Monte Marshall

WILLIAM J. ELLIOTT

PACIFIC SLOPE GEOLOGY OF NORTHERN BAJA CALIFORNIA AND ADJACENT ALTA CALIFORNIA

Geological Guidebook for the 1970 Fall Field Trip of the Pacific Sections of the American Association of Petroleum Geologists, the Society of Economic Paleontologists and Mineralogists, and the Society of Economic Geophysicists

Field Trip Committee:

Edwin C. Allison	San Diego State College, San Diego, California
M. G. Acosta	Mobil Oil Corp., Los Angeles, California
Donald L. Fife	California Division of Mines and Geology, Los Angeles, California
John A. Minch	University of California, Riverside, California
Katsuo Nishikawa	Instituto de Investigaciones Oceanologicas, Ensenada, Baja California

6-8 November 1970

Ensenada, Baja California, México

GRAVITY SURVEY AND REGIONAL GEOLOGY OF THE SAN DIEGO EMBAYMENT, SOUTHWEST SAN DIEGO COUNTY, CALIFORNIA*

William J. Elliott, Southern California Testing Laboratory Inc., San Diego, California

INTRODUCTION

During the summer of 1963, a regional study of the Peninsular Ranges batholith was undertaken by Dr. R. Gordon Gastil, Dr. E. C. Allison, and students at San Diego State College and the Universidad Autonoma de Baja California (Ensenada). Along with areal mapping, a regional gravity survey was continued over several summers. The purpose of this survey was to provide additional information regarding the nature of the Peninsular Ranges batholith and its relationship with surrounding sedimentary and metamorphic rocks. Because of poor horizontal and vertical elevation control in Baja California, the gravity survey was started in San Diego County where U.S.G.S. topographic maps and U.S.C.&G.S. level lines provided adequate control. During subsequent summers in Baja California, altimeters, student transit surveys and a small number of benchmarks were used for vertical control. Thirty-three degrees north latitude was chosen as the northern boundary for the survey which would eventually reach far south into Baja California. The author worked primarily in western San Diego County with some reconnaissance lines extending east into the Peninsular Ranges and south into Baja California. This paper covers only work done in the San Diego and La Jolla quadrangles and in the western third of El Cajon and Jamul quadrangles (Fig. 1).

The purpose of this paper is to present the results and interpretation of gravity and geologic studies to determine (1) the depth and configuration of the basement surface (pre-Upper Cretaceous), and (2) the thickness and extent of sedimentary formations in the San Diego area. Interpretation was done in two phases. First, a basement map was constructed using the simple Bouguer gravity map, available well data and surface geology (Figs. 2 and 3; see Weber, 1963, for geologic map). Second, isochore maps of the Upper Cretaceous Rosario Formation and the total Eocene formations were constructed using the basement map as a base, formation thicknesses from wells and surface geology (Figs. 4 and 5). Finally, three east-west structure sections were constructed to illustrate the vertical geology in the San Diego Embayment (Fig. 6).

PREVIOUS WORK

Prior to 1963, no gravity mapping had been completed in the immediate area of this investigation. The reader is referred to gravity papers in surrounding areas for further information: Biehler (1965), Chapman (1966), Harrison <u>et al</u>. (1966), Kovach <u>et al</u>. (1962), McCulloh (1960), Slyker <u>et al</u>. (1966), and Worzel and Harrison (1963). Unpublished senior thesis gravity projects have been completed in the San Diego area by students at San Diego State College (Mattick, 1961; Bjerregaard, 1962; Elliott, 1964; and Slyker, 1964).

For previous geologic papers in this area the reader is referred to Weber (1963) for a comprehensive bibliography and to other papers in this guidebook.

GEOLOGIC SETTING

The area of investigation lies in the northwestern portion of the Peninsular Ranges Province of Southern California. Three west to east physiographic-petrographic

*Supported by NSF Grant No. GE-1209; this paper is an expanded version of a talk presented to the AAPG-SEPM at Long Beach (Elliott, 1966).

divisions can be recognized in the province: (1) coast marine sedimentary rocks, (2) foothill volcanic, plutonic and metamorphic rocks, and (3) central plutonic and metamorphic rocks. Together, these divisions comprise the westward tilted fault block which represents the regional structure (Gastil, 1961, p. 1-3; Hinds, 1952, p. 197-215).

Lower Cretaceous Alisitos sedimentary and volcanic rocks, Upper Jurassic Santiago Peak volcanic and sedimentary rocks (Fife et al., 1967) and older sedimentary rocks of the Julian Schist series are metamorphosed, folded and faulted as consequences of the Middle Cretaceous (130-105 m.y., Bushee, et al., 1963) Peninsular Ranges orogeny. Upper Cretaceous sedimentary rocks of the Rosario Formation rest on an irregular topography formed by deformed and eroded crystalline rocks of Lower Cretaceous and older formations (Peterson and Nordstrom, 1970; contributions of this guidebook). Eocene mudstones, sandstones, and conglomerates overlie Rosario and underlying rocks with marked disconformable and nonconformable distinctions but generally with slight angular discordances. Pliocene and Pleistocene strata are even less deformed (Weber, 1963; Thomas, 1961).

THE GRAVITY SURVEY

Three hundred and eighty-eight gravity stations were occupied in the study area (Fig. 1) with a student model Worden gravity meter. Sixty-five of these stations in the La Jolla-Del Mar area were metered by Bob Slyker (1964) for his senior thesis. One to two mile station spacing was maintained over most of the area except in some remote eastern parts where control was limited by access roads. Gravity stations are not shown on the Bouguer Map (Fig. 2), small circles shown are abandoned oil wells. All stations were tied to gravity station WA-85 at Lindbergh Field, San Diego (Behrendt and Woollard, 1961; Chapman, 1966).

The gravity data were reduced to a mean sea level datum by standard methods found in Dobrin (1960), Jakosky (1957) and Nettleton (1940). Corrections were made for drift, elevation and latitude. Terrain corrections at selected stations were generally less than one milligal and were therefore not computed for most of the area.

Within the study area, three different elevation factors (k) were used for smaller individual senior thesis areas. Bob Slyker (1964) used k = 0.0648 (2.3 gm/cc) and computed terrain corrections for all of his stations in the La Jolla-Del Mar area. The author (1964) used k = 0.066 (2.2 gm/cc) in the San Ysidro area and did not compute terrain corrections. Throughout the remainder of the area k = 0.060 (2.67 gm/cc) was used and terrain corrections were not computed. Data from all three k factor reductions were integrated together onto one Bouguer Gravity Map (Fig. 2). Different k factors within the mapped area were easily joined together to form Figure 2 because of low station elevation and wide spacing; contour shapes remained nearly constant.

Data reduction was carried out to 0.1 mgals with a probable maximum cumulative error of 0.5 mgals per station due to instrument, elevation and latitude errors. Original Bouguer map contouring was at 2.0 mgals and re-drawn at 5.0 mgals for this presentation and regional interpretation.

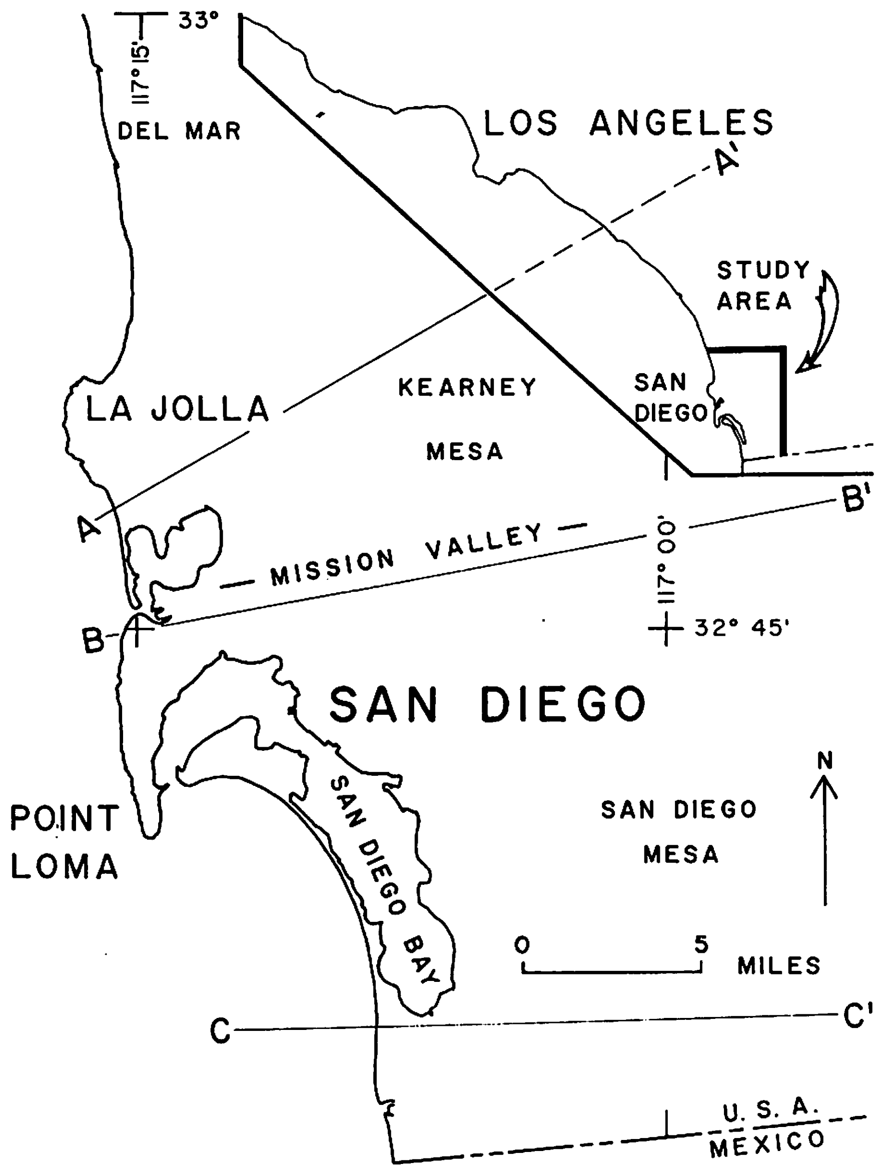
Rock density information in the San Diego area is sparse. Crystalline plutonic and metamorphic basement rock densities were assumed to be 2.67 gm/cc (Nettleton, 1940, p. 101). Pre-batholith Santiago Peak meta-volcanic rock densities measured by the author averaged 2.80 to 2.85 gm/cc. Density data were not available for Upper Cretaceous, Eocene and Plio-Pleistocene sedimentary rocks, however, densities of 2.4, 2.3, and 2.2 gm/cc respectively can be reasonably assumed (Nettleton, 1940, p. 101, and Jakosky, 1957, p. 264-266). Density contrasts, actually used in gravity calculations, were found to range from 0.3 to 0.6 gm/cc for good agreement with known geology.

The simple Bouguer gravity map shows several prominent features and trends (Fig. 2). An estimated -1 to -3 mgal/mile easterly regional gradient was not removed.

Figure 1. Index map showing the area covered by the gravity survey and regional geologic study of the San Diego Embayment, southwest San Diego County, California. Structure section locations A-A', B-B', and C-C', and the four post-batholith structural-stratigraphic blocks: Point Loma, La Jolla, San Diego Mesa, and Kearney Mesa are shown.

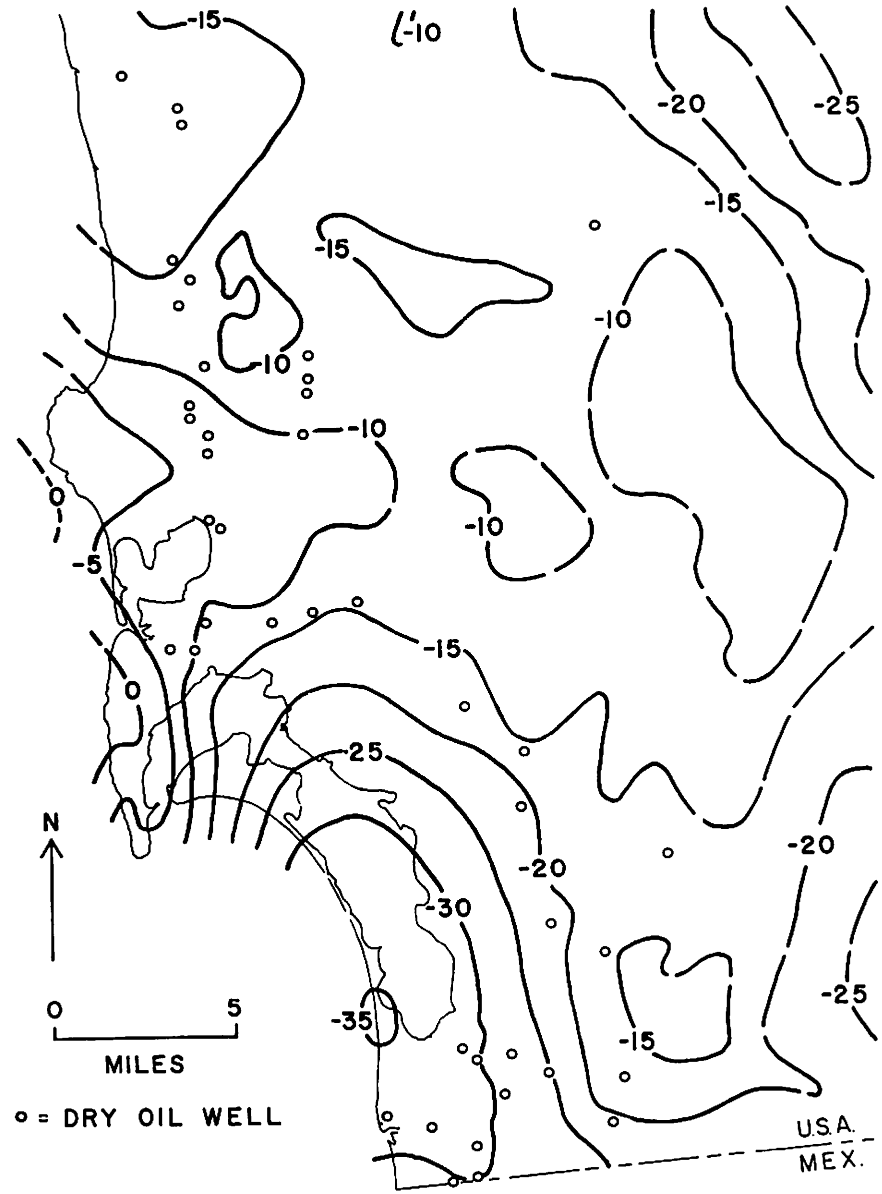
Figure 2. Simple Bouguer gravity map. 388 gravity stations at 1 to 2 mile spacing, contoured at 5 mgals. Minimum anomalies in northwest and southwest parts of the map are caused by Upper Cretaceous and Cenozoic sedimentary rocks; minimum anomalies in the northeast and southeast part of the map are caused by rooted sialic batholith complex rocks. Small circles are abandoned dry oil wells.

FIGURE 1



INDEX MAP
SOUTHWEST SAN DIEGO COUNTY
CALIFORNIA

FIGURE 2



BOUGUER GRAVITY MAP
388 GRAVITY STATIONS SPACED 1-2 MILES

Sufficient relief appeared to be present on major features to make regional interpretations. In general, gravity contours trend north-northwest subparallel to surface geologic units and the Peninsular Ranges (Figs. 2, 3, 4, and 5). Minimum gravity anomalies over sialic batholith rocks exposed in the northeastern portion of the area are at least -26 mgals and decrease to -70 mgals several miles to the east near the center of the Peninsular Ranges batholith (not shown on Fig. 2). Minimum anomalies such as this indicate that the Peninsular Ranges batholith has sialic roots. Through the central portion of the map along the belt of dense (2.85 gm/cc) Santiago Peak meta-volcanic rocks, an undulating contour pattern and small positive anomalies occur over larger Santiago Peak meta-volcanic exposures. This area represents a transition zone between crystalline basement rocks to the east and sedimentary rocks to the west. Near Del Mar, in the northwest corner of the area, a gravity minimum shown by the open -15 mgal contour decreases to -19 mgals near the center and appears to be opening up to become more negative offshore. This gravity minimum is due to less dense sedimentary section. Near shore and estuarine Eocene formations in the Del Mar area may be the southeastern edge of a much larger basin extending northwestward, offshore. In the San Diego Bay area the broad northwest trending -36 mgal minimum anomaly is due to a ±6,000 foot deep sedimentary basin. A recently drilled well (1962) near the south end of San Diego Bay, penetrated approximately 530 m (1,750 ft.) of Pliocene, 610 m (2,000 ft.) of Eocene, and 460 m (1,500 ft.) of Upper Cretaceous sedimentary rocks before penetrating probable Santiago Peak meta-volcanic rocks at about 5,250 feet. This basin probably represents the onshore edge of a much larger and deeper offshore sedimentary basin extending westward. At La Jolla and Point Loma, in the west central part of the area, near zero and +4 mgal contours represent positive anomalies over exposed Upper Cretaceous rocks as well as a positive offshore gradient toward the continental borderland. The steep 9 mgal/mile gradient just east of Point Loma at the north end of San Diego Bay probably represents a fault contact between Upper Cretaceous and younger sediments, and is probably the southward extension or a branch of the Rose Canyon fault in the La Jolla area (Figs. 4, 5, and 6).

INTERPRETATION OF THE SAN DIEGO EMBAYMENT

A generalized interpretation of the San Diego Embayment is based on the newly completed Bouguer gravity map, well data, and surface geology. Well data comes from published sources (Hertlein and Grant, 1939; and Jennings and Hart, 1956; California Division of Oil and Gas open files; and oral communication with well owners). Surface geology was obtained from Weber (1968), Strand (1962) and others.

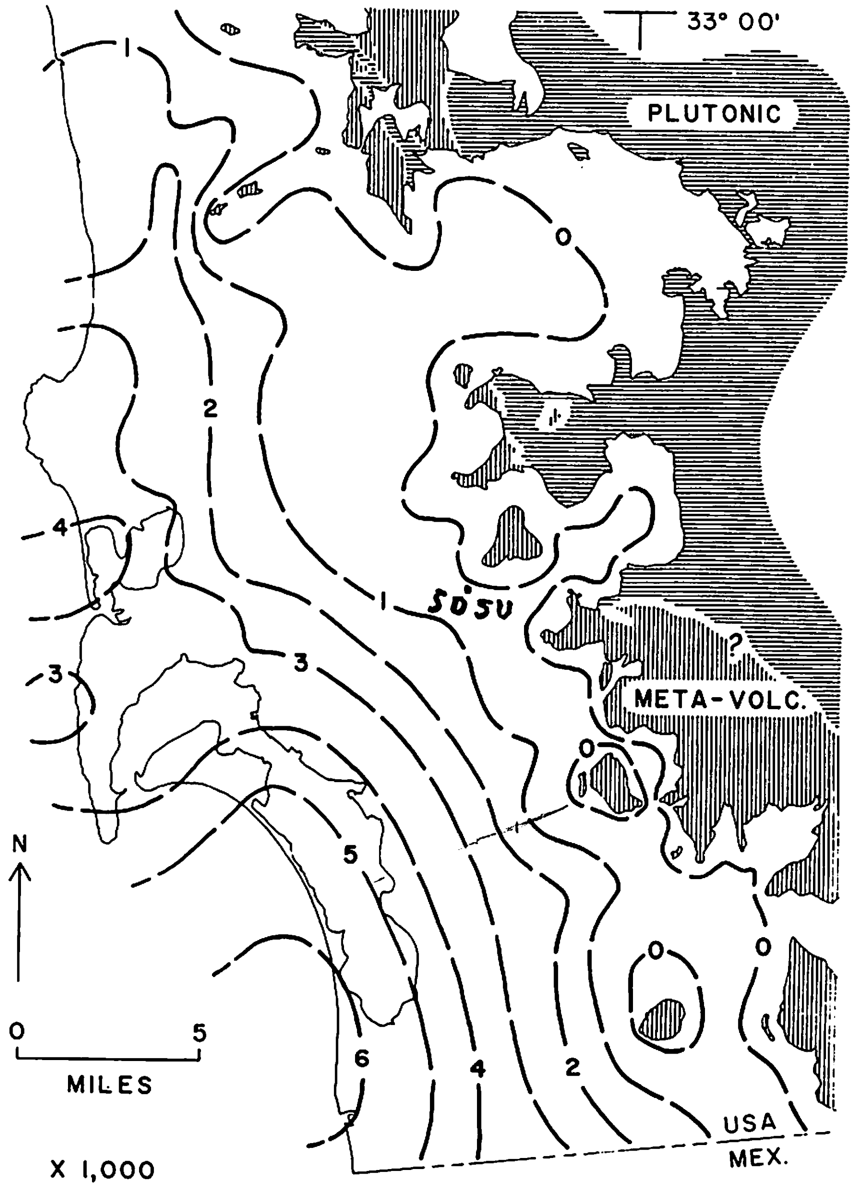
Three maps and structure sections (Figs. 3, 4, 5, and 6) illustrate the general configuration of the basement surface, and thickness and distribution of the Upper Cretaceous and Eocene sedimentary formations. Intersecting structure sections provide consistent 3-D interpretation. The basement surface map, constructed first, is based on surface geology, 19 wells believed to have penetrated basement, and Bouguer gravity to add shape and depth in uncontrolled areas (Fig. 3, control wells not shown). An isochore map of the Upper Cretaceous Rosario Formation, constructed next, employs the basement structure contour map (Fig. 3) as a base and adds thicknesses of Upper Cretaceous sedimentary rocks found in outcrop and in wells (Fig. 4, control wells not shown). An isochore map of Eocene formations, constructed third, uses intermediate structure map on top of basement-Upper Cretaceous as a base and adding the thicknesses of Eocene sedimentary rocks found in outcrop and wells (Fig. 5, control wells not shown). Finally, three east-west structure sections constructed from the foregoing maps show vertical dimensions (Fig. 6). Note that gravity is used only to determine basin depth and shape and not thicknesses or extent of individual units within the basin. The principal gravity contrast is between basement and overlying sedimentary rocks; individual density contrasts within the sedimentary section are relatively weak.

A combined basement outcrop and structural contour map (Fig. 3) outlines a basement surface which dips gently beneath a westward thickening wedge of Upper Cretaceous and Cenozoic strata. That surface has a maximum depth of about -1800 m (-6000 ft.)

Figure 3. Structural contour map on top of basement formations, crystalline batholith complex and Santiago Peak meta-volcanic rocks. The basement surface dips westerly and reaches a depth of 6,000+ feet at the southwest end of San Diego Bay. This paleotopography affected lithology and distribution of subsequent sedimentary formations.

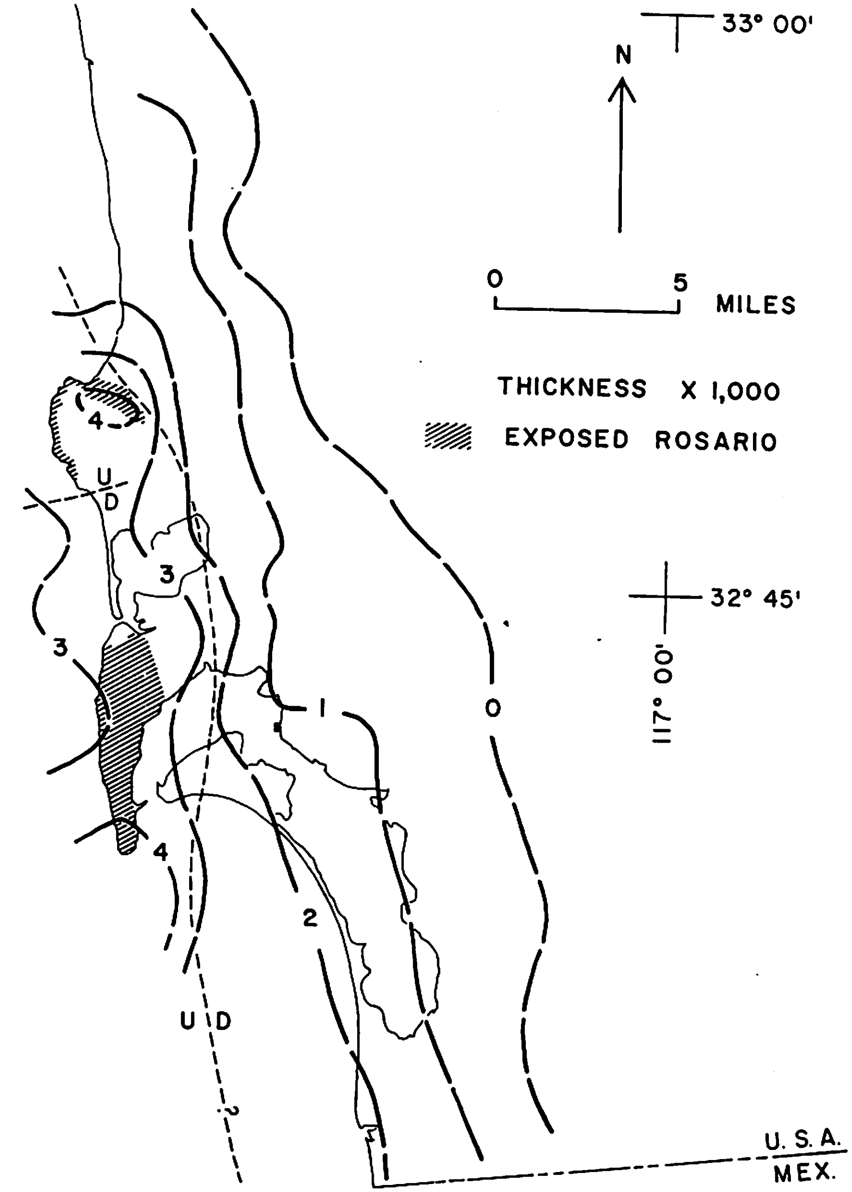
Figure 4. Isochore map of the Upper Cretaceous Rosario Formation. The formation thickens westward from a zero depositional edge to about 4,000 feet where it is exposed at Point Loma and La Jolla. Primary structures at Point Loma and La Jolla indicate a west to northwestward direction of transport and paleoslope.

FIGURE 3



STRUCTURAL CONTOUR MAP OF THE BASEMENT FORMATIONS

FIGURE 4



ISOCHORE MAP OF THE CRETACEOUS, ROSARIO FORMATION southwest of San Diego Bay and shallows to -900 m to -1200 m (-3000 ft. to -4000 ft.) under Point Loma and La Jolla. Prominent features within the map area include a southwestward trending high under Mission Bay and a westward trending ridge along Los Peñasquitos Canyon. Santiago Peak volcanics crop out along the trend of the latter feature.

These basement features mark and separate subareas with slightly different histories and have influenced the lithology and distribution of overlying sedimentary formations. The southwestern depressed area has repeatedly or continuously subsided since the Late Cretaceous, receiving up to 1800 m (6000 ft.) of mostly marine sediments while relatively stable areas northward and eastward have received less than 1000 m (3000 ft.) of sediment. Basement highs in the vicinity of Los Peñasquitos Canyon roughly correspond to the southern boundary of a large area of non-marine and marginal marine Eocene units, including the distinctive Torrey Sandstone and Delmar Sandstone.

The isochore map of the Upper Cretaceous Rosario Formation (Fig. 4) shows a 3 to 9 km (2 to 6 mi.) wide belt with a north-northwesterly trend. Its eastern zero edge forms the irregular western margin of a parallel belt of Santiago Peak basement rocks (Fig. 3). A Late Cretaceous shoreline was situated approximately parallel to and a few kilometers east of the present coast. Upper Cretaceous sections thicken westward towards Point Loma and La Jolla where they attain thicknesses to 1200 m (4000 ft.). Outcrop sedimentologic data there support this paleogeographic interpretation (Maytum and Elliot this guidebook). Upper Cretaceous rocks also are exposed on the sea floor and near Oceanside (Strand, 1962). The Rose Canyon Fault (Fig. 4) separates uplifted and deformed Upper Cretaceous and younger strata along the coast from nearly flat lying Eocene and younger strata exposed inland.

The isochore map of the Eocene formations (Fig. 5) includes the La Jolla Formation and Poway Conglomerate. Thicknesses and distributions of Eocene units are variable and irregular, ranging from a zero edge along the eastern part of the map to 760 m (2500 ft.) in the San Diego Bay area. Zero edges also occur at Point Loma and La Jolla where recent uplift and erosion has exposed underlying Upper Cretaceous rocks. Inland and south from Mission Valley, Eocene strata dip under Plio-Pleistocene strata and are encountered in wells near the south end of San Diego Bay at about -520 m (-1700 ft.) below sea level.

Relationships between and within major rock stratigraphic units above the crystalline basement are shown in 3 east-west structural sections (Fig. 6) across northern (A-A'), central (B-B'), and southern (C-C') parts of the map area. A westward dipping contact between Santiago Peak volcanic rocks and batholithic rocks is suggested. An absence of Miocene and other parts of the onshore post-Cretaceous stratal record offers interesting possibilities for hydrocarbon accumulations in offshore areas of up dip terminations of these missing sections.

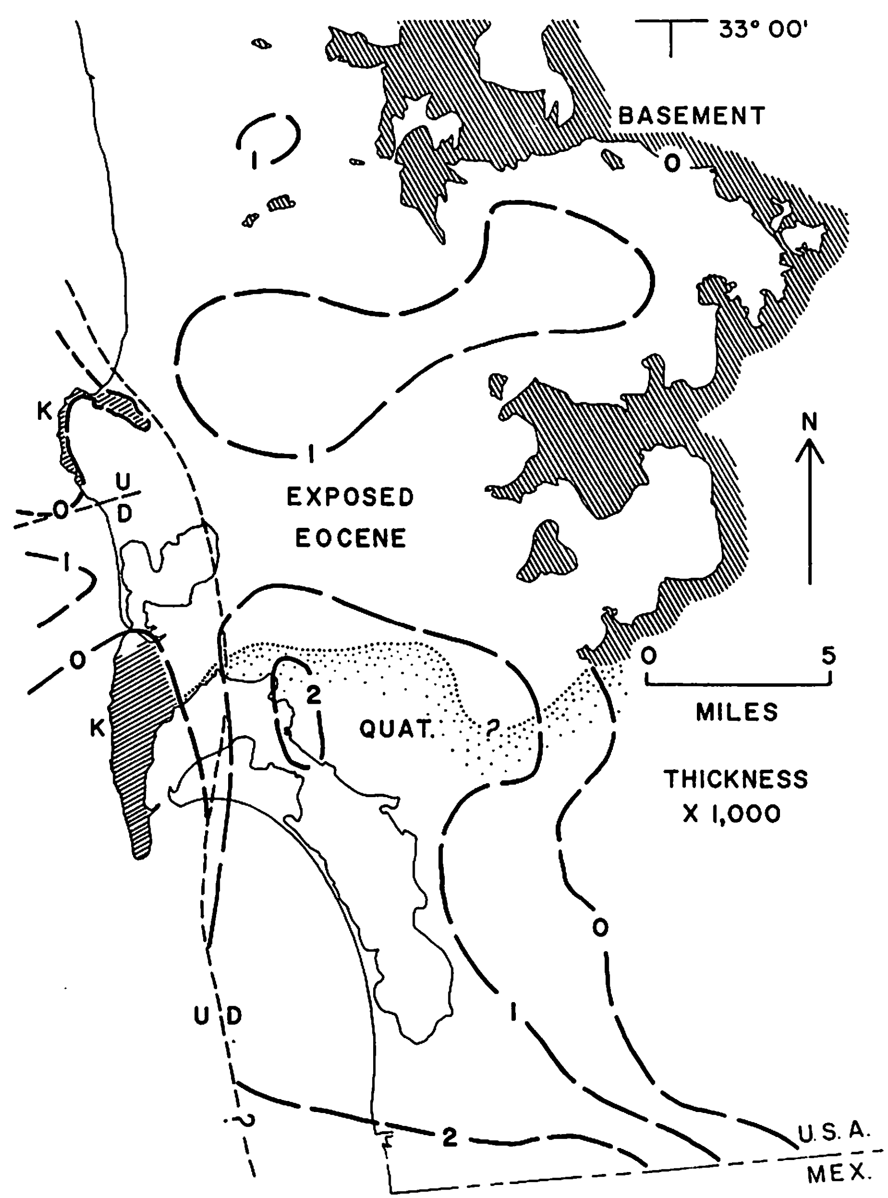
CONCLUSIONS

Bouguer gravity minimum anomalies along the west side of the map delineate the shape and size of an Upper Cretaceous-Cenozoic embayment which is deepest and best developed in the San Diego area. North-northwest trending maximum anomalies through the center of the map mark the eastern edge of Upper Cretaceous-Cenozoic deposition and follow the discontinuously exposed belt of Santiago Peak meta-volcanic rocks. Minimum anomalies along the eastern part of the map are over the western edge of the sialic crystalline batholith rocks. Structural contours on top of the Santiago Peak and crystalline batholith basement rocks show an irregular west dipping north-northwest trending surface. Paleotopographic irregularities on this surface have controlled the extend and distribution of younger formations. Upper Cretaceous rocks trend north-northwest and are confined to a narrow onshore belt which thickens westward from a zero shoreline to about 4000 feet in the La Jolla-Point Loma areas. Eocene rocks are more widely distributed to the east than are Upper Cretaceous rocks and fill many of the irregularitie and estuaries in the older topography. Eocene sections reach a maximum thickness of

Figure 5. Isochore map of the Eocene formations, La Jolla Formation and Poway Conglomerate. The Eocene thickens westward from an irregular depositional edge to 2,500+ feet around San Diego Bay. Zero erosional edges occur at Point Loma and La Jolla where Upper Cretaceous is exposed. Eocene rocks crop out in the north part of the area and are found at about -1,700 feet in deep wells near the south end of San Diego Bay.

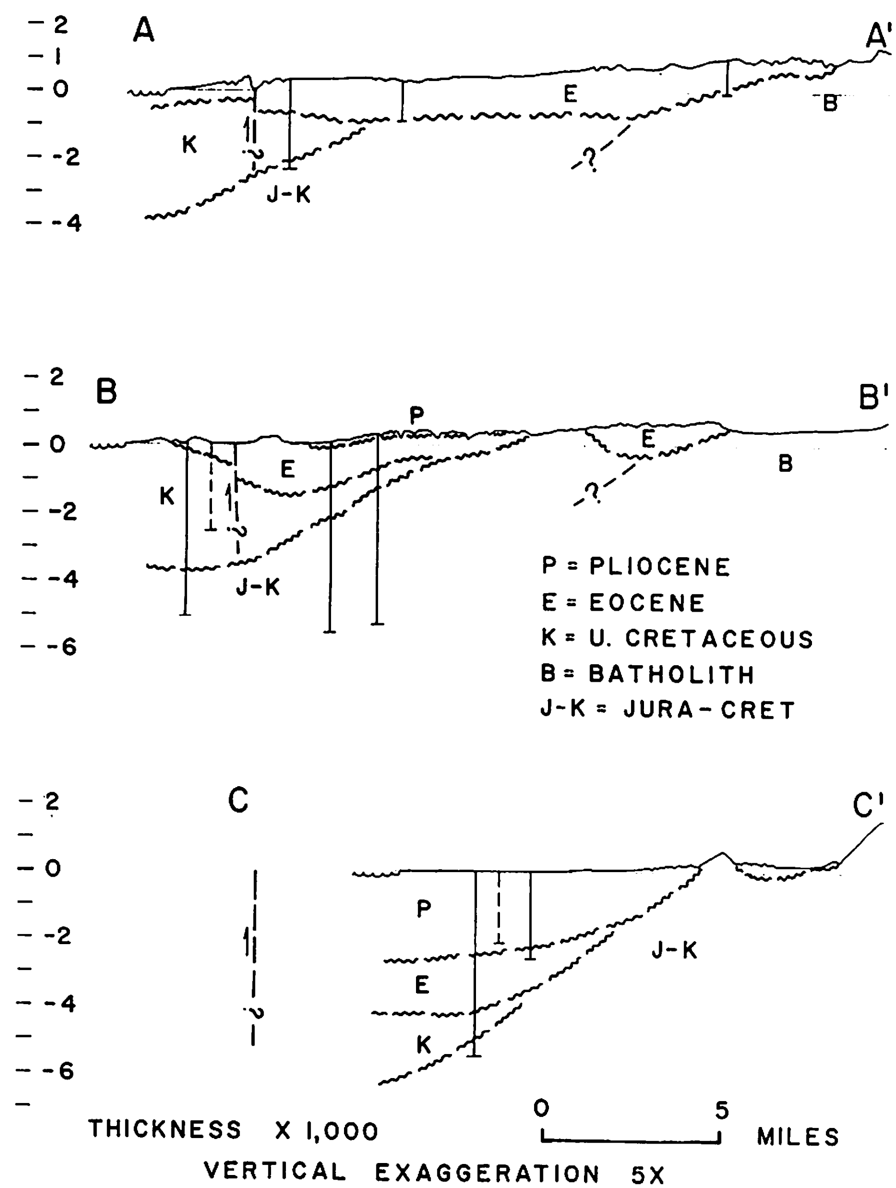
Figure 6. East-west structure sections showing vertical view in the northern, A-A', central, B-B', and southern C-C' part of the area. Upper Cretaceous rocks are restricted to the western part of the area. Eocene rocks were deposited over most of the area and buried by Pliocene sedimentary rocks to the south.

FIGURE 5



ISOCHORE MAP OF THE EOCENE FORMATIONS

FIGURE (



CROSS SECTIONS

SEE INDEX MAP FOR LOCATIONS

about 600 m (2000 ft.) in the San Diego Bay area and thin to a depositional zero eastward. Up to 760 m (2500 ft.) of marine Pliocene rocks are found in the San Diego Bay area and only a thin veneer of Pleistocene rocks mantles older formations to the north and east. East-west structure sections illustrate the eastward thinning and shoreline locations of Late Cretaceous and younger formations and the possibilities of updip stratigraphic hydrocarbon accumulations. Miocene rocks which occur on the Coronado Islands offshore to the southwest pinch out or are faulted out before reaching the San Diego Area.

The San Diego area can be divided into four distinct post-batholith structural blocks separated by an east-west hinge line through Mission Valley, and the north-south trending Rose Canyon Fault. Each block has had a distinctly different structural and sedimentary history. West of the Rose Canyon fault, sedimentary rocks have been uplifted, tilted and folded whereas to the east little or no deformation has occurred. South of the Mission Valley hinge line, thick sediments have accumulated on a sinking block, while north of the hinge line, thinner sediments have accumulated on a stable block. The northwest La Jolla block has been uplifted, folded, faulted and eroded exposing Upper Cretaceous and Eocene rocks. The southwest Point Loma block, separated from the La Jolla block by synclinal Mission Bay, has been uplifted, tilted eastward and eroded exposing Upper Cretaceous and Eocene rocks. It is unlikely that any significant Pliocene deposition occurred on either of these two blocks, although a Pleistocene veneer covers much of these areas. The southeast San Diego block has received about 600 m (2000 ft.) each of Upper Cretaceous, Eocene, and Pliocene sedimentary rocks and probably has been sinking more or less continuously since the Late Cretaceous. Across the Mission Valley hinge line, the northeast Kearney Mesa block has remained relatively stable and has received only about 300 m (1000 ft.) of Eocene sediment and a thin veneer of Pleistocene sedimentary rocks. Batholith and older rocks along the eastern part of the area form a block which has been relatively stable throughout most of Upper Cretaceous and Cenozoic depositional time. For the last 100 m.y. or so, the San Diego area has remained at the eastern edge of the San Diego embayment.

ACKNOWLEDGMENTS

Most of the gravity survey was financed through National Science Foundation grant No. GE-1209. Dr. R. Gordon Gastil, Dr. E. C. Allison and most of the student summer participants in the 1963 N.S.F. project helped with various phases of field work and data reduction. Drs. R. Phillips, E. Roberts, R. Berry, and G. Peterson offered many suggestions regarding theoretical parts of the investigation and interpretation. Bob Slyker metered most of the La Jolla-Del Mar area and helped in the interpretation with stimulating discussions. Mr. Robert Egger kindly loaned the author electric logs of the Egger No. 1 oil well, abandoned.

REFERENCES

Behrendt, J. C., and Woolard, G. P., 1961, An evaluation of the gravity control network in North America: Geophysics, v. 26, p. 57-76.

Biehler, Shawn, 1965, Gravity studies in Southern California: Trans., Am. Geophysical Union, v. 46, n. 3, p. 557-560.

Bjerregaard, Robert, 1962, Investigation of the gravity anomaly over the Peninsular Range of Southern California: Senior Thesis, San Diego State College, Unpublished.

Bushee, J., Holden, J., Geyer, B., and Gastil, G., 1963, Lead-Alpha dates for some basement rocks of southwestern California: Geol. Soc. America Bull., v. 74, p. 803-806.

Chapman, Rodger H., 1966, Gravity base station network: Calif. Div. Mines and Geology, Spec. Rept. 90, 49 p.

Dobrin, M. B., 1960, Introduction to geophysical prospecting: McGraw-Hill Book Co. Inc., N. Y., p. 169-262.

Elliott, W. J., 1964, Gravity survey of the southeast quarter of the San Diego quadrangle, California: Senior Thesis, San Diego State College, Unpublished.

Elliott, W. J., 1966, Gravity survey and analysis of San Diego Embayment, southwest San Diego County, California (Abs.): Am. Assoc. Petroleum Geologists Bull., v. 50, p. 646-647.

Elliott, W. J., and Maytum, J. R., 1966, Sedimentary structures in the Late Cretaceous Rosario Formation, San Diego County, California (Abs.): Geol. Soc. America Spec. Paper 87, p. 202.

Fife, D. L., Minch, J. A., and Crampton, P. J., 1967, Late Jurassic age of the Santiago Peak Volcanics, California: Geol. Soc. America Bull., v. 78, p. 299-304.

Gastil, R. G., 1961, The elevated erosion surfaces: in Guidebook for Field Trips, Geol. Soc. America Meetings at San Diego State College, B. E. Thomas Ed., p. 1-3.

Harrison, J. C., von Huene, R. E., and Corbato, C. E., 1966, Bouguer gravity anomalies and magnetic anomalies off the coast of Southern California: Jour. Geophy. Research, v. 71, n. 20, p. 4921-4941.

Hertlein, L. G., and Grant, U. S., IV, 1939, Geology and oil possibilities of southwestern San Diego County: Calif. Jour. Mines and Geol., v. 35, n. 1, p. 57-78.

Hertlein, L. G., and Grant, U. S., IV, 1954, Geology of the Oceanside-San Diego coastal area, Southern California: Calif. Div. Mines Bull. 170, ch. 2, p. 53-63.

Hinds, N. E. A., 1952, Evolution of the California landscape: Calif. Div. Mines Bull. 158, p. 197-215.

Jakosky, J. J., 1957, Exploration geophysics: Trija Pub. Co., Newport Beach, Calif., 2nd ed., p. 247-436.

Jennings, Charles W., and Hart, Earl W., 1956, Exploratory wells drilled outside of oil and gas fields in California to December 31, 1953: Calif. Div. Mines Spec. Rept. 45, p. 71, 104 p., 1 map.

Kovach, Robert L., Allen, Clarence R., and Press, Frank, 1962, Geophysical investigations in the Colorado Delta Region: Jour. Geophysical Research, v. 67, no. 7, p. 2845-2871.

Mattick, Robert E., 1961, Isostasy determination in the Jacumba Mountains and Imperial Valley region of Southern California: Senior Thesis, San Diego State College, Unpublished.

McCulloh, T. H., 1960, Gravity variation and the geology of the Los Angeles Basin of California: U. S. Geol. Survey Prof. Paper 400-B, p. B320-B325.

Milow, E. D., and Ennis, D. B., 1961, Guide to geologic field trip of southwestern San Diego County: in Guidebook for Field Trips, Geol. Soc. America meeting at San Diego State College, B. E. Thomas Ed., p. 23-43.

Peterson, G. L., and Nordstrom, C. E., 1970, Sub-La Jolla unconformity in the vicinity of San Diego, California: A.A.P.G. Bull., v. 54, n. 2, p. 265-274.

Slyker, Robert, 1964, A gravity investigation of the western part of the La Jolla quadrangle, San Diego County, California: Senior Thesis, San Diego State College, Unpublished.

Slyker, R. G., Elliott, W. J., and Marshall, M., 1966, Preliminary results of gravity investigations in northern Baja California, Mexico (Abs.): Geol. Soc. America Spec. Paper 87, p. 229.

Strand, R. G., 1962, Geologic map of California, San Diego-El Centro sheet: Calif. Div. Mines and Geol., map.

Thomas, B. E. ed., 1961, Guidebook for field trips: Geol. Soc. America meetings at San Diego State College, 70 p.

Weber, F. H., 1963, Geology and mineral resources of San Diego County, California: Calif. Div. Mines and Geology, County Report 3, 309 p.

Worzel, J. Lamar, and Harrison, J. C., 1963, Gravity at sea: in The Sea, M. N. Hill ed., v. 3, Interscience Publishers a Div. of John Wiley & Sons, N. Y., p. 134-174.