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1940 E. W. SCRIPPS CRUISE TO THE GULF OF CALIFORNIA

Part I. Geology of Islands and Neighboring Land Areas

By Charles A. Anderson

Part II. Megascopic Paleontology and Marine Stratigraphy

By J. Wyatt Durham

Part III. Submarine Topography of the Gulf of California

By Francis P. Shepard

Part IV. Report on the Pleistocene and Pliocene Foraminifera

By M. L. Natland

Part V. Sedimentation and Oceanography: Survey of Field Observations

By Roger Revelle

August 10, 1950

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PREFACE

During the fall of 1940, the auxiliary research schooner E. W. SCRIPPS made a scientific cruise to the Gulf of California, supported jointly by The Geological Society of America and the Scripps Institution of Oceanography of the University of California. The voyage lasted 78 days, from October 5 to December 22. A total distance of 6400 nautical miles was travelled; 4600 miles were logged during the 65 days that the vessel was in the Gulf, and the remaining 1800 miles were covered enroute to and from the area.

The ship was under the command of Captain E. D. Hammond, assisted by a crew of six. Seven men made up the personnel of the scientific party. The work at sea was under the joint supervision of Roger Revelle and Francis P. Shepard. Sydney C. Rittenberg was in charge of the chemical and bacteriological studies made on the Gulf waters and on sediment samples collected from the bottom. Kenneth O. Emery and Robert S. Dietz assisted in all the operations at sea and were particularly responsible for the taking of cores and other samples of bottom sediments. Charles A. Anderson studied the geology of the island and land areas in and surrounding the Gulf. He was assisted in the field by J. Wyatt Durham, who joined the ship in Guaymas and also acted as paleontologist.

C. Francisco Diaz Salcido of the Mexican Departmento de Marina accompanied the expedition as representative of the Mexican Government. In addition to his official duties, Senor Diaz kindly acted as interpreter and as contact man with public officials, merchants, and others. His services were invaluable, particularly to the geologists ashore. It is appropriate here also to acknowledge the gratitude felt by all the members of the expedition for the unfailing co-operation and courtesy extended to them by the representatives of the Mexican Government in San Diego, Guaymas, and other ports visited.

Considerable scientific exploration of the peninsula of Baja California has been carried out in the past, and many biological collecting expeditions have visited the islands and waters of the Gulf, but until 1939 there was virtually no information concerning either the geology of the Gulf Islands and sea floor or the physical and chemical oceanography of its waters. In 1939 the E. W. SCRIPPS made a reconnaissance expedition to the entire Gulf. The soundings, cores of bottom sediments, and the brief glimpses of land geology suggested that in the Gulf are many of the conditions that have characterized certain past basins of sedimentation of great geologic interest.

The purpose of the 1940 expedition was to study the geologic processes which are or have been active in the Gulf, through co-ordinated investigations of the recent geologic history of the land, of the bottom topography and sediments, and of the nature of the marine environment. In its unity of purpose, which was constantly kept in mind both in planning the work and in discussing results, it is believed that the expedition differed from most of its predecessors.

On the 1939 expedition, soundings, cores, and hydrographic data were obtained on a series of cross sections at more or less regular intervals between the entrance to the Gulf and a point about 30 miles below the mouth of the Colorado. Accordingly it was believed that maximum results could be obtained by concentrating the work in 1940 on certain relatively small areas of diverse character. Four such areas were selected:

(1) The region around Guaymas, with a relatively broad shallow shelf in the southern portion at the mouths of the Yaqui and Mayo rivers, and a mountainous coast north of the city, was chosen as representative of the range of conditions to be found on the eastern side of the Gulf.

(2) The Carmen Island area in the western gulf, a region of complex submarine topography, and of many islands on which extensive exposures of fossiliferous marine Tertiary rocks occur.

(3) The Concepcion Bay area also in the western gulf, of less complex bottom topography but with a variety of sedimentational environments and extensive Pliocene and Pleistocene deposits.

(4) The Tibúron area, a region of special interest not only because it forms a constricted transition zone between the deep southern portion of the Gulf and the relatively shallow, gently sloping northern third, but because it contains the long, straight, and deep fault trough of the Sal si Puedes Basin, between Angel de la Guarda Island and the peninsula.

In addition to these four areas, surveys of bottom topography in two submarine canyons were made while enroute to Guaymas, and the course of the vessel was so laid at other times that soundings could be taken in regions of topographic interest.

Reports on the geology of certain islands and of a portion of the coast are included in the present volume, in papers by Anderson, Durham, and Natland. A discussion of the submarine topography is given by Shepard, together with a series of charts and a glossary of place names. Revelle presents a brief survey of the field observations of marine sedimentation and of physical, chemical, and biological oceanography.

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1940 E. W. SCRIPPS CRUISE TO THE GULF OF CALIFORNIA

PART I

GEOLOGY OF ISLANDS AND NEIGHBORING LAND AREAS

BY
CHARLES A. ANDERSON
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August 10, 1950

ACKNOWLEDGMENTS

The writer is greatly indebted to Dr. J. W. Durham for his able assistance in the field and for his co-operation in the writing of the report. Señor Francisco Diaz-Salcido of the Departamento de Marina accompanied the expedition as representative of the Republic of Mexico, and his aid as interpreter is gratefully acknowledged; in addition he accompanied Durham and the writer on many land expeditions, and his enthusiastic assistance was greatly appreciated. Señor Angel Murillo of Guaymas served as guide for much of the work around Guaymas, and his familiarity with the country was of great service. The unfailing co-operation and courtesy extended by the representatives of the Mexican Government in San Diego, Guaymas, Carmen Island, and Loreto are gratefully acknowledged. Captain E. D. Hammond, in command of the E. W. SCRIPPS, was very helpful in expediting landings on the islands, and to him and the members of the crew the writer is indebted for many courtesies. Special thanks are due Doctors Roger Revelle and F. P. Shepard for their splendid co-operation in arranging co-ordination of the land and submarine studies. To Doctors C. M. Gilbert and Howel Williams, I am indebted for helpful comments in the writing of this report. Grateful acknowledgment is made to The Geological Society of America for the award of a grant from the Penrose Bequest which helped to make the expedition possible.

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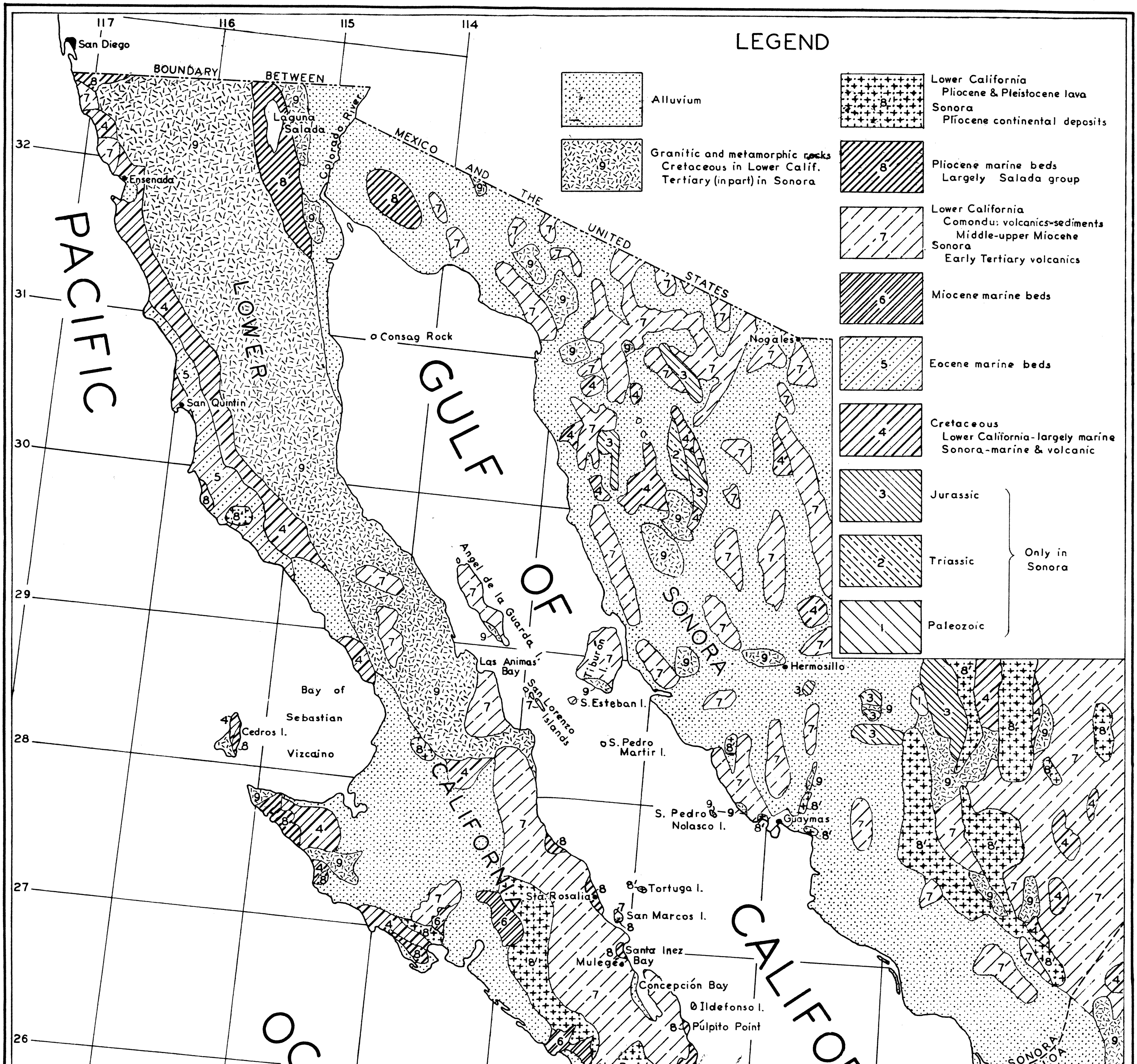

GENERALIZED GEOLOGIC MAP OF LOWER CALIFORNIA AND SONORA

ABSTRACT

Observations made on the 1940 E. W. Scripps cruise to the Gulf of California add information concerning the later geologic history of the Gulf and of Lower California. Granitic rocks are found in Lower California, on some of the islands, and in Sonora; they may all be part of the late Cretaceous batholith of Lower California. The islands along the western margin of the Gulf consist largely of tilted volcanic rocks (Comondú formation) of middle to late Miocene age, overlain unconformably by sediments of Pliocene age (Salada group). In Lower California the Comondú dips gently west. The Pliocene sediments, conglomerates, sandstones, and limestones were deposited in small embayments with the older rocks rising topographically above, identical to the environment of recent similar sediments. Evidence shows that the Gulf of California and peninsula of Lower California were blocked out essentially in their present form by early Pliocene time. Locally the lower and middle Pliocene rocks have been folded and faulted, whereas the upper Pliocene sediments have only been upwarped and faulted. Numerous Pleistocene terraces occur on most of the islands, and some have been faulted. Pliocene and Pleistocene volcanic rocks have been recognized on some of the islands, but only one island possibly represents a volcanic cone built on the Gulf floor.

INTRODUCTION

In 1939 the Scripps Institution of Oceanography of the University of California sponsored a reconnaissance expedition in the auxiliary schooner E. W. Scripps to the Gulf of California. The results suggested that further study upon certain areas would yield valuable geologic information concerning the Gulf. The 1940 expedition, sponsored jointly by the Scripps Institution and The Geological Society of America, was to examine critically the land as well as submarine geology of these areas. In addition oceanographic studies were made of the marine waters of the Gulf. The writer studied the land geology, and the results are given in this paper.

The areas included certain islands as well as local areas in Lower California and Sonora. Little information was available about the geology of the islands except statements that many were volcanic and some were composed of granite. Following the California Academy of Science expedition to the Gulf in 1921, papers appeared on the paleontology of the later Tertiary formations of several islands, but little was added to the stratigraphy. Fortunately Lower California and Sonora have been covered by sufficient reconnaissance studies to relate the geology of the islands to both the peninsula and the mainland and to obtain a definite picture of the geologic history of the Gulf.

Dr. J. Wyatt Durham, who assumed full responsibility for the paleontology of the Tertiary and Quaternary deposits, assisted the writer in the field. With the aid of a grant from the Penrose Bequest of The Geological Society of America, Durham studied the fossils collected on the expedition. Obviously all the writer's statements concerning stratigraphy are the result of co-operation with Durham both in field examination and later discussions based upon his paleontologic studies. His paper on the paleontology of the Tertiary and Quaternary is a companion paper to this study, and cross references have been given in both papers to avoid needless repetition. Fossil localities have been marked on maps and cross section. Readers are referred to Durham's paper for discussion of the faunas.

The expedition left San Diego, October 5, 1940, returning December 22. Areas selected for field studies included the region around Guaymas in Sonora (Pl. 1), the Carmen Island region including part of Lower California (Lat. 26° N.), the San Marcos Island region including Santa Inez Bay in Lower California (Lat. 27° N.), and the northern islands, Angel de la Guarda, San Lorenzo, and Tiburón. Tiburón, however, is discussed in this report with the Guaymas area as the geology is more closely related. In addition a brief stop was made in Lower California north of San Carlos Bay (Lat. 25°20′ N.). These field studies were made only by reconnaissance methods using as a base maps of the Gulf of California prepared by the U. S. Hydrographic Office. Some elevations are given on these maps; others were determined by aneroid barometer checking as frequently as possible by returning to sea level. Thicknesses of strata were measured by differences in elevation or by pacing; rarely were sections measured by tape. In some localities when time was limited thicknesses were only estimated, and cross sections were sketched with insufficient horizontal or vertical control. In spite of these inaccurate methods, it is believed that the essential stratigraphic and structural features were obtained.

EASTERN MARGIN OF THE GULF

GENERAL STATEMENT

In order to relate the geology of the islands to the history of the Gulf of California a generalized map was prepared of Lower California and a part of the mainland of Mexico (Pl. 1). This map illustrates some of the major differences between the west and eastern margin of the Gulf. The latter is represented by most of the state of Sonora and northern part of the state of Sinaloa. The geology (Pl. 1) for the mainland of Mexico was taken partly from a recent map published by the Instituto Geologico de México (Anonymous, 1936). Although this map is generalized (scale 1/6,500,000), it was particularly valuable in obtaining information for nothern Sonora. For the area south of Lat. 29° N., and east of Long. 111° W., King's (1939) recent map was used.

King (1939) subdivided the mainland into the Plateau or Sierra Madre Occidental province (east of Long. 109° W. and north of Lat. 27° N.), the province of Parallel Ranges and Valleys (between Long. 109° and 110° W.), the Sonoran Desert province (north of Lat. 28° N. and west of Long. 110° W.), and the Coastal Plain southeast of Guaymas (Long. 111° W., Lat. 28° N.). The chief interest here is in the Sonoran Desert province and Coastal Plain.

No better description of the arid Sonoran Desert province can be given than McGee's (1897, p. 89–91):

> "To the casual observer traversing its expanse it seems a region of mountains, for rugged buttes, mesas, and sierras are always in sight and usually dominate the landscape; but more careful observation shows that it is primarily a plains region, since fully four-fifths of its area consists of plains, hardly one-fifth of mountains. . . . By reason of heat and aridity the Sonoran district is desert or sub-desert throughout; the vegetation is too scant, stunted, and scattered to protect the surface from storms; . . . At first sight the Sonoran district appears to be one of half-buried mountains, with broad alluvial plains rising far up their flanks, and so strong is this impression on one fresh from humid lands that he finds it difficult to trust his senses when he perceives that much of the valley-plain is not alluvium, but planed rock similar to or identical with that constituting the mountains. To the student of geomorphology this is the striking characteristic of the Sonoran region—the mountains rise from the plains, but both mountain and plain (in large part) are carved out of the same rocks. The valley interior and lower lowlands are, indeed, built of torrent-laid debris, yet most of the valley area carries but a veneer of alluvium so thin that it may be shifted by a single great storm. Classed by surface,

one-fifth of the area of the Sonoran district, outside of the Sierra and its foothills, is mountain, four-fifths plain; but of the plain something like one-half or two-fifths of the entire area, is planed rock, leaving only a like fraction of thick alluvium."

South of Guaymas (Lat. 28° N.) the mountains and intervening plains of the Sonoran desert are replaced by the coastal plain formed by coalescence of the deltas of the Yaqui, Mayo, and Fuerte rivers.

Paleozoic and early Mesozoic rocks are exposed only locally and consist largely of limestones, sandstones, and shales. Cretaceous rocks, however, are widespread and include volcanic and sedimentary types; the former are largely andesitic and include pyroclastics and flows and, in central Sonora, constitute most of the Cretaceous. The most widespread rocks are King's "early Tertiary volcanics" including rhyolite and andesite flows and tuffs and some flows of basalt, which rest with marked unconformity upon the Cretaceous. These early Tertiary volcanics are overlain by the Báucarit formation, largely terrestial sediments and associated basalt flows. A marked unconformity separates the Báucarit formation from the older rocks. King (1939, p. 1679) reported that an important period of mid-Tertiary diastrophism separated the two. No fossils were found in the Báucarit by King, but because of its similarity to the late Tertiary terrestial deposits in southwestern United States he suggested that the age of the Báucarit is also Pliocene.

The age of the granites in the Sonoran region has been a subject of disagreement. King reported the intrusive relationship of the granites to the Paleozoic and Mesozoic, and in many places to the early Tertiary volcanic rocks. Because the Báucarit formation contains fragments of granite, King suggested that some of the granites were intruded during the mid-Tertiary period of diastrophism. He did note, however, that some of the granites might be older, a suggestion confirmed by the writer in the Guaymas area.

GUAYMAS AREA

General statement.—Although the area around Guaymas was only covered in reconnaissance manner, data can be added to the excellent account by Flores (1929, p. 237–242) who was limited to studies along the railroad. Except for the hills surrounding Guaymas Harbor the only available base map was on a scale of 1/644,841, and fairly accurate locations could be made only along the shore line. The geology of the Guaymas area has been sketched (Fig. 1); the area bordering the railroad from Guaymas northeastward was drawn from Flores' map.

The rocks in this area include granitic types, of which some are the oldest rocks in the region, whereas others associated with granite porphyry are younger. A very thick sequence of rhyolite and andesite flows and pyroclastics, possibly equivalents of King's early Tertiary volcanic rocks, is exposed at Guaymas and along the coast northwest. These have been folded into a broad anticline and the axis strikes northeast. A local deposit of terrestrial sediments unconformable upon the rhyolite-andesite series may be equivalent to the Báucarit formation. Olivine basalt flows are the youngest volcanic rocks. The areas indicated as alluvium may include Pleistocene marine beds and fluvial deposits. According to King (1939, p. 1693) it has been reported that a deep well at Empalme penetrated Tertiary marine sediments, but no confirmation of this is suggested by the rocks exposed above the alluvial flats.

Granodiorite.—The only granitic rock older than the volcanic sequence is exposed along the sea cliffs about 15 miles west of Guaymas, presumably close to the anticlinal axis. Much of the rock is decomposed, but locally fresh samples can be found. The texture is coarse-grained and typically granitic. The minerals are quartz, oligoclase-andesine in excess of orthoclase, biotite, and hornblende. Accessory minerals are apatite, sphene, and magnetite. The rock should be classified as biotite-hornblende granodiorite.

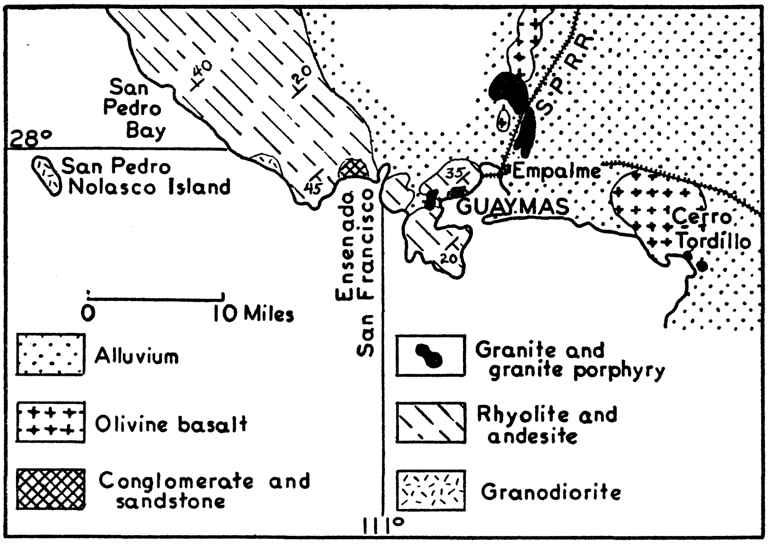

FIGURE 1.—*Geologic map of the Guaymas area*

At the top of the sea cliffs, aphanitic, spherulitic, and glassy lavas are exposed resting on a smooth surface cut from the granodiorite. There is no indication of an intrusive relationship of the plutonic rock; on the contrary, inclusions of granodiorite are found in the overlying volcanics. The evidence is convincing that the granodiorite is older than the volcanics and represents the basement on which they accumulated. As will be mentioned later, this granodiorite may be related to the granitic rocks of Cretaceous age in Lower California.

San Pedro Nolasco Island rises abruptly above the surface of the Gulf 16 miles west of the mainland exposures of granodiorite. No time was available to stop here, but Dr. Yale Dawson, a botanist on one of the Hancock Expeditions to the Gulf of California reported (personal communication) that the island rock is granitic; with no other evidence, it is indicated (Fig. 1) as granodiorite, and it may be of pre-volcanic age.

About 15 miles north of San Pedro Bay (beyond limit of Fig. 1) several exposures of biotite-hornblende granodiorite and biotite-quartz monzonite cut by aplite and pegmatite dikes were noted. However, relations to the rhyolite-andesite series could not be determined as no contacts were found. These granitic rocks are older than the olivine basalt flows that cap mesas in the region, but that relationship is possible even if the granodiorite is intrusive in the rhyolite-andesite series. The age of these granitic rocks in the Guaymas region is therefore doubtful.

Rhyolite-andesite series.—The most widespread rocks, other than alluvium, consist of rhyolite and andesite lava flows and pyroclastics, and minor amounts of other petrographic types. These rocks have been deformed into a broad anticline striking northeast. Guaymas is on the southeastern flank of this structure.

The lavas, resting on the granodiorite along the Gulf Coast, include spherulitic obsidian, brownish pitchstones, and quartz keratophyre. The keratophyre contains turbid albite phenocrysts and spherulites with quartz crystals as nuclei set in a microgranular groundmass of quartz and feldspar. It may be an albitized dacite. The remaining rocks are rhyolitic; the glass has a refractive index of 1.494 ± .003.

One traverse was made into the hills 15 miles northwest of Guaymas (dip symbol 20°, Fig. 1) where the rocks are dominantly rhyolitic, consisting of an alternating series of obsidian, spherulitic perlitic obsidian, banded felsites in places spherulitic, white tuffs, pumice-lapilli tuffs, and reddish welded tuffs. The glass from both obsidians and tuffs has refractive indices between 1.490 and 1.495, indicating rhyolitic characters. The felsites have a "patchy" to cryptocrystalline texture suggestive of devitrification of former obsidians; the spherulites also support this conclusion. The pumice-lapilli tuffs show partial crystallization, and there are all gradations to welded tuffs in which the pumice is completely collapsed and crystallized, and in which the pyroclastic texture can be recognized only in thin section. Intercalated with the rhyolitic rocks are a few flows of reddish porphyritic hornblende-augite andesite, olivine (?) basalt, and augite latite, and last-named containing andesine and subordinate orthoclase phenocrysts.

The area behind San Pedro Bay also consists of perlitic obsidians, spherulitic obsidians, spherulitic felsites, and tuff-breccias, largely rhyolitic. One flow of olivine (?) basalt was noted. Here also the dips are northwest indicating a position on the northwestern limb of the anticline.

On the south limb of the anticline as studied in the area north and west of Ensenada San Francisco, spherulitic obsidian and rhyolite tuffs are exposed dipping southeast. However, most of the volcanic rocks are more basic, consisting largely of purple aphyric andesites and reddish porphyritic augite dacites with a few intercalated vesicular subophitic olivine basalt flows. There are also interbeds of massive tuffaceous sandstone with angular fragments of andesite and felsite. Andesites seem to dominate in the southeasterly limb of the anticline, whereas rhyolites make up the bulk of the northwesterly limb. The rhyolites seem the older. Probably two different centers of vulcanism are responsible for this distribution.

Most rocks in the hills around Guaymas are lava flows with minor interbedded breccias and tuffs. Many are reddish to pale-gray porphyritic andesites; in some augite is an accessory, but in others the original femic minerals are altered to iron oxide. Another common rock resembles the andesite except that it contains orthoclase phenocrysts subordinate to the andesine phenocrysts. Presumably these rocks are latites; similar rocks were observed interbedded with the rhyolites 15 miles northwest of Guaymas. Some flows of biotite-hornblende dacite were noted as well as a bed of white tuff containing quartz and plagioclase crystals. The ash has crystallized so that it is uncertain whether it is rhyolitic or dacitic. Flores (1929, p. 239) reported subordinate amounts of spherulitic rhyolite as well as reddish and black basalts associated with the andesites.

Granite and granite porphyry.—Excellent exposures of granite porphyry are present along the highway leading west from Guaymas; the porphyry is part of a small stock, and numerous dike offshoots up to 50 feet wide clearly intrude the andesites. Border facies have a much finer-grained groundmass. The porphyry is light gray mottled with red; a few shreds of biotite remain to indicate the original ferromagnesian mineral. The numerous phenocrysts are largely orthoclase and subordinate oligoclase and quartz. The groundmass is fine granular containing abundant orthoclase. The largest outcrops of the post-andesite intrusives are north of Empalme where the texture of the rocks is more granular and their composition is granitic. Dike offshoots into the tilted andesites and latites and fine-grained border facies again attest to the intrusion of the granite into the volcanics. South of Cerro Tordillo also, the granite porphyry shows an intrusive relationship to tilted andesite lavas. Here some of the porphyry grades into a hypidiomorphic granular rock in which oligoclase is more conspicuous and augite is an accessory. This rock may be classified as quartz monzonite.

The rhyolitic rocks in the rhyolite-andesite series suggest King's (1939, p. 1679) early Tertiary volcanic rocks in contrast to the Cretaceous volcanic rocks which to date have not been reported as containing silicic lavas. The granite porphyry and granite are probably related to the granitic intrusions reported by King.

Conglomerate and sandstone.—North of Ensenada San Francisco, several hundred feet of conglomerate and sandstone rest with a marked angular discordance upon the tilted rhyolite-andesite (Pl. 2, fig. 1). The younger rocks dip less than 10° and appear to be folded into a gentle syncline and the axis strikes northwest, opposite to the prevailing strike of the underlying volcanic rocks. The sediments show channeling and crossbedding; most of the foreset beds dip south suggesting a northerly source. The underlying surface had a relief of at least 300 feet. The conglomerates contain pebbles and cobbles of the rhyolite-andesite series as well as granodiorite, implying a local source and considerable erosion before sedimentation in order to expose the underlying granodiorite. The characters of the sediments, particularly the marked lateral and vertical grain-size variation, suggest continental deposition, presumably fluvial. The uncomformable relationship to the rhyolite-andesite suggests an analogy to the Bâucarit formation of late Tertiary age (King, 1939, p. 1688).

Olivine basalt.—The latest volcanic eruptions in the Guaymas area produced extensive olivine basalt flows, the largest field composing Cerro Tordillo, essentially a tableland of about 500-feet elevation. Erosion produced narrow canyons at the margin, revealing that several flows make up the lava field. Another basalt field 4 miles north of Empalme forms a gently-westward sloping mesa. Several isolated erosional remnants indicate a greater westward extension. The large basalt field 10 miles north of Empalme was not visited, but according to Flores (1929, p. 241) it is similar to the others. The lava is holocrystalline containing olivine partly altered to iddingsite, augite, and labradorite in a subophitic texture or porphyritic and an intergranular groundmass. In the two areas visited the basalt rests upon an eroded surface cut from the rhyolite-andesite series and granite porphyry or granite. Since there is no indication of deformation, and the lavas have not been extensively eroded, it is assumed that they are younger than the continental deposits north of Ensenada San Francisco. Judging from their general fresh appearance they may be Pleistocene.

Similar olivine basalt flows were noted in the area 15 miles north of San Pedro Bay (north of Fig. 1). Possibly they are less eroded, and a definite shield structure is suggested in one lava field. Here olivine is not conspicuous, and the texture is porphyritic with an intersertal or intergranular groundmass. One mesa is capped by olivine basalt resting on granodiorite; this basalt is obviously older than the other flows in this northern area which may be Pleistocene or Recent.

Pleistocene and Recent.—The most obvious event in the Pleistocene or Recent history of the Guaymas area was the down-warping of the area adjacent to Guaymas which formed the harbor and indented the coast line. At the western margin of Cerro Tordillo, valleys cut into the basalt have been drowned indicating recent submergence. That this warping may have been differential is suggested by Dumble's (1900, p. 125) report that Pleistocene shell reefs outcrop in the flat country north of Empalme. Sedimentation forming the coastal plain is still continuing as well as modification by marine currents forming bars and spits.

TIBURÓN ISLAND

General statement.—Tiburón, the largest island in the Gulf of California, is 20 miles wide and 30 miles long. There is a north-south valley in the central portion of the island and the highest range in the eastern margin rises to nearly 4000 feet. Tiburón is separated from the mainland by a strait 2–4 miles wide and 15 miles long and so shallow that a 20-foot drop in sea level would result in a land connection. It is the only large island on the east side of the Gulf; all others of considerable size are along the western margin.

The Seri Indians who live there part of the year have attracted attention to Tiburón Island, but little has been noted of the geology except that it consists largely of eruptive andesites and rhyolites (Jones, 1910) and that some metamorphic rocks are exposed (Anonymous, 1924a, p. 377). The schedule of the E. W. SCRIPPS allowed for only 3 days of field work along the southern margin, but a variety of rocks and structures were recognized indicating a varied history.

Quartz diorite and metamorphic rocks.—The oldest rocks observed are exposed at the southeastern tip of the island (Fig. 2)—black hornfels, quartzites, chlorite schists, and gray mottled marble. These have been intruded by quartz diorite and pegmatite dikes. Mr. Ed. Davis, a member of the 1939 Scripps Expedition to the Gulf, found quartz diorite on Turners Island indicating that the granitic rocks extend southward. Large exposures of granitic rocks cut by many aplite dikes occur 6 miles west in the hills bordering the south shore (Fig. 2). Thin sections reveal that the granitic rocks are biotite-quartz diorites, although some specimens contain hornblende, and orthoclase may appear in minor amounts interstitial to the oligoclase-andesine.

Red beds and arkoses.—From data available, probably the oldest post-quartz diorite rocks are red beds and arkoses exposed in an arroyo about 2 miles northeast of Red Bluff Point. There is a small exposure of quartz diorite in this area, and northward red siltstones and cross-bedded arkoses dip toward the quartz diorite indicating a fault contact. The later age of the arkoses is amply demonstrated by included pebbles of quartz diorite. Presumably these sediments represent continental deposition because of the red color of the interbedded siltstones. The thickness cannot be estimated because of extensive faulting.

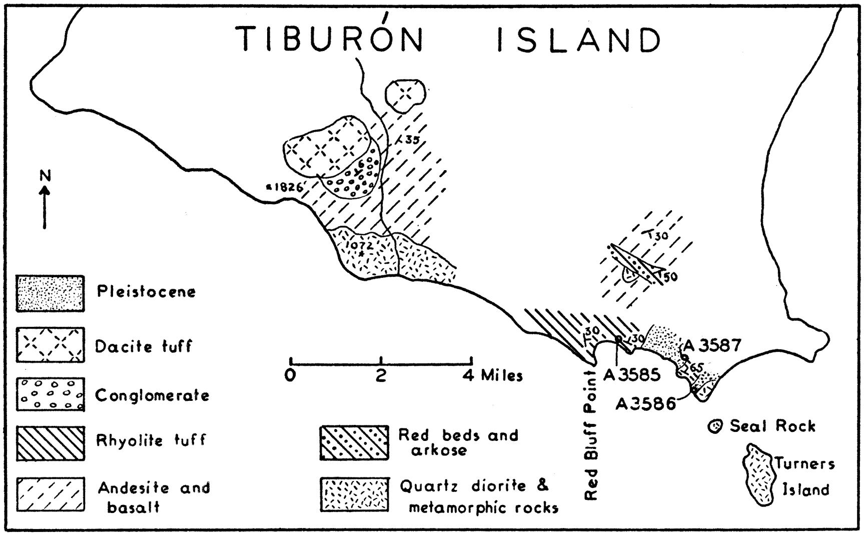

FIGURE 2.—*Sketch map of the southern part of Tiburón Island*

Andesite-basalt series.—In this same area plugs of massive andesite 200–300 feet in diameter intrude the red beds; the relationship is proved by baked sediments at the contact. These plugs contain inclusions of quartz diorite 2–3 feet in size indicating that the quartz diorite is older. The andesite is holocrystalline and consists of numerous hornblende phenocrysts pseudomorphed by granular magnetite, scattered andesine phenocrysts, in a groundmass of oligoclase-andesine microlites separated by a microgranular low-index aggregate that probably is alkalic feldspar. North of the reddish continental beds a sequence of andesitic breccias and tuffs with interbedded olivine basalt flows dip south. The basalt flows are more common in the upper part of the section. Apparently a fault separates the red beds from the volcanic sequence. The continental sediments are probably older because they have been intruded by the andesite plugs and they contain no volcanic debris. The volcanic breccias contain fragments of hornblende andesite similar to the plugs except they have more conspicuous plagioclase phenocrysts. This sequence of andesitic breccia and interbedded olivine basalt covers a large area, for southwest of the red beds it rests on quartz diorite at one locality and is exposed in a large area 6 miles west (Fig. 2). The olivine basalt has conspicuous olivine phenocrysts, partly or completely altered to iddingsite, imbedded in a groundmass of plagioclase and augite, that varies from subophitic to coarsely pilotaxitic in texture.

Rhyolite tuffs.—At Red Bluff Point and eastward along the coast line, red and white rhyolitic tuffs, breccias, and banded felsites dip northeast at variable angles. Interbedded stratified tuffs contain rounded volcanic fragments suggesting water deposition in part. Two thin flows of vesicular olivine basalt were noted. Unfortunately no observations were made that indicate the relationship of this rhyolitic sequence to the andesite and basalts. Since the andesitic breccia was found locally on quartz diorite, the rhyolitic sequence is probably younger than the andesite. Some of the pyroclastic rocks are welded tuffs with beautiful vitroclastic structure, now represented by microcrystalline and spherulitic aggregates. Scattered crystals of quartz, sanidine, and oligoclase suggest a rhyolitic or quartz latitic composition. The felsites consist of a cryptocrystalline felt showing fluidal structure separated locally by secondary quartz veinlets. Some tuffs contain streaks of obsidian several inches to a foot wide, a common feature of welded tuffs.

Conglomerate and sandstone.—Four miles west of Red Bluff Point, an arroyo provides easy access to the interior of the island, and 2 miles from the shore line there are extensive deposits of pebble conglomerate and cross-bedded sandstones resting with marked angular unconformity on the andesitic breccias. The pebbles consist of banded felsite, spherulitic rhyolite, andesite, quartz diorite, and pegmatite, indicating a varied provenance at the time of deposition and proving that the sediments are younger than the rhyolitic sequence of Red Bluff Point. Dips in the sediments are variable but low in contrast to the higher dips in the older volcanic sequence. Similar sediments, resting on the quartz diorite and andesite breccia, were noted near the southeastern tip of the island, but the exposed area is small, and the beds are thin.

Dacite tuffs.—More than 300 feet of essentially horizontally bedded dacite tuffs form a mesa 1000 feet in elevation 7 miles northwest of Red Bluff Point. The underlying pebble conglomerate dips gently under the tuffs. The oldest tuffs were apparently water-transported as they show excellent stratification, partial rounding of pumice fragments, and some incorporation from the underlying beds. There is an angular discordance between the pebble conglomerate and tuff; the dips in the underlying rocks are steeper, and the tuff overlaps onto the andesitic breccia. Most of the tuffs are massive, loosely consolidated pumice-lapilli tuffs, but two beds, one near the bottom and another near the top, are like welded tuffs, the pumice lapilli being collapsed and glassy. Associated crystal fragments are andesine, labradorite, and augite. The index of refraction of the glass ranges from 1.496 to 1.503. These values and associated crystals indicate that the tuff is probably dacitic. Presumably the welded tuffs represent the products of pelēan eruptions, but there is no indication as to the location of the vents.

Pleistocene sediments.—Pleistocene terraces thinly capped by sediments yielded the only fossils from Tiburón Island. East of Red Bluff Point a well-developed terrace at 30–40 feet is covered by coral fragments. At fossil locality A 3586 (Fig. 2) a shallow canyon cut into the andesite breccia is filled with stratified siltstones and cobble gravel, while at A 3587 the beds are largely coralline algae; all contain Pleistocene fossils.

Summary.—Upon a basement of metamorphic rocks and quartz diorite is a local accumulation of red siltstones and arkose intruded by andesite plugs that may be contemporaneous with widespread andesitic breccias that contain intercalations of olivine basalt flows in the upper part of the section. Of unknown relationship to the andesite breccia is a series of rhyolite tuffs, welded in part and locally of sedimentary origin. These sedimentary and volcanic rocks were tilted, faulted, and eroded. Then followed an accumulation of pebble conglomerates and sandstones that are partly buried by flat-lying dacite pumice-lapilli tuffs, some of which are welded. Near the southeastern corner of the island Pleistocene terraces and sediments indicate recent emergence. No ages can be definitely assigned to any of the pre-Pleistocene rocks, but by comparison with the Guaymas area the quartz diorite may be of the same age as the granodiorite since it is older than the volcanic rocks. The red beds—arkose, andesite breccia-basalt, and rhyolite tuffs—may be the equivalent of the early Tertiary volcanic rocks of the Sonoran area where (King, 1939, p. 1678) has reported clastic sediments in association with the volcanics and the deformation is comparable. The pebble conglomerate is separated from the older rocks, as in the Guaymas area, by a marked unconformity and by analogy might be referred to the Báucarit formation of late Tertiary age. The dacite tuffs cannot be compared with any similar known rocks in Sonora. McGee and Johnson (1896, p. 128) noted sediments carrying recent marine shells on the mainland east of Tiburón Island, and these may represent a Pleistocene indentation corresponding to the terrace deposits on Tiburón Island.

LOWER CALIFORNIA

Lower California is some 800 miles long and 30 to 130 miles wide. The eastern margin rises abruptly from the Gulf of California, the mountain crests ranging from 1000 to 10,000 feet in elevation. The western slopes are gentle (Darton, 1921, p. 722–724). The mountain chain breaks at La Paz near the southern end of the peninsula where a north-south belt of alluvium separates the southern mountains from those to the north. Wide alluvial plains appear behind Magdalena Bay and the Bay of Sebastian Vizcaino; elsewhere the western slopes reach the Pacific Ocean (Pl. 1). The climate of the peninsula and neighboring islands is hot and dry (Nelson, 1921).

The geology of Lower California (Pl. 1) was taken from a map compiled by the Marland Oil Company (Anonymous, 1924c, p. 52) with additions from Flores (1931).[1] The northern half of Lower California is composed largely of granitic and metamorphic rocks. No distinction (Pl. 1) was made between the two. Lower and upper Cretaceous rocks are exposed along the northern half of the west coast. Böse and Wittich (1913, p. 347–351) suggested that the granites intrude the lower part of the upper Cretaceous, whereas upper upper Cretaceous sediments are unmetamorphosed. Woodford and Harriss (1938, p. 1328) discussed this problem, concluding that the plutonic rocks are probably of upper Cretaceous age. Woodford (1939) later reviewed the evidence and suggested that the plutonic rocks are mid-Cretaceous or upper Cretaceous. Small patches of crystalline rocks appear on Cedros Island along the coast south of the Bay of Sebastian Vizcaino and on the islands forming the outer barrier of Magdalena Bay. The south end of the peninsula from La Paz to Cape San

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[1] Since the submission of this manuscript for publication in October 1942, Carl H. Beal has written and published a memoir *Reconnaissance of the geology and oil possibilities of Baja California, Mexico* (Geol. Soc. Am., Memoir 31, 1948). An excellent reconnaissance geologic map of Lower California accompanies his report, showing much more detail than Plate 1 of this report. Beal described the rocks in considerable detail, and numerous stratigraphic sections are given.

Lucas is composed of a variety of granite and metamorphic rocks (Galvez, 1927) covered in part by younger rocks. No evidence is available to date the southern granite except that it is pre-Tertiary, but Galvez suggests a Cretaceous age.

Marine Eocene sediments are limited to a long belt exposed on the western slopes of Lower California between Lat. 29° and 31° N. On the Marland Oil Company's map, Eocene rocks are shown south of the Bay of Sebastian Vizcaino between Lat. 27° and 28° N., but according to Hanna (1926, p. 86) Cretaceous fossils were found on Cedros Island in beds lithologically similar to those along the coast to the southeast. Hence they have been indicated as Cretaceous (Pl. 1). At Lat. 24° 34′ N., the Tepetate formation (Heim, 1922, p. 534) is exposed containing small *Orbitoides* which indicate a late Eocene age. Later the Marland Oil Company (Anonymous, 1924b) referred all the Eocene beds in Lower California to the Tepetate formation, but Santillan and Barrera (1930, p. 14) referred to the lower Eocene of northern Lower California as the Sepultura formation.

Sandstones, shales, diatomites, and cherts of limited thickness have been called "Monterey" by Darton (1921, p. 731) and Heim (1922, p. 538) because of their similarity to the Monterey of California. The Marland Oil Company (Anonymous, 1924b, p. 420) designated these beds the San Gregorio formation and the writer follows their usage. The San Gregorio is found south of Lat. 27° N. and only two known exposures appear on the eastern margin of Lower California. Darton and the Marland Oil Company considered its age as lower Miocene, but on the basis of *Cornwallius* teeth collected on the 1940 expedition the age is probably late Oligocene (VanderHoof, 1942). A more detailed discussion is given by Durham (1950, p. 34). The San Gregorio is grouped with the Miocene (Pl. 1).

Soft loamy sandstones and clays with a yellow tint, overlying the San Gregorio locally, were called "yellow beds" by Darton (1921, p. 733) but later designated the Isidro formation by Heim (1922, p. 539). As to their age, Darton suggested upper Miocene; Heim, Miocene; and the Marland Oil Company lower Miocene, reporting that the Isidro was only a different facies of the San Gregorio. Loel and Corey (1932, p. 160) concluded that most of the fauna were equivalent to that of the Vaqueros-Temblor transition zone of California (lower Miocene) but that, because of certain forms found, further stratigraphic studies and collecting would reveal both Vaqueros and Temblor equivalents there. As Durham (1950, p. 28) uses the terms this would include lower middle Miocene.

Overlying the San Gregorio and Isidro formations, locally with angular unconformities, is a thick accumulation of lava flows, volcanic breccias and tuffs grading to finer and thinner clastic sediments to the west. This volcanic material covers much of the southern half of Lower California and crops out on many neighboring islands. The western sandy facies was called the "mesa sandstone" by Gabb (1869, p. 114) and by Darton (1921, p. 741), but the term has also been used for Cretaceous sandstone to the north (Willis, 1912, p. 644). Use of the more comprehensive term "Comondú formation" (Heim, 1922, p. 542), which includes the eastern volcanic members and western sandstones and conglomerates is desirable. The Marland Oil Company (Anonymous, 1924b, p. 422) also used "Comondú" for these rocks. Comondú age assignments vary from the Miocene to the Pliocene, but the writer found ample evidence to prove that the Comondú is pre-lower Pliocene, and since it rests on the Isidro of lower to possibly lower middle Miocene the Comondú is limited to the middle and (or) upper Miocene.

Scattered over Lower California and western Gulf islands are marine Pliocene deposits, and from exposures east of Magdalena Bay on the western slope of Lower California Heim (1922, p. 544) named the Salada formation. Later the Marland Oil Company (Anonymous, 1924b; 1924c) used Salada for all the marine Pliocene of Lower California. They stated that the Salada is the marine equivalent of the terrestrial Comondú (Anonymous, 1924b, p. 422). Later (Anonymous, 1924c, p. 43) they stated that sands and shales of the Pliocene are in separate localities, and evidence from fossils does not indicate contemporaneous periods of deposition, but later work will result in the division of the Salada into various formations. Touwaide (1930, p. 120–122) did this at Santa Rosalia, separating it into the Lower Salada or Ore series, and Upper Salada or Calcareous series.

No evidence was found of contemporaneity of the Pliocene sediments with the Comondú. Rather in all places examined, evidence is clear that marine Pliocene sediments are younger than the Comondú, and wherever the contact was observed, an unconformity separates the two. Paleontological as well as stratigraphic evidence made possible a division of the Salada into three formations. Because the "Salada" includes all the Pliocene deposits, it is desirable to refer to all of the marine Pliocene as the "Salada group". The oldest of these three has been called the San Marcos because of its appearance on San Marcos Island; it is early Pliocene. The middle formation is called the Carmen because of excellent exposures on Carmen Island; it is middle Pliocene. The youngest is the Marquer named from Marquer Bay on Carmen Island; it is late Pliocene[2]. The writer discusses their stratigraphy, and Durham (1949) their paleontology.

On the western slopes of Lower California are extensive basalt flows younger than the Comondú, and these were considered Pliocene by the Marland Oil Company (Anonymous, 1924c, p. 43). Marine Pleistocene sediments appear on the islands and eastern margin of Lower California. Some are merely veneers on uplifted terraces; others are slightly deformed sediments locally truncated by uplifted marine terraces.

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[2] Ivan F. Wilson, U. S. Geological Survey, spent 7 months in detailed field studies during parts of 1943 to 1946, in the Boleo copper district, centered at Santa Rosalia, Lower California. He has published one paper *Buried topography, initial structures, and sedimentation in Santa Rosalia area, Baja California, Mexico* (Am. Assoc. Pet. Geol. Bull., vol. 32, p. 1762–1807, 1948) and the economic and geologic results are to be published by the U. S. Geological Survey. In the paper cited, Wilson divided the Pliocene beds into three formations—Boleo, lower Pliocene; Gloria, middle Pliocene; Infierno, upper Pliocene.

The Boleo formation consists of conglomerate, gypsum, and tuff; the last named contains copper and manganese ore beds. The San Marcos formation on San Marcos Island, 12 miles from Santa Rosalia, consists of clastic sediments, gypsum, and pebbly limestone. These two formations of lower Pliocene age are of sufficient lithologic similarity and proximity to indicate that they are the same formation.

Wilson's middle Pliocene Gloria formation is composed of conglomerate grading into nonmarine facies inland, and fossiliferous sandstone grading seaward into siltstone and clay. The middle Pliocene Carmen formation on Carmen Island, 125 miles southeast of Santa Rosalia, consists of conglomerate, sandstone, and fossiliferous marl and siltstone.

The upper Pliocene Infierno formation at Santa Rosalia consists of conglomerate and fossiliferous sandstone whereas the upper Pliocene Marquer formation on Carmen Island consists of conglomerate, calcareous sandstone, marl, coquina, and limestone.

The formations of the Salada group were deposited in separate basins, connected with the Pliocene Gulf of California, and the faunal evidence indicates that the Boleo is equivalent to the San Marcos; the Gloria is equivalent to the Carmen; and the Infierno is equivalent to the Marquer. Future work in the Gulf islands and Lower California may determine that the formational names of the Salada group used in this paper are unnecessary.

TABLE 1.—*Correlation chart*

		Lower California		Western Islands		Tiburón Island	Guaymas Area	Sonora (After King)
PLEISTOCENE		Terraces Marine beds		Terraces Marine beds		Terraces Marine beds	Marine beds	
PLIOCENE	U	Marquer	Salada group	Marquer	Salada group	Dacite tuff	Olivine basalt	
	M	Carmen		Carmen		Conglomerate and sandstone	Conglomerate and sandstone	Báucarit
	L	San Marcos		San Marcos				
		Unconformity		Unconformity		Unconformity	Unconformity	Unconformity
MIOCENE	U	Comondú		Comondú			Granite and granite porphyry	Granite
	M							
	L	Isidro						
OLIGOCENE	U	San Gregorio						
						Rhyolite tuff Andesite-basalt Red beds	Andesite Rhyolite	Early Tertiary volcanics
EOCENE	U	Tepetate						
	M							
	L	Sepultura						
				Unconformity		Unconformity	Unconformity	Unconformity
CRETACEOUS		Sediments Granitic rocks intrusive into lower and lower upper Cretaceous		Granitic rocks		Quartz diorite	Granodiorite	Sediments Volcanic rocks

In the latter the older sediments are referred to the lower Pleistocene. Some lava flows and lithified calcareous dunes are considered Pleistocene.

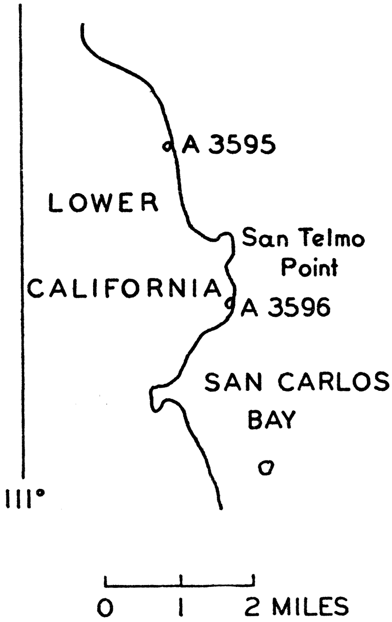

FIGURE 3.—*Sketch map of San Carlos Bay*
A 3595 fossil locality of *Cornwallius;* A 3596, Pleistocene sediments.

SAN CARLOS BAY

A short stop was made north of San Carlos Bay, west of Santa Cruz Island, at Lat. 25° 20′ N. and Long. 111° W. This locality was selected because of exposures of marine Miocene rocks indicated on the Marland Oil Company map (Anonymous, 1924c, p. 52). These sediments are exposed beneath the Comondú in the axis of a broad anticline striking northeast and truncated by the coast line. Near San Carlos Bay the sediments dip gently north, covered by tuffs and lava flows of the Comondú. Some faulting has occurred, but time was insufficient to determine the magnitude or effect upon the structure.

The oldest beds observed crop out at the beach line 3 miles north of San Carlos Bay (Fig. 3) and consist of massive well-cemented sandstones overlain by 125 feet of thin-bedded sandstones, siltstones, and shales with interbeds and lenses of black to dark-gray cherts. These resemble the sediments that Darton (1921, p. 731) called Monterey and the Marland Oil Company (Anonymous, 1924c, p. 43) designated the San Gregorio formation. In both citations, the age is given as lower Miocene. In the lower massive sandstone (A 3595, Fig. 3) Durham collected two teeth of *Cornwallius sookensis*, a rare sirenian mammal found elsewhere only in the Sooke formation of British Columbia. VanderHoof (1942) states that these teeth provide excellent evidence for correlation with the Sooke formation of latest Oligocene or earliest Miocene age.

A thick bed of pink pumice-lapilli tuff, undoubtedly rhyolitic, overlies the San Gregorio formation. The index of refraction of the glass is only 1.485 ± 0.003. Associated with the lapilli are small scattered plagioclase and biotite crystals. Lavas of the Comondú formation cover the tuff, but owing to the lack of time these were not studied.

North of San Carlos Bay and exposed along the sea cliffs are sediments (A 3596, Fig. 3) consisting of coral-reef zones, algal limestones, and interbedded fossiliferous gravels. These contain a Pleistocene fauna similar to that collected on Coronado Island. At an elevation of 20 feet the beds are truncated by a terrace which is capped in turn by unconsolidated fossiliferous gravels also of Pleistocene age. The implication is that the older beds are early Pleistocene.

CARMEN ISLAND AND VICINITY

GENERAL STATEMENT

Carmen Island is in the center of an area selected for intensive study which includes Coronado and Monserrate islands as well as the adjoining eastern margin of Lower California.

CARMEN ISLAND

General statement.—Carmen Island is elongated north-northeast in contrast to the north-south trend of the neighboring Lower California coast line. The island is 18 miles long and 2 miles wide for the major part but widens to 5 miles to the north (Fig. 4). It has three physiographic units; the major part is a north-northeast irregular ridge with a summit elevation of 1382 feet near the southern end, dropping to less than 600 feet 2 miles north, then rising to a maximum elevation of 1572 feet west of Salinas Bay. The northern part contains a flat-floored graben near sea level occupied by a workable salt deposit. The graben merges to the north into a series of low-rolling hills. The north-south ridge east of the salt deposit is about 600 feet above sea level. Where the Pliocene limestones crop out, the surfaces usually slope gently seaward, and the elevations rarely rise to 400 feet. These are trenched by narrow gullies. The rest of the island, except for the graben, is rather rugged and cut by deep canyons. Vegetation is sparse except in some arroyos. Twelve days were spent studying the island.

Comondú formation.—On Carmen Island, the Comondú formation consists largely of reddish andesite tuff breccias and lava flows. Many are massive, preventing determination of the structure unless interbeds of fine breccia or tuff are exposed. Near Perico Point (Fig. 4) 30 feet of well-stratified reddish siltstone and shale are overlain by volcanic breccia which grades upward into well-bedded tuffaceous sandstone. This was the only place on the island where sediments were observed interbedded with lavas and breccias. In the northwest part of the island lava flows appeared to dominate over breccias.

The lava flows are essentially red porphyritic andesites, containing conspicuous white andesine associated with biotite and basaltic hornblende phenocrysts. The groundmass is usually pilotaxitic containing occasional augite microphenocrysts. Hornblende and biotite crystals are partly replaced by granular magnetite. In the breccias some lithic fragments are pale gray but have the same minerals and texture

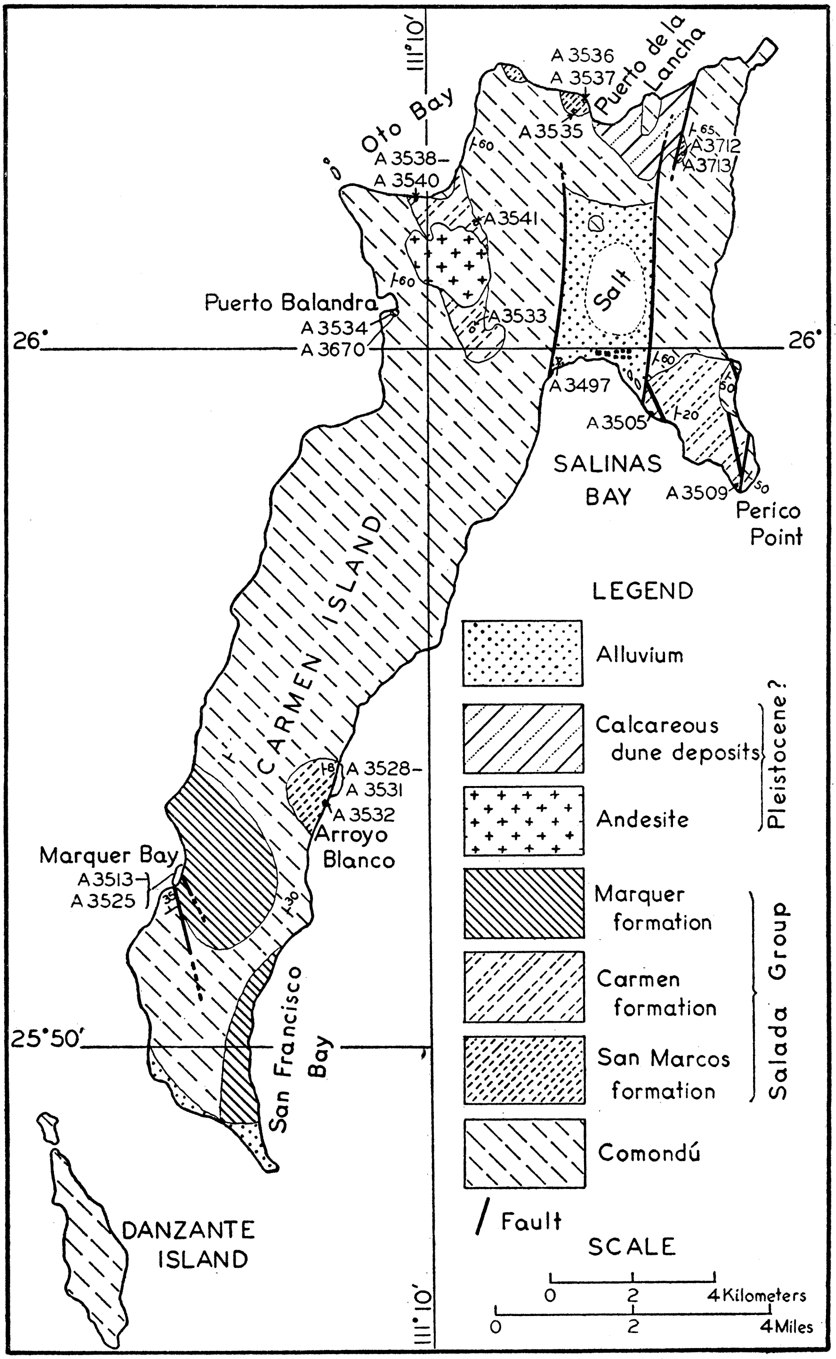

FIGURE 4.—*Geologic map of Carmen Island*

as the red fragments. In some augite is conspicuous, and biotite absent. The matrix of the breccias is broken plagioclase, hornblende, biotite, and augite crystals mixed with angular groundmass chips of andesites.

In the northern part of the island the Comondú beds are homoclinal having uniform strikes east of north and steep dips east. The central part of the island was not visited. In the southern part strikes and dips vary more, partly because of post-Pliocene faulting, but in part it may be due to folding. An anticlinal structure is suggested southeast of Marquer Bay.

Two areas were observed where lavas and pyroclastics were bleached possibly by solfataric action. One is west of Salinas Bay along the coast, the other north of Perico Point. However, both are near post-Pliocene faults and may represent hydrothermal alteration unrelated to Comondú volcanism. South of Puerto Balandra a quartz vein several feet wide cuts the andesites; two prospect holes are present but no sign of metal mineralization. This was the only vein noted in the Comondú on any of the islands.

San Marcos formation.—A mile north of Arroyo Blanco, along the coast line, the Comondú consists of volcanic breccias and lava flows. Resting on the Comondú is about 200 feet of volcanic gravels, sandstones, and siltstones; many of the finer clastics contain pectens, echinoids, and molds of other fossils. Dips in the sediments are low with some large-scale crossbedding. The structure in the adjacent Comondú is difficult to determine but bedding planes appear at a much higher angle than in the overlying sediments, implying an unconformity. The sediments strike into the Comondú, but no fault occurs along the contact, suggesting that a basin was carved from the underlying Comondú and filled with clastic sediment in a marine environment. The fossils indicate correlation with the San Marcos formation (lower Pliocene) (Durham, 1950, p. 23).

South, approaching Arroyo Blanco, thin white calcarous beds overlie gravels and sandstones. The younger rocks include algal limestone, reef beds, and marls, not exceeding 40–50 feet thick. Lithologically these beds resemble calcareous members of the Carmen formation (middle Pliocene) and Marquer formation (upper Pliocene) but the fossils (A 3532, Fig. 4) are not diagnostic. The beds are included with the San Marcos formation (Fig. 4).

A small area of San Marcos formation is exposed along the western shore of Puerto de la Lancha. An irregular surface carved from the tilted Comondú underlies the formation. The lower 150 feet are volcanic conglomerate derived from surrounding Comondú volcanics. The upper 120 feet is alternating layers of volcanic gravel and limestone, some of the latter composed almost entirely of *Chione* shells.

Southeast 2 miles (A 3712) erosional remnants of fossiliferous sandstone and limestone rest upon the Comondú with marked angular discordance. To the west they are separated from the Comondú by a fault. *Lyropecten mediacostatus* (Hanna) (Durham, 1950, p. 22) indicates correlation with the San Marcos and suggests that these sediments are an extension of the lower Pliocene sediments exposed at Puerto de la Lancha.

Carmen formation.—A well-exposed section of the Carmen formation along the eastern shore of Salinas Bay to Perico Point (Fig. 4) is selected as the type. Several normal faults cut the sequence so that a complete section is not available. Most of the formation is volcanic pebble and cobble conglomerate rather poorly bedded. Dips are 20°–35° east. Near Perico Point to the north, the Carmen formation is in fault contact with the Comondú formation. South of Lat. 26 N., however, the contact is depositional and irregular, and "islands" of Comondú rise through the conglomerate indicating considerable relief for the surface on which the Carmen formation was deposited. The conglomerate strikes into the depositional contact indicating that the sediments overlapped upon an irregular surface, and the Comondú rose topographically to the north at the time of sedimentation. Dips of the Comondú are steeper (50–60°) than those in the Carmen proving an angular unconformity between the two.

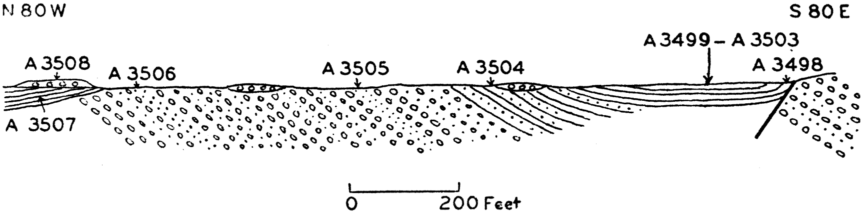

FIGURE 5.—*Cross section east of Salinas Bay, Carmen Island*

Taped section exposed along the sea cliffs. Largely Carmen formation; A 3507, lower Pleistocene siltstones; A 3508, Pleistocene terrace gravels.

Along the shore of Salinas Bay, where the thickest section of the Carmen formation crops out, the base is not exposed. The maximum thickness of the Carmen formation is about 1500 feet, all but the upper 150 feet consists of volcanic conglomerate. Scattered through the conglomerate are interbeds of volcanic sandstone usually 1–2 feet thick containing fragmentary fossils indicating a marine environment of deposition.

An excellent section accessible along the shore immediately east of the graben (A 3506) representing about 450 feet of the upper Carmen was measured, and a number of fossil localities found (Fig. 5). The lower 400 feet consists of volcanic pebble and cobble conglomerate with a few fossiliferous sandstone interbeds. The upper 50 feet consists of flat-lying buff-colored marls and siltstones. From these beds most of the fossils were collected. To the east the siltstones are in fault contact with the lower volcanic conglomerates. Some drag occurs in the siltstones along the fault (Fig. 5).

The structure is essentially the same northwest of Perico Point (Fig. 6), but about 150 feet of the upper siltstones and marls is exposed, including 50 feet of gypsiferous siltstones containing a few thin beds of gypsum. Rosettes of gypsum crystals are scattered through the siltstones. A few interbeds of calcareous sandstones and conglomerates are also present. Undoubtedly the marine phase of deposition was followed by lagoonal conditions near the close of sedimentation.

The volcanic pebbles and cobbles in the Carmen formation are similar to the volcanic rocks in the Comondú and are undoubtedly of local derivation. Possibly the observed dip is not a measure of the post-Carmen deformation, as these coarse clastics may have had some initial dip at the time of deposition. In both sections the dip is less where the sediments are fine-textured. Crossbedding on a large scale might be expected, but no examples were found.

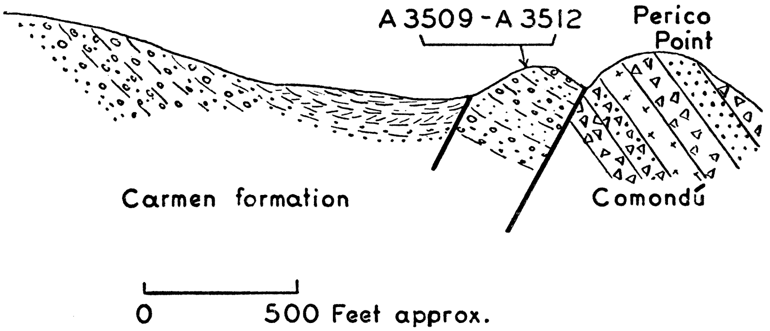

FIGURE 6.—*Cross section near Perico Point, Carmen Island*
Drawn from field sketches with limited vertical control.

The history is that of a basin carved from tilted Comondú volcanics and filled with pebble and cobble gravels derived from the surrounding Comondú. As the basin filled with coarse clastics, fine-textured sediments and calcareous deposits became increasingly abundant, and near the closing stages the basin was isolated from marine waters so that gypsiferous sediments accumulated. Durham (1950, p. 17) discussed reasons for assigning this formation to the middle Pliocene; he placed it later than the beds referred to the San Marcos formation.

The irregularity of the surface upon which the Carmen formation was deposited on the north side of the island is well seen along the shore of Oto Bay. Here the Carmen formation is largely calcareous beds and some volcanic conglomerate capped by limestone; the latter is exposed largely south of the covering of younger andesite (Fig. 4). In these southern exposures are some intercalated thin-bedded cream-colored opaline cherts which appear to represent original deposits since no evidence of replacement of limestone is discernible even in thin section. The Carmen formation is essentially flat lying in this area, but no accurate estimate of thickness can be given. Lithologically the beds closely resemble the Marquer formation as exposed along Marquer Bay, but the fossils indicate correlation with the Carmen formation (Durham, 1950, p. 22).

Marquer formation.—The Marquer formation is well exposed in the sea cliffs and arroyos behind Marquer Bay, and this area has been chosen as the type locality; the fossils indicate an upper Pliocene age (Durham, 1950, p. 20). The Marquer formation is white to grayish white, in contrast to the surrounding red Comondú. The rocks are calcareous conglomerates containing volcanic pebbles, calcareous sandstones, marls, coquina, algal limestone, and coral-reef material. Fossils are abundant, but in some of the sandstones all but pectens and echinoids are leached. In some arroyos the underlying Comondú volcanics are exposed, but, since they are absent along the coast, the underlying surface presumably rises to the east. This same conclusion is reached from the distribution of the Marquer formation, surrounded on three sides by the Comondú rising topographically above it, in fault contact only at the south. Dips of the calcareous beds are low, and in the arroyos the angular discordance is easily seen; the Comondú dips more steeply beneath the calcareous beds. No adequate measure of the thickness of the Marquer formation can be given. The sea cliffs are 20–40 feet high, and this gives a minimum thickness. The same approximate value is obtained from arroyos where the Comondú is exposed. Since the surface on which the Marquer formation rests is probably irregular, the thickness undoubtedly varies but probably does not exceed 200 feet.

The history is apparently similar to that of the other Pliocene formations on the island. An embayment was carved out of deformed Comondú, and in this basin some clastic material was deposited. Most of the sediment, however, represents calcium-carbonate deposition (shell accumulation, algal growths, and coral reefs). Some of this material was fragmented by the waves, yielding coquina and marls. Later the region was uplifted and perhaps tilted seaward.

The Marquer formation is exposed along the south side of Puerto Balandra (A 3670), but outcrops are few, and the total thickness is only about 40 feet. Most of the sediments are calcareous containing a prominent coral-reef zone similar to those exposed at Marquer Bay. The Comondú volcanics are massive here, but the regional dip steep to the east can be measured. The calcareous sediments are flat proving a marked unconformity. Fossils indicate a correlation with Marquer formation (Durham, 1950, p. 23).

An area of Marquer formation is indicated west of San Francisco Bay (Fig. 4). It was not possible to visit this area, but, as viewed from the E. W. SCRIPPS, white flat-lying rocks resembling the Marquer formation are exposed along the sea cliffs Paredes (1920, p. 13) noted that fossiliferous limestones and clays 30–50 feet thick are exposed here. Fossil collections must be made, however, to be certain of this assignment to the Marquer.

Calcareous dune deposits.—Southeast of Puerto de la Lancha are excellent exposures of nonfossiliferous cross-bedded calcareous sandstones. Thin sections reveal rounded to subrounded shell fragments. The beds cover some of the fossiliferous limestones assigned to the San Marcos but encroach largely upon the Comondú. Similar cross-bedded limestones of limited extent cover gravel lenses containing Pleistocene fossils (Durham, 1950, p. 22). Distribution of the lithified cross-bedded deposits and rounding of the shell fragments point strongly to wind as the depositing agent. A terrestrial gastropod (*Bulimulus*) was found in a similar limestone at Oto Bay. Recent unconsolidated calcareous dune sands appear south of Oto Bay at 150–200-foot elevations. Considering the strong northwest winds that blow down the gulf in winter and spring, sand dunes are not out of place, and similar winds were undoubtedly important in the past. Since most of these deposits are lithified, they are not considered Recent. At Oto Bay they must be Pleistocene, but at Puerto de la Lancha possibly they might correlate with the Marquer (upper Pliocene). However, all are tentatively assigned to the Pleistocene.

Post-Comondu andesite.—South of Oto Bay is a small shield volcano of low-dipping blocky andesite flows. The summit elevation is 800 feet (barometer), and the andesite covers Carmen (middle Pliocene) limestones at 200-foot elevations, indicating a volcano some 600 feet high. Because there are no indications of submarine eruptions such as might be expected if the andesite were erupted during sedimentation in the middle Pliocene Oto Bay embayment, uplift of the limestones must have preceded eruption. Moreover, since a Pleistocene andesite volcano was built on Coronado Island 10 miles northwest, and the Carmen Island cone resembles it in amount of erosion, it may be of the same age. The post-Carmen andesite resembles the Comondú andesite petrographically; it is red with labradorite, basaltic hornblende, and hypersthene phenocrysts imbedded in pilotaxitic groundmass.

Possibly other post-Comondú volcanic rocks are on Carmen Island. From a distance it appeared that southwest of Oto Bay lava flows were discordant with the Comondú, but no time was available for close examination. South of Puerto de la Lancha exposures of a dense black andesite suggest erosional remnants of a flow, and, if this conclusion is tenable, the flow would be discordant with the underlying Comondú. A faint Pleistocene terrace is mantled with cobbles of similar andesite which are absent in the gravels intercalated with the lower Pliocene limestones as the latter consist of typical red and gray Comondú porphyritic andesites. Microscopically the dense andesite has a hyalopilitic groundmass and small phenocrysts of plagioclase, augite, and hypersthene. Similar pyroxene andesite occurs along some talus slopes bordering the east side of the salt flat; unfortunately no time was available to examine neighboring ridges. Possibly careful study would reveal more younger lava flows discordant with the Comondú.

Pleistocene sediments and terraces.—The first exposures noted on the shore east of Salinas Bay (Fig. 5) are gently westward-dipping massive and thin-bedded siltstones containing a lower Pleistocene fauna. Only a few feet is exposed, and no similar beds are found elsewhere on the island. These siltstones are overlain unconformably by a coral reef covered by horizontally bedded gravels having a combined thickness of 4 feet. These younger gravels undoubtedly represent a later stage in the Pleistocene as they form a definite low-elevation terrace with no evidence of deformation.

Pleistocene terraces are common on the island, truncating the Pliocene formations but are absent on the more resistant Comondú volcanics. They are usually covered by several feet of loosely consolidated gravels with admixtures of shells and coral fragments; in a few places well-developed thin coral reefs are capped by gravels. These Pleistocene sediments usually truncate the beveled edges of the underlying Pliocene formations. At Marquer Bay, the highest terrace level is at 330 feet, and it has considerable areal extent. A second terrace occurs at 300 feet and is also well developed. Narrow terraces covered by gravels and fossils appear at 20 and 10 feet, and the 20-foot terrace is displaced 5 feet by a normal fault. The 10-foot terrace occurs only in the arroyos and might be confused with Indian kitchen middens of which there are numerous examples. However, this terrace is marked by coral at the base of the gravel and shell accumulations.

There is some consistency in terrace levels at various localities on the island. At Puerto Balandra a Pleistocene terrace covered by gravels and shells is 40 feet above sea level; however, it is of very limited extent. At Puerto de la Lancha is a terrace level at 270 feet. At Perico Point a small remnant of unconsolidated gravel with fossils is found at 300 feet. A lower terrace is conspicuous at 20 feet. Behind Arroyo Blanco are two terraces, one at 120 feet and the other at 200 feet, carved from San Marcos gravels. A well-developed terrace occurs at 30 feet where the upper limestones crop out. Because these are all aneroid-barometer measurements, some inaccuracy is involved, but terraces at 300 feet and 30–40 feet seem widespread. Locally terraces appear at intermediate levels.

Salinas graben.—The salt flat north of Salinas Bay occupies a graben of rather recent formation. Evidence supporting the fault origin of the basin is entirely physiographic, as no fault surfaces were observed. On both sides of the low-lying salt flat are straight steeply rising slopes marked by faceted spurs suggesting eroded fault scarps (Pl. 3, fig. 3). Normal faults east of the flat, all with down-dropped blocks to the west (Figs. 5, 6), strengthen this suggestion. The graben dies out to the north; low-rolling hills of Comondú separate the salt basin from the north shore.

Following the graben formation a northward extension of Salinas Bay occurred, and marine waters occupied most of the area now filled with alluvium and salt. Evidence for this is the widely distributed coral reefs and associated molluscan shells exposed around the margin of the salt deposits. Grewingh (1848) noted this coral. The origin of the salt deposit is rather simple; after the graben formation and extension of Salinas Bay, long-shore currents built a bar from east to west. This is shown by the cobble beach at the extreme east end grading to pebbles and sand to the west. Evaporation of trapped sea water in the desert environment led to concentration of the salt and eventual crystallization. According to Cook (1908) drill holes penetrated the flat 40 feet, passing through horizontal layers of marine sands impregnated with salt intermixed with muds and sands washed in from surrounding hills. The salt deposits are at elevations slightly below the high-water level of the bay. Since these deposits have been worked since the Spanish settled Lower California, it might be supposed that, if the salt represented only the concentration from the initial lagoon, the deposits would have been exhausted long ago. Cook (1908) and Hisazumi (1930, p. 78) suggested replenishment of sea water from Salinas Bay through the beach barrier formed ponds a few inches deep and upon evaporation additional salt is yielded. Certainly the cobble and pebble barrier is permeable for additional supplies of sea water. There is no evidence that high-tide marine water floods the salt flats by passing over the barrier. At present a wooden pipe exposed at low tide carries sea water for replenishment to the salt flat.

DANZANTE ISLAND

Danzante Island, a small island near the southern tip of Carman Island (Fig. 4), was not visited, but the E. W. Scripps passed close to it on several occasions, and the rocks looked like the Comondú formation as exposed on Carmen Island. Johnson (1924, p. 956) reported the island has structures similar to those of the Sierra Giganta (composed of Comondú) and probably represents less-elevated fragments of that mass.

MONSERRATE ISLAND

Only part of a day was available to study Monserrate Island, 20 miles southwest of Carmen Island. Because of a strong northwest wind, landing could be made only on the southeastern side of the island, and observations were limited to this area. Monserrate is 4 miles along and 2 miles wide; the highest elevation of 734 feet is in the south-central part. From a distance a terraced appearance is apparent; this is produced by thin gently dipping light-colored limestones at various levels. These are in marked contrast to the underlying red to brown volcanic rocks.

The volcanic rocks presumably are part of the Comondú formation and are largely andesitic lava flows, volcanic breccias, and minor intercalated volcanic sandstones, dipping 50° E. The strike is slightly west of north. In some of the lavas are brilliant black hornblende phenocrysts over 10 mm. long imbedded in a light-gray microporphyritic matrix containing labradorite, augite, hypersthene, and hornblende microphenocrysts separated by a pilotaxitic aggregate of the same minerals. Some of the volcanic breccias contain many blocks of these conspicuous hornblende andesites. Others are dark-brown amygdaloidal, containing andesine and augite phenocrysts in a pilotaxitic to hyalopilitic groundmass.

Resting on the Comondú volcanics with marked angular discordance are light-gray to buff fossiliferous limestones. These are usually separated from the Comondú by a basal conglomerate of variable thickness, rarely exceeding 10 feet. The limestones dip about 5°–6° E. and strike N. 20° E. The thickness varies for the underlying surface is irregular, and "islands" of Comondú rise above the limestones. In places only 20–30 feet of limestone is exposed, but near the summit of the island the limestone is about 100 feet thick. Fossils in the limestone are badly leached, but a sufficient number of pectens were collected to establish the age as Carmen (middle Pliocene) (Durham, 1950, p. 26).

Resting on the limestones and truncating the beveled edges of the stratification planes are thin poorly consolidated gravels containing well-preserved fossils. According to Durham (1950, p. 26) they indicate a Pleistocene age. The middle Pliocene limestones and Pleistocene gravels were faulted into several terraces or mesas. The highest level is at 700 feet (barometer); the highest peak near by at 734 feet consists of Comondú. The Pleistocene gravels overlap upon a surface cut from the Comondú. The second highest "mesa" in the southern part of the island is at 560 feet, and the fault contact between the Pliocene-Pleistocene sediments and Comondú volcanics is obvious. The fault strikes N. 30° W. Time was not available to measure the elevation of other lower "mesas" which also represent faulted Pliocene and Pleistocene beds. In the southwest part middle Pliocene limestone appears at only 30 feet.

A younger Pleistocene terrace appears at 40 feet and is cut into both Comondú and Carmen limestone, indicating that it formed after the faulting which displaced the Pleistocene gravels. Presumably the faulted Pleistocene gravels are early Pleistocene.

To summarize: After accumulation of the Comondú volcanics and interbedded sandstones, the rocks were tilted eastward, and an irregular erosion surface was carved. In middle Pliocene time the area was depressed, and up to 100 feet of calcareous sediments accumulated. These beds were tilted slightly east, and during the early Pleistocene a transgression of the sea left a thin veneer of fossiliferous gravels upon the underlying limestones and volcanics. This surface was broken into fault blocks, the faults striking west of north, and in the central part of the island there was considerable elevation of the fault blocks. Following faulting and during the later Pleistocene, a marine terrace was formed which is now 40 feet above sea level.

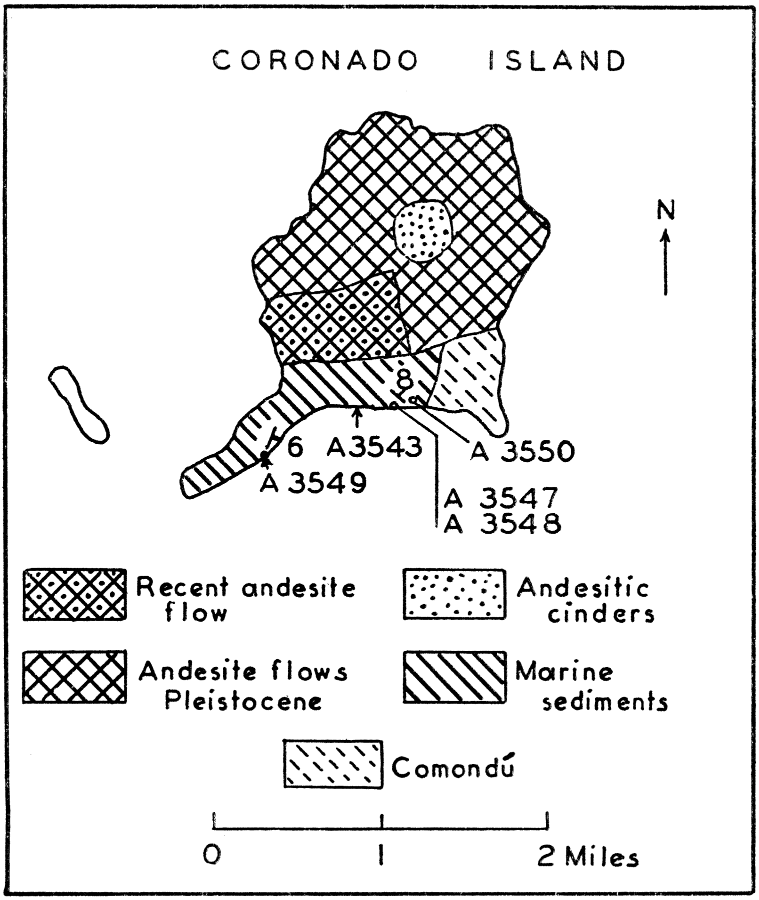

FIGURE 7.—*Geologic map of Coronado Island*

CORONADO ISLAND

Coronado Island[3], 10 miles northwest of Carmen Island, lies only 2 miles from the peninsula of Lower California. The intervening water is less than 6 fathoms deep. Coronado Island consists largely of a single andesite cone (Pl. 3, fig. 2) on a basement including lower Pleistocene sediments.

The Comondú formation, exposed at the southeastern part of the island (Fig. 7), is hornblende andesite lava flows and volcanic breccias; the dip is about 20° E. the strike N. 20° W. In the central part of the southern shore a single exposure of volcanic breccias along the sea cliffs is overlain by younger sediments that dip westward (Fig. 8, A 3545). These younger rocks are calcareous clays whose fossils suggest

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[3] Indicated as "Coronados Island" on the maps of the U. S. Hydrographic Office. According to Paredes (1920, p. 9), it should be Coronado Island.

correlation with the Carmen or Marquer formations. No similar exposures were observed elsewhere on the island. To the west, in fault contact, are eastward-dipping volcanic conglomerates with local calcareous matrices containing marine fossils ranging in age from San Marcos to Carmen (Fig. 8, A 3544). These conglomerates may be equivalent to the San Marcos (lower Pliocene) and older than the neighboring westward-dipping clays, or they may be equivalent to the clays and may represent a different facies brought into fault contact. The fossils are not sufficiently diagnostic to eliminate either possibility, and the question must remain open.

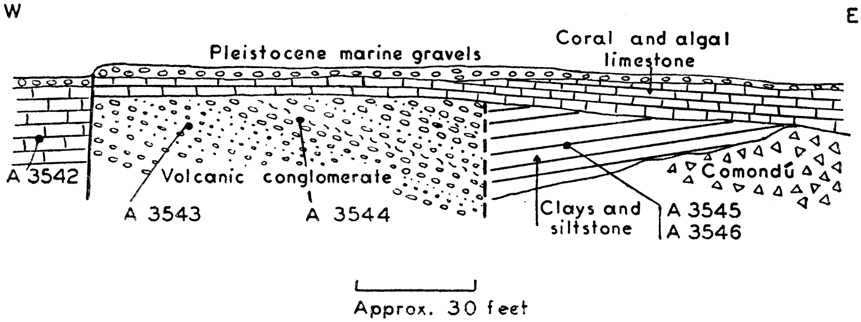


FIGURE 8.—*Cross section in sea cliffs, south shore of Cornado Island*

Location of A 3543 indicated on Figure 7.

The volcanic breccia, volcanic conglomerate, and clays are overlain with a marked angular unconformity by limestone (Fig. 8, A 3542), usually with scattered volcanic cobbles and boulders at the base. The lower part of the section is predominantly light-colored algal limestone, while the upper part is a coral-reef zone or reworked coral limestone. Along the sea cliffs or arroyo banks only 20–30 feet of these limestones is exposed in isolated exposures, but they cover a considerable area in the southern part of the island, always with a low easterly dip. Too many faults were observed to calculate the thickness. Presumably not more than 100 feet of limestone are present, but admittedly this is only a rough estimate.

Many well-preserved lower Pleistocene fossils were collected from these limestones (Durham, 1950, p. 25). Upper Pleistocene marine sands and gravels and recent coral sand dunes (Pl. 3, fig. 2) cap much of the older Pleistocene limestones. Several faults displaced the Pleistocene terrace gravels, and the one shown (Fig. 8) has a displacement of 4 feet. On the east side of the fault only 4 feet of lower Pleistocene limestone is exposed, while on the west side 30 feet is exposed in the cliff section. This suggests that the fault was active prior to deposition of the late Pleistocene gravels as well as later. All these faults displacing the Pleistocene limestones range in strike from N. to N. 30° W.

The volcano forming the main part of the island consists of blocky andesite flows discharged from a central vent now capped by a cinder cone in which a crater is poorly preserved. The summit elevation is 928 feet (Hydrographic Office map). The blocky flows poured over the lower Pleistocene limestones now exposed between tongues of andesite; hence the volcano is no older than early Pleistocene. Comondú volcanics at the southeastern corner of the island are truncated by a terrace 140 feet above sea level surrounded by a lower terrace with a beach line at 100 feet cut into the Pleistocene andesite flows. No trace of the higher terrace was found in the latter flows. This suggests two possibilities. (1) The volcano was built during the formation of the 140-foot terrace, and the beach line was covered by later flows; or (2) the volcano was built later during the formation of the 100-foot terrace, and the distal ends of the andesite flows were attacked by the waves. This limits the age of the volcano to within the Pleistocene.

The andesite is dense black on fresh surfaces but is weathered slightly to a dark brownish black. However, the southwestern sector is jet-black andesite (Pl. 3, fig. 2) that was discharged from several vents along the flanks of the volcano. Since this flow passes over the 100-foot terrace level without any suggestion of a shore line or terracing it must be younger; in fact it appears to represent the latest product of volcanic activity. Its exact age is uncertain, for in this desert environment freshness of lava and lack of vegetation are not valid criteria for indicating recency of eruption. Possibly it is only several thousand years old.

The lava of the cone is a dense black andesite devoid of conspicuous phenocrysts. Thin sections reveal microphenocrysts of hypersthene, augite, and calcic andesine imbedded in a hyalopilitic groundmass with brown glass and magnetite separating the microlites.

NORTH OF LORETO

General statement.—For interpretation of the Pliocene history of the Gulf of California, there is a very important area 15 miles northwest of Carmen Island and 6 miles north of Loreto. Excellent exposures of fossiliferous lower Pliocene sediments are in the arroyos passing eastward into middle and upper Pliocene sediments. Unfortunately, only 1½ days were spent in this critical area. Gabb (1869, p. 116) noted these sediments of "post-Pliocene" age containing fairly well preserved fossils and "all of living species". On the geologic map of Lower California prepared by the Marland Oil Company (Anonymous, 1924c p. 52) the beds are indicated as the Salada. On a private map loaned to the writer by Dr. W. S. W. Kew, one of the members of the Marland Oil Company expedition to Lower California, an anticlinal axis is shown extending from the center of the Pliocene beds toward Concepcion Bay. Baker, while a member of the Academy of Science Expedition of 1921, collected fossils from these beds and made notes on the lithology, and according to Hanna and Hertlein (1927) the age is Pliocene.

Near Loreto the steep eastern front of the Sierra Giganta is several miles west of the Gulf shore, and a broad alluvial plain some 10 miles long borders the coast. At the north end of this plain hills composed of fossiliferous Pliocene sediments rise 600–700 feet (barometer). The road from Loreto to Mulegé follows the most southerly arroyo, Arroyo de Gua, for about a mile, crosses a low divide to the north into Arroyo de Arce, and follows this for a comparable distance before heading north. Observations were made along the road in both arroyos, and the rocks dip 40° E. In Arroyo de Arce as far west as observations were made, the beds dip east, but looking up the arroyo it appeared that the rocks dip west, confirming the anticlinal structure.

Comondú formation.—Near the anticlinal axis in the hills north of Arroyo de Arce andesite flows and volcanic breccias, exposed beneath fossiliferous sediments, are presumed to belong to the Comondú formation. The lava is porphyritic andesite with numerous large andesine and smaller biotite and basaltic hornblende phenocrysts set in a hyalopilitic groundmass in which are scattered augite microphenocrysts. The breccias are fragments of similar andesite. No structure was determined in the Comondú, so that it is not certain if there is an angular discordance between it and the Pliocene sediments as observed elsewhere. In two places belts of the overlying sediments are surrounded on both sides by the volcanic rocks. At the time, this relationship was attributed to faulting, but after observing elsewhere how the Pliocene sediments were deposited in embayments eroded from the Comondú formation, the writer believes that an irregular erosion surface buried by the Pliocene sediments may have been revealed by erosion. Certainly there is no indication of interfingering of the sediments with the Comondú.

San Marcos formation.—The oldest fossiliferous sediments exposed along Arroyo de Gua and Arroyo de Arce are correlated with sediments on San Marcos Island as the fossils indicate early Pliocene (Durham 1950, p. 22). Along Arroyo de Arce the San Marcos formation is a volcanic conglomerate containing interbedded sandstones, and shell reefs. Fossils are more prevalent in the finer clastics which are common throughout the section implying that the entire sequence is marine. Only pectens, oysters, and echinoids are easily collected as the other fossils are badly leached. Where studied along Arroyo de Arce, the dips are 30°–42° E.; the steeper dips occur nearer the anticlinal axis. However, the dip varies considerably throughout the section, perhaps caused in part by variation in initial dip at the time of deposition. Also some small normal strike faults may have modified the dip locally by drag. Of considerable interest is a pecten-reef bed, 100–150 feet thick (Fig. 9) formed almost exclusively of *Aequipecten abietis* (Jordan and Hertlein). Overlapping of the underlying beds by this reef indicates some scour prior to accumulation of the pecten shells. This does not seem to represent any important break in sedimentation as fossils higher in the section appear to indicate the same period of deposition. Presumably 3000–4000 feet of sediment is exposed in the San Marcos formation along Arroyo de Arce.

Some granitic cobbles were noted in the conglomerates and according to Carl H. Beal (personal communication), granitic rocks are now exposed in the headwaters of Arroyo de Arce. Gabb (1869, p. 96) reported that at Rancho San Juan, about 15 miles north of Loreto, "metamorphic sandstones" (presumably the Comondú formation) abut a mass of granite which covers the base of this portion of the Sierra Giganta. If the granite cobbles in the San Marcos formation were derived from granite beneath the Comondú, it would imply considerable deformation and erosion to uncover the granite by San Marcos time, unless the pre-Comondú granite surface were highly irregular, a subject about which we know very little.

Carmen and Marquer formations.—Where the hills rise from the alluvial plain (Fig. 9), beds with a much lower dip appear in the walls of the arroyo, and at one locality a marked angular discordance can be observed between the San Marcos formation and overlying rocks. The older beds dip 32–37° and these are truncated and overlain by beds of similar lithology but which dip 10° E. Fossils from the adjacent overlying beds appear to indicate correlation with the Carmen formation (middle Pliocene) on Carmen Island (Durham, 1950, p. 21). The Carmen formation consists of volcanic conglomerate, sandstone, and siltstone, but reef beds were not observed. Here also the common occurrence of the fossiliferous beds indicates that the entire sequence is marine.

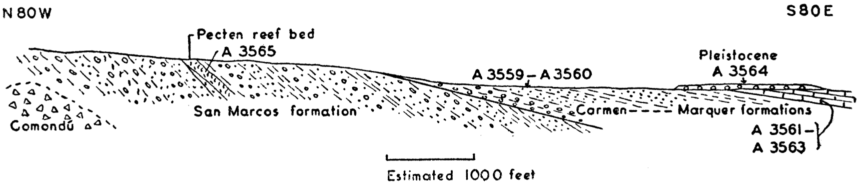


FIGURE 9.—*Cross section along Arroyo de Arce, Lower California*
Located north of Loreto. Vertical and horizontal control only estimated.

On the alluvial plain no exposures are visible except for alluvium in the low banks of the arroyo, but along the cliffs of the Gulf shore buff fossiliferous calcareous siltstones and shelly limestones are exposed dipping 10° E. This concordance in structure with the Carmen formation indicates that the rocks are conformable. The lithologic character of the calcareous beds suggests the Marquer formation (upper Pliocene) of Carmen Island, and the pectens and echinoids in these beds confirm this correlation (Durham, 1950, p. 21). The total thickness of the combined Carmen-Marquer formations is estimated at 600 feet. There is no suggestion of a boundary between the two.

The Marquer formation is covered by Pleistocene terrace gravels near the Gulf shore, and in some of the shallow arroyos only these flat-lying gravels are exposed.

PUERTO ESCONDIDO

Puerto Escondido, 5 miles west of the south end of Carmen Island, is of some interest because of the contrast to Sierra Giganta to the west and Carmen Island to the east. Formerly, the bay was a strait separating the peninsula from a small island, but a tombolo has connected the island and peninsula to the north, and the remaining entrance to the south is extremely narrow and shallow, kept open only by tidal currents (Fig. 10). The area south of the entrance provides excellent anchorage during severe northwest storms.

The Comondú formation—grayish-brown tuff breccias and lava flows—dips east at a moderate angle. Almost all the fragments in the breccia are porphyritic augite andesite; each contains conspicuous andesine-labradorite and a smaller number of greenish-black augite phenocrysts. Microscopically the groundmass is hyalopilitic. or pilotaxitic containing interstitial fibrous chlorite areas with or without calcite. At the north end of the tombolo a hill of greenish-gray platy aphyric andesite is exposed. In thin section a few microphenocrysts of augite are revealed, but the bulk of the rock is trachytoid—plagioclase prisms separated by granules of augite and magnetite. Although this andesite differs considerably from the fragments in the tuff breccias, it also appeared to belong to the Comondú. Overlying the Comondú with an angular discordance but also dipping east (Fig. 10) are a series of brownish-black olivine basalt flows that might correlate with the post-Comondú basalts on the western slope of the peninsula. The basalt is holocrystalline with scattered olivine partly altered to iddingsite imbedded in a subophitic arrangement of labradorite and augite. Magnetite is accessory.

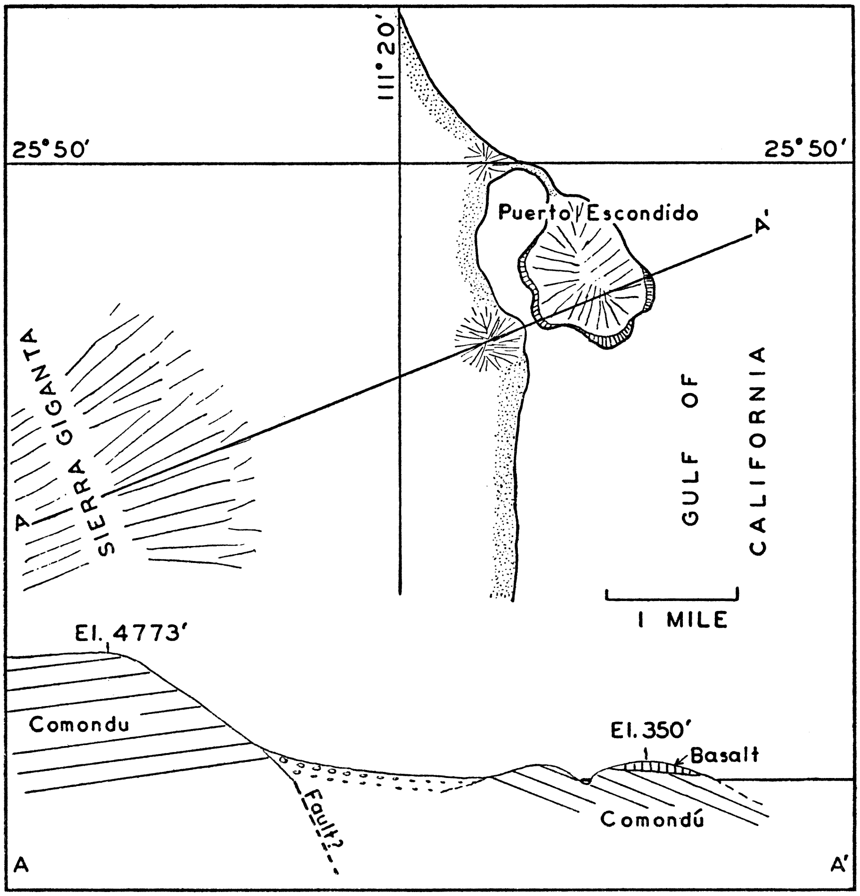


FIGURE 10.—*Sketch map and cross section, Puerto Escondido, Lower California*

The base of the steep eastern slope of Sierra Giganta is about 2 miles west of Puerto Escondido (Fig. 10), and the intervening area is covered largely with alluvial-fan deposits. Time was not available to study the Comondú in the Sierra Giganta, but, according to Darton's (1921) sections and Gabb's (1869) reports, the Comondú dips gently westward there. The eastern slope of the Sierra looks like an eroded fault scarp, so the structure as revealed around Puerto Escondido is of particular importance (Fig. 10), for the Comondú dips east at a moderate angle. This may represent a faulted anticline or a down-dropped block tilted during faulting. With only several hundred feet more of depression, the block east of Sierra Giganta would be covered by the Gulf, and the shore line would border the eastern base of Sierra Giganta.

A possible Pleistocene terrace occurs on the hill east of Puerto Escondido. A well-defined bench at 110 feet (barometer) is covered with rounded cobbles and pebbles. However, the associated clam and oyster shells are broken and may well have been carried there by Indians. Near the entrance to Puerto Escondido is a definite Pleistocene terrace at 20 feet. Here gray coral fragments in a fine silty matrix carrying pectens compose the surface which overlies a layer of clam shells. The clam and pecten shells might suggest a kitchen midden, but the numerous coral fragments favor a natural marine accumulation.

A number of small faults striking slightly west of north are visible in the rocks around Puerto Escondido. They suggest that the original strait either originated directly from faulting or from erosion along a fault zone.

SAN MARCOS ISLAND AND VICINITY

GENERAL STATEMENT

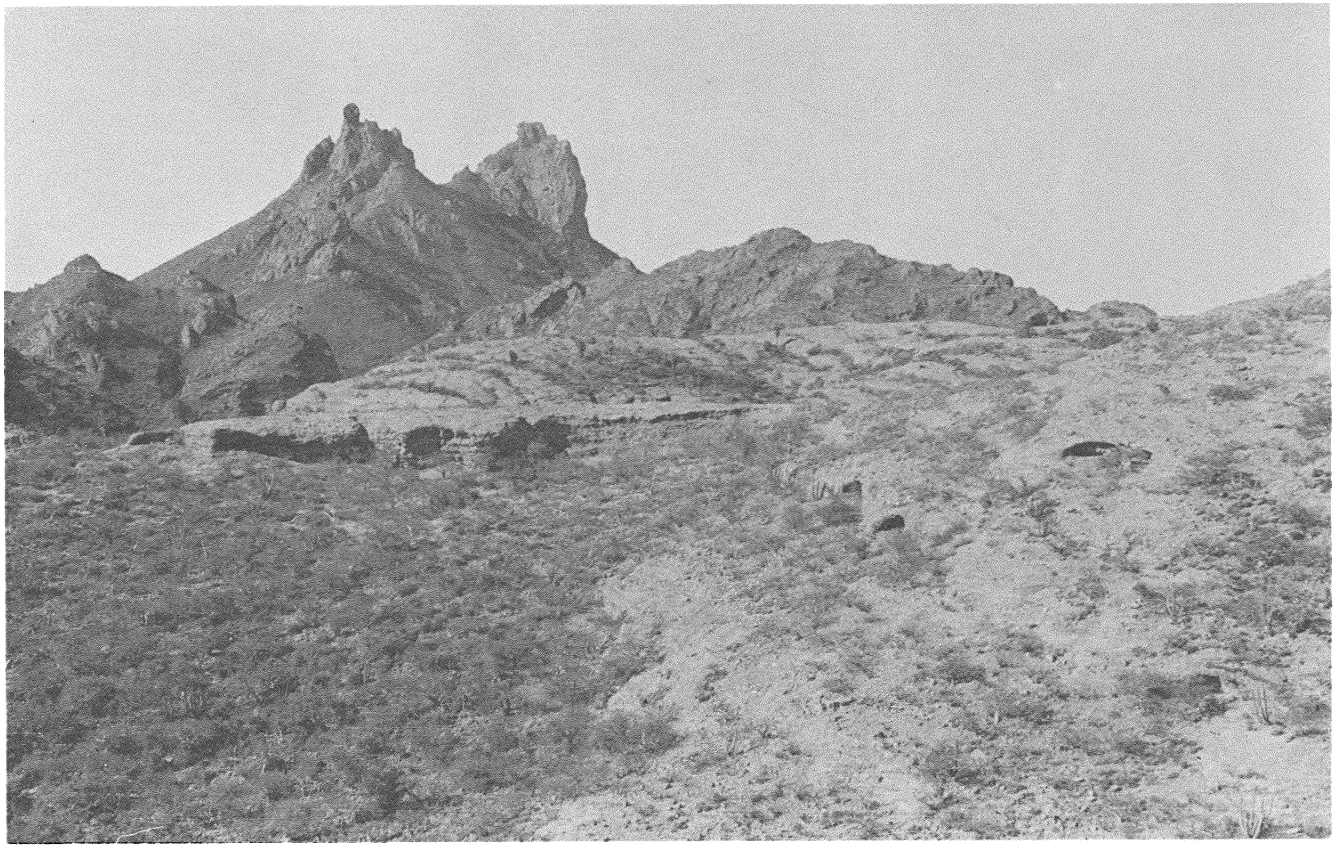
San Marcos Island, one of the smaller western islands in the Gulf, is located about the center of the eastern shore line of the peninsula. It marks the north end of an area selected for study which included Santa Inez and Concepcion bays.

SAN MARCOS ISLAND

General statement.—Only 4 days were available for land studies in this region, and some time was used in traveling from one locality to another, so that only 1½ days could be spent on San Marcos Island concentrating on the southern end where there is a large gypsum deposit now being mined. The gypsum is associated with fossiliferous marine sediments which yielded a good fauna indicating lower Pliocene age. These sediments including the gypsum were designated the San Marcos formation. The type section, exposed on the east side of the island, was selected as the sediments contain many fossils that correlate with the Imperial formation of southeastern California. The island is almost 6 miles long and about 2½ miles wide and elevations are moderate; the highest peak is only 891 feet high.

Comondú formation.—The Comondú formation—lava flows, volcanic breccias, and tuffs with a moderate west or northwest dip—is the oldest formation exposed. It crops out north of the gypsum area and along the southeastern shore line (Fig. 11), always with a marked angular discordance to the overlying sediments. Along the coast line it can be seen that the sediments were deposited on an irregular surface (Pl. 3, fig. 1). One of the lava flows is of interest in that small irregular vesicles are rimmed with a brownish chlorophaeite-like mineral, and the interior is lined by greenish fibers of much higher index suggesting celadonite. Most of the rock is an intergranular arrangement of labradorite, augite, and magnetite and small scattered plagioclase phenocrysts. The rock might be basaltic in composition as suggested by the labradorite, but in the absence of chemical analysis a definite classification is impossible.

San Marcos formation.—The San Marcos formation includes clastic sediments as well as gypsum, and along the southeastern shore and southern contact of volcanic rocks the base of the formation consists of 100–150 feet of volcanic sandstone and interbedded volcanic conglomerate resting on and butting into the Comondú volcanics. These sediments have no marine fossils and probably represent continental deposits. They contain carbonized wood and leaf fragments.



GUAYMAS AREA

North of Ensenada San Francisco. Conglomerates and sandstones with low dip in foreground; andesite-rhyolite series dipping steeply to left in background.

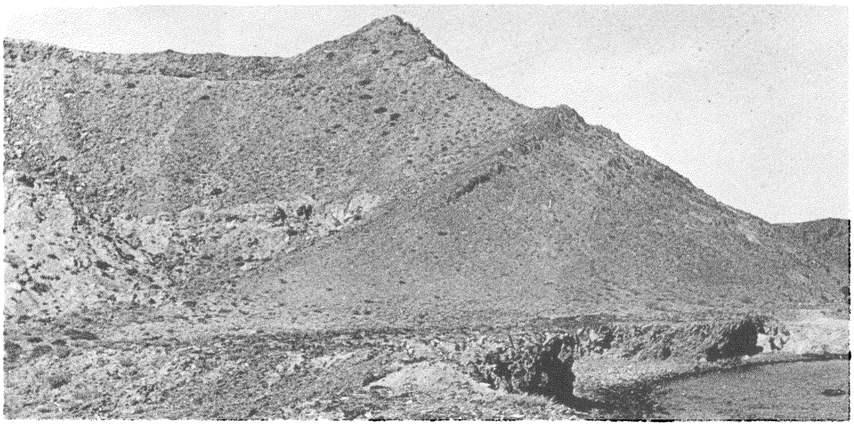


Figure 1. East Shore of San Marcos Island
Comondú dipping left (west). Gypsum (light-gray area, left center); fossiliferous sediments near top butting into Comondú. Marine terrace in foreground.

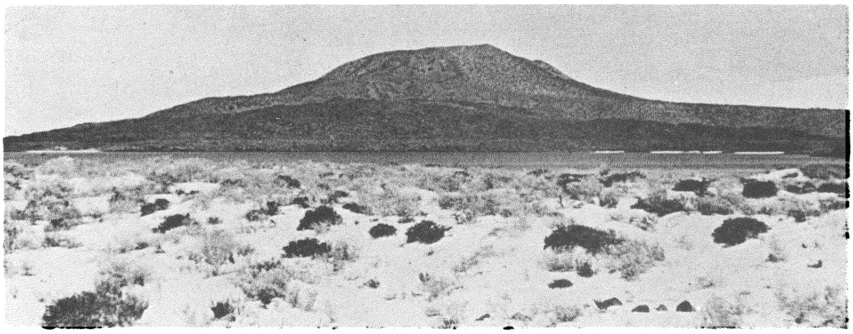


Figure 2. Coronado Island
Andesitic volcanic cone. Dark area in middle ground, recent flank eruption. Calcareous dune sands in foreground.

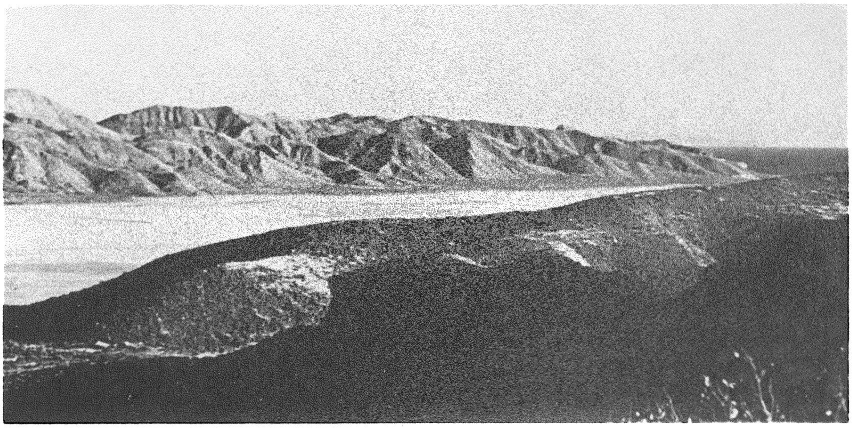


Figure 3. Carmen Island
Salinas graben, looking southeast.

SAN MARCOS, CORONADO, AND CARMEN ISLANDS

The gypsum beds, exposed in the central part of the southern end of the island, are conformable with the underlying clastic beds. The gypsum is mined north of the village near the southwestern corner of the island, and in the quarries are good exposures

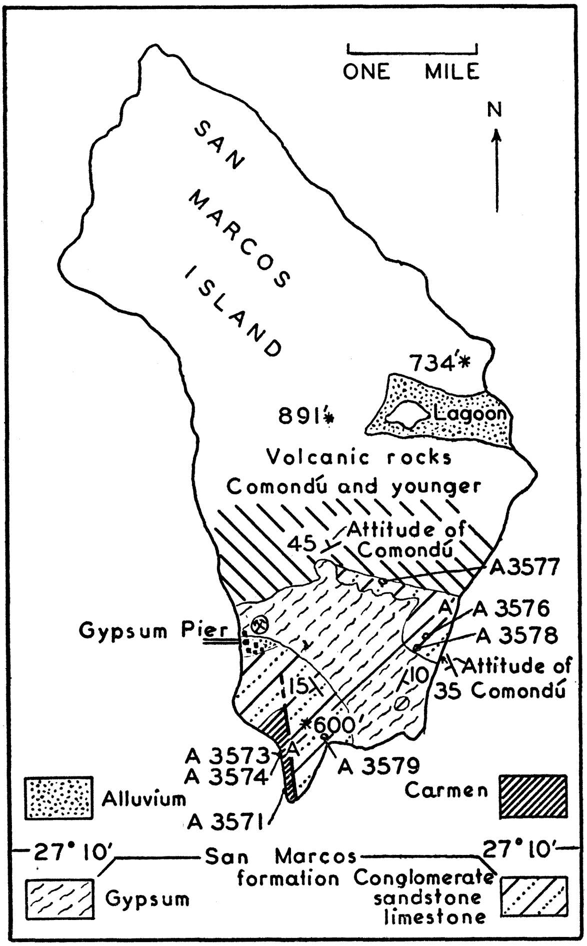


Figure 11.—*Geologic map of the south end of San Marcos Island*

of gray crystalline gypsum interbedded with thin lenses of sandstone and shale. Small carbonized plant fragments are common in the shale. Considerable minor folding in the gypsum makes it difficult to measure thickness, but it is approximately 400 feet at the quarries. North and east the gypsum is thinner. Surface exposures of the gypsum are strikingly barren and only scattered dwarfed plants relieve the monotony of the grayish-white weathered gypsum. Small ridges in the exposed gypsum possibly have formed by expansion as the result of insolation as the surface temperatures are high during summer.

In the north-central part of the gypsum area, volcanic gravels and sands grade into the thinning beds of gypsum. In the northern bank of a deep wide arroyo, at the same level on the strike as the gypsum beds to the south, only 20 feet is present of yellowish clay containing scattered gypsum crystals and thin interbedded lenses of crystalline gypsum. Apparently this marks the approximate edge of the gypsum deposit and the shore line of the ancient saline lake or lagoon in which the gypsum accumulated. To the north the Comondú volcanics rise above the gypsum indicating that a basin was carved out of the deformed Comondú.

Marine fossils occur (Pl. 3, fig. 1) in sediments conformably overlying the gypsum northeast and southwest of the main gypsum area. Northeast about 200 feet of fossiliferous sediments remains after erosion, but southwest the fossiliferous sediments are thicker (Fig. 12). The lower part of the section is volcanic sandstone, while the upper part is calcareous conglomerate and pebbly limestones locally quite fossiliferous. In the upper fossiliferous section granite pebbles and cobbles occur but are absent below. Near Santa Rosalia, 15 miles northwest of San Marcos Island, Touwaide (1930, p. 118) described granodiorite beneath the Comondú volcanics, and possibly sufficient erosion took place after uplift and deformation of the Comondú to expose the underlying granitic rocks as source for sedimentation in the San Marcos gravels.

The San Marcos has been folded into a broad anticline plunging southeast, and the gypsum beds have been buckled into numerous minor folds, possibly the result of expansion by hydration of original anhydrite.

At Santa Rosalia (Touwaide, 1930, p. 119) gypsum occurs in beds up to 320 feet thick resting on an irregular surface on the Comondú volcanics. The gypsum is a part of Touwaide's "Lower Salada", and according to Durham (1950, p. 28) the fossils indicate correlation with the San Marcos formation. To account for the erratic and varied distribution of the gypsum Touwaide suggested that it originated by precipitation of calcium sulphate from hydrothermal submarine springs. However, on San Marcos Island the regularity of the gypsum deposits interbedded everywhere between stratified sediments indicates that evaporation of a partly enclosed body of water is a better explanation. The absence of marine fossils in the sediments underlying the gypsum casts doubt upon the possibility that gypsum crystallized from a lagoon formerly connected with the Gulf. The underlying and immediately overlying sediments may represent continental deposits, and the gypsum may have crystallized from a saline lake. In the latter case, possibly hydrothermal springs supplied the calcium sulphate. Although the evidence seems clear that the gypsum represents a saline lake deposit, a final decision requires additional data.

Carmen formation.—At the southern tip of San Marcos Island limestones and conglomerates dipping steeply east and southeast are in fault contact with the upper San Marcos sediments (Figs. 11, 12). Boulders of fossiliferous San Marcos in this formation indicate that the original relationship was unconformable. Fossils suggest correlation with the Carmen formation of Carmen Island (middle Pliocene) (Durham, 1950, p. 26). The high dips presumably resulted from drag against the fault.

Post-San Marcos lavas.—North of the gypsum area (Fig. 11) lava flows above the conglomerate cap the gypsum, but the fossiliferous limestones are absent. Possibly this represents an unconformity, the upper part of the San Marcos formation having been removed prior to extrusion of the lavas. They are dark brown to black, and in the sample collected only augite and olivine phenocrysts appear imbedded in a pilotaxitic groundmass of plagioclase microlites, augite, and magnetite granules. The olivine suggests a basalt, but the plagioclase is too minute for accurate determination. It seems that two volcanic sequences are represented on the island, the older deformed Comondú volcanics and the post-San Marcos lava flows. How much of the Central and northern part are younger volcanics must be decided by future work. There is no hint on the relationship of the later volcanics to the Carmen formation exposed on the southern tip of the island.

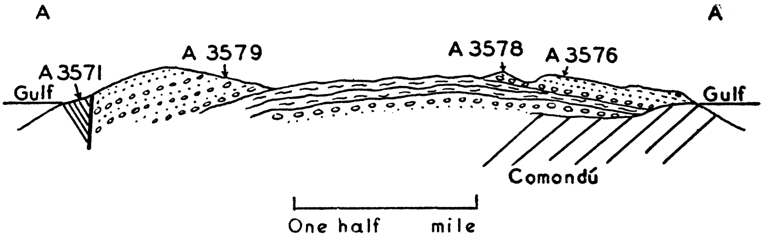


FIGURE 12.—*Cross section through San Marcos Island*
Location of section given on Figure 11.

Pleistocene terrace.—A well-defined uplifted terrace is cut into the Comondú volcanics on the east side of the island (Pl. 3, fig. 1) at 20 feet. Presumably this represents a Pleistocene terrace comparable to those found on other islands. Two similar terraces, the lower truncated by the upper at about 15 feet, occur at the south end of the island (A 3573, A 3574).

SANTA INEZ BAY

One day was available for studies in the headland at the northern end of Santa Inez Bay. A landing was made $1\frac{1}{2}$ miles west of Chivato Point, and a traverse made to the point, then south to Santa Inez Bay (Fig. 13).

The Comondú formation is well exposed along the cliffs west of Chivato Point as the shore is approximately at right angles to the strike. As on San Marcos Island the dips are westerly. The exposed rocks are alternating flows of lava, massive volcanic breccias, and finer pyroclastics including white tuffs and red "cinder" tuffs. Small faults strike between N. and N. 10° E. and dip steeply east. These cause considerable repetition in the volcanic series. Although the white tuffs are andesitic, they are deficient in dark minerals and contain calcic oligoclase to sodic labradorite crystals and only traces of augite and basaltic hornblende. The bulk of the tuff is fine glass shards of variable refractive index, but ranging around 1.520 which indicates a silica content of 62–65 per cent (George, 1924, p. 366). The lava flows are medium gray, holocrystalline, and probably basaltic, for thin sections reveal olivine partly altered to iddingsite imbedded in an intergranular aggregate of andesine-labradorite, augite, and magnetite. This rock is of interest as an olivine-bearing lava within the Comondú formation; all other lavas studied to the south are andesites devoid of olivine.

West and southwest of Chivato Point are small patches of fossiliferous San Marcos limestone resting with marked angular discordance on the underlying Comondú. Some patches are pebbly and resemble the calcareous beds above the gypsum on San Marcos Island. The patches continue almost to Santa Inez Bay. Along the shore line west of Santa Inez Point are a series of calcareous sandy and silty beds dipping gently eastward. Some fossils occur, largely pectens, echinoids, and oysters, and these indicate correlation with the San Marcos formation (Durham, 1950, p. 27). Presumably these represent an extension of the San Marcos formation that must have completely covered the headland at one time.

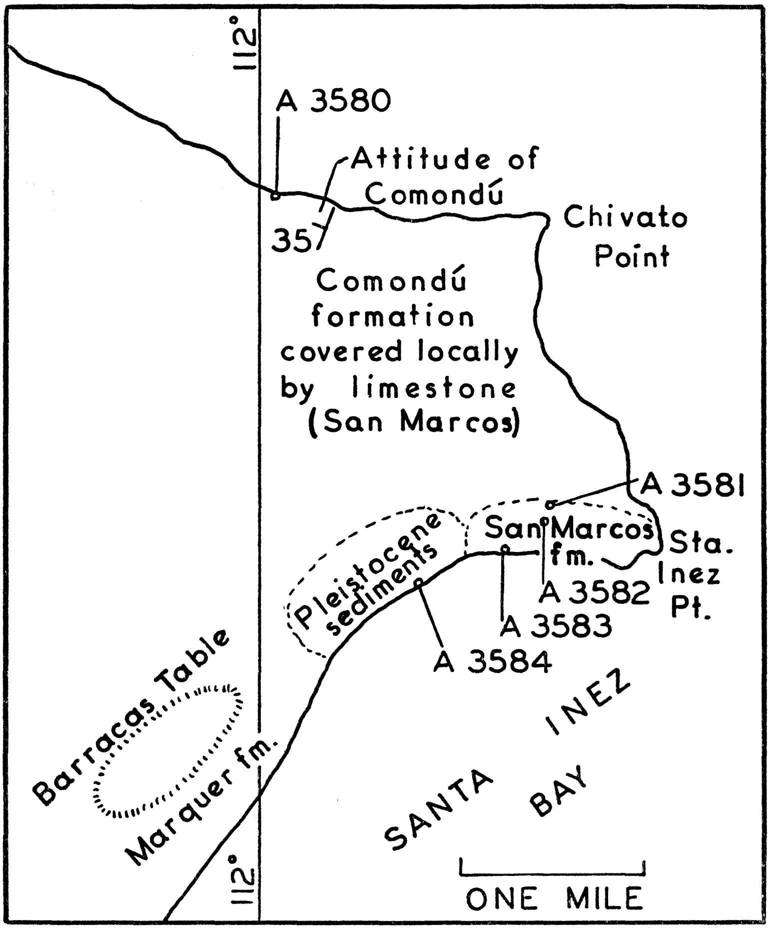


FIGURE 13.—*Sketch map of the northern headland of Santa Inez Bay*

At Barracas Table, a mesa with a 300-foot elevation, occur horizontal beds of fossiliferous sandstones and limestones 200 feet thick. Barracas Table was not visited, but members of the 1939 Scripps expedition collected fossils there, and according to Durham (1950, p. 27) these indicate correlation with the Marquer formation (upper Pliocene). No other exposures of Marquer formation are known in this region.

Between Barracas Table and Santa Inez Point flat-lying calcareous sandstones and limestones contain abundant Pleistocene fossils. Whether these represent sediments accumulated when some of the near-by terraces were cut is debatable. A well-developed terrace occurs west of Chivato Point at 45 feet, and a questionable shore line may be present at 320 feet.

COYOTE BAY

A landing was made at Coyote Bay, a small indentation along the western margin of Concepcion Bay, about 8 miles south of the entrance to the latter (Pl. 1). The exposed rocks are Comondú, largely coarse volcanic breccias without discernible structure. The blocks are andesitic of varying texture; a common type is porphyritic hornblende-hypersthene andesite containing conspicuous white sodic andesine phenocrysts. In other samples augite is present. In another clusters of tridymite were noted in the pilotaxitic groundmass. In a poor exposure with the relationships unknown, a massive grayish-white pumice-lapilli tuff appears; the pumice carries small green hornblende and calcic andesine crystals. The glass index of refraction is 1.508 suggesting 66–67 per cent silica. The rock is probably between andesite and dacite. Except for the lower refractive index of the glass, this lapilli tuff is similar to the white crystal vitric tuff west of Chivato Point, some 25 miles north.

Pleistocene terraces were noted at 10 and 20 feet, capped by thin fossiliferous sediments.

NORTHERN ISLANDS

GENERAL STATEMENT

The northern islands in the Gulf were selected for special study; Tiburón Island belongs to this group but was discussed earlier because of its close association to Sonora. The western islands here include San Lorenzo and Angel de la Guarda. Landings were made on these as well as in Lower California in Las Animas Bay.

SAN LORENZO ISLANDS

General statement.—San Lorenzo Islands, 20 miles southeast of Angel de la Guarda Island, represent an emerged portion of the submarine ridge extending from the latter island. The ridge is covered by less than 100 fathoms of water, and two islets as well as Sal si Puedes Island (Fig. 14) rise above the surface. Of the San Lorenzo Islands the larger is to the south, 10 miles long, and less than 2 miles wide. North San Lorenzo Island is over 3 miles long but less than a mile wide. No summit elevations are known, but higher elevations are estimated about 1000 feet. One day was available for observations here, and several stops were made along the southwestern shore; landings were possible from a skiff in spite of a rather bold steep sea coast. The only excursion inland was in the central part of the south island where gypsum is exposed (Fig. 14).

Quartz diorite and metamorphic rocks.—The southern part of south San Lorenzo Island is quartz diorite, and although no landings were made at the southern end the appearance of the rocks viewed from the E. W. SCRIPPS suggested that the entire southern part is granitic. The quartz diorite is medium-grained, largely oligoclase-andesine and accessory quartz, biotite, and hornblende. Orthoclase occurs in minor amounts interstital to the quartz and plagioclase. Minor accessories include apatite, zircon, sphene, and magnetite. Toward the central part of the island the rock becomes finer-grained and darker, and thin sections reveal a large amount of foreign material—granular quartz lenses containing interstitial orthoclase and bands of sericite and non-pleochroic pale-brown mica associated with abundant sphene—suggesting the rock is a mixture of metamorphosed sediment and quartz diorite. Around the gypsum area metamorphic rocks are well exposed and include black hornfels, and andalusite-mica schists, conglomerates with a black hornfels matrix, and dark to medium-gray quartzites. Obviously, the rocks represent a metamorphosed sedimentary sequence.

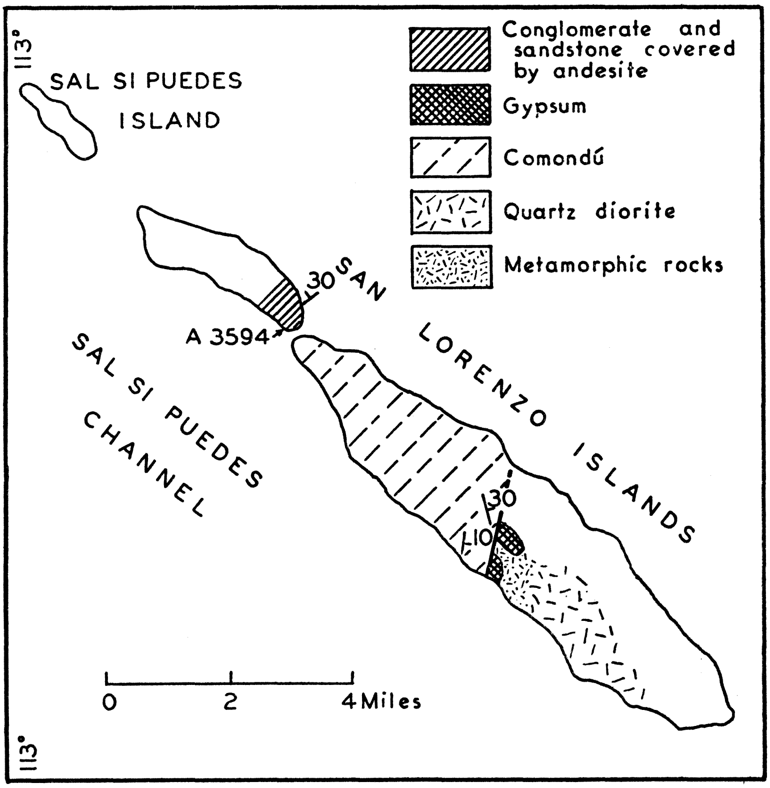


FIGURE 14.—*Sketch map of San Lorenzo Islands*

Comondú formation.—The north half of south San Lorenzo Island is andesitic lava flows and interbedded volcanic breccias and tuffs, many well stratified. These have been referred to the Comondú formation, but admittedly San Lorenzo Islands are in the northern area of postgranitic volcanics, and correlations with the typical Comondú is subject to doubt. The Comondú rocks are cut by numerous faults, and in several places along the coast small areas of quartz diorite are in fault contact with them. At the north end of the island many faults obscure the attitude of the Comondú, but the dip seems more northwest than east as in the central part of the island.

Gypsum.—The main interest in south Lorenzo Island is the gypsum and associated rocks in the central part of the island. Along the coast at 350 feet (barometer) and resting with an angular discordance upon tilted Comondú is 150 feet of white granular gypsum separated from the underlying rocks by only 2 feet of greenish sand. Covering the gypsum in erosional remnants is about 50 feet of sandstone in turn overlain conformably by dense black porphyritic andesite. The lava contains labradorite, augite, and hypersthene phenocrysts imbedded in a hyalopilitic brownish glass groundmass.

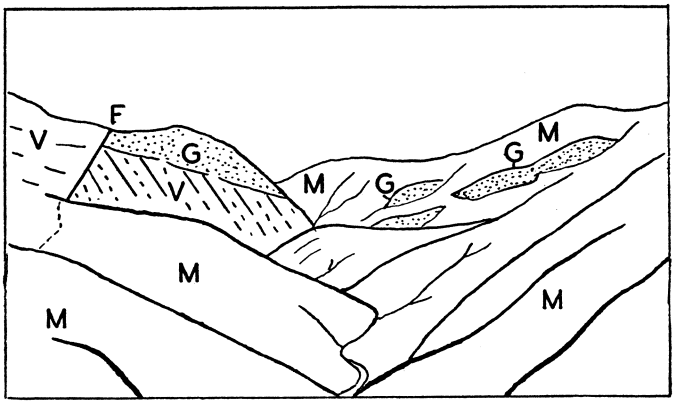


FIGURE 15.—*Looking east on south San Lorenzo Island*

Sketched from a photograph. M, metamorphic rocks; V, volcanic (Comondú); G, gypsum; F, thrust fault.

The general area of gypsum has no cover of younger sediments or lava flows, but the angular discordance to the underlying Comondú is striking (Fig. 15). The Comondú dips toward the metamorphic rocks implying a fault contact, and a fault must separate the Comondú from metamorphic rocks to the west (Fig. 15). The gypsum extends south and rests also upon metamorphic rocks, implying that faulting between the Comondú and metamorphic assemblage took place prior to the gypsum deposition. On the other hand, the gypsum is separated from the northern exposures of Comondú by a steep thrust fault which extends to the coast on the west (Fig. 14). Some of the faulting transverse to the trend of the island must be of postgypsum age.

Conglomerate and sandstone.—A landing was made on the south end of north San Lorenzo Island, but only a limited time could be spent in the area. The rocks here consist of about 200 feet of conglomerate and sandstone dipping northwest and capped with lava. A few fossils were found in thick-bedded sandstone interbedded between conglomerates (Fig. 16) indicating that at least part of the section is marine. Abundant worm tubes occur in these sandstones at their base. The conglomerates include cobbles and pebbles of quartz diorite and andesite suggesting a local source. The lava flow is a platy gray andesite consisting of augite and plagioclase phenocrysts set in a pilotaxitic groundmass. A thrust fault transverse to the island dips steeply north (Fig. 16) partly duplicating the section.

These beds may be the northward extension of the sediments overlying the gypsum in the central part of south San Lorenzo Island; in both places clastic sediments are overlain by andesite. The lava, however, is not precisely similar as the northern exposures are holocrystalline lava whereas that to the south is partly glassy, and hypersthene occurs to the south and not to the north. However, these are differences one might expect from one flow to another in a volcanic sequence. The fossils indicate that the sediments on north San Lorenzo are lower Pliocene and can be correlated with the San Marcos formation (Durham, 1950, p. 26). Since the gypsum on south San Lorenzo Island is at an angular discordance to the Comondú, the gypsum is undoubtedly Pliocene in age and also may be San Marcos (lower Pliocene).

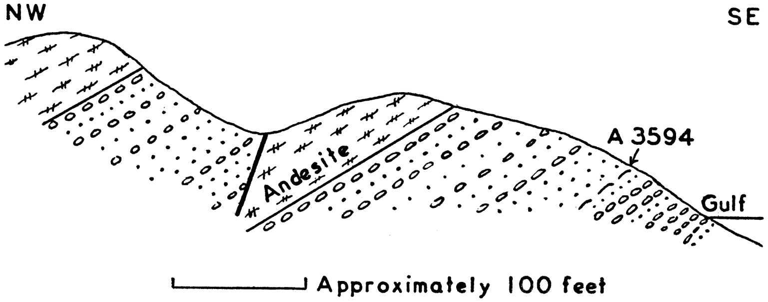


FIGURE 16.—*Cross section at south end of north San Lorenzo Island*
San Marcos formation covered by andesite. Dawn from field sketches with limited vertical and horizontal control.

Possibly the two islands are separated by a fault zone along which the waves were able to erode more rapidly. It was noted earlier that the Comondú is badly broken by numerous faults at the north end of south San Lorenzo Island.

ANGEL DE LA GUARDA ISLAND

General statement.—The longest island in the Gulf of California is Angel de la Guarda, 47 miles long and 12 miles wide in the south-central part. The topography is rugged culminating in a ridge parallel to the western margin of the island and west of the main axis. In the north half, elevations rise to 4315 feet, but in the south half the highest peak is 1000 feet lower. Elevation decreases in the ridge between Humbug Bay and Ensenada del Pulpito, as only 1100 feet was recorded (aneroid barometer). The climate is very arid, and the island is almost devoid of vegetation except in the arroyos.

Only two days were available for studies on Angel de la Guarda, so little progress was made in the understanding of this interesting island, but some new observations are worth recording. A landing was made south of Pond Island (Fig. 17) and a day was spent there. On the Marland Oil Company map (Anonymous, 1924 c, p. 52) the central part of the island is indicated as Salada formation, so a landing was made at Ensenada del Púlpito, and a traverse made across to Humbug Bay. However, only lava flows, tuffs, and volcanic gravels were found.

Granitic and metamorphic rocks.—Apparently the oldest rocks on Angel de la Guarda are metamorphic rocks intruded by granite (used in a general sense). Johnson (1924, p. 955) noted a small granite islet in Puerto Refugio, but Paredes (1920,

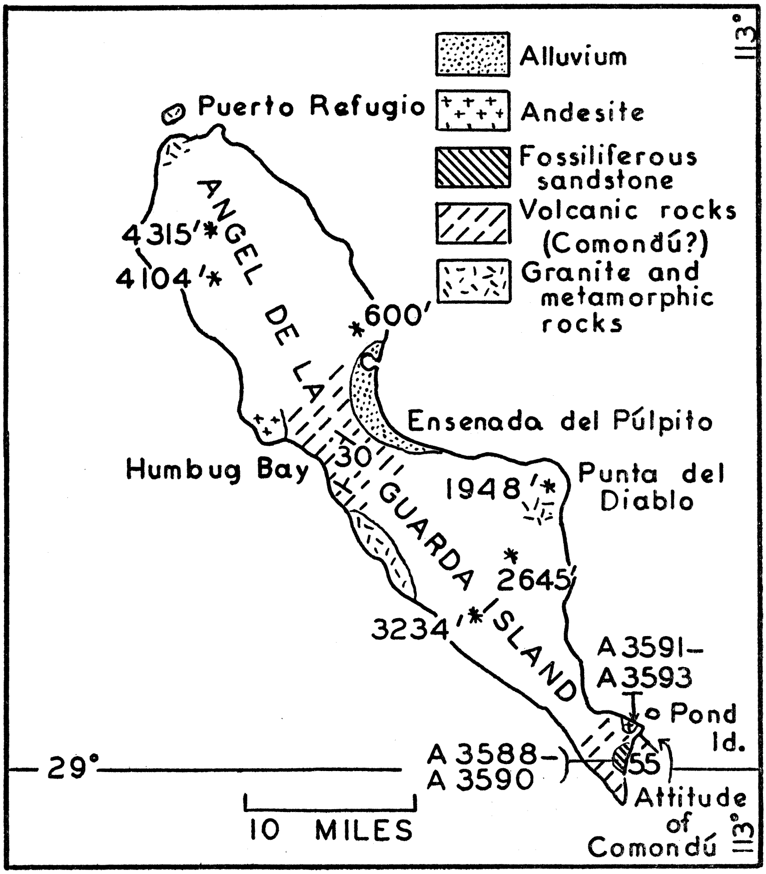


FIGURE 17.—*Angel de la Guarda Island*

p. 6) noted the several areas on the island where granite and metamorphic rocks are exposed, such as southwest of Punta del Diablo, south of Humbug Bay and southwest of Puerto Refugio (Fig. 17). The writer was unable to visit these areas, but the area south of Humbug Bay was visible from the E. W. SCRIPPS. Contortions of the foliation in the metamorphic rocks are beautifully exposed along the sea cliffs, and many dikes cut these rocks. From the boat it appeared that lava flows and pyroclastics were exposed at the top of the sea cliffs, resting upon the granite and metamorphics.

South end.—Along the southeastern sea cliffs massive volcanic breccias and lava flows containing interbeds of lapilli tuff and reddish siltstones and clays strike N. 30° W. and dip 55° SW. The breccias contain fragments of dark-gray hypersthene-augite andesite. One lava flow exhibits flow banding with a few greenish-brown hornblende and andesine phenocrysts set in a cryptocrystalline groundmass; possibly chemical analysis might prove this rock dacitic. The lapilli tuff has dark-gray to white pumice fragments with labradorite crystals imbedded in the vesicular glass of index of refraction near 1.510 ± .005 suggesting andesite. The red clay breaks down in water readily without appreciable swelling. It has an index of refraction of about 1.540 suggesting montmorillonite. A few glass shards indicate that the rock probably formed by decomposition of volcanic ash. Minute calcite rhombs are distributed throughout, suggesting that the environment of deposition was probably lacustrine or marine. However, no marine fossils were found in spite of considerable search.

Resting on these tilted volcanic rocks a series of fossiliferous sediments dip gently east. These are of variable thickness because of the underlying irregular surface. Near the northern exposures only 20–30 feet is present, but southward no volcanics are exposed, and the sediments aggregate at least 150 feet. The sediments are variable; they consist largely of gravels containing pebbles of spherulitic rhyolite, andesite, granite, quartzite, and schist. Obviously, the older rocks were exposed at the time of deposition of the sediments. Interbedded with the gravels are sandstones and siltstones, frequently calcareous and fossiliferous, particularly near the base. A little secondary gypsum was noted coating minor fault surfaces. The finer-grained clastic rocks contain considerable andesitic debris; some beds are composed of water-worn andesite pumice-lapilli similar to the lapilli tuff from the underlying volcanics. The fossils indicate a late Pliocene age and suggest correlation with the Marquer formation (Durham, 1950, p. 21).

Southwest of Pond Island, a small exposure of black porphyritic andesite rests, apparently conformably, on upper Pliocene sediments. Thin sections reveal conspicuous labradorite phenocrysts and smaller augite and hypersthene phenocrysts imbedded in a dark-brown hyalopilitic groundmass. Whether this flow is late Pliocene or Pleistocene is debatable.

Numerous faults of small displacement are visible in the arroyos and sea cliffs. There is noticeable terracing of the fossiliferous sediments separated by scarps parallel to the coast line, which suggested Pleistocene marine terraces except that no sediments or fossils could be found. At the base of some of the scarps were a series of depressions suggesting that the surface has been broken by several recent faults, and the down-dropped blocks occur to the east.

Central part.—The traverse from Ensenada del Pulpito to Humbug Bay is of interest in that a different variety of rocks was encountered as compared to the south end of the island. West of Ensenada del Pulpito the surface is covered by alluvial material for a distance of 1½–2 miles. A few hills of bedrock rise above the surface possibly suggesting pediments rather than alluvial fans, but none of the recent storm gullies were trenched deeply enough to confirm this suspicion. The main ridge is massive gray to pink hornblende-biotite dacite; no individual flows were recognized. West of the main ridge, the rocks are volcanic breccias, volcanic gravels, volcanic sandstones, and white and pink pumice-lapilli tuffs. All strike northwest and dip about 30° SW. On the western slope these clastic rocks are interrupted by plugs several hundred yards in diameter, consisting of massive reddish biotite-hornblende dacite somewhat brecciated at the margin. The clastic beds strike into these hills suggesting that the massive dacite intrudes the volcanic sediments and tuff. Possibly the massive dacite in the summit region also intrudes the clastic beds, for like the dacite of the western plugs it is holocrsytalline containing phenocrysts of andesine, biotite, and hornblende, the latter partly or largely replaced by magnetite. Quartz phenocrysts are rare. The groundmass is microgranular andesine, quartz, sanidine, and augite.

Many of the volcanic gravels and sandstones are cross-bedded indicating fluvial deposition. However, some of the interbedded pumice-lapilli tuffs are massive suggesting original pyroclastic accumulations. The pink lapilli tuffs are dacitic as they contain labradorite, hypersthene, brown hornblende, and biotite crystals imbedded in a colorless glassy base with an index of refraction of 1.500 ± .003. This value (George, 1924) indicates a silica content of about 70 per cent for the glass. The white pumice-lapilli tuffs contain very few phenocrysts, and the index of refraction of the glass is 1.494 ± .003 indicating a higher content of silica; possibly they are rhyolitic.

Nearer Humbug Bay the volcanic gravels contain pebbles of black obsidian and flow-banded felsites in addition to dacite and andesite pebbles. According to Durham and Emory who followed a different traverse across the island, obsidian and banded felsite occur along the summit ridge resting on the massive dacite. The absence of these silicic rocks in the gravels to the east may imply that the silicic lavas were erupted later in the volcanic sequence. These volcanic clastic rocks are truncated by an erosional surface sloping gently westward and locally capped by gravels up to 10 feet thick, stratified parallel to the erosion surface. This older erosion surface in turn is trenched by arroyos 10–20 feet deep. Presumably the erosion surface represents a pediment in process of dissection.

The traverse ended at the north end of Humbug Bay, and from this point it appeared that the same sequence of volcanic clastic rocks was exposed at the south end of the bay, dipping to the northwest. If so, there is a synclinal structure and the axis occurs about the eastern margin of Humbug Bay. Unfortunately, terrace gravels completely mask the underlying rocks around the north end of Humbug Bay, and there was not sufficient time to reach the southern end.

Northwest of Humbug Bay dark-gray platy andesite is exposed, apparently representing several flows, approximately horizontal, similar to the andesite which overlies the upper Pliocene sediments near the south end of the island. This platy andesite differs, however, in being aphyric containing only rare microphenocrysts of andesine in a felty groundmass exhibiting flow structure.

Summary.—Upon a basement of granitic and metamorphic rocks accumulated a series of volcanic rocks including andesitic flows and breccias, dacite flows and tuffs, rhyolite tuffs and obsidian, volcanic conglomerates and sandstones; these were intruded locally by dacite plugs. Perhaps this sequence belongs to the Comondú. This volcanic accumulation was folded and eroded by late Pliocene. At the south end of the island sediments accumulated in a marine embayment. During the marine phase or more likely after uplift and only gentle tilting of the late Pliocene sediments, andesitic lavas were locally discharged. Two pediments were carved from the volcanic rocks on both sides of the island in the central portion during the late history of the island.

LAS ANIMAS BAY

Several hours were spent along the southwestern shore of Las Animas Bay, 15 miles southwest of the southern tip of Angel de la Guarda Island. Red andesites with local green zones show contorted flow banding; some massive breccias occur, but they also suggest nothing as to the regional structure of the volcanic rocks south of the bay. The andesites contain large brilliant andesine, biotite, and hornblende phenocrysts imbedded in a groundmass containing microphenocrysts of the same minerals separated by a cryptocrystalline base. In the green andesite numerous irregular cavities are lined with rosettes of cristobalite and rare tridymite. These minerals are also present in the red andesite but in much smaller quantity; perhaps the green color is related to escaping gases that were responsible for the rather abundant occurrence of these silica minerals. Another variety of the andesite contained large reddish-brown basaltic hornblende phenocrysts associated with inconspicuous andesine crystals enveloped by a cryptocrystalline groundmass. Since individual flows could not be separated, the lavas may be intrusive or mark centers of eruption.

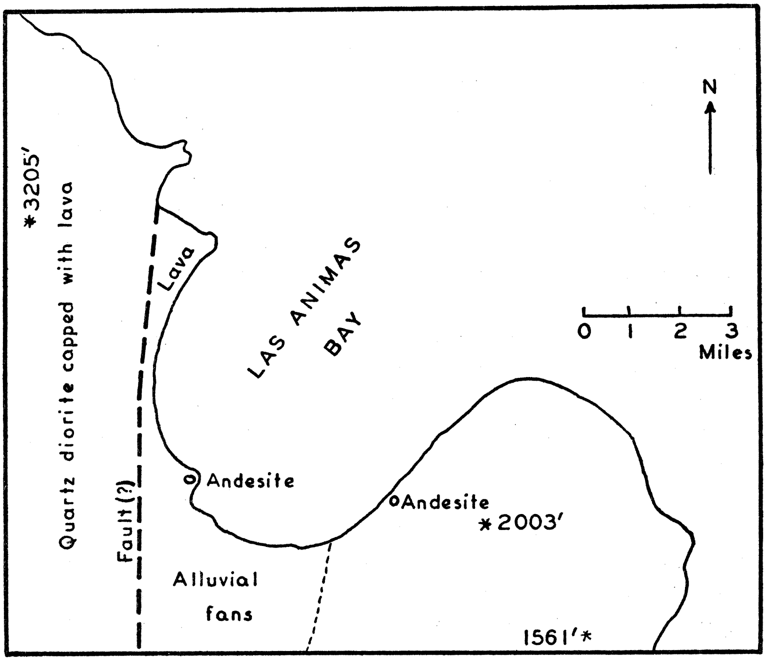


FIGURE 18.—*Sketch map of Las Animas Bay, Lower California*

West of the bay a north-south mountain range rises to over 3000 feet. The east-facing slope is very straight and steep. Members of the 1939 expedition collected samples from this escarpment, and they have been determined by Dr. Cordell Durrell of the University of California at Los Angeles who kindly made his observations available. The lower part of the slope consists of pink and gray biotite-quartz diorite; in individual samples there may be interstitial orthoclase. The top of the range is capped by volcanic rocks including gray hornblende andesites, dark-brown vesicular augite andesite, and olivine basalt.

The limited evidence suggests that this mountain range is a fault block with an eroded fault scarp facing Las Animas Bay. On physiographic evidence there is a suggestion that the east block was tilted west as the slope rises gently to the summit and drops steeply to the Gulf. If this is correct Las Animas Bay occupies the depressed northern margin of this tilted block. The fault (?) scarp west of Las Animas Bay has a north-south trend in contrast to the northwest trend of Angel de la Guarda and San Lorenzo islands as well as the general trend of the east shore of the peninsula.

SUMMARY OF GEOLOGY

PRE-TERTIARY BASEMENT

Quartz diorite crops out at Las Animas Bay, the eastern margin of the granitic area of northern Lower California. On San Lorenzo and Tiburón islands it is associated with metamorphic rocks. On Angel de la Guarda Island metamorphic and granitic rocks are exposed, but the petrographic types are not known. Near Guaymas, granodiorite crops out along the coast, and San Pedro Nolasco Island is granitic rock. Quartz monzonite and granodiorite are found in limited areas to the northwest of Guaymas. At all localities except those northwest of Guaymas, the granitic and metamorphic rocks are clearly the basement for younger volcanic and sedimentary rocks. The granitic rocks in Lower California are probably mid-Cretaceous or upper Cretaceous, and undoubtedly the granitic rocks on Angel de la Guarda and San Lorenzo islands are part of the same intrusive body. The age of the quartz diorite and granodiorite at Tiburón Island and Guaymas is indeterminate but is undoubtedly pre-Tertiary. Possibly these granitic rocks are eastward extensions of the Lower California batholith, and in this connection Woodford and Harriss (1938, p. 1331) noted that the granitic rocks of northwestern Lower California are typically quartz diorite.

Consag Rock at the extreme north end of the Gulf is also granitic according to Dawson (personal communication) and is undoubtedly related to the neighboring granitic rocks of Lower California. At Santa Rosalia granodiorite (Touwaide, 1930, p. 119) appears at the base of Sierra Giganta, and Gabb (1869, p. 115) reported granitic rocks under the volcanic rocks north of Loreto. Among the southern islands, all of Santa Catalina,[4] Santa Cruz, and San Diego islands and parts of San José and Cerralvo are granitic (Johnson, 1924, p. 956–957). These are probably related to the granitic rocks composing the southern tip of the peninsula.

EARLY TERTIARY

Around Guaymas and on Tiburón Island lava flows and pyroclastics, largely andesitic and rhyolitic but containing some latite and basalt, rest on the quartz diorite and granodiorite. On Tiburón Island continental red beds and arkose are probably closely related in age. These rocks are all assumed to be early Tertiary, following King (1939); they were deformed and, in the Guaymas area, intruded by granite porphyry and granite. The deformation and igneous intrusions took place in mid-Tertiary (King, 1939, p. 1715). No comparable rocks can be related to the

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[4] According to Paredes (1920, p. 9), who also noted the granitic rocks on this island, the correct name is "Catalana" Island, but on the charts of the U. S. Hydrographic Office, it is given as "Santa Catalina" Island.

early Tertiary in Lower California or the western islands unless the folded volcanic and sedimentary rocks of Angel de la Guarda Island belong to this episode.

OLIGOCENE AND MIOCENE

Marine sediments of late Oligocene or early Miocene age outcrop along the eastern peninsular coast north of Lat. 25° N. No other early or middle Tertiary marine sediments appear on the eastern margin of Lower California except north of La Paz, and none are known on any of the islands.

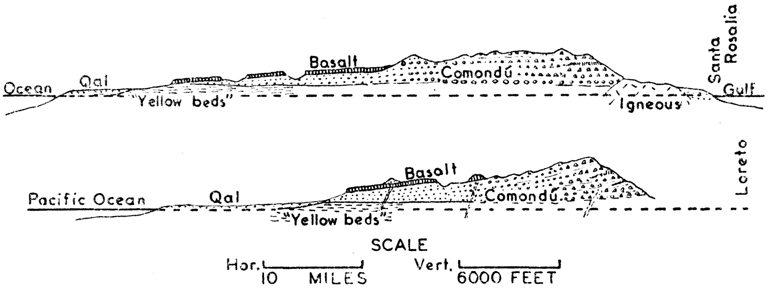

FIGURE 19.—*Cross sections through Lower California*

After Darton (1921). These cross sections are in the southern half of the peninsula and illustrate the thickening of the Comondú to the east. In the upper cross section, the "igneous" rocks near Santa Rosalia are probably granodiorite (Touwaide, 1930).

The most extensive formation along the eastern margin of the southern half of Lower California is the Comondú; it is widespread on all of the western islands from San Marcos to Monserrate, and it may make up part of San José (Anonymous, 1924c, map opp. p. 52). It is largely andesite flows, breccias, and tuffs, usually hornblende-bearing with or without biotite, augite, and hypersthene. A few pyroxene andesites were noted. Around San Marcos Island basalt appears. To the south, rhyolite tuffs occur north of San Carlos Bay (north of Lat. 25° N.). Interbedded sediments were found only on Monserrate and the eastern part of Carmen islands; in these, however, there is no indication of marine deposition. To the north on San Lorenzo Islands andesitic volcanics are important. At Las Animas Bay hornblende-bearing andesites, pyroxene andesites, and olivine basalts occur. Angel de la Guarda consists largely of flows, breccias, and tuffs and interbedded volcanic sediments ranging from andesite, dacite, to rhyolite, intruded by dacite plugs. However, as noted above, these may not be Comondú but possibly should be related to the early Tertiary volcanics of Sonora, or they may represent a separate volcanic center. The Comondú in Lower California dips gently west (Fig. 19); only along the Gulf coast are there exceptions, and these are always east of the main eastern slope of the mountain ranges. The islands are largely homoclinal, but with much steeper dips than in the peninsula. At Puerto Escondido, Carmen, Monserrate, and Coronado islands the dips are east. At San Marcos Island and Santa Inez Bay the dips are west. There is a suggestion of a fold on the south end of Carmen Island and possibly on south San Lorenzo Island, but on the latter faulting complicates the structure badly. On Angel de la Guarda there is fair evidence of a syncline, but again these may not be Comondú volcanics.

PLIOCENE

The Pliocene of eastern Lower California and the western islands is represented by scattered exposures of marine sediments referred to the Salada group. In a few areas continental deposits are associated. The Salada embraces the entire Pliocene and has been divided into three formations—the San Marcos, Carmen, and Marquer—corresponding to the early, middle, and late Pliocene respectively.

The San Marcos formation on San Marcos Island is represented by continental conglomerates, sandstones, and gypsum grading upward into fossiliferous marine pebble conglomerates and limestones. Similar San Marcos rocks with interbeds of chalcocite ore make up the Boleo copper deposit at Santa Rosalia (Touwaide, 1930). The formation also appears on north San Lorenzo Island, and possibly the gypsum of south San Lorenzo Island should be included. Marine sediments, largely conglomerates, sandstones, and limestones of early Pliocene age crop out near Santa Inez Bay, north of Loreto (Arroyos de Gua and de Arce), and on Carmen Island at Arroyo Blanco and Puerto de la Lancha. An angular unconformity clearly separates the San Marcos formation from the underlying deformed Comondú on San Marcos Island, Chivato Point near Santa Inez Bay, and Puerto de la Lancha. The evidence of unconformity is only suggestive at Arroyo Blanco; no information on this point was obtained north of Loreto. An excellent angular unconformity separates the gypsum from the underlying volcanic rocks on San Lorenzo Islands.

The Carmen formation (middle Pliocene) is conglomerate, sandstone, and limestone, and east of Salinas Bay on Carmen Island it grades upward into gypsiferous sediments. It also appears on Carmen Island at Oto Bay. The formation is largely limestone on Monserrate Island, and here and at the two areas on Carmen Island an angular unconformity separates the sediments from the underlying Comondú. North of Loreto the Carmen formation is separated from the San Marcos by an angular unconformity. Some of the fossiliferous sediments on Coronado Island may be Carmen; these beds are unconformable on the Comondú. On San Marcos Island, Carmen limestones and conglomerates are in fault contact with the San Marcos formation, but boulders of fossiliferous San Marcos limestone in the Carmen imply an unconformity at time of deposition. At Santa Rosalia, Touwaide (1930, p. 122) reported that his "Upper Salada" (Carmen; Durham, 1950, p. 27) contains pebbles and cobbles of the underlying "Lower Salada" (San Marcos, Durham, 1950, p. 27) indicating an unconformity.

The Marquer formation of late Pliocene age is largely calcareous and of limited thickness. At Marquer Bay and Puerto Balandra on Carmen Island it is separated from the underlying Comondú by an angular unconformity. North of Loreto the Marquer appears to be conformable to the underlying Carmen. It outcrops at Barracas Table west of Santa Inez Bay, but its relations to the older rocks are unknown. It is the only known Pliocene marine formation on Angle de la Guarda Island and is separated from the underlying volcanics by an angular unconformity.

The San Marcos formation is folded into a broad anticline on San Marcos Island and appears in a similar structure with steeper dips north of Loreto.[5] On San Lorenzo

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[5] Wilson (Am. Assoc. Petrol. Geol., Bull., vol. 32, p. 1762–1807, 1948) has given good evidence that the folds in the Pliocene rocks at Santa Rosalia are related to initial topography, and later deformation is the result of tilting, warping, and faulting.

Island the structure is homoclinal; dips reach 30°. Elsewhere the San Marcos formation is but gently deformed. No folds have been recognized in the Carmen formation, but faults offset the beds particularly at Salinas Bay and on Monserrate Island. The dips are usually moderate, except near a fault on San Marcos Island. The Marquer formation shows little deformation other than warping and minor faulting.

On the southern islands, San José, Espiritu Santo, and Cerralvo, Hanna (1927, p. 6–7) reported marine Pliocene sediments, but their place in the Salada group must wait further study. It should be emphasized that the known marine Pliocene is limited to the western islands or Lower California; no record has been made of similar rocks on the eastern islands or in Sonora.

On Tiburón Island and near Guaymas conglomerate and sandstone with structural characters indicating continental deposition may be the equivalent of the Báucarit formation that is widely distributed in Sonora and which King (1939, p. 1692) suggested to be Pliocene. In a general way these continental deposits may be equivalent to the Salada group to the west.

PLIO-PLEISTOCENE VOLCANICS

Lava flows and pyroclastics younger than the Comondú of Lower California and early Tertiary volcanics of Sonora occur at various localities around the Gulf. At Puerto Escondido near Carmen Island, olivine basalt flows lie with angular discordance on the Comondú, but the basalt also has been tilted east. On San Lorenzo Island andesite flows are conformable with the tilted San Marcos formation, but on Angel de la Guarda Island andesite flows above the Marquer formation are not deformed. On San Marcos Island olivine basalt flows are concordant to the underlying San Marcos formation, but there is some evidence of an erosional period between the two. On Coronado Island an andesitic cone is definitely of Pleistocene age, and one of its flank eruptions probably Recent. A similar cone on Carmen Island is younger than the Carmen formation and may also be Plesistocene. Tortuga Island, northeast of San Marcos Island, is a volcanic cone (Hanna, 1927, p. 2), but the character of the lava is unknown. In Sonora olivine basalt flows are largely undeformed and may be Pleistocene to Recent. On Tiburón Island dacite tuffs make up an appreciable deposit; they show little or no deformation but are extensively eroded.

PLEISTOCENE

The Pleistocene includes some of the volcanic rocks mentioned above. At the north end of Carmen Island extensive lithified crossbedded calcareous sands are probably Pleistocene dune accumulations. Some marine Pleistocene sediments are gently tilted and eroded and in many exposures covered by later Pleistocene sediments. The older rocks probably represent the early Pleistocene and were extensively found on Coronado Island. Other exposures occur on Carmen Island near Salinas Bay and in Lower California north of San Carlos Bay. On Monserrate, Carmen, and Coronado islands, these sediments were offset by faults. Uplifted marine terraces commonly covered by fossiliferous sediments are along the east coast line of Lower California and the islands, including Tiburón. The elevations range usually from 20 to 40 feet, but on Carmen Island and back of Santa Inez Bay the high terraces reach 300 feet.

Pleistocene sediments were reported on Sonora east of Tiburón Island (McGee and Johnson, 1896, p. 128) and east of Guaymas (Dumble, 1900, p. 125). Depression of the land immediately adjacent to Guaymas accounts for its beautiful harbor and indented coast line. Pleistocene and Recent fluvial and deltaic sedimentation developed the extensive coastal plain in Sonora, particularly south of Guaymas.

HISTORY OF THE GULF

In Sonora the scattered exposures of Paleozoic sediments indicate little as to the paleogeography. During the Triassic, fresh- and brackish-water sediments accumulated grading upward into marine Triassic and Jurassic rocks (King, 1939). Whether or not they extended to the west is unknown. During the early Cretaceous, marine sediments accumulated in Sonora (King, 1939) and the western margin of Lower California (Darton, 1921). No evidence suggests that these seas were connected. In northern Sonora an unconformity separates the lower from the upper Cretaceous deposits (Taliaferro, 1933); the latter contain some marine sediments. This is the only known occurrence of marine upper Cretaceous in Sonora, and the sea extended north and east. In Lower California deformation and invasion of the plutonic rocks occurred during the middle or early-late Cretaceous. More evidence is needed to determine if this orogeny extended to Sonora and coincides with the deformation in northern Sonora reported by Taliaferro. During late Cretaceous time a marine transgression left upper Cretaceous sediments along the western margin of Lower California, but apparently they did not extend to the Gulf region.

In the northern islands—Angel de la Guarda, San Lorenzo, and Tiburón—are plutonic rocks similar to those in northern Lower California. Similar rocks also occur near Guaymas. On the eroded surfaces of these quartz diorites and granodiorites are continental sediments and volcanic rocks. In Sonora and Tiburón Island this cover is presumably early Tertiary. On the western islands and in northern Lower California part of the cover may be early Tertiary or may represent the Comondú (middle Tertiary). Evidence seems clear that during early to middle Tertiary the northern half of the present Gulf was land. Because no known marine Tertiary deposits have been recognized in Sonora, except for a patch of probable Pliocene in the extreme northwest, probably all of Sonora has been land since the Cretaceous. Possibly when the early Tertiary volcanics were being extruded in Sonora, marine Eocene sediments were deposited in a marginal sea along the western border of Lower California, but this sea did not advance as far as the present Gulf, except possibly at the southern end.

During late Oligocene and early Miocene a sea invaded Lower California to Lat. 27° N. but only reached the present Gulf site near Lat. 25° N. If this middle Tertiary sea covered the lower part of the present Gulf, the evidence has been eroded, for the southern islands are composed of granite or granite covered by Comondú volcanics or Salada sediments. A minor unconformity separates the San Gregorio (late Oligocene) formation from the Isidro (lower-lower middle Miocene).

During middle or late Miocene or possibly throughout this period, volcanic rocks accumulated in southern Lower California; the volcanic centers coincided with the present western margin of the Gulf. The location of the volcanic centers is indicated by the following points; to the west only sandstones appear, and they grade eastward into volcanic conglomerates which in turn pass into volcanic breccias, tuff, and lava flows (Fig. 19). Along the eastern margin of Lower California only the last-named are exposed, and according to Hisazumi (1930, p. 61) many dikes cut these. On the neighboring islands interbedded sediments appear only on those farthest east—Monserrate and eastern Carmen—indicating thinning of the volcanic rocks and appearance of finer clastic sediments to the east. There is no indication of interfingering of marine sediments with the Comondú, implying that the present site of the Gulf was still a land area during the late Miocene. The Comondú rests on granitic rocks, San Gregorio, and Isidro formations (Darton's "yellow beds"); often an angular discordance marks the contact between the last two and the Comondú, implying deformation and erosion after deposition of the Isidro (lower to lower middle Miocene) and before accumulation of the Comondú.

After accumulation of the Comondú volcanics and associated sediments, deformation along the eastern border of Lower California resulted in tilting and probable folding of the Comondú in the area now occupied by the Gulf. On the peninsula, the Comondú was tilted slightly west. This was followed by invasion of the sea east of Lower California extending into southeastern California where the Imperial formation (lower Pliocene) accumulated. Probably this forerunner of the modern Gulf was narrow and limited to the region adjacent to Lower California as there is no known record of it in Sonora or Tiburón Island. Doubtless many islands rose above this early Pliocene gulf as shown by the sporadic appearance of the San Marcos formation. The mid-Tertiary diastrophism and intrusion of granitic rocks in Sonora may be related to this post-Comondú—pre-San Marcos diastophism in the western Gulf area.

The Imperial formation in southeastern California is very important in the Gulf history, for it was deposited in a southern embayment, and its fauna has Caribbean and Panamic characters different from those of the formations in the coastal area of California (Woodring, 1932, p. 18). Hence, the age of the Imperial formation has been difficult to determine as the fauna cannot be compared directly with those from adjacent parts of California, and hitherto little has been known of the Lower California faunas. Durham (1950, p. 30) discussed this and concludes that the Imperial formation can be correlated with the San Marcos (lower Pliocene). This is important, for it indicates that the Imperial formation had no connection with the San Gregorio or Isidro formations of late Oligocene to middle Miocene age but was deposited in the initial Gulf of California that first developed in early Pliocene time, after deformation of the Comondú volcanics. At the north end of the Gulf two areas of Salada are indicated (Pl. 1). On the source maps these were marked as marine Miocene, but no confirmation of this age has been obtained from the literature, and it is assumed that they represent southern extensions of the Imperial or younger formations. Additional information about these beds is needed.

The recorded history during the Pliocene in the Gulf area was the filling by sediment of embayments carved out of the deformed Comondú. According to Durham (1950, p. 13) most of the fossils indicate shallow-water deposition, and it should be noted that modern sediments accumulating in present embayments in the islands or in Lower California contain sediments of similar lithology. Deformation was not limited to the pre-Pliocene. Although the whole Pliocene is represented by marine deposits of local accumulations, early and middle Pliocene sediments have been appreciably folded or faulted. The Imperial formation has undergone a comparable history. Late Pliocene sediments have been warped, though not intensely. Mobility in this area continued during the Pleistocene as illustrated by uplifted terraces and faulting of Pleistocene beds. The most striking example of the latter is on Monserrate Island where the offsets reach several hundred feet.

The submarine topography suggests that faulting may have been important in the formation of some of the submarine troughs, and from the relationship of these depressions to some of the islands, particularly Angel de la Guarda and San Lorenzo, the islands may in part represent masses elevated along faults (Shepard, 1950). Since late Pliocene sediments are present on Angel de la Guarda, part of this uplift is probably Pleistocene. The graben formation on Carmen Island is certainly later than middle Pliocene and probably took place during the Pleistocene.

The physiographic form of Lower California suggests a fault block tilted west, like the Sierra Nevada of California. The Marland Oil Company report (Anonymous 1924c, p. 44) suggests that, at the time of peninsular uplift by faulting on the east, the deep depressions were formed in the Gulf. Probable fault scarps were noted west of Puerto Escondido and Las Animas Bay at the eastern margin of the mountain ranges. Hisazumi (1930, p. 61) suggested a fault at the base of Sierra Giganta near Mulegé. Had the peninsula reached its present elevation at the time of post-Comondú deformation as result of faulting, the fault scarps would presumably be deeply eroded. More likely uplift continued through the Pliocene and Pleistocene, for Wittich (1920) reported marine terraces and scattered shells comparable to living species at elevations as high as 2000 feet on the west slopes of Lower California.

The history of the Salton Sea basin in southeastern California, though somewhat removed from the main subject of this paper, is definitely related to that of the Gulf. Through the kindness of the Standard Oil Company of California, private reports on the geology and paleontology of the Salton Sea basin were made available, and the pertinent data have been summarized by Durham (1950, p. 23). Although the sediments are largely continental except for the thick marine section at the base of the Imperial formation, sufficient fossils have been found throughout the sections to demonstrate that the Gulf of California has repeatedly invaded southeastern California throughout the Pliocene and Pleistocene. Angular unconformities, however, separate the older from the younger Pliocene beds. Of great significance is the record of Pleistocene Foraminifera in some of the Lake Coahuila deposits and the observation that certain Foraminifera still live in Salton Sea. As Durham reports (1950, p. 24):

> "The record of Foraminifera in Lake Coahuila and the Salton Sea is important, for although the genera and species listed can live in waters of low salinity, they cannot live in fresh water and must have entered this area when these bodies of water were connected with the head of the Gulf of California."

Ross (1914, p. 46) concluded that the salinity of Salton Sea did not suggest a former connection with the Gulf of California but was caused by evaporation of Colorado River water. Buwalda and Stanton (1930) suggested that the Salton Sea basin formed by the simultaneous sinking of the basin and building of the Colorado delta and cone, the latter forming a dam across the southern edge of the basin so that the marine waters of the Gulf never occupied the basin. It is rather difficult to disprove this interesting possibility, particularly since the Salton Sea has only one-tenth the salinity of ocean water (Ross, 1914, p. 45), but the Foraminifera now living in Salton Sea do suggest that the Gulf formerly occupied the present basin and was cut off by the Colorado cone and delta. The problem is still unanswered as to why the salinity is low unless, in the early stages, Colorado River water was able to freshen appreciably the Gulf water before isolation was complete and evaporation lowered the surface below sea level.

CONCLUSIONS

The Gulf of California formed at the close of the Miocene or beginning of the Pliocene following considerable crustal deformation along the present west margin of the Gulf. Throughout the Pliocene recorded sedimentation took place in shallow embayments in the islands and the peninsula of Lower California. Crustal disturbances continued, resulting in local folding of the older Pliocene and faulting and warping of younger beds. Uplift of the peninsula of Lower California to its present elevation and depression of the submarine troughs in the Gulf may be later than the post-Miocene diastrophism. The islands represent blocks of granitic rocks, deformed volcanics, and local accumulations of Pliocene sediments. Only Tortuga Island may represent a volcanic cone built on the Gulf floor.

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1940 E. W. SCRIPPS CRUISE TO THE GULF OF CALIFORNIA

PART II

MEGASCOPIC PALEONTOLOGY AND MARINE STRATIGRAPHY

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ABSTRACT

The oldest marine beds examined may be correlated with the upper Oligocene Sooke formation of Vancouver Island, British Columbia. All other marine beds examined in the area are younger than the widespread middle and upper Miocene Comondú formation which is involved in the formation of the Peninsula of Lower California. Post-Comondú marine beds are referred to the Pliocene and Pleistocene. The boundary between Pliocene and Pleistocene has been chosen rather arbitrarily on paleontologic grounds. The Pliocene is divided into three formations. Each has characteristic but closely related faunas. The middle formation (Carmen) may be correlated with the San Diego formation as exposed at Pacific Beach, which is accepted as of middle Pliocene age. Because of its close relationship to the Carmen formation, the lower formation (San Marcos) is considered lower Pliocene.

The San Marcos formation is correlated with the Imperial formation of southeastern California, which is therefore considered lower Pliocene. Evidence presented shows that the Imperial formation is the basal member of a series of recurrent late Tertiary and Pleistocene marine invasions of southeastern California.

A total of 273 species of pelecypods, gastropods, echinoids, corals, and barnacles have been examined and identified; of these 67 are presumed extinct. Forty-three species and subspecies are recorded or described as new. Pelecypods and gastropods constitute most of the fauna, although echinoids of the genus *Encope* are very important. Considerable selective leaching of fossils has taken place in the older Pliocene rocks, and consequently the faunas collected and recorded from those rocks are not representative. Examination of data on chemical composition of shells and tests shows that those containing the greatest amount of $MgCO_3$ resist leaching the longest.

The Gulf of California faunal "province" is discussed, and physical data on the present Gulf are given. Of approximately 100 species each of living gastropods and pelecypods studied in the Gulf of California fauna, 10 and 30 per cent respectively are also living on the Pacific Coast at San Diego. This furnishes a standard for comparison and correlation of fossil faunas from the Gulf of California with those of the Pacific Coast of California.

From a limited survey of the ecology of living representatives of the fossil faunas, it is apparent that most of the latter lived in shallow waters, many of them in depths of less than 15 meters. The paleo-distribution of the reef coral genera *Pocillopora* and *Psammocora* (*Stephanaria*) indicates that at one or more intervals during the Pleistocene the temperatures were warmer in the Gulf than at present.

INTRODUCTION

During the 1940 E. W. Scripps Expedition to the Gulf of California, fossils were collected from about 100 localities between San Carlos Bay on the south and Angel de la Guarda Island on the north (Fig. 1). Except for three localities on Tiburón Island, all the material is from the islands on the western side of the Gulf and the adjacent eastern shore of Lower California.

This paper discusses the larger Mollusca, echinoids, corals, and barnacles of the collections and the age and correlation of the beds examined. Manley L. Natland has prepared a separate report on most of the Foraminifera collected. Dr. J. A. Cushman kindly prepared an article on an interesting occurrence of the foraminiferan *Ramulina*. Many of the minute pelecypods and gastropods in the collections have not been examined. However, as all this small material occurs in either the late Pliocene or

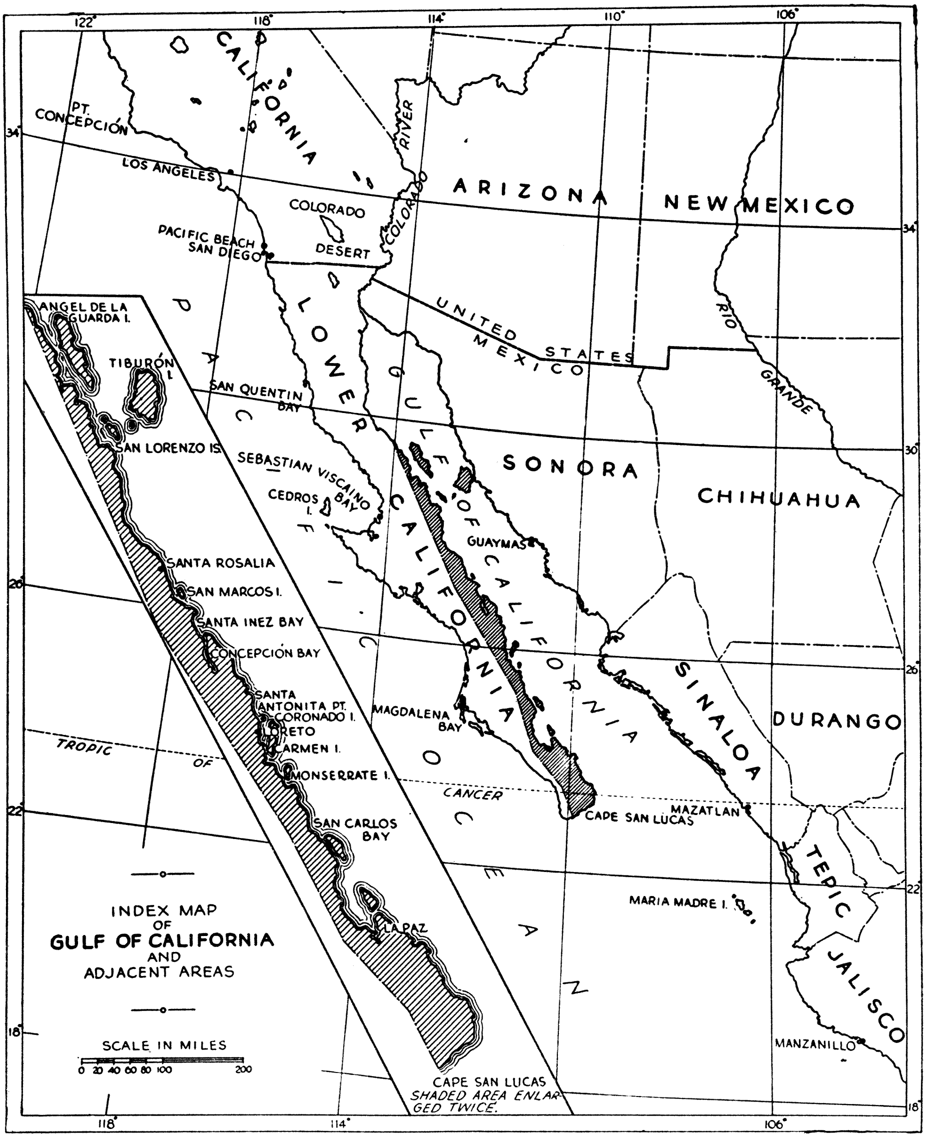

FIGURE 1.—*Index map of Gulf of California and adjacent areas*

Pleistocene, it is believed that its examination would not materially alter the conclusions presented. Probably there are numerous undescribed species in the unexamined small Mollusca for neither the living or fossil minute species of this faunal province have been critically studied. Several minor groups of fossils, such as Bryozoa and Scaphopoda, are also represented in the unexamined material. Dr. Charles A. Anderson and the author made most of the collections. Because of the reconnaissance nature of the geological work and the limited time available, the amount of material collected was necessarily small. All collections made were deposited in the Museum of Paleontology of the University of California. Duplicate material, where possible, has been forwarded to the government of Mexico. All primary types, where obtained from the present collections, have been deposited in the type collections of the Museum of Paleontology at the University of California.

This report has been prepared in conjunction with one on the geology of the same area by Dr. Charles A. Anderson. Reference to that paper should be made in all cases for details of the geology, stratigraphic relationship, and areal distribution of the various fossil-bearing beds. The formational names used in this paper are defined by Anderson. Only geological data that were immediately necessary have been introduced here.

Representative samples of the matrix of each fossil locality were forwarded to Dr. Roger P. Revelle of the Scripps Institution of Oceanography who was to examine them and compare them with the recent sediments of the same area. However, other duties have prevented him from preparing the report.

PREVIOUS WORK

Hanna and Hertlein (1927, p. 138–139) discussed the few early references to late Tertiary fossils from the Gulf of California area. It is not necessary to review most of those early works as they are of historical interest only. However, Jordan and Hertlein (1926b) described a number of species from the Pliocene of Maria Madre Island, which also occur in the Gulf of California area. Hanna and Hertlein (1927) published the only general account of late Tertiary and Pleistocene paleontology of this area. From 18 localities they listed 86 species including 2 new ones. The fauna was considered upper Pliocene. These localities represent all the Pliocene—lower, middle, and upper—as recognized in the present paper.

Touwaide (1930) listed Pliocene and Pleistocene fossils from the vicinity of Santa Rosalia, with identifications by U. S. Grant IV. Grant and Gale (1931) incidentally note the occurrence of Pliocene and Pleistocene Mollusca found in the Gulf of California area and occasionally comment on their occurrence.

Hanna (1926) gave an excellent summary and bibliography of earlier work and described and listed the fauna of the type area of the Imperial formation of southeastern California. He believed that the lower beds were probably of lower Pliocene age and that the upper beds might even include upper Pliocene. Grant and Gale (1931, p. 49–51) discussed the Imperial formation and concluded that it was of Pliocene age. Woodring (1931) summarized earlier work in that area, reviewed the distribution of the Imperial formation, and suggested that it might be of lower Miocene age. Bramkamp (1934) in an abstract noted the tropical character of the fauna of the Imperial formation and tentatively correlated it with the middle Miocene. Woodring (1938), in a paper on lower Pliocene faunas from the Los Angeles Basin, contributed incidental data on the Imperial formation. Mansfield (1932) compared a few fossils from the Pliocene of Florida with similar species in the Imperial formation. Tarbet and Holman (1944) assigned the Imperial formation to the upper Miocene.

SELECTIVE LEACHING OF FOSSILS

The high aridity of the Gulf of Claifornia area and seasonal rainfall, probably in conjunction with other unnoted factors, have resulted in the thorough leaching of many of the surface exposures of the sedimentary formations of the area, particularly in the older Pliocene. All fossils except the ostreas, spondylids, pectens, barnacles, and echinoids have been removed from many outcrops by leaching. An inspection of the data given by Clarke and Wheeler (1917) indicated that representatives of all groups not leached (except *Ostrea*, given by Chatin and Muntz, 1895, and *Spondylus* for which no data are given) contain a higher percentage of $MgCO_3$ than the other associated fossils. Echinoids as a whole vary from 5.99 to 10.38 per cent $MgCO_3$, while *Encope californica*, representing a genus very abundant in fossil record of the Gulf area, contains the greatest amount. This perhaps explains the fact that the Encopes were often preserved where all other fossils were represented only by molds. The 2 pectens and the oysters analyzed vary from 0.73 to 1 per cent of $MgCO_3$, while the other 9 pelecypods (except *Placuna*) analyzed contained only traces of it. Similarly, of the 19 gastropods reported on, only 2—*Nassa insculpta* Carpenter and *Tachyrynchus erosa* Couthouy—contained a similar amount of $MgCO_3$; the other 17 are very low in it. Barnacles were reported to contain 0.75–2.49 per cent. Other groups high in $MgCO_3$ and consequently which might withstand solution longest are: Crustacea (other than barnacles), 4.84–15.99 per cent; crinoids, 7.86–13.37 per cent; calcareous algae (*Lithothamnion* and similar forms, not *Halimeda*) 10.94–25.17 per cent. Clarke and Wheeler (1917, p. 55) also note that organisms from warm water are much richer in $MgCO_3$ than those from cold water. On the basis of the preceding data, it is presumed that the selective leaching of fossils noted in this area is due to the presence or absence of $MgCO_3$.

GULF OF CALIFORNIA FAUNAL PROVINCE

The Gulf of California is a long narrow embayment, parallel to the western coast of Mexico. It extends nearly 700 miles from about 23° N. lat. to nearly 32° N. lat. The average width is close to 100 miles. Large areas range in depth from 500 to 3000 meters. The north end is less than 1° south of the latitude of San Diego; the mouth is within the Tropic of Cancer.

Sverdrup (1939) briefly discussed the physical conditions within the gulf. The surface temperature during the February-March interval ranges from about 20° C. at the mouth to about 14° C. near the head of the Gulf. Further, the deep inner half of the Gulf appears to be separated from similar depths in the outer half by a shallow sill with the consequence that at depths as great as 5000 feet in the inner basin the temperature remains at about 11° C., whereas in the outer areas the normal temperature at this depth is about 3°–4° C. The surface salinity varies from about 34.5‰ near the mouth of the gulf to 35.5‰ north of Angel de la Guarda Island and 35.12‰ at a point about 40 miles from the mouth of the Colorado River. Thus the influx of fresh water from the Colorado River seems to have but little effect on the salinity of the Gulf, possibly because of excessive evaporation in winter.

Dall (1921, p. 2) named the recent fauna of this area as the "Gulf of California" but did not cite his evidence for separating it from the Panamic. Other authors

(Carpenter, 1857, p. 350–358; Cooper, 1895; Jordan, 1924; Steinbeck and Ricketts, 1941, p. 177–179, 306–312) have noted the distinctiveness of the Gulf fauna and submitted varying bits of evidence. The work of Steinbeck and Ricketts is the most comprehensive, but they state that it is merely preliminary groundwork. Out of about 520 species of all phyla studied by Steinbeck and Ricketts, the geographic range of 415 species was determined. Of these 72 appear to be limited to the Gulf (Magdalena Bay was included within the Gulf area in some cases). There are 160 species ranging only to the south, 42 species range north outside the Gulf, 68 species range both north and south (they note that the northward range is usually limited by Magdalena Bay or Cedros Island and rarely extends beyond Southern California, although some species may occur in Monterey Bay, and a few extend north even to Puget Sound or Alaska), 39 species are "tropicopolitan" or cosmopolitan, 20 species are West Indian, and 14 species are Indo-Pacific. Steinbeck and Ricketts note that in general the fauna is a northward extension of the Panamic province.

The boundary between the Gulf fauna and the more northern faunas has not been adequately defined. Jordan (1924, p. 146) considered the boundary to be near Cedros Island. Steinbeck and Ricketts (1941, p. 307) state that the northward range is usually limited by Magdalena Bay. Bartsch (1921, p. 507) places the boundary at Cape San Lucas. On the basis of a study of the living corals, the author is inclined to believe that the greatest break is at Cape San Lucas, but collections between Cape San Lucas and Magdalena Bay are lacking.

Cooper (1895, p. 37) estimated that there were 700–800 species of mollusks within the Gulf. The Magdalena Bay Pleistocene fauna closely allied to the Gulf fauna, contains 442 species and subspecies (Jordan, 1936, p. 109). Lowe (1935) lists 105 species of bivalves and 168 species of univalves from the vicinity of Punta Penasco, a locality well up toward the head of the Gulf. Pilsbry and Lowe (1932, p. 39) list 90 species of bivalves and 110 species of gastropods from La Paz, while they list 71 species of bivalves and 218 species of gastropods from San Juan del Sur, Nicaragua. The same authors list over 275 species of pelecypods and 575 species of gastropods collected by Lowe from 15 "stations" between Guaymas and Panama. These "stations" included localities from the beach out to 20 fathoms depth. Steinbeck and Ricketts list 42 species of pelecypods and 90 species of gastropods as common intertidal and subtidal species in the Gulf (1941, p. 511, 534–538). A summary of their geographic distribution is as follows:

	Gastropods	*Pelecypods*
Restricted to Gulf	17	6
Ranging only to north	2	1
Ranging only to south	42	18
Ranging both north and south	18	13
Range unknown	11	4

The Peninsula of Lower California was apparently formed in pre-San Marcos time (equals pre-Imperial time, which is here considered as early Pliocene). Thus the marked separation between the Gulf of California fauna and the coastal California fauna has existed since before the lower Pliocene. Therefore the faunas of the Pliocene in the Gulf of California should have no greater percentage of species in common with the Pliocene of coastal California than that which now prevails.

In this report, 96 species of gastropods and 97 species of pelecypods found as fossils are also represented in the living fauna. Of these recent species, about 29 pelecypods and 10 gastropods are now living as far north as San Diego. This amounts to about 30 per cent and 10 per cent respectively, in the two groups. Despite the small fauna here recorded from the Carmen formation (middle Pliocene), which is correlated with the San Diego Pliocene, 3 of the 10 extinct species and 2 of the 7 living species of pelecypods are also found in the San Diego Pliocene. Considering the vagaries of collecting and hazards of comparing partial faunas, this seems a very comparable percentage to that of the living faunas.

COMPOSITION OF FAUNAS

The collections here reported upon include primarily material collected on the 1940 trip of the E. W. Scripps, plus some critical material in the Stanford University collections, and important species found in collections made by the 1921 Expedition of the California Academy of Sciences to the Gulf of California.

Table 1.—*Summary of species examined*

	Total	Pre-sumed extinct	*Lower Pliocene*		*Middle Pliocene*		*Upper Pliocene*		*Pleistocene*	
			total	*extinct*	*total*	*extinct*	*total*	*extinct*	*total*	*extinct*
Cirripedia	1	—	1	—	—	—	1	—	—	—
Coelenterata	7	2	—	—	—	—	1	—	7	2
Echinoidea	23	16	10	8	5	3	8	4	6	2
Gastropoda	116	20	11	4	5	3	33	5	104	10
Pelecypoda	126	29	26	13	19	10	59	6	92	5
Total	273	67	48	25	29	16	102	15	209	19
Per cent extinct	24.5		52		55.1		14.7		9	

Because of the reconnaissance nature of the geological work, the lack of time, and the lack of means of transportation in the field, little attention was paid to molds of fossils, although they were often extremely abundant in the older beds. Only in the upper Pliocene and Pleistocene are the listed species representative of the faunas existing at those times. The faunas from localities A 3519, A 3534, A 3548, A 3550, A 3582, A 3684, and A 3596 should be compared with those from localities A 3552, A 3555, A 3556, A 3576, and A 3580 where the fauna was equally abundant but represented almost entirely by molds. With ample time and equipment, each of these last localities would yield a large and varied fauna.

Because of the aforementioned vagaries of collection, the percentage method of dating cannot be used with assurance for the present collections from any of the older beds. Further the present material has not been fully examined. All the minute gastropods, many of the small pelecypods, the scaphopods, most of the barnacles, the bryozoans, and the calcareous algae have not been examined.

The distribution of the species examined and reported upon is shown in Table 1.

Among the preceding groups, the echinoids and pectens were examined with the

TABLE 2.—*Check list of Pliocene and Pleistocene Pelecypoda*

Extinct		Pliocene																																																												Pleistocene																						Recent San Diego.
		Lower																								Middle													Upper																																													
		A3528	A3529	A3530	A3531	A3532	A3535	A3536	A3537	A3543	A3544	A3552	A3555	A3556	A3557	A3558	A3565	A3576	A3577	A3578	A3579	A3581	A3583	A3594	A3712	A3713	CAS. 795	A3498	A3505	A3506	A3509	A3510	A3527	A3533	A3541	A3559	A3566	A3568	A3571	A3513	A3516	A3517	A3518	A3519	A3520	A3521	A3523	A3524	A3534	A3545	A3546	A3549	A3561	A3562	A3563	A3588	A3589	A3590	A3591	A3592	A3593	A3670	A3497	A3507	A3508	A3514	A3515	A3522	A3525	A3538	A3547	A3548	A3550	A3564	A3569	A3573	A3574	A3582	A3584	A3586	A3587	A3596	A3597	A3598	
*	*Aequipecten abietis* (Jordan and Hertlein)	x	x	?	x	x			x			x	x	x	x		x		x	x											x	x		x	x	x			x	x	x		x					x		x			x				x	x																											
*	*A. antonitaensis* n. sp.																										x																																																										
	A. circularis (Sowerby)																																											x		x	x							x					x	x												x	x			x		x	x	x		x			x
*	*A. circularis* subsp. *bramkampi* n. subsp.																						x																																																														
*	*A. deserti* (Conrad)																				x	x	x																																																													
*	*A. revellei* n. sp.																											x	x								x	x																																															
*	*A. sverdrupi* n. sp.																	x					x	x																																																												
	Americardia biangulata (Broderip and Sowerby)																																	x										x	x				x													x			x	x				x		x	x					x	x			x		x	x
	Anadara (Anadara) formosa (Sowerby)?	x												x																																																																						
	A. (Larkinia) multicostata (Sowerby)							x																										x	x									x	x				x					x								x	x		x				x			x	x					x	x			x		x	x
	Anodontia edentuloides (Verrill)																																																																														x						x
	Apolymetis clarki n. sp.																																																x													x																x	x			x		x	
	Arca (Arca) mutabilis (Sowerby)																																																																									x												
	Barbatia (Acar) gradata (Broderip and Sowerby)																																																																								x						x							x
	B. (A.) illota (Sowerby)																																																																												x		x							
	B. (A.) solida (Sowerby)																																																x																														x							
	B. (Calloarca) alternata (Sowerby)																																																																														x	x						
*	*B. (Cucullaearca) bramkampi* n. sp.																																											x					x																																				
	B. (C.) reeveiana d'(Orbigny)																																											x					x										x									x					x										x			x
*	*Basterotia californica* n. sp.																																																																														x							
*	*B. hertleini* n. sp.																																											x	x																	x																							
	B. peninsulare (Jordan)																																																																							x													
	Cardita crassicostata (Sowerby)																																																																									x									x			
	C. megastropha (Gray)																																												x																							x						x	x	x		x			x					x		
	Chama echinata Broderip																																														x		x																																	x				
	C. frondosa Broderip																																											x																																								x			x
	C. pellucida Broderip																																																																	x		?	x						?				x						x	x
	C. squamuligera Pilsbry and Lowe																																											x					x																						x	x					x							
	Chione (Anomalocardia) kellettii (Hinds)																																																																															x					
	C. (A.) mariae (d'Orbigny)																																																																														x						
	C. (A.) subrugosa (Sowerby)																																																																														x							
	C. (A.) tumens Verrill																																																			x																																				
	C. (Chione) cf. *amathusia* (Philippi)																																											x	x																					x							x	x			x	x	x				x		x	
	C. (C.) californiensis (Broderip)																																												x							x																																					x
	C. (C.) undatella Sowerby																																											x															x	x	x										x			x		x	x		x	x	x		x
	C. (C.) undatella var. *simillima* (Sowerby)						x	?																											x									x					x						?													x				x	x	x					x						x	x
*	*Chlamys corteziana* n. sp.																				x																																																															
*	*C. dallasi* (Jordan and Hertlein)																											x	x																																																									
	Codakia distinguenda (Tryon)													?																														x					x																x		x				x	x	x										x	x		
	C. (Jagonia) chiquita Dall																																																																							x													
	C. (J.) mexicana Dall																																											x					x																								x						x						x	
	Corbula (Lentidium luteola Carpenter																																																																														x							x
	Crassatellites digueti Lamy																																																																														x	x						
	C. laronus Jordan																																																																							x													
	Crassinella mexicana Pilsbry and Lowe																																																																														x							
	Cryptomya californica (Conrad)																																																																															x						x
	Cyathodonta dubiosa Dall																																																														x																x							x
	Divaricella lucasana Dall and Ochsner																																											x	x																	x										x						x							
	Dosinia ponderosa (Gray)					x		x																										x											x																	x										x						x	x						x
	Glans affinis (Sowerby)																																											x					x																x											x	x								
	G. radiata (Sowerby)																																																																																x					x	
	Glycymeris gigantea (Reeve)							x																																									x													x			x														x			x		x	
	G. maculata (Broderip)																																																x																x					x		x						x	x			x			
	G. multicostata (Sowerby)																																											x					x																x						x	x	x					x	x					x	x
	Laevicardium elatum (Sowerby)																																																																							x						x	x						x
	L. elenense (Sowerby)																																											x	x				x													x										x						x							
	Lima tetrica Gould																																																																							x													
	Lucina (Bellucina) cancellaris Philippi																																																														x																x							
	L. (Cardiolucina ?) lampra (Dall)																																											x																	x										x													
	L. (C.) lingualis Carpenter)																																											x	x																x																x							
	L. (Lucinisca) nuttalli Conrad																																												x																										x												x
	L. (Parvilucina) approximata (Dall)																																																													x																							x
*	*Lyropecten mediacostatus* Hanna																	x								x																																																											
*	*L. modulatus* (Hertlein)?													x																																																																					
	L. subnodosus (Sowerby)								x							?				x									x	x								?				x		x		x		x					x		x				x							x			x	x		x	x	x			x		x	x			x		x	
	Macrocallista squalida (Sowerby)																																											x	x				x									x				x			x		x		x	x	x	x	x			x	x	x	x			x		x	
	Mactrotoma revellei n. sp.																																																																							x													
	Miltha xantusi (Dall)																																																																							x													
	Nucula (Nucula) declevis Hinds																																																																														x							
	Nuculana (Saccela) elenensis (Sowerby)																																																																														x	x						
	Ostrea chilensis Philippi							x														x																																																												x			
	O. cumingiana Dunker																																											x		x			x																					x				x					x			x	x		x	
*	*O. erici* Hertlein																														x	x																																																					
	O. fischeri Dall										x				x																								x							x																							x	x																
	O. megadon Hanley	x	x	x												x												x									x	x																																																
*	*O. vespertina* Conrad	x	x	x			x	x		x	x		x		x	x		x		x		x	x	x					x	x	x	x		x	x	x	x	x		x							x	x		x	x	x	x		x		?	x	x	x		x																								
	Panope taeniata Dall																																																																														x							
	Papyridea aspera (Sowerby)																																																																							x						x	x						
*	*Patinopecten bakeri* (Hanna and Hertlein)			x											x	x																																																																					
*	*P. bakeri* subsp. *diazi* n. subsp.																										x	x	?						x		x	?																																																	
*	*P. marquerensis* n. sp.																																										x																																														
*	*Pecten (Euvola) keepi* Arnold																					x	x	x																																																													
*	*P. (E.) refugioensis* Hertlein																										x																																																											
*	*Pecten (Pecten) bellus* var. *hemphilli* Dall																										x																																																											
*	*P. (P.) bösei* Hanna and Hertlein							x																			x										x																																																	
*	*P. (P.) carrizoensis* Arnold																	x		x																																																																	
	P. (P.) vogdesi Arnold				x																															x	x			x		x		x	x	x	x	x	x					x								x			x							x	x			x	x	x	x			x		x	
	Pedalion janus (Carpenter)																																											x					x																																				
	Periglypta multicostata (Sowerby)																																																																	x		?														x			
	Petricola robusta Sowerby																																																																							x				x									
	Pinctada mazatlanica (Hanley)																																x											x					x																x			x					x									x			
*	*Pinna corteziana* n. sp.																																																																						x														
*	*P. latrania* Hanna ?													x																																																																							
	P. rugosa Sowerby																																																																						x														
	Pitar newcombianus (Gabb)																																																																														x							x
*	*Plicatula inezana* n. sp.																																																																					x							x	x						
	P. penicillata Carpenter																																											x					x																									x												
	P. spondylopsis de Rochebrune																																											x										x																																
*	*Protothaca coronadosensis* n. sp.																																																			x																																				
	P. (?) fluctifraga (Sowerby)																																																										x																						x					x
	P. grata (Say)																																																																														x			x				
	Pseudochama exogyra (Conrad)																																											x																													x												x
	Semele flavescens (Gould)																																																?																																					x	x
*	*S. hertleini* n. sp.																																																																							x						x							
	S. jaramija Pilsbry and Olsson																																																																														x							
	Solecardia eburnea Conrad																																																																							x													
	Spondylus crassisquama Lamarck																																																																			x	x																
	S. victoriae Sowerby	?																																																																					x	x													
	S. sp.														x																																																																						
	Tagelus (Mesopleura) subteres (Conrad)																																																													x										x						x							
	T. (Tagelus) affinis (Adams)																																																																															x					x
	T. (T.) californica (Conrad)																																																													x																x							
	T. (T.) violascens (Carpenter) ?																																																																															x						
	Taras sericatus (Reeve)																																																																														x							x
	T. subquadrata (Carpenter)																																																x																								x	x					x	x						x
	Tellina (Angulus) panamensis Dall																																																													x																x							x
	T. (Eurytellina ?) simulans Adams																																																													x																x	x						
	T. (Merisca) reclusa Dall																																																																						x						x							
	T. (Scrobiculina) ochracea Carpenter																																											x					x																								x	x												
	T. (Tellina) cumingii Hanley																																																x																								x						x	x						
	T. (T.) idae Dall																																																													x																							x
	Tivela byronensis (Gray)																																																																														x	x						
	Trachycardium (Trachycardium) consors (Sowerby)																																																																					x		x						x	x			x			
	T. (Mexicardia) procerum (Sowerby)																																																																														x	x						x
	Venus isocardia Verrill																																																																					x	x													
	Volsella capax (Conrad)																																												x																																			x	x					x	x

greatest care because they were well preserved and widely distributed and were represented at one or more localities by abundant individuals. Thus the range of variation of the species could be determined within rather close limits. The treatment of the Pectinidae in this paper differs greatly from that by Grant and Gale (1931). Many more specific units are recognized. The author believes these are justified because at any one locality with abundant specimens the characters used are relatively constant, and these characters have a stratigraphic value. Echinoids of the genus *Encope* have been similarly treated.

Tables 2–6 list the species reported upon.

Among the pelecypods, the Pectinidae appear to be more abundantly represented than is actually the case. This is largely because of the differential leaching and the consequent mode of collecting. Similar reasoning applies to the Ostreidae. It is believed that when the remaining mollusks of the beds here reported on have been fully collected and examined in the same manner as the two aforementioned families the total number of species will be double or triple the number here reported. (For comparison *see* figures cited under "Gulf of California Faunal Province".)

None of the genera here reported are found exclusively in more northern faunas. Most of the them are typical of tropical and subtropical faunas. Of the living species, only 30 pelecypods and 10 gastropods now live as far north as San Diego (Fig. 1) on the Pacific Coast. This amounts to 30 per cent and 10 per cent respectively of the total faunas recorded in the present paper.

Geographic ranges for many species that extend their range south are not readily available, but the literature indicates that a much larger percentage is found in the Panamic area.

The pelecypods apparently are more numerous than the gastropods except in the Pleistocene. This reflects the mode of collecting, dependent upon shell composition (*see* "Selective Leaching of Fossils"), and is not a true representation of the fauna. The echinoids appear excessively abundant in number of species; this is due not only to the preceding cause, but also apparently to the fact that the Gulf furnished optimum conditions for the existence of the genus *Encope*, of which 11 extinct species and subspecies are described. Six of these species lived during the early Pliocene, including one group of species which became extinct, in this area at least, during the late Pliocene (group of *Encope scrippsae* and *angelensis*).

Other species not known to have living descendents in this area are:

Echinolampas (?) sp.—San Marcos formation (lower Pliocene)
Basterotia spp.—Marquer formation (upper Pliocene) and Pleistocene
Lyropecten mediacostatus (Hanna)—San Marcos formation (lower Pliocene)
Patinopecten spp.—San Marcos (lower Pliocene) to Marquer formation (upper Pliocene)
Pecten (*Euvola*) *keepi* Arnold.—San Marcos formation (lower Pliocene)
Pecten (*Euvola*) *refugioensis* Hertlein.—Carmen formation (middle Pliocene)
Pinna corteziana n. sp.—Pleistocene
Gyrineum strongi Jordan—Pleistocene
Oliva davisae n. sp.—Pleistocene
Turritella marcosensis n. sp.—San Marcos formation (lower Pliocene)

It is probable that living Basterotias will be found, for it is a small and inconspicuous pelecypod, but it is believed the others have no living representatives.

TABLE 3.—*Check list of Pliocene and Pleistocene marine Gastropoda*

No gastropods were collected from the following localities: A3498, A3505, A3506, A3509, A3513, A3516, A3517, A3518, A3521, A3523, A3524, A3527, A3528, A3530, A3531, A3532, A3537, A3541, A3544, A3546, A3552, A3555, A3556, A3557, A3558, A3559, A3561, A3563, A3564, A3565, A3566, A3568, A3771, A3578, A3581, A3583, A3588, A3589, A3590, A3591, A3594, A3712, A3713.

Extinct		*Pliocene*																		*Pleistocene*																				*Living at San Diego*
		Lower							Middle		Upper																													
		A 3529	A 3535	A 3536	A 3543	A 3553	A 3576	A 3577	A 3510	A 3533	A 3519	A 3520	A 3534	A 3545	A 3549	A 3562	A 3592	A 3593	A 3670	A 3507	A 3508	A 3514	A 3515	A 3522	A 3525	A 3538	A 3547	A 3548	A 3550	A 3569	A 3573	A 3574	A 3582	A 3584	A 3586	A 3587	A 3596	A 3597	A 3598	
	Acanthina muricata (Broderip)																									?		x			x						x		x	
*	*Acanthina* cf. *tuberculata* (Gray)	x																																						
	Acmaea dalliana Pilsbry																											x												
*	*Alabina strongi* n. sp.																																	x						
	Anachis coronata (Sowerby)																											x	x											
	Architectonica nobilis Bolten																																x	x						
*	*Astraea* (*Pomaulax*) *subundosa* n. sp.														x																									
*	*Astraea* (*Uvanilla*) *shepherdi* n. sp.																										x													
	Bulla aspersa Adams																											x					x	x						
	Bursa californica (Hinds)																											x												x
	Calliostoma bonita Strong, Hanna, and Hertlein																																x							
	Calliostoma eximium (Reeve)																											x					x	x			x		x	x
	Cancellaria cassidiformis Sowerby																																x	x						
*	*Cancellaria coronadosensis* n. sp.																											x												
	Cancellaria haemostoma Sowerby																											x												
	Cassis (*Levina*) *coarctata* Sowerby																											x	x											
*	*Centrifuga inezana* n. sp.																																	x						
	Cerithidea hegewischii (Philippi) s.s.																			x													x		x					
	Cerithidea hegewischii var. *albonodosa* Carpenter																x																							
	Cerithium adjustum Kiener																																	x						
	Cerithium maculosum Kiener										x		x								x							x									x			
	Cerithium ocellatum Bruguière																						x																	

	“Clathrodrillia” nautica Pilsbry and Lowe?																																x						
	Clava gemmata (Hinds)									x		x																							x			
	Conus bartschi Hanna and Strong																												x									
*	*Conus* cf. *brunneus* Mawe	x																																				
	Conus princeps Linnaeus									x										x		x		x			x	x		x	x		x			x			
	Conus puncticulatus Hwass				x																				?			x								x			
	Conus recurvus Broderip																					?										x	x				x		
	Conus regalitatus Sowerby																										x												
	Conus regularis Sowerby	?							?	x																	x									x			
	Conus scalaris Valenciennes																										x												
	Conus ximenes Gray																										x					x	x						
	Coralliophila nux (Reeve)																											x											
	Crassispira kluthi Jordan																										x												
	Crepidula onyx Sowerby																										x					x	x			?			
	Crucibulum imbricatum (Sowerby)									x		x					x			x		x					x						x						
	Crucibulum spinosum (Sowerby)																															x	x						
	Cypraea annettae Dall									x												x					x	x				x	x					x	
	Diodora alta (Adams)											x																x				x	x						
	Diodora inaequalis (Sowerby)									x		x																x											
	Elaeocyma aegina Dall ?																															x							
	Enaeta cumingii (Broderip)																										x												
	Engina contracta (Reeve)																											x											
	Fasciolaria princeps Sowerby																			x																x			
	Fusinus cinereus (Reeve)																											x											
	Fusinus fragosus (Reeve)																										x					x	x						
*	*Gyrineum strongi* Jordan																											x										x	
	Hanetia anomala (Reeve)									x																		x				x	x						
*	*Heliacus lowei* n. sp.																											x											
*	*Heliacus* (?) *robertsae* n. sp.									x																													
	Hemitoma hermosa Lowe																											x								x			
*	*Hemitoma natlandi* n. sp.																										x												
*	*Hemitoma scrippsae* n. sp.										x																												
	Hipponix grayanus Menke																			x																			
	Hipponix serratus Carpenter									x		x								x		x			x						x					x		x	x

TABLE 3.—*Continued*

Extinct		*Pliocene*																		*Pleistocene*																				*Living at San Diego*
		Lower							Middle		Upper																													
		A 3529	A 3535	A 3536	A 3543	A 3558	A 3576	A 3577	A 3510	A 3533	A 3519	A 3520	A 3534	A 3545	A 3549	A 3562	A 3592	A 3593	A 3670	A 3507	A 3508	A 3514	A 3515	A 3522	A 3525	A 3538	A 3547	A 3548	A 3550	A 3569	A 3573	A 3574	A 3582	A 3584	A 3686	A 3587	A 3596	A 3597	A 3598	
	Jaton erinaceoides (Valenciennes)																																	x						x
	Knefastia tuberculifera (Broderip and Sowerby)																											x												
	Liocerithium incisum (Sowerby)										x								x		x																			
	Malea ringens (Swainson)					x															x																			
	Melampus trilineatus (Adams)																			x																				
	Melongena patula (Broderip and Sowerby)																																	x						
	Mitra catalinae (Dall)																											x	x					x						x
	Mitra tristis Broderip												x																											
	Modulus cerodes Adams										x																	x	x											
	Murex elenensis Dall																																	x						
	Muricopsis squamulatus (Carpenter)																												x											
	Nassarius angulicostis (Pilsbry and Lowe)										x																	x					x	x			x			
	Nassarius complanatus (Powis)																																x							–
	Nassarius tiarula (Kiener)										x																						x							
*	*Nerita* sp								x																															
	Nerita bernhardi Recluz?																													x										
	Neverita reclusiana (Deshayes)									x																		x					x	x						x
*	*Oliva davisae* n. sp.																																x	x						
	Oliva incrassata (Solander)																																	x						
	Oliva spicata (Bolten)	x	x	x							x	x	x						x		x	x	x			x		x	x			x	x	x			x		x	
	Olivella dama (Mawe)										x		x													x		x	x			x	x	x			x		x	
	Olivella gracilis (Broderip and Sowerby)																																x							
	Olivella tergina (Duclos)										x															x														
	Parametaria cedo-nulli (Reeve)										x																		x										x	
	Patella mexicana Broderip and Sowerby?																				x																			
	Phyllonotus erythrostomus (Swainson)																																x	x		x			x	
	Phyllonotus nitidus (Broderip)																				x																			

	Phyllonotus oxyacanthus (Broderip)																																			x			
	Phyllonotus princeps (Broderip)																											x											
	Polinices bifasciatus (Gray)							?				x	x									x			x		x	x				x				x			
	Polystira nobilis (Hinds)																																x						
	Pyramidella conica Adams																											x				x							
	Pyrene fuscata (Sowerby)													x								x					x	x								x			x
	Strombina maculosa (Sowerby)										x																x	x					x			x			
	Strombus galeatus Swainson										x	x								x						x	x					x				x	x		
	Strombus granulatus Mawe																			x			x																
*	*Strombus granulatus* subsp. *acutus* n. subsp.							x			?		?															x				x	x			x		x	
	Strombus gracilior Sowerby																															x	x		x				
*	*Strombus subgracilior* n. sp.									x						?																							
	Tegula mariana (Dall)										x		x		x												x	x				x			x	x			x
*	*Teinostoma gallegosi* Jordan																										x												
	Terebra (*Strioterebrum*) *pedroana* var. *hemphilli* Vanatta																															x							x
	Terebra (*Strioterebrum*) *panamensis* Dall																															x	x						
	Terebra (*Strioterebrum*) *specillata* Hinds																															x				x			
	Terebra (*Strioterebrum*) *variegata* Gray										x											x					x					x	x						
	Terebra (*Terebra*) *strigata* Sowerby																															x							
	Trivia solandri (Gray in Sowerby)										x																x	x										x	
	Turbo fluctuosus Wood	x									x		x		x	x				x	x	x		x	x		x	x		x	x		x			x			
	Turbo squamiger Reeve																											x											
	Turbo squamiger Reeve, var.																									x	x						x						
	Turricula maculosa (Sowerby)																																x						
*	*Turritella* (?) sp.								x																														
	Turritella broderipiana d'Orbigny																																x						
	Turritella gonostoma Valenciennes	?																		x										x	x	x	x						
*	*Turritella marcosensis* n. sp.						x																																
	Turritella nodulosa King																															x	x						x
	Turritella pasada Pilsbry and Olsson																															x	x						
	Vermicularia eburnea (Reeve)																																x						
	Vasum caestus (Broderip)																																x			x			

TABLE 4.—*Check list of Pliocene and Pleistocene Echinoidea*

	Pliocene																													*Pleistocene*						*Recent*
	Lower														Middle				Upper																	
	A 3712	LSJU 805	A 3594	A 3528	A 3529	A 3531	A 3536	A 3551	A 3552	A 3554	A 3557	A 3576	A 3580	A 3583	CAS 795	A 3559	A 3650	A 3566	A 3516	A 3517	A 3519	A 3523	A 3534	A 3539	A 3561	A 3562	A 3588	A 3590	A 3591	A 3547	A 3548	A 3564	A 3582	A 3584	A 3596	
Agassizia scrobiculata Valenciennes		x																																		x
Clypeaster bowersi Weaver													x		x																					
C. marquerensis n. sp.																				x		x			x											
C. revellei n. sp.																	x																			
C. speciosus Verrill																		?							x					x				x		x
Dendraster granti n. sp.																x																				
Echinolampas (?) sp.												x																								
Encope angelensis n. sp.																											x	x								
E. arcensis n. sp.					x					x	x																									
E. californica Verrill																															x	x	x	x	x	x
E. carmenensis n. sp.																				x																
E. chaneyi n. sp.									x																											
E. grandis Agassiz																																				x
E. grandis subsp. *inezana* n. subsp.																															x	x	x	x		
E. loretoensis n. sp.							x	x	x	x																										
E. micropora Agassiz																																				x
E. perspectiva Agassiz																																				x
E. scrippsae n. sp.			?					x																												
E. shepherdi n. sp.																				x		x		x		x			x							
E. sverdrupi n. sp.		x				x								x																						
E. n. sp. *A*	x																																			
E. n. sp. *B*																															x					
Eucidaris thouarsii (Valenciennes)																					x		x								x					x
Lovenia hemphilli Israelsky																		x																		
Meoma sp.				x																	x														x	
Moira cf. *clotho* (Michelin)																			x																	

TABLE 5.—*Check list of Pliocene and Pleistocene Madreporaria*

	Upper Pliocene						*Pleistocene*																	*Living*
	A3519	A3520	A3521	A3534	A3549	A3670	A3508	A3514	A3515	A3522	A3525	A3547	A3548	A3550	A3567	A3569	A3573	A3574	A3582	A3584	A3585	A3596	A3597	
Astrangia (*Astrangia*) *concepcionensis* Durham																			x					x
A. (*A.*) *coronadosensis* Durham													x											
A. (*A.*) *santelmoensis* Durham																						x		
Pocillopora robusta Verrill							x								x	x						x		x
Porites californica Verrill	x	x	x	x	x	x	x		x	x	x	x	x				x	x			x	x	x	x
P. nodulosa Verrill								?				x	x	x					x	x				x
Psammocora (*Stephanaria*) *stellata* (Verrill)												x												x

TABLE 6.—*Check list of Cirripedia and nonmarine Gastropoda*

CIRRIPEDIA	
Coronula diadema (Linnaeus)	Locs. A3518, A3532, lower and upper Pliocene
Nonmarine GASTROPODA	
Bulimulus sp.	Loc. A3540, Pleistocene

ECOLOGY

Their limited areal distribution, usually limited thicknesses, and unconformable relationships to the older rocks suggest that most of the upper Pliocene and Pleistocene sediments in this area were deposited in small local coast-line embayments, similar to the small bays and other indentations now existing along the western shore of the Gulf of California. The older Pliocene rocks are less readily interpreted; they were not examined in sufficient detail or in as many places and were more often lacking in fossils, but probably they were deposited under essentially similar conditions.

Fortunately many localities in the upper Pliocene and Pleistocene contain more or less numerous specimens of the colonial coral *Porites*. *Porites californica* Verrill was found at localities A 3519, A 3520, A 3521, A 3534, A 3549, A 3508, A 3515, A 3522, A 3525, A 3547, A 3548, A 3573, A 3574, A 3585, A 3596, and A 3597. (*See* description of localities.) The greatest development of the genus *Porites* in the Hawaiian Islands (Vaughan, 1907, p. 18–21) is between low tide and a depth of 6 feet, although dwarfed and slender forms are recorded from depths as great as 79 meters. From available data on the bathymetric distribution of *Porites* in the Gulf of California and from Vaughan's Hawaiian data, it appears probable that the sediments at the various localities named were deposited in waters less than 15 meters deep.

Encope grandis subsp. *inezana* n. subsp. and *Encope californica* Verrill occur in large numbers at localities A 3582 and A 3584, while *Encope shepherdi* n. sp. (closely related to *E. grandis*) is rather abundant in the upper Pliocene at Marquer Bay, Carmen Island. Steinbeck and Ricketts (1941, p. 193, 400–401) note that *E. grandis* and *E. californica* were found living in large numbers at depths of 1–3 feet below low tide in quiet-water sand flats. It is thus suggested that sediments at these three localities where the afore-mentioned species of *Encope* or their close relatives are abundant were deposited in protected areas in very shallow waters, probably less than 10 feet deep.

Woodring (1938, Pl. 3) indicated the depth-frequency distribution of living species of *Ostrea* similar to *O. vespertina* Conrad. This latter species is widespread, occurring in most localities examined. According to the data presented by Woodring all localities where this species is present would represent areas of deposition in waters of 100-fathoms depth or less. This species was not recorded from localities A 3594, A 3531, A 3532, A 3537, A 3552, A 3556, A 3565, A 3577, A 3579, A 3712, and A 3713 within the lower Pliocene. Possibly excepting locality A 3594, it is believed that its absence is due to collection failure. Within the middle Pliocene it is notably absent from localities A 3498, A 3504, A 3511, A 3512, and was not recorded from A 3527 and A 3571. Excepting the last two, these localities are in highly foraminiferal beds which Manley L. Natland (personal communications) believes were deposited in deep water, a conclusion which would agree with the absence of *Ostrea vespertina.* This is in contrast to somewhat similar beds of corresponding age on Monserrate Island (localities A 3566, A 3568) where *Ostrea vespertina* does occur in limited numbers. Probably these last two localities represent an environment near the lower limit of bathymetric distribution of *Ostrea.* But few localities within the upper Pliocene and Pleistocene are without this oyster or a closely allied form, and where this species is not found it is believed that this is due to collection failure.

Similarly Woodring (1938) indicates that *Anadara multicostata* (Sowerby) and *Macrocallista* spp. are confined to depths of less than 100 fathoms. These forms appear in many localities in the upper Pliocene and Pleistocene; together with the Ostreas they appear to indicate that all the post-middle Pliocene beds were deposited in waters less than 100 fathoms deep.

At localities A 3557, A 3558, and A 3565 in the Arroyo de Arce–Arroyo de Gua sections there are immense numbers of *Aequipecten abietis* (Jordan and Hertlein) associated with only minor numbers of other pectens and oysters. One of these reef beds (loc. A 3565) is 150–200 feet thick. Several less important beds were noted below this one in the section, but none above it. It seems that at repeated intervals the environment in this area was extremely favorable to the growth of *Aequipecten* culminating in an optimum growth at the time of deposition of the *Pecten* reef at locality A 3565. After that time conditions were never again so extremely favorable. Hertlein's (1935, p. 312–313) records for *A. circularis* (Sowerby), a closely related living species, seem to indicate that its optimum development is between depths of 10 and 35 fathoms, probably nearer the latter. Consequently it appears possible that the great development of *Aequipecten abietis* in the lower Pliocene of the Arroyo de Arce–Arroyo de Gua section was in waters of similar depth.

Few gastropods were collected in the lower and middle Pliocene deposits, but they are rather abundant in some localities in the upper Pliocene and Pleistocene. Three species, *Conus princeps* Linnaeus, *Oliva spicata* (Bolten), and *Turbo fluctuosus* Wood are usually present and sometimes abundantly so at localities A 3508, A 3514, A 3515, A 3519, A 3520, A 3525, A 3529, A 3534, A 3535, A 3536, A 3538, A 3548, A 3549, A 3550, A 3562, A 3573, A 3574, A 3582, A 3584, A 3596, A 3598, and A 3670.

TABLE 7.—*Probable depth in meters at time of deposition*

	0–10	10–20	20–40	40–60	60–80	80–100	100–185	Over 185		0–10	10–20	20–40	40–60	60–80	80–100	100–185	Over 185
A3497	—	—	—	—	—	—	—		A3549	xx							
A3498								x	A3550	xx							
A3499								x	A3551		—	—					
A3500								x	A3552			—	—				
A3501								x	A3553		—	—					
A3502								x	A3554		—	—					
A3503								x	A3555	—	—	—	—	—	—	—	
A3504								x	A3556			—	—				
A3505	—	—	—	—	—	—	—		A3557			xxx	xxx	x			
A3506	—	—	—	—	—	—	—		A3558			xxx	xxx	x			
A3507	—	—	—	—	—	—	—		A3559	—	—	—	—	—	—	—	
A3508	xx								A3560	—	—	—	—	—	—	—	
A3509	—	—	—	—	—	—	—		A3561	—	—	—	—	—	—	—	
A3510	—	—	—	—	—	—	—		A3562	xx							
A3511								x	A3563	—	—	—	—	—	—	—	
A3512								x	A3564	xx							
A3513	—	—	—	—	—	—	—		A3565			xxx	xxx	x			
A3514	xx								A3566	—	—	—	—	—	—	—	
A3515	xx								A3567	xx							
A3516			xxx	xxx					A3568	—	—	—	—	—	—	—	
A3517	xx								A3569	xx							
A3518			xxx	xxx					A3571			—	—				
A3519	xx								A3573	xx							
A3520	xx								A3574	xx							
A3521	xxx	xx							A3576	—	—	—	—	—	—	—	
A3522	xxx	xx							A3577	—	—	—	—	—	—	—	
A3523	xx								A3578	—	—	—	—	—	—	—	
A3524	—	—	—	—	—	—	—		A3579	—	—	—	—	—	—	—	
A3525	xx								A3580	?	?	?					
A3528	—	—	—	—	—	—	—		A3581	—	—	—	—	—	—	—	
A3529	xx								A3582	xx							
A3530	—	—	—	—	—	—	—		A3583	—	—	—	—	—	—	—	
A3531			—	—					A3584	xx							
A3532			—	—					A3585	xxx	x						
A3533	—	—	—	—	—	—	—		A3586	—	—	—	—				
A3534	xx								A3587	—	—	—	—				
A3535	xx								A3588	—	—	—	—	—	—	—	
A3536	xx								A3589	—	—	—	—	—	—	—	
A3537			—	—					A3590	—	—	—	—	—	—	—	
A3538	xx								A3591	—	—	—	—	—	—	—	
A3539	xx								A3592	—	—	—	—	—	—	—	
A3540			nonmarine						A3593	—	—	—	—	—	—	—	
A3541	—	—	—	—	—	—	—		A3594		?	?	?				
A3542	—	—	—						A3595	—	—	—	—	—	—	—	
A3543	—	—	—	—	—	—	—		A3596	xx							
A3544	—	—	—	—	—	—	—		A3597	xxx	x						
A3545	—	—	—	—	—	—	—		A3598	xx							
A3546	—	—	—	—	—	—	—		A3670	xx							
A3547	xxx	x							A3712	—	—	—	—				
A3548	xx								A3713	—	—	—	—				

x reliable data.
—— generalized or estimated limits.

Conus princeps commonly inhabits reefs and rocks exposed at extreme low tide. Similarly 155 records of the genus *Conus* give a depth range of 0-1134 meters, median 0 meters (0 taken as low tide). *Turbo fluctuosus* Wood commonly inhabits the littoral on rocky beaches. Seventy-five depth records of the genus *Oliva* give a range of 0-135 meters and a median of 10 meters. From the data available for the three species, it appears probable that the sediments at the various localities where they were collected were deposited in depths varying from low tide to 10 meters.

Table 7 summarizes probable depths of water at the various localities at time of deposition.

The bed immediately beneath the coral reef at locality A 3519 (Marquer Bay) and the beds at localities A 3542 and A 3547 (Coronado Island) were laid down under conditions permitting a great development of coralline algae. These beds all contain *Porites* spp. developed in slender branching forms indicating quiet water probably less than 46 meters deep.

No evidence of temperatures colder than those now prevailing within the Gulf of California were noted at any locality. On the contrary, within the Pleistocene, at localities A 3508, A 3567, A 3569, and A 3596, the coral *Pocillopora robusta* Verrill is found. These localities are all farther north than its present northern limit of distribution which is near La Paz, and they probably indicate intervals when the marine climate was warmer than at present. Similarly the coral *Psammocora* (*Stephanaria*) *stellata* (Verrill) occurs in the Pleistocene of Coronado Island (loc. A 3547), indicating a warmer temperature than now, as it is not known to be living north of La Paz.

AGE AND CORRELATION

CLASSIFICATION OF STRATA

Rather arbitrarily, the appearance of *Encope grandis* subsp. *inezana* n. sp. and the disappearance of *Encope shepherdi* n. sp. have been taken to indicate the beginning of the Pleistocene. These two species together with the living *E. grandis* have been carefully studied, and the range of variation rather accurately determined. The strata carrying *Encope grandis* subsp. *inezana* are largely horizontal but in a few areas, as on Coronado Island, may be slightly tilted. As in Marquer Bay, Carmen Island, the Pleistocene may include numerous terrace levels and has been faulted.

The Pleistocene fauna includes, in addition to the aforementioned *Encope*, *E. californica* Verrill, *E. micropora* Agassiz, *E.* n. sp. *B.*, *Aequipecten circularis* (Sowerby) *Basterotia californica* n. sp., *B. peninsulare* (Jordan), *Ostrea cumingiana* Dunker, *Pinna corteziana* n. sp., *P. rugosa* Sowerby, *Plicatula inezana* n. sp., *Alabina strongi* n. sp. *Astraea* (*Uvanilla*) *shepherdi* n. sp., *Cancellaria coronadosensis* n. sp., *Gyrineum strongi* Jordan, *Heliacus lowei* n. sp., *Oliva davisae* n. sp., *Strombus granulatus* subsp. *acutus* n. subsp., *S. gracilior* Sowerby, and numerous other living species.

Discordantly underlying the Pleistocene in Marquer Bay is a group of slightly warped beds mapped as a single unit. They are designated as the Marquer formation by Anderson. The fauna includes *Encope shepherdi* n. sp. (the immediate ancestor of *E. grandis* subsp. *inezana*), *E. carmenensis* n. sp., *Clypeaster marquerensis* n. sp., *Aequipecten abietis* (Jordan and Hertlein), *A. circularis* (Sowerby), *Basterotia hertleini* n. sp., *Ostrea cumingiana* Dunker, *Ostrea vespertina* Conrad, and *Patinopecten marquerensis* n. sp. Wherever found these species seem to occur in beds in the same stratigraphic position beneath the Pleistocene and therefore are considered as index species for beds equivalent in age to the Marquer formation.

On the east side of Salinas Bay, Carmen Island, there is a well-developed series of volcanic conglomerates with interbedded foraminiferal marls and clays. Anderson designates these as the Carmen formation. The faunas studied were nearly all obtained from the foraminiferal beds and immediately adjacent strata. The megafauna is not large, but it includes *Aequipecten abietis* (Jordan and Hertlein), *A. revellei* n. sp., *Chlamys dallasi* (Jordan and Hertlein), *Ostrea erici* Hertlein, *Ostrea vespertina* Conrad, and *Patinopecten bakeri* subsp. *diazi* n. subsp. Not far to the south on the southern end of Monserrate Island there is a group of calcareous beds very similar to the foraminiferal beds of the Carmen formation. These calcareous beds contain the same fauna as the latter and in addition *Pecten* (*Pecten*) *bösei* Hanna and Hertlein and *Lovenia hemphilli* Israelsky. The species named are believed to be characteristic, and strata at various localities are correlated on that basis.

On San Marcos Island there is a group of continental sediments overlain by marine beds and in turn unconformably separated from strata believed to be equivalent in age to the Carmen formation. These continental and marine beds are designated as the San Marcos formation by Anderson. They rest unconformably on the Comondú volcanics, presumably of Miocene age. The marine fauna includes *Aequipecten abietis* (Jordan and Hertlein), *Aequipecten sverdrupi* n. sp., *Chlamys corteziana* n. sp., *Lyropecten mediacostatus* (Hanna), *Ostrea vespertina* Conrad, *Pecten* (*Pecten*) *carrizoensis* Arnold, and *Turritella marcosensis* n. sp. A short distance south on the shore of Santa Inez Bay somewhat similar marine strata rest on the Comondú volcanics and are overlain by Pleistocene beds. These lower strata contain *Aequipecten deserti* (Conrad), *Aequipecten sverdrupi* n. sp., and *Ostrea vespertina* Conrad. On the basis of similar stratigraphic position and species common to the San Marcos formation, the Santa Inez Bay strata are believed to be of the same age. In addition they also carry *Encope sverdrupi* n. sp. and *Pecten* (*Euvola*) *keepi* Arnold.

The age relationships of the San Marcos and Carmen formations and of their faunas are not too clear. They may be of the same age, or one may be older than the other. However, on the basis of the following points it is believed that the San Marcos formation is older.

(1) Most of the species of the San Marcos formation are characteristic of it and are also characteristic of the Imperial formation of southeastern California. Most of them, insofar as known, are found in the basal part of the Imperial. These include *Aequipecten deserti* (Conrad), *Aequipecten sverdrupi* n. sp., *Chlamys corteziana* n. sp., *Lyropecten mediacostatus* (Hanna), *Pecten* (*Euvola*) *keepi* Arnold, and *Pecten* (*Pecten*) *carrizoensis* Arnold. The Imperial formation is the oldest late Tertiary marine formation found at the head of the old Gulf of California seaway, being unconformable on older, largely nonmarine formations.

(2) The next younger beds on San Marcos Island contain leached fossiliferous boulders of the San Marcos formation. These beds are in turn highly tilted and well consolidated; with the tilting probably due to near-by major faulting. The only important fossil in these beds is *Aequipecten abietis* (Jordan and Hertlein) which, however, ranges from the San Marcos formation up into the middle of the Marquer formation. The age of these beds is therefore somewhat uncertain, but, because they are highly tilted and well consolidated, they are believed to be the age equivalent of the Carmen formation.

(3) The fauna in the beds north of Arroyo Blanco, Carmen Island, which are cor-

TABLE 8.—*Stratigraphic distribution of the more important fossils in the post-Miocene of the Gulf of California area*

	Pliocene			*Pleistocene*	*Recent*
	Lower	Middle	Upper		
ECHINOIDEA					
Clypeaster bowersi Weaver	x x x x x x	x x x x x x			
C. marquerensis n. sp.			x x x x x x		
C. revellei n. sp.		x x x x x x			
Dendraster granti n. sp.		x x x x x x			
Encope angelensis n. sp.			x x x x x x		
E. arcensis n. sp.	x x x x x x				
E. californica Verrill				x x x x x x	x x x x x x
E. carmenensis n. sp.			x x x x x x		
E. chaneyi n. sp.	.... x x x x				
E. grandis Agassiz					x x x x x x
E. grandis subsp. *inezana* n. subsp.				x x x x x x	
E. loretoensis n. sp.	.... x x x x				
E. micropora Agassiz				x x x x x x	x x x x x x
E. perspectiva Agassiz					x x x x x x
E. scrippsae n. sp.	x x x x x x				
E. shepherdi n. sp.			x x x x x x		
E. sverdrupi n. sp.	x x x x x x				
E. n. sp. *A*	x x x x				
E. n. sp. *B*				x x x x	
Lovenia hemphilli Israelsky		x x x x x x			
Moira cf. *clotho* (Michelin)			x x		
PELECYPODA					
Aequipecten abietis (Jordan and Hertlein)	x x x x x x	x x x x x x	x x x x		
A. antonitaensis n. sp.		x x x x x x			
A. circularis (Sowerby)			.... x x x x	x x x x x x	x x x x x x
A. circularis subsp. *bramkampi* n. subsp.	x x				
A. deserti (Conrad)	x x x x				
A. revellei n. sp.		x x x x x x			
A. sverdrupi n. sp.	x x x x				
Basterotia californica n. sp.				.... x x x ..	

Pelecypoda					
B. hertleini n. sp.	....	....	x x x x x x	....	....
B. peninsulare (Jordan)	....	....	....	x x x	....
Chlamys corteziana n. sp.	x x x x	....	....	....	....
C. dallasi (Jordan and Hertlein)	....	x x x x x x	....	....	....
Lyropecten mediacostatus (Hanna)	x x x x	....	....	....	....
L. modulatus (Hertlein)	.... x x x x	....	....	....	....
Ostrea cumingiana Dunker	....	....	.... x x x x	x x x x x x	x x x x x x
O. erici Hertlein	....	x x x x x x	....	....	....
O. vespertina Conrad	x x x x x x	x x x x x x	x x x x	....	....
Patinopecten bakeri (Hanna and Hertlein)	x x x x x x	....	....	....	....
P. bakeri subsp. *diazi* n. subsp.	....	x x x x x x	....	....	....
P. marquerensis n. sp.	....	....	x x x x x x	....	....
Pecten (*Pecten*) *bellus* var. *hemphilli* Dall	....	x x x x x x	....	....	....
P. (*P.*) *bösei* Hanna and Hertlein	.... ?	x x x x x x	....	....	....
P. (*P.*) *carrizoensis* Arnold	x x x x	....	....	....	....
P. (*Euvola*) *keepi* Arnold	x x x x	....	....	....	....
P. (*E.*) *refugioensis* Hertlein	....	x x x x x x	....	....	....
Pinna corteziana n. sp.	....	....	....	x x x x x x	....
P. latrania Hanna ?	.... x x	....	....	....	....
P. rugosa Sowerby	....	....	....	x x x x x x	x x x x x x
Plicatula inezana n. sp.	....	....	....	x x x x x x	....
Protothaca coronadosensis n. sp.	....	....	x x x x x x	....	....
Gastropoda					
Astraea (*Pomaulax*) *subundosa* n. sp.	....	....	x x x x x x	....	....
A. (*Uvanilla*) *shepherdi* n. sp.	....	....	....	x x x x	....
Cancellaria coronadosensis n. sp.	....	....	....	x x x x	....
Gyrineum strongi Jordan	....	....	....	x x x x x x	....
Oliva davisae n. sp.	....	....	....	x x x x x x	....
Strombus granulatus Mawe	....	....	....	 x	x x x x x x
S. granulatus subsp. *acutus* n. subsp.	.... x x	....	.... x x	x x x x x ..	....
S. cf. *obliteratus* Hanna	x x x	....	....	....	....
S. gracilior Sowerby	....	....	....	x x x x x x	x x x x x x
S. subgracilior n. sp.	....	...... x x x	x x x x x x	....	....
Turritella marcosensis n. sp.	x x x x	....	....	....	....

related with the San Marcos formation, includes *Patinopecten bakeri* (Hanna and Hertlein) which is closely related to *Patinopecten bakeri* subsp. *diazi* n. subsp. of the Carmen formation; it is distinguished largely by the different relative width of the ribs and interspaces. This character is believed to be evolutionary in trend.

(4) Several extinct species found in the type San Marcos formation such as *Aequipecten sverdrupi* n. sp., *A. deserti* (Conrad), *Chlamys corteziana* n. sp., *Lyropecten mediacostatus* (Hanna), *Pecten* (*Euvola*) *keepi* Arnold, *Pecten* (*Pecten*) *carrizoensis* Arnold, and *Encope sverdrupi* n. sp. have not been found in the Carmen formation.

(5) As will be shown later, the Carmen formation may be correlated on the basis of its fauna with the San Diego formation (as exposed at Pacific Beach), which is here considered as of middle Pliocene age. On the other hand, the fauna of the San Marcos formation shows no close relationship to the fauna of the San Diego formation or any younger coastal California fauna, indicating that it probably is older than the fauna of the Carmen formation.

The Marquer formation may be shown to be younger than either the San Marcos or Carmen formations by the following facts:

(1) The Marquer formation contains *Encope shepherdi* n. sp. which is closely related to the living *Encope grandis* Agassiz. While the San Marcos and Imperial formations contain several species of *Encope*, they are all extinct, and none are closely related to living species.

(2) *Aequipecten abietis* (Jordan and Hertlein) appears to be replaced by the related *A. circularis* (Sowerby) in the upper part of the Marquer formation. This species is still living but does not appear in either the San Marcos or Carmen formations. Similarly *Ostrea vespertina* Conrad is replaced by *O. cumingiana* Dunker.

(3) Only 14 out of 106 species occurring in the Marquer formation or equivalent strata are extinct.

(4) The Marquer formation or beds correlated with it are only gently warped or deformed, whereas those of the Carmen and San Marcos formations are usually more or less strongly deformed.

A summary of the preceding evidence indicates that the following succession of marine formations or their equivalents is found in this area, beginning at the base: the San Marcos, Carmen, and Marquer formations. The Marquer in turn being overlain by the Pleistocene deposits.

Using the preceding succession as a basis for the succession of faunas, the important species and their ranges have been listed (Table 8) by eliminating from the general check lists all species now living except those that have closely related species or subspecies occurring in the fossil faunas. For reasons discussed later the San Marcos formation has been assigned to the lower Pliocene, the Carmen formation to the middle Pliocene, and the Marquer formation to the upper Pliocene.

Table 8 includes not only species from the type areas of the various formations but also those occurring in association with them at other localities believed to be of the same age.

LOCAL CORRELATION

Table 9 is a correlation chart of the various fossiliferous strata examined, based upon Table 8.

TABLE 9.—*Local correlation of strata in Gulf of California area*

			San Telmo Point	*Monserrate Island*	*Carmen Island*						*Coronado Island*	*Arroyo de Arce-Arroyo de Gua Area*	*Santa Antonita Point*	*Concepción Bay*	*Santa Inez Bay Area*	*San Marcos Island*	*San Lorenzo Island*	*Angel de la Guarda Island*	*Tiburón Island*	*Santa Rosalia (after Touwaide)*	*Colorado Desert, Southwestern California*
					Marquer Bay	Puerto Balandra	Arroyo Blanco	Salinas Bay	Puerto de la Lancha Area	Oto Bay Area											
PLEISTOCENE			Marine terrace Unconformity Strata with *Encope californica* *Aequipecten circularis* *Ostrea cumingiana* *Strombus granulatus* subsp. *acutus* *Pocillopora robusta*	Terrace levels with *Pocillopora robusta* Faulting Faulted terraces	Terrace levels with Recent molluscs and *Pocillopora robusta*	Terrace level		Terrace level with Recent molluscs Minor unconformity ? Strata with Recent molluscs	Cross-bedded eolian limestone Unconformity	Cross-bedded eolian limestone Unconformity Marine conglomerates beneath eolian limestone	Marine terrace Unconformity Marls and algal limestones with *Encope grandis* subsp. *inezana* *E.* n. sp. *B.* *Aequipecten circularis* *Ostrea cumingiana* *Pinna corteziana* *Astraea* (*Uvanilla*) *shepherdi* *Cancellaria coronadosensis* *Gyrineum strongi* *Strombus granulatus* subsp. *acutus*	Terrace level with *Encope grandis* subsp. *inezana*		Terrace level with *Gyrineum strongi* *Strombus granulatus* subsp. *acutus*	Terrace level with *Encope grandis* subsp. *inezana* *Oliva davisae* *Strombus granulatus* subsp. *acutus*	Terrace levels with living molluscs			Terrace level with *Porites californica* and Deposits with living molluscs	"Pleistocene" with mammoth remains and *Gyrineum strongi*	Sediments of Lake Coahuila with *Elphidium*, *Rotalia* cf. *beccarii*, and others.
			Unconformity	Unconformity	Unconformity	Unconformity		Unconformity		Unconformity	Unconformity	Unconformity		Unconformity	Unconformity	Unconformity			Unconformity	Unconformity	Unconformity
PLIOCENE	UPPER	SALADA GROUP			Marquer fm. with *Clypeaster marquerensis* *Encope carmenensis* *E. shepherdi* *Aequipecten circularis* *A. abietis* *Ostrea cumingiana* *O. vespertina* *Patinopecten marquerensis* *Strombus granulatus* subsp. *acutus*	Marquer fm. with *Ostrea cumingiana* *O. vespertina* *Strombus granulatus* subsp. *acutus*				Represented by boulders carrying *Encope shepherdi* in Pleistocene marine conglomerate	? Strata with *Aequipecten abietis* *Ostrea vespertina* *Protothaca coronadosensis* *Astrea* (*Pomaulax*) *subundosa*	Strata with *Clypeaster marquerensis* *Encope shepherdi* *Aequipecten circularis* *A. abietis* *Ostrea vespertina*			"Barracas Table" strata with *Encope shepherdi* *Aequipecten abietis* *Ostrea vespertina*			Strata with *Encope shepherdi* *Aequipecten circularis* *Ostrea vespertina* and strata with *Encope angelensis* *Aequipecten abietis* *A. circularis* *Ostrea vespertina*		??	Borrego fm. Non-marine and brackish water faunas. Contains boulders of Imperial fm. Zone of *Mulinia pallida* 5000 feet above base.
					Unconformity	Unconformity					Unconformity							Unconformity			Unconformity
	MIDDLE			Carmen fm., marls with *Lovenia hemphilli* *Aequipecten revellei* *Ostrea vespertina* *Patinopecten bakeri* subsp. *diazi* *Pecten* (*Pecten*) *bösei*				Carmen fm: foraminiferal marls, volcanic pebble conglomerates with: *Aequipecten abietis* *A. revellei* *Chlamys dallasi* *Ostrea erici* *O. vespertina* *Patinopecten bakeri subsp. diazi*		Strata with *Aequipecten abietis* *Ostrea vespertina* *Patinopecten bakeri* subsp. *diazi* ? Strata with *Strombus subgracilior* n. sp.	? Volcanic conglomerates with: *Ostrea vespertina* (stratigraphic position uncertain)	Strata with *Clypeaster revellei* *Dendraster granti* *Aequipecten abietis* *Ostrea vespertina*	C.A.S. loc. 795, strata with *Clypeaster bowersi* *Aequipecten abietis* *Chlamys dallasi* *Patinopecten bakeri* subsp. *diazi* *Pecten* (*Janira*) *bellus* var. *hemphilli* *Pecten* (*Janira*) *bösei* *P.* (*Euvola*) *refugioensis*			? Strata with *Aequipecten abietis* and carrying boulders of San Marcos fm.				"Upper Salada" with *Patinopecten bakeri* subsp. *diazi*	Palm Spring fm. largely nonmarine but locally *Ostrea vespertina*. ? Upper Imperial fm. Marine to brackish
				Unconformity				Unconformity				Unconformity				Unconformity				Unconformity	
	LOWER						Strata with *Encope arcensis* *E. sverdrupi* *Aequipecten abietis* *Ostrea vespertina* *Patinopecten bakeri*		Strata with *Encope loretoensis* *Aequipecten abietis* *Ostrea vespertina* ? *Pecten* (*Pecten*) *bösei* and Strata with *Encope* n. sp. *A.* *Lyropecten mediacostatus*			Strata with *Encope arcensis* *E. loretoensis* *E. scrippsae* *Aequipecten abietis* *Lyropecten modulatus* *Ostrea vespertina* *Patinopecten bakeri*			San Marcos fm. with *Encope sverdrupi* *Aequipecten sverdrupi* *A. deserti* *Ostrea vespertina* *Pecten* (*Euvola*) *keepi* ? limestone with *Clypeaster bowersi*	San Marcos fm. with *Aequipecten abietis* *A. sverdrupi* *Chlamys corteziana* *Lyropecten mediacostatus* *Ostrea vespertina* *Pecten* (*Pecten*) *carrizoensis*	Strata beneath andesites with ? *Encope scrippsae* *Aequipecten circularis* subsp. *bramkampi*			"Lower Salada" with *Aequipecten abietis* *Pecten* (*Pecten*) *carrizoensis* *Pecten* (*Euvola*) *keepi*	Basal Imperial fm. with *Clypeaster bowersi* *Encope tenuis* *Aequipecten circularis* subsp. *bramkampi* *Aequipecten deserti* *A. sverdrupi* *Chlamys corteziana* *Lyropecten mediacostatus* *Ostrea vespertina* *Pecten* (*Pecten*) *carrizoensis* *Pecten* (*Euvola*) *keepi*
							Unconformity		Unconformity	Unconformity		?Unconformity?			Unconformity	Unconformity	Unconformity			Unconformity	Unconformity
MIOCENE	UPPER			Comondú formation	Comondú formation		Comondú formation	Comondú formation	Comondú formation	Comondú formation	Comondú formation	Comondú formation		Comondú formation	Comondú formation	Comondú formation	Comondú formation	Comondú formation		Comondú formation	Alverson Canyon formation

In addition to localities visited by the E. W. SCRIPPS Expedition, Touwaide's (1930) section around Santa Rosalia, the California Academy of Science locality (C. A. S. loc. 795) at Santa Antonita Point, and the section in the Colorado Desert area of southeastern California have been included. Comments on the various localities and sections are as follows.

ANGEL DE LA GUARDA ISLAND: Localities A 3591, A 3592, and A 3593 are within a few feet stratigraphically of one another, and their fauna may be considered as a whole. *Encope shepherdi* n. sp. and *Ostrea vespertina* indicate a correlation with the Marquer formation.

Localities A 3588, A 3589, and A 3590 appeared to represent approximately the same horizon in the field; therefore the fauna is considered as a whole. *Ostrea vespertina* Conrad, *Aequipecten abietis* (Jordan and Hertlein), and *Aequipecten circularis* (Sowerby) indicate a correlation with the Marquer formation.

Paredes (1920, p. 7) noted the occurrence of fossils between lavas at the north end of the island. This may correspond to a similar occurrence at localities A 3591–93 which are also overlain by lava.

ARROYO DE ARCE-ARROYO DE GUA AREA: The entire post-Comondú section appears to be represented in this area, but the basal contact with the volcanics was not observed. The extreme amount of leaching prevented extensive collecting except of certain species, although a large and varied fauna was observed to be present. The localities were segregated according to their faunal and stratigraphic relationships as follows:

Locality A 3564 contains *Encope grandis* subsp. *inezana* n. subsp. and is therefore referred to the Pleistocene.

Localities A 3561, A 3562, and A 3563, are in the upper part of the section and contain *Encope shepherdi* n. sp., *Clypeaster marquerensis* n. sp., *Aequipecten abietis* (Jordan and Hertlein), *Aequipecten circularis* (Sowerby), and *Ostrea vespertina* Conrad. These localities may therefore be correlated unquestionably with the Marquer formation.

Localities A 3559 and A 3560 are only about 15 feet apart stratigraphically and may be considered together. No characteristic species of any of the three formations are present, but, because they are stratigraphically lower than localities A 3561, A 3562, and A 3563 and because *Clypeaster revellei* n. sp. is in the same lineage as *Clypeaster marquerensis* n. sp., these two localities are correlated with the Carmen formation. Admittedly this evidence is weak.

Not far below these localities is a well-marked unconformity. Below the unconformity the following localities are found, arranged in stratigraphic order from top to bottom, A 3565, A 3557, A 3558, A 3552, A 3551, A 3556, A 3555, and A 3554. A minor unconformity separates locality A 3565 from those lower in the section. Unfortunately only one species, *Aequipecten abietis* (Jordan and Hertlein), was collected here. Therefore because the locality is below the major unconformity in the section it is considered with the lower localities. However, the possibility is admitted that this locality (A 3565) should be correlated with the Carmen formation, and all localities above the major unconformity correlated with the Marquer formation

Additional collections are needed to decide this point. The fauna of the remaining localities may be grouped together and consists of the following important species:

Encope arcensis n. sp.
Encope chaneyi n. sp.
Encope loretoensis n. sp.
Encope scrippsae n. sp.
Aequipecten abietis (Jordan and Hertlein)
Lyropecten modulatus (Hertlein)
Ostrea vespertina Conrad
Patinopecten bakeri (Hanna and Hertlein)
Pinna latrania Hanna?

Of the preceding species, *Encope arcensis* n. sp. and *Patinopecten bakeri* (Hanna and Hertlein) occur in the same beds on Carmen Island (localities A 3529, A 3530, and A 3531) as *Encope sverdrupi* n. sp. which in turn is known elsewhere only from the beds equivalent to the San Marcos formation in Santa Inez Bay. On this meager evidence, plus the fact that the beds are near the base of the section, the lower Arroyo de Arce-Arroyo de Gua section is correlated with the San Marcos formation. The lack of other species common to the San Marcos formation is believed due to a difference in facies; the lower Arroyo de Arce-Arroyo de Gua section is sandy and conglomeratic, whereas the typical fossiliferous San Marcos formation is decidedly calcareous. However, the possibility that these strata may be slightly younger than the typical San Marcos formation should be considered in future work. Unfortunately present collections are insufficient to determine this point.

Carmen Island-Oto Bay Area: Locality A 3538. Fauna consists of living species, the beds must be of Pleistocene age because boulders in the conglomerate contain *Encope shepherdi* n. sp. which is characteristic of the upper Pliocene. The overlying cross-bedded limestone contains a poorly preserved specimen of the terrestrial gastropod *Bulimulus* (locality A 3540) which would tend to confirm its being a terrestrial eolian deposit.

Locality A 3539. *Encope shepherdi* n. sp., collected from boulders in the conglomerate at locality A 3538, indicates that sediments corresponding in age to the Marquer formation had been laid down in this vicinity and subjected to erosion before the deposition of the sediments of locality A 3538.

Locality A 3533. The three species, *Aequipecten abietis* (Jordan and Hertlein), *Ostrea vespertina* Conrad, and *Strombus subgracilior* n. sp. do not indicate a definite age assignment. The areal geology suggests that this locality is in the same set of beds as locality A 3541 and it is therefore correlated with the Carmen formation.

Locality A 3541. Among other species, this locality contains *Patinopecten bakeri* subsp. *diazi* n. subsp. and therefore is correlated with the Carmen formation.

Carmen Island-Puerto de la Lancha Area: Localities A 3535, A 3536, and A 3537 appear to be from the same series of beds and are considered together. *Encope loretoensis* n. sp. indicates a correlation with the lower Arroyo de Arce-Arroyo de Gua section and therefore possibly a correlation with the San Marcos formation. A single poor specimen of what was questionably identified as *Pecten* (*Pecten*) *bösei* Hanna and Hertlein also occurs here. It was not found elsewhere associated with the lower faunas. Possibly it may represent some other species, or one or the other of the two species has a longer range than here believed.

Localities A 3712 and A 3713 are apparently from the same beds. *Lyropecten mediacostatus* (Hanna) indicates a correlation with the San Marcos and Imperial formations.

CARMEN ISLAND-SALINAS BAY AREA: Localities A 3497 and A 3508 contain only living species and are referred to the Pleistocene.

Locality A 3507 contains only living species but is slightly unconformable beneath locality A 3508, and probably is to be referred to the Pleistocene.

Localities A 3498, A 3505, A 3506, A 3509, A 3510: type section of Carmen formation. *Ostrea erici* Hertlein was originally recorded as *O. tayloriana* Gabb by Jordan and Hertlein from the Pliocene of Elephant Mesa, Scammon Lagoon quadrangle, Lower California, from beds correlated with the San Diego Pliocene.

CARMEN ISLAND-PUERTO BALANDRA: Localities A 3534 and A 3670 are in the coral reef and adjacent sands. *Ostrea cumingiana* Dunker, *Ostrea vespertina* Conrad, and *Basterotia hertleini* n. sp. indicate a correlation with the Marquer formation.

CARMEN ISLAND, ARROYO BLANCO AREA: Localities A3528, A 3529, A 3530, A 3531, and A 3532 are apparently in the same group of beds; therefore the fauna is considered as a whole. *Encope arcensis* n. sp. and *Patinopecten bakeri* (Hanna and Hertlein) indicate a correlation with the lower Arroyo de Arce-Arroyo de Gua section. *Encope sverdrupi* n. sp. furnishes a tie to the San Marcos formation.

CARMEN ISLAND, MARQUER BAY AREA: Localities A 3514, A 3515, A 3522, and A 3525 are from various terrace levels of post Marquer formation age and are therefore considered as of Pleistocene age.

Localities A 3513, A 3516, A 3517, A 3518, A 3519, A 3520, A 3521, A 3523, and A 3524 are all from the Marquer formation. In the field, all these localities seemed to represent the same group of beds and to be merely different facies of the same formation. However, localities A 3513, A 3516, A 3518, and A 3524 appear to be older than the remaining localities on the basis of their fauna. *Ostrea vespertina* Conrad is the only important species common to both sets of localities. The last-named set is marly, while the others are sandy or coralline. This facies difference may account for the difference in fauna, or else the marly beds may be somewhat older. Future workers should examine the area with care.

COLORADO DESERT, SOUTHEASTERN CALIFORNIA: The Tertiary and Pleistocene deposits of the Colorado Desert have been the subject of much speculation. The age and faunal relationships of the fossiliferous beds have been studied by Kew (1914), Vaughan (1917), Dickerson (1917), Hanna (1926), Woodring (1931), Grant and Gale (1931), Bramkamp (1934; 1935), and Tarbet and Holman (1944). Vaughan (1917) summarized earlier reports. In addition, various oil companies have had detailed private investigations made of the area. Through the courtesy of the Geological Department of the Standard Oil Company of California two reports (Holman 1940; Tarbet, 1942) have been available, and permission to use some of the information contained therein has been given. The stratigraphy of the area was well worked out by Tarbet (1942) and Tarbet and Holman (1944). Their stratigraphic column for the area follows:

(1) Recent alluvium.

(2) Terrace deposits and Lake deposits from ancient Lake Coahuila (Cahuilla).

Unconformity

(3) Borrego formation, nonmarine and brackish-water sediments up to 7600 feet thick, with a zone of *Mulinia pallida* (Broderip and Sowerby) 5000 feet above the base and a microfauna comparable to that found in the sediments of Lake Coahuila and in the Salton Sea.

(4) Palm Spring formation, largely nonmarine, up to 6100 feet thick, considerable fossil wood, a few poor fragments of vertebrate bones in the Split Mountains, but with *Ostrea vespertina* and other marine fossils in San Felipe Hills about 5000 feet above the base.

(5) Imperial formation, divided into lower (5–200 feet), middle (70–1800 feet), and upper (800–1650 feet). All marine, but upper member begins transition to nonmarine Palm Spring formation. The best-known fauna of the Imperial formation is derived from the lower member.

Unconformity and diastrophism

(6) Alverson Canyon formation, sandstones overlain by basic igneous flows and associated tuffaceous sandstone and conglomerates, presumably nonmarine. About 700 feet thick.

Unconformity and diastrophism

(7) Split Mountain formation, 2700 feet of fanglomerates and sandstones with associated marine sandstones and shale containing *Textularia* (?) sp.

Unconformity and diastrophism

(8) Basement complex.

Tarbet and Holman state that a meager fauna from the Split Mountain formation suggests Miocene age. Holman (1940) lists Foraminifera and a few of the larger fossils from the Imperial and Palm Spring formations. In 1944, he and Tarbet refer the Imperial formation to the upper Miocene. He notes that the Imperial formation represents a cycle of marine deposition with the lower member having a marine littoral fauna, the middle member a shallow neritic fauna, and the upper member another littoral fauna. He lists respectively 40, 15, and 5 species of Foraminifera from the lower, middle, and upper members and notes that the depth of the middle member was "no greater than 100 fathoms." He records abundant ostracods and chara with the occasional *Elphidium* sp. and *Rotalia* cf. *beccarii* in the basal part of the Palm Spring formation. Finally, and of great importance in the interpretation of the area, he records that *Elphidium*, *Rotalia* cf. *beccarii*, ostracods, chara, small gastropods, and bivalves lived in ancient Lake Coahuila (also known as Cahuilla) and that, in addition to the preceding forms, small *Quinqueloculina* (?) and *Cibicides* are now living in the Salton Sea. The record of Foraminifera in Lake Coahuila and the Salton Sea is important, for, although the genera and species listed can live in waters of low salinity, they cannot live in fresh water and must have entered this area when these bodies of water were connected with the head of the Gulf of California.

From the preceding evidence, it is apparent that the Colorado Desert area has had at least intermittent marine incursions from the beginning of Imperial time up into the Recent.

It appears probable that the terrace deposits and sediments from ancient Lake Coahuila represent the Pleistocene in this area, with Lake Coahuila corresponding to other large Pleistocene lakes of Western America. Preceding this is the nonmarine and brackish-water Borrego formation with *Mulinia pallida*. The writer would assign it to the upper Pliocene, although Tarbet has referred it to the Pleistocene, but certainly it is older than the terrace deposits and lake sediments and younger than the Palm Spring formation.

The best published report upon the fauna of the Imperial formation is that of Hanna (1926). Among the listed extinct species are:

Clypeaster bowersi Weaver
Aequipecten deserti (Conrad)
Lyropecten mediacostatus (Hanna)
Ostrea vespertina Conrad
Pecten (Pecten) carrizoensis Arnold
Pecten (Euvola) keepi Arnold
Pinna latrania Hanna
Strombus obliteratus Hanna

Also *Aequipecten circularis* subsp. *bramkampi* n. subsp. and *Chlamys corteziana* n. sp. were found in the University of California collections from the Imperial formation.

The two preceding lists contain 10 of the 15 important species of mollusks here recognized from the San Marcos formation or its equivalents. Only *Clypeaster bowersi* Weaver and *Ostrea vespertina* Conrad are known to occur in younger beds, the former in an equivalent of the Carmen formation, the latter in beds as young as the Marquer formation. Available evidence thus indicates that the basal part at least of the Imperial formation may be correlated with the San Marcos formation. Possibly, however, the entire Imperial formation may be the equivalent of the San Marcos formation, and the Palm Spring formation the equivalent of the Carmen formation.

CONCEPCIÓN BAY: Locality A 3598 contains *Gyrineum strongi* Jordan and *Strombus granulatus* subsp. *acutus* n. subsp. and is therefore referred to the Pleistocene.

According to information supplied by Dr. J. A. Noble (Personal Communication, March 1, 1947), Dr. H. E. Vokes identified *Turritella imperialis* Hanna and *Patinopecten* sp. aff. *bakeri* subsp. *diazi* n. subsp. (of this paper) among a collection of fossils (U. S. G. S. loc. 15615) made by I. F. Wilson from Santo Domingo Bay on the west side of Point Concepción. Noble reports that the fossils came from a thick shell bed which rests on the Comondú formation with a high angular unconformity. This area is only about 15 miles southeast of loc. A 3580 of the Santa Inez Bay area, and about 30 miles southeast of San Marcos Island. The occurrence of *Turritella imperialis* Hanna at the base of the post-Comondú section corroborates the correlation of the San Marcos formation with the Imperial formation, and loc. A 3580 with the San Marcos formation. Vokes' faunal list shows an association of numerous species now living, together with extinct species, and generally corroborates the Pliocene age assignment of the Imperial formation, rather than an older age.

CORONADO ISLAND: Localities A 3547, A 3548, and A 3550 appear to be of the same age, on the basis of both fauna and field occurrence. The presence of *Encope grandis* subsp. *inezana* n. subsp. indicates a Pleistocene age in the terminology used here. Otherwise the many extinct species would cause them to be correlated with the Marquer formation, which the sequence of beds resembles lithologically. Extinct species and subspecies are:

Encope n. sp. *B.*
Basterotia hertleini n. sp.
Pinna corteziana n. sp.
Plicatula inezana n. sp.
Astraea (Uvanilla) shepherdi n. sp.
Cancellaria coronadosensis n. sp.
Gyrineum strongi Jordan
Strombus granulatus subsp. *acutus* n. subsp.

Locality A 3549, because of its similar attitude and lithology, is presumed to be of the same age as localities A 3545 and A 3546, which are unconformable beneath locality A 3547. The species present do not indicate any age other than a generalized

Pliocene. The localities are doubtfully correlated with the upper Pliocene Marquer formation.

Localities A 3543 and A 3544 contain only *Ostrea vespertina* Conrad. They are found in a fault block with a different attitude and lithology than the beds at localities A 3545, A 3546, and A 3549. Lithologically the beds are similar to the conglomerates of the Carmen formation; therefore they are correlated with it.

MONSERRATE ISLAND: Localities A 3567, A 3569 are late terrace levels, with the fossils including only species that are still living.

Localities A 3566 and A 3568 contain the same fauna and are considered together. *Aequipecten revellei* n. sp. and *Patinopecten bakeri* subsp. *diazi* n. subsp. indicate a correlation with the Carmen formation.

SAN LORENZO ISLAND: Locality A 3594. *Aequipecten circularis* subsp. *bramkampi* n. subsp. is also found in the Imperial formation, and there are a few very poor fragments of an *Encope* that suggest *E. tenuis* Kew of the same formation. The best-preserved echinoid appears to be *E. scrippsae* n. sp. These fossils suggest a correlation with the San Marcos and Imperial formations.

SAN MARCOS ISLAND: Localities A 3573 and A 3574 are from terrace levels. All the fossils represent living species and are therefore referred to the Pleistocene.

Locality A 3571 is in steeply tilted well-consolidated beds that contain leached fossiliferous boulders of the San Marcos formation. The only fossil is *Aequipecten abietis* (Jordan and Hertlein). Because the beds are obviously younger than the San Marcos formation and yet are highly tilted and well consolidated they are correlated with the Carmen formation.

Localities A 3576, A 3577, A 3578, and A 3579 are from the first marine beds above the gypsum in the type San Marcos formation.

SAN TELMO POINT AREA: Locality A 3596. No fossils characteristic of the Pliocene were found. *Strombus granulatus* subsp. *acutus* appears to indicate a Pleistocene age.

Locality A 3595. The two species of mollusks found here, *Anadara* (*Cunearca*) *vanderhoofi* n. sp. and *Strombina* (?) *carlosensis* n. sp. are not known elsewhere. However, the occurrence of the marine mammal *Cornwallius*, described by VanderHoof (1942a), in a locality stratigraphically beneath but apparently within the same sequence of beds, indicates a correlation with the upper Oligocene Sooke formation of Vancouver Island, British Columbia.

SANTA ANTONITA POINT: California Academy of Science locality 795. *Chlamys dallasi* (Jordan and Hertlein), *Patinopecten bakeri* subsp. *diazi* n. subsp., and *Pecten* (*Pecten*) *bösei* Hanna and Hertlein indicate a correlation with the Carmen formation. This is an important locality, for the Academy collections contain several species that indicate a correlation with the San Diego Pliocene. Hanna and Hertlein's list (1927, p. 145) includes several species not recognized by the present author, who re-examined the collections and made the following changes in identifications:

Hanna and Hertlein (1927, p. 145) Present determinations
Pecten carrizoensis Arnold—No specimens or labels found
Pecten circularis Sowerby—No specimens or labels found
Pecten deserti Conrad—*Aequipecten antonitaensis* n. sp.
Pecten mendenhalli Arnold—*Aequipecten abietis* (Jordan and Hertlein)
Pecten stearnsii Dall—? immature *Patinopecten bakeri* subsp. *diazi* n. subsp.

In addition *Pecten* (*Pecten*) *bellus* var. *hemphilli* Dall and *Pecten* (*Euvola*) *refugioensis* Hertlein were also identified in this collection. Future investigators should examine this area with care.

Santa Inez Bay Area: Localities A 3582 and A 3584 are evidently of the same age and may be grouped together. Both contain *Encope grandis* subsp. *inezana* and are referred to the Pleistocene.

Localities A 3581 and A 3583 have the same fauna and therefore appear to belong to the same formation. Leland Stanford Jr. Univ. locality 805 is in part equal to locality A 3583; the remainder is Pleistocene. *Aequipecten deserti* (Conrad), *A. sverdrupi* n. sp., and *Pecten* (*Euvola*) *keepi* Arnold indicate a correlation with the San Marcos formation.

Locality A 3580 contains only *Clypeaster bowersi* Weaver, indicating correlation with either the San Marcos or Carmen formations. It is suggested that the strata are of San Marcos age.

Barracas Table: This locality was not visited on the 1940 trip, but members of the 1939 E. W. Scripps Expedition visited it and collected fossils which include *Encope shepherdi* n. sp., *Ostrea vespertina* Conrad, and *Aequipecten abietis* (Jordan and Hertlein). *Encope shepherdi* indicates a correlation with the Marquer formation. Beds of this age have not been identified elsewhere in this vicinity, but detailed investigations would probably show that they are widespread.

Santa Rosalia Area: Part of the fossil material noted by Touwaide (1930, p. 118, 120, 121, 122) was found in the collections at Stanford University and examined with the hope of establishing correlation with Pliocene sequence elsewhere within the Gulf of California. The following notes were made:

"Lower Salada"

(1) "Dolomitic limestone", resting on Gypsum. Numerous fossils, not identifiable.

(2) From "arenaceous tuffs" according to label. On top of basal dolomite. Apparently represented by fossils listed from the Lower Salada (Touwaide, 1930, p. 121). The following were identified:

Aequipecten abietis (Jordan and Hertlein)
Aequipecten sp.
Cardium sp.
Glycimeris sp.
Pecten (*Pecten*) *carrizoensis* Arnold
Cassis cf. *abreviatus* Lamarck
Conus sp.

In addition Touwaide listed "*Pecten* (*Pecten*) *keepi* Arnold" and "*Pecten* (*Plagioctenium*) *circularis aequisulcatus* Carpenter"; the last-named identification is probably based upon the specimens here identified as *Aequipecten abietis* (Jordan and Hertlein). The presence of *Pecten* (*Pecten*) *carrizoensis* Arnold and *Pecten* (*Euvola*) *keepi* Arnold indicates an age corresponding to that of the Imperial formation.

"Upper Salada"

(3) No fossils corresponding to the list given by Touwaide (1930, p. 22) from the "Upper Salada" were found. However, Grant and Gale (1931, Pl. 4, figs. 1a, 1b) figure as "*Pecten* (*Janira*) *stearnsii* Dall variety *bakeri* Hanna and Hertlein" a specimen Touwaide collected from Santa Rosalia. This apparently is the specimen listed as *Pecten* (*Patinopecten*) *bakeri* Hanna and Hertlein by Touwaide, for his identifications are credited to Grant (Touwaide, 1930, p. 113, footnote 2). From examination of Grant and Gale's figures this specimen appears to be *Patinopecten bakeri* subsp. *diazi* n. subsp. and would therefore indicate a middle Pliocene age for Touwaide's "Upper Salada."

Pleistocene.

(4) Two lots of fossils are marked "upper conglomerate formation" and "upper conglomerate". These appear to come from Touwaide's Pleistocene conglomerate (1930, p. 118, 122–123). Fossils present are:

Chama pellucida
Ostrea sp. (indet.)
Ostrea fischeri Dall (?)
Gyrineum strongi Jordan
Oliva spicata (Bolten)
Turritella cf. *gonostoma* Valenciennes

In addition, Touwaide (1930, p. 123) lists mammoth remains. These corroborate the presence of *Gyrineum strongi* Jordan which to date has been found only within the Pleistocene.

In summary: From the fossil collections examined it appears that Touwaide's "Lower Salada" is of the same age as the Imperial formation and corresponds to the similar lower Pliocene succession on San Marcos Island and that his "Upper Salada" is equivalent to the middle Pliocene. No fossils characteristic of the upper Pliocene were noted; his assignment of the "upper conglomerate" to the Pleistocene is corroborated by "mammoth remains" and *Gyrineum strongi* Jordan. The data available at the present time suggest that upper Pliocene, as the term is used in this paper, is not represented in this area unless it is by the "coquina" which Touwaide (1930, p. 118) shows underneath the "Conglomerate" in his Pleistocene and above the "Unconformity?" separating the "Upper Salada" and "Pleistocene."

TIBURÓN ISLAND: Localities A 3585, A 3586, and A 3587: All localities contain only representatives of living species. They are therefore referred to the Pleistocene.

REGIONAL CORRELATION

With the exception of locality A 3595 which appears to be in the San Gregorio formation, as defined by the Marland Oil Company (Anonymous, 1924, p. 420), all fossiliferous localities reported upon here are in strata which, wherever the basal contact was observed, were unconformable, often with marked discordance, upon the Comondú formation. This latter formation is widespread throughout Lower California, from the southern end of the peninsula to about 29° 30′ N. Lat. It rests unconformably upon various older rocks, including the Isidro formation (Heim, 1922, p. 539). Hertlein and Jordan (1927, p. 618) consider their faunas, which in large part at least came from the Isidro formation, equivalent in age to the lower Temblor formation of California and possibly in part to the upper Vaqueros formation; that is, lower middle, and upper lower Miocene in the terminology used in this paper. Later Loel and Corey (1932, p. 160) stated that they believed that most of Jordan and Hertlein's material was equivalent in age to the Vaqueros-Temblor transition zone, but, because certain forms occurred, that further stratigraphic studies and collecting would reveal both Vaqueros and Temblor equivalents there. The author is inclined to agree with this latter view. Allowing a reasonable interval for the accumulation of the Comondú formation, the minor preceding, and major following orogenic movements, it does not appear that the post-Comondú beds can be older than upper Miocene and probably not older than lower Pliocene.

Of the post-Comondú sequence, only the Carmen formation and its equivalents show any relationship with described north Pacific Coast Tertiary faunas outside the Gulf of California Province. The fauna of the Carmen formation and its equivalents appears most closely related to that of the San Diego Pliocene of Southern

California. A few species are common, and others may be called analogous species—that is, species which are closely related and have reached a similar stage of development but separated by minor differences. These species are:

Carmen formation and equivalents	San Diego formation and equivalents
Lovenia hemphilli Israelsky	*Lovenia hemphilli* Israelsky
Ostrea erici Hertlein	*Ostrea erici* Hertlein
Ostrea vespertina Conrad	*Ostrea vespertina* Conrad
Pecten (*Pecten*) *bellus* var. *hemphilli* Dall	*Pecten* (*Pecten*) *bellus* var. *hemphilli* Dall
Pecten (*Pecten*) *bösei* Hanna and Hertlein	*Pecten* (*Pecten*) *stearnsii* Dall

This list includes 5 of the 15 extinct species recorded here from the Carmen formation, or 33⅓ per cent. As noted elsewhere, of the living species studied, only 10 per cent of the gastropods and 30 per cent of the pelecypods are common to the two areas. Of the extinct species, *Lovenia hemphilli* Israelsky and *Pecten* (*Pecten*) *bellus* var. *hemphilli* Dall are the most important. *Lovenia hemphilli* is not listed from beds other than the San Diego Pliocene or its equivalents by Grant and Hertlein (1938, p. 137). *Pecten* (*Pecten*) *bellus* var. *hemphilli* Dall also appears restricted to the San Diego Pliocene and its approximate equivalents. It is abundant in the Pliocene of Cedros Island, which was correlated with the San Diego Pliocene by Jordan and Hertlein (1926a, p. 420–424). *Pecten* (*Pecten*) *stearnsii* Dall, the apparent analogue of *Pecten* (*Pecten*) *bösei* Hanna and Hertlein, is largely confined to the San Diego Pliocene and its approximate equivalents (Grant and Gale, 1931, p. 223). *Pecten* (*Pecten*) *bösei* Hanna and Hertlein differs from *Pecten* (*Pecten*) *stearnsii* Dall in having much lower ribs on both valves. The number of ribs and relative width is the same in both species.

The preceding evidence for correlating the Carmen formation with the San Diego Pliocene is admittedly meager but is the best now available. No other formation in coastal or northern California shows any relationship to the Gulf of California faunas. The percentage of identical species in the two formations, 27 per cent, is approximately the same as that of the living pelecypods studied in this paper. Because of the paucity of the recorded fauna of the Carmen formation, the use of the percentage method is obviously subject to numerous errors. The San Diego Pliocene was considered by Woodring, Stewart, and Richards (1940, p. 112–113, and correlation chart) to range from lower to upper Pliocene in age, but the strata at Pacific Beach were restricted to the upper Pliocene. It is to be noted however that these authors use the terms in a relative sense only (p. 104). The author's correlations are made with the strata at Pacific Beach. However, Grant and Gale (1931, p. 61, 69, 70) consider that these same strata correlate with the European middle Pliocene. Jordan and Hertlein (1926a, p. 423) also consider the San Diego strata at Pacific Beach as approximately middle or lower upper Pliocene. Weaver *et al.* (1944) place it as middle Pliocene. The author also considers the San Diego formation (referring only to the strata at Pacific Beach) as of middle Pliocene age. This is in part at least merely a matter of convenience, allowing easy reference to the three related formations in the Gulf of California.

Jordan and Hertlein (1926a, p. 422–423) correlated the Pliocene of Cedros Island with the San Diego Pliocene. Its faunal affinities are largely with the northern faunas and not with the Gulf of California faunas. This agrees with the fact that the Recent molluscan fauna of the Cedros Island area is part of the Californian Province and not the Panamic (Schenck and Keen, 1936, p. 931), whereas the Gulf of California fauna is Panamic in character. The Cedros Island Pliocene has the same species common to the Carmen formation and its equivalents as with the San Diego Pliocene.

The Pliocene of Maria Madre Island was described by Jordan and Hertlein (1926b). An examination of their material indicates some changes in their identifications as follows:

Pecten (*Pecten*) *stearnsii* Dall, probably an immature *Patinopecten bakeri* subsp. *diazi.* n. subsp. In any case it is not *stearnsii.*

Pecten (*Patinopecten*) near *caurinus* Gould = a right valve of either *Patinopecten bakeri* subsp. *diazi.* n. subsp. or *P. marquerensis* n. sp.

Pecten (*Plagioctenium*) *circularis* Sowerby = *Aequipecten abietis* (Jordan and Hertlein).

Pecten (*Plagioctenium*) *invalidus* Hanna = young or small specimens of *Aequipecten abietis* (Jordan and Hertlein).

After these changes in identifications have been made in the listed fauna, it is apparent that it is to be correlated with the Carmen formation on the basis of the occurrence of *Chlamys dallasi* (Jordan and Hertlein). The *Solenastrea* sp. appears to be *S. fairbanksi* Vaughan or a close relative. This is the first time any Imperial formation coral have been noted outside the type area of that formation. Unfortunately this specimen was found loose in an arroyo, and it is not certain that it was derived from the same beds as the rest of the fossils.

As shown under local correlation the Imperial formation may be correlated with the San Marcos formation and its equivalents. The San Marcos formation in itself, with the available information, affords little basis for correlation with other areas outside the Gulf of California. However, the Imperial formation, because of its unique fauna when compared to other California faunas, has been the subject of considerable conjecture and investigation. A review of the earlier age assignments is given by Hanna (1926, p. 433–434). Of the more detailed reports, Vaughan (1917, p. 369) concluded that "The fauna of Carrizo Creek is related to Pliocene and post Pliocene faunas of Florida and the West Indies and can scarcely be older than lower Pliocene"; Hanna (1926, p. 434) believed that it could not be older than lower Pliocene and that most of the formation might be middle and upper Pliocene; Woodring (1931, p. 25) concluded that the Imperial formation was of late lower Miocene age, corresponding to the upper Vaqueros formation; Bramkamp (1934, p. 385) believed the Imperial formation to be of middle Miocene age, corresponding to the Temblor formation of California. Woodring (1942, p. 79–81) accepts Bramkamp's conclusion; Grant and Gale (1931, p. 50) considered the Imperial formation to be of lower Pliocene age. Tarbet and Holman (1944) refer it to the upper Miocene.

As shown in the first part of this chapter on regional correlation the Imperial formation cannot be of lower or middle Miocene age on the basis of the regional geology in Lower California, if the Imperial formation is correctly correlated with the San Marcos formation.

However, conceding that the correlation of the Imperial formation and San Marcos formation may be doubtful, the evidence of Woodring and Bramkamp, the chief proponents of the lower or middle Miocene age for the formation, is subject to the following comments:

(1) Woodring compared the volcanics underneath the Imperial formation with the volcanics underneath the Vaqueros formation at the south end of the San Joaquin Valley. However, according to Tarbet (1942) the Imperial formation is unconformable on these volcanics, whereas the Vaqueros formation apparently conformably overlies or is interbedded with the basalts. Further, there are similar outbreaks of vulcanism, including basalts, as late as upper Miocene in Southern California (Reed, 1933, p. 203–205). Therefore the evidence from volcanism is not conclusive as to correlation.

(2) Woodring suggested that the diastrophic evidence favored contemporaneity of the Imperial transgression with that of the Vaqueros. However, it could equally well correspond to the Pliocene transgressions in coastal Southern California and in the San Joaquin Valley.

(3) Woodring noted the absence of any allied species in the fauna of the Imperial formation and the Pliocene of Coastal Southern California. As noted elsewhere the living fauna of the Gulf of California has very few species in common with that of coastal Southern California. In fact Bartsch (1921, p. 526) lists only two species common to his Californic and Mazatlanic (including the Gulf of California) subprovinces, out of totals of 173 and 101 species, respectively, in the Pyramidellid gastropods. Considering the poor molluscan faunas known from the coastal lower Pliocene, the apparent disparity of the faunas of the two areas is to be expected.

(4) Woodring compares *Turritella imperialis* Hanna to certain "frilled" forms of *T. inezana* Conrad. However, *T. imperialis* is also related to *T. exoleta* Linnaeus, now living in the Gulf of Mexico area, and to *T. mariana* Dall living off the west coast of Mexico and Lower California (Merriam, 1941, p. 46–47). *Turritella mariana* Dall is here figured (Pl. 28, fig. 16) for comparison with *T. imperialis* (Pl. 28, figs. 5, 11). Merriam (1941, p. 46, 112, Pl. 27) indicates the extremely close relationship of *T. imperialis* to *T. altilira* cf. var. "*tornata* Guppy" from the middle to upper Miocene of Colombia, Venezuela, and Trinidad. It is well to note, however, that only certain variants of each "form" resemble one another, and that there are other variants in each complex that are not so similar. The "*altilira*" group occurs in strata at least as old as upper Eocene in Colombia (Clark and Durham, 1946, p. 25) and is living today, while several species such as *T. altilira* and *T. inezana* have a large complex of variation. Therefore the author doubts that the similarity of *T. imperialis* and "*tornata* Guppy" indicates an equivalent age for the containing beds.

(5) Woodring stressed the Caribbean affinities of *Cassis subtuberosa* Hanna; no other species of the genus is known in either recent or fossil faunas of the Pacific Coast. However, there is also a living species in the East Indies that is identified by some authors as *Cassis tuberosa*, indicating that this group of species has been widespread in the past. Further, it must be admitted that the Miocene and Pliocene faunas of the west coast of Mexico and Central America are very poorly known as yet, and it is in that area where the genus would be expected to appear for it is a tropical and not a temperate genus.

(6) Woodring strongly emphasized the Caribbean Miocene affinities of the Imperial fauna, noting that species of several genera—*Malea*, *Solenosteira*, group of *Cancellaria obesa* Sowerby, group of *Conus fergusoni* Sowerby, group of *Ficus decus-*

sata (Wood)—have analogous species in the Caribbean Miocene. It should also be remembered that each group is also now living on the Pacific Coast and most of them in the Gulf of California. Further, the group of *Ficus decussata* (Wood) is represented on the Pacific Coast at least as early as the lower Oligocene (*Ficus gesteri* Wagner and Schilling), while *Solenosteira* appears in the Vaqueros formation (*Solenosteira venturana* Loel and Corey).

(7) Woodring suggests that it is unlikely that various stocks of Caribbean affinities would have survived from the middle Miocene, when the Central American seaway was closed, into the Pliocene. Possibly modern concepts of systematic differences may alter some of Carpenter's (1857, p. 362–365) conclusions, but he lists 35 living species of mollusks as identical in the Atlantic and Pacific oceans, 34 which may be identical, 41 separated by slight differences, and 26 analogous but distinct species, in all a total of 136 species. Smith (1944, p. XI–XIII) lists 42 identical species and 42 species with analogues in the Pacific and Caribbean faunas. Thus if these species are so closely related as to be considered identical or analogous, they must have had common ancestor when the two areas were connected by a seaway and they must have lived in each area since that time. Therefore Woodring's argument that the stocks would not have survived does not appear tenable.

(8) Woodring cites Vaughan to the effect that the Imperial formation corals have distinct Caribbean generic and specific affinities. With regard to generic affinities—although they are not now living on the Pacific Coast—*Siderastrea* is present in the Eocene of California and the Oligocene of Washington, *Eusmilia* occurs in the upper Oligocene Blakeley formation of Washington, and Vaughan (1919, p. 230) reports *Meandra* from the Oligocene of Panama. As for the specific affinities, Vaughan believed that they were closest to the West Indian Pliocene and Recent species.

(9) Woodring notes that Jackson (1917) pointed out the similarity of certain Gatun echinoids to Imperial echinoids. However, Jackson himself noted that they were not very closely related.

(10) Bramkamp (1935), in his unpublished thesis which formed the basis of his 1934 abstract, lists 22 species which he identified as identical with species of the Caribbean or Panamic Miocene. The author re-examined Bramkamp's material, available in the University of California collections. Comparisons were made with Panamic and Caribbean material in many cases and with figures and descriptions in others. Most of Bramkamp's specimens seem more closely related to other living or fossil species (mostly Pacific Coast) than to the Panamic and Caribbean forms with which he identified them. Other identifications seem open to doubt. The author believes that Bramkamp would not have made the same identifications and tentative correlation had the present material and data been available for his consideration.

Thus for all Woodring's evidence for the lower Miocene age of the Imperial formation there is an alternative explanation which is compatible with a later age, while Bramkamp's determination of the age as middle Miocene, insofar as it was based on the occurrence of species characteristic of the tropical middle Miocene, is not supported by a re-examination of his material. Bramkamp also notes several genera which are living today only in the Caribbean area. It may be noted though that it is not the later distribution, but its previous distribution, that is the most critical in evaluating the significance of a species or genus. Neither Bramkamp nor Woodring has advanced any positive evidence supporting the theory that the correlation of the Imperial and San Marcos formations is at fault.

It is believed that the San Marcos and Imperial formations are best assigned to the lower Pliocene, in terms of the commonly accepted California marine section, for the following reasons:

(1) The San Marcos and Imperial formations appear to be equivalent.

(2) The San Marcos formation is unconformable, wherever the contact was seen, upon the Comondú formation, which in turn is unconformable upon the Isidro formation which includes sediments at least as young as the Vaqueros-Temblor transition beds in California of lower to middle Miocene age. Making allowances for the minor preceding and major post-Comondú orogeny and the accumulation of the Comondú formation, it does not appear that the San Marcos formation can be older than upper Miocene and probably not older than lower Pliocene.

(3) The Imperial formation represents the basal late Tertiary marine incursion in an area where the sea has recurrently transgressed until at least Pleistocene time, with the transgressions appearing to be merely the shoreward oscillations of a continuous seaway, the ancestral Gulf of California.

(4) The San Marcos together with the subsequent Carmen and Marquer formations and the marine Pleistocene form a related sequence similar to that of the Colorado Desert area, more purely marine in character, but also broken by minor unconformities and gaps.

(5) The San Marcos formation fauna is related to that of the Carmen formation which in turn may be correlated with the San Diego formation (middle Pliocene). Three and possibly 4 of the 15 extinct species of the Carmen formation are also found in the San Marcos formation, indicating a close relationship of the two faunas. Further, at least two other species have closely related forms in the San Marcos formation.

(6) Although the percentage method of age determination is subject to numerous errors in the San Marcos formation because of the mode of collecting, the percentage of living species (47 per cent) is not incompatible with a lower Pliocene age. Similarly a summary of Hanna's (1926) list indicates about 60 per cent of living species for the Imperial formation, although Bramkamp (1934) gives a much lower figure (about 25 per cent).

(7) Vaughan (1917, p. 369) states that the Imperial formation corals are related to the Pliocene and post-Pliocene faunas of Florida and the West Indies.

Mansfield (1932) listed several species from the Pliocene of Florida as similar to species in the Imperial formation. Woodring (1938, p. 46–47) noted that all the species listed by Mansfield except one compare equally well with West Indian and Central American Miocene species. However, this one exception, *Pecten* (*Lyropecten*) *tamiamensis* Mansfield, is also allied to an apparently unnamed species in the University of California collections from the probable Pliocene (or upper Miocene?) of Venezuela (loc. S-254, cliff at Las Piedras on western side of Paraguana Peninsula, about 350 meters S. 10° E. of village of Carirubana, from a large oyster bed underlying the limestone cap forming the top of the tableland). The anterior ear of the

Venezuelan species is somewhat longer than that of the Florida species, and there are only about 20 major ribs instead of 23, but they are obviously of the same stock. The relationship between the Florida Pliocene and the Imperial formation appears to be one of similar facies and possibly of common ancestry for certain species.

Pilsbry and Olsson (1941) described an interesting Pliocene fauna from western Ecuador. The fauna is more truly tropical than that of the Gulf of California, containing an abundance of Terebras, Cancellarias, Nassids, Arcids, Chiones, and Tellinids. Nevertheless some 19 species are also found in the late Pliocene, Pleistocene, and Recent faunas of the Gulf of California, and an additional 12 species are also found only in the living fauna. The faunas of the Canoa and Jama formations cannot be correlated exactly with those of the Gulf of California, but they appear to have the aspect of the upper Pliocene.

Pilsbry and Olsson also mention the Pliocene of Puna Island about 35 miles south of Guayaquil. There are small lots of fossils from this island in the University collections (locs. S-94 to S-99); these contain, among other fossils, numerous specimens of *Aequipecten abietis* (Jordan and Hertlein). It appears probable therefore that these beds are older than uppermost upper Pliocene. Without other evidence it is suggested that the Puna Island Pliocene may be of about middle Pliocene age.

Olsson (1942) described the molluscan fauna of the Charco Azul formation of western Panama, while Coryell and Mossman (1942) described the foraminiferal fauna. Both Coryell and Mossman, and Olsson consider that the fossils found indicate deposition in waters around 400 fathoms deep. Because of the difference in facies there are but few species common to the Gulf of California faunas and those described by Olsson. The described molluscan fauna comes from various parts of the formation. On the basis of the deep-water character of the fauna the author believes that it corresponds with the lower and middle Pliocene of the Gulf of California, and possibly may include the upper Pliocene also.

The only pre-Pliocene fossiliferous strata examined were those of the San Gregorio formation north of San Telmo Point. VanderHoof (1942a, p. 299) has indicated that, from the occurrence of the sirenian *Cornwallius*, the containing strata may be correlated with the Sooke formation of southern Vancouver Island. Darton (1921, p. 733, 736, 737; Fig. 2, section 15; Fig. 17) indicated that the San Gregorio ("Monterey") is overlain unconformably in many places by the Isidro formation ("Yellow beds"). As noted previously the Isidro formation is, in part at least, equivalent in age to the Vaqueros-Temblor transition zone of California and possibly includes equivalents of both Vaqueros and Temblor. Consequently the San Gregorio formation is at least older than Vaqueros-Temblor transition time. Hisazumi (1930, p. 57, Lamina 1 [II], 2 [II]) indicated a similar relationship for the "Monterey" and Isidro formations. Darton regarded his "Monterey" as of the age of the Vaqueros formation on the basis of 13 species, of which only one was specifically determined.

VanderHoof (1942b, p. 41) implied that the Vaqueros formation may be of the same age as the Sooke and San Gregorio formations. It has also been suggested that, on the basis of the occurrence of the Silicoflagellate *Rocella gemma* Hanna in the San Gregorio formation (Hanna, 1930) and in the "Santos Shale" of Carneros Creek, Kern County, California (identified by K. Lowman, U. S. Geological Survey, per-

TABLE 10 —*General correlation chart of Pacific Coast marine Cenozoic strata from Southern California to Ecuador*

EPOCH		COLORADO DESERT AREA	GULF OF CALIFORNIA	PENINSULA OF LOWER CALIFORNIA	CEDROS ISLAND TURTLE BAY	COASTAL SOUTHERN CALIFORNIA	MARIA MADRE ISLAND	PANAMA	ECUADOR
PLEISTOCENE		Lake Coahuila deposits Terrace deposits	Marine beds and terraces	Magdalena Bay Pleistocene, marine terraces		Upper San Pedro Lower San Pedro	Marine Pleistocene	Armuelles formation	"Punta Canoa Pleistocene"
PLIOCENE	Upper	Borrego formation	Marquer formation	"Salada formation"		"Santa Barbara zone"			?Canoa formation ?Jama formation
	Middle	Palm Spring formation	Carmen formation		"Pliocene"	San Diego formation	"Pliocene" ? ↓	Charco Azul formation	?Pliocene at Puna Island
	Lower	Imperial formation	San Marcos formation			"Chione elsmerensis zone"		Burica sandstone	
MIOCENE	Upper	Alverson Canyon formation	Comondú formation	Comondú formation	"Miocene"	Modelo formation	Miocene Diatomite	Limones shale	Bajada formation
	Middle	Split Mountain formation	Isidro formation	Isidro formation		Topanga formation		Gatun formation	
	Lower					Vaqueros formation		Caimito formation	
OLIGOCENE	Upper		San Gregorio formation	San Gregorio formation		Sespe formation (nonmarine)		Emperador limestone	Manta shale
	Middle							Culebra formation	Ancon Point sandstone
	Lower								Seca shale
EOCENE	Upper			Tepetate formation				Tranquilla shale Bucaru formation	Socorro form. Clay Pebble beds
	Middle					Llajas formation			Middle Grits Guayaquil limestone
	Lower			Sepultura formation		Santa Susana form. "Martinez form."			
		"Basement Complex"		Cretaceous	Cretaceous	Cretaceous		Cretaceous	Cretaceous

sonal communication, G. D. Hanna, Jan. 6, 1947), these two formations are to be correlated. The "Santos Shale" is considered to be older than the Vaqueros-Temblor transition zone (Kleinpell, 1938, Fig. 14; 1944, Chart), but younger than the Pleito formation of the south end of the San Joaquin Valley (Beck *et al.*, 1944), and the San Ramon formation of the Mount Diablo-Martinez area (Clark, 1944, Chart; Schenck *et al.*, 1944, Chart), and is thus, in part at least, equivalent to the Vaqueros formation (restricted). The San Ramon formation, and thus indirectly the Pleito formation (for they have the same molluscan fauna), has been correlated by the author (Durham, 1944b, p. 113–114) with the Sooke formation of Vancouver Island and the upper Twin Rivers formation of Washington. Inasmuch as the Pleito formation is overlain unconformably by the Vaqueros formation (Wagner and Schilling, 1923, p. 249, 250, Pls. 43–44; Loel and Corey, 1932, p. 97–98), some one of the preceding correlations must be in error.

VanderHoof's (1942a) correlation of the Sooke formation with the lower California sirenian-bearing beds is probably the most accurate, being based on mammalian evidence. To the author, the correlation of the Sooke and San Ramon-Pleito formations is more reliable than the correlation of the San Gregorio and "Santos Shale", being based upon groups of Mollusca which have been more thoroughly studied than the Silicoflagellates. These discrepant correlations between Lower California and the southern end of the San Joaquin valley may be due to any one of several different factors. Some of these factors are:

1. The time span of individual species of Silicoflagellates may be greater than commonly considered.
2. The time span of the San Gregorio formation may be greater than that assigned to it by the author (Durham, 1944a), with the *Cornwallius*-bearing beds occurring near the base of the formation and the Silicoflagellate-bearing beds near the top of the formation.
3. The *Cornwallius*-bearing beds of Lower California may be incorrectly referred to the San Gregorio formation and may represent an older epoch.

If the Sooke formation and the Pleito formation are correctly correlated, then the San Gregorio formation (or at least the sirenian bearing beds) must be correlated with the Pleito formation and not the "Santos Shale", unless the San Gregorio formation has a longer time span than the Pleito formation.

Whatever the interpretation or value given to the proposed San Gregorio-"Santos Shale" correlation, it does not affect the correlation of the overlying Isidro formation in Lower California with the Vaqueros-Temblor transition zone, for the "Santos Shale" is also older than that zone.

Using papers of Clark (1941), Grant and Gale (1931), Santillan and Barrera (1930), Senn (1940), and the previously discussed data, a general correlation chart (Table 10) of the Pacific Coast marine Cenozoic strata from Southern California to Ecuador has been compiled. Following Senn, the Aquitanian is included in the Oligocene. Separate columns are used for the Gulf of California area and Lower California, not because they are different provinces but because the faunas from the Gulf of California have been personally examined and the faunas from the Peninsula have not.

SYSTEMATIC CATALOGUE AND DESCRIPTIONS

In the following catalogue certain conventions have been observed. The "Range" is the geologic range observed in the Gulf of California; reported occurrences elsewhere are not included unless the specimens have been examined by the author. The "Occurrence" includes the records of the occurrences at the various fossil localities included in the present report. Unless otherwise stated all types are deposited in the Museum of Paleontology at the University of California. Specimens characteristic of the author's concept of each species have been selected and deposited in the Museum of Paleontology for the convenience of later workers.

University of California Museum of Paleontology localities are given as "loc. no. A 3519 or loc. no. 9217"; all localities of other Institutions are preceded by the Institution's official designation as "C. A. S. loc. 982" for California Academy of Science localities, and "L. S. J. U. loc. 805" for Stanford University localities.

Phylum COELENTERATA
Class ANTHOZOA
Order SCLERACTINIAE
Family SERIATOPORIDAE

Genus **Pocillopora** Lamarck

Pocillopora LAMARCK (1816), Hist. Nat. Anim. sans Vert., vol. 2, p. 273; VAUGHAN (1918), Carnegie Inst. Washington, Publ. Dept. Mar. Biol., vol. 9, p. 75.

Genotype: *Pocillopora acuta* Lamarck

Pocillopora robusta Verrill

(Plate 36, figure 6)

Pocillipora capitata, var. *robusta* VERRILL (1870), Trans. Conn. Acad. Arts Sci., vol. 1, p. 521–522; PALMER (1928), Proc. Am. Philos. Soc., vol. 67, p. 21, pl. II, fig. 1.
Pocillipora capitata, var. *pumila* VERRILL (1870), Trans. Conn. Acad. Arts Sci., vol. 1, p. 522–523.
Pocillopora palmata PALMER (1928), Proc. Am. Philos. Soc., vol. 67, p. 31, pl. 2, figs. 2–3, pl. 3, fig. 1.
Pocillopora robusta Verrill, DURHAM (1947), Geol. Soc. Am., Mem. 20, p. 17–18, pl. 7, figs. 1, 2, pl. 8, fig. 6.

Hypotype no. 15491 (loc. A 3596, Pleistocene).

OCCURRENCE: loc. A 3508, Carmen Island (Pleistocene); locs. A 3567, A 3569, Monserrate Island (Pleistocene); loc. A 3596, San Telmo Point (Pleistocene); Recent, La Paz, Lower California.

RANGE: Pleistocene, Carmen Island to Coast of Oaxaca, Mexico; Recent, La Paz to Oaxaca, Mexico.

Family THAMNASTERIIDAE

Genus **Psammocora** Dana

Psammocora DANA (1846), U. S. Expl. Exped., Zooph., p. 344.

Genotype: *Pavona obtusangula* Lamarck

Subgenus **Stephanaria** Verrill

Stephanocora VERRILL (1866), Proc. Boston Soc. Nat. Hist., vol. 10, p. 330, *not* Ehrenberg, 1834.
Stephanaria VERRILL (1867), Trans. Conn. Acad. Arts Sci., vol. 1, p. 340; Vaughan (1907), U. S. Nat. Mus., Bull. 59, p. 142.

Subgenotype: *Stephanocora stellata* Verrill (monotypic)

Psammocora (Stephanaria) stellata (Verrill)

(Plate 36, figure 5)

Stephanocora stellata VERRILL (1866), Proc. Boston Soc. Nat. Hist., vol. 10, p. 330.
Stephanaria stellata VERRILL (1870), Trans. Conn. Acad. Arts Sci., vol. 1, p. 545, pl. 9, figs. 4, 4a; VAUGHAN (1907), U. S. Nat. Mus. , Bull. 59, p. 142–143, pl. 43, figs. 2, 2a, 2b, 3, 3a.
Psammocora (Stephanaria) stellata (Verrill), DURHAM (1947), Geol. Soc. Am., Mem. 20, p. 19, pl. 8, figs. 1, 2, pl. 13, fig. 1.

Hypotypes nos. 15493, 15494, 15496 (all from A 3547).

OCCURRENCE: loc. A 3547 (Pleistocene); Recent, from La Paz to the Pearl Islands, Hawaiian Islands (Vaughan).

REMARKS: None of the specimens from the Peabody Mus. Nat. Hist. are as large as the dimensions given in the original description (3 inches); the largest specimen examined has a greater diameter of 52 mm, a lesser diameter of 39 mm, and an approximate height of 35 mm. The largest fossil specimen (hypotype no. 15494) has a greater diameter of 86 mm. Both Vaughan and Verrill note the absence of walls between the calices; however, examination of the fossil specimens and of the interior structure of recent individuals reveals an irregular, sometimes interrupted wall beginning slightly below the surface. Occasionally on part of weathered fossil specimens this wall is prominently displayed at the surface, forming a crest between adjacent calices. In a few calices of the fossil specimens there is a ring of synapticula. In most of the fossils the denticles of the septal margins have been eroded away, but an occasional better-preserved calice shows denticles corresponding to those of Recent specimens. There may be 10 or more denticles to a well-developed septum.

Family PORITIDAE

Genus ***Porites*** Link

Porites LINK (1807), Beschr. Natur. Samml. Univ. Rostock, p. 162.

Genotype: *Madrepora porites* Pallas

Porites californica Verrill

(Plate 36, figure 7)

?*Porites* sp. GREWINGK (1848), Verh. Russisch-Kaiserl. Miner., Gessellsch. St. Petersburg, 1847, p. 146.
Porites californica VERRILL (1870), Trans. Conn. Acad. Arts Sci., vol. 1, p. 504; BERNARD (1905), Brit. Mus. (Nat. Hist.), Cat. Madreporarian Corals, vol. 5, part 1, p. 106–107; DURHAM (1947), Geol. Soc. Am., Mem. 20, p. 20–22, pl. 13, figs. 3, 5, 6; pl. 14, figs. 1–5.
Porites porosa VERRILL (1870), Trans. Conn. Acad. Arts Sci., vol. 1, p. 504; BERNARD (1905), Brit. Mus. (Nat. Hist.), Cat. Madreporarian Corals, vol. 5, part 1, p. 107.

Hypotypes nos. 14869 and 14870 (loc. A 3519).

OCCURRENCE: C.A.S. loc. 982 (Magdalena Bay, Pleistocene); Univ. Calif. Mus. Paleo. locs. A 3508, A 3515, A 3519, A 3520, A 3521, A 3522, A 3525, A 3534, A 3547, A 3548, A 3549, A 3573, A 3574, A 3585, A 3596, A 3597, A 3670.

RANGE: upper Pliocene to Recent.

REMARKS: At loc. A 3508 in a Pleistocene terrace level on Carmen Island there is a zone of coral material 12–18 inches thick at the base of the terrace, composed of *Porites* and *Pocillopora*. *Porites* was dominant in the material by a ratio of at least 10:1. However, in the top of the zone *Pocillopora* became more abundant. The largest *Porites* head observed was 12 inches in diameter.

On Coronado Island in the early Pleistocene (loc. A 3548) this species formed large columnar heads up to 2 feet in diameter and 4 feet tall, with the coral reef pinching and swelling laterally (over a distance of about 200 yards). The corals were more luxuriant in the reef than those growing off the island at the present time. The only other coral found associated with them was an occasional *Astrangia*.

In the Pleistocene terraces on San Marcos Island (A 3573) heads of *Porites* were noted up to 15 inches in height. The Pleistocene terrace on Tiburón Island (loc. A 3585) also carried heads of *Porites* up to 12 inches in diameter. Recent *Porites* heads were scarce along the shores of Tiburón Island.

At Marquer Bay, Carmen Island (loc. A 3519), a coral reef composed of this species is found in the upper Pliocene. It is up to 10 feet thick and can be traced for 150 yards in one direction and 100 yards laterally approximately at right angles to the first direction, with the strata in the other directions removed by erosion. The reef was about 10 feet thick at the thickest part and thinned out laterally to a feather edge. At the base it was rather loose and incoherent; at the top it was moderately well cemented by calcareous algae. The molluscan fauna recorded from loc . A 3519 was collected from the lower part of the reef. Coral fragments were found at this same horizon throughout the area, and a smaller reef about 5 feet thick appeared again in the same position at the north end of the bay. The reef rests on an irregular surface with occasional large boulders. The underlying bed is a marly sand with abundant calcareous algae.

What is apparently the same horizon at Puerto Balandra, Carmen Island (loc. A 3534), also has a well-developed reef. It was deposited on an extremely irregular surface of at least 25 feet relief with considerable conglomerate derived from the underlying volcanics at the base. The reef is up to 20 feet thick, topped by a Pleistocene terrace and composed of vertically elongated heads of this species. There are occasional lenses of molluscan fossils, and calcareous algae become rather abundant at the top.

Porites nodulosa Verrill

(Plate 36, figure 4)

Porites nodulosa VERRILL (1870), Trans. Conn. Acad. Arts Sci., vol. 1, p. 505–506; BERNARD (1905), Brit. Mus. (Nat. Hist), Cat. Madreporarian Corals, vol. 5, part 1, p. 107; DURHAM (1947), Geol. Soc. Am., Mem. 20, p. 22–23, pl. 12, figs. 1–3, pl. 13, fig. 4.

Hypotypes nos. 14880, 14881, 14883, 14884, 14885, 14887 (all from loc. A 3550).

OCCURRENCE: locs. A 3547, A 3548, A 3550, A 3582, A 3584. Numerous badly worn specimens from loc. A 3514 may be either this species or *P. californica;* U. S. Nat. Mus. specimen from Margarita Island (no. 547377) (Pleistocene).

RANGE: Pleistocene to Recent, reported only from the Gulf of California area and the Pleistocene of Magdalena Bay.

Family ASTRANGIIDAE

Genus ***Astrangia*** Milne Edwards and Haime

Astrangia MILNE EDWARDS AND HAIME (1848), Comptes-Rendu Acad. Sci. Paris, vol. 27, p. 496.

Genotype: *Astrangia michelinii* Milne Edwards and Haime

Subgenus ***Astrangia s.s.***

Astrangia (Astrangia) concepcionensis Durham

(Plate 36, figure 8)

Astrangia (Astrangia) concepcionensis DURHAM (1947), Geol. Soc. Am., Mem. 20, p. 26–27, pl. 4, fig. 5.

Holotype no. 14827 (loc. A 3651), paratype no. 14825 (loc. A 3582).

OCCURRENCE: loc. A 3582.

RANGE: Pleistocene, Recent.

Astrangia (Astrangia) coronadosensis Durham

(Plate 36, figure 1)

Astrangia (Astrangia) coronadosensis DURHAM (1947), Geol. Soc. Am., Mem. 20, p. 27, pl. 4, figs. 3, 4.

Holotype no. 14828 (loc. A 3548).

OCCURRENCE: loc. A 3548.

RANGE: Pleistocene.

Astrangia (Astrangia) santelmoensis Durham

(Plate 36, figures 2, 3)

Astrangia (*Astrangia*) *santelmoensis* DURHAM (1947), Geol. Soc. Am., Mem. 20, p. 30, pl. 5, figs. 1, 2.

Holotype no. 14829 (loc. A 3596).
OCCURRENCE: loc. A 3596.
RANGE: Pleistocene.

Phylum ECHINODERMATA
Class ECHINOIDEA Bronn
Order CIDAROIDA Duncan
Family CIDARIIDAE Müller

Genus ***Eucidaris*** Pomel

Eucidaris POMEL (1883, Class. Meth. et Gen. Echin. Viv. Foss., p. 109.

Genotype: *Cidaris metularia* Lamarck (subs. desig. Clark, 1909)

Eucidaris thouarsii (Valenciennes)

(Plate 37, figure 2)

Cidaris thouarsii VALENCIENNES in AGASSIZ AND DESOR (1846), Ann. Sci. Nat. (Zool.), ser. 3, vol. 6, p. 326.
Eucidaris thouarsii Valenciennes, GRANT AND HERTLEIN (1938), Univ. Calif., Publ. Math. Phys. Sci., vol. 2, p. 7–8, pl. 2, figs. 1, 2.

Hypotype no. 15406 loc. A 3519.
OCCURRENCE: loc. A 3519, A 3534, A 3548.
RANGE: upper Pliocene, Pleistocene, Recent.
REMARKS: Only fragmentary tests have been noted.

Order EXOCYCLOIDA Jackson

Family CLYPEASTRIDAE Agassiz

Genus ***Clypeaster*** Lamarck

Clypeaster LAMARCK (1801), Syst. Anim. sans Vert., vol. 1, p. 349.

Genotype: *Echinus rosaceous* Linnaeus (subs. desig., Clark 1911).

Clypeaster speciosus Verrill

(Plate 45, figures 1, 3, 4, 6, 7)

Clypeaster speciosus VERRILL (1870), Am. Jour. Sci., 2d ser., vol. 49, p. 95.

Hypotypes nos. 15405 (Recent); 15404 (loc. A 3584); Stanford Univ. Paleo. Type Coll. no. 7372 (L.S.J.U. loc. 805).

OCCURRENCE: locs. A 3547, A 3561, ?A 3566, A 3584, Recent; L.S.J.U. loc 805 (Pleistocene).

RANGE: middle Pliocene (?) to Recent.

REMARKS: Some of the specimens from the Santa Inez Bay area Pleistocene (locs. A 3584, L.S.J.U. 805) are considerably higher, and the margins of the test are much thicker than the Recent specimens. (*See* Pl. 45, figs. 1, 4.) Possibly abundant material would indicate that they should be described as a new subspecies.

Clypeaster bowersi Weaver

(Plate 42, figure 9; Plate 46, figures 1, 2)

Clypeaster bowersi WEAVER (1908), Univ. Calif. Publ., Bull. Dept. Geol., vol. 5, p. 271–272, pl. 21, fig. 1; pl. 22, fig. 1; GRANT AND HERTLEIN (1938), Univ. Calif. Los Angeles, Publ. Math. Phys. Sci., vol. 2, p. 43–45.

Hypotypes nos. 15394, 15411, 15412 (loc. A 3580), and Calif. Acad. Sci., Paleo. Type Coll. no. 7854, C.A.S. loc. 795.

OCCURRENCE: loc. A 3580, C.A.S. loc. 795.

RANGE: lower and middle Pliocene.

REMARKS. At first the author was inclined to separate the sepecimens here noted as a new species, differentiating them from typical *C. bowersi* by their more evenly convex abactinal profile, whereas in the type of *bowersi* the abactinal surface is only slightly convex and has sharply rounded sides. However, examination of considerable material from the Imperial formation shows that there are variants similar to the Gulf of California material at some localities, and that at each locality only one variant is present. As far as the poor stratigraphic data at hand indicates, all are from the base of the Imperial formation. Future workers should collect in that area with care to determine whether the base of the formation represents the same time plane at all places. It is possible that the different variants of *C. bowersi* represent different stratigraphic horizons.

Clypeaster marquerensis n. sp.

(Plate 43, figures 2, 3)

Test fairly large, of medium height; outline pentagonal, indented in each interambulacral area; margin about 5 mm thick, rounded; petals large, almost completely closed, extending about two thirds of the distance to the margin; 12–13 tubercles between pore pairs of right anterior ambulacrum; anterior petal of same length as posterior paired petals, and slightly longer than anterior paired petals; periproct on actinal surface, close to margin; actinal surface nearly flat.

DIMENSIONS: holotype, length 132.8 mm, width 121.2 mm, height 25.3 mm.

Holotype no. 14893 (loc. A 3517).

OCCURRENCE: locs. A 3517, A 3523, ?A 3561.

RANGE: upper Pliocene.

REMARKS: This species is closely allied to *C. rotundus* (Agassiz) as evidenced by the shape of the petals and spacing of the tubercles, but may be distinguished by its pentagonal shape, higher test, and more completely closed petals.

Clypeaster revellei n. sp.

(Plate 43, figures 1, 7)

Test large, flattened, but raised centrally, subtrigonal in shape, corners rounded; margin thin, 3–6 mm thick; actinal surface very slightly concave, abactinal surface low except for moderately raised petaliferous area, petals large, ovate, extending about two thirds of the distance to the margin, almost closed; there appears to be about 12 or 13 tubercles between each pore pair of right anterior ambulacrum; periproct just inside margin on actinal surface.

Dimensions of holotype: Length 146.8 mm, width 121.3 mm, height 25.3 mm.

Holotype no. 14892 (loc. A 3560).

OCCURRENCE: loc. A 3560.

RANGE: middle Pliocene.

REMARKS: Although resembling *C. rotundus* (Agassiz) in many respects, this species may be distinguished by its elongate subtrigonal shape and greater height.

Family SCUTELLIDAE Agassiz

Genus ***Dendraster*** Agassiz

Dendraster AGASSIZ, in AGASSIZ AND DESOR (1847), Ann. Sci. Nat. (Zool.), ser. 3, vol. 7, p. 135.

Genotype: *Echinarachnius excentricus* Valenciennes, 1832 = *Scutella excentricus* Eschschotz, 1831 (monotypic).

Dendraster granti n. sp.

(Plate 47, figures 3–12)

Test rather small, flattened, raised centrally. Similar in general appearance to *D. vizcainoensis* Grant and Hertlein (1938, p. 90, pl. 8, figs. 1–3), but smaller; outline of test variable, rounded or roughly pentagonal, usually somewhat elongate; margins about 2 mm thick, rounded; periproct on actinal surface, distant its diameter from margin; petals only slightly ovate, almost parallel-sided, inflated to varying degrees; apical system slightly excentric; ambulacral furrows branching once near peristome, any further branching indistinct; tubercles on actinal surface large and relatively few.

Dimensions of holotype: length 35.7 mm, width 37 mm, height 6.1 mm.

Holotype no. 14985, paratypes nos. 14986, 14987, 14988, 14989, 14991, 14992, 15382, 15385, and Calif. Acad. Sci. Paleo. Type Coll. nos. 7848, 7849, 7850 (all from loc. A 3559).

OCCURRENCE: loc. A 3559.

RANGE: middle Pliocene.

REMARKS: This species may be distinguished from *D. vizcainoensis* by the larger tubercles on the actinal surface and apparently by its smaller size. *D. cedrosensis* Israelsky has smaller tubercles and does not have the centrally raised apical system. *D. pacificus* Kew has the same type of tubercles but does not have the centrally raised apical system.

Genus *Encope* Agassiz

Encope AGASSIZ (1840), Cat. Ectyp. Echin. p. 9, 17.

Genotype: *Encope grandis* Agassiz (monotypic)

Agassiz first proposed this genus in 1840 (p. 9) and listed only the species "*grandis* Ag. (species viva) Martinique"; farther on (p. 17) a diagnosis of the genus was given. Later Agassiz (1841, p. 45–61, 146) gave a more detailed treatment of the genus and listed numerous species, of which *Echinodiscus emarginatus* Leske was the first. Later Clark (1911, p. 599, 605) designated *Echinodiscus emarginatus* Leske as the type of *Encope* Agassiz, 1841.

According to the International Rules of Zoological Nomenclature, Articles 30c and e, and opinion 46, *Echinodiscus emarginatus* Leske is excluded from consideration because it was not in Agassiz's original list, thus invalidating Clark's designation of it as type. If it is claimed that *E. grandis* is a *nomen nudem* as of 1840, opinion 46 of the Rules says "—if only one species is involved, the generic description is equivalent to the publication of *X-us albus* n. g. sp.". Thus according to the Rules *Encope* Agassiz, 1840, is monotypic, with *grandis* Agassiz, 1840, as the type.

The genus *Encope* is represented by several species living in tropical and subtropical waters on both the Atlantic and Pacific sides of the Americas. The oldest-known species are found in the middle or lower Miocene of these areas. At least four species: *E. grandis* Agassiz, *E. californica* Verrill, *E. micropora* Agassiz, and *E. perspectiva* Agassiz are living in the Gulf of California.

Thirteen species and one subspecies are here reported from the Pliocene and Pleistocene of this area. In addition *E. tenuis* Kew was described from the lower Pliocene of Carrizo Creek. *E. chaneyi* n. sp., *E. shepherdi* n. sp., and *E. grandis* subsp. *inezana* n. subsp. form a lineage up to the recent *E. grandis*. *E. loretoensis* n. sp., *E. tenuis* Kew, and *E.* sp. *A*. may form a lineage leading up to *E. californica*; however these three species are quite definitely related to the *E. emarginata* stock of the Caribbean. The living *E. micropora* lineage may be represented in the fossil state by *E. arcensis* n. sp. and *E. carmenensis* n. sp. *E. angelensis* n. sp. and *E. scrippsae* n. sp. have no living analogue in this area, although the living *E. stokesii* Agassiz may belong to the same stock.* *E. sverdrupi* does not appear to have any close relatives.

Abundant specimens of *E. grandis*, *E. grandis* subsp. *inezana*, *E. californica*, and of a fossil species from the Pliocene of Venezuela permitted statistical studies. These studies are the basis on which the present species are described. Characters found most important are: (1) position of interambulacral lunule with regard to a line connecting the distal ends of the posterior petals; (2) general shape and size of the lunule; (3) length of petals in proportion to radius of test; (4) open or closed

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*These two species, together with *E. stokesii* of the recent fauna should be referred to *Mellitella* Duncan (1889), which should be raised to full generic rank, rather than be regarded as a subgenus of *Encope*, as is done by Mortensen (Mon. Echinoidea, vol. 4, pl. 2, pp. 448–451, 1948). The different internal structure, the slightly posterior apical system, the long anterior petal, the different pattern of the ambulacral food grooves, and the position of the interambulacral lunule posterior to a line connecting the distal ends of the adjacent petals are characteristic of this genus. J. W. D., Oct. 14, 1949.

character of ambulacral notches and their relative depth; (5) height of test together with abactinal profile; and (6) position of periproct. The width and shape of the petals may vary tremendously in a species at a single locality. In some species the angle between the bivium varies greatly as the interambulacral lunule varies in size.

KEY TO SPECIES OF *ENCOPE* FROM GULF OF CALIFORNIA AREA

- A More than half of interambualcral lunule anterior to a line connecting distal ends of posterior petals.
  - B Ambulacral notches open.
    - C Interambulacral lunule long and narrow. *E. loretoensis* n. sp.
    - CC Interambulacral lunule ovate.
      - D Margin of test thin, fairly sharp. *E. arcensis* n. sp.
      - DD Margin of test thick, rounded.
        - E Abactinal profile without any noticeable concavity, length of interambulacral lunule usually about one sixth length of test.
          - F Posterior lateral anbulacral notches one seventh the radius of test. *E. chaneyi* n. sp.
          - FF Posterior lateral ambulacral notches one third to one fourth radius of test. *E. shepherdi* n. sp.
        - EE Abactinal profile definitely concave just inside margin.
          - G Interambulacral lunule one fourth length of test. *E. grandis inezana* n. subsp.
          - GG Interambulacral lunule one third length of test. *E. grandis* Agassiz.
            (*Note:* several specimens are necessary to establish the difference between *E. grandis* and *E. grandis inezana.*)
  - BB Ambulacral notches closed, test highest anteriorly.
    - H Anterior end of interambulacral lunule nearest to center of apical system. *E. perspectiva* Agassiz.
    - HH Anterior end of interambulacral lunule nearer to distal end of posterior petals. *E. micropora* Agassiz.
- AA More than half of interambulacral lunule posterior to a line connecting distal ends of posterior petals.
  - I Test highest posteriorly at the anterior end of interambulacral lunule.
    - J Ambulacral notches closed. *E. californica* Verrill.
    - JJ Ambulacral notches open.
      - K Posterior petals three fourths distance to ambulacral notches. *E. tenuis* Kew.
      - KK Posterior petals seven eights distance to ambulacral notches. *E.* n. sp. *A*.
  - II Test highest centrally or anteriorly.
    - L Interambulacral lunule elongate, narrow. *E. sverdrupi* n. sp.
    - LL Interambulacral lunule ovate or rounded.
      - M Test highest anteriorly.
        - N Abactinal profile entirely convex. *E. micropora* Agassiz.
        - NN Abactinal profile concave near margin. *E. carmenensis* n. sp.
      - MM Test highest centrally.
        - O Ambulacral notches closed, narrowly ovate. Interambulacral lunule small, narrowly ovate. *E. angelensis* n. sp.
        - OO Ambulacral notches usually closed, broadly ovate to subrounded. Interambulacral lunule large, broadly ovate. *E. scrippsae* n. sp.

Encope angelensis n. sp.

(Plate 37, figure 15; Plate 42, figures 1, 3, 4, 10)

Test small to medium in size, outline rounded, somewhat similar to *E. scrippsae* n. sp.; margins thin, with three faint indentations between ambulacral notches; central area of test raised, amount variable on different specimens; petals elongated, extending one third of distance to margins; on some specimens petals faintly raised; ambulacral notches closed to form lunules, elongate oval, fairly large; interambulacral lunule small, elongate, narrow, much nearer to posterior margin than to a line connecting distal ends of posterior petals; periproct slightly nearer to peristome than to interambulacral lunule.

DIMENSIONS (in mm):	*Length*	*Width*	*Height*
Holotype no. 14959		77.4	11.9
Paratype no. 14965		72.0 (estimated)	9.8
Paratype no. 14962	47.2	50.1	7.3

Holotype no. 14959; paratypes nos. 14965, 14962, and Calif. Acad. Sci. Paleon. Type Coll. nos. 7846, 7847, all from loc. A 3590.

OCCURRENCE: locs. A 3588, A 3590.

RANGE: middle Pliocene.

REMARKS: This species may be distinguished from *E. scrippsae* n. sp. by its shorter petals, narrower ambulacral lunules, smaller interambulacral lunule, and the periproct being slightly nearer the peristome.

Encope arcensis n. sp.

(Plate 37, figure 8; Plate 40, figures 5, 6)

Test large, outline rounded, truncated posteriorly, margins thin; ambulacral notches elongate ovate, with a tendency to close; anterior notch only about half as deep as posterior; interambulacral lunule ovate, a little less than one fifth total length of test in length, roughly divided in two by a line connecting distal ends of posterior petals; petals elongate, extending three fifths of the distance to margin, those of bivium longest; periproct at anterior end of interambulacral lunule; test highest centrally, abactinal profile evenly convex.

DIMENSIONS (in mm):	*Length*	*Width*	*Height*
Holotype no. 14903	92.6	105.0 (estimated)	11.2
Paratype no. 14894	113.5	121.0 (restored)	10.2

Holotype no. 14903 (loc. A 3554; paratype no. 14894) (loc. A 3529).

OCCURRENCE: locs. A 3529, A 3554, A 3557 (one specimen at each locality).

RANGE: Pleistocene, Recent.

REMARKS: This species belongs in the *E. micropora* stock but may be distinguished by its open ambulacral notches.

Encope californica Verrill

(Plate 37, figure 2; Plate 38, figures 1, 5)

Encope californica VERRILL (1870), Am. Jour. Sci., 2nd ser., vol. 49, p. 97; GRANT AND HERTLEIN (1938), Univ. Calif. Los Angeles, Publ. Math. Phys. Sci., vol. 2, p. 96, pl. 11, fig. 4, pl. 30, fig. 2.

Hypotypes nos. 14946 (Recent), 14942 (loc. A 3582), 14950 (loc. A 3584), 14953 (loc. A 3584).

OCCURRENCE: Recent, Gulf of California; Pleistocene, locs. A 3548, A 3564, A 3582, A 3584, A 3596. L.S.J.U. loc. 805.

RANGE: lower Pliocene.

REMARKS: A large number of specimens are available from locs. A 3582 and A 3584. A statistical study of various characters revealed no differences from the living specimens, except that a few were slightly thicker. Apparently the *E. californica* stock has not evolved as fast as that of *E. grandis.*

Encope carmenensis n. sp.

(Plate 37, figure 5; Plate 40, figure 4, Plate 44, figure 1)

Test large, fairly heavy, resembling *E. micropora* to which it may be ancestral; ambulacral lunules closed, interambulacral lunule elongate oval and moderately large; anterior end of interambulacral lunule nearer distal ends of posterior petals than to center of abactinal system; test highest anteriorly, about midway between abactinal system and margin; petals large, extending six sevenths of the distance to ambulacral lunules; the central area of the abactinal surface, nearly half the diameter of the test, is slightly raised, beginning to take on the character of *E. peruviana* Brighton (1926, p. 61–69) although not to such a marked extent; the upper surface of the test between this raised area and the margin is slightly concave; margins moderately thin.

Dimensions of holotype: length 117.8 mm, width 115.2 mm, thickness 13.6 mm.

Holotype no. 14896, paratype no. 14895, both from loc. A 3517.

OCCURRENCE: loc. A 3517.

RANGE: upper Pliocene.

REMARKS: This species may be distinguished from *E. micropora* and *E. perspectiva* by the central slightly raised area, the concave upper surface extending out to the margin and the shorter petals.

Encope chaneyi n. sp.

(Plate 37, figure 7; Plate 43, figure 6)

Test of medium size, heavy, general outline rounded; ambulacral notches all shallow, "V" shaped, about a fifth the radius of test in depth; margins of test rounded, about 3 mm thick; profile of test slightly concave inside margin, flattened in center of abactinal system; petals moderately well developed, extending slightly over two thirds distance to ambulacral notch; interambulacral lunule ovate, about a third the length of radius of test, about equally divided by a line connecting distal ends of posterior petals.

Dimensions of holotype: length 81.4 mm, width 84.5 mm, height 10.8 mm.

Holotype no. 30057 (loc. A 3552).

OCCURRENCE: loc. A 3552.

RANGE: lower Pliocene.

REMARKS: Similar to *E. tatetlaensis* Böse (1906, p. 71–72, pl. VI, figs. 1, 2; pl. VII, figs. 1, 2), but differs from his description in being much thicker, having deeper anterior and anterior lateral ambulacral notches, and a more elongate interambulacral lunule.

Encope grandis Agassiz

(Plate 37, figure 9; Plate 38, figures 2, 3)

Encope grandis AGASSIZ (1840), Cat. Ectyp. Echin., p. 9; AGASSIZ (1841), Mon. Echin. Viv. Foss., Seconde Mon. Scutel., p. 57, pl. 6, figs. 1–9; *Partim* GRANT AND HERTLEIN (1938), Univ. Calif. Los Angeles, Publ. Math. Phys. Sci., vol. 2, p. 96–97.

Grant and Hertlein gave an exhaustive synonymy of this large and heavy recent species. However, it should be noted that the references from the Pliocene and Pleistocene apply to forms here separated from *E. grandis* (Pliocene, *Encope shepherdi* n. sp.; Pleistocene, *Encope grandis* subsp. *inezana* n. subsp.).

The interambulacral lunule is large and oval, usually with a raised margin; its length averages about 0.3 that of the test. Figures 2 and 3 show the variation of this character. The margins are thick and rounded. The upper surface of the test is slightly concave between the margins and the abactinal system.

Hypotypes nos. 14905, 14906, 14908, 14909 (loc. A 3639).

OCCURRENCE: Widespread in Gulf of California.

RANGE: Recent.

Encope grandis subsp. ***inezana*** n. subsp.

(Plate 37, figure 10; Plate 38, figure 4)

Encope grandis Agassiz, ISRAELSKY (1923), Univ. Calif. Publ., Bull. Dept. Geol. vol. 14, p. 381, pl. 70, fig. 1, pl. 71, fig. 1, pl. 72, fig. 2; E. K. JORDAN (1924), Bull. South. Calif. Acad. Sci., vol. 23, p. 148; E. K. JORDAN (1936), Contrib. Dept. Geol., Stanford Univ., vol. 1, p. 111.

A statistical analysis of 45 specimens from locality A 3584 and 22 from A 3582 reveals that the interambulacral lunule of the Pleistocene specimens is smaller than that of the recent form. (See Figures 2, 3.) In the living species (33 specimens) the lunule averages 0.3 the length and 0.18 the width of the test. In the specimens from the aforementioned localities the lunule is 0.25 the length and 0.15 the width of the test. Thus the lunule of the recent species is one fifth larger than that of the Pleistocene subspecies. Individuals of both groups are identical so that the new subspecies may not always be identified on the basis of a single specimen. The upper surface of the test is not so markedly concave between the margin and the abactinal system as in *E. grandis* ss.

DIMENSIONS (in mm):	*Length*	*Width*	*Greatest height*	*Length of lunule*
Holotype 14910	84.9	82.4	13.7	19.6
Paratype 14913	86.7	85.4	15.0	17.9
Paratype 14915	89.0	87.6	16.2	22.6
Paratype 14912	94.6	93.4	16.8	25.9

Holotype no. 14910; paratypes nos. 14912, 14913, 14915 (all from loc. A 3584); Stanford Univ. Paleo. Type Coll. no. 7370; and Calif. Acad. Sci. Paleo. Type Coll. no. 916 (*E. grandis* of Israelsky, 1923).

OCCURRENCE: locs. A 3548, A 3582, A 3584, A 3564, C.A.S. locs. 754, 982.

RANGE: Pleistocene.

REMARKS: Variation in the proportion of the length to width of the interambulacral lunule is common. In addition the test varies considerably in outline.

Encope loretoensis n. sp.

(Plate 37, figure 4; Plate 41, figures 1, 4, 5)

Test fairly large, moderately heavy, general outline similar to *E. tenuis* Kew except for position of interambulacral lunule; margins thin, outline rounded, truncated posteriorly; ambulacral notches U-shaped, extending in about a fifth the distance to oculogenital system, except for anterior notch which is shallower; interambulacral lunule an elongate slot about a sixth the total length of test; a line connecting distal ends of bivium includes about two thirds of the lunule; lunule equally narrow on actinal surface, with a constriction about midway; petals elongate, with bivium longest, extending about two thirds the distance to margin; periproct just anterior to interambulacral lunule; highest part of test at anterior end of interambulacral lunule; abactinal profile gently convex.

DIMENSIONS (in mm):	*Length*	*Width*	*Thickness*
Holotype 14888	99.8	101.1	12.0
Paratype 14889	103.1	103.0 (estimated)	11.5
Paratype 14891			10.9

Holotype no. 14888; paratypes nos. 14889, 14891 and Calif. Acad. Sci. Paleo. Type Coll. no. 7856 (all from loc. A 3552).

OCCURRENCE: locs. A 3551, A 3552, A 3557, A 3536.

RANGE: lower Pliocene.

REMARKS: This species may be separated from *E. tenuis* Kew by the interambulacral lunule of that species being almost entirely posterior to a line connecting the distal ends of the posterior petals, and it may be distinguished from *E. arcensis* n. sp. by having slightly shallower ambulacral notches, usually not tending to close as is the case in that species. Further the interambulacral lunule in *E. arcensis* is broad and not constricted on the actinal surface.

Encope micropora Agassiz

(Plate 37, figure 1; Plate 39, figures 1, 2)

Encope micropora AGASSIZ (1841), Mon. Echin. Viv. Foss., Seconde Mon. Scutel., p. 50, 146, pl. 10a, figs. 4–8; pl. 19a, fig. 7; *Partim* GRANT AND HERTLEIN (1938), Univ. Calif. Los Angeles, Publ. Math. Phys. Sci., vol. 2, p. 98, 99, *not* pl. 29, fig. 6.

Hypotype no. 14979, Gulf of California.

Occurrence: Recent, Gulf of California to Panama Bay and Peru. Pleistocene (*fide* Grant and Hertlein), Magdalena Bay; Santa Ynez Point; Oaxaca, Mexico; San Ignacio Lagoon, etc.

Remarks: As noted elsewhere the specimens on which Grant and Hertlein based their record from the Pliocene of El Pulpito Point should probably be referred to a new species, for they have a thick margin, are not highest anteriorly, and the interambulacral lunule is a narrow elongate slit.

The specimen figured by Grant and Hertlein (1938, pl. 29, fig. 6) as this species (Calif. Acad. Sci. Paleo. Type Coll. no. 6941) from the Galapagos Islands has open ambulacral notches, and the distance from the ends of the petals to the ambulacral notches is greater than that of any of a large series of living specimens of all sizes of *E. micropora*. It presumably is a variant of *E. galapagiensis* A. H. Clark.

E. micropora may be characterized by its elongate interambulacral lunule of which two thirds is posterior to a line connecting the distal ends of the posterior petals; by the petals extending six sevenths of the distance to the inner ends of the ambulacral notches; and by the small closed ambulacral notches.

No specimens were found in the present fossil collections.

Encope perspectiva Agassiz

(Plate 37, figure 12; Plate 39, figures 3, 5)

Encope perspectiva Agassiz (1841), Mon. Echin. Viv. Foss., Seconde Mon. Scutel; p. 51, 146, pl 10b, figs. 1–5; Grant and Hertlein (1938), Univ. Calif. Los Angeles, Publ. Math. Phys. Sci., vol. 2, p. 100

Hypotype no. 15398, "Pacific Coast".

Occurrence: Living, Ballenas Bay, Lower California, to Costa Rica.

Range: Recent.

Remarks: This species is characterized by the test being highest anteriorly; by the petals extending nine tenths of the distance to the inner ends of the ambulacral notches; by the closed ambulacral notches; by more than three fourths of the interambulacral lunule being anterior to a line connecting the distal ends of the posterior petals; and by the anterior end of the interambulacral lunule being nearer to the center of the apical system than to the distal ends of the posterior petals.

Encope scrippsae n. sp.

(Plate 37, figure 14; Plate 42, figures 2, 5–8)

Test of medium size, rounded in outline, margin thin with three shallow notches between each ambulacral notch; central area of test raised, profile from central area to margins concave; individual petals slightly raised, elongate, extending about half the distance to margin; ambulacral notches fairly large, varying from elongate ovate to ovate, open in smaller individuals, usually closed in larger specimens; interambulacral lunule large, rounded ovate, situated midway between margin and a line connecting distal ends of posterior petals; periproct just anterior to interambulacral lunule.

Dimensions (in mm):	*Length*	*Width*	*Height*
Holotype no. 14954	69.8		9.6
Paratype no. 14958		59.5	9.0
Paratype no. 14957		71.2 (estimated)	9.8
Paratype no. 14956		76.0 (estimated)	11.1
Paratype no. 14955		66.0	11.0

Holotype no. 14954; paratypes nos. 14955, 14956, 14957, 14958, all from loc. A 3551.

Occurrence: loc. A 3551.

Range: lower Pliocene.

Encope scrippsae n. sp?

(Plate 41, figures 2, 3, 6)

Numerous poorly preserved and fragmentary specimens found at loc. A 3594 seem to be referrable to this species. The fragmentary individuals appear to have had the size, outline, profile, and variable ambulacral notches of the better-preserved material from loc. A 3551. However, the petals on two specimens may have been slightly shorter and the interambulacral lunule smaller in proportion to the total size. The variation in size of the ambulacral notches is also greater.

Hypotypes nos. 14966, 14967, 14968, 14969 (all from loc. A 3594).

OCCURRENCE: loc. A 3594.

RANGE: lower Pliocene.

Encope shepherdi n. sp.

(Plate 37, figure 11; Plate 38, figure 6; Plate 40, figure 2)

Encope grandis (?) Agassiz, HANNA AND HERTLEIN (1927), Proc. Calif. Acad. Sci., ser. 4 , vol. 16, p 140, 147.

Test moderately large and heavy, similar to living *E. grandis*. In comparison with the recent species marginal notches are usually slightly smaller; edges of test thinner (3–4 mm compared to about 6 mm); surface of test between abactinal system and margin nearly straight or very slightly concave, whereas the living form is distinctly concave; finally the interambulacral lunule is much smaller (*see* Figures 2, 3) and its range of variation does not overlap that of *E. grandis*, averaging only slightly over half as large.

DIMENSIONS (in mm):	*Length*	*Width*	*Height*	*Length of lunule*
Holotype 14917	100.4	99.5	19.0	17.4
Paratype 14919	106.7	101.0	19.0	22.8
Paratype 14918	80.4	82.2	15.0	15.1

Holotype no. 14917 (loc. A 3517); paratypes nos. 14919 (loc. A 3523), 14918 (loc. A 3517).

OCCURRENCE: locs. A 3517, A 3523, A 3539, A 3591, A 3562.

RANGE: upper Pliocene.

REMARKS: This is without question the ancestor of *E. grandis* and *E. grandis* subsp. *inezana*.

Encope sverdrupi n. sp.

(Plate 37, figure 6; Plate 39, figures 4, 6)

Encope tenuis Kew, (*partim*), GRANT AND HERTLEIN (1938), Univ. Calif. Los Angeles, Publ. Math. Phys. Sci., vol. 2, p. 100.

Test of medium size, outline rounded, truncated posteriorly; margins thin, ambulacral notches deep, ovate, occasionally partly closed; interambulacral lunule small, elongate, narrow, usually about one ninth total length of test, with a line connecting distal ends of posterior petals excluding two thirds of its length; petals moderately elongate, extending a little more than half the distance to margin; highest point of test central, abactinal profile may be evenly convex or on some specimens become slightly concave near margin; periproct anterior to lunule, not quite half the distance to peristome.

DIMENSIONS (in mm):	*Length*	*Width*	*Height*
Holotype no. 15395	93.9	96.4	10.0
Paratype no. 15397	84.5	86.4	
Paratype no. 15396	69.0	70.9	
Paratype L.S.J.U. no. 7371	96.4	101.8	

Holotype no. 15395, paratypes, nos. 15397, 15396 and Calif. Acad. Sci. Paleo. Type. Coll. no. 7855, all from loc. A 3583, and paratype Stanford Univ. Paleo. Type Coll. no. 7371, loc. L.S.J.U. 805.

OCCURRENCE: locs. A 3583, A 3531, L.S.J.U. no. 805 (= A 3583).

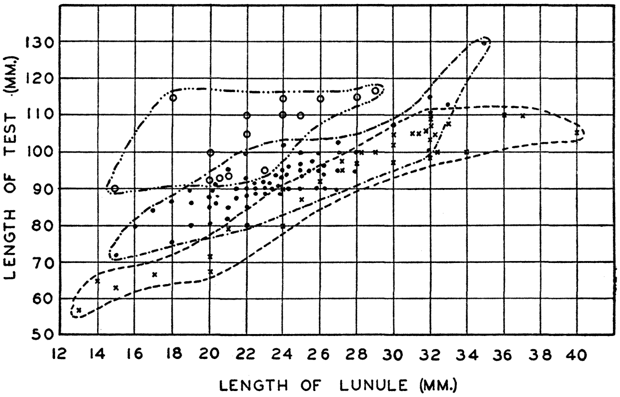

FIGURE 2.—*Variation of length of lunule in Encope spp.*

Explanation of symbols: ○—*Encope shepherdi* n.sp., upper Pliocene; ●—*Encope grandis* subsp. *inezana* n.subsp., Pleistocene; X—*Encope grandis* Agassiz, Recent.

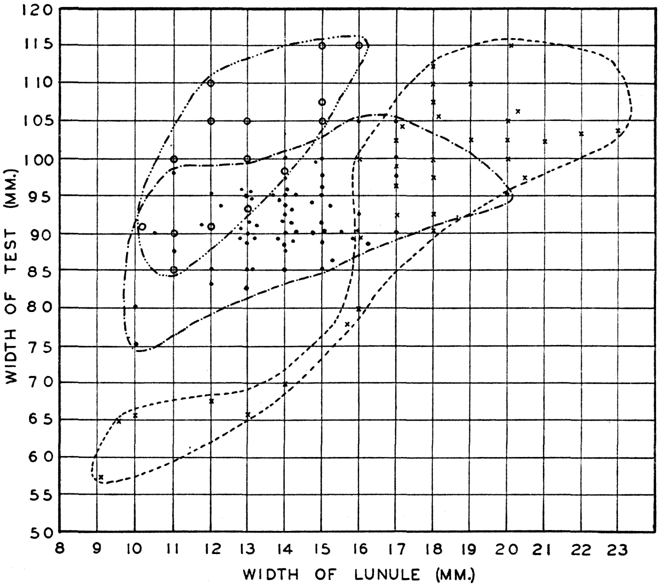

FIGURE 3.—*Variation of width of lunule in Encope spp.*

Explanation of symbols: ○— *Encope shepherdi* n.sp., upper Pliocene; ●—*Encope grandis* subsp. *inezana* n.subsp., Pleistocene; X—*Encope grandis* Agassiz, Recent.

RANGE: lower Pliocene.

REMARKS: This species may be distinguished from *E. tenuis* Kew by its greatest height being central instead of posterior.

Encope n. sp. *A.*

(Plate 37, figure 3; Plate 40, figure 3)

A large species, apparently similar to *E. loretoensis* but with test much higher at anterior end of interambulacral lunule. Unfortunately only numerous fragments are available.

Hypotypes nos. 15387, 15388, 15389 (all from loc. A 3712).

OCCURRENCE: loc. A 3712.

Encope **n. sp.** ***B.***

(Plate 37, figure 13; Plate 40, figure 1)

The major part of a large *Encope* apparently belonging to the *E. californica* group was found at loc. A 3548. Unfortunately the segment bearing the interambulacral lunule is missing. The species may be distinguished from all other described forms with closed ambulacral lunules by its thick margin (5–6 mm) and moderately high thick test. The petals are somewhat broader than those of the living *E. californica* but extend to about the same distance from the margin.

Dimensions of holotype: length 120 mm (estimated), width 120 mm (estimated), height 17 mm.

Hypotype no. 14900 (loc. A 3548).

OCCURRENCE: loc. A 3548.

RANGE: Pleistocene.

REMARKS: The imperfect specimens upon which the record of *E. micropora* Agassiz in the Pliocene of El Pulpito Point (Grant and Hertlein, 1938, p. 98) may possibly be this species. They do not appear to be *E. micropora* for they have a rather thick margin, are not highest anteriorly, and the interambulacral lunule is a narrow elongate slit.

Suborder CASSIDULINA Hawkins

Family CASSIDULIDAE Agassiz

Genus ***Echinolampas*** Gray

Echinolampas GRAY (1835), Ann. Phil., ser. 2, vol. 10, p. 429.

Genotype: *Echinanthus ovatus* Leske

Echinolampas (?) sp.

(Plate 44, figure 5)

Hypotype no. 30055 (loc. A 3576).

OCCURRENCE: loc. A 3576.

RANGE: lower Pliocene.

REMARKS: A single incomplete specimen showing two complete long narrow slightly petaloid ambulacra which extend to the ambitus. Oral surface missing. Apical system small, 4 genital pores, madreporite large. Both ambulacral and interambulacral areas with abundant small tubercles. Specimen probably originally 60 mm or more in length.

Family HEMIASTERIDAE Clark

Genus ***Agassizia*** Valenciennes

Agassisia VALENCIENNES (1846), Voy. Venus, Zoöph., pl. 1, figs. 2–2f.
Agassizia Valenciennes, AGASSIZ AND DESOR (1847), Ann. Sci. Nat. (Zool.), ser. 3, vol. 8, p. 20.

Genotype: *Agassizia scrobiculata* Valenciennes (monotypic)

Agassizia scrobiculata Valenciennes

(Plate 43, figures 4, 5, 8, 9)

Agassisia scrobiculata VALENCIENNES (1846), Voy. Venus, Zoöph., pl. 1, figs. 2–2f.
Agassizia scrobiculata Valenciennes, GRANT AND HERTLEIN (1938), Univ. Calif., at Los Angeles, Publ. Math. Phys. Sci., vol. 2, p. 114–115, pl. 29, figs. 2, 3; pl. 30, fig. 12; text fig. 10.

Hypotype no. 30149 and Stanford Univ. Paleo. Type Coll. no. 7373, both from L.S.J.U. loc. 805.

RANGE: Recent.

REMARKS: Ten specimens are in the collection from L.S.J.U. loc. 805. Considerable variation is apparent; some are much higher than the others, and in one specimen the posterior petals are shorter than normal.

Genus ***Moira*** Agassiz

Moera MICHELIN (1855), Rev. Mag. Zool., ser. 2, vol. 7, p. 245. Not *Moera* Hübner, 1916.
Moira AGASSIZ (1872), Mem. Mus. Comp. Zool., vol. 3, pt. 1, p. 146.

Genotype: *Spatangus atropos* Lamarck (subs. desig. Clark, 1917)

Moira cf. ***clothro*** (Michelin)

(Plate 45, figures 2, 5)

Moera clotho MICHELIN (1855), Rev. Mag. Zool., p. 247.
Moira clotho Michelin, AGASSIZ (1872), Ill. Cat. Mus. Comp. Zool., no. 7 (Mem. Mus. Comp. Zool., vol. 3), pt. 1, p. 147; GRANT AND HERTLEIN (1938), Univ. Calif. at Los Angeles, Publ. Math. Phys. Sci., vol. 2, p. 125.

Hypotype no. 14897 (loc. A 3516).

OCCURRENCE: loc. A 3516.

RANGE: upper Pliocene.

REMARKS: Only a single slightly distorted specimen was found. Anteriorly it appears to be less rounded and posteriorly it seems to be higher than the living species in the Gulf of California, but it is possible that these are apparent differences caused by its present distortion.

Family SPATANGIDAE Gray

Genus ***Meoma*** Gray

Meoma GRAY (1852), Ann. Mag. Nat. Hist., ser. 2, vol. 7, p. 131, 132.

Genotype: *Meoma grandis* Gray (monotypic)

Meoma sp.

(Plate 47, figure 1)

Hypotype no. 15402 (loc. A 3528).

OCCURRENCE: locs. A 3519, A 3528, A 3596.

RANGE: lower Pliocene to Recent.

REMARKS: The specimen from locality A 3528 is poorly preserved and crushed but was about 113 mm long by 85 mm wide. The peripetalous fasciole is visible. Only a few fragments were found at loc. A 3519.

Genus ***Lovenia*** Desor

Lovenia Desor, in AGASSIZ AND DESOR (1847), Ann. Sci. Nat. (Zool.), ser. 3, vol. 6, pl. 16, fig. 16; vol. 8, p. 10–11.

Genotype: *Lovenia hystrix* Desor (monotypic)

Lovenia hemphilli Israelsky

(Plate 44, figures 2, 3, 4, 6)

Lovenia hemphilli ISRAELSKY (1923), Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 14, p. 384, pl. 74, figs. 1a, 1b, 1c, 2; GRANT AND HERTLEIN (1938), Univ. Calif. Los Angeles, Publ. Math. Phys. Sci., vol. 2, p. 137, pl. 13, figs. 3, 4.

Hypotype no. 15410 (loc. A 3566).

OCCURRENCE: loc. A 3566, and San Diego Pliocene.

RANGE: middle Pliocene.

REMARKS: The single specimen found is slightly crushed, but it has the proportions and shape of Israelsky's types. The primary tubercles are arranged somewhat differently, but an examination of a series of the living *L. cordiformis* Agassiz indicates that they vary in position on different individuals. The posterior truncation is slanting as in the San Diego specimens. A large topotype, better preserved than either of the original types, is in the Univ. Calif. Collections (hypotype no. 15408). The dimensions are: length 83.7 mm, width 65.1 mm, height 22.7 mm. The specimen from loc. A

3566 has the following approximate dimensions: length 71 mm, width 53 mm, height (estimated) 18 mm.

Phylum MOLLUSCA

Class PELECYPODA

Family NUCULIDAE

Genus **Nucula** Lamarck

Nucula LAMARCK (1799), Mem. Soc. Hist. Nat. Paris, vol. 1, p. 87.

Genotype: *Arca nucleus* Linnaeus

Nucula (Nucula) declevis Hinds

(Plate 1, figures 18, 19)

Nucula declevis HINDS (1843), Proc. Zool. Soc. London, p. 93.
Nucula (*Nucula*) *declevis* Hinds, HERTLEIN AND STRONG (1940), Zoologica, Sci. Contrib. New York Zool. Soc., vol. 25, pt. 4, p. 380, pl. 1, figs. 1–3, 6–7.

Hypotypes nos. 30519, 30525 (loc. A 3582).

OCCURRENCE: loc. A 3582.

RANGE: Pleistocene, Recent.

REMARKS: Hertlein and Strong have compared this shell with other species. The fine radial striations are hard to discern on the fossils but can be seen in the proper lighting. The ventral margins of some valves are markedly crenulate.

Family NUCULANIDAE

Genus **Nuculana** Link

Nuculana LINK (1807), Beschreib. Natur. Samml. Univ. Rostock, p. 155.
Leda SCHUMACHER (1817), Essai Nouv. Syst. Test., p. 55, 173.

Genotype: *Arca rostrata* Chemnitz (monotypic)

Subgenus **Saccella** Woodring

Ledina SACCO (Dec., 1898), Moll. Terr. Terz. Piemonte e Liguria, pt. 26, p. 53; *non Ledina* DALL (April, 1898).
Saccella WOODRING (1925), Carnegie Inst. Washington, Publ. 366, p. 15.

Subgenotype: *Arca fragilis* Chemnitz (orig. desig.)

Nuculana (Saccella) elenensis (Sowerby)

(Plate 1, figures 10, 11)

Nucula elenensis SOWERBY (1833), Proc. Zool. Soc. London for 1832, p. 198.
Nuculana (*Saccella*) *elenensis* Sowerby, HERTLEIN AND STRONG (1940), Zoologica, vol. 25, pt. 4, p. 393–394, pl. 1, figs. 12, 14–19, 22.

Hypotypes nos. 30547 (loc. A 3582), 30546 (loc. A 3584).

OCCURRENCE: locs. A 3582, A 3584.

RANGE: Pleistocene, Recent.

REMARKS: Hertlein and Strong have given an excellent discussion of the great variability of this species.

Family ARCIDAE

Genus **Arca** Linnaeus

Arca Linnaeus (1758), Syst. Nat., Ed. 10, p. 693.

Genotype: *Arca noae* Linnaeus (subs. desig. Schmidt, 1818)

Subgenus ***Arca*** s.s.

Arca (Arca) mutabilis (Sowerby)

(Plate 2, figure 7)

Byssoarca mutabilis SOWERBY (1833), Proc. Zool. Soc. London, p. 17.
Arca mutabilis Sowerby MAURY (1922), Palaeont. Am., vol. 1, p. 167, pl. 29, fig. 5.
Arca (*Arca*) *mutabilis* Sowerby, HERTLEIN AND STRONG (1943), Zoologica, vol. 28, p. 154.

Hypotype no. 15508 (loc. A 3550).

OCCURRENCE: loc. A 3550.

RANGE: Pleistocene, Recent.

REMARKS: A single specimen 27.7 mm long, 19.6 mm high, and 12.3 mm thick (one valve) was found. It agrees well with the description given by Maury.

Genus ***Anadara*** Gray

Anadara GRAY (1847), Proc. Zool. Soc. London, p. 198.

Genotype: *Arca antiquata* Linnaeus (orig. desig.)

Anadara (Anadara) formosa (Sowerby) ?

(Plate 2, figure 9)

Arca formosa SOWERBY (1833), Proc. Zool. Soc. London, p. 20.
Scapharca (*Scapharca*) *formosa* Sowerby, MAURY (1922), Palaeont. Am., vol. 1, p. 190–191, pl. 31 fig. 11.
Arca (*Anadara*) *formosa* Sowerby, HERTLEIN AND STRONG (1943), Zoologica, vol. 28, p. 156.

Hypotype no. 15506 (loc. A 3556).

OCCURRENCE: localities A 3528, A 3556.

RANGE: lower Pliocene, Recent.

REMARKS: The large specimen from loc. A 3556 is about 73 mm long and somewhat poorly preserved. There seem to have been about 34 ribs, some of which are definitely grooved. The specimen appears somewhat narrower posteriorly than the one figured by Maury. It is possible that good material might show that it is a new species.

Subgenus ***Cunearca*** Dall

Cunearca DALL (1898), Trans. Wagner Free Inst. Sci., vol. 3, p. 618.

Subgenotype: *Arca incongrua* Say

Anadara (Cunearca) vanderhoofi n. sp.

(Plate 1, figures 1, 2)

Shell usually moderately thin, beaks rather high, of medium size, not too well preserved; dorsal margin straight, posterior margin slanting obliquely down and out, ventral margin evenly convex rounding into the decidedly convex anterior margin; right valve (holotype) with 28 medium-sized, square-sided ribs, interspaces of equal width; ribs apparently not noded; other right and left valves with about 24 ribs; all left valves with ribs wider than interspaces; ligamental area apparently with two broadly inverted V-shaped chevrons, widest anterior to beak but longest posterior; teeth eroded from all hinges available.

Dimensions of holotype: Length 17.8 mm, height 14.1 mm, thickness (one valve, approximate) 5.8 mm.

Holotype no. 30548, paratypes nos. 30549, 30550, 30551, 30552, 30553 (all from loc. A 3595).

OCCURRENCE: loc. A 3595.

RANGE: San Gregorio formation, upper Oligocene.

REMARKS: This species is very abundant here but is poorly preserved.

Subgenus ***Larkinia*** Reinhart

Larkinia REINHART (1935), Bull. Mus. Roy. Hist. Nat. Belg., vol. 11, no. 13, p. 41–42.

Subgenotype: *Anadara larkinii* (Nelson) (orig. desig.)

Anadara (Larkinia) multicostata (Sowerby)

(Plate 1, figures 15, 16, 17)

Arca multicostata SOWERBY (1833), Proc. Zool. Soc. London, p. 21.
Arca (Arca) multicostata Sowerby, GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 139.
Arca (Larkinia) multicostata Sowerby, HERTLEIN AND STRONG (1943), Zoologica, vol. 28, p. 162.

Hypotypes nos. 15525 (loc. A 3582), 15528 (loc. A 3520), 15529 (loc. A 3596).

OCCURRENCE: localities A 3497, A 3508, A 3519, A 3520, A 3525, A 3533, A 3534, A 3536, A 3541, A 3548, A 3550, A 3562, A 3582, A 3584, A 3596, A 3598, A 3670.

RANGE: upper Pliocene, Recent.

REMARKS: This species varies greatly. There may be a sharp posterior ventral angle, or it may be nearly square, the chevrons for attachment of the ligament may be few or many, although they are commonly few. The specimens may attain a height of more than 85 mm.

Genus ***Barbatia*** Gray

Barbatia GRAY (1842), Synopsis of the contents of the British Museum, Ed. 44, p. 81.

Genotype: *Arca barbata* Linnaeus (subs. desig. Gray, 1847)

Subgenus ***Acar*** Gray

Acar GRAY (1857), Ann. Mag. Nat. Hist., ser. 2, vol. 19, p. 369.

Subgenotype: (*Arca*) *gradata* Broderip and Sowerby (subs. desig. Woodring, 1925)

Barbatia (Acar) gradata (Broderip and Sowerby)

(Plate 1, figure 13)

Arca gradata BRODERIP AND SOWERBY (1829), Zool. Jour., London, vol. 4, p. 369.
Arca (Arca) gradata Broderip and Sowerby, MAURY (1922), Palaeont. Am., vol. 1, p. 18–19; HERTLEIN AND STRONG (1943), Zoologica, vol. 28, p. 155.

Hypotype no. 15999 (loc. A 3582).

OCCURRENCE: locs. A 3548, A 3582.

RANGE: Pleistocene, Recent.

Barbatia (Acar) illota (Sowerby)

(Plate 1, figure 6)

Byssoarca illota SOWERBY (1833), Proc. Zool. Soc. London, p. 18.
Barbatia (Acar) illota Sowerby, MAURY (1922), Palaeont. Am., vol. 1, p. 182–183, pl. 30, figs. 8, 14.

Hypotypes nos. 15548 (loc. A 3582), 15537 (loc. A 3573).

OCCURANCE: loc. A 3573, A 3582.

RANGE: Pleistocene, Recent.

REMARKS: Only two specimens were found. The specimen from loc. A 3582 is 35.6 mm long, 22.8 mm high, and 18.2 mm thick (both valves), while the specimen from loc. A 3573 is 21.5 mm long. 17.2 mm high, and 6.8 mm thick (one valve). Their proportions are thus considerably different, but Maury states that the species varies considerably, and there is no other difference by which they can be separated.

Barbatia* (*Acar*) *solida (Sowerby)

(Plate 1, figure 12)

Byssoarca solida SOWERBY (1833), Proc. Zool. Soc. London, p. 18.
Barbatia (*Fossularca*) *solida* Sowerby, MAURY (1922), Palaeont. Am., vol. 1, p. 183–184, pl. 30, figs. 7, 12.
Arca (*Arcopsis*) *solida* Sowerby, HERTLEIN AND STRONG (1943), Zoologica, vol. 28, p. 158.

Hypotypes nos. 15908, 15912, 15914, 15915 (all from loc. A 3582).

OCCURRENCE: localities A 3534, A 3582.

RANGE: Pleistocene, Recent.

REMARKS: This species is abundant at loc. A 3582, where about 25 specimens were found. The largest is 14.7 mm long, 19.1 mm high, and 4.4 mm thick (one valve).

Subgenus ***Calloarca*** Gray

Calloarca GRAY (1857), Ann. Mag. Nat. Hist., ser. 2, vol. 19, p. 369.

Subgenotype: *Byssoarca alternata* Sowerby (monotypic)

Barbatia* (*Calloarca*) *alternata (Sowerby)

(Plate 1, figure 14)

Byssoarca alternata SOWERBY (1833), Proc. Zool. Soc. London, p. 17.
Barbatia (*Cucullaria*) *alternata* Sowerby, MAURY (1922), Palaeont. Am., vol. 1, p. 22–23, pl. 11, fig. 2.
Arca (*Calloarca*) *alternata* Sowerby, HERTLEIN AND STRONG (1943), Zoologica, vol. 28, p. 159.

Hypotype no. 15971 (loc. A 3584).

OCCURRENCE: locs. A 3582, A 3584.

RANGE: Pleistocene, Recent.

REMARKS: One specimen from loc. A 3584 and three smaller ones from loc. A 3582 were collected. The specimen from loc. A 3584 is 26.4 mm long.

Subgenus ***Cucullaearca*** Conrad

Cucullaearca CONRAD (1865), Am. Jour. Conch., vol. 1, p. 11.

Subgenotype: *Byssoarca lima* Conrad (subs. desig. Stoliczka)

Barbatia* (*Cucullaearca*) *bramkampi n. sp.

(Plate 1, figures 5, 7, 9)

Shell large, rather flattened, beaks low, shape more or less irregularly subquadrate, similar in outline to *B. reeveana* (d'Orbigny); a low rounded angulation from the beak to ventral part of posterior margin; dorsal margin straight; posterior margin straight, making an angle of about 135° with dorsal margin, then rounding evenly into slightly curved ventral margin which slopes upward anteriorly to short rounded anterior margin; radial sculpture of 90–100 fine radial ribs, somewhat coarser and more nodose on anterior half of shell, posteriorly every fourth or sixth rib may be coarse, occasional fine secondaries intercalated; radial ribs crossed by fine growth lines which produce small nodes on anterior ventral margin; ligamental area with numerous inverted V-shaped chevrons; hinge with 5 coarse teeth and 10 finer ones inside them anteriorly, then a smooth area, followed by about 5 small teeth and 7 large ones posteriorly—on some specimens the smooth central area is also covered with fine teeth, and there may be 10 large ones posteriorly.

Dimensions of holotype: Length 41.0 mm, height 25.4 mm, thickness (1 valve) 8.2 mm.

Holotype no. 15552, paratypes nos. 15551, 15553, 15554 (loc. A 3519).

OCCURRENCE: loc. A 3519.

RANGE: upper Pliocene.

REMARKS: The outline of different specimens varies considerably. *B. bramkampi* may readily be distinguished from *B. reeveana* by its finer and more numerous radial ribs, particularly on the anterior and posterior dorsal margins where the radial ribs on that species are rather coarse.

Barbatia (Cucullaearca) reeveana (d'Orbigny)

(Plate 1, figures 3, 4, 8)

Arca reeveana D'ORBIGNY (1846), Voy. Am. Merid., Moll., p. 635.
Arca (*Barbatia*) *reeveana* d'Orbigny, HERTLEIN AND STRONG (1943), Zoologica, vol. 28, p. 158–159.

HYPOTYPES nos. 15902, 15903, 15904, 15905, 15906, 15907 (all from loc. A 3519).

OCCURRENCE: localities A 3515, A 3519, A 3534, A 3548, A 3590, A3596.

RANGE: upper Pliocene to Recent.

REMARKS: This species varies greatly in its shape and position of the beaks. There is a suggestion that in the material from loc. A 3519 the beaks average somewhat closer to the anterior end than in the living form, but there is not sufficient Recent comparative material to establish the variability.

Genus ***Glycymeris*** Da Costa

Glycymeris DA COSTA (1778), Historia Naturalis Testaceorum Britanniae, p. 168; not *Glycimeris* LAMARCK.

Genotype: *Arca glycymeris* Linnaeus (tautonomy)

Glycymeris gigantea (Reeve)

(Plate 2, figures 1, 8)

Pectunculus giganteus REEVE (1843), Conch. Icon., vol. 1, *Pectunculus*, pl. 1, figs. 3a, 3b.
Pectunculus giganteus Broderip, LAMY (1909), Jour. de Conchyl., vol. 57, p. 208.
Glycimeris maculata (Broderip), GRANT AND GALE (in part) (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 136.
Glycimeris (*Glycimeris*) *gigantea* Reeve, HERTLEIN AND STRONG (1943), Zoologica, vol. 28, p. 150

Hypotypes nos. 30554 (loc. A 3670), 30555 (loc. A 3534).

OCCURRENCE: locs. A 3497, A 3508, A 3534, A 3536, A 3584, A 3598, A 3670.

RANGE: upper Pliocene to Recent.

REMARKS: The specimen here figured agrees well with Reeve's figures, showing the long oblique teeth that distinguish it from *G. maculata* with short, more nearly vertical teeth.

Glycymeris maculata (Broderip)

(Plate 2, figures 3, 5)

Pectunculus maculatus BRODERIP (1832), Proc. Zool. Soc. London, p. 126; REEVE (1843), Conch. Icon., vol. 1, *Pectunculus*, pl. 1, fig. 4; LAMY (1909), Jour. de Conchyl., vol. 57, p. 209.
Glycymeris maculata (Broderip), GRANT AND GALE (in part) 1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 136.
Glycimeris (*Glycimeris*) *maculata* Broderip, HERTLEIN AND STRONG (1943), Zoologica, vol. 28, p. 150–151.

Hypotypes nos. 30556, 30557 (loc. A 3582).

OCCURRENCE: locs A 3508, A 3534, A 3538, A 3548, A 3582, A 3584, A 3596.

RANGE: upper Pliocene to recent.

REMARKS: The teeth are more nearly vertical in this species in contrast to the horizontal teeth in *G. gigantea*. Possibly a large series might show a gradation between the two types of hinges. Externally they are very similar when fossilized.

Glycymeris multicostata (Sowerby)

(Plate 2, figures 2, 4)

Pectunculus multicostatus SOWERBY (1833), Proc. Zool. Soc. London for 1832, p. 195; REEVE (1843), Conch. Icon., vol. 1, *Pectunculus*, pl. 5, fig. 6; LAMY (1909), Jour. de Conchyl., vol. 57, p. 208.
Glycymeris multicostata (Sowerby), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 133–134.
Glycimeris (*Tuceta*) *multicostata* Sowerby, HERTLEIN AND STRONG (1943), Zoologica, vol. 28, p. 151.

Hypotypes nos. 30558, 30559 (loc. A 3550).

OCCURRENCE: locs. A 3508, A 3519, A 3534, A 3547, A 3548, A 3550, A 3582, A 3584, A 3598.

RANGE: upper Pliocene to Recent.

REMARKS: This species is abundantly represented at locs. A 3534, A 3550, A 3582.

Genus ***Pinna*** Linnaeus

Pinna LINNAEUS (1758), Syst. Nat., Ed. 10, p. 707.

Genotype: *Concha pinna* Hasselquist (*Pinna muricata* Linnaeus) (tautonomy)

Pinna corteziana n. sp.

(Plate 3, figures 2, 3)

Shell large, thin, elongate, resembling *P. latrania* Hanna; apical angle acute, 22°–23°; cross section approximately square and angular even at maturity; a heavy longitudinal sulcus in each valve filled with cartilage and beginning near beak; left half of each valve almost equal to right half; exterior of valves largely decorticated but with traces of 2–3 longitudinal ribs on each side of median sulcus, probably also spinose or tubercled.

Dimensions of holotype: length 302 mm (broken), height 117 mm, thickness (both valves) 113 mm.

Holotype no. 30560; paratype no. 30561 (loc. A 3547).

OCCURRENCE: loc. A 3547.

RANGE: Pleistocene.

REMARKS: This species most closely resembles *P. latrania* Hanna but may be separated by its smaller apical angle (23° compared to 27°) and by the more nearly square cross section (*P. latrania* is rhomboidal). *P. rugosa* Sowerby has a flattened cross section at maturity.

Pinna latrania Hanna

Pinna latrania HANNA (1926), Proc. Calif. Acad. Sci., ser. 4, vol. 14, p. 475, pl. 27, fig. 1, text fig. 1

Hypotype no. 30484 (loc. A 3556).

OCCURRENCE: loc. A 3556.

RANGE: lower Pliocene.

REMARKS: A single incomplete specimen with about the same apical angle and cross section as Hanna's species.

Pinna rugosa Sowerby

(Plate 4, figures 3, 4)

Pinna rugosa SOWERBY (1835), Proc. Zool. Soc. London, p. 84; REEVE (1858), Conch. Icon., vol. 11. *Pinna*, pl. 26, fig. 50; LAMY (1909), Jour. de Conchyl., vol. 57, p. 226; HERTLEIN AND STRONG (1943), Zoologica, vol. 28, p. 165.

Hypotypes nos. 30482, 30483 (loc. A 3547).

OCCURRENCE: loc. A 3547.

RANGE: Pleistocene, Recent.

REMARKS: The broader apical angle and more flattened cross section readily separate this species from *P. corteziana* n. sp.

Family PTERIDAE

Genus ***Pinctada*** Bolten

Pinctada BOLTEN (1798), Mus. Boltenianum, p. 166.
Meleagrina LAMARCK (1819), Anim. sans Vert., vol. 6, p. 150.

Pinctada mazatlanica (Hanley)

(Plate 2, figure 6)

Margaritiphora mazatlanica HANLEY (1855), Cat. Rec. Biv. Shells, p. 388, pl. 24, fig. 40.
Pinctada mazatlanica Hanley, HERTLEIN AND STRONG (1943), Zoologica, vol. 28, p. 164–165.

Hypotypes nos. 15965, 15966 (loc. A 3596).

OCCURRENCE: locs. A 3508, A 3519, A 3522, A 3527, A 3534, A 3550, A 3596.

RANGE: middle Pliocene to Recent.

Family PEDALIONIDAE

Genus ***Pedalion*** Solander

Pedalion SOLANDER, in HUDDESFORD (1770), edition of Martin Lister, Historiae Synopsis Conchyliorum, Index II, p. 22, 23.

Pedalion janus (Carpenter)

(Plate 3, figures 1, 4)

Isognomen janus CARPENTER (1856), Cat. Reigen Coll. Mazatlan Moll., p. 151–152.

Hypotypes nos. 30562, 30563, (loc. A 3534).

OCCURRENCE: loc. A 3519, A 3534.

RANGE: upper Pliocene to Recent.

REMARKS: This species may be separated from *P. chemnitzianum* by the generally thinner shell and the presence of fine radiating ribs.

Family OSTREIDAE

Genus ***Ostrea*** Linnaeus

Ostrea LINNAEUS (1758), Syst. Nat., Ed. 10, p. 696.

Genotype: *Ostrea edulis* Linnaeus (subs. desig. Children 1823)

Ostrea cumingiana Dunker

(Plate 5, figures 4, 6)

Ostrea cumingiana DUNKER (1846), Zeitschr. Malakozool., p. 48; PHILIPPI (1847) Abbild. Beschr. Conchyl., vol. 2, p. 81, *Ostrea*, pl. 1, figs. 1–4.

Hypotypes nos. 15424, 15425 (loc. A 3519).

OCCURRENCE: locs. A 3519, A 3521, A 3528, A 3534, A 3550, A 3582, A 3587, A 3596, A 3598.

RANGE: upper Pliocene to Recent.

Ostrea chilensis Philippi

(Plate 4, figure 1)

Ostrea chilensis Philippi, KUSTER (1845), Conch. Cab., ed. 2, p. 74, pl. 13, figs. 7–8; LAMY (1929), Jour. de Conchyl., vol. 73, p. 41–42.

Hypotypes nos. 15505 (loc. A 3536), 15549, 15550 (paired valves, loc. A 3596).

OCCURRENCE: locs. A 3536, A 3581, A 3596, Recent.

REMARKS: The hypotype from loc. A 3536 has an altitude of 160 mm, a length of 117 mm, and a thickness of about 38 mm (one valve). The ligamental groove is about 39 mm long and 42 mm wide.

Ostrea erici Hertlein

(Plate 4, figure 2)

Ostrea tayloriana Gabb, JORDAN AND HERTLEIN (1926), Proc. Calif. Acad. Sci., ser. 4, vol. 15, p. 428, pl. 33, fig. 3, not of GABB, 1869.
Ostrea erici HERTLEIN (1929), Jour. Paleo., vol. 3, p. 295.

Hypotype no. 15426, (loc. A 3509).

OCCURRENCE: locs. A 3509, A 3510.

RANGE: middle Pliocene.

Ostrea fischeri Dall

(Plate 6, figures 1, 4)

Ostrea jacobea DE ROCHEBRUNE (1895), Bull. Mus. Hist. Nat. Paris, vol. 1, p. 241; not of LINNEAUS (1758).
Ostrea fischeri DALL (1914), Nautilus, vol. 28, p. 1, new name for *O. jacobea* de Rochebrune, not Linneaeus; HERTLEIN AND STRONG (1945), Zoologica, vol. 31, p. 54–55.

Hypotypes nos. 15503, 15504 (loc. A 3521); 15502 (loc. A 3522).

OCCURRENCE: locs. 3521, A 3522, A 3525, A 3544, A 3557, A 3571.

RANGE: lower Pliocene to Recent.

REMARKS: The specimens referred to this species are large, flat, commonly about equidimensional, plicate forms. Those from localities A 3521 and A 3557 are very heavy, the others rather thin-shelled.

Ostrea megadon Hanley

(Plate 5, figure 3)

Ostrea megadon HANLEY (1946), Proc. Zool. Soc. London, p. 106; HERTLEIN AND STRONG (1946), Zoologica, vol. 31, p. 55.
Ostrea cerrosensis GABB (1866), Geol. Surv. Calif., Paleo., vol. 2, p. 35; (1868–9); p. 106, pl. 11, fig. 61.

Hypotype no. 15967 (loc. A 3558).

OCCURRENCE: locs. A 3498, A 3528, A 3529, A 3530, A 3558, A 3566, A 3568.

RANGE: lower and middle Pliocene, Recent.

REMARKS: This species occurred at numerous localities in the middle Pliocene beds where it was not collected.

Ostrea vespertina Conrad

(Plate 5, figures 1, 2, 5, 7)

Ostrea vespertina CONRAD (1854), Jour. Acad. Nat. Sci. Philadelphia ser. 2, vol. 2, p. 300; WOODRING (1938), U. S. Geol. Surv., Prof. Paper 190, p. 42–47, pl. 8, figs. 1, 2, 3, 4, 8, 9; pl. 9, fig. 5.
Ostrea veatchii GABB (1866), Geol. Surv. Calif., Paleo., vol. 2, p. 35; (1869) Geol. Surv. Calif., Paleo., vol. 2, p. 60, 106, pl. 11, fig. 59; pl. 17, fig. 21a.

Hypotypes nos. 15957 (loc. A 3557), 15955 (loc. A 3524), 15956 (loc. A 3591).

OCCURRENCE: locs. A 3498, A 3505, A 3506, A 3509, A 3510, A 3513, A 3523, A 3524, A 3528, A 3529, A 3530, A 3533, A 3535, A 3536, A 3441, A 3543, A 3544, A 3545, A 3546, A 3549, A 3555, A 3557, A 3558, A 3559, A 3561, A 3563, A 3566, A 3568, A 3576, A 3578, A 3581, A 3583, A 3589, A 3590, A 3591, A 3592, A 3670.

RANGE: lower to upper Pliocene.

REMARKS: *O. veatchii* Gabb has previously been thrown into the synonymy of *O. vespertina* Conrad by Stewart and later workers. However, it is noticeable in the present collections that most of the specimens are of the *O. veatchii* type rather than the typical *O. vespertina*. Those specimens from localities A 3555, A 3557, and A 3558 (from the older beds) are very close to the typical form. Associated with the *vespertina-veatchii* types at various localities are large circular plicate forms that closely resemble *O. heermani* Conrad. However, there are all gradations from these into the ovate plicate type. The *O. veatchii* forms are the most common in the younger beds and ordinarily may be distinguished from the *O. vespertina* form by their greater number of plications. The recent *O. cumingiana* Dunker may be separated by commonly having the area beneath the ligament rather deeply excavated, by the muscle scar being nearly at right angles to the altitude of the shell, and by the left valve being plicate only around the periphery. In *O. vespertina* the muscle scar slants obliquely upward and forward and is drawn out in a point in this direction, and the excavation, when present beneath the ligament, is very shallow.

Family PECTINIDAE

Genus ***Pecten*** Müller

Pecten MÜLLER (1776), Zoologia Danicae Prodromus, p. 31, 248.

Genotype: *Ostrea maxima* Linnaeus (subs. desig. Children, 1823)

Subgenus ***Pecten*** s.s.

Pecten (Pecten) bellus var. ***hemphilli*** Dall

(Plate 7, figures 3, 5)

Pecten hemphilli DALL (1879), Proc. U. S. Nat. Mus., vol. 1, p. 15.
Pecten (Pecten) bellus Conrad, JORDAN AND HERTLEIN (in part) (1926), Proc. Calif. Acad. Sci., ser. 4, vol. 15, p. 430–431, pl. 32, fig. 2; pl. 33, figs. 1, 2; pl. 34, figs. 2, 3, 4.
Pecten (Janira) bellus (Conrad) var. *hemphilli* Dall, GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 226–227, pl. 3, figs. 1a, 1b.

Hypotypes: Calif. Acad. Sci. Paleo. Type Coll. nos. 5985, 7860, C.A.S. loc. 795.

OCCURRENCE: C.A.S. loc. 795.

RANGE: middle Pliocene.

REMARKS: This species was not noted from this locality in Hanna and Hertlein's list (1927, p. 145) but was found during an examination of the original material. Inasmuch as it has not been found elsewhere within the Gulf of California collections, the possibility of it having been accidentally mixed in the collections was considered. Examination of matrix adhering to it revealed that the mineral assemblage present was the same as in other undoubted material from the locality and not the same as is found at San Diego or Cedros Island where this species commonly occurs.

Further examination of uncleaned material from this locality revealed two fragmentary and one very large complete right valve (Pl. 7, fig. 5). This last specimen has a height of 109 mm high. During its later growth stages the ribs become somewhat lower and more rounded. The smaller specimen with both valves exactly matches some specimens of *hemphilli* from the type area.

No specimens having the character of typical *bellus* were noted.

Pecten (Pecten) bösei Hanna and Hertlein

(Plate 7, figure 1)

Pecten (Pecten) bösei HANNA AND HERTLEIN (1927), Proc. Calif. Acad. Sci., ser. 4, vol. 16, p. 153–154, pl. 5, figs. 2, 3.
Pecten (Janira) stearnsii Dall var. *bakeri* Hanna and Hertlein, GRANT AND GALE (in part) (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 224, 225.

Hypotype no. 16000 (loc. A 3566).

OCCURRENCE: locs. A 3536; A 3566, C. A. S. loc. 795.

RANGE: middle Pliocene.

REMARKS: This species may be distinguished from *P. bakeri* by the right valve being much more convex than the left which is but slightly convex, and by the nondevelopment of the secondary riblets on the primaries of the left valve when the specimen is over 60 mm high.

A very similar species occurs in the late Miocene or Pliocene of Venezuela. (*See* pl. 7, fig. 2.) This later species may be separated by its more rounded ears and slightly deeper byssal notch.

Pecten* (*Pecten*) *carrizoensis Arnold

(Plate 8, figures 1, 3)

Pecten carrizoensis ARNOLD (1906), U. S. Geol. Surv., Prof. Paper 47, p. 59–60, pl. 4, figs. 1–3a.
Pecten carrizoensis Arnold, HANNA (1926), Proc. Calif. Acad. Sci., ser. 4, vol. 14, p. 470.

Hypotypes nos. 15973, 15974, (loc. A 3576).

OCCURRENCE: locs. A 3576, A 3578.

RANGE: lower Pliocene.

REMARKS: A right valve (incomplete) has a present altitude of 41.2 mm, a left valve is 51.1 mm high. *Pecten* (*Pecten*) *lecontei* Arnold from Cedros Island is very similar except that the left valve is usually entirely concave instead of first concave and then convex as in *P. carrizoensis*.

Pecten* (*Pecten*) *vogdesi Arnold

(Plate 8, figures 4, 6)

Pecten dentatus G. B. SOWERBY (1835), Proc. Zool. Soc. London, p. 109. Not *Pecten dentatus* J. SOWERBY (1829), Min. Conch. Gt. Brit., vol. 6, p. 143, pl. 574, fig. 1.
Pecten (*Pecten*) *vogdesi* ARNOLD (1906), U. S. Geol. Surv., Prof. Paper 47, p. 100, pl. 33, figs. 1, 1a; pl. 34, fig. 1; HERTLEIN AND STRONG (1946), Zoologica, vol. 31, p. 57.
Pecten (*Euvola*) *cataractes* DALL (1914), Nautilus, vol. 27, p. 121, new name for *Pecten dentatus* G. B. Sowerby.

Hypotypes nos. 15975, 15976 (loc. A 3521).

OCCURRENCE: locs. A 3508, A 3513, A 3517, A 3519, A 3520, A 3521, A 3524, A 3527, A 3531, A 3534, A 3548, A 3550, A 3559, A 3562, A 3566, A 3573, A 3574, A 3582, A 3584, A 3596, A 3598, A 3670.

RANGE: lower Pliocene to Recent.

REMARKS: No consistent difference has been noted between the Pliocene and Recent specimens. The secondary riblets are rarely present.

Subgenus ***Euvola*** Dall

Euvola DALL (1898), Trans. Wagner Free Inst. Sci., vol. 3, p. 694.

Subgenotype: *Ostrea ziczac* Linnaeus (original designation)

Pecten* (*Euvola*) *keepi Arnold

(Plate 6, figures 5, 6)

Pecten (*Pecten*) *keepi* ARNOLD (1906), U. S. Geol. Surv., Prof. Paper 47, p. 60–61, pl. V, fig. 1; pl. VI, figs. 1, 1a.

Hypotypes nos. 15427, 15429 (loc. A 3583).

OCCURRENCE: locs. A 3581, A 3583, Imperial formation (type area).

RANGE: lower Pliocene, San Marcos and Imperial formations.

REMARKS: The ears of the left valve are more concave and more definitely set off than on *P. refugioensis* Hertlein; further, the apical angle is greater.

Pecten* (*Euvola*) *refugioensis Hertlein

(Plate 6, figure 3)

Pecten (*Pecten*) *refugioensis* HERTLEIN (1925), Proc. Calif. Acad. Sci., ser. 4, vol. 14, p. 7, pl. 1, fig. 2; pl. 5, fig. 9.

Hypotype: Calif. Acad. Sci. Paleo. Type Coll. no. 604, C.A.S. loc. 795.

OCCURRENCE: C.A.S. loc. 795.

RANGE: middle Pliocene.

Genus *Aequipecten* Fischer

Aequipecten FISCHER (1886), Man Conchyl., p. 944.

Genotype: *Ostrea opercularis* Linnaeus (monotypic)

Aequipecten abietis (Jordan and Hertlein)

(Plate 10, figures 4, 7; Plate 11, figure 4)

Pecten (*Plagioctenium*) *abietis* JORDAN AND HERTLEIN (1926), Proc. Calif. Acad. Sci., ser. 4, vol. 15, p. 214–215, pl. 23, figs. 1, 3, 7.

Hypotypes nos. 15511, 15512, 15513, 15514, 15515, 15516, 15517, 15520, 15521, 15522 (all from loc A 3557).

OCCURRENCE: localities A 3509, A 3510, A 3513, A 3516, A 3518, A 3524, A 3528, A 3529, A 3530, A 3531, A 3532, A 3533, ? A 3537, A 3541, A 3545, A 3552, A 3555, A 3556, A 3557, A 3559. A 3561, A 3565, A 3571, A 3578, A 3589, A 3590.

REMARKS: The byssal notch varies somewhat in depth but is never so deep as in the living *Pecten purpuratus* or *Pecten circularis;* further, the anterior ear is not so produced in proportion to its width as in those two species. The ribs normally have a low V-shaped profile, thus differing from the two aforementioned living forms in which the sides of the ribs are nearly vertical.

This species is very abundant in the Arroyo de Gua-Arroyo de Arce area where it is by far the dominant form in thick *Pecten* reef beds. Over 50 well-preserved specimens from loc. A 3557 were examined. Many more could have easily been collected if there had been facilities for bringing them in from the field.

In some well-preserved specimens at loc. A 3524 the byssal notch is extremely shallow, in others it is of the normal type. Two individuals from loc. A 3555 have much higher ribs than the average. A specimen from loc. A 3559 is 110 mm high, and as heavy as *A. hakei* (Hertlein), but appears to have the ears of the present species. At loc. A 3589 many small specimens have the V-shaped ribs flat-topped, but on the larger individuals these ribs grade into those of the typical form.

A few specimens from loc. A 3557 are very close to *Pecten mendenhalli* Arnold, but the rest are more typical of *A. abietis*. It is possible that additional collecting at Santa Rosalia (type locality for *P. mendenhalli*) may show that the two species are the same.

Aequipecten antonitaensis n. sp.

(Plate 9, figures 1, 5)

Shell small, resembling *A. percarus* (Hertlein); moderately convex, nearly equivalved; ornamented by 22 moderately high, rounded ribs with nearly vertical sides; on right valve interspaces about half as wide as ribs, on left valve equal in width to ribs; radial ribs crossed by fine concentric growth lines; extreme lateral margins smooth; hinge line 0.6 length of shell; ears unequal, elongate, anterior slightly longer than posterior; a large byssal notch in right valve; anterior ear of left valve decidedly alate; posterior ears slightly drawn out; anterior ear with about 7 radial ribs, posterior ear with about 8.

Dimensions of holotype: Length 41.8 mm, height 41 mm, length of hinge line 25 mm.

Holotype: Calif. Acad. Sci. Paleo. Type Coll. no. 5957, paratypes Univ. Calif. Mus. Pal. nos. 30472, 30473; all from C.A.S. loc. 795.

OCCURRENCE: C.A.S. loc. 795.

RANGE: middle Pliocene.

REMARKS: The long narrow anterior ear with that of the left valve being drawn out is very characteristic. The ears suggest *A. percarus* (Hertlein) but are longer in proportion to length of shell. It is also similar to some specimens of *A. impostor* (Hanna) but may be separated by the more produced posterior ears of the present species.

Aequipecten circularis (Sowerby)

(Plate 10, figures 1, 5)

Pecten circularis SOWERBY (1835), Proc. Zool. Soc. London, p. 110; (1842) Thes. Conch., vol. 1, p. 51, pl. 12, fig. 23.
Pecten ventricosus SOWERBY (1842), Thes. Conchyl., vol. 1, p. 51, pl. 12, figs. 18, 19, 26.
Pecten (*Plagioctenium*) *circularis* Sowerby, HERTLEIN AND STRONG (1946), Zoologica, vol. 31, p. 57–58

Hypotypes nos. 15625, 15628, 15706, 15740 (all from loc. A 3523).

OCCURRENCE: locs. A 3519, A 3521, A 3523, A 3548, A 3550, A 3562, A 3573, A 3582, A 3584, A 3588, A 3591, A 3592, A 3596.

RANGE: upper Pliocene to Recent.

REMARKS: Some of the specimens from locs. A 3519, A 3521, A 3523 have a lower height in proportion to their length, but the number of specimens available is not sufficient to determine whether this character is consistent.

Aequipecten circularis subsp. ***bramkampi*** n. subsp.

(Plate 9, figures 2, 4, 8)

Shell of medium size, resembling *A. circularis* in general outline, but with high, prominent beaks; 19 ribs, wide and rounded, interspaces narrow and channeled at bottom; beaks laterally compressed and slightly overhanding hinge line, with ears sharply delimited by an impressed area; anterior ear of right valve with about four radial ribs; byssal notch deep and sharply pointed; posterior ear of right valve with extremely faint and fine radial ribs. Both ears of left valve with 6–8 fine radial ribs.

Dimensions (in mm):	*Height*	*Length*	*Thickness*
Holotype (right valve)	44.1	43.2	14.0
Paratype (left valve)	38.8	37.3	10.6

Holotype no. 30035, paratype no. 30045 (loc. A 1268).

OCCURRENCE: loc. A 1268 (Imperial formation), A 3594.

RANGE: lower Pliocene.

REMARKS: The material from loc. A 3594 is poorly preserved but appears to be conspecific with the much better material from the Imperial formation. This latter material because of its preservation has been made the type of the subspecies. The high, overhanging, laterally compressed beaks separate this subspecies from the typical form.

Aequipecten deserti (Conrad)

(Plate 11, figures 5, 6)

Pecten deserti CONRAD (1855), "Descr. Foss. and Rec. Shells", House Doc. 129, p. 15; (1856), U. S. Pac. R. R. Surv. Rept., vol. 5, p. 325, pl. 5, fig. 41.
Pecten (*Plagioctenium*) *deserti* Conrad, ARNOLD (1906), U. S. Geol. Surv., Prof. Paper 47, p. 85, pl. 26, figs. 1–4a.

Hypotypes nos. 15485, 15486, 15489 (loc. A 3583).

OCCURRENCE: locs. A 3581, A 3583, Imperial formation (type area).

RANGE: lower Pliocene, San Marcos and Imperial formations.

Aequipecten revellei n. sp.

(Plate 9, figures 3, 6, 9)

Shell of medium size, equivalved, beaks low, not prominent, very similar to *A. subdolus* (Hertlein); right valve with 22–23 low rounded ribs with very narrow V-shaped interspaces; left valve with corresponding ribs but wider interspaces; anterior ear of right valve with a moderately developed byssal notch and about four fairly wide radial ribs; posterior ear with numerous fine radial ribs, becoming obsolete near hinge line; ears of left valve correspondingly ornamented; hinge line between seven-twelfths and two-thirds the length of the shell, thus separating this species from *A. subdolus* (Hertlein) which has a hinge line only very slightly over half as long as the length of the shell.

Dimensions of holotype: Length 60.0 mm, height 58.1 mm, thickness (both valves) 25 mm, length of hinge line 36.4 mm.

Holotype no. 15510, paratypes nos. 15555, 15556, 15623 (all from loc. A 3566).

OCCURRENCE: locs. A 3498, A 3505, A 3566, A 3568.

RANGE: middle Pliocene.

Aequipecten sverdrupi n. sp.

(Plate 8, figures 2, 5; Plate 9, figure 7)

Shell of medium size, fairly heavy, resembling *A. impostor* (Hanna) but having only 17 or 18 heavy rounded ribs; obliqueness of valves varying considerably, some specimens being markedly oblique to posterior; ribs rounded, interspaces about half as wide; in one small specimen the younger half of shell, after a heavy constriction representing a marked pause in growth, shows very high ribs on right valve with relatively narrow interspaces, while on left valve the ribs are high but with wide interspaces; anterior ears missing from all six valves at hand; however, the traces of byssal notch present indicate that it was deep and fairly sharply angled, like that of *A. circularis*.

Dimensions (in mm):	*Height*	*Length*	*Thickness*
Holotype (right valve)	54.4	56.8	13.7 (approx.)
Paratype (left valve)	50.4	53.4	12.3

Holotype no. 15995, paratypes nos. 15996, 15997, 15998 (all from loc. A 3583).

OCCURRENCE: locs. A 3576, A 3583, loc. 740 (Imperial formation).

RANGE: lower Pliocene.

REMARKS: The 17–18 heavy rounded ribs appear to be characteristic of this species.

Genus **Chlamys** Bolten

Chlamys BOLTEN (1798), Mus. Boltenianum, p. 161.

Genotype: *Pecten islandicus* (Linnaeus) (subs. desig. Herrmannsen)

Chlamys corteziana n. sp.

(Plate 10, figures 2, 3, 6)

Pecten sancti-ludovici Anderson and Martin, HANNA (1926), Proc. Calif. Acad. Sci., ser. 4, vol. 14, p. 473, pl. 22, figs. 1, 2, 3; not *Pecten sancti-ludovici* ANDERSON AND MARTIN (1914).

Shell of medium size, right valve slightly more inflated than left; sculpture discrepant on the two valves; right valve with 17–18 low rounded ribs with interspaces about equal in size, ribs and interspaces each bearing equally spaced finely beaded riblets with an occasional tertiary riblet present; near umbo the primary ribs are higher and nearly square-sided but as shell becomes larger ribs spread out and become low and rounded; anterior ear of right valve with about 12 fine beaded riblets; riblets on posterior ear less distinct than on anterior; left valve with a corresponding number of high, square-sided and noded ribs about two thirds as wide as flat-bottomed interspaces, occasionally a secondary beaded, flat-sided riblet is developed on sides of primary rib.

Dimensions of holotype (incomplete ventral margin): Length 32.8 mm, height (estimated) 31.5 mm, thickness (one valve, estimated) 7 mm.

Holotype no. 30564 (loc. A 3579); paratype nos. 34031, 34032 (loc. A 1267).

OCCURRENCE: locs. A 1267 (Imperial formation) and A 3579 (San Marcos formation).

RANGE: lower Pliocene.

REMARKS: This species somewhat resembles *Chlamys lowei* (Hertlein) living in the Gulf of California but may easily be separated by the larger posterior ear and more rounded interspaces on the right valve. *Pecten* (*Chlamys*) *buchivacoanus* F. and H. Hodson and its subspecies from the Miocene of Venezuela is another closely related species, but its left valve has many more secondary and tertiary riblets.

This species is rather abundant in the Imperial formation at loc. A 1267.

Chlamys dallasi (Jordan and Hertlein)

(Plate 6, figure 2)

Pecten (*Chlamys*) *dallasi* JORDAN AND HERTLEIN (1926), Proc. Calif. Acad. Sci., ser. 4, vol. 15, p. 213–214, pl. 23, figs. 2, 5, 6, 8.

Hypotypes nos. 15451, 15454 (loc. A 3505); 15461 (loc. A 3498).

OCCURRENCE: locs. A 3498, A 3505.

RANGE: middle Pliocene, Carmen formation.

REMARKS: Only three specimens were found in the collections.

Genus ***Lyropecten Conrad***

Lyropecten CONRAD (1862), Proc. Acad. Nat. Sci. Philadelphia, vol. 14, p. 291.

Genotype: *Pallium estrellanum* Conrad (subs. desig. Dall, 1898)

Lyropecten mediacostatus (Hanna)

(Plate 7, figure 4)

Pecten mediacostatus HANNA (1926), Proc. Calif. Acad. Sci., ser. 4, vol. 14, p. 472, pl. 22, fig. 6; pl. 24, fig. 2.

Hypotype no. 30046 (loc. A 3576).

OCCURRENCE: locs. A 3576, A 3713, Imperial formation (type area).

RANGE: lower Pliocene, San Marcos and Imperial formations.

REMARKS: Two incomplete right valves were found at loc. A 3576. They have about 24 low rounded ribs with an intercalary in each interspace. Interspaces about half as wide as ribs. Posterior ear smooth above, faintly striated below. The hypotype is 47.2 mm high and 46.0 mm long (approximate). Hanna's specimens are compressed laterally so that the figures appear to have a much narrower apical angle. *Pecten interlineatus aidei* (Williston MS) Harris (Hodson, Hodson and Harris, 1927, p. 29, pl. 15, figs. 6, 9) from the Miocene of Venezuela is closely related but may be distinguished by the much heavier interribs in the interspaces.

Lyropecten modulatus (Hertlein)

(Plate 11, figure 7)

Pecten (*Lyropecten*) *modulatus* HERTLEIN (1925), Proc. Calif. Acad. Sci., ser. 4, vol. 14, p. 11–12, pl. 3, fig. 6.

Hypotype no. 15449 (loc. A 3556).

OCCURRENCE: loc. A 3556; Salada formation (Mesa west of Mesa de los Auras, Scammon Lagoon quadrangle—the type locality).

RANGE: lower Pliocene.

REMARKS: The single specimen is somewhat crushed, a right valve with only 9 ribs and the interspaces about half as wide as the ribs. The altitude of the specimen is 64.4 mm, the length 65.2 mm, the thickness (one valve) 13.5 mm.

Lyropecten subnodosus (Sowerby)

(Plate 11, figure 1)

Pecten subnodosus SOWERBY (1835), Proc. Zool. Soc. London, p. 109; (1842), Thes. Conch., vol. 1, p. 65, pl. 15, figs. 97, 112.

Pecten (*Lyropecten*) *subnodosus* Sowerby, HERTLEIN AND STRONG (1946), Zoologica, vol. 31, p. 58.

Hypotype no. 15414 (loc. A 3548).

OCCURRENCE: locs. A 3498, A 3505, A 3506, A 3508, A 3517, A 3519, A 3521, A 3522, A 3524, A 3525, A 3537, A 3548, A 3550, ? A 3558, A 3561, 3563, A 3568, A 3573, A 3578, A 3582, A 3584, A 3591, A 3596.

RANGE: lower Pliocene to Recent.

REMARKS: Grant and Gale (1931, p. 179–182) united this species with *Pecten nodosus* (Linnaeus). However, the two may easily be separated by the fewer interribs (usually 3 or 4) of that species compared to 6 or 8 on Sowerby's species. Further, *L. subnodosus* is usually more inflated. A large specimen from loc. A 3591 has much less than the normal degree of inflation but still retains the greater number of interribs. Many of the specimens from loc. A 3521 are similarly less inflated, a condition that has not been noted in any of the recent specimens. In all, over 75 fossil specimens have been examined. The specimens from locs. A 3558 and A 3568 are much less inflated than the typical form, and, inasmuch as they are from the older beds, they may represent a new species, but as they are not well preserved one cannot be certain. *Pecten subnodosus* Sowerby of Hanna (1926, p. 474, pl. 25, fig. 6) seems to represent an undescribed species. The valve has very little convexity and appears to have only 2 or 3 interribs.

A large right valve from loc. A 3547 has an altitude of 170.5 mm, a length of 174.3 mm, and a thickness (one valve) of 44 mm.

Genus ***Patinopecten Dall***

Patinopecten DALL (1898), Trans. Wagner Free Inst. Sci., vol. 3, p. 695.

Genotype: *Pecten caurinus* Gould (orig. desig.)

Patinopecten bakeri (Hanna and Hertlein)

(Plate 12, figure 1; Plate 13, figure 7)

Pecten (*Patinopecten*) *bakeri* HANNA AND HERTLEIN (1927), Proc. Calif. Acad. Sci., ser. 4, vol. 16, p. 153–154, pl. 5, fig. 1.

Pecten (*Janira*) *stearnsii* Dall var. *bakeri* Hanna and Hertlein, GRANT AND GALE (in part) (1931). Mem. San Diego Soc. Nat. Hist., vol. 1, p. 224–225, not pl. 4, figs. 1a, 1b.

Hypotypes nos. 30050, 30053 (both from loc. A 3557).

OCCURRENCE: locs. A 3530, A 3557, A 3558.

RANGE: lower Pliocene.

REMARKS: Six specimens ranging in geight from 46–143 mm were found at loc. A 3557 which is near the type locality.

The ribs on the left valve are rather low and are not distinctly square-sided, but have a rounded appearance. On the surface of the primary ribs there are three to four fine secondary ribs. Laterally on the left valve, both anteriorly and posteriorly, there is a considerable area of fine ribbing. This species may easily be distinguished from *Pecten healeyi* Arnold by the less prominent ribs and by the greater apical angle. It is obviously of the same stocks as *P. caurinus* Gould, rather than the *P. stearnsii* Dall stock to which Grant and Gale assigned it. Their figured specimen appears to be *P. bakeri* subsp. *diazi* n. subsp. *P. bakeri* may be separated from the subspecies *diazi* by having the interspaces and ribs of the right valve of approximately the same width.

Patinopecten bakeri subsp. ***diazi*** n. subsp.

(Plate 12, figure 2; Plate 13, figure 4)

Pecten (*Janira*) *stearnsii* Dall var. *bakeri* Hanna and Hertlein, GRANT AND GALE (in part) (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 224–225, pl. 4, figs. 1a, 1b.

At a number of localities Patinopectens of the *P. bakeri* stock may be separated from the typical form by the partial or complete obsolescence of the anterior and posterior areas of fine ribbing and by the squarer sides of the major ribs of the left valve. On the same valve, the secondary riblets on the primary ribs are commonly entirely absent or very feeble, and the tertiary intercalaries in the interspaces are missing. In the central areas of the right valve the primary ribs are $1\frac{1}{4}$–$1\frac{1}{2}$ times as wide as the interspaces, whereas in the typical form they are approximately of equal width.

Dimensions of holotype: Height 122.8 mm, length 136.3 mm, thickness (approximate, both valves) 21.0 mm.

Holotype no. 15968, paratypes nos. 15969, 15970 (loc. A 3566).

OCCURRENCE: locs. A 3498, ? A 3505, A 3541, A 3566, ? A 3568; C.A.S. loc. 795; Santa Rosalia (Grant and Gale, 1931, figured specimen).

RANGE: middle Pliocene.

REMARKS: Ten left valves from loc. A 3566 were available for examination. The smallest is 66 mm, and the largest 136 mm high. Several specimens of both typical *bakeri* and the new subspecies have both valves associated and show that the left valve is about one-twentieth larger than the right. The specimen figured by Grant and Gale appears to be typical of this subspecies.

Patinopecten marquerensis n. sp.

(Plate 14, figures 1, 2)

Shell large; in general outline, ornamentation, and size very similar to *P. bakeri.* Right valve with about 20 prominent primary ribs, $1\frac{1}{2}$ times as wide as the interspaces. Anterior and posterior to these are several finer ribs. Interspaces without intercalaries. Left valve with an equivalent number of low inverted V-shaped primary ribs, with three secondary riblets, one on each side and one at apex of V. Interspaces with a single intercalary riblet. On an unworn specimen the posterior margin has an area of fine ribbing similar to that on typical *P. bakeri.*

Dimensions of holotype: Height 154.5 mm, length 176.4 mm, thickness (both valves) 33.4 mm.

Holotype no. 15475, paratypes nos. 15462, 15470 (loc. A 3518).

OCCURRENCE: loc. A 3518.

RANGE: upper Pliocene.

REMARKS: One complete specimen, four left valves, and three right valves were available for examination from loc. A 3518. The inverted V-shaped ribs with three secondaries on the left valve together with the absence of any intercalaries on the right valve, and the central primary ribs of the right valve being half again as wide as the interspaces separates this species from *P. bakeri* and its subspecies *diazi.*

Family LIMIDAE

Genus *Lima* Cuvier

Lima CUVIER (1798) Tabl. Elem. Hist. Nat. Anim., p. 421.

Genotype: *Ostrea lima* Linnaeus (tautonomy)

Lima tetrica Gould

(Plate 11, figures 2, 3)

Lima tetrica GOULD (1851), Proc. Boston Soc. Nat. Hist., vol. 4, p. 93; 1857), Boston Jour. Nat. Hist., vol. 6, p. 405, pl. 16, fig. 6; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 239.

Lima (Lima) tetrica Gould, HERTLEIN AND STRONG (1946), Zoologica, Vol. 31, p. 65.

Hypotype no. 30665 (loc. A 3548).

OCCURRENCE: loc. A 3548.

RANGE: Pleistocene, Recent.

REMARKS: Of the four fossil specimens at hand, one is somewhat more inflated than the others.

Family SPONDYLIDAE

Genus *Spondylus* Linnaeus

Spondylus Linnaeus (1758), Syst. Nat., Ed. 10, p. 690.

Genotype: *Spondylus gaederopus* Linnaeus

Spondylus crassisquama Lamarck

(Plate 15, figure 1)

Spondylus crassisquama LAMARCK (1819), Hist. Nat. Anim. sans Vert., vol. 6, p. 191; JORDAN AND HERTLEIN (1926), Proc. Calif. Acad. Sci., ser. 4, vol. 15, p. 445.

Hypotypes nos. 15415, 15417 (loc. A 3522)
OCCURRENCE: locs. A 3522, A 3525.
RANGE: Pleistocene, Recent.

Spondylus victoriae Sowerby

(Plate 15, figure 3)

Spondylus victoriae SOWERBY (1859), Proc. Zool. Soc. London, p. 428, pl. 49, fig. 8; CARPENTER (1864), Rept. Brit. Assoc. Adv. Sci., p. 41.

Hypotypes nos. 15418, 15422 (A 3548).
OCCURRENCE: locs. ? A3528, A 3547, A 3548.
RANGE: lower Pliocene, Pleistocene, Recent.

REMARKS: This species is higher in proportion to its length, has a broader hinge line, heavier teeth, and fewer less prominent spines than *S. crassisquama* Lamarck. The present specimens agree very well with recent specimens labelled as being this species but have not been compared with Sowerby's original figures.

Spondylus sp.

Hypotypes nos. 15963, 15964 (loc. A 3557).
OCCURRENCE: loc. A 3557.
RANGE: lower Pliocene.

REMARKS: About a third of each valve of a single individual were found. Besides the primary rows of spines there are numerous fine spines of various ranks, strongly suggesting some specimens of *S. crassisquama.*

Genus *Plicatula* Lamarck

Plicatula LAMARCK (1801), Syst. Anim. sans Vert., vol. 1, p. 132.

Genotype: *Spondylus plicatus* Linnaeus (*Plicatula imbricata* SOWERBY, Thes. Conch., vol. 1, p. 437, pl. 91, figs. 15, 16) (subs. desig. Schmidt, 1818).

Plicatula inezana n. sp.

(Plate 13, figures 1, 3, 6)

Shell of medium size, inflated, right valve considerably deeper than left. Ornamented by 18–25 imbricated plications of which some bifurcate near margin. These imbrications are drawn out to form prominent semitubular spines up to 4 mm long. Spines are most prominent on posterior medial plications.

Dimensions of holotype: Height 41.4 mm, length 34.8 mm, thickness 25 mm (approximate, both valves).

Hypotype no. 15532; paratypes nos. 15533, 15534 (all from loc. A 3584).

OCCURRENCE: locs. A 3547, A 3582, A 3584.

RANGE: Pleistocene.

REMARKS: The outer layer of the shell which bears the spines is very easily lost; one of the paratypes shows this condition and produces a greatly different-appearing shell. This species apparently most closely resembles *P. ramosa* Lamarck as figured by Reeve. However, according to the description that species lacks the spines present on this one.

Plicatula penicillata Carpenter

(Plate 13, figures 2, 5)

Plicatula penicillata CARPENTER (1856), Cat. Reigen Coll. Mazatlan Mollusca, p. 155–156; REEVE (1873), Conch. Icon., vol. 19, *Plicatula*, pl. 1, fig. 3; LAMY (1909), Jour. de Conchyl., vol. 57, p. 217; HERTLEIN AND STRONG (1946), Zoologica, vol. 31, p. 63.

Hypotypes nos. 15918, 15921, 15927, 15928 (two complete individuals from loc. A 3550).

OCCURRENCE: loc. A 3519, A 3534, A 3550.

REMARKS: The specimens referred to this species are small, rather irregular, with the right valve much deeper than the left.

Plicatula spondylopsis de Rochebrune

(Plate 15, figure 2)

Plicatula spondylopsis DE ROCHEBRUNE (1895), Bull. Mus. Hist. Nat. Paris, vol. 1, p. 242; HERTLEIN AND STRONG (1946), Zoologica, vol. 31, pp. 63–64, pl. 1, figs. 15, 16.
Plicatula gibbosa Lamarck var. *spondylopsis* de Rochebrune, LAMY (1909), Jour. de Conchyl., vol. 57, p. 216.

Hypotype no. 14898 (loc. A 3563).

OCCURRENCE: locs. A 3519, A 3563.

RANGE: upper Pliocene, Recent.

REMARKS: The large, heavy, elongate, plicated shell without any spines easily separates this species.

Family MYTILIDAE

Genus ***Volsella*** Scopoli

Volsella SCOPOLI (1777), Introd. Hist. Nat., p. 397.
Modiolus LAMARCK (1799), Mem. Soc. Hist. Nat. Paris, p. 87.

GENOTYPE: *Mytilus modiolus* Linnaeus (subs. desig., Gray, 1847).

Volsella capax (Conrad)

(Plate 16, figure 12)

Modiola capax CONRAD (1837), Jour. Acad. Nat. Sci. Philadelphia, vol. 7, p. 242.
Volsella capax (Conrad), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 249.
Modiolus capax Conrad, JORDAN (1936), Contrib. Dept. Geol., Stanford Univ., vol. 1, p. 122–123.
Volsella (*Volsella*) *capax* Conrad, HERTLEIN AND STRONG (1946), Zoologica, vol. 31, p. 72.

Hypotype no. 30566 loc. (3582).

OCCURRENCE: locs. A 3520, A 3582, A 3584, A 3598.

RANGE: Pleistocene, Recent.

Family THRACIIDAE

Genus *Cyathodonta* Conrad

Cyathodonta CONRAD (1849), Proc. Acad. Nat. Sci. Philadelphia, vol. 4, p. 155, 156.

Genotype: *Cyathodonta undulata* Conrad (monotypic)

Cyathodonta dubiosa Dall

(Plate 16, figures 2, 7)

Cyathodonta dubiosa DALL (1915), Proc. U. S. Nat. Mus., vol. p. 445; HERTLEIN AND STRONG (1946), Zoologica, vol. 31, p. 96.
Thracia (*Cyathodonta*) *undulata* (Conrad), GRANT AND GALE (in part) 1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 259.
Thracia (*Cyathodonta*) *dubiosa* Dall. PILSBRY AND LOWE (1933), Proc. Acad. Nat. Sci. Philadelphia vol. 84, p. 138.

Hypotype no. 30567 (loc. A 3670).

OCCURRENCE: locs. A 3582, A 3670.

RANGE: upper Pliocene to Recent.

REMARKS: The plications become obsolete on the posterior margin of the shell. The pallial sinus reaches a point directly under the beak.

Family CRASSATELLITIDAE

Genus *Crassatellites* Krueger

Crassatellites KRUEGER (1823), Geschichte der Urwelt, vol. 2 p. 466.

Genotype: *Crassatella sinuata* Lamarck (= *Crassatella gibbosula* Lamarck), Eocene, Paris Basin (subs. desig. Harris, 1897)

Crassatellites digueti Lamy

(Plate 16, figures 5, 13)

Crassatella undulata SOWERBY (1932), Proc. Zool. Soc. London, p. 56; not *Crassatella undulata* LAMARCK 1805, not SAY 1824.
Crassatellites digueti LAMY (1917), Jour. de Conchyl. vol. 62, p. 217.
Crassatellites (*Hypolophus*) *digueti* Lamy, HERTLEIN AND STRONG (1946), Zoologica, vol. 31, p. 102–103.

Hypotype no. 30568 (loc. A 3584).

OCCURRENCE: locs. A 3582, A 3584.

RANGE: Pleistocene, Recent.

REMARKS: This species is sharply elongated posteriorly, fairly tumid, with moderately prominent beaks. The sides of the anterior and middle (posterior obsolete) cardinals have prominent vertical grooves; those of the left valve interlock with those of the right.

Crassatellites laronus Jordan

(Plate 16, figures 8, 14)

Crassatellites laronus JORDAN (1932), Nautilus, vol. 46, no. 1, p. 9; JORDAN (1936), Contrib. Dept. Geol., Stanford Univ., vol. 1, p. 124–125, pl. 17, figs. 6, 7.

Hypotype no. 30569 (loc. A 3548).

OCCURRENCE: loc. A 3548.

RANGE: Pleistocene, Recent.

REMARKS. Only a single broken right valve of this species was noted. It is flattened with the beaks not very prominent. The anterior cardinal is almost completely obsolete; only a faint trace of it shows on the valve margin. The middle cardinal is rather thin, and the posterior cardinal is represented only by a small short ridge diverging from the middle of the middle cardinal. There does not appear to be any trace of the vertical grooves on the cardinals like that found on *C. digueti*.

Genus ***Crassinella*** Guppy

Thetis ADAMS (1845), Proc. Boston Soc. Nat. Hist., vol. 2, p. 9; not *Sowerby* (1826).
Crassinella GUPPY (1872), Geol. Mag., Decade 2, vol. 1, p. 442; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1. p. 269.

Genotype: *Thetis parua* C. B. Adams (? = *Crassatella martinicensis* d'Orbigny)

Crassinella mexicana Pilsbry and Lowe

(Plate 16, figures 9, 10)

Crassinella mexicana PILSBRY AND LOWE (1932), Proc. Acad. Nat. Sci. Philadelphia, vol. 84, p. 103–104, pl. 14, figs. 8, 9.
Crassinella pacifica mexicana Pilsbry and Lowe, HERTLEIN AND STRONG (1946), Zoologica, vol. 31, p. 104.

Hypotype no. 30570 (loc. A 3582).
OCCURRENCE: loc. A 3582.
RANGE: Pleistocene, Recent.

Family CARDITIDAE

Genus ***Cardita*** Bruguière

Cardita BRUGUIÈRE (1792), Encycl. Meth., Vers, vol. 1, pt. 2, p. 401.

Genotype: *Cardita sulcata* Bruguière (*Chama antiquita* Linnaeus) (subs. desig. Children, 1823)

Cardita crassicostata (Sowerby)

(Plate 16, figures 1, 3, 4)

Venericardia crassicostata SOWERBY (1825), Cat. Shells Tankerville, append. 4; not DALL (1902).
Cardita cuvieri BRODERIP (1832), Proc. Comm. Sci. Zool. Soc. London, pt. 17, p. 56; REEVE (1843), Conch. Icon., vol. 1, *Cardita*, pl. 5, fig. 24; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 275; HERTLEIN AND STRONG (1946), Zoologica, vol. 31, p. 105.
Venericardia (*Cardites*) *cuvieri* Broderip, LAMY (1921), Jour. de Conchyl., vol. 66, p. 330–332.

Hypotypes nos. 30586 (loc. A 3550), 30590 (loc. A 3596).
OCCURRENCE: locs. A 3550, A 3596.
RANGE: Pleistocene, Recent.
REMARKS: The heavy ribs with deeply channeled interspaces are characteristic. Lamy indicated that his species is *Venericardia crassicostata* Sowerby (1825) but considered Sowerby's name a homonym of *Venericardia crassicosta* Lamarck (1819). Hertlein and Strong incorrectly cited Lamarck's name as *crassicostata*. According to Art. 36 of the Rules of Zoological Nomenclature *crassicostata* should not be rejected as a homonym of *crassicosta*.

Cardita megastropha (Gray)

(Plate 16, figures 6, 11)

Venericardia megastropha GRAY (1825), Ann. Phil., ser. 2, vol. 9, p. 137; LAMY (1921), Jour. de Conchyl., vol. 66, p. 295–296.
Venericardia flammea MICHELIN (1831), Magasin de Zool., vol. 1, p. 6.

Venericardia crassicostata Sowerby, DALL (1902), Proc. Acad. Nat. Sci. Philadelphia, vol. 54, p. 707; not *Venericardia crassicostata* SOWERBY(1825).
Cardita megastropha Gray, HERTLEIN AND STRONG (1946), Zoologica, vol. 31, p. 106.

Hypotypes nos. 30617, 30618 (loc. A 3547).

OCCURRENCE: locs. A 3508, A 3520, A 3547, A 3548, A 3550, A 3569, A 3582, A 3597.

RANGE: upper Pliocene to Recent.

REMARKS: This species is very abundant and well preserved at localities A 3547 and A 3550, usually with the valves associated. The ratio of the height to length varies considerably; some specimens are very tall.

Lamy indicated that the type of *V. crassicostata* Sowerby (1825) is the same as *Cardita cuvieri* Broderip (1832) and is not the same as the present species.

Genus *Glans* Megerle von Mühlfeld

Glans MEGERLE VON MÜHLFELD (1811), Mag. Ges. Naturf. Freunde zu Berlin, vol. 5, p. 68.

Genotype: *Chama trapezia* Linnaeus (monotypic)

Glans affinis (Sowerby)

(Plate 17, figures 2, 9)

Cardita affinis SOWERBY (1833), Proc. Zool. Soc. London, p. 195; REEVE (1843), Conch. Icon., vol. 1, *Cardita*, pl. 1, fig. 6; JORDAN (1936), Contrib. Dept. Geol., Stanford Univ., vol. 1, p. 126.
Cardita californica DESHAYES (1852), Proc. Zool. Soc. London, p. 100.
Glans affinis (Sowerby), GRANT AND GALE (1932), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 278.
Cardita (*Carditamera*) *affinis* SOWERBY, HERTLEIN AND STRONG (1946), Zoologica, vol. 31, p. 107–108.

Hypotypes nos. 30619, 30620 (loc. A 3574); 30626 (loc. A 3508).

OCCURRENCE: locs. A 3508, A 3519, A 3534, A 3573, A 3574.

RANGE: upper Pliocene to Recent.

Glans radiata (Sowerby)

(Plate 17, figures 1, 7)

Cardita radiata SOWERBY (1833), Proc. Zool. Soc. London, p. 195.
Cardita radiata Broderip, REEVE (1843), Conch. Icon., vol. 1, *Cardita*, pl. 1, fig. 5.
Cardita (*Carditamera*) *radiata* Sowerby, LAMY (1921), Jour. de Conchyl., vol. 66, p. 261–262; HERTLEIN AND STRONG (1946), Zoologica, vol. 31, p. 108.

Hypotypes nos. 30627, 30628, (loc. A 3584).

OCCURRENCE: locs. A 3584, A 3598.

RANGE: Pleistocene, Recent.

REMARKS: The presence of well-marked spines only on the first posterior dorsal rib appears to be characteristic of this species.

Family CHAMIDAE

Genus *Chama* Linnaeus

Chama LINNAEUS (1758), Syst. Nat., Ed. 10, p. 691.

Genotype: *Chama lazarus* Linnaeus (subs. desig., Children, 1823)

Chama echinata Broderip

(Plate 17, figures 8, 11)

Chama echinata BRODERIP (1835), Trans. Zool. Soc. London, vol. 1, p. 305, pl. 39, figs. 5, 7; HERTLEIN AND STRONG (1946), Zoologica, vol. 31, p. 108–109.

Hypotype no. 30635 (loc. A 3523).

OCCURRENCE: locs. A 3523, A 3534, A 3587.

RANGE: upper Pliocene to Recent.

REMARKS: The triangularily inflated, sharply angulated left valve appears to be very characteristic of this species.

Chama frondosa Broderip

(Plate 17, figures 5, 10)

Chama frondosa BRODERIP (1835), Proc. Zool. Soc. London, vol. 2, p. 148; (1835), Trans. Zool. Soc. London, vol. 1, p. 302, pl. 38, figs. 1, 2; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 280; HERTLEIN AND STRONG (1946), Zoologica, vol. 31, p. 109.

Hypotypes nos. 30636, 30637 (loc. A 3519).

OCCURRENCE: locs. A 3519, A 3596.

RANGE: upper Pliocene, Recent.

REMARKS: The specimens here recorded agree very closely with the original figures.

Chama pellucida Broderip

(Plate 17, figure 12)

Chama pellucida BRODERIP (1835), Proc. Zool. Soc. London, vol. 2, p. 149; (1835), Trans. Zool. Soc. London, vol. 1, p. 302, pl. 38, fig. 3; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 279.

Chama pellucida Sowerby, KEEP (1888), West Coast Shells, p. 182, fig. 155; HERTLEIN AND STRONG (1946), Zoologica, vol. 31, p. 109.

Hypotype no. 30638 (loc. A 3522).

OCCURRENCE: locs. A 3508, ? A 3515, A 3522, ? A 3564, A 3582, A 3598.

RANGE: upper Pliocene to Recent.

REMARKS: Some shells become extremely large and heavy, in which case the flat scales appear to be more or less obsolete.

Chama squamuligera Pilsbry and Lowe

(Plate 17, figures 3, 6)

Chama squamuligera PILSBURY AND LOWE (1933), Proc. Acad. Nat. Sci. Philadelphia, vol. 84, p. 103, pl. 14, fig. 10; HERTLEIN AND STRONG (1946), Zoologica, vol. 31, p. 110.

Hypotypes nos. 30639, 30640 (loc. A 3519).

OCCURRENCE: locs. A 3519, A 3534, A 3548, A 3550, A 3582.

RANGE: upper Pliocene to Recent.

REMARKS: This species is very abundant at loc. A 3519 and is represented by typical specimens.

Genus ***Pseudochama*** Odhner

Pseudochama ODHNER (1917), Kungl. Svenska Vetenskaps.—Akademiens Handlingar, vol. 52, no. 16, p. 28–31.

Genotype: *Chama cristella* Lamarck

Pseudochama exogyra (Conrad)

(Plate 17, figures 4, 13)

Chama exogyra CONRAD (1837), Jour. Acad. Nat. Sci. Philadelphia, vol. 7, p. 256.

Pseudochama exogyra (Conrad), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 281.

Hypotypes nos. 32821, 32822 (loc. A 3519); 32820 (loc. A 3548).

OCCURRENCE: locs. A 3519, A 3548.

RANGE: upper Pliocene to Recent.

REMARKS: The attached right valve readily separated this species from the other chamids of this area.

Family CODAKIIDAE

Genus **Codakia** Scopoli

Codakia SCOPOLI (1777), Introd. Hist. Nat., p. 398.

Genotype: *Chama codak* Adanson (*Venus punctata* Linnaeus)

Subgenus **Codakia** *s. s.*

Codakia (Codakia) distinguenda (Tryon)

(Plate 18, figures 2, 15)

Lucina (*Codakia*) *distinguenda* TRYON (1872), Proc. Acad. Nat. Sci. Philadelphia, p. 130, pl. 3, fig. 6.
Codakia colpoica DALL (1901), Proc. U. S. Nat. Mus., vol. 23, p. 801, 821, pl. 41, fig. 4.
Codakia distinguenda (Tryon), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 283.
Codakia distinguenda Tryon, HERTLEIN AND STRONG (1946) Zoologica, vol. 31, p. 117–118.

Hypotypes nos. 32873, 32874, (loc. A 3548).

OCCURRENCE: locs. A 3508, A 3515, A 3519, A 3534, A 3547, A 3548, A 3550, A 3596, A 3597, ? A 3556.

RANGE: lower Pliocene (?), upper Pliocene to Recent.

REMARKS: This species is very common in the coral reef at loc. A 3519 but attains a maximum length of only 80 mm, while at loc. A 3548 individuals with a length of over 130 mm. are present.

Subgenus **Jagonia** Recluz

Jagonia RECLUZ (1869), Mélanges Malac., p. 14; DALL (1901), Proc. U. S. Nat. Mus., vol. 23, p. 798, 799.

Subgenotype: *Venus orbiculata* Montagu

Codakia (Jagonia) chiquita Dall

(Plate 18, figures 6, 18)

Codakia (*Jagonia*) *chiquita* DALL (1901), Proc. U. S. Nat. Mus., vol. 23, p. 801, 823, pl. 39, fig. 1.
Ctena chiquita Dall, HERTLEIN AND STRONG (1946), Zoologica, vol. 31, p. 118.

Hypotypes nos. 32840, 32841, (loc. A 3548).

OCCURRENCE: loc. A 3548.

RANGE: Pleistocene, Recent.

REMARKS: The present specimens are slightly more elongate than Dall's figured type but appear to fall within the range of variation. The hinge is identical with that of *C. mexicana.*

Codakia (Jagonia) mexicana Dall

(Plate 18, figures 7, 14)

Codakia (*Jagonia*) *mexicana* DALL (1901), Proc. U. S. Nat. Mus., vol. 23, p. 801, 822, pl. 40, fig. 6.
Codakia mexicana Dall, PILSBRY AND LOWE (1932), Proc. Acad. Nat. Sci. Philadelphia, vol. 84, p. 136.
Ctena mexicana Dall, HERTLEIN AND STRONG (1946), Zoologica, vol. 31, p. 119.

Hypotypes nos. 32837, 32838, (loc. A 3548).

OCCURRENCE: locs. A 3519, A 3534, A 3548, A 3582, A 3598.

RANGE: upper Pliocene to Recent.

REMARKS: According to Dall this species is very close to the genotype of *Jagonia*.

Genus ***Anodontia*** Link

Anodontia LINK (1807), Beschreib. Natur. Samml. Univ. Rostock, p. 56.
Lucina (Bruguière) LAMARCK, of DALL (1901), Proc. U. S. Nat. Mus., vol. 23, p. 801, 802.
Pegophysema STEWART (1930), Spec. Publ. no. 3, Acad. Nat. Sci. Philadelphia, p. 185.

Genotype: *Venus edentula* Linnaeus (monotypic, *fide* Dall, 1903); of *Pegophysema* Stewart, *Lucina schrammi* Crosse (orig. desig.).

Anodontia edentuloides (Verrill)

(Plate 18, figures 11, 16)

Loripes edentuloides VERRILL (1870), Am. Jour. Sci., 2d ser., vol. 49, p. 226.
Lucina edentuloides Verrill, DALL (1901), Proc. U. S. Nat. Mus., vol. 23, p. 802.
Anodontia edentuloides (Verrill), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 292.
Anodontia edentuloides Verrill, HERTLEIN AND STRONG (1946), Zoologica, vol. 31, p. 117.

Hypotype no. 32830 (loc. A 3584).

OCCURRENCE: loc. A 3584.

RANGE: Pleistocene and Recent.

REMARKS: This species is more tumid, and the beaks are more central than *A. edentula* of the Gulf of Mexico. Two paired valves and a third smaller specimen were found. The lunule is very narrow and rather inconspicuous. The dimensions of the paired valves (hypotype no. 32830) are: length 52.5 mm, height 48.8 mm, thickness (both valves) 31.3 mm. This species is much more inflated than "*Lucina*" *spherica* Dall and Oschner from the Galapagos.

Genus ***Lucina*** Bruguière

Lucina BRUGIÈRE (1797), Encycl. Meth., Tabl. Vers, pl. 284; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 283–284.

Genotype: *Venus pensylvanica* Chemnitz (subs. desig., Schumacher, 1817).

Subgenus ***Bellucina*** Dall

Bellucina Dall (1901), Proc. U. S. Nat. Mus., vol. 23, p. 806.

Subgenotype: *Lucina pisum* Reeve (1850) (*Parvilucina eucosmia* Dall, 1901) (not *Lucina pisum* Sowerby, 1837; d'Orbigny, 1841; nor Philippi, 1850).

Lucina (Bellucina) cancellaris Philippi

(Plate 18, figures 8, 13)

Lucina cancellaris PHILIPPI (1846), Zeitschr. Malakozool., no. 7, p. 21; JORDAN (1936), Contrib. Dept. Geol., Stanford Univ., vol. 1, p. 130.
Lucina (Bellucina) cancellaris Philippi, GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 290; HERTLEIN AND STRONG (1946), Zoologica, vol. 31, p. 112.

Hypotypes nos. 32869 (loc. A 3670); 32849, 32850, 32865, 32867 (all from loc. A 3582).

OCCURRENCE: locs. A 3582, A 3670.

RANGE: Pleistocene, Recent.

REMARKS: The variation in the ribs is great. Some specimens have as few as 8 broad heavy ribs; others, by intercalation of secondaries and bifurcation of the primary radial ribs, may have as many as 20 medium-sized ribs.

Subgenus *Cardiolucina* Sacco

Cardiolucina SACCO (1901), I Molluschi dei Terreni Terziarii del Piemonte e della Liguria, part. 29, p. 89.

Subgenotype: *Cardium agassizii* Michelotti (orig. desig.)

Lucina (Cardiolucina ?) lampra (Dall)

(Plate 18, figures 1, 9)

Phacoides (*Cavilucina*) *lamprus* DALL (1901), Proc. U. S. Nat. Mus., vol. 23, p. 827, pl. 39, fig. 9.
Lucina (*Myrtea*) *lampros* (Dall), GRANT AND GALE (1931), Mem. San. Diego Soc. Nat. Hist., vol. 1, p. 286.
Lucina lampra (Dall), JORDAN (1936), Contrib. Dept. Geol., Stanford Univ., vol. 1, p. 130–131.
Lucina (*Cavilinga*) *lampra* Dall, HERTLEIN AND STRONG (1946), Zoologica, vol. 31, p. 112–113.

Hypotypes nos. 32826, 32827 (loc. A 3548).

OCCURRENCE: locs. A 3519, A 3548, A 3670.

RANGE: upper Pliocene to Recent.

REMARKS: The double laterals of the left valve are obscure in most specimens of this species but show up well occasionally. The middle cardinal of right valve is more nearly vertical, and the anterior laterals are closer to the beak than in *L. lingualis*. Jordan has discussed the relationship of these two species.

Lucina (Cardiolucina) lingualis Carpenter

(Plate 18, figures 3, 10)

Lucina lingualis CARPENTER (1864), Ann. Mag. Nat. Hist., ser. 3, vol. 13, p. 313; JORDAN (1936), Contrib. Dept. Geol., Stanford Univ., vol. 1, p. 131.
Lucina (*Myrtea*) *lingualis* Carpenter, GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 286.
Lucina (*Cavilinga*) *lingualis* Carpenter, HERTLEIN AND STRONG (1946), Zoologica, vol. 31, p. 113.

Hypotypes nos. 32831, 32833 (loc. A 3519)

OCCURRENCE: locs. A 3519, A 3520, A 3582, A 3670.

RANGE: upper Pliocene to Recent.

REMARKS: This species is very abundant at loc. A 3519; over 100 specimens were collected. As noted under *L. lampra* the anterior laterals are more distant from the beaks than in that species.

Subgenus *Lucinisca* Dall

Lucinisca Dall (1901), Proc. U. S. Nat. Mus., vol. 23, p. 805.

Subgenotype: *Lucina nassula* Conrad

Lucina (Lucinisca) nuttalli Conrad

(Plate 18, figures 4, 5)

Lucina nuttalli CONRAD (1837), Jour. Acad. Nat. Sci. Philadelphia, vol. 7, p. 255, pl. 20, fig. 2.
Lucina (*Myrtea*) *nuttallii* Conrad, GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 288, pl. 14, figs. 4a, 4b, 18.
Lucina (*Lucinisca*) *nuttallii* Conrad, JORDAN (1936), Contrib. Dept. Geol., Stanford Univ., vol. 1, p. 132.
Lucina (*Lucinisca*) *nuttalli* Conrad, HERTLEIN AND STRONG (1946), Zoologica, vol. 31, p. 114–115.

Hypotypes nos. 32835, 32836, (loc. A 3548).

OCCURRENCE: locs. A 3520, A 3548.

RANGE: upper Pliocene, Recent.

REMARKS: The two specimens from loc. A 3520 are more tumid than usual for this species, but occasional specimens in the Recent collections approach it. Dall noted that this was the Pacific analogue of the type of the subgenus.

Subgenus *Parvilucina* Dall

Parvilucina DALL (1901), Proc. U. S. Nat. Mus., vol. 23, p. 806.

Subgenotype: *Lucina tenuisculpta* Carpenter (orig. desig.)

Lucina (Parvilucina) approximata (Dall)

(Plate 18, figures 12, 17)

Phacoides (*Parvilucina*) *approximatus* DALL (1901), Proc. U. S. Nat. Mus., vol. 23, p. 813, 828, pl. 39, fig. 4.
Lucina (*Myrtea*) *tenuisculpta* Carpenter var. *approximata* (Dall), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 289, pl. 14, figs. 8a, 8b.
Lucina approximata (Dall), JORDAN (1936), Contrib. Dept. Geol., Stanford Univ., vol. 1, p. 129–130.
Lucina (*Parvilucina*) *approximata* Dall, HERTLEIN AND STRONG (1946), Zoologica, vol. 31, p. 115–116.

Hypotypes nos. 32845, 32846, 32847, 32848 (loc. A 3670).

OCCURRENCE: loc. A 3670.

RANGE: upper Pliocene, Recent.

REMARKS: Jordan has given a good comparison of this species and *L. tenuisculpta.*

Genus ***Miltha*** H. and A. Adams

Miltha H. and A. Adams (1857), Gen. Rec. Moll., vol. 2, p. 468.

Genotype: *Lucina childrenae* Gray (1825)

Miltha xantusi (Dall)

(Plate 19, figures 3, 8)

"*Lucina childreni* Gray", CARPENTER (1864), Brit. Assoc. Adv. Sci. Rept. for 1863, p. 552, 620; not *Lucina childrenae* GRAY (1825) nor *Lucina childreni* Gray, SOWERBY (1827), nor *Tellina childreni* Gray, WOOD (1828).
Phacoides (*Miltha*) *xantusi* DALL (1905), Nautilus, vol. 18, p. 111.
Lucina (*Miltha*) *xantusi* (Dall), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 291–292, pl. 14, figs. 20a, 20b.
Phacoides xantusi Dall, PILSBURY AND LOWE (1933), Proc. Acad. Nat. Sci. Philadelphia, vol. 84, p. 137.
Lucina (*Miltha*) *xantusi* Dall, HERTLEIN AND STRONG (1946), Zoologica, vol. 31, p. 115.

Hypotypes nos. 32824, 32825, (loc. A 3548); Stanford Univ. Paleo. Type Coll. no. 7557, L.S.J.U. loc. 805.

OCCURRENCE: loc. A 3548, L.S.J.U. loc. 805.

RANGE: Pleistocene, Recent.

REMARKS: Pilsbry and Lowe noted that this species was found on the tide flats at La Paz and is of rare occurrence.

Family UNGULINIDAE

Genus ***Taras*** Risso

Taras RISSO (1826), Hist. Nat. Eur. Mérid., vol. 4, p. 344; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 293.
Diplodonta BRONN (1831), Ergebnisse meiner naturhistorischökonomischen Reisen, vol. 2, p. 484 (type *Venus lupinus* Brocchi, subs. desig. Herrmannsen, 1847).

Genotype: (of *Taras*) *Taras antiquatus* Risso (monotypic)

Taras sericatus (Reeve)

(Plate 19 figures 1, 18)

Lucina sericata REEVE (1850), Conch. Icon., vol. 6, *Lucina*, pl. 9, fig. 55.
Taras parilis (Conrad) var. *sericatus* (Reeve), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 295, pl. 14, figs. 12a, 12b.
Diplodonta sericata (Reeve), JORDAN (1936), Contrib. Dept. Geol., Stanford Univ., vol. 1, p. 128–129.

Hypotype no. 32396 (loc. A 3582).

OCCURRENCE: loc. A 3582.

RANGE: Pleistocene, Recent.

REMARKS: This species appears to vary considerably in the length to height ratio.

Taras subquadratus (Carpenter)

(Plate 19, figures 4, 14)

Diplodonta subquadrata CARPENTER (1855), Proc. Zool. Soc. London, p. 230.

Hypotypes nos. 32397, 32398, 32399, (loc. A 3582).

OCCURRENCE: locs. A 3534, A 3548, A 3550, A 3582, A 3584.

RANGE: upper Pliocene to Recent.

REMARKS: The large specimens from loc. A 3582 are fully as inflated as *Taras orbellus* (Gould) but have the outline of *subquadratus*. Small specimens are typical but grade up into the large form. The large hypotype (no. 32397) has the following dimensions: length 28.6 mm, height 26.7 mm, thickness (one valve) 10.0 mm.

Genus ***Divaricella*** von Martens

Cyclas Klein, MÖRCH (1853), Cat. Conchyl. Yoldi, pt. 2, p. 32; not *Cyclas* LAMARCK (1798).
Divaricella VON MARTENS (1880), in MOEBIUS' Beitrage zur Meeresfauna der Insel Mauritius und der Seychellen. Mollusken, p. 321.

Genotype: *Lucina angulifera* von Martens (= *Lucina ornata* Reeve, *fide* Dall, 1903) (monotypic)

Divaricella lucasana Dall and Ochsner

(Plate 19, figures 5, 15)

Lucina eburnea REEVE (1850), Conch. Icon., vol. 6, *Lucina*, pl. 8, fig. 49; not *Lucina eburnea* DESHAYES (1835), not *Lucina eburnea* ANDRZEJOWSKI (1835).
Divaricella dentata (Wood) var. *eburnea* (Reeve), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 296, pl. 14, figs. 1a, 1b.
Divaricella columbiensis LAMY (1934), Bull. Mus. Hist. Nat. Paris, ser. 2, vol. 6, no. 5, p. 433.
Divaricella lucasana DALL AND OCHSNER (1928), Proc. Calif. Acad. Sci., ser. 4, vol. 17, p. 122, pl. 2, figs. 17, 21, 24; HERTLEIN AND STRONG (1946), Zoologica, vol. 31, p. 119–120.

Hypotypes nos. 32422, 32423, 32424, (loc. A 3548); 32421, (loc. A 3520).

OCCURRENCE: locs. A 3519, A 3520, A 3548, A 3582, A 3670.

RANGE: UPPER Pliocene, Recent.

REMARKS: Grant and Gale noted that the Pacific Coast species may be distinguished from the East Coast *D. dentata* (Wood) by a larger, always present posterior lateral tooth. Some of the specimens from loc. A 3548 are 30 mm high, much larger than normal.

Family ERYCINIDAE

Genus ***Solecardia*** Conrad

Solecardia CONRAD (1849), Proc. Acad. Nat. Sci. Philadelphia, vol. 4, p. 155.

Genotype: *Solecardia eburnea* Conrad (monotypic)

Solecardia eburnea Conrad

(Plate 19, figures 10, 16)

Solecardia eburnea CONRAD (1849), Proc. Acad. Nat. Sci. Philadelphia, vol. 4, p. 155; PILSBRY AND LOWE (1932), Proc. Acad. Nat. Sci. Philadelphia, vol. 84, p. 136; LOWE (1935), Trans. San Diego Soc. Nat. Hist., vol. 8, p. 29.

Scintilla cumingii DESHAYES (1855), Proc. Zool. Soc. London, p. 173; REEVE (1874), Conch. Icon., vol. 19, *Scintilla*, sp. 3, pl. 1, figs. 3a, 3b.

Hypotype no. 32411 (loc. A 3548).

OCCURRENCE: loc. A 3548.

RANGE: Pleistocene, Recent.

REMARKS: This species has rarely been recorded. Conrad's type has never been figured, but the specimens fit his description and the figure of Reeve. Pilsbry and Lowe first put the two species in synonomy; Pilsbry probably had access to Conrad's type. The single complete specimen here noted is a left valve. Two right (?) valves were also found, but the hinge has been destroyed on each. The finely crenulate sculpture is very characteristic.

Family CARDIIDAE

Genus ***Americardia*** Stewart

Americardia STEWART (1930), Spec. Publ. no. 3, Acad. Nat. Sci. Philadelphia, p. 267.

Genotype: *Cardium medium* Linnaeus (orig. desig.)

Americardia biangulata (Broderip and Sowerby)

(Plate 19, figures 7, 13)

Cardium biangulatum BRODERIP AND SOWERBY (1829), Zool. Jour. London, vol. 4, p. 367; JORDAN (1936), Contrib. Dept. Geol., Stanford Univ., vol. 1, p. 133.

Cardium (*Fragum*) *biangulatum* Sowerby, LAMY (1909), Jour. de Conchyl., vol. 57, p. 234.

Fragum biangulatum (Broderip and Sowerby), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 312.

Hypotypes nos. 32534, 32535, (loc. A 3584).

OCCURRENCE: locs. A 3508, A 3514, A 3519, A 3520, A 3533, A 3534, A 3538, A 3548, A 3550, A 3582, A 3584, A 3596, A 3598, A 3670.

RANGE: middle Pliocene to Recent.

Genus ***Laevicardium*** Swainson

Laevicardium SWAINSON (1840), Treat. Malac., p. 373.

Genotype: *Cardium europaeum* Wood (*Cardium norvegicum* Spengler) (sub. desig. Bucquoy, Dautzenberg, and Dollfuss, 1887)

Laevicardium elatum (Sowerby)

Cardium elatum SOWERBY (1833), Proc. Zool. Soc. London, pt. 1, p. 84; REEVE (1844), Conch. Icon., vol. 2., *Cardium*, pl. 8, fig. 41.

Cardium (*Laevicardium*) *elatum* Sowerby, LAMY (1909), Jour. de Conchyl., vol. 57, p. 235; DALL (1921), U. S. Nat. Mus., Bull. 112, p. 40.

Laevicardium (*Laevicardium*) *elatum* (Sowerby), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 304.

Hypotype no. 32395 (loc. A 3548).

OCCURRENCE: locs. A 3548, A 3582, A 3584.

RANGE: Pleistocene, Recent.

REMARKS: Large specimens of this species are usually broken and hard to collect.

Laevicardium elenense (Sowerby)

(Plate 19, figures 2, 12)

Cardium elenense SOWERBY (1841), Proc. Zool. Soc. London, pt. 8, p. 109; REEVE (1845), Conch. Icon., vol. 2, *Cardium*, pl. 20, fig. 104; JORDAN (1936), Contrib. Dept. Geol., Stanford Univ., vol. 1, p. 134.

Cardium (*Laevicardium*) *elenense* Sowerby, LAMY (1907), Jour. de Conchyl., vol. 57, p. 235.

Hypotypes nos. 32541, 32548, (loc. A 3519).

OCCURRENCE: locs. A 3519, A 3520, A 3534, A 3548, A 3582, A 3670.

RANGE: upper Pliocene to Recent.

REMARKS: This small species is very abundant at loc. A 3548. It may be separated easily from *L. substriatum* (Conrad) by its more pronounced obliqueness.

Genus ***Papyridea*** Swainson

Papyridea SWAINSON (1840), Treat. Malac., p. 374.

Genotype: *Cardium soleniforme* Bruguière (*C. spinosum* Meuschen) (subs. desig. Gray 1847).

Papyridea aspersa (Sowerby)

(Plate 19, figures 6, 19)

Cardium aspersum SOWERBY (1833), Proc. Zool. Soc. London, pt. 1, p. 85.

Cardium (*Papyridea*) *spinosum* Meuschen var. *aspersum* Sowerby, LAMY (1909), Jour. de Conchyl., vol. 57, p. 234.

Papyridea spinosa (Meuschen) var. *aspersa* (Sowerby), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 311.

Hypotypes nos. 32538, 32539 (loc. A 3584).

OCCURRENCE: locs. A 3548, A 3582, A 3584.

RANGE: Pleistocene, Recent.

REMARKS: This species is very close to the Atlantic *P. spinosa* but may be separated from it by more deeply channeled interspaces between the ribs, by the lesser posterior elongation, by the posterior lateral teeth being slightly closer to the beaks, and by the cardinal tooth sloping more anteriorly.

Genus ***Trachycardium*** Mörch

Trachycardium MÖRCH (1853), Cat. Conchyl. Yoldi, pt. 2, p. 34.

Genotype: *Cardium isocardium* Linnaeus (subs. desig. Dall, 1901).

Subgenus ***Trachycardium*** *s.s.*

Trachycardium (Trachycardium) consors (Sowerby)

(Plate 19, figures 9, 17)

Cardium consors SOWERBY (1833), Proc. Zool. Soc. London, pt. 1, p. 85; REEVE (1843), Conch. Icon., vol. 2, *Cardium*, pl. 17, sp. 86; JORDAN (1936), Contrib. Dept. Geol., Stanford Univ., vol. 1, p. 133.

Cardium (*Trachycardium*) *consors* Sowerby, LAMY (1909), Jour. de Conchyl., vol. 57, p. 233.

Laevicardium (*Trachycardium*) *consors* (Sowerby), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 306.

Hypotypes nos. 32550 (loc. A 3548), 32549 (loc. A 3584).

OCCURRENCE: locs. A 3538, A 3548, A 3582, A 3584, A 3596.

RANGE: Pleistocene, Recent.

REMARKS: Some individuals are much higher than others.

Subgenus ***Mexicardia*** Stewart

Mexicardia STEWART (1930), Spec. Publ. Acad. Nat. Sci. Philadelphia, no. 3, p. 263.

Subgenotype: *Cardium procerum* Sowerby (orig. desig.)

Trachycardium (Mexicardia) procerum (Sowerby)

(Plate 19, figure 11; Plate 20, figure 2)

Cardium procerum SOWERBY (1833), Proc. Zool. Soc. London, pt. 1, p. 83; JORDAN (1936), Contrib. Dept. Geol., Stanford Univ. vol. 1, p. 135.
Cardium (*Ringicardium*) *procerum* (Sowerby), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 305.

Hypotypes nos. 32551, 32552 (loc. A 3582).
Occurrence: locs. A 3582, A 3584.
RANGE: Pleistocene, Recent.

Family VENERIDAE

Genus ***Venus*** Linnaeus

Venus LINNAEUS (1758), Syst. Nat., Ed. 10, p. 684.

Genotype: *Venus verrucosa* Linnaeus (sub. desig. Gray, 1847)

The only apparent distinctions between *Antigona* Schumacher (1817) and *Venus* Linnaeus are that the anterior lateral tooth of the left valve of *Venus* is smaller; the lunule of *Antigona* has radial ribs where as that of *Venus* lacks them; and the outline of *Antigona* is more elongate.

Venus isocardia Verrill

(Plate 20, figures 5, 9)

Venus isocardia VERRILL (1870), Am. Jour. Sci., 2d ser., vol. 49, p. 221–222.
Cytherea (*Ventricola*) *rigida* (Dillwyn), DALL (in part) (1902), Proc. U. S. Nat. Mus., vol. 26, p. 372, 390.
Venus (*Antigona*) *multicostata* Sowerby, GRANT AND GALE (in part) (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 316–317. Not *Antigona rugosa* Gmelin, OLSSON (1922), Bull. Am. Pal., vol. 9, p. 412–413, pl. 30, fig. 4.

Hypotypes nos. 15979, 15980 (loc. A 3548).
OCCURRENCE: locs. A 3547, A 3548.
RANGE: Pleistocene, Recent.

REMARKS: *See* under *Periglypta multicostata* (Sowerby). Dall, in 1902, united this species with *V. rigida* Dillwyn from the Caribbean area despite Verrill's having given a clear description of the differences in the hinge. This statement was as follows:

> "This massive species is allied to *V. rugosa* [*V. rigida* Dillwyn] of the West Indies which it resembles in form and sculpture, but it has a different and stronger hinge. The posterior tooth of the right valve, especially, is much larger and longer, extending beyond the middle of the ligament. In the left valve the posterior tooth is also much elongated and reaches beyond the middle of the ligament, but is much less elevated than in *V. rugosa*, and less separated from the ligament plate, there being only a shallow groove between."

The outline is considerably different in mature specimens; the typical *V. rigida* has a nearly circular outline, whereas *V. isocardia* is ovate, the anterior ventral margin being much less rounded.

This is one of the species which Dall considered as common to both the Caribbean and Pacific faunas. Olsson also considered his Costa Rica Miocene form the same as the living form, but judging from his figure it is distinct from both the Caribbean and Pacific species.

Genus **Chione** Megerle von Mühlfeld

Chione MEGERLE VON MÜHLFELD (1811), Mag. Ges. Naturf. Freunde Zu Berlin, vol. 5, p. 51.

Genotype: *Venus dysera* Chemnitz = *Venus cancellata* Linnaeus

Subgenus **Chione** *ss.*

Chione (Chione) cf. ***amathusia*** (Philippi)

(Plate 20, figures 6, 7)

Venus amathusia PHILIPPI (1844), Abbild. Beschr. Conchyl., vol. 1, p. 129, *Venus* Tab. 2, fig. 4.

Hypotype no. 32871 (loc. A 3586).

OCCURRENCE: loc. A 3586

RANGE: Pleistocene.

REMARKS: This species is externally fairly similar to *C. amathusia*, but internally the middle cardinal is not bifid. Unfortunately there is only a single imperfect right valve in the collection.

Chione (Chione) californiensis (Broderip)

(Plate 21, figures 8, 9)

Venus succincta VALENCIENNES (1833), in HUMBOLDT AND BONPLAND, Recueil d'Observ. Zool., vol. 2, p. 219, figured in Atlas to Zoology, vol. 2, 1811; not *Venus succincta* LINNAEUS (1771), Mantissa 2, p. 546.

Venus californiensis BRODERIP (1835), Proc. Zool. Soc. London, p. 43; SOWERBY (1855), Thes. Conchyl., vol. 2, p. 711, pl. 154, figs. 40, 41.

Venus nuttalli CONRAD (1837), Jour. Acad. Nat. Sci. Philadelphia, vol. 7, p. 251, pl. 19, fig. 16, not fig. 14.

Venus (Chione) succincta Valenciennes, GRANT AND GALE (in part) (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 321–322, pl. 16, figs. 1–4.

Hypotypes nos. 32602, loc. A 3520; 32566, 32567, 32568, 32570, (loc. A 3549).

RANGE: upper Pliocene to Recent.

REMARKS: This species is represented only by a few poorly preserved specimens at loc. A 3520. At loc. A 3549 it is very abundant but not too well preserved. Some specimens at this locality have a slightly different hinge from that in the living individuals.

Chione (Chione) undatella (Sowerby)

(Plate 21, figures 7, 12)

Venus undatella SOWERBY (1835), Proc. Zool. Soc. London, p. 22; (1855), Thes. Conchyl., vol. 2, p. 711, pl. 153, fig. 22.

Venus neglecta SOWERBY (1839), Zool. Beechey's Voy., Blossom, p. 151, pl. 41, fig. 8.

Venus (Chione) succincta Valenciennes, GRANT AND GALE (in part) (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 321–322, pl. 16, figs. 1–4.

Hypotypes nos. 32581, 32582, 32586, 32588, (all from loc. A 3548); 32583, 32585, (both from loc. A 3582).

OCCURRENCE: locs. A 3519, A 3548, A 3573, A 3582, A 3584, A 3587, A 3592, A 3593, A 3596, A 3597, A 3670.

RANGE: upper Pliocene to Recent.

REMARKS: In typical *undatella* the middle cardinal of the right valve is heavy, and the two sides of the tooth have only a slight angle of divergence. In the subspecies *simillima* the same tooth is typically not very heavy, and the anterior side of the tooth curves forward anteriorly so that the angle of divergence of the two sides of the tooth is rather great. There are all gradations between these two types of teeth.

Chione (Chione) undatella subsp. ***simillima*** (Sowerby)

(Plate 21, figures 5, 11)

Venus simillima SOWERBY (1855), Thes. Conchyl., vol. 2, p. 708, pl. 153, fig. 17, not 18.
Venus (Chione) succincta Valenciennes, GRANT AND GALE (in part) (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 321–323, pl. 16, figs. 1–4.

Hypotypes nos. 32572, 32573, (loc. A 3550).

OCCURRENCE: locs. A 3515, A 3519, A 3534, A 3535, ? A 3536, A 3541, A 3547, A 3548, A 3550, ? A. 3563, A 3582, A 3598.

RANGE: upper Pliocene to Recent.

REMARKS: The specimens from the various localities do not appear to differ from those now living. some individuals could equally well be assigned to the typical *undatella*.

Subgenus ***Anomalocardia*** Schumacher

Anomalocardia SCHUMACHER (1817), Essai Meth., p. 134, pl. 20, fig. 4.

Subgenotype: *Venus flexuosa* Linnaeus

Chione (Anomalocardia) kellettii (Hinds)

(Plate 20, figure 10)

Venus kellettii HINDS (1844), Voyage of the *Sulphur*, Mollusca, p. 65, pl. 19, fig. 5.
Chione (Lirophora) kellettii (Hinds), DALL (1902), Proc. U. S. Nat. Mus., vol. 26, p. 394.

Hypotype no. 32407 (loc. A 3584).

OCCURRENCE: loc. A 3584.

RANGE: Pleistocene, Recent.

REMARKS: A single small specimen 20.5 mm long and 6.2 mm high.

Chione (Anomalocardia) mariae (d'Orbigny)

(Plate 20, figures 4, 8)

Venus mariae D'ORBIGNY (1846), Voy. Am. Merid., Moll., p. 563.
Venus (Chione) mariae d'Orbigny, GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 324.
Chione mariae (d'Orbigny), JORDAN (1936), Contrib. Dept. Geol., Stanford Univ., vol. 1, p. 138–139.

Hypotypes nos. 32553, 32554 (loc. A 3582).

OCCURRENCE: loc. A 3582.

RANGE: Pleistocene, Recent.

REMARKS: The concentric ribs in most recent specimens are not as closely appressed as in the individuals here noted.

Chione (Anomalocardia) subrugosa (Sowerby)

(Plate 21, figure 3)

Venus subrugosa SOWERBY (1834), Genera of Shells, *Venus*, fig. 2; (1855), Thes. Conchyl., vol. 2, p. 721, pl. 155, fig. 63.
Anomalocardia subrugosa (Sowerby), DALL (1902), Proc. U. S. Nat. Mus., vol. 26, p. 396.

Hypotypes nos. 32556, 32559 (loc. A 3549).

OCCURRENCE: loc. A 3549.

RANGE: upper Pliocene.

REMARKS: Among the recent specimens in the University of California collections those from the Gulf of California are considerably more elongated than those from Panama. The two specimens now at hand closely resemble those from Panama and not those from the Gulf of California.

Chione (Anomalocardia) tumens Verrill

(Plate 21, figure 4, 6)

Venus subimbricata SOWERBY (in part) (1835), Proc. Zool. Soc. London, p. 21; (1855), Thes. Conchyl., vol. 2, p. 711, pl. 154, fig. 38.
Chione tumens VERRILL (1870), Am. Jour. Sci., 2d ser., vol. 49, p. 222.
Anomalocardia subimbricata (Sowerby), DALL (in part) (1902), Proc. U. S. Nat. Mus., vol. 26, p. 396.

Hypotypes nos. 32592, 32593 (loc. A 3519); 32594 (loc. A 3596).

OCCURRENCE: locs. A 3508, A 3519, A 3520, A 3548, A 3550, A 3573, A 3574, A 3582, A 3596, A 3598.

RANGE: upper Pliocene to Recent.

Genus ***Dosinia*** Scopoli

Dosinia SCOPOLI (1777), Introd. Hist. Nat., p. 399.

Genotype: *Chama dosin* Adanson = *Dosinia africana* Hanley (monotypic)

Dosinia ponderosa (Gray)

(Plate 22, figures 3, 6)

Artemis ponderosa GRAY (1838), Analyst, p. 309; REEVE (1850), Conch. Icon., vol. 6, *Artemis*, pl. 1, fig. 4.
Dosinia ponderosa (Gray), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 351–352, pl. 15, figs. 1a–1c.

Hypotypes nos. 15953, 15954 (loc. A 3548).

OCCURRENCE: locs. A 3520, A 3532, A 3533, A 3536, A 3548, A 3582, A 3584, A 3670.

RANGE: lower Pliocene to Recent.

REMARKS: The recent species is rather variable in outline, but there seems to be a tendency for the Pliocene specimens to be less elongated and more rounded. Unfortunately there is not enough material on hand to check this by statistical methods.

Genus ***Macrocallista*** Meek

Macrocallista MEEK (1876), Rept. U. S. Geol. Surv. Territories, vol. 9, p. 179.

Genotype: *Venus gigantea* Gmelin (monotypic)

Macrocallista squalida (Sowerby)

(Plate 23, figures 4, 5, 8)

Cytherea squalida SOWERBY (1835), Proc. Zool. Soc. London, p. 23.
Pitar (*Megapitaria*) *squalidus* (Sowerby), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 347.

Hypotypes nos. 15942, 15943, 15944, 15945, 15946, 15947, 15951, 15952 (all from loc. A 3548), 15994 (loc. A 3520).

OCCURRENCE: locs. A 3508, A 3515, A 3519, A 3520, A 3525, A 3534, A 3538, A 3547, A 3548, A 3550, A 3573, A 3574, A 3582, A 3584, A 3590, A 3596, A 3598, A 3670.

RANGE: upper Pliocene to Recent.

REMARKS: The variation in this species is very great. On a large specimen (length 144 mm) from loc. A 3548 the hinge is only 9 mm wide, while on a smaller, more typical specimen (length 114 mm) the hinge is 13 mm wide. An unusual specimen (Pl. 23, fig. 5) from loc. A 3520 (hypotype no. 15994) is extremely elongated posteriorly (length 107 mm, height 78 mm), shortened anteriorly, and with a consequent shifting of the dental armature. A ridge divides the anterior cardinal socket of the left valve. This same condition is seen in a similar valve associated with the normal form in a collection of living specimens from the Gulf of California. Some of the individuals from loc. A 3519 are not produced as much anteriorly as the common living form, but associated individuals are identical.

Genus **_Periglypta_** Jukes Brown

Periglypta JUKES BROWN (1914), Proc. Malac. Soc. London, vol. 11, p. 72.
Cytherea BOLTEN (1798), Mus. Boltenianum, p. 177; DALL (1902), Proc. U. S. Nat. Mus., vol. 26, p. 354; not Fabricius (1794).

Genotype: *Venus puerpera* Linnaeus (orig. desig.)

Venus oblonga Hanley (= *V. Zealandica* Gray), the genotype of *Dosina* Gray (1830), differs from *V. puerpera* Linnaeus in having only a very small V-shaped pallial sinus, in the escutcheon being practically obsolete without the deeply impressed line around it, in the lunule having a deeper impressed line around it, and in the radial sculpturing being obsolete except for a slight area anteriorly on the shell.

Periglypta multicostata (Sowerby)

(Plate 20, figures 1, 3; Plate 21, figure 2)

Venus multicostata SOWERBY (1835), Proc. Zool. Soc. London, p. 22; (1853), Thes. Conchyl., vol. 2, p. 706, pl. 152, fig. 10.
Venus thouarsii VALENCIENNES (1846), Voy. Venus, Atlas Zool., Moll., pl. 16, figs. 1, 1a.
Venus (Antigona) multicostata Sowerby, GRANT AND GALE (in part) (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 316–317. Not *Antigona multicostata* Sowerby, OLSSON (1922), Bull. Am. Pal., vol. 9, p. 411–412, pl. 30, fig. 1.

Hypotypes nos. 15935, 15936 (loc. A 3596).

OCCURRENCE: locs. A 3508, ? 3515, A 3596, Recent.

RANGE: Pleistocene, Recent.

REMARKS: Two species have been confused under this name in the Gulf of California and Panamic areas because of their similar external appearance and the lack of a description or figure of the hinge in Sowerby's original work. However, a careful examination of the original figure of *multicostata* indicates that it is the species which is to be referred to the genus *Periglypta*. It may be separated from *Venus isocardia* Verrill, the other externally similar species by its more produced anterior ventral margin, by its straighter ventral margin, by its slightly crenulated, prominent concentric lamellae, and by its escutcheon bounded by an incised line.

The hinge of *multicostata* has the two posterior cardinal teeth of the right valve bifid and no anterior lateral tooth in the left valve. In *Venus isocardia* the left valve has a small anterior lateral tooth, and the middle cardinal tooth is very wide and slightly bifid in contrast to the narrow middle cardinal of the left valve of *multicostata*. *Venus isocardia* is the species which Grant and Gale (1931, p. 316–317) considered as *Venus (Antigona) multicostata* Sowerby.

Valenciennes gave excellent figures of both the exterior and the hinge of his *Venus thouarsii*. There is no question of the identity of his species and Sowerby's.

Olsson's specimen appears to represent a new species; it is much shorter in proportion to its height and much less pouting in the lunular area.

The specimens from loc. A 3596 possibly should be regarded as subspecifically distinct from the living form inasmuch as it has a straighter dorsal margin, the angulation from the dorsal margin to the posterior margin is sharper, and the anterior area just below the lunule is more pouting. However, in view of the lack of sufficient specimens to establish whether or not these characters are constant it is here referred to the living species.

Genus **_Pitar_** Römer

Pitar RÖMER (1857), Krit. Untersuch. Mollusk. Venus, p. 15.

Genotype: *Cytherea tumens* Gmelin

Pitar newcombianus (Gabb)

(Plate 21, figure 1, 10)

Lioconcha newcombiana GABB (1865), Proc. Calif. Acad. Sci. for 1865, p. 189; (1868) Geol. Surv. Calif., Palaeo., vol. 2, p. 96.
Pitar newcombianus (Gabb), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist. vol. 1, p. 345–346.

Hypotype no. 32580 (loc. A 3582).

OCCURRENCE: loc. A 3582.

RANGE: Pleistocene, Recent.

REMARKS: Only a single right valve was noted. Its length is 22.2 mm, height 18.2 mm, thickness (one valve) 5.7 mm.

Genus ***Protothaca*** Dall

Protothaca DALL (1902), Proc. U. S. Nat. Mus., vol. 26, p. 364.

Genotype: *Venus thaca* Molina (+ *V. dombeyi* Lamarck)

Protothaca (?) ***coronadosensis*** n. sp.

(Plate 22, figures 2, 9, 11)

Shell inflated, subtrigonal, resembling *P. fluctifraga,* detailed outline somewhat variable; beaks from a fourth to a third distant from anterior end, closely inturned; lunule not present on specimens at hand; a small distinctly beveled escutcheon; a broad shallow groove running from beaks to a point just in front of posterior ventral angulation; ornamented by about 20 broad, heavy radial ribs anterior to posterior angulation, about four similar ribs posterior to angulation; further ornamented by superimposed, closely spaced concentric ribs that are heavy and poorly reflexed anteriorly (but obsolete posteriorly); hinge similar to that of *P.* (?) *fluctifraga*; inner margin of valve crenulated.

Dimensions of holotype: Length 42 mm, height 39.2 mm, thickness (both valves) 27.6 mm.

Holotype no. 32596; paratypes nos. 32597, 32598, 32599 (all from loc. A 3549).

OCCURRENCE: loc. A 3549.

RANGE: upper Pliocene.

REMARKS: This species may be distinguished from *P.* (?) *fluctifraga* by its greater degree of inflation, its fewer and coarser radial ribs (only about 4 ribs posterior to the posterior angulation, compared to numerous finer ribs), by its distinct, beveled escutcheon, and by the more anterior position of the umbones.

Protothaca (?) ***fluctifraga*** (Sowerby)

(Plate 22, figures 4, 5, 8, 10)

Venus fluctifraga SOWERBY (1853), Thes. Conchyl., vol. 2, p. 712, pl. 154, figs. 42–43.
Venus (*Chione*) *fluctifraga* SOWERBY, GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 323.

Hypotypes nos. 32577, 32578, (loc. A 3586); 32574, 32575, 32576 (from loc. A 3592).

OCCURRENCE: loc. A 3586, A 3592.

RANGE: upper Pliocene to Recent.

REMARKS: The assignment of this species to *Protothaca* is only tentative, but certainly it is not a *Chione*, for it lacks a well-developed lunule and escutcheon (the lunule may be entirely absent or incipient), the pallial sinus is deeper, and there is a differentiation of the sculpture anteriorly and posteriorly.

The specimens from loc. A 3592 are generally more inflated and more subtrigonal than those from loc. A 3586, but both can be matched in the Recent fauna.

Protothaca grata (Say)

(Plate 22, figures 1, 7)

Venus grata SAY (1831), Am. Conch., pt. 3, pl. 26; REEVE (1863), Conch. Icon., vol. 14, *Venus*, pl. 3, figs. 8a, 8b.
Venerupis (*Protothaca*) *grata* (Say), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 328–329.

Hypotype no. 32603 (loc. A 3582).

OCCURRENCE: locs. A 3582, A 3587.

RANGE: Pleistocene, Recent.

REMARKS: Only three specimens of this species were noted.

Genus ***Tivela*** Link

Tivela LINK (1807), Beschr. Natur. Samml. Univ. Rostock, pt. 2, p. 152.

Genotype: *Venus corbicula* Gmelin (*Venus mactroides* Born)

Tivela byronensis (Gray)

(Plate 23, figures 6, 7)

Cytherea radiata SOWERBY (1835), Proc. Zool. Soc. London, p. 23 (not MEGERLE VON MÜHLFELD).
Trigona byronensis GRAY (1838), Analyst, vol. 8, p. 304.
Tivela byronensis Gray, DALL (1903), Proc. U. S. Nat. Mus., vol. 26, p. 385.
Meretrix (*Tivela*) *byronensis* Gray, LAMY (1909), Jour. de Conchyl., vol. 57, p. 240, 241.

Hypotypes nos. 32589, 32590 (loc. A 3584).

OCCURRENCE: locs. A 3582, A 3584.

RANGE: Pleistocene and Recent.

REMARKS: This species is sometimes very abundant on sandy beaches. Average large specimens may be about 50 mm long, 40 mm high, and nearly 30 mm thick (both valves).

Family PETRICOLIDAE

Genus ***Petricola*** Lamarck

Petricola LAMARCK (1801), Syst. Anim. sans Vert., p. 121.

Genotype: *Venus lithophagus* Retzius

Petricola robusta Sowerby

(Plate 23, figure 15)

Petricola robusta SOWERBY (1834), Proc. Zool. Soc. London, p. 47; LAMY (1909), Jour. de Conchyl., vol. 57, p. 248.

Hypotype no. 32606 (loc. A 3548).

OCCURRENCE: locs. A 3548, A 3573.

RANGE: Pleistocene, Recent.

REMARKS: The largest specimen here noted has a length of 34.5 mm, height 27.4 mm, thickness (1 valve) 12.6 mm. There are also two smaller paired valves. The large size and coarse posterior radial ribs are very characteristic.

Family TELLINIDAE

Genus ***Tellina*** Linnaeus

Tellina LINNAEUS (1758), Syst. Nat., Ed. 10, p. 674.

Genotype: *Tellina radiata* Linnaeus (subs. desig. Children, 1823).

Subgenus *Tellina ss.*

Tellina (Tellina) cumingii Hanley

(Plate 23, figures 11, 17)

Tellina cumingii Hanley (1844), Proc. Zool. Soc. London, p. 59; Jordan (1936), Contrib. Dept. Geol., Stanford Univ., vol. 1, p. 112, 144.
Tellina (Tellinella) cumingii Hanley, Lamy (1909), Jour. de Conchyl., vol. 57, p. 251.

Hypotypes nos. 32618, 32619 (loc. A 3548).
Occurrence: locs. A 3534, A 3548, A 3582, A 3584.
Range: upper Pliocene to Recent.

Tellina (Tellina) idae Dall

(Plate 23, figures 1, 2)

Tellina idae Dall (1891), Proc. U. S. Nat. Mus., vol. 14, p. 183, pl. 6, fig. 3; pl. 7, figs. 1, 4; Grant and Gale (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 358.

Hypotype no. 32620 (loc. A 3670).
Occurrence: loc. A 3670.
Range: upper Pliocene, Recent.
Remarks: This species is unreported other than from the type locality at Long Beach, California, and from the Pleistocene of San Quentin Bay, Lower California. The single specimen now at hand is a small right valve and agrees very well with small specimens from the type locality.

Subgenus *Angulus* Megerle von Mühfeld

Angulus Megerle von Mühfeld (1811), Mag. Ges. Naturf. Freunde zu. Berlin, vol. 5, p. 47.

Subgenotype: *Tellina lanceolata* Linnaeus (subs. desig. Gray, 1847).

Tellina (Angulus) panamensis Dall

(Plate 23, figures 13, 14)

Tellina (Angulus) panamensis Dall (1900), Proc. U. S. Nat. Mus., vol. 23, p. 319–320, pl. 3, fig. 3.

Hypotype no. 32621 (loc. A 3670).
Occurrence: locs. A 3582, A. 3670.
Range: upper Pliocene to Recent.
Remarks: This species is small and delicate and probably often overlooked.

Subgenus *Eurytellina* Fischer

Eurytellina Fischer (1887), Man. Conchyl., p. 1147.

Subgenotype: *Tellina punicea* Born (monotypic)

Tellina (Eurytellina ?) simulans Adams

(Plate 23, figures 3, 10)

Tellina simulans Adams (1852), Ann. Lyceum. Nat. Hist. New York, vol. 5, p. 508.
Tellina rubescens Hanley, Grant and Gale (in part) (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 360, 361; not *Tellina rubescens* Hanley (1844), nor Jordan (1936).

Hypotypes nos. 32643, 32647, 32649 (loc. A 3584).
Occurrence: locs. A 3582, A 3584, A 3670.
Range: upper Pliocene to Recent.

REMARKS: This species may be distinguished from *T. rubescens* Hanley by the straighter posterior ventral margin. There is a slight degree of rostration on the specimens; otherwise they agree well with the subgenus *Eurytellina.*

Subgenus ***Merisca*** Dall

Merisca DALL (1900), Proc. U. S. Nat. Mus., vol. 23, p. 290.

Subgenotype: *Tellina crystallina* Wood (orig. desig.)

Tellina (Merisca) reclusa Dall

(Plate 23, figures 12, 16)

Tellina (Merisca) reclusa DALL (1900), Proc. U. S. Nat. Mus. vol. 23, p. 315, pl. 3, fig. 2.
Tellina reclusa Dall, GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 360; JORDAN (1936), Contrib. Dept. Geol., Stanford Univ., vol. 1, p. 145.

Hypotype no. 32608 (loc. A 3548).

OCCURRENCE: locs. A 3548, A 3582.

RANGE: Pleistocene, Recent.

REMARKS: Jordan has discussed the relation of this to other species.

Subgenus ***Scrobiculina*** Dall

Scrobiculina DALL (1900), Proc. U. S. Nat. Mus., vol. 23, p. 290–291; (1900) Trans. Wagner Free Inst. Sci., vol. 3, p. 1013.

Subgenotype: *Scrobicularia viridotincta* Carpenter (orig. desig.)

Tellina (Scrobiculina) ochracea Carpenter

(Plate 23, figures 9, 18)

Tellina (Peronaederma) ochracea CARPENTER (1864), Ann. Mag. Nat. Hist., ser. 3, vol. 13, p. 311.
Tellina (Scrobiculina) ochracea Carpenter, DALL (1900), Proc. U. S. Nat. Mus., vol. 23, p. 302.
Tellina ochracea Cpr., PILSBRY AND LOWE (1932), Proc. Acad. Nat. Sci. Philadelphia, vol. 84, p. 132.

Hypotypes nos. 32616 (loc. A 3548), 32617 (loc. A 3519).

OCCURRENCE: locs. A 3519, A 3534, A 3548, A 3550.

RANGE: upper Pliocene to Recent.

REMARKS: Recent shells of this large species are tinted with yellow internally. Externally there are abundant fine radial striae and occasional indistinct radial rays.

Genus ***Apolymetis*** Salisbury

Metis H. AND A. ADAMS (1856), Gen. Rec. Moll., vol. 2, p. 399; *non Metis* GISTEL (1848).
Apolymetis SALISBURY (1929), Proc. Malac. Soc. London, vol. 18, p. 258; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 363.

Genotype: *Tellina meyeri* Philippi

Apolymetis biangulata (Carpenter)

(Plate 24, figure 1; Plate 25, figure 12)

Tellina alta CONRAD (1837), Jour. Acad. Nat. Sci. Philadelphia, vol. 7, p. 258; not *Tellina alta* CONRAD (1833).
Scrobicularia biangulata CARPENTER (1855), Proc. Zool. Soc. London, pt. 23, p. 213, 230.
Metis alta CONRAD. *auct.*
Apolymetis biangulata (Carpenter), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 363–364 pl. 20, fig. 16.

Hypotypes nos. 32622, 32626, Recent, San Diego.

OCCURRENCE: loc. 1668, Recent, Santa Barbara to San Diego.

RANGE: Miocene (?) to Recent.

REMARKS: In view of the differences noted on the hinge of the following form which is externally very similar to the typical *A. biangulata*, the fossil records of this species should be re-examined. It is here figured for comparison.

Apolymetis clarki, n. sp.

(Plate 24, figure 12; Plate 25, figure 14)

? *Metis alta* Conrad, DALL (1918), Nautilus, vol. 32 p. 24; JORDAN (1924), Bull. South. Calif. Acad. Sci., vol. 23, p. 149; JORDAN (1926), Proc. Calif. Acad. Sci., ser. 4, vol. 15, p. 244; JORDAN (1936), Contrib. Dept. Geol., Stanford Univ., vol. 1, p. 111.

Shell externally similar to that of *A. biangulata* (Carpenter) except that the ligament is not quite so long and internally the hinge plate is only about half as wide; with the two anterior cardinals of right valve in same position, but about half again as high; posterior cardinal and lateral of right valve obsolete (present in *A. biangulata*); ligamental groove very shallow, about half the depth of the aforementioned species; beaks central.

Dimensions of holotype: Length 61.2 mm, height 50 mm, thickness (both valves) 26.9 mm.

Holotype no. 32615 (loc. A 3582); paratypes nos. 32613, 32614 (loc. A 3596).

OCCURRENCE: locs. A 3534, A 3582, A 3584, A 3596, A 3598, A 3670.

RANGE: upper Pliocene to Recent.

REMARKS: Fourteen specimens are available; all have the hinge as described. *Apolymetis excavata* Sowerby (1867) is much more abruptly truncated posteriorly and less inflated.

Family SEMELIDAE

Genus *Semele* Schumacher

Semele SCHUMACHER (1817), Essai Nouv. Syst. Test., p. 165.
Amphidesma LAMARCK (1818), Hist. Anim. sans Vert., vol. 5, p. 489.

Genotype: *Tellina reticulata* Spengler (*Tellina proficua* Pulteney, monotypic)

Semele flavescens (Gould)

(Plate 24, figure 2; Plate 25, figure 10)

Amphidesma flavescens GOULD (1851), Proc. Boston Soc. Nat. Hist., vol. 4, p. 89.
Amphidesma proximum ADAMS (1852), Ann. Lyceum Nat. Hist. New York, vol. 5, p. 513.
Semele flavescens (Gould), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 376.
Semele proxima (Adams), JORDAN (1936), Contrib. Dept. Geol., Stanford Univ., vol. 1, p. 112.

Hypotypes nos. 32627, 32630 (loc. A. 3598).

OCCURRENCE: locs. ? A 3534, A 3598.

RANGE: upper Pliocene (?), Pleistocene, Recent.

REMARKS: Only five specimens were found. The hypotype is 59 mm long, 55 mm high, and 23.5 mm thick (both valves). Externally this species is quite similar to *Semele decisa* Conrad, but the character of the anterior lateral separates it. The specimen from loc. A 3534 is immature, if it is correctly referred to this species.

Semele hertleini, n. sp.

(Plate 24, figure 6; Plate 25, figure 7)

A small shell resembling *S. guaymasensis* Pilsbry and Lowe and *S. jaramija* Pilsbry and Olsson in shape but slightly more elongate; nearly subrhomboidal in shape; beaks about a third the length from posterior end; shell slightly convex; sculpture fine and delicate, near beaks dominantly concentric, but soon equally composed of numerous fine concentric and radial ribs over entire shell; about 60 radial ribs forming a small obtuse spine or frill at their intersection with concentric ribs.

Dimensions: Holotype, length 15.8 mm, height 11.1 mm, thickness (1 valve) 2.2 mm.

Holotype no. 30367 (loc. A 3548); paratype no. 30368 (loc. A 3582).

Occurrence: locs. A 3548, A 3582.

Range: Pleistocene.

Remarks: The group of small Semeles—*S. pacifica* Dall, *S. quentinensis* Dall, *S. guaymasensis* Pilsbry and Lowe, *S. jaramija* Pilsbry and Olsson, and the present one appear to be closely related. The very fine and evenly distributed concentric and radial ribs of this species appear to be characteristic on the basis of the specimens now available.

Semele jaramija Pilsbry and Olsson

(Plate 24, figure 7; Plate 25, figure 6)

Semele jaramija Pilsbry and Olsson (1941), Proc. Acad. Nat. Sci. Philadelphia, vol. 93, p. 70, pl. 17, fig. 5.

Hypotypes nos. 32888, 32889 (loc. A 3582).

Occurrence: loc. A 3582.

Range: Pleistocene; Pliocene of Ecuador.

Remarks: Two well-preserved right valves of this species were found.

Family Sanguinolariidae

Genus ***Tagelus*** Gray

Tagelus Gray (1847), Proc. Zool. Soc. London, pt. 15, p. 189.

Genotype: *Solen guinensis* Gray (orig. desig.)

Subgenus ***Tagelus ss.***

Tagelus (Tagelus) affinis (Adams)

(Plate 24, figures 4, 13)

Solecurtus affinis Adams (1852), Cat. Panama Shells, p. 300.
Tagelus affinis Ads., Pilsbry and Lowe (1933), Proc. Acad. Nat. Sci. Philadelphia, vol. 84, p. 131.

Hypotypes nos. 32653, 32654 (loc. A 3586).

Occurrence: loc. A 3586.

Range: Pleistocene, Recent.

Remarks: The pallial sinus extending to a point just anterior to the beaks easily separates this species from the other common forms in this area.

Tagelus (Tagelus) californianus (Conrad)

(Plate 24, figures 3, 9)

Solecurtus (Cultellus) californianus Conrad (1837), Jour. Acad. Nat. Sci. Philadelphia, vol. 7, p. 233, pl. 18, fig. 3.
Tagelus californianus (Conrad), Grant and Gale (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 384; Jordan (1936), Contrib. Dept. Geol., Stanford Univ., vol. 1, p. 112.

Hypotypes nos. 32666, 32667 (loc. A 3582).

Occurrence: loc. A 3582, A 3670.

Range: upper Pliocene to Recent.

Remarks: The specimens from loc. A 3670 seem to be slightly shorter in proportion to their height than those from loc. A 3582 but agree in all other respects.

Tagelus (Tagelus) violascens (Carpenter) ?

(Plate 24, figures 8, 11)

Solecurtus violascens Carpenter (1857), Cat. Mazatlan Shells, p. 27, footnote.

Hypotype no. 32651 loc. A 3584.

Occurrence: loc. A 3584.

RANGE: Pleistocene.

REMARKS: A single specimen 34.5 mm long, curved ventrally in a broad arc. It closely resembles small specimens identified as Carpenter's species in the California Academy of Science collections, although the mature shell does not have the broad arc. Possibly this form may represent an undescribed species and not be a young *T. violascens.* Unfortunately there are not enough specimens available now to decide the point.

Subgenus ***Mesopleura*** Conrad

Mesopleura CONRAD (1867), "Cat. Solenidae" Am. Jour. Conch., vol. 3, appendix, p. 23.

Subgenotype: *Solen divisius* Spengler

Tagelus (Mesopleura) subteres (Conrad)

(Plate 24, figures 5, 10)

Solecurtus (Cultellus) subteres CONRAD (1837), Jour. Acad. Nat. Sci. Philadelphia, vol. 7, p. 233, pl. 17, fig. 10.

Tagelus subteres (Conrad), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 385

Hypotypes nos. 32662, 32664 (loc. A 3670).

OCCURRENCE: locs. A 3548, A 3582, A 3670.

RANGE: Pleistocene, Recent.

REMARKS: The internal rib, directed ventrally from the beaks, characteristic of this subgenus, readily separates this species from the others here noted.

Family MACTRIDAE

Genus ***Mactrotoma*** Dall

Mactrotoma DALL (1894), Nautilus, vol. 8, p. 26; (1898), Trans. Wagner Free Inst. Sci., vol. 3, p. 876; LAMY (1917), Jour. de Conchyl., vol. 63, p. 178, 179; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 392.

Genotype: *Mactra fragilis* Gmelin (*Mactra fragilis* Chemnitz), (orig. desig.), here figured (Pl. 25, figs. 2, 17).

ORIGINAL DIAGNOSIS: "Anterior left lateral tooth bidentate, right vental tooth tridentate."

Supplementary observations on the type, *M. fragilis*, are as follows: shell elongate, convexity rather low, a fairly large posterior gape; shell thin; escutcheon well defined; a second ridge outside escutcheon, extending from umbo to posterior ventral margin; area between escutcheon and umbonal ridge with fine irregular radial striae, these striae not readily apparent on small shells, but plainly evident on large specimens; lunule not evident on immature specimens (35 mm) but well defined and large on mature specimens (60 mm); internally pallial sinus is large and horizontal, extending almost to a point underneath umbo, and with a height slightly over a third the altitude of the shell; ligament visible externally, separated by a ridge from chondrophore; laterals fairly short, not vertically striated; posterior half of V-shaped middle cardinal very short.

Observations on other species show that there is a well-defined group of mactroid shells having the following characters: a marked posterior gape; an umbonal ridge outside the escutcheon, running to the posterior ventral margin; a large horizontal pallial sinus; posterior side of the V-shaped cardinal shortest; laterals short; large mature shells with a large elongate "lunule." The preceding may be taken as a supplementary diagnosis of *Mactrotoma* Dall which is here raised to generic rank and separated from *Mactra* and *Spisula* by the above characters.

Mactra stultorum (Linnaeus), the type of *Mactra*, does not gape, has no escutcheon (or if the posterior area inside the umbonal ridge is considered as an escutcheon, has no umbonal ridge corresponding to that in *Mactra fragilis*), the pallial sinus is short, broad, and ascending, the posterior side of the V-shaped cardinal tooth is as long as the anterior, and the lateral teeth are proportionally much longer.

Mactra solida (Linnaeus), the type of *Spisula*, is a heavy shell with no gape, no escutcheon, the pallial sinus is short, small, and ascending, the lateral teeth are long and vertically striated. It should be noted that none of the Pacific Coast species commonly referred to *Spisula* have the heavy shell and vertically striated laterals of the type species.

"Mactra" californica Conrad (1837) appears to be the Pacific Coast analogue of *"Mactra" fragilis*. It is the type of *Micromactra* Dall (1894) which does not appear to be separable from typical *Mactrotoma*. Probably *Mactra* (*Mactrotoma*) *nasuta* Gould of Dall (1894) may also be referred to this genus. According to Gould (1862) his *Mactra nasuta* was extremely close to *M. falcata* Gould, a species that could not by any stretch of imagination be assigned to *Mactrotoma*.

Although *Mactra angusta* Deshayes was considered by Dall and later by Packard to be a synonym of *M. californica*, Pilsbry and Lowe (1932) have shown that it can be separated. It, together with *Mactra* (*Micromactra*) *isthmica* Pilsbry and Lowe, and *Mactra* (*Micromactra*) *vanattae* Pilsbry and Lowe, from the Panamic fauna, are all referable to *Mactrotoma*. These three species have been well figured by those authors.

Several undescribed species of this group appear to be represented in the C. A. S. collections from the Gulf of California-Panama area, one of which is here described. Another apparently undescribed species is represented in the Univ. Calif. collections by a pair of valves. They are 75 mm long and at first were thought to be a large *"Mactra" californica*, but they are of different proportions, have a larger pallial sinus, and a slightly different hinge.

Mactrotoma revellei n. sp.

(Plate 25, figures 1, 5)

Shell large, thin, subtriangular, moderately compressed, gaping posteriorly, somewhat rostrate anteriorly; in general resembling *Mactra hemphilli* Dall in outline, but more truncate posteriorly across gape and less rostrate anteriorly; a well-marked narrow escutcheon, outside of escutcheon a sharp angulation running from umbo to posterior ventral margin; a second indistinct line running from umbo vertically to ventral margin, internally the anterior end of pallial sinus coincides with this line; a poorly defined, narrow, elongate lunule present; internally pallial sinus is very large, horizontal, with its width a third the height of the shell; ligament visible externally, separated from chondrophore by a ridge; posterior laterals of right valve are moderately short, with anterior laterals about the same length.

Dimensions of holotype (right valve): Length 111 mm, height 80.5 mm, thickness (one valve) 19 mm.

Holotype no. 32237, paratype 32235 (loc. A 3548).

OCCURRENCE: loc. A 3548 and Recent, Gulf of California.

RANGE: Pleistocene and Recent.

Family MYACIDAE

Genus ***Cryptomya*** Conrad

Cryptomya CONRAD (1848), Proc. Acad. Nat. Sci. Philadelphia, vol. 4, p. 121.

Genotype: *Sphaenia californica* Conrad (monotypic)

Cryptomya californica (Conrad)

(Pate 26, figures 7, 9)

Sphaenia californica CONRAD (1837), Jour. Acad. Nat. Sci. Philadelphia, vol. 7, p. 234, pl. 17, fig. 11.
Cryptomya californica (Conrad), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 417, pl. 21, figs. 7, 8a, 8b, 11, 14a, 14b.

Hypotype no. 32388 (loc. A 3584).

OCCURRENCE: loc. A 3584.

RANGE: Pleistocene, Recent.

REMARKS: A single broken left valve with the chondrophore intact and the posterior end more pointed than usual for this species. The radial striations are very faint and fewer in number than on the Recent specimens examined. Possibly more abundant and better material might show that this is a new species. It is probable that Grant and Gale threw too many forms in synonymy.

Family CORBULIDAE

Genus **Corbula** Bruguière

Corbula BRUGUIÈRE (1797), Encycl. Meth., pl. 230.

Genotype: *Corbula nucleus* Lamarck (subs. desig. Children, 1823)

Subgenus **Lentidium** Cristofori and Jan

Lentidium CRISTOFORI AND JAN (1832), Catalogus, sect. 2, p. 8; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 421.

Subgenotype: *Lentidium maculatum* Cristofori and Jan (*Corbula mediterranea* (da Costa), *fide* Monterosato, 1884).

Corbula* (*Lentidium*) *luteola Carpenter

(Plate 25, figures 15, 16)

Corbula luteola CARPENTER (1864), Brit. Assoc. Adv. Sci., Rept. for 1863, p. 637.
Corbula (*Lentidium*) *luteola* Carpenter, GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 421–422, pl. 19, figs. 2, 7.

Hypotypes nos. 32655, 32660 (loc. A 3582).
OCCURRENCE: loc. A 3582.
RANGE: Pleistocene, Recent.

Family BASTEROTIIDAE

Genus **Basterotia** Mayer

Basterotia MAYER in HORNES (1870), Abh. der K. K. Geolog. Reichsanstalt, vol. 4, p. 40.

Genotype: *Basterotia corbuloides* Mayer (monotypic)

Basterotia californica n. sp.

(Plate 25, figures 9, 13)

Shell small, moderately thin, elongate subquadrate, moderately inflated; ornamented by irregular concentric growth lines; beak not very prominent; an angulation running from umbo to posterior ventral margin; beak slightly anterior to midpoint of shell; a prominent projecting cardinal tooth in each valve, slanting anteriorly, a deep "socket" adjacent posteriorly in left valve.

Dimensions of holotype: Length 8.5 mm, height 4.9 mm, thickness 1.7 mm (one valve).
Holotype no. 32668 (loc. A 3582).
OCCURRENCE: loc. A 3582.
RANGE: Pleistocene.

REMARKS: Only one specimen of this species was found. It differs from both *B. peninsulare* and *B. hertleini* in that the beak is more nearly central, the posterior angulation less pronounced, the ventral margin is parallel to the dorsal margin, and the cardinal tooth slants much more anteriorly.

Basterotia hertleini n. sp.

(Plate 25, figures 4, 11)

Shell in general resembling *B. peninsulare* (Jordan) but more elongate and normally less inflated; subquadrate, moderately thin, ornamented by irregular concentric growth lines only; beaks not very prominent; an angulation running from umbo to posterior ventral margin; umbos situated about a fourth the length from the anterior end; a prominent projecting cardinal tooth in each valve, with adjacent deep "socket" anterior to it in right valve.

Dimensions of holotype: Length 13.2 mm, height 7.8 mm, thickness 3.6 mm (one valve).

Holotype no. 32274; paratypes nos. 32328, 32372 (loc. A 3670).

OCCURRENCE: locs. A 3519, A 3520, A 3670.

RANGE: upper Pliocene.

REMARKS: This species may be distinguished from *B. peninsulare* (Jordan) by its greater length, greater width between the angulation and the posterior ventral margin, normally lesser inflation, and usually less sharp angulation. There are six specimens from locality A 3670.

Basterotia peninsulare (Jordan)

(Plate 25, figures 3, 8)

Anisodonta peninsulare JORDAN (1936), Contrib. Dept. Geol., Stanford Univ., vol. 1, p. 147, pl. 18, figs. 11, 12.

Hypotypes nos. 32271, 32272, 32273 (loc. A 3548).

OCCURRENCE: loc. A 3548.

RANGE: Pleistocene.

REMARKS: This species is assigned to *Basterotia* rather than *Anisodonta* for the following reason: The type of *Anisodonta* (*A. complanata* Deshayes) has both middle and posterior cardinals whereas the present species has only one prominent tooth and a marked socket almost dividing the hinge plate into two parts; the type of *Basterotia* (*B. corbuloides* Mayer) has but a single prominent tooth and a marked socket similar to that in the present species.

There are 16 specimens in the present lot. All are markedly inflated and have a prominent angulation from the umbo to the posterior ventral margin; some specimens are somewhat shorter than the others, but in general they agree well with Jordan's types.

"*Corbula*" *quadrata* Hinds is a living species of *Basterotia* in the Pacific. It has a much sharper posterior umbonal ridge.

Family SAXICAVIDAE

Genus ***Panope*** Ménard de la Groye

Glycimeris LAMARCK (1799), Mém. Soc. Hist. Nat. Paris, vol. 1, p. 83; not *Glycymeris* DA COSTA (1778).

Panope MÉNARD DE LA GROYE (1807), Mémoire sur un Nouveau Genre de Coquille bivalve-équivalve de la Famille des Solenoides, p. 16, 30.

Genotype: *Panope aldrovandi* Ménard de la Groye (*Mya glycimeris* Born, 1778)

Panope taeniata Dall

(Plate 26, figures 10, 12)

Panope (*generosa* Gould var. ?) *taeniata* n. sp. ? DALL (1918), Nautilus, vol. 32, p. 25.

Panope (*Panope*) *generosa* Gould, GRANT AND GALE (in part) (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 424–425.

Panope taeniata Dall, JORDAN (1936), Contrib. Dept. Geol., Stanford Univ., vol. 1, p. 112, 146.

Hypotypes nos. 32266, 32267 (loc. A 3582).

OCCURRENCE: loc. A 3582.

RANGE: Pleistocene.

REMARKS: According to Dall

> "the shell of *taeniata* is more arcuate, more attenuated behind, less squarely truncate, the valve more inflated with more of a cavity under the beak, with a shorter ligament, and with the posterior adductor scar nearly circular, while in *generosa* it forms an elongate oval; the anterior scar is also larger and wider than in *generosa*."

The present specimens agree well with the above description except that they lack the low rounded rib present on the type from near the beak to the lower margin near the base of the truncation, which Dall supposed might be an individual mutation.

Class GASTROPODA

Family BULLIDAE

Genus *Bulla* Linnaeus

Bulla LINNAEUS (1758), Syst. Natura, Ed. 10, p. 725, *non* p. 427.
Bullus MONTFORT (1810), Conchyl. Syst., vol. 2, p. 330–332; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 455–456.

Genotype: *Bulla ampulla* Linnaeus (subs. desig., Schumacher, 1817)

Opinion 124, International Rules of Zoological Nomenclature, indicates that *Bulla* Linnaeus is valid.

Bulla aspersa Adams

(Plate 30, figure 21)

Bulla aspersa ADAMS *in* SOWERBY (1850), Thes. Conch., vol. 2, p. 578, pl. 123, fig. 78; REEVE (1868), Conch. Icon., vol. 16, *Bulla*, pl. 6, sp. 18.
Bullaria aspersa A. Adams, DALL (1910), Proc. U. S. Nat. Mus., vol. 37, p. 199.
Bullus aspersus (A. Adams), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 456; JORDAN (1936), Contrib. Dept. Geol. Stanford Univ., vol. 1, p. 113.

Hypotype no. 32800 (loc. A 3582).
OCCURRENCE: locs. A 3548, A 3582, A 3584.
RANGE: Pleistocene, Recent.

Family BULIMULIDAE

Genus *Bulimulus* Leach

Bulimulus LEACH (1814), Zool. Misc., vol. 1, p. 41; PILSBRY (1946), Acad. Nat. Sci. Phila., Mon. 3, vol. 2, pt. 1, p. 4.

Bulimulus sp.

Hypotype no. 32892 (loc. A 3540).
OCCURRENCE: loc. A 3540.
RANGE: Pleistocene.

Family ELLOBIIDAE

Genus *Melampus* Montfort

Melampus MONTFORT (1810), Conchyl. Syst., vol. 2, p. 318–320; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 461.

Genotype *Bulimus conijormis* Bruguière = *Bulla coffea* Linnaeus

Melampus trilineatus (Adams)

(Plate 27, figure 4)

Auricula trilineata ADAMS (1852), Cat. Panama Shells, p. 212; (1852) Ann. Lyceum Nat. Hist. New York, vol. 5, p. 436.
Melampus trilineatus (C. B. Adams), SMITH (1944), Panamic Marine Shells, p. 45, no. 600C.

Hypotypes nos. 32695, 32696 (loc. A 3507).
OCCURRENCE: loc. A 3507.
RANGE: Pleistocene, Recent.

Family TEREBRIDAE

Genus ***Terebra*** Bruguière

Terebra BRUGUIÈRE (1789), Encycl. Meth. Hist. Nat. vers, vol. 1, p. XV; LAMARCK (1799), Mem. Soc. Hist. Nat. Paris, p. 71; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 464.

Genotype: *Buccinum subulatum* Linnaeus (monotypic, Lamarck, 1799, as Bruguière did not list any species)

Genus ***Terebra*** s.s.

Terebra (***Terebra***) ***strigata*** Sowerby

(Plate 33, figure 16)

Terebra strigata SOWERBY (1825), Cat. Shells Tankerville, Append., p. 23; REEVE (1860), Conch. Icon., vol. 12, *Terebra*, pl. 2, sp. 51; JORDAN (1936), Contrib. Dept. Geol. Stanford Univ., vol. 1, p. 115; SMITH (1944), Panamic Marine Shells, p. 36, no. 470.

Terebra (*Terebra*) *strigata* Sowerby, GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 415.

Hypotype no. 32789 (loc. A 3582).

OCCURRENCE: loc. A 3582.

RANGE: Pleistocene, Recent.

Subgenus ***Strioterebrum*** Sacco

Strioterebrum SACCO (1891), Moll. Terr. Terziari Piemonte e Liguria, pt. 10, p. 33; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 466.

Subgenotype: *Terebra basteroti* Nyst (orig. desig.)

Terebra (***Strioterebrum***) ***panamensis*** Dall

(Plate 33, figure 21)

Terebra (*Strioterebrum*) *panamensis* DALL (1908), Bull. Mus. Comp. Zool., vol. 43, p. 250, pl. 5, fig. 10; SMITH (1944), Panamic Marine Shells, p. 36, no. 469.

Hypotype no. 32719 (loc. A 3582).

OCCURRENCE: locs. A 3582, A 3584.

RANGE: Pleistocene, Recent.

Terebra (***Strioterebrum***) ***pedroana*** var. ***hemphilli*** Vanatta

(Plate 33, figure 20)

Terebra pedroana hemphilli VANATTA (1925), Proc. Acad. Nat. Sci. Philadelphia, vol. 76, p. 425 fig. 3.

Hypotype no. 32770 (loc. A 3582).

OCCURRENCE: loc. A 3582.

RANGE: Pleistocene, Recent.

Terebra (***Strioterebrum***) ***specillata*** Hinds

(Plate 33, figure 5)

Terebra specillata HINDS (1844), Proc. Zool. Soc. London for 1843, p. 155; REEVE (1860), Conch. Icon., vol. 12, *Terebra*, pl. 17, sp. 75; JORDAN (1936), Contrib. Dept. Geol. Stanford Univ. vol. 1, p. 115; SMITH (1944), Panamic Marine Shells, p. 36, no. 467.

Terebra (*Strioterebrum*) *specillata* Hinds, GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 467.

Hypotype no. 32780 (loc. A 3596).

OCCURRENCE: locs. A 3582, A 3596.

RANGE: Pleistocene, Recent.

Terebra* (*Strioterebrum*) *variegata Gray

(Plate 33, figures 10, 22)

Terebra variegata GRAY (1834), Proc. Zool. Soc. London, p. 61; REEVE (1860), Conch. Icon., vol. 12. *Terebra*, pl. 4, sp. 12; HANNA AND HERTLEIN (1927), Proc. Calif. Acad. Sci., ser. 4, vol. 16, p 143; JORDAN (1936), Contrib. Dept. Geol. Stanford Univ., vol. 1, p. 115; SMITH (1944), Panamic Marine Shells, p. 36, no. 465.

Terebra (*Strioterebrum*) *variegata* Gray, GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 466.

Hypotypes nos. 32801 (loc. A 3582), 32802 (loc. A 3519).

OCCURRENCE: locs. A 3515, A 3519, A 3548, A 3582, A 3584.

RANGE: upper Pliocene to Recent.

Family TURRIDAE

Genus ***Clathrodrillia*** Dall

Clathrodrillia DALL (1918), Proc. U. S. Nat. Mus., vol. 54, p. 317.

Genotype: *Pleurotoma gibbosa* Reeve (orig. desig.)

"*Clathrodrillia*" *nautica* Pilsbry and Lowe?

(Plate 32, figure 3)

Clathrodrillia nautica PILSBRY AND LOWE (1932), Proc. Acad. Nat. Sci. Philadelphia, vol. 84, p. 44; pl. 2, fig. 1.

Hypotype no. 32132 (loc. A 3584).

OCCURRENCE: loc. A 3584.

RANGE: Pleistocene, Recent.

REMARKS: The present specimen is rather worn and consequently is difficult to identify with certainty. The suture does not appear to be as wavy as Pilsbry and Lowe's figure indicates, and there does not appear to be any spiral lines on the fasciole. The reference of this species to *Clathrodrillia* is highly problematical, but in the present confused state of turrid nomenclature it is left where Pilsbry and Lowe put it.

Genus ***Crassispira*** Swainson

Crassispira SWAINSON (1840), Treat. Malac., p. 152, 313; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 580–581.

Genotype *Pleurotoma bottae* Valenciennes (subs. desig. Herrmannsen, 1847)

Crassispira kluthi Jordan

(Plate 33, figure 3)

Crassispira kluthi JORDAN (1936), Contrib. Dept. Geol. Stanford Univ., vol. 1, p. 153, pl. 18, fig. 1.

Hypotype no. 32693 (loc. A 3548).

OCCURRENCE: loc. A 3548.

RANGE: Pleistocene.

Genus ***Elaeocyma*** Dall

Elaeocyma DALL (1918), Proc. U. S. Nat. Mus., vol. 54, p. 317.

Genotype: *Drillia empyrosia* Dall (orig. desig.)

Elaeocyma aegina Dall?

(Plate 33, figure 13)

Alaeocyma aegina DALL (1919), Proc. U. S. Nat. Mus., vol. 56, p. 12–13, pl. 4, fig. 2.

Clavus (*Cymatosyrinx*) *pallidus* (Sowerby), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. His., vol. 1, p. 576–577 (*pro parte*), *non* figs. 16a, 16b, 17.

Hypotype no. 32692 (loc. A 3582).

OCCURRENCE: loc. A 3582.

RANGE: Pleistocene, Recent.

REMARKS: The present specimen agrees well with Dall's figure except that the spiral sculpture does not show on the area of the anal fasciole. It is assumed that this may be an individual variation or that erosion has removed it from this area.

Grant and Gale's treatment of *Elaeocyma* and *E. aegina* is completely unjustified. The species and supraspecific units lumped together are in most cases markedly distinct.

Genus ***Knefastia*** Dall

Knefastia DALL (1919), Proc. U. S. Nat. Mus., vol. 56, p. 3; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 484.

Genotype: *Pleurotoma olivacea* Sowerby, ***non*** Reeve (1843) (orig. desig.)

Knefastia tuberculifera (Broderip and Sowerby)

(Plate 32, figure 10)

Pleurotoma tuberculifera BRODERIP AND SOWERBY (1829), Zool. Jour. London, vol. 4, p. 378; REEVE (1843), Conch. Icon., vol. 1, *Pleurotoma*, pl. 8, sp. 63.

Clavatula (*Knefastia*) *tuberculifera* (Broderip and Sowerby), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 485, pl. 25, figs. 10a, 10b.

Turris tuberculiferas (Broderip and Sowerby), SMITH (1944), Panamic Marine Shells, p. 38, no. 496.

Hypotype no. 32141 (loc. A 3548).

OCCURRENCE: loc. A 3548.

RANGE: Pleistocene, Recent.

REMARKS: Reeve's figure is very indeterminate, the identity of the present specimen with that figure may well be questioned, but the specific identity with the specimen figured by Grant and Gale is certain.

Genus ***Polystira*** Woodring

Polystira WOODRING (1928), Carnegie Inst. Wash., Publ. 385, p. 145–146.

Genotype: *Pleurotoma albida* Perry (orig. desig.)

Polystira nobilis (Hinds)

(Plate 32, figure 11)

Pleurotoma nobilis HINDS (1843), Proc. Zool. Soc. London, p. 37; (1844) voy. Sulfur, vol. 2, Mollusca, p. 15, pl. 5, figs. 1, 2.

Pleurotoma oxytropis Sowerby, TRYON (1884), Man. Conch., vol. 6, p. 168 (*pro parte*), pl. 4, fig. 39, *non* figs. 37, 38.

Hypotype no. 32109 (loc. A 3584).

OCCURRENCE: loc. A 3584.

RANGE: Pleistocene, Recent.

REMARKS: The present specimen is broken anteriorly, but agrees very closely with Hinds' Figure 1. This species is much closer to the genotype of *Polystira* than to that of *Turris.*

Genus ***Turricula*** Schumacher

Turricula SCHUMACHER (1817), Essai nouv. syst. vers test., p. 217; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 486–487.

(Genotype: *Turricula flammea* Schumacher = *Murex javanus* Linnaeus (monotypic)

Turricula maculosa (Sowerby)

(Plate 32, figure 14)

Pleurotoma maculosa SOWERBY (1833), Proc. Zool. Soc. London, p. 135; REEVE (1843), Conch. Icon., vol. 1, *Pleurotoma*, pl. 6, sp. 45; CARPENTER (1857), Cat. Mazatlan Shells, p. 391–392.

Turricula maculosa (Sowerby), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 488–489, pl. 25, figs. 11a, 11b.
Elaeocyma maculosa (Sowerby), SMITH (1944), Panamic Marine Shells, p. 38, no. 501.

Hypotype no. 32137 (loc. A 3584).

OCCURRENCE: loc. A 3584.

RANGE: Pleistocene, Recent.

REMARKS: The present specimen is rather badly decorticated.

Family CONIDAE

Genus **Conus** Linnaeus

Conus LINNAEUS (1758), Syst. Natura, Ed. 10, p. 712; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 471–472.

Genotype: *Conus marmoreus* Linnaeus (subs. desig. Children, 1823)

Conus bartschi Hanna and Strong

(Plate 32, figures 1, 7)

Conus bartschi HANNA AND STRONG (1949), Proc. Calif. Acad. Sci., ser. 4, vol. 26, p. 271–272, pl. 5, fig. 5.

Hypotypes nos. 31323, 31343 (loc. A 3550).

OCCURRENCE: loc. A 3550.

RANGE: Pleistocene, Recent.

REMARKS: The present specimens were identified by Dr. G. D. Hanna.

Conus cf. **brunneus** Mawe

(Plate 32, figure 8)

Conus brunneus MAWE (1828), *in* WOOD, Index Test., Suppl., pl. 3, fig. 1.

Hypotype no. 32673 (loc. A 3529).

OCCURRENCE: loc. A 3529.

RANGE: lower Pliocene.

REMARKS: The single specimen is rather poorly preserved. It probably represents a new species. The spire is a little higher, and the shell is slenderer than typical *C. brunneus.*

Conus princeps Linnaeus

(Plate 32, figure 15)

Conus princeps LINNAEUS (1758), Syst. Natura, Ed. 10, p. 713; REEVE (1843), Conch. Icon., vol. 1, pl. 7, sp. 36a; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 475; JORDAN (1936), Contrib. Dept. Geol. Stanford Univ., vol. 1, p. 113.
Conus princeps princeps Linnaeus, SMITH (1944), Panamic Marine Shells, p. 37, no. 486.

Hypotype no. 31260 (loc. A 3519).

OCCURRENCE: locs. A 3508, A 3515, A 3519, A 3525, A 3548, A 3550, A 3573, A 3574, A 3584, A 3596.

RANGE: upper Pliocene to Recent.

Conus puncticulatus Hwass

(Plate 32, figure 2)

Conus puncticulatus HWASS (1792), Encycl. Meth., Hist. Nat. Vers, vol. 1, Genus *Conus*, p. 704; REEVE (1843), Conch. Icon., vol. 1, *Conus*, pl. 20, sp. 116.

Hypotypes nos. 30653, 30665 (loc. A 3550).

OCCURRENCE: locs. A 3538 (?), A 3543, A 3550, A 3596.

RANGE: lower Pliocene to Recent.

REMARKS: The correct name to apply to this species is puzzling. *Conus comptus* Gould, to judge by the original figure, has a much squarer shoulder and a more concave spire. *Conus lucidus* Mawe, in the original figure, has far fewer revolving lines, as does *Conus reticulatus* Sowerby, but this last has more than *lucidus*. Except for the number of spiral lines the present specimens agree well with Sowerby's *reticulatus*. *Conus lucidus*, as figured by Smith (1944, p. 37, sp. 485A), is much more inflated anteriorly and would not appear to be *lucidus* of Mawe. The specimens agree most closely with *puncticulatus* as figured by Reeve, unless the heavy lines on the shoulder in Reeve's figure are supposed to indicate nodes.

Conus recurvus Broderip

(Plate 32, figure 13)

Conus recurvus BRODERIP (May, 1833), Proc. Zool. Soc. London, p. 54; DALL (1910), Proc. U. S. Nat. Mus., vol. 37, p. 207.
Conus incurvus Broderip, SOWERBY (June 1833), Conch. Ill., fig. 36.

Hypotypes nos. 31349, 31350 (loc. A 3582).

OCCURRENCE: locs. A 3515 (?), A 3582, A 3584, A 3597.

RANGE: Pleistocene, Recent.

REMARKS: The relationships of *C. scalaris*, *regularis* and *recurvus* are very obscure. Abundant material needs to be gathered and compared.

Conus regalitatus Sowerby

(Plate 32, figure 21)

Conus regalitatus SOWERBY (1834), Proc. Zool. Soc. London, p. 19; REEVE (1844), Conch. Icon., vol. 1, *Conus*, pl. 40, sp. 218; CARPENTER (1857), Cat. Mazatlan Shells, p. 403.
Conus purpurascens regalitatis Sowerby, SMITH (1944), Panamic Marine Shells, p. 37.

Hypotype no. 31352 (loc. A 3548).

OCCURRENCE: loc. A 3548.

RANGE: Pleistocene, Recent.

Conus regularis Sowerby

(Plate 32, figure 9)

Conus regularis SOWERBY (1833), Conch. Ill., pt. 29, fig. 29; (1841), Conch. Ill., pt. 36, fig. 45; REEVE (1843), Conch. Icon., vol. 1, *Conus*, pl. 26, sp. 146; CARPENTER (1857), Cat. Mazatlan Shells, p. 401–402; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 476; SMITH (1944), Panamic Marine Shells, p. 37, no. 488.

Hypotype no. 31499 (loc. A 3519).

OCCURRENCE: locs. A 3519, A 3529 (?), A 3533 (?), A 3550, A 3596.

RANGE: lower Pliocene to Recent.

Conus scalaris Valenciennes

(Plate 32, figure 17)

Conus scalaris VALENCIENNES (1832), in Humbolt and Bonpland, Recueil D'Observat. Zool., vol. 2, p. 338; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 475–476.
Conus ? scalaris CARPENTER (1857), Cat. Mazatlan Shells, p. 406.

Hypotype no. 31355 (loc. A 3548).

OCCURRENCE: loc. A 3548.

RANGE: Pleistocene, Recent.

Conus ximenes Gray

(Plate 32, figure 19)

Conus ximenes GRAY (1839), Zool. Beechey's Voyage, p. 119, pl. 33, fig. 2; SMITH (1944), Panamic Marine Shells, p. 37.
Conus ximines Gray, GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 477.

Hypotype no. 31346 (loc. A 3548).

OCCURRENCE: locs. A 3548, A 3582, A 3584.

RANGE: Pleistocene, Recent.

REMARKS: The present specimens have been identified by Dr. G. D. Hanna. The figured hypotype has a height of 58 mm. and was noted by Hanna as being the largest specimen of this species he had ever seen.

Family CANCELLARIIDAE

Genus ***Cancellaria*** Lamarck

Cancellaria LAMARCK (1799), Mem. Soc. Hist. Nat. Paris, p. 71.

Genotype: *Voluta reticulata* Linnaeus (monotypic)

Cancellaria cassidiformis Sowerby

(Plate 29, figure 13)

Cancellaria cassidiformis SOWERBY (1832), Proc. Zool. Soc. London, p. 53; (1849), Thes. Conchyl., vol. 2, p. 438, pl. 92, fig. 15; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 620–621.

Hypotype no. 30683 (loc. A 3582).

OCCURRENCE: locs. A 3582, A 3584.

RANGE: Pleistocene, Recent.

Cancellaria coronadosensis n. sp.

(Plate 26, figures 2, 8)

Shell resembling typical living *C. obesa* Sowerby but with a more inflated body whorl and a noticeable shoulder below suture; axial ribs obsolete except in earliest whorls; spiral ribs present throughout, but not marked except last eight on base of body whorl; spire of medium height.

Dimensions of holotype: height 43.7 mm, diameter of body whorl 29.4 mm, height of aperture 30.2 mm.

Holotype no. 30465, paratypes nos. 30466, 30467 (loc. A 3548).

OCCURRENCE: loc. A 3548.

RANGE: Pleistocene.

REMARKS: Distinguished from *C. obesa* Sowerby (Pl. 26, fig. 6) by the lower spire, broader body whorl, and shoulder below the suture. Six specimens were found, of which one has less of a shoulder on the body whorl and more nearly approaches *C. obesa.*

Cancellaria haemostoma Sowerby

(Plate 29, figure 12)

Cancellaria haemostoma SOWERBY (1832), Proc. Zool. Soc. London, p. 54; REEVE (1858), Conch. Icon., vol. 10, *Cancellaria,* pl. 7, figs. 30a, 30b.

Hypotype no. 30680 (loc. A 3548).

OCCURRENCE: loc. A 3548.

RANGE: Pleistocene, Recent.

REMARKS: Some specimens of this species are in Recent collections under the name *Cancellaria rugosa* Lamarck, a Chinese form.

Family OLIVIDAE

Genus ***Oliva*** Martyn

Oliva MARTYN (1786), Univ. Conch., vol. 3, explanatory table and pl. 111.

Genotype: *Oliva corticata* Martyn (? = *Voluta incrassata* Solander), (subs. desig. Dall, 1905)

Oliva davisae n. sp.

(Plate 26, figures 3, 5)

Shell large, heavy, spire very low, obconical; spire of about 7 whorls including protoconch; nuclear whorls about 3, small; suture channeled; outer lip thickened, aperture elongate; inner lip only slightly callused; four plications at base of inner lip, above these about 10 faintly discernible plaits inside aperture.

Dimensions of holotype: height 39.3 mm, diameter 25.5 mm.

Holotype no. 34568, paratype no. 34569 (loc. A 3584).

OCCURRENCE: locs. A 3582, A 3584.

RANGE: Pleistocene.

REMARKS: This species also occurs in the Pleistocene of Magdalena Bay.

A large series of Recent Pacific Coast specimens of *Oliva* were examined to find comparable material. Some specimens of *Oliva spicata* Bolten approach this in size, but the spire is always higher, and shell is never so markedly obconic. *Oliva incrassata* (Solander) is somewhat similar to this species but has a higher spire and less prominent and more rounded shoulder.

Oliva incrassata (Solander)

(Plate 29, figure 2)

Voluta incrassata SOLANDER (1786), Portland Catalogue, p. 171.
Oliva corticata Martyn var. *incrassata* (Solander), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 624.

Hypotype no. 32811 (loc. A 3584).

OCCURRENCE: loc. A 3584.

RANGE: Pleistocene, Recent.

REMARKS: *O. incrassata* has a more gently rounded shoulder than *O. davisae* n. sp. However, the specimen here figured does not have the flattened, inclined shoulder of typical *incrassata.*

Oliva spicata (Bolten)

(Plate 29, figure 1)

Porphyria spicata BOLTEN (1798), Mus. Boltenianum, p. 35.
Oliva spicata (Bolten), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 624.

Hypotype no. 32812 (loc. A 3548).

OCCURRENCE: locs. A 3508, A 3514, A 3515, A 3519, A 3520, A 3529, A 3534, A 3535, A 3536, A 3538, A 3548, A 3550, A 3574, A 3582, A 3584, A 3596, A 3598, A 3670.

RANGE: upper Pliocene to Recent.

REMARKS: The spire of this species is still higher than that of *O. incrassata.*

Genus ***Olivella*** Swainson

Olivella Swainson (1831), Zool. Ill., ser. 2, vol. 2, Expl. pl. 58 (*Oliva*, pl. 2).

Genotype: *Oliva purpurata* Swainson (= *Voluta dama* Mawe), (subs. desig. Dall 1909)

Olivella dama (Mawe)

(Plate 29, figure 5)

Voluta dama MAWE (1828), *in* WOOD, Index Test., Suppl., p. 11, pl. 4, fig. 37.
Olivella dama (Wood), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 626.

Hypotypes nos. 32808, 32809 (loc. A 3519).

OCCURRENCE: locs. A 3519, A 3534, A 3538, A 3548, A 3550, A 3574, A 3582, A 3584, A 3596, A 3598.

RANGE: upper Pliocene to Recent.

REMARKS: This species varies considerably in height of spire and in ratio of diameter to height. Most of the upper Pliocene and Pleistocene specimens are smaller than the Recent material.

Olivella gracilis (Broderip and Sowerby)

(Plate 29, figures 9, 10)

Oliva gracilis BRODERIP AND SOWERBY (1829), Zool. Jour. London, vol. 4, p. 379; REEVE (1850), Conch. Icon., vol. 6, *Oliva*, pl. 20, fig. 46.

Olivella gracilis (Broderip and Sowerby), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 627–628.

Hypotypes nos. 32767, 32768 (loc. A 3582).

OCCURRENCE: loc. A 3582.

RANGE: Pleistocene, Recent.

Olivella tergina (Duclos)

(Plate 29, figures 3, 4)

Oliva tergina DUCLOS (1835), Mon. Oliv., pl. 2, figs. 13–16; REEVE (1850), Conch. Icon., vol. 6, *Oliva*, pl. 26, figs. 80a, 80b.

Hypotypes nos. 32702, 32703 (loc. A 3519).

OCCURRENCE: locs. A 3519, A 3538.

RANGE: upper Pliocene to Recent.

Family VOLUTIDAE

Genus ***Enaeta*** H. and A. Adams

Enaeta H. AND A. ADAMS (1853), Gen. Rec. Moll., vol. 1, p. 167.

Genotype: *Voluta harpa* Barnes (*non* Lamarck) = *Voluta barnesii* Gray (subs. desig. Gray 1857)

Enaeta cumingii (Broderip)

(Plate 32, figure 5)

Voluta cumingii BRODERIP (1832), Proc. Zool. Soc. London, p. 33; REEVE (1849), Conch. Icon., vol. 6, *Voluta*, pl. 1, sp. 1.

Enaeta cumingi Broderip, DALL (1907), Smithson. Misc. Coll., vol. 48, no. 3, p. 352.

Enaeta cumingii (Broderip), SMITH (1944), Panamic Marine Shells, p. 33, no. 444.

Hypotype no. 32771 (loc. A 3548).

OCCURRENCE: loc. A 3548.

RANGE: Pleistocene, Recent.

REMARKS: The present specimen has a higher spire than that shown in Reeve's figure, but it agrees well with some Recent specimens from the Gulf of California.

Family VASIDAE

Genus ***Vasum*** Bolten

Vasum BOLTEN (1798), Mus. Boltenianum, pt. 2, p. 56; WINCKWORTH (1945), Proc. Malac. Soc. London, vol. 26, p. 145.

Genotype: *Vasum turbinellus* Bolten = *Voluta turbinellus* Linnaeus, 1767 = *Murex turbinellus* Linnaeus, 1758 = *Turbinella cornigera* Lamarck (subs. desig. Cossmann, 1901).

Vasum caestus (Broderip)

(Plate 35, figure 11)

Turbinella caestus BRODERIP (1833), Proc. Zool. Soc. London, p. 8; REEVE (1847), Conch. Icon., vol. 4, *Turbinella*, pl. 6, sp. 34a, 34b; CARPENTER (1857), Cat. Mazatlan Shells, p. 456.

Vasum caestus Broderip, DALL (1910), Proc. U. S. Nat. Mus., vol. 37, p. 211; PILSBRY AND LOWE (1932), Proc. Acad. Nat. Sci. Philadelphia, vol. 84, p. 113.
Vasum caestum Broderip, HANNA (1926), Proc. Calif. Acad. Sci., ser. 4, vol. 14, p. 459–460.
Vasum caestus (Broderip), JORDAN (1936), Contrib. Dept. Geol. Stanford Univ., vol. 1, p. 115; SMITH (1944), Panamic Marine Shells, p. 33, nos. 407, 412.

Hypotype no. 30678 (loc. A 3584).

OCCURRENCE: locs. A 3584, A 3596.

RANGE: Pleistocene, Recent.

Family MITRIDAE

Genus *Mitra* Linnaeus

Mitra LINNAEUS (1758), Systema Natura, Ed. 10, p. 732.

Genotype: *Mitra episcopalis* Linnaeus (subs. desig., Children, 1823)

Mitra catalinae (Dall)

(Plate 32, figures 16, 20)

Strigatella (*Atrimitra*) *catalinae* DALL (1919), Proc. U. S. Nat. Mus., vol. 56, p. 308.
Strigatella catalinae Dall, JORDAN (1926), Proc. Calif. Acad. Sci., ser. 4, vol. 15, p. 245.
Mitra catalinae (Dall), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 636, pl. 28, fig. 4.

Hypotypes nos. 32717 (loc. A 3548), 32718 (loc. A 3584).

OCCURRENCE: locs. A 3548, A 3550, A 3584.

RANGE: Pleistocene, Recent.

REMARKS: The specimens at hand agree very well with some of the more inflated individuals collected off San Diego, California.

Mitra tristis Broderip

(Plate 32, figure 6)

Mitra tristis BRODERIP (1835), Proc. Zool. Soc. London, p. 194.
Strigatella tristis Broderip, CARPENTER (1857), Cat. Mazatlan Shells, p. 461.
Mitra tristis Swainson (Broderip), REEVE (1844), Conch. Icon., vol. 2, *Mitra*, pl. 15, fig. 114.
Mitra tristis Swainson, SMITH (1944), Panamic Marine Shells, p. 33, no. 423.

Hypotype no. 30645 (loc. A 3534).

OCCURRENCE: loc. A 3534.

RANGE: upper Pliocene, Recent.

REMARKS: Carpenter describes both a slender and a broad form. The present specimen is more inflated than Reeve's figure and is more acuminate than the specimen figured by Smith.

Family FASCIOLARIIDAE

Genus *Fasciolaria* Lamarck

Fasciolaria LAMARCK (1799), Mem. Soc. Hist. Nat. Paris, ser. 1, vol. 1, p. 73; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 637.

Genotype: *Murex tulipa* Linnaeus (monotypic)

Fasciolaria princeps Sowerby

(Plate 31, figure 15)

Fasciolaria princeps SOWERBY (1825), Cat. Shells Tankerville, Append., p. 16; REEVE (1847), Conch, Icon., vol. 4, *Fasciolaria*, pl. 1, fig. 3; CARPENTER (1857), Cat. Mazatlan Shells, p. 458–459, 544; CARPENTER (1872), Smithson. Misc. Coll., no. 252, p. 27, 48, 110, 183; HANNA (1926), Proc. Calif. Acad. Sci., ser. 4, vol. 14, p. 448; Hanna and Hertlein (1927), Proc. Calif. Acad. Sci., ser. 4, vol. 16, p. 143, 150; Grant and Gale (1931), Mem. San Diego Soc. Nat. Hist. vol. 1, p. 637; Smith (1944), p. 32, nos. 404, 415.

Hypotype no. 30644 (loc. A 3596).

Occurrence: locs. A 3508, A 3596.

Range: Pleistocene, Recent.

Remarks: Hanna has recorded this species from the lower Pliocene Imperial formation. The specimens at hand have a lower spire than the published illustrations.

Genus ***Fusinus*** Rafinesque

Fusinus Rafinesque (1815), Analyse de la Nature, p. 145 (new name for *Fusus* Bruguière, 1789 *non* Hebling, 1779).

Genotype: *Murex colus* Linnaeus (monotypic Lamarck, 1799)

Fusinus cinereus (Reeve)

(Plate 31, figure 3)

Turbinella cinerea Reeve (1847), Conch. Icon., vol. 4, *Turbinella*, pl. 13, sp. 68; Lowe (1936), San Diego Soc. Nat. Hist., Trans., vol. 8, p. 26.

Hypotype no. 30856 (loc. A 3550).

Occurrence: loc. A 3550.

Range: Pleistocene, Recent.

Remarks: The present specimen has the tip of the anterior canal and the outer lip broken. As a result, the presence or absence of lirations on the inside of the outer lip cannot be determined; they are not present posterior to the point of fracture. Otherwise the specimen agrees very well with Reeve's figure. *Fusus taylorianus* Reeve has more numerous spiral ribs.

Short-canaled species such as this should not be assigned to *Fusinus ss.*, but none of the subgeneric names used on the Pacific Coast appear to be suitable, and time has not been taken to investigate others.

Fusinus fragosus (Reeve)

(Plate 31, figure 6)

Fusus fragosus Reeve (1848), Conch. Icon., vol. 4, *Fusus*, pl. 19, sp. 71.
Fusus ambustus Gould (1852), Boston Journ. Nat. Hist., vol. 6, p. 374; (1862), Otia Conchologica, p. 187; Carpenter (1864), Rept. Brit. Assoc. Adv. Sci. for 1863, p. 535.
Non Fusus ambustus Gould, Carpenter (1864), Rept. Brit. Assoc. Adv. Sci. for 1863, p. 664 = *F. luteopictus* Dall.
Non Fusus luteopictus Dall, Williamson (1892), Proc. U. S. Nat. Mus., vol. 15, p. 217, pl. 20, fig. 1
Non Fusus fragosus Reeve, Grabau (1904), Smithson. Misc. Coll. no. 1417, p. 62–63, pl. 7, figs. 11, 12, 13.

Hypotype no. 30666 (loc. A 3584).

Occurrence: locs. A 3548, A 3582, A 3584.

Range: Pleistocene, Recent.

Remarks: Reeve did not know where his type specimen of *fragosus* came from. The present specimen agrees very well with Reeve's figure. The very tip of the anterior canal is broken on the specimen. Carpenter noted in 1864 (p. 535) that Gould's type was identical with Reeve's type. *F. luteopictus* Dall as figured by Williamson (the identification was by Dall) is a completely unrelated species with a short canal. If Grabau's identification of *fragosus* as a Mediterranean species is correct, Gould's name should be used, for the present species differs from Grabau's in the slightly bent anterior canal and somewhat different spiral ribbing.

Family NEPTUNEIDAE

Genus ***Hanetia*** Jousseaume

Hanetia Jousseaume (1880), Le Naturaliste, 2nd year, p. 335.

Genotype: *Murex haneti* Petit (orig. desig.)

From Petit's figure one cannot determine the apertural characters of his species. If, like *Cantharus tincta* Conrad, of the West Indies, it has a tooth on the inner lip just below the posterior canal, Dall's *Solenosteira*, with *Pyrula anomala* Reeve as type, should be revived. As figured by Petit, *Murex haneti* has a shorter and more twisted anterior canal than *Pyrula anomala.*

Hanetia anomala (Reeve)

(Plate 31, figures 10, 12)

Pyrula anomala REEVE (1847), Conch. Icon., vol. 4, *Pyrula*, pl. 3, sp. 9, 12.
Solenosteira anomala Reeve, DALL (1890), Trans., Wagner Inst. Sci., vol. 3, p. 122; DALL (1918), Nautilus, vol. 32, p. 23; HANNA (1926), Proc. Calif. Acad. Sci., ser. 4, vol. 14, p. 453.
Cantharus anomalus (Reeve), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 648 (*pro parte*); SMITH (1944), Panamic Marine Shells, p. 32, no. 396.
Solenosteira anomala (Reeve), JORDAN (1936), Contrib. Dept. Geol. Stanford Univ., vol. 1, p. 114.

Hypotypes nos. 30805 (loc. A 3582), 30803 (loc. A 3550).

OCCURRENCE: locs. A 3519, A 3550, A 3582, A 3584.

RANGE: upper Pliocene to Recent.

REMARKS: Broderip and Sowerby's *pallida* has a more angulated whorl and a higher spire. If the range of variation of species should include that form, the name *pallida* has priority (1829) over *anomala*. Hypotype no. 30803 represents the typical form of *anomala* as described by Reeve while no. 30805 compares closely with the variant figured by Reeve (his Figure 9).

Genus ***Melongena*** Schumacher

Galeodes BOLTEN (1798), Mus. Boltenianum, pt. 2, p. 53; Winckworth (1945), Proc. Malac. Soc. London, vol. 26, p. 140.
Melongena SCHUMACHER (1817), Essai nouv. syst. vers test., pp. 64, 212.
Non Galeodes OLIVIER (1791), (Arachnid).

Genotype: of *Melongena*, *Murex melongena* Linnaeus = *Galeodes melongena* Bolten, the type of *Galeodes* Bolten (monotypic)

Melongena patula (Broderip and Sowerby)

(Plate 35, figure 4)

Pyrula patula BRODERIP AND SOWERBY (1829), Zool. Jour. London, vol. 1, p. 377; REEVE (1847), Conch. Icon., vol. 4, *Pyrula*, pl. 6, sp. 20; CARPENTER (1857), Cat. Mazatlan Shells, p. 501–502.
Galeodes patulus Broderip, DALL (1910), Proc. U. S. Nat. Mus., vol. 37, p. 213.
Galeodes patula (Broderip), SMITH (1944), Panamic Marine Shells, p. 32, no. 385.

Hypotype no. 30677 (loc. A 3584).

OCCURRENCE: loc. A 3584.

RANGE: Pleistocene, Recent.

Family NASSARIIDAE

Genus ***Nassarius*** Duméril

Nassarius DUMÉRIL (1806), Zool Analytique, p. 166; WOODRING (1928), Carnegie Inst. Wash., Publ. 385, p. 264–265; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 670–671.

Genotype: *Buccinum arcularia* Linnaeus (monotypic)

Nassarius angulicostis (Pilsbry and Lowe)

(Plate 31, figure 13)

Nassa angulicostis PILSBRY AND LOWE (1932), Proc. Acad. Nat. Sci. Philadelphia, vol. 84, p. 69, pl. 6, fig. 2.
Nassa anglicostis (Pilsbry and Lowe), SMITH (1944), Panamic Marine Shells, p. 29, no. 389.

Hypotype no. 32153 (loc. A 3582).

OCCURRENCE: locs. A 3519, A 3548, A 3582, A 3584, A 3596.

RANGE: upper Pliocene to Recent.

Nassarius complanatus (Powis)

(Plate 31, figure 7)

Nassa complanata POWIS (1835), Proc. Zool. Soc. London, p. 96; REEVE (1853), Conch. Icon., vol. 8, *Nassa*, pl. 17, sp. 111; STEARNS (1894), Proc. U. S. Nat. Mus., vol. 17, p. 181.
Nassa complanata var. *major* STEARNS (1894), Proc. U. S. Nat. Mus., vol. 17, p. 181.
Alectrion (*Hima*) *complanatus* Powys, DALL (1910), Proc. U. S. Nat. Mus., vol. 37, p. 214.
Nassarius (*Nassarius*) *complanatus* (Powys), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 671–672.
Nassa complanatus complanatus (Powis), SMITH (1944), Panamic Marine Shells, p. 29.
Nassa complanatus major Stearns, Smith (1944), Panamic Marine Shells, p. 29.

Hypotype no. 32110 (loc. A 3582).

OCCURRENCE: loc. A 3582.

RANGE: Pleistocene, Recent.

REMARKS: The greater number of longitudinal ribs (13–14) will easily separate this species from small specimens of *N. tegula* (Reeve).

Nassarius tiarula (Kiener)

(Plate 31, figure 16)

Buccinum tiarula KIENER (1835), Spec. gén. icon. Coquilles, p. 111, pl. 30, fig. 4.
Nassa tiarula Kiener, REEVE (1853), Conch. Icon., vol. 8, *Nassa*, pl. 14, sp. 92.

Hypotypes nos. 32725, 32726 (loc. A 3582).

OCCURRENCE: locs. A 3519, A 3582.

RANGE: upper Pliocene to Recent.

REMARKS: The present specimens agree very closely with Reeve's figures of Kiener's species. Carpenter (1857, p. 496) remarks on the similarity of Reeve's *tegula* and *tiarula* as figured, but specimens currently identified as *tegula* are larger and have the nodes compressed vertically to a greater extent than the present specimens. Except on the base of the body whorl there is no trace of spiral ribbing on the present specimen.

Genus ***Engina*** Gray

Engina GRAY (1839), Zool. Beechey's Voy., p. 112.

Genotype: *Engina zonata* Gray (subs. desig. Gray 1847)

Engina contracta (Reeve)

(Plate 31, figure 11)

Ricinula contracta REEVE (1846), Conch. Icon., vol. 3, *Ricinula*, pl. 5, sp. 32.
Engina contracta Reeve, DALL (1910), Proc. U. S. Nat. Mus., vol. 37, p. 214.

Hypotype no. 32671 (loc. A 3550).

OCCURRENCE: loc. A 3550.

RANGE: Pleistocene, Recent.

REMARKS: The present specimen is about half the size of Reeve's figure and appears to be immature.

Family PYRENIDAE

Genus *Anachis* H. and A. Adams

Anachis H. AND A. ADAMS (1853), Gen. Rec. Moll., vol. 1, p. 184; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 684–685.

Genotype: *Columbella scalarina* Sowerby (subs. desig. Tate, 1875)

Anachis coronata (Sowerby)

(Plate 32, figure 18)

Columbella coronata SOWERBY (1832), Proc. Zool. Soc. London, p. 114; Reeve (1858), Conch. Icon., vol. 11, *Columbella*, pl. 6, sp. 29.
Anachis coronata Sowerby, CARPENTER (1857), Cat. Mazatlan Shells, p. 508.
Anachis (*Anachis*) *coronata* (Sowerby), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 685.
Anachis coronata (Sowerby), JORDAN (1936), Contrib. Dept. Geol. Stanford Univ., vol. 1, p. 155–156; SMITH (1944), Panamic Marine Shells, p. 27, no. 347.

Hypotype no. 32715 (loc. A 3548).

OCCURRENCE: locs. A 3548, A 3550.

RANGE: Pleistocene, Recent.

REMARKS: The strength of the sculpturing is quite variable in this species.

Genus *Parametaria* Dall

Meta REEVE (1859), Conch. Icon., vol. 11, *Columbella*, under discussion of *C. picata*, sp. 206; REEVE (1859), Conch. Icon., vol. 11, *Meta;* GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 680.
Non Meta KOCH (1835), Arachnidae.
Parametaria DALL (1916), Nautilus, vol. 30, p. 25. New name for *Meta* Reeve.

Genotype: *Meta dupontiae* Kiener (Reeve) = *Conus dupontiae* Kiener

Parametaria cedo-nulli (Reeve)

(Plate 32, figures 4, 12)

Meta cedo-nulli REEVE (1859), Conch. Icon., vol. 11, *Meta*, pl. 1, figs. 3a, 3b—*non* 3c, 3d; CARPENTER (1872), Smithson. Misc. Coll., no. 252, p. 53.
Parametaria dupontii (Kiener), JORDAN (1936), Contrib. Dept. Geol., Stanford Univ., vol. 1, p. 114.

Hypotypes nos. 30898 (loc. A 3519), 31168 (loc. A 3550).

OCCURRENCE: locs. A 3519, A 3550, A 3598.

RANGE: upper Pliocene to Recent.

REMARKS: This species has been identified by various authors as *P. dupontii.* However Reeve's figures show that species to have a lower spire, and it is reported to come from Ichabo, South Africa. Carpenter in 1872 reported *Meta cedo-nulli* from La Paz, Cape San Lucas, and Panama.

Genus *Pyrene* Bolten

Pyrene BOLTEN (1798), Mus. Boltenianum, p. 134; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 680–681.

Genotype (monotypic): *Pyrene rhombiferum* Bolten = *Voluta discors* Gmelin

Pyrene fuscata (Sowerby)

(Plate 33, figure 11)

Columbella fuscata SOWERBY (1832), Proc. Zool. Soc. London, p. 117; REEVE (1858), Conch. Icon., vol. 11, *Columbella*, pl. 2, sp. 9; HANNA AND HERTLEIN (1927), Proc. Calif. Acad. Sci. ser. 4, vol. 16, p. 142.
Pyrene (*Pyrene*) *fuscata* (Sowerby), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 680.
Pyrene fuscata (Sowerby), SMITH (1944), Panamic Marine Shells, p. 27, no. 332.

Hypotype no. 30684 (loc. A 3548).

OCCURRENCE: locs. A 3515, A 3545, A 3548, A 3550, A 3596.

RANGE: upper Pliocene to Recent.

Genus ***Strombina*** Mörch

Strombina MÖRCH (1852), Cat. Conchyl. Yoldi, p. 85; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 698.

Genotype: *Columbella lanceolata* Sowerby (subs. desig. Cossmann, 1901).

This species was also listed first by Mörch, with *C. gibberula* Sowerby as the second and only other form listed.

Strombina (?) ***carlosensis*** n. sp.

(Plate 26, figures 11, 13)

Shell of medium size, moderately elongate, 5 visible whorls (nuclear whorls gone); spire high, pointed; aperture broken, but somewhat elongate, sutures shallow; ornamentation on early whorls of about 9 low longitudinal ribs, reduced to low indistinct elongate nodes on last whorl; lower part of body whorl with 4 or 5 fine spiral ribs with interspaces about 3 times as wide; anterior canal slightly broken, slightly recurved, faintly notched; inner lip callused.

Dimensions of holotype: height (nucleus and tip of anterior canal broken) 20.6 mm, diameter 8.9 mm.

Holotype no. 30362 (loc. A 3595).

OCCURRENCE: loc. A 3595.

RANGE: San Gregorio formation, upper Oligocene.

REMARKS: Because the matrix at this locality is full of secondary crystalline calcite it is very hard to prepare specimens. Fragmentary material of numerous specimens probably representing this species is available.

Strombina maculosa (Sowerby)

(Plate 33, figures 12, 17)

Columbella maculosa SOWERBY (1832), Proc. Zool. Soc. London, p. 116; REEVE (1858), Conch Icon., vol. 11, *Columbella*, pl. 14, sp. 19.
Strombina maculosa (Sowerby), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 699; SMITH (1944), Panamic Marine Shells, p. 28, no. 355 (*pro parte*).

Hypotypes nos. 32121, 32122 (loc. A 3548).

OCCURRENCE: locs. A 3519, A 3548, A 3550, A 3584, A 3596.

RANGE: upper Pliocene to Recent.

REMARKS: Reeve's figure indicates a form somewhat more nodose than specimens usually referred to this species. The first of Smith's two figures under no. 355 is an entirely different species from *S. maculosa*.

Family MURICIDAE

Genus ***Murex*** Linnaeus

Murex LINNAEUS (1758), Syst. Natura, Ed. 10, p. 746.

Genotype: *Murex pecten* Montfort = *Murex tribulus* Linnaeus (subs. desig., Montfort, 1810)

Murex elenensis Dall

(Plate 35, figure 8)

Murex plicatus SOWERBY (1834), Conch. Ill., *Murex*. pl. 2, fig. 6; (1840), Proc. Zool. Soc. London p. 139; CARPENTER (1857), Cat. Mazatlan Shells, p. 518.
Murex elenensis DALL (1910), Proc. U. S. Nat. Mus., vol. 37, p. 218; SMITH (1944), Panamic Marine Shells, p. 24, no. 279.

Hypotype no. 30804 (loc. A 3584).

OCCURRENCE: loc. A 3584.

RANGE: Pleistocene, Recent.

REMARKS: The present specimen is a moderately young individual. As shown by a series of Recent specimens there is some variation in the prominence and number of spines on the anterior canal, and there is a tendency for the second major spine on the body whorl in the youthful stages to become obsolete as maturity is attained.

Genus ***Muricopsis*** Bucquoy and Dautzenberg

Muricopsis BUCQUOY AND DAUTZENBERG (1882), Moll. marin Roussillon, vol. 1, p. 19.

Genotype: *Murex blainvillei* Payraudeau (monotypic)

Muricopsis squamulatus (Carpenter)

(Plate 28, figures 13, 15)

Muricidea dubia, var. *squamulata* CARPENTER (1865), Proc. Zool. Soc. London, p. 281–282.
Muricopsis squamulata Cpr., PILSBRY AND LOWE (1932), Proc. Acad. Nat. Sci. Philadelphia, vol. 84, p. 119.

Hypotype no. 32877 (loc. A 3550).

OCCURRENCE: loc. A 3550.

RANGE: Pleistocene, Recent.

Genus ***Phyllonotus*** Swainson

Phyllonotus SWAINSON (1833), Zool. Illustrations, ser. 2, vol. 3, pl. 109; (1840), Treat. Malac. p. 296.

Genotype (monotypic): *Murex* (*Phyllonotus*) *imperialis* Swainson (*M. pomum* Gmelin)

The genus *Chicoreus* Montfort (1810) is closely allied to *Phyllonotus*, but the spines and varices of the genotype, *Murex ramosus* Linnaeus, are much more foliaceous than those of *M. pomum* Gmelin. Furthermore the anterior canal of *M. pomum* is shorter and recurved more to the left, instead of backwards as in *M. ramosus*.

Phyllonotus erythrostomus (Swainson)

(Plate 35, figure 7)

Murex erythrostomus SWAINSON (1831), Zool. Illust., ser. 2, vol. 2, p. 16, pl. 73.
Murex bicolor VALENCIENNES (1832), *in* HUMBOLDT AND BONPLAND, Recueil D'Observat. Zool.

vol. 2, p. 301; REEVE (1845), Conch. Icon., vol. 3, *Murex*, pl. 11, sp. 44; JORDAN (1936) Contrib. Dept. Geol. Stanford Univ., vol. 1, no. 4, p. 114.
Murex hippocastanum PHILIPPI (1845), Abb. und Beschr. Conchylien, vol. 1, p. 191–192, *Murex*, Tab. 1, fig. 2.
Phyllonotus bicolor, Val., CARPENTER (1857), Cat. Mazatlan Shells, p. 524.
Chicoreus (*Phyllonotus*) *hippocastanum* (Philippi), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 730.
Phyllonotus bicolor (Valenciennes), SMITH (1944), Panamic Marine Shells, p. 24, no. 285.
Non Murex hippocastanum LINNAEUS (1758), Syst. Natura, Ed. 10, p. 751.
Non Murex bicolor RENIER (1804), Tavola alfab. Conch. Adriat., IX.
Non Murex bicolor RISSO (1826), Hist. Nat. Europe Merid., vol. 4, p. 194.

Hypotype no. 30669 (loc. A 3587).

OCCURRENCE: locs. A 3582, A 3584, A 3587, A 3598.

RANGE: Pleistocene, Recent.

Phyllonotus nitidus (Broderip)

(Plate 35, figure 1)

Murex nitidus BRODERIP (1832), Proc. Zool. Soc. London, p. 175; SOWERBY (1832), Conch. Ill., *Murex*, sp. 84, fig. 4; REEVE (1845), Conch. Icon., vol. 3, *Murex*, pl. 17, sp. 70.
Phyllonotus nitidus Brod., CARPENTER (1857), Cat. Mazatlan Shells, p. 523.
Phyllonotus nitidus (Broderip), SMITH (1944), Panamic Marine Shells, p. 24, no. 294.

Hypotype no. 30668 (loc. A 3508).

OCCURRENCE: loc. A 3508.

RANGE: Pleistocene, Recent.

REMARKS: Dr. Harald A. Rehder has informed me (personal communication, March 21, 1947) that the U. S. National Museum possesses a suite of specimens grading from the young form like that figured by Sowerby up to mature individuals rather closely resembling *Murex nigritus* Philippi. The present specimen is worn and somewhat incrusted. There are three Recent specimens of *nitidus* from Magdalena Bay in the Golisch Collection of the California Institute of Technology that very closely resemble the present fossil specimens. The height of the spire is somewhat variable, and all three have a cafe-au-lait color. One appears to have been treated to produce a high gloss, but the other two are not so glossy and have no evidence of such treatment.

Phyllonotus oxyacanthus (Broderip)

(Plate 28, figures 19, 20)

Murex oxyacantha BRODERIP (1832), Proc. Zool. Soc. London, p. 176; CARPENTER (1856), Rept. Brit. Assoc. Adv. Sci. 1856, p. 182, 208.
Phyllonotus oxycantha Brod., PILSBRY AND LOWE (1932), Proc. Acad. Nat. Sci. Philadephia, vol. 84, p. 118.

Hypotype no. 32890 (loc. A 3596).

OCCURRENCE: loc. A 3596.

RANGE: Pleistocene, Recent.

Phyllonotus princeps (Broderip)

(Plate 35, figure 3)

Murex princeps BRODERIP (1832), Proc. Zool. Soc. London, p. 175; REEVE (1845), Conch. Icon., vol. 3, *Murex*, no. 23, pl. 6, fig. 23; JORDAN (1936), Contrib. Dept. Geol. Stanford Univ., vol. 1, p. 114.
Phyllonotus princeps, Brod., CARPENTER (1857), Cat. Mazatlan Shells, p. 525–526.
Chicoreus (*Phyllonotus*) *princeps* (Broderip), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 730.
Phyllonotus princeps (Broderip), SMITH (1944), Panamic Marine Shells, p. 24, no. 281.

Hypotype no. 30676 (loc. A 3548).

OCCURRENCE: loc. A 3548.

RANGE: Pleistocene, Recent.

REMARKS: a single worn specimen, identified by comparison with Recent shells.

Family THAIDIDAE

Genus ***Acanthina*** Fischer de Waldheim

Acanthina FISCHER DE WALDHEIM (1807), Mus. Démidoff, vol. 3, p. 174; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 719.

Genotype: *Buccinum monoceros* Chemnitz = *B. calcar* Martyn (subs. desig. Gray, 1847)

Acanthina muricata (Broderip)

(Plate 31, figures 1, 2, 4)

Purpura muricata BRODERIP (1832), Proc. Zool. Soc. London, p. 125.
Purpura truncata DUCLOS (1833), Mag. de Zool., pl. 22, fig. 2.
Monoceros muricatum Broderip, REEVE (1846), Conch. Icon., vol. 3, *Monoceros*, pl. 2, sp. 7.
Purpura muricata Gray, CARPENTER (1857), Cat. Mazatlan Shells, p. 476–477.
Acanthina muricata (Broderip), JORDAN (1936), Contrib. Dept. Geol. Stanford Univ., vol. 1, p. 112; SMITH (1944), Panamic Marine Shells, p. 26, no. 326.

Hypotypes nos. 30807, 30808 (loc. A 3598).

OCCURRENCE: locs. A 3538 (?), A 3548, A 3573, A 3596, A 3598.

RANGE: Pleistocene, Recent.

REMARKS: The figure given by Reeve for this species has a lower spire than any specimen seen. Smith's figure is very similar to hypotype no. 30808. Hypotype no. 30807 is quite similar to Reeve's figure of *Monoceros tuberculatum* Gray. It is possible that Duclos' name may have been published in 1832 in Ann. Sci. Nat. and should have priority over Broderip's name.

Acanthina cf. ***tuberulata*** (Gray)

(Plate 31, figures 14, 17)

Monoceros tuberculatum GRAY (1832), Conch. Ill., *Monoceros*, fig. 9; REEVE (1846), Conch. Icon., vol. 4, *Monoceros*, pl. 2, sp. 5.
Acanthina tuberculata (Gray), SMITH (1944), Panamic Marine Shells, p. 26, no. 323.

Hypotype no. 32885 (loc. A 3529).

OCCURRENCE: loc. A 3529.

RANGE: lower Pliocene.

REMARKS: Unfortunately the single specimen is partially decorticated and has the spire missing. However, the ribs were much less prominent than in Gray's or Reeve's figures, and body whorl appears to be less inflated. Adequate material would probably show that this is a new species.

Genus ***Centrifuga*** Grant and Gale

Centrifuga GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 706–707.

Genotype: *Murex centrifuga* Hinds (orig. desig.)

Centrifuga inezana n. sp.

(Plate 26, figures 1, 4)

Shell generally similar to genotype but with shorter spines; spire high, probably of about 5 whorls; body whorl rather high; aperture ovate, not toothed; anterior canal elongate, tightly closed over, fairly wide; ornamented•by 3 thin spinose varices (now somewhat worn) crossing all whorls; one triangular spine pointing up and outward on whorls of spire; below this major spine on body whorl there are 3 small incipient spines; major spine flattened, formed by posterior part of varix being reflected anteriorly and then pressed upon itself so that it contains a flattened hollow space; alternating with varices is a prominent domelike node on center of each whorl; 4 small, distant, spiral ribs on body whorl, most prominent in center of whorl.

Dimensions of holotype: height (tip of spire broken) 49.0 mm, diameter 23.6 mm.

Holotype no. 30470 (loc. A 3584).

OCCURRENCE: loc. A 3584.

RANGE: Pleistocene.

REMARKS: This species may be separated from *C. centrifuga* by its shorter spines and wider anterior canal. *Murex* (*Pteropupura*) *carpenteri* Dall and *Murex* (*Pteropurpura*) *petri* Dall may possibly be related, but their varices are much more prominent.

Genus ***Jaton*** Pusch

Jaton PUSCH (1837), Polens Paleont., pt. 2, p. 135.

Genotype: *Murex decussatus* Linnaeus (Gmelin) = *Murex lingua-vervecina* Chemnitz (figured in Reeve, Conch. Icon., vol. 3, *Murex*, pl. 27, fig. 121, 1845)

Jaton erinaceoides (Valenciennes)

(Plate 35, figure 2)

Murex erinaceoides VALENCIENNES (1832), *in* HUMBOLDT AND BONPLAND, Recueil D'Observat. Zool., vol. 2, p. 302; OLDROYD (1927), Stanford Univ. Publ., Univ. Ser., Geol. Sci., vol. 2, pt. 2, p. 9–10.

Alipurpura erinaceoides Valenciennes, SMITH (1944), Panamic Marine Shells, p. 21, no. 321.

Hypotype no. 30679 (loc. A 3584).

OCCURRENCE: loc. A 3584.

RANGE: Pleistocene, Recent.

REMARKS: Only a single poorly preserved specimen was found. It appears possible that it might have been slightly more slender than the typical living *J. erinaceoides*. The ornamentation of this species is quite similar to that of *Murex lingua-vervecina* Chemnitz as figured by Reeve except for the anterior canal being slightly shorter and twisted a little more to the left. It might possibly be better referred to some other genus than *Jaton*.

Family CORALLIOPHILIDAE

Genus ***Coralliophila*** H. and A. Adams.

Coralliophila H. AND A. ADAMS (1853), Gen. Rec. Moll., vol. 1, p. 135; WOODRING (1928), Carnegie Inst. Wash., Publ. 385, p. 296.

Genotype: *Coralliophila violacea* (Kiener) = *Purpura violacea* Kiener = *Murex neritoideus* Chemnitz, *non* Linnaeus (subs. desig. Cox, 1927)

Coralliophila nux (Reeve)

(Plate 31, figure 9)

Murex nux REEVE (1846), Conch. Icon., vol. 3, *Murex*, pl. 35, sp. 181.

Rhizocheilus nux Reeve, CARPENTER (1857), Cat. Mazatlan Shells, p. 484–485.

Coralliophila nux (Reeve), SMITH (1944), Panamic Marine Shells, p. 26, no. 320.

Hypotype no. 32694 (loc. A 3550).

OCCURRENCE: loc. A 3550.

RANGE: Pleistocene, Recent.

REMARKS: The relationships of this species to *Rhizochilus* (*Coralliophila*) *californica* A. Adams, *Purpura osculans* C. B. Adams, and "*Rhizochilus niveus*" A. Adams and other species are in need of careful investigation. The present specimen does not agree well with Reeve's figure.

Family BURSIDAE

Genus *Bursa* Bolten

Bursa BOLTEN (1798), Mus. Boltenianum, pt. 2, p. 128; WINCKWORTH (1945), Proc. Malac. Soc. London, vol. 26, p. 137; DALL (1904), Smithson, Misc. Coll., vol. 47, p. 119–121; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 731.

Genotype: *Bursa monitata* Bolten = *Murex bufonius* Gmelin (subs. desig. Jousseaume, 1881)

Bursa californica (Hinds)

(Plate 35, figure 10)

Ranella californica HINDS (1843), Ann. Nat. Hist., vol. 11, p. 255; (1844), Zool. Voy. Sulphur, Moll., p. 12, pl. 2, figs. 4, 5; REEVE (1844), Conch. Icon., vol. 2, *Ranella*, pl. 2, sp. 9a, 9b.

Bursa californica HINDS, GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 731–732; JORDAN (1936), Contrib. Dept. Geol. Stanford Univ., vol. 1, p. 113.

Hypotype no. 30670 (loc. A 3548).

OCCURRENCE: loc. A 3548.

RANGE: Pleistocene, Recent.

Genus *Gyrineum* Link

Gyrineum LINK (1807), Beschr. Natur. Samml. Univ. Rostock, p. 123.

Genotype: *Murex gyrineus* Linnaeus (subs. desig. Dall, 1904)

Gyrineum strongi Jordan

(Plate 29, figures 19, 22)

Gyrineum strongi JORDAN (1936), Contrib. Dept. Geol. Stanford Univ., vol. 1, p. 160, pl. 18, fig. 10.

Hypotype no. 32810 (loc. A 3550).

OCCURRENCE: locs. A 3550, A 3598.

RANGE: Pleistocene.

REMARKS: This species has been reported elsewhere only from the Pleistocene of Magdalena Bay.

Family CASSIDAE

Genus *Cassis* Scopoli

Cassis SCOPOLI (1777), Introd. Hist. Nat., p. 393; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 739.

Genotype: *Buccinum cornutum* Linnaeus (subs. desig. Montfort, 1810)

Subgenus *Levenia* Gray

Levenia GRAY (1847), Proc. Zool. Soc. London, p. 137; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 740.

Genotype: *Cassis coarctatum* Gray = *Cassis coarctata* Sowerby (orig. desig.)

Cassis* (*Levenia*) *coarctata Sowerby

(Plate 34, figures 3, 4)

Cassis coarctata SOWERBY (1825), Cat. Shells Tankerville, Append., p. 21; HANNA AND HERTLEIN (1927), Proc. Calif. Acad. Sci., ser. 4, vol. 16, p. 142.
Cassis (*Levenia*) *coarctata* SOWERBY, GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 740.
Cassis coarctatus GRAY, SMITH (1944), Panamic Marine Shells, p. 22, no. 256.

Hypotype no. 30677 (loc. A 3550).

OCCURRENCE: locs. A 3548, A 3550.

RANGE: Pleistocene, Recent.

REMARKS: *Levenia* Gray does not seem to differ from *Cassis ss.* except in the slightly more elongate shape and lack of a terminal varix.

Family TONNIDAE

Genus ***Malea*** Valenciennes

Malea VALENCIENNES (1832), *in* HUMBOLDT AND BONPLAND, Recueil D'Observat. Zool., vol. 2, p. 324; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 740–741.

Genotype: *Malea latilabris* Valenciennes = *Cassis ringens* Swainson (subs. desig. Hermannsen, 1847)

Malea ringens (Swainson)

(Plate 34, figure 1)

Cassis ringens SWAINSON (1822), Bligh Cat., Appendix, p. 4.
Malea latilabris VALENCIENNES (1832), *in Humboldt and Bonpland*, Recueil D'Observat. Zool., vol. 2, p. 325; CARPENTER (1857), Rept. Brit. Assoc. Adv. Sci. for 1856, p. 171, 238, 269, 292, 337.
Malea ringens SWAINSON, HANNA (1926), Proc. Calif. Acad. Sci., ser. 4, vol. 14, p. 450.
Malea ringens (Swainson), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 741; JORDAN (1936), Contrib. Dept. Geol. Stanford Univ., vol. 1, p. 114; SMITH (1944), Panamic Marine Shells, p. 21, nos. 261, 263.

Hypotype no. 30542 (loc. A 3553).

OCCURRENCE: locs. A 3508, A 3553.

RANGE: lower Pliocene to Recent.

Family CYPRAEIDAE

Genus ***Cypraea*** Linnaeus

Cypraea LINNAEUS (1758), Syst. Natura, Ed. 10, p. 718.

Genotype: *Cypraea tigris* Linnaeus (subs. desig. Montfort, 1810)

Cypraea annettae Dall

(Plate 30, figures 7, 8)

Cypraea sowerbyi KIENER (1845), Spec. Gen. Icon. Coq. Viv., vol. 1, *Porcelaine*, p. 38, pl. 7, fig. 5.
Cypraea annettae DALL (1909), Nautilus, vol. 22, p. 125; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 752; JORDAN (1936), Contrib. Dept. Geol. Stanford Univ., vol. 1, p. 113.
Zonaria annettae (Dall), SMITH (1944), Panamic Marine Shells, p. 21, no. 249.

Hypotypes nos. 30810, 30811 (loc. A 3548).

OCCURRENCE: locs. A 3515, A 3519, A 3548, A 3550, A 3582, A 3584, A 3598.

RANGE: upper Pliocene to Recent.

Genus *Trivia* "Gray", Broderip

Trivia Gray, Broderip (1837), Penny Cyclopedia, vol. 8, p. 256, *fide* Iredale (1916), Proc. Malac. Soc. London, vol. 12, p. 35.

Genotype: *Cypraea europaea* Montagu = *Voluta jonesis* Pennant (subs. desig. Gray, 1847)

Trivia solandri (Gray in Sowerby)

(Plate 30, figure 11)

Cypraea solandri Gray *in* Sowerby (1841), Conch. Illust., *Cypraea*, p. 14, fig. 43.
Trivia solandri (Gray in Sowerby), Grant and Gale (1931), Mem. San Diego. Soc. Nat. Hist., vol. 1, p. 754.
Trivia solandri (Gray), Jordan (1936), Contrib. Dept. Geol. Stanford Univ., vol. 1, p. 115.
Trivia solandri Gray, Smith (1944), Panamic Marine Shells, p. 21, no. 239.

Hypotype no. 30813 (loc. A 3548).

Occurrence: locs. A 3519, A 3548, A 3550, A 3598.

Range: upper Pliocene to Recent.

Family STROMBIDAE

Genus *Strombus* Linnaeus

Strombus Linnaeus (1758), Syst. Natura, Ed. 10, p. 742.

Genotype: *Strombus pugilis* Linnaeus (subs. desig., Montfort, 1810)

Strombus galeatus Swainson

(Plate 34, figure 6)

Strombus galeatus Swainson (1823), Philos. Mag., vol. 62, p. 401; Reeve (1850), Conch. Icon., vol 6, Strombus, pl. 3, fig. 3; Hanna (1926), Proc. Calif. Acad. Sci., ser. 4, vol. 14, p. 454; Hanna and Hertlein (1927), Proc. Calif. Acad. Sci., ser. 4, vol. 16, p. 143; Grant and Gale (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 756; Jordan (1936), Contrib. Dept. Geol. Stanford Univ., vol. 1, p. 114.
Strombus galeatus Sowerby, Smith (1944), Panamic Marine Shells, p. 20, no. 214.

Hypotype no. 30643 (loc. A 3582).

Occurrence: locs. A 3508, A 3519, A 3520, A 3547, A 3548, A 3582, A 3596, A 3597.

Range: upper Pliocene to Recent.

Remarks: Hanna also reported this species from the Imperial formation of lower Pliocene age.

Strombus gracilior Sowerby

(Plate 27, figure 6)

Strombus gracilior Sowerby (1825), Cat. Shells Tankerville, Append., p. 20; Grant and Gale (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 755; Jordan (1936), Contrib. Dept. Geol. Stanford Univ., vol. 1, p. 114; Smith (1944), Panamic Marine Shells, p. 20, nos. 226, 229.

Hypotype no. 30469 (loc. A 3584).

Occurrence: locs. A 3582, A 3584, A 3587.

Range: Pleistocene, Recent.

Strombus granulatus Mawe

(Plate 27, figures 3, 8)

Strombus granulatus Mawe (1823), Linnaean Syst. Conch., p. 125, 127, pl. 25, fig. 3; (*partim*) Grant and Gale (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 755.

Hypotype no. 30478 (loc. A 3637) (Recent, Gulf of California).

OCCURRENCE: Pleistocene locs. A 3508, A 3522; Recent, Gulf of California.

RANGE: late Pleistocene, Recent.

REMARKS: *See S. granulatus* subsp. *acutus* n. subsp.

Strombus granulatus subsp. ***acutus*** n. subsp.

(Plate 27, figures 1, 2, 5)

Strombus granulatus GRAY, HANNA AND HERTLEIN (1927), Proc. Calif. Acad. Sci., ser. 4, vol. 16, p. 143.

Strombus granulatus MAWE, (*partim*) GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 755.

Shell similar to that of *S. granulatus* but with longer and sharper nodes; with spiral ribbing usually less well developed; and averaging smaller in size.

Dimensions of holotype: height 56.5 mm., maximum diameter 33.7 mm.

Holotype no. 30579 (loc. A 3550); paratype no. 30480 (loc. A 3582).

OCCURRENCE: locs. ? A 3519, ? A 3534, A 3550, A 3577, A 3582, A 3584, A 3596, A 3598.

RANGE: lower Pliocene (?), to Pleistocene.

REMARKS: Over 50 specimens of this subspecies are available for comparison with an equivalent number of the typical form which is living in the Gulf of California. None of the specimens from localities where this form has been definitely identified agree with the common variants of the living species. On the other hand only two specimens of the Recent material examined have the long sharp nodes characteristic of the Pleistocene specimens. These two specimens were larger than most of the Pleistocene material. The present subspecies has an average height of about 60 mm., whereas the living form is from 75–80 mm. tall. The living form may have the nodes nearly obsolete to coarse and rounded, rarely long and slender.

Strombus subgracilior n. sp.

(Plate 27, figure 7)

Shell moderately large, stromboid, resembling *S. gracilior* Sowerby; spiral conical, not "stepped"; immature whorls of spire with about 11 small nodes; last $2\frac{1}{4}$ whorls smooth; suture appressed and immediately below shoulder of preceding whorl, so that side profile of spire is only slightly wavy; body whorl inflated, outer lip flaring; posterior siphonal notch large; no apparent ornamentation.

Dimensions of holotype: height 73.5 mm., greatest diameter (including outer lip) 56.4 mm.

Holotype no. 30468 (loc. A 3533).

OCCURRENCE: loc. A 3533, ? A 3562.

RANGE: middle and upper Pliocene.

REMARKS: This species may be distinguished from *S. gracilior* Sowerby (Pl. 27, fig. 5) by the straight-sided spire, the higher suture, and the lack of nodes on the body whorl.

Family CERITHIIDAE

Genus ***Cerithium*** Bruguière

Cerithium BRUGUIÈRE (1789), Encycl. Meth. Hist. Nat. Vers., vol. 1, p. XV; (1792), Encycl. Meth. Hist. Nat. Vers., vol. 1, p. 467; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 756.

Genotype: *Cerithium adansonii* Bruguière (see Grant and Gale)

Cerithium adjustum Kiener

(Plate 33, figure 14)

Cerithium adjustum KIENER (1841), Spéc. Gén. Icon. Coq. Viv., vol. 5, *Cerite*, p. 37, pl. 13, fig. 2. (*non* fig. 3); CARPENTER (1857), Cat. Mazatlan Shells, p. 333–334, (under discussion of *C.*

maculosum); TRYON (1887), Man. Conch., vol. 9, p. 126, pl. 21, fig. 52, *non* fig. 51; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 756; JORDAN (1936), Contrib. Dept. Geol. Stanford Univ., vol. 1, p. 113; SMITH (1944), Panamic Marine Shells, p. 18, no. 205.

Hypotype no. 32777 (loc. A 3584).

OCCURRENCE: loc. A 3584.

RANGE: Pleistocene, Recent.

REMARKS: Carpenter in 1857 was apparently the first to recognize Kiener's error in labelling his plates.

Cerithium maculosum Kiener

(Plate 33, figure 1)

Cerithium maculosum KIENER (1841), Spéc. Gén. Icon. Coq. Viv., vol. 5, *Cerite*, p. 36, no. 25, pl. 13, fig. 3, (*non* fig. 2); CARPENTER (1857), Cat. Mazatlan Shells, p. 333–334; JORDAN (1936), Contrib. Dept. Geol. Stanford Univ., vol. 1, p. 113

Cerithium nebulosum Sowerby, REEVE (1865), Conch. Icon., vol. 15, *Cerithium*, pl. 2, sp. 7a, 7b.

Hypotypes nos. 32787, 32788 (loc. A 3534).

OCCURRENCE: locs. A 3508, A 3519, A 3534, A 3548, A 3596.

RANGE: upper Pliocene to Recent.

REMARKS: Carpenter (1857) gave a good description of the variation in this species.

Cerithium ocellatum Bruguière

(Plate 33, figure 2)

Cerithium ocellatum BRUGUIÈRE (1792), Encycl. Meth. Hist. Nat. Vers. vol. 1, p. 499; REEVE (1865), Conch. Icon., vol. 15, *Cerithium*, pl. 4, sp. 23; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 757; JORDAN (1936), Contrib. Dept. Geol. Stanford Univ., vol. 1, p. 113; SMITH (1944), Panamic Marine Shells, p. 18, no. 208.

Hypotypes nos. 32779, 32780 (loc. A 3515).

OCCURRENCE: loc. A 3515.

RANGE: Pleistocene, Recent.

Genus ***Cerithidea*** Swainson

Cerithidea SWAINSON (1840), Treat. Malac., p. 198, 203, 205, 206, 342; PILSBRY AND HARBISON (1933), Proc. Acad. Nat. Sci. Philadelphia, vol. 85, p. 115; BEQUAERT (1942), Nautilus, vol. 56, p. 20.

Genotype: *Cerithidea lineolata* (Griffith and Pidgeon) 1834 = *Cerithium obtusum* Lamarck (1822), subs. desig. Pilsbry and Harbison (1933). *Murex decollatus* Linnaeus (1767) has been cited as the genotype by many authors, but it is unavailable as it was not included in Swainson's original list of species.

Cerithidea hegewischii (Philippi) s.s.

(Plate 33, figure 18)

Cerithium (*Potamides*) *hegewischii* PHILLIPI (1848), Zeitschr. f. Malak., vol. 5, p. 19; (1849), Abb. Beschr. Conchyl., vol. 3, pt. 4, p. 15, *Cerithium*, pl. 1, fig. 6; BEQUAERT, (1942), Nautilus, vol. 56, p. 23–24.

Cerithidea ? varicosa Sow. var. *mazatlanica* CARPENTER (1857), Cat. Mazatlan Shells, p. 344–345; BEQUAERT (1942), Nautilus, vol. 56, p. 24.

Cerithidea mazatlanica CARPENTER, REEVE (1866), Conch. Icon., vol. 15, *Cerithidea*, pl. 1, sp. 8; CARPENTER (1872), Smithson. Misc. coll., no. 252, p. 108, 141, 186.

Cerithidea hegewischii hegewischii (Philippi), SMITH (1944), Panamic Marine Shells, p. 18, no. 204.

Hypotypes nos. 32781, 32782 (loc. A 3586).

OCCURRENCE: locs. A 3507, A 3582, A 3586.

RANGE: Pleistocene, Recent.

REMARKS: Both Carpenter (1872, p. 108, 141) and Bequaert have noted the close relationship of this species to *C. californica* (Haldeman).

Cerithidea hegewischii var. ***albonodosa*** Carpenter

(Plate 33, figure 19)

Cerithidea albonodosa CARPENTER (1856), Proc. Zool. Soc. London, p. 205; (1872), Smithson. Misc. Coll. no. 252, p. 153, 186; REEVE (1866), Conch. Icon., vol. 15, *Cerithidea*, pl. 1, sp. 1a, 1b; BEQUAERT (1942). Nautilus, vol. 56, p. 25.

Cerithidea hegewischii var. *albonodosa* CARPENTER, BEQUAERT (1942), Nautilus, vol. 56, p. 25; SMITH (1944), Panamic Marine Shells, p. 18, no. 204.

Hypotypes nos. 32772, 32773 (loc. A 3592).

OCCURRENCE: loc. A 3592.

RANGE: upper Pliocene, Recent.

REMARKS: This form is closely allied to typical *C. hegewischii* (*mazatlanica* Carpenter) but may be separated by the wider interspace between the second and third spiral ribs.

Genus ***Clava*** Martyn

Clava MARTYN (1784), Univ. Conch., vol. 1, nos. 12, 13; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 758.

Genotype: *Clava rugata* Martyn (subs. desig. Pilsbry, 1901)

Clava gemmata (Hinds)

(Plate 33, figures 6, 9)

Cerithium gemmatum HINDS (1844), Zool. Voy. Sulphur, Moll., p. 27.

Vertagus gemmatus HINDS, CARPENTER (1857), Cat. Mazatlan Shells, p. 339–340; REEVE (1866), Conch. Icon., vol. 15, *Vertagus*, sp. 5.

Clava gemmata (Hinds), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 758; SMITH (1944), Panamic Marine Shells, p. 19, no. 207.

Hypotypes nos. 32785, 32786 (loc. A 3596).

OCCURRENCE: locs. A 3519, A 3534, A 3596.

RANGE: upper Pliocene to Recent.

REMARKS: Reeve's figure shows the median row of nodes well developed, but the median row of nodes on the present specimens is absent, as on some living specimens associated with the typical variety. This species is the type of the subgenus *Ochetoclava* Woodring 1928.

Genus ***Liocerithium*** Tryon

Liocerithium TRYON (1887), Man. Conch., vol. 9, p. 113, 142.

Genotype: *Cerithium incisum* Sowerby (orig. desig.)

Liocerithium incisum (Sowerby)

(Plate 33, figure 4)

Cerithium incisum SOWERBY (1855), Thes. Conch., vol. 2, p. 868, pl. 182, fig. 152.

Thericium incisum (Sowerby), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 757.

Hypotype no. 32727 (loc. A 3519).

OCCURRENCE: locs. A 3508, A 3519, A 3670.

RANGE: upper Pliocene to Recent.

Family ALABINIDAE

Genus *Alabina* Dall

Alabina DALL (1902), Nautilus, vol. 15, p. 127; Woodring (1928), Carnegie Inst. Washington, Spec. Publ. 385, p. 338–339.

Genotype: *Bittium cerithidioide* Dall (orig. desig.)

Alabina strongi, n. sp.

(Plate 33, figure 7)

Shell small, slender, turrited, slightly eroded; nuclear whorls about 2, smooth; postnuclear whorls about 6½; spiral ribs on postnuclear whorls 4, 3 evenly spaced and a fourth smaller one just above suture; middle of 3 major spirals forming an angulation on midpoint of whorl; interspaces nearly twice as wide as spiral ribs; axial ribs about 18, subobsolete on body whorl; base of body whorl with 4 fine spiral ribs; suture slightly channeled.

Dimensions of holotype: height 4.3 mm., diameter of body whorl 1.5 mm.

Holotype 32700 (loc. A 3584).

OCCURRENCE: loc. A 3584.

RANGE: Pleistocene.

REMARKS: This species resembles *A. diomedae* Bartsch but has 18 instead of 24 to 26 axial ribs, its apical angle is slightly less, and the axial ribs tend to become obsolete on the body whorl.

Family MODULIDAE

Genus *Modulus* Gray

Modulus GRAY (1842), Synopsis Contents British Museum, Ed. 44, p. 60 (genus without species); (1847), Proc. Zool. Soc. London, p. 150.

Genotype: *Trochus modulus* Linnaeus (orig. desig., 1847)

Modulus cerodes Adams

(Plate 31, figures 5, 8)

Modulus cerodes ADAMS (1850), Proc. Zool. Soc. London, p. 204; CARPENTER (1864), Rept. Brit. Assoc. Adv. Sci. for 1863, p. 666; CARPENTER (1872), Smithson. Misc. Coll., no. 252, p. 153; SMITH (1944), Panamic Marine Shells, p. 17, no. 193.

Hypotypes nos. 31511, 31512 (loc. A 3550).

OCCURRENCE: locs. A 3519, A 3548, A 3550.

RANGE: upper Pliocene to Recent.

Family VERMETIDAE

Genus *Vermicularia* Lamarck

Vermicularia LAMARCK (1799), Mém. Soc. Hist. Nat. Paris. vol. 1, p. 78; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 776.

Genotype: *Serpula lumbricalis* Linnaeus (monotypic)

Vermicularia eburnea (Reeve)

(Plate 33, figure 15)

Vermetus eburneus REEVE (1842), Conch. Syst., vol. 2, p. 46, pl. 152, fig. 2; CARPENTER (1857), Cat. Mazatlan Shells, p. 304–305.

Vermetus (*Vermicularia*) *pellucidus* Broderip and Sowerby, var. *eburneus* Reeve, TRYON (1886), Man. Conch., vol. 8, p. 188, pl. 56, fig. 6.

Vermicularia eburnea (*Reeve*), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 776–777.

Vermicularia eburnea REEVE, SMITH (1944), Panamic Marine Shells, p. 13, no. 141.

Hypotype no. 32672 (loc. A 3584).
OCCURRENCE: loc. A 3584.
RANGE: Pleistocene, Recent.

Family TURRITELLIDAE

Genus *Turritella* Lamarck

Turritella LAMARCK (1799), Mém. Soc. Hist. Nat. Paris, ser. 1, vol. 1, p. 74.

Genotype: *Turbo terebra* Linnaeus (monotypic)

Turritella broderipiana d'Orbigny

(Plate 29, figure 21)

Turritella broderipiana D'ORBIGNY (1846), Voy. Am. Mérid., Moll., p. 388; REEVE (1849), Conch. Icon., vol. 5, *Turritella*, pl. 2, sp. 6.
Turritella goniostoma Valenciennes, (*partim*) REEVE (1849), Conch. Icon., Vol. 5, *Turritella*, pl. 3, fig. 10a (not 10b); (*partim*) *in* TRYON (1886), Man. Conch., ser. 1, vol. 8, p. 198. pl. 60, fig. 51; pl. 61, figs. 53, 54, (not figs. 52, 55–57).

Hypotype no. 32670 (loc. A 3584).
OCCURRENCE: loc. A 3584.
RANGE: Pleistocene, Recent.

Turritella gonostoma Valenciennes

(Plate 28, figure 23, 25)

Turritella gonostoma VALENCIENNES, *in* HUMBOLDT AND BONPLAND (1832), Recueil D'Observat. Zool., vol. 2, p. 275; MERRIAM (1941), Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 26, no. 1, p. 56, pl. 36, fig. 3.
Turritella goniostoma Valenciennes, REEVE (1849), (*partim*), Conch. Icon., vol. 5, *Turritella* sp. 10. pl. 3, fig. 10b (not 10a); KIENER (1873), Spéc. Gén. Icon. Coq. Viv., vol. 10, *Turritella*, p. 21–22, pl. 10, fig. 1; (*partim*) TRYON (1886), Man. Conch., ser. 1, vol. 8, p. 198, pl. 60, fig. 52; pl. 61, figs. 55–57, (not figs. 51–53, 54); GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 773–774.

Hypotypes nos. 32885 (loc. A 3582), 32884 (loc. A 3574).
OCCURRENCE: locs. A 3508, ? A 3529, A 3573, A 3574, A 3582, A 3584.
RANGE: lower Pliocene (?), Pleistocene, Recent.

REMARKS: Although Reeve and Kiener included *T. broderipiana* with this form in their illustrations and discussions, it is to be distinguished by its lack of the heavy spiral ribbing typical of *T. gonostoma* and by a difference in development of early spiral ornamentation which is typically mesocostate in *T. gonostoma*. The early whorls of *T. gonostoma* are medially keeled, shortly being joined by a small rib on either side. The middle rib, or keel, continues the same size or degenerates, and the remaining ribs enlarge, the basal one generally becoming the stronger. In *broderipiana* the young whorls are likewise medially keeled, but lateral ribs do not develop. A small rib adjacent to the lower suture of each whorl is present with the keel, but degenerates with it or does not become prominent.

Turritella marcosensis n. sp.

(Plate 28, figure 3)

Shell moderately large, number of whorls uncertain, but at least 10; apical angle apparently between 15° and 17°; adult whorls moderately bicarinate, one carina just above suture, the other about midway on whorl; suture deep, overhung by previous whorl; whorl profile straight from suture to first carina, concave between two carinae and rounded from lower carina into suture; each carina with 2 medium sized sharp spiral ribs on it; 3 primary spiral ribs above upper carina, with slightly smaller interribs; 2 fine interribs between carinae; 2 small primaries and finer secondary ribs below lower carina; base of whorl with 12 to 15 fine ribs.

Dimensions of holotype (incomplete): height 30.5 mm., diameter of body whorl 15.4 mm.

Holotype no. 30373 (loc. A 3576).

OCCURRENCE: loc. A 3576.

RANGE: lower Pliocene, San Marcos formation.

REMARKS: This species is represented by one good mold and several poor fragments. It has considerable similarity to one of the paratypes of *T. vanvlecki* subsp. *teglandae* Merriam (1941, pl. 37, fig. 4) from the Pliocene of southwestern California.

Turritella nodulosa King

(Plate 28, figures 1, 2)

Turritella nodulosa KING (1835), Zool. Jour. London, vol. 5, p. 347; REEVE (1849), Conch. Icon., vol. 5, *Turritella* sp. 11, pl. 4, figs. 11a, 11b; TRYON (1886), Man. Conch., ser. 1, vol. 8, p. 202, pl. 63, figs. 78–80.

Turritella papillosa KIENER (1873), Spéc. Gén. Icon. Coq. Viv., vol. 10, *Turritella*, p. 31, pl. 14, fig. 3.

Hypotypes nos. 32815, 32816 (loc. A 3584).

OCCURRENCE: locs. A 3582, A 3584.

RANGE: Pleistocene, Recent.

REMARKS: The specimens in general compare favorably with Figure 11a in Reeve. King's original description declares the lower rib to be the largest, which is contrary to Reeve's illustration and those of others, but this may be due to his manner of orienting the specimen while describing it. The present specimens differ from the description of recent forms in the lack of granulation on the lower rib, which is but rarely obscurely nodular.

An examination of the development of the spiral ribbing shows that two equal primaries develop medially, the upper enlarging and becoming nodular while the basal ribs decrease, generally disappearing. At about the time or shortly before the granulation of the upper ribs develops, a third rib, inferior to the diminishing primary, appears and increases in strength, only rarely becoming very obscurely nodular with age.

Turritella pasada Pilsbry and Olsson

(Plate 28, figure 21)

Turritella pasada PILSBRY AND OLSSON (1941), Proc. Acad. Nat. Sci. Philadelphia, vol. 93, p. 42, pl. 11, figs. 3, 4.

Hypotype no. 32881 (loc. A 3582).

OCCURRENCE: locs. A 3582, A 3584.

RANGE: Pleistocene, Recent.

REMARKS: This form is said by the authors to be "nearly related to the recent *Turritella tigrina* Kiener . . . but differs by its more uniform and finer spiral sculpture." It is also less attenuate in the upper part according to them. The almost exact agreement of the specimens at hand with the illustration of Pilsbry and Olsson, and the lack of detail in the early illustration of *tigrina* in Kiener, Reeve, and Tryon, determine the placement here. The specimen figured by Merriam (1941, p. 56, pl. 39, fig. 11) can be separated only with difficulty. Examination of several specimens will probably show that the two species should be thrown into synonomy.

Turritella (?) sp.

(Plate 27, figures 9, 10)

The basal part of a large shell consisting of nearly 2 whorls; shell extremely thick and heavy; externally presenting traces of 2 or 3 coarse heavy spiral ribs; whorl straight-sided, base irregularly flat; sides and base of whorl nearly as thick as diameter of living chamber; columella thick and massive.

Dimensions of hypotype: height 48.2 mm., diameter 45.2 mm., diameter of living chamber about 8 or 9 mm.

Hypotype no. 30371 (loc. A 3510).

OCCURRENCE: loc. A 3510.

RANGE: middle Pliocene.

REMARKS: This is an extremely heavy shell; it hardly appears possible for the animal to have moved about carrying its weight. Probably it is an extremely gerontic stage of some *Turritella* like *T. gonostoma* Valenciennes.

Family ARCHITECTONICIDAE

Genus ***Architectonica*** Bolten

Architectonica BOLTEN (1798), Mus. Boltenianum, pt. 2, p. 78; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, pl. 785.

Genotype: *Architectonica perspectiva* Bolten = *Trochus perspectivus* Gmelin (subs. desig., Gray, 1847)

Architectonica nobilis Bolten

(Plate 34, figures 5, 7)

Architectonica nobilis BOLTEN (1798), Mus. Boltenianum, pt. 2, p. 78; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 785–786.

Architectonica granulata (Lamarck), SMITH (1944), Panamic Marine Shells, p. 15, no. 166.

Hypotype no. 30799 (loc. A 3584).

OCCURRENCE: locs. A 3582, A 3584.

RANGE: Pleistocene, Recent.

REMARKS: Grant and Gale have listed the synonomy and discussed this species in detail.

Genus ***Heliacus*** d'Orbigny

Heliacus D'ORBIGNY (1841), *in* DE LA SAGRA, Hist. Phys., Polit. et Nat. de l'Ile de Cuba, Moll., vol. 2, p. 68.

Genotype: *Solarium cylindraceum* Chemnitz (*fide* Herrmannsen)

Heliacus lowei, n. sp.

(Plate 30, figures 16, 17, 18)

Shell small, generally resembling *H. planispira* Pilsbry and Lowe. Preservation moderate. Nuclear whorls about 1½, smooth. Adult whorls just slightly over 3. Suture impressed, channeled. Two angulations on periphery, upper one slightly more prominent than lower. A noded cord just below suture, with about 40 nodes in the last volution. About 68 straight, retractive, radial ribs extending out from the subsutural cord to the periphery and over the two peripheral angulations. Spacing of radial ribs with regard to subsutural nodes irregular. A channel just above upper peripheral cord. A fairly deep channel between the two peripheral cords. Umbilicus not too well preserved but wide. Umbilical cord only moderately prominent, with about 34 nodes on it. Two very prominent, shelf-like spirals on umbilical wall below umbilical cord, a third broader spiral just above suture on umbilical wall. A faint spiral just below lower peripheral spiral, then two more moderately prominent spirals between it and umbilical cord. Radial ribs continuing in to umbilical cord.

Dimensions of holotype: height 2.2 mm, diameter 5.9 mm.

Holotype no. 32674 (loc. A 3550).

OCCURRENCE: loc. A 3550.

RANGE: Pleistocene.

REMARKS: This species may be separated from *H. planispira* Pilsbry and Lowe by the greater number of radial ribs and the fewer spirals on the base.

Heliacus* (?) *robertsae n. sp.

(Plate 28, figures 6, 22, 24)

Shell of medium size, spire subplanate, umbilicus large; nucleus of $1\frac{1}{4}$ smooth whorls, planispiral; postnuclear whorls $3\frac{3}{4}$; suture prominent, channeled; whorls rounded, carinated by 2 equal-sized prominent ribs, with a channel between them; three similarly sized ribs with narrow interspaces between suture and topmost peripheral rib, a fine secondary rib in each interspace; a slightly heavier rib marks periphery of umbilicus; between it and lowermost peripheral rib are 3 ribs similar to those on upper surface, and with 5 interribs; within umbilicus are 2 prominent ribs on umbilical wall, but with interspaces wider than ribs, narrow interribs in interspaces; numerous slightly retractive radial ribs extend out from suture to periphery and then forward again over base of whorl into umbilicus, producing nodes at intersection with spiral ribs; from growth line it appears that labral profile was vertical; umbilicus wide and deep.

Dimensions of holotype: height 4.4 mm., diameter 9.2 mm., major diameter of umbilicus about 5.5 mm.

Holotype no. 30409 (loc. A 3519).

OCCURRENCE: loc. A 3519.

RANGE: upper Pliocene, *Marquer* formation.

REMARKS: If *Solarium cylindraceum* is the genotype of *Heliacus*, it appears probable that most of the species with depressed spires, such as *H. planispira* Pilsbry and Lowe, *H. mazatlanicus* Pilsbry and Lowe, *H. chiquita* Pilsbry and Lowe, *H. panamensis* Bartsch, and the present species, should be referred to some other genus. Unfortunately the author has very little material of this genus at hand.

Genus ***Hipponix*** Defrance

Hipponix DEFRANCE (1819), Journ. Phys. Chem. Hist. Nat. Arts. vol. 88, p. 217; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 788.

Genotype: *Patella cornucopia* Lamarck (subs, desig. Gray, 1847)

Hipponix grayanus Menke

(Plate 30, figures 14, 15)

Hipponyx grayanus MENKE (1853), Zeitschr. f. Mal., p. 115.
Hipponyx (*Amalthea*) *grayanus* MENKE, CARPENTER (1857), Cat. Mazatlan Shells, p. 299–300.
Hipponix grayanus MENKE, JORDAN (1936), Contrib. Dept. Geol. Stanford Univ., vol. 1, p. 113; SMITH (1944), Panamic Marine Shells, p. 15 .

Hypotypes nos. 32764, 32765 (loc. A 3508).

OCCURRENCE: loc. A 3508.

RANGE: Pleistocene, Recent.

Hipponix serratus Carpenter

(Plate 30, figures 9, 10)

Hipponyx serratus CARPENTER (1857), Cat. Mazatlan Shells, p. 298–299.
Hipponix serratus CARPENTER, SMITH (1944), Panamic Marine Shells, p. 15.

Hypotypes nos. 31518, 31519 (loc. A 3519).

OCCURRENCE: locs. A 3508, A 3515, A 3519, A 3534, A 3538, A 3574, A 3596, A 3598.

RANGE: upper Pliocene to Recent.

Family CREPIDULIDAE

Genus *Crepidula* Lamarck

Crepidula LAMARCK (1799), Mém. Soc. Hist. Nat. Paris, ser. 1, vol. 1, p. 78; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 789

Genotype: *Patella fornicata* Linnaeus (monotypic)

Crepidula onyx Sowerby

(Plate 30, figures 2, 4, 5, 6)

Crepidula onyx SOWERBY (1824), Genera of Shells, no. 23, fig. 2; Reeve (1859), Conch. Icon., vol. 11, *Crepidula* pl. 2, sp. 9; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 790–791, pl. 32, fig. 34; JORDAN (1936), Contrib. Dept. Geol. Stanford Univ., vol. 1, p. 113.
Crepidula onyx Broderip, SMITH (1944), Panamic Marine Shells, p. 14, nos. 155, 162.

Hypotypes nos. 31521, 31522 (loc. A 3548).

OCCURRENCE: locs. A 3548, A 3582, A 3584, A 3596(?).

RANGE: Pleistocene, Recent.

REMARKS: Typical *C. onyx*, as represented by hypotype no. 31522, is present only at loc. A 3548. The variety represented by hypotype no. 31521 is present at loc. A 3548 as well as the other localities. This last form somewhat resembles *C. grandis* Middendorf, but is also matched by some living specimens identified as *onyx* from the Gulf of California.

Family CALYPTRAEIDAE

Genus *Crucibulum* Schumacher

Crucibulum SCHUMACHER (1817), Ess. nouv. syst. vers. test., p. 56, 182.

Genotype: *Crucibulum planum* Schumacher = *Patella auricula* Gmelin (monotypic)

Crucibulum imbricatum (Sowerby)

(Plate 30, figures 12, 13)

Calyptraea imbricata SOWERBY (1824), Genera of Shells, pl. 23, fig. 5.
Crucibulum imbricatum SOWERBY, CARPENTER (1857), Cat. Mazatlan Shells, p. 287–289; REEVE (1858), Conch. Icon., vol. 11, *Crucibulum*, pl. 3, sp. 9
Crucibulum imbricatum (Sowerby), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 793; JORDAN (1936), Contrib. Dept. Geol. Stanford Univ., vol. 1, p. 113; SMITH (1944), Panamic Marine Shells, p. 14, no. 153.

Hypotypes nos. 31516, 31517 (loc. A 3548).

OCCURRENCE: locs. A 3508, A 3515, A 3519, A 3534, A 3548, A 3584, A 3593.

RANGE: upper Pliocene to Recent.

Crucibulum spinosum (Sowerby)

(Plate 30, figures 24, 25)

Calyptraea spinosa SOWERBY (1824), Genera of Shells, pl. 23, figs. 4, 7.
Crucibulum spinosum SOWERBY, CARPENTER (1857), Cat. Mazatlan Shells, p. 291–294; REEVE (1859), Conch. Icon., vol. 11, *Crucibulum*, pl. 4, sp. 10.
Crucibulum spinosum (Sowerby), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 793; JORDAN (1936), Contrib. Dept. Geol. Stanford Univ., vol. 1 p. 113; SMITH (1944), Panamic Marine Shells, p. 14, no. 154.

Hypotype no. 31515 (loc. A 3582).

OCCURRENCE: locs. A 3582, A 3584.

RANGE: Pleistocene, Recent.

Family NATICIDAE

Genus *Neverita* Risso

Neverita RISSO (1826), Hist. Nat. Eur. Mérid., vol. 4, p. 149, pl. 4, fig. 43; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 800.

Genotype: *Neverita josephina* Risso = *N. olla* de Serres (monotypic)

Neverita reclusiana (Deshayes)

(Plate 34, figure 8)

Natica reclusiana DESHAYES (1839), Rev. Zool. Soc. Cuv., p. 361; REEVE (1855), Conch. Icon., vol. 9, Natica, pl. 1, sp. 3.
Polinices (*Neverita*) *reclusianus* (Deshayes), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 800–803, text figs. 13, 14.
Polinices reclusianus (Deshayes), JORDAN (1936), Contrib. Dept. Geol. Stanford Univ., vol. 1, p. 114.
Polinices (*Neverita*) *reclusiana* (Deshayes), SMITH (1944), Panamic Marine Shells, p. 12, no. 121.

Hypotype no. 32792 (loc. A 3584).

OCCURRENCE: locs. A 3533, A 3548, A 3582, A 3584.

RANGE: upper Pliocene to Recent.

REMARKS: The figured specimen is one of the low-spired variants.

Genus *Polinices* Montfort

Polinices MONTFORT (1810), Conch. Syst., vol. 2, p. 222; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 799.

Genotype: *Polinices albus* Montfort = *Helix mammilaris* Linnaeus (orig. desig.)

Polinices bifasciatus (Gray)

(Plate 34, figure 2)

Natica befasciata GRAY, *in* GRIFFITH'S Cuvier (1834), Anim. Kingd., Moll., p. 598, pl. 1, fig. 2; REEVE (1855), Conch. Icon., vol. 9, *Natica*, pl. 10, sp. 40.
Polinices (*Polinices*) *bifasciatus* (Gray), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 800.
Natica bifasciata GRAY, SMITH (1944), Panamic Marine Shells, p. 11, no. 139.

Hypotype no. 32794 (loc. A 3548).

OCCURRENCE: locs. A 3515, A 3520, A 3534, A 3538, A 3548, A 3550, A 3577(?), A 3582, A 3596.

RANGE: lower Pliocene (?) to Recent.

Family PYRAMIDELLIDAE

Genus *Pyramidella* Lamarck

Pyramidella LAMARCK (1799), Mém. Soc. Hist. Nat. Paris, vol. 1, p. 76.

Genotype: *Trochus dolabratus* (monotypic)

Pyramidella conica Adams

(Plate 33, figure 8)

Pyramidella conica ADAMS (1852), Cat. Panama Shells, p. 200, 318; (1852), Ann. Lyceum Nat. Hist. New York, vol. 5, p. 424, 542.
Pyramidella (*Longchaeus*) *conica* C. B. ADAMS, SMITH (1944), Panamic Marine Shells, p. 9, no. 82.

Hypotypes nos. 32704, 32705 (loc. A 3548).

OCCURRENCE: locs. A 3548, A 3582.

RANGE: Pleistocene, Recent.

Family TURBINIDAE

Genus **Turbo** Linnaeus

Turbo LINNAEUS (1758), Syst. Nat., Ed., 10, p. 761.

Genotype: *Turbo petholatus* Linnaeus (subs. desig. Montfort, 1810)

Turbo fluctuosus Wood

(Plate 29, figure 23)

Turbo fluctuosus WOOD (1828), Index Test., Suppl., pl. 6, fig. 44.

Turbo (*Callopoma*) *fluctuosus* WOOD, GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 816.

Hypotype no. 31510 (loc. A 3519).

OCCURRENCE: locs. A 3508, A 3514, A 3515, A 3519, A 3525, A 3529, A 3534, A 3538, A 3548, A 3549, A 3550, A 3562, A 3573, A 3574, A 3584, A 3596.

RANGE: lower Pliocene to Recent.

REMARKS: This species is very abundant at some localities.

Turbo squamiger Reeve

(Plate 29, figure 17)

Turbo squamiger REEVE (1842), Proc. Zool. Soc. London, p. 186; (1847), Conch. Icon., vol. 4, *Turbo*, pl. 5, fig. 21.

Turbo squamiger RVE., PILSBRY AND LOWE (1932), Proc. Acad. Nat. Sci. Philadelphia, vol. 84, p. 127.

Hypotype no. 32188 (loc. A 3550).

OCCURRENCE: loc. A 3550.

RANGE: Pleistocene, Recent.

REMARKS: This species and the following form have customarily been identified in Pacific Coast collections as Reeve's species which was described from the Galapagos Islands. Comparison with the original figure indicates that this identification is probably wrong but since the writer lacks comparative material from the Galapagos Islands he is following the accepted identifications. Reeve notes that the species is distinguished by its "scaly sculpture". The scaly sculptured form appears to be rather rare with the following form the most common.

Turbo squamiger Reeve, var.

(Plate 29, figure 11)

Turbo squamiger REEVE, of authors.

Hypotype no: 30648 (loc. A 3548).

OCCURRENCE: locs. A 3547, A 3548, A 3584.

RANGE: Pleistocene and Recent.

REMARKS: *See* under preceding.

Genus **Astraea** Bolten

Astraea Bolten (1798), Mus. Boltenianum, pt. 2, p. 79.

Genotype: *Trochus imperialis* Gmelin (*Trochus heliotropium* Martyn), (subs. desig. Suter, 1913)

Subgenus **Pomaulax** Gray

Pomaulax Gray (1850) Fig. Moll. Anim., vol. 4, p. 87.

Subgenotype: *Trochus undosus* Wood

Astraea* (*Pomaulax*) *subundosa n. sp.

(Plate 28, figures 12, 18)

Shell resembling *A. undosa* (Wood) but with a slightly smaller apical angle; basal carina not overly prominent, with 12–14 poorly defined nodes; base slightly concave with poorly defined spiral ribs apparently corresponding to those on *A. undosa*; sculpture of about 30 (estimated) axial ribs approximately parallel to left side of spire and extending from suture across whorl onto basal carina; a distinct girdling depression just above basal carina, above this one indistinct heavy spiral rib and then 2 fine spiral ribs.

Dimensions of holotype (incomplete): height 21.0 mm., diameter 27.6 mm.

Holotype no. 30403, paratype no. 30407 (loc. A 3549).

OCCURRENCE: loc. A 3549.

RANGE: middle ? Pliocene.

REMARKS: This species may be distinguished from *A. undosa* by its lesser apical angle, concave base, greater number of axial ribs, and less distinct basal carina. The holotype consists of approximately half a shell, sectioned vertically so as to include the columella. The paratype is a fraction of the last volution showing the basal ornamentation and surface sculpture.

Subgenus **Uvanilla** Gray

Uvanilla GRAY (1850), Fig. Moll. Anim., vol. 4, p. 87.

Subgenotype: *Trochus olivaceus* Wood

Astraea* (*Uvanilla*) *shepherdi n. sp.

(Plate 28, figures 17)

Shell tall, conical, resembling *A. unguis* (Wood); apical angle about 55°; about 6 whorls; aperture decidedly oblique, ovate; base flat to slightly convex, with about 6 revolving ribs, of which the inner 4 are the heaviest; base of whorls carinated, with about 14 flattened spines, excavated on the under side; axial sculpture of poorly defined, small ribs approximately parallel to left side of spire, corresponding to spines in number on earlier whorls, but about double in number on body whorl.

Dimensions of holotype: height 29.3 mm., diameter 27 mm.

Holotype no. 30463, paratype no. 30464 (loc. A 3547).

OCCURRENCE: loc. A 3547.

RANGE: Pleistocene.

REMARKS: This species may be distinguished from *A. unguis* (Wood) by its higher spire, slightly convex base, and less prominent spines.

Family NERITIDAE

Genus **Nerita** Linnaeus

Nerita LINNAEUS (1758), Syst. Natura, Ed. 10, p. 776; SUTER (1913), Man. New Zealand Mollusca, p. 171.

Genotype: *Nerita albicilla* Linnaeus

Nerita bernhardi Recluz ?

(Plate 35, figures 6, 9)

Nerita bernhardi RECLUZ (1850), Journ. de Conchyl., vol. 1, p. 285; Reeve (1855), Conch. Icon., vol. 9, *Nerita*, pl. 12, no. 57; CARPENTER (1857), Cat. Mazatlan Shells, p. 257; DALL (1910), Proc. U. S. Nat. Mus., vol. 37, p. 241; SMITH (1944), Panamic Marine Shells, p. 6.

Hypotype no. 32796 (loc. A 3569).

OCCURRENCE: loc. A 3569.

RANGE: Pleistocene, Recent.

REMARKS: In some respects this shell more closely resembles *N. fulgurans* from the Caribbean. It is larger (height 22 mm.) than most specimens of *bernhardi* and has about 24 primary spiral ribs (most specimens of *bernhardi* have about 18 primary spirals on shell about half the size of the present one). Unfortunately the shell is rather worn.

Nerita sp.

(Plate 35, figure 5)

Hypotype no. 32798 (loc. A 3510).

OCCURRENCE: loc. A 3510.

RANGE: middle Pliocene.

REMARKS: The present specimen unfortunately is not complete, but it probably represents a new species. The spire was very low as in *N. bernhardi.* It was sculptured by 16 very prominent spiral ribs nearly twice the width of their interspaces. The interspaces are very deep and square-sided, with no secondary ribs. Unfortunately the aperture and columella are missing on the specimen.

Family TROCHIDAE

Genus ***Calliostoma*** Swainson

Calliostoma SWAINSON (1840), Treat. Malac., p. 218, 351.

Genotype: *Trochus conulus* Linnaeus (subs. desig. Herrmannsen, 1846)

Calliostoma bonita Strong, Hanna, and Hertlein

(Plate 29, figure 18)

Calliostoma bonita STRONG, HANNA, AND HERTLEIN (1933), Proc. Calif. Acad. Sci., ser. 4, vol. 21, p. 121, pl. 5, figs. 5, 6.

Hypotypes nos. 31500, 31507 (loc. A 3582).

OCCURRENCE: loc. A 3582.

RANGE: Pleistocene, Recent.

Calliostoma eximium (Reeve)

(Plate 29, figure 20)

Trochus eximius REEVE (1842), Proc. Zool. Soc. London, p. 185; (1842), Conch. Syst., vol. 2, p. 165, pl. 208, fig. 12.

Calliostoma eximium (Reeve), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 835.

Hypotypes nos. 31508, 31509 (loc. A 3584).

OCCURRENCE: locs. A 3548, A 3582, A 3584, A 3596, A 3598.

RANGE: Pleistocene, Recent.

Genus ***Tegula*** Lesson

Tegula LESSON (1835), Illust. de Zoologie, Liv. 17, pl. 51; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 825.

Genotype: *Tegula elegans* Lesson = *Trochus pellis-serpentis* Wood (monotypic)

Tegula mariana (Dall)

(Plate 29, figures 14, 15, 16)

Omphalius turbinatus PEASE (1869), Am. Journ. Conch., vol. 5, p. 84, pl. 8, fig. 15; *non* A. ADAMS (1851).
Chlorostoma coronulatum C. B. ADAMS, PILSBRY (1889), Man. Conch., vol. 11, p. 177, 178, pl. 24, figs. 80–83.
Chlorostoma coronulatum var. *turbinatum* PEASE, PILSBRY (1889), Man. Conch., vol. 11, p. 178, pl. 24, fig. 90.
Omphalius marianus DALL (1919), Proc. U. S. Nat. Mus., vol. 56, p. 359.
Tegula (Omphalius) mariana (Dall), PILSBRY AND LOWE (1932), Proc. Acad. Nat. Sci. Philadelphia, vol. 84, p. 84–85, pl. 10, figs. 9, 9a, 9b, 10.
Tegula mariana DALL, SMITH (1944), Panamic Marine Shells, p. 4.
Non Chlorostoma turbinatum A. ADAMS (1859).
Non Trochus coronulatus C. B. ADAMS (1852).

Hypotypes nos. 31513, 31514 (loc. A 3550); 32711, 32712, 32713 (loc. A 3549).

OCCURRENCE: locs. A 3519, A 3534, A 3548, A 3549, A 3550, A 3582, A 3587, A 3596.

RANGE: upper Pliocene to Recent.

REMARKS: Hypotypes nos. 31513, 31514 are like Dall's species as figured by Pilsbry and Lowe, yet one of them (no. 31513) has faint nodes immediately below the suture such as described for *T. mariana* subsp. *mariamadre* Pilsbry and Lowe. This latter subspecies is supposed to have rather prominent spiral sculpture. Some of the specimens from locality A 3549 have the suture a little more prominently crenulate than Recent variants of the species.

Family VITRINELLIDAE

Genus ***Teinostoma*** H. and A. Adams

Teinostoma H. AND A. ADAMS (1853), Gen. Rec. Moll., vol. 1, p. 122; (1858), Gen. Rec. Moll., vol. 2, p. 615; PILSBRY AND OLSSON (1945), Proc. Acad. Nat. Sci. Philadelphia, vol. 97, p. 250–251.

Genotype: *Teinostoma politum* Adams (virtual monotypy)

Teinostoma gallegosi Jordan

(Plate 29, figures 6, 7, 8)

Teinostoma gallegosi JORDAN (1936), Contrib. Dept. Geol. Stanford Univ., vol. 1, p. 163, pl. 18, figs. 6, 7, 8.

Hypotype no. 32769 (loc. A 3548).

OCCURRENCE: loc. A 3548.

RANGE: Pleistocene.

REMARKS: The species appears to be closely allied to *T. politum* and *T. politum ultimum* Pilsbry and Lesson (1945, p. 252–253, pl. 22, figs. 1, 1a, 1b, 6) but differs in that the suture shows over 4 complete whorls, while there is no evidence of spiral ribbing.

Family FISSURELLIDAE

Genus ***Diodora*** Gray

Diodora GRAY (1821), London Med. Repos., Monthly Journ. and Review, vol. 15, p. 233; GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 849–850.
Diadora GRAY (1847), Proc. Zool. Soc. London, p. 147; *Auct.*

Genotype: *Patella apertura* Montagu (monotypic)

Diodora alta (Adams)

(Plate 30, figures 26, 27)

Fissurella alta ADAMS (1852), Cat. Panama Shells, p. 236, 320, no. 355; (1852) Ann. Lyceum Nat. Hist. New York, vol. 5, p. 460, 544, no. 355.
Glyphis alta C. B. ADAMS, CARPENTER (1857), Cat. Mazatlan Shells, p. 221–222.
Diadora alta (C. B. ADAMS), SMITH (1944), Panamic Marine Shells, p. 3, no. 15a.

Hypotypes nos. 30646, 30647 (loc. A 3534).

OCCURRENCE: locs. A 3534, A 3550, A 3582, A 3584.

RANGE: upper Pliocene to Recent.

Diodora inaequalis (Sowerby)

(Plate 30, figures 19, 20)

Fissurella inaequalis SOWERBY (1835), Proc. Zool. Soc. London, pt. 2, p. 126; REEVE (1849), Conch. Icon., vol. 6, *Fissurella*, pl. 7, sp. 50.
Glyphis inaequalis SOWERBY, CARPENTER (1857), Cat. Mazatlan Shells, p. 220–221.
Diodora inaequalis (Sowerby), GRANT AND GALE (1931), Mem. San Diego Soc. Nat. Hist., vol. 1, p. 850; JORDAN (1936), Contrib. Dept. Geol. Stanford Univ., vol. 1, p. 113.
Diodora inaequalis inaequalis (Sowerby), SMITH (1944), Panamic Marine Shells, p. 3, no. 17.

Hypotype no. 31520 (loc. A 3534).

OCCURRENCE: loc. A 3519, A 3534, A 3550.

RANGE: upper Pliocene to Recent.

Genus ***Hemitoma*** Swainson

Hemitoma SWAINSON (1840), Treat. Malac., p. 356.

Genotype: *Hemitoma tricostata* (Sowerby) (monotypic)

Hemitoma hermosa Lowe

(Plate 28, figures 4, 10)

Hemitoma hermosa LOWE (1935), Trans. San Diego Soc. Nat. Hist., vol. 8, p. 24, pl. 4, fig. 4.

Hypotypes nos. 30476 (loc. A 3596); 30477 (loc. A 3550).

OCCURRENCE: locs. A 3550, A 3596.

RANGE: Pleistocene, Recent.

REMARKS: Six specimens referable to this species were collected; the smallest agrees rather well with Lowe's figured type. The largest (height 15.4 mm. aperture 24.3 mm. by 19.2 mm.) is nearly 4 times as large as his specimen. A description based upon this specimen (hypotype no. 30476) follows.

Shell large, heavy, rugose, conical; apex curved backwards; aperture ovately polygonal; anal notch short, lying in center of anterior margin, with a groove running up inside of shell to apex; anal groove represented by a raised ridge on exterior; radial sculpture of 8 primary heavy ribs radiating from apex, of which 2 on either side of rib representing anal groove are much heavier, with intercalated secondary, tertiary, and quaternary ribs of smaller size; concentric sculpture of a few heavy rugose irregular rings, forming heavy nodes where they interesect radials.

Hemitoma natlandi n. sp.

(Plate 28, figures 7, 8)

Shell of medium size, thin, conical; apex slightly curved posteriorly; aperture ovately polygonal; anal notch of medium size, lying in center of anterior margin, with a groove extending up interior of shell to apex, represented by a sharp ridge on exterior; radial sculpture of four primary, narrow, and sharp ribs, with 2 slightly smaller ribs laterally and 2 similarly sized ribs side by side posteriorly opposite "anal ridge"; secondary and tertiary ribs intercalated between aforementioned ribs; concentric sculpture of growth lines only.

Dimensions of holotype: height 8.5 mm., aperture 10.1 mm. by 15 mm.

Holotype no. 30474 (loc. A 3548).

OCCURRENCE: Loc. A 3548.

RANGE: Pleistocene.

REMARKS: May be separated from *H. hermosa* Lowe by the more central, less recurved apex, lack of concentric ribs, finer radial ribs on a different plan, and slightly larger anal notch.

Hemitoma scrippsae n. sp.

(Plate 28, figures 9, 14)

Shell of medium size, depressed conical; apex faintly posteriorly pointed; aperture ovately hexagonal; anal notch of medium size, lying in center of anterior margin, with a faint groove extending up inside of shell to apex; a prominent external ridge representing this groove on exterior; radial ribs with same pattern as on *H. natlandi* n. sp.—4 primaries, with 2 subequally prominent ribs intercalated laterally and 2 paired ribs posteriorly opposite "anal ridge", successively finer secondary and tertiary ribs intercalated between primaries; concentric ornamentation of growth lines only, producing a cancellated effect at intersection with finer secondary and tertiary radial ribs.

Dimensions of holotype: height 5.6 mm., aperture 17.8 mm. by 11.7 mm.

Holotype no. 30363 (loc. A 3520).

OCCURRENCE: loc. A 3520.

RANGE: upper Pliocene, Marquer formation.

REMARKS: This species may be separated from the two previously noted by its much lower spire. Only a single specimen was found.

Family ACMAEIDAE

Genus ***Acmaea*** Escholtz

Acmaea ESCHOLTZ *in* KOTZEBUE (1830), Neue Reise um die Welt in den Jahren 1823, 24, 25, and 26, Weimar, vol. 2, appendix, p. 24 (Genus without species); ESCHOLTZ *in* RATHKE (1833), Zool. Atlas, pt. 5, p. 16; WOODRING (1928), Carnegie Inst. Wash., Publ. 385, p. 458.

Genotype: *Acmaea mitra* Escholtz (subs. desig. Dall. 1871)

Acmaea dalliana Pilsbry

(Plate 30. figures 22, 23)

Acmaea dalliana PILSBRY (1891), Man. Conch., vol. 13, p. 13, pl. 7, figs. 57–60.

Hypotype no. 31523 (loc. A 3548).

OCCURRENCE: loc. A 3548.

RANGE: Pleistocene, Recent.

REMARKS: The present specimen is a little higher than normal, but otherwise agrees very well with Pilsbry's species.

Family PATELLIDAE

Genus ***Patella*** Linnaeus

Patella LINNAEUS (1758), Systema Natura, Ed. 10, p. 296.

Genotype: *Patella vulgata* Linnaeus

Patella mexicana Broderip and Sowerby?

(Plate 30, figures 1, 3)

Patella mexicana BRODERIP AND SOWERBY (1829), Zool. Jour. London, vol. 4, p. 369; CARPENTER (1857), Cat. Mazatlan Shells, p. 199–200; SMITH (1944), Panamic Marine Shells, p. 4, no. 11.

Hypotype no. 32723 (loc. A 3508).
OCCURRENCE: loc. A 3508.
RANGE: Pleistocene, Recent.
REMARKS: A small (24.5 mm.) specimen, possibly referable to this species.

Phylum ARTHROPODA

Class CRUSTACEA

Subclass CIRRIPEDIA

Family BALANIDAE

Genus ***Coronula*** Bruguière

Coronula BRUGUIÈRE (1792), Encyl. Meth. Hist. Nat. vers, p. 144, pl. 165.

Genotype: *Lepas diadema* Linnaeus

Coronula diadema (Linnaeus)

Lepas diadema LINNAEUS (1767), Syst. Nat., Ed. 12, p. 1108.

Hypotype no. 30642 (loc. A 3518).
OCCURRENCE: loc. A 3518.
RANGE: upper Pliocene, Recent.

NOTE ON *RAMULINA GLOBULIFERA* H. B. BRADY

By J. A. Cushman

Plate 48 gives figures of the interior of a *Plicatula* shell from Univ. Calif. Mus. Paleo. loc. A 3563, Upper Pliocene, near mouth of Arroyo de Arce, north of Loreto, Lower California. The interiors of both valves have a mass of tests very closely resembling forms that have been assigned to *Ramulina globulifera* H. B. Brady. The chambers are globular, united by stoloniferous tubes as is usual in this species. An enlargement of a part of the general interior is shown and also a still greater enlargement of two individual chambers connected by the stolonlike tube. Numerous other tubular projections occur on the free side of the chambers.

The interior of the valves was occupied by a solid mass of material shown in Figure 5, Plate 48. This shows the outline of the muscle scars and other lines of the interior of the shell. Apparently this inner filling had shrunk and become consolidated, leaving an open area at each side; this space later was filled by the *Ramulina*. Probably therefore the *Plicatula* and *Ramulina* are not of the same geologic age.

Such a mass of *Ramulina* chambers is very unusual and has apparently not previously been recorded in any such numbers. The occurrence therefore seems worthy of record.

DESCRIPTION OF LOCALITIES

All but 15 of the following localities are also shown on the maps and cross sections in the accompanying geological report by Anderson. Reference should be made to it for more exact relationships of the localities here described. Unless otherwise noted, all localities are within the Gulf of California area.

UNIVERSITY OF CALIFORNIA, MUSEUM OF PALEONTOLOGY LOCALITIES

A 740	Lower Pliocene, Imperial formation, southeastern California. Near contact of lava and sandstone. Alverson Canyon, Coyote mountains.
A 1267	Lower Pliocene, Imperial formation, southeastern California. Upper part of basal sandstone and conglomerate series on northwest side of Carrizo Mountain. S. 5° 30′ E. of Carrizo station, Imperial Co.
A 1268	As preceding locality. Oyster reef on ridge running west from east side of meander of stream in badland area. About halfway between loc. A 1267 and Carrizo station.
A 3497	Pleistocene, Salinas Bay, Carmen Island. From raised bar across mouth of salt lagoon, close to west side.
A 3498	Middle Pliocene, Carmen formation, east side of Salinas Bay, Carmen Island. Nearly half way from salt works to Perico Point. Yellow calcareous marly sediments against a fault. Pebble and cobble conglomerates on east side of fault. Exposed along sea cliff.
A 3499	Middle Pliocene, Carmen formation, east side of Salinas Bay, Carmen Island; 50 feet west of loc. A 3498 and probably same bed. Exposed along sea cliff.
A 3500	As preceding locality. Composite sample through 10 feet of foraminiferal marly clay overlying loc. A 3499.
A 3501	As preceding locality; 8 feet of yellow foraminiferal marly clay with occasional pumice fragments. Immediately above loc. A 3500.
A 3502	As preceding locality; 7 feet of yellow foraminiferal marly clay. Immediately above loc. A 3501.
A 3503	As preceding locality; 10 feet of foraminiferal marly clay. Immediately above loc. A 3502.
A 3504	As preceding locality; 10 feet of foraminiferal marly clay. Immediately above loc. A 3503.
A 3505	As preceding locality, but at west end of outcrop of yellow marly beds. Pecten reef beds at base of yellow beds, contains boulders up to 7 feet in diameter. Possibly same horizon as loc. A 3498.
A 3506	As preceding locality, but a few feet west of and stratigraphically below it. Fossils from a poorly sorted silty sand interbedded in volcanic cobble conglomerate. Abundant casts of small pelecypods also.
A 3507	Pleistocene, same area as preceding locality. A 2-foot massive silt bed below 3 feet of thin-bedded silts. This sequence in turn overlain with slight angular discordance by a terrace level (loc. A 3508). Entire Pleistocene sequence rests with marked angular discordance on volcanic conglomerates and sand of loc. A 3506.
A 3508	*See* preceding locality. A low terrace level with a zone of corals 12–18 inches thick at base.
A 3509	Middle Pliocene, Carmen formation, exposed in seacliff to northwest of Perico Point, Salinas Bay, Carmen Island. From calcareous beds intercalated in volcanic conglomerate. All material from boulders at base of cliff.
A 3510	As preceding locality but all material *in situ.*
A 3511	As preceding locality but from a lense of foraminiferal shale near base of cliff.
A 3512	As preceding locality, but just below it.
A 3513	Upper Pliocene, Marquer formation, Marquer Bay, Carmen Island. From yellow calcareous sands exposed on south rim of large northern arroyo, about a quarter of a mile from beach. Elevation about 250 feet (aneroid barometer reading).
A 3514	Pleistocene, Marquer Bay, Carmen Island. From terrace level at 300 feet elevation (aneroid barometer) and back about three eights of a mile from beach.
A 3515	As preceding locality, but from a terrace level at about 330 feet elevation (aneroid barometer), and farther back from beach.

A 3516	Upper Pliocene, Marquer formation, Marquer Bay, Carmen Island. Along seacliff in center of bay just south of south central arroyo (small), and just north of small fault that displaces latest terrace level. In soft yellow sandstone below a zone of oysters and pectens.
A 3517	As preceding locality, but about 100 yards south along beach. From calcareous sands above gravel beds.
A 3518	As loc. A 3513, but in cliff facing bay, just south of northern arroyo. About 150 feet above sea level. Same bed as at loc. A 3513, and about 20 feet below a coral-reef horizon.
A 3519	As preceding localities but near south end of bay. Coral reef exposed in cliff on north side of large southern arroyo at its junction with seacliff. Rests on bed of calcareous algae and sandy marl with an irregular contact marked by boulders of volcanic material.
A 3520	As preceding locality, but in next small arroyo to north, back about 125 yards from beach, at top of small waterfall. Appears to be lateral equivalent of loc. A 3519. Overlain by terrace level.
A 3521	As preceding localities. In sea cliff to north of loc. A 3519. From sandy beds with calcareous algae, resting on crossbedded (?), steeper-dipping sands and gravels.
A 3522	Late Pleistocene, Marquer Bay, Carmen Island. From a small protected area of unconsolidated sands just inside mouth of small arroyo to north of loc. A 3521.
A 3523	Upper Pliocene, Marquer formation, Marquer Bay, Carmen Island. From sea cliff to north of loc. A 3522, in part at least, equivalent to loc. A 3517.
A 3524	As preceding locality. From pecten and oyster bed above loc. A 3516.
A 3525	Late Pleistocene, Marquer Bay, Carmen Island. From late 5-foot terrace level exposed along north central part of bay.
A 3527	Middle Pliocene, Carmen formation, Salinas Bay, Carmen Island. Same loc. as A 3503, but weathered out on surface.
A 3528	Lower Pliocene, sea cliffs north of Arroyo Blanco, Carmen Island. About 200 yards south of big arroyo to north of Arroyo Blanco. Fossils from near base of sand and gravel sequence.
A 3529	As preceding locality, but 20 feet stratigraphically higher.
A 3530	As preceding locality, but near middle of big cliff. About the same horizon as loc. A 3528.
A 3531	As preceding locality, but at long low point near south end of big cliff. Fossils from lens of sand and gravel near base of big conglomerate.
A 3532	As preceding locality, but from gravel beds and limestone at top of conglomerate.
A 3533	Middle Pliocene, to north of trail between salt flats and Puerto Balandra, Carmen Island From isolated hilltop to north of trail on east side of first north-south valley back from Puerto Balandra. Approximately a mile inland and 150 yards from trail.
A 3534	Upper Pliocene, Puerto Balandra, Carmen Island. Coral reef outcropping in sea cliff in southeast corner of Bay. Top truncated by Pleistocene terrace level.
A 3535	Lower Pliocene, Puerto de la Lancha area, Carmen Island. To southwest of Puerto de la Lancha, on south slope of hill, coming up from salt lagoon. About a quarter of a mile from beach.
A 3536	As preceding but from outcrops in sea cliff to north and west of Puerto de la Lancha.
A 3537	As preceding locality. Weathered material lying on top of cliff.
A 3538	Pleistocene, Oto Bay, Carmen Island. From marine conglomerate underneath cross-bedded eolian limestone, just to east of main arroyo entering bay.
A 3539	Upper Pliocene, Oto Bay, Carmen Island. From boulders in conglomerate at loc. A 3538.
A 3540	Pleistocene, as loc. A 3538. Gastropod from overlying cross-bedded eolian limestone.
A 3541	Middle Pliocene, Oto Bay, Carmen Island. From *Chione* reef beds in main arroyo, back about three quarters of a mile from beach.
A 3542	Upper Pliocene or Pleistocene, south side of Coronado Island. From calcareous algae and marly sandstone with abundant small stick corals. West central part of sea cliff on south side of island. West of a fault.
A 3543	Middle (?) Pliocene, Coronado Island. From a calcareous lense in conglomerates in fault block east of loc. A 3542.
A 3544	As preceding locality. In same fault block as locality A 3543, but a short distance east.

A 3545	Upper Pliocene, Coronado Island. From low, westward-dipping orange-brown clays, unconformable on volcanic breccias, and unconformably overlain by low eastward-dipping Pleistocene calcareous algal sandstone. Immediately east of fault on west side of loc. A 3544.
A 3546	As preceding locality, but 3–4 feet higher stratigraphically, and below unconformity.
A 3547	Pleistocene, Coronado Island. From algal sandstone, unconformably overlying loc. A 3546.
A 3548	As preceding locality, but from *Porites* reef bed overlying algal sandstone. In turn unconformably overlain by late Pleistocene terrace.
A 3549	Upper Pliocene, Coronado Island. From beds outcropping along beach on southeast side long point extending southwest from island.
A 3550	Pleistocene, Coronado Island. From white calcareous beds outcropping in arroyo about 200 yards northeast of loc. A 3548.
A 3551	Lower Pliocene, Arroyo de Gua, north of Loreto, Lower California. On north side of arroyo, about a quarter of a mile below point where road passes over divide into Arroyo de Arce. A 2-foot zone of echinoids interbedded in sandstones and conglomerates.
A 3552	As preceding locality. An echinoid-pecten bed just above loc. A 3551.
A 3553	As preceding locality, about 100 feet stratigraphically lower than loc. A 3551. In sandstone.
A 3554	As preceding locality. Along east side of road in divide where it passes over from Arroyo de Gua into Arroyo de Arce. Approximately 300 yards west of loc. A 3553, and stratigraphically lower (dip 40° E.). In sandstone.
A 3555	As preceding locality but 15–20 feet higher stratigraphically.
A 3556	As preceding localities, on north side of arroyo, about half way between locs. A 3553 and A 3554.
A 3557	As preceding localities, but stratigraphically higher. On north side of arroyo, about 250 yards west of point where road from Loreto descends to bottom of arroyo. Pecten reef beds.
A 3558	As preceding locality but about 150 feet stratigraphically lower, although still considerably higher than loc. A 3551.
A 3559	Middle (?) Pliocene, Arroyo de Arce, north of Arroyo de Gua, Lower California. In cliff along north side of arroyo. Estimated to be about three quarters of a mile from beach. Stratigraphically higher than unconformity in section. In low-dipping alternating gravels and leached calcareous beds.
A 3560	As preceding locality, about 15 feet higher stratigraphically.
A 3561	Upper Pliocene, along beach about a quarter of a mile north of mouth of Arroyo de Arce, Lower California. In sea cliff.
A 3562	As preceding locality, in algal sandstone above conglomerate.
A 3563	As preceding localities, but in small arroyo about 100 yards to south. Calcareous beds.
A 3564	Pleistocene, north of Arroyo de Arce, Lower California. From sandstone exposed in a small arroyo about 300 yards southwest of loc. A 3563.
A 3565	Lower Pliocene, Arroyo de Arce, north of Loreto, Lower California. From massive yellow pecten reef beds at point where Arroyo de Arce narrows down, and just before lower arroyo widens out. A small unconformity at base of beds. Probably about 2 miles from beach.
A 3566	Middle Pliocene, Monserrate Island. From pecten beds in calcareous "sandstone" overlying algal sandstone which is in fault contact with breccia. On east side of southern tip of island
A 3567	Pleistocene, Monserrate Island. From 20-foot terrace level at south end of island.
A 3568	Middle Pliocene, south side of Monserrate Island. From uplifted block at about 560 feet elevation, in south-central part of island. Appears to be a terrace from distance, but fossiliferous beds are slightly truncated by a later terrace level.
A 3569	Pleistocene, central part of Monserrate Island Uplifted terrace level at approximately 700 feet elevation. Up to 5 feet thick on top of middle Pliocene.
A 3571	Middle (?) Pliocene, south end of San Marcos Island. From steeply dipping calcareous beds on west side of fault at extreme southern point of island. Beds contain leached boulders of San Marcos formation.
A 3572	Lower Pliocene, San Marcos formation. Leached boulder found in beds at loc. A 3571.
A 3573	Pleistocene, San Marcos Island. From 5-foot terrace level on west side of southern point of island.

A 3574 As preceding locality but from 15-foot terrace level which overlies 5-foot terrace (loc. A 3573).

A 3576 Lower Pliocene, San Marcos formation San Marcos Island. On east side of island in northeast corner of outcrop of gypsum beds. From cliff in mesalike hill. In grey calcareous algal sandstone some 150–200 feet stratigraphically higher than gypsum. Overlies conglomerate and is overlain by a conglomerate containing pebbles of granite.

A 3577 Lower Pliocene, San Marcos formation, San Marcos Island. From an isolated area on north side of big arroyo which separates main body of gypsum from volcanics to north. Calcareous beds resting on lavas.

A 3578 Lower Pliocene, San Marcos formation, San Marcos Island. Same horizon as loc. A 3576 but from isolated hill on top of gypsum to southwest of loc. A 3576.

A 3579 Lower Pliocene, San Marcos formation, San Marcos Island. A boulder from fossiliferous beds above gypsum on southern end of island.

A 3580 Lower (?) Pliocene, from mainland southeast of San Marcos Island, some distance west of Chivato Point. From highly leached conglomeratic limestone in residual patches resting uncomformably on volcanics.

A 3581 Lower Pliocene, west of Santa Inez Point, Santa Inez Bay, Lower California. About half a mile from beach, at edge of hill. From conglomerates and shale underneath leached calcareous sediments.

A 3582 Pleistocene, Santa Inez Bay, Lower California. From 20-foot terrace level extending from loc. A 3581 to beach.

A 3583 Lower Pliocene, Santa Inez Bay, Lower California. From sandstones outcropping on beach west of Santa Inez Point and unconformably overlain by Pleistocene terrace (loc. A 3582).

A 3584 Pleistocene, Santa Inez Bay, Lower California. From Pleistocene terrace exposed in sea cliffs west of loc. A 3583. No older beds exposed here.

A 3585 Pleistocene, Tiburón Island. From 30-foot terrace level northeast of Red Bluff Point, south end of island.

A 3586 Pleistocene, Tiburón Island. From silty sandstone and gravels deposited in a small valley cut in volcanics. Exposed on beach northwest of Seal Rock, southeastern end of island.

A 3587 Pleistocene, Tiburón Island. From calcareous algal sandstones with abundant chiones exposed in old lagoon about half way between locs. A 3585 and A 3586.

A 3588 Upper Pliocene, south end of Angel de la Guarda Island. Exposed in cliffs in large arroyo about half way between Pond Island and southern point of island. On south side of arroyo from fossil-bearing bed near top of sandy phase of sediments, overlain by conglomerates.

A 3589 As preceding locality, but farther up arroyo, in clay shale exposed in south branch of arroyo just before it enters main arroyo.

A 3590 As preceding locality. Same horizon as loc. A 3588, exposed in cliff on northeast side of mouth of arroyo.

A 3591 As preceding localities, but from just south of tip of point extending out to Pond Island. Terrace-like deposits unconformable on Comondú and overlain by lava flow. From lower shales and calcareous sandstone.

A 3592 As preceding locality but from a 1-foot sandy bed with abundant chiones, overlying loc. A 3591.

A 3593 As preceding locality but from gravels immediately underneath lava.

A 3594 Lower Pliocene, south end of North San Lorenzo Island. On west side of island a short distance north of southern end. From well-bedded coarse sandstone dipping northwest, overlain by conglomerates and volcanics.

A 3595 Upper Oligocene, San Gregorio formation, north of San Telmo Point, Lower California (approximately 25° N. Lat.). From sea cliff to north of large arroyo. In a massive calcareous pebbly sandstone, carrying abundant arcas, at top of thin-bedded cherty sands and shales. Approximately 150 feet stratigraphically higher than *Cornwallius* teeth, but fragments of bone were noted scattered through section to about this level.

A 3596 Pleistocene, immediately south of San Telmo Point, Lower California. From calcareous beds interbedded in gravels.

A 3597 Pleistocene. A lot of fossils which had lost their label when examined in laboratory, but from matrix and assemblage appear to be from loc. A 3547.

A 3598	Pleistocene, Concepción Bay, Lower California. From 10–20 foot terrace level exposed as small residuals on east side of small point extending into Coyote Bay from north, just north of first small island in Coyote Bay.
A 3670	Upper Pliocene, Puerto Balandra, Carmen Island. From sands at left end of outcrop and below base of coral reef (loc. A 3534).
A 3712	Lower Pliocene, Carmen Island. From a fault block along face of hills to northeast of northeast corner of salt lagoon.
A 3713	As preceding locality, and close to it. Apparently same beds.

California Academy of Sciences Localities

C.A.S. 754	Pleistocene, Magdalena Bay, Lower California. Just north of village of Magdalena Bay. (*See* Jordan, 1936.)
C.A.S. 795	Middle Pliocene, Santa Antonita Point, Lower California. Collected along a canyon about half a mile inland and which empties near point. *See* Hanna and Hertlein (1927, p. 144–145).
C.A.S. 982	Pleistocene, Magdalena Bay, Lower California. From 1–1½ miles south of village of Magdalena Bay. (*See* Jordan, 1936.)

Stanford University Locality

L.S.J.U. 805	Lower Pliocene in part (corresponds to locality A 3583), Pleistocene in part (corresponds to locality A 3582).

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A contribution from the Museum of Paleontology, University of California, Berkeley, California.

EXPLANATION OF PLATES

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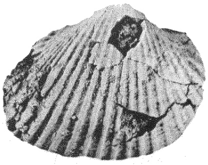
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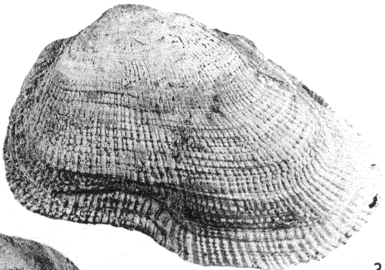
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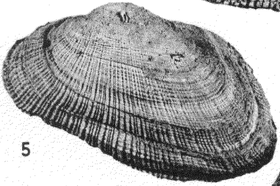
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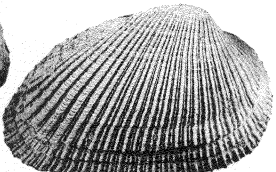
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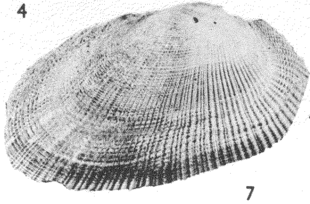
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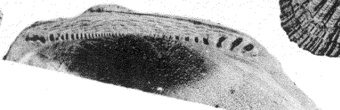
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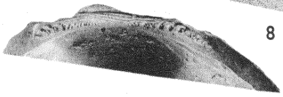
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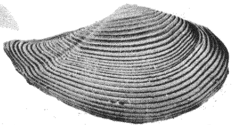
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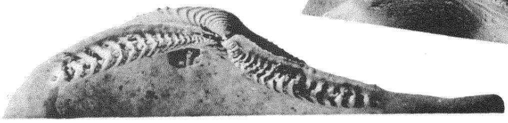
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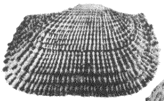
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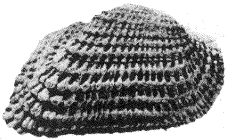
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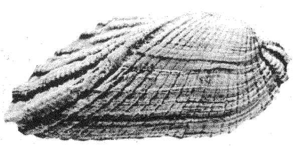
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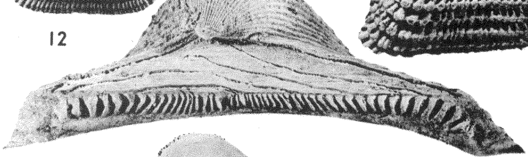
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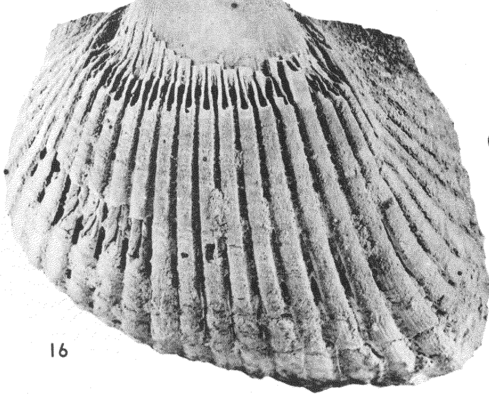
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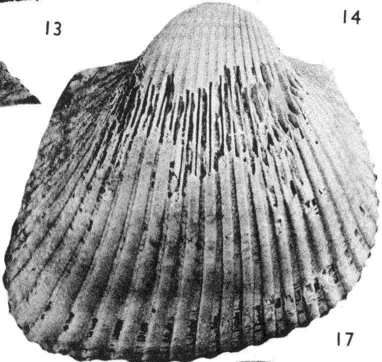
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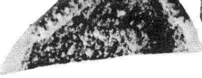
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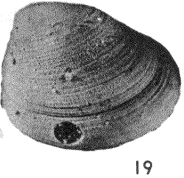
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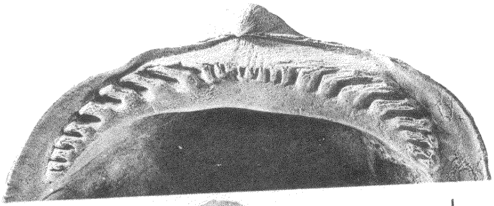
CENOZOIC PELECYPODA



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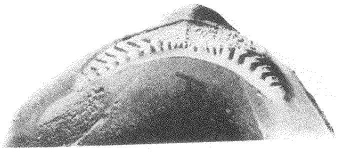

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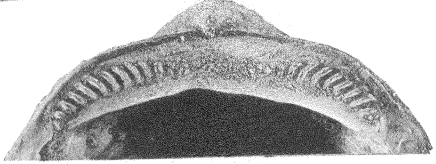

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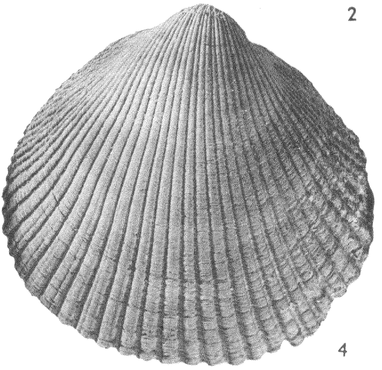

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CENOZOIC PELECYPODA

PLATE 2.—CENOZOIC PELECYPODA

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1, 8.	*Glycymeris gigantea* (Reeve) (1) Hypotype no. 30554 (loc. A 3670) (×1). (8) Same (×0.8)	56
2, 4.	*Glycymeris multicostata* (Sowerby) (×1). Hypotype no. 30558 (loc. A 3550)	56
3, 5.	*Glycymeris maculata* (Broderip) (×1). Hypotype no. 30557 (loc. A 3582)	56
6.	*Pinctada mazatlanica* (Hanley) (×0.6). Hypotype no. 15965 (loc. A 3596)	58
7.	*Arca* (*Arca*) *mutabilis* (Sowerby) (×1). Hypotype no. 15508 (loc. A 3550)	53
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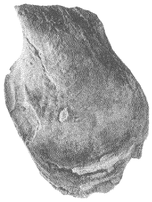
2, 3.	*Pinna corteziana* n. sp. (×0.5). (2) Holotype no. 30560 (loc. A 3547). (3) Same, interior of valve	57



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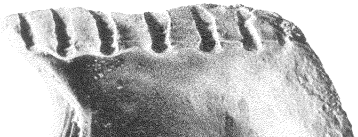

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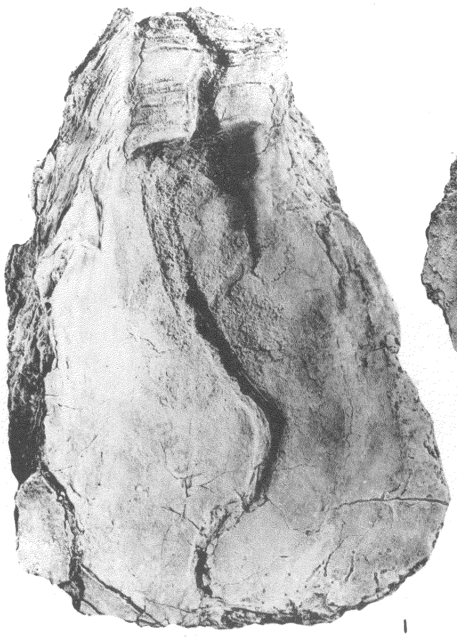
CENOZOIC PELECYPODA



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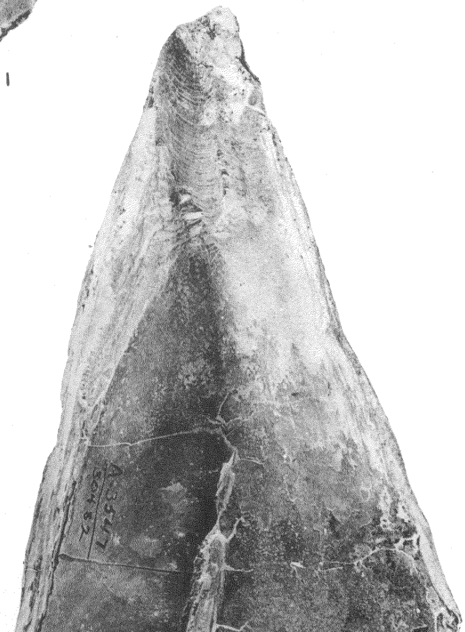

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CENOZOIC PELECYPODA

PLATE 4.—CENOZOIC PELECYPODA

Figure		Page
1.	*Ostrea chilensis* Philippi (×0.5). Hypotype no. 15505 (loc. A 3536)	58
2.	*Ostrea erici* Hertlein (×0.6). Hypotype no. 15426 (loc. A 3509)	59
3, 4.	*Pinna rugosa* Sowerby (×0.5). Hypotype no. 30482 (loc. A 3547)	57

PLATE 5.—CENOZOIC PELECYPODA

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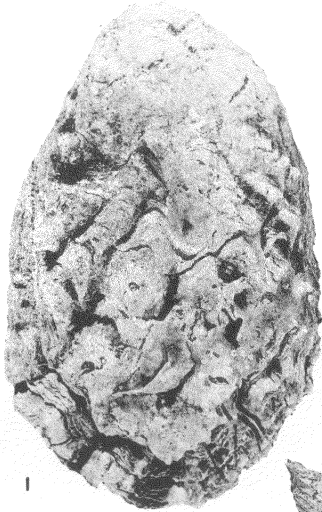
1, 2, 5, 7.	*Ostrea vespertina* Conrad (1, 2) Hypotype no. 15956 (loc. A 3591) (×0.6). (5) Hypotype no. 15957 (loc. A 3557) (×1). (7) Hypotype no. 15955 (loc. A 3524) (×0.6)	59
3.	*Ostrea megadon* Hanley (×1). Hypotype no. 15967 (loc. A 3558)	59
4, 6.	*Ostrea cumingiana* Dunker (×1). (4) Hypotype no. 15425 (loc. A 3519). (6) Hypotype no. 15424 (loc. A 3519)	58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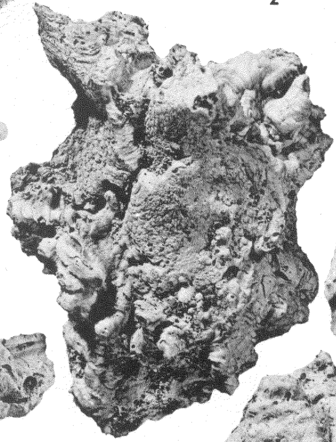
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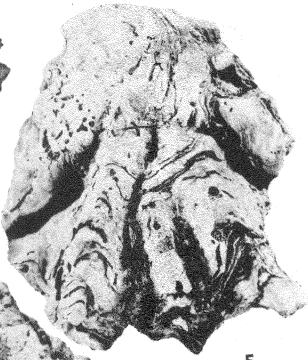
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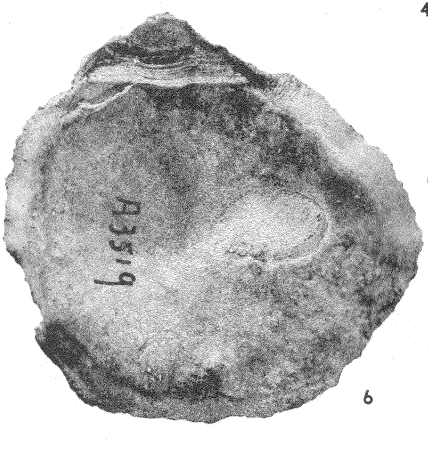

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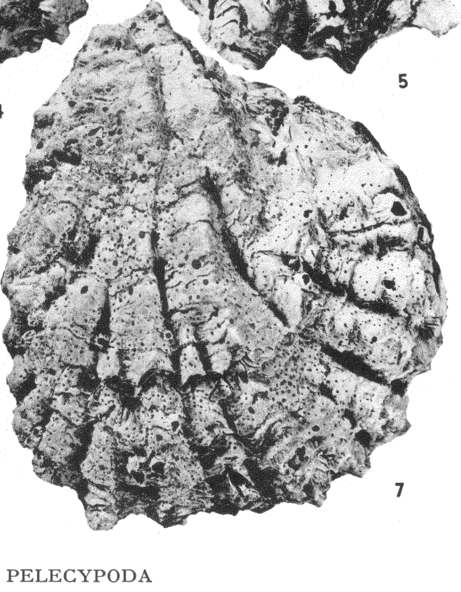
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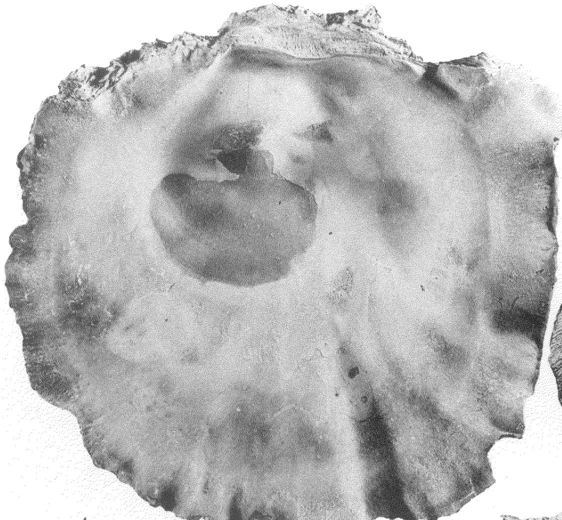
CENOZOIC PELECYPODA



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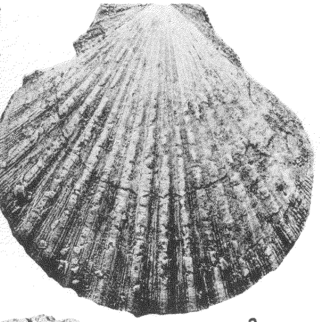

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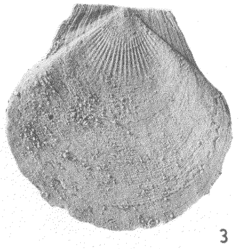

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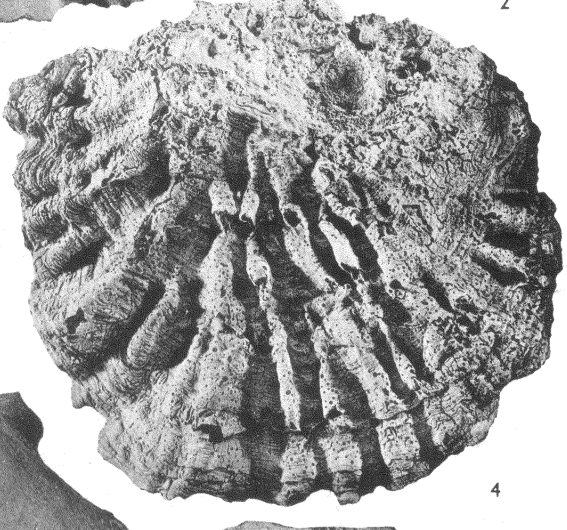

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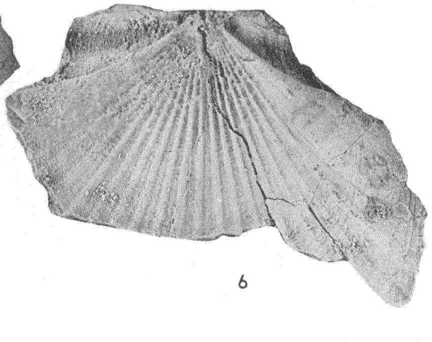

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CENOZOIC PELECYPODA

Plate 6.—CENOZOIC PELECYPODA

Figure		Page
1, 4.	*Ostrea fischeri* Dall (×0.5). Hypotype no. 15502 (loc. A 3522)	59
2.	*Chlamys dallasi* (Jordan and Hertlein) (×1). Hypotype no. 15451 (loc. A 3505)	65
3.	*Pecten* (*Euvola*) *refugioensis* Hertlein (×1). Hypotype Calif. Acad. Sci. Paleo. Type Coll. no. 604 (C.A.S. loc. 795)	61
5, 6.	*Pecten* (*Euvola*) *keepi* Arnold (×1). (5) Hypotype no. 15429 (loc. A 3583). (6) Hypotype no. 15427 (loc. A 3583)	61

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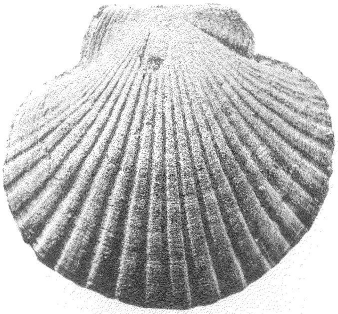
Figure		Page
1.	*Pecten* (*Pecten*) *bösei* Hanna and Hertlein (×0.5). Hypotype no. 16000 (loc. A 3566)	60
2.	*Pecten* (*Pecten*) sp. (×1). Hypotype no. 32891 (loc. S 364), near Puerto Cumarebo, Venezuela. Upper Miocene or lower Pliocene. Compare with Figure 1	60
3, 5.	*Pecten* (*Pecten*) *bellus* var. *hemphilli* Dall. (3) Hypotype Calif. Acad. Sci. Paleo. Type Coll. no. 5985 (C.A.S. loc. 795) (×1). (5) Hypotype Calif. Acad. Sci. Paleo. Type Coll. no. 7860 (C.A.S. loc. 795) (×0.7)	60
4.	*Lyropecten mediacostatus* (Hanna) (×1). Hypotype no. 30046 (loc. A 3576)	65



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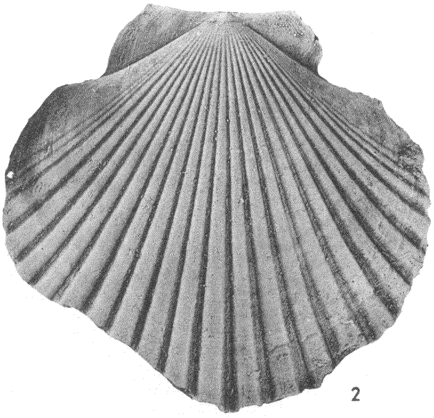

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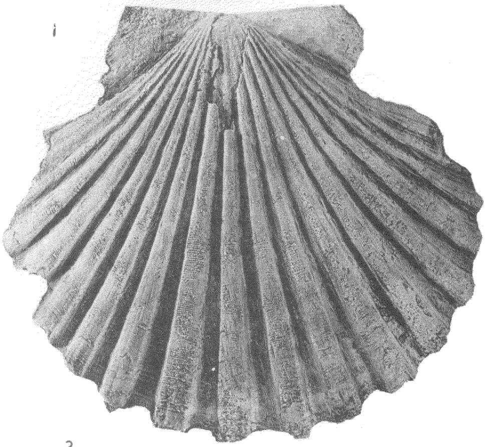

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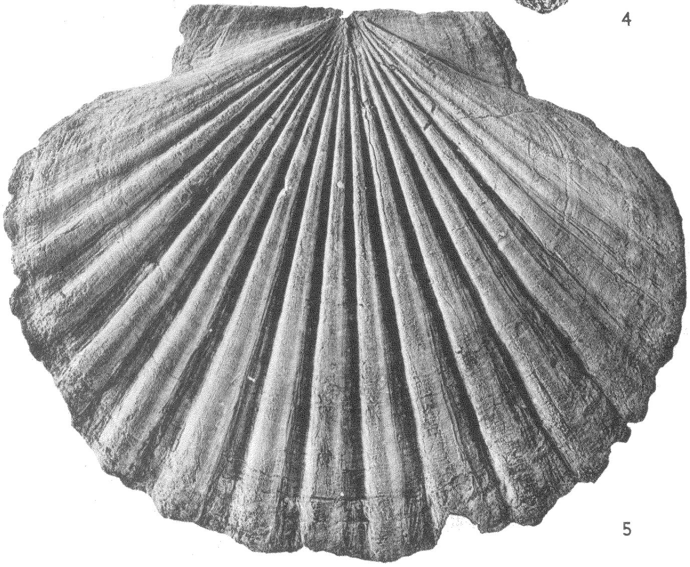

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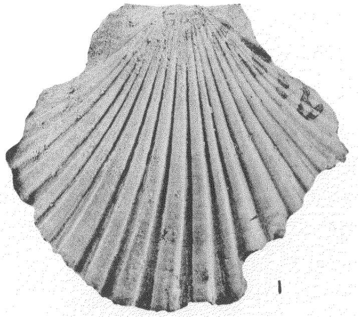
CENOZOIC PELECYPODA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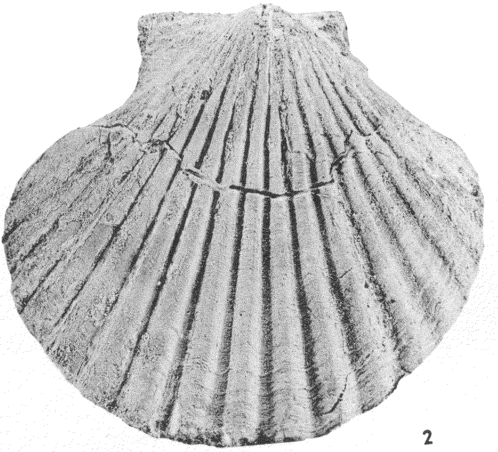
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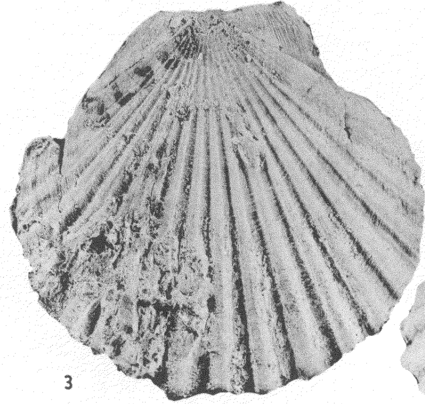
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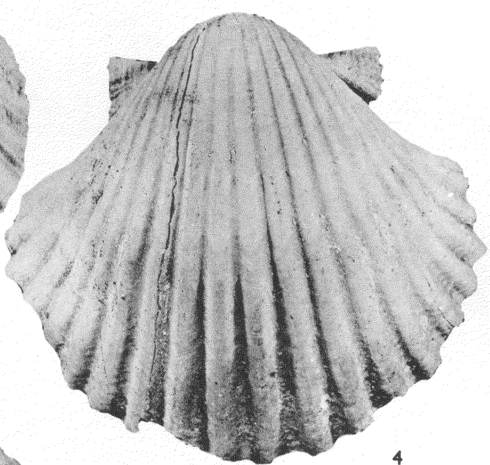
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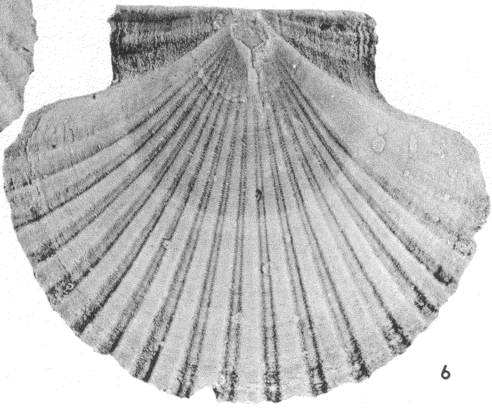
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CENOZOIC PELECYPODA

PLATE 8.—CENOZOIC PELECYPODA

Figure		Page
1, 3.	*Pecten* (*Pecten*) *carrizoensis* Arnold (×1). (1) Hypotype no. 15974 (loc. A 3576). (3) Hypotype no. 15973 (loc. A 3576)	61
2, 5.	*Aequipecten sverdrupi* n. sp. (×1). (2) Paratype no. 15996 (loc. A 3583). (5) Holotype no. 15995 (loc. A 3583)	64
4, 6.	*Pecten* (*Pecten*) *vogdesi* Arnold (×1). (4) Hypotype no. 15976 (loc. A 3521). (6) Hypotype no. 15975 (loc. A 3521)	61

Plate 9.—CENOZOIC PELECYPODA

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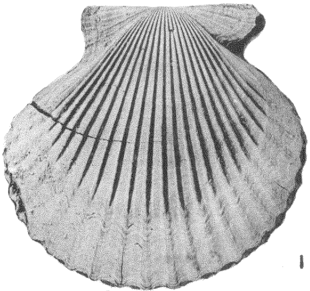
3, 6, 9.	*Aequipecten revellei* n. sp. (×1). Holotype no. 15510 (loc. A 3566)	63
7.	*Aequipecten sverdrupi* n. sp. (×1). Paratype no. 15998 (loc. A 3583)	64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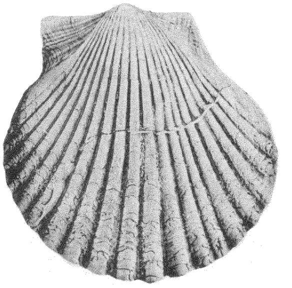
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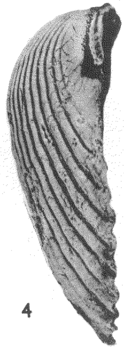
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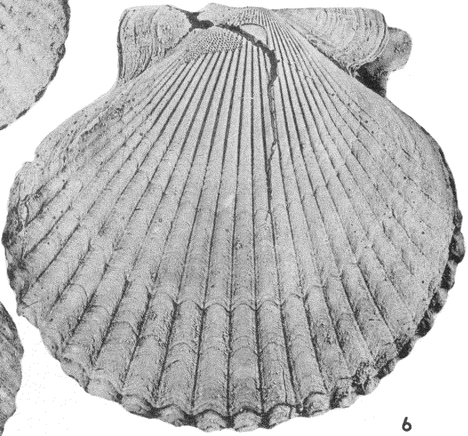
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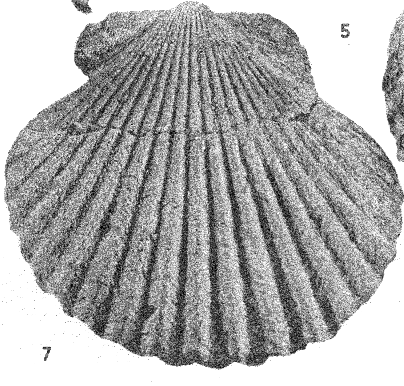
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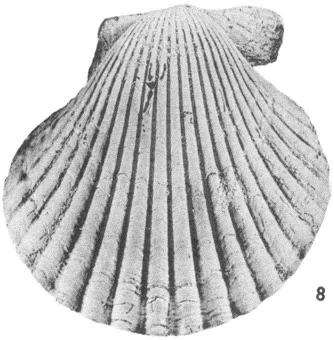
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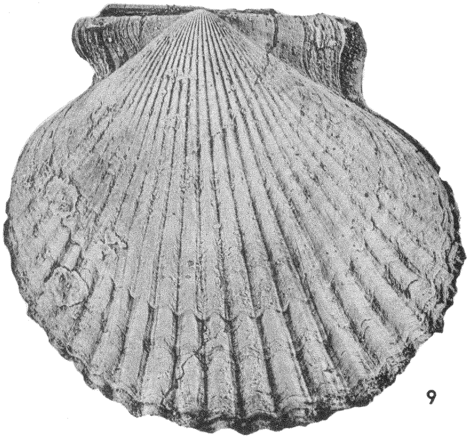
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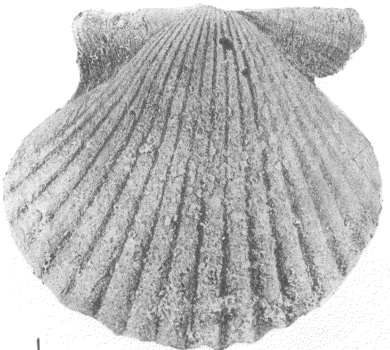
CENOZOIC PELECYPODA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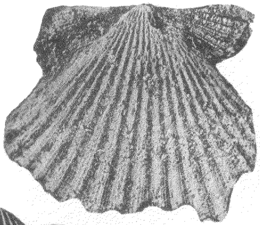
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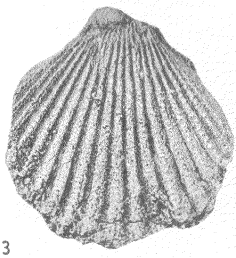
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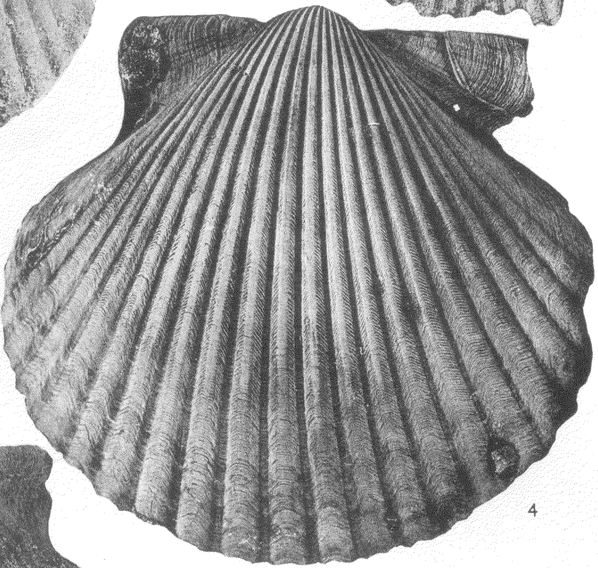
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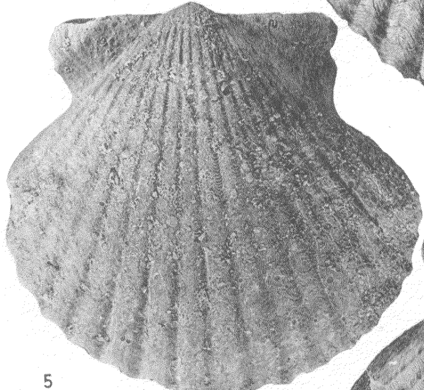
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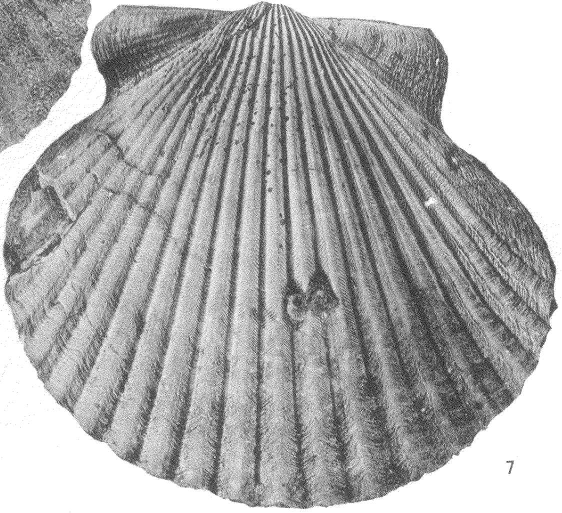
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PLATE 10.—CENOZOIC PELECYPODA

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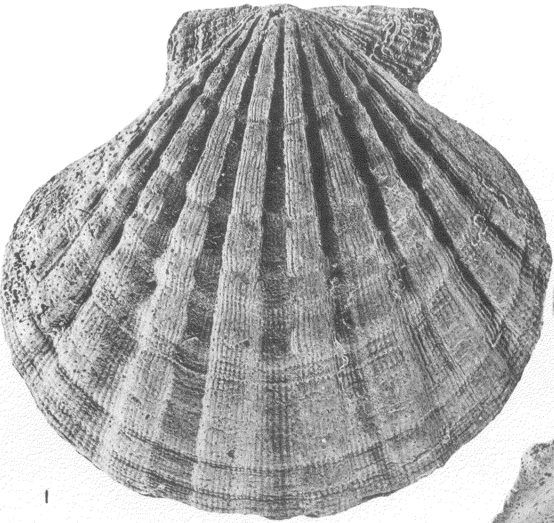
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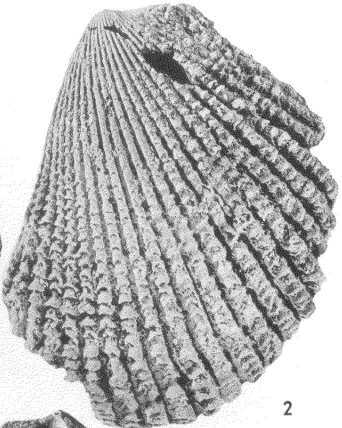
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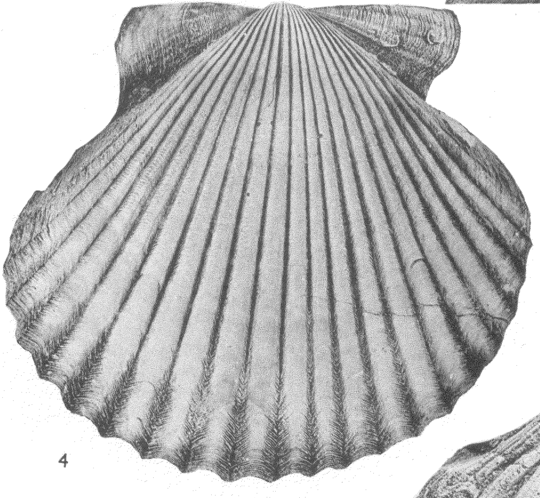
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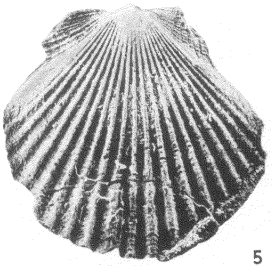
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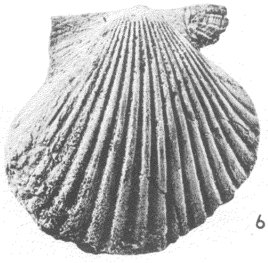
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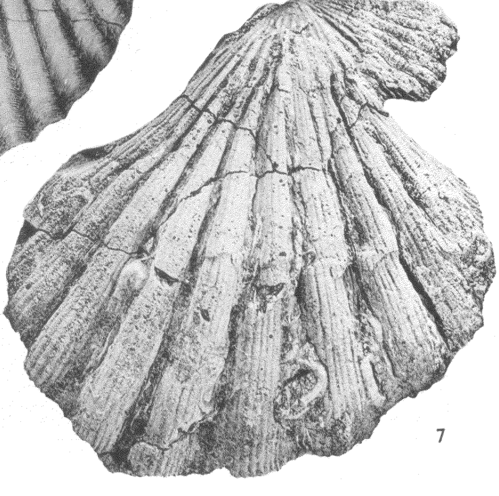
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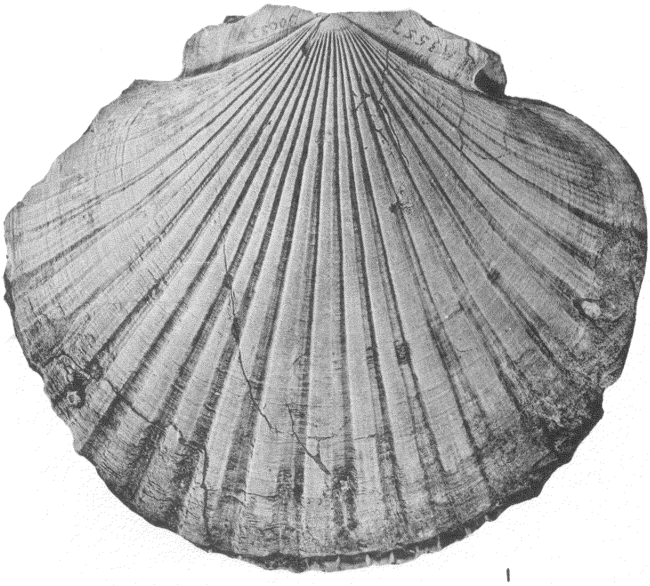

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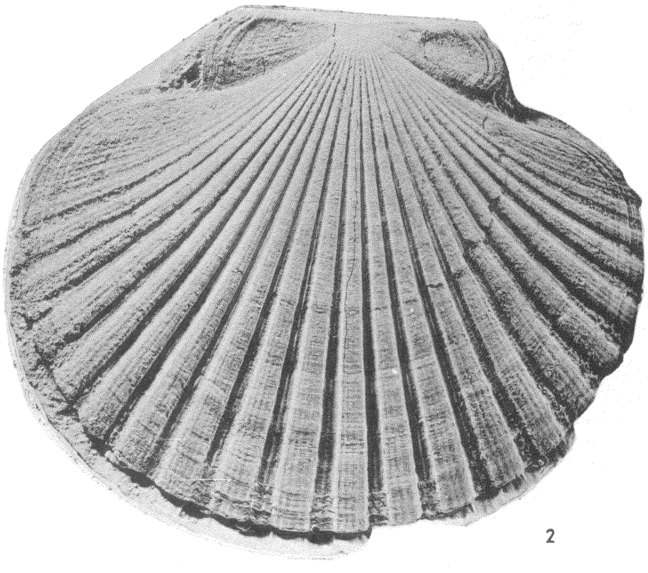

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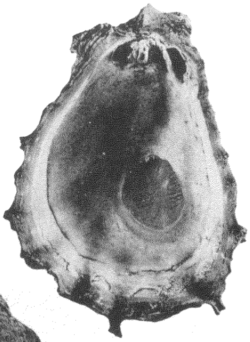
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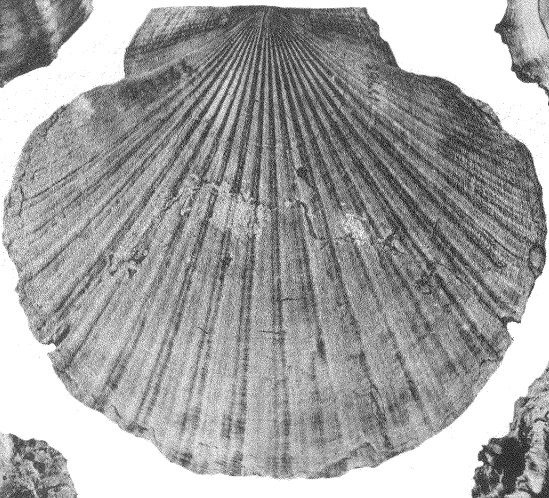
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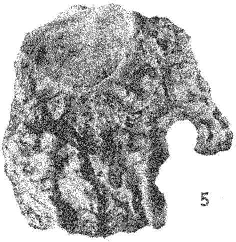
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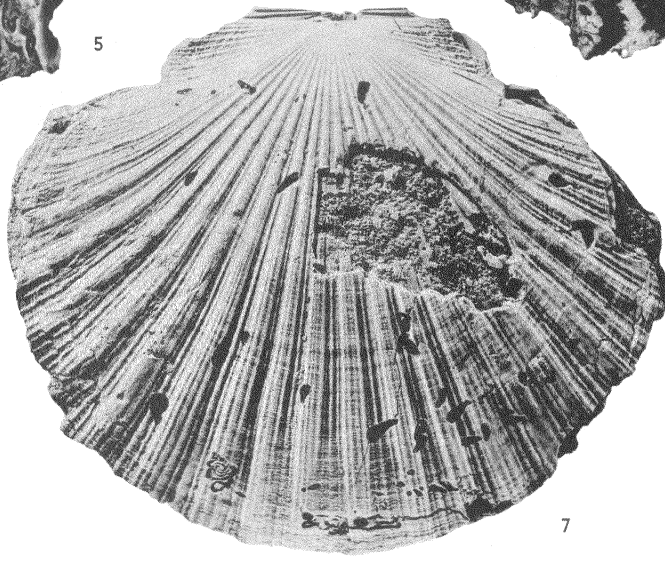
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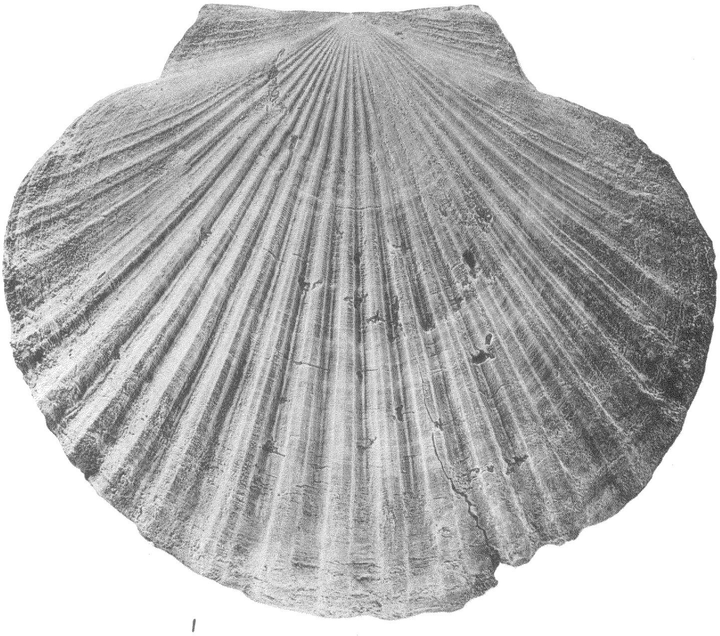

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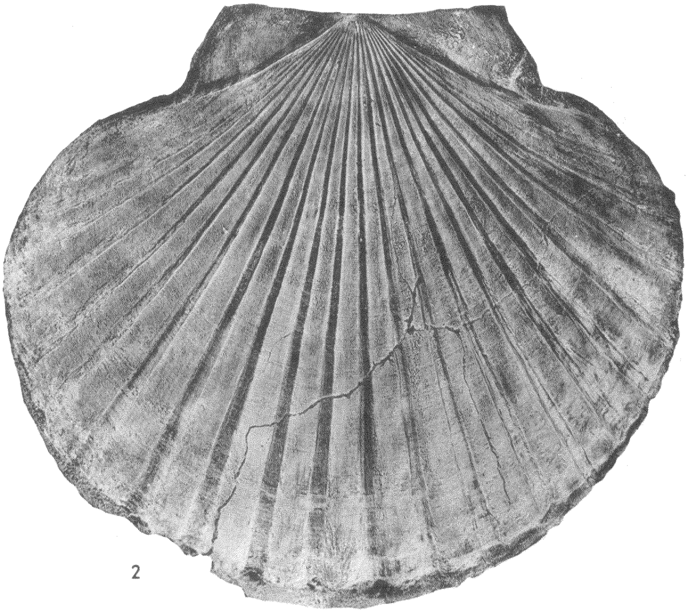

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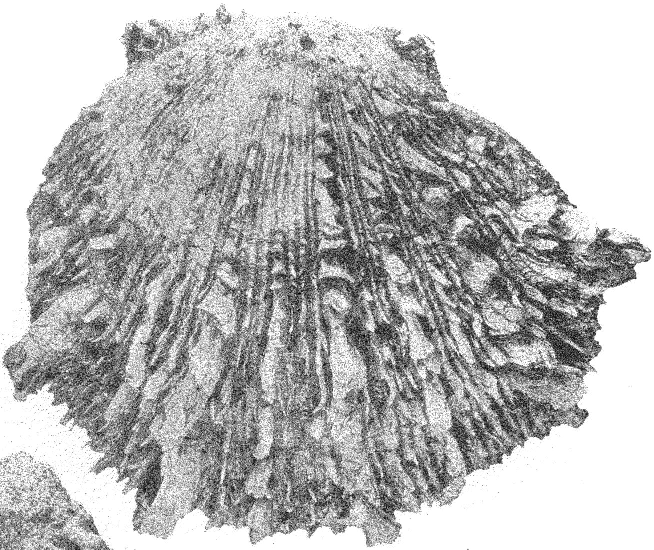

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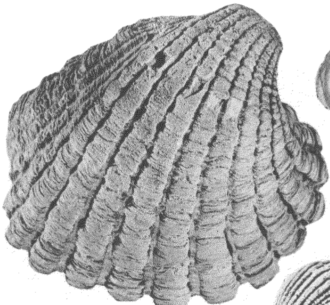
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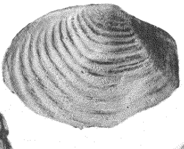
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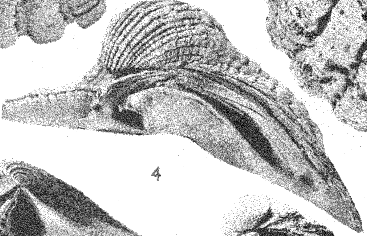
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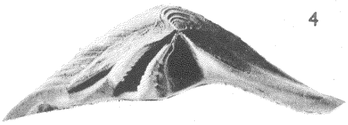
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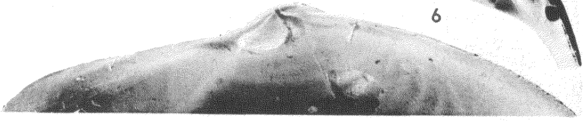
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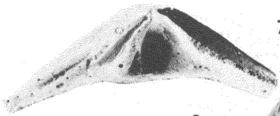
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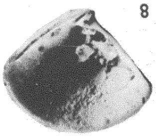
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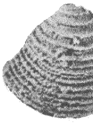
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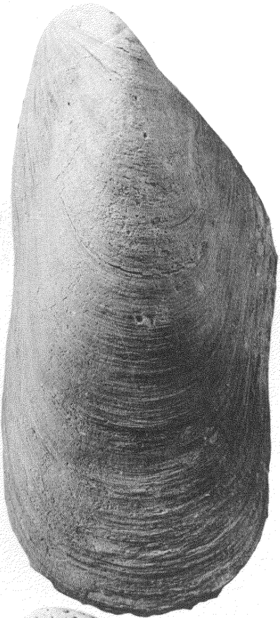
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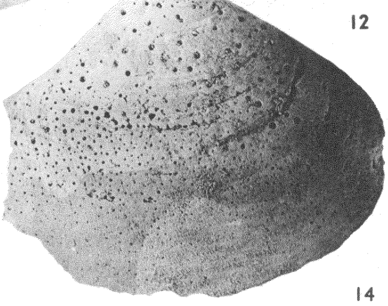
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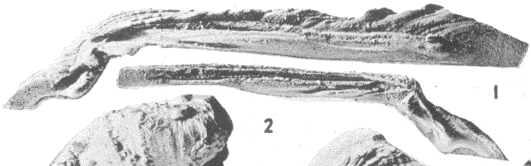
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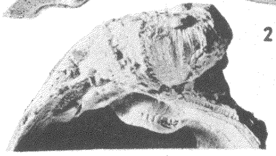
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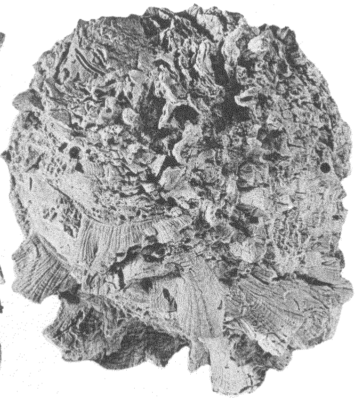
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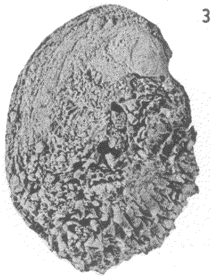
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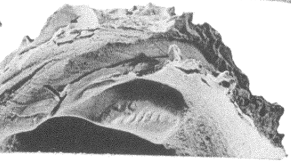
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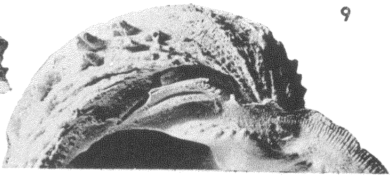
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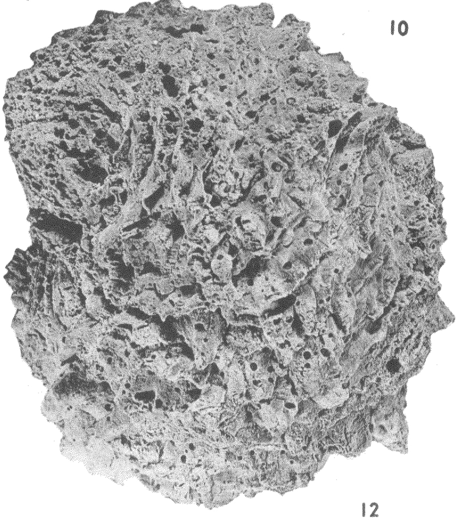
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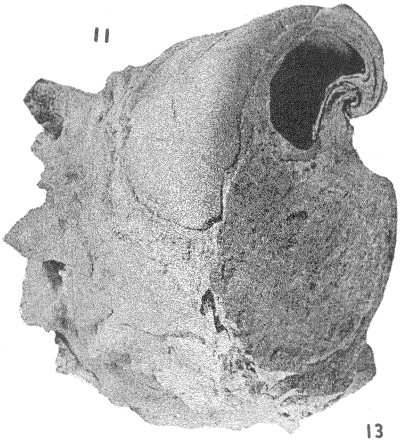
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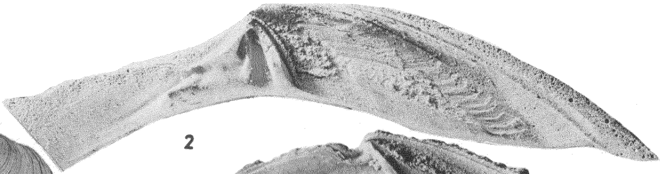
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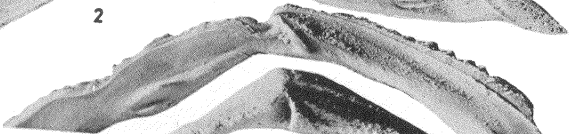
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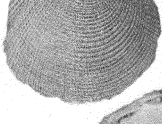
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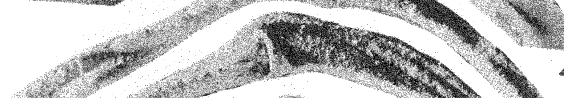
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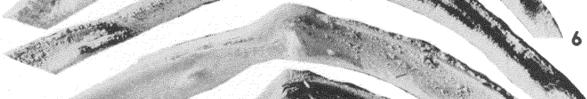
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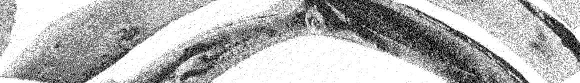
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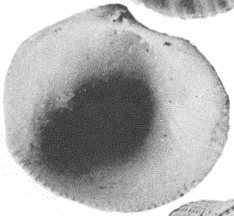
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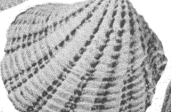
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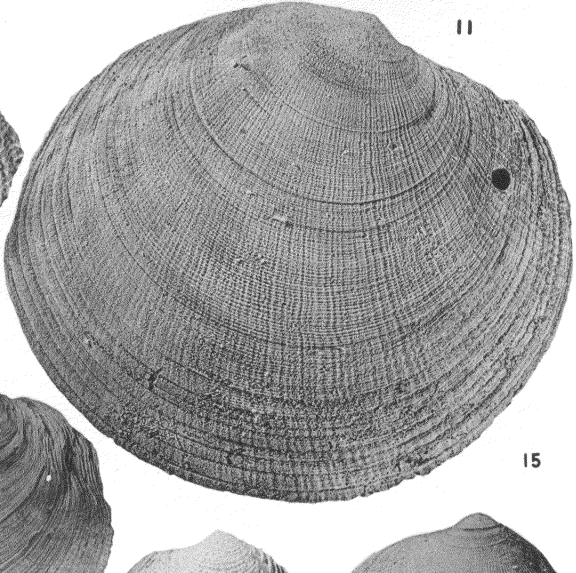
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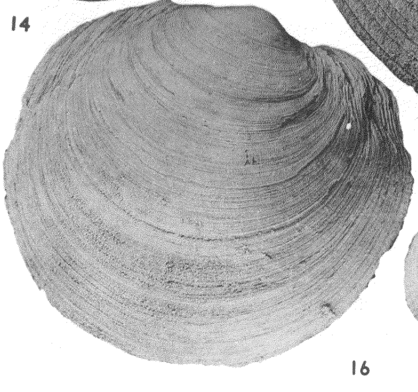
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PLATE 18.—CENOZOIC PELECYPODA

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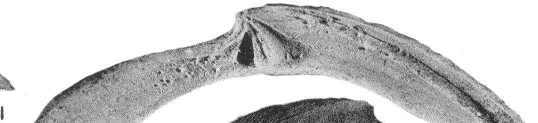
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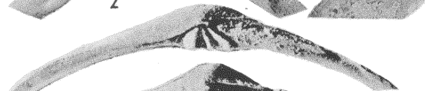
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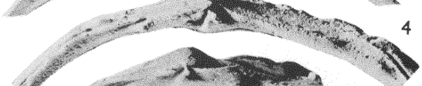
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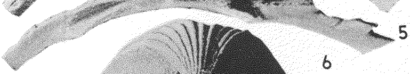
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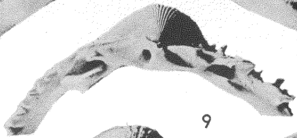
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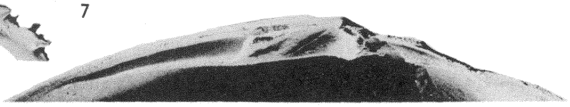
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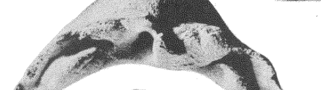
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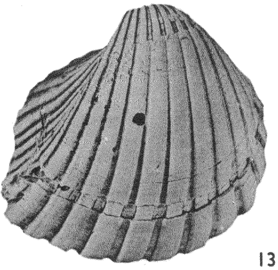
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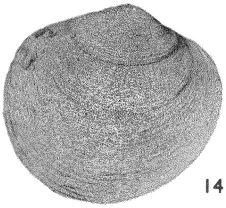
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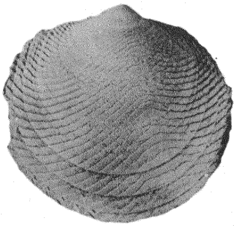
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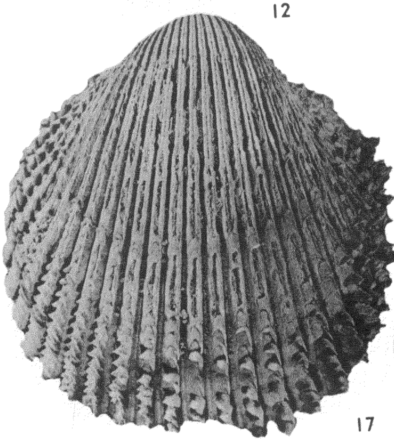
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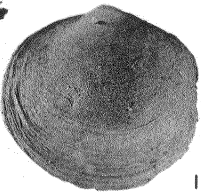
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CENOZOIC PELECYPODA


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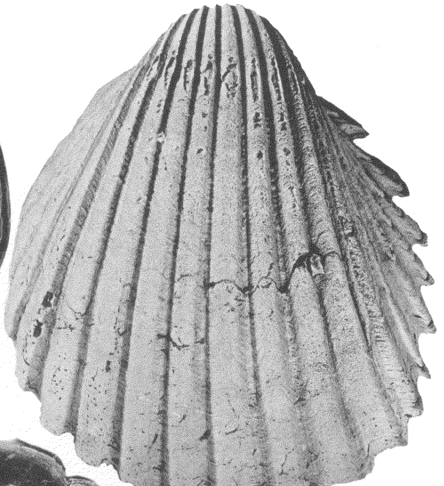
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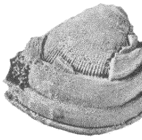
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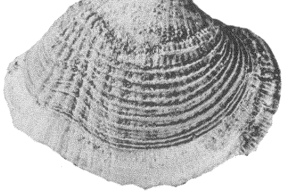
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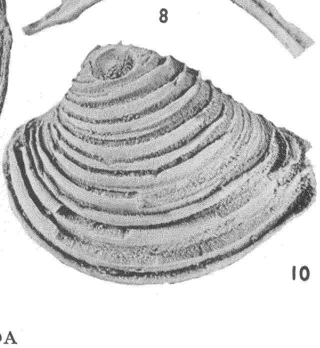
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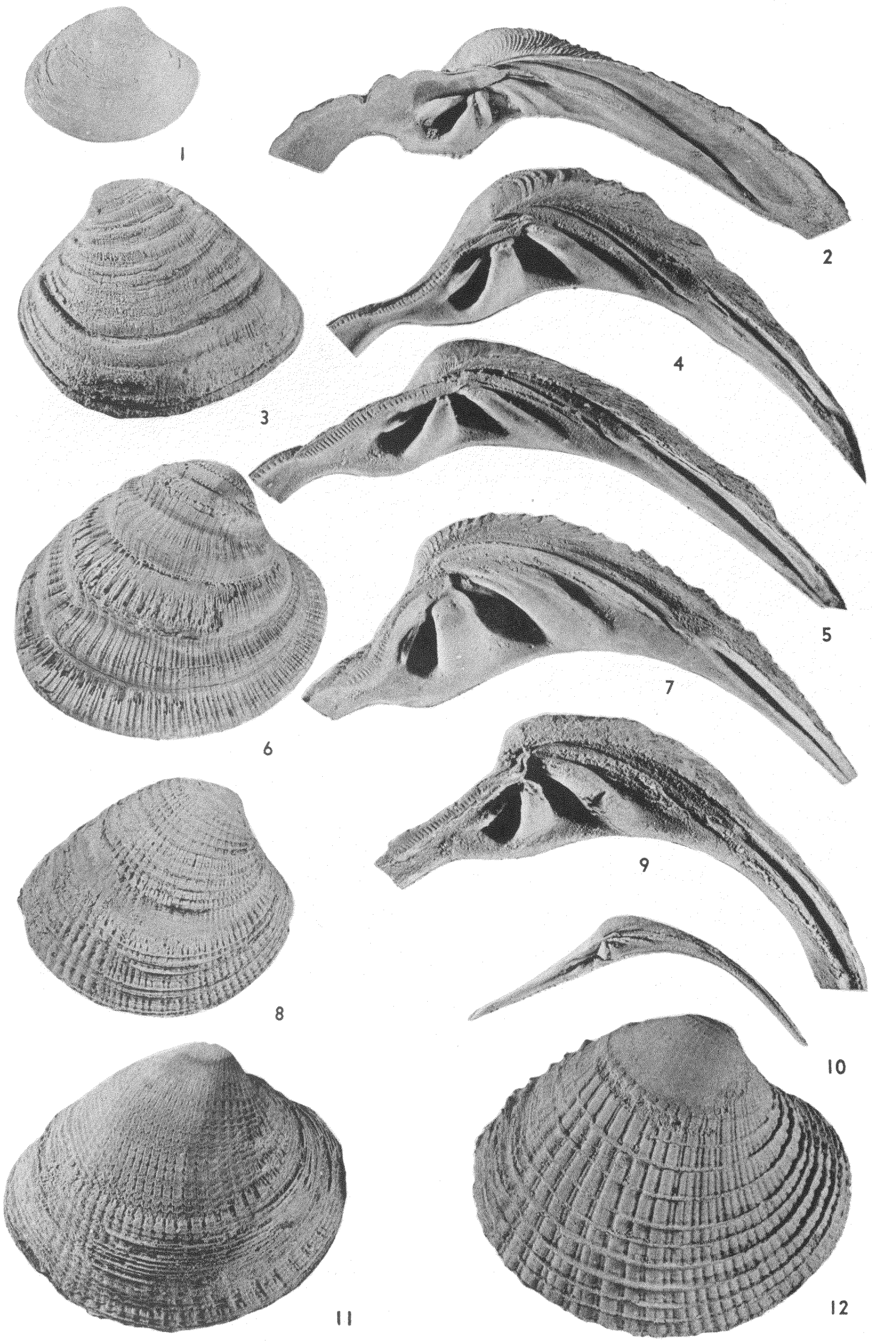
CENOZOIC PELECYPODA

PLATE 20.—CENOZOIC PELECYPODA

Figure		Page
1, 3.	*Periglypta multicostata* (Sowerby). (1) Hypotype no. 15935 (loc. A 3596) (×0.6). (3) Same (×1)	85
2.	*Trachycardium* (*Mexicardia*) *procerum* (Sowerby) (×1). Hypotype no. 32551 (loc. A 3582)	81
4, 8.	*Chione* (*Anomalocardia*) *mariae* (d'Orbigny). (4) Hypotype no. 32553 (loc. A 3582) (×2). (8) Same (×4)	83
5, 9.	*Venus isocardia* Verrill. (5) Hypotype no. 15979 (loc. A 3548) (×1). (9) Same (×0.6)	81
6, 7.	*Chione* (*Chione*) cf. *amathusia* Philippi. (6) Hypotype no. 32871 (loc. A 3586) (×2). (7) Same (×1)	82
10.	*Chione* (*Anomalocardia*) *kellettii* (Hinds) (×2). Hypotype no. 32407 (loc. A 3584).	83

PLATE 21.—CENOZOIC PELECYPODA

Figure		Page
1, 10.	*Pitar newcombianus* (Gabb). (1) Hypotype no. 32580 (loc. A 3582) (×1). (10) Same (×2)	86
2.	*Periglypta multicostata* (Sowerby) (×1). Hypotype no. 15936 (loc. A 3596)	85
3.	*Chione* (*Anomalocardia*) *subrugosa* (Sowerby) (×1). Hypotype no. 32556 (loc. A 3549)	83
4, 6.	*Chione* (*Anomalocardia*) *tumens* Verrill. (4) Hypotype no. 32594 (loc. A 3596) (×2). (6) Same (×1)	84
5, 11.	*Chione* (*Chione*) *undatella* subsp. *simillima* (Sowerby). (5) Hypotype no. 32572 (loc. A 3550) (×2). (11) Hypotype no. 32573 (loc. A 3550) (×1)	83
7, 12.	*Chione* (*Chione*) *undatella* (Sowerby) (×1). (7) Hypotype no. 32588 (loc. A 3548). (12) Hypotype no. 32586 (loc. A 3548)	82
8, 9.	*Chione* (*Chione*) *californiensis* (Broderip). (8) Hypotype no. 32568 (loc. A 3549) (×1). (9) Hypotype no. 32567 (loc. A 3549) (×2)	82



CENOZOIC PELECYPODA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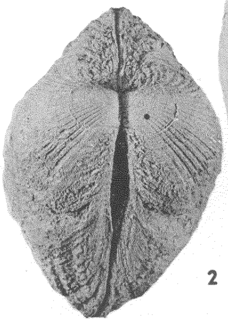
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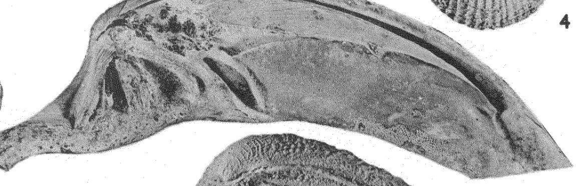
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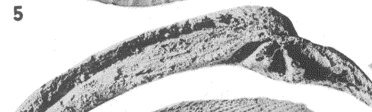
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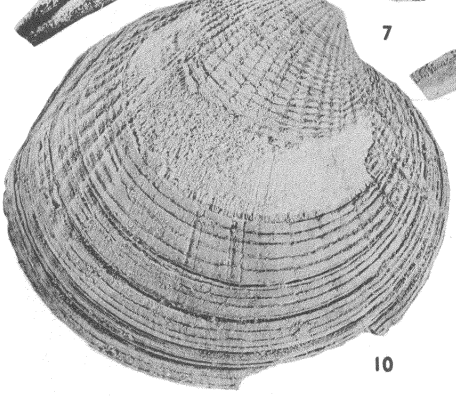
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CENOZOIC PELECYPODA

PLATE 22.—CENOZOIC PELECYPODA

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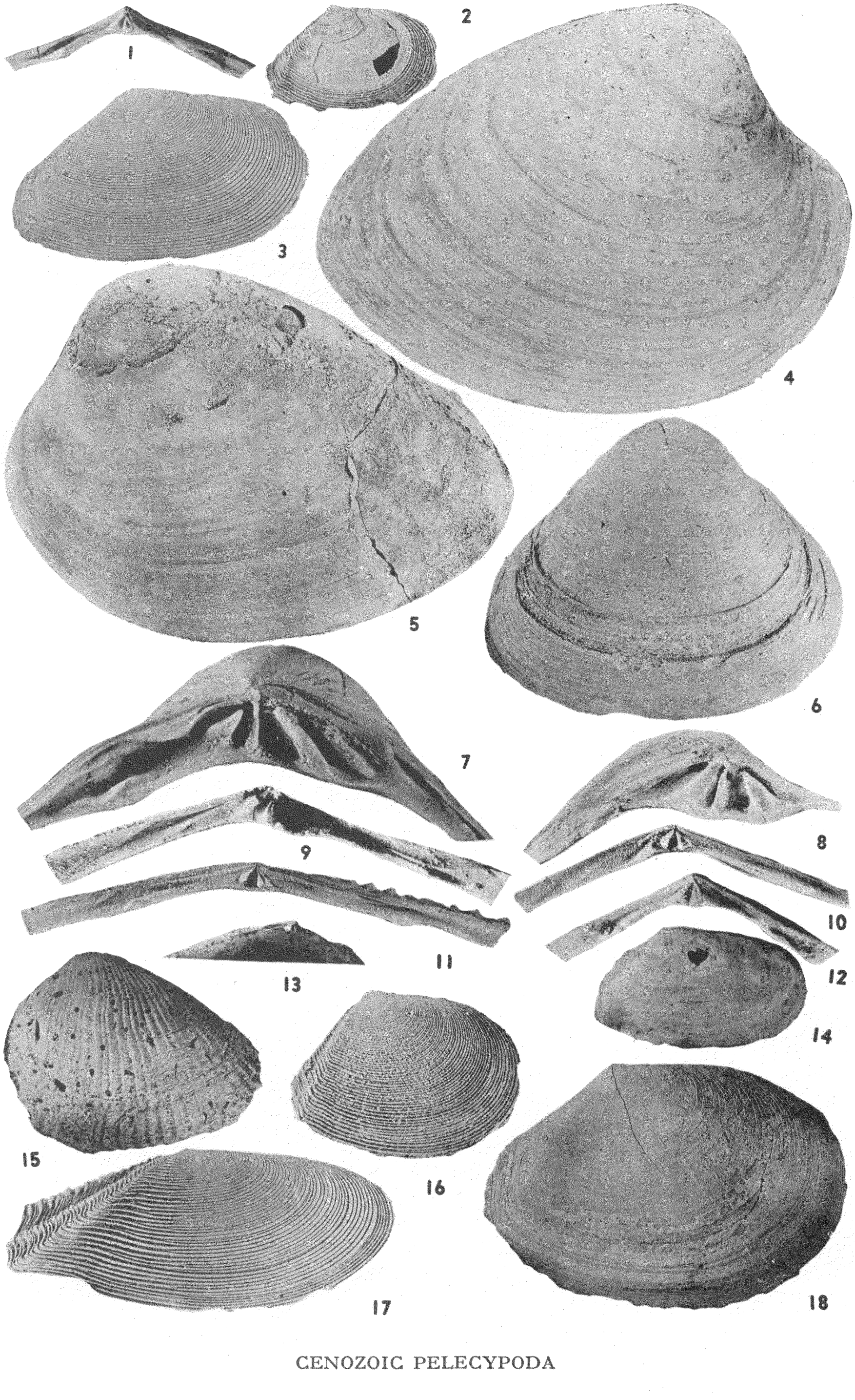
1, 7.	*Protothaca grata* (Say). (1) Hypotype no. 32603 (loc. A 3582) (×1). (7) Same (×2)...	87
2, 9, 11.	*Protothaca* (?) *coronadosensis* n. sp. (2, 11) Holotype no. 32596 (loc. A 3549) (×1). (9) Same (×2)........	86
3, 6.	*Dosinia ponderosa* (Gray). (3) Hypotype no. 15953 (loc. A 3548) (×0.5). (6) Hypotype no. 15954 (loc. A 3548) (×0.6)........	84
4, 5, 8, 10.	*Protothaca* (?) *fluctifraga* (Sowerby). (4) Hypotype no. 32578 (loc. A 3586) (×1). (5) Hypotype no. 32574 (loc. A 3592) (×1). (8) Hypotype no. 32576 (loc. A 3592) (×2). (10) Hypotype no. 32577 (loc. A 3586) (×1)........	86

PLATE 23.—CENOZOIC PELECYPODA

Figure		Page
1, 2.	*Tellina* (*Tellina*) *idae* Dall. (1) Hypotype no. 32620 (loc. A 3670) (×4). (2) Same (×2.2)	88
3, 10.	*Tellina* (*Eurytellina?*) *simulans* Adams. (3) Hypotype no. 32643 (loc. A 3584) (×1). (10) Same (×2)	88
4, 5, 8.	*Macrocallista squalida* (Sowerby) (×0.6). (4) Hypotype no. 15942 (loc. A 3548). (5) Hypotype no. 15994 (loc. A 3520)	84
6, 7.	*Tivela byronensis* (Gray). (6) Hypotype no. 32590 (loc. A 3584) (×1). (7) Same (×2)	87
9, 18.	*Tellina* (*Scrobiculina*) *ochracea* Carpenter. (9) Hypotype no. 32616 (loc. A 3548) (×2) (18) Same (×1)	89
11, 17.	*Tellina* (*Tellina*) *cumingii* Hanley. (11) Hypotype no. 32618 (loc. A 3548) (×2). (17) Same (×1)	88
12, 16.	*Tellina* (*Merisca*) *reclusa* Dall. (12) Hypotype no. 32608 (loc. A 3548) (×4). (16) Same (×2)	89
13, 14.	*Tellina* (*Angulus*) *panamensis* Dall (×5). Hypotype no. 32621 (loc. A 3582)	88
15.	*Petricola robusta* Sowerby (×1). Hypotype no. 32606 (loc. A 3548)	87



CENOZOIC PELECYPODA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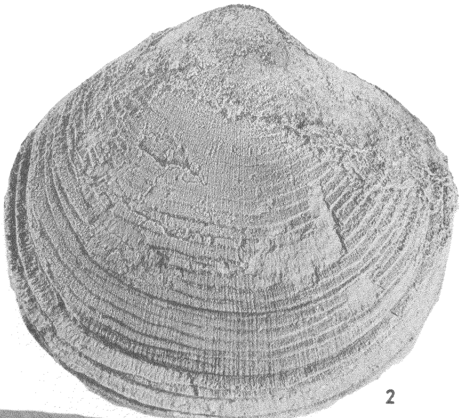
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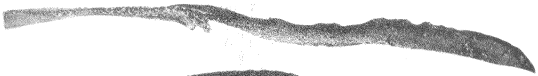
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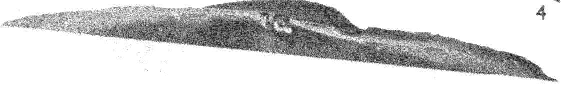
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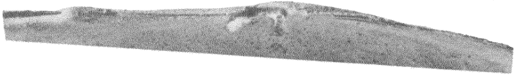
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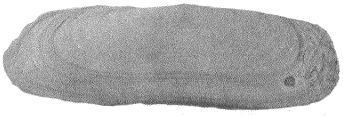
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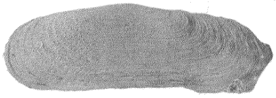
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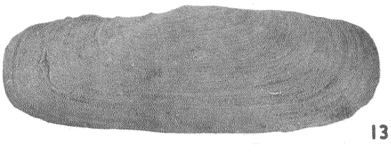
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CENOZOIC PELECYPODA

Plate 24.—CENOZOIC PELECYPODA

Figure		Page
1.	*Apolymetis biangulata* (Carpenter) (×1). Hypotype no. 32626 (loc. 1668)	89
2.	*Semele flavescens* (Gould) (×1). Hypotype no. 32627 (loc. A 3588)	90
3, 9.	*Tagelus* (*Tagelus*) *californianus* (Conrad). (3) Hypotype no. 32666 (loc. A 3582) (×1). (9) Same (×2)	91
4, 13.	*Tagelus* (*Tagelus*) *affinis* (Adams). (4) Hypotype no. 32654 (loc. A 3586) (×2). (13) Same (×1)	91
5, 10.	*Tagelus* (*Mesopleura*) *subteres* (Conrad). (5) Hypotype no. 32664 (loc. A 3670) (×2). (10) Same (×1)	92
6.	*Semele hertleini* n. sp. (×2.3). Holotype no. 30367 (loc. A 3548)	90
7.	*Semele jaramija* Pilsbry and Olsson (×2). Hypotype no. 32888 (loc. A 3582)	91
8, 11.	*Tagelus* (*Tagelus*) *violascens* (Carpenter) ? (8) Hypotype no. 32651 (loc. A 3584) (×4). (11) Same (×1)	91
12.	*Apolymetis clarki* n. sp. (×1). Holotype no. 32615 (loc. A 3582)	90

PLATE 25.—CENOZOIC PELECYPODA

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1, 5.	*Mactrotoma revellei* n. sp. (×0.6). Holotype no. 32237 (loc. A 3548)	93
2, 17.	*Mactra fragilis* Chemnitz. (2) Hypotype no. 32661 (loc. 1704) (×1). (17) Same (×2.3).	
3, 8.	*Basterotia peninsulare* (Jordan). (3) Hypotype no. 32273 (loc. A 3548) (×2). (8) Same (×6)	95
4, 11.	*Basterotia hertleini* n. sp. (4) Holotype no. 32274 (loc. A 3670) (×2). (11) Same (×6)	94
6.	*Semele jaramija* Pilsbry and Olsson (×5). Hypotype no. 32888 (loc. A 3582)	91
7.	*Semele hertleini* n. sp. (×6). Holotype no. 30367 (loc. A 3548)	90
9, 13.	*Basterotia californica* n. sp. (9) Holotype no. 32268 (loc. A 3582) (×2). (13) Same (×6)	94
10.	*Semele flavescens* (Gould) (×2). Hypotype no. 32627 (loc. A 3598)	90
12.	*Apolymetis biangulata* (Carpenter) (×2). Hypotype no. 32626 (loc. 1668)	89
14.	*Apolymetis clarki* n. sp. (×2). Holotype no. 32615 (loc. A 3582)	90
15, 16.	*Corbula* (*Lentidium*) *luteola* Carpenter. (15) Hypotype no. 32655 (loc. A 3582) (×5). (16) Same (×4.5)	94


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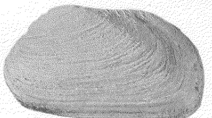
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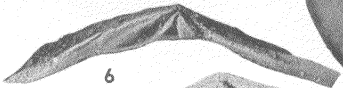
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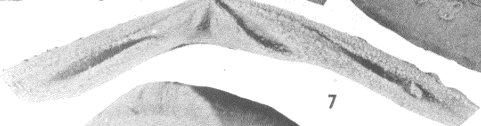
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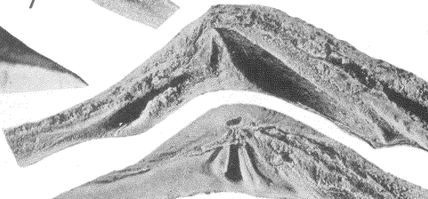
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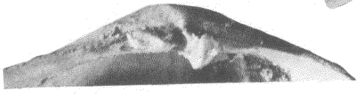
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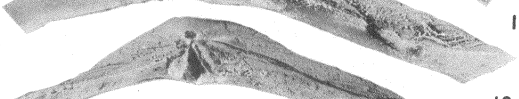
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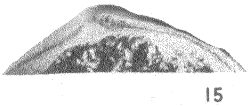
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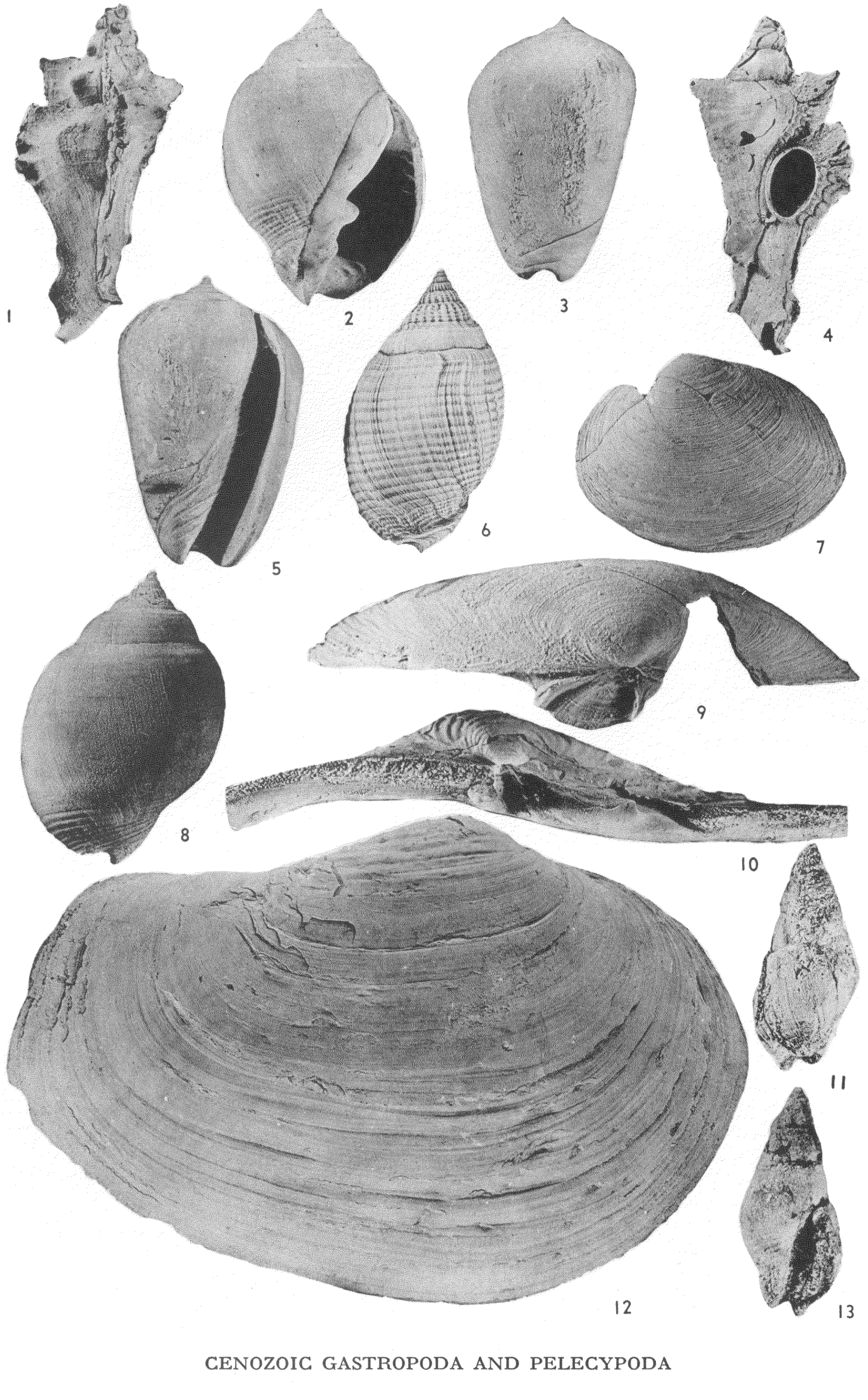
CENOZOIC PELECYPODA



CENOZOIC GASTROPODA AND PELECYPODA

PLATE 26.—CENOZOIC GASTROPODA AND PELECYPODA

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1, 4.	*Centrifuga inezana* n. sp. (×1). Holotype no. 30470 (loc. A 3584)	113
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7, 9.	*Cryptomya californica* (Conrad). (7) Hypotype no. 32388 (loc. A 3584) (×1). (9) Same (×2)	93
10, 12.	*Panope taeniata* Dall. (10) Hypotype no. 32266 (loc. A 3582) (×1). (12) Same (×0.6)	95
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3, 8.	*Strombus granulatus* Mawe (×1). Hypotype no. 30478 (loc. A 3637)...................	117
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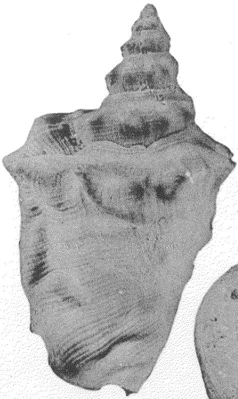
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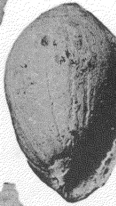
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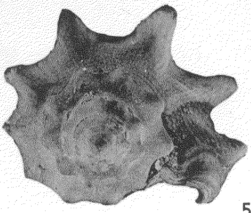
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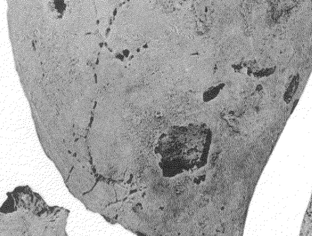
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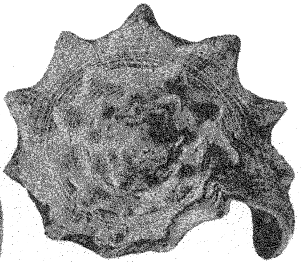
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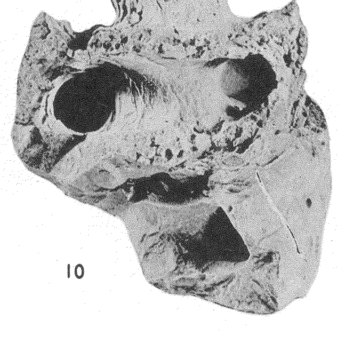
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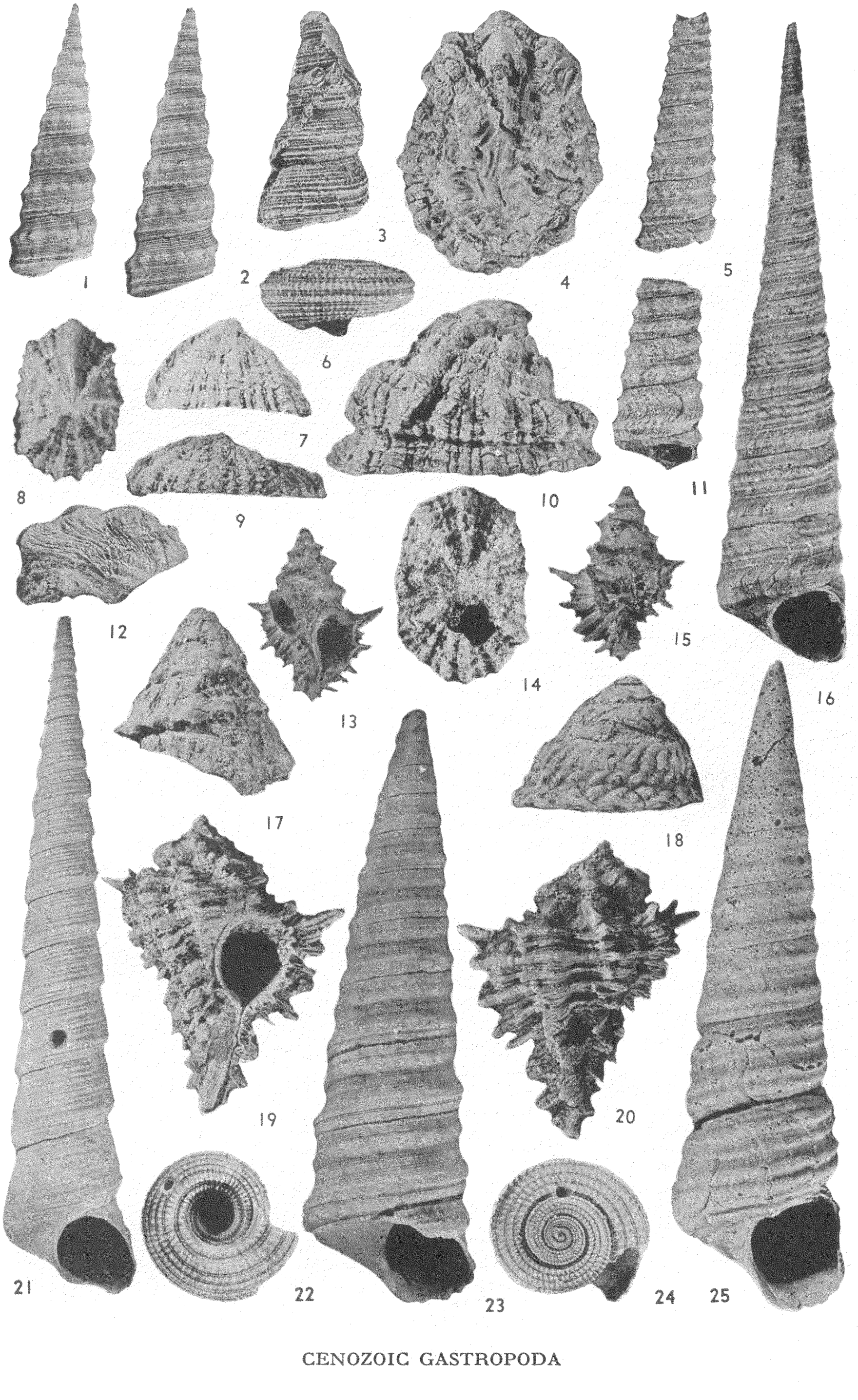
CENOZOIC GASTROPODA



CENOZOIC GASTROPODA

PLATE 28.—CENOZOIC GASTROPODA

Figure		Page
1, 2.	*Turritella nodulosa* King (×1). Hypotypes (1) no. 32815, (2) no. 32816, (loc. A 3584).	123
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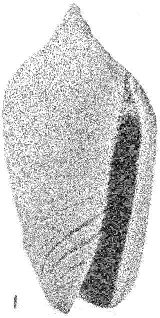
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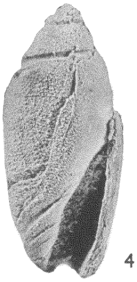
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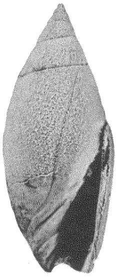
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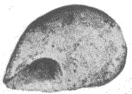
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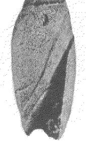
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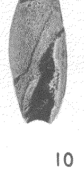
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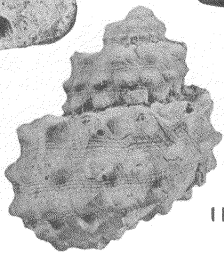
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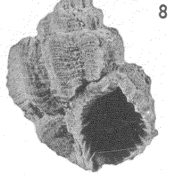
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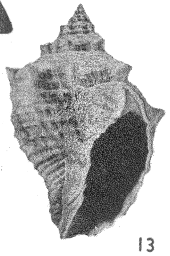
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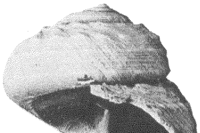
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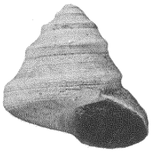
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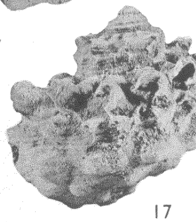
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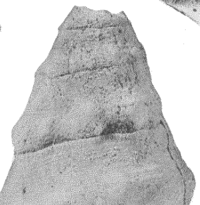
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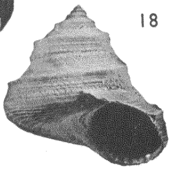
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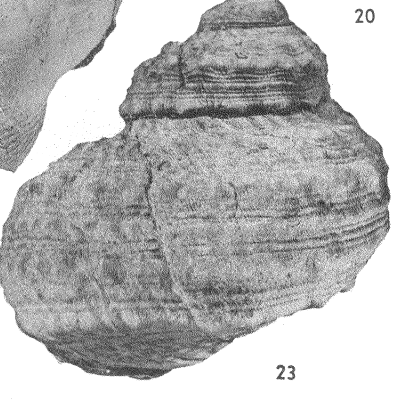
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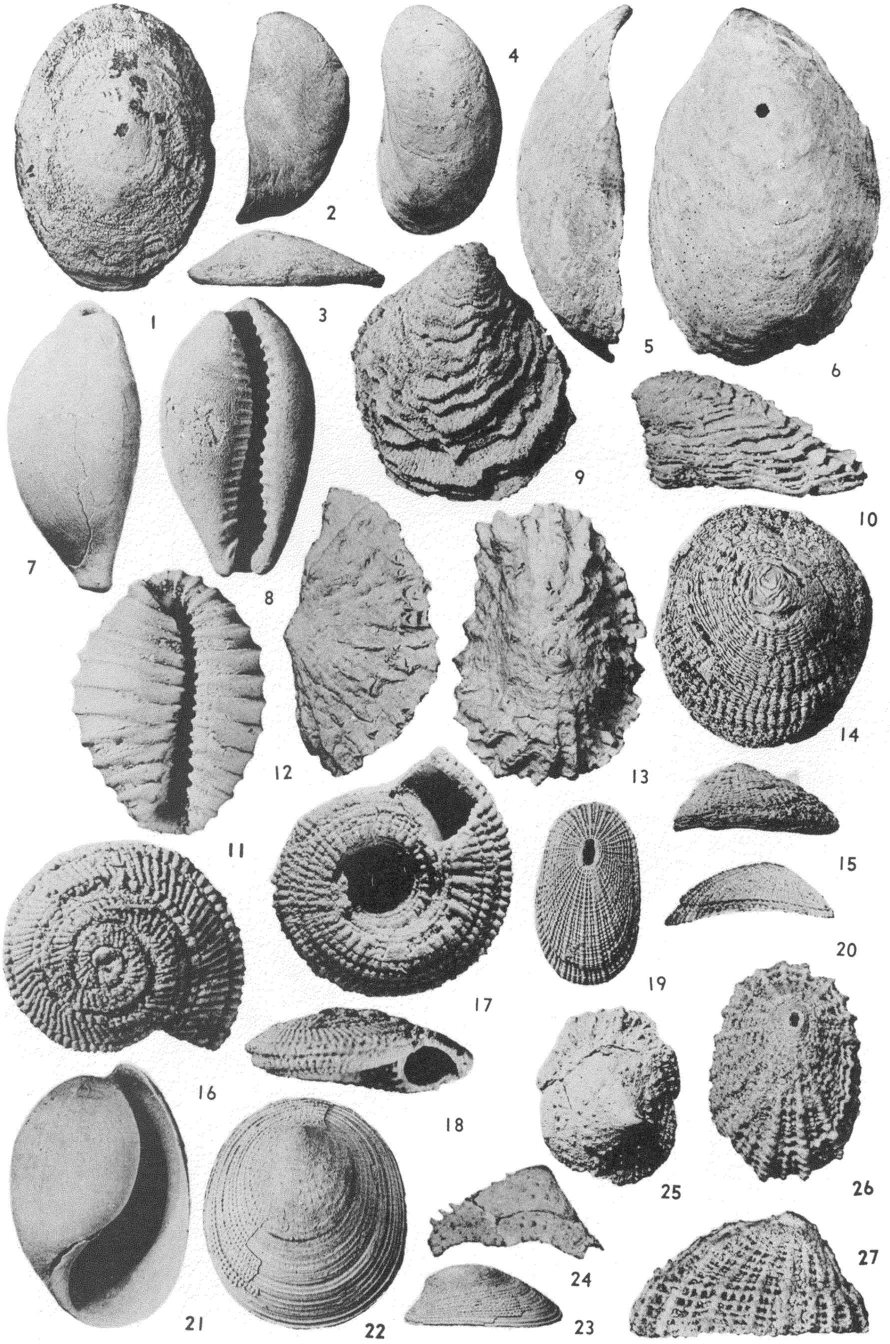

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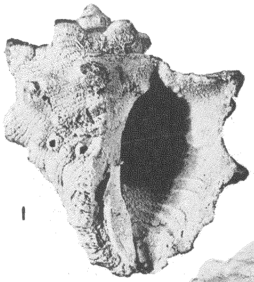
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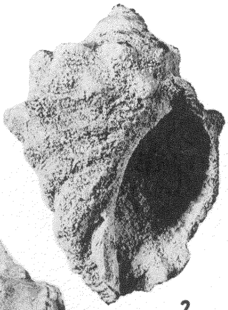
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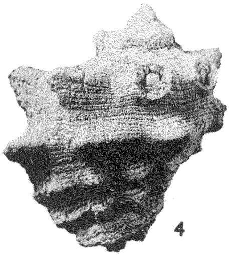
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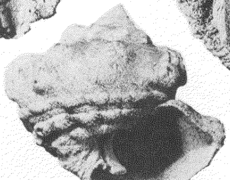
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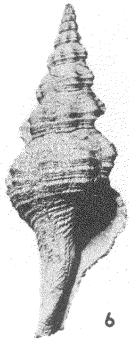
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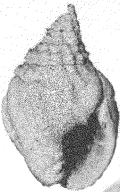
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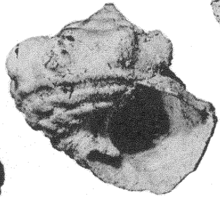
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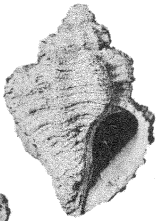
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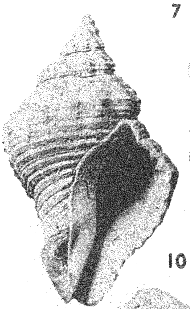
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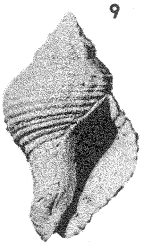
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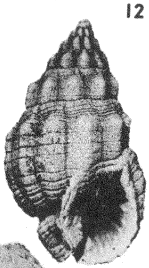
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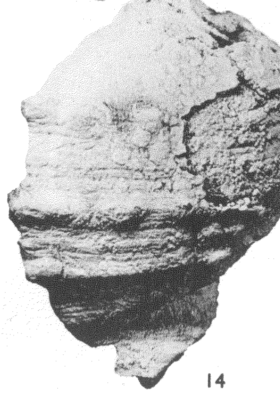
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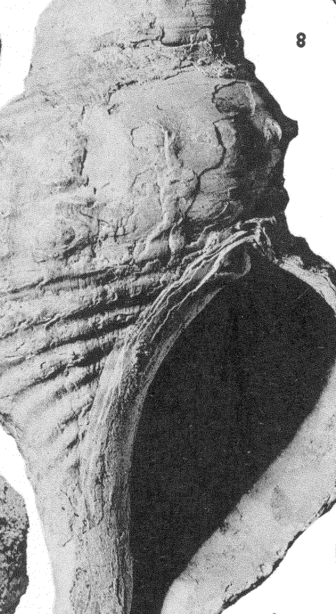
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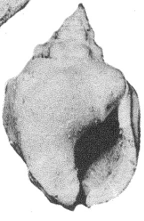
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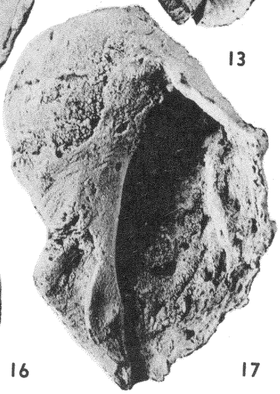
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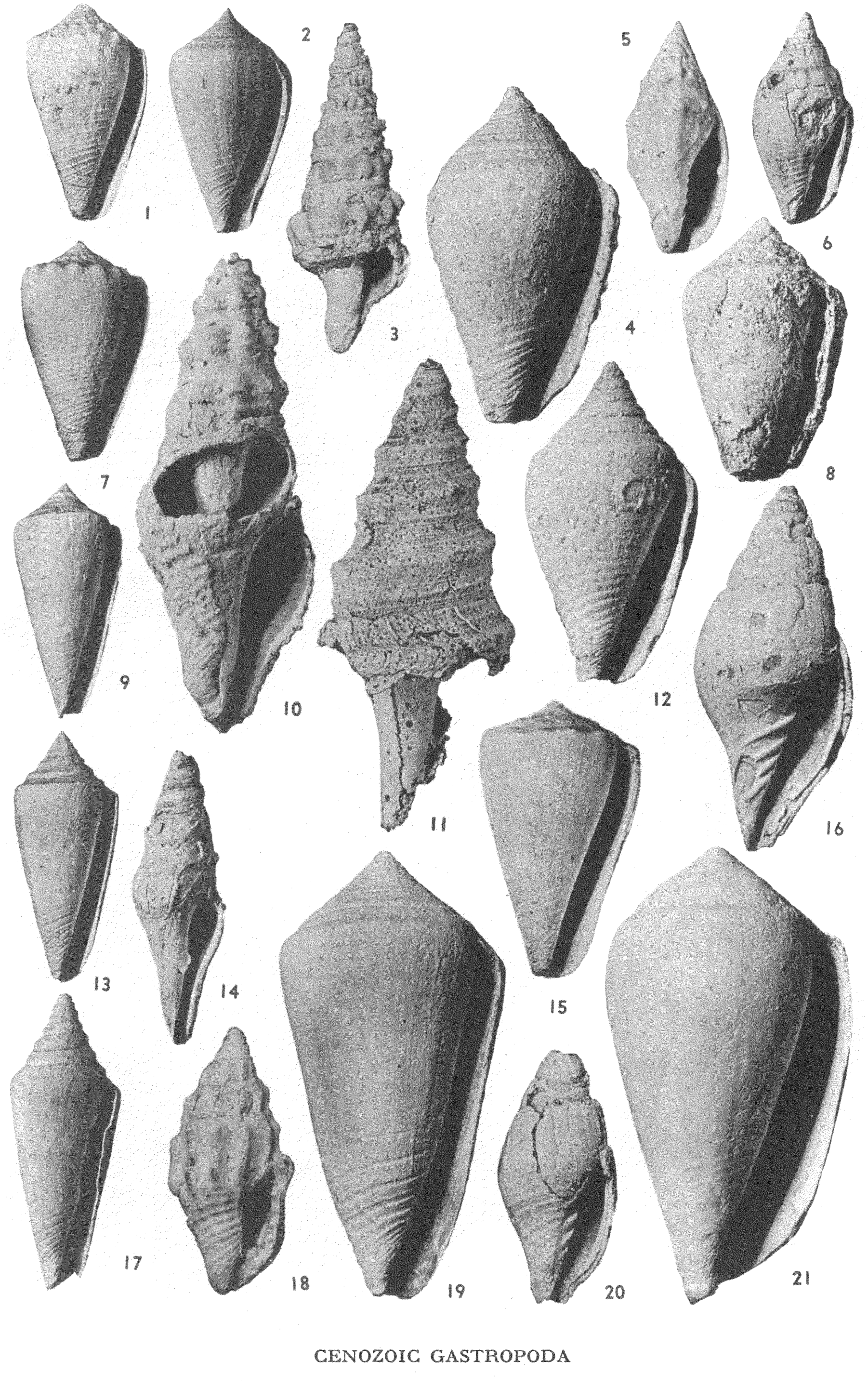

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PLATE 32.—CENOZOIC GASTROPODA

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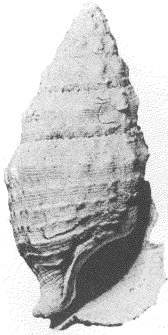
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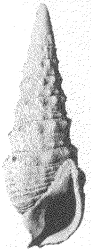
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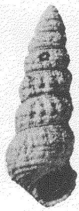
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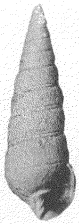
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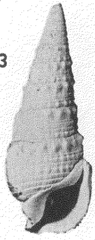
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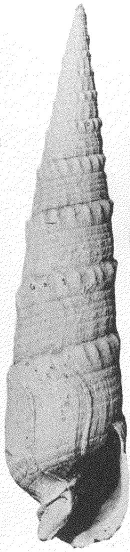
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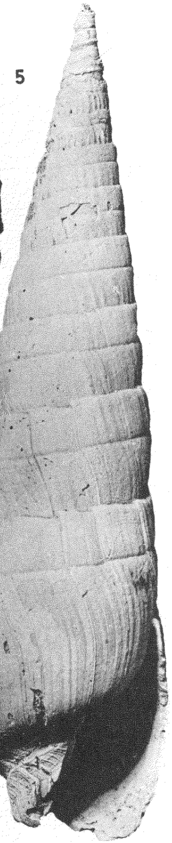
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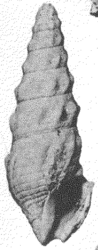
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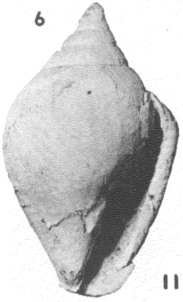
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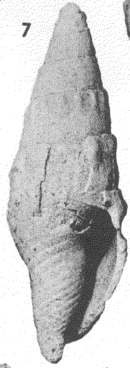
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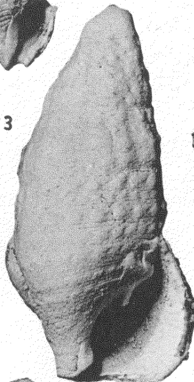
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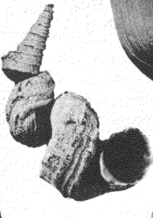
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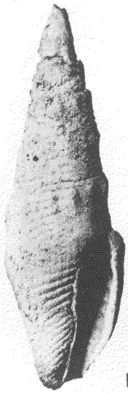
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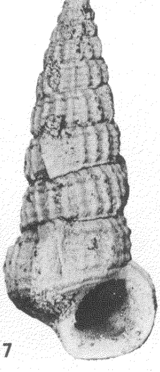
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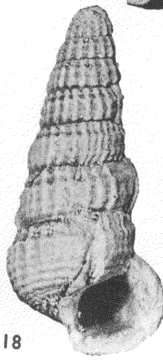
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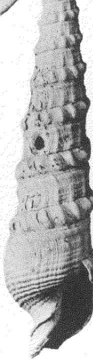
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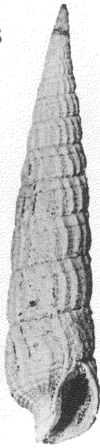
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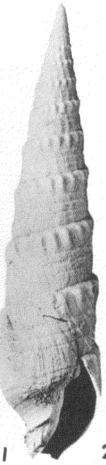
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CENOZOIC GASTROPODA

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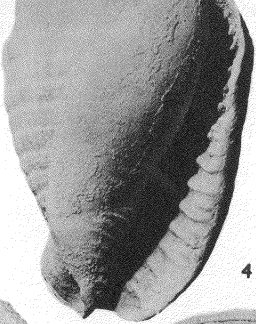

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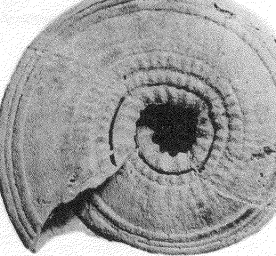

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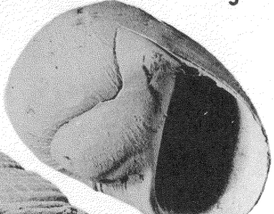

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CENOZOIC GASTROPODA

PLATE 34.—CENOZOIC GASTROPODA

Figure		Page
1.	*Malea ringens* (Swainson) (×1.5). Hypotype no 30542 (loc. A 3553)	116
2.	*Polinices bifasciatus* (Gray) (×1). Hypotype no. 32794 (loc. A 3548)	127
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5, 7.	*Architectonica nobilis* Bolten (×1). Hypotype no. 30799 (loc. A 3584)	124
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Plate 35.—CENOZOIC GASTROPODA

Figure		Page
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2.	*Jaton erinaceoides* (Valenciennes) (×1). Hypotype no. 30679 (loc. A 3584)	114
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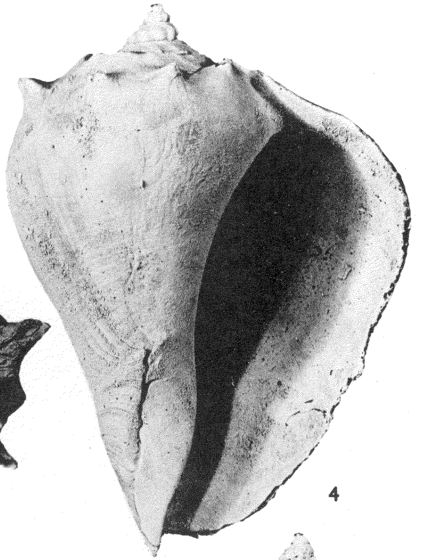
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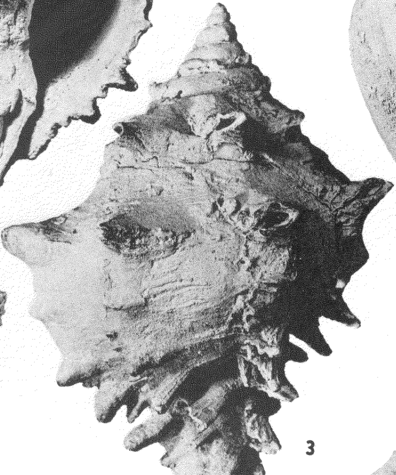
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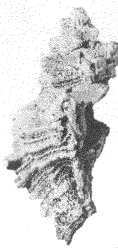
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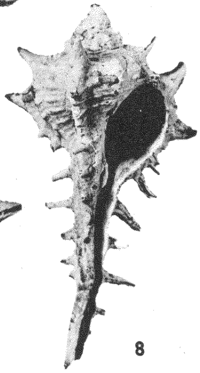
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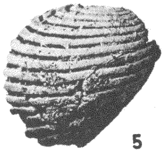
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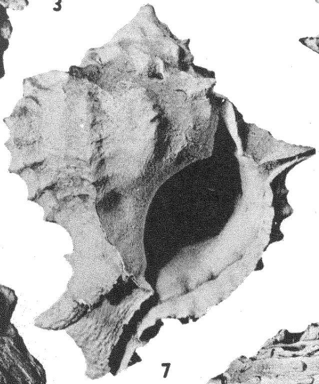
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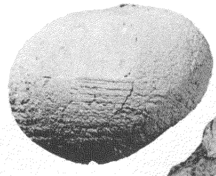
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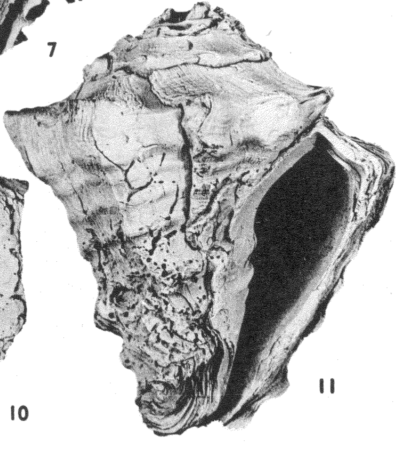
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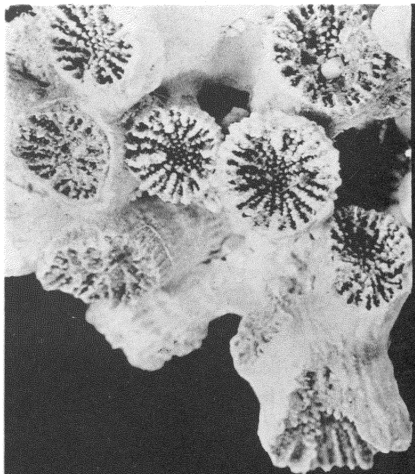
CENOZOIC GASTROPODA



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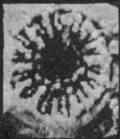

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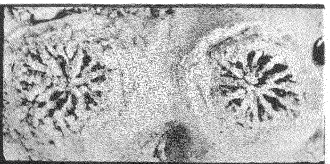

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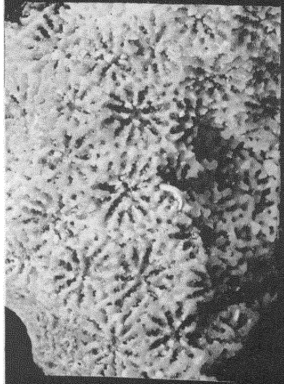

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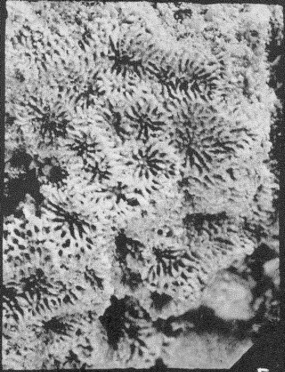

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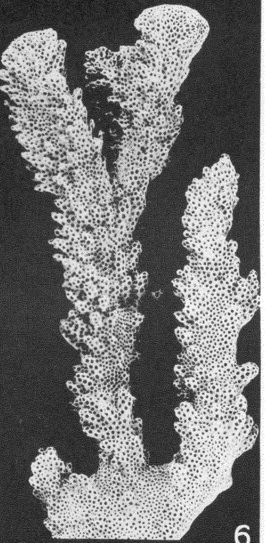

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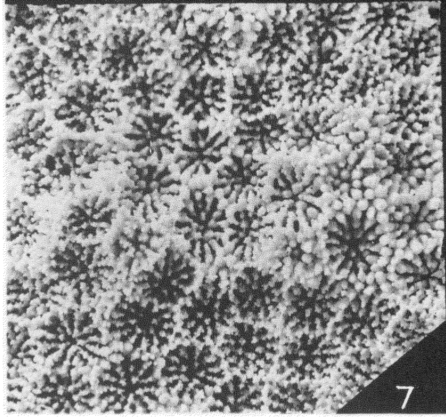

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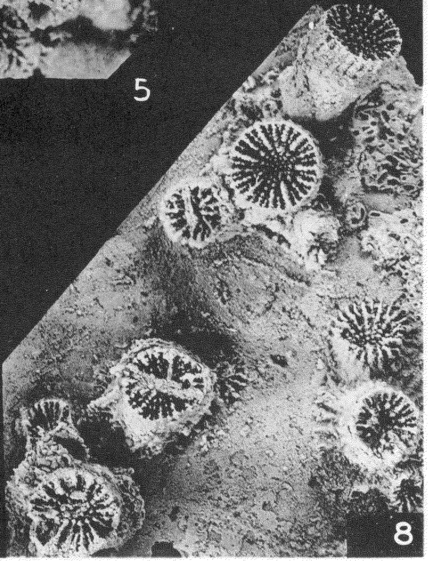

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CENOZOIC MADREPORARIA

PLATE 36.—CENOZOIC MADREPORARIA

Figure		Page
1.	*Astrangia (Astrangia) coronadosensis* Durham (×4.6). Holotype no. 14828 (loc. A 3548), Coronado Island. Pleistocene	39
2, 3.	*Astrangia (Astrangia) santelmoensis* Durham (×6). (2) Holotype no. 14829 (loc. A 3596), San Telmo Point, Peninsula of Lower California. Pleistocene. Detail of a well-preserved calice. (3) Same, cross sections showing heavy septa	40
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6.	*Pocillopora robusta* Verrill (×0.5). Lectotype, Peabody Mus. Nat. Hist. no. 3872, La Paz, Lower California. Recent. Part of the type specimen	37
7.	*Porites californica* Verrill (×6.5). Hypotype no. 14866 (loc. A 3645), Recent, Salinas Bay, Carmen Island. Abnormal calices surrounded by normal calices	38
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PLATE 37.—CENOZOIC ECHINOIDEA

Lateral profiles of *Encope* species. Anterior end to right. All figures (×0.7).

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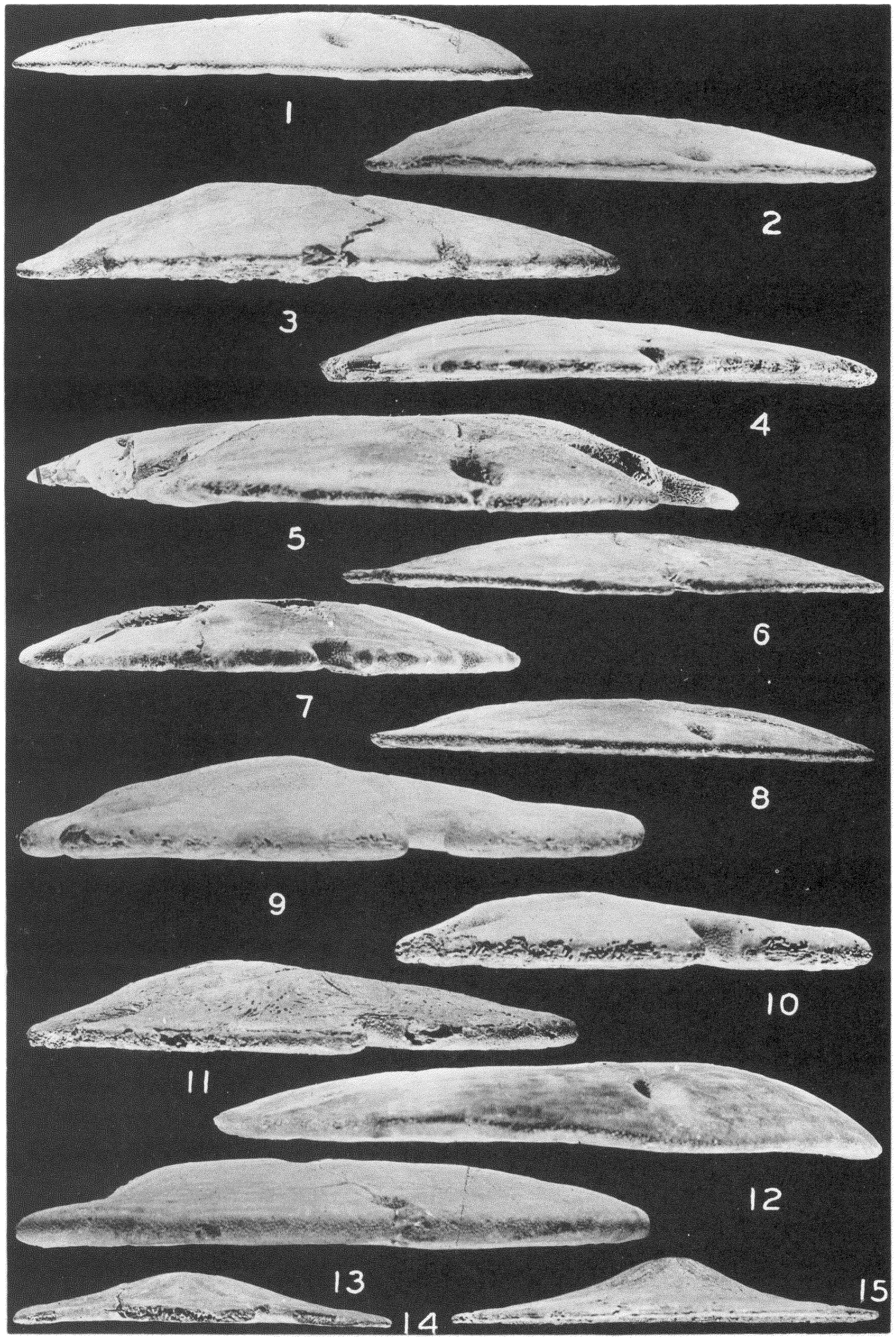
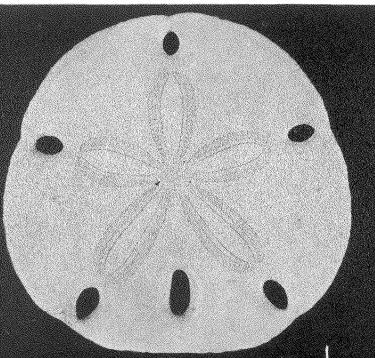
1. *Encope micropora* Agassiz. Hypotype no. 14979, Gulf of California, Recent	46
2. *Encope californica* Verrill. Hypotype no. 14946, Gulf of California, Recent	44
3. *Encope* n. sp. *A*. Hypotype no. 15387 (loc. A 3712), lower Pliocene	49
4. *Encope loretoensis* n. sp. Paratype no. 14889 (loc. A 3552), lower Pliocene	46
5. *Encope carmenensis* n. sp. Holotype no. 14896 (loc. A 3517), upper Pliocene	44
6. *Encope sverdrupi* n. sp. Holotype no. 15395 (loc. A 3583), lower Pliocene	48
7. *Encope chaneyi* n. sp. Holotype no. 30057 (loc. A 3552), lower Pliocene	45
8. *Encope arcensis* n. sp. Holotype no. 14903 (loc. A 3554), lower Pliocene	44
9. *Encope grandis* Agassiz. Hypotype no. 14905 (loc. A 3639), Las Animas Bay, Recent	45
10. *Encope grandis* subsp. *inezana* n. subsp. Holotype no. 14910 (loc. A 3584), Pleistocene	45
11. *Encope shepherdi* n. sp. Holotype no. 14917 (loc. A 3517), upper Pliocene	48
12. *Encope perspectiva* Agassiz. Hypotype no. 15398, Pacific Coast, Recent	47
13. *Encope* n. sp. *B*. Hypotype no. 14900 (loc. A 3548), lower Pleistocene. Photographically reversed, posterior end imperfect	50
14. *Encope scrippsae* n. sp. Holotype no. 14954 (loc. A 3551), lower Pliocene	47
15. *Encope angelensis* n. sp. Holotype no. 14959 (loc. A 3590), upper Pliocene	43



CENOZOIC ECHINOIDEA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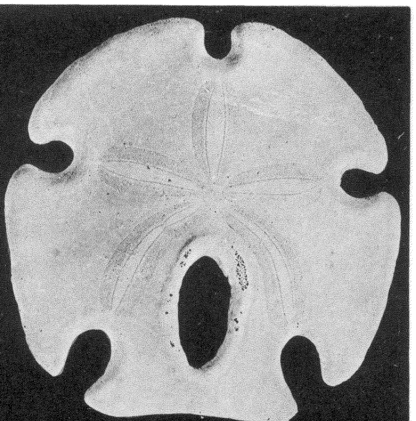
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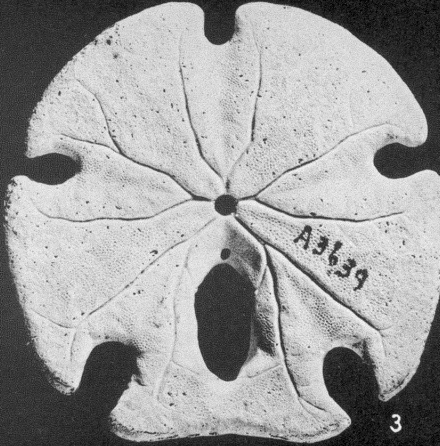

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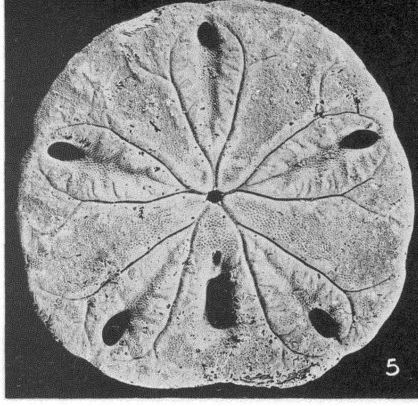
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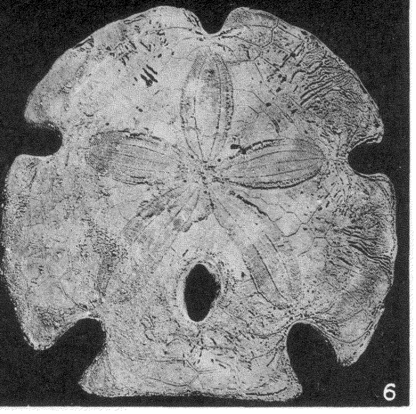
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CENOZOIC ECHINOIDEA

PLATE 38.—CENOZOIC ECHINOIDEA

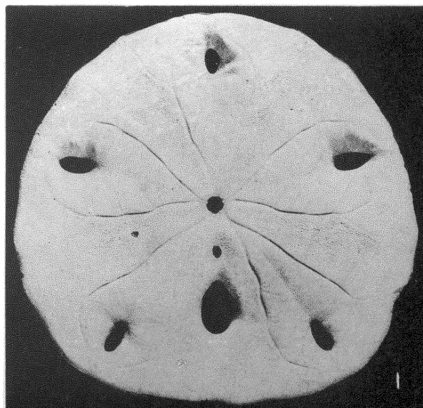
All (×0.5)

Figure		Page
1, 5.	*Encope californica* Verrill. (1) Hypotype no. 14946 (loc. A 3639), Las Animas Bay, Recent. (5) Hypotype no. 14953 (loc. A 3584), Pleistocene	44
2, 3.	*Encope grandis* Agassiz. Hypotype no. 14905 (loc. A 3639), Las Animas Bay, Recent	45
4.	*Encope grandis* subsp. *inezana* n. subsp. Holotype no. 14910 (loc. A 3584), Pleistocene	45
6.	*Encope shepherdi* n. sp. Holotype no. 14917 (loc. A 3517), upper Pliocene	48

PLATE 39.—CENOZOIC ECHINOIDEA

All (×0.5)

Figure		Page
1, 2.	*Encope micropora* Agassiz. Hypotype no. 14979, Gulf of California, Recent	46
3, 5.	*Encope perspectiva* Agassiz. Hypotype no. 15398, Pacific Coast, Recent	47
4, 6.	*Encope sverdrupi* n. sp. Holotype no. 15395 (loc. A 3583), lower Pliocene	48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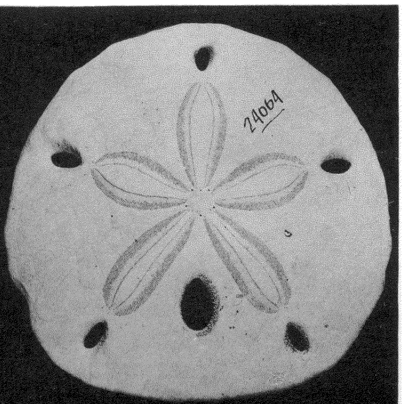

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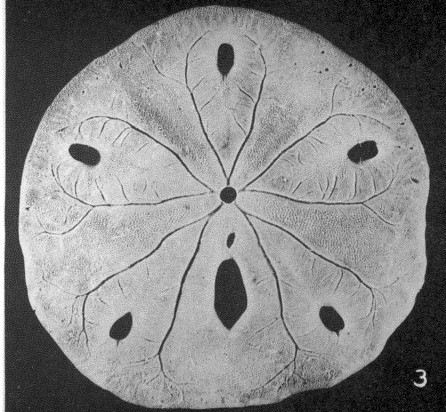
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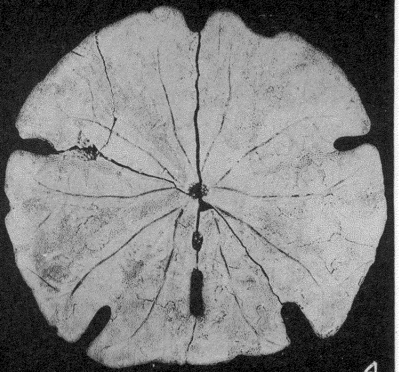
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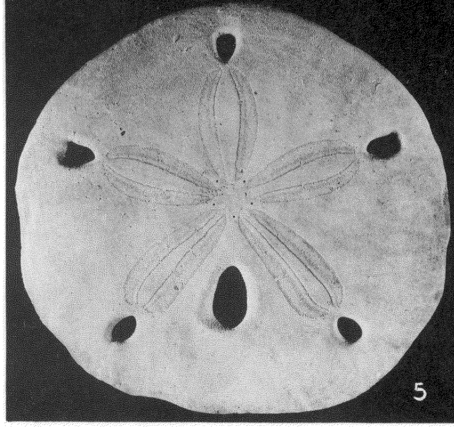
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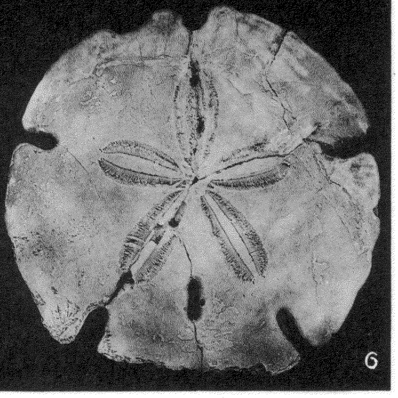
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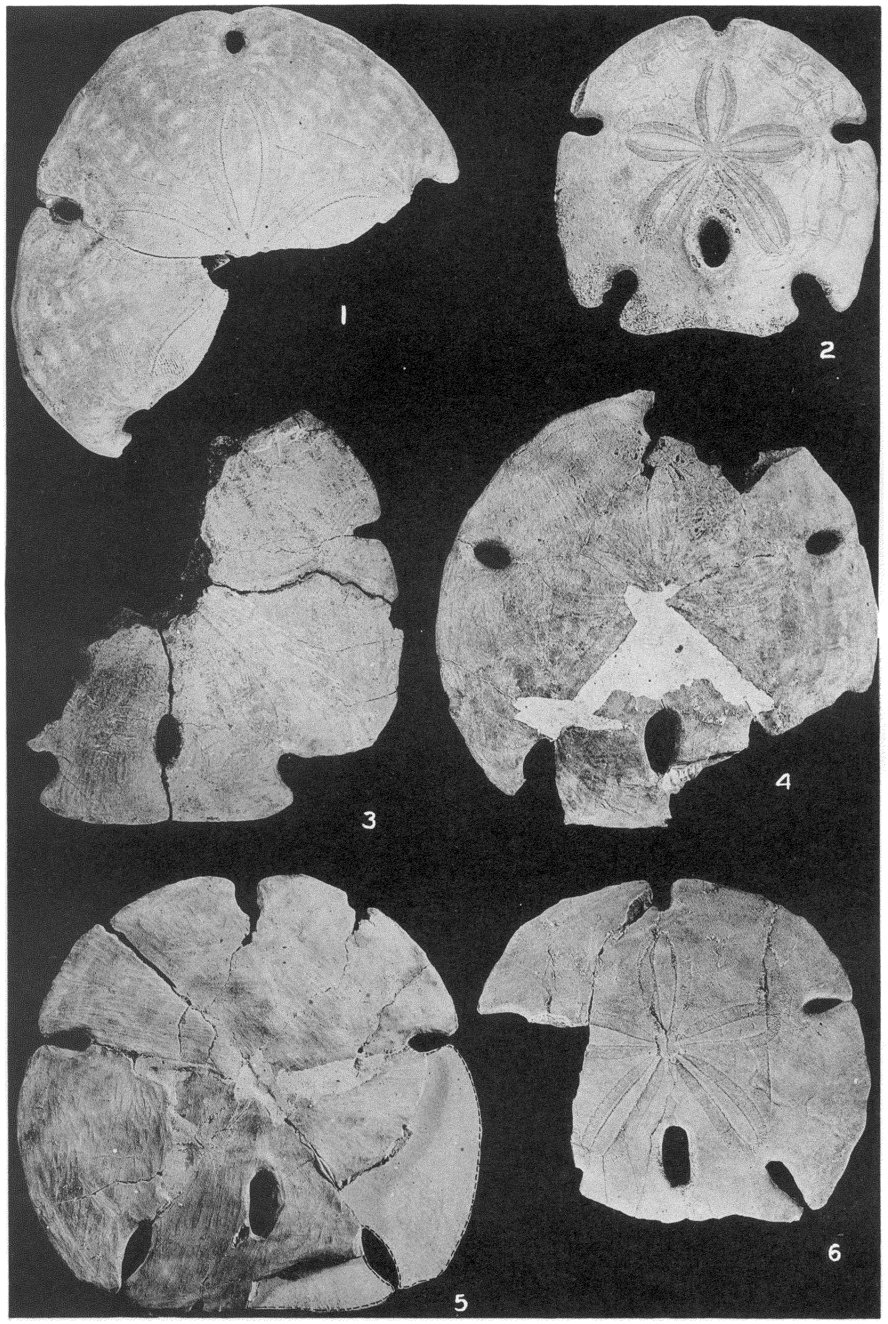
CENOZOIC ECHINOIDEA



CENOZOIC ECHINOIDEA

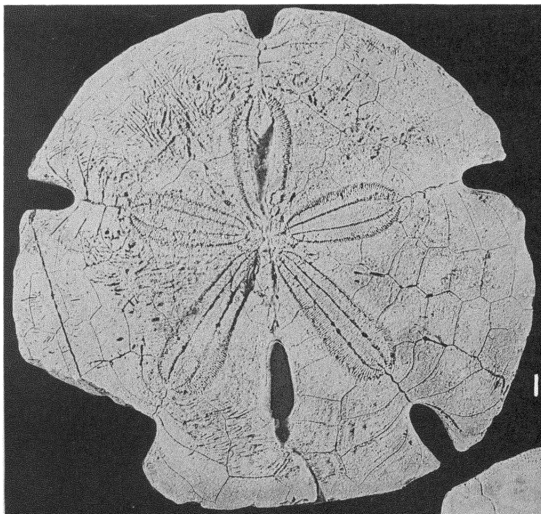
PLATE 40.—CENOZOIC ECHINOIDEA

All (×0.5)

Figure		Page
1.	*Encope* n. sp. *B*. Hypotype no. 14900 (loc. A 3548), Pleistocene	50
2.	*Encope shepherdi* n. sp. Paratype no. 14918 (loc. A 3517), upper Pliocene	48
3.	*Encope* n. sp. *A*. Hypotype no. 15387 (loc. A 3712), lower Pliocene	49
4.	*Encope carmenensis* n. sp. Holotype no. 14896 (loc. A 3517), upper Pliocene	44
5, 6.	*Encope arcensis* n. sp. (5) Paratype no. 14894 (loc. A 3529), lower Pliocene. (6) Holotype no. 14903 (loc. A 3554), lower Pliocene	44

PLATE 41.—CENOZOIC ECHINOIDEA

Figure		Page
1, 4, 5.	*Encope loretoensis* n. sp. (1) Holotype no. 14888 (loc. A. 3552) (×0.7), lower Pliocene. (4) Paratype no. 14889 (loc. A 3552) (×0.7), lower Pliocene. (5) Paratype no. 14889 (loc. A 3552) (×0.8)	46
2, 3, 6.	*Encope scrippsae* n. sp. (×0.7). Hypotypes (2) no. 14967, (3) no. 14966, (6) no. 14968, (All from loc. A 3594), lower Pliocene	48



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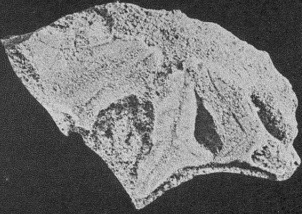

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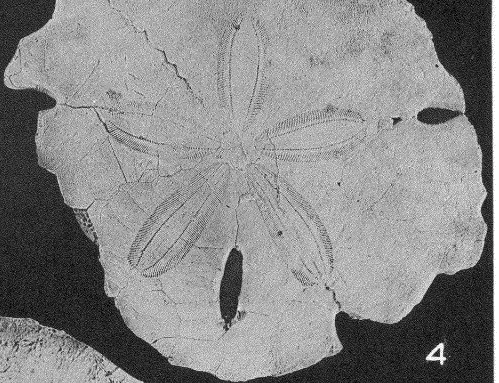

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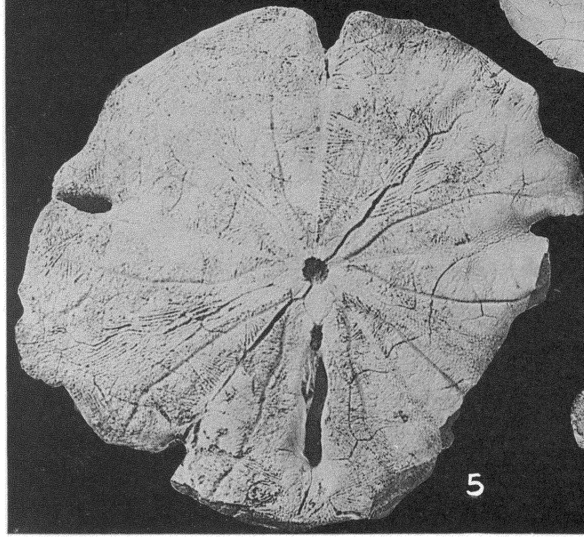

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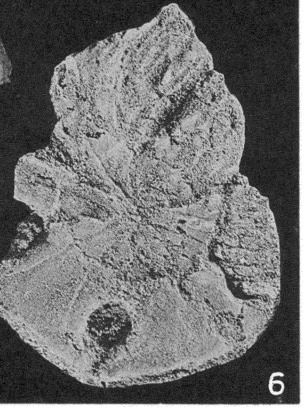

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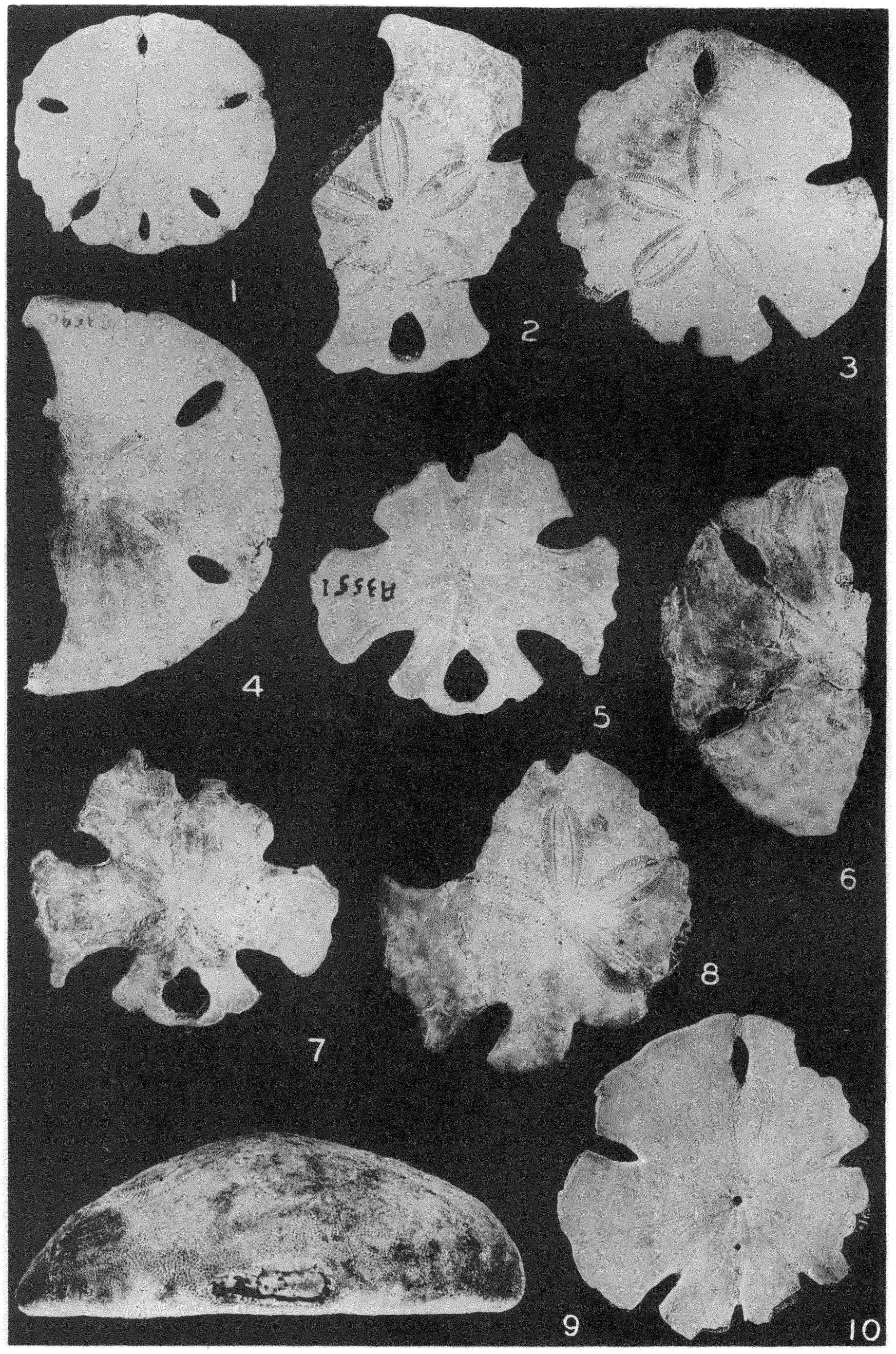
CENOZOIC ECHINOIDEA



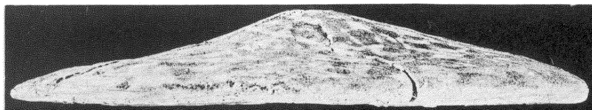
CENOZOIC ECHINOIDEA

PLATE 42.—CENOZOIC ECHINOIDEA

Figure		Page
1, 3, 4, 10.	*Encope angelensis* n. sp. (×0.7). Paratypes (1) no. 14962, (3) no. 14965. (4) Holotype no. 14959. (10) Same as (3). All loc. A 3590, upper Pliocene	43
2, 5, 6, 7, 8.	*Encope scrippsae* n. sp. (×0.7). (2) Holotype no. 14954. Paratypes (5) no. 14958, (6) no. 14957, (7) Same as (5), (8) no. 14956. All loc. A 3551, lower Pliocene	47
9.	*Clypeaster bowersi* Weaver (×0.5). Hypotype, Calif. Acad. Sci. Paleo. Type Coll. no. 7854 (loc. C.A.S. 795), lower Pliocene. Lateral profile	40

PLATE 43.—CENOZOIC ECHINOIDEA

Figure		Page
1, 7.	*Clypeaster revellei* n. sp. (×0.5). Holotype no. 14892 (loc. A 3560), middle Pliocene...	41
2, 3.	*Clypeaster marquerensis* n. sp. (×0.5). Holotype no. 14893 (loc. A 3517), upper Pliocene......	41
4, 5, 8, 9.	*Agassizia scrobiculata* Valenciennes (×1). (4) Hypotype no. 30149 (L.S.J.U. loc. 805), lower Pliocene. (5) Hypotype Stanford Univ. Paleo. Type Coll. no. 7373 (L.S.J.U. loc. 805), lower Pliocene. (8) Same as (4). (9) Same as (5)............	50
6.	*Encope chaneyi* n. sp. (×1). Holotype no. 30057 (loc. A 3552), lower Pliocene.......	45



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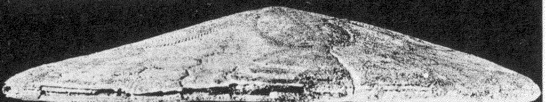

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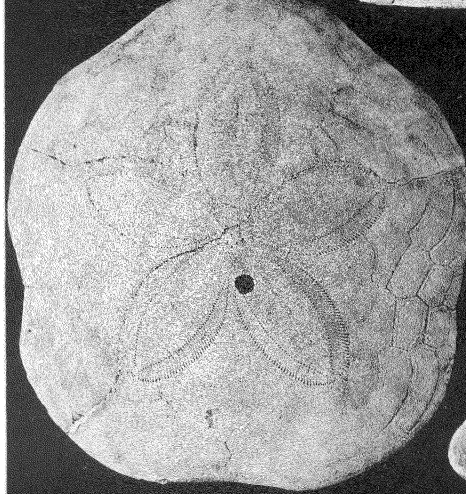

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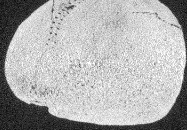

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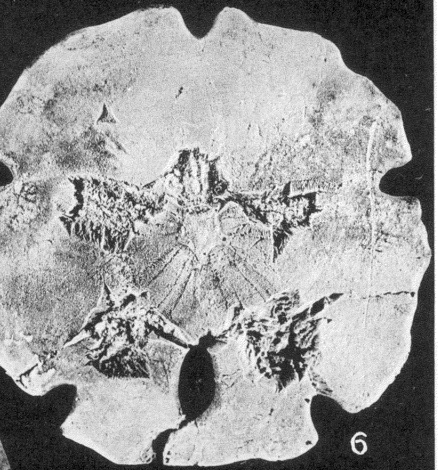

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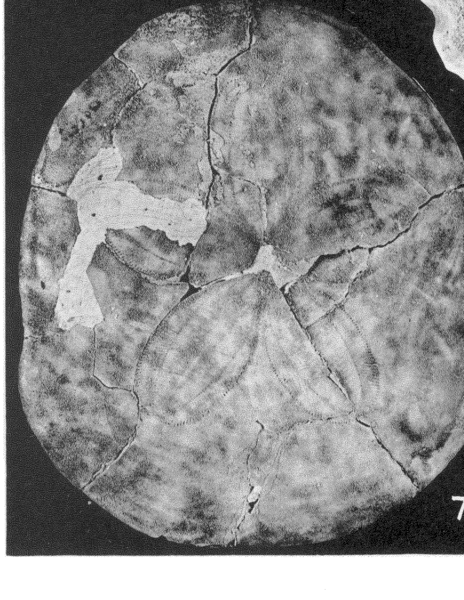

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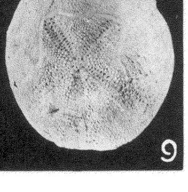

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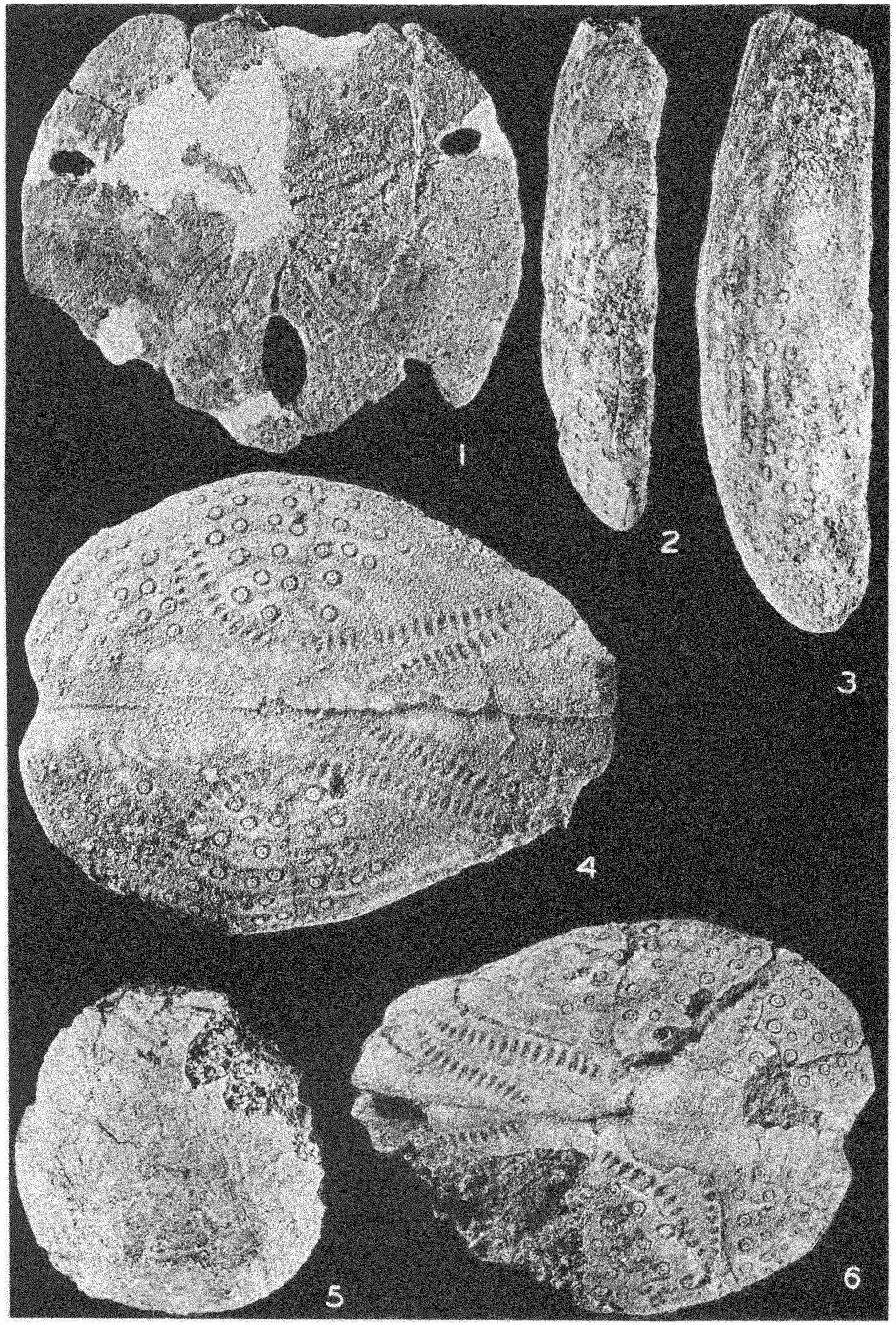

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PLATE 45.—CENOZOIC ECHINOIDEA

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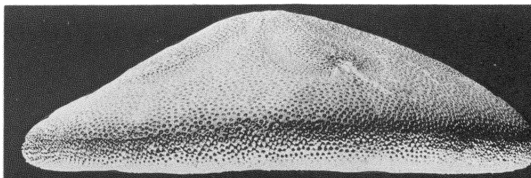

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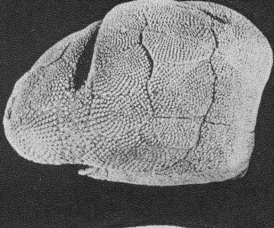

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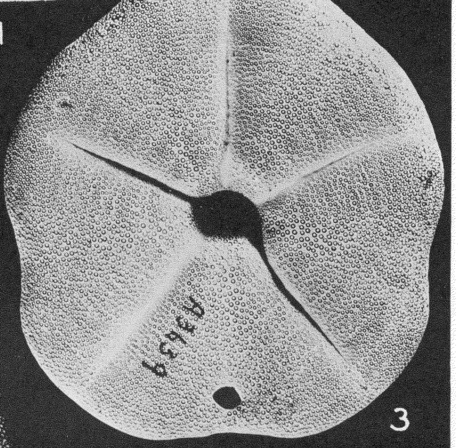

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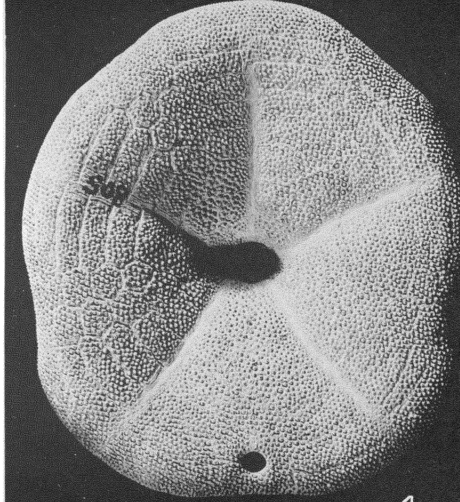

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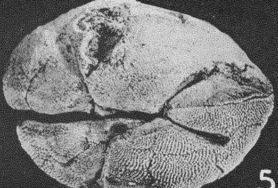

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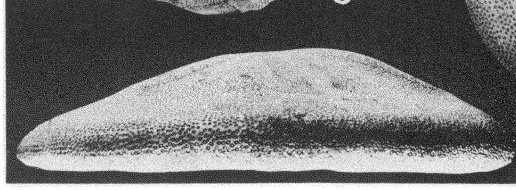

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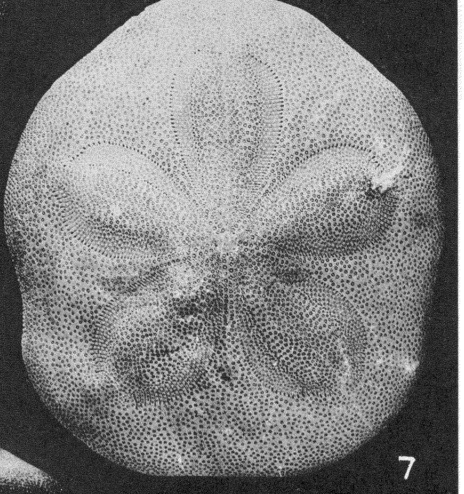

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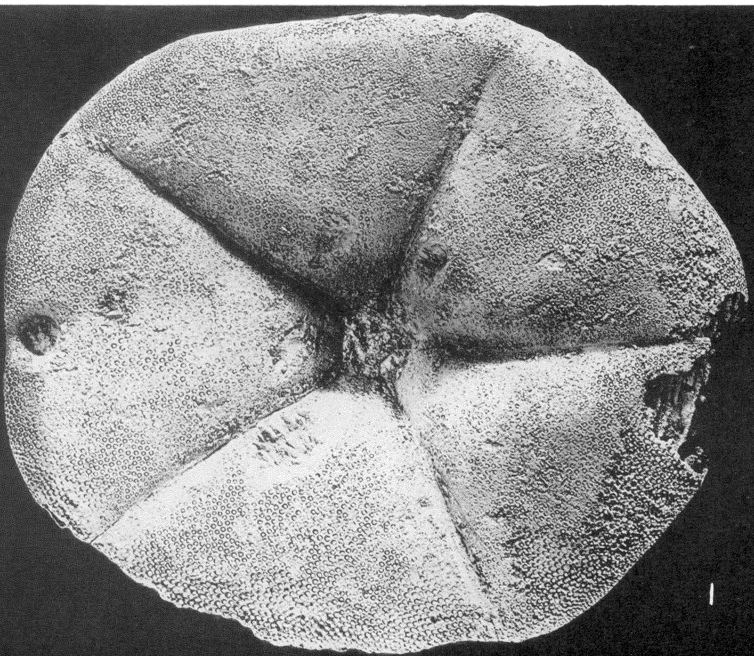

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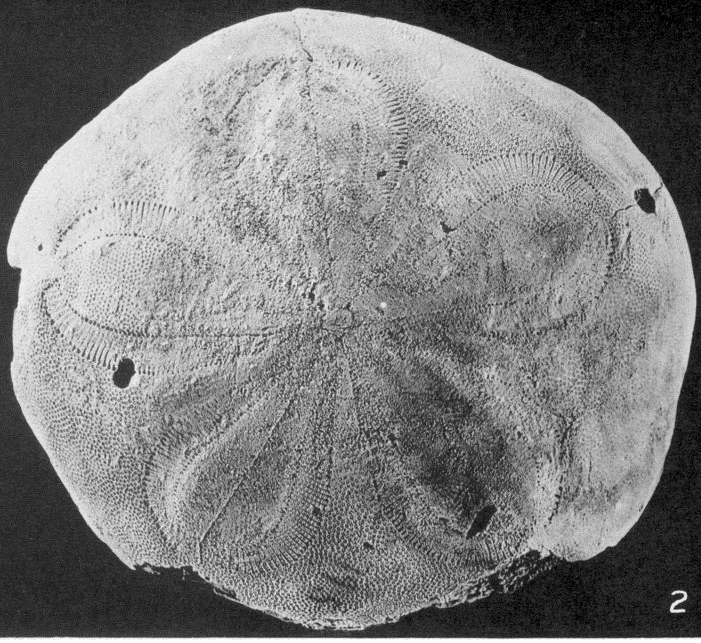

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PLATE 46.—CENOZOIC ECHINOIDEA

Figure		Page
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PLATE 47.—CENOZOIC ECHINOIDEA

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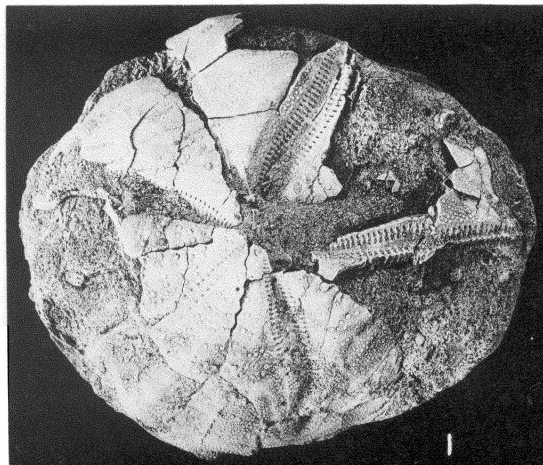
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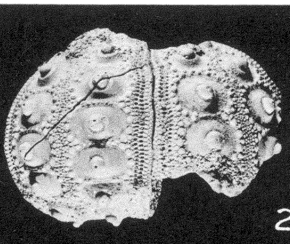
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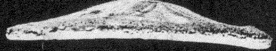
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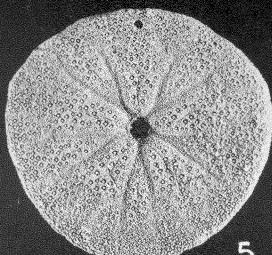
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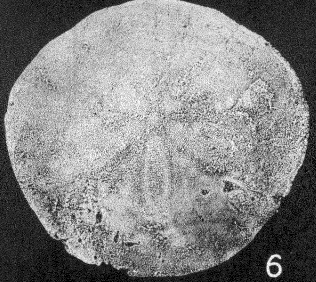
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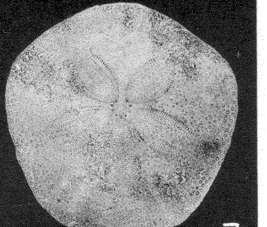
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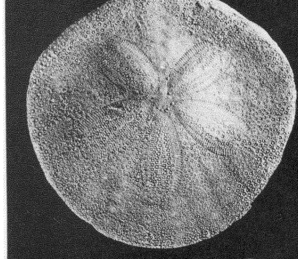
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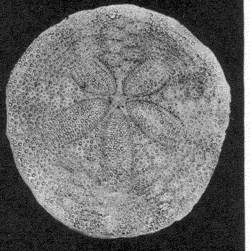
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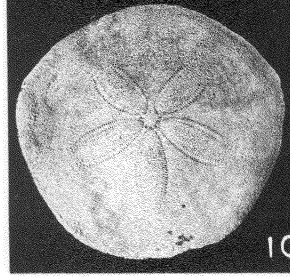
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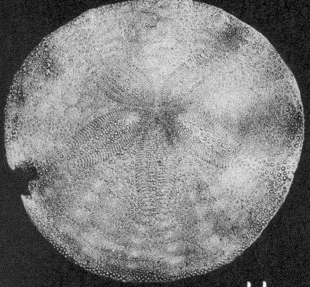
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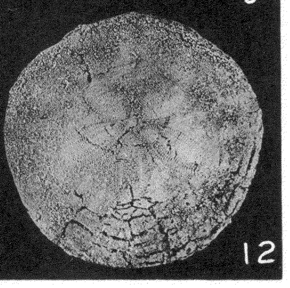
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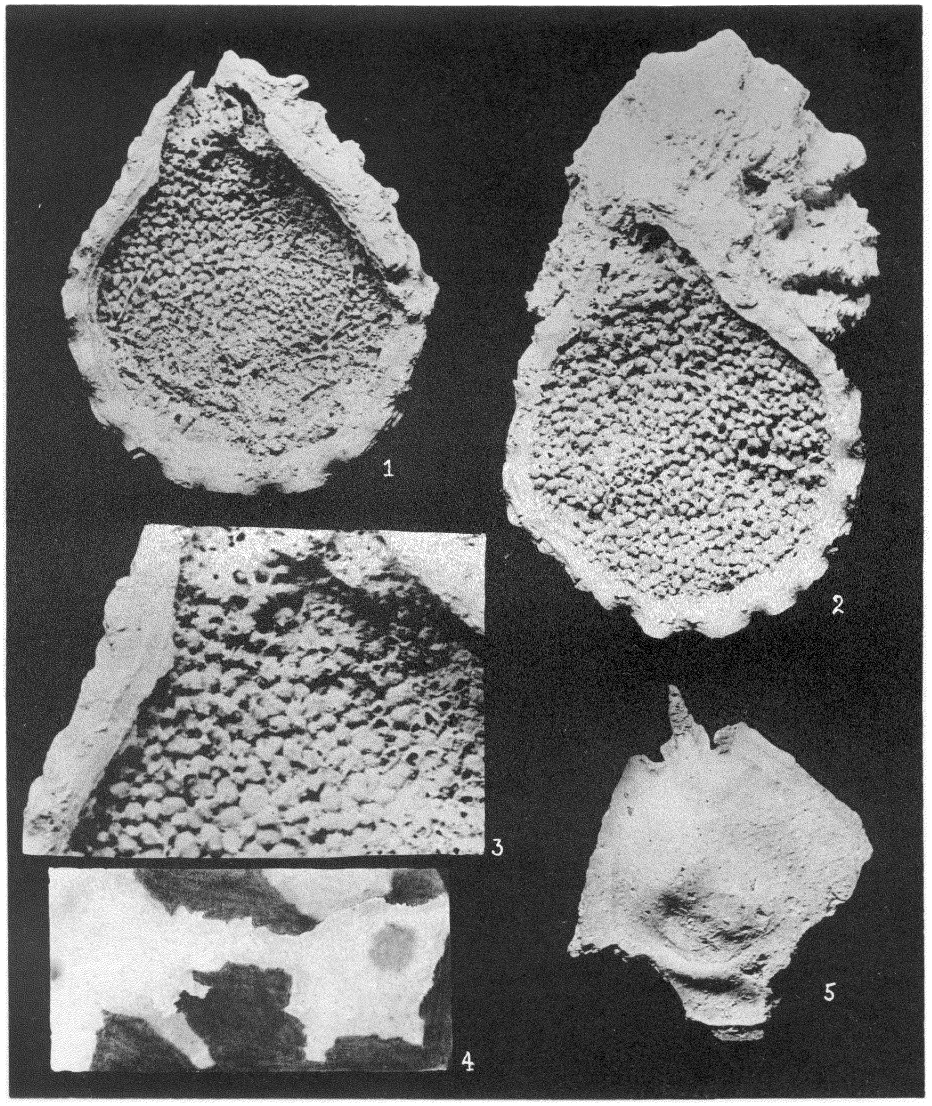

RAMULINA GLOBULIFERA

Plate 48.—RAMULINA GLOBULIFERA

Figure		Page
1, 2.	Interior of opposite valves of *Plicatula* lined with chambers of *Ramulina globulifera* H. B. Brady (×1). Hypotype, Univ. Calif. Mus. Paleo. no. 14898, loc. A 3563	135
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1940 E. W. SCRIPPS CRUISE TO THE GULF OF CALIFORNIA

PART III

SUBMARINE TOPOGRAPHY OF THE GULF OF CALIFORNIA

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ABSTRACT

Two Scripps Institution expeditions to the Gulf of California provided 28,000 new soundings in a poorly charted area. These new data have been the chief source of information for construction of contour charts which indicate the remarkable basins and extensive submarine fault scarps of the Gulf area. *V*-shaped trenches and flat-floored troughs abut against most of the mountainous east coast of Lower California with no appreciable intervening continental shelf. Various possible explanations of the scarps leading to these deeps are discussed, and their origin as fault scarps is shown to be the most likely. In general the trenches trend to the northwest-southeast, whereas the long dimension of the troughs is north-south. These same directions are prominently indicated in the coast line on both sides of the Gulf. Analogies are drawn between the sea-floor topography of the Gulf and that of the southern California area and the West Indies. The combination of large-scale vertical movements and horizontal shearing of the San Andreas type is suggested as a cause of the submarine topography.

During the expedition several hitherto unsounded submarine canyons were discovered, and others were explored. The canyons were found only in the southern portion of the Gulf; they are particularly well developed around the tip of southern California where the climate is less arid than farther north. Conspicuous absence of submarine canyons is found along the supposed submarine fault scarps. The topography of the canyons in the Gulf is strongly suggestive of subaerial erosion. The cutting appears to have been prior to the time of formation of the submarine fault scarps. Surveys around Guadalupe Island off Lower California, which were made en route to the Gulf, indicated possible canyons of amphitheater shape in the slopes off this volcanic mass, but the alternative explanation of volcanic collapse or explosion was considered somewhat more probable than that of submerged river valleys.

INTRODUCTION

The Gulf of California is 680 miles long terminating northward at the delta of the Colorado River. Prior to 1939 most of the soundings in this long, relatively narrow body of water were confined to near shore and shallow-water areas. The U. S. Navy made a few depth measurements during the nineteenth century in the deep central portions and in the troughs along the west side of the Gulf. As a result, the 1:1,000,000 International map, which depicts the submarine relief within the Gulf, is far from accurate. In the spring of 1939 the first expedition of the auxiliary schooner E. W. SCRIPPS added approximately 3000 soundings to the area, including a number of sounding lines crossing the Gulf. Roger Revelle compiled these soundings and, at the 1939 meeting of the Geological Society, exhibited a general contour map showing the new developments resulting from these traverses. In the fall of 1940, a second expedition to the Gulf added approximately 25,000 soundings. The writer and his assistants have plotted these soundings and co-ordinated them with those of the earlier cruise and with the soundings of the Navy. The new charts (Fig. 1) have utilized all available information. Contour maps based on these new sounding compilations provide considerable information concerning the submarine relief, although much generalization is still necessary.

During the second cruise a considerable number of soundings were taken on the west side of Lower California. Also in one of the 1938 geological cruises of the E. W. SCRIPPS lines were run along the northwest side of Lower California. These soundings have been utilized in making the general map (Chart I). However, the submarine contours off the west side of Lower California are based chiefly on the soundings of Hydrographic Office charts and were taken by various ships over a long period. The scarcity of these soundings and their poor co-ordination make accurate contouring impossible. Guadalupe Island, lying 150 miles off Lower California, was also visited on the way to the Gulf. Several sounding lines were run in this area.

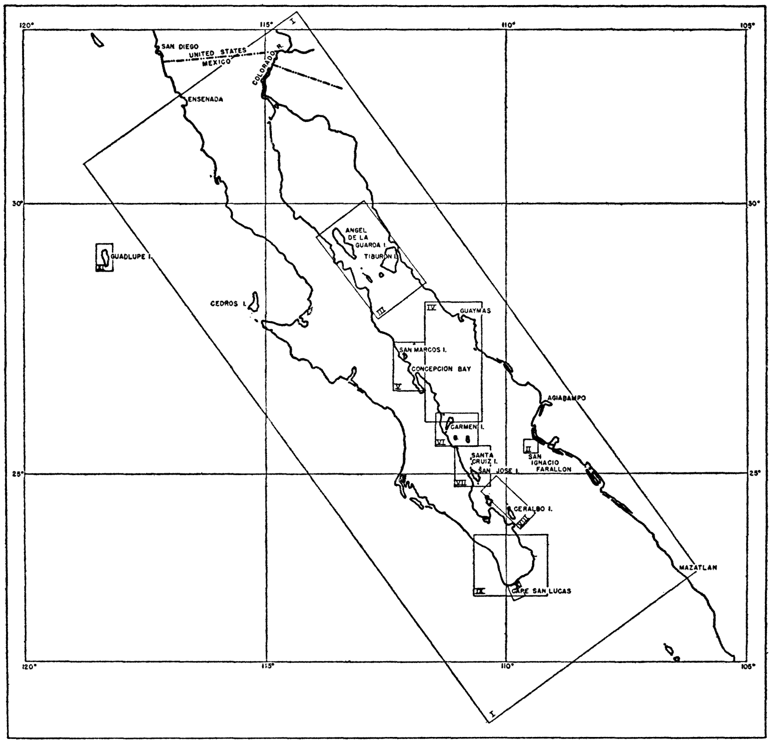

FIGURE 1.—*Outline map showing location of the charts*

The new contour maps and profiles drawn from the soundings show that the topography in the Gulf is much more complicated than would have been supposed from the International 1:1,000,000 map. The tectonic origin of much of the relief is evident, and some of the fault scarps indicated on the sea floor can be correlated with established faults on land. The study of the submarine topography can therefore give considerable information concerning the geological history of the Gulf.

RELATIVE ACCURACY OF SURVEYS

ERRORS IN SOUNDINGS

Some erroneous impressions have been prevalent among geologists as to the accuracy of soundings. Depth readings obtained by either wire or sonic methods can be highly accurate in water less than 100 fathoms deep but in deeper water are less accurate. Wire soundings may be in error because of currents deflecting the wire from the vertical. Visual echo soundings,[1] of the Fathometer type used in the present investigation, become increasingly subject to misinterpretation as the depth increases. Down to depths of about 500 to 1500 fathoms, depending on water conditions, it was possible to read the depth by a flash of light on a dial. However, beyond depths of 250 fathoms[2] the observer had to add to the indicated depth 250 fathoms or a multiple thereof. In crossing a steep slope the observer may fail to take account of the number of cycles to be added. Relatively easy checks can be made especially where the bottom flattens out so that the observer is not pressed for time. At great depths (in general, below about 800 fathoms in the work to be described) a co-ordination of eye and ear was used to judge the depth. Since sound travels approximately 810 fathoms per second in sea water, it is not difficult to make an error of from 10 to 30 fathoms by this method. The fainter echoes of the greatest depths add to the difficulty of making accurate observations. The recent development of recording echo-sounding devices which operate to all depths will make future soundings much more accurate.

ERRORS OF POSITION

Positions along sounding lines are ordinarily obtained by taking horizontal sextant angles between three or more land objects. Where only two objects of known position are visible, the less accurate method of pelorus bearings is used. Accuracy of location is possible where three or more accurately located objects are relatively close and clearly visible, and where the arcs subtended between them are large. Errors increase with the inaccuracy of location of points, with the lack of sharpness of such features as mountain tops, and with the distance from the objects. As is the case with soundings, human error is always possible, but the plotting of fixes and comparison with dead-reckoning runs eliminates some of this source of error. Also where cross lines are available some adjustments can be made.

Out of sight of land, positions are much less accurate.[3] Sextant shots on stars at dawn and dusk obtain positions with an expectable error averaging about a mile. Sun sights are much less accurate since they give only lines of position, and these lines can scarcely be considered as less than a mile wide.

In the Gulf of California the U. S. Navy surveys were made before accurate triangulation was possible. Thus, positions of mountains and other objects are not very accurate. Good choice of objects was made, however, by these early surveyors so that it was not difficult to pick out the features indicated on the charts. Wherever practical, angles were taken between a number of different points so that an average position could be used. Also the angles were always plotted immediately so that any considerable discrepancy between plotted and dead-reckoning positions could be promptly detected. When necessary, new objects were chosen.

COMPARISON WITH OTHER SURVEYS

It is, of course, very difficult to compare surveys. We could not claim to have the skill which comes from long experience by such groups as the Coast and Geodetic

---

[1] In recent years these visual soundings have been replaced by tape recordings.

[2] Which is the limit of the dial of the type of Fathometer on the E. W. SCRIPPS during the Gulf expeditions.

[3] Except where obtained by Shoran, Loran, or Radio Acoustic Range Finding (Shepard, 1948, p. 15–17) which were not adaptable to scientific work at the time of the expeditions.

Survey. Our instruments were poorer, the base maps were less accurate, and the short-handed scientific crew on the E. W. Scripps made it necessary for the surveyors to carry on more tasks than desirable. However, the surveying was conducted by experienced members of the party.

One way to judge results of a survey is to compare the crossing of lines. Surveys at comparable depths made within the last decade by the Coast and Geodetic Survey with echo soundings show decidedly better sounding crossings where land points were visible. However, where Radio Acoustic Range Finding was employed for locations out of sight of land, the deep-water crossings appear to be no better than those obtained by the E. W. Scripps in the Gulf with the aid of visual fixes. On the other hand, the Coast and Geodetic Survey lines are, in general, much closer spaced, providing a better basis for contouring. The lines run by the E. W. Scripps at night or out of sight of land in the Gulf are subject to considerable uncertainty of position, but these lines are not important in connection with the contouring on the large-scale charts, except in the case of the Central Gulf Area (Chart IV) where a considerable number of lines were run between Carmen Island and Guaymas, and much of the length of these lines is based on dead reckoning. Practically all other lines within 30 miles of land on both sides of the Gulf were controlled by visual fixes.

GENERAL CHARACTER OF THE GULF OF CALIFORNIA

The Gulf of California has a decidedly rectangular shape (Chart I). Examination of the general map will show that there is little variation in the width from north to south. Near the southern end it is about 120 miles wide, while it is about 100 miles near the head of the Gulf. The only point of significant convergence, just south of Tiburon Island, shows a decrease to 60 miles. Because of this rectangular shape the Gulf resembles the Red Sea and the Persian Gulf. An examination of a relief map of North America will also show that the Gulf is in line with the similarly rectangular Great Valley of California, being separated only by the San Bernardino and the Tehachapi mountains of southern California. The Valley of California also compares with the Gulf in having a series of small ranges on its western side which may be the counterpart of the islands along the western side of the Gulf. While the Gulf is about 80 per cent wider than the Valley, deep submergence of the Valley of California would widen it considerably.

In one important respect the Gulf differs from the Valley of California. The floor of the Valley is for the most part very flat, while the floor of the Gulf is quite irregular and has considerable relief. On the other hand, the northern end of the Gulf and its landward continuation in Imperial Valley reveal a stretch of about 200 miles where the floor is as flat as that of the Great Valley of California. Both flat areas have been subject to large fill, whereas most of the Gulf appears not to have received much sediment. This leads to the speculation that the basement rock surface of the Great Valley may have as great relief as is exhibited by the Gulf.

CONTINENTAL SHELVES

The term continental shelf refers to the shallow-water platforms, marginal to the continents, with depths mostly less than 100 fathoms and with gentle slopes in con-

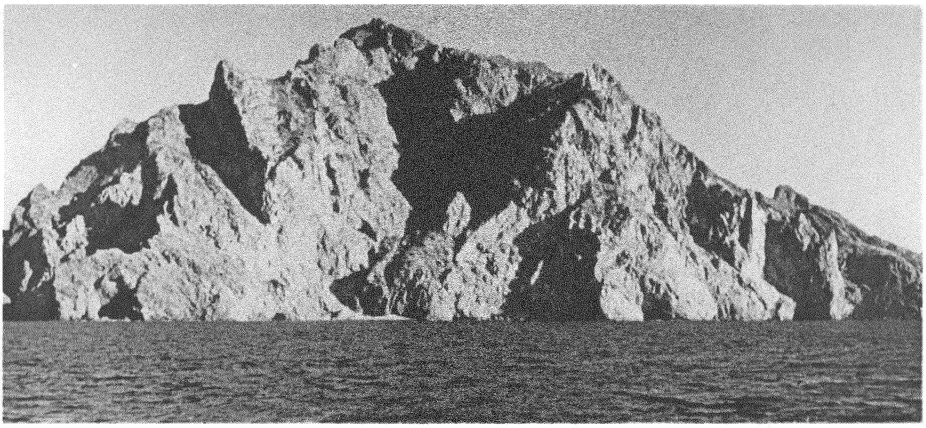

Figure 1. Typical Marine Cliffs near Guaymas
·They have been partly submerged and have deep water at their base.

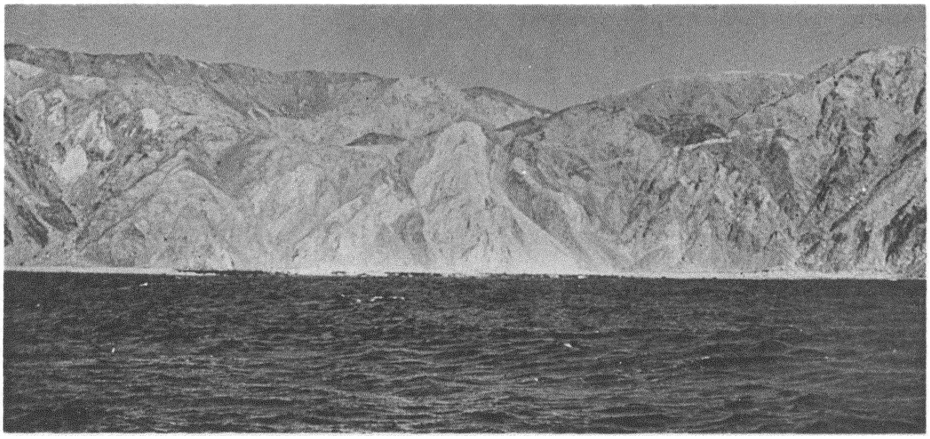

Figure 2. Exposed Portion of the Fault Scarp along West Side of Angel de la Guarda
Note the structures truncated at the coast. Photo taken from position where water is 200 fathoms deep.

Figure 3. Exposed Portion of Fault Scarp along West Side of Santa Cruz Island.
Photo taken from position where water is over 400 fathoms in depth.

ISLANDS AND COAST IN THE GULF

FIGURE 1. GRANITE PINNACLES WHICH BORDER THE HEAD OF SAN LUCAS CANYON

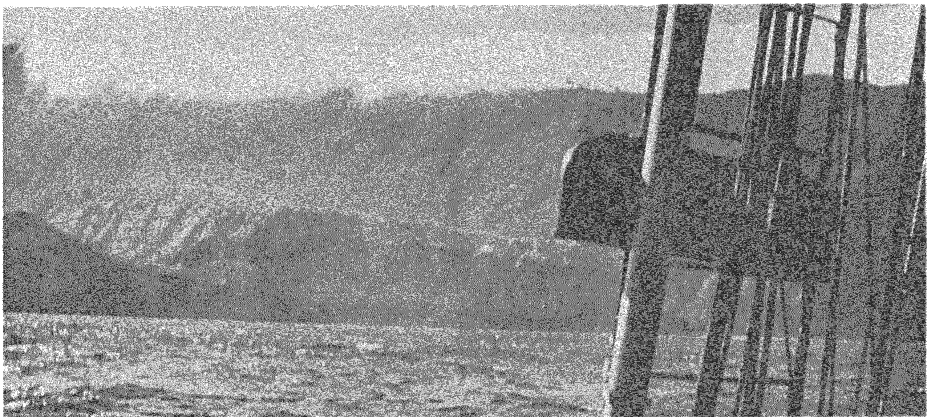

FIGURE 2. NORTHEAST SIDE OF GUADALUPE ISLAND
Landward of the cirque-like indentation in the submarine slope. The streak on the cliff represents an ash bed. The typical fog cover of the north end of the island is also shown.

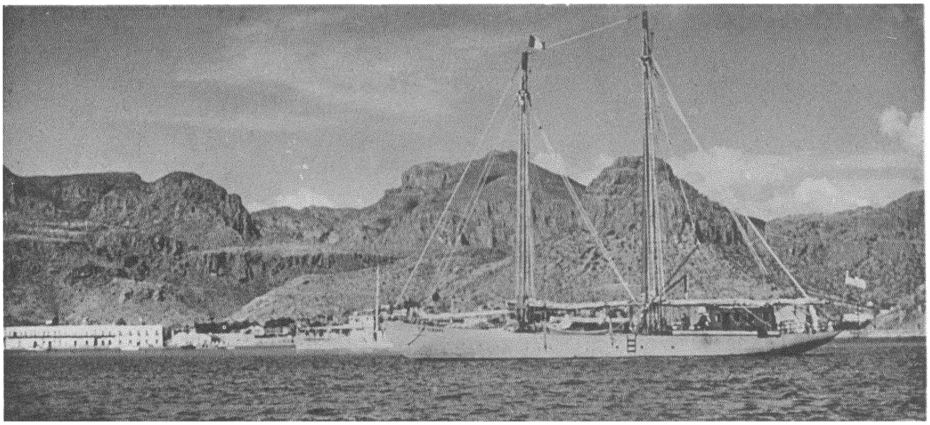

FIGURE 3. *E. W. SCRIPPS* AT ANCHOR
In Guaymas Harbor, which is a drowned valley.

COASTAL VIEWS IN THE GULF AND OF GUADALUPE ISLAND trast to much steeper slopes beyond. At the head of the Gulf there is a broad shallow-water area which is in a sense a shelf, although it does not terminate outward with the usual abruptness of a typical shelf.

Farther south the continental shelves are inconspicuous and are confined almost entirely to the east side. On the west, deep water extends in close to the land except in a few localities where shelves a few miles wide are encountered. Even on the east side shelves are lacking at some localities. Off the southwest side of Tiburon Island (Chart III) the water deepens rapidly. Off the area west and north of Guaymas (Chart IV) the 100-fathom curves approaches the coast, and there is no indication of abrupt steepening beyond this depth. Similarly off Point Lobos there is no appreciable shelf.

To appreciate the significance of the virtual absence of shelves, it should be borne in mind that shelves, many miles wide, occur off practically all other coasts of the continents. In general, the coasts known to have been free from diastrophism in recent periods have wide shelves, while those that have had Tertiary or Quaternary movements have narrow shelves. Shelf widths are also commonly related to the steepness of the coastal area; wide shelves are found off coastal plains, and narrow shelves off mountainous coasts. The shelves in the Gulf of California conform to both these rules since they are conspicuous only on the east side off the coastal lowlands, which appear to be largely deltas. Also, the west side has many indications of recent diastrophism.

Considering the origin of shelves in general, their absence in areas where there has been recent large-scale faulting is understandable. A shelf may be cut into a coast as the result of wave erosion producing a wave-cut terrace, or a shelf may be formed as a result of subsidence of deltas or other coastal lowlands. Wave-built terraces may constitute another origin, but the abundance of chart notations of rock bottom on the outer shelves and upper continental slopes off the areas where wave-built terraces might be expected leaves little support for these purely hypothetical features. In stable areas, the gradual eating into the various coasts has produced the shallow-water shelves, but in areas of recent faulting there has been no time for such cutting. Also previously cut shelves in faulted areas are likely to have been either deeply submerged or elevated above sea level.

Along portions of the west coast of the Gulf wave-cut cliffs are bordered by narrow terraces not exceeding a few fathoms in depth. Some of these can be seen through the clear water. On the east coast, however, the sea cliffs, insofar as could be determined, have rather deeply submerged terraces adjacent to them. The cliffs off the headlands around Guaymas (Pl. 1, fig. 1; Chart IV) appear to extend below water to depths of around 25 fathoms. Beyond that, there are narrow shelves. Also the rocky island of San Ignacio Farallon (Chart II) has abrupt cliffs on all sides, and a platform around it lies at a depth of about 30 fathoms. Probably these terraces have been submerged, and the absence of wave erosion at the present level suggests very recent submergence. As further indication of the same conclusion, the indented shore around Guaymas has only insignificant bay-head deltas (Chart IV). Also elevated terraces, common on the west coast, are conspicuously absent on the east coast.

If, as seems likely, the east coast has recently been submerged, the shelves may be the result of the sinking of the deltas. The relatively gentle, even slope may be due to the submergence of alluvial fans. The narrowness of the shelf off points such as Point Lobos and Isla de Santa Maria is probably due to recent encroachment by the formation of cuspate forelands. The southeast coast of the United States shows an example of the same thing, particularly where Cape Hatteras has been built out across most of the shelf. The narrowness or virtual absence of the shelves off the mountainous coast north and west of Guaymas can be explained by this submergence, since the submergence of a mountain range would not produce a terrace.

In many textbooks offshore bars or barrier beaches are referred to as characteristics of shore lines of emergence. Objections to this practice have been mentioned elsewhere (Shepard, 1937, p. 604–605). While such bars may develop as the result of either emergence or submergence, many of the best examples are found off delta coasts which have been recently submerged. Russell (1936) called attention to their development off the submerging Mississippi delta, and they are found off many other large deltas where submergence is highly probable, due both to compaction of delta sediments and to sinking of the earth's crust. The presence of bars along with evidence of submergence on the east side of the Gulf adds weight to this contention.

SUBMARINE SCARPS AND TROUGHS IN THE GULF

GENERAL

Search for fault scarps on the sea floor is impeded because outcrops and structural indications of faulting are not visible except where the upper portions rise above the surface on islands or the mainland. Dredging on the rocky slopes which are so common on the sea floor might yield this structural evidence. In the cruises to the Gulf of California the crowded program did not permit any dredging, although a few rock samples were recovered in a clam-shell snapper devised by K. O. Emery.[4] On the other hand, submarine fault scarps are not subject to the subaerial erosion[5] which has so modified many land fault scarps as to make the character of the fault, or even its existence, difficult to recognize. Some qualification of this statement is probably necessary, since there is evidence that many submarine slopes have been eroded subaerially at a time or times probably not later than mid-Pleistocene (Shepard and Emery, 1941, p. 126–133). However, much faulting has occurred since that time along the Pacific Coast and numerous submarine escarpments lack the canyons which are indicative of subaerial erosion[6]. Where free from thick sediment mantles, these submarine slopes should give a truer picture of the topography of unmodified fault scarps than is found on land. The soundings of the escarpments and basins of the Gulf provide such information and are therefore considered for each area.

ANGEL DE LA GUARDA-TIBURON AREA

The northernmost basin in the Gulf (Chart III) is unusual in its narrowness and the steepness of its walls. The basin extends for about 130 miles; its northern termi-

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[4] For a more recent model *see* LaFond and Dietz (1948).

[5] As yet the ideas suggested by various authors of important submarine erosion have received no appreciable support from field investigations (Shepard, 1948, p. 207–250).

[6] Recent tape recordings have revealed the existence of small canyons along some of these slopes.

nus is about 40 miles north of Angel de la Guarda Island, but its deep portion lies between Lower California and the string of islands extending from Angel de la Guarda to San Lorenzo. Between the islands and shore the basin does not exceed 10 miles in width. In this section, wall slopes up to 45° were found. This basin compares with Death Valley in the height and steepness of its wall (Fig. 2); however, its floor is narrower and is even *V*-shaped in some sections. The walls rise about as high as those of the Grand Canyon, but have a considerably greater average declivity, although a more uniform slope. Along its length this basin alternates twice between a *V* shape and trough shape (Chart III). The *V*-shaped zones trend north-northwest. while the broader trough portion trends north. The east side of Angel de la Guarda also trends north.

Consideration of the cross sections alone might suggest that river erosion was involved in the production of some of the relief, but, since the *V*-shaped portions extend to the greatest basin depths, rivers could not have been involved.[7] So far as the structure could be observed from the E. W. SCRIPPS in skirting the shore, folds appear to have been truncated diagonally by the escarpment (Pl. 1, fig. 2) as would be expected if faulting were the cause. The narrowness of the shelf adjacent to the islands on the east side of the trench suggests relatively recent movement. The cliffs along the side of the islands have facetted spurs which are not due to wave erosion since submerged terraces are absent along the coast. The submerged walls of the basin are straight, contrasting with the exposed portion of the walls which are creased with canyons.

Of further interest is the bend in the axis of Sal si Puedes Basin observable in the vicinity of Las Animas Bay. Similar bends are found in the submarine basins of the Gulf.

Between Tiburon and Angel de la Guarda islands another extensive basin[8] of much less impressive vertical dimensions—Tiburon Basin—is saucer-shaped and, except in its southeastern extension between San Esteban and Tiburon, is characterized by gently sloping walls.

CENTRAL GULF AREA

South of Tiburon Island, the Gulf (Charts I, IV) consists of a broad trough bounded by relatively steep slopes on both sides and cut off by a northwest-trending escarpment on the north in the same way in which the head of the Gulf is terminated by a northwest-trending shore line. Within the trough there are many irregularities, undoubtedly even more than have yet been discovered. The most impressive features within the trough are the zig-zag-trending basins which alternate in direction between northwest and north. Where the trend is north the basins are considerably wider than where the trend is northwest. Also, with one exception, the deepest zones trend northwest. The same tendency is developed on a somewhat smaller scale in Sal si Puedes Basin in the northern area. Also the changing trends of

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[7] Another *V*-shaped depression off southern California appears to be explicable as the result of diastrophism (Shepard and Emery, 1941, p. 21–25).

[8] The sill of this basin between San Lorenzo and San Esteban is based on temperature observations which show that this passageway must have a sill not deeper than 200 fathoms. The rim depth is indicated where the temperature gradient ceases.

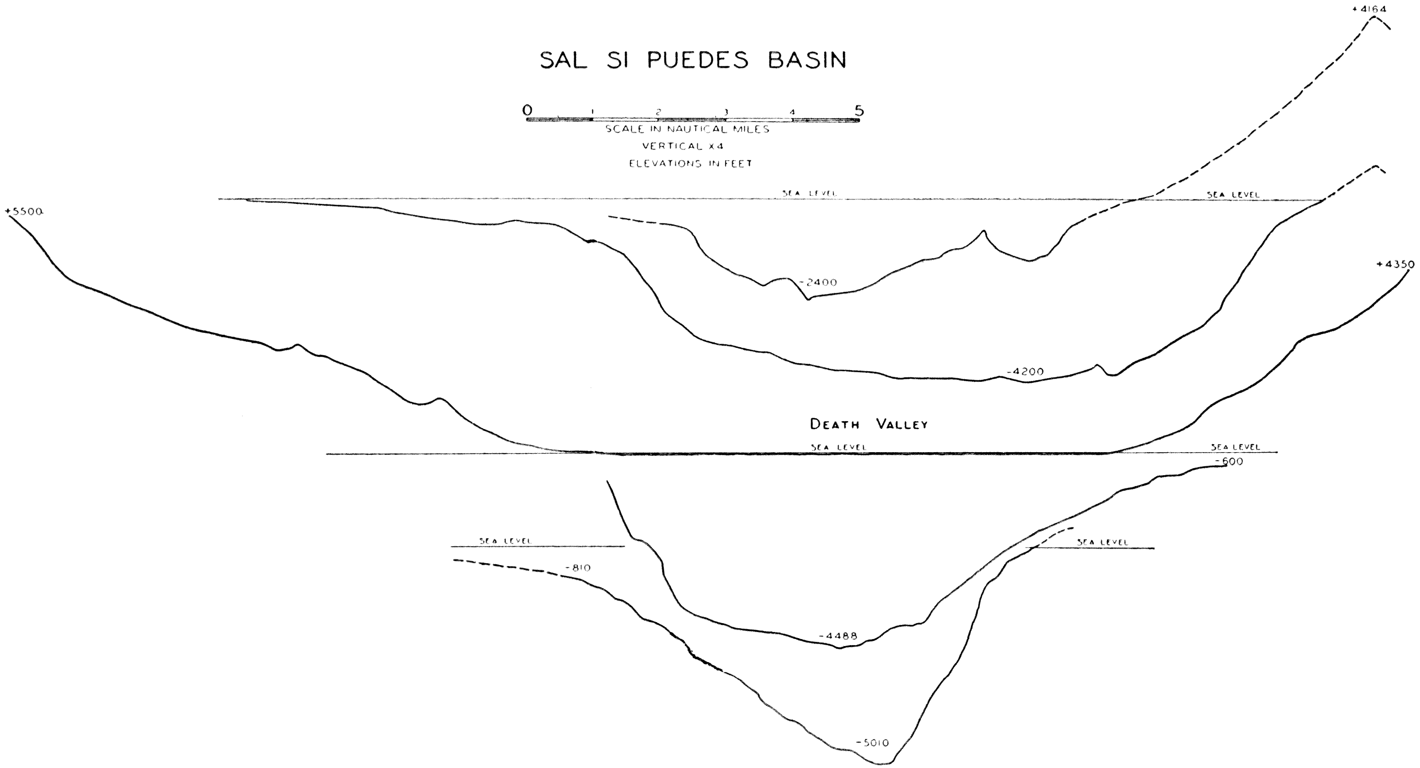

FIGURE 2.—*Sections in Angel de la Guarda area compared with Death Valley*

Note that the sea-level line for Death Valley is the same as for the submarine trough below. *See* Chart III.

these central basins are reflected in the bends of the east coast, suggesting a genetic relationship.

Several of the sounding lines (Pl. 3) show deep terraces terminated by abrupt slope changes. Rock was discovered at several places on these slopes. The deepest portions of the Gulf lie at the foot of these inner slopes. Insofar as could be determined, the deep portions of the inner basins are relatively short. The deep zone northeast of Carmen Island called Carmen Basin (Chart IV) was the most nearly completely surveyed, and this terminates rather abruptly at both ends, much like Saline Valley in southeastern California (Ballarat quadrangle).

Withdrawal of the sea would leave a lake in the central Gulf approximately 240 miles long and about 25 miles wide, giving it an area of approximately 6000 square miles.[9] The deepest portion called Farallon Basin, is particularly impressive. It has a depth below sea level of 1765 fathoms (10,590 feet), with a sill depth of about 900 fathoms (5400 feet), giving it a basin depth of 5190 feet. For comparison, Crater Lake, the deepest lake in the United States, has a maximum known depth of 2000 feet, but Saline Valley has a floor depth below its rim of 3900 feet. Lake Baikal, the deepest known lake in the world, has a measured depth of 4997 feet. Therefore, the Gulf basin is deeper than any known lake.

CONCEPCION BAY AREA

In Concepcion Bay (Chart V) a shallow inner depression contrasts with the deep troughs elsewhere along the west side of the Gulf. The water in Concepcion Bay does not exceed 20 fathoms and varies little along its length of 24 miles. This bay follows the structural trend. The trend of the bay bends similarly to that of Sal si Puedes Basin, and another structural offset in the same direction is suggested by the near-by Santa Ynez Point. Also there is a shallow channel at the southern end of the strait inside San Marcos Island. To the north a few soundings show that this inner depression becomes very deep.

North of Concepcion Bay there is a shelf 8 miles wide; this shelf may be a filled portion of one of the inner channels just as Concepcion Bay seems also to have been filled. Outside the island and north of Santa Ynez Point the shelf is very narrow and is bordered by a steep escarpment which has a maximum slope of 17°. This is a continuation of the same escarpment which extends south well beyond Illdefonso Island. Beyond this escarpment the slope is very gentle and extends uniformly into a central basin which has no pronounced inner deep at this point.

CARMEN ISLAND AREA

The area around Carmen Island is characterized by a structural trend transverse to the general course of the Gulf (Chart VI). The island trends well to the east of north, and both troughs and ridges north of it have similar trends. The east and west coasts of the main portion of the island are bounded seaward by straight, steep scarps, lacking valley indentations. The soundings indicate that there is scarcely any shelf on either side of the main portion of the island. Also deep water is found at a very short distance from the southwest coast.

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[9] This may be compared with 9960 square miles for Lake Erie.

The escarpment on the east side of the main portion of the island cuts across the strike of the formations on land. It trends northward into a land escarpment which lies west of the salt flat shown on the map. Anderson found that this land slope is a fault scarp; he also found another fault scarp on the east side of the salt flat. The elevated area farther east appears to be a horst which can be traced southward as a submarine ridge extending through Monserrate Island down to Marcial Point on the mainland. The irregular deeps west of this ridge are in line of continuation with the salt flat area on Carmen Island.

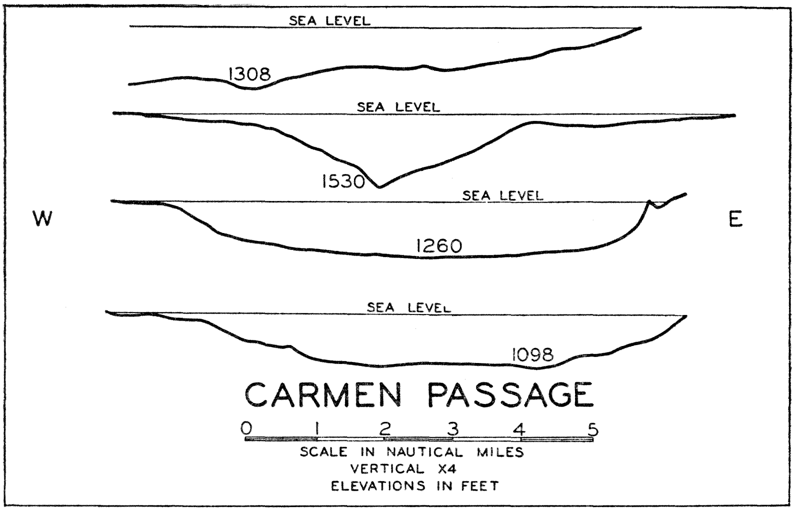
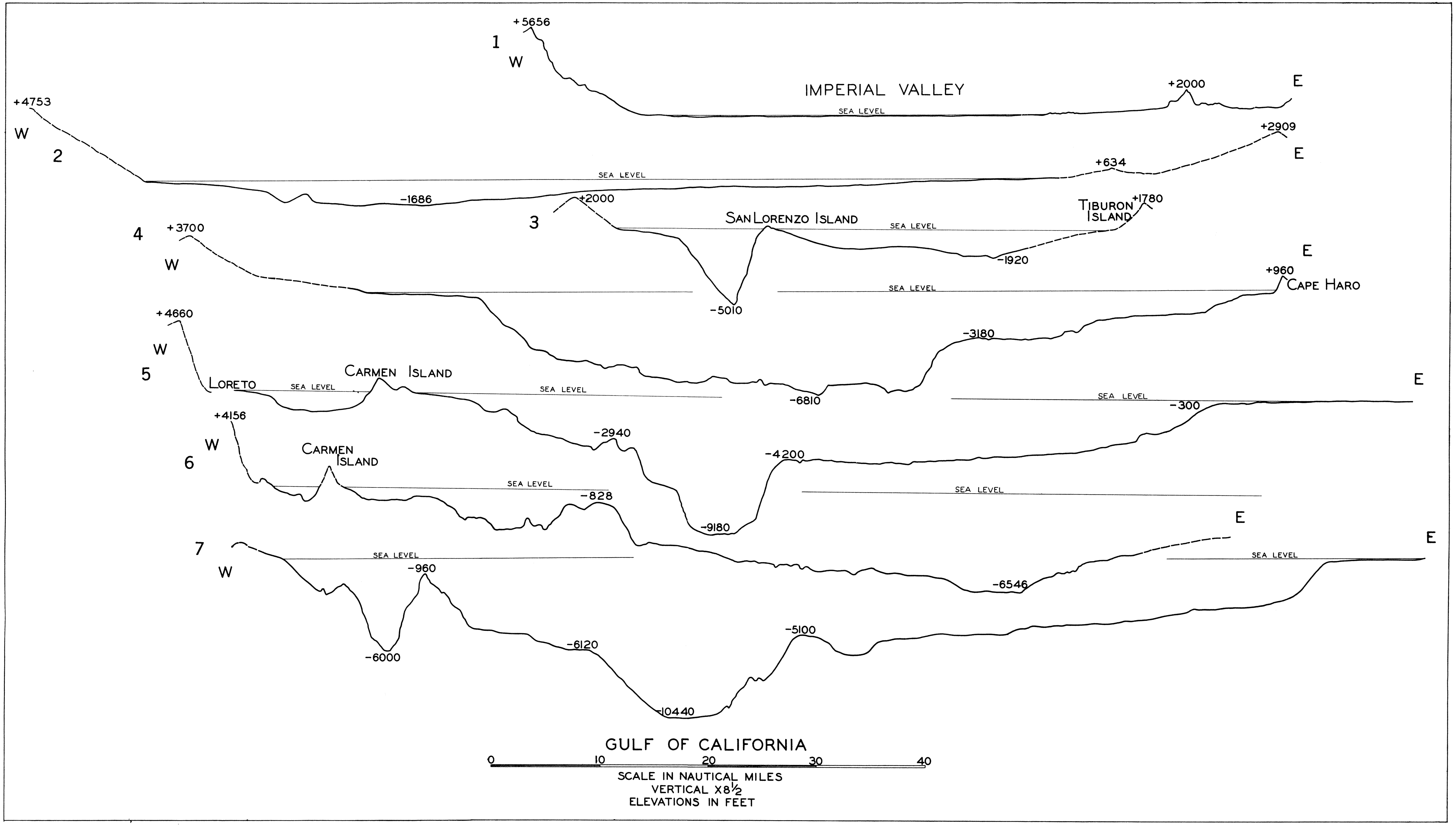


FIGURE 3.—*Sections of Carmen Passage*

The V-shape section is opposite the volcanic Coronados Island. *See* Chart VI.

Carmen Passage on the west of Carmen Island differs from Concepcion Bay to the north in its greater depth and in being open at both ends. South of Coronados Island (Fig. 3) this bay has the characteristics of Sal si Puedes Basin in that there is a narrow, rather V-shaped arm to the south trending north-northwest, and this extends into a much broader basin which trends a little east of north. However, in the vicinity of Coronados Island the similarity to Sal si Puedes Basin ceases. There is a section here which is V-shaped, but the trend does not change to the north-northwest, although the shore line of Carmen Island bends to the north in this vicinity, and a submerged projection also extends north of the island. Probably the V shape indicated at this place is due in part to the seaward growth of Coronados Island which is a volcano. There is some indication of a continuation of the trough north of Coronados Island (Chart IV).

The granitic Catalina Island appears to be separated from the Monserrate ridge by a deep channel, although the exact nature of this channel has not yet been ascertained. A northward continuation of Catalina Island was found in the form of a curving ridge. A sample indicated that there was rock bottom on this ridge, although the character of the rock was not determined. On the outside of this ridge an escarpment



GENERAL SECTIONS ACROSS THE GULF OF CALIFORNIA AND ACROSS IMPERIAL VALLEY AT THE HEAD OF THE GULF

Gaps in sections represent points where slight diagonal offsets were made.

slopes 15° down to the 600- to 700-fathom plateau. At the base of this escarpment a small depression was discovered. Recent faulting on land both in Carmen Island and Monserrate was indicated. Anderson discovered that the elevated wave-cut terraces of Monserrate were faulted, and the writer found the same to be true of the terraces in the center of Carmen Island.

SANTA CRUZ ISLAND AREA

Twenty miles south of Catalina Island, Santa Cruz Island, another granite mass, rises very abruptly out of deep water with straight cliffs (Pl. 1, fig. 3; Chart VII). A little over a mile southwest of the island, the water is over 400 fathoms deep. A sounding line about a mile north of the island shows a knife-edge ridge rising to a peak of 118 fathoms and sloping approximately 25° on either side. Southeast of the island a trough about 250 fathoms deep is succeeded by a ridge rising to 125 fathoms. This ridge appears to be a northward continuation of San Diego Island. Beyond this ridge the descent to 500 fathoms is especially abrupt with declivities of about 30° in one place. Off Las Animas Rocks a depth of 940 fathoms was observed at a distance of approximately 2 miles, so that the average slope is 25°.

The passageway inside Santa Cruz Island is comparable with Carmen Passage, except for the lack of a volcano at the north end. The northern portion of this passageway has a broad trough shape with a north-south trend. To the south between San Jose Island and the mainland there is a much narrower passageway with the usual north-northwest trend. No lines were run in this passage, but the available Navy soundings indicate it is comparatively deep and probably V-shaped.

CERALBO ISLAND AREA

Ceralbo Island (Chart VIII), another granitic island, represents the southernmost of the chain of islands along the west side of the Gulf. The east side of Ceralbo, as observed from the sea, looks like a typical basin range fault scarp. The submarine escarpment on this side is a continuation of the mountainous slope of the island, except that the former is virtually free from slope indentations. It descends in about 3.5 miles to the floor of a deep basin. Somewhat south of the island this basin has its greatest known depth of 1000 fathoms. This basin is another one of the roughly *V*-shaped troughs, although there is some flattening at the bottom. Like the other narrow troughs, it has a north-northwesterly trend. While the soundings are not complete there is some indication that this basin may run into a broader north-trending trough north of Ceralbo Island.

The slope into the basin on the east side of Ceralbo Island appears to be a direct continuation of the island scarp with no intervening wave-cut platform. The declivity varies from about 20° at the north to about 10° at the south.

EASTERN GULF AREA

The submarine slopes on the east side of the Gulf appear less precipitous than those on the west. This is certainly the case north of Guaymas, except southwest of Tiburon near San Pedro Nolasco. Between latitudes 27° and 28° very gentle slopes are indicated, although soundings are so scattered that escarpments may exist. South of Guaymas and south of Point Lobos (Lat. 27° 20′) steep slopes exist, and an impressive escarpment was found south of San Ignacio Farallon Island. As possible indication that, at least, these steeper slopes have rock foundations is the finding of rock off Guaymas at the edge of the shelf and on the submerged hills 10 miles west of Point Lobos. Further evidence of the nature of the outer slopes is provided by the rocky islands near the outer edge of the shelf in three places off the east coast.

A notable feature of the eastern slopes is their angular pattern. There appear to be the same two trends, north and northwest, which are found in the Gulf basins and in the escarpments of the west side.

ORIGIN OF THE GULF ESCARPMENTS AND BASINS

GENERAL

The preceding description of the escarpments and basins provides a basis for considering the origin of these features. It is evident that diastrophism in some form has been responsible for the formation of the deeply submerged basins, but this does not of itself prove that the escarpments on the sides of the basins are fault scarps. In addition to faulting, escarpments are known to be due to erosion, deposition, and warping. Davis (1903), Gilbert (1928), and Blackwelder (1928) provide abundant criteria for recognizing various types of scarps, particularly fault scarps. However, no one has discussed in detail the origin of submarine escarpments, presumably because until recently so little was known of these features. Therefore, the ways in which the submarine escarpments of the Gulf might have been formed and the criteria which could be used to differentiate them will be considered. These submarine escarpments might have been formed by deposits built out over a gentle slope like the foreset beds of coalescing deltas or the advancing slope of a wave-built terrace. The outward growth of a coral reef encroaching onto its own talus, as described by Daly (1916), could produce an escarpment. Escarpments cut by river erosion or by wave erosion can become submerged. Downwarping of a gentle slope could form a submarine escarpment, and finally downfaulting of blocks of the crust could form the scarps. Of course, deposition could modify escarpments made by any of the above methods.

The works of other writers, especially Gilbert (1928) and Blackwelder (1928), are used freely in discussing the criteria or characteristics used to determine the origin of the escarpments in the Gulf of California from the soundings and other available information.

Scarps due to coalescing delta fronts could be distinguished by:

(1) Existence of the scarps off areas where a series of rivers come to the coast.

(2) Declivities comparable with those off deltas known to have been built onto gently sloping sea floors. (This criterion is rather limiting insofar as the Gulf scarps are concerned, since the foreset slopes of most deltas are very low, the Mississippi, for example, is only about 0.5°, the Niger 1.0°, and the Nile 1.0°. Steep slopes are found off deltas built onto steep marine or lacustrine slopes where the steepness was anticedent.)

(3) Arcuate outbends of the escarpment off the principal land canyons or river valleys.

(4) General absence of rock on the escarpments.

(5) Gradual decrease of the steepness of slope at depth and gradation into the floor of the outying basin.

(6) The topset delta area should be found along the coast.

Scarps due to outbuilding by wave-built terraces are more difficult to distinguish because diligent search and inquiry for some years has revealed no clear examples of this type of feature, nor does the literature afford much help. However, if they do exist, as some writers seem convinced, we can assume that they would have some of the following characteristics:

(1) They should conform with deltaic foreset slopes in items (4) and (5) listed above.

(2) They should be found off wave-cut terraces and thus would be absent where no continental shelf existed.

(3) Steep slopes should be rare.

Scarps due to encroaching coral reefs should show:

(1) Broad coral flats or barrier reefs inside the slopes.

(2) Coral talus on the slopes.

(3) Evidence that the area is or was one of extensive coral growth.

Submerged river eroded escarpments might be distinguished by the presence of:

(1) Submerged valleys or canyons cut into the face of the scarp while it was above sea level.

(2) Longitudinal river valleys at the base of the scarp.

(3) Hogbacks or hard layers parallel to the scarps on the islands and along the coasts inside the scarps.

Submerged wave-cut cliffs should be distinguished by:

(1) Drowned valleys and canyons cut in the scarps as in the preceding group.

(2) Presence of wave-cut terraces at the base of the escarpment.

Submarine scarps due to downwarping should have the following accompaniment:

(1) Formations on the adjacent land with predominant seaward dips and strike, in general, parallel to the coast.

(2) Submerged valleys where subaerially eroded slopes had been warped below the sea.

(3) Gradation into the submarine basins below, rather than sharp angular contacts with these basins.

(4) Great variation in declivity along the scarps.

Submarine scarps due to faulting should be recognized by:

(1) Relatively high slopes.

(2) Straight slopes.

(3) Depressions at the slope base, both trench-like depressions of the rift type and elongate basins like the Dead Sea or Death Valley.

(4) Occurrence of rocks on the scarps (which might also be found on downwarped slopes).

(5) Absence of submarine valleys and canyons, unless the foot wall had been depressed, which would be rather unusual, or if changes of the sea level had occurred subsequent to faulting.

(6) Longitudinal continuation of the submarine scarps into land scarps where evidence of fault origin could be found from field studies.

(7) Truncation of the formations on land by the emerged portions of the scarps along a coast which lacked a submerged shelf.

(8) Presence of triangular facets along the coasts inside the scarps, a criterion becoming doubly significant where shelves did not exist along the shore.

If the fault scarps were recent they should show:

(1) Absence of wave-cut terraces or shelves along the coast.

(2) Earthquake evidence supporting their fault origin.

(3) Angular contact with the adjacent submarine basin (since deposition would not have had time to round off the slope).

ORIGIN OF WESTERN GULF SCARPS

If the preceding criteria are reliable, there appears to be no great difficulty in deciding the most likely mode of origin of the escarpments and basins of the western Gulf, particularly the escarpments along the coast and next to the islands on the western side of the Gulf. Here origin by deposition encounters many difficulties. Coral outgrowth is ruled out because reefs known in the area are of negligible dimensions, and no broad coral flats were seen along the coast. Deltas are virtually absent along the entire west coast, and the slopes of the submarine scarps are too steep and too straight to suggest foreset beds of deltas. The absence of any appreciable wave-cut benches along the precipitous coasts goes far to invalidate the wave-built terrace idea for the scarps. All depositional origins are opposed by the abrupt break in slope at the foot of the escarpment in various places. Also the finding of rock on the scarp faces at most places where tests were made is irreconcilable with depositional origin.

Possibly a small percentage of the scarps on the west side of the Gulf could be submerged river-eroded escarpments, but the great majority lack submerged valleys, except at the southern extreme of the peninsula, extend down into basins rather than into submarine canyons parallel to the scarps, and in only a few places do tilted resistant layers extend along the coast. Therefore this origin is very unlikely.

Nor is the hypothesis of submerged wave-cut cliffs supported since, in addition to lacking submerged valleys and extending into basins, the slopes have no terraces which could have been wave-cut during the submergence.

For many of the escarpments in the west Gulf, downwarping cannot easily be disproved, but nothing was found favoring the idea. No localities were noted where the formations dipped seaward parallel to the scarps. The absence of drowned valleys and the presence of sharp contact with the adjacent basin floors both oppose the downwarping origin.

The following points favor faulting as the basic cause of the west coast scarps:

(1) Truncation of structures on the exposed portions of the escarpments along the coasts of the islands and the mainland in many places as, for example, at Angel de la Guarda (Pl. 1, fig. 2).

(2) Common occurrence of facetted spurs along the island fronts above the submerged scarps (absence of a shelf indicates that these were not wave-cut facets).

(3) Straightness of the scarps for distances comparable to those of fault scarps in southern California.

(4) Depressions at the base of the scarps and deep trenches parallel to them.

(5) The finding at Carmen Island that a submarine scarp, similar to the others, traces northward into a land scarp where faulting could be demonstrated.

(6) The two trends of scarps which appear to have some tectonic significance.

(7) Determination of earthquake epicenters in the vicinity of the northern scarps (Richter, 1940).

ORIGIN OF EASTERN GULF SCARPS

Much less information is available concerning the east Gulf escarpments except in a few areas. The scarps in the vicinity of Tiburon have the same indications of fault origin as those on the west side of the Gulf. Insofar as known the east Gulf scarps are as straight as those on the west, and they have the same zigzag pattern and the same two trends. The slopes into the inner basins in the central Gulf area are as steep on the east side as on the west. Rock was found in a few places on the east coast scarps. On the other hand, some of the east Gulf submarine slopes may have a depositional origin since, judging from a small number of available soundings, in some areas the slopes off river valleys are gentle. The best example is off Mayo River. Somewhat opposed to a depositional origin is the failure of the slopes to bend out in arcs around the main rivers.

FAULT SCARPS OF THE SEA FLOOR COMPARED TO LAND

Studies in the Great Basin indicate that most normal faults have relatively high angles but range from 19° to 70° (Gilbert, 1928, p. 48). If the escarpments in the Great Basin were due to normal faults, their original slopes should have been precipitous, averaging about 45°. On the other hand, submarine escarpments, particularly those which are not cut by submarine canyons and thus appear to postdate the canyon-cutting period (if there was such a period), should give a more accurate representation of the true angle of slope resulting directly from the fault movements. Of course, the submarine fault scarps, even if virtually free from erosion, may have been modified by deposition. In some places, samples from these slopes indicate their rocky nature, but elsewhere deposition may have reduced the slopes.

To compare land and sea scarps, 50 escarpments of presumed fault origin were measured from topographic maps of California and Nevada. These land slopes are plotted to the nearest 5° (Fig. 4). Most of the slopes are between 5° and 15° with a mean value of 12° and a median of $11\frac{1}{2}$°.

Profiles based on echo soundings show slopes of somewhat lesser angle than actually exist, but, as Veatch and Smith (1939, p. 56–61) have shown, the application of slope corrections is both difficult and impractical. The differences, except for slopes steeper than most of those in the Gulf, are insignificant. With this point in mind, 50 sounding profiles, more or less directly crossing the pronounced escarpments in the Gulf, were measured. The steepest portions of the slopes ranged between 5° and 15°, with a mean slope of 13° and a median of 12°. This suggests that these scarps on the sea floor are, in general, no steeper than the fault scarps of Nevada and southern California. Kuenen (1935, p. 25) suggests that a considerable blanking out of the echo followed by marked change in depth may indicate a steep fault scarp. He considers that such scarps were discovered by the SNELLIUS expedition in the

Dutch East Indies and in the Red Sea. Similar cessation of echoes was observed on both sides of the deep trough northeast of Carmen Island (Chart IV), but the interpretation of such slopes as high-angle escarpments is somewhat hazardous since echoes may fail to come in for other reasons, such as the roughness of the bottom or softness of the mud.

The relatively gentle slope of the Gulf escarpments will no doubt surprise many readers and may lead to incredulity regarding either the accuracy of the soundings or even of the fault origin of the slopes. However, the results agree with results from soundings along probable fault scarps off California (Shepard and Emery, 1941, Fig. 9) and other areas. In the California area there was even more evidence that the slopes were tectonic rather than depositional or erosional.[10] The greatest escarpment off southern California is closely similar in declivity to the greatest land scarp in the United States, namely the escarpment on the west side of Owens Valley (Shepard and Emery, 1941, Fig. 10). The submarine escarpment in question has yielded rock in several dredgings. Iddings and Olsson (1928) refer to the "Pacific fault" off the west coast of South America as having a dip of only 6°. This slope is remarkably even according to available soundings so it may represent the fault dip. Another prominent submarine escarpment generally considered to be of fault origin terminates the outer portion of the Blake Plateau east of the Florida coast and

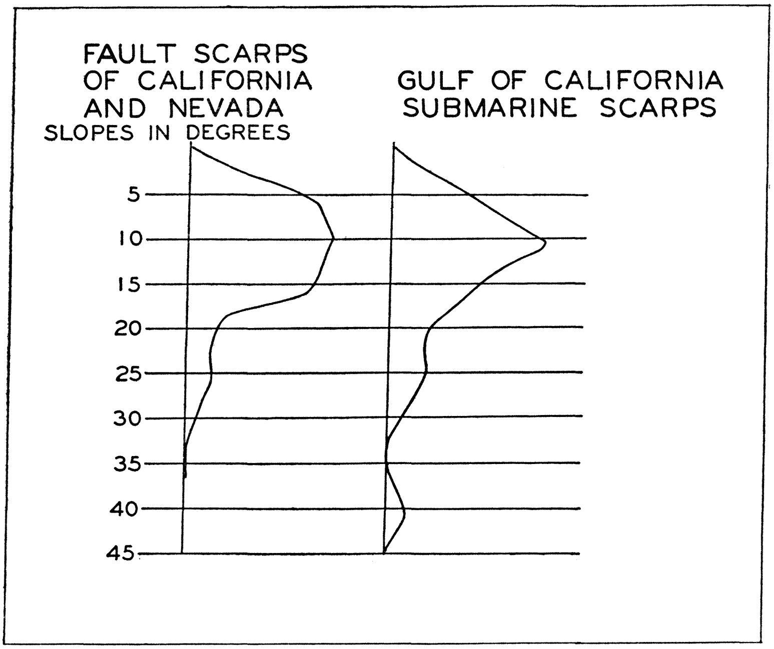


FIGURE 4.—*Graphic comparison of the inclinations of fault scarps of Nevada and California with supposed fault scarps of the Gulf of California*

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[10] Trenches found recently by R. S. Dietz along the base of some of these escarpments add weight to this interpretation.

has slopes of 5°, 7°, and 10°, respectively, according to three different profiles. The great submarine fault scarp south of the Cuba coast which extends down into Bartlett Deep has slopes of 15° to 35°. According to profiles of soundings of the Coast and Geodetic Survey (Murray, 1945) the steeper portions of the northern side of the great Aleutian foredeep have slopes of 5° to about 25°. The Tuscarora Deep off Japan has slopes up to 25°. The Mindanao Deep off the Philippines has slopes up to 30°. Around the Dutch East Indies a slope of 11° is found off Timor and of 33° on the north side of the Java Deep. Therefore, the slopes in the Gulf of California apparently are rather typical of submarine fault escarpments and do not differ greatly in declivity from land fault scarps of southern California and Nevada.

POSSIBLE EXPLANATION OF UNERODED LOW-ANGLE FAULT SCARPS

The discovery that the presumably uneroded scarps of probable fault origin on the sea bottom are closely comparable with fault escarpments on land is somewhat disturbing. Unless these sea scarps have been lowered by deposition, which seems unlikely because of occurrence of rock in most places where evidence is available, either the faults of the sea floor must dip much more gently than those of the land, or the land fault scarps have not been lowered as much by erosion as is commonly supposed. The first possibility is the less likely, since the Gulf of California appears to be very closely related to the structures of the continent and, in fact, is a southern continuation of a portion of the continent and lies between two continental masses. One would expect the faults of the Gulf to have characteristics similar to those of the adjacent land. Can it be that the fault scarps of the southwestern United States still have their slopes reduced only to a minor degree except where canyons are cut into them?[11] In view of the supposed recency of such fault scarps as the east slope of the Sierra Nevada (Matthes, 1939) one would expect precipitous fault scarps in the Great Basin wherever the rocks were resistant to erosion. However, no fault scarps have been reported with slopes at all comparable to the sides of such glaciated valleys as the Yosemite. Gilbert (1928, p. 14–18) refers to some cases where fault scarps have slopes comparable to the fault dips, but in these cases the faults all dip relatively low. Longwell (1945) calls attention to various low-angle normal faults in the Great Basin, some less than 10°. Possibly the formation of pediments at the base of fault scarps tends to maintain their declivity. Also the studies of Gilbert (1928) and others indicate that the great fault scarps may be the result of a series of step faults or of a fault zone, so that the net product is a relatively gentle escarpment resulting from a series of high-angle faults with depositional smoothing of the profiles.

POSSIBLE IMPORTANCE OF STRIKE-SLIP FAULTING

Examination of the various escarpments within the Gulf has shown that there is considerable complexity but that a definite pattern can be distinguished in many places. Narrow, more or less *V*-shaped troughs alternate with broad flat-floored troughs. The narrow troughs trend a little west of the north-northwest trend of the Gulf, and the broad troughs trend approximately north. The broad troughs have

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[11] It should be noted that the land profiles used in the comparisons avoided canyons.

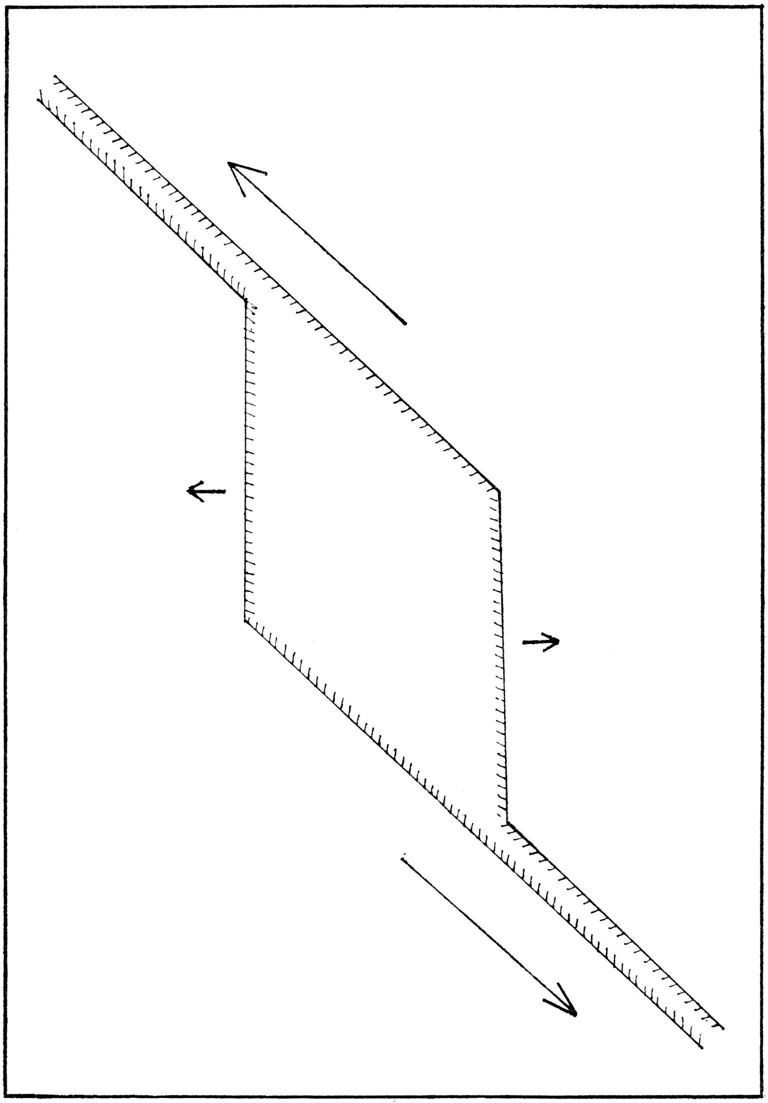

FIGURE 5.—*Rhombic shape of the basins*

Illustrating the possible nature of the forces which may have accounted for such development.

roughly a diamond shape. A generalized picture of this pattern is shown in Figure 5. It may be significant that this agrees closely with the pattern outlined by Hess (1932) for the deeps in the West Indies. An inverted mirror image of a diagram taken from Hess agrees with the directions in the Gulf. Hess suggested that this pattern in the West Indies was the result of forces acting from the west on the south side, and thus opening up Bartlett Deep. Whether or not forces of this type offer the solution either for the West Indies structures or those of the Gulf, the analogy is interesting, and particular significance may be attached to this suggestion in the Gulf, because the San Andreas fault extends down to Imperial Valley, and a strike-slip fault which had 15 feet displacement in 1940 crosses the Mexican border near Mexicali not far from the head of the Gulf. The well-known northwest shift of the southwest side of the San Andreas and associated faults would set up forces which would agree with those in Figure 5.

The above considerations suggest that horizontal shift forces may have played some part in the development of the structure of the Gulf just as they have in southern California.

AGE OF FAULT MOVEMENTS

Anderson found that movements on the islands and mainland adjacent to the Gulf may extend from Pliocene to Recent. The fault escarpments shown by the soundings in the Gulf cannot be dated accurately. In some cases post-faulting formation of wave-cut shelves is indicated landward from the escarpments. However, in most places there is so little evidence of important marine erosion into the coasts after the faulting that the sea coasts can be classified as fault coasts (Shepard, 1937, p. 617–619). The relative recency of the faulting is especially indicated by finding some coasts where transverse-striking formations of unequal resistance are bordered by escarpments without notable indentation of the softer formations. This is illustrated in the middle of the east coast of Carmen Island where Pliocene uplifted sediments lie adjacent to much more resistant volcanic rock formations.

As another indication of recent movements, earthquake records maintained at the Seismological Laboratory of the California Institute of Technology (Richter, 1940, and personal communication) indicate that "there are many shocks in or adjacent to the Gulf of California, some of them of large size . . . . The most active region is about latitude 29° north and longitudes 113° to 115° west." These limits are only very rough according to Richter, but they include the Sal si Puedes Basin. Also the determination of an epicenter of 31° 59′ N. and 115° 12′ W. for the large earthquake of December 30 and 31, 1934 (Richter, personal communication), places recent activity "in the line of the Cocopah Mountains just west of the head of the Gulf" (Chart I).

SUBMARINE CANYONS

DISTRIBUTION

The term submarine canyon as used here denotes a large feature having river-canyon characteristics which is cut into the submarine slopes. These canyons are roughly *V*-shaped, have long winding courses, and extend out from the lands toward the deeps without appreciable basin depressions along their length. By using this definition we can exclude from consideration the minor discontinuous indentations which might be found along almost any slope whether or not it had been subject to erosion. Applying this restricted definition, the submarine canyons in the Gulf of California exist only at the southern end. One series of canyons can be traced from a point a little south of Ceralbo Island around the southern tip of Lower California. Another canyon was surveyed on the east side of the Gulf off the prominent point of land just north of San Ignacio Farallon. There are some indications of relatively small canyons in lines south of San Ignacio Farallon, and there are extensive areas in which no soundings have been made along the same slope farther south. In most of the northern and central Gulf the soundings are sufficiently complete to indicate the absence of large canyons.

DESCRIPTION OF THE CANYONS

San Lucas Canyon.—The existence of a series of canyons around the southern end of Lower California (Chart IX) was indicated on the Hydrographic Office charts, although nothing was known about their extension into deep water. During the 1940 voyage to the Gulf the canyon that enters the Harbor of Cape San Lucas was surveyed (Chart X; Fig. 6, secs. A–E). By running a series of transverse lines, the canyon was traced outward to a depth of 1200 fathoms. A line run at greater depth was thought at first to indicate that the canyon had terminated, but, after another line was run in toward the coast, it became evident that the canyon might continue still deeper provided its axis curved to the southeast. Unfortunately, there was no opportunity to check this possible continuation.

The survey shows that San Lucas Canyon has the characteristics of the typical canyons off the California coast. Its head practically touches the shore in San Lucas Bay (Chart X). The Navy found water 50 fathoms deep at a distance of 1200 feet from shore, giving a slope of 12° from the beach out to this depth. The slope between 50 and 100 fathoms is 18°, which is comparable with the steepest gradients found in canyon heads off the California coast. Beyond 100 fathoms the gradient appears to be quite variable, but averages over 6° out to depths of 5000 feet and slightly over 4° from 5000 to 7000 feet. Comparison with gradients for canyons from other parts of the world (Shepard and Beard, 1938) shows that this is among the steepest of the canyons.[12] This high gradient helped in surveying the canyon; because of the small distance involved the same three shore stations could be used for sextant angles in almost the entire survey, allowing good co-ordination of the sounding lines. The gradient of the principal tributary from the east is surprising since it has a steep head, but farther out there is a distance of 5.7 miles between 660 and 715 fathoms, giving this section a gradient of only 0.5°. Possibly the two parts of this tributary, as it is shown on the map, do not actually belong together. All the lines normal to the canyon showed progressive deepening outward, but a few vertical cast soundings by the Navy indicate that there may be a small basin in the inner portion. However, with more complete soundings this depression may disappear as has happened to apparent basins off California when additional data have been added.

While the canyon extends transverse to the general slope direction, it has a winding course which persists out to the limits of the survey. Tributaries extend into the canyon with a somewhat dendritic pattern. In cross section (Fig. 6, secs. A–E), it is *V*-shaped, but the steepness of walls varies considerably. The canyon, therefore, has true river-valley characteristics. The name "gully" sometimes applied carelessly to submarine canyons would certainly be inappropriate for this canyon with its steep walls rising in places over 2000 feet above the floor. Comparison with land

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[12] Most of the steeper canyons referred to in the quoted article have not been traced out to such great depths as the San Lucas Canyon.

canyons shows that it must be similar to San Gabriel Canyon in southern California (U. S. Geol. Survey, Pomona quadrangle) or Virgin Canyon in Zion National Park, Utah (U. S. Geol. Survey, special map).

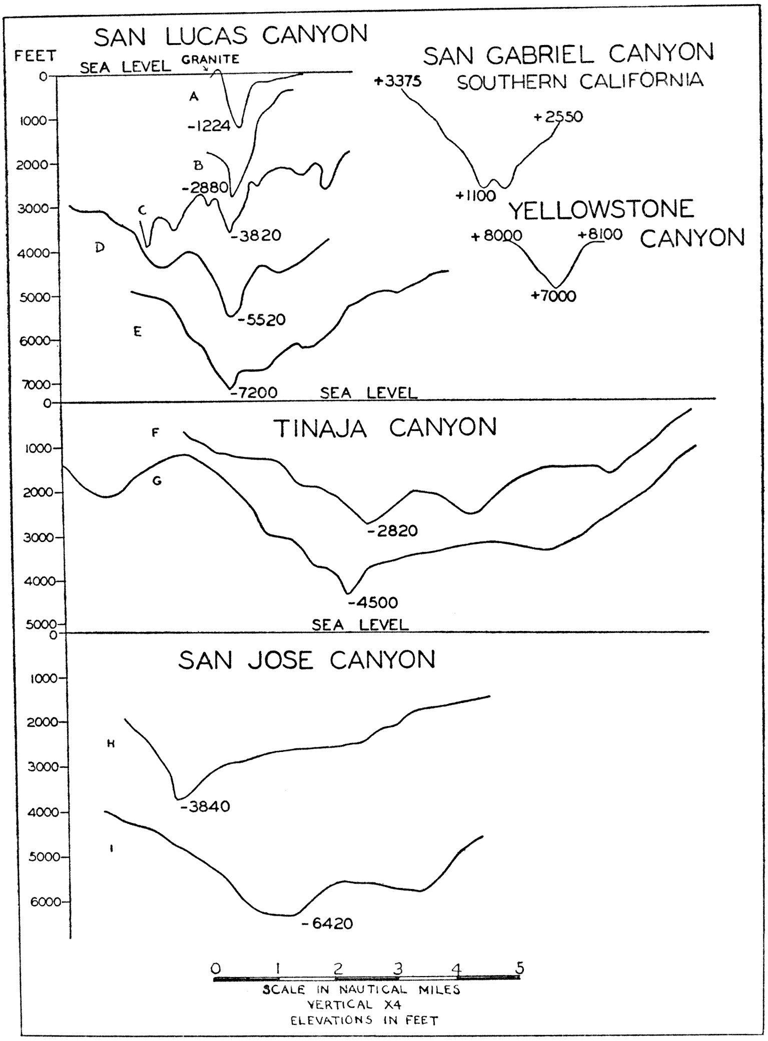

Figure 6.—*Sections of submarine canyons off the southern tip of Lower California*
Compared with land canyons. All sections have the same scales.

Unfortunately no opportunity was found to dredge the walls of San Lucas Canyon, but there is indirect evidence concerning the walls near shore. The promontory along the south side of San Lucas Bay consists of a series of pinnacles of granite (Fig. 6, sec. A; Pl. 2, fig. 1). Since the canyon has a steep wall which abuts against this promontory, it is reasonable to suppose that the canyon is also cut in granite. Furthermore, all the known rock of the southern tip of Lower California is granite.

Landward from the San Lucas Canyon, there is a broad valley which, from the sea, looks as if it had a pediment in its bottom. Judging from available maps, this valley is not one of the main valleys of the area.

San Jose Canyon.—A canyon even larger than San Lucas Canyon is located off the San Jose River which appears to have the largest valley of this area. The character of this canyon is not as well known as that of San Lucas. It does not come in quite so close to the shore as the latter, nor does it extend into such a prominent bight of the land. It appears to persist outward for about 22 miles to depths of 6400 feet, although the outermost line is rather widely separated from that next toward the shore. This canyon is also wider than San Lucas Canyon and has more gently sloping walls (Fig. 6, secs. H, I; Chart IX). The gradient is lower—about 3° out to 4000 feet and 2° from 400° to 6000 feet. It is, on the other hand, comparable with San Lucas Canyon in its twisting course and in the series of tributaries which join it, particularly from the eastern side.

A puzzling feature in the outer line which crosses this canyon is the relatively shallow depths on the ridges on either side of the canyon. The ridge on the east side of the canyon extends out in marked contrast to the relatively straight shore line inside. A great increase in irregularity of shore line would result from an uplift of this area.

Canyons and troughs west of Cape San Lucas.—The bottom configuration is even more remarkable off the west side of the lower end of the peninsula (Chart IX). However, some portions of this topography are not well established, particularly at the southern end where a few soundings were taken by the U. S. Navy toward the end of the last century and other soundings have been reported from various vessels. The elongate ridge that parallels the coast seems to be established beyond reasonable doubt, although its exact shape is uncertain. Tinaja Canyon, between this ridge and the land, was crossed by three of the E. W. SCRIPPS sounding lines. Prior to the running of these lines there was no evidence of a canyon here, although the outer ridge was indicated. The canyon is like those farther east. In cross section it is *V*-shaped (Fig. 6, secs. F, G). The three lines that cross it show progressive deepening to the south. It is cut deeper below its surroundings than either of the two main canyons to the east, having in one section (Fig. 6, sec. G) walls that are respectively 3300 and 4000 feet high. This section is about 6 miles across so it is comparable to most large land canyons. The northern lines indicate a series of tributaries entering the canyon from the east side. A possible tributary from the west side is also indicated by a depression in the southernmost line. The outer extension of the canyon is entirely problematical. The sounding of 1048 fathoms well out from the main part of the canyon may indicate an outer continuation. In the inner portion its axis drops from 470 to 750 fathoms in 9.7 miles, giving it a gradient in this portion of about 2°, which is less than in the other canyons. The course of the canyon is not definitely established.

The ridge which extends for at least 20 miles along the side of the canyon and may extend much farther differs from the ridge on the east of San Jose Canyon in that it does not deepen progressively to the south. One of the shoalest depths, 20 fathoms, comes from the southern limit of the soundings. The ridge appears to have two rises at the southern end, and the feature interpreted as a tributary coming into the canyon from the east may be a northward extension of the depression between the two portions of the ridge.

West of the ridge a broad trough also extends in the same direction as the canyons to the east. All the lines that cross this feature seem to substantiate its trough-like character. It certainly is not *V*-shaped. It appears to have a scarp of modest dimensions at its head, as shown by the close proximity of the 500- and 600-fathom contours. Another trough is indicated still farther west. The ridge separating these two troughs, like the ridge to the east, has hills along its course rather than a continuous southward slope.

Examination of Chart I shows that the canyons, the ridges, and the troughs west of the southern end of Lower California are all south of a chopped-off end of the continental shelf which extends south of Magdalena Bay.

Canyons south of Ceralbo Island.—Canyons are also found on the east side of Lower California south of Ceralbo Island (Chart IX). In this area the soundings are too scarce for accurate contouring, but the two sounding lines run by the E. W. SCRIPPS in 1940 confirm the presence of canyons which were suggested by the scattered Navy soundings along the coast.

These canyons occur along a coast having a very narrow shelf and have been cut into a steep slope, much of it steeper than 5°. Insofar as could be told, the canyons also have a high gradient; the most impressive canyon, just south of Los Frailes, has a gradient of about 6° out to 700 fathoms. The walls do not appear to be very precipitous nor are the canyons cut very deeply into the slopes; the maximum wall height is about 1500 feet. Nevertheless, their profiles indicate that these features are sufficiently impressive to justify the name canyon rather than "sea valley" which has been applied to some of the minor valleys of the sea floor.

The heads of these small canyons extend in relatively close to the shore. For example, the one south of Los Frailes has a U. S. Navy sounding of 140 fathoms at a distance of about 4500 feet from the shore. The head of this canyon is directly off one of the many arroyos of the coast. Other canyons appear also to be related to the land valleys although the data are too uncertain for definite correlations.

There is no evidence available regarding the nature of the walls of these canyons, but the canyon south of Los Frailes is probably cut into volcanic rocks since this headland has the appearance of volcanic rock. Pescadero canyon heading in Palmas Bay farther north may be cut into sedimentary rocks since the geological map (Anderson, Part I, Pl. 1) indicates that this area has marine Miocene on shore. We can conclude that the canyons off the southern end of Lower California are found alike off areas with intrusives, volcanics, and sedimentary rocks.

San Ignacio Canyon.—Along the east coast of the Gulf only one significant canyon was discovered (Chart II). This lies just north of the small island of San Ignacio Farallon and heads in toward San Ignacio Bay for which it is named. The survey of this canyon was handicapped because there was only the island for taking locations. Lines were run radially out from the island as much as possible, and log readings were used for distances. The canyon has a series of branches giving it a shape similar to that of Carmel submarine canyon off central California. There are indications that this canyon extends down the steep slope to depths of at least 1000 fathoms. If so, the canyon penetrates slightly below the sill level of the basin to the west. The gradient of this canyon averages about 5° between depths of 100 fathoms and 970 fathoms.

It may be significant that this outstanding canyon of the east side of the Gulf is located near the mouth of the Rio del Fuerte which appears to be the principal river entering on this side.

Possible submarine valleys within the Gulf.—It is by no means certain that submarine canyons are absent along the slopes of the inner Gulf. Examination of the charts shows that a considerable area is virtually unexplored. Elsewhere some indications of small valleys were found. Examples are to be seen in the relatively gentle slope off Guaymas (Chart IV). A valley may exist off the Yaqui River and may extend out to a depth of 900 fathoms. Some of the lines do not fit the valley concept very well, but survey errors could account for such discrepancies. Other valleys are suggested by the indentations in the gentle slope north and east of Carmen Island. These indentations do not resemble typical submarine canyons and may be due to diastrophic movements such as produced the ridges and basins of this area.

Single lines suggest the presence of submarine valleys in the slope south of Concepcion Bay (Chart IV) and in the slope southeast of San Ignacio Farallon Island. Also a valleylike feature appears to exist in the slope northwest of San Pedro Martir Island. One line along the escarpment off Ceralbo Island may indicate the presence of valleys, but a line run farther out from the island failed to show that the valleys persisted (Chart VIII).

Submarine slopes without appreciable valleys.—There is abundant evidence that long stretches of submarine slopes in the Gulf lack anything which remotely resembles a typical submarine canyon. The lines run along the steep fault scarps of the Angel de la Guarda area are particularly significant in this connection (Chart III). The indentations are readily explained as due to offsets in the fault scarps such as are found in all parts of the Gulf. Other scarps where canyons are conspicuously absent include the one south of Tiburon Island (Chart III), those on both sides of Carmen Island (Chart VI), and the escarpments in the vicinity of Santa Cruz and San Jose islands (Chart VII).

Gentle slopes in the Gulf are also free from canyons. Examples include the slope extending northwest from the Guaymas area, the slope outside Ildefonso Island (south of Concepcion Bay), and the slope north of Ignacio Canyon on the east side of the Gulf. Insofar as known, the very gentle slope south of the Mayo River Delta (central Gulf, east side) is also free from valleys.

The slopes along the west coast of Lower California are also virtually free from canyons. Sounding lines run both along steep escarpments and along gentle slopes verify this claim. There are some definite valleys near Ensenada, and San Pablo Canyon approaches close into the coast south of Cedros Island and extends along the north side of San Pablo Point, very much as does Dume Canyon along the side of Point Dume in southern California.

Slope indentations off Guadalupe Island.—En route to the Gulf, Guadalupe Island was visited to determine whether the submarine slopes of this truly oceanic island have canyons. A sounding line was run around the island, and three lines were run across a large slope indentation that was discovered. The results of this work (Chart XI) leave a little uncertainty as to whether canyons exist around the island. The soundings show decided indentations into the steep slope which surrounds the island. In cross section these features do not differ particularly from profiles of some submarine canyons. However, the only slope indentation investigated proved to be very different from all the well-sounded submarine canyons off both the east and west coasts of North America. It is cirque-shaped, and its head wall extends down directly from the land with a slope of at least 25°; the sides have approximately the same slope as the head. If there is any shelf along the coast, which seems unlikely, the slope at the head is even steeper. Photographs of the coast (Pl. 2, fig. 2) show that it is very steep, but the steepness may not be due to wave action, since the slope appears to continue below sea level.

Valleys with cirquelike heads found in the Hawaiian Islands have been attributed to stream erosion and the headward sapping of inclined layers of volcanic rock in areas with high rainfall (Stearns and Vaksvik, 1935). However, Guadalupe does not appear to have such cirquelike valleys on land, nor does it have the high rainfall of the Hawaiian areas. Furthermore most of the Hawaiian valleys become *V*-shaped downstream which apparently is not the case in the amphitheatre off the coast of Guadalupe.

The explanation of this cirquelike feature off Guadalupe may be connected with the vulcanism that appears to have played a major role in developing the topography of this barren island. Concavities in the sides of volcanoes are developed as the result of subsidence or explosions. This explanation for the submarine feature on Guadalupe Island appears to fit the situation somewhat better than erosion because:

(1) The feature differs from the valleys seen on the island.

(2) If the feature were due to erosion by streams followed by submergence, the submergence must have been very recent since there has been no appreciable shelf cut inside the slope. Recent submergence is unlikely since the shoreline should have more estuaries.

(3) The recent vulcanism would have probably filled canyons previously cut in the slopes of the island.

This submarine amphitheatre is similar to an indentation found on the side of San Juan Seamount (Shepard and Emery, 1941, Pl. 3, p. 27–29), a probable submarine volcano 150 miles off the coast of southern California. Supposedly, it is coincidental that both features were found on the northeast corner of a mountain mass. Both these mountain masses have approximately the same length and width which supports the volcanic origin of San Juan Seamount.

ORIGIN AND HISTORY OF GULF CANYONS

GENERAL

One aim of the 1940 expedition was to obtain new data relative to submarine canyons. This purpose was fulfilled (1) by obtaining more data relative to the character of submarine canyons; (2) by showing how features due to diastrophism or vulcanism can simulate submarine canyons; and (3) by showing more about the character of submarine slopes which lack canyons. The new data appear to support the following hypothesis of canyon origin: (1) that the canyons were cut by rivers; (2) that the submergence of the canyons is at least as remote as the Pleistocene; and (3) that some features considered as canyons may be of diastrophic or even volcanic origin and that diastrophism may have played an important role in the original shaping of some canyons. This last point may obviate the explanation of the very great depths of the canyons as due entirely to the submergence of subaerially cut valleys.

FAVORING SUBAERIAL EROSION

The following observations in the Gulf area either favor subaerial origin or oppose submarine origin:

(1) The canyons have the dendritic tributary system and winding courses so characteristic of subaerially eroded valleys.

(2) The canyons appear to slope outward along their courses and lack significant basin depressions such as would be expected if the canyons were cut by artesian springs (Johnson, 1939) or submarine landslides.

(3) The canyons are on too large a scale to be explained by excavation by bottom currents in the relatively short time available in this unstable area.

(4) At least San Lucas Canyon appears to have been cut out of granite where it enters San Lucas Bay past the granite portals and must therefore have required a powerful erosion agent such as a river.

(5) The granitic rocks landward of the Peninsula canyons are of a type that precludes extensive artesian spring sapping.

(6) Most of the canyons appear to be related to drainage systems on land.

(7) Existence of canyons all around the end of Lower California appears to be a serious objection to an origin by tsunamis (Bucher, 1940), since the waves would presumably have come from one side and be damped out on the opposite side.

(8) The absence of even small canyons[13] on the submarine fault scarps in contrast to the existence of large land canyons on the emerged portions of the fault scarps suggests that submarine erosion is incapable of duplicating subaerial erosion even on a small scale.

FAVORING PLEISTOCENE ORIGIN

If the islands and the mainland of Lower California were submerged, there would be many submarine canyons. In many places the fault scarps of the land extend deep beneath the adjacent sea, but the topography changes from deeply dissected slopes above water to slopes that are relatively straight and undissected. While the rainfall is somewhat less in the areas lacking submarine canyons, there are stream-cut canyons above the water line. It seems evident, therefore, that the submarine escarpments to the north have not been exposed to the erosion which has cut the slopes around the end of the peninsula. This might indicate either that there was differential movement which allowed the cutting of canyons to the south but not to the north; or the escarpments to the north resulted from faulting after the emergence which allowed the canyons to be cut. The following considerations favor the second explanation:

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[13] Because of the recent discoveries of small canyons along similar scarps in the California area, this statement appears to require verification with the new echo-recording devices. However, there is no doubt that the supposed fault scarps are far less dissected than the slopes around the end of Lower California.

(1) The escarpments free of canyons are in areas where the lack of wave-cut shelves suggests recent development of fault scarps.

(2) The canyons terminate where the fault-block islands and adjoining basins appear along the west side of the Gulf, and they are, therefore, missing in areas where recent diastrophism is particularly indicated. If, on the other hand, the canyons were the result of differential movements, they should be found where there are indications of recent movement and should be missing off the more stable areas.

(3) The worldwide distribution of canyons, as explained elsewhere (Shepard and Emery, 1941 p. 136–145), appears to favor a general emergence for the canyon cutting such as would have resulted either from a lowering of the sea level or a large uplift of all the continents. If this idea is correct, all continental slopes should have canyons, except where the slopes were due to fault scarps which formed after the canyon-cutting episode. The absence of canyons in the Gulf on what appear to be recent fault scarps is in keeping with this hypothesis.

(4) If there had been recent drowning of the coast producing the submarine canyons, estuaries should extend deep into the coasts inside the submarine canyons. The slight indentation at San Lucas Bay is the only feature resembling an estuary inside a submarine canyon along this part of the coast. Therefore, it may be supposed that there has been a considerable period since submergence, during which estuaries have been filled and coasts straightened.

These points are supported by evidence from other parts of the world. If due to rivers, the canyons were probably cut during the Pleistocene preceding the last glacial epoch (Shepard and Emery, 1941, p. 126–133).

DIASTROPHISM AND VULCANISM IN RELATION TO CANYON ORIGIN

Examination of the contours and sections of a canyon such as that which extends south out of San Lucas Bay shows that neither diastrophism nor vulcanism could be the sole cause of such canyons. Pointing to an erosional origin is the winding axis, the dendritic pattern of entering tributaries, and the continuous outward slope of the canyon floor toward the deeper parts of the ocean. On the other hand, examination of the topography of the adjacent area strongly suggests that diastrophism localized the canyon. Both east and west of the three main canyons which have river-valley characteristics there are submarine troughs and ridges which also run north and south. Assuming that these troughs are due to diastrophism, it is not unreasonable to suppose that troughs also may have existed on the sea floor prior to any emergence which allowed erosion at the site of the present canyons. Emergence would have allowed rivers to flow into these troughs and to superimpose on their emerged portions the characteristics of river-cut canyons.

It is often assumed that fault valleys differ from river-cut canyons in that the former are trough-shaped while the latter are *V*-shaped. However, *V*-shaped valleys of probable fault origin are relatively common within the Gulf. Therefore, it is unwise to conclude that the presence of a *V*-shaped valley on the sea floor proves of itself that erosion has taken place. The outer portions of most submarine canyons in the Gulf as elsewhere are so poorly sounded that one cannot differentiate them from the narrow basins in the Angel de la Guarda areas. Possibly, the outer part of the San Ignacio Canyon, which extends below the rim of the basin, may be the result of faulting.

In most places vulcanism could not be considered a contributary cause of submarine canyons, but the large amphitheatre indentation into the submarine slope off Guadalupe Island illustrates the possibility of confusing volcanic with erosional features where the soundings are scarce.

SUMMARY AND CONCLUSIONS

The new surveys of the Gulf of California carried on by the two E. W. SCRIPPS expeditions have shown much more complex topography in the Gulf than had hitherto been known. Impressive inner basins with water up to 1800 fathoms deep were discovered. Farallon Basin probably extends deeper below its sill than the deepest lake in the world. The basins have a zig-zag pattern with long narrow zones extending northwest, which alternate with broad zones extending north and south. There are so many examples of this alternation that it probably indicates the nature of some of the tectonic forces which have shaped the area. The pattern suggests application of horizontal forces in a northwesterly direction on the southwest side as has been the case along the San Andreas fault. This conclusion may be significant since the San Andreas fault system can be traced to the Imperial Valley where in 1940 the surface was broken by a horizontal shift of 15 feet at a locality within 60 miles of the head of the Gulf. The en echelon termination of ranges on the two sides of the Gulf is also indicative of horizontal shearing.

The inner basins appear to be downfaulted in relation to the general level of the Gulf floor, suggesting the development of fault troughs within fault troughs, just as craters develop within craters in volcanoes. Most of the inner basins are centrally located, but to the north one of the deepest basins is situated along the west side of the Gulf.

Probable fault scarps are especially pronounced along the east coast of Lower California and adjacent to the numerous islands which extend along most of this coast. On this side of the Gulf there are no appreciable continental shelves, although locally narrow shelves are found. The shelf absence appears to indicate recent faulting which has not allowed subsequent cutting of shelves. There is also an indication that wave-cut terraces have been recently uplifted along various islands of the Lower California coast.

On the east side of the Gulf a narrow continental shelf, particularly off deltaic coastal lowlands, probably indicates a relatively short period of stability on this side, because the sea cliffs along various parts of the east coast plunge to depths of 30 fathoms below sea level with a very narrow shelf beyond. Probably recent slight submergence has produced the shelf by the drowning of the deltas and alluvial plains along the east side and by the drowning of narrow wave-cut shelves off the highland areas. The outline of the east coast resembles the zigzag basins outside, and the tectonic forces may have also contributed considerably to its origin.

The submarine canyons of the area are almost entirely confined to the southern tip of Lower California and to the east side of the Gulf in the vicinity of San Ignacio Farallon Island. The canyons have river-valley characteristics such as winding courses, dendritic tributaries, and *V*-shaped cross sections. They are found off various land valleys. The absence of canyons along the slopes of the rest of the Gulf, in contrast to most other submarine slopes around the world, appears to be explicable in several ways. Many of these slopes are considered as due to faulting, which is thought to have postdated the canyon-cutting episode or episodes. Also some of the slopes are gentle, and conceivably valleys cut into them have been subsequently either filled or so modified as to be unrecognizable.

The soundings around Guadalupe Island show how a feature which appears to be due to volcanic subsidence or a volcanic explosion might be confused with a submarine canyon. Also the fault troughs of the Gulf, particularly those with *V*-shaped cross sections, indicate features which somewhat resemble canyons but are probably not due to erosion. Finally, there is evidence that the valleys off the southern tip of Lower California may be, at least in part, of tectonic origin.

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1940 E. W. SCRIPPS CRUISE TO THE GULF OF CALIFORNIA

PART IV

REPORT ON THE PLEISTOCENE AND PLIOCENE FORAMINIFERA

BY
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August 10, 1950

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ABSTRACT

Sixteen samples were collected from outcrops exposed on North San Lorenzo, Carmen, Monserrate, and Coronados islands. Two samples were taken from exposures at Santa Ynez Bay. All these localities are in the Gulf of California and were collected by C. A. Anderson and J. Wyatt Durham during the 1940 cruise of the E. W. SCRIPPS. Seventy-two species of Foraminifera were found in beds thought to be of Pleistocene age, and 83 species were found in beds considered to be Upper Pliocene. In general, the Pleistocene fauna suggests a clear-water tropical environment with a depositional depth of less than 50 meters, since it is practically identical with the Recent shallow-water fauna in the Gulf. The Upper Pliocene fauna was probably laid down in water ranging from 275 to 500 meters deep, since it is very similar to the Recent fauna which is not found beyond this range off the west coast of Central America. The Upper Pliocene fauna correlates with that found in the Charco Azul Pliocene formation of Panama and with *Uvigerina peregrina* beds of the Los Angeles and Ventura basins. These beds lie beneath those containing *Cassidulina limbata* Cushman and Hughes, and above those which contain *Bulimina subacuminata* Stewart and Stewart.

The collection contains five species which are considered new and two species to which new names have been assigned.

INTRODUCTION

Only 16 of the numerous samples collected by C. A. Anderson and J. Wyatt Durham, during the 1940 cruise of the E. W. SCRIPPS to the Gulf of California, have been studied for this report. Therefore, only the broad and more obvious divisions of the formations, based on their foraminiferal fauna, can be made at this time. When longer sections are sampled at close stratigraphic intervals, many subzones will undoubtedly be found and will be useful for purposes of correlation over a limited area.

The locations of the samples are shown on maps included in Anderson's report on the geology and stratigraphy of the Gulf of California (Part I). A lithologic description of them can be found in Durham's report on the megafauna of the Gulf.

Most of the species found in the Pleistocene and Upper Pliocene have living representatives in nearly identical form off the west coast of Central America. It is therefore possible to determine, approximately, the environment in which the ancient sediments were accumulated. The many references in this report to the known bathymetric ranges of most of the species were taken from a manuscript chart by the writer showing the distribution of Foraminifera in 170 samples ranging from 1 to 4140 meters deep off the west coast of Central America. These samples were collected by the Coast and Geodetic Survey ships and were kindly made available for study by Dr. Harold Sverdrup, of the Scripps Institution of Oceanography at La Jolla, California. This chart, together with other pertinent data, is to be published in the near future. The bathymetric ranges indicated for the same species off Southern California were, for the most part, taken from a chart (Natland, 1933) showing the known distribution of Foraminifera from off Long Beach, California.

Holotype specimens of the new species described, together with all other species listed in this report, are deposited at the U. S. National Museum, in Washington, D. C.

Seventy-two species of Foraminifera were found in the beds considered to be of Pleistocene age, and 83 species were found in beds thought to be of Upper Pliocene age. In general, these fauna are closely related to the fauna of the Panamanian Province which is here considered to begin in the Gulf of California and to extend southward at least to the Gulf of Panama. The shallow-water (1–50 meters) fauna of this province contains many tropical species and is usually accompanied by an abundance of Lithothamnion and molluscan fragments. From 50 to 275 meters, small *Bolivinas*, *Virgulinas*, *Uvigerinas*, *Nonions*, *Pulvinulinellas*, and *Buliminas* predominate. From 275 to approximately 500 meters, *Pulvinulinella bradyana*, *Gyroidina soldanii* var. *rotundimargo*, *Bolivina interjuncta*, *Uvigerina attenuata*, and *Cancris inflata* are the most abundant species.

From 500 to 4140 meters numerous species appear forming zones which correlate with the deeper divisions previously established off Southern California.

PREVIOUS WORK

No previous work has been done on the fossil Foraminifera from the Gulf of California area. J. A. Cushman and Irene McCulloch (1939–1942) recently published a number of articles on the Gulf fauna found in several sea-bottom samples which were collected by the Hancock Foundation Expedition. However, a considerable amount of work has been done on both Recent and fossil mollusks of the Gulf of California region.

AGE AND ECOLOGIC SIGNIFICANCE OF THE FAUNAS

Samples A-3519, A-3521, A-3547, A-3548, A-3550, and A-3582 contain a shallow-water foraminiferal fauna which is nearly identical to that found Recent in the Gulf and along the west coast of Central America. This Recent affinity strongly suggests a Pleistocene age for the fauna. Sample A-3566 contains essentially the same fauna but also has *Cassidulina limbata* and *Cassidulina quadrata*, which indicate a somewhat deeper depositional environment; it is therefore perhaps older. Samples A-3584 and A-3594 contain no foraminiferal fauna, but the abundant molluscan fragments suggest that they may belong in the Pleistocene. The ecologic and probable age equivalent of this Pleistocene fauna in Southern California is the Upper San Pedro (Woodring, Bramlette, and Kew, 1946) which is for the most part composed of barren sands, or it may correlate with the Lower San Pedro which is also predominantly sand but contains an abundance of molluscan fragments and occasional shallow-water Foraminifera.

The Pleistocene fauna indicates the following condition of deposition: The water was clear and tropically warm, perhaps with a temperature ranging from 70° to 85°F. This conclusion is based on the presence of such species as *Amphisorus hemprichii*, *Loxostoma mayori*, *Peneroplis pertusus*, and *Reussella spinulosa* which are now living in the Gulf of California and are known to occur in shallow water southward to the Gulf of Panama. They have not been observed in samples north of Cape San Lucas, at the tip end of Lower California. Lithologically, these samples can best be described as a calcareous sand with abundant molluscan fragments, together with abundant Lithothamnion, Bryozoa, and echinoid spines. Ostracods are also plentiful. These beds probably correlate with the Lake Cohuilla formation which is exposed along the western border of the Imperial Valley, California, and is of probable Pleistocene age. These correlations are based more on the similarity of environments indicated by the faunas, than on the similarity of the faunas. Correlations of this sort do not necessarily tie beds of the same age together, as it is certainly possible to have shallow-warm-water conditions in one part of a basin, and deep cold-water conditions in another, both being contemporaneous but with vastly different faunas. In general, the accuracy of correlations based on shallow-water foraminiferal faunas in this and other regions must be held in doubt.

Samples A-3500, A-3501, A-3502, A-3503, A-3504, A-3511, and A-3512 are considered to be of Upper Pliocene age. According to Durham, they are composed of yellow, foraminferal marly clay with occasional pumice fragments. Samples A-3500 to A-3504 are from beds exposed in Salinas Bay, Carmen Island. These beds are unconformably overlain by Pleistocene and underlain by a bed of volcanic pebble-to-cobble conglomerate. A-3500 is the lowest stratigraphically, and A-3504 is the highest; the intervening samples are taken at 10-foot stratigraphic intervals. Samples A-3511 and A-3512 were collected from Perico Point, Carmen Island, from beds of foraminiferal marl and clay which occur as lenses in volcanic pebble-to-cobble conglomerate.

The fauna herein considered Upper Pliocene correlates best with the Charco Azul formation which is considered to be of Pliocene age by Coryell and Mossman (1942). In the Imperial Valley, the fauna present in the lower part of the Middle Imperial is roughly equivalent to that of the Carmen Island Upper Pliocene. In Southern California, the Carmen Island Upper Pliocene (Table 1) correlates with the so-called Middle Pico beds which contain abundant *Uvigerina peregrina.* These beds occur below sediments abundant with *Cassidulina limbata* and *Uvigerina juncea*, and above those abundant with *Bulimina subacuminata* (Wissler, 1941).

The abundant foraminiferal fauna in these samples is similar to that found Recent off the west coast of Central America. This fauna prefers to live, at the present time, between 275 and 500 meters deep where the temperature ranges from about 42° to 48°F. The presence of *Bolivina subadvena* in Samples A-3511 and A-3512 indicates that the water was somewhat deeper at Perico Point than at Salinas Bay, or that the Perico Point samples are from beds slightly older than the Salinas Bay samples but are still of Upper Pliocene age. Badly worn *Amphisteginas* are present in the samples from Salinas Bay. Undoubtedly, the *Amphisteginas*, because of their rugged construction, withstood transportation from shallow shoreline waters to depths below 275 meters. They also suggest that the surface waters, during Upper Pliocene time, were warm enough to be considered tropical, as this species is generally confined to tropically warm water. *Cancris inflata* is, perhaps, the most typical species of the Upper Pliocene and serves to tie this fauna to the Panamanian Province. This species is not known to occur Recent off California but is common in certain horizons of the Upper Pliocene of the Ventura and Los Angeles basins.

DESCRIPTION OF TABULAR PRESENTATION

Table 1 includes most of the species found in the Pleistocene and Pliocene. Several rare, poorly preserved, unidentifiable specimens were omitted. The species are listed alphabetically for each formation, and immediately to the right of the species name is shown the page on which can be found taxonomical and other data regarding the species in the text. The symbols are meant to show roughly the abundance of each species recovered, with "rare" indicating 1–10 specimens per sample; "common," 11–50; and "very abundant," above 50 specimens per sample. Where no estimate of the relative abundance is available, a circle is used to indicate that the species has been reported from the formation indicated.

The Pleistocene samples A-3919 to A-3594 are listed first, followed by the Pliocene samples A-3500 to A-3512, to show the tremendous faunal difference between the Pleistocene and Pliocene. As seen on the chart, most of the species which are abundant, and common to both the Pleistocene and Pliocene, are pelagic and belong to the Globigerinidae. Other species such as *Bolivina parva* and *Cassidulina quadrata* have but a single specimen occurring in the Pleistocene beds and probably should be shown with the Pliocene group rather than with the Pleistocene.

The columns labelled "Recent Off the West Coast of Central America," "Recent off Southern California," and "Recent Off Florida" indicate the species present in these areas which also occur in the Pleistocene and Pliocene sediments of the Gulf. Of the 72 species which occur in the Gulf Pleistocene, 60 are found Recent off Central America, 45 off Southern California, and 30 off Florida. These figures indicate clearly the affinity of the Gulf fauna to that which occurs Recent off the west coast of Central America. This tie is further accentuated when the relative abundance is considered. Forty five of the 72 Pleistocene species are found in the California Pleistocene. The most notable difference between the Gulf Pleistocene and the California Pleistocene is the presence of tropical forms in the Gulf Pleistocene and their absence in the California Pleistocene. There are 56 species in the Pliocene which are not present in the Pleistocene. For the most part, these species are very abundant, giving a totally different appearance to the Pliocene fauna. Forty six of the 56 Pliocene species are found Recent off the west coast of Central America, whereas 37 of them are found Recent off Southern California, and only 6 are known to occur off Florida. The columns showing the occurrences of Gulf species in the Southern California section indicate that 38 of the 56 Gulf Pliocene species occur in the *Uvigerina peregrina* zone, which is a greater number by far than in any other division listed. Many of the abundant Gulf Pliocene forms are also abundant in the Upper Miocene of California Such species as *Bolivina parva*, *Bulimina* cf. *uvigerinaformis*, and *Virgulina californiensis* are not found younger than Upper Miocene in Southern California. Their presence in the Upper Pliocene beds of the Gulf indicates that conditions were more suitable for their continued growth in the Gulf region after the close of Miocene time in California. The abundant species *Bulimina* cf. *uvigerinaformis*, which in Southern California is an excellent marker for the Lower Mohnian, is very abundant in most of the Gulf Pliocene samples examined. The Gulf specimens differ but slightly from those in Southern California, and, unless a large number is examined, most workers would consider them to be the same species. None of the species in the Pleistocene are thought to be extinct, but five species in the Pliocene are, insofar as known, extinct. Eighteen of the 46 species found in the Gulf Pliocene were found by Coryell and Mossman in the Charco Azul formation of Panama. However, they also listed 8 species which were not found in the Gulf Pliocene. These species, in general, occur in

TABLE 1. *Pleistocene and Pliocene Foraminifera from Carmen Island region, Gulf of California, Mexico*

Legend:
Rare /
Abundant c
Very Abundant •
Reported o

Pleistocene and Pliocene Species	Page in Text	A-3519	A-3521	A-3547	A-3548	A-3550	A-3566	A-3582	A-3584	A-3594	A-3500	A-3501	A-3502	A-3503	A-3504	A-3511	A-3512	Recent off the West Coast of Central America	Recent off Southern California	Recent off Florida	Fossil Occurrence in Southern California Pleistocene	Pliocene UPPER PICO (Upper Pliocene)	MIDDLE PICO	LOWER PICO	REPETTO (Lower Pliocene)	Miocene	Oligocene	Eocene	Extinct	Charco Azul Formation Pliocene Panama Reported by Coryell and Mossman
Amphisorus hemprichii Ehrenberg	16, 32			/	/			/																						
Amphistegina sp. A	3, 27						•				•	c	c	/				/		•										
Angulogerina occidentalis (Cushman)	25				/		c				•	c	c	c	c	c	c	/	/		/	/								
Annulocibicides sp. A	40	/																/		/										
Anomalina schmitti Cushman and Wickenden	38		/	c	•		•	/								c	/	/	c	?	c	/	/	/	/					
Articulina lineata H.B.Brady	9			/	/													/		/										
Bifarina hancocki Cushman and McCulloch	24						/	/			/							/												
Bolivina acuminata Natland	22			/							•	c	c	c	c	c	c	•	c		/	/	/							
Bolivina parva Cushman and Galliher	4, 20					/					•	•	•	•	•	•	•									•				
Bolivina plicatella Cushman	19				/	/												/	/											
Bryozoa	2	c		c	•	c		c							/	/		c	c	c	c	c								
Buliminella elegantissima (d'Orbigny)	17					/												c	c		c	/	/	/	/					
Cassidulina cf. limbata Cushman and Hughes	33						/										c		•		/	•	/	/	/					
Cassidulina quadrata Cushman and Hughes	2,4,34						/				c	c	/	/	c	c	c	/	•		/	•	•	•						
Cornuspira involvens (Reuss)	11				/	c		/										/	/		/									
Diatoms	*			/	/	/									/			c	c		/	/	/	/		•	/	•		
Discorbis isabelleana (d'Orbigny)	26							/										/	/		/									
Discorbis orbicularis (Terquem)	27				/	/		/										/	/	/	/									
Discorbis parkeri Natland	27					/		/										/												
Discorbis cf. pulvinata (H.B.Brady)	27			/		/		c										/	/		/									
Discorbis rosaceus (d'Orbigny)	26	/			/	c		c			c	c	/	/	/	c	/	c	c		c	/	/	/	/					
Discorbis subaraucana Cushman	28						/									c	/			/										
Discorbis sp. B	28				/																									
Discorbis sp. C	28							/																						
Dyocibicides biserialis Cushman and Valentine	39			c	c	•		c								/		/	/	?	/									
Echinoid spines	*	c	c	c				c			/							c	c	c	c	/								
Elphidium articulatum (d'Orbigny)	15			/	c	•		c						/			/	c	c		c	/								
Elphidium excubitor Nicols	14		/	•	•	/		c			/	/				c		c	c		c	/								
Elphidium poeyanum (d'Orbigny)	15				/			c										/	c	c	c									
Eponides incertus (Cushman)	29				/	•					/	/				c		/		/										
Eponides mansfieldi Cushman	30	/		c	c			c										/	/		/	/				/				
Eponides repanda (Fichtel and Moll)	30			c	•	•	/					/						c	c	/	/	/								
Gaudryina arenaria Galloway and Wissler	6	/					/											/	c		c	c	/	/						
Globigerina bulloides d'Orbigny	36				c	c	c	c			c	•	•	•	•	c		•	•	•	•	•	•	•		•	/	c		o
Globigerina conglomerata Schwager	36			/							•		/	c			c	•	•		•	c	/							
Globigerinoides cyclostoma (Galloway and Wissler)	36				/		/				•	c	/	•	c	•	•	c	c		c	/	/							
Globorotalia menardii (d'Orbigny)	37						/					/			/	c	/	•	/	•	/	/	/	/	/					o
Hauerina bradyi Cushman	10	/		c	c	/		c										/	c	/	/									
Loxostoma mayori (Cushman)	2							/										/												
Lithothamnion	2	•	•	•	•	•	c																							
Massilina durhami Natland	8				c			/																						
Massilina pulcherrima Cushman and Valentine	9							/										/	/		/									
Massilina robustior Cushman and Valentine	9			c	c	c		c										/	/		/									
Mollusk Fragments	*	•	•	•	•	•		•		•								•	•	•	•	•	/	/	/	•	•	•		
Nonion grateloupi (d'Orbigny)	14				/		/	/			/	/	/	c	c	c	/	•	•	/	•	/	/	/	/					
Orbulina universa d'Orbigny	37				/		/	/			/	/	/	c	c	c	/	c	•	•	c	c	c	c		c	?	?		o
Ostracods	2	c	c	c	•	c	c																							
Patellina corrugata Williamson	26				/	/		/										/	c		/	/								
Peneroplis pertusus (Forskål)	2, 16					/												/		/										
Planispirinella exigua (H.B.Brady)	11				/	/												/												
Planorbulinoides retinaculata (Parker and Jones)	40	/	/	/		•	/	/										/	/	/	/									
Planulina cf. faveolata (H.B.Brady)	38			/			•	/			c	/	/	c	c	c	c	c	•		•	c	/							
Pyrgo denticulata (H.B.Brady)	11			c	/	c		/										/	/	/	/									
Pyrgo elongata (d'Orbigny)	11					c												c	c		/									
Quinqueloculina angulo-striata Cushman and Valentine	8	/			/	c		c										/	/		/									
Quinqueloculina catalinensis Natland	7			•	•	c		c										c	c		c									
Quinqueloculina costata d'Orbigny	8	/																/	/	/	/									
Quinqueloculina flexuosa d'Orbigny	7					/												/	/		/									
Quinqueloculina laevigata d'Orbigny	7	/		/	c	c		c										/	/	/	/									
Quinqueloculina lamarckiana d'Orbigny	7	/		c	•	c		c										c	•	/	c									
Quinqueloculina microcostata Natland	7				/													/	c		/									
Quinqueloculina sp. A	8	/																												
Quinqueloculina sp. B	8	/																												
Rectobolivina sp. A	23							/																						
Rectobolivina sp. B	23						/																							
Reussella spinulosa (Reuss)	2, 24			/	/			c						/				c		c										
Rotalia avalonensis Natland	30							/										/	c		/									
Rotalia rosea d'Orbigny	31				/			/										/		/										
Rotalia sp. A	31				/																									
Spirillina vivipara Ehrenberg	26					c		/										/	/	/	/									
Spiroloculina antillarum d'Orbigny	9					/												/		/										
Textularia lateralis Lalicker	6	/		c	c	/	/	c						/		/		/												
Textulariella pacifica Cushman	6						/											/			/									
Tretomphalus bulloides (d'Orbigny)	33			c	c	c	/	c										c	c	/	/									
Triloculina circularis Bornemann	11				/	c												c	c	c	/									
Triloculina inflata d'Orbigny	10					c												/												
Triloculina oblonga (Montagu)	10	/	c	/	c	c												c	c	c	/									
Triloculina rotunda d'Orbigny	10	/		/				/										/		/										
Pliocene Species																														
Angulogerina carinata Cushman	25										•	•	•	c	c	/	c	•	•			/	/							o
Bolivina argentea Cushman	20																c	•	•				/							o
Bolivina interjuncta Cushman	2, 20										•	•	•	c	c	•	•	•	•			/	•							o
Bolivina plicata d'Orbigny	21										•	•	•	c	•		•	•					/	/	/					o
Bolivina pseudobeyrichi Cushman	21											c	c	/	c		c	c	c				c	/	/					o
Bolivina punctata d'Orbigny	22															/	/	/	/				/	/	/					
Bolivina seminuda Cushman	21											c	c	/	c			/	c				/	/	/	•				o
Bolivina subadvena Cushman	3, 22															•	•	c	•				c	•	/					
Bolivina tongi Cushman	23										/	c	/	/	/		c	/	/				/	/	/					
Bulimina marginata d'Orbigny	18										c	c	/	c	/		c	•	•		/	c	/	/	/					
Bulimina ovula d'Orbigny	18										/	c	/		c			•	•			c	c	c	c	•	c	c		o
Bulimina cf. uvigerinaformis Cushman and Kleinpell	4, 18										•	•	c	c												•			/	
Buliminella subfusiformis Cushman	17										•	•	•	•	•	•	•	c	c			c	c	c	c	•	c	c		o
Cancris auricula (Fichtel and Moll)	32										c	c	c	c	/	/		c	c			c	c	/	/					
Cancris carmenensis Natland	32										•	•	c	•	c	c													/	
Cancris inflata d'Orbigny	2,3,31										•	•	•	•	•	•	•	•					c							o
Cassidulina corbyi Cushman and Hughes	34										c	c	c	c	c	c	c	c	c			c	/							o
Cassidulina cushmani R.E.Stewart and K.C.Stewart	34										•	•	•	c	•	c	c	•	•			c	c	•						o
Cassidulina oblonga Reuss	34											c		/	c	c	c	c	/				/							
Cassidulina cf. tortuosa Cushman and Hughes	35															c			•		/	•	/							
Cibicides gallowayi Cushman and Valentine	39													c		/		c	c		/	/								
Dentalina cf. communis (d'Orbigny)	12										/	/						/				?/				/				
Discorbis sp. A	28										/																			
Ehrenbergina compressa Cushman	35													/				c	c			/	c	/	/					
Entosolenia sp. A	19														/															
Eponides cf. rosaformis Cushman and Kleinpell	30										/	/														/				
Fish Remains	*													c				c	c		c	c	c	c	c	•	•	•		
Gaudryina cf. atlantica (Bailey)	6										/	/				/		/												
Globigerina quinqueloba Natland	36											/		/				c	c		c	c	•	/						
Globigerinoides rubra d'Orbigny	37															c	c	c												
Globigerinoides sacculifera H.B.Brady	37										/	/		/				/		•										o
Globigerinoides sp. A	37														c	c	c	c												
Globobulimina pacifica Cushman	19												c	•				•	•			c	c	c	c	•	c	c		
Globulina gibba d'Orbigny	14													/		/		/	/	/	/	/								
Guttulina quinquecosta Cushman and Ozawa	13													/				/	c		/	c								
Gyroidina carmenensis Natland	28															c	c		/											
Gyroidina rothwelli Natland	29											c	c	•	c	c	•	•				c								
Gyroidina soldanii v. rotundimargo Coryell and Mossman	2, 29										•		•	•	•		•	•	•			c	c	c	c		?	c		o
Lagena hexagona (Williamson) var. scalariformis (Williamson)	13												/	/				/	/	/	/	/	/	/	/					
Lagena sulcata (Walker and Jacob)	13													/				/	/	/		/	/							
Lagena williamsoni (Alcock)	13										/		/	/				/	/	/	/	/	/	/	/					
Loxostomum instabile Cushman and McCulloch	23													/			/	o	c			/	/	/						
Nodogenerina advena Cushman and Laiming	17										/				/	c	/						/	/	/		/	/	/	
Nodogenerina lepidula (Schwager)	16										c	/	c	/	/			/					/	/	/					
Nodosaria moniliformis Ehrenberg	12											/	/									/	/						/	
Planulina ornata d'Orbigny	38											/	/					c	c			/	c	c	c	c				o
Pullenia malkinae Coryell and Mossman	35										/					c	c	c												o
Pullenia cf. moorei Kleinpell	35										/	c	c	/	c	c	c									c?				
Pulleniatina obliquiloculata (Parker and Jones)	37											/	/	c	/	c	/	c												o
Pulvinulinella bradyana Cushman	2, 33											c		/			c	•	c			c	•	c	c	/				
Pulvinulinella relizensis Kleinpell	33										•	•	•	c	•	c	•						c	c	•				/	
Radiolaria	*														c			•	•		/	/	/	/	/	•	c	•		
Robulus cushmani Galloway and Wissler	12										c		/				/	c	c			/	c	c	/					o
Sigmoilina tenuis (Cjcezk)	9											/				/		c	c			/	c	c	/	/	/			
Sponge spicules	*										/	/	c	c	c			c	c	c	c	c	c	c	c	c	c	c		
Suggrunda eckisi Natland	23										/	c	c	c	c	/	c	•	c			c	c	c						
Uvigerina attenuata Coryell and Mossman	2, 25										•	•	•	•	•		/	•	c			c								o
Valvulineria cf. araucana (d'Orbigny)	28,32										/																			
Virgulina californiensis Cushman	4, 19										c	c	c	•	•	/	c									•			/?	
Charco Azul Species Not Found in the Carmen Island Pliocene																														
Bolivina subadvena Cushman = B. pomposa Coryell and Mossman	3, 22																	•	•			c	c	c						o
Bulimina affinis d'Orbigny	*																	/	c			c	c	/						o
Bulimina pagoda Cushman	*																	/	/			/	/	/						o
Cassidulina californica Cushman and Hughes	34																	/	•			/	•	c	/					o
Chilostomella czjzeki Reuss	*																													o
Epistomina bradyi Galloway and Wissler	*																					/	/	/	/	/				o
Planulina limbata Natland = Cibicides terryi Coryell and Mossman	*																	c												o
Valvulineria inaequalis (d'Orbigny)	*																	c	c			/								o

* No reference in text.

water somewhat deeper than the indicated depth range for the Gulf Pliocene. This may suggest that the depositional environment of the Charco Azul was deeper or perhaps older than that of the Gulf Pliocene. From the above data it seems most reasonable, in spite of the occurrence of species which are elsewhere confined to the Miocene, to place the Carmen Island fauna in the Upper Pliocene, principally because of its very high affinity to the Charco Azul Pliocene fauna and to the Upper Pliocene fauna of Southern California.

The foraminiferal illustrations (Pls. 1–11) are made from photographic enlargements. In most cases the degree of magnification is relative to the size of the specimen. A minor amount of retouching was necessary to bring out more clearly the essential features of some species.

SYSTEMATIC DESCRIPTIONS

Family Textulariidae

Subfamily Textulariinae

Genus ***Textularia*** Defrance, 1824

Textularia lateralis Lalicker

(Plate 1, figures 4a, b, 5a, b)

Textularia lateralis Lalicker, C. G., Smithsonian Inst. Coll., Washington, D. C., U. S. A., vol. 91, no. 22, 1935 (Pub. 3328, p. 1, pl. 1, figs. 3–5).

Length 0.71 mm.; breadth 0.70 mm.; thickness 0.41 mm.

Abundant in Pleistocene beds and rare in Pliocene of the region under discussion. Common in Recent sediment off west coast of Central America, where it has a known depth range of 29–210 meters. As yet it has not been found off Southern California.

Lalicker found it to occur in 240–300 fathoms of water off the northern part of Puerto Rico, which is considerably deeper than it is found off Central America.

This species differs from *Textularia articulata* d'Orbigny by being thinner, with a wider apical angle. It differs from *T. schencki* Cushman and Valentine by being more angular throughout.

Family Verneuilinidae

Genus ***Gaudryina*** d'Orbigny, 1839

Gaudryina cf. ***atlantica*** (Bailey)

(Plate 1, figures 1a, b)

Guadryina atlantica (Bailey), Smithsonian Inst., Contrib. Knowledge, Washington, D. C., U. S. A. vol.2, art. 3, 1851, p. 12, figs. 38–43.

Length 1.10 mm.; breadth 0.76 mm.; thickness 0.62 mm.

Several specimens were found in samples A-3500, A-3501, A-3511. They were compared with specimens from a sample collected by Woods Hole Oceanographic Institute from 153 meters of water, a few miles north of Bailey's Locality off Woods Hole, and found to be identical in shape but smaller.

Found rarely in water shallower than 70 meters and persistently common to abundant from 70 to 260 meters off the west coast of Central America.

Gaudryina arenaria Galloway and Wissler

(Plate 1, figures 2a, b)

Gaudryina arenaria Galloway and Wissler, Jour. Paleont., vol. 1, pt. 1, 1927, p. 68, pl. 11, fig. 5 Cushman and McCulloch, Hancock Pacific Exped., vol. 6, no. 1, 1939, p. 91, pl. 8, figs. 2, 3.

Length 0.29 mm.; breadth 0.18 mm.; thickness 0.18 mm.

Only two small broken specimens found, one at Locality A-3519 and the other at Locality 3566. Not found in any of the 171 samples recently examined from depth range 1–4140 meters off Central America. Abundant in Recent, Pleistocene, and Upper Pliocene sediments of Southern California. Boundary between Central American Recent fauna and California Recent fauna is probably at Cape San Lucas, at southern extremity of Lower California. The scarcity of this species, as well as many others abundant north of Cape San Lucas in the Pleistocene and Pliocene sediments of Carmen Island region, suggests that Cape San Lucas has been an effective barrier since Pliocene time.

Family Valvulinidae

Genus ***Textulariella*** Cushman, 1927

Textulariella pacifica Cushman

(Plate 1, figures 3a, b)

Textulariella pacifica Cushman, Cushman Lab. Foram. Res., Spec. Pub., Sharon, Mass., U. S. A. no. 8, p. 67, 1937, pl. 7, figs. 11–13.

Diameter 1.06 mm.; length 0.53 mm. (broken specimen).

Three small, immature specimens found at Locality A-3566. Off Central America, Recent depth range of this species is 1–270 meters, most abundant at about 70 meters.

Family MILIOLIDAE

Genus *Quinqueloculina* d'Orbigny, 1826

Quinqueloculina flexuosa d'Orbigny

(Plate 1, figures 6a, b, c)

Quinqueloculina flexuosa D'ORBIGNY, Voy. Amér. Mérid., 1839, "Foraminifères," p. 73, pl. 4, figs. 4–6. CUSHMAN AND VALENTINE, Contrib. Dept. Geol. Stanford Univ., vol. 1, no. 1, 1930, p. 11, 1, 2, figs. 3a, b, c.

Length 0.76 mm.

Rare at Locality A-3550 and somewhat smaller than specimens found off Southern California. Chambers of d'Orbigny's type figure are quite angular, whereas those of this collection, and chambers of specimens referred to this species by Cushman and Valentine from off Southern California, are round in contour. *Quinqueloculina nussdorfensis* d'Orbigny is quite similar to this species, except that the figures indicate it to be somewhat thinner in cross section. *Quinqueloculina gregaria* Andreae appears to be close to this species, but without type material it would be impossible to make a positive identification. Abundant in Lithothamnion beds of Avalon Bay, Santa Catalina Island, California.

Quinqueloculina catalinensis Natland

(Plate 1, figures 7a, b, c)

Quinqueloculina catalinensis NATLAND, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 4, no. 5, 1938, p. 142, pl. 4, figs. 3a, b, c.

Length 1.00 mm.; breadth 0.71 mm.; thickness 0.58 mm.

Specimens of collection are identical with those described from off Southern California.

Quinqueloculina lamarckiana d'Orbigny

(Plate 1, figures 8a, b, c)

Quinqueloculina lamarckiana D'ORBIGNY, *in* DE LA SAGRA, Hist. Fis. Pol. Nat. Cuba, 1839, "Foraminifères," p. 189, pl. 11, figs. 14, 15. CUSHMAN AND VALENTINE, Contrib. Dept. Geol. Stanford Univ., vol. 1,, no. 1, 1930, p. 10, pl. 1, figs. 9a, b, c, 10a, b, c. NATLAND, Scripps Inst. Oceanog. Bull., Tech. Serv., vol. 4, no. 5, 1938, p. 142, pl. 2, figs. 2a, b, c.

Length 1.18 mm.; breadth 0.85 mm.; thickness 0.59 mm.

The specimens commonly referred to this species from off California have sub-angular peripheral margins, whereas d'Orbigny's figure indicates the type to be sharply angled. The type also is shown to have an extended neck which is not found on the specimens from this region. It might be well to give this species a new name.

Quinqueloculina microcostata Natland

(Plate 2, figure 1a, b, c)

Quinqueloculina microcostata NATLAND, Scripps Inst. Oceanog., Bull. Tech. Ser., vol. 4, no. 5, 1838, p. 142, pl. 4, figs. 6a, b, c.

Length 0.94 mm.; breadth 0.71 mm.; thickness 0.53 mm.

Specimens from Locality A-3548 are more angular than those originally described from off Santa Catalina Island. However, the average difference is not thought sufficient to warrant assigning a new name to the specimens of this collection.

Quinqueloculina laevigata d'Orbigny

(Plate 2, figures 2a, b, c, 3a, b, c)

Quinqueloculina laevigata D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1836, p. 301, no. 6; *in* BARKER, WEBB AND BERTHELOT, Hist. Nat. Îsles Canaries, 1839, vol. 2, pt. 2, "Foraminifères," p. 143, pl. 3, figs. 31 to 33. CUSHMAN, Carnegie Inst., Washington, Pub. 311, 1922, p. 65, pl. 13, fig. 2. CUSH-

MAN AND T. R. D. WICHENDEN, U. S. Nat. Mus., Pro., vol. 75, 1929, art. 9, p. 2, pl. 1, figs. 4a–c.
Quinqueloculina seminula (LINNÉ) of NATLAND, Scripps Inst. Oceanogr., Bull., Tech. Ser., vol. 3, 1933, no. 10, line 61 of included chart.

Length 0.94 mm.; breadth 0.45 mm.; thickness 0.18 mm.

Figure 2 has a neck somewhat longer than the average, suggesting that it is probably not referrable to this species. However, the shape of the average specimen, shown as Figure 3, seems to lie within the range of individual variation for specimens commonly referred to this species. It was called *Quinqueloculina seminula* d'Orbigny after Cushman and Valentine (1930, pl. 1, figs. 8a, b, c; and in Natland, 1933, line 61 of the included chart). However, the species seems more closely related to *Q. laevigata.*

Quinqueloculina costata d'Orbigny

(Plate 2, figures 4a, b, c)

Quinqueloculina costata D'ORBIGNY, Ann. Sci. Nat., vol. 7, no. 3, 1826, p. 301. CUSHMAN AND VALENTINE, Contrib. Dept. Geol., Stanford Univ., vol. 1, no. 1, 1930, p. 12, pl. 3, figs. 1a, b, c.

Length 1.00 mm.; breadth 0.588 mm.; thickness 0.43 mm.

Abundant in beds referred to Pleistocene in this report. Abundant in shallow water, (5 to 60 meters) both off Central America and off Southern California.

Quinqueloculina angulo-striata Cushman and Valentine

(Plate 2, figures 6a, b, c; Plate 3, figures 3a, b, c)

Quinqueloculina angulo-striata CUSHMAN AND VALENTINE, Contrib. Dept. Geol., Stanford Univ., vol. 1, no. 1, 1930, p. 12, pl. 2, figs. 5a, b, c.

Length 0.76 mm.; breadth 0.53 mm.; thickness 0.41 mm.

The specimens of this collection are not as costate as the type from off Southern California but are otherwise similar. Most abundant in water shallower than 30 meters, off Southern California Figures 3a, b, c of Plate 3 illustrate what is thought to be a small emaciated variety of *Q. angulo-striata.* In general it is similar to the following previously described species: *Quinqueloculina sulcata* d'Orbigny, *Q. soldanii* d'Orbigny, *Q. limbata* d'Orbigny, *Q. lachesis* Karrer.

Quinqueloculina sp. A

(Plate 3, figures 2a, b, c)

This form, closely related to *Quinqueloculina lamarckiana,* is rare at Locality A-3519. It may be a young stage of some larger species. An insufficient number of specimens are at hand to warrant the assignment of a new name.

Quinqueloculina sp. B

(Plate 3, figures 4a–c)

Length 0.35 mm.; breadth 0.26 mm.; thickness 0.18 mm.

A few specimens of this type were found. They are probably internal molds and therefore not identifiable.

Genus ***Massilina*** Schlumberger, 1893

Massilina durhami Natland, n. sp.

(Plate 2, figures 5a, b, c)

Test large, elongate, broadest near middle, 4 chambers visible on each side, partially involute; somewhat angular; sutures rather distinct, irregular, slightly depressed; walls rather thick, roughened with usually 1–3 large subround ridges extending from posterior to about half way toward apertural end on outer sides of chambers; aperture small, oval, with small bifid tooth.

Length 1.75 mm.; breadth 0.86 mm.; thickness 0.42 mm.

Holotype, U. S. Nat. Mus., No. 560205, from Locality A-3548; Pleistocene beds exposed on south side of Coronado Island, Gulf of Lower California, Mexico. From Porites reef bed overlying algal limestone, which in turn is overlain unconformably by a Late Pleistocene terrace.

Common in Sample No. A-3548 and rare in Sample No. A-3582. Similar to *Massilina inaequalis* Cushman but differs from it by being thick and not depressed in middle, and by having prominent longitudinal ridges forming an irregular cross section for chambers.

Named after J. Wyatt Durham, of the University of California at Berkeley, California.

Massilina robustior Cushman and Valentine

(Plate 3, figures 1a, b, c)

Massilina robustior CUSHMAN AND VALENTINE, Contrib. Dept. Geol., Stanford Univ., vol. 1, no. 1, 1930, p. 13, pl. 3, figs. 5a, b, c. NATLAND, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 3, no. 10, 1933, line 46 on included chart.

Length 0.94 mm.; breadth 1.01 mm.; thickness 0.69 mm.

Abundant at several localities. Identical to specimens found in Lithothamnion-covered bottoms of Avalon Bay, Santa Catalina Island, California. A shallow-water species, not too sensitive to temperature but more usually found near coral reefs or in sheltered island coves.

Massilina pulcherrima Cushman and Valentine

(Plate 3, figures 5a, b)

Massilina pulcherrima CUSHMAN AND VALENTINE, Contrib. Dept. Geol., Stanford Univ., vol. 1, no. 1, 1930, p. 13, pl. 4, figs. 2a, b.

Length 0.70 mm.; breadth 0.37 mm.; thickness 0.17 mm.

Found only at Locality A-3582 where it was rare. Spines are not as prominent on specimens from this locality as on those from off Southern California. However, with most spinose species the degree of spine development is quite variable from specimen to specimen and even more so from locality to locality. Its known habitat is clear, shallow water such as the Bay of Avalon, Santa Catalina Island, where it is common.

Genus ***Spiroloculina*** d'Orbigny, 1826

Spiroloculina antillarum d'Orbigny

(Plate 3, figures 6a, b)

Spiroloculina antillarum D'ORBIGNY, *in* DE LA SAGRA, Hist. Fis. Pol. Nat., Cuba, 1839, "Foraminifères," p. 166, pl. 9, figs. 3, 4. CUSHMAN, U. S. Nat. Mus., Bull. 104, 1929, pt. 6, p. 43, pl. 9, fig. 3.

Length 0.70 mm.; breadth 0.36 mm.; thickness 0.12.

A single specimen was found at Locality A-3550. Comparably close to those originally described from West Indies region.

Genus ***Sigmoilina*** Schlumberger, 1887

Sigmoilina tenuis (Czjzek)

(Plate 3, figures 7a, b)

Quinqueloculina tenuis CZJZEK, Haidinger's Nat. abhandl., vol. 2, 1847, p. 149, pl. 13, figs. 31–34.
Sigmoilina tenuis (Czjzek) CUSHMAN, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 1, no. 10, 1927, p. 139.

Length 0.47 mm.; breadth 0.26 mm.; thickness 0.117 mm.

Rare in Pliocene beds of this report. Occurs Recent off Central America, in water 38–2100 meters deep. Off Southern California, its known depth range is 20–1100 meters. Also abundant in Upper and Lower Pliocene of the Los Angeles and Ventura Basins of Southern California.

Genus ***Articulina*** d'Orbigny, 1826

Articulina lineata H. B. Brady

(Plate 3, figures 9a, b)

Articulina lineata H. B. BRADY, Rept. Voy. Challenger, Zoology, vol. 9, 1884, p. 183, pl. 12, figs. 19 to 21. CUSHMAN, U. S. Nat. Mus., Bull. 104, 1929, pt. 6, p. 52, pl. 11, figs. 8–10; pl. 12, fig. 1.

Length 0.70 mm.

A few broken specimens of this species were found at Localities A-3547 and A-3548. They compare closely with those figured from Tortugas region off Florida, and their presence in the above samples indicates a tropical depositional environment for the beds from which they were collected.

Genus ***Hauerina*** d'Orbigny, 1839

Hauerina bradyi Cushman

(Plate 3, figures 8a, b, c)

Hauerina compressa H. B. BRADY (not *H. compressa* D'ORBIGNY), Rept. Voy., Challenger, Zoology, vol. 9, 1884, p. 190, pl. 11, figs. 12, 13.

Hauerina bradyi CUSHMAN, U. S. Nat. Mus., Bull. 71, pt. 6, 1917, p. 62, pl. 23, fig. 2. CUSHMAN AND VALENTINE, Contrib. Dept. Geol., Stanford Univ., vol. 1, pt. 1, 1930, p. 14, pl. 3, figs. 7a, b, c. CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 22, pt. 1, 1946, p. 11, pl. 2, figs. 14, 20, 21

Length 0.54 mm.; breadth 0.41 mm.; thickness 0.16 mm.

The specimens commonly referred to this species have smooth, unornamented walls, whereas most of the specimens found in our samples, and from bottom samples off Southern California, are ornamented—especially in the early chambers—with prominent radial ridges crossed by fine costae. It appears to be related to *Hauerina lowelli* Bermudez and *H. ornatissima*, from the Cuban and Tortugas regions off Florida. However, until a larger number of specimens are at hand, it does not seem advisable to erect a new species name for these specimens.

Genus ***Triloculina*** d'Orbigny, 1826

Triloculina inflata d'Orbigny

(Plate 3, figures 11a, b, c)

Triloculina inflata D'ORBIGNY, A. D., Tableau méthodique de la classe des Céphalopodes. Ann. Sci. Nat., Paris, France, sér.1, tome 7, 1836, p. 300. D'ORBIGNY, Foram. Foss. du Bassin Tert. de Vienne, Paris, France, 1846, pl. 17, figs. 13–15.

Length 0.65 mm.; breadth 0.49 mm.; thickness 0.37 mm.

The figure shown in the 1846 reference is almost identical with that shown here on Plate 3, although it somewhat resembles *Triloculina laevigata* d'Orbigny, *T. pyrula* Karrer, and *T. subinflata* Ruess. *T. inflata* can be distinguished from *T. rotunda* because it is more compressed, with less-inflated chambers.

Triloculina rotunda d'Orbigny

(Plate 3, figures 12a, b, c)

Triloculina rotunda D'ORBIGNY, Ann. Sci. Nat., vol. 7, no. 4, 1826, p. 299. CUSHMAN, U. S. Nat. Mus., Bull. 104, pt. 6, 1929, p. 59, pl. 14, figs. 3a–c.

Length 0.56 mm.; breadth 0.41 mm.; thickness 0.40 mm.

Rare in Pleistocene shallow-water beds. Similar to *Triloculina circularis* in general features but differs from it by having a distinct bifid tooth in place of a semicircular plate.

Triloculina oblonga (Montagu)

(Plate 3, figures 13a, b, c)

Vermiculum oblongum MONTAGU, Test. Brit., 1803, p. 522, pl. 14, fig. 9.

Triloculina oblonga D'ORBIGNY, Ann. Sci. Nat., vol. 7, 1826, p. 300, no. 16; Modèles No. 95; *in* DE LA SAGRA, Hist. Fis. Pol. Nat., Cuba, 1839, "Foraminifères," p. 175, pl. 10, figs. 3–5. CUSHMAN, U. S. Nat. Mus., Bull. 104, pt. 6, 1929, p. 57, pl. 13, figs. 4, 5. NATLAND, Scripps Inst. Oceanog., Bull., Tech. Serv., vol. 3, no. 10, 1933, line 23 on included chart.

Length 0.47 mm.; breadth 0.26 mm.; thickness 0.20 mm.

A common species in this collection. Off Southern California and Central America it is found most abundant in water shallower than 60 meters. Similar to *Triloculina inflata* but smaller and has thinner walls.

Triloculina circularis Bornemann

(Plate 3, figures 14a, b, c)

Triloculina circularis BORNEMANN, Zeitschr. deutsch. geol. Ges., vol. 7, 1855, p. 349. CUSHMAN AND VALENTINE, Contrib. Dept. Geol., Stanford Univ., vol. 1, no. 1, 1930, p. 15, pl. 4, figs. 4a, b, c. NATLAND, Scripps Inst. Oceanog., Bull., vol. 3, no. 10, 1933, line 16 on included chart.
Miliolina circularis H. B. BRADY, Rept. Voy. Challenger, Zoology, vol. 9, 1884, p. 169, pl. 4, figs. 3a, b, c; pl. 5, figs. 13, 14.

Length 0.35 mm.; breadth 0.41 mm.; thickness 0.20 mm.

Differs from many other similar forms by having a plate-like tooth instead of a bifid one. Typically broader than long and usually much more inflated than is shown by Figure 14. Its walls are usually thin, white, brittle, and glossy. Off Southern California and Central America it is most abundant in water shallower than 40 meters, most prolific in clear water on rocky bottoms covered with shell material.

Genus *Pyrgo* Defrance, 1824

Pyrgo denticulata (H. B. Brady)

(Plate 3, figures 10a, b)

Biloculina ringens Lamarck var. *denticulata* H. B. BRADY, Rept. Voy. Challenger, Zoology, vol. 9, 1884, p. 143, pl. 3, figs. 4, 5.
Biloculina denticulata CUSHMAN, U. S. Nat. Mus., Bull. 71, pt. 6, 1917, p. 80, pl. 33, fig. 1.
Pyrgo denticulata CUSHMAN, U. S. Nat. Mus., Bull. 104, pt. 6, 1929, p. 69, pl. 18, figs. 3, 4.

Length 0.78 mm.; breadth 0.76 mm.; thickness 0.59 mm.

Specimens from Pleistocene of Gulf of California are not as denticulate as those shown from the West Indies and the Indio-Pacific regions. Dentitions are only faintly represented. They are similar in all other respects, both having an elongate aperture with distinctive bifid tooth.

Pyrgo elongata (d'Orbigny)

(Plate 4, figures 1a, b)

Biloculina elongata D'ORBIGNY, Ann. Sci. Nat., vol. 7, no. 4, 1826, p. 298.
Pyrgo elongata (d'Orbigny) CUSHMAN, U. S. Nat. Mus., Bull. 104, pt. 6, 1929, p. 70, pl. 19, figs. 2, 3. NATLAND, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 3, no. 10, 1933, line 15 on included chart.

Length 0.52 mm.; breadth 0.33 mm.; thickness 0.33 mm.

A common shallow-water species along the Pacific shores and typically represented in this collection.

Family OPHTHALMIDIIDAE

Subfamily CORNUSPIRINAE

Genus *Cornspira* Schultze, 1854

Cornuspira involvens (Reuss)

(Plate 4, figures 2a, b)

Operculina involvens REUSS, Denkschr. Akad. Wiss. Wien, vol. 1, 1850, p. 370, pl. 46, fig. 30.
Cornuspira involvens (REUSS), Sitz. Akad. Wiss. Wien, vol. 48, abt. 1, 1863, p. 39, pl. 1, fig. 2. CUSHMAN, U. S. Nat. Mus., Bull. 104, pt. 6, 1929, p. 80, pl. 20, figs. 6, 8. NATLAND, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 3, no. 10, 1933, line 65 on included chart.

Diameter 0.23 mm.; thickness 0.6 mm.

This small delicate species is not often found preserved in fossil material. It is probably more abundant and widespread than indicated on Figure 1. Both off Southern California and off the west coast of Central America it is only known to occur in water shallower than 40 meters.

Subfamily OPHTHALMIDIINAE

Genus *Planispirinella* Wiesner, 1931

Planispirinella exigua (H. B. Brady)

(Plate 4, figures 3a, b)

Hauerina exigua H. B. BRADY, Quart. Jour. Micro. Sci., vol. 19, 1879, p. 53.
Planispirina exigua H. B. BRADY, Rept. Voy. Challenger, Zoology, vol. 9, p. 196, pl. 12, figs. 1–4. CUSHMAN, U. S. Nat. Mus., Bull. 161, pt. 1, 1932, p. 71, pl. 16, figs. 7a, b.

Length 0.70 mm.; breadth 0.59 mm.; thickness 0.14 mm.

Common in Pleistocene beds exposed on south side of Coronado Island. Usually found living in a tropical environment, and therefore such an environment is suggested for these beds.

Family LAGENIDAE

Subfamily NODOSARIINAE

Genus ***Robulus*** Montfort, 1808

Robulus cushmani Galloway and Wissler

(Plate 4, figures 4a, b)

Robulus cushmani GALLOWAY AND WISSLER, Jour. Paleont., vol. 1, pt. 1, 1927, p. 51, pl. 8, figs. 11a, b. NATLAND, Scripps Inst. Oceanog., Bull., vol. 3, no. 10, 1933, line 149 on included chart.

Length 0.93 mm.; breadth 0.82 mm.; thickness 0.53 mm.

Present in Pliocene only, common at Locality A-3500 and rare at A-3502. Found abundant and widespread off west coast of Central America and has a known depth range of 38–384 meters, optimum development between 90 and 270 meters. Off Southern California its known bathymetric range is 40–800 meters, with an occasional occurrence at greater depth. However, most occurrences below 270 meters are thought to have been carried out to deeper water from shallower depths.

Also abundant in Upper and Middle Pliocene of Los Angeles and Ventura basins. Coryell and Mossman recently describe a new variety of *Robulus cushmani* from Charco Azul Formation, Pliocene, of Panama. It is the writer's opinion that this variety falls within the range of individual variation of *R. cushmani* and should therefore be classed as the same.

This form is also similar to *Robulus lucida* (Cushman) described from the Atlantic Ocean about 100 miles south of Woods Hole but has much larger and clearer umbilical areas. Also compares closely with figures shown of *Robulus trigonostoma* (Reuss) and *Robulus inornatus* (d'Orbigny). However, the latter name has been used as a dumping grounds for numerous species of California *Robulus*, especially those of the Eocene.

Genus ***Dentalina*** d'Orbigny, 1826

Dentalina cf. ***communis*** (d'Orbigny)

(Plate 4, figures 10a, b, 11)

Nodosaria communis D'ORBIGNY, Ann. Sci. Nat., Paris, France, 1826, sér. 1, tome 7, p. 254. FLINT, U. S. Nat. Mus., 1897, p. 310, pl. 56, fig. 2.

A few broken specimens were found in the Pliocene beds exposed on Carmen Island. More than 15 species, according to their figures, are similar to this form. Of these, *Dentalina partschi* Neugeboren compares most favorably in all respects. Flint's figures of *Dentalina communis* are identical to those from Carmen Island, but it is doubtful that they are *Nodosaria communis* of d'Orbigny which typically has much more oblique sutures.

Off the west coast of Central America, its bathymetric range is 67–360 meters.

Genus ***Nodosaria*** Lamarck, 1812

Nodosaria moniliformis Ehrenberg

(Plate 4, figures 12a, b)

Nodosaria moniliformis EHRENBERG, 1860 (nom. nud.)

Nodosaria moniliformis EHRENBERG, Preuss. Akad. Wiss., 1872, p. 285, pl. 6 (Group 3, fig. 11).

Length 1.00 mm.

No specimens were found with more than the first three chambers preserved, which makes identification difficult. However, they resemble *Nodosaria moniliformis* described by Ehrenberg from a Recent sample collected from a depth of 4754 meters, approximately 800 miles west of Point Antonio, Lower California, Mexico. *Nodosaria tornata* Schwager, which is abundant in the Pliocene of Southern California, closely resembles this species but differs slightly by having more embracing chambers which are much broader than high.

Subfamily LAGENINAE

Genus *Lagena* Walker and Jacob, 1798

Lagena williamsoni (Alcock)

(Plate 4, figure 5)

Entosolenia williamsoni ALCOCK, Lit. Philos. Soc., Pr., vol. 4, 1865, p. 193.
Lagena williamsoni WRIGHT, Belfast Nat. Field Club, Pr., App. 4, p. 104, pl. 4, fig. 14, 1876–77.
Bagena williamsoni (Alcock), NATLAND, Scripps Inst. Oceanog., Bull., vol. 3, no. 10, 1933, on line 96 of included chart.

Length 0.29 mm.; diameter 0.18 mm.

Found only in the samples from the Pliocene exposed in Salinas Bay, Carmen Island. Known depth range of this species, off the west coast of Central America, is 123–1875 meters, being rather common and widespread. Off Southern California, its known range is 45–2120 meters. The specimens from Carmen Island, as well as the Recent ones, are rather difficult to distinguish from *Lagena acuticosta* Reuss because the reticulate collar at the apertural end shows varying degrees of development; it may well be that they should all be referred to *Lagena acuticosta*.

Lagena hexagona (Williamson) var. ***scalariformis*** (Williamson)

(Plate 4, figure 6)

Entosolenia squamosa (Montagu) var. *scalariformis* WILLIAMSON, Rec. Foram., Great Britain, 1858, p. 13, pl. 1, fig. 30.
Lagena scalariformis REUSS, Sitz. Akad. Wiss. Wien., vol. 46, pt. 1, 1862 (1863) p. 333, pl. 5, figs. 69–71.
Lagena hexagona (Williamson) var. *scalariformis* (Williamson), CUSHMAN, U. S. Nat. Mus., Bull. 71, pt. 3, 1913, p. 17, pl. 6, fig. 4. NATLAND, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 3, no. 10, 1933, on line 41 of included chart.

Length 0.29 mm.; diameter 0.20 mm.

Several specimens of this species were found in the Pliocene beds exposed on Carmen Island. It is rare off the west coast of Central America but is common off Southern California and extends from Recent to Pliocene. Known bathymetric range off Southern California is 6–650 meters.

Lagena sulcata (Walker and Jacob)

(Plate 4, figure 7)

"*Serpula* (*Lagena*) *striata sulcata rotundata*" WALKER AND BOYS, Test. Min., 1784, p. 2, pl. 1, fig. 6.
Serpula (*Lagena*) *sulcata* WALKER AND JACOB, Adams' Essays, Kanmacker's ed., 1798, p. 634, pl. 14, fig. 5.
Lagena sulcata PARKER AND JONES, Philos. Trans., vol. 155, 1865, p. 351. CUSHMAN, U. S. Nat. Mus., Bull. 104, pt. 4, 1923, p. 57, pl. 11, fig. 1. NATLAND, Scripps Inst. Oceanog., Bull., vol. 3, no. 10, 1933, on line 127 of included chart.

Length 0.42 mm.; diameter 0.29 mm.

A single specimen found at Locality A-3503 compares favorably with figures of this species, except that its costae do not coalesce at the base but terminate about three fourths of the way down, leaving the distal end rather smooth.

This species, off the west coast of Central America, has a known bathymetric range of 40–1272 meters. Off Southern California, its known range is 60–1354 meters. Also commonly found in Upper Pliocene and rare in Repetto Formation (Lower Pliocene) of Southern California.

Family POLYMORPHINIDAE

Subfamily POLYMORPHININAE

Genus *Guttulina* d'Orbigny, 1839

Guttulina quinquecosta Cushman and Ozawa

(Plate 4, figures 8a, b)

Guttulina quinquecosta CUSHMAN AND OZAWA, U. S. Nat. Mus., Pr., vol. 77, no. 2829, art. 6, 1930, p. 46, pl. 11, figs. 3a–c. NATLAND, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 3, no. 10, 1933, line 104 on included chart.

Length 0.47 mm.; breadth 0.32 mm.

A single specimen from Locality A-3503 is referred to this species. Common, both Recent and fossil, in Southern California, but as yet not known from off the west coast of Central America. Off Southern California its bathymetric range is 30–150 meters. Rare in Pleistocene, common in Upper Pico (Pliocene), and rare in upper part of Middle Pico (Pliocene) of Los Angeles and Ventura Basins, California.

Genus ***Globulina*** d'Orbigny, 1839

Globulina gibba d'Orbigny

(Plate 4, figures 9a, b, c)

Globulina gibba D'ORBIGNY, Ann. Sci. Nat., vol. 7, no. 10, 1826, p. 266, Mòdeles No. 63. (For synonomy see) CUSHMAN AND OZAWA, U. S. Nat. Mus., Pr., vol. 77, art. 6, 1930, p. 60–64, pl. 16, figs. 1–4.
Globulina sp. NATLAND, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 3, no. 10, 1933, line 137 on included chart.

Length 0.50 mm.; breadth 0.42 mm.; thickness 0.35 mm.

Two specimens were found in the Pliocene beds of Carmen Island. They are identical to those found off Santa Catalina Island, California, where their known bathymetric range is 30–150 meters. Species common in Upper Pliocene beds exposed in Palos Verdes Hills and at Bath House Beach Santa Barbara, California. Also present in Relizian (Middle Miocene) and in Zemorrian (Lower Miocene or Upper Oligocene) of California.

Family NONIONIDAE

Genus ***Nonion*** Montfort, 1808

Nonion grateloupi (d'Orbigny)

(Plate 4, figures 13a, b)

Nonionina grateloupi D'ORBIGNY, Ann. Sci. Nat., vol. 7, no. 19, 1826, p. 294.
Nonionina scapha CUSHMAN (not FICHTEL AND MOLL), U. S. Nat. Mus., Bull. 103, 1918, p. 73, pl. 25, figs. 6a, b.
Nonion grateloupi CUSHMAN, Florida State Geol. Survey, Bull. No. 4, 1930, p. 36, pl. 6, figs. 1–3.

Length 0.38 mm.; breadth 0.31 mm.; thickness 0.13 mm.

Present in both Pleistocene and Pliocene beds of Carmen Island region. As Cushman pointed out (1930), this species often becomes asymmetrical like *Nonionella*. Most of the Carmen Island specimens are quite asymmetrical but some are not; hence, they are all thought to lie within the range of variation for this species.

It closely resembles *Nonionella auris* (d'Orbigny), but a study of specimens from off Chile and Ecudor show this species to be much thicker, with a well-developed lobe extending over the umbilical area on the dorsal side.

Genus ***Elphidium*** Montfort, 1808

Elphidium excubitor Nicols

(Plate 4, figures 14a, b)

Elphidium excubitor NICOLS, Jour. Paleont., vol. 18, no. 2, 1944, p. 178, pl. 29, figs. 4, 8.

Length 0.70 mm.; breadth 0.65 mm.; thickness 0.35 mm.

Mr. Nicols has done an admirable job of splitting the *Elphidium "crispum"* type into several species, and, no doubt, much could be gained by subjecting all of our species to such a critical examination. However, the more specimens one studies from a wider variety of environments, the stronger becomes the conclusion that along the west coast of North America we have two principle types of *E. "crispum"*. One, in general, has a biconvex cross section and prefers a shallow-water intertidal environment; the other has a diamond-shaped cross section, with the sides of some specimens showing a tendency to become slightly biconcave in cross section, and prefers a slightly colder and deeper-water environment.

Elphidium fax pinque Nicols, *E. excubitor* Nicols, and *E. concinnum* Nicols fall into the biconvex group and should probably all be considered as one species. *Elphidium fax barberensi* Nicols and *E. fax fax* Nicols belong in the latter group.

Molluscan data have quite conclusively shown that during Pleistocene time the cool-water molluscan species from north of Cape Mendocino migrated southward at least as far as San Diego, California, bringing with them the *E. fax fax* type described by Nicols from the Straits of Juan de Fuca, Washington. *E. fax fax*, with the diamond-shaped cross section, is now living off Santa Catalina Island in great abundance, below 70 meters of water at a temperature of approximately 11° Centigrade (51.8° Fahrenheit). According to Mr. Nicols' chart (1944, p. 175), *E. fax fax* is now living off Washington in water of about the same surface temperature, which suggests, that temperature may be a significant environmental control for this species.

Elphidium poeyanum (d'Orbigny)

(Plate 4, figures 15a, b)

Polystomella poeyana D'ORBIGNY, *in* DE LA SAGRA, Hist. Fis. Pal. Nat., Cuba, 1839, "Foraminifères," p. 55, pl. 6, figs. 25, 26.

Elphidium transluceus NATLAND, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 4, no. 5, 1938, p. 144, pl. 5, figs. 3, 4. CUSHMAN AND MCCULLOCH, Allan Hancock Pacific Exped., vol. 6, no. 3, 1940, p. 172, pl. 19, fig. 9.

Length 0.53 mm.; breadth 0.47 mm.; thickness 0.29 mm.

During the War, Albert Brown, an officer in the Merchant Marine, collected anchor samples from numerous widely scattered localities over the world. These samples, for the most part, as they were all from water shallower than 40 meters, contained this species in abundance. Those from the Tortugas region of Florida, in general, have fewer chambers than those found off Southern California. The most consistent distinguishing characteristic is its thin, perforated, glassy, translucent walls. After study of a large number of specimens, some from near the type locality, it is quite obvious that *Elphidium translucens* is synonymous with *E. poeyanum*, as probably is *E. granulosum* (Galloway and Wissler).

Elphidium spinatum Cushman and Valentine is closely related to this species, if not the same. In fact, the spines on *E. spinatum* are all that distinguish it from *E. poeyanum*. These spines show various degrees of development from one each to the last four chambers, to only one spine, faintly visible, on the last chamber. When the spines are not present or if the last few chambers are broken off, it is indistinguishable from *E. poeyanum*.

E. poeyanum is common in the youngest Pleistocene beds of Southern California. Its presence in the Carmen Island Pleistocene indicates a depositional environment of less than 70 meters.

This is truly a shallow-water species, found the world over in water shallower than 70 meters. Those found at a greater depth were probably transported there from lesser depths. Apparently, it has a tolerance for a wide temperature range; it seems equally abundant in the tropical waters of the Tortugas region of Florida or the cooler waters off California.

Elphidium articulatum (d'Orbigny)?

(Plate 4, figures 16a, b)

Polystomella articulata D'ORBIGNY, Voy. Amér. Mérid., vol. 5, pt. 5, 1839, "Foraminifères," p. 30, pl. 3, figs. 9, 10.

Elphidium articulatum CUSHMAN, U. S. Nat. Mus., Bull. 104, no. 7, 1930, p. 26, pl. 10, figs. 5, 6–8. NATLAND, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 3, no. 10, 1933, line 4 on included chart.

Length 0.42 mm.; breadth 0.35 mm.; thickness 0.22 mm.

D'Orbigny's figures of *Elphidium poeyanum* and *E. articulatum* are quite similar; so much so that they might be considered as equals. This thought is further strengthened when one examines specimens from the vicinity of the type locality. However, until more conclusive evidence is at hand, it seems more advisable to use *E. articulatum*, a name which locally has been used to designate specimens of this type.

Earlier workers have often referred this species to *E. stricto-punctata*. A similar form called *E. incentum*, in the Atlantic Ocean, is widely distributed. It is abundant in the Pleistocene and rare in the Pliocene of the Carmen Island region.

Family PENEROPLIDAE
Subfamily SPIROLININAE

Genus ***Peneroplis*** Montfort, 1808
Peneroplis pertusus (Forskål)

(Plate 4, figures 17a, b)

Nautilus pertusus FORSKÅL, Descr. Anina., 1775, p. 125, no. 65.
Peneroplis pertusus Jones, PARKER, Foram. Crag., 1865, p. 19. CUSHMAN, U. S. Nat. Mus., Bull. 104, 1930, pt. 7, p. 35, pl. 12, figs. 3–6.

Diameter 0.41 mm.; thickness 0.28 mm.

Found only at Locality A-3550 where it was rare. Its presence here indicates a tropical environment for the strata. It is a rare species in the West Indies region, has not been found Recent off the west coast of Central America but should occur there because of its tropical environment, and is not known from off Southern California.

Subfamily ORBITOLITINAE

Genus ***Amphisorus*** Ehrenberg, 1840
Amphisorus hemprichii Ehrenberg

(Plate 5, figures 1a, b)

Amphisorus hemprichii EHRENBERG, Abhandl. K. Akad. Wiss. Berlin, 1838, p. 134, pl. 3, fig. 3.
"*Orbulites duplex* type," W. B. CARPENTER, Philos. Trans., 1856, p. 120, pl. 5, fig. 10; pl. 9, fig. 10.
Orbulites duplex W. B. CARPENTER, Rept. Voy. Challenger, Zoology, pt. 21, 1883, p. 25, pl. 3, figs. 8–14; pl. 4, figs. 6–10; pl. 5, figs. 1–13. CUSHMAN, U. S. Nat. Mus., Bull. 104, pt. 7, 1930, pp. 50–52, pl. 18, figs. 5–7.

Diameter 1.25 mm.; thickness 0.18 mm.

Only fragmental specimens were found, which makes certain identification difficult, and a careful examination of them leaves some doubt as to whether there are one or two layers of chambers. However, their general appearance is more similar to figures of *Amphisorus* than the described species of *Sorites*. Presence of this form in the samples indicates a tropical depositional environment such as found in the Florida region. Not known from the San Diego region northward along the coast but rare in shallow water off the west coast of Central America.

Family HETEROHELICIDAE
Subfamily EOUVIGERININAE

Genus ***Nodogenerina*** Cushman, 1927
Nodogenerina lepidula (Schwager)

(Plate 5, figures 3a, b)

Nodosaria lepidula SCHWAGER, Novara Exped. Geol. Theil, Bd. 2, abt. 2, p. 210, pl. 5, figs. 27–28.
Nodogenerina lepidula (Schwager), NATLAND, Scripps. Inst. Oceanog., Bull., Tech. Ser., vol. 3, no. 10, 1933, line 268 on included chart.

Length 0.82 mm.; diameter 0.18 mm.

In the Carmen Island region, this species is known only from Pliocene. Abundant in the Repetto formation of Lower Pliocene age and from the Upper Eocene of California, U. S. A. Two specimens were found in Recent sediments, at a depth of 1450 m., off the west coast of Panama. However, these occurrences are thought to be reworked from older rocks. *Nodosaria lepidula* Schwager var. *hispidula* (Cushman), a similar form, was reported from off Mindinao, Philippine Islands, at a depth of 903 meters. It is closely related to *N. egregia* Franzenau, a species reported from the older Tertiary of Budapest, Hungary. However, the figures of this species do not show the fringe of spines which are around the lower side of each chamber in typical specimens of *N. lepidula*. *Nodosaria antillea* (Cushman) is thought to be a synonym of *N. lepidula* (Schwager). Dr. Cushman reported *N. antillea* from a depth of 307 meters, off the Carolina coast, U. S. A.

Nodogenerina advena Cushman and Laiming

(Plate 5, figures 4a, b)

Nodogenerina advena Cushman and Laiming, Jour. Paleont., vol. 5, no. 2, 1931, p. 106, pl. 11, figs. 19a, b. See Kleinpell (Inclusive Synonymy), Miocene Stratigraphy of California, A. A. P. G. Spec. Pub., 1938, p. 243, pl. 9, fig. 10. Natland, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 3, no. 10, 1933 (line 288 on included chart).

Length 0.89 mm.; diameter 0.24 mm.

In the Carmen Island region, known only from the Pliocene. Not known from Recent sediment and therefore thought to be extinct. In California Tertiary section, its known range is from Lower Pliocene to Eocene, being most abundant in Lower Pliocene and Miocene.

Family Buliminidae

Subfamily Turrilininae

Genus ***Buliminella*** Cushman, 1911

Buliminella subfusiformis Cushman

(Plate 5, figures 5a, b)

Buliminella subfusiformis Cushman, Contrib. Cushman Lab. Foram. Res., vol. 1, no. 8, 1925, p. 33, pl. 5, fig. 12. Cushman and Moyer, Contrib. Cushman Lab. Foram. Res., vol. 6, pt. 3, 1930, p. 56, pl. 7, fig. 20. Natland, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 3, no. 10, 1933 (line 163 on included chart).

Length 0.48 mm.; diameter 0.17 mm.

One of the most abundant found in Pliocene beds. In California, it ranges from the Recent sediments to Eocene, but not without considerable variation. Recent forms are in general more elongated and less inflated than those found in the Pliocene, and the Miocene specimens tend to be more inflated than those of the Pliocene. *Buliminella bassendorfensis* Cushman and Parker, described from the Oligocene, probably belongs to this species. It is an easy task to distinguish several species in this group, when only a few isolated localities are considered, but when collected from several hundred localities scattered over a wide area it becomes increasingly difficult to make even vague generalities hold. There is an unbroken gradation between those called *Buliminella subfusiformis* v. *tenuata* Cushman to *B. curta* Cushman.

However, some of the variations have local stratigraphic significance and should probably be set up as varieties rather than as separate species (Coryell and Mossman, 1942, p. 243; pl. 36, fig. 45). *Buliminella inconstans*, of Coryell and Mossman (not Egger), should probably be included with this species. Egger's figures of *B. inconstans* show this species to be much more inflated than the average *B. subfusiformis*.

Off the west coast of Central America the known bathymetric range of this species is 480–2250 meters, being most abundant from 480 to 1200 meters. Off Southern California its depth range is 50–2200 meters, and it is most abundant between 500 and 1000 meters.

Buliminella elegantissima (d'Orbigny)

(Plate 5, figure 6)

Bulimina elegantissima D'Orbigny, Voy. Amér. Mérid., vol. 5, pt. 5, 1839, "Foraminifères," p. 51, pl. 7, figs. 13–14.

Buliminella elegantissima Cushman, U. S. Nat. Mus., Bull. 71, pt. 2, 1911, p. 89. Natland, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 3, No. 10, 1933 (line 2 on included chart).

Length 0.35 mm.; diameter 0.80 mm.

This small species is represented by only three specimens from Locality A-3550. Its scarcity in the shallow-water Pleistocene of the Carmen Island region can probably be attributed to the lack of muddy bottom environments since the world over, regardless of temperature, this species abounds on shallow, muddy bottoms. In the California Tertiary, it is found abundantly in sediments from Recent to Miocene age.

Off the west coat of Central America its known bathymetric range is 6–640 meters, being most abundant between 63 and 104 meters. Off Southern California its bathymetric range is 1–550 meters, being most abundant between 1 and 25 meters.

Subfamily BULIMININAE

Genus *Bulimina* d'Orbigny, 1826

Bulimina ovula d'Orbigny

(Plate 5, figures 7a, b)

Bulimina ovula D'ORBIGNY, Voy. Amér. Mérid., vol. 5, pt. 5, "Foraminifères," 1839, p. 51, pl. 1, figs. 10, 11. CUSHMAN AND PARKER, Contrib. Cushman Lab. Foram. Res., vol. 16, pt. 1, 1940, p. 10, pl. 2, figs. 13–15. NATLAND, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 3, no. 10, 1933 (line 241 on included chart).

Length 1.17 mm.; diameter 0.70 mm.

Common in the Pliocene sediments of Carmen Island. The specimen figured is similar to *Bulimina affinis* because it contains more whorls than the usual *B. ovula*, but the average specimen from Carmen Island lies within the range of *B. ovula*, where, in the adult form, the last two chambers make up more than half the test. This is probably the same species as was called *B. affinis* by Coryell and Mossman (1942).

This species ranges throughout the California Tertiary, usually occurring with bathyl or abyssal faunules. Its bathymetric range off the west coast of Panama is 384–2560 meters, most prolific between 384 and 1650 meters. Off Southern California, its known range is 80–1800 meters; it is most abundant between 500 and 1000 meters.

Bulimina cf. *uvigerinaformis* Cushman and Kleinpell

(Plate 5, figures 8a, b)

Bulimina uvigerinaformis CUSHMAN AND KLEINPELL, Contrib. Cushman Lab. Foram. Res., vol. 10, pt. 1, 1934, p. 5, pl. 1, figs. 14a, b. KLEINPELL, R. M., Spec. Publ., Am. Assoc. Petrol. Geol., 1838, p. 259.

Length 0.83 mm.; diameter 0.42 mm.

Quite abundant at Localities A-3500, A-3501, A-3502, and A-3503. Not found at Locality A-3504 which is only 10 feet stratigraphically below A-3503. The other samples from the Pliocene contained much the same fauna but were also lacking in this species, which suggests that *Bulimina uvigerinaformis* probably has a limited stratigraphic range and should therefore make an excellent minor zonule for purposes of correlation in the Carmen Island region. In Southern California this species is confined to the Lower Mohnian stage which is placed in the Upper Miocene. Its occurrence in the Pliocene of Carmen Island suggests that perhaps the so-called Pliocene may be Miocene, but considering the entire Carmen Island fauna Pliocene seems more reasonable.

Bulimina marginata d'Orbigny

(Plate 5, figures 9a, b)

Bulimina pulchella D'ORBIGNY, Voy. Amér. Mérid., vol. 5, pt. 5, "Foraminifères," 1839, p. 50, pl. 1, figs. 6, 7. NATLAND, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 3, no. 10, 1933 (line 7 on included chart).

Bulimina patagonica CUSHMAN AND KELLETT (not D'ORBIGNY), U. S. Nat. Mus., Pr., vol. 75, art. 25, 1929, p. 7, pl. 3, figs. 4a, b.

Bulimina serrata BAILEY, Smithsonian Contrib., vol. 2, art. 3, 1851, p. 12, pl., 2, figs. 32–34.

Bulimina marginata D'ORBIGNY, Am. Sci. Nat., Ser. 1, vol. 7, 1826, p. 269, pl. 12, figs. 10–12. CUSHMAN AND PARKER, Contrib. Cushman Lab. Foram. Res., vol. 16, pt. 1, 1940, p. 9, pl. 2, figs. 8, 9.

Length 0.41 mm.; diameter 0.24 mm.

Widely distributed in both Recent and fossil sediments. Its shape, in general, is quite uniform, but degree of ornamentation differs considerably. Some specimens have chambers which are quite round, with only a suggestion of a basal spiny fringe. The other extreme is a test sharply undercut with numerous well-developed spines.

The following species are thought to be similar or closely related to *Bulimina marginata: Bulimina pagoda* Cushman var. *denudata* Cushman and Parker, *B. pagoda* Cushman var. *deformata* Cushman and Parker, *B. laevigata* d'Orbigny, *B. gibba* Fornasini var. *marginata* Fornasini, *B. fusiformis* Williamson var. *pupoides* Fornasini, *B. fusiformis* var. *marginata* Fornasini, *B. baccata* Fornasini, *B. elegans* d'Orbigny var. *marginata* Fornasini, *B. serrata* Bailey, *B. etnea* Seguenza.

Bulimina marginata prefers a muddy bottom environment. Off both the west coast of Central America and Southern California it is most abundant between 10 and 275 meters.

Genus ***Globobulimina*** Cushman, 1927

Globobulimina pacifica Cushman

(Plate 5, figures 10a, b)

Globobulimina pacifica CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 3, pt. 1, 1927, p. 67, pl. 14, figs. 12a, b. KLEINPELL, Am. Assoc. Petrol. Geol., Spec. Pub., 1938, p. 260, pl. 8, fig. 7. NATLAND, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 10, no. 3, 1933, line 194 on included chart.

Length 0.57 mm.; diameter 0.38 mm.

Has thin, translucent walls which are not easily preserved in fossil sediments. When found they usually are preserved as internal molds of calcite or pyrite. They range throughout the Tertiary of Southern California. Off Central America, its bathymetric range is 49–4140 meters. The abundance of this species is so uniform over the wide range in depth as to suggest a pelagic mode of life for the species. Off Southern California the species ranges from 275 to 1100 meters. No valid reason is forthcoming as to why *Globobulimina pacifica* does not extend into as shallow water off Southern California as off Central America.

Genus ***Entosolenia*** Ehrenberg, 1848

Entosolenia sp. A

(Plate 5, figures 2a, b)

A single specimen was found at Locality A-3504.

Subfamily VIRGULININAE

Genus ***Virgulina*** d'Orbigny, 1826

Virgulina californiensis Cushman

(Plate 5, figures 11a, b)

Virgulina californiensis CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 1, pt. 2, 1925, p. 32, pl. 5, figs. 11a, b, c. KLEINPELL, Amer. Assoc. Petrol. Geol., Spec. Pub., 1938, p. 251, pl. 15, fig. 4.

Length 0.70 mm.; diameter 0.24 mm.

Rare to common in the Carmen Island Pliocene beds. Abundant in the Miocene of Southern California, is not known to occur in beds from Recent to Pliocene age. This fact, together with the occurrence of *Bulimina uvigerinaformis*, strongly suggests an Upper Miocene age for the so-called "Pliocene" bed of Carmen Island. This species differs from *Virgulina schreibersiana* by having sutures which are normal to the long axis of the test. In *Virgulina schreibersiana*, as well as *V. bramlettei*, the sutures bend downward at a considerable angle. Also, the chambers of the two latter species mentioned above are much longer than *V. californiensis*.

Genus ***Bolivina*** d'Orbigny, 1839

Bolivina plicatella Cushman

(Plate 5, figures 12a, b)

Bolivina plicatella CUSHMAN, Florida State Geol. Survey, Bull. 4, 1930, p. 46, pl. 8, figs. 10a, b. CUSHMAN AND PARKER, U. S. Nat. Mus., Pr., vol. 80, art. 3, 1931, p. 15, pl. 3, fig. 19.

Bolivina sp. A, NATLAND, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 3, no. 10, 1933, line 24 on included chart.

Length 0.29 mm.; breadth 0.13 mm.; thickness 0.08 mm.

A rare species occurring only at Localities A-3548 and A-3550. As a rule it prefers a shallow-water habitat, being seldom found Recent at depths greater than 50 meters. Cushman originally described it from the Miocene Choctowatchee marl of Florida. Not reported from sediments older than Pleistocene in Southern California.

Bolivina argentea Cushman

(Plate 5, figures 13a, b)

Bolivina argentea Cushman, Contrib. Cushman Lab. Foram. Res., vol. 2, pt. 2, 1926, p. 42, pl. 6, fig. 5. Cushman, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 1, no. 10, 1927, p. 155, pl. 3, fig. 5. Natland, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 3, no. 10, 1933, line 200 on included chart.

Bolivina dottianna Coryell and Mossman, Jour. Paleont., vol. 16, no. 2, 1942, p. 239, pl. 36, fig. 33.

Length 0.77 mm.; breadth 0.35 mm.; thickness 0.18 mm.

Found only at Locality A-3512 where it was rare. In Southern California it ranges from Recent to Pliocene. A similar form, *Bolivina marginata* Cushman, ranges throughout the Miocene and Upper Oligocene.

Off Southern California, its bathymetric range is 275–2000 meters. Off Central America it extends from 360 to 2280 meters.

The occurrence of this species at Locality A-3512 suggests that the water was deeper here than at the other Pliocene localities herein considered.

It is rather obvious from both the figure and the description of *Bolivina dottianna* that it belongs with *B. argentea*.

Bolivina parva Cushman and Galliher

(Plate 5, figures 14a, b)

Bolivina hughesi Cushman var. *parva* Cushman and Galliher, Contrib. Cushman Lab. Foram. Res., vol. 10, pt. 1, 1934, p. 25, pl. 4, figs. 10a, b.

Bolivina parva Cushman, Woodring, Bramlette and Kleinpell, Am. Assoc. Petrol. Geol., Bull., vol. 20, no. 2, 1936, p. 141. Kleinpell, Am. Assoc. Petrol. Geol., 1938, p. 278.

Length 0.44 mm.; breadth 0.20 mm.; thickness 0.18 mm.

Compares closely to *Bolivina parva* but lacks the *seminuda* sutures present in the more typical specimens. Also closely related to *Bolivina brevior* and *B. vaughani* but nearly twice as large as these species.

The presence of this species in the Carmen section further suggests a Miocene age for the beds in which it occurs.

Bolivina interjuncta Cushman

(Plate 5, figures 16a, b)

Bolivina costata d'Orbigny var. *interjuncta* Cushman, Contrib. Cushman Lab. Foram. Res., vol. 2, pt. 2, 1926, p. 41, pl. 6, fig. 3.

Bolivina interjuncta Galloway and Wissler, Jour. Paleont., vol. 1, no. 1, 1927, p. 70, pl. 11, figs. 10, 11a, b, 12a, b, 13. Natland, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 3, no. 10, 1933, line 168 of included chart.

Bolivina interjuncta var. *bicostata* Cushman, Contrib. Cushman Lab. Foram. Res., vol. 2, pt. 2, 1926, p. 42. Cushman and Moyer, Contrib. Cushman Lab. Foram. Res., vol. 6, pt. 3, 1930, p. 57. Cushman, Spec. Pub. 9, Cushman Lab. Foram. Res., 1937, p. 116, pl. 22, fig. 23. Coryell and Mossman, Jour. Paleont., vol. 16, 1942, p. 241, pl. 36, figs. 35–38. Cushman and McCulloch, Allan Hancock Pacific Exped., vol. 6, no. 4, 1942, p. 195, pl. 23, figs. 9–11, 13–16. Cushman and Gray, Cushman Lab. Foram. Res., Spec. Pub. No. 19, 1946, p. 35, pl. 6, fig. 3.

Length 0.88 mm.; breadth 0.35 mm.; thickness 0.18 mm.

One of the most abundant species found in the Carmen Island Pliocene. In Southern California, it is abundant in the Upper Pliocene and in parts of the Upper Miocene.

Off Central America, its known bathymetric range is 45–2300 meters; it is rare from 45 to 81 meters, very abundant from 81 to 585 meters, and again rare from 585 to 2300 meters. Off Southern California, its known bathymetric range is 270–1000 meters.

The degree of costate ornamentation characterizing this species seems to vary with the depth of water in which it lived. At about 300 meters deep they generally develop 4 strong costae, some coalescing at the top of the test. From this depth downward there is a gradual weakening of the costae; first, the outer 2 shorten or disappear, then the 2 inner ones all but fade out, rendering the specimen difficult to separate from *Bolivina argentea* Cushman which is a smooth-walled species.

This change in degree of costation is very evident in our Pliocene section of California. In the Upper Pliocene the costae are strong, and as one proceeds lower in the section the specimens exhibit a weakening of costae until they disappear in the so-called "Lower Pico" beds. Therefore, it has seemed appropriate to place *Bolivina interjuncta* and *B. bicostata* in the same category, as their external ornamentation grades one into the other, making consistent differentiation impossible.

Bolivina plicata d'Orbigny

(Plate 5, figures 17a, b)

Bolivina plicata D'ORBIGNY, Voy. Amér. Mérid., vol. 5, pt. 5, "Foraminifères," 1839, p. 62, pl. 8, figs. 8, 9. CUSHMAN, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 1, no. 10, 1927, p. 154, pl. 3, figs. 11, 12.

Bolivina sinuata var. *praevia* CORYELL AND MOSSMAN, Jour. Paleont., vol. 16, no. 2, 1942, p. 242, pl. 36, fig. 41.

Length 0.76 mm.; breadth 0.30 mm.; thickness 0.24 mm.

Very abundant in Carmen Island Pliocene. Listed as *Bolivina sinuata* var. *praevia* by Coryell and Mossman from the Charco Azul formation of Panama. In Southern California, it is intermittently common in the Upper Pliocene and is found associated with many other species which today are abundant off Panama but not off Southern California. Off the west coast of Central America, its known bathymetric range is 66–2100 meters; it is extremely rare above 150 meters, very abundant from 270 to 1075 meters, and rare to common below 1075 meters.

Its closest relative is *Bolivina sinuata* of Galloway and Wissler but it differs by usually having two prominent central costae with trenches in between.

Bolivina pseudobeyrichi Cushman

(Plate 5, figures 18a, b)

Bolivina beyrichi Reuss var. *alata* CUSHMAN (not SEQUENZA), U. S. Nat. Mus., Bull. 71, pt. 2, 1911, p. 35, figs. 57a, b.

Bolivina pseudobeyrichi CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 2, pt. 2, 1926, p. 45. NATLAND, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 3, no. 10, 1933, line 214 on included chart. CORYELL AND MOSSMAN, Jour. Paleont., vol. 16, no. 2, 1942, p. 242, pl. 36, fig. 40.

Length 0.60 mm.; breadth 0.36 mm.; thickness 0.20 mm.

Common in Carmen Island Pliocene. Coryell and Mossman reported it from the Charco Azul Pliocene formation of Panama. It occurs in both the Upper and Lower Pliocene of Southern California. Off the west coast of Central America its known bathymetric range is 290–2100 meters. Off Southern California, its known range is 400–1300 meters.

Bolivina seminuda Cushman

(Plate 5, figures 19a, b)

Bolivina seminuda CUSHMAN, U. S. Nat. Mus., Bull. 71, pt. 2, 1911, p. 35, fig. 55; Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 3, no. 10, 1933, line 209 on included chart.

Bolivina seminuda var. *foraminata* R. E. AND K. C. STEWART, Jour. Paleont., vol. 4, no. 1, p. 66, pl. 8, figs. 5a, b.

Bolivina foraminata CORYELL AND MOSSMAN, Jour. Paleont., vol. 16, no. 2, 1942, p. 239, pl. 36, fig. 34.

Length 0.88 mm.; breadth 0.24 mm.; thickness 0.18 mm.

Common in Carmen Island Pliocene. Coryell and Mossman found it in the Charco Azul formation, Pliocene of Panama. In Southern California, it ranges from Recent to Miocene, though generally absent in Pleistocene which was not laid down in water sufficiently deep to permit this species' growth. Off the west coast of Central America, its known bathymetric range is 147–2250 meters; it is most abundant between 360 and 1760 meters. Off Southern California its known depth ranges from 270 to 1000 meters. Cushman described it first from Bowers Bank, in the Bering Sea, from a depth of 1067 meters.

There are but few constant characteristics in this species to be used to distinguish it. These are: an oval cross section, sutures only slightly depressed and almost normal to the median line, and thin perforate walls. Width of the clear shell band around the upper part of each chamber varies so much from locality to locality as to permit no valid distinction between *Bolivina seminuda* and *B. foramininata.* The extremes of the two species are distinguishable, but when all of the intermediate variants are known, consistent assignment becomes impossible, and therefore it seems more practicable to put them together.

Bolivina subadvena Cushman

(Plate 5, figures 20a, b)

Bolivina subadvena CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 2, pt. 2, 1926, p. 44, pl. 6, figs. 6a, b. NATLAND, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 3, no. 10, 1933, line 249 on included chart.

Bolivina pomposa CORYELL AND MOSSMAN, Jour. Paleont., vol. 16, 1942, p. 241, pl. 36, fig. 39.

Length 0.82 mm.; breadth 0.29 mm.; thickness 0.25 mm.

This abundant and widespread species is found in the Carmen Island Pliocene and in the Upper and Lower Pliocene of Southern California. Coryell and Mossman recorded it from the Charco Azul formation under the name *Bolivina pomposa* which is here referred to as *B. subadvena.*

Its known bathymetric range off the west coast of Central America is 360–2100 meters, and off Southern California its known range is 884–1981 meters.

This species is quite variable but is consistently characterized by a heavy, coarsely perforated wall and a thicker cross section than most *B. spissa.* Its sutures show varying degrees of crenulation.

Bolivina acuminata Natland

(Plate 5, figures 21a, b)

Bolivina subadvena var. *serrata* NATLAND (not CHAPMAN, 1892), Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 4, no. 5, 1938, p. 145, pl. 5, figs. 8, 9.

Bolivina subadvena var. *acuminata* CUSHMAN AND GRAY, Cushman Lab. Foram. Res., Spec. Pub. no. 19, 1946, p. 34, pl. 5, fig. 46.

Length 0.41 mm.; breadth 0.24 mm.; thickness 0.12 mm.

Abundant in the Carmen Island Pliocene and common in the Pleistocene and Pliocene of Southern California. Off the west coast of Central America its known bathymetric range is 17–2260 meters; it is rare to common from 17 to 80 meters, very abundant from 80 to 304 meters, and rare below that depth. Off Southern California it ranges from 60 to 670 meters.

This species is probably a shallow-water variety of *Bolivina spissa* Cushman, as it gradually loses its spinose ornamentation when a series collected from shallow to deep water is studied. However, this species is so tremendously abundant in the Carmen Island fauna and off Central America that it is thought to merit specific designation.

Bolivina punctata d'Orbigny

(Plate 5, figures 22a, b)

Bolivina punctata D'ORBIGNY, Voy. Amér. Mérid., vol. 5, pt. 5, "Foraminifères," 1839, p. 63, pl. 8, figs. 10–12. NATLAND, Scripps Inst. Oceanog., Bull., vol. 3, no. 10, 1933, line 75 on included chart.

Bolivina acerosa Cushman var. *pacifica* CUSHMAN AND MCCULLOCH, Allan Hancock Pacific Exped., vol. 6, no. 4, 1942, p. 185, pl. 21, figs. 2, 3. CUSHMAN AND GRAY, Cushman Lab. Foram. Res., Spec. Pub. no. 19, 1946, p. 36, fig. 6.

Length 0.43 mm.; breadth 0.14 mm.; thickness 0.117 mm.

Rare in the Carmen Island Pliocene, also known from the Upper and Lower Pliocene of Southern California. It is similar to *Bolivina acerosa* of Cushman and may well be the same species, as the main difference appears to be that *B. acerosa* has costae and *B. punctata* does not. Ornamentation of the type present on this species is not sufficiently consistent to alone form ground for erecting a new species. d'Orbigny's figure of the type from off Chile is not good but shows the characteristic features of *B. punctata*: very elongate, slender, numerous chambers, sutures oblique to the median line, oval in cross section. *Bolivina acerosa* var. *pacifica* Cushman and McCulloch undoubtedly should be placed with *B. punctata.*

Bolivina punctata is a widespread Pacific species which, off the west coast of Central America, has a known depth range of 17–2250 meters, being most prolific from 63 to 625 meters. Off Southern California its known depth range is 20–884 meters. This species is rarely found fossil because of its fragile walls.

Bolivina tongi Cushman

(Plate 5, figures 23a, b)

Bolivina tongi Cushman, Contrib. Cushman Lab. Foram. Res., vol. 5, pt. 4, 1929, p. 93, pl. 13, figs. 29a, b. Natland, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 3, no. 10, line 173 on included chart.

Length 0.35 mm.; breadth 0.16 mm.; thickness 0.08 mm.

This unique *Bolivina* is rare to common species in the Carmen Island Pliocene and in the Pliocene of Southern California. Off the west coast of Central America its known bathymetric range is 22–1911 meters, most prolific from 64 to 640 meters. Off Southern California, its known range is 121–243 meters.

Bolivina tongi var. *filacostata* Cushman and McCulloch probably belongs under this species. There are no other known species Recent or in the West Coast Tertiary to confuse with it, as it stands quite by itself in size and shape.

Genus ***Rectobolivina*** Cushman, 1927

Rectobolivina sp. A

(Plate 5, figures 24a, b)

Length 0.47 mm.; breadth 0.15 mm.; thickness 0.117 mm.

One incomplete specimen was found at Locality A-3582.

Rectobolivina sp. B

(Plate 5, figures 25a, b)

Length 0.44 mm.; breadth 0.18 mm.; thickness 0.117 mm.

A single specimen was found at Locality A-3582. No name is assigned to it because the specimen is fragmental. It is similar in some respects to *Rectobolivina parvula* Finlay.

Genus ***Suggrunda*** Hoffmeister and Berry, 1937

Suggrunda eckisi Natland, new name

(Plate 9, figures 12a, b)

Bolivina pygmaea Cushman and Moyer (not H. B. Brady), Contrib. Cushman Lab. Foram. Res., vol. 6, pt. 3, 1930, p. 57, pl. 8, fig. 4. Natland (not Brady), Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 3, no. 10, 1933, line 215on included chart.

Length 0.29 mm.; breadth 0.21 mm.; thickness 0.12 mm.

Holotype, U. S. National Museum Cat. No. 560206.

Often referred to *Bolivina pygmaea* of H. B. Brady but has a distinct transverse aperture which places it in *Suggrunda.* Also, the typical *Bolivina pygmaea* has much higher chambers than this species. *Suggrunda eckisi* resembles *Textularia variabilis* Williamson var. *difformis* Williamson. Our specimens are more than twice as thick as that figured by Williamson and are therefore probably different.

Abundant in Carmen Island Pliocene and common in Pliocene and Upper Miocene of Southern California. Off the west coast of Central America, its known bathymetric range is 81–1760 meters. Off Southern California its known range is 260–600 meters.

This species has been named for Mr. Rollin Eckis, Chief Geologist of the Richfield Oil Corporation, Los Angeles, California.

Genus ***Loxostomum*** Ehrenberg, 1854

Loxostomum instabile Cushman and McCulloch

(Plate 5, figures 15a, b)

Bolivina beyrichi Reuss, Zeitschr. Deutsch. Geol. Gesell., vol. 3, 1851, p. 83, pl. 6, fig. 51. Natland, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 3, no. 10, 1933, line 207 on included chart.

Loxostomum instabile CUSHMAN AND MCCULLOCH, Allan Hahcock Pacific Exped., vol. 6, no. 4, 1942, p. 221, pl. 27, figs. 15–17; pl. 28, figs. 1–7. CUSHMAN AND GRAY, Cushman Lab. Foram. Res., Spec. Pub., no. 19, 1946, p. 36, pl. 6, figs. 7–9.

Length 0.66 mm.; breadth 0.29 m.; thickness 0.25 mm.

Rare in Carmen Island Pliocene. Common in Upper Pliocene of Southern California.

Off the West coast of Central America its bathymetric range is 40–1700 meters, noticeably more abundant between 80 and 290 meters. Off Southern California it is rare, with a depth range from 290 to 700 meters.

This species has heretofore been referred to *B. beyrichi*, a species originally described from the Eocene of Germany. Although the figure given for *B. beyrichi* is imilar to our specimens, it seems unlikely that this Eocene species could be the same as our local Recent and Late Tertiary form. It seems more appropriate to place it with *Loxostomum instabile.* However, it is quite difficult to distinguish this species from *B. bramlettei* Kleinpell as shown by Cushman and McCulloch. The typical Miocene form is much more coarsely perforated than any Recent forms observed.

Loxostomum mayori (Cushman)

(Plate 6, figures 1a, b)

Bolivina mayori CUSHMAN, Carnegie Inst. Wash., Pub. no. 311, 1922, p. 27, pl. 3, figs. 5–6.
Loxostoma mayori BERMUDEZ, Mem. Soc. Cubana Hist. Nat., vol. 9, 1935, p. 197. CUSHMAN AND PARKER, U. S. Nat. Mus., Pr., vol. 80, art. 3, 1931, p. 6, pl. 3, fig. 24. CUSHMAN AND MCCULLOCH, Allan Hancock Exped., vol. 6, no. 4, 1942, p. 224, pl. 28, figs. 11, 12.

Length 0.94 mm.; breadth 0.29 mm.; thickness 0.19 mm.

Two typical specimens were found at Locality A-3582. It is not known to occur in either Recent or fossil sediments of Southern California, but off the west coast of Central America its known bathymetric range is 2.7–45 meters, with one single specimen found at 72 meters.

Genus ***Bifarina*** Parker and Jones, 1872

Bifarina hancocki Cushman and McCulloch

(Plate 6, figures 2a, b)

Bifarina hancocki CUSHMAN AND MCCULLOCH, Allan Hancock Pacific Exped., vol. 6, no. 4, 1942, p. 225, pl. 28, figs. 13–19.

Broken specimen: Length 0.29 mm.; breadth 0.18 mm.; thickness 0.12 mm.

Only a few fragmental specimens were found in the Pleistocene and Pliocene. Extremely abundant off the west coast of Central America where its known bathymetric range is 17–1530 meters. As yet not reported from Southern California region, which suggests that it prefers to live in southern, more tropical regions.

Subfamily REUSSELLINAE

Genus ***Reussella*** Galloway, 1933

Reussella spinulosa (Reuss)

(Plate 6, figures 3a, b)

Verneuilina spinulosa (REUSS), Denkscher. Akad. Wiss. Wien., vol. 1, 1950, p. 374, pl. 47, fig. 12.
Reussia spinulosa SCHWAGER, Boll. Com. Geol. Ital., vol. 8, 1877, p. 26, pl. 00, fig. 66.
Reussella spinulosa CUSHMAN, Contrib. Cushman Lab. Foram. Res., vol. 21, pt. 2, 1945, p. 33, pl. 6, figs. 8, 9.

Length 0.59 mm.; breadth 0.25 mm.

Rare in both the Pleistocene and Pliocene of the Carmen Island region. As yet it has not been recorded from sediments of this age in Southern California. Abundant off the west coast of Central America where its bathymetric range is 17–260 meters, most prolific from 17 to 56 meters. It has not been reported from off Southern California, which suggests that it prefers to live in tropical conditions.

Subfamily UVIGERININAE

Genus *Uvigerina* d'Orbigny, 1826

Uvigerina attenuata Coryell & Mossman

(Plate 6, figures 4a-e)

Uvigerina striata CORYELL AND MOSSMAN (not D'ORBIGNY), Jour. Paleont., vol. 16, no. 2, 1942, p. 245, pl. 36, figs. 53–54.
Uvigerina striata v. *attenuata* CORYELL AND MOSSMAN, Jour. Paleont., vol. 16, no. 2, 1942, p. 245, pl. 36, fig. 55.
Uvigerina sp. CUSHMAN AND GRAY, Cushman Lab. Foram. Res., Spec. Pub. no. 19, 1946, p. 37, pl. 6, fig. 15.
Uvigerina sp. NATLAND, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 3, no. 10, 1933, line 227 on included chart.

Length 1.06 mm.; diameter 0.47 mm.

Extremely abundant in Carmen Island Pliocene and abundant in Middle Pliocene of Southern California. Off the west coast of Central America, its known bathymetric range s 147–1160 meters, most prolific from 260 to 640 meters. Off Southern California, its known range is 275–1000 meters.

D'Orbigny's figure of *Uvigerina striata* differs considerably from this West Coast species. Therefore, it seems desirable to refer it to *Uvigerina attenuata*, a more recent name given to it by Coryell and Mossman. This species is extremely variable, and the variety called *attenuata*, with a tapering apertural end, probably represents the senile stage of the species. The varietal name *attenuata* is raised to specific rank.

It closely resembles *Uvigerina segundoensis* Cushman and Galliher, a Miocene species from California.

The distinguishing characteristic of this species is its numerous, parallel, low, thin costate ornamentation.

Genus *Angulogerina* Cushman, 1927

Angulogerina carinata Cushman

(Plate 6, figures 5a, b, c)

Angulogerina carinata CUSHMAN, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 1, no. 10, 1927, p. 159, pl. 4, fig. 3.

Length 0.84 mm.; breadth 0.42 mm.

This unique species is abundant in the Carmen Island Pliocene, as well as in the Upper Pliocene of Southern California. Coryell and Mossman (1942) reported it from the Charco Azul Pliocene formation of Panama.

Off the west coast of Central America, its known bathymetric range is 104–2100 meters, most abundant between 150 and 640 meters. Off Southern California, its known depth range is 60–1000 meters, with its greatest development below 275 meters.

Angulogerina occidentalis (Cushman)

(Plate 6, figures 6a, b)

Uvigerina angulosa CUSHMAN (not WILLIAMSON). *Uvigerina occidentalis* CUSHMAN, U. S. Nat. Mus., Bull. 104, pt. 4, 1923, p. 169.
Angulogerina occidentalis (CUSHMAN), Florida State Geol. Survey, Bull. 4, 1930, p. 50, pl. 9, figs. 8, 9.
Angulogerina angulosa NATLAND (not WILLIAMSON), Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 3, no. 10, 1933, line 153 on included chart.

Length 0.65 mm.; breadth 0.29 mm.

Rare to common in Pleistocene and rare to abundant in Pliocene of Carmen Island region. In Southern California, it is rare to abundant from Recent to Lower Pliocene, with a questionable occurrence in the Zemorrian Stage (Lower Miocene or Oligocene).

Off the west coast of Central America, its known bathymetric range is 27–2100 meters, sporadically very rare to rare throughout the entire range. Off Southern California its known range is 50–2200 meters.

It closely resembles *Angulogerina angulosa* (Williamson) and may well be a variety of this species. It is more angular throughout than *Angulogerina semitrigona* or *A. hughesi.*

Family ROTALIIDAE

Subfamily SPIRILLININAE

Genus ***Spirillina*** Ehrenberg, 1843

Spirillina vivipara Ehrenberg

(Plate 6, figures 7a, b)

Spirillina vivipara EHRENBERG, Abhandl. K. Akad. Wiss. Berlin, 1841, p. 422, pl. 3, sec. 7, fig. 41. CUSHMAN, U. S. Nat. Mus., Bull. 104, pt. 8, 1931, p. 3, pl. 1, figs. 1–4.

Diameter 0.29 mm.; thickness 0.07 mm.

This distinctive species is present in the shallow-water Pleistocene beds of the Carmen Island region. The Pliocene was deposited at too great a depth to permit its growth. This form is also common in the Pleistocene of Southern California. It was found at U. S. S. Hannibal Locality 12, off Cape Mala, at 29 meters, and on the west side of Avalon Bay, Santa Catalina Island, at 10 meters where the bottom was composed of approximately 90 per cent Lithothamnion and where the water is relatively clean and quiet. Its limited Recent occurrence indicates it to be a specialized form requiring shallow, clean, quiet water.

Subfamily DISCORBINAE

Genus ***Patellina*** Williamson, 1858

Patellina corrugata Williamson

Patellina corrugata WILLIAMSON, Rec. Foram. Great Britain, 1858, p. 46, pl. 3, figs. 86–89. CUSHMAN, U. S. Nat. Mus., Bull. 104, pt. 8, 1931, p. 11, pl. 2, figs. 6, 7.

Only a few specimens, too poorly preserved to photograph, were found in the Pleistocene beds.

Genus ***Discorbis*** Lamarck, 1804

Discorbis isabelleana (d'Orbigny)?

(Plate 6, figures 8a, b, c)

Rosalina isabelleana D'ORBIGNY, Voy. Amér. Mérid., vol. 5, pt. 5, 1839, p. 43, pl. 6, figs. 10–12.
Discorbis isabelleana (d'Orbigny)? CUSHMAN AND VALENTINE, Contrib. Dept. Geol., Stanford Univ., vol. 1, no. 1, 1930, p. 23, pl. 6, figs. 6, 7a–c, 8a–c.

Length 0.54 mm.; breadth 0.42 mm.; thickness 0.18 mm.

Rare in Pleistocene and not found in Pliocene. It is an attached form, often taking the shape of the object on which it grows. D'Orbigny's original figure resembles this species in a very superficial way. Therefore, it should probably be given a different name. It is common in the Pleistocene of Southern California. Off the west coast of Central America, its known bathymetric range is 20–82 meters. Off Southern California its known range is 10–300 meters. However, specimens found deeper than 100 meters are thought to have been washed out from shallower depths.

The species here referred to *Discorbis isabelleana* d'Orbigny? closely resembles Rhumbler's *D. irregularis* from the Marshall Islands, but, lacking comparative material, it seems more appropriate to follow previous workers in assigning this local species.

Discorbis rosaceus (d'Orbigny)

(Plate 6, figures 9a, b, c)

Rotalia rosacea D'ORBIGNY, Ann. Sci. Nat., 1836, p. 273; Modèles no. 39.
Asterigerina rosacea D'ORBIGNY, Prodrome de Paleont., vol. 3, 1852, p. 158.
Discorbina rosacea H. B. BRADY, Trans. Linn. Soc. London, vol. 25, no. 69, 1864, p. 473; Rept. Voy. Challenger, Zoology, vol. 9, 1884, p. 644, pl. 87, figs. 1, (4?). CUSHMAN, U. S. Nat. Mus., Bull. 104, pt. 8, 1931, p. 31.
Discorbis rosacea CUSHMAN, U. S. Nat. Mus., Bull. 71, pt. 5, 1915, p. 13, text fig. 13. CUSHMAN AND VALENTINE, Contrib. Dept. Geol., Stanford Univ., vol. 1, no. 1, 1930, p. 23, pl. 6, fig. 5. NATLAND, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 3, no. 10, 1933. line 48 on included chart. CUSHMAN AND GRAY, Cushman Lab. Foram. Res., Spec. Pub. no. 19, 1946, p. 38, pl. 6, fig. 21.

Length 0.47 mm.; breadth 0.41 mm.; thickness 0.17 mm.

A common, widespread species, both Recent and fossil. Common in both Pleistocene and Pliocene in Carmen Island region, as well as in Southern California. Off the west coast of Central America its known bathymetric range is 20–210 meters. Off Southern California it has approximately the same range.

According to Cushman (1931) *Rotalia rosacea* d'Orbigny is an *Amphistegina*. Therefore, this typical *Discorbis*-like West Coast species should have a new name.

Discorbis parkeri Natland, n. sp.

(Plate 6, figures 11a–c)

Discorbis nitida CUSHMAN AND PARKER (not WILLIAMSON), U. S. Nat. Mus., Pr., vol. 80, art. 3, 1931, p. 19, pl. 4, figs. 4a–c.

Test usually plano-concave, strongly depressed into a very low spiral coil, periphery subacute, with a narrow limbate keel; 4 or 5 distinct smooth chambers rapidly increasing in size make up the last whorl, with final chamber forming nearly half the whorl; sutures distinct, limbate, very slightly depressed, arcuate, radial; walls very finely perforate and smooth, often translucent; aperture formed on ventral side near umbilicus, in an indentation along inner margin of last chamber.

Diameter 0.29 mm.; thickness 0.06 mm.

Holotype, U. S. National Museum Cat. No. 560202.

This is a rather common species along the west coast of Mexico and Central America. Cushman and Parker reported it from Rio de Janeiro Harbor and questionably referred it to *Discorbis nitida* (Williamson). Numerous specimens at hand show this species to differ from *D. nitida* by having fewer chambers and a more-depressed test, with the last chamber making up nearly half the test. It is a shallow-water species, to date not found deeper than 25 meters.

This species was named after Frances L. Parker who, with Dr. J. A. Cushman, published an excellent figure of it in the above reference.

Discorbis cf. ***pulvinata*** (H. B. Brady)

(Plate 6, figures 14a-c)

Discorbina pulvinata (H. B. BRADY), Rept. Voy. Challenger Exped., vol. 9, pt. 22, 1884, p. 650, pl. 88, figs. 10a–b.

Diameter 0.44 mm.; thickness 0.29 mm.

Questionably referred to the above species described by Brady from the shallow waters of the Southwest Pacific, in the vicinity of the Admiralty Islands. Also related to *Discorbis globosa* (Sidebottom), a species which he described from off Delos Island in the Grecian Archipelago.

Main features are a *Globigerina*-like test, with suture on dorsal side radiating from a central orifice which is often capped over with a calcareous plate. Faint radiate costae are generally present on dorsal side.

This form is rare to abundant in Pleistocene of Gulf of California and off Southern California. Its known bathymetric range off west coast of Central America is 30–38 meters. Common in calcareous bottom of Avalon Bay, Santa Catalina Island, California.

Discorbis obicularis (Terquem)

(Plate 6, figures 12a–c)

Rosalina orbicularis TERQUEM, Anim., sur la Plage de Dunkerque, p. 75, pl. 9, figs. 4a, b, 1876.
Discorbis orbicularis BERTHELIN, Foram, de Borgneuf et Pornichet, p. 39, no. 63, 1878. CUSHAMN AND PONTON, Florida State Geol. Survey, Bull. no. 9, 1932, p. 89, pl. 13, figs. 6a–c.

Diameter 0.22 mm.; thickness 0.07 mm.

Rare to common in Pleistocene and not present in our samples from Carmen Island Pliocene. Terquem's figure is surprisingly similar to that of our specimen.

Off the west coast of Central America, the known bathymetric range of this species is 27–116 meters, abundant from 27 to 45 meters and rare from 47 to 58 meters, with only a few rare scattered occurrences from 58 to 116 meters. It has not been found in any material from off Southern California but is found in the Upper Pliocene exposed at Timm's Point, San Pedro, California.

It is also similar to *Discorbis concinna* (Brady), which occurs in deep water off Tahiti and in shallow water off the Admiralty and Philippine Islands, and to *Discorbis malovensis*, Heron-Allen and Earland.

Discorbis subaraucana Cushman

(Plate 6, figures 13a–c)

Discorbis subaraucana Cushman, Carnegie Inst. Washington, Pub. 311, 1922, p. 41, pl. 7, figs. 1, 2. CUSHMAN, Florida State Geol. Survey, Bull. 4,1930, p. 52, pl. 10, figs. 1a–c.

Diameter 0.83 mm.; thickness 0.30 mm.

The specimens from the Gulf of California region are identical to those found Recent off Florida. It is present in both the Pleistocene and Pliocene beds of the Carmen Island region.

Discorbis sp. A

(Plate 6, figures 10a–c)

Three specimens of this species were found in the Pliocene of the Carmen Island region, and two were found in samples from off the west coast of Panama. They perhaps should be described as a new species, but not until more specimens are available. It differs from *Discorbis rosacea* by being plano-concave, and from *B. parkeri* by having 7 instead of 4 chambers in the last whorl.

Discorbis sp. B

(Plate 7, figures 1a–c)

Length 0.47 mm.; breadth 0.41 mm.; thickness 0.27 mm.

Three incomplete specimens, as figured, were found at Locality A-3548. Their walls are very coarsely perforated, and they have radial limbate sutures. They resemble *Discorbis valvulata* var. *granulosa*, of Heron-Allen and Earland.

Discorbis sp. C

(Plate 7, figures 2a–c)

Diameter 0.364 mm.

A single specimen was found at Locality A-3582. It is quite distinctive, being slightly concave dorsally and highly arched ventrally.

Genus *Valvulineria* Cushman, 1926

Valvulineria cf. *araucana* (d'Orbigny)

(Plate 7, figures 5a–c)

Length 0.47 mm.; Breadth 0.38 mm. Thickness 0.24 mm.

A few poorly-preserved specimens are referred to this species. They were found in only one sample in the Carmen Island Pliocene.

Genus *Gyroidina* d'Orbigny, 1826

Gyroidina carmenenis, n. sp.

(Plate 7, figures 6a–c)

Test small, delicate, low involute spire; periphery round, slightly convex dorsally, ventral side with central umbilicus; chambers distinct, elongate, 9 or 10 in last whorl; sutures distinct, slightly depressed, nearly radial on the ventral side, somewhat oblique on the dorsal side; walls calcareous, very finely perforate; aperture a low-arch opening at base of last, chamber midway between umbilicus and periphery.

Diameter 0.24 mm.; thickness 0.14 mm.

U. S. Nat. Museum Catalogue No. 560200. Locality A-3511, Carmen Island, Gulf of California. Pliocene age.

Abundant at localities A-3511 and A-3512. Resembles *Eponides rosaformis* Cushman and Kleinpell but has twice as many chambers in the last whorl. To my knowledge it has not been found off the west coast of North America.

Gyroidina rothwelli, n. sp.

(Plate 7, figures 8a–c)

Test small, trochoid, involute spire, plano-convex, with dorsal side flat, ventral side arched, with broad deep umbilical pit; 7–9 chambers in last whorl; chambers slightly peaked to form a row of knobs around the umbilicus; sutures oblique on both sides, distinct, often with a sharp crenulation near top ends on ventral side; slightly limbate on dorsal side, moderately depressed on ventral side; periphery with narrow carina, wall calcareous, finely perforated; aperture near the periphery along the lower margin of the septal face of the last chamber.

Diameter 0.38 mm.; thickness 0.235 mm.

Holotype, U. S. National Museum Catalogue No. 560198.

Gyroidina florealis and *Gyroidina minuta* both of White, which he described from the Upper Cretaceous Mendez formation of Mexico, are close relatives of this species but differ by exhibiting slightly concave ventral sides in contrast to the convex side of this species.

This species is abundant in Carmen Island Pliocene and occasionally abundant in Upper Pliocene of Los Angeles and Ventura basins in Southern California.

Off the west coast of Central America, its known bathymetric range is 90–2300 meters. It is very rare from 90 to 260 meters, very abundant from 260 to 380 meters, and rare to abundant from 380 to 2300 meters. As yet it has not been reported as Recent off Southern California.

Gyroidina soldanii var. ***rotundimargo***, R. E. and K. C. Stewart

(Plate 7, figures 7a–c)

Gyroidina soldanii var. *rotundimargo*, R. F. AND K. C. STEWART, Jour. Paleont., vol. 4, no. 1, 1930, p. 68, pl. 9, fig. 3.

Gyroidina soldanii var. *multilocula*, CORYELL AND MOSSMAN, Jour. Paleont., vol. 16, no. 2, 1942, p. 237, pl. 36, fig. 20.

Maximum diameter 0.58 mm.; thickness 0.30 mm.

Abundant in the Carmen Island Pliocene and absent in the Pleistocene. Coryell and Mossman recorded it from the Charco Azul formation, Pliocene of Panama, under the new varietal name listed above.

In Southern California its known geologic range is from Recent to Eocene, being generally absent in the Pleistocene.

Off the west coast of Central America its known bathymetric range is from 275 to 2100 meters, being most abundant from 290 to 1700 meters. Off Southern California its known range is from 790 to 884 meters.

Genus ***Eponides*** Montfort, 1808

Eponides incertus (Cushman)

(Plate 7, figures 9a–c)

Pulvinulina incerta CUSHMAN, Carnegie Inst. Washington, Pub. 311, 1922, p. 51, pl. 9, figs. 1, 2, 3.

Maximum diameter 0.83 mm.; thickness 0.46 mm.

The following species are similar to this form but differ in minor respects: *Eponides pulvinus* Galloway and Hemingway, *Eponides parantillarum* Galloway and Hemingway, *Eponides ouachitaensis* Howe and Wallace, *Eponides frizzelli* Kleinpell, *Eponides ellisorae* Garrett, *Eponides budensis* (Hantken) var. *planata* Cushman, *Eponides jacksonensis* (Cushman and Applin), *Eponides lotus* (Schwager), *Eponides berthelotiana* (d'Orbigny) var. *subornata* (Cushman), *Eponides byramensis* (Cushman).

Topotype specimens of *Eponides incertus* from the Tortugas region off Florida compare very closely with the Carmen Island specimens.

Off the west coast of Central America the known bathymetric range of this species is 27–90 meters. It is not known from off Southern California.

Eponides cf. ***rosaformis*** Cushman and Kleinpell

(Plate 7, figures 10a–c)

Eponides rosaformis CUSHMAN AND KLEINPELL, Contrib. Cushman Lab. Foram. Res., vol. 10, pt. 1, 1934, p. 14, pl. 2, fig. 18.

Maximum diameter 0.24 mm.; thickness 0.14 mm.

A few specimens similar to this species were found in several Carmen Island Pliocene samples.

In Southern California its known range is from Recent to Miocene.

Off the west coast of Central America its known bathymetric range is from 1346 to 2560 meters.

Eponides sp. A

(Plate 7, figures 11a, b, c)

A single specimen was found at Locality A-3504. It is closely related to *Gyroidina carmenensis* but differs by being nearly flat on the dorsal side and by not have an umbilical pit. The umbilicus has a small plug formed by the proloculum.

Eponides repanda (Fichtel and Moll)

(Plate 8, figures 1a–c)

Nautilus repandus FICHTEL AND MOLL, Test. Micr., 1798, p. 35, pl. 3, figs.a–d.
Eponides repanda CUSHMAN, U. S. Nat. Mus., Bull. 104, pt. 8, 1931, p. 49, pl. 10, figs. 7a–c.

Maximum diameter 1.30 mm.; thickness 0.41 mm.

Rare to abundant in Pleistocene and rare in Pliocene of Carmen Island region. Abundant in Pleistocene and Upper Pliocene of Los Angeles and Ventura basins. Off West Coast of Central America, known bathymetric range of this species is 22–210 meters. Off Southern California its known range is from 34 to 400 meters.

Eponides cf. ***repanda*** (Fichtel and Moll)

(Plate 8, figures 2a–c)

Maximum diameter 1.24 mm.; thickness 0.82 mm.

There are several specimens in our collection which have, in general, the same shape as *Eponides repanda* but differ by having thick limbate sutures on the dorsal side and by not being depressed in the umbilical region.

These specimens may represent the megalo-spheric form of *E. repanda*, or they may be a new variety.

Eponides mansfieldi Cushman

(Plate 8, figures 3a–c)

Eponides mansfieldi Cushman, CUSHMAN AND PARKER, Cushman Lab. Foram. Res., Contrib., vol. 7, pt. 1, 1931, p. 12, pl. 2, figs. 10a–c.

Maximum diameter 0.52 mm.; thickness 0.23 mm.

Rare to common in Pleistocene in Carmen Island region and rare to common in Pleistocene to Middle Miocene of Southern California.

Genus ***Rotalia*** Lamarck, 1804

Rotalia avalonensis Natland (new name)

(Plate 8, figures 4a–c)

Rotalia depressa NATLAND (not MUNSTER), Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 4, no. 5, 1938, p. 147, pl. 5, figs. 15a–c.

Maximum diameter 0.27 mm.; thickness 0.16 mm.

U. S. National Museum Catalogue No. 560203.

A few typical specimens were found only in the Pleistocene samples. Off the west coast of Central America this species ranges from 27 to 57 meters. Off Southern California it has been found only in the clear waters of Avalon Bay, Santa Catalina Island, California. Apparently it prefers to live in sheltered, tropical to temperate, clear-water embayments.

The name *Rotalia depressa* was preoccupied both by Munster, in 1938, and by Ehrenberg, in 1843. Consequently, the new name *R. avalonensis* has been assigned to this species.

Rotalia rosea d'Orbigny

(Plate 8, figures 5a–c)

Rotalia rosea D'ORBIGNY, Ann. Sci. Nat., vol. 7, no. 7, 1826, p. 272, Modèles No. 36. CUSHMAN, U. S. Nat. Mus., Bull. 104, pt. 8, 1931, p. 62, pl. 13, figs. 4a–c.

Maximum diameter 0.53 mm.; thickness 0.32 mm.

Several typical specimens were found only in the Pleistocene samples, which further indicates the depositional environment of the Pleistocene sediments to have been shallow, quiet, clear and tropically warm water, as this species off Florida and other tropical Atlantic areas is generally confined to such a habitat.

Rotalia sp. A

(Plate 8, figures 6a–c)

A single specimen was found at Locality A-3548. It is similar to *Rotalia avalonensis* but differs by a more lenticular cross section and broad limbate sutures.

Subfamily BAGGININAE

Genus ***Cancris*** Montfort, 1808

Cancris inflata (d'Orbigny)

(Plate 7, figures 3a–c, 4a–c)

Valvulina inflata D'ORBIGNY, Voy. Amér. Mérid., vol. 5, pt. 5, 1839, p. 48, pl. 7, figs. 7–9.

Valvulineria scintillans CORYELL AND MOSSMAN, Jour. Paleont., vol. 16, no. 2, 1942, p. 236, pl. 3, figs. 13–15.

Valvulineria scintillans var. *sinecarina* CORYELL AND MOSSMAN, Jour. Paleont., vol. 16, no. 2, 1942, p. 236, pl. 36, figs. 16–18.

Valvulineria inflata (d'Orbigny), CORYELL AND MOSSMAN, Jour. Paleont., vol. 16, no. 2, 1942, p. 235, pl. 36, figs. 7–9.

Valvulineria johnsoni CORYELL AND MOSSMAN, Jour. Paleont., vol. 16, no. 2, 1942, p. 235, pl. 36, figs. 10–12.

Rosalina hitchcockae GALLOWAY AND WISSLER, Jour. Paleont., vol. 1, no. 1, 1927, p. 62, pl. 10, figs. 2a–c.

Figure 3. Maximum diameter 0.67 mm.; thickness 0.38 mm.

Figure 4. Maximum diameter 0.88 mm.; thickness 0.58 mm.

After studying numerous specimens from many localities both Recent and fossil, and discussing them with local authorities, it has seemed advisable to refer this species to *Cancris*, because it has the windows of clear shell material in the septal face of the last chamber. The stellate appearance of the ventral side apparently results from the incomplete covering of these clear spaces by the subsequently added chambers. Many specimens show a tendency for the clear material to become partial-perforate with small foramins, and some of the more poorly preserved specimens exhibit no clear window.

A very close relative of this species is *Cancris panamensis* Natland, which is a typical *Cancris* in almost every respect. Because of this relationship it seems most proper to place this *Cancris inflata* (d'Orbigny), as well as many others having a clear window, in *Cancris* rather than in *Valvulineria* where they are now assigned. This form is extremely variable, and from a single sample one can set up almost as many species or varieties as there are specimens. D'Orbigny originally described this species as *Valvulina inflata* from off the coast of Chile. Topotype material indicates that this form is the same as that described by Coryell and Mossman as *Valvulineria scintillans* var. *sinecarina*. *V. johnsoni* and *Rosalina hitchcockae* Galloway and Wissler, which are rather common in the Middle Pico (Upper Pliocene) of the Los Angeles and Ventura Basins, are also here placed with this species.

The typical form has a flat to slightly concave, nearly evolute, spirally coiled dorsal side, with a very convex ventral side. A pronounced carina is usually present, but this characteristic is variable, with many specimens being nearly round on the periphery. The walls are prominently perforated except for an area in the septal wall of the last chamber which is clear. Sutures are limbate in the early chambers and depressed in the later ones. The last chamber usually has a plate, as in *Valvulineria*, which covers the aperture located in the umbilicus at the base of the last chamber.

The specimens referred to *Valvulineria inflata* (d'Orbigny) by Cushman (1927) appear to be a variety of *Valvulineria araucana* (d'Orbigny).

Off the west coast of Central America the known bathymetric range of this species is 55–1875 meters, rare from 55 to 260 meters, abundant from 260 to 1025 meters, and rare from 1025 to 1875 meters. Its maximum abundance and development occurs between 275 and 384 meters. It has not been observed in any Recent samples from off Southern California.

Cancris auricula (Fichtel and Moll)

(Plate 8, figures 7a–c; see Plate 6; more *Cancris*)

Nautilus auricula, Var. A, FICHTEL AND MOLL, Test. Mico., 1803, p. 108, pl. 20, figs. a–c; Var. B, Beta, pl. 20, figs. d–f.

Cancris auricula CUSHMAN, U. S. Nat. Mus., Bull. 104, pt. 8, 1931, p. 72, pl. 15, figs. 1a–c. (Good synonymy.)

Length 0.70 mm.; breadth 0.47 mm.; thickness 0.23 mm.

Confined to Carmen Island Pliocene samples. In Southern California, it has been recorded from the Pleistocene and Upper Pliocene sediments. Off the west coast of Central America its known bathymetric range is 18–1911 meters, most abundant between 54 and 290 meters. Off Southern California its known range is 40–800 meters.

Cancris carmenensis, n. sp.

(Plate 9, figures 1a–c)

Test biconvex, longer than broad, periphery broadly rounded, evolute; chambers distinct, curved elongate, inflated, 7 or 8 in last whorl; sutures distinct, becoming increasingly depressed in adult, slightly arcuate on both ventral and dorsal sides; walls smooth, very finely perforated, with an indistinct window of clear shell material near base of last chamber, which is usually extended in the form of a flap which covers a part of umbilical area; aperture, a low arched opening at base of last chamber.

Length 1.06 mm.; breadth 0.76 mm.; thickness 0.53 mm.

Holotype, U. S. National Museum Cat. No. 560204, Type Locality A-3500, Upper Pliocene, Carmen Island, Gulf of Lower California.

Abundant in all Upper Pliocene samples from Carmen Island. Not observed in material elsewhere. Closely related to *Cancris baggi* Cushman and Kleinpell but more compressed.

Family AMPHISTEGINIDAE

Genus ***Amphistegina*** d'Orbigny, 1826

Amphistegina sp. A

Numerous broken and badly worn specimens were found in both Pleistocene and Pliocene samples. According to our best ecologic interpretation Carmen Island Pliocene was deposited under at least 275 meters of water, which is usually too deep for *Amphistegina*. This fact, and their worn condition, indicates that the specimens were washed out from shallow, near-shore waters. As *Amphistegina* is known to prefer a tropical, clear-water habitat, it seems reasonable to conclude that the shallow water during Upper Pliocene time in the Carmen Island region was warm enough to support tropical life.

Family CYMBALOPORIDAE

Genus *Tretomphalus* Moebius, 1880

Tretomphalus bulloides (d'Orbigny)

(Plate 9, figures 2a, b)

Rosalina bulloides D'ORBIGNY, *in* DE LA SAGRA, Hist. Fis. Pol. Nat. Cuba, 1839, "Foraminifères," p. 104, pl. 3, figs. 2–5.

Tretomphalus bulloides (d'Orbigny), CUSHMAN, U. S. Nat. Mus., Bull. 104, pt. 8, 1931, p. 86, pl. 16, figs. 5a–c.

Maximum diameter 0.35 mm.

Many typical specimens with float chambers were found in only the Pleistocene samples. In Southern California, this species is rare in the Pleistocene. Off the west coast of Central America, its known bathymetric range is 27–71 meters. Abundant in Avalon Bay, Santa Catalina Island, California, and also found in shallow tide pools near La Jolla, California. Apparently it prefers a shallow, clean, relatively quiet-water habitat.

Family CASSIDULINIDAE

Subfamily 1 CERATOBULIMININAE

Genus *Pulvinulinella* Cushman, 1926*

Pulvinulinella bradyana Cushman

(Plate 9, figures 3a–c)

Pulvinulinella bradyana CUSHMAN, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 1, no. 10, 1927, p. 165, pl. 5, figs. 11–13.

Length 0.40 mm.; breadth 0.34 mm.; thickness 0.18 mm.

Common in several Carmen Island Pliocene samples. Abundant in Pliocene and questionably present in Miocene of Southern California. Off the west coast of Central America, its known bathymetric range is 210–2300 meters, most abundant between 275 and 782 meters. Off Southern California it is comparatively rare, with only a few known occurrences in the San Pedro Channel at 275 meters.

Pulvinulinella relizensis Kleinpell

(Plate 9, figures 4a–c)

Pulvinulinella relizensis KLEINPELL, Miocene Strat. California, Am. Assoc. Petrol. Geol., Pub., 1938, p. 329, pl. 10, figs. 10a–c.

Length 0.35 mm.; breadth 0.29 mm.; thickness 0.14 mm.

Topotype specimens of this species have been carefully compared with those from the Carmen Island Pliocene, and they seem identical. Locally, this species has often been referred to *subperuviana* and may well be a variety of this species. It is the writer's opinion that *Pulvinulinella bradyana* and *P. subperuviana* are very close, if not the same species. Both have a subacute periphery, in contrast to the round periphery of *P. relizensis*.

This species is very abundant in the Carmen Island Pliocene and abundant in the Pliocene of Southern California. It is not known to occur Recent. The *Pulvinulinella bradyana* type, however, is very abundant in the Pacific, off the west coast of North and Central America.

Subfamily CASSIDULININAE

Genus *Cassidulina* d'Orbigny, 1826

Cassidulina cf. ***limbata*** Cushman and Hughes

(Plate 9, figures 5a, b)

Cassidulina limbata CUSHMAN AND HUGHES, Contrib. Cushman Lab. Foram. Res., vol. 1, no. 1, 1925, p. 12, pl. 2, figs. 2a–c. CUSHMAN AND GRAY, Cushman Lab. Foram. Res., Spec. Pub. No. 19, 1946, p. 42, pl. 7, figs. 14–16.

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* Now referred to *Pseudoparrella* Cushman and Ten Dam, 1948.

Length 0.35 mm.; breadth 0.24 mm.; thickness 0.12 mm.

The specimens from the Carmen Island region are close to but much smaller than the *Cassidulina limbata* found in Southern California. *C. limbata*, in general, is very rare in the marine sediments south of the Gulf of California and abundant north of the Gulf in water 60–275 meters deep. Also found in Pleistocene and Pliocene of Southern California.

Cassidulina oblonga Reuss

(Plate 9, figures 6a–b)

Cassidulina oblonga REUSS, Akad. Wiss. Wien., Math. Nat. Cl., Denkschr., Wien., Osterreich, 1850, Bd. 1, p. 376, pl. 48, figs. 5, 6.

Length 0.44 mm.; breadth 0.33 mm.; thickness 0.24 mm.

Common in Carmen Island Pliocene. Compares most favorably with *C. oblonga* but is probably related to *C. suboblonga* var. *producta* Chapman and Parr and *C. crassa* var. *porrecta* Heron-Allen and Earland. Distinguished by the tendency of the later chambers to become elongate with an extended apertural end.

Rare in Pliocene of Southern California. Off the west coast of Central America, its known bathymetric range is 290–2100 meters. It occurs Recent off Southern California, but its range is not known.

Cassidulina quadrata Cushman and Hughes

(Plate 9, figures 7a–c)

Cassidulina subglobosa H. B. Brady var. *quadrata* CUSHMAN AND HUGHES, Contrib. Cushman Lab. Foram. Res., vol. 1, pt. 1, 1925, p. 15, pl. 7, fig. 7.

Cassidulina quadrata GALLOWAY AND WISSLER, Jour. Paleont., vol. 1, 1927, p. 79, pl. 12, fig. 8. CUSHMAN AND GRAY. Cushman Lab. Foram. Res., Spec. Pub. No. 19, 1946, p. 42, pl. 7, figs. 11–13.

Length 0.31 mm.; breadth 0.25 mm.; thickness 0.25 mm.

Easily distinguished from other similar forms by the 30° angle at which the sutures meet on the periphery. In most similar forms such as *Cassidulina californica*, this angle is around 90°.

Rare in Pleistocene and abundant in Carmen Island Pliocene. In Southern California abundant from Recent to Upper Miocene. Off the west coast of Central America, its known bathymetric range is 275–1483 meters. Its range off Southern California is not clearly defined.

Cassidulina corbyi Cushman and Hughes

(Plate 9, figures 8a, b)

Cassidulina corbyi CUSHMAN AND HUGHES, Contrib. Cushman Lab. Foram. Res., vol. 1, pt. 1, 1925, p. 14, pl. 2, figs. 3a, b. CUSHMAN, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 1, no. 10, 1927, p. 166, pl. 6, fig. 3.

Length 0.41 mm.; breadth 0.32 mm.; thickness 0.23 mm.

The Carmen Island Pliocene is abundant with this species, as is the Upper Pliocene of Southern California. *Cassidulina pulchella*, of Coryell and Mossman (not d'Orbigny), is probably the same as this species.

Off the west coast of Central America, its known bathymetric range is 133–2100 meters, very rare 133–275 meters, very abundant 275–782 meters, and rare to common 782–2100 meters. Not found in our samples from off Southern California.

Cassidulina cushmani R. E. Stewart and K. C. Stewart

(Plate 9, figures 9a, b)

Cassidulina cushmani R. E. STEWART AND K. C. STEWART, Jour. Paleont., vol. 4, no. 1, 1930, p. 71, pl. 9, figs. 5a, b. CORYELL AND MOSSMAN, Jour. Paleont., vol. 16, no. 2, 1942, p. 243, pl. 36, fig. 48.

Length 0.37 mm.; breadth 0.30 mm.; thickness 0.17 mm.

This small species is abundant in Carmen Island Pliocene. In Southern California it ranges from Recent to Upper Miocene. Off the west coast of Central America, its known bathymetric range is 275–2250 meters, being most prolific 520–782 meters. Off Southern California it ranges from 250 to 2700 meters.

***Cassidulina* cf. *tortuosa* Cushman and Hughes**

(Plate 9, figures 10a, b)

Cassidulina tortuosa CUSHMAN AND HUGHES, Contrib. Cushman Lab. Foram. Res., vol. 1, no. 1, 1925, p. 14, pl. 2, fig. 4. CUSHMAN AND GRAY, Cushman Lab. Foram. Res., Spec. Pub. no. 19, 1946, p. 42, pl. 7, figs. 17a–c.

Length 0.71 mm.; breadth 0.61 mm.; thickness 0.41 mm.

Sample A-3511 contains an abundance of this species. It differs from the typical *tortuosa* by having more radial sutures. In the usual *C. tortuosa*, the sutures have a rather sharp bend about midway between the periphery and the umbo.

At present, this type of *Cassidulina* is abundant from off Alaska to the southern end of Lower California. From this point south to the equator, insofar as known, it is extremely rare. Its known bathymetric range is 40–275 meters, except where there is slumping of marine sediments down rather steep slopes such as exist around Santa Catalina Island. *Cassidulina* in this area has been carried down by sliding to depths of 3000 feet.

In Southern California this species is confined to the Pleistocene and Upper Pliocene.

Subfamily EHRENBERGININAE

Genus ***Ehrenbergina*** Reuss, 1850

Ehrenbergina compressa Cushman

(Plate 9, figures 11a–c)

Ehrenbergina compressa CUSHMAN, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 1, no. 10, 1927, p. 168, pl. 6, fig. 7.

Ehrenbergina bradyi CUSHMAN AND GRAY (not CUSHMAN), Cushman Lab. Foram. Res., Spec. Pub. no. 19, 1946, p. 43, pl. 8, figs. 1a–c.

Length 0.46 mm.; breadth 0.30 mm.; thickness 0.145 mm.

Only a few specimens were found at Locality A-3503. They are typical *Ehrenbergina compressa*, differing from *E. bradyi* by being flatter, with no long spines on the periphery and no ornamentation along the median line. Our specimens from Timm's Point, San Pedro, California, as well as from many other localities in beds of the same age, are all of the *E. compressa* type. No definite *E. bradyi* have been found in the Pleistocene or uppermost Pliocene of the region, probably because, insofar as known, *E. bradyi* prefers to live in water deeper than 2560 meters off the west coast of Central America and not shallower than 1000 meters off the California coast; *E. compressa*, off the west coast of Central America, ranges from 210 to 1700 meters, and off Southern California, from 130 to 1820 meters.

Family CHILOSTOMELLIDAE

Subfamily ALLOMORPHINELLINAE

Genus ***Pullenia*** Parker and Jones, 1862

Pullenia* cf. *moorei Kleinpell

(Plate 9, figures 13a, b)

Pullenia moorei KLEINPELL, Miocene Stratig. Calif., Am. Assoc. Petrol. Geol. Pub. 1938, p. 340, pl. 18, figs. 11, 16. Contrib. Cushman Lab. Foram. Res., vol. 19, pt. 1, 1943, p. 18, pl. 3, figs. 7a, b.

Length 0.89 mm.; breadth 0.65 mm.; thickness 0.64 mm.

This species has been questionably referred to *Pullenia moorei Kleinpell.* It has more-rounded contours and is more lobulate on the periphery. On the average, it is somewhat broader than *P. malkinae*, a closely related species from the Pliocene of Panama, although it may grade into this form.

In the Carmen Island Pliocene, it is common to abundant, and not present in the Pleistocene. In the Recent, it is related to *P. elegans* Cushman and Todd.

Pullenia malkinae Coryell and Mossman

(Plate 9, figures 14a, b)

Pullenia malkinae CORYELL AND MOSSMAN, Jour. Paleont., vol. 16, no. 2, 1942, p. 234, pl. 36, figs. 2, 3. CUSHMAN AND TODD, Contrib. Cushman Lab. Foram. Res., vol. 19, pt. 1, 1943, p. 21, pl. 3, figs. 12a, b.

Length 0.88 mm.; breadth 0.79 mm.; thickness 0.41 mm.

Our specimens seem closely related to this species, although *Pullenia malkinae* could be a variety of *P. salisburyi*. The latter species usually has 6 chambers in the last whorl, while *P. malkinae* has 8 chambers.

In the Recent Pacific off the west coast of North America, there are three distinct species of *Pullenia*: *salisburyi, elegans*, and *bulloides*. *P. bulloides* is an abyssal form, *elegans* prefers depths of 275 to 1000 meters. *P. salisburyi* is most often found between 40 and 275 meters but has been found rare as deep as 1760 meters off the west coast of Central America.

Family GLOBIGERINIDAE
Subfamily GLOBIGERININAE

Genus ***Globigerina*** d'Orbigny, 1826
Globigerina conglomerata Schwager

(Plate 10, figures 1a–c)

Globigerina conglomerata SCHWAGER, Novara Exped., Geol. Theil., pt. 2, 1866, p. 255, pl. 7, fig. 113. CUSHMAN, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 1, no. 10, p. 172.

Globigerina eggeri RHUMBLER, Brandt, K. Nordischis Plankton, 1901, Lief. 1, Nr. 14, p. 19, p. 20, tf. 20.

Length 0.59 mm.; breadth 0.49 mm.; thickness 0.41 mm.

Rare in Pleistocene and abundant in Pliocene of Carmen Island. Abundant in the North and South Pacific Ocean. In Southern California, abundant in Pleistocene and rare in Pliocene.

Rhumbler's figure of *G. eggeri* is identical to ours, so apparently this species belongs in synonymy with *G. conglomerata*.

Globigerina bulloides d'Orbigny

(Plate 10, figures 2a–c)

Globigerina bulloides D'ORBIGNY, Ann. Sci., Nat., vol. 7, 1826, p. 277, no. 1, Modèles nos. 17, 76, 1826. CUSHMAN, Contrib. Cushman Lab. Foram. Res.,vol. 17, pt. 2, 1941, p. 38, pl. 10, figs. 1–13.

Length 0.40 mm.; breadth 0.35 mm.; thickness 0.29 mm.

Typical specimens are abundant in both the Pleistocene and Pliocene samples.

Globigerina quinqueloba Natland

(Plate 10, figures 3a–c)

Globigerina quinqueloba NATLAND, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 4, no. 5, 1938, p. 149, pl. 6, figs. 7a–c.

Length 0.24 mm.; breadth 0.20 mm.; thickness 0.14 mm.

Only a few typical specimens were found in Sample A-3501. It is easily distinguished from *Globigerina bulloides* because it has 5 instead of 4 chambers in the final whorl.

This species may be synonymous with *G. concinna* Reuss which is also a 5-chambered species with about the same dimensions.

Genus ***Globigerinoides*** Cushman, 1927
Globigerinoides cyclostoma (Galloway and Wissler)

(Plate 10, figures 4a–c)

Globigerina cyclostoma GALLOWAY AND WISSLER, Jour. Paleont., vol. 1, no. 1, 1927, p. 42, pl. 7, figs. 8a, b.

Length 0.47 mm.; breadth 0.47 mm.; thickness 0.37 mm.

This species has a very low spiral arrangement, in contrast to the high spire of *Globigerinoides rubra*. It is a pelagic species widely distributed in the Pacific, and common in the Pleistocene and Pliocene of the Southern California area.

Globigerinoides sacculiferus (Brady)

(Plate 10, figures 5a–c)

Globigerina sacculifera BRADY, Rept. Voy. Challenger, Zoology, vol. 9, 1884, p. 604, pl. 80, figs. 11–17.

(Broken specimen) Length 0.70 mm.; breadth 0.53 mm.; thickness 0.47 mm.

Most specimens have the proboscis-shaped last chamber broken off, which is to be expected because of the weak attachment it has to the rest of the test. *Globigerinoides sacculiferus* prefers to live in warm, tropical surface water. Not observed in any marine sediments from Southern California.

Globigerinoides rubra (d'Orbigny)

(Plate 10, figure 7)

Globigerina rubra (d'Orbigny) *in* DE LA SAGRA, Hist. Fis. Pal. Nat., Cuba, 1893, "Foraminifères," p. 94, pl. 4, figs. 12–14. CUSHMAN, U. S. Nat. Mus., Bull. 104, pt. 5, pl. 3, figs. 4–7.

Length 0.47 mm.; breadth 0.38 mm.

A few high-spired specimens referable to this species were found in the Pliocene of Carmen Island.

Globigerinoides sp. A

(Plate 10, figure 6)

Diameter 0.24 mm.

A few small, round specimens of the type figured were found. They may be either the young stage of some larger form or a variety of *Globigerinoides bradyi* or *G. minuta* Natland. The two later species may be synonymous.

Subfamily ORBULININAE

Genus ***Orbulina*** d'Orbigny, 1839

Orbulina universa d'Orbigny

(Plate 10, figure 10)

Orbulina universa D'ORBIGNY, *in* DE LA SAGRA, Hist. Phys. Pol. Nat., Cuba, 1839.

Diameter 0.44 mm.

A pelagic form, of little or no value for local age determination.

Subfamily PULLENIATININAE

Genus ***Pulleniatina*** Cushman, 1927

Pulleniatina obliquiloculata (Parker and Jones)

(Plate 10, figures 8a, b)

Pullenia sphaeroides (d'Orbigny) var. *obliquiloculata* PARKER AND JONES, Royal Soc. London, Philos. Trans., vol. 155, 1865, p. 365, 368, pl. 19, figs. 4a–b.
Pulleniatina obliquiloculata CUSHMAN, Cushman Lab. Foram. Res., vol. 3, 1927, p. 90.

Maximum diameter 0.55 mm.

Rare to common in most of the Carmen Island Pliocene samples. Not found in Pleistocene, which is difficult to understand since it is a pelagic form found generally in tropically warm surface waters, and the Pleistocene, from our evidence, was laid down in warm water.

Family GLOBOROTALIIDAE

Genus ***Globorotalia*** Cushman, 1947

Globorotalia menardii (d'Orbigny)

(Plate 10, figures 9a–c)

Rotalia menardii D'ORBIGNY, Ann. Sci. Nat., Paris, vol. 7, no. 26, p. 273, Modèles No. 10.

Maximum diameter 0.70 mm.; thickness 0.30 mm.

Rare in Pleistocene and common in Pliocene of Carmen Island. Prefers warm tropic surface waters, which probably explains its scarcity in both the Recent and fossil sediments of Southern California.

Family ANOMALINIDAE

Subfamily ANOMALININAE

Genus ***Anomalina*** d'Orbigny, 1826

Anomalina schmitti Cushman and Wickenden

(Plate 10, figures 11a–c)

Anomalina schmitti CUSHMAN AND WICKENDEN, U. S. Nat. Mus., Pr., vol. 75, art. 9, 1929, p. 14, pl. 6, figs. 5a–c. CUSHMAN AND VALENTINE, Contrib. Dept. Geol., Stanford Univ., vol. 1, no. 1, 1930, p. 28, pl. 8, figs 6a–c; pl. 9, figs. 3a–c.

Maximum diameter 0.94 mm.; thickness 0.41 mm.

Typical specimens occur in both the Pleistocene and Pliocene. This is essentially a shallow-water species, usually found attached to sea weed, eel grass, or rocks. Specimens found in deep water are thought to have been transported there from shallow water.

Genus ***Planulina*** d'Orbigny, 1826

Planulina ornata (d'Orbigny)

(Plate 11, figures 4a, b)

Truncatulina ornata D'ORBIGNY, Voy. Amér. Mérid., vol. 5, pt. 5, 1839, "Foraminifères."
Planulina ornata CUSHMAN, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 1, no. 10, 1927, p. 176, pl. 6, fig. 12. NATLAND, Spriggs Inst. Oceanog., Bull., vol. 3, no. 10, 1933, (line 84 on included chart).

Maximum diameter 0.67 mm.; thickness 0.12 mm.

A few typical specimens were found in the Carmen Island Pliocene.

The bathymetric range of this species, off the west coast of Central America, is 360–4140 meters, with a maximum development 360–1700 meters. Off Southern California they occur in shallower water, being rare to abundant 30–2800 meters.

Planulina cf. ***faveolata*** (H. B. Brady)

Anomalina faveolata H. B. BRADY, Rept. Voy. Challenger, Zoology, vol. 9, 1884, p. 674, pl. 94, figs. 1a–c.
Planulina faveolata CUSHMAN, U. S. Nat. Mus., Bull. 104, pt. 8, 1931, p. 11, pl. 20, figs. 2, 3.
Planulina depressa NATLAND (?) (not D'ORBIGNY), Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 3, no. 10, 1933, line 116 on included chart.

Maximum diameter 0.76 mm.; thickness 0.14 mm.

Rare to abundant in both Pleistocene and Pliocene sediments of the Carmen Island region, as well as in Southern California.

It is questionably referred to *P. faveolata* because our specimens compare favorably with figures of this species shown by Cushman. It somewhat resembles *P. appressa* and *P. baggi*, both of Kleinpell.

Off the west coast of Central America its known bathymetric range is 18–304 meters, with a single specimen at 1310 meters. Off Southern California it ranges from 20 to 300 meters.

Subfamily CIBICIDINAE

Genus ***Cibicides*** Montfort, 1808

Cibicides pseudoungeriana (Cushman)

(Plate 11, figures 1a–c)

Truncatulina ungeriana H. B. BRADY (not *Rotalina ungeriana* D'ORBIGNY), 1826 and 1846, Rept. Voy. Challenger, Zoology, vol. 9, 1884, p. 664, pl. 94, figs. 9a–c.
Truncatulina pseudoungeriana CUSHMAN, U. S. Geol. Survey, Prof. Paper 129-E, 1922, p. 97, pl. 20, fig. 9; 129-F, 1922, p. 136; 133, 1923, p. 40.
Cibicides pseudougeriana (Cushman) NATLAND, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 3, no. 10, 1933, p. 225–230, line 154 on included chart.

Maximum diameter 0.65 mm.; thickness 0.25 mm.

Occurs abundantly in both Pliocene and Pleistocene of Carmen Island region. It has been referred to *Cibicides pseudoungeriana* but may be close to *C. fletcheri* of Galloway and Wissler. In Southern California this species is abundant in Upper Pliocene and Pleistocene. A similar form is occasionally found in the Middle Miocene. Off the west coast of Central America, the known bathymetric range of this species is 17–1310 meters, extremely rare 17–45 meters, common to abundant 45–90 meters, persistently very abundant 90–304 meters, with only a single specimen deeper, at 1310 meters. Off Southern California its known range is 40–300 meters. The data indicate that this species prefers to live at depths shallower than 304 meters; off both Central and North America it has not been found below that depth except the single specimen at the one station mentioned which in all probability was transported there. This species often attaches itself to sea weeds and other benthonic plant life which, when uprooted, may float over areas of deep water where the attached forams could fall to the bottom, thereby producing an erratic occurrence in deep water.

Cibicides basiloba (Cushman)

(Plate 11, figures 2a–c)

Truncatulina basiloba Cushman, U. S. Geol. Survey, Bull, 676, 1918, p. 64, pl. 21, fig. 2.
Cibicides basiloba Natland, Scripps Inst. Oceanog., Bull., Tech. Ser., vol. 3, no. 10, 1933, line 90 on included chart.
Cibicides sp. Cushman and Valentine, Contrib Dept. Geol. Stanford Univ., vol. 1, no. 1, 1930.

Maximum diameter 0.53 mm.; thickness 0.19 mm.

In both Recent and fossil sediments of this region, this species is abundant. Referred to several different species by many authors, it is often called *Cibicides lobatulus* Walker and Jacob. It is here referred to *C. basiloba* because of the distinctive ornamentation near the umbilical region on the dorsal side. However, this feature is developed more strongly in some individuals than others. The figures given by Cushman, of *Cibicides concentrica*, show a similar ornamentation. Consequently, it is assumed that this species is closely related to *basiloba.*

Cibicides basiloba is usually found attached to sea weed or other material in Recent samples. Off the west coast of Central America, the known bathymetric range of this species is 1–1700 meters, rare to abundant from 1 to 95 meters, rare to extremely abundant from 95 to 275 meters, and rare to common from 275 to 1700 meters. Off Southern California it ranges from 40 to 900 meters.

Cibicides gallowayi Cushman and Valentine

(Plate 11, figures 3a–c)

Cibicides gallowayi Cushman and Valentine, Contrib. Dept. Geol., Stanford Univ., vol. 1, pt. 1, 1930, p. 30, pl. 10, figs. 4a–c. Natland, Scripps Inst. Oceanog., Bull., vol. 3, no. 10, 1933, line 165 on included chart.

Length 0.82 mm.; breadth 0.60 mm.; thickness 0.26 mm.

A few specimens were found in the Pliocene beds. *C. gallowayi* is quite unique, having rather large perforation with a deep umbilical pit on the ventral side, and the spiral suture on the dorsal side is usually not joined but is somewhat detached, leaving an opening between the whorls. It closely resembles *C. lobatula* (Walker and Jacob).

Off the west coast of Central America, its known bathymetric range is 55–290 meters, with a single specimen at 1310 meters. Off Southern California it ranges from 50 to 280 meters.

It is abundant in the Pleistocene and Upper Pliocene sediments of Southern California.

Genus ***Dyocibicides*** Cushman and Valentine, 1930

Dyocibicides biserialis Cushman and Valentine

(Plate 11, figures 5a–c)

Dyocibicides biserialis Cushman and Valentine, Contrib. Dept. Geol., Stanford Univ., vol. 1, no. 1, 1930, p. 31, pl. 10, figs. 1, 2a–b.

Length 0.76 mm.; breadth 0.60 mm.; thickness 0.32 mm.

Persistently abundant in Pleistocene and absent in Pliocene. It prefers a shallow, clear-water habitat and generally grows attached to seaweed and other plants.

Genus ***Annulocibicides*** Cushman and Ponton, 1932

Annulocibicides sp. A

(Plate 11, figures 7a–b)

Length 1.00 mm.; breadth 0.76 mm.; thickness 0.18 mm.

A single broken specimen apparently belonging to this genus was found at Locality A-3519.

Family PLANORBULINIDAE

Genus ***Planorbulinoides*** Cushman, 1928

Planorbulinoides retinaculata (Parker and Jones)

(Plate 11, figures 6a–c)

Planorbulina retinaculata PARKER AND JONES, Royal Soc. London, Philos. Tr., vol. 155, 1865, p. 421, pl. 19, fig. 2.

Diameter .78 mm.; thickness .17 mm.

Common in Pleistocene and absent in Pliocene. It prefers to live in clear, quiet water where it usually grows attached to rocks or plants.

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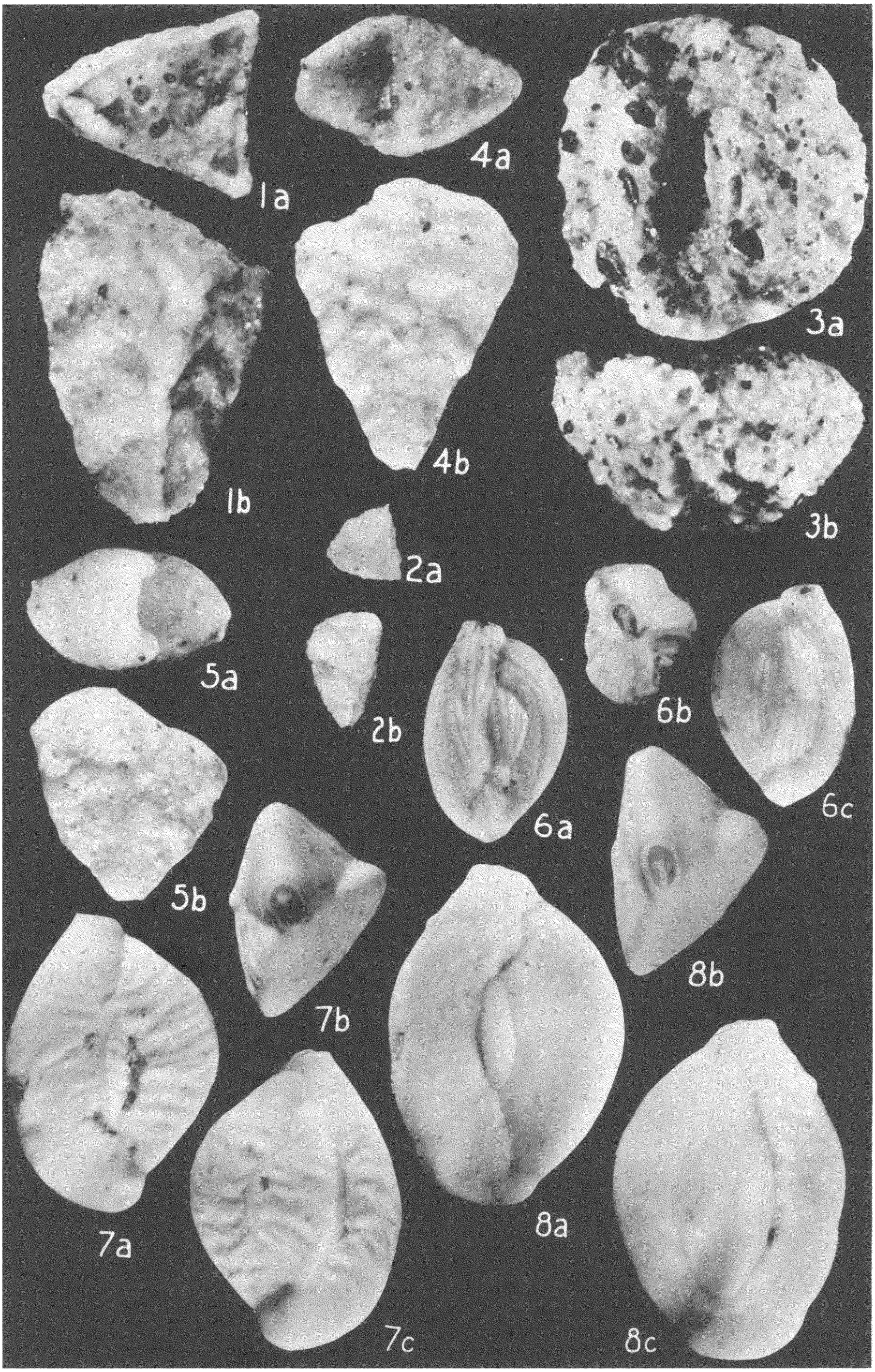

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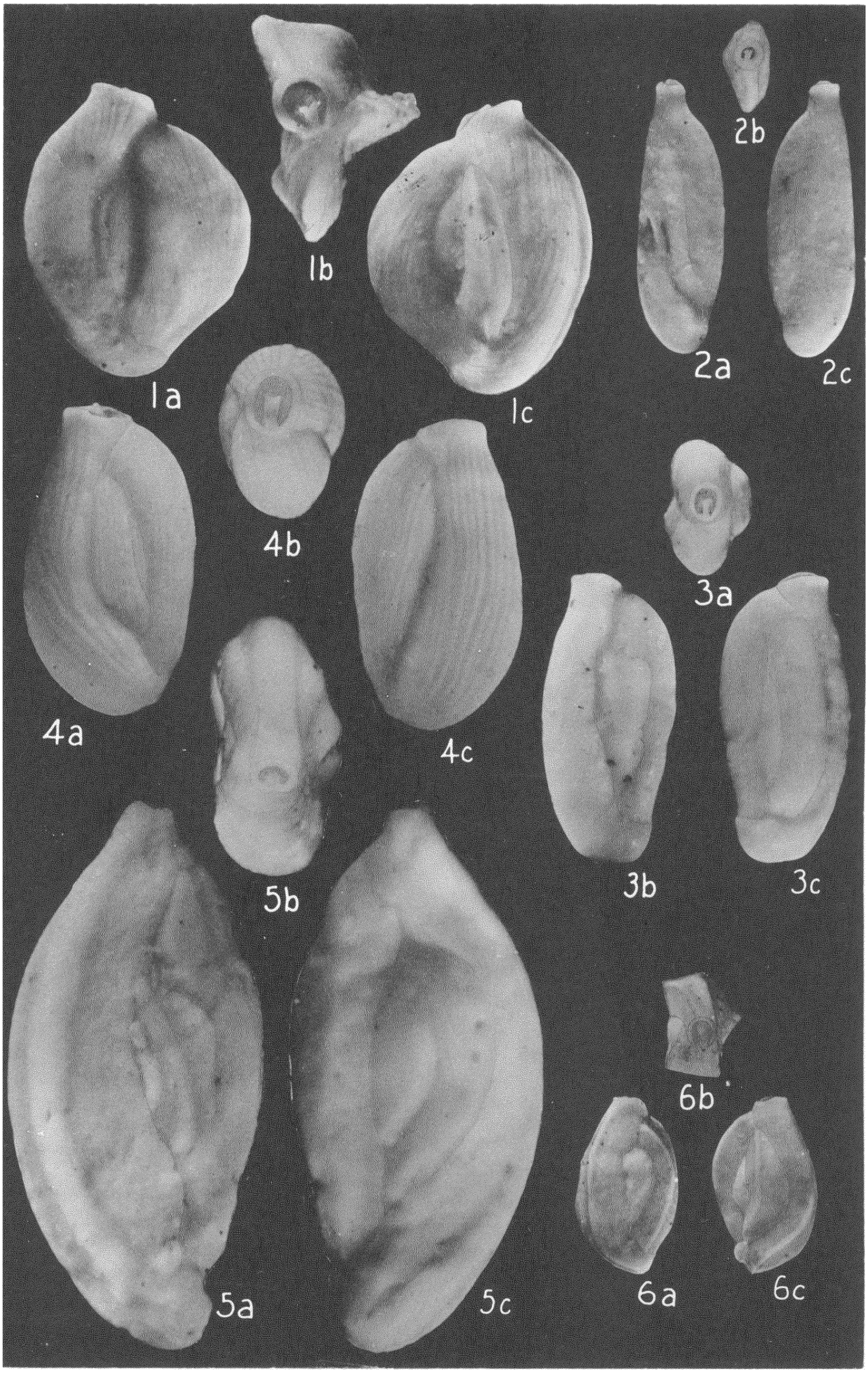

PLEISTOCENE AND PLIOCENE FORAMINIFERA

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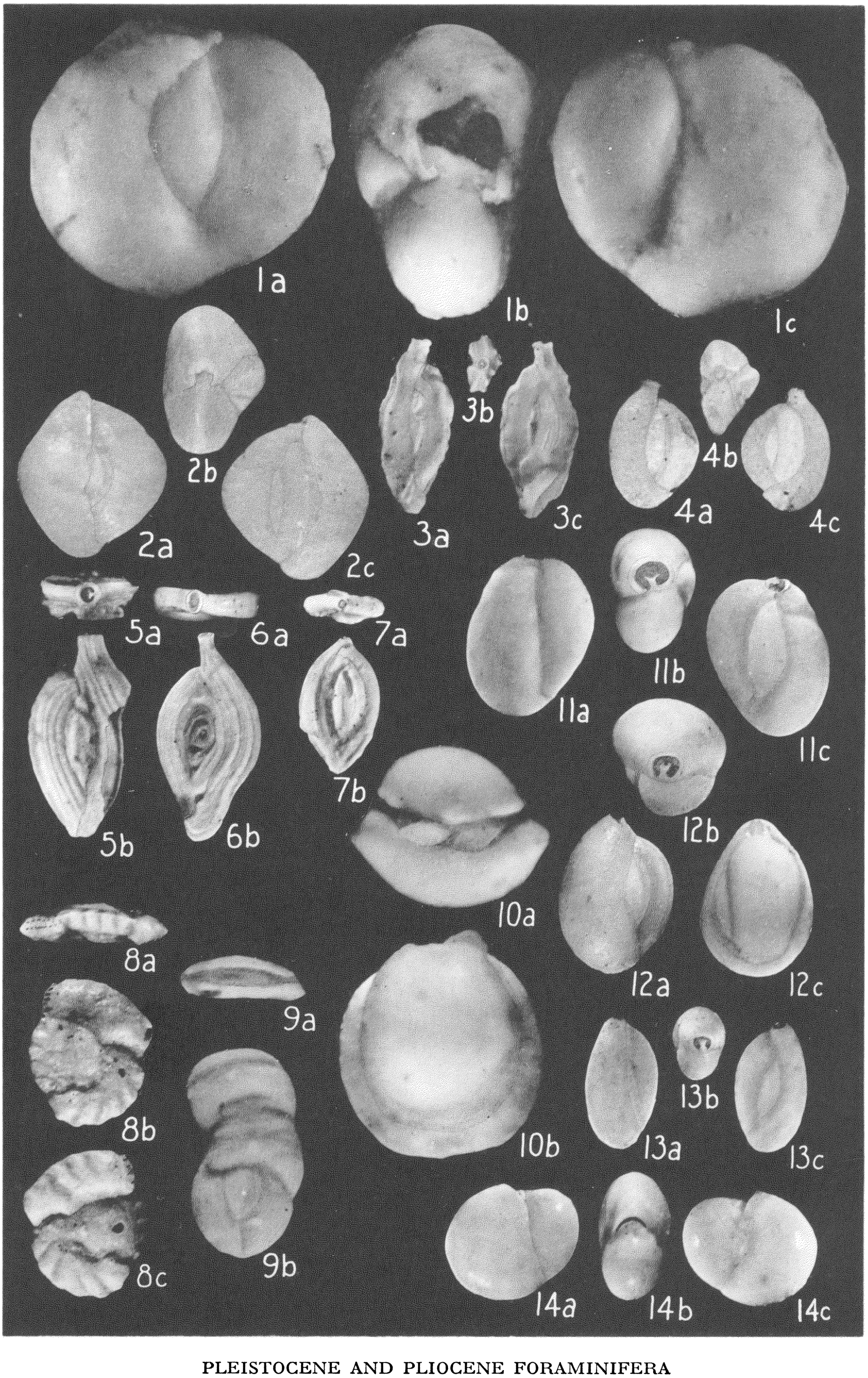

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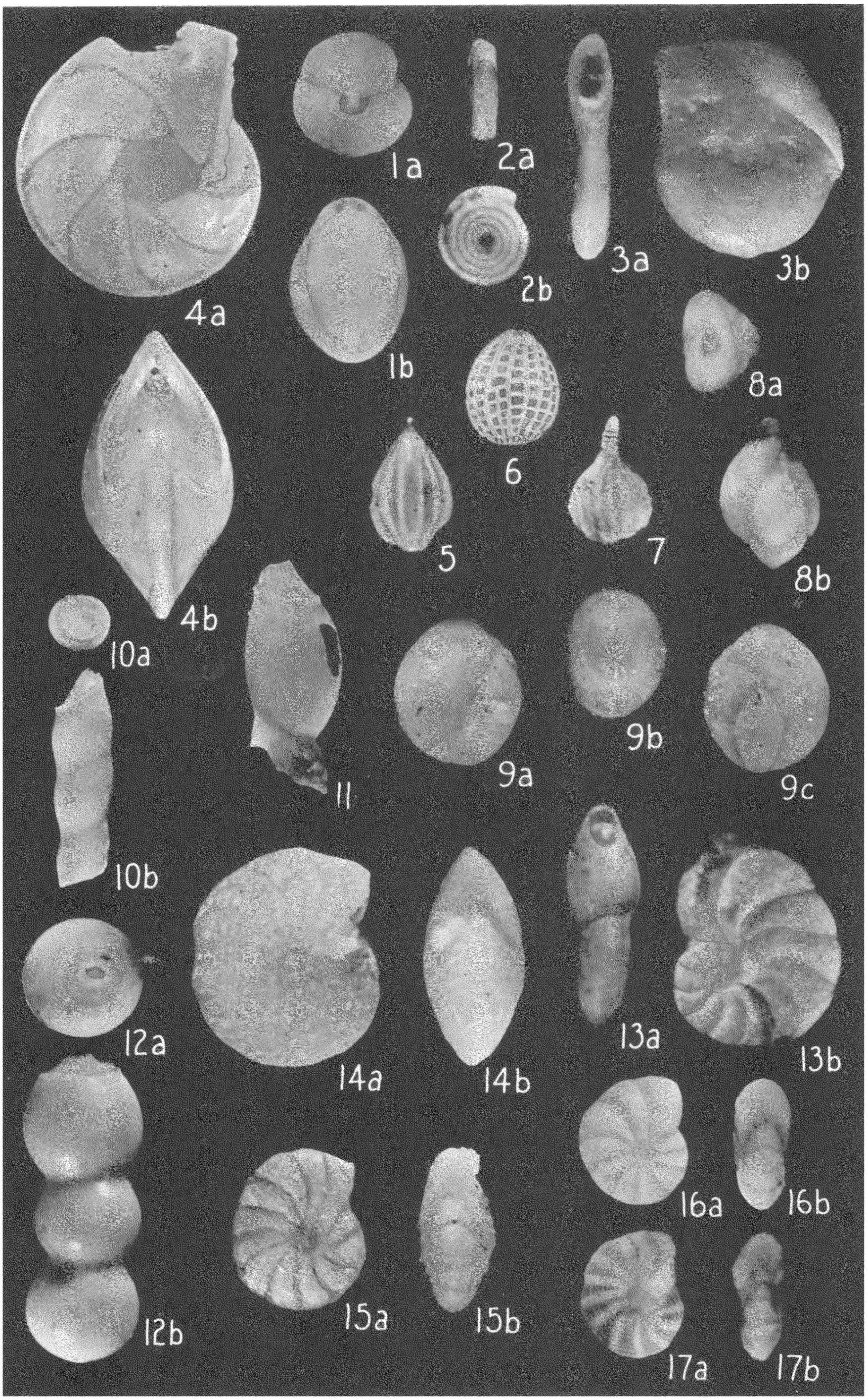

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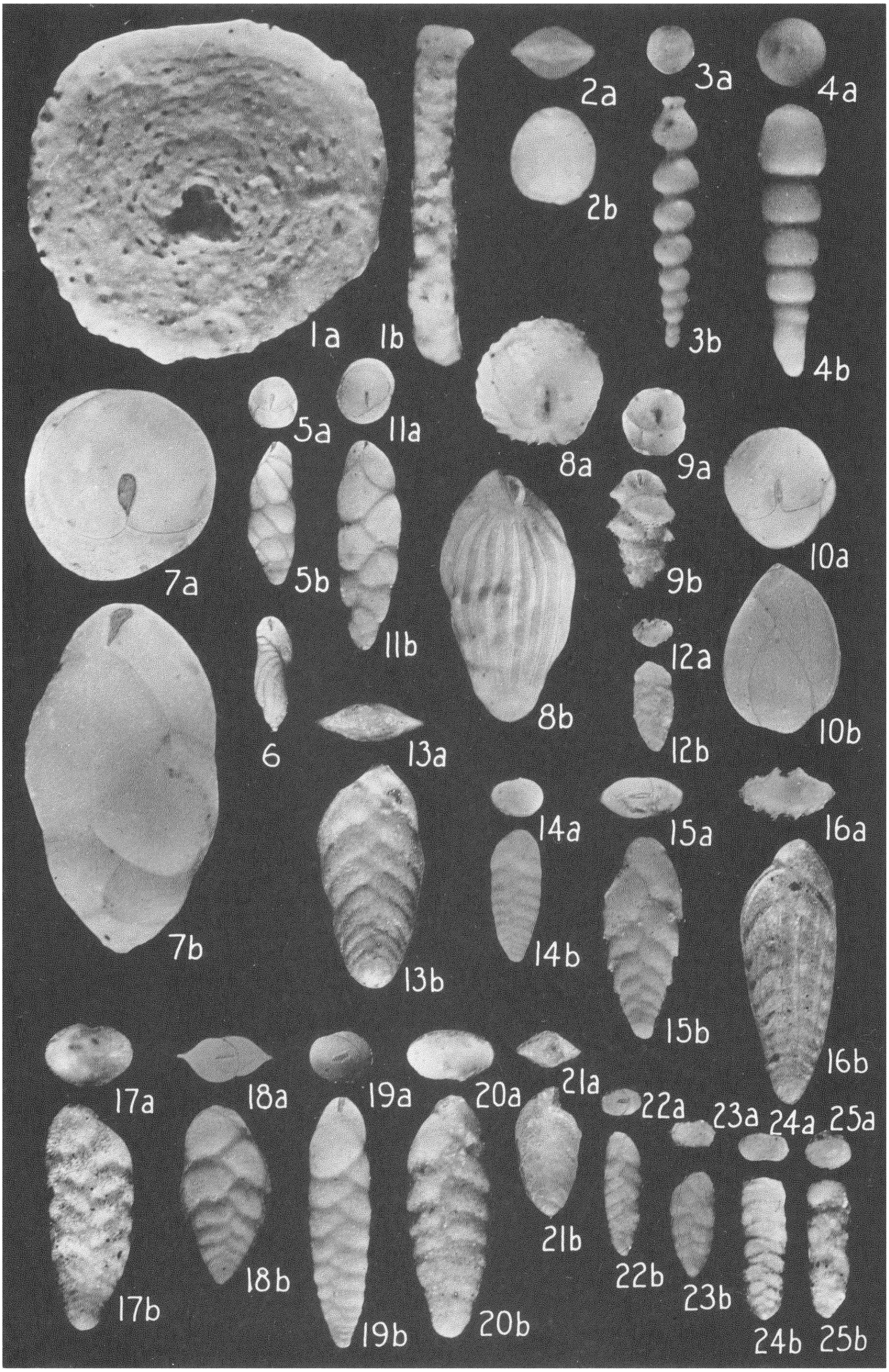

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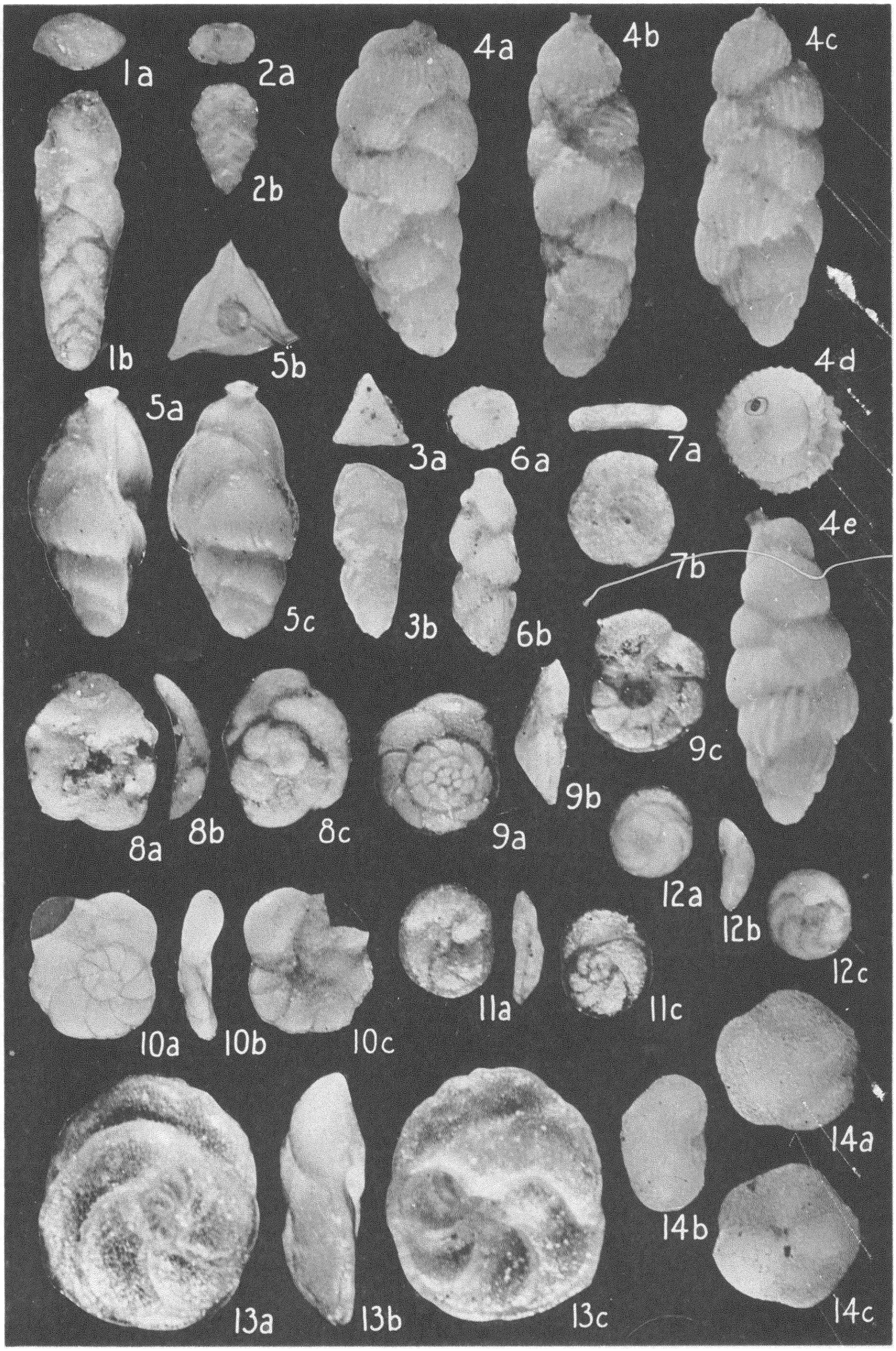

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PLATE 6.—PLEISTOCENE AND PLIOCENE FORAMINIFERA

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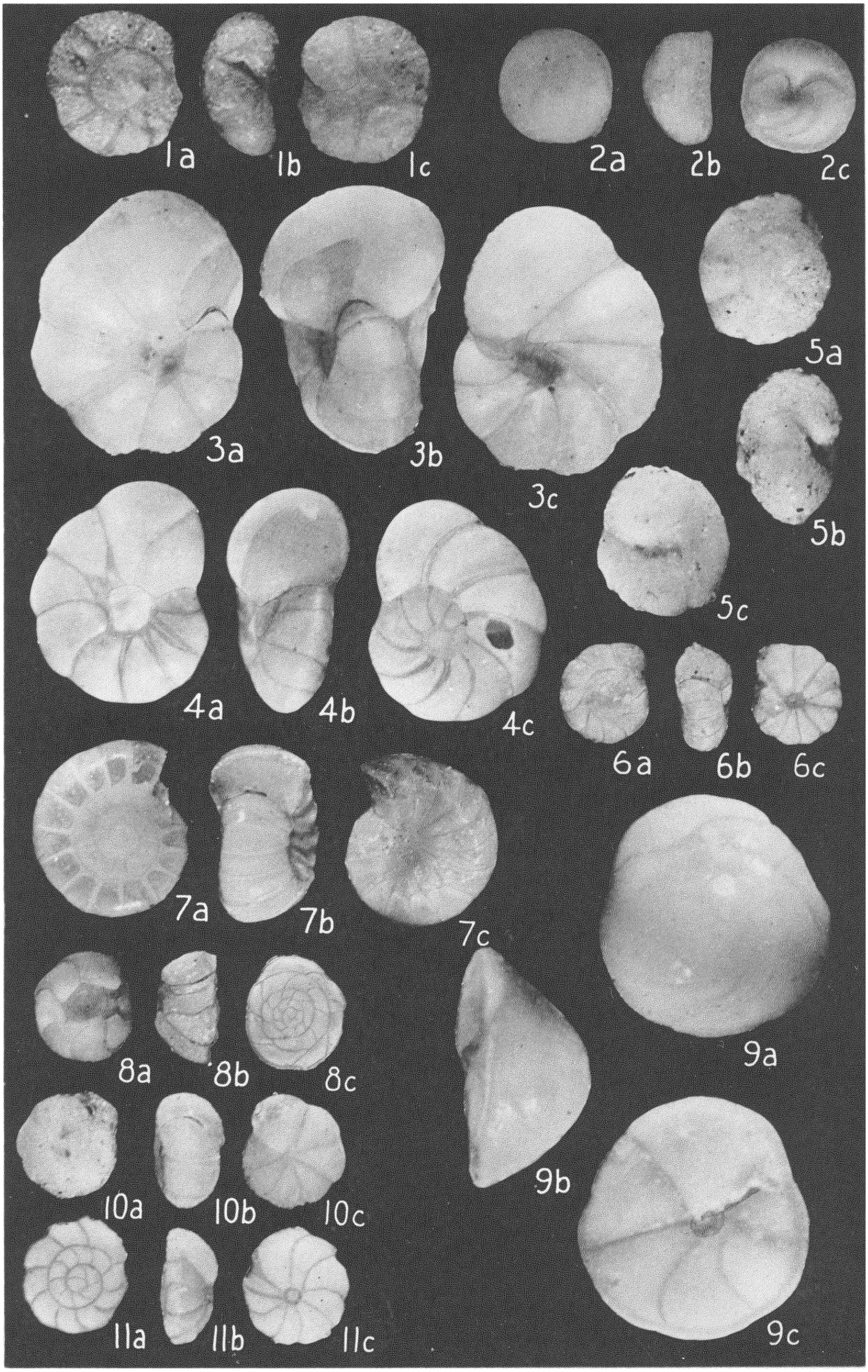

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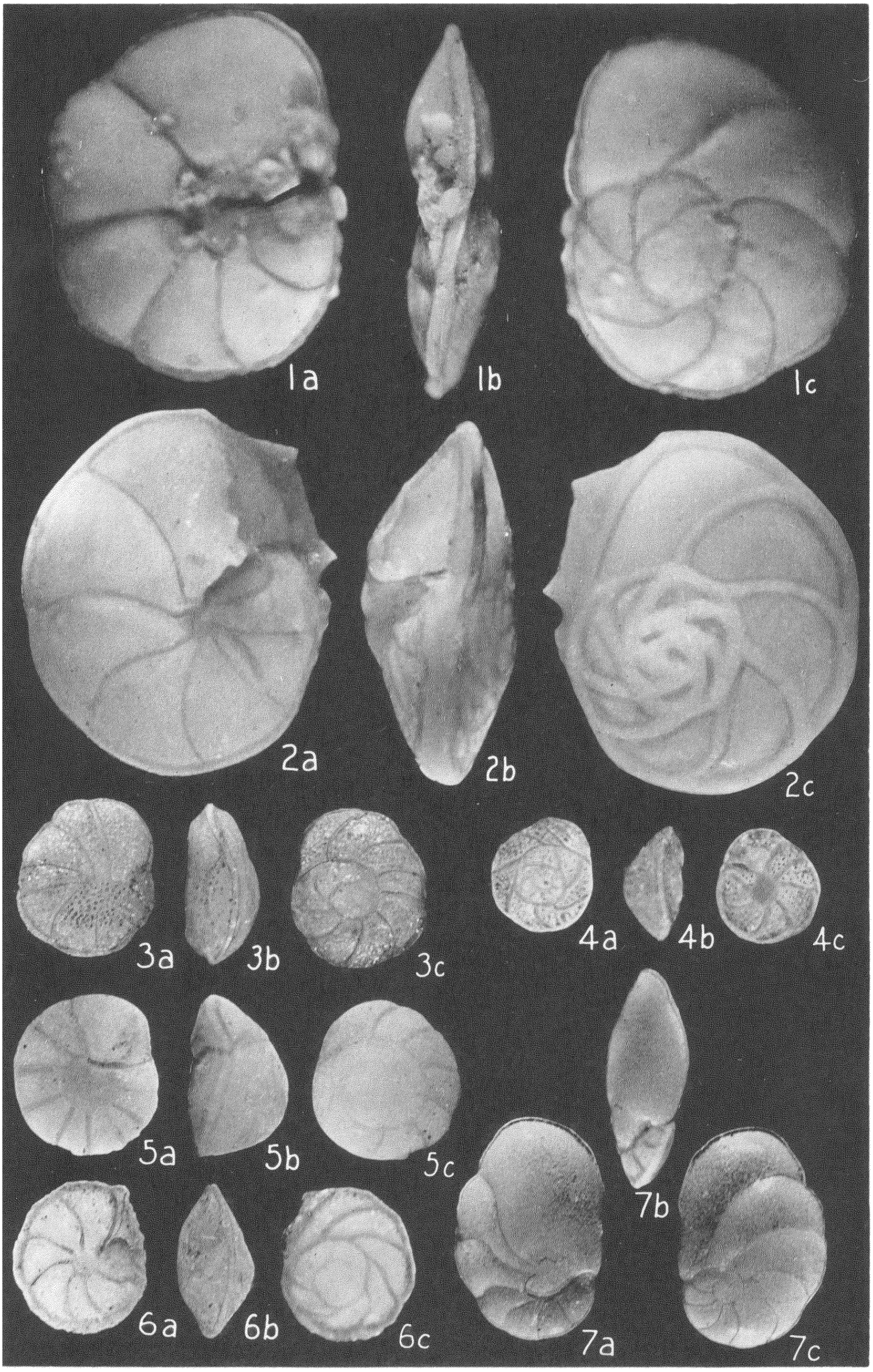

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PLATE 8.—PLEISTOCENE AND PLIOCENE FORAMINIFERA

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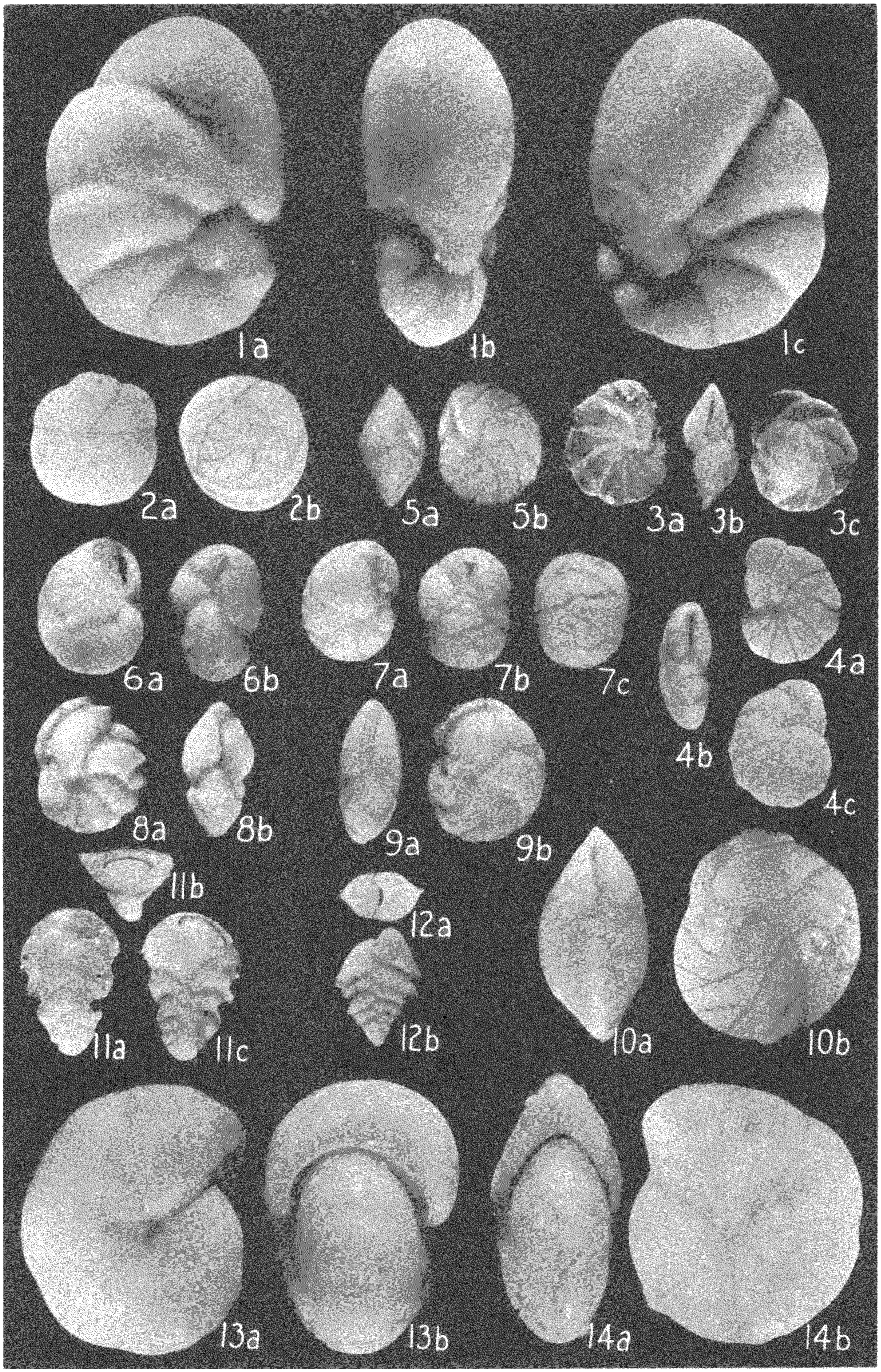

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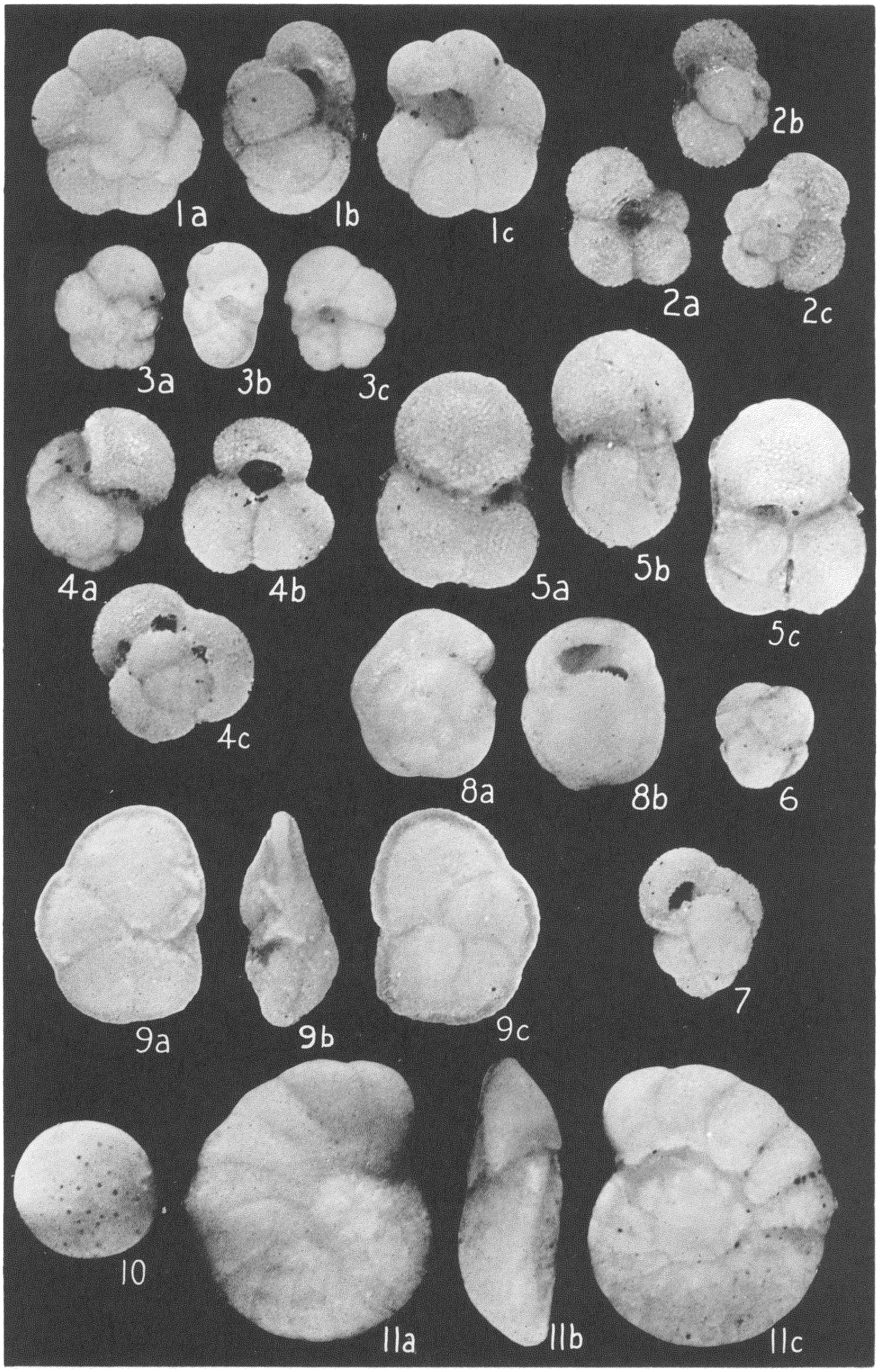

PLEISTOCENE AND PLIOCENE FORAMINIFERA

PLATE 10.—PLEISTOCENE AND PLIOCENE FORAMINIFERA

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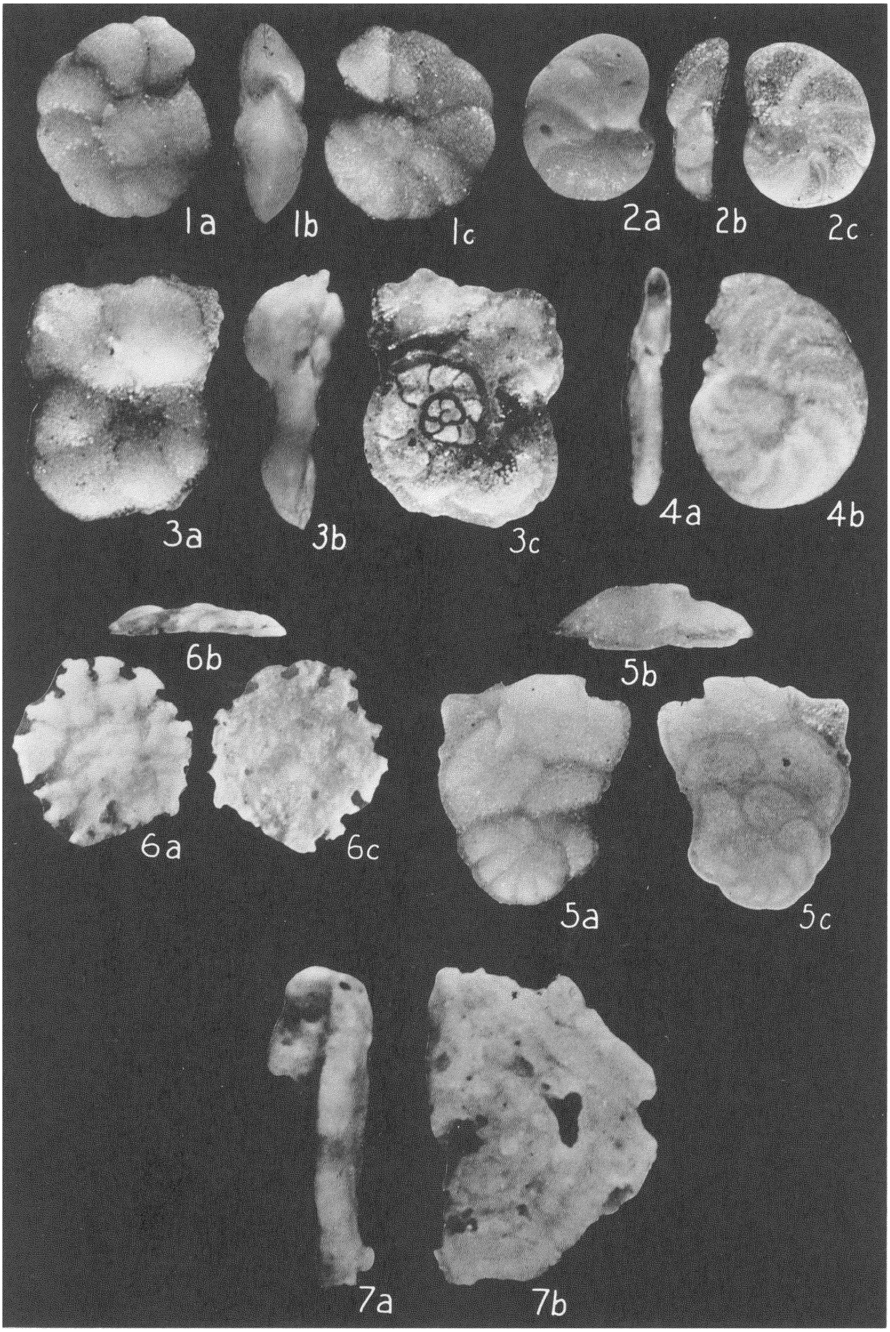

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1940 E. W. SCRIPPS CRUISE TO THE GULF OF CALIFORNIA

PART V

SEDIMENTATION AND OCEANOGRAPHY: SURVEY OF FIELD OBSERVATIONS

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SEDIMENTATION

DESCRIPTIONS OF SEDIMENTS COLLECTED

The cores obtained with the Emery-Dietz coring device were at the time the longest on record from the open sea (Table 1). It is believed that the unusual lengths of the cores resulted from the relatively soft character of some of the bottom muds, and also from the use of core barrels 20 feet in length and 2½ inches in diameter, equipped with liners of thin flexible celluloid in place of the metal or glass previously used.

Several cores collected in the Guaymas area were over 15 feet long, and one was nearly 17 feet. Approximately 50 cores and about 10 surface snapper samples were taken in this region. The coring was done systematically, along six lines at right angles to the coast, extending from the inner continental shelf to depths of 400 to 1000 fathoms, 20 to 30 miles from shore. In the northern part of the area, the deeper cores were usually finely laminated diatomaceous muds stinking of H_2S from top to bottom, and apparently high in organic matter. When dry, the laminations were clearly seen as alternating white and green bands about .2 to 1 mm thick, which became more closely spaced toward the bottom of the core, probably owing to compaction. One core 7 inches long showed about 200 white bands. If these represent annual layers corresponding to seasonal fluctuations in the production of plankton diatoms in the overlying waters, the rate of deposition of these relatively loose muds may be calculated as about 1 foot in 350 years. The rate of accumulation of the compacted sediments is probably considerably slower, however.

Appreciable amounts of an inflammable gas, possibly methane, were present in the lower parts of several cores of diatomaceous mud. Yellowish layers, often up to an inch in thickness, which may be bentonite, occur in many of the diatomaceous muds of the middle third of the Gulf. These may represent one of the episodes of recent vulcanism known to have occurred in this region and suggest that volcanic activity has supplied some of the silica utilized by diatoms and removed when their skeletons were deposited.

In the southern part of the Guaymas area, the laminated diatomaceous muds are intercalated with gray sand, silt, and clay layers ranging from 1 mm to 4 or more cm in thickness. These may represent flood materials carried by the Yaqui or Mayo rivers; they agree in appearance with the gray to chocolate-brown stratified deposits on the shallow shelf between Guaymas and Isla Lobos at the mouth of the Yaqui river. In general the relatively gentle bottom topography of much of the area and the evidence of recent subsidence, given by both the shore geology and the presence of submarine terrace levels at depth, indicate that the Guaymas area is one of considerable sediment accumulation. On the other hand the presence of several steep slopes, some of which are apparently bare of recent deposits, and of two steep sided ridges suggests that this accumulation is extremely variable in thickness, depending on the bottom topography and the distribution of bottom currents. Probably continuing diastrophic activity accompanies and frequently interrupts the sedimentation.

In contrast to the east side of the Gulf, where a relatively large amount of detritus is carried to the sea during floods by intermittent streams of Sonora and Sinaloa, little clastic debris of sand size occurs in the sediments of the west side. On the 1939 expedition calcareous sands and gravels were found on many of the beaches and in shallow-water areas near shore on the west side of the gulf, while glauconitic and foraminiferal muddy sands cover some of the off-lying ridges. In order to study the distribution of these calcareous deposits, several lines of closely spaced snapper samples were run out from shore during the 1940 expedition in both the Carmen Island and Conception Bay areas. It was found that nearly pure calcareous sands and gravel occur only in depths less than about 30 fathoms on the open shelf, and that beyond the shelf or in deeper water there is a relatively abrupt transition through foraminiferal muddy sands to muds containing little carbonate. In protected embayments such as Concepcion Bay, there are gray muds, of low carbonate content but with abundant shells, while, off the occasional flood plains, detrital sands and muds predominate. Many of the late Pliocene and Pleistocene deposits of the islands and the Peninsula closely resemble lithologically the calcareous deposits found on the shallower parts of the open shelf and therefore were probably deposited under the same conditions. Systematic coring lines were run out from shore in both the Carmen Island and Concepcion Bay areas although delays due to bad weather and other causes prevented the taking of as many cores as would have been desirable. Laminated diatomaceous muds and green nonlaminated muds were found. Some of the cores contain sandy or silty layers, made up of glauconite grains and foraminiferal tests.

TABLE 1.—*Summary of coring operations*

Type of sediment	No. of cores collected	Average length inches	Range in length inches
Laminated diatomaceous mud	32	156	48–201
Green or gray silty and clayey muds	20	86	49–180
Sandy or shelly muds	14	64	14– 91
Gravel, sand and shell	19	22	2– 65
Hard gray clay	9	15	4– 42
Total no. of cores collected	94		
Total no. of trials	119 (5 from rocky areas)		

An area of relatively complex bottom topography occurs in the channel between Tiburon and Angel de la Guarda islands. The characteristic deposit at this point is an extremely compact gray or greenish clay overlain by muddy sands and gravels, the latter often containing subangular pebbles up to several centimeters in diameter. Sands and gravels are widespread at depths as great as 220 fathoms, although in the small basins in this channel fine-grained green muds are found. In the deep Sal si Puedes basin, west of Angel de la Guarda Island, a core several feet thick of relatively well sorted muddy sand was collected, and at another point, 600 fathoms deep, a coarse shell gravel was found. Fine-grained muds occur in the deepest part of the basin. These results make credible the finding by Natland of widespread gravelly sands containing relatively deep-water forams in the Pliocene of the Ventura basin of southern California.

Laminated diatomaceous muds occur in the deep, broad basin to the south of the Tiburon area. These differ from those found near Guaymas in their firm, relatively stiff character, suggesting the action of diagenetic processes, perhaps a change in the nature of the colloidal silica.

TABLE 2.—*Statistical summary of analyses of sediments*

Type of measurement	No. of cores studied	No. of individual portions of cores examined
Hydrogen ion concentration (pH)	95	1200
Oxidation reduction potential	8	70
Amount of decomposable organic matter	27	105
Sulphate-reducing bacteria	32	100
Sulphide content	8	40
Quantitative measurements of bacterial distribution	9	60
Qualitative tests for presence of viable bacteria	26	50

CHEMICAL AND BACTERIOLOGICAL STUDIES OF SEDIMENTS

Various types of investigations were carried out on freshly collected cores in order to study the chemical and biological conditions under which diagenetic processes are occurring in the muds. Sidney C. Rittenberg was in charge of this phase of the work.

Quantitative bacterial counts were made on the mud from nine cores, representing most of the types of sediments found. The aerobic and anaerobic populations were determined from the top to the bottom of the mud column; an average of seven levels per core were sampled. The bottom layers of 26 other cores, from 6 to 16 feet in length, were also tested for both aerobic and anaerobic bacteria by enrichment-culture techniques. Although micro-organisms are abundant in the top layers of the sediments, they are absent or very scarce near the bottoms. Geologically this may mean that the role of bacteria in diagenesis is confined to the topmost layers of sediment.

The source and fate of the hydrogen sulphide found in many cores were investigated. If the sulphide results from the reduction of sulphate ion in sea water, sulphate-reducing bacteria should be present, and accordingly 32 cores were tested for sulphate reducers at three or more levels from the surface to the bottom. Sulphate-reducing bacteria were found only near the surface. Chemical examination, both qualitative and quantitative, showed that in the green muds little or no H_2S occurs in the surface layers, where sulphate-reducing bacteria are found, but that the H_2S content rises to a maximum several feet below the surface, and then frequently decreases with depth. No acid-soluble iron sulphide is present in the green muds, even those containing more than 100 milligrams of hydrogen sulphide per liter of interstitial water. On the other hand gray muds from Guaymas harbor, and black muds from the Carmen Island salt lagoon, contain considerable acid-soluble sulphide and little if any hydrogen sulphide. Evidently, in these sediments, H_2S is precipitated as iron sulphide as fast as it is formed. The failure of iron sulphide to form in the green muds suggests that the iron in these muds is present in highly insoluble compounds.

The hydrogen ion concentration (pH) of the interstitial mud waters was determined at all depths in most of the cores collected. Each general type of sediment seems to have its characteristic pH. Values range from 7.40 to 9.50. In cores of uniform composition the pH tends to increase with depth—that is, the interstitial water tends to become more alkaline. The pH also tends to increase with increasing particle size.

The amount of organic matter available for oxidation by micro-organisms was determined in 27 cores, by measuring the amount of oxygen consumed in stored water samples containing some of the mud in suspension. The results indicate that an appreciable fraction of the total organic matter in the sediments is readily decomposable.

PHYSICAL AND CHEMICAL OCEANOGRAPHY

CURRENT MEASUREMENTS

The coarse sands and gravels found on the bottom in the Tiburon area have undoubtedly been deposited under nearly the conditions of the present day, but the mechanism of transportation of the sand grains and pebbles is difficult to understand. Strong tidal currents occur in this area, however, and possibly under extreme spring tide conditions the bottom currents might be competent to transport coarse sand and pebbles. To test this possibility, bottom-current measurements were made during a 12-hour period at a depth of about 220 fathoms in the channel between Tiburon and Angel de la Guarda islands. Later the vessel was anchored for 13 hours at a depth of 700 fathoms in Sal si Puedes basin, while currents at various depths from the surface to the bottom were measured. In both instances appreciable bottom currents were observed with velocities up to a third of a knot. The period of observation was one of rather small tides, but the currents at the bottom were about half as strong as the observed surface currents. The latter are known to reach velocities of several knots, so that the maximum bottom currents may be expected to be at least 1 or 2 knots. Such currents may be able to move small pebbles down a small slope. The facts that relatively high velocities were observed several hundred fathoms below the sill in the Sal si Puedes basis, and that the velocity at the bottom was in general opposite in direction to that at the surface, indicate that the currents in this area are associated with an internal wave and are not true tidal currents, since the latter are constant in direction from top to bottom, and cannot exist in a basin below sill depth.

Bottom-current measurements with a tripod were made at depths of about 1000 fathoms during two nights while the ship was drifting in the basins east of the Carmen Island and Concepcion Bay areas. The observed currents were of very small magnitude, usually less than a few hundredths of a knot. The cores collected in these localities were uniformly fine-grained laminated diatomaceous muds.

On two occasions the ship was anchored in the southwestern part of the Guaymas area, where the bottom sediments consist of alternating clay, silt, or sand layers and diatomaceous muds. At the first anchor station, measurements were continued for 24 hours; on the second, the vessel lay at anchor in about 700 fathoms for 5 days.

Current measurements were made simultaneously at the surface, 200, 500, and 800 meters, and at the bottom by means of instruments specially constructed by C. I. Johnson of the Scripps Institution, which were so designed that they could all be suspended on the wire at the same time. At intervals between current observations, the vertical distribution of temperature, salinity, and oxygen from the surface to 1000 meters was obtained. Velocities up to more than 1 knot were found at all depths above the bottom, while even at the bottom very appreciable currents were observed, in spite of the marked frictional drag on water movements which must be exerted by the uneven sea floor. It seems certain that part of the current motion was tidal in origin, and the existence of an internal wave of tidal or longer period is suggested by the general tendency for the current at the surface and the bottom to flow in opposite directions.

TABLE 3.—*Summary of hydrographic work accomplished*

Type of observation	No. of stations	No. of series	No. of observations
Water temperature	13	29	334
Water samples for chlorinity	13	29	269
Dissolved oxygen content	13	28	265
Dissolved phosphate content	9	16	172
Dissolved silica content	10	16	172
Phytoplankton distribution	13	17	104
Rate of photosynthesis	4	6	25
Content of decomposable dissolved organic matter	5	5	49
Bacterial distribution	9		18
Amount of suspended matter in deep water	9	13	47
Current measurements	6		463

RATE OF DEPOSITION OF ORGANIC REMAINS

The occurrence of laminated diatomaceous muds on the Gulf floor raises three important questions: (1) Are the laminations seasonal, perhaps representing seasonal rhythms in the rate of diatom production in the subsurface waters of the Gulf? (2) What peculiar conditions in the water allow the deposition of the diatom frustules on the bottom to form a deposit which is perhaps unique on the present sea floor? (3) What is the origin of the silica continually extracted from the sea water by the diatoms and permanently removed by the deposition of their frustules on the bottom? In an attempt to partially answer these questions investigations of various types were carried out on the Gulf waters (Table 3).

The seasonal character of phytoplankton production in the Gulf is demonstrated by means of information obtained on the two E. W. SCRIPPS expeditions. On the 1939 cruise, which took place in February and March, the Gulf lived up to the name given it by Cortez: "The Vermilion Sea", for the waters over large areas were reddened and opaque, so great was the phytoplankton population. When the 1940 expedition first reached the Gulf, the amount of phytoplankton as shown by quantitative sampling was very small, and the waters were correspondingly blue and clear.

Silica and phosphate, both essential substances for the growth of diatoms, were present in very low concentrations in the waters near the surface. There was little possibility of a supply being brought from below, for the warm temperature of the surface waters, built up during the summer and fall seasons of generally weak southeasterly winds, caused the existence of an effective density stratification, which prevented mixing. With the development of northwesterly winds of gale force, beginning in November, repeated measurements of the vertical distribution of temperature, salinity, and oxygen showed that the warm surface waters were being blown southward, while upwelling of cold water of low oxygen content from moderate depths, and mixing of surface and subsurface waters, were taking place. Simultaneous measurements of the amount of dissolved phosphate and silica showed a marked increase in the surface layers, which was followed by a decrease as growing diatoms and other phytoplankton utilized these substances. The relatively rapid rate of phytoplankton growth was measured directly by determining the amount of oxygen produced *in situ* at depths between the surface and 40 meters. Amounts of oxygen were liberated in one day equivalent to about 2 milligrams of dry organic matter production per square centimeter of sea surface, or about 100 pounds of diatoms per acre, per day. At the same time quantitative phytoplankton samples showed a marked increase, and small patches of red water were seen in December.

Large-scale phytoplankton growth and huge diatom populations occur elsewhere, notably off the American west coast, yet the bottom deposits are not notably diatomaceous, because the frustules settling into deep water become dispersed and dissolved. In contrast to these open sea areas, the deep waters of the Gulf were found by quantitative samples of the suspended water to contain an abundance of diatom frustules, and determinations of dissolved silica indicated that the deep waters have about 30 per cent more silica in solution than do those of the open sea. The amount of silica in the deep water increases from the mouth of the Gulf to the region west of Guaymas, indicating that the deep waters of the latter region are perhaps nearer to saturation and thus allow diatom frustules to settle without dissolving. Furthermore, this difference in silica content of the deep water can be interpreted as meaning that there is a constant supply of silica to the Gulf from the open sea, which is removed by deposition on the bottom. That is, silica-rich water flows into the Gulf at depth, and silica-poor water is replaced near the surface.