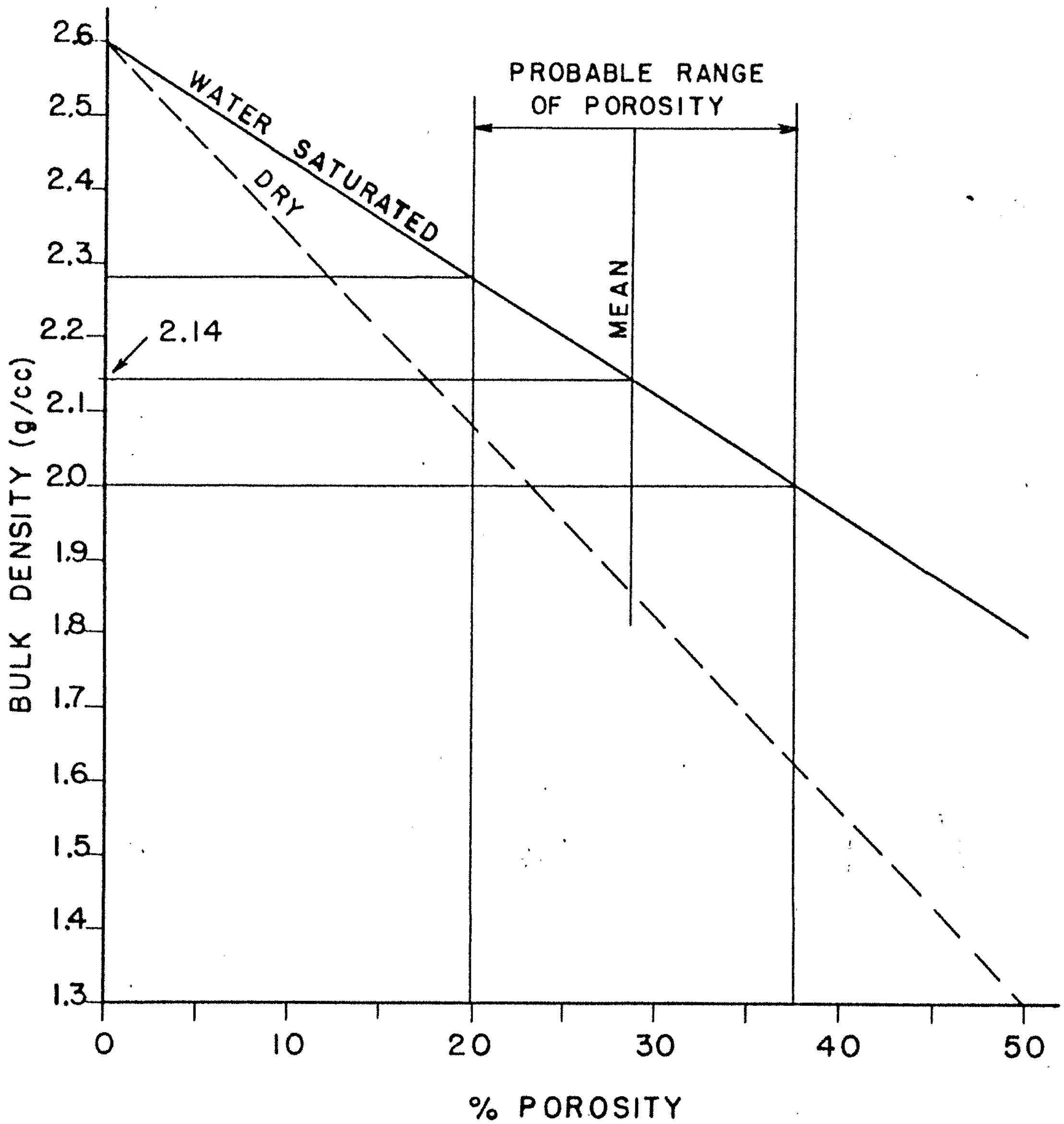
[2] Jakosky, J. J., Exploration Geophysics, 2nd ed., (Los Angeles, 1950) p. 206.



PLOT OF BULK DENSITY vs. POROSITY FOR SEDIMENTS WHICH ARE ASSUMED TO BE DERIVED FROM ROCKS OF AVERAGE DENSITY 2.6 g/cc

FIG. 3

GRAVITY SURVEY

All gravity readings were made with Worden gravimeter No. 111 which is the property of the New Mexico Institute of Mining and Technology. The quantity measured is the relative value of the vertical component of the force of gravity compared to its value at some designated base station. The scale constant of the meter is 0.0876 milligals/scale division, and a vernier permits readings to 0.1 scale division. The quantity used in all computations was the gravity unit (GU) = 0.1 milligal. The instrument was set at a sensitivity such that one could easily read to ± 0.5 scale divisions, giving an instrument reading error of ± 0.44 GU for any observation.

Aerial photos were used to locate the gravity stations, from which they were transferred to the United States Geological Survey Socorro Quadrangle Sheet (scale 1:62,500) with an estimated precision of ± 100 feet. Since the latitude correction to gravity in this area is 12.80 GU/mile, this introduces an estimated error of ± 0.24 GU in this correction. The elevation survey was made with a transit and stadia board. Elevations were carried to 0.1 foot, and the error for any one station probably does not exceed ± 0.5 foot. Based on an assumed density of valley fill of 2.1 g/cc, this would introduce an estimated error in the elevation correction of ± 0.34 GU.

Table 2 shows a tabulation of the gravity data for all stations and the computed corrections. The instrument drift was very regular, and the instrument was returned to the base station at least once every 70 minutes during the course of all surveys. The estimated error in the drift correction is ± 0.2 GU. Hammer's[3] charts and tables were used to compute terrain corrections to an estimated accuracy of ± 0.5 GU. Fig. 10, in the appendix, shows contours of the terrain corrections due to features more than 5018 feet from the station.

A factor which is difficult to evaluate is the error introduced by assuming an incorrect density for the Bouguer correction. Fortunately, each 0.1 g/cc error in estimating the Bouguer correction density leads to only 1.27 GU error for a 100 foot elevation correction. A value of 2.1 g/cc was used in making all elevation corrections.

From the above estimates of the errors of the individual factors which led to a final corrected value of gravity for each station, the estimated error of the corrected value of gravity was computed by taking the square root of the sum of the squares of the individual estimated errors[4]. Neglecting

[3]Hammer, Sigmund, "Terrain Corrections for Gravimeter Stations," *Geophysics*, Vol. IV (1939), pp. 184-194.

[4]Worthing, Archie G. and Joseph Geffner, *Treatment of Experimental Data*, 1st ed., (New York, 1943), pp. 206-207.

Table 2. Tabulation of Socorro Gravity Data and Applied Corrections

(All Gravity Values in GU = 0.1 milligal)

Map Sta. No.	Notes Sta. No.	Drift and Latitude Corrected Gravity	Terrain Corrections to 5018'	Terrain Corrections 5018'–71,996'	Elev. Feet Above MSL	Elev. Diff. From Sta. 2	Elev. Corr. Sta. 2 Datum Corr. Den.=2.1 K = 0.673	Bouguer Gravity
1	19W	183.4	+ 6.2	+ 10.6	5180.5	- 93.6	- 63.0	+ 137.2
2	18W	115.5	+ 6.4	+ 10.4	5274.1	0	0	+ 132.3
3	17WA	145.4	+ 3.8	+ 10.0	5226.2	- 47.9	- 32.2	+ 127.0
4	16WA	249.5	+ 1.9	+ 9.4	5067.8	-206.3	- 138.8	+ 122.0
5	15WA	257.5	+ 1.3	+ 8.8	5034.5	-239.6	- 161.3	+ 106.3
6	14WA	276.0	+ 0.9	+ 7.8	4990.0	-284.1	- 191.2	+ 93.5
7	13WA	284.0	+ 0.6	+ 7.1	4961.6	-312.5	- 210.3	+ 81.4
8	12WA	278.4	+ 0.7	+ 6.6	4950.3	-323.8	- 217.9	+ 67.8
9	11WB	259.5	+ 2.4	+ 6.3	4949.6	-324.5	- 218.4	+ 50.3
10	10WA	295.2	+ 2.4	+ 6.2	4882.4	-391.7	- 263.6	+ 40.2
11	9W	351.9	+ 0.8	+ 6.1	4781.5	-492.6	- 331.5	+ 27.3
12	8W	362.4	+ 0.3	+ 6.0	4757.8	-516.3	- 347.5	+ 21.2
13	7W	368.8	+ 0.2	+ 5.8	4747.7	-526.4	- 354.3	+ 20.5
14	6W	394.0	+ 0.4	+ 5.5	4710.1	-564.0	- 379.6	+ 20.3
15	5W	402.1	+ 0.6	+ 5.1	4700.9	-573.2	- 385.8	+ 22.0
16	4W	416.1	+ 0.5	+ 5.0	4686.1	-588.0	- 395.7	+ 25.9
17	3W	429.6	+ 0.4	+ 4.7	4674.4	-599.7	- 403.6	+ 31.1
18	2W	447.8	+ 0.2	+ 4.4	4658.2	-615.9	- 414.5	+ 37.9
19	1WA	473.4	+ 0.1	+ 4.4	4636.7	-637.4	- 429.0	+ 48.9
20	0	482.7	0	+ 4.3	4631.5	-642.6	- 432.5	+ 54.5
21	1E	544.1	0	+ 3.6	4609.1	-665.0	- 447.5	+ 100.2
22	2EA	551.9	+ 0.1	+ 3.3	4607.7	-666.4	- 448.5	+ 106.8
23	L-8	528.0	+ 0.2	+ 3.2	4629.1	-645.0	- 434.1	+ 102.5
24	3E	558.6	+ 0.4	+ 3.0	4613.2	-660.9	- 444.8	+ 117.2
25	4E	514.1	+ 0.5	+ 2.5	4669.4	-604.7	- 407.0	+ 110.1
26	5EA	481.7	+ 0.6	+ 2.3	4714.2	-559.9	- 376.8	+ 107.8
27	6EA	458.2	+ 1.0	+ 2.3	4759.7	-514.4	- 346.2	+ 115.3

Table 2.- cont. Tabulation of Socorro Gravity Data and Applied Corrections

(All Gravity Values in GU = 0.1 milligal)

Map Sta. No.	Notes Sta. No.	Drift and Latitude Corrected Gravity	Terrain Corrections to 5018'	Terrain Corrections 5018'-71,996'	Elev. Feet Above MSL	Elev. Diff. From Sta. 2	Elev. Corr. Sta. 2 Datum Corr. Den. = 2.1 K = 0.673	Bouguer Gravity
28	7E	439.3	+ 1.9	+ 2.6	4811.8	-462.3	- 311.1	+ 132.7
29	8E	343.0	+ 0.6	+ 2.6	4952.7	-321.4	- 216.3	+ 130.1
30	9E	317.3	+ 0.9	+ 2.3	5008.0	-266.1	- 179.1	+ 142.1
31	L-1	532.3	0	+ 3.8	4611.6	-662.5	- 445.9	+ 90.2
32	L-2	552.0	+ 0.1	+ 3.8	4611.1	-663.0	- 446.2	+ 109.7
33	L-3	544.6	+ 0.2	+ 3.6	4635.0	-639.1	- 430.1	+ 118.3
34	L-4	485.8	+ 0.6	+ 3.3	4728.8	-545.3	- 367.0	+ 122.7
35	L-5	440.1	+ 0.3	+ 3.1	4785.6	-488.5	- 328.8	+ 114.7
36	L-6	425.6	+ 0.8	+ 2.8	4803.3	-470.8	- 316.8	+ 112.4
37	L-7	397.6	+ 0.3	+ 2.6	4867.5	-406.6	- 273.6	+ 127.9
38	976	508.6	0	+ 3.5	4601.9	-672.2	- 452.4	+ 59.7
39	975½	513.6	0	+ 3.6	4603.8	-670.3	- 451.1	+ 66.1
40	975	518.8	0	+ 3.7	4605.8	-668.3	- 449.8	+ 72.7
41	974.52	521.4	0	+ 3.9	4608.0	-666.1	- 448.3	+ 77.0
42	974	517.4	+ 0.2	+ 3.8	4610.4	-663.7	- 446.7	+ 74.7
43	973 +2839	509.1	+ 0.5	+ 3.9	4615.7	-658.4	- 443.1	+ 70.4
44	973	490.6	+ 0.1	+ 3.9	4621.2	-652.9	- 439.4	+ 55.2
45	972.57	475.0	0	+ 3.9	4629.7	-644.4	- 433.7	+ 45.2
46	972	466.0	0	+ 3.9	4626.9	-647.2	- 435.6	+ 34.3
47	971.51	455.0	0	+ 3.9	4628.7	-645.4	- 434.4	+ 24.5
48	971	449.0	0	+ 3.8	4627.3	-646.8	- 435.3	+ 17.5
49	970½	442.1	0	+ 3.8	4629.0	-645.1	- 434.2	+ 11.7
50	970	437.2	0	+ 3.7	4631.2	-642.9	- 432.7	+ 8.2
51	969½	436.2	0	+ 3.7	4633.5	-640.6	- 431.1	+ 8.8
52	969	435.7	0	+ 3.7	4636.4	-637.7	- 429.2	+ 10.2
53	968½	437.5	0	+ 3.8	4640.3	-633.8	- 426.5	+ 14.8

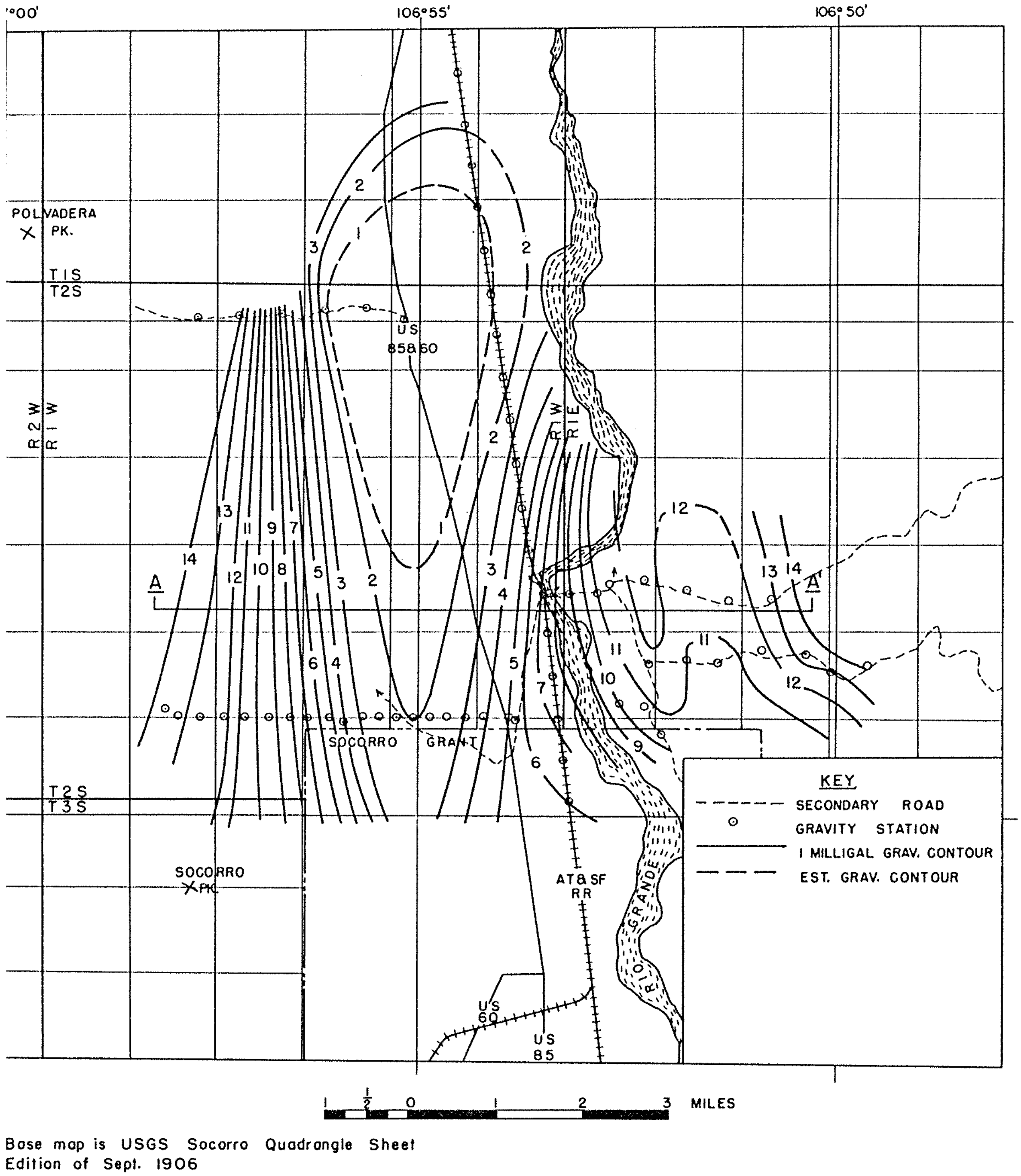
Table 2.- cont. Tabulation of Socorro Gravity Data and Applied Corrections

(All Gravity Values in GU = 0.1 milligal)

Map Sta. No.	Notes Sta. No.	Drift and Latitude Corrected Gravity	Terrain Corrections to 5018'	Terrain Corrections 5018' 71,996'	Elev. Feet Above MSL	Elev. Diff. From Sta. 2	Elev. Corr. Sta. 2 Datum Corr. Den.=2.1 K = 0.673	Bouguer Gravity
54	968	443.2	0	+ 3.7	4641.5	-632.6	- 425.7	+ 21.2
55	976½	452.2	0	+ 3.6	4646.6	-627.5	- 422.3	+ 33.5
56	L-9	376.2	+ 0.2	+ 4.3	4681.1	-593.0	- 399.1	- 18.4
57	L-10	347.0	+ 0.3	+ 5.1	4734.2	-539.9	- 363.4	- 11.0
58	L-11	314.3	+ 0.7	+ 6.0	4813.5	-460.6	- 310.0	+ 11.0
59	L-12	280.1	+ 1.2	+ 6.8	4943.6	-330.5	- 222.4	+ 65.7
60	L-13	252.7	+ 1.6	+ 7.7	5106.0	-168.1	- 113.1	+ 148.9
61	L-14	213.2	+ 1.9	+ 8.5	5273.1	- 1.0	- 0.7	+ 202.1

the error resulting from a poor assumption of Bouguer correction density, this value was found to be ± 0.81 GU. This is certainly negligible, since the interpretation methods are incapable of defining the anomaly-producing structure to this degree of accuracy.

Fig. 4 shows the anomalous gravity contours at 1 milligal (10 GU) intervals. The individual gravity stations are also shown, and provide an indication of the reliability of the contours. The striking feature of the anomaly is its very pronounced two dimensionality which permits analysis with standard two dimensional charts. It is not possible to say, on the basis of present evidence, whether the closed gravity low is a result of an actual depression in the top of the bedrock surface or whether it is a result of a very large area of light sediments in the Tertiary fill or, possibly, whether it reflects a relative thickening of the Permian sediments at the expense of the heavier Pennsylvanian sediments in the bedrock.



MAP OF ANOMALOUS GRAVITY NEAR SOCORRO, NEW MEXICO

(Contour Interval is 1 milligal)

FIG. 4

ANALYSIS OF DATA

Since the gravity anomaly, as shown in Fig. 4, is very much longer in the north-south direction than in the east-west direction, the analysis was made by making a cross-section of the anomalous gravity along section A-A' and then calculating the cross-section of an infinite north-south trough which could produce this anomaly. As a first approximation to the actual shape of the cross-section of the trough, an elliptical form was calculated which would produce an anomaly approximating the observed Bouguer anomaly along section A-A'. Based on a comparison of the anomaly from the elliptical section with the observed anomaly, modifications were made to the elliptical section to produce a section with a gravity anomaly more nearly approximating the observed Bouguer anomaly. The following paragraphs describe the process of analysis in greater detail.

Prior to analysing the gravity data, it was necessary to determine the nature of the anomaly-producing structure and the densities of the component rocks. The anomaly-producing structure was assumed to be a trough composed of pre-Tertiary rocks filled in with lighter Tertiary sediments and volcanics. For the following analysis, a density of 2.7 g/cc was assigned to all the pre-Tertiary rocks which include the Pre-Cambrian, Pennsylvanian and Permian. From Table 1 it can be seen that the weighted average of the densities of the Pre-Cambrian and Pennsylvanian rocks is 2.7 g/cc; and for the Permian rocks, 2.6 g/cc. However, surface geologic evidence indicates the Permian sediments are very thin along or absent from section A-A'. The value of density which should be assigned to the Tertiary rocks is dependent on whether the Tertiary fill is primarily volcanics and consolidated sediments, or primarily unconsolidated sediments. Since, at present, the actual situation is unknown, two interpretations were made. For the first interpretation it was assumed that most of the fill is unconsolidated material of average effective density of 2.1 g/cc. From this density contrast between Tertiary and pre-Tertiary rocks of 0.6 g/cc, a minimum section was obtained. For the second interpretation, most of the fill was assumed to be consolidated sediments or volcanics of average effective density of 2.4 g/cc, giving a density contrast of 0.3 g/cc from which a maximum section was obtained. These assumptions span the probable cases indicated by present evidence. These interpretations must be qualified by the knowledge, from seismic work by the New Mexico Institute of Mining and Technology Geophysical Laboratory, that the unconsolidated sediments are known to be more than 600 feet thick under the Rio Grande in this area.

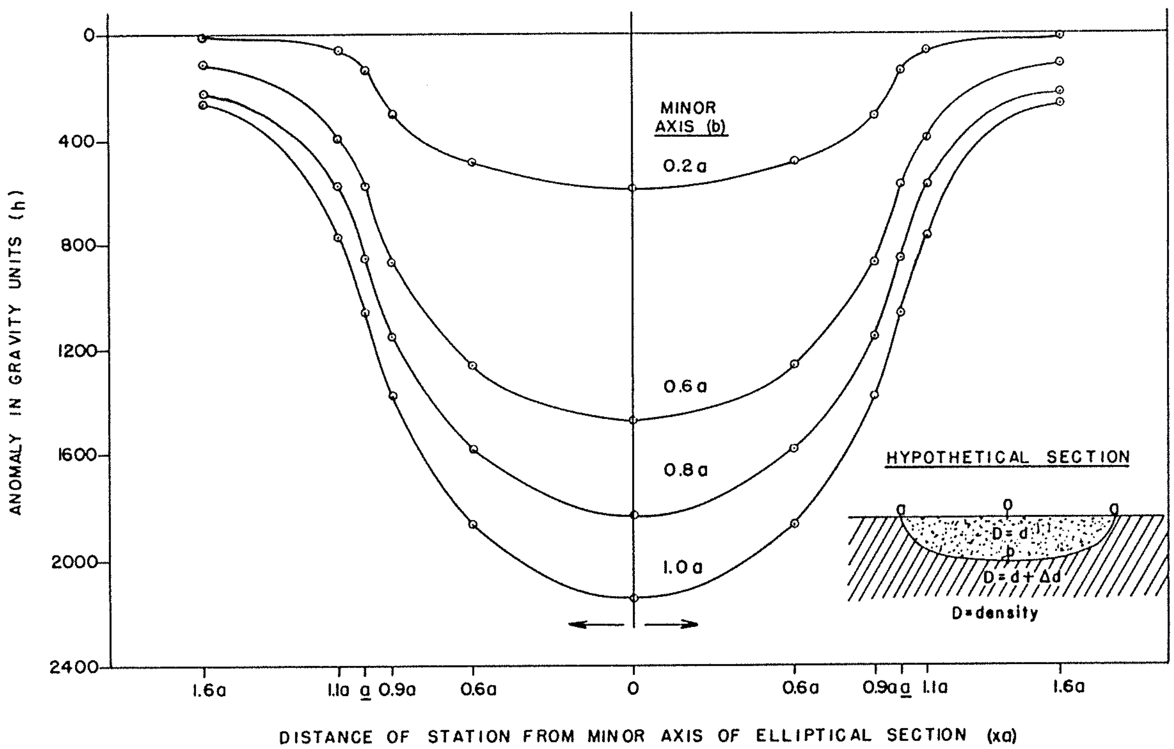
It is well known that a body of unknown shape producing a given gravity anomaly, or any other potential field anomaly, can not be uniquely determined from the anomaly curve and physical property contrast only. However, for any assumed or given density contrast and with a knowledge of the depth to the anomaly-producing body at any one point, a unique distribution producing the observed anomaly can be determined. In this case of a valley structure, it is known where the edges of the valley outcrop and, therefore, a unique solution for the valley form for any assumed density distribution can be determined.

Fig. 7-A shows a plot of the corrected gravity (observed Bouguer anomaly) along section A-A'. Following a method used by the Geophysical Laboratory at New Mexico Institute of Mining and Technology, the theoretical anomaly curves of Figs. 5 and 6 were used to obtain an elliptical valley section as a first approximation to the actual valley section. The following procedure shows how this was done in the case of the minimum section (density contrast 0.6 g/cc):

A Determination of the major axis of the elliptical section of best fit to the observed Bouguer anomaly of Fig. 7-A.

(1) The inflection point on the west side of the observed Bouguer anomaly curve of Fig. 7-A was chosen at 120 GU. This point corresponds to the west edge of a hypothetical elliptical trough.

(2) The distance from the axis of the anomaly to this inflection point is the semi-major axis (a) of the

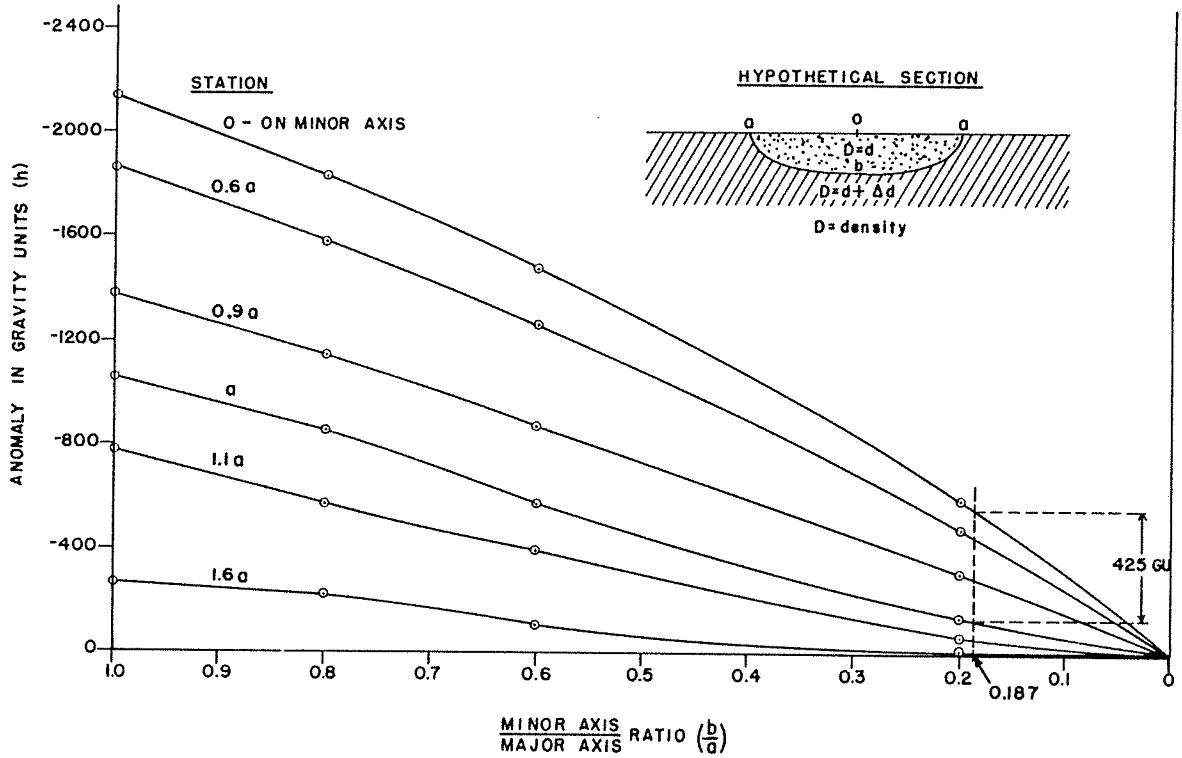


Anomaly (h'), in gravity units, at point xa on the major axis of an elliptical section with given b/a ratio and with semi-major axis (a), in miles, and density contrast Δd, in g/cc, is - h' = a/5 Δd (h).

GRAVITY ANOMALIES PRODUCED BY ELLIPTICAL VALLEYS

AT STATIONS ALONG THE MAJOR AXIS OF THE ELLIPSE

FIG. 5



Anomaly (h'), in gravity units, at point xa on the major axis of an elliptical section with given b/a ratio and with semi-major axis (a), in miles, and density contrast Δd, in g/cc, is - $h' = a/5\ \Delta d\ (h)$

GRAVITY ANOMALIES PRODUCED BY ELLIPTICAL VALLEYS

AT STATIONS ALONG THE MAJOR AXIS OF THE ELLIPSE

FIG. 6

elliptical section. Therefore, (a) is 2.02 miles or 10,700 feet.

(3) The anomaly difference from the minimum gravity point at the axis of the anomaly (Sta. "0" of Figs. 5 and 6) to the inflection point (Sta. "a" of Figs. 5 and 6) is h' = 120 - 17 = 103 GU.

B Conversion to units used in the type curves of Figs. 5 and 6.

(4) The equivalent anomaly difference (h) for use with Figs. 5 and 6 between the curves for Stations "0" and "a," corresponding to the h', is:

$$h = \frac{5}{a\,\Delta d}\,h' = \frac{5}{2.02 \times 0.6}\,(103) = 425 \text{ GU.}$$

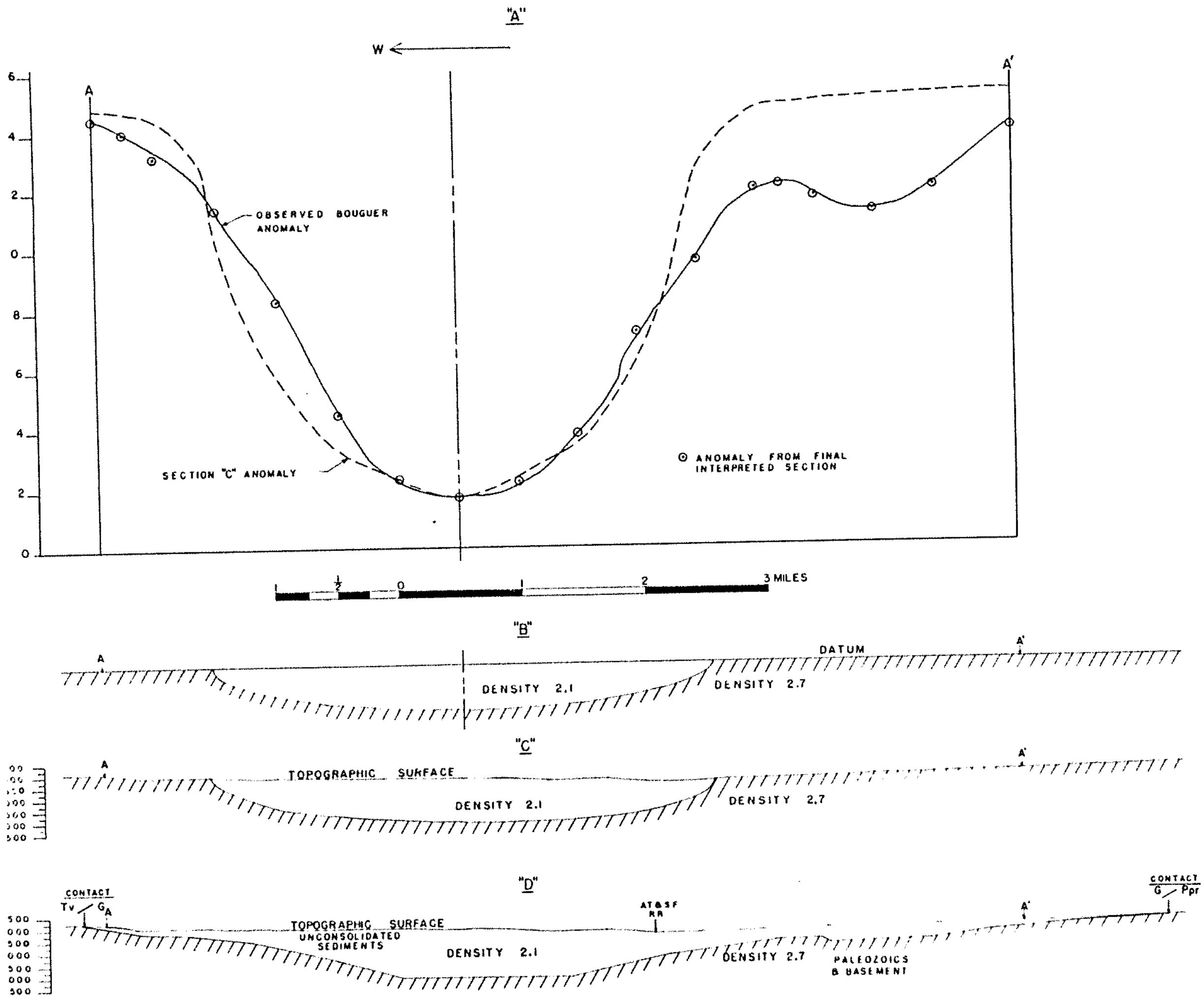
C Determination of the semi-minor axis of the elliptical section.

(5) From the curves of Fig. 6 it may be seen that a b/a ratio of 0.187 corresponds to an anomaly difference of 425 GU between Stations "0" and "a."

(6) Therefore, the semi-minor axis (b) of the ellipse = 0.187a = 2000 feet.

This first approximation, elliptical valley section is shown in Fig. 7-B, with the major axis of the ellipse used as a datum.

Now the problem of determing how this datum (the major axis of the ellipse) was related to the datum to which the gravity data ~~was~~ were reduced had to be solved. From Table 2 it may be seen that the elevation of Station 2 was used as a reference for the elevation corrections. Letting g_1 be the observed gravity (corrected for everything but elevation),



COMPUTATION OF SECTION ALONG A-A'

ASSUMING MAXIMUM PROBABLE DENSITY CONTRAST (0.6 g/cc)

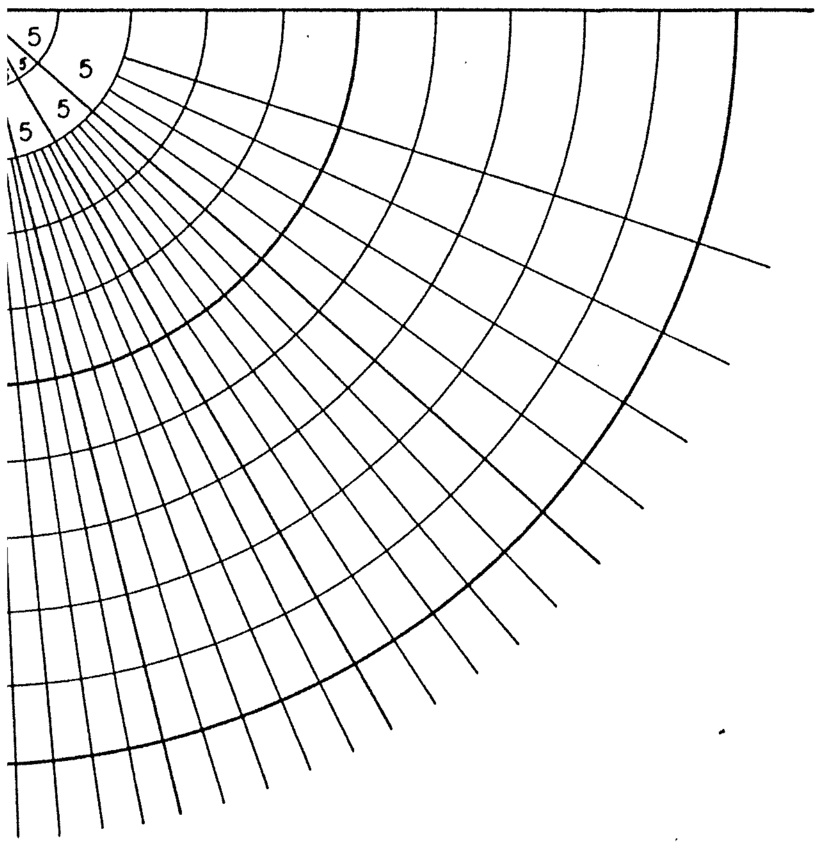
TO OBTAIN A MINIMUM DEPTH TO THE TOP OF THE PALEOZOIC ROCKS

A Observed Gravity Anomaly and Anomalies from Various Assumed Sections
B First Approximation, Elliptical Section Using the Major Axis as the Datum
C First Approximation, Elliptical Section with the Major Axis Datum Formed to Topographic Surface
D Final Computed "Minimum Section"

FIG. 7

e the Bouguer gravity (with elevation correction), z be
elevation difference between gravity station and refer-
e level, and K be the elevation correction factor; then
: $g_1 + Kz$. However, it is important to note that the
ermined value of g is not the same value which would be
tained if all gravity readings were made at the reference
vel. If G denotes the value obtained by reading gravity at
reference level, then $G = g_1 + Kz + dg/dz\ (z)$, where dg/dz
the unknown vertical gradient of gravity resulting from
structure. That is, g would equal G only if dg/dz were
ual to zero. Some reflection on this problem of determining
datum for the computations of the form of the anomaly-pro-
cing structure led to the conclusion that the topographic
rface is the datum. The applied elevation and terrain
rrections remove the effect of a homogeneous earth from the
ta, leaving only the effect of the anomaly-producing struc-
re on the stations, in their actual position along the
rve of the topographic surface. Fig. 7-C shows the first
proximation, elliptical section after the datum was made to
nform to the topographic surface, with the resultant changes
the valley shape. The dotted curve of Fig. 7-A shows the
sultant anomaly.

Following this determination of a first approximation,
liptical section, modifications were made to the valley
rm and their effects were computed by means of a two dimen-
onal anomaly chart similar to that shown in Fig. 8. The
per left corner of this chart was placed at various points



G=6.67 PDC 10^{-6} milligals

G= gravity anomaly (vertical component)

D= density contrast (g/cc)

P= l/scale ratio

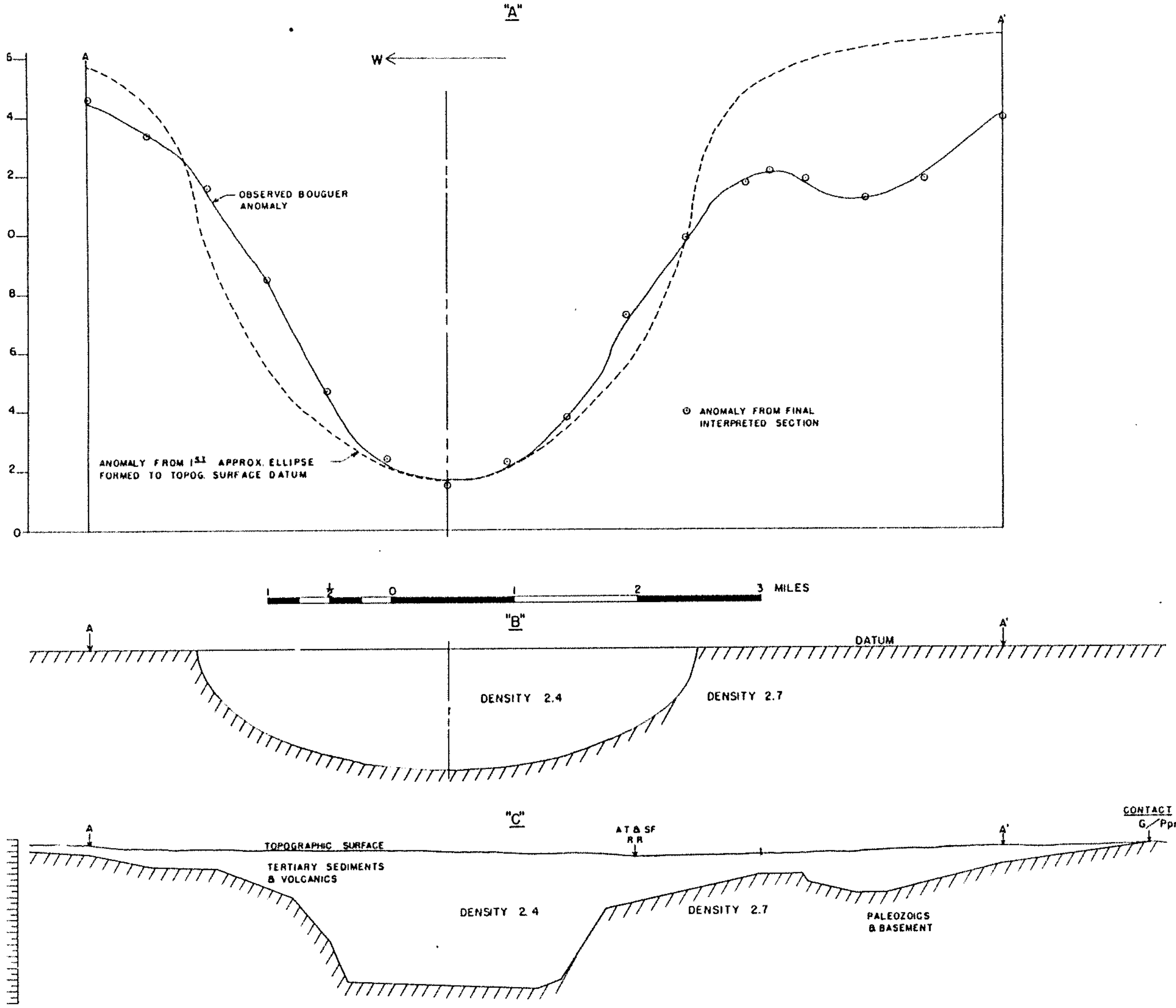
C= counts from diagram

CHART FOR COMPUTING GRAVITY ANOMALIES
PRODUCED BY BODIES ASSUMED INFINITE
IN LENGTH ALONG THEIR STRIKE

FIG. 8

along the topographic surface of the cross-section, and the number of boxes enclosed by the assumed valley structure was counted. Then the formula of Fig. 8 was used to calculate the anomaly produced at this point by the assumed valley shape. This trial and error process was repeated until a satisfactory correspondence was achieved between the observed Bouguer anomaly and the anomaly calculated from the assumed section.

Fig. 7-D shows the computed valley shape for the 0.6 g/cc density contrast, and Fig. 7-A shows how the anomaly from the computed valley section compares with the observed anomaly. Fig. 9 shows the results obtained with a density contrast of 0.3 g/cc. The greatest thickness of Tertiary rocks for the minimum section was measured from Fig. 7-D and is 2100 feet. The maximum section was calculated in the same manner as the minimum section by using a density contrast of 0.3 g/cc as shown in Fig. 9. The greatest thickness of Tertiary rocks for the maximum section is 5800 feet as measured from Fig. 9-C.



COMPUTATION OF SECTION ALONG A-A'

ASSUMING MINIMUM PROBABLE DENSITY CONTRAST (0.3 g/cc)

) OBTAIN A MAXIMUM DEPTH TO THE TOP OF THE PALEOZOIC ROCKS

Observed Gravity Anomaly and Anomalies from Various Assumed Sections
First Approximation, Elliptical Section Using the Major Axis as the Datum
Final Computed "Maximum Section"

FIG. 9

CONCLUSIONS

From the minimum (Fig. 7) and maximum (Fig. 9) computed ections along A-A', it may be concluded that the greatest hickness of Tertiary rocks in this area lies between 2100 eet and 5800 feet. These limiting values are based on easonable assumptions for the densities of the valley rocks s determined from presently available evidence. A signifi- ant secondary valley may be seen along the east side of the ain valley.

One may not deny that further evidence may well be found o change the interpreted picture. A possible condition would e the discovery of great thicknesses of basaltic flows, which ould permit a greater thickness of Tertiary rocks. The prin- ipal value of the gravity picture should be in checking any ssumed hypotheses concerning the structure and the composi- ion of the valley fill. Besides satisfying the geologic vidence, any such hypothesis must now also be consistent with his gravity picture. If, at some future date, true depths o the pre-Tertiary rocks are found by test wells or seismic ork, a more accurate valley profile may be easily computed, nd the value for the effective density of the valley fill ay be determined within narrow limits.

APPENDIX

Contours for the value of terrain correction due to
tures more than 5018 feet from the station are shown in
. 10, on the following page. These were calculated with
mer's[5] charts and tables. A separate value of mean density,
ying between 2.1 g/cc for valley areas to 2.6 g/cc for
ntainous areas, was estimated for each chart ring. This
should remove considerable labor from the computation of
rain corrections for other gravity stations which may be
ablished in this area. Terrain corrections are always additive.

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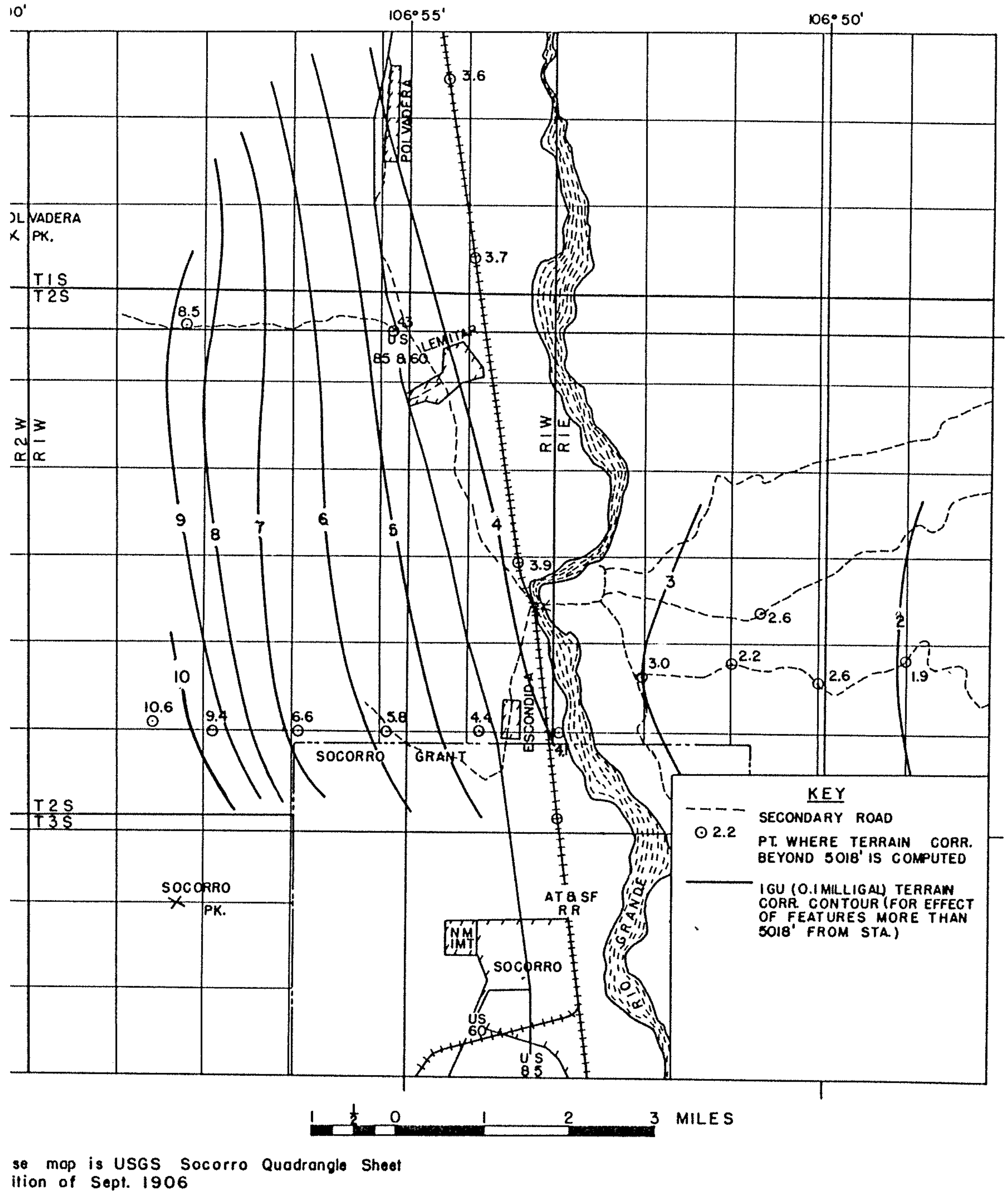
mmer, op. cit., p. 12



TERRAIN CORRECTIONS DUE TO MAJOR TOPOGRAPHIC FEATURES

(For Features 5000 feet to 72,000 feet from Station)

FIG. 10

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