BOUGUER GRAVITY MAP OF CALIFORNIA

NEEDLES SHEET

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INTRODUCTION

The area of the Needles sheet of the Bouguer Gravity Map of California lies entirely within the Mojave Desert physiographic province in southeastern California between 34° and 35° North latitude and 114° and 116° West longitude. The area is characterized by ridges and mountain ranges of small to moderate size, separated by broad sandy valleys. Elevations range from less than 400 feet near the Colorado River in the southeast part of the area to more than 7000 feet in the Providence Mountains in the northwest part of the area. Drainage is internal, except near the Colorado River, and enclosed basins and dry lake playas are common. The index map (figure 1) shows names of geographic and some geologic features used in this report.

GRAVITY DATA

Gravity data for the Needles sheet were compiled by the authors and consist of values from approximately 800 stations. Most of the gravity values are from stations occupied by Jan Rietman (unpublished data, 1968–1971); the remainder represent work by the California Division of Mines and Geology (unpublished data, 1970–1976), the U.S. Geological Survey (Peterson, 1969a; Peterson and others, 1972), Standard Oil Company of California (written communication, 1968), Shawn Biehler (1976), Bear Creek Mining Company (1968), and West and Sumner (1973). Much of the field work and data reduction by Jan Rietman and the Division of Mines and Geology was accomplished with financial and equipment assistance from the U.S. Army Map Service (now Defense Mapping Agency). The map sheet includes a complete listing of the sources of data and the distribution of these data sets is shown in Figure 2.

Most gravity stations were read near bench marks and spot elevations from U.S. Geological Survey topographic maps and unpublished manuscript sheets. Less than 5 percent of the stations utilized elevations that were estimated from 40– or 80–foot contours at known points. La Coste and Romberg geodetic gravity meters were used for about 90 percent of all the gravity stations. The calibrations of these meters were checked on one or more of the U.S. Geological Survey calibration ranges in California (Barnes and others, 1969).

The values of observed gravity were adjusted to a common datum using the California gravity base station network (Chapman, 1966), which, in turn, is based on the United States network (Woollard and Rose, 1963).

Terrain corrections for all stations were made manually to a radius of 2.29 kilometers (km) using Hayford–Bowie templates (Swick, 1942). The remaining corrections out to a radius of 166.7 km were then computed using a U.S. Geological Survey terrain correction program (Plouff, 1966). The gravity data were then processed to Bouguer anomalies using a U.S. Geological Survey gravity reduction program (Oliver, 1973, p. 3–5).

Bouguer anomaly values were contoured with a 5–milligal (mgal) contour interval and overprinted on the Needles sheet of the Geologic Map of California, Olaf P. Jenkins edition (Bishop, 1963). A tabulation of the principal facts for the stations used and a map showing station numbers and locations are available on request from the Sacramento District Office of the California Division of Mines and Geology.

REGIONAL GEOLOGY

Two–thirds of the Needles sheet area is covered by Cenozoic deposits – chiefly Quaternary alluvium, with some Quaternary lake beds, dune sand, Pleistocene continental deposits, and Tertiary and Quaternary volcanic and intrusive rocks. Pre–Tertiary rocks crop out in the remaining third, chiefly in the mountain ranges. The pre–Tertiary rocks include Precambrian gneisses and coarsely crystalline plutonic rocks, stratified marine sedimentary rocks of Paleozoic age, and Mesozoic intrusive and some metavolcanic rocks. The Precambrian and Mesozoic intrusive rocks are mostly granitic but include some rocks of more basic composition (Dibblee and Hewett, 1966, p. 64). The few exposures of Mesozoic metavolcanic rocks are mostly andesite porphyry.

Cenozoic deposits lie unconformably on pre–Cenozoic rocks that were deeply eroded during Cretaceous and early Tertiary time. No early Tertiary sedimentary rocks are known to be present in the Needles sheet area. The most extensive Tertiary unit is an unnamed assemblage of up to 10,000 feet of volcanic flows, breccias, tuffs, and some sedimentary rocks of probable Oligocene to early Miocene age (Dibblee and Hewett, 1966, p.

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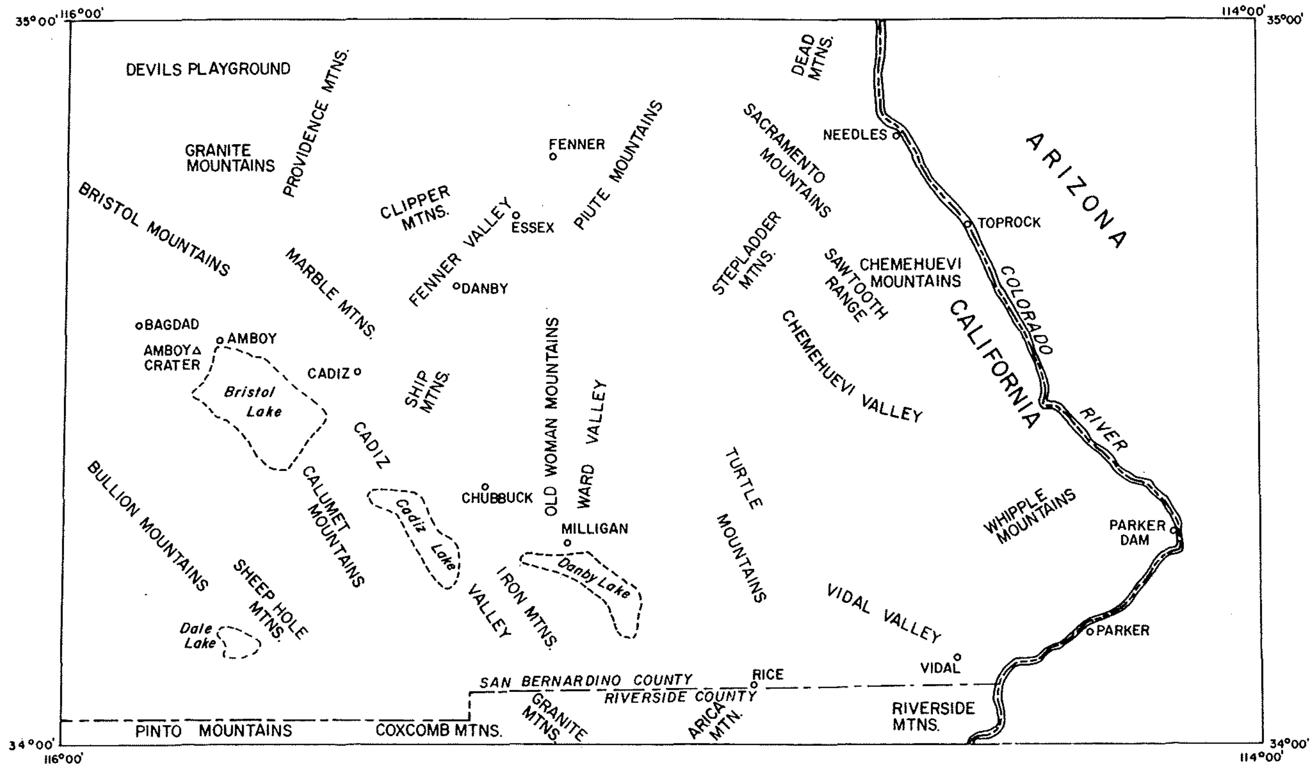

Figure 1. Index map showing the location of geographic names used in this report.

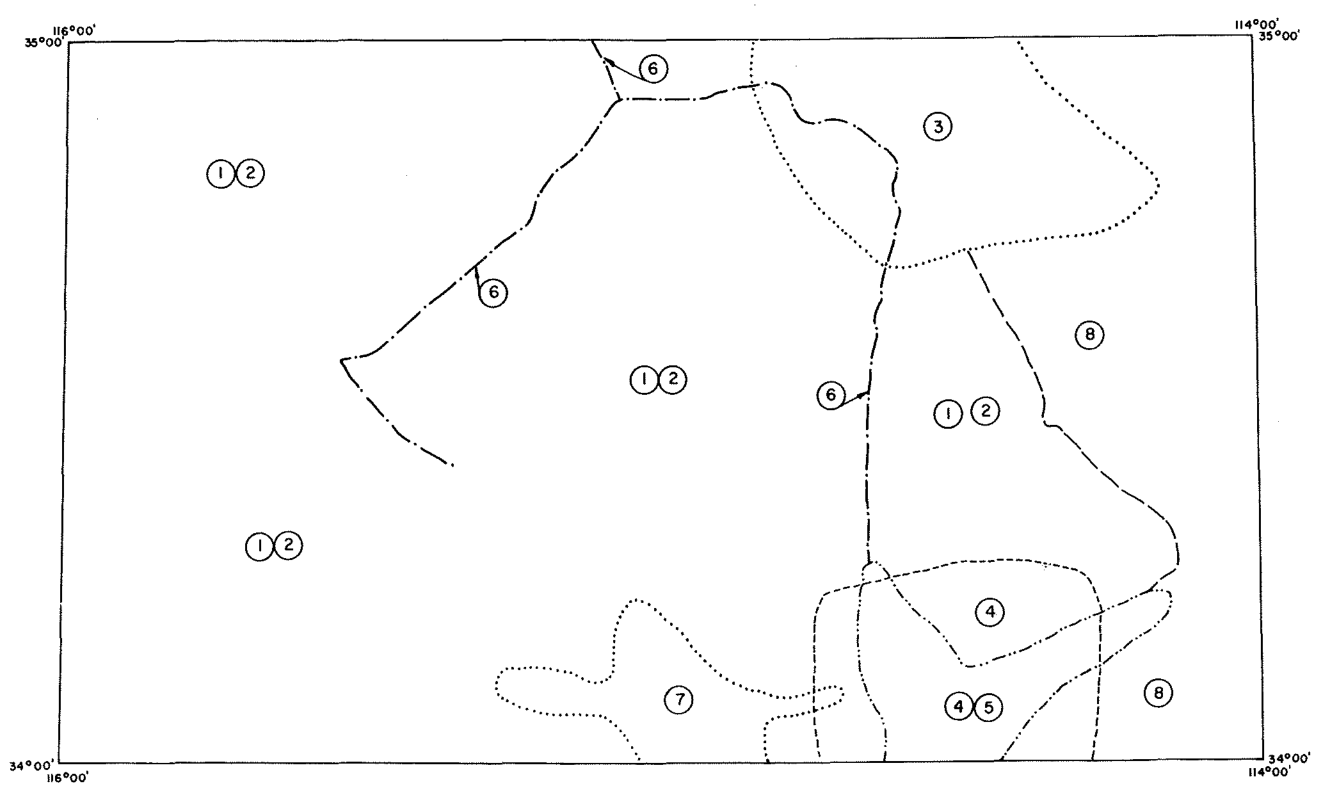

Figure 2. Index map to gravity surveys used in the compilation of the Needles Sheet. (1) Rietman, unpublished data (1968–1971); (2) California Division of Mines and Geology, unpublished data (1970–1976); (3) Peterson (1969a); (4) Biehler, unpublished data (1976); (5) Peterson and others (1972); (6) Bear Creek Mining Company, unpublished data (1968); (7) Standard Oil Company of California, unpublished data (1968); (8) West and Sumner (1973).

64); it is exposed in the northern and eastern parts of the area. The volcanic rocks in this unit range in composition from rhyolite through andesite to basalt. Quaternary volcanic rocks include local basalt flows and cinder cones. The most prominent cinder cone in the area is Amboy Crater, near Amboy. This feature and the associated lava flows are Holocene (Parker, 1963).

In general, the structural pattern of the Mojave Desert in the Needles sheet area differs from that of the Mojave Desert to the west and is more like that of the Basin and Range province to the north. For example, the mountain ranges in this area commonly trend northwest or approximately north and only rarely northeast or east. The most prominent fault trend in the map sheet area is northwest (Jennings, 1975); but a secondary east-west trend is present, in apparent alignment with the structure of the Transverse Ranges.

The three principal playas in the southwestern part of the area—Bristol, Cadiz, and Danby dry lakes—are parts of a large trough that crosses the Mojave Desert here in a general south-easterly direction, transverse to the dominant structural trends of the region. Bassett and Kupfer (1964, p. 41–42) suggested that an intergrated drainage system once connected the western Mojave Desert with the Colorado River by way of this trough. Another such possible drainage is represented by Dale Lake in the southwestern corner of the map area (Hewett, 1954, p. 19).

ROCK DENSITY MEASUREMENTS

Although no density measurements were made of rock samples during this study, the rock types exposed in the Needles sheet area are expected to have density values similar to those in the surrounding areas. Table 1 summarizes published density values from surrounding parts of California and Nevada.

MINERAL DEPOSITS

Nonmetallic Minerals

The most important mineral commodities produced in the Needles sheet area are sodium chloride, calcium chloride, gypsum, and sodium sulfate produced from the evaporite deposits found in some of the dry lake basins. Sodium chloride (common salt) is mined from beds at Bristol Lake and Danby Lake and has been obtained from the brines of Dale Lake (Smith, 1966a, p. 356–361). Calcium chloride is produced from the brines of

Table 1. Rock densities

Age	Rock Type	Number of Samples	Density in g/cm³ Range	Density in g/cm³ Average
TEUTONIA PEAK (CIMA DOME) AREA, SAN BERNARDINO COUNTY, CALIFORNIA[1]				
Tertiary	Volcanic rocks (undifferentiated)	—	2.55 - 2.73	—
Late Cretaceous	Teutonia quartz monzonite	—	2.60 - 2.62	—
Mesozoic and Paleozoic	Sedimentary rocks (undifferentiated)	—	2.61 - 2.72	—
Precambrian	Basement rocks (undifferentiated)	—	2.68 - 2.71	—
CLARK COUNTY, NEVADA[1]				
Tertiary	Granite	8	2.45 - 2.68	2.55
	Andesite	1	—	2.55
Mesozoic	Limestone	1	—	2.70
	Limestone (sandy)	1	—	2.55
	Sandstone	1	—	2.51
Paleozoic	Limestone	4	2.67 - 2.73	2.71
	Dolomite	2	—	2.84
Precambrian	Granite gneiss	17	2.53 - 2.75	2.65
	Schist	2	2.93 - 2.98	2.96
	Gneiss	1	—	2.80
	Diorite gneiss	3	2.71 - 2.74	2.73
	Quartzite	1	—	2.64
WESTERN MOJAVE DESERT, SAN BERNARDINO COUNTY, CALIFORNIA[2]				
Tertiary	Volcanic rocks (undifferentiated)	—	1.4 - 2.9	2.4
	Sedimentary rocks	—	1.9 - 2.6	2.2
Mesozoic	Plutonic rocks (undifferentiated)	—	2.6 - 3.0	2.7
Precambrian	Metamorphic rocks	—	2.6 - 2.9	2.7

[1]After Healey, 1973.
[2]After Mabey, 1960.

Bristol Lake and is present in the brines of Cadiz Lake (Smith, 1966b, p. 117–119). Gypsum has been mined at Bristol Lake and is present at Cadiz Lake (Withington, 1966, p. 188–198). Sodium sulfate has been obtained from brines of Dale Lake and is present as disseminated crystals in Danby Lake (Ver Planck, 1957, p. 543–545).

Limestone has been mined from Precambrian rocks near Chubbuck at the northern end of the Iron Mountains and from Paleozoic rocks in the Marble and Bristol Mountains. Perlite is produced from Tertiary volcanic rocks in the Bristol and Turtle Mountains. Volcanic cinders are also produced from Tertiary volcanic rocks in the Bristol Mountains.

Metallic Minerals

Metallic minerals of possible commercial importance include iron, copper, gold, lead and silver, manganese, and tungsten.

The Vulcan mine in the Providence Mountains and the Iron Age mine in the Pinto Mountains have produced significant tonnages of iron ore. At the Vulcan mine, a contact metamorphic deposit of magnetite and hematite in Paleozoic carbonate rocks is associated with Mesozoic granitic intrusive rocks (Lamey, 1948, p. 85–95). The Iron Age deposit consists of veins and fissure fillings of hematite containing some magnetite in Mesozoic granitic rocks (Wright and others, 1953, p. 95). The Vulcan mine produced more than 2.6 million long tons, mostly between 1942 and 1947. The Iron Age mine produced more than 273,000 long tons up to the end of 1963 (Moore, 1966, p. 208–209). Other relatively minor iron occurrences are known in the Ship Mountains, the Marble Mountains, the Bristol Mountains, and the Bullion Mountains.

Minor production of copper has come from veins and mineralized zones in Precambrian rocks in the Whipple and the Turtle Mountains (Wright and others, 1953, p. 60–69). Gold deposits have been worked in the Pinto, the Whipple, and the Sheep Hole Mountains (Wright and others, 1953, p. 67–86). The gold deposits are usually found in veins and shear zones and may be genetically related to Mesozoic intrusive rocks. At the America mine (active in 1976) at the northern end of the Sheep Hole Mountains, free gold is associated with quartz, hematite, and lesser amounts of arsenopyrite and chalcopyrite in veins found in alaskite.

Lead-silver ore has been produced from replacement–type deposits in Paleozoic carbonate rocks in the Providence Mountains (Wright and others, 1953, p. 100–113). Some manganese ore has been mined from fissure zones in Tertiary sedimentary rocks containing manganese oxide minerals in the Whipple Mountains (Wright and others, 1953, p. 114–121). Minor tungsten deposits have been mined in the Old Woman and the Clipper Mountains where scheelite occurs in contact metamorphic deposits in Precambrian rocks (Wright and others, 1953, p. 140–153).

GRAVITY ANOMALIES

Gravity anomaly values in the Needles sheet area range from more than –25 mgal in the Riverside Mountains in the southeastern part of the area, to less than –125 mgal east of the Providence Mountains on the north edge of the area at about 115° 15′ West longitude. The regional gravity field in the map sheet area slopes downward to the north or northwest and has a gradient of less than 0.5 mgal/mile (0.3 mgal/km). This gradient probably is caused by a gradual decrease in the density of crustal rocks or by a local crustal thickening from the south toward the north or northwest. Local gravity anomalies are superimposed on this regional gravity field.

In general, positive gravity anomalies in the area are associated with the mountainous areas and negative anomalies with the intervening basins. Thus, anomaly trends commonly follow the trends of the topographic features. The most prominent positive anomalies in the area, however, are associated with relatively dense Precambrian igneous and metamorphic rocks (table 1). For example, an alignment of positive anomalies just west of the Colorado River extends from the Riverside Mountains in the south, where one arc is convex to the east, through the Whipple, the Chemehuevi, and the Sacramento Mountains to the Dead Mountains in the north, where a second arc is convex to the west. These anomalies reach a maximum amplitude of about 35 mgal. Other strong positive anomalies with amplitudes of a few tens of milligals are associated with similar Precambrian and metamorphic rocks in the Turtle, the Iron, the Old Woman, the Arica, and the Marble Mountains and in the southeastern end of the Bristol Mountains. A local positive anomaly with an amplitude of about 10 mgal is also associated with Mesozoic basic intrusive rocks at the northern end of the Sheep Hole Mountains.

Exposures of Mesozoic granitic rocks are usually characterized by positive gravity anomalies with relatively low amplitudes (up to 10 mgal). Table 1 shows that rocks of this type have a density of 2.60–2.62 g/cm³, which is close to the value used for the reduction of the gravity data (2.67 g/cm³). Thus, areas characterized by these rocks should show anomaly values approximately intermediate between the values in areas with higher and lower rock densities. For example, the southern end of the Calumet Mountains, which are composed largely of granitic rocks, is encircled by the –70 mgal contour. This indicates a local positive anomaly of from 5 to 10 mgal.

Prominent negative anomalies are associated with some of the sediment–filled basins in the map area. These include the lows with a few tens of milligals that mark Bristol, Dale, Cadiz, and Danby Lakes and Chemehuevi, Fenner, and Ward Valleys. These negative anomalies undoubtedly reflect the thicknesses of alluvium and lake sediments filling the valleys. Included with this type of anomaly is the northeast–trending negative anomaly associated with the southern extension of Ivanpah Valley, just north of the Devils Playground. This anomaly continues beyond the Needles sheet area and into the adjacent Kingman sheet area. According to Healey (1973), this anomaly may represent a fault–controlled basin. The southwest end of this postulated basin might be related to a northwestward continuation of the fault mapped near Foshay Pass in the Providence Mountains (Hazzard, 1954, plate 2).

The lowest gravity values (less than – 125 mgal) measured in the map area are found northwest of Fenner and east of the Providence Mountains. This relatively deep gravity low culminates to the north in Lanfair Valley (Kingman sheet), yielding a subcircular anomaly (–145 mgal contour) over Tertiary volcanic rocks. Healey (1973) suggested this anomaly is caused by a possible caldera filled with volcanic and sedimentary rocks.

The steep northwest–trending gravity gradient southwest of the Sacramento Mountains and the Sawtooth Range may represent a fault with several thousand feet of vertical displacement. This postulated fault may form the boundary between the depression represented by Chemehuevi Valley on the southwest and the adjoining mountain ranges on the northeast. The southwest side of Chemehuevi Valley is marked by a northwest–trending gravity gradient adjacent to the Turtle Mountains. This gradient also may represent a fault.

The steep arcuate gravity gradient trending northwest to north, east of the Sacramento and the Dead Mountains, passing near the city of Needles, may also represent a fault or a series of faults. The steep gravity gradient trending just north of west between Bristol Lake and the Bristol Mountains could be caused by a fault on which the relative movement has been down to the southwest. The moderately steep west-trending gravity gradient (downward toward the north) on the north side of the Pinto Mountains in the southwestern part of the map area may reflect an eastern extension of the Pinto Mountain fault or a related fault (Bassett and Kupfer, 1964, plate 1). This steep gradient is abruptly truncated by the predominant northeast trends of the western Mojave Desert east of the Sheep Hole Mountains (S.H. Biehler, personal communication, 1976). This termination of the gravity gradient probably marks the eastern termination of the fault. Other faults may be represented by some of the numerous relatively steep gravity gradients present in many parts of the map area. However, the sparse data distribution does not allow anomalies to be accurately defined in many parts of the map area.

Gravity measurements are widely spaced near Amboy Crater, northwest of Amboy. This cinder cone and the associated flows were deposited on the playa surface of Bristol Lake (Parker, 1963). Evidence of this feature is not apparent on the gravity map. The gravity contours reflect the basin associated with Bristol Lake but do not show a local anomaly that might be related to the volcanic features, at least not at the station spacing and contour interval used. This suggests that there is no large intrusive mass underlying the volcano.

The positive anomaly (–65 mgal contour) centered west of the Ship Mountains encompasses this mountain range and the southern Marble Mountains, the southeastern Bristol Mountains to the north and northwest, and possibly the Calumet Mountains to the southwest. The presence of one large anomaly in this area indicates that these mountain ranges represent one block or mass and that the Cenozoic deposits in the intervening valley areas do not represent major structural depressions. Such areas near mountain ranges, characterized by relatively thin Cenozoic deposits, may be pediments and are of interest in prospecting for minerals related to the basement rocks. Similar gravity anomalies can be found near other mountain ranges in the area. The area between the Clipper Mountains and the Providence Mountains in the northwestern part of the area, and the area between the Old Woman Mountains and the Iron Mountains in the south–central part of the area, exhibit this type of gravity anomaly.

Although gravity stations are not well distributed in many parts of the Needles sheet area, there is sufficient information to define the major structural features and to suggest the need for further study. Some of the minor anomalies, including those not discussed in the text, may also warrant more detailed study.

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