# 4. GEOLOGY OF THE OCEANSIDE-SAN DIEGO COASTAL AREA, SOUTHERN CALIFORNIA

By Leo George Hertlein * and U. S. Grant †

## INTRODUCTION

A brief summary of the stratigraphy, structure, and general geology of the Oceanside-San Diego coastal area, in the extreme southwestern part of California, is presented in this paper. Fundamentally, this area forms a segment of a narrow coastal plain, but many geologists have grouped it, for convenience, with the Peninsular Ranges, which adjoin it on the east. The geologic map (fig. 1) shows the southern part of the area discussed in the following paragraphs.

The visitor familiar with the geology and physiography of the Los Angeles region will at once notice four striking features that distinguish the Oceanside-San Diego area. These are (1) the mesa-land topography (fig. 2), (2) the thin sedimentary cover that lies upon older "basement" rocks, (3) the complete absence of Oligocene and Miocene sediments, and (4) the comparatively slight structural deformation of beds that are Upper Cretaceous or younger.

The writers have studied the southern part of the present area in considerable detail and the results of these investigations were published in 1944. On the other hand, their investigations of the Oceanside district to the north have been of a reconnaissance nature, and the excellent papers of Hanna (1926, 1927) have provided most of the detailed data for this part of the area.

## PHYSIOGRAPHY

The land surface of the Oceanside-San Diego area represents, in the main, a series of marine wave-cut terraces that have been carved into gently dipping conglomerates, sandstones, siltstones, and shales of Cretaceous, Eocene, and Pliocene age. These terraces can be summarized as follows:

*Chiefly north of the San Diego River*

| *Terrace* | *Elevation above sea level* |
|---|---|
| Poway terrace | 900-1,200 ft. |
| Linda Vista terrace | 300-500 ft. |
| La Jolla terrace | 25-200 ft. |

*Chiefly south of the San Diego River*

| *Terrace* | *Elevation above sea level* |
|---|---|
| Otay terrace | 430-525 ft. |
| Sub-Otay terrace | 425 ft. (approx.) |
| Avondale terrace | 200-250 ft. |
| Chula Vista terrace | 100-130 ft. |
| Nestor terrace | 25-100 ft. |
| Tijuana terrace | 20-50 ft. |
| Modern coastal flats | 0-20 ft. |

In the southern part of the area, the terraces increase in altitude as the Mexican boundary is approached. The lower terraces rise slightly as the La Jolla-Soledad Mountain block is approached from the south, and the Linda Vista terrace is poorly developed or is not recognizable on portions of Soledad Mountain (fig. 1).

The Poway, or highest broad terrace, is now eroded away over much of its former extent, but it is typically developed and well preserved in the area between Cowles Mountain and Twin Peak. It was cut on pre-Tertiary igneous and metamorphic rocks east of the area discussed in the present report. This terrace may have been developed during Pliocene time. Traces of other terraces at points as high as 1,300 feet were recorded by Hanna (1926) from Cowles Mountain. In the Peninsular Ranges farther east, the physiographic relations suggest that an old-age land surface with numerous monadnocks was rejuvenated in late Cenozoic time.

The Linda Vista terrace, 300 to 500 feet in altitude (fig. 3), was recognized by Ellis and Lee (1919). It was reported to extend from Poway Mesa to Soledad Mountain, and to represent a northern extension of the Otay terrace that is so well developed in the southern portion of this area. Likewise, the La Jolla terrace, which is 25 to 200 feet in altitude and is well developed at and south of La Jolla (fig. 4), perhaps may correspond to the Chula Vista terrace south of San Diego. Remnants of ancient beach ridges and abundant small, reddish-brown cemented sand concretions are interesting features on the Linda Vista terrace.

Several flat-bottomed, alluvium-filled valleys in this region are important agricultural assets. Among the larger of these are Poway Valley and El Cajon Valley, which lie at altitudes of 400 to 600 feet. The streams draining these valleys are entrenched as a result of uplift. According to Hanna (1926), these valleys resulted from erosion along the contact between old rocks and conglomerates that underlie the Poway terrace.

An interesting feature of the Otay terrace surface is the occurrence there of prairie mounds. These mounds may have been formed as a result of an earlier plant cover, combined with effects of deflation and deposition by the wind. Their origin was discussed by the present authors in 1944.

The Silver Strand along the southwest side of San Diego Bay, and Mission Beach along the west side of Mission Bay (False Bay), are shoreline accumulations of materials that have been brought to

* Associate Curator, Department of Geology, California Academy of Sciences.
† Professor of Geology, University of California, Los Angeles.

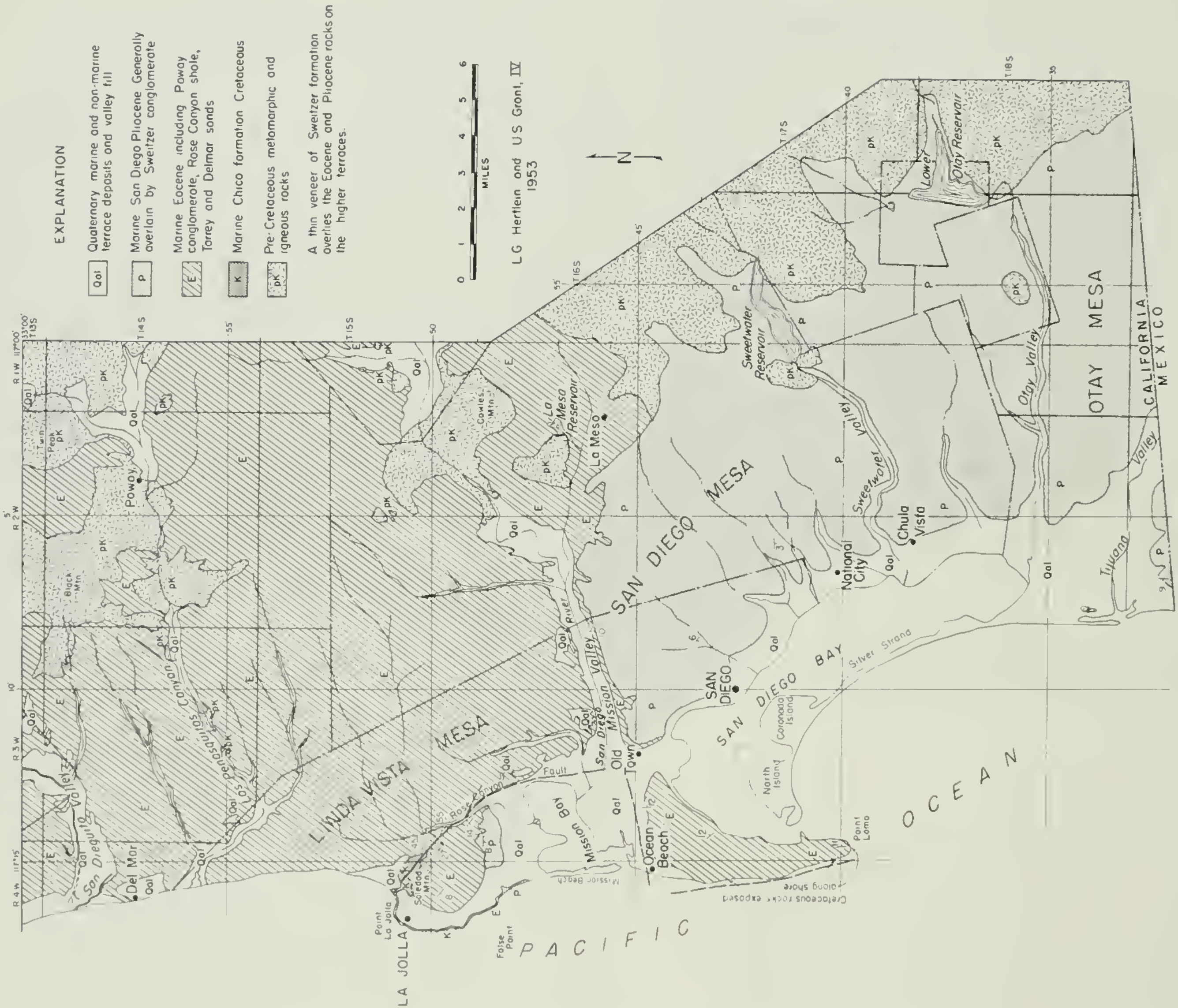


**FIGURE 1.** Geologic map of a part of the Oceanside—San Diego coastal area, southern California.

the coast by streams and then were shifted along the shore by currents and waves. Bay Point (Crown Point) may have been built in a manner similar to that of the Mission Beach sand spit, or perhaps it represents the wave-built portion of the La Jolla terrace.

Rainfall in this region is light, averaging only about 10 inches annually, and it occurs chiefly between October and April. The drainage is all westward. The San Dieguito River and Soledad Creek, in the northern portion of the area, reach the ocean through partly submerged valleys. The largest stream, the San Diego River, now empties into Mission Bay, but during earlier times it occasionally flowed into San Diego Bay. Its deltaic deposits form the lowland between Point Loma and Old Town (fig. 1). Smaller, intermittent streams flow in Sweetwater Valley, Otay Valley, Tijuana Valley, and other minor valleys. All these streams are practically at grade in the mesa lands area.

The presence of lagoons and low, marshy deltas at the mouths of streams such as the San Dieguito River is evidence of rather recent subsidence in the northern part of the area under discussion. Construction of dams and establishment of reservoirs on the major streams have reduced flow in their lower courses to comparatively small amounts except during years of exceptional precipitation, but there is much historic evidence of former great floods.

## PRE-TERTIARY IGNEOUS AND METAMORPHIC ROCKS

The oldest rocks in this area are the Black Mountain volcanics and metamorphics (also known as the Santiago Peak series), which are exposed in the foothills east of the Tertiary sedimentary belt. This series consists mainly of dark-colored intrusive and effusive rocks of basic and intermediate composition, and includes andesitic and trachytic flows, agglomerates, tuffs, and metamorphosed conglomerates, sandstones, and shales. Quartzite and fissile shales are present in the eastern portion of the La Jolla quadrangle. The Cretaceous and younger sediments were deposited upon a "basement" of these older rocks.

The Black Mountain volcanic and metasedimentary rocks have been intruded by plutonic rocks such as quartz diorite and biotite granite. These may be parts of the southern California batholith, and hence may be of Cretaceous age. They are plainly older than the Cretaceous sedimentary rocks in the area, however. Roof pendants of the older rocks occur within the intrusives at various localities.

No fossils have been found in the Black Mountain series, but similar rocks in the Santa Ana Mountains to the north are underlain by fossiliferous rocks that are believed to be of Triassic age. These old rocks are very resistant to erosion, and commonly stand out as peaks and ridges in the eastern parts of the area. Hanna reports the thickness of the Black Mountain series to be more than 2,000 feet. Estimates of thickness must be approximate, as the attitude of layering and foliation in these rocks varies considerably from place to place. The structure is even less discernible to the south. Sweetwater Dam, about 10 miles east of San Diego, and Hodges Dam, on the San Dieguito River, are located on these rocks.

The quartz diorite is well exposed in the higher areas east of Black Mountains, as well as east of La Mesa at Grossmont. This rock contains about 40 percent quartz and 20 percent biotite, and most of the remainder is sodic plagioclase. Pegmatite and aplite dikes extend from the masses of quartz diorite into older rocks that flank these masses.

Gabbro is exposed in three small areas within the La Jolla quadrangle. The largest of these is west of Black Mountain. A smaller one, involving more basic gabbro, lies at the eastern end of the south branch of Poway Valley, near the eastern margin of the La Jolla quadrangle. The third area also is small, and lies near the head of Shepherd Canyon, in the east-central part of the quadrangle. Hanna (1926) identified the rock in this area as a gabbro or basic diorite. Some specimens contain 50 to 60 percent of oligoclase-andesine feldspar. Quartz is absent from parts of the rock, but in other parts, it is present to the extent of as much as 10 percent. The contact between the gabbro and the quartz diorite has not been observed, but Hanna (1926) believed the gabbro to be younger than the diorite.

A basalt dike 2 feet to 30 feet wide cuts Eocene rocks along the seashore about ¼ mile north of Scripps Institution of Oceanography. A greenstone dike has been reported from an area along the southeast side of Point Loma, where it apparently intrudes Cretaceous rocks.

## SEDIMENTARY ROCKS

Unmetamorphosed Cretaceous, Eocene, Pliocene, and Pleistocene sedimentary rocks form a section whose estimated maximum thickness is less than 4,000 feet. All these rocks were deposited in comparatively shallow water, and for the most part have experienced but slight deformation. They are chiefly sandstones, siltstones, and shales; minor amounts of conglomerate also are present. A columnar section of these rocks is presented in figure 5.

*Cretaceous Rocks.* Cretaceous sedimentary rocks are exposed only in narrow zones along the west shore of Point Loma and along the shore farther north, in the vicinity of La Jolla (figs. 1, 4); in the core of an anticline on Soledad Mountain (fig. 6); and in an area, perhaps 2 or 3 square miles in extent, that lies about 5 miles southeast of Carlsbad. The maximum thickness of this section is unknown, but it is believed to be about 500 feet at most localities. These rocks apparently lie upon the eroded surface of the Black Mountain series.


FIGURE 2. Air view eastward over San Diego Mesa from a point above south side of Mission Valley. Note the steep-sided, V-shaped young tributaries of Mission Valley, the flat-topped mesa, and the Peninsular Ranges of crystalline rocks in the distance. The obscure Eocene-Pliocene contact is exposed on the canyon slopes. *Air Photo by Spence, February 21, 1931.*

However, at a locality about 6 miles south of San Diego, a drilled well penetrated 269 feet of "red beds" that are above the Black Mountain series and below the marine sedimentary rocks of Cretaceous age. These "red beds" have been referred to the Trabuco formation of the Santa Ana Mountains where beds of similar lithology are believed to be of nonmarine origin.

The marine Cretaceous rocks are massive to well bedded, brown to gray, well cemented sandstones and fine-bedded shales that are in part carbonaceous and locally are concretionary (fig. 4). In these sediments are such fossil Foraminifera and mollusks as *Guadryina oxycona* Reuss, *Globotruncana obtusa* Cushman, *Acila demessa* Finlay, *Coralliochama orcutti* White, *Neomodon vancouverensis* Whiteaves, *Oligoptycha obliqua* Gabb, *Baculites fairbanksi* Anderson, *Hamites vancouverensis* Meek, and *Parapachydiscus catarinae* Hanna & Anderson, which indicate Campanian, upper Senonian, Upper Cretaceous age. *Coralliochama orcutti* White was collected by Frank Stephens and others from Cretaceous sediments, about 100 feet thick, that are exposed southeast of Carlsbad. There shale with some thin layers of sandy limestone are present over an area of about 2 or 3 square miles, where they dip about 3° NW and lie unconformably upon crystalline "basement" rocks. Foraminifera from those rocks have been described by Bandy (1951). A characteristic Campanian, Upper Cretaceous foraminifer, *Globotruncana arca* Cushman, is reported to occur abundantly in the faunal assemblage.

Beds containing a Cretaceous fauna similar to that of the San Diego region occur at Gualala, middle California, in the Coalinga district, and at Todos Santos Bay, in Baja California, Mexico. On Point Loma, the carbonaceous character of these beds once led to the sinking of a shaft in search for coal, and some deposits of coal were reported many years ago from points near Del Mar.

*Eocene Rocks.* Eocene rocks are represented in this area by the La Jolla formation and Poway conglomerate, whose combined thickness is about 1,575 feet. These rocks are believed to be middle Eocene or early upper Eocene in age.

The La Jolla formation is made up of three members. The lowest, which lies unconformably upon Cretaceous beds, is the Delmar sand, 100 feet in thickness. It occurs only along the coast north of La Jolla, and is well exposed in the sea cliffs and near the town of Del Mar (fig. 3). It is composed of greenish, gray, purple, and reddish sands and sandy shale. Some beds contain fossil mollusks such as *Ostrea idriaensis* Gabb, *Potamides carbonicola* Cooper, and *Unio? torreyensis* M. A. Hanna, which suggests that they were deposited in shallow brackish water. The Delmar sandstone may correspond to some portion of the Capay formation.

The Torrey sand, 20 feet to 200 feet in thickness, conformably overlies the Delmar sand in some places, and lies directly upon the Black Mountain volcanics in others. This unit is well exposed in the bluffs along the Torrey Pines grade (fig. 3), and it can be seen as erosional remnants high on the hillsides in the general vicinity of the mouth of Soledad Canyon south of Del Mar. The beds are composed of coarse-grained sand that commonly is cross-bedded, and are white or locally reddish in coloration. Marine fossils have been found in them, almost all the species of which also occur in the overlying Rose Canyon shale. It seems quite possible that the Torrey sand reflects approximately the same type of geologic events as those suggested by the Eocene Ione formation in the foothills of the Sierra Nevada, farther north in the State. It probably was deposited in a lagoonal and near-shore environment during a period of humid, semi-tropical climate.

The Rose Canyon shale, 300 feet thick, lies conformably upon the Torrey sand over much of the La Jolla quadrangle. In places it rests directly upon the Black Mountain volcanics, or upon Cretaceous sedimentary rocks. It is composed mainly of gray to brownish shales and silty mudstones, with minor amounts of conglomerate and a few thin beds of poorly stratified limestone. It contains characteristic marine Eocene fossils such as *Discocyclina cloptoni* Vaughan, *Flabellum sandiegoensis* M. A. Hanna, *Acila decisa* Conrad, *Crassatellites semidentata* Cooper, *Pelecyora aequilateralis* Gabb, *Turritella applini* M. A. Hanna, and *Aturia myrli* M. A. Hanna. These fossils indicate upper Eocene, approximately Domengine age.

The Rose Canyon beds are covered by Pliocene strata south of San Diego, but they have been encountered in many wells in the southern part of the area and hence may have a fairly extensive distribution. An analysis of the mineral content of Rose Canyon shale underlying the Pliocene beds on the south side of Mission Valley suggests, according to G. A. MacDonald, that the climate at the time of deposition favored pronounced chemical weathering. This evidence of warm, humid conditions is substantiated by the fossil mollusks, which represent forms whose living relatives are warm-water forms.

*Poway Conglomerate.* The Poway conglomerate, about 1,000 feet in thickness, overlies the La Jolla formation, in places conformably and in others unconformably. It appears to be mostly of nonmarine origin, and is composed largely of rounded pebbles and boulders as much as 3 feet in diameter. Andesitic boulders are most abundant. This conglomerate can be seen high on the sides of canyons east of Soledad Mountain. Lenses of sandstone within the conglomerate have yielded fossil marine Foraminifera and mollusks including *Brachidontes ornatus* Gabb, *Cardium breweri* Gabb, *Crassatellites*

FIGURE 3. Air view southeastward from mouth of San Dieguito Valley, showing the Linda Vista Mesa, a northern extension of the San Diego Mesa; the type locality of the white, quartzose Eocene Torrey sand near the top of the highway grade; and a partial exposure of the Eocene Delmar siltstone and sandstone in the lower part of the near end of the beach cliff. *Fairchild Aerial Surveys photo, 1932.*

FIGURE 4. Air view southeastward toward La Jolla. Most of the buildings are on La Jolla terrace. A lower terrace lies between the broadly curving street and the shore, and a much higher, partially dissected and subdued terrace is present on the south flank of Soledad Mountain in the distance. The rocks along the shore are hard, concretionary sandstone of Cretaceous age. *Fairchild Aerial Surveys photo, 1932.*

*mulales* M. A. Hanna, *Ostrea idriaensis* Gabb, *Pitar uvasanus* Conrad, *Pteria* cf. *P. pellucida* Gabb, *Tellina tehachapi* Anderson & Hanna, *Conus remondii* Gabb, *Ficopsis remondii* Gabb, *Pseudaliva volutaeformis* Gabb, and *Turritella applini* M. A. Hanna. This assemblage of fossils is in general comparable to that of the upper Eocene type Tejon beds in Kern County to the north. Some vertebrate fossils also have been recovered from the Poway conglomerate; these, too, indicate on upper Eocene age.

*Absence of Oligocene and Miocene Rocks.* Oligocene sediments are lacking in this region, so far as is known; indeed, no sediments appear to represent the interval between Eocene and Pliocene. Recently, however, Emery et al. (1952, p. 523) have recorded the presence of Foraminifera in shaly beds that are interlayered with volcanic rocks on South Island, one of the Coronados Islands group, in Mexican waters just south of the international boundary. These Foraminifera are thought to represent a middle Miocene age. The associated volcanic rocks have been referred to the San Onofre breccia (see Woodford et al., Contribution 5, this chapter).

*Pliocene Rocks.* Pliocene fossils were identified by Dall in 1874 from beds in a water well dug in Cabrillo Canyon, Balboa Park, San Diego. These beds are a part of the San Diego formation, which is about 1,250 feet thick and is composed chiefly of yellowish and gray sandstone and siltstone, with minor amounts of conglomerate. This Pliocene formation lies with slight angular discordance upon the Rose Canyon shale, or, in places, on the Poway conglomerate or Black Mountain volcanics. It is well exposed at Pacific Beach, where it overlies Eocene beds and is overlain by Pleistocene sand, and is widely exposed in canyon and valley slopes in the San Diego Mesa. It is not known to occur north of the south slope of Soledad Mountain.

The San Diego formation contains typical invertebrate fossil echinoids and mollusks of middle Pliocene or early upper Pliocene age. Among these are *Dendraster ashleyi* Arnold, *Dendraster ashleyi ynezensis* Kew, *Lovenia hemphilli* Israelsky, *Merriamaster pacificus* Kew, *Arca trilineata* Conrad, *Ostrea erici* Hertlein, *Ostrea vespertina* Conrad, *Pecten bellus* Conrad, *Pecten (Lyropecten) cerrosensis* Gabb, *Pecten (Patinopecten) healeyi* Arnold, *Pecten (Swiftopecten) parmeleei* Dall, *Pecten (Pecten) stearnsii* Dall, *Pecten (Plagioctenium) subdolus* Hertlein, *Opalia anomala* Stearns, and *Opalia varicostata* Stearns. Beds containing many of the same species occur in the Santa Maria district, California, and at Cedros Island and Turtle Bay, Baja California. The fauna suggests water warmer than that now encountered in the San Diego region, and probably more like the present water in the vicinity of Cedros Island, Baja California.

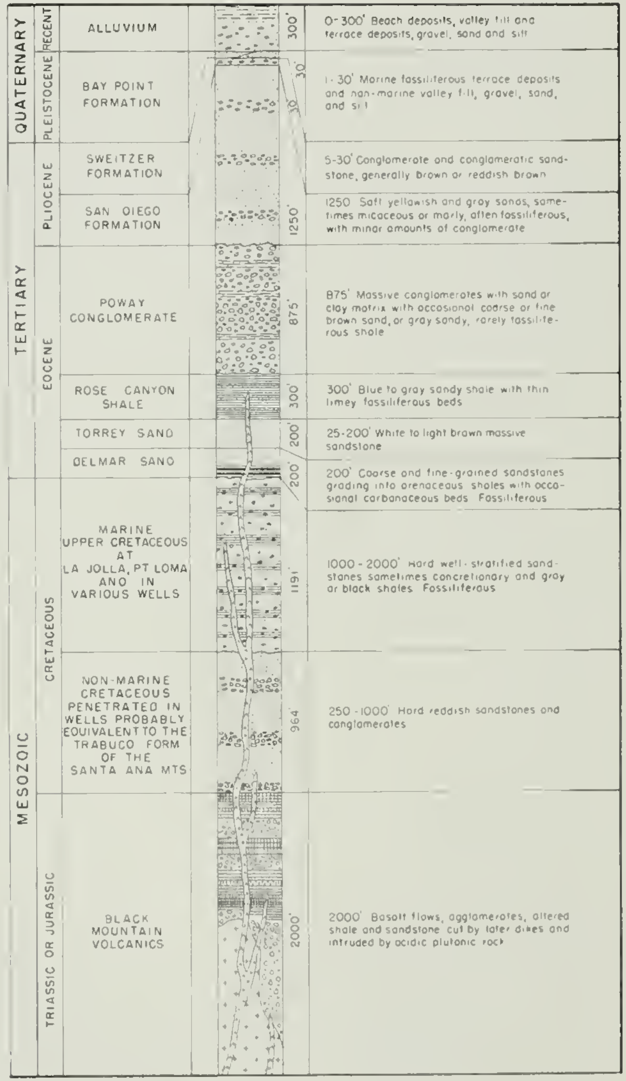


FIGURE 5. Columnar section of the rocks in southwestern San Diego County, as developed mainly from surface outcrops. Only the uppermost part of the Cretaceous section is exposed; the remainder has been encountered in various wells.

On the Sixth Avenue grade near Mercy Hospital, on the south side of Mission Valley, the Pliocene beds lie upon the Eocene Rose Canyon shale (fig. 2). Casts of *Trophosycon* have been found in the Pliocene beds at this place. Here the beds dip south about 10°; the dip, however, varies greatly from place to place, and only a short distance to the south the dip decreases and the beds are nearly horizontal.

The Pliocene rocks are mostly light brown, buff, or bluish gray, fine-grained sandstone, but local lenses of pebbles are present. A conglomerate that is more than 100 feet thick is exposed west of Tijuana. This and some other conglomerates apparently were deposited by rivers that drained the high mountainous areas to the east. Marly beds occur here and there on top of San Diego Mesa, chiefly near its eastern limits. Some cross-bedding, several lenses of conglomerate, and the absence of shale all suggest shallow-water deposition, possibly from low tide to a depth of 50 fathoms. The mineral grains are much fresher and less weathered than those in the Eocene rocks, possibly indicating a less warm and less humid climate.

Thin beds of bentonite occur on the sides of the mesa in Otay and Las Chollas Valleys, and in a shaft sunk near the Natural History Museum in Balboa Park, San Diego. These represent the only evidence of volcanic activity in this area during the Pliocene epoch, but volcanic rocks of probable Pliocene age are widely distributed in areas only a few miles south of the Mexican boundary.

Samples of sediments dredged from the sea floor off San Diego are lithologically similar to the San Diego formation and to the overlying Sweitzer beds. These have been described by Emery, et al. (1952, p. 525). Possibly a Pliocene wedge of shallow-water sediments extends for some distance west of the present shoreline.

*Sweitzer Formation.* The San Diego formation is unconformably overlain by a stratum of reddish-brown conglomerate and pebbly sandstone about 20 feet in maximum thickness. This is known as the Sweitzer formation. It can be seen capping most of the mesas south of Mission Valley, and a similar formation on the mesa north of Mission Valley may be a correlative. At places it continues as a blanket over the edges of the Otay terrace (mesa top) to lower terraces. No fossils have been found in these beds, which may be of late Pliocene or early Pleistocene age. The general mineral content is similar to that of the San Diego formation, and indicates that the rate of erosion in the source area was rapid in comparison to the rate of weathering of the mineral particles.

*Pleistocene Deposits.* Marine fossiliferous Pleistocene deposits occur as terrace material at many localities along the coast, and are especially well developed near San Diego, at Pacific Beach, and in Mission Bay at the west side of Bay Point or Crown Point. Excellent exposures once were available at the foot of Twenty Sixth Street in San Diego, as well as on the west side of Spanish Bight, but most of these are now covered.

The Pleistocene deposits are thin and have a maximum known thickness of 30 feet. They contain marine fossils, some of which are warm-water species not now living north of Scammon Lagoon, Baja California. The list of warm-water species includes *Cardium procerum*, *Chione gnidia*, *Dosinia ponderosa*, and *Turritella gonostoma broderipiana*. A terrace deposit on the west side of Point Loma contains species now living in the same region. It apparently is younger than the terrace beds at Pacific Beach and Mission Bay. Other similar terraces are present at low altitudes at numerous localities along the coast.

Some of the non-fossiliferous terrace cover and deeper valley fill may be Pleistocene in age. Recent alluvium occurs in most of the valley bottoms, delta flats, and bay flats.

## STRUCTURE

There has been but little folding in the rocks of post-Black Mountain age. This may be due to the thin cover of sediments overlying the Black Mountain volcanics and metamorphics, and the crystalline rocks that intrude them. In this area the entire Cretaceous and Tertiary section is less than a mile thick, whereas more than 5 miles of sedimentary cover is present in the Ventura basin and the San Joaquin Valley.

The only major fold in the Oceanside-San Diego area is the asymmetrical anticline about a quarter of a mile northeast of the summit of Soledad Mountain (fig. 6). It trends northwest, and has a nearly vertical north limb and a gently dipping south limb. This fold appears to grade into a fault along Rose Canyon, where the beds near the Santa Fe Railroad trestle have a steep northerly dip. The presence of a fault in Rose Canyon is evidenced by the difference in altitude of beds on opposite sides of the canyon. Apparently the southwest side moved northwestward, and beds on the west side of Mission Bay dropped down with respect to the beds on the east.

The Pliocene beds on the south slope of Soledad Mountain dip about 8° SE., an angle probably higher than their slope of initial deposition, and terraces on Soledad Mountain are higher than those that may be their correlatives in the mesa lands to the east. No evidence of Pliocene beds has been found on the north slope of Point Loma, and it appears that Mission Bay represents a syncline, the south limb of which has been dropped down along the north side of Point Loma by a fault that trends along Mission Valley. The beds

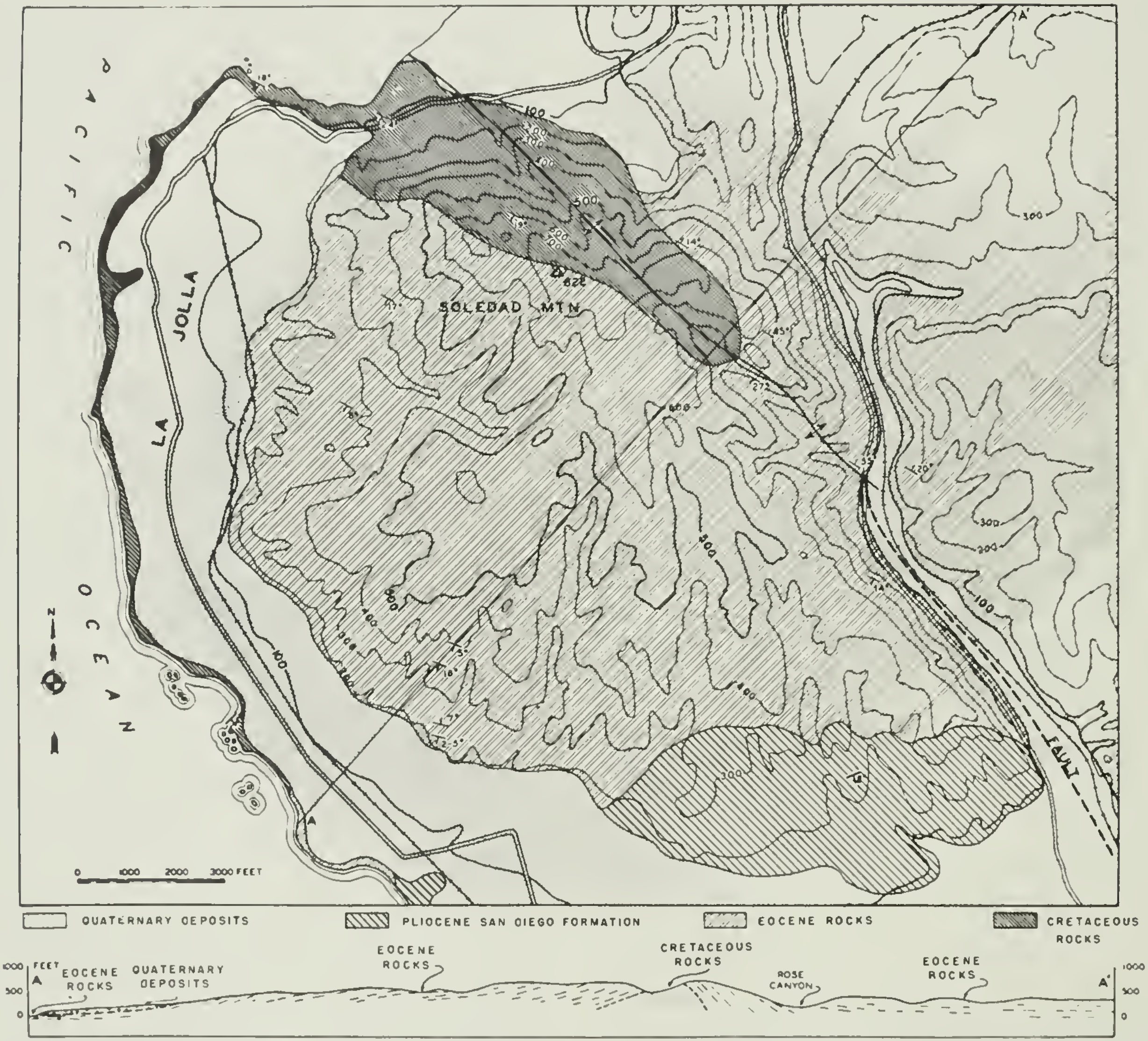


FIGURE 6. Geologic map and cross-section of the Soledad Mountain area. The thin veneer of terrace deposits is not shown on the map or section, but the Pleistocene and Recent alluvium on La Jolla terrace have been combined, and are shown together as Quaternary.

on Point Loma dip eastward 10° to 12°, and it appears likely that these beds have been tilted because of faulting along the western side of this block. Whether or not the Rose Canyon fault continues into San Diego Bay is not known.

The dip of most of the San Diego Pliocene beds is low, ranging from 6° to horizontal. Some of the conglomeratic beds in the Pliocene section along the international boundary near Tijuana dip about 9° W. These might represent foreset beds of an old delta that may have been tilted after its development.

Several small normal faults with a few feet of throw are exposed in bluffs and roadcuts in the mesa region south and east of San Diego. These and other small faults in the sea cliffs north of La Jolla are not shown on the accompanying map (fig. 1).

## ECONOMIC GEOLOGY

More than fifty wells have been drilled in this area in an unsuccessful search for petroleum. The deepest holes reached points more than 5,000 feet beneath the surface, and penetrated the Black Mountain volcanics and metamorphics.

Some of the crystalline rocks in the area have been used for building purposes and for road metal. Clay for bricks and pottery has been obtained from the Eocene and Pliocene sediments. Bentonite has been mined at times from Pliocene beds on Otay Mesa. Common salt (NaCl), bromine, and magnesium salts have been obtained by solar evaporation of sea water in San Diego Bay.

## REFERENCES

Arnold, Ralph, 1903, The paleontology and stratigraphy of the marine Pliocene and Pleistocene of San Pedro, California: California Acad. Sci. Mem., vol. 3, pp. 1-420. Reprinted as Contributions from the Hopkins Seaside Laboratory of Leland Stanford Jr., University, XXXI.

Bandy, O. L., 1951, Upper Cretaceous Foraminifera from the Carlsbad area, San Diego County, California: Jour. Paleontology, vol. 25, pp. 488-513.

Ellis, A. J., and Lee, C. H., 1919, Geology and ground waters of the western part of San Diego County, California: U. S. Geol. Survey Water-Supply Paper 446, 321 pp.

Emerson, W. K., and Addicott, W. O., 1953, a Pleistocene invertebrate fauna from the southwest corner of San Diego County, California: San Diego Soc. Nat. History Trans., vol. 11, No. 17, pp. 429-444.

Emery, K. O., Butcher, W. S., Gould, H. R., and Shepard, F. P., 1952, Submarine geology off San Diego, California: Jour. Geology, vol. 60, pp. 511-548.

Fairbanks, H. W., 1893, Geology of San Diego County; also portions of Orange and San Bernardino Counties: California Min. Bur. Rept. 11, pp. 76-120.

Goodyear, W. A., 1888, San Diego County: California Min. Bur. Rept. 8, pp. 516-528.

Goodyear, W. A., 1889, San Diego County: California Min. Bur. 9th Rept., pp. 139-154.

Hanna, M. A., 1926, Geology of the La Jolla quadrangle, California: Univ. California, Dept. Geol. Sci. Bull., vol. 16, pp. 187-246.

Hanna, M. A., 1927, An Eocene invertebrate fauna from the La Jolla quadrangle, California: Univ. California, Dept. Geol. Sci. Bull., vol. 16, pp. 247-398.

Hertlein, L. G., and Grant, U. S., IV, 1939, Geology and oil possibilities of southwestern San Diego County: California Jour. Mines and Geology, vol. 35, pp. 57-78.

Hertlein, L. G., and Grant, U. S., IV, 1943, Southwestern San Diego County: California Div. Mines Bull. 118, pp. 367-369.

Hertlein, L. G., and Grant, U. S., IV, 1944, The geology and paleontology of the marine Pliocene of San Diego, California. Pt. 1. Geology: San Diego Soc. Nat. History Mem., vol. 2, pp. 1-72.

Hinds, N. E. A., 1952, Evolution of the California landscape: California Div. Mines Bull. 158, pp. 206-212.

Merrill, F. J. H., 1916, The counties of San Diego, Imperial: California Min. Bur. Rept. 14, pp. 635-743. Also issued separately and titled Mines and mineral resources of the counties of San Diego, Imperial: California Min. Bur., December 1914, pp. 1-113.

Stephens, Frank, 1929, Notes on the marine Pleistocene deposits of San Diego County, California: San Diego Soc. Nat. History Trans., vol. 5, pp. 245-256.

Webb, R. W., 1937, Paleontology of the Pleistocene of Point Loma, San Diego County, California: San Diego Soc. Nat. History Trans., vol. 8, pp. 337-348.