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GRAVITY SURVEY OF THE NEVADA TEST SITE AND VICINITY, NYE, LINCOLN, AND CLARK COUNTIES, NEVADA--INTERIM REPORT*

By

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This report is preliminary and has not been edited for conformity with Geological Survey format.

*Prepared on behalf of the U.S. Atomic Energy Commission.

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INTRODUCTION

The gravity survey of the Nevada Test Site and contiguous areas of southern Nevada and southeastern California (fig. 1) has been made by the U.S. Geological Survey on behalf of the U.S. Atomic Energy Commission.

The objective of this study is to delineate and interpret gravity anomalies and regional trends so that the configuration and depth of the buried erosional surface of the Paleozoic rocks may be determined. This buried surface is of utmost importance in understanding the geologic history of the Nevada Test Site region, the thickness and distribution of the overlying volcanic rocks and alluvium, and the movement of ground water. The Paleozoic rocks cause positive gravity anomalies where they outcrop or occur near the surface and negative anomalies where they are buried in valleys or capped by low-density Tertiary volcanic rocks.

Gravity trends which extend over the entire area provide a basis for computing the regional gravity gradient. The regional gravity gradient must be removed from the data for geologic interpretation of the paleotopographic surface in any limited area.

Knowledge of the thickness of low-density material overlying the paleotopographic surface is useful in several ways. Proposed

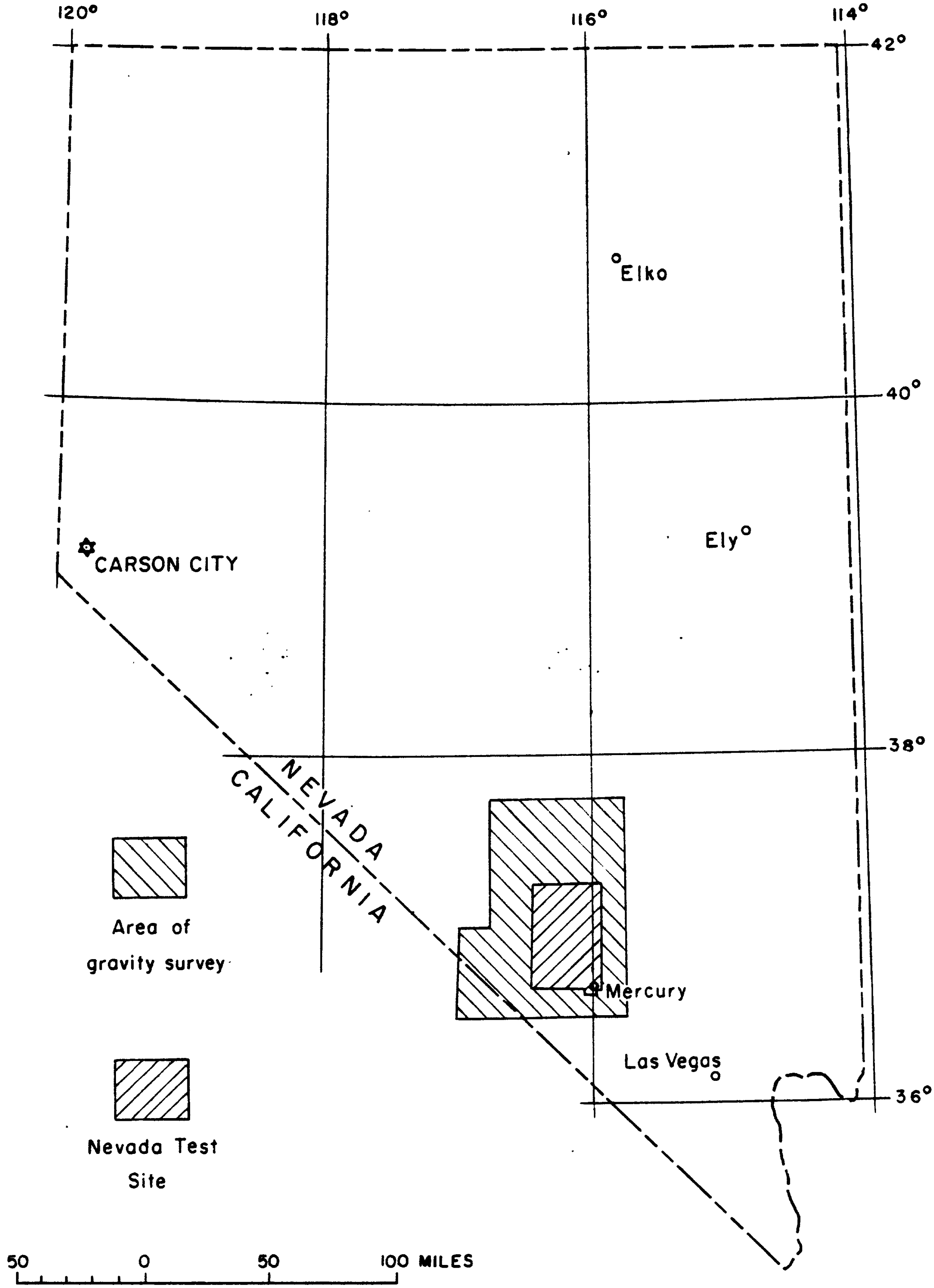

Figure 1.--Index map of Nevada showing the Nevada Test Site and area of gravity survey.

underground test sites, such as drill holes and tunnels, may be evaluated in terms of rock unit thickness and alluvial cover requirements. Recent work by the Water Resources Division of the U.S. Geological Survey has demonstrated ground-water movement through the Paleozoic rocks in the vicinity of the Nevada Test Site. Therefore, knowledge of the position of buried Paleozoic rocks is important in evaluating (a) the rate and direction of flow of the ground water, (b) ground-water supplies for domestic and industrial uses, and (c) the possibility of radioactive contamination of ground water. Finally, regional gravity trends and paleotopography are useful in working out the structural history of the area in connection with geologic studies now in progress.

The purpose of this interim report is to present the major part of the gravity data obtained as of December 31, 1961. The data are presented as a complete Bouguer gravity anomaly map. Although the gravity contours are somewhat generalized because the map has a scale of 1:250,000 and a contour interval of 5 milligals, the largest anomalies are adequately delineated.

Preliminary results of this gravity survey have been reported by Wilmarth and others, 1960, and by Diment and others, 1959 and 1960.

TOPOGRAPHY

Southern Nevada and southeastern California are included in the Basin and Range province (Fenneman, 1931, p. 330). The region is characterized by typical Basin and Range structure consisting of fault block mountains and deep intermontane valleys. The succession of basins and ranges is illustrated on figure 2.

Elevation (altitude) of the region ranges from below sea level at Death Valley (J-1) to more than 8,000 feet at Kawich Range (A-6) and Belted Range (B-8). Figure 2 shows an increase in average elevation from south to north that continues into central Nevada. Mabey (1960b, p. B284), using the elevations of selected points, determined the average elevation for the topography within a diameter of 128 kilometers. Diment and others (1961, p. 202), using the elevations of points separated by 5 minutes of latitude and longitude on a grid, averaged the topographic elevation in a circle with a radius of 80 kilometers. As determined by either method, the highest average elevation in Nevada is west of Ely (fig. 1). Mabey (1960b) found that the lowest complete Bouguer gravity anomaly in Nevada coincides with the highest average topographic elevation. Mabey concluded that this inverse correlation between elevation and gravity represents some form of isostatic compensation.

GEOLOGY AND STRUCTURE

The region is characterized by structurally complex, thick deposits of sedimentary rocks of Precambrian and Paleozoic age, that are overlain in places by faulted volcanic and sedimentary rocks of Tertiary age. Except for a volcanic province in the west-central part near Pahute Mesa (fig. 3), the entire area is a sequence of basins and ranges.

Some of the mountain ranges are composed of sedimentary rocks of Paleozoic age; others are composed of or capped by volcanic rocks of Tertiary age. The Funeral Mountains (I-2) are unique in that they are made up predominantly of Precambrian rocks (Jennings, 1958). The range is composed of schist and gneiss with local occurrences of sedimentary rocks. Precambrian gneiss, schist and pegmatite (Cornwall and Kleinhampl, 1961b) are also exposed at Bullfrog Hills west of Beatty (G-1).

The Precambrian sequence includes rocks of two distinct lithologies. The older Precambrian rocks include metamorphic schist, gneiss, and pegmatite. The younger rocks are dominantly clastic with interbedded siltstone, carbonates, and some marble. These two rock types will hereafter be referred to as Precambrian crystalline and clastic rocks.

The Paleozoic sequence at the Nevada Test Site includes rocks of Cambrian to Permian age. Earlier, Johnson and Hibbard (1957) thought that the total thickness of the Paleozoic sequence was at least 22,000 feet. Current geologic mapping, however, indicates that more than 28,000 feet of Paleozoic sedimentary rocks were deposited.

Rocks of Cambrian age aggregate more than 11,000 feet in thickness. They consist of a lower half that is predominantly clastic and an upper half that is predominantly carbonate rock.

Ordovician, Silurian, and Devonian beds aggregate approximately 6,500 feet in thickness. All three sequences are composed predominantly of limestone and dolomite with some quartzite and are herein grouped together because of their similar lithology.

Rocks of Mississippian and Pennsylvanian age aggregate approximately 10,000 feet (Poole and others, 1961, p. D-100). The Mississippian sequence is predominantly clastic rock and the Pennsylvanian sequence is predominantly carbonate rock. Rocks of Permian age aggregate just over 1,000 feet in thickness and are predominantly carbonate rock.

Three intrusive granitic bodies, probably Mesozoic in age, crop out in the northern part of the region (fig. 3). Two are north of Yucca Valley (E-7, E-8) and the third is in Cactus Range (B-3).

Tertiary rocks that include both sedimentary and volcanic materials overlie Paleozoic rocks in some of the ranges and all basins. The Tertiary section is mostly volcanic with minor amounts of sedimentary rocks in the lower part of the section. In places the alluvium is considered to be Tertiary in age. The volcanic rocks in much of the area consist of a series of welded and nonwelded ash flow tuffs; however, at Timber Mountain (F-5) and Belted Range (C-8) the rocks are predominantly rhyolite flows. Flow rocks of basaltic, andesitic, and rhyodacitic composition also are present locally in considerable quantity. The total aggregate thickness of the Tertiary rocks is unknown, but it probably exceeds 10,000 feet.

Quaternary alluvium generally lies directly on Tertiary volcanic beds although locally it rests on Paleozoic rocks. The maximum measured thickness of alluvium is 1,870 feet in south-central Yucca Valley where it is penetrated by a drill hole.

The Paleozoic rocks were extensively thrust faulted, probably during the Late Cretaceous (Johnson and Hibbard, 1957, p. 378). Many normal faults displace both the Paleozoic sedimentary rocks and the Tertiary volcanic rocks. Vertical displacements on the normal faults range from a few feet to several thousands of feet.

The Las Vegas Valley shear zone (Longwell, 1960) has had profound influence on the present structure of the southeast part of the region. This major shear zone may be traced 100 miles northwestward from Boulder City, Nev., to the area enclosed by grids J-10, J-9, and I-8 (fig. 3). East of Mercury, Nev. (fig. 3, I-9 and I-10), the mountain ranges trend east-west in sharp contrast to the north-south trend of the ranges farther north. The east-west trend is the result of right-lateral movement along the shear zone. Horizontal movement along the shear zone has been estimated at 25 miles by Longwell (1960) and 27 miles by B. C. Burchfiel (written commun., 1961).

BULK DENSITIES

More than 500 bulk density determinations have been made on rocks from the Nevada Test Site. Table 1 shows the age, range in density, and average density for each rock type.

The average density for alluvium, based on 10 samples from drill holes, is 1.92 g/cc (grams per cubic centimeter). This value is higher than the average of 1.65 g/cc for near-surface alluvium and may indicate some compaction with depth. The density for thick

Table 1.--Density range and average density of rock types at the Nevada Test Site and vicinity

Age and rock type	Source of information	Range in density (g/cc)	Average density (g/cc)	Remarks
Quaternary:				
Alluvium----------	A. M. Piper (written commun., 1952)-----	1.30-1.81	1.65	Depth from 2 to 16 feet in Yucca Valley.
Do-------------	D. D. Dickey (written commun., 1961 and 1962).	1.81-2.12	1.92	Depth from 540 to 1,500 feet in Yucca Valley.
Sand--------------	Jakosky (1950)--------------------------	1.4-1.8	1.6	
Gravel------------	--do------------------------------------	1.4-2.2	1.8	
Do-------------	Berman, Daly, and Spicer (1942)---------	---------	1.89	
Tertiary:				
Tuff--------------	Keller (1959)---------------------------	1.77-2.34	1.94	Rainier Mesa.
Do-------------	D. D. Dickey (written commun., 1961 and 1962).	1.49-2.34	2.0±0.1	Nevada Test Site area.
Altered tuffs-----	--do------------------------------------	2.18-2.52	2.37	North Jackass Flats.
Rhyolite----------	--do------------------------------------	2.0-2.70	2.36	Nevada Test Site area.
Andesite----------	--do------------------------------------	2.45-2.71	-------	Cane Spring quadrangle.
Rhyodacite--------	--do------------------------------------	1.78-2.67	2.39	Do.
Latite------------	--do------------------------------------	2.48-2.76	2.62	Nevada Test Site area.
Basalt------------	F. M. Byers (written commun., 1961)-----	2.50-2.87	2.68	Do.
Dacite------------	D. D. Dickey (written commun., 1961 and 1962).	2.29-2.39	2.36	Cane Spring quadrangle.
Mesozoic(?):				
Granodiorite------	Izett (1960)----------------------------	2.66-2.68	2.67	Climax stock.
Quartz monzonite--	D. D. Dickey (written commun., 1961 and 1962).	2.60-2.63	2.61	Gold Meadows stock.
Granite-----------	Berman, Daly, and Spicer (1942)---------	2.52-2.81	2.67	
Paleozoic:				
Dolomite----------	C. H. Roach (oral commun., 1959)--------	2.83-2.85	2.84	Northwest Yucca Valley.
Limestone---------	D. D. Dickey (written commun., 1961 and 1962).	2.62-2.70	2.67	Nevada Test Site area.
Quartzite---------	--do------------------------------------	2.52-2.71	2.62	Do.
Argillite---------	--do------------------------------------	---------	2.65	Northwest Yucca Valley.

sections of alluvium (1,000 feet) had previously been estimated at 1.80 g/cc plus 0.2 g/cc or minus 0.1 g/cc by Diment and others (1959, p. 8).

The Tertiary tuffaceous rocks range from 1.49 to 2.34 g/cc and average 2.00 $\pm$ 0.1 g/cc. At Rainier Mesa (E-7) the Tertiary section averages 1.94 g/cc (Keller, 1959). Northeast of Yucca Valley (E-8) the Tertiary section averages 1.95 g/cc (F. M. Byers, oral commun., 1961). At these locations the Tertiary rocks are welded and nonwelded tuff. Locally, where the more dense extrusive rocks such as rhyodacite, andesite, latite, rhyolite, and basalt are abundant the average density of the Tertiary rocks will be greater. Basalt with an average of 2.68 g/cc is the most dense Tertiary rock but is confined to several small areas.

Mesozoic(?) rocks from three intrusive bodies occur in grids E-7, E-8, and B-3. The rocks at Gold Meadows stock (E-7) are quartz monzonite and have an average bulk density of 2.61 g/cc. At Climax stock (E-8) the rocks are granodiorite and quartz monzonite and have an average bulk density of 2.67 g/cc. Density determinations have not been made on the granitic rocks from the intrusive in Cactus Range (B-3); however, these rocks probably are similar to the Gold Meadows and Climax stocks.

The bulk densities for the Paleozoic rocks range from a low of 2.52 g/cc for quartzite to a high of 2.85 g/cc for dolomite. The average density of these rocks is 2.67 g/cc, but local variations are common. The clastic Precambrian rocks have densities equal to those shown for the Paleozoic rocks in table 1. Density data are not yet available for the Precambrian crystalline rocks of the Funeral Mountains and Bullfrog Hills. However, bulk-density data for schist and gneiss, taken from the literature, indicate that the Precambrian crystalline rocks are slightly more dense than the Paleozoic and clastic Precambrian rocks and probably average 2.72 g/cc (Jakosky, 1950, p. 264; Berman and others, 1942, p. 23).

Because of the similar densities of alluvium (average of 1.91 g/cc) and tuffaceous rocks (average of 2.0 ± 0.1 g/cc) the two are grouped into one unit with an assumed average density of 2.0 g/cc for purposes of gravity-data interpretation. This assumed density is valid only where the Tertiary section is largely welded and nonwelded tuff. Where the more dense Tertiary rocks are abundant the average density should be determined or assumed locally.

The wide range in density of the pre-Tertiary rocks makes it necessary to determine an average density for these rocks locally for detailed interpretation. For generalized interpretations, however, the average density contrast of 0.7 g/cc between the combined alluvium and tuffaceous rocks (2.0 g/cc) and the Paleozoic rocks (2.67 g/cc) may be used.

FIELD METHODS AND DATA REDUCTION

Standard geophysical methods were used throughout this gravity survey. Details of field procedure and interpretation of data are found in Nettleton (1940), Heiland (1946), and Jakosky (1950).

Worden Educator type gravimeters were used to obtain the gravity data. Seven different meters were used at various times throughout the survey with instrument constants ranging from 0.0820 to 0.5391 mgal (milligals) per scale division. Each instrument constant was rough checked by obtaining readings at two or more base stations with accurately established gravity values.

All gravity observations were made on bench marks, at photogrammetric spot elevations listed on topographic maps or on surveyed points. Contract transit crews from Holmes and Narver, Inc., Los Angeles, Calif., surveyed approximately 100 miles of traverse lines. Gravity stations were established at intervals approximately half a mile apart along these lines. A tellurometer survey by the Topographic Division of the U.S. Geological Survey established the location and elevation of 38 stations on outcropping Paleozoic rocks at scattered points along the north, east, and south borders of the map. Members of the Geologic Division of the U.S. Geological Survey who were assigned to the project established many additional stations by planetable surveys. The transit and tellurometer surveys are considered accurate to within 1 foot vertically, whereas the planetable surveys are considered accurate to within 3 feet vertically. Photogrammetric spot elevations are considered accurate to within ±1/2 the 20-foot contour interval or 10 feet vertically. A 10-foot error in elevation results in a Bouguer anomaly error of 0.6 mgal, which is below the allowable error for most interpretations.

All the gravity data obtained by this survey have been reduced to a common datum by means of a network of 16 base stations that is tied to a master station at McCarran Field in Las Vegas, Nev. The master station was established by Woollard (1958) as part of a nationwide network and has an absolute value of 979,604.7 mgal.

A combined elevation factor of 0.06 mgal per foot, which corresponds to a density of 2.67 g/cc (Nettleton, 1940, p. 55) was used to reduce the data to a sea-level datum. Terrain corrections through zone L (Hammer, 1939), a radial distance of 9 miles, were applied to all stations. A standard correction for latitude was made (Nettleton, 1940).

INTERPRETATION

Problems of interpretation

The inherent ambiguity of the gravitational method prohibits a unique interpretation for the configuration of a geologic structure producing the gravity anomaly; however, control information, such as drill-hole depths or accurate density data, established reasonable limits to any interpretation. Most drill hole depth control is concentrated in the immediate vicinity of Yucca Valley (E-8) at this time, although additional drilling at scattered points within the Test Site boundary is planned for the future. Outside the Test Site boundaries drill-hole control is lacking except for one or two locations. Likewise, bulk densities have been determined for samples of the various rock types occurring at the Test Site, but the samples are concentrated around Yucca Valley. The density contrasts determined for the Yucca Flat area are extrapolated to the outlying region where bulk-density data are sparse or lacking. The relationship between density contrast and computed thicknesses of valley fill material is illustrated on figure 4 (after Mabey, 1960a, p. 59). It is evident from this graph that density contrast is important in estimating the thickness of fill material from the gravity anomalies associated with two-dimensional features. For example, if the assumed contrast is 0.8 g/cc and the true contrast is 0.7 g/cc, the estimated thickness will be about 90 percent of the true thickness. Likewise, if the assumed density contrast is 0.8 g/cc and the true contrast is 0.5 g/cc, the estimated thickness will be 60 percent of the true thickness. In the vicinity of the Nevada Test Site the density contrast is usually between 0.5 g/cc and 0.9 g/cc. If 0.7 g/cc is taken as the average density contrast, the maximum error in the estimation of thickness can be expected to be about 30 percent.

The complete Bouguer gravity data (fig. 5) indicate a northward-sloping regional gravity gradient of approximately 1 mgal per mile. This regional gradient is not removed from the gravity data as presented; however, it is removed before any interpretation is made.

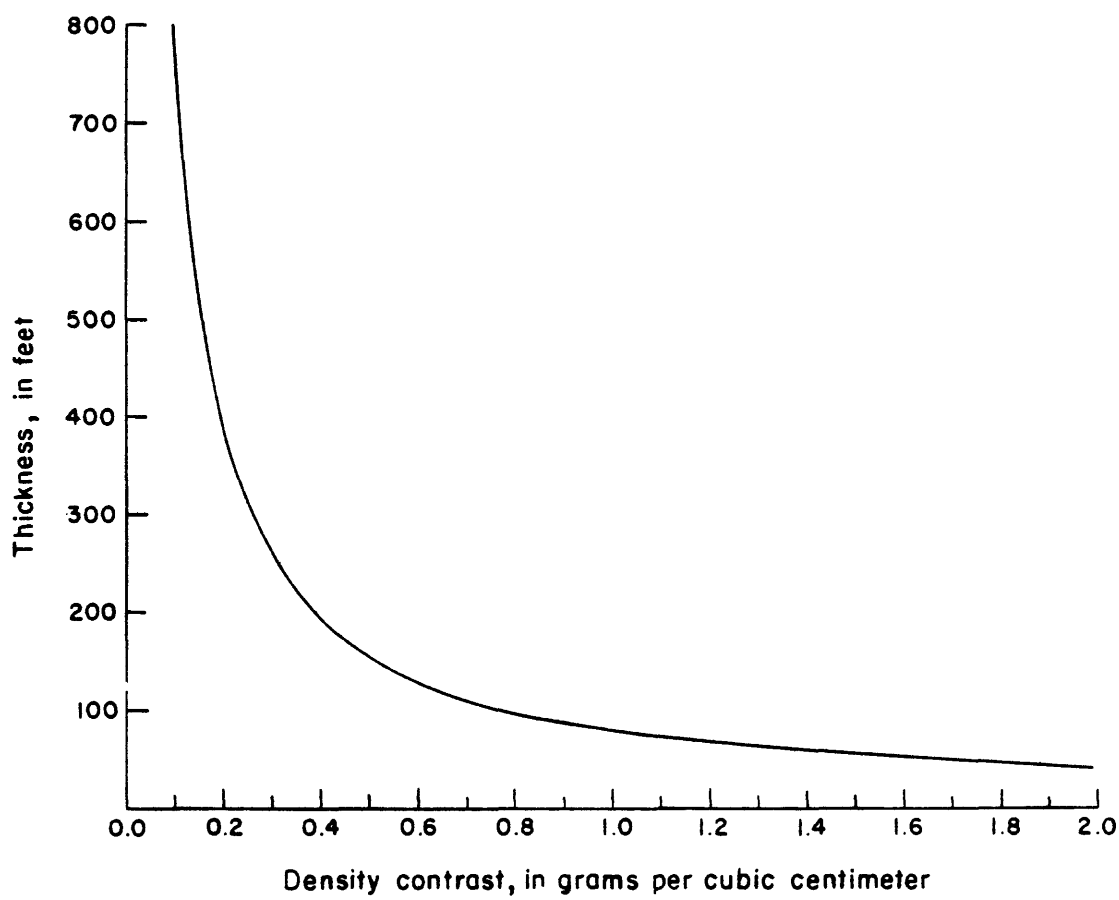

Figure 4.--Graph showing relation between density contrast and the thickness of a layer of infinite horizontal extent required to produce 1-milligal anomaly (after Mabey, 1960a).

Range in gravity anomalies

The Bouguer gravity data ranges from a high of -80 mgal at the Funeral Mountains (J-2) to a low of -218 mgal in Penoyer Valley (A-10) for a total range of 138 mgal. Other low areas that exceed -215 mgal are Pahute Mesa (E-5) and Kawich Valley (C-7). The gravity survey at Pahute Mesa is incomplete but projection of the nearby gravity trends suggests that Pahute Mesa has the lowest gravity values and, therefore, the thickest Tertiary section in the report area.

Areas of gravity lows

Prominent gravity low anomalies (hachured) are associated with each of the larger basin areas or valleys and are of special interest because they occur where the Paleozoic erosional surface is deeply buried. Yucca Valley (E-8, F-8) and Frenchman Valley (H-9), Kawich Valley (B-7), Gold Flat (C-5), and Peyoyer Valley (B-9, A-10) are discussed in the following text.

Yucca Valley

A prominent gravity low is associated with Yucca Valley (E-8, F-8). The buried Paleozoic erosional surface has been studied more thoroughly in Yucca Valley than in any other valley in the region. Here gravity data, refraction seismic data, and drill information have been combined to define the concealed paleotopographic surface. Interpretation of the gravity data indicate a section of Quaternary alluvium and Tertiary rocks 3,000 feet thick in north-central Yucca Valley. Information obtained from a drill hole completed in November 1961 verifies this thickness computation. The gravity data also indicate that the Quaternary and Tertiary rocks reach a maximum thickness of 4,500 feet in the south-central part of Yucca Valley. This estimate is supported by refraction seismic data (Diment and others, 1959, p. 24).

The elongate gravity high extending northward from Mine Mountain (SE cor. F-7) up Yucca Valley is a buried ridge of Paleozoic rocks that was unsuspected prior to the survey. The top of this ridge is 72 feet beneath the surface about 5 miles north of Mine Mountain, and 132 feet beneath the surface 10 miles farther north.

Frenchman Valley

A prominent gravity low of -170 mgal coincides with Frenchman Valley (H-9). A three-dimensional calculation of the subsurface configuration of the valley, based on the method described by Talwani and Ewing (1960), is shown on figure 6. This computation shows a basin elongated to the northeast and filled with approximately 4,500 feet of Quaternary alluvium and Tertiary volcanic and sedimentary rocks. The density contrast applied here was 0.8 g/cc, which is larger than the average density contrast of 0.7 g/cc, because of the high proportion of high-density carbonate rocks anticipated in the bedrock on the basis of geologic mapping; therefore, the 4,500-foot thickness of fill indicated may be a minimum.

A limited amount of seismic work was done in Frenchman Valley without much success apparently because a high-speed bed, perhaps welded tuff or basalt, made it very difficult to penetrate deeper than 2,700 feet by the refraction seismic method (John Roller, oral commun., 1960).

Deep electrical resistivity measurements now being made in Frenchman Valley may help to establish the true thickness of valley fill in this structural feature.

The steep gravity gradient on the southeast side of the valley may represent a major normal fault. Such a fault could trend westward and connect with the fault that B. C. Burchfiel (written commun., 1961) says occurs beneath the alluvium of Rock Valley (I-7).

Kawich Valley

Kawich Valley (B-7) is an elongate, north-trending structural and topographic feature. It is approximately 8 miles wide and 30 miles long and lies between the Kawich Range (B-6) and the Belted Range (C-8).

Kawich Valley has an associated gravity low of approximately 40 mgal. To determine the thickness of valley fill material a two-dimensional interpretation, using the method described by Dobrin (1952), was made along line B-B' shown on figure 5. The result is presented on figure 7. The analysis is based on the average density contrast of 0.7 g/cc between the Paleozoic rocks and the low density

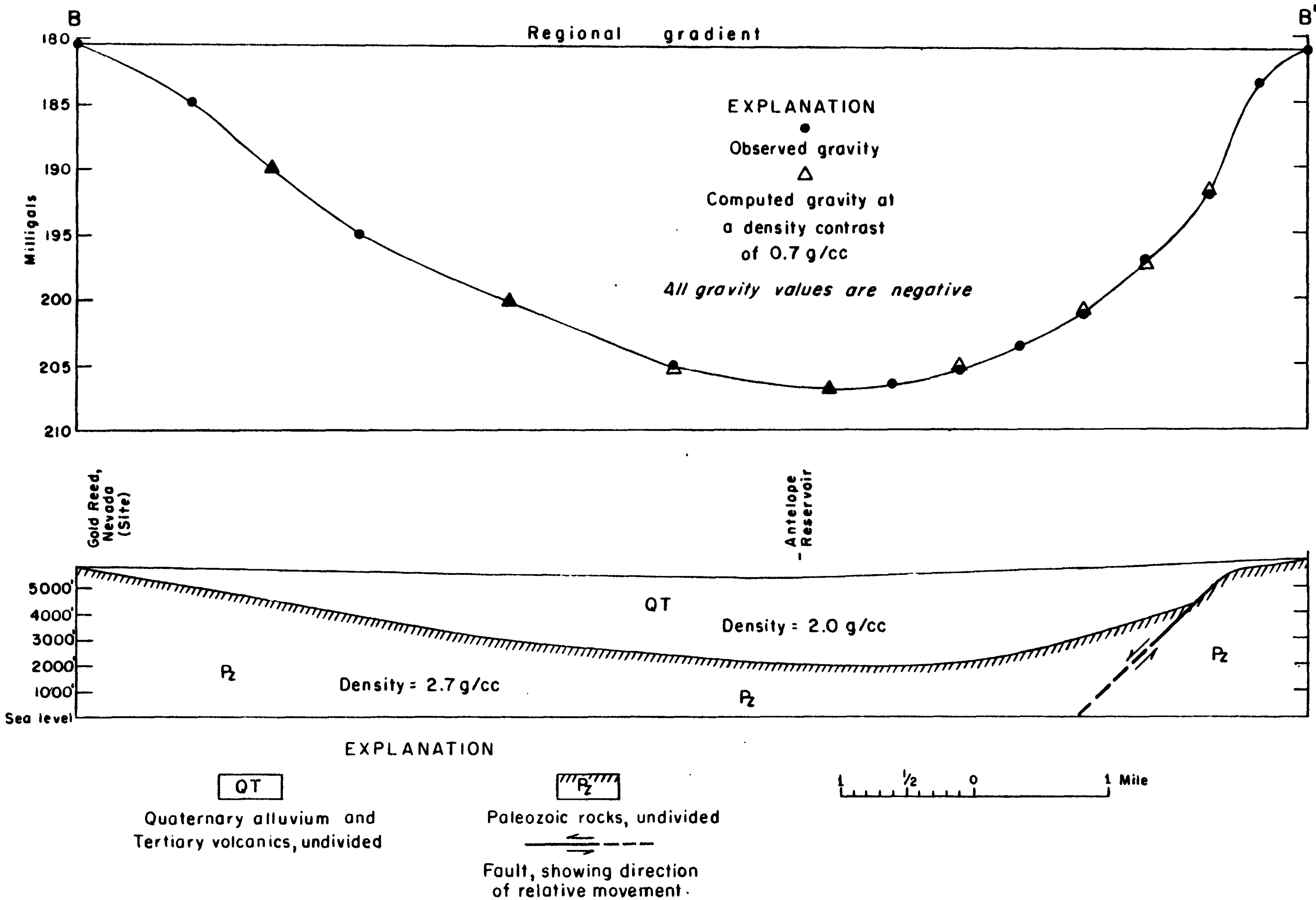

Figure 7.--A two-dimensional graticule analysis of gravity data across Kawich Valley, Nye County, Nev. Line of section shown on figure 5.

material in the valley. The calculated thickness of fill for this part of the valley is 3,400 feet. However, the gravity data indicates that the deepest part of the valley occurs about 5 miles south of profile B-B' where the fill may be 1,000 feet thicker.

Gold Flat

Gold Flat (C-5) is a prominent, intermontane basin separated from Kawich Valley by Quartzite Mountain (B-6). The geology of the region is not well known as mapping is still incomplete.

The gravity survey of Gold Flat is limited thus far to several scattered stations; however, the available data define a south-trending gravity anomaly greater than -210 mgal. This gravity low may continue southward and merge into the -215 mgal low at Pahute Mesa. Additional work is planned in the Silent Canyon area (D-5) when the new topographic maps for this area become available.

The Gold Flat anomaly has about the same magnitude as the Kawich Valley anomaly and probably indicates a similar thickness of valley fill.

Penoyer Valley

Penoyer Valley (B-9, A-10) is a prominent topographic low that trends northeast in contrast to the north trend of the adjacent mountains and valleys (fig. 2). This change conforms to the northeast-trending gravity anomaly associated with the valley (fig. 5). Both topography and anomaly may represent a regional fault that caused the abrupt termination of the Timpahute Range (B-10, fig. 3) on the north.

The Penoyer Valley gravity anomaly is similar in magnitude to that of Kawich Valley. If the density contrast is the same (0.7 g/cc assumed), the fill in Penoyer Valley is about 4,500 feet deep.

Areas of gravity high

The large gravity high anomalies exhibited on figure 5 are all associated with mountain ranges in which the Precambrian and Paleozoic rocks crop out. Prominent high anomalies are associated with the Funeral Mountains (J-2), Bare Mountain (H-3), Skeleton Hills (J-6), Specter Range (J-7), Mercury Ridge (I-9), Mine Mountain (G-7), Eleana Range (E-7, F-7), Belted Range (C-8), and Quartzite Mountain (B-6).

Funeral Mountains

The highest gravity value in the region (-80 mgal) occurs over the Funeral Mountains (J-2), which are underlain predominantly by Precambrian crystalline rocks. This maximum can be attributed to the facts that the Precambrian crystalline rocks are more dense than the Paleozoic rocks (table 1) and are closer to the surface here. This correlation between outcropping Precambrian rocks and gravity highs is also seen to the south and southeast of the report area (Diment and others, 1961, fig. 2).

Bare Mountain

Bare Mountain (H-3) is separated from the Funeral Mountains by the topographically low Amargosa Desert. Bare Mountain is a prominent topographic feature that rises abruptly out of the desert floor and is composed of sedimentary rocks of Precambrian through Mississippian age. In general, these rocks decrease in age from the south to the northeast (Cornwall and Kleinhampl, 1961a). Thrust faults produce repetition of the section in many places.

The gravity anomaly at Bare Mountain is near the southern end of the mountain and coincides with exposures of the Johnnie Formation, which is Precambrian in age (Cornwall and Kleinhampl, 1961a). This correlation between the high gravity anomaly and the clastic Precambrian rocks probably indicates the presence of dense, near-surface Precambrian crystalline rocks.

A two-dimensional analysis (method described by Dobrin, 1952) was made across the Amargosa Desert (fig. 5, line C-C') to define the subsurface configurations. Approximately 2,400 feet of valley fill is indicated by the analysis using an assumed density contrast of 0.7 g/cc (fig. 8) in lieu of local density data.

Northeast of line C-C' the very steep gravity gradient on the east side of Bare Mountain suggests a major north-trending fault concealed by the alluvium of Crater Flat.

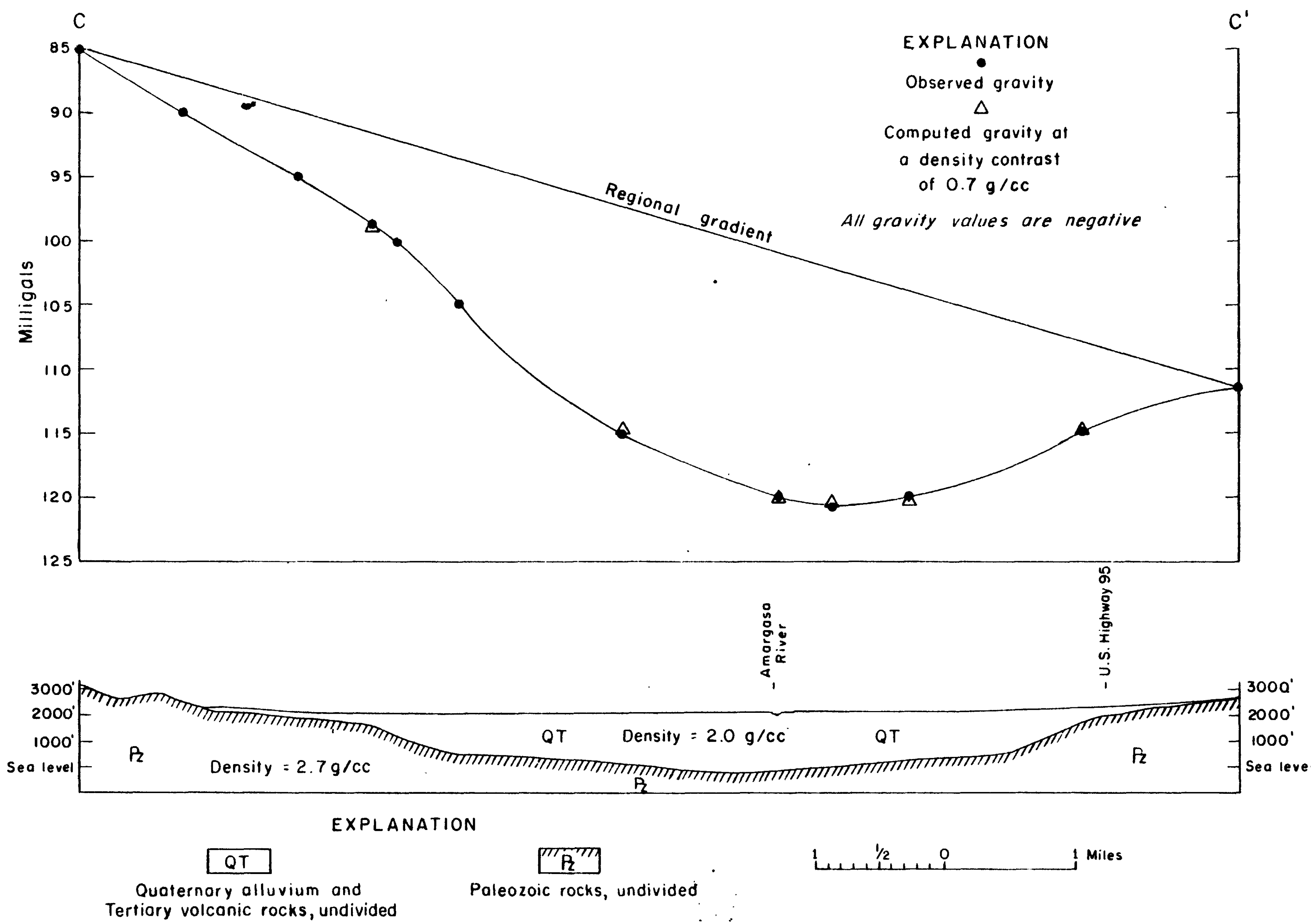

Figure 8.--A two-dimensional graticule analysis of gravity data across the Amargosa Desert, Nye County, Nev. Line of section shown on figure 5.

Skeleton Hills

In the Skeleton Hills area (J-6) Paleozoic rocks crop out as low, rounded hills composed of Cambrian, Silurian, and Devonian sedimentary rocks that are predominantly carbonates.

The Skeleton Hills gravity anomaly is a high that trends generally north with a lobe that extends eastward to the Specter Range (J-7). It includes an isolated Paleozoic outcrop south of the Hills although a saddle in the gravity data occurs between the Skeleton Hills and the outcrop. A north-trending gravity low parallels the western boundary of the Paleozoic rocks of Skeleton Hills (fig. 3). The presence of this low infers a north-trending, deep paleotopographic trough or a fault with the downthrown side to the west.

Specter Range

Specter Range (J-7) trends generally northwest and has moderate topographic relief. The outcropping rocks range in age from Early Cambrian to Devonian and are predominantly quartzite and carbonates; the rocks have been complexly faulted. The Specter Range gravity high is a -115 mgal anomaly.

A -105 mgal anomaly (J-8), the second highest shown on figure 5, occurs south of the Specter Range, in a topographically low alluviated area studded with small exposures of the Precambrian Johnnie Formation (B. C. Burchfiel, written commun., 1961). The gravity high indicates the presence of dense Precambrian rocks near the surface. The stratigraphic position of the Johnnie Formation strengthens this conclusion. This high, together with those at Bare Mountain and the Funeral Mountains, supports the correlation between high gravity values and the dense Precambrian crystalline rocks.

Mercury Ridge

Mercury Ridge (I-9) is located east of Camp Mercury. The ridge is composed of Paleozoic rocks, mostly quartzites and carbonates, that are Cambrian to Mississippian in age. Normal faults cut these rocks in many places and one thrust fault has been mapped.

The gravity high anomaly associated with this area correlates with outcropping rocks except in two places. One gravity low anomaly in the southeast corner of grid I-9 may be the result of a density contrast between Cambrian and Ordovician rocks on the north and Devonian and Mississippian rocks on the south, brought into horizontal juxtaposition by the thrust fault shown on figure 3 (I-9). A density contrast of 0.2 g/cc could produce an anomaly of this magnitude. The other gravity low that occurs northeast of Mercury Ridge (NE cor. I-10) may be the result of low-density material of the Tertiary, Eocene(?), Horse Spring Formation adjacent to the thrust fault that trends into the area from grid H-10.

Las Vegas Valley shear zone

The Las Vegas Valley shear zone, first described by Longwell (1960) and later by B. C. Burchfiel (written commun., 1961), is in the topographic low that separates Specter Range from Mercury Ridge (fig. 2, I-8, J-9, and J-10). This shear zone is a major structural feature that extends into the area from near Boulder City, Nev., about 100 miles to the southeast.

The course of the shear zone is marked by the three closed -130 mgal gravity lows on figure 5 (I-8, J-9). These gravity lows define the shear zone as far northwest as it is known to exist. B. C. Burchfiel (written commun., 1961) has postulated that this shear zone turns west through the central part of Specter Range. Since the gravity anomaly does not extend beyond grid I-8, there is no evidence to support this theory.

Mine Mountain

The rocks of Mine Mountain (G-7), near the southwest end of Yucca Valley, are Cambrian to Permian in age and are composed of quartzites, argillites, and carbonates. A thrust fault and several normal faults have been mapped.

A gravity high is associated with the Mine Mountain area. In general, the -140 mgal contour line coincides with the outcropping Paleozoic rocks. The normal fault (NE cor. G-7) that trends northeast through the central part of Mine Mountain is also defined by a gravity anomaly. Recent evidence suggests that major movement along the fault was left lateral (P. P. Orkild, oral commun., 1961). The gravity anomaly associated with this fault suggests a northward continuation of the fault along the west side of the gravity high in Yucca Valley. Another normal fault trends north through a small -150 mgal low on the west side of Mine Mountain. P. P. Orkild (oral commun., 1961) believes that these two faults merge southwest of Mine Mountain and extend south toward Jackass Flats (H-6). The lineation of gravity lows in this area supports this conclusion.

Eleana Range

The Eleana Range (E-7, F-7) is a prominent ridge that trends north-south along the west side of Yucca Valley. It is composed of Paleozoic sedimentary rocks that range in age from Cambrian through Permian and include quartzites, argillites, conglomerates, limestones, and dolomites, with quartzite the dominant rock type. Part of the range is capped by Tertiary volcanic rocks. Thrust faults and many normal faults have been mapped in this area.

The gravity high associated with the Eleana Range extends from Mine Mountain to a point beyond the Eleana Range to the northeast. The area of outcropping Paleozoic rocks is well defined by the gravity anomaly. The thrust fault mapped at the north end of the range coincides with the nose in the -155 mgal contour line. This secondary gravity high can be explained by the fact that the dolomitic rocks of the overriding thrust block are about 0.2 g/cc more dense than the surrounding Paleozoic rocks.

The Gold Meadows stock in the northwest corner of grid E-7 has an associated northwest-trending gravity nose. The stock, which is probably Mesozoic in age, intruded Paleozoic sedimentary rocks and was later surrounded by Tertiary volcanic rocks up to 3,600 feet in thickness. The density contrast of 0.6 g/cc between the quartz monzonite of the stock (2.62 g/cc) and the surrounding Tertiary volcanic rocks (2.03 g/cc) is sufficient to cause the anomaly.

The Climax stock lies northeast of the Eleana Range in grid E-8 (see fig. 3). The stock is composed of granodiorite and quartz monzonite and is surrounded by Paleozoic rocks. Since both the intrusives and the Paleozoic rocks have similar densities, there is no density contrast and no gravity anomaly exists.

Belted Range and Quartzite Mountain

Belted Range (C-8) and Quartzite Mountain (B-6) are herein grouped together for convenience of discussion although they are separated by the narrow, north-trending Kawich Valley. Both ranges are composed of Cambrian and Ordovician rocks that are dominantly quartzites and carbonates. Belted Range also has a thick section of Tertiary volcanic rocks that include tuff and rhyolite.

Caldera structures

Timber Mountain, which is composed largely of rhyolite, is part of a volcanic province that interrupts the Basin and Range topography. The Timber Mountain area (F-5) is believed to be a collapse caldera from which much of the Tertiary volcanic material in the area was extruded (P. P. Orkild, oral commun., 1960). The low area surrounding Timber Mountain (fig. 2) is regarded as the caldera moat that has been filled with low-density Tertiary and Quaternary materials. Some Quaternary basalt is present locally.

Preliminary interpretation of the gravity data tends to support the collapse caldera hypothesis. A southeast-trending gravity low that extends across grids E-5 and F-6 apparently defines the moat on its east side. Gravity lows also are found on the south (G-5) and on the west (F-4) sides of Timber Mountain suggesting that the moat is present on these sides also.

The steep gravity gradient west of the Eleana Range (E-7, F-7) is interpreted as an abrupt thickening of the Tertiary rocks into the collapse area of the Timber Mountain caldera. Depth calculations based on preliminary two-dimensional profiles indicate the caldera fill may be as thick as 8,000 feet. This depth is based on an assumed density contrast of 0.6 g/cc, which was used in lieu of local density determinations. The 0.6 g/cc contrast is believed to be applicable here due to greater amounts of welded tuff, rhyolite and basalt in the Tertiary section. Because density data for the caldera fill is lacking, this calculated depth is an approximation that has a possible error of +35 or -25 percent if the actual density contrast is 0.4 or 0.8 g/cc, respectively.

Black Mountain (D-3) is also thought to be a caldera structure. However, only reconnaissance geologic mapping has been done and gravity coverage that might verify this postulation is lacking. If Black Mountain is a caldera, the collapse structure around it, together with that of Timber Mountain, could possibly combine to produce the gravity low at Pahute Mesa (E-5).

SUMMARY

The gravity data herein presented provide background information on the regional structure of the Nevada Test Site and adjacent areas in southern Nevada and southeastern California. A better knowledge of the regional structure in turn aids in the interpretation of local complex structures.

The density contrast between the sedimentary Paleozoic rocks and the Tertiary and Quaternary rocks and alluvium varies according to the density of the rocks present locally. Many bulk-density determinations on the various rocks within the Nevada Test Site have been made. The alluvium ranges from less than 1.81 to 2.12 and averages 1.92 g/cc. The Tertiary tuff ranges from 1.49 to 2.34 and averages about 2.0 g/cc. The Paleozoic rocks range from 2.52 to 2.85 and average about 2.67 g/cc. An average density contrast of 0.7 g/cc obtained from these data was applied to outlying areas where specific density data are lacking. In these areas thickness computations, based on the average of 0.7 g/cc, have a probable error of ±30 percent due to the possible wide range in the density contrast. Locally, where the density contrast is known and applied to the calculations, the computed thicknesses should be accurate to within ±10 percent.

From 2,400 to 8,000 feet of Tertiary and Quaternary valley fill is present in the deepest parts of the basins. These thicknesses are calculated from gravity anomalies using both two-dimensional and three-dimensional methods and are believed to be representative values for the combined Tertiary and Quaternary valley fill in this area.

Proposed drilling at scattered locations throughout the Nevada Test Site will provide information that will allow future refinement of the gravity interpretations in the outlying areas described in this report.

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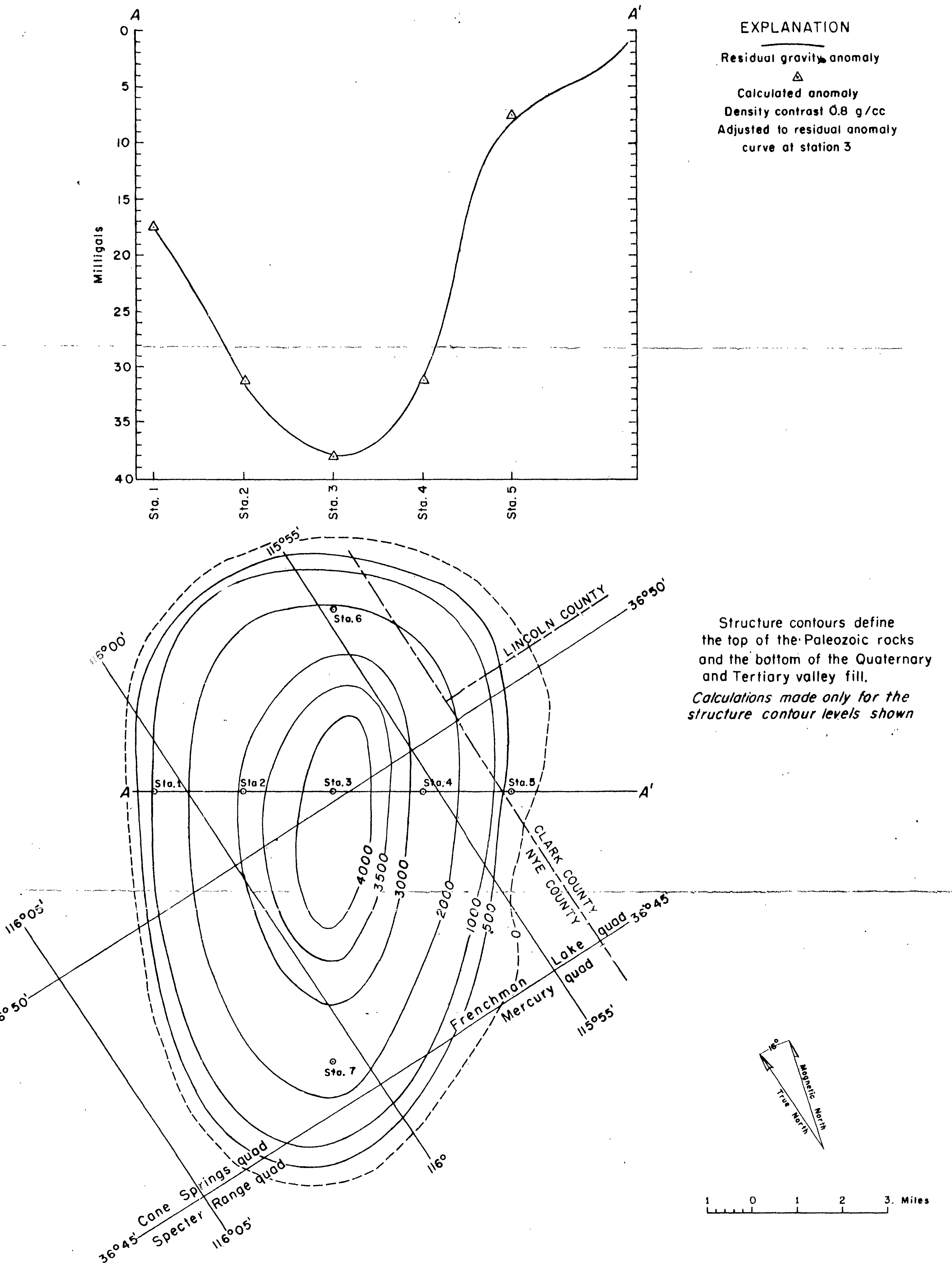

FIGURE 6 - A PRELIMINARY THREE-DIMENSIONAL INTERPRETATION OF GRAVITY DATA, FRENCHMAN VALLEY, NYE, LINCOLN, AND CLARK COUNTIES, NEVADA