UNITED STATES DEPARTMENT OF THE INTERIOR
Harold L. Ickes, Secretary
GEOLOGICAL SURVEY
W. C. Mendenhall, Director

Professional Paper 190

LOWER PLIOCENE MOLLUSKS AND ECHINOIDS FROM THE LOS ANGELES BASIN, CALIFORNIA

AND THEIR INFERRED ENVIRONMENT

BY

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UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1938

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LOWER PLIOCENE MOLLUSKS AND ECHINOIDS FROM THE LOS ANGELES BASIN, CALIFORNIA, AND THEIR INFERRED ENVIRONMENT

By W. P. Woodring

ABSTRACT

The Repetto formation, which is considered of lower Pliocene age, embraces the principal oil-bearing strata in most of the major oil fields of the Los Angeles Basin. Twenty-six forms of mollusks and one echinoid are described from the Repetto formation of this region, and other larger fossils are recorded. These fossils were collected from outcrops and from cores representing 56 wells distributed widely over the basin. Imperfect remains from 10 additional wells are undetermined or undeterminable.

The fossils are assigned to three depth-range groups on the assumption that they represent essentially the same depth range as modern species from the eastern Pacific, to which they are closely allied. These groups are (1) fossils of shallow-water facies; (2) fossils of intermediate-depth facies, inferred to represent a range from shallow water into deep water; (3) fossils of deep-water facies.

The fossils of deep-water facies consist of at least 8 species, possibly 12 species, embracing mollusks, an echinoid, a sponge, and doubtfully a coral. The first fossil representatives of the echinoid family Echinothuriidae found in America are included in this group. Inasmuch as the fossils of deep-water facies belong to genera or subgenera that, with one exception, have not been found in California Pliocene formations characterized by a shallow-water facies, it is inferred that they represent deep water or cool water. The hypothesis that they represent upwelling cool water is considered and rejected, and the probability that they lived in deep water is considered reasonably certain. Most of the deep-water fossils are closely allied to species dredged by the *Albatross* off the coast of Oregon and California, but some closely resemble species that have not yet been found north of Central America, and allies of one species of probable deep-water facies are unknown in the eastern Pacific.

The fossils of deep-water facies are widely distributed throughout the basin. They suggest that during Repetto time the Los Angeles Basin sea had depths of 300 to 600 fathoms (roughly 2,000 to 4,000 feet).

Fossils of shallow-water facies have so far been found near the northern border of the basin and near the western margin. The fossils of intermediate-depth facies are more widely distributed than those of shallow-water facies. Some evidence points to areas of shallow water near the northern border of the basin. The association of fossils of deep-water, intermediate, and shallow-water facies and of land fossils in part of this region, however, suggests proximity to land and transportation of the shallow-water and land fossils by unknown agencies. The source of a shallow-water fossil from a locality near the western margin of the basin is not known but may have been an area of shallow water farther south.

The widespread distribution of fossils of deep-water facies in the Repetto formation and the depth facies of the overlying Pliocene and Pleistocene formations support the interpretation, already suggested, that the deposition of sediments of decreasing depth facies during Pliocene and Pleistocene time was a factor in the accumulation of the 6,000 to 10,000 feet of Pliocene and Pleistocene sediments in the basin. Unless, however, the depth of the Repetto sea was much greater than now appears probable, subsidence also was a factor.

The inferred deep-water environment of the Repetto formation supports the comparison, also already made, of the Los Angeles Basin during Repetto time with the modern deep-water basins on the Continental Shelf of southern California. These modern basins have depths of 300 to 1,000 fathoms. According to recent investigations, sand is being deposited on the ridges between the modern basins regardless of depth, and the fine-grained sediments in the basins are relatively rich in organic matter.

The age relations of the fossils are briefly discussed. Most of the fossils of deep-water facies closely resemble modern species, and many are similar to Miocene and Oligocene forms. The shallow-water species have a middle Pliocene aspect in terms of current age assignments.

INTRODUCTION

The Repetto formation, which is assigned to the lower Pliocene, embraces the principal oil zones in most of the major oil fields of the Los Angeles Basin. The extensive foraminiferal fauna of this formation has been exhaustively studied on account of its value in oil-field correlations, but the results of these studies have not yet appeared in print aside from a few brief accounts dealing with single species or local areas. Apparently only one record of a Repetto larger fossil [1] from core material in the basin has been published.[2]

I am greatly indebted to Dr. W. S. W. Kew, of the Standard Oil Co. of California, and to Mr. S. G. Wissler, of the Union Oil Co. of California, for the opportunity to study Repetto larger fossils from 60 wells distributed over the basin. These fossils have accumulated in the Standard and Union micropaleontology laboratories during the last few years. The officials of these companies and of other companies whose wells are represented in the core collections kindly gave permission to publish the data on the fossils. Mr. Wissler also permitted publication of records of *Lima hamlini* and *Hyalopecten* aff. *H. randolphi tillamookensis* based on specimens in his laboratory from six additional wells.

[1] The term "larger fossils" is used to contrast mollusks, echinoids, and other relatively large fossils with microscopic ones; it corresponds to the term "megafossils."

[2] Hertlein, L. G., New species of marine fossil Mollusca from western North America: Southern California Acad. Sci. Bull., vol. 24, p. 43, pl. 4, fig. 6, 1925.

Dr. Kew presented to the National Museum the material accumulated under his direction. Mr. Wissler donated to the Museum the types, other figured specimens, and additional material from his collection; the other specimens from his collection have been returned to the Union Oil Co.'s laboratory. Mr. Alex Clark, of the Shell Oil Co., donated to the Museum the specimen of *Lunatia* cf. *L. caurina* from the Inglewood field; permitted publication of the record of *Lima hamlini*, based on the specimen in his collection from the excavation for the Times Building in Los Angeles; and guided me to collecting localities in the Repetto Hills.

It is to be hoped that additional material will be collected as cores are sampled, for almost any Repetto larger fossil is of interest. A special effort should be made to collect Repetto larger fossils from wells in the Ventura Basin. It is quite probable that some events in the Pliocene history of the Los Angeles Basin and the Ventura Basin were similar. Repetto larger fossils resembling in facies those from the Los Angeles Basin might be expected to occur in the Ventura Basin. Apparently no record of Repetto larger fossils from cores taken in Ventura Basin wells has been published.

In addition to the core material, outcrop collections from Los Angeles, the Repetto Hills, and the Palos Verdes Hills—all along the border of the Los Angeles Basin—were studied in the preparation of this report. Several small collections were recently gathered in Los Angeles by Mr. W. H. Holman, of the Standard Oil Co. of California. The principal material from Los Angeles was collected by Homer Hamlin in 1901, when the Third Street tunnel was excavated between Hope Street and Hill Street. Hamlin's collection furnished material for the description of several new species. A list of the fossils from the Third Street tunnel was published by Ralph Arnold in 1907. W. H. Dall and Arnold recognized that the fossils from the Third Street tunnel are of Pliocene age. Material collected in the type region of the Repetto formation in the Repetto Hills is not included in the description of species, aside from the specimens of "*Nassa*" *hamlini* and *Acila semirostrata*. These collections from the Repetto Hills represent horizons assigned by micropaleontologists to the transition zone between the Repetto formation and the overlying Pico formation. Lists of species in the collections from the Repetto Hills are included in the discussion under the heading "Age relations of larger fossils."

The sponge remains were identified by Dr. M. W. de Laubenfels, of Pasadena; the corals by Dr. J. E. Hoffmeister, of the University of Rochester; the decapod crustaceans by Dr. M. J. Rathbun, of the United States National Museum; the echinoids by Dr. Th. Mortensen, of the Zoological Museum of the University of Copenhagen, and Dr. A. H. Clark, of the United States National Museum; and the plants by Mr. R. W. Brown, of the United States Geological Survey. Dr. Mortensen kindly permitted use of his identification and comments on the echinothuriids. I prepared the description of the echinothuriid material under the supervision of Dr. A. H. Clark. Mr. H. L. Driver, of the Standard Oil Co. of California, verified the stratigraphic data for the specimens in the Standard collection. Mr. Wissler prepared a chart showing the stratigraphic distribution of the larger fossils with reference to foraminiferal zones. Though the data on this chart are cited only in general terms, they were very useful in attempting to interpret the significance of the fossils. Dr. L. G. Hertlein, of the California Academy of Sciences, loaned specimens for comparison. Mr. D. D. Hughes, of the Texas Co. (California), supplied information about a locality on Newport Lagoon. Dr. H. A. Pilsbry, of the Philadelphia Academy of Natural Sciences, kindly made available the type lots of *Ostrea vespertina* and *Ostrea veatchii*. Mr. W. E. Schevill, of the Museum of Comparative Zoology, kindly loaned material from the type lot of *Pecten peckhami* and presented to the National Museum a squeeze of the lectotype. This study of Repetto mollusks could not have been attempted without access to the dredgings of the United States Fish Commission steamer *Albatross* from the eastern Pacific, and I wish to acknowledge my indebtedness to Dr. Paul Bartsch, Dr. H. A. Rehder, and Dr. J. P. E. Morrison, all of the Division of Mollusks of the United States National Museum, for facilities and courtesies. The manuscript, except the systematic paleontology, was read by Dr. Kew and Mr. Wissler, and the entire manuscript was read by several of my colleagues on the Geological Survey. I have profited from their criticisms and suggestions.

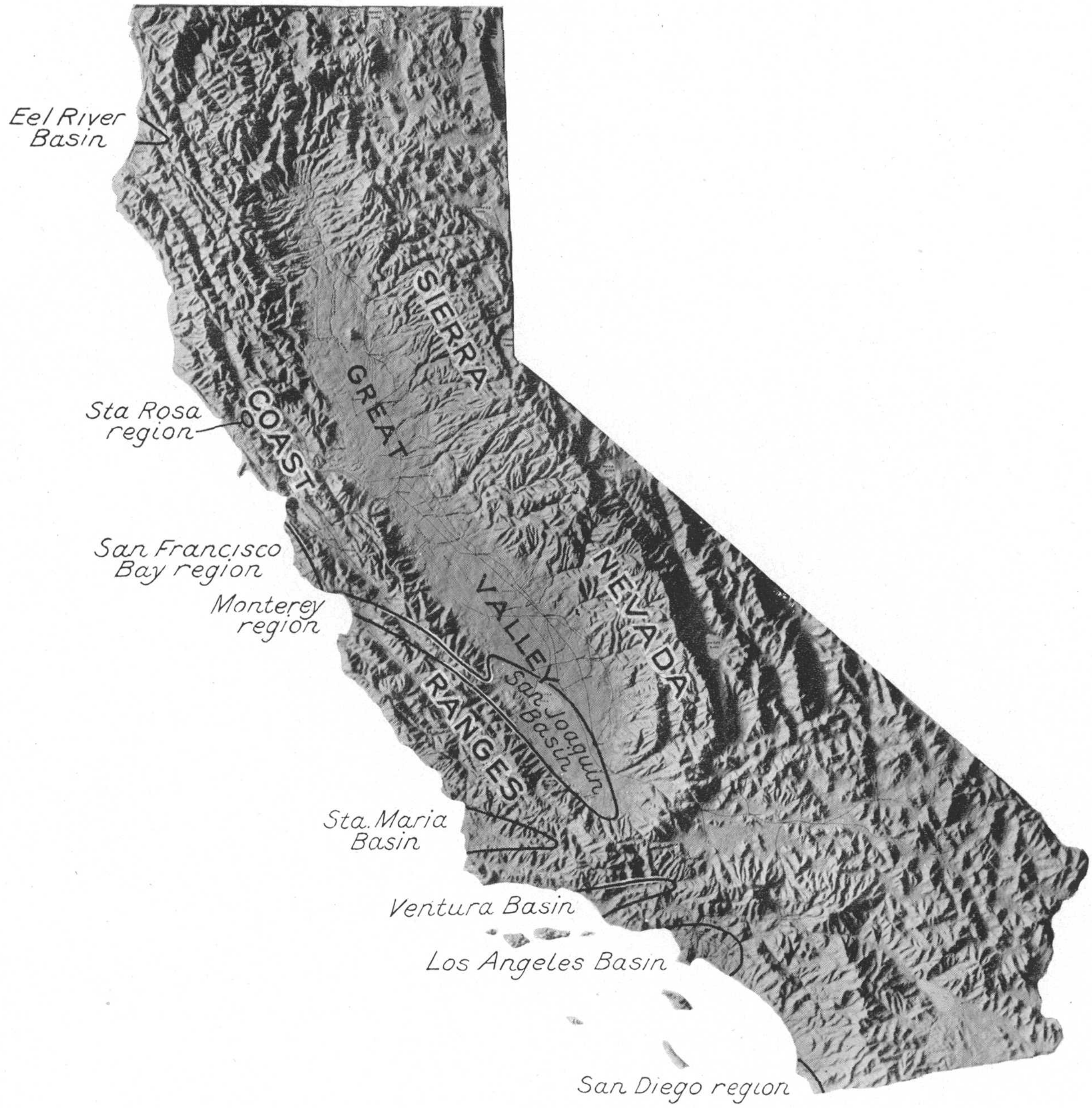
NEW SYSTEMATIC NAMES PROPOSED

The following new names are proposed:

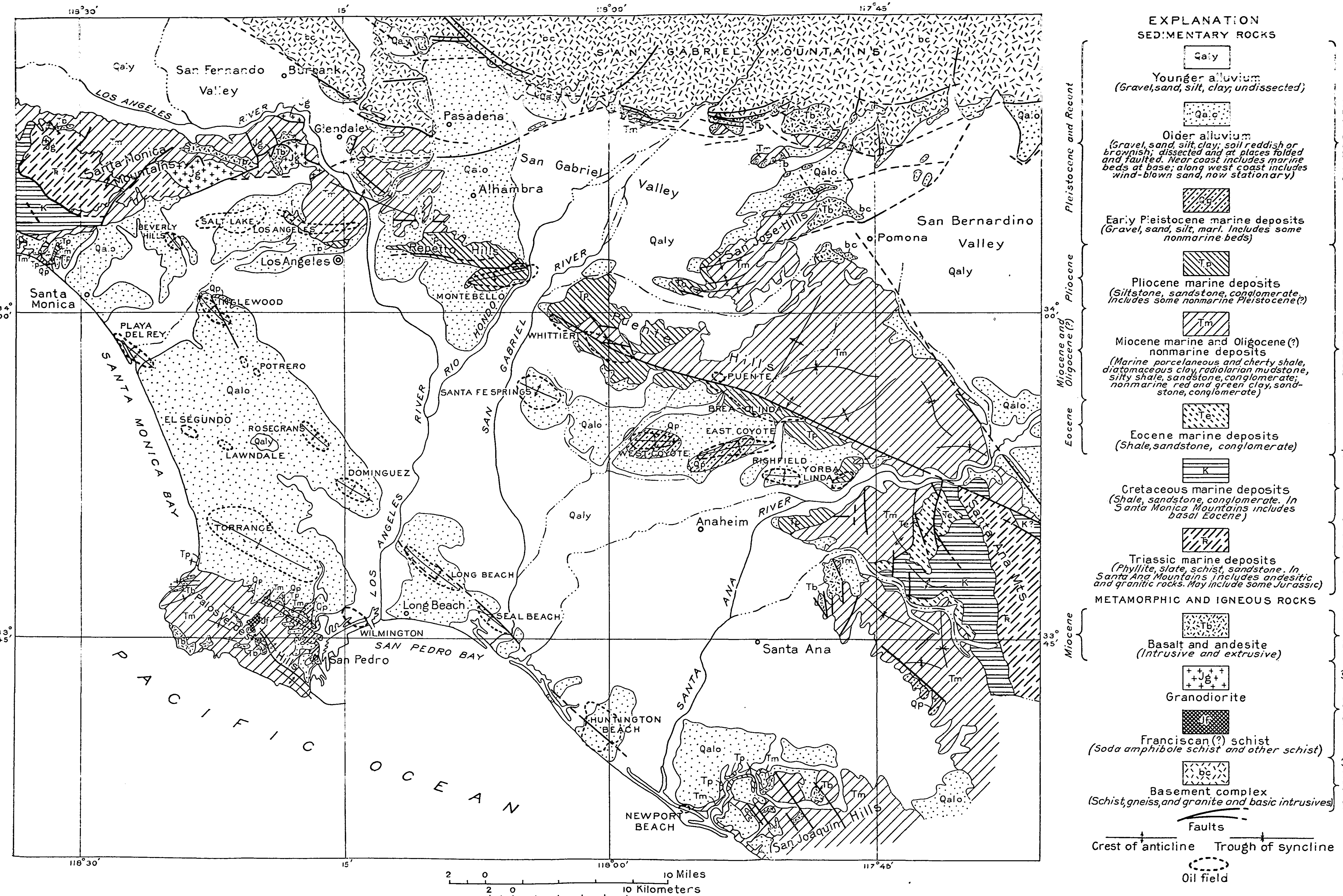
- *Limopsis* (*Felicia*) *phrear*, n. sp. (p. 31).
- *Phreagena*, n. gen., Vesicomyacidae?. Type, *Phreagena lasia*, n. sp. (p. 50).
- *Ectenagena*, n. gen., Vesicomyacidae. Type, *Calyptogena elongata* Dall (p. 51).
- *Periploma cryphia*, n. sp. (p. 56).
- *Periploma cryphia stenopa*, n. var. (p. 57).

GENERAL FEATURES OF LOS ANGELES BASIN

The principal areas of marine Pliocene formations in California are found in relatively small regions extending inland from the present coast, aside from the extensive inland San Joaquin Basin and its seaward prolongation and the Santa Rosa region. As shown on plate 1, the Los Angeles Basin is one of these coastal regions. The term "Los Angeles Basin" is here used in a physiographic sense for the lowland extending seaward from Los Angeles. The basin is bounded on the north by the Santa Monica Mountains and by hills extending southeastward from the Santa Monica Mountains to the Santa Ana Mountains, including the Repetto Hills and the Puente Hills; on the east by the



RELIEF MAP OF CALIFORNIA SHOWING PRINCIPAL AREAS OF MARINE PLIOCENE FORMATIONS.



GENERALIZED GEOLOGIC MAP OF LOS ANGELES BASIN AND BORDERS.

After Hoots and Kew (16th Internat. Geol. Cong. Guidebook 15, pl. 6, 1932) and Eckis (California Div. Water Resources Bull. 45, pls. A, B, C, 1934). Modifications from original sources in area covered by Palos Verdes Hills.

foothills of the Santa Ana Mountains and the San Joaquin Hills; on the south by the ocean and the Palos Verdes Hills (or San Pedro Hills); and on the west by the ocean. (See pl. 2.) The basin includes the flat seaward-sloping Los Angeles Plain, low hills enclosed by the plain, and mesas that rise above the plain along part of the bordering uplands. As thus defined the basin has an area of about 800 square miles.

The term "Los Angeles Basin" is also used for the Tertiary and Pleistocene depositional basins. During Pliocene time the sea extended beyond the present physiographic basin. The Miocene basin was also much more extensive than the present basin. At that time the sea extended entirely across the Santa Monica Mountains, the Palos Verdes Hills, and the San Joaquin Hills; covered part of the Santa Ana Mountains; and extended northward at least to the foot of the present San Gabriel Range. Possibly the Miocene sediments within the northern part of the present basin are thicker than in the bordering uplands, but only the upper part of the Miocene has so far been reached by wells within this part of the basin. The pre-Miocene history of the basin is not known. In the Santa Monica Mountains and the Santa Ana Mountains a thick succession of nonmarine Oligocene (?) and marine Eocene, Upper Cretaceous, and Triassic formations (the last not dated in the Santa Monica Mountains) lies below the Miocene. These formations may underlie the northern part of the basin, north of the Newport-Inglewood uplift. Seismic observations are interpreted as indicating that the basement, presumably consisting of granitic rocks, is at a depth of about 45,000 feet in the syncline northeast of the uplift.[3] In the Palos Verdes Hills and also in the Wilmington, Torrance, Playa del Rey, and El Segundo fields—south of the Newport-Inglewood uplift, which is thought by many geologists to mark a deep-seated fault—Miocene rests directly on a basement of Franciscan (?) schist of Jurassic (?) age.[4] It has been suggested that if a deep-seated fault lies along the Newport-Inglewood uplift, the fault probably marks the boundary between the Franciscan (?) basement and the granitic basement.[5]

Brief accounts of the geology of the basin and its borders have recently appeared.[6] Plate 2 is a generalized geologic map of the basin and its borders. Most of the major oil fields of the basin lie along two northwestward-trending lines of anticlines—the Coyote Hills uplift and the Newport–Inglewood uplift. The largest fields are Santa Fe Springs and Long Beach, which together have produced about 1,000,000,000 barrels of oil since they were discovered in 1921. Other fields are located on anticlines in the basin and on anticlines and faulted monoclines along the northern border of the basin. The principal oil-bearing strata are in the lower Pliocene Repetto formation, in which the fossils described in this report were found. In some fields productive zones are found also in the overlying Pico formation and in the underlying Miocene.[7]

The Los Angeles Basin has a general basinlike structure, except at the seaward margins. At many places, however, the structure of the border of the basin is modified by faults and folds. In part of the city of Los Angeles the structure is relatively simple, and Pliocene strata dip toward the basin. Also in the Repetto Hills, in part of the Puente Hills, and in the Palos Verdes Hills Pliocene and Pleistocene formations dip basinward.

REPETTO FORMATION OF LOS ANGELES BASIN

GENERAL FEATURES

The Pliocene of the Los Angeles Basin and bordering hills was assigned long ago to the Fernando formation, a name introduced by Eldridge and Arnold.[8] Kew[9] raised Fernando to group rank to include the newly defined Pico formation and Hershey's Saugus formation, the type regions of both being in the Santa Clara Valley, in the Ventura Basin. (For location of Ventura Basin see pl. 1.) After the Pico formation was defined the Pliocene of the Los Angeles Basin and its borders was assigned to the Pico. When the succession of foraminiferal zones in the Pliocene subsurface section of the basin was worked out, it was evident to micropaleontologists that two well-marked major faunal divisions are represented, which were designated by some geologists lower Pico and upper Pico. After the outcrop sections were sampled and studied it was found that the lower faunal division may not be represented in the type region of the Pico on the south side of the Santa Clara Valley or, if represented, has a different facies. The lower division in the Los Angeles Basin accordingly was designated lower Pliocene and the upper division Pico. Finally a committee of the Pacific section of the Society of Economic Paleontologists and Mineralogists in 1930 proposed to use the new name "Repetto formation" for the lower division in the Los Angeles Basin and Pico formation for the upper division. The Repetto formation was first defined in print in 1932.[10] Some field geologists object to this classifica-

[3] Gutenberg, B., and Buwalda, J. P., Seismic reflection profile across Los Angeles Basin [abstract]: Geol. Soc. America Proc., 1935, pp. 327-328, 1936.

[4] See Woodring, W. P., Bramlette, M. N., and Kleinpell, R. M., Miocene stratigraphy and paleontology of Palos Verdes Hills, California: Am. Assoc. Petroleum Geologists Bull., vol. 20, pp. 133, 140, 142, fig. 3, 1936.

[5] Reed, R. D., and Hollister, J. S., Structural evolution of southern California: Am. Assoc. Petroleum Geologists Bull., vol. 20, pp. 1678-1679, 1936.

[6] Hoots, H. W., General geology of the Los Angeles Basin: 16th Internat. Geol. Cong. Guidebook 15, pp. 23-26, pl. 6, figs. 1-2, 1932. Eckis, Rollin, South Coastal Plain investigations; Geology and ground-water storage capacity of valley fill: California Div. Water Resources Bull. 45, pp. 23-76, pls. A-D, 1934. Hoots, H. W., and Herold, S. C., Natural-gas resources of California: Geology of natural gas, pp. 172-220, figs. 19-36, Tulsa, 1935. Reed, R. D., and Hollister, J. S., op. cit., pp. 1658-1681, figs. 42-48, pl. 9, 1936.

[7] See Hoots, H. W., Oil development in the Los Angeles Basin: 16th Internat. Geol. Cong. Guidebook 15, table opp. p. 26, 1932.

[8] Eldridge, G. H., and Arnold, Ralph, The Santa Clara Valley, Puente Hills, and Los Angeles oil districts: U. S. Geol. Survey Bull. 309, p. 22, 1907.

[9] Kew, W. S. W., Geology and oil resources of a part of Los Angeles and Ventura Counties, Calif.: U. S. Geol. Survey Bull. 753, pp. 69-70, 1924.

[10] Reed, R. D., Section from the Repetto Hills to the Long Beach oil field: 16th Internat. Geol. Cong. Guidebook 15, p. 31, footnote, 1932.

tion and nomenclature. They claim that the two formations are similar in field characters and that they are differentiated principally by their foraminiferal faunas. Such geologists continue to use lower Fernando and upper Fernando, or similar terms, for the two divisions. Inasmuch as faunal divisions do not constitute a satisfactory basis for subdividing into formations an essentially uniform lithologic sequence, this objection deserves consideration. Pending a consideration of this matter, the term "Repetto formation" is here used, as it has the advantage of essentially unequivocal significance to geologists and paleontologists familiar with this region.

If the upper faunal division is to have a formation name, it is doubtful whether the name "Pico formation" is an appropriate one. The usage of this name implies correlation with the type region of the Pico in the eastern part of the Ventura Basin. The implied correlation rests on faunal grounds. When the name "Repetto formation" was proposed it was recognized that the type region of the Pico formation may include deposits of Repetto age represented by a different facies. The implied correlation between the Los Angeles and Ventura Basins may rest on a correlation of faunal facies and not on a correlation of chronologic successions of faunas.

OUTCROP LOCALITIES

Repetto Hills.—The type region of the Repetto formation is in the basinward-dipping monocline in the Repetto Hills on the north side of the basin described by Driver, Holman, and Ferrando,[12] Reed,[13] and Edwards.[14] Here the formation consists of 2,000 to 2,500 feet of buff siltstone. All except the lowest few hundred feet of the formation is exposed almost continuously in street cuts along the west side of the valley followed by Atlantic Boulevard (through the "o" of "Repetto" in "Repetto Hills" of pl. 2). The Repetto rests conformably on diatomaceous shale referred to the Miocene Puente formation (Modelo formation of some geologists and Monterey formation of others). The top of the Repetto is drawn "at the top of three beds of coarse feldspathic sandstone ranging in thickness from a few inches to several feet." [15] Overlying the thin beds of sandstone at the top of the formation is siltstone carrying, according to Reed, a mixture of Repetto and Pico Foraminifera (the transition zone of micropaleontologists), above which is the siltstone assigned to the Pico formation. Mollusks collected from beds assigned to the transition zone in this section are considered under the heading "Age relations of larger fossils."

[12] Driver, H. L., Holman, W. H., and Ferrando, A., Foraminiferal section in Repetto Hills (unpublished report presented before Pacific section of Society of Economic Paleontologists and Mineralogists, 1928).

[13] Reed, R. D., op. cit., pp. 31-33; Geology of California, pp. 239-240, Tulsa, 1933.

[14] Edwards, E. C., Pliocene conglomerates of Los Angeles Basin and their paleogeographic significance: Am. Assoc. Petroleum Geologists Bull., vol. 18, pp. 795-796, 1934.

[15] Reed, R. D., op. cit., p. 31, footnote, 1932.

Puente Hills.—The Pliocene of the Puente Hills, east of the Repetto Hills, embraces thick units of conglomerate and sandstone as well as siltstone.[16] According to Edwards, the pebbles in the conglomerates were derived from the Perris Plateau, which now stands at a relatively low altitude northeast of the Puente Hills, beyond the eastern limit of the area shown on plate 2. Foraminifera of Repetto and Pico age have been found in the Pliocene of the Puente Hills,[17] but there is no published record of a subdivision of the Pliocene section. According to recent investigations, the lower part of the 5,000-foot section assigned by English to the Fernando group is of Miocene age.[18] Mollusks from the Pliocene of this region are mentioned under the heading "Age relations of larger fossils."

San Joaquin Hills.—Lower Pliocene and upper Pliocene siltstone and sand at the west end of the San Joaquin Hills, which lie along the southeastern border of the basin, were mentioned by Edwards.[19] According to a communication from Kew, Holman has found larger fossils in the lower Pliocene of this region. Strata apparently assignable to the upper Pliocene contain an *Acila*, probably the same as one in the subsurface Repetto (*Acila semirostrata*).

Palos Verdes Hills.—The only Pliocene formation recognized in the Palos Verdes Hills (or San Pedro Hills), on the south border of the basin, consists of gray to buff siltstone containing Repetto Foraminifera.[20] The best exposures are in a syncline on the sea cliff at Malaga Cove, at the northwest end of the hills. (The syncline is shown on pl. 2, but the scale of the map is too small for an adequate representation of the geology.) At this locality a thickness of 85 feet of siltstone is well exposed, and an estimated additional thickness of about 65 feet is concealed by slump at the top of the cliff. The siltstone of the Repetto formation at Malaga Cove lies conformably on the Malaga mudstone member of the Monterey shale (Puente shale of some geologists and Modelo shale of others), which is considered of upper Miocene age.[21] At most accessible places on the cliff the contact between the two units appears to be gradational through a thickness of a few inches. About halfway up the cliff on the south limb of the syncline a lens of sand 1 foot thick lies between the brown radio-

[16] English, W. A., Geology and oil resources of the Puente Hills, southern California: U. S. Geol. Survey Bull. 768, pp. 39-44, 1926. Edwards, E. C., op. cit., pp. 800-803.

[17] Stewart, R. E., and Stewart, K. C., "Lower Pliocene" in eastern end of Puente Hills, San Bernardino County, Calif.: Am. Assoc. Petroleum Geologists Bull., vol. 14, pp. 1445-1450, 1 fig., 1930. Edwards, E. C., op. cit., p. 802.

[18] Krueger, M. L., The Sycamore Canyon formation [abstract]: Am. Assoc. Petroleum Geologists Bull., vol. 20, p. 1520, 1936.

[19] Edwards, E. C., op. cit., pp. 803-804.

[20] Reed, R. D., A siliceous shale formation from southern California: Jour. Geology, vol. 36, pp. 342-361, 4 figs., 1928. (The "foraminiferal rock" described on pp. 353-357 represents the Repetto formation. The "nonforaminiferal siliceous shale" is now assigned to the Valmonte diatomite member and the Malaga mudstone member of the Monterey shale, both considered of upper Miocene age.) Woodring, W. P., San Pedro Hills: 16th Internat. Geol. Cong. Guidebook 15, pp. 38, 40, fig. 6, 1932. Edwards, E. C., op. cit., p. 804.

[21] Woodring, W. P., Bramlette, M. N., and Kleinpell, R. M., op. cit., pp. 146-148.

larian mudstone of the Malaga and the gray glauconitic foraminiferal siltstone of the Repetto. The Repetto is unconformably overlain by sand assigned to the Palos Verdes sand, of late Pleistocene age. Elsewhere in the Palos Verdes Hills lower Pleistocene strata unconformably overlie the Repetto. The Repetto at Malaga Cove contains two thin beds of fine-grained vitric volcanic ash, which has been examined by M. N. Bramlette. Isolated small pebbles of schist and black basaltic rock are found in a few places. A caudal vertebra of a whale, identified by Dr. Remington Kellogg, of the United States National Museum, was collected by H. W. Hoots about 10 feet above the base of the formation. A few specimens of *Lima hamlini*, the most abundant and widespread of the larger fossils in the Repetto of the basin, have been found in a thin zone 5 to 10 feet below the lower bed of volcanic ash on the north limb of the syncline.

Other outcrops of buff siltstone of the Repetto formation have been recognized at the head of the fourth ravine west of Walteria, where fragmentary remains of *Lima hamlini* were found, at Lomita Quarry, and in an area straddling Western Avenue. These localities are near the north edge of the Palos Verdes Hills and, with the exception of the small area in the ravine near Walteria, are shown on a recently issued generalized geologic map.[22] Farther east the Repetto is overlapped by lower Pleistocene strata that rest unconformably on different parts of the Miocene.

Santa Monica Mountains.—Potrero Canyon (the second canyon northwest of Santa Monica shown on pl. 2) is the only locality along the foot of the Santa Monica Mountains where strata of Repetto age have been found. At this locality an isolated section of Pliocene deposits is revealed under the cover of the Santa Monica Plain.[23] As described by Hoots, this Pliocene section consists of about 1,000 feet of mountainward-dipping clay shale and sandy clay shale, faulted against Miocene shale at several places. Angular fragments of limestone in the Pliocene sediments apparently were derived from the underlying Miocene. A foraminiferal fauna of Repetto age characterizes the lower part of the section, and one of Pico age the upper part. Larger fossils were found in the Pico formation,[24] and, according to a communication from Kew, Holman has recognized fragmentary remains of *Lima hamlini* and *Fusitriton* in the Repetto formation.

Los Angeles.—Exposures of the Repetto formation are accessible in street cuts in Los Angeles close to the north edge of the Los Angeles Plain. The Pliocene section in this region, which has a thickness of 900 to 1,275 feet according to a communication from Kew, has been described by Holman, Ferrando, and Driver,[25] Soper and Grant, [26] and Edwards.[27] Siltstone carrying Repetto Foraminifera rests conformably on Miocene diatomaceous shale, as in the Repetto Hills. According to a communication from Kew, the thickness of the Repetto ranges from 600 to 975 feet, and the thickest sections are found in the eastern part of the area. Thin beds of conglomerate, described by Edwards, are found at a horizon about 500 feet above the base of the formation. They consist predominantly of limestone pebbles, chips, and slabs, which are thought by Edwards to have been derived from the Miocene nearby. Soper and Grant divided this Pliocene section into three parts. Their structure section shows an unconformity between their lower Pliocene and middle Pliocene and a disconformity between their middle Pliocene and upper Pliocene.

The collection of fossils made by Hamlin when the Third Street tunnel was excavated in Los Angeles is the largest one studied in the preparation of the present report. These fossils, which were assigned to the upper Pliocene by Gale [28] and to the middle Pliocene by Grant,[29] are considered further under the next heading. Other collections of Repetto fossils have recently been made in Los Angeles by W. H. Holman, of the Standard Oil Co. of California. Larger fossils from a horizon in the Pico formation near the top of the exposed section have been listed and discussed by Moody [30] and Grant.[31]

SUBSURFACE SECTION

The Repetto of the subsurface section in the Los Angeles Basin has been briefly described in recent accounts by Hoots [32] and by Hoots and Herold.[33] Data on the character and thickness of the formation are presented in reports on Los Angeles Basin oil fields issued in the "Summary of operations, California oil fields, California Division of Oil and Gas", and in the "Bulletin of the American Association of Petroleum Geologists", particularly in reports issued since 1930. At Santa Fe Springs,[34] for example, the Repetto, has a thickness of about 4,000 feet and consists of alternating

[22] Woodring, W. P., Bramlette, M. N., and Kleinpell, R. M., op. cit., fig. 1.

[23] Hoots, H. W., Geology of the eastern part of the Santa Monica Mountains, Los Angeles County, Calif.: U. S. Geol. Survey Prof. Paper 165, pp. 115–119, 1931. In addition to the geologic map (pl. 16), see pl. 27.

[24] Woodring, W. P., in Hoots, H. W., idem, p. 116.

[25] Holman, H. W., Ferrando, A., and Driver, H. L., Pliocene of a part of the city of Los Angeles (unpublished report presented before Pacific section of Society of Economic Paleontologists and Mineralogists, 1931).

[26] Soper, E. K., and Grant, U. S., Geology and paleontology of a portion of Los Angeles, Calif.: Geol. Soc. America Bull., vol. 43, pp. 1041–1068, 7 figs., 1932 [1933].

[27] Edwards, E. C., op. cit., pp. 796–797.

[28] Gale, H. R., in Grant, U. S., IV, and Gale, H. R., Catalogue of the marine Pliocene and Pleistocene Mollusca of California: San Diego Soc. Nat. History Mem., vol. 1, p. 40, 1931.

[29] Grant, U. S., in Soper, E. K., and Grant, U. S., op. cit., pp. 1056–1058.

[30] Moody, C. L., Fauna of the Fernando of Los Angeles: California Univ., Dept. Geology, Bull., vol. 10, pp. 39–62, pls. 1–2, 1916.

[31] Grant, U. S., in Soper, E.K., and Grant, U. S., op. cit., pp. 1059–1064.

[32] Hoots, H. W., Oil development in the Los Angeles Basin: 16th Internat. Geol. Cong. Guidebook 15, pp. 26–30, pls. 6–8, 1932.

[33] Hoots, H. W., and Herold, S. C., Natural-gas resources of California: Geology of natural gas, pp. 172–220, figs. 19–36, Tulsa, 1935.

[34] Trask, P. D., Results of the American Petroleum Institute research project on environment of source sediments: Am. Petroleum Inst. Proc., vol. 14, sec. 4, Production Bull. 211, p. 24, figs. 6, 7, 1933.

units of sand, sandy shale, and clay shale, ranging in thickness from a fraction of an inch to 100 feet. Similar alternating units are found in other fields. Sand is apparently more abundant on at least some of the anticlines than in the intervening synclines,[35] suggesting that the anticlines were growing ridges on the floor of the Repetto sea. In several fields the underlying Miocene has been penetrated. Micropaleontologists recognize a transition zone between the Repetto and the Miocene. The contact between the Pliocene and Miocene in the basin appears to be gradational.

A wealth of data on the subsurface Repetto has been accumulated by the geologic staffs of many oil companies—data on the character, thickness, and fluid content of the sediments and on the composition and stratigraphic relations of the many foraminiferal zones and subzones that are recognized and have stood the test of exacting oil-field correlations. As the immediate economic interest of these data diminishes it is hoped that they will be put on record, for they represent more detailed information than is available for any other area of comparable size in California.

LARGER FOSSILS FROM REPETTO FORMATION

OUTCROP LOCALITIES

Homer Hamlin was in Los Angeles when the Third Street tunnel was excavated and sent to the National Museum fossils collected during the excavation. The first lot of fossils, apparently consisting only of the specimens Dall described as *Lima hamlini*, was forwarded to Washington in 1900. Most of the material was collected in January 1901, and Hamlin used Geological Survey field labels that have a notebook citation. At the time when the tunnel was excavated Hamlin was an assistant city engineer. According to a written communication from Mrs. Carrie D. Hamlin, of Los Angeles, his geologic observations were made apart from his official duties. Mrs. Hamlin kindly forwarded a notebook containing many carefully recorded observations on the geology of the city, made during the period from April to August 1900. The Third Street tunnel is mentioned, but the notes on the fossil collections probably were made at a later date. Among Dall's papers is a letter from Hamlin to T. W. Stanton, dated January 24, 1901, transmitting the fossils, a geologic map, and a description of the geology of the city. This material is valuable, but it does not include a detailed description of the geology of the tunnel, and fossil localities in the tunnel are not recorded. Therefore, it is not known from what part of the tunnel the fossils were collected. According to the maps accompanying the reports of Holman, Ferrando, and Driver and of Soper and Grant, the Miocene-Pliocene contact is close to the intersection of Third and Figueroa Streets, two blocks northwest of the northwest portal of the tunnel, but at that locality the contact is concealed by alluvium. These maps also show that the upper part of the Repetto formation was penetrated in the tunnel. Most of the fossils in Hamlin's collections have a characteristic preservation and a matrix of gray foraminiferal siltstone. Samples of this matrix from specimens in the second lot of *Lima hamlini* were forwarded to Wissler and Driver, who report that they carry well-preserved Repetto Foraminifera. It is hoped that these micropaleontologists will put on record their appraisal of the age relations of these Foraminifera. Whatever the age relations are in terms of the foraminiferal zones in the basin, *Lima hamlini* from the tunnel is preserved in a matrix carrying characteristic Repetto Foraminifera, and it is assumed that other specimens with similar preservation and matrix were collected from the Repetto.

Hamlin's collections were used for the description of a number of new species. Several mollusks—*Lima hamlini*,[36] a supposed rudistid (*"Radiolites" hamlini*),[37] *Priene oregonensis* Redfield var. *angelensis*,[38] and *Nassa hamlini*[39]—were described by Dall, Stearns, and Arnold. A flightless auk, the first fossil bird to be described from California (*Mancalla californiensis*) was described by Lucas;[40] and a fiddler crab (*Uca hamlini*) by Rathbun.[41] Arnold published a list of the fossils in 1907,[42] and essentially the same list was issued in another report in the same year.[43]

Only the mollusks that have a matrix of gray foraminiferal siltstone are accepted as undoubtedly from the Repetto. The following species listed by Arnold, which lack this matrix and have a different preservation, are rejected:

Fossils in Third Street tunnel collection, identified by Arnold, rejected as doubtful Repetto fossils

Pecten latiauritus Conrad. (Incomplete left (?) valve showing some color markings. A little matrix remaining consists of silty sand.)

Pecten opuntia Dall. (Small fragment stained with ferruginous stain. A little matrix remaining is ferruginous.)

Pecten stearnsii Dall. (Small fragment stained with ferruginous stain. A little matrix remaining consists of ferruginous silty sand.)

Fissuridea murina Carpenter. (Figured by Arnold. Virtually complete specimen stained with ferruginous stain.)

[35] Trask, P. D., Proportion of organic matter converted into oil in Santa Fe Springs oil field, California: Am. Assoc. Petroleum Geologists Bull., vol. 20, pp. 249-250, 1936.

[36] Dall, W. H., A new species of *Lima*: Nautilus, vol. 14, pp. 15-16, 1900.

[37] Stearns, R. E. C., The fossil shells of the Los Angeles tunnel clays: Science, new ser., vol. 12, no. 247, pp. 247-250, 1900.

[38] Arnold, Ralph, New and characteristic species of fossil mollusks from the oil-bearing Tertiary formations of southern California: U. S. Nat. Mus. Proc., vol. 32, pp. 536-537, pl. 50, fig. 11, 1907.

[39] Idem, pp. 537-538, pl. 50, fig. 9.

[40] Lucas, F. A., A flightless auk, *Mancalla californiensis*, from the Miocene of California: U. S. Nat. Mus. Proc., vol. 24, pp. 133-134, 3 figs., 1901.

[41] Rathbun, M. J., The fossil stalk-eyed Crustacea of the Pacific slope of North America: U. S. Nat. Mus. Bull. 138, pp. 30-31, pl. 8, fig. 1, 1926.

[42] Arnold, Ralph, op. cit., p. 527. For an earlier list see Arnold, Ralph, Tertiary and Quaternary pectens of California: U. S. Geol. Survey Prof. Paper 47, pp. 91, 116, 1906.

[43] Arnold, Ralph, in Eldridge, G. H., and Arnold, Ralph, The Santa Clara Valley, Puente Hills, and Los Angeles oil districts, southern California: U. S. Geol. Survey Bull. 309, p. 152, 1907.

This may appear to be summary treatment, particularly as it disposes of the most troublesome species ("*Pecten*" *latiauritus*) so far as age assignment is concerned. There appears to be some doubt as to whether the imperfect valve is *latiauritus* in the restricted sense, as it has relatively strong grooves on the ribs near the ventral margin and strong riblets in the interspaces in the same area. Nevertheless, it apparently is a form of *latiauritus*, which is not recorded elsewhere in formations earlier than those assigned to the Pleistocene. These rejected specimens may have come from a layer or layers of different lithology within the Repetto, or from some other part of the section, or they may possibly have come from some other locality. These suppositions cannot now be tested, and so long as there is doubt about the specimens they are rejected. Their rejection has no bearing on the interpretation of the environment other than the exclusion of four additional species of shallow-water facies.

Dall made a shrewd estimate of the age of the fossiliferous beds as "probably Pliocene" when he described *Lima hamlini*. In the same year Stearns described a supposed rudistid from Hamlin's collection and claimed a Cretaceous age for these beds. Dall[44] quoted Vaughan's opinion to the effect that the specimen thought to be the upper valve of the supposed *Radiolites* is a solitary coral, probably *Stephanotrochus* [*Stephanocyathus*]. The supposed lower valve Dall considered problematic. The material representing the coral may be in the collection of fossil corals at the National Museum, but an attempt to find it at the present time is not practicable. Similar solitary corals are found in the subsurface Repetto. According to a letter from Hamlin to Dall, dated June 14, 1900, "*Radiolites*" was found in the Third Street tunnel near the top of the section and in the Broadway tunnel near the middle. (The strata in the Broadway tunnel are now assigned to the Miocene.) Moody[45] quoted Dall to the effect that the elongate part of the "*Radiolites*" is probably a barnacle—a statement of Dall's that I am unable to find.

It is not known whether the bird bone was associated with the Repetto mollusks. There is no matrix on the specimen, which was available through the kindness of Dr. C. W. Gilmore, of the United States National Museum. As the bird has no direct bearing on the mollusks, it is retained as a Repetto fossil. Remains referred to this auk have recently been found in the Pliocene San Diego formation at San Diego.[46] The coral and the fiddler crab also are retained as Repetto fossils.

Some old collections from Los Angeles, consisting principally of molds of paired shells doubtfully identified as *Phreagena lasia*, may represent the Repetto formation. One of these collections was made by Stearns in 1892 at Sixth and Lucas Streets, at an altitude of 370 feet. In addition to three doubtful molds of *Phreagena lasia*, this collection includes pieces of coarse-grained sandstone containing molds and impressions of *Calyptraea*, *Turritella?*, *Bittium?*, *Chione?*, and *Solen?*, fragments of *Ostrea*, and shark teeth. According to the maps cited, the lower part of the Repetto formation strikes through the intersection of these streets. These fossils represent a shallow-water facies. Three recent collections made by W. H. Holman in Los Angeles consist of *Lima hamlini*, *Fusitriton* aff. *F. oregonensis*, a cassidulid echinoid, and cone scales of a pine.

Other outcrop material considered in the systematic account embraces specimens of *Lima hamlini* from Malaga Cove, on the west coast of the Palos Verdes Hills, and specimens of "*Nassa*" *hamlini* and *Acila semirostrata* from the transition zone between the Repetto and Pico formations in the Repetto Hills.

SUBSURFACE LOCALITIES

Hertlein's record of *Pecten* (*Pseudamusium*) *vancouverensis fernandoensis* from a depth of 2,800 feet in a well in the Long Beach field[47] appears to be the only subsurface record of a Repetto larger fossil in the basin. The Standard and Union collections of core fossils represent 60 wells, most of which are in fields that produce oil from the Repetto.[48] Several wildcat wells also are represented in these collections. Wissler identified *Lima hamlini* and *Hyalopecten* aff. *H. randolphi tillamookensis* in material from 6 additional wells that was not forwarded to Washington, making a total of 66 wells, in 56 of which the fossils are determined at least generically. The location of the oil fields is shown on plates 2 and 4.

Wissler and Driver kindly verified the assignment of the fossils to the Repetto formation. Geologists and micropaleontologists who are familiar with the details of oil-field correlation in the basin have at their disposal data to determine the stratigraphic position of the species and to determine whether any zonal arrangement is apparent. Wissler submitted a chart showing the stratigraphic distribution of the larger fossils with reference to foraminiferal zones. These data are cited only in general terms. It is hoped that Wissler will eventually publish them. The records may be too scattered to work out any zonal arrangement. Molluscan zones in the Repetto are likely to be facies zones. Changes in facies, however, may have been controlled

[44] Dall, W. H., On the true nature of *Tamiosoma:* Science, new ser., vol. 15, no. 366, p. 7, 1902; The Miocene of Astoria and Coos Bay, Oregon: U. S. Geol. Survey Prof. Paper 59, p. 141, 1909.

[45] Moody, C. L., op. cit., p. 41. This statement is repeated by Soper and Grant (op. cit., p. 1043) without a citation.

[46] Miller, Loye, The Lucas auk of California: Condor, vol. 35, pp. 34–35, 1933.

[47] Hertlein, L. G., New species of marine fossil Mollusca from western North America: Southern California Acad. Sci. Bull., vol. 24, p. 43, pl. 4, fig. 6, 1925. I am indebted to S. G. Wissler for examining samples from wells in the area where this species was recorded. According to Wissler, the horizon is near the top of the Repetto formation.

[48] See Hoots, H. W., Oil development in the Los Angeles Basin: 16th Internat. Geol. Cong. Guidebook 15, table opp. p. 26, 1932.

by events that took place at about the same time over a considerable area in the basin, and any zone may therefore be of chronologic value.

Owing to the character of the material or to meager representation, many of the specimens in both outcrop and core collections are indefinitely identified. Some of the fossils, including all the material from a few wells, are listed as "undetermined." Much of this material is properly classifiable as undeterminable; some species could be provisionally determined if better specimens were available from other localities. For the most part the undetermined specimens are not considered in the descriptions of species.

The Standard collection includes material from 5 wells assigned by Driver and Wissler to the Miocene and material from 9 wells assigned to the Pico formation. This material is not included in the descriptions of species other than to furnish records of Miocene and Pico occurrences of Repetto species or of forms that are similar to Repetto species.

FOSSILS

The outcrop and core fossils are listed in the following lists. To facilitate ready comparison, the names used by Arnold for the Third Street tunnel fossils are cited opposite the names here used for the species from that locality.

Fossils from outcrop localities of Repetto formation on borders of Los Angeles Basin

Third Street tunnel, Los Angeles

[Homer Hamlin, collector, 1900, 1901. U. S. G. S. localities 3432 (1900) and 3426 (1901)]

Name used in this report	Name used by Arnold
Coral:	
Stephanocyathus? (presumably represented in type material of "Radiolites" hamlini Stearns).[1]	Coral.
Mollusks:	
(Rejected)	Fissuridea murina Carpenter (figured).
Astraea cf. A. gradata Grant and Gale (figured).	(Not considered.)
Undetermined naticid	Neverita recluziana Petit.
Fusitriton aff. F. oregonensis (Redfield) (figured).	Priene oregonensis Redfield var. angelensis Arnold (type locality).
"Nassa" hamlini Arnold	Nassa hamlini Arnold (type locality).
Plicifusus? sp. (figured)	Pleurotoma sp. undet.
Buccinum? sp. (figured)	Buccinum sp. undet.
Anadara camuloensis (Osmont) (figured).	Arca multicostata Sowerby.
(Rejected)	Pecten stearnsii Dall.
(Rejected)	Pecten opuntia Dall.
(Rejected)	Pecten latiaturitus Conrad.
Lyropecten cerrosensis (Gabb) (figured).	Pecten ashleyi Arnold.

Name used in this report	Name used by Arnold
Mollusks—Continued.	
Hyalopecten aff. H. randolphi (Dall).	Pecten pedroanus Trask (figured).
Ostrea vespertina Conrad (figured).	Ostrea veatchii Gabb.
Lima hamlini Dall (type locality; figured).	Lima hamlini Dall.
(Not recognized)	Astarte sp.
Phreagena lasia Woodring, n. gen., n. sp. (figured).	Carditoid.
Lucinoma aff. L. aequizonata (Stearns) (figured).	(Not considered).
Trachycardium cf. T. quadragenarium (Conrad) (figured).	(Not considered.)
Undetermined	Macoma sp. undet.
Decapod crustacean:	
Uca hamlini Rathbun (type locality).[1]	(Not mentioned. A crab claw is mentioned in U. S. Geol. Survey Prof. Paper 47, p. 91, 1906.)
Bird:	
Mancalla californiensis Lucas (type locality).[1]	Bird bones.

[1] Not known to have been associated with the Repetto mollusks.

Other outcrop localities

Fossil	Locality	Collector	U. S. G. S. locality
Fusitriton aff. F. oregonensis (Redfield). Pinus cf. P. muricata D. Don (cone scales).	100 feet northeast and 90 feet northwest from northeast corner Second and Hill Sts., Los Angeles; about 4 feet above level of Hill St.	W. H. Holman	13862.
Lima hamlini Dall	10 feet northwest from preceding locality	do	13862a.
Cassidulid echinoid	North side of Wilshire Blvd., 200 feet east from center line of Bixel St.	do	13923.
Lima hamlini Dall	Malaga Cove, west coast of Palos Verdes Hills, north limb of northern syncline near trough; 5 to 10 feet below lower bed of volcanic ash in Repetto formation.	W. P. Woodring	13838.
Lima hamlini Dall	Same locality, north limb of syncline just north of trough; not more than 10 feet below lower bed of volcanic ash.	S. G. Wissler	(Collection of Union Oil Co.)

Fossils from subsurface localities of Repetto formation in Los Angeles Basin

Fossil	Locality	Company	Lease	Well	Depth (feet)	U. S. G. S. locality
Hyalopecten aff. H. randolphi (Dall) (figured).	Montebello field	Standard	Baldwin	41	3, 600	13907.
Astacus? sp	do	do	do	72	1, 926	13863.
2 undetermined pelecypods, 1 of which evidently is a small mactrid.	do	do	do	72	3, 750	13863a.
Solemya aff. S. johnsoni Dall (figured). Phreagena lasia Woodring, n. gen., n. sp. (figured holotype).	do	do	do	73	3, 340–3, 358	13864.
Periploma cryphia stenopa Woodring?, n. var.	do	do	do	73	4, 745	13864a.
Fusitriton aff. F. oregonensis (Redfield).	do	do	do	74	1, 955–1, 975	13865.
Undetermined pelecypod, possibly a small lucinid.	do	do	do	75	1, 740–1, 750	13866.
Undetermined pelecypod, possibly a small oyster.	do	do	do	75	6, 015	13866a.
Phreagena lasia Woodring, n. gen., n. sp.	do	do	do	77	4, 500	13867.
Phreagena lasia Woodring, n. gen., n. sp.	do	do	Temple	18	3, 044	13868.
Fusitriton aff. F. oregonensis (Redfield).	do	do	do	19	1, 265	13869.
Phreagena lasia Woodring?, n. gen., n. sp. Calyptogena n. sp?	do	do	do	19	4, 811–4, 825	13869a.
Undetermined pelecypod	do	do	do	19	4, 966–4, 986	13869b.
Limatula aff. L. "subauriculata (Montagu)" (figured).	do	Universal Consolidated.	Nutt	2	3, 627–3, 655	13871.
Fusitriton aff. F. oregonensis (Redfield).	Puente Hills, sec. 30, T. 2 S., R. 10 W.	Union	Sansinena	11	818	(Collection of Union Oil Co.)
Macrocallista sp. Corbula gibbiformis Grant and Gale (figured).	East Coyote field.	Great American	Tuffree	2	3, 351–3, 356	13873.
Several undetermined genera of small gastropods and pelecypods.	West Coyote field.	Standard	Murphy Coyote	113	4, 450	13874.
Araeosoma sp. (figured)	do	do	do	117	4, 400	13875.
Lima hamlini Dall (figured)	do	do	do	117	5, 910	13875a.
Callianassa sp	do	do	do	123	4, 255–4, 273	13876.
Undeterminable leaf	do	do	Emery	50	5, 105	13877.
Fusitriton aff. F. oregonensis (Redfield).	do	do	do	52	3, 625–3, 626	13878.
Undetermined pelecypod, possibly Thracia.	do	do	do	52	3, 640	13878a.
Fusitriton aff. F. oregonensis (Redfield).	do	do	do	52	3, 653	13878b.
Fusitriton aff. F. oregonensis (Redfield).	do	do	do	52	3, 663	13878c.
"Nassa" hamlini Arnold (figured)	do	do	do	52	3, 695	13878d.
Lima hamlini Dall	do	do	do	53	4, 273	13879.
Lima hamlini Dall	do	do	do	53	6, 194	13879a.
Calyptogena n. sp. (figured)	do	do	do	54	4, 230	13880.
Phreagena lasia Woodring?, n. gen., n. sp.	do	do	do	54	5, 900	13880a.
Undetermined small pelecypod	do	do	do	56	4, 341–4, 347	13881.
Limopsis phrear Woodring, n. sp	do	do	do	57	5, 265	13882.
Undetermined pelecypod, possibly a small Limopsis.	do	do	do	59	4, 270	13883.
Lima hamlini Dall	do	do	do	59	4, 304	13883a.
Undetermined echinoid spines. Undeterminable leaf	do	do	Bastanchury ranch.	1	6, 414	13884.
Hyalopecten aff. H. randolphi (Dall).	Santa Fe Springs field.	Union	Bell	43	5, 518	14012.
Lima hamlini Dall	do	do	do	45	5, 564	(Collection of Union Oil Co.)
Lima hamlini Dall	do	do	do	53	6, 237	Do.
"Nassa" hamlini Arnold	do	do	do	69	3, 642	Do.
Acila? cf. A. castrensis (Hinds) (figured).	do	do	Farwell	17	5, 631	13885.
Limopsis phrear Woodring, n. sp	Culver City	Taylor	Uharriet	1	3, 221	13887.
Lunatia cf. L. caurina (Gould) (figured).	Inglewood field	Standard	Baldwin-Cienega	105	2, 221	13890.

Fossils from subsurface localities of Repetto formation in Los Angeles Basin—Continued

Fossil	Locality	Company	Lease	Well	Depth (feet)	U. S. G. S. locality
Lima hamlini Dall	Inglewood field	Standard	Baldwin-Cienga	105	5, 713	13890a.
Limopsis phrear Woodring, n. sp. (figured).	do	Pacific Western	Cone	16	2, 926–2, 945	13892.
Limopsis phrear Woodring, n. sp	do	Western Consolidated.	Smith	1	3, 941	13924.
Lima hamlini Dall	Rosecrans field	Barnsdall	Trust	1	5, 760	(Collection of Union Oil Co.)
Lima hamlini Dall	do	Union	Rosecrans	15	5, 686	14013.
Undetermined gastropod, apparently a neptuneid.	Dominguez field	do	Callender	17	5, 463	(Collection of Union Oil Co.)
Fusitriton aff. F. oregonensis (Redfield) (figured).	do	do	do	22	4, 146	13895.
Limopsis phrear Woodring, n. sp. (figured paratype).	do	do	do	27	4, 998	13896.
Undetermined naticid, possibly Lunatia.	do	do	Hellman	10	4, 193	(Collection of Union Oil Co.)
Undetermined pelecypod, possibly Malletia.	do	do	do	14	4, 505	Do.
Periploma cryphia Woodring, n. sp. (figured).	do	do	do	14	5, 102	13897.
Periploma cryphia Woodring, n. sp. (figured holotype).	do	do	do	17	3, 939	13898.
Lima hamlini Dall	do	do	do	17	4, 216	(Collection of Union Oil Co.)
Periploma cryphia stenopa Woodring, n. var. (figured holotype).	do	do	do	18	4, 076	13899.
Undetermined gastropod, possibly "Nassa."	do	do	do	19	3, 940	(Collection of Union Oil Co.)
Limopsis phrear Woodring, n. sp	do	do	do	19	4, 292	Do.
Lima hamlini Dall	do	Shell	Reyes	43	4, 135	14014.
Lima hamlini Dall	do	do	do	43	4, 841	(Collection of Union Oil Co.)
Limopsis phrear Woodring, n. sp	do	do	do	43	5, 128	Do.
Limopsis phrear Woodring, n. sp. (figured holotype).	do	do	do	101	5, 245	13900.
Lima hamlini Dall	Seal Beach field	Standard	San Gabriel	25	4, 929	13901.
Lima hamlini Dall	Huntington Beach field.	do	Bolsa	7	3, 720	13904.
Stephanocyathus? sp	do	do	do	32	3, 466	13906.
Limopsis phrear Woodring, n. sp	do	do	do	38	3, 874–3, 894	13974.
Hyalopecten aff. H. randolphi tillamookensis (Arnold) (figured).	do	Julian	Farnsworth	2	2, 081	13908.
Sponge of family Farreidae, probably Farrea. Hyalopecten aff. H. randolphi tillamookensis (Arnold).	do	do	do	2	2, 135	13908a.
Hyalopecten aff. H. randolphi tillamookensis (Arnold).	do	Huntington Signal.	Hand	2	3, 454	13909.
Undetermined small pelecypod, possibly a lucinid.	East of Santa Monica, sec. 9, T. 2 S., R. 15 W.	Hines	Happy Days	1	6, 517	(Collection of Union Oil Co.)
"Nassa" hamlini Arnold	Playa del Rey field.	Ohio	Recreation	1	3, 821	Do.
Lima hamlini Dall	do	do	Del Rey	2	4, 001	14015.
Anadara camuloensis (Osmont) (figured).	do	A. T. Jergins Trust.	Robertson	1	3, 830	13911.
Undetermined pelecypod, possibly Malletia.	do	Mohawk	J	1	3, 848	(Collection of Union Oil Co.)
Stephanocyathus? sp	El Segundo field	Republic	El Segundo	1	4, 421	13914.
Limopsis phrear Woodring, n. sp	Northeast of Lawndale field, sec. 10, T. 3 S., R. 14 W.	Signal Finance	Woods	1	5, 100	(Collection of Union Oil Co.)
Lima hamlini Dall	Lawndale field	Shell	Barkdall	1	5, 346	Do.
Lima hamlini Dall	Southeast of Lawndale field, sec. 22, T. 3 S., R. 14 W.	Standard	Bodger	1	5, 398	14002.
Katherinella aff. K. subdiaphana (Carpenter) (figured).	Torrance field	Chanslor-Canfield Midway.	Torrance	71	3, 245	13915.
Acila semirostrata (Grant and Gale) (figured).	Wilmington field	Wilmington Terminal.	Banning	1	3, 265	13916.

The following table, in which the undetermined mollusks are omitted, summarizes the occurrence of the fossils and the occurrence of single-valve and paired specimens of pelecypods:

Larger fossils from Repetto formation of Los Angeles Basin

[S, Single-valve pelecypods; P, paired (double-valve) pelecypods; ×, occurrence of fossils other than pelecypods]

Species	Outcrop		Subsurface																	
	Los Angeles	Palos Verdes Hills	Montebello field	Puente Hills	East Coyote field	West Coyote field	Santa Fe Springs field	Near Culver City	Inglewood field	Rosecrans field	Dominguez field	Seal Beach field	Huntington Beach field	Playa del Rey field	El Segundo field	Northeast of Lawndale field	Lawndale field	Southeast of Lawndale field	Torrance field	Wilmington field
Sponge (identification by M. W. de Laubenfels):																				
Sponge of family Farreidae, probably Farrea	---	---	---	---	---	---	---	---	---	---	---	---	×	---	---	---	---	---	---	---
Coral (identification by J. E. Hoffmeister):																				
Stephanocyathus? sp	---	---	---	---	---	---	---	---	---	---	---	---	×	---	×	---	---	---	---	---
Gastropods:																				
Astrea cf. A. gradata Grant and Gale (pl. 5, fig. 17)	×	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Lunatia cf. L. caurina (Gould) (pl. 5, fig. 19)	---	---	---	---	---	---	---	---	×	---	---	---	---	---	---	---	---	---	---	---
Fusitriton aff. F. oregonensis (Redfield) (pl. 5, figs. 21–23)	×	---	×	×	---	×	---	---	---	---	×	---	---	---	---	---	---	---	---	---
"Nassa" hamlini Arnold (pl. 5, fig. 16)	×	---	---	---	---	×	×	---	---	---	---	---	---	×	---	---	---	---	---	---
Plicifusus? sp. (pl. 5, fig. 18)	×	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Buccinum? sp. (pl. 5, fig. 15)	×	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Pelecypods:																				
Solemya aff. S. johnsoni Dall (pl. 5, fig. 14)	---	---	P	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Acila semirostrata (Grant and Gale) (pl. 5, figs. 10, 11)	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	S
Acila? cf. A. castrensis (Hinds) (pl. 5, fig. 20)	---	---	---	---	---	---	S	---	---	---	---	---	---	---	---	---	---	---	---	---
Anadara camuloensis (Osmont) (pl. 6, figs. 10, 13–16)	S	---	---	---	---	---	---	---	---	---	---	---	---	S	---	---	---	---	---	---
Limopsis phrear Woodring, n. sp. (pl. 5, figs. 7–9, 12, 13)	---	---	---	---	---	S	---	S	S	---	P	---	S	---	---	S	---	---	---	---
Lyropecten cerrosensis (Gabb) (pl. 7)	S	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Hyalopecten aff. H. randolphi (Dall) (pl. 6, fig. 7)	S	---	S	---	---	---	S	---	---	---	---	---	---	---	---	---	---	---	---	---
Hyalopecten aff. H. randolphi tillamookensis (Arnold) (pl. 6, fig. 3)	---	---	---	---	---	---	---	---	---	---	---	---	S	---	---	---	---	---	---	---
Ostrea vespertina Conrad (pl. 9, fig. 5)	S	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Lima hamlini Dall (pl. 8, figs. 5, 7, 10, 11)	P	S	---	---	---	S	S	---	S	P	S	S	S	S	---	---	S	P	---	---
Limatula aff. L. "subauriculata (Montagu)" (pl. 8, fig. 6)	---	---	S	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Phreagena lasia Woodring, n. gen., n. sp. (pl. 5, figs. 3, 4)	P	---	P	---	---	?S	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Calyptogena n. sp. (pl. 5, figs. 5, 6)	---	---	?S	---	---	S	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Lucinoma aff. L. aequizonata (Stearns) (pl. 5, fig. 1)	S	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Trachycardium cf. T. quadragenarium (Conrad) (pl. 9, fig. 1)	S	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Katherinella aff. K. subdiaphana (Carpenter) (pl. 6, fig. 12)	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	S	---
Macrocallista sp	---	---	---	---	S	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Corbula gibbiformis Grant and Gale (pl. 6, figs. 8, 9)	---	---	---	---	S	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Periploma cryphia Woodring, n. sp. (pl. 9, figs. 4, 6)	---	---	---	---	---	---	---	---	---	---	S	---	---	---	---	---	---	---	---	---
Periploma cryphia stenopa Woodring, n. var. (pl. 9, fig. 7)	---	---	?S	---	---	---	---	---	---	---	S	---	---	---	---	---	---	---	---	---
Echinoids (identifications by Th. Mortensen and A. H. Clark):																				
Araeosoma sp. (pl. 9, figs. 2, 3)	---	---	---	---	---	×	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Cassidulid	×	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Decapod crustaceans (identifications by M. J. Rathbun):																				
Uca hamlini Rathbun	×	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Callianassa sp	---	---	---	---	---	×	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Astacus? sp	---	---	×	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Plants (identifications by R. W. Brown):																				
Pinus cf. P. muricata D. Don (cone scales)	×	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Undeterminable leaves	---	---	---	---	---	×	---	---	---	---	---	---	---	---	---	---	---	---	---	---
Bird:																				
Mancalla californiensis Lucas	×	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

INFERRED ENVIRONMENT OF LARGER FOSSILS

This discussion of the environment and paleogeographic implications of the larger fossils of the Repetto formation rests on the basic assumption that the Repetto animals represent essentially the same environment as modern animals to which the fossils are closely allied by the similarity of the parts preserved as fossils. This assumption, which is habitually made by paleontologists, has been casually noticed,[49] but no analysis of it has come to my attention, and it may not be worth an elaborate analysis. The principle that stability in physiologic (biochemical and biophysical) characters is correlated with stability in morphologic characters and that evolution in the two sets of characters keeps close pace is implied in the assumption. The physiologic characters of many marine animals are still unknown, except so far as they are reflected in their distribution and habits. Inasmuch as there is a general but not invariable correlation between affinity determined by selected morphologic characters—the criterion most frequently used by zoologists and the one perforce used by paleontologists—and affinity determined by physiologic characters in the forms that have been considered,[50] the assumption may not be justified. Other things being equal, the validity of the assumption probably varies inversely with the duration of time involved—that is, in general terms it is more probable that the assumption is justified in dealing with Pleistocene animals that are indistinguishable from modern ones on the basis of selected morphologic characters, or are closely allied to them on this basis, than in dealing with Pliocene or earlier fossils. The probable validity of the assumption for the Repetto fossils is considered from another point of view in the discussion of the number of Repetto fossils that indicate a particular environment and their distribution at other localities in California where marine Pliocene formations are found. (See p. 15.)

DEPTH RANGE OF ALLIED MODERN SPECIES

The depth range of modern Pacific coast mollusks and echinoids that are considered closely allied to Repetto fossils is graphically shown on plate 3. In the preparation of the graphs only the species whose affinity is regarded as reasonably close or those representing genera the modern species of which have an invariable shallow-water (*Ostrea*, *Trachycardium*, *Macrocallista*) or deep-water (*Araeosoma*) habitat, were used. The data are drawn from the collections of the United States National Museum, which include the dredgings of the United States Fish Commission steamer *Albatross*. The dredgings of the *Albatross* are the only ones now available from deep water in the eastern Pacific. The depth divisions on plate 3 are units of 100 fathoms. The width of a graph at the midpoint between depth division lines represents the percentage of dredging records for that species within the depth unit. The figures in the vertical columns represent the total number of hauls, and the number of additional lots that have no depth data are added in parentheses. These lots without depth data probably represent material from shallow water. As the graphs are not weighted for the number of hauls, the figures should be kept in mind in comparing the graphs. Many of these modern mollusks have not yet been adequately studied, and some of them may represent a group of closely allied forms rather than one form. This distinction should have no essential effect on the interpretation of the Repetto fossils under the assumption specified. For the purpose of this discussion shallow-water species are defined as those ranging from the intertidal zone to 100 fathoms; deep-water species as those ranging from 100 to 2,000 fathoms; and abyssal species as those below 2,000 fathoms. The faunal regions are those recognized by Bartsch,[51] most of whose names are altered so as to have terminations that seem to be more euphonious. The regions and their limits are as follows:

Faunal regions on Pacific coast of North America and Central America

[After Bartsch]

Arctic. From summer limit of pack ice southward to winter limit—that is, from Sea-Horse Islands south to Hagemeister Island. (Not represented.)

Aleutian. Aleutian Islands and southeast to Sitka.

Oregonian. Sitka, Alaska, south to Point Conception, California.

Californian. Point Conception, California, to Cape St. Lucas, Lower California.

Mazatlanian. Gulf of California south to Acajutla, Guatemala.

Panamanian. Acajutla, Guatemala, south probably to Aguja Point, Peru.

This arrangement has recently been criticized [52] and doubtless can be improved, but it is sufficient for this discussion, as it has no essential bearing on the interpretation.

On the basis of depth range these modern species fall into three groups, arranged from left to right in the graphs—(1) shallow-water species; (2) species ranging from shallow water into deep water; (3) deep-water species. Increase in depth with decrease in latitude is shown in the graphs of species, or groups of forms, that range through more than one faunal region, particularly in the graphs of *Hyalopecten randolphi tillamookensis*, *H. randolphi*, and *Solemya*.

[49] Robson, G. C., The species problem, pp. 103–104, London, 1928. Woodring, W. P., Fossils from the marine Pleistocene terraces of the San Pedro Hills, California: Am. Jour. Sci., 5th ser., vol. 29, no. 171, p. 300, 1935. Broch, Hjalmar, Some zoogeographical problems of the northern Pacific: Science, new ser., vol. 83, no. 2144, p. 102, 1936. Doubtless other workers have considered this assumption, but I have not attempted to pursue the matter.

[50] Robson, G. C., op. cit., pp. 53–88.

[51] Bartsch, Paul, Ocean currents, the prime factor in the distribution of the marine mollusks on the west coast of America: Bernice P. Bishop Mus. Special Pub. 7, p. 507, 1921.

[52] Schenck, H. G., and Keen, A. M., Marine molluscan provinces of western North America: Am. Philos. Soc. Proc., vol. 76, pp. 921–938, 6 figs., 1936.

Dredging records for many of the species are inadequate. The irregularity in the upper depth limit of *Solemya* is probably due to inadequate records in the Oregonian and Mazatlanian regions. Gaps in the graphs presumably would be filled by additional dredgings, unless the isolated graphs in each column represent different forms, which is improbable for most of the columns. It is doubtful, however, whether the range of the deep-water species will be moved upward into shallow water by additional records, for much more is known about the distribution in shallow water than in deep water. The single record of *Fusitriton oregonensis* in the Californian province at a depth of 1,081 to 1,100 fathoms surely is not an adequate representation of the depth distribution in this province, as is indicated by the steep depth gradient between the Oregonian and Californian provinces. It is improbable that *oregonensis* occurs in shallow water in the Californian province, but it may now live there at depths considerably less than 1,081 fathoms, and during Pliocene and Pleistocene time it may have lived in this region at depths of less than 100 fathoms. It is recorded from Pliocene deposits in the Eel River Basin, San Francisco Bay region, Santa Maria Basin, Ventura Basin, and Los Angeles Basin. Its associates afford grounds for doubting whether it represents depths greater than 100 fathoms at most of these localities. If it lived only at depths greater than 100 fathoms off the coast of California during Pleistocene time, my suggestion that its presence at one locality in the Palos Verdes sand of the Palos Verdes Hills is due to storm transportation from an offshore habitat [53] is erroneous. The Repetto representative of *oregonensis* is placed in the group of fossils of intermediate depth range inferred to represent a range from shallow water into deep water.

The condition of many of the deep-water specimens leaves no room for reasonable doubt that they lived at the depth where they were dredged. Most specimens of the two forms of *Hyalopecten* consist of paired shells, in some of which the dried soft parts are distinguishable through the thin translucent shell. Many of the specimens of *Solemya johnsoni* are paired shells on which the long, thin periostracum is virtually intact. Both species of *Limopsis* are represented by many paired shells that have an intact periostracum.

INFERRED DEPTH RANGE OF LARGER FOSSILS

The larger fossils are classified in three depth-facies groups corresponding to the three groups of analogous modern species.

Shallow-water facies.—Modern allies of five Repetto species are restricted to shallow water. For the most part the modern species represent depths of only a few fathoms. Species similar to *Lyropecten cerrosensis* and *Corbula gibbiformis* appear to be extinct in the eastern Pacific. From the facies at other Pliocene localities where these two species are found, it is inferred that they belong in the group of fossils of shallow-water facies. A fiddler crab (*Uca hamlini*) and a mud shrimp (*Callianassa*) also are placed in this group.

Intermediate-depth facies.—The fossils of intermediate-depth facies embrace species that are inferred to represent a range from shallow water into deep water. In addition to three species whose modern analogs are shown on plate 3, two others (*Lunatia* cf. *L. caurina*, and *Acila?* cf. *A. castrensis*) are placed in this group. The affinities of these two forms are uncertain, but probably they are allied to the modern species with which they are compared. Suites of shells from the California coast arranged under *Lunatia caurina* at the National Museum have a depth range of 68 to 822 fathoms. *Acila castrensis* is represented in the same region by suites having depth records of 16 to 233 fathoms.

Deep-water facies.—The fossils of deep-water facies are the most interesting. This group embraces the seven species whose modern analogs are shown on plate 3. The sponge from the Huntington Beach field is an additional representative of this group. The sponge remains were identified by De Laubenfels as belonging in the family Farreidae and almost certainly in the genus *Farrea*. De Laubenfels pointed out in a written communication that this sponge represents a deep-water type and that a species of *Farrea* was dredged by the *Albatross* off San Diego at a depth of 359 fathoms.[54] Other species of *Farrea* were dredged at depths of 685 fathoms off Washington and Lower California.[55] Additional fossils of deep-water facies may be represented by the coral *Stephanocyathus?* and by the mollusks *Plicifusus?*, *Buccinum?*, and *Periploma cryphia*. The coral without much doubt belongs in the deep-water group, but the preservation is too poor for certain identification. *Plicifusus?* sp. and *Buccinum?* sp. appear to be shells of northern aspect and therefore probably of deep-water facies. At all events they apparently are not similar to shallow-water forms living in this region nor to Pliocene fossils from other localities in southern California. *Periploma cryphia* has no known modern analog in the eastern Pacific but appears to resemble most closely modern deep-water species from other areas.

Lima hamlini and *Limopsis phrear* are the most widespread of the fossils of deep-water facies. *Lima hamlini* is closely allied to *L. agassizii*, known from only one specimen dredged in the Panamanian region at a depth of 322 fathoms. Both species belong to a group of

[53] Woodring, W. P., op. cit. (Am. Jour. Sci., 5th ser., vol. 29), pp. 303-304. When the account of the terrace fossils was written a small imperfect specimen from a depth of 53 fathoms off Santa Rosa Island (U. S. Nat. Mus. No. 211299), evidently a *Barbarofusus*, then arranged under *Fusitriton oregonensis* in the collections of the U. S. National Museum, was accepted as *oregonensis* without examination.

[54] Schulze, F. E., Amerikanische Hexactinelliden nach dem Materiale der *Albatross*-Expedition, pp. 71-72, Jena, 1899.

[55] Idem, pp. 68-71.

giant thin-shelled Limas of the subgenus *Acesta* that has a wide distribution in deep water, as shown in the following table, which summarizes the data for the modern species:

Dredging records of giant deep-water Limas of the subgenus Acesta [1]

Species	Locality	Depth (fathoms)	Bottom temperature (degrees Fahrenheit)	Character of bottom
excavata (Fabricius)	Norway	[2] 150–300	--------	
	Azores to Norway	[3] 150–1, 450	--------	
patagonica Dall [4]	Southern Chile	258	47. 9	Blue mud.
		348	49. 9	Do.
		449	46. 9	Do.
agassizii Dall [5]	Gulf of Panama	322	46	Green mud.
goliath Sowerby	Japan	[6] 775	--------	
bartschi Thiele [7]	Philippine Islands	280	46. 8	Dark-gray sand.
		281	--------	Soft green mud.
		432	53. 5	Green mud, sand.
		505	--------	Gray mud, fine sand.
		508	49. 8	Gray mud, coral sand.
philippinensis Bartsch [8]	--------	190	--------	Gray mud.
rathbuni Bartsch [9]	Philippine Islands	83(?)	--------	Green mud.
		161	57. 4	Fine coral sand.
		175	54. 3	Globigerina.
		182	54. 3	Globigerina, sand.
		186	--------	Shell, coral.
		209	52. 4	Soft green mud.
		220	53. 9	Green mud.
		226	53. 3	Do.
celebensis Bartsch [10]	Celebes	519	--------	Do.
butonensis Bartsch [11]	do	559	39. 2	Do.
borneensis Bartsch [12]	Borneo	305	43. 2	Do.
indica Smith [13]	Eastern Arabian Sea	430	--------	

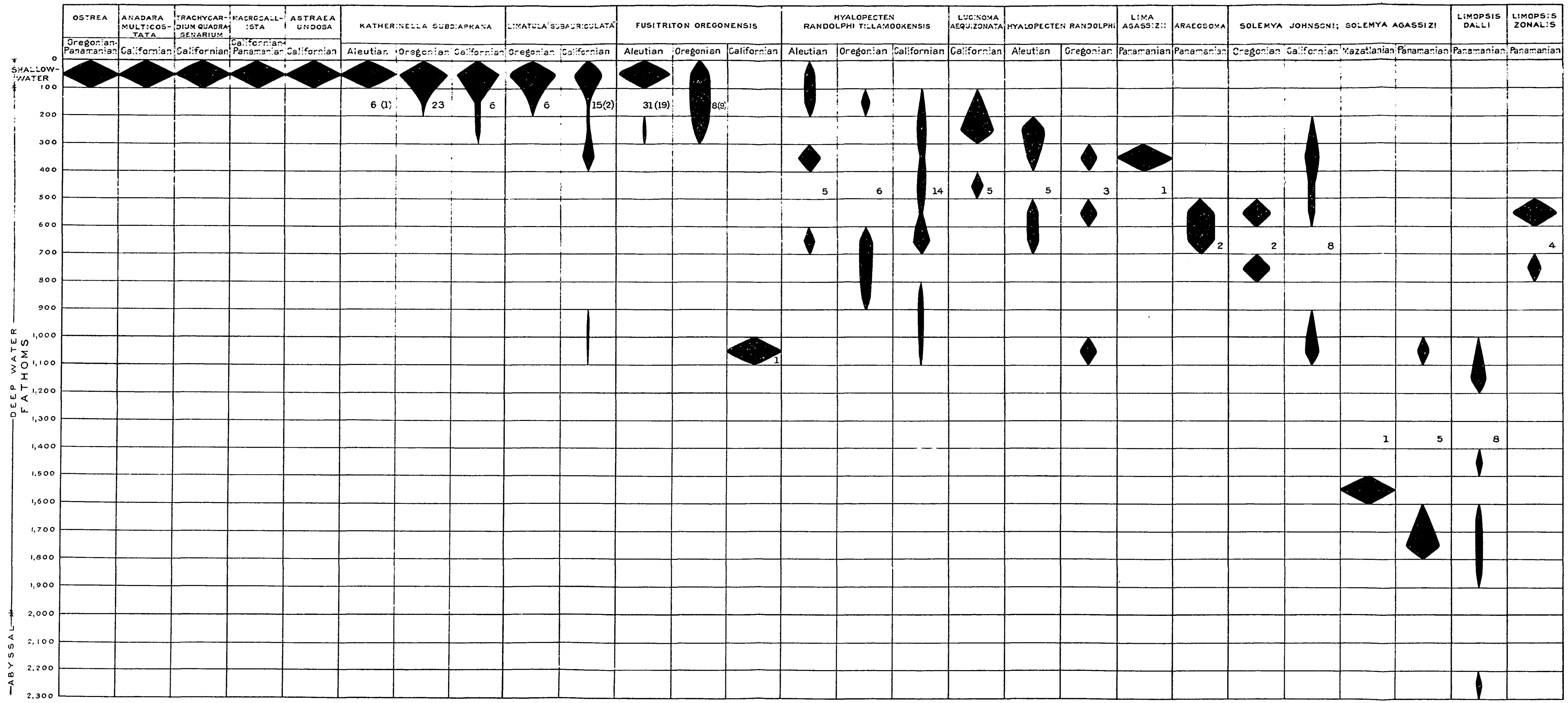
[1] There is no dredging record for *niasensis* Thiele, 1918, from Nias. *L. diomedae* Dall, 1908 (Galapagos, 385 fathoms), and *verdensis* Bartsch, 1913 (Philippines, 394 fathoms), apparently do not belong to this group of thin-shelled species, and it appears to be doubtful whether *smithi* Sowerby, 1888 (Japan), does.
[2] Dall, W. H., Notes on the giant Limas: Nautilus, vol. 16, p. 16, 1902.
[3] Thiele, J., Familia Limidae: Systematisches Conchylien-Cabinet, vol. 7, pt. 2a, p. 20, 1918.
[4] Dall, W. H., The Mollusca and the Brachiopoda [*Albatross* Rept.]: Harvard College Mus. Comp. Zoology Bull., vol. 43, p. 407, 1908. A specimen (U. S. Nat. Mus. 95987), not mentioned by Dall, was dredged at a depth of 258 fathoms.
[5] Dall, W. H., idem.
[6] Dall, W. H., op. cit. (1902), p. 16.
[7] *L. smithi* Bartsch, Paul, The giant species of the molluscan genus *Lima* obtained in Philippine and adjacent waters: U. S. Nat. Mus. Proc., vol. 45, pp. 236–237, 1913. Thiele, J., op. cit., p. 24; *L. bartschi* n. name for *L. smithi* Bartsch, 1913, not Sowerby, 1888. Bartsch, Paul, Nautilus, vol. 37, pp. 69–70, 1923; *L. hughi* n. name for *L. smithi* Bartsch, 1913, not Sowerby [1888].
[8] Bartsch, Paul, op. cit. (1913), p. 237. The label reads 338 fathoms.
[9] Idem, pp. 237–239.
[10] Idem, p. 240.
[11] Idem, p. 240. The only specimen is a very small, presumably young specimen. The temperature record is taken from the label.
[12] Idem, p. 239. The only specimen is a small, presumably young specimen that may need comparison with young shells of *rathbuni* of the same size, which are not available.
[13] Smith, E., A., On Mollusca from the Bay of Bengal and the Arabian Sea: Annals and Mag. Nat. History, 7th ser., vol. 4, p. 251, 1899.

Limopsis phrear is closely allied to the modern Panamanian *L. dalli*, which is represented in the *Albatross* collections by 8 lots that have the remarkable depth distribution of 1,067 to 2,232 fathoms—the latter the greatest depth at which the *Albatross* dredged in the eastern Pacific. This Repetto species is also allied to *L. zonalis*, which has a range in the same region of 546 to 782 fathoms and was differentiated from *L. dalli* principally on the basis of characters not available in fossils. Dredging records for the species of *Limopsis* allied to *L. phrear* are presented in the table below as follows:

Dredging records of species of Limopsis allied to L. phrear [1]

Species	Locality	Depth (fathoms)	Bottom temperature (degrees Fahrenheit)	Character of bottom
dalli Lamy ("compressus" Dall)	Gulf of Panama	1, 067	37	Yellow Globigerina ooze.
		1, 132	36. 3	Gray Globigerina ooze.
		1, 175	36. 8	Green mud, sand, rock.
		1, 471	36. 6	Green ooze.
		1, 672	36. 4	Fine black and green sand.
		1, 793	35. 8	Green mud.
		1, 823	36. 4	Green ooze.
	Off northern Central America	2, 232	35. 8	Green mud.
zonalis Dall	Gulf of Panama	546	40. 1	Soft black mud.
		555	40. 2	Green sand.
		556	38	Sand.
		782	38. 5	Green sand.
jousseaumi Mabille and Rochebrune	Chile	369	46. 9	Green mud.
		122	47. 9	Blue mud.

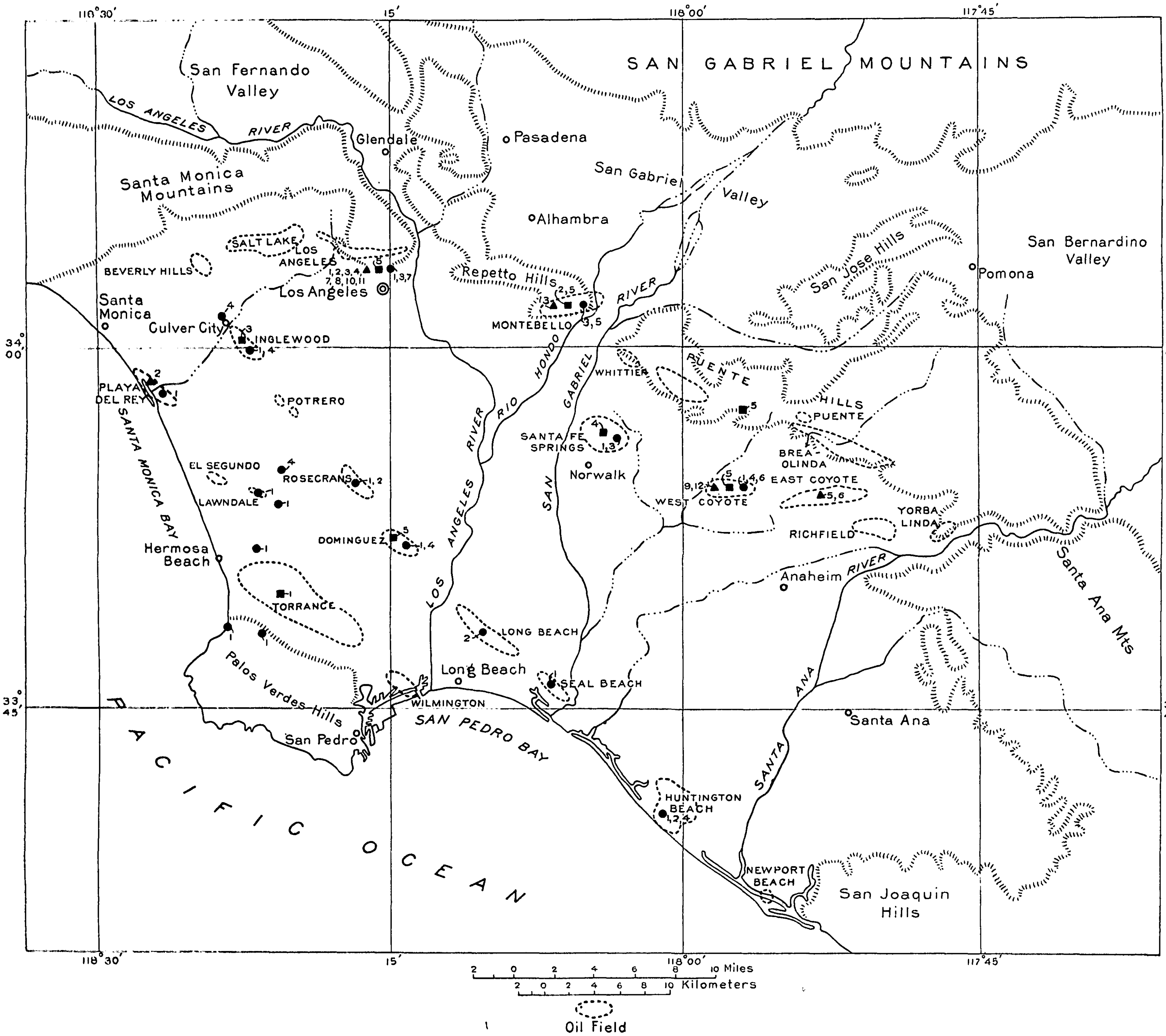
[1] Data from Dall, W. H., The Mollusca and the Brachiopoda [*Albatross* Rept.]: Harvard College Mus. Comp. Zoology Bull., vol. 43, pp. 393–395, 1908. Character of bottom from Townsend, C. H., Dredging and other records of the U. S. Fish Commission steamer *Albatross:* U. S. Fish Comm. Rept. for 1900, pp. 387–562, pls. 1–7, 1901.



DEPTH FREQUENCY GRAPHS OF MODERN PACIFIC COAST MOLLUSKS AND ECHINOIDS ALLIED TO REPETTO FOSSILS.

Width of graph at midpoint between depth division lines represents percentage of dredging records for that species within depth unit. Numbers in vertical columns represent number of dredging records; those in parentheses represent number of lots that lack depth records. Data based on collections of U. S. National Museum.

Modern species	Analogous Repetto fossils
Ostrea spp	Ostrea vespertina.
Anadara multicostata	Anadara camuloensis.
Trachycardium quadragenarium	Trachycardium cf. T. quadragenarium.
Macrocallista spp	Macrocallista sp.
Astraea undosa	Astraea cf. A. gradata.
Katherinella subdiaphana	Katherinella aff. K. subdiaphana.
Limatula "subauriculata"	Limatula aff. L. "subauriculata."
Fusitriton oregonensis	Fusitriton aff. F. oregonensis.
Hyalopecten randolphi tillamookensis.	Hyalopecten aff. H. randolphi tillamookensis.
Lucinoma aequizonata	Lucinoma aff. L. aequizonata.
Hyalopecten randolphi	Hyalopecten aff. H. randolphi.
Lima agassizii	Lima hamlini.
Araeosoma eurypatum; A. leptaleum	Araeosoma sp.
Solemya johnsoni; S. agassizi	Solemya aff. S. johnsoni.
Limopsis dalli; L. zonalis	Limopsis phrear.



▲ SHALLOW-WATER, LAND, AND FRESH-WATER FOSSILS

1. Ostrea vespertina.
2. Anadara camuloensis.
3. Lyropecten cerrosensis.
4. Trachycardium cf. T. quadragenarium.
5. Macrocallista sp.
6. Corbula gibbiformis.
7. Astraea cf. A. gradata.
8. Uca hamlini.
9. Callianassa sp.
10. Mancalla californiensis.
11. Pinus cf. P. radiata.
12. Leaves of dicotyledonous land plants.
13. Astacus? sp.

■ SHALLOW-WATER TO DEEP-WATER FOSSILS

1. Katherinella aff. K. subdiaphana.
2. Limatula aff. L. "subauriculata."
3. Lunatia cf. L. caurina.
4. Acila? cf. A. castrensis.
5. Fusitriton aff. F. oregonensis.

● DEEP-WATER FOSSILS

1. Lima hamlini.
2. Hyalopecten aff. H. randolphi tillamookensis.
3. Hyalopecten aff. H. randolphi.
4. Limopsis phrear.
5. Solemya aff. S. johnsoni.
6. Araeosoma sp.
7. Lucinoma aff. L. aequizonata.

MAP OF LOS ANGELES BASIN SHOWING DISTRIBUTION OF REPETTO FOSSILS OF DIFFERENT DEPTH FACIES.

Base adapted from Hoots and Kew (16th Internat. Geol. Cong. Guidebook 15, pl. 6, 1932).

The genus *Araeosoma* is a representative of the family Echinothuriidae, which embraces echinoids that have a leathery flexible test. This family has a widespread distribution in deep water. One oriental genus (*Asthenosoma*), however, lives in shallow water from the littoral zone to a depth of about 50 fathoms, and *Asthenosoma varium* has been observed feeding on human feces along the shore.[56] *Araeosoma* is represented in the eastern Pacific by *A. eurypatum*,[57] from a depth of 671 fathoms near the Galapagos, and *A. leptaleum*,[58] dredged off Panama at a depth of 581 fathoms. The undeterminable species of *Araeosoma* from the Repetto formation is the first fossil echinothuriid recorded from America and apparently the first Tertiary representative of the family from any region in the form of more complete material than isolated spines.

Modern allies of *Lima hamlini*, *Limopsis phrear*, and *Araeosoma* sp. have not yet been found in the eastern Pacific north of the Panamanian region. Future dredging may show that the apparent extinction of these forms in the region along the coast of California is not real. If the apparent extinction is due to inadequate dredging records, modern representatives of these forms might be expected in depths greater than 1,000 fathoms off the California coast, which appears improbable. The *Albatross* occupied about 100 deep-water dredging stations along the coast from Puget Sound to San Diego and almost the same number along the coast from Lower California to Panama. None of the hauls in the northern division were at depths greater than about 1,000 fathoms, whereas 23 hauls in the southern division were taken at depths between 1,000 and 2,300 fathoms.[59]

The remaining species in the group of fossils of deep-water facies have modern analogs off the coast of California.

INTERPRETATION OF FOSSILS OF DEEP-WATER FACIES

The meager Repetto fauna of larger fossils now known embraces species of shallow-water facies, species of deep-water facies, and others of intermediate-depth facies.

If only one or two species of deep-water facies were found in the Repetto formation, it might be argued that there is a reasonable doubt whether the fossils lived in the same environment as their modern analogs—that is, whether the assumption on which this discussion is based is justified. But the graphs show seven species of deep-water facies. The sponge is an additional species, and four others may be represented. The seven species of deep-water facies shown on the graphs belong to six genera. These genera, or the subgenera represented, are not known to embrace modern California species of shallow-water or intermediate-depth range, with the exception of *Lucinoma*. One modern species of *Lucinoma*, *L. annulata*, has an intermediate-depth range along the coast of California (10 to 414 fathoms). This species appears to be well differentiated from the deep-water *L. aequizonata*. Moreover, three of the species of deep-water facies (*Lima hamlini*, *Limopsis phrear*, and *Araeosoma* sp.) belong to genera or subgenera that so far have not been found in the Pliocene deposits of any other region on the Pacific coast. The other four species represent genera that are not recorded in southern California Pliocene deposits characterized by a shallow-water facies, again with the exception of *Lucinoma*. *Solemya* is recorded from the Pliocene of the Eel River Basin, in northern California, where it is associated with species of cool-water facies. *Hyalopecten* is recorded from a locality in the Pliocene of the western part of the Ventura Basin. As it is the only species recorded from this locality, the facies is uncertain. Forms of *Lucinoma annulata* are found at many California localities in Pliocene strata of shallow-water facies.

The fossils of deep-water facies evidently are unusual. Those of shallow-water and intermediate facies are not unusual in California, with the exception of *Limatula*, one of the group of intermediate-depth facies.

The possibility that the fossils of deep-water facies represent cool shallow water instead of cool deep water needs consideration. That they represent shallow water cooled by changes in climate or oceanic circulation appears improbable. Some of the associated shallow-water fossils are of warm-water facies, and apparently none are of unequivocal cool-water facies. The lower Pliocene shallow-water faunas of southern California are generally thought to indicate a warmer facies than the modern fauna in the same latitude. Some conflicting evidence on this matter is apparent, but evidence for a pronounced lowering of the temperature of the lower Pliocene shallow seas is not.

The present California coast is marked by regions of pronounced upwelling of cool water. The upwelling is generally attributed to displacement of warmer surface water near the coast by offshore currents set in motion by winds blowing roughly parallel to the coast from a northerly quadrant.[60] Inasmuch as the modern deep-

[56] Mortensen, Th., A monograph of the Echinoidea, II, pp. 112, 279, Copenhagen, 1935.

[57] Agassiz, Alexander, and Clark, H. L., Hawaiian and other Pacific Echini: Harvard College Mus. Comp. Zoology Mem., vol. 34, pp. 181–183, pl. 66, figs. 18, 19; pls. 73–75, 1909.

[58] Idem, pp. 183–185, pls. 76–77.

[59] Data from Townsend, C. H., Dredging and other records of the United States Fish Commission steamer *Albatross*: U. S. Fish Comm. Rept. for 1900, pp. 387–562, pls. 1–7, 1901.

[60] Bigelow, H. B., and Leslie, Maurine, Reconnaissance of the waters and plankton of Monterey Bay, July 1928: Harvard College Mus. Comp. Zoology Bull., vol. 70, pp. 464–478, 1930. Literature citations may be found in this account. For a discussion of upwelling along the Pacific coast of South America, where this feature was recognized as a result of observations made during the voyage of the *Venus* a century ago, see Murphy, R. C., Oceanic birds of South America, vol. 1, pp. 95–97, 267–268, New York, 1936.

water species shown on plate 3 have not been found in shallow water, even in regions of pronounced upwelling, it is improbable that upwelling was a major factor in introducing animals of deep-water facies into the Pliocene basin. It might be postulated that conditions were favorable for exceptionally pronounced and long-continued upwelling in the Pliocene Los Angeles Basin, but that postulate implies exceptional localization that should be supported by independent evidence.

As it is unlikely that the fossils of deep-water facies lived in cool shallow water, the probability that they lived in deep water is considered reasonably certain.

DISTRIBUTION OF FOSSILS OF DIFFERENT DEPTH FACIES

The distribution of the three groups of fossils is shown on plate 4. Land and fresh-water fossils—a flightless shore bird (*Mancalla californiensis*), cone scales of a pine similar to a modern coastal species (*Pinus* cf. *P. radiata*), undeterminable dicotyledonous leaves, and a doubtfully identified crayfish (*Astacus?*)—are shown by the same symbol as that used for fossils of shallow-water facies. The following fossils, whose depth facies is uncertain, are omitted from the map:

Repetto fossils omitted from distribution map (pl. 4) and their probable depth facies

	Probable depth facies
Stephanocyathus? sp	Deep water.
"Nassa" hamlini Arnold	Intermediate or deep water.
Plicifusus? sp	Deep water.
Buccinum? sp	Do.
Acila semirostrata (Grant and Gale)	Intermediate.
Phreagena lasia Woodring, n. gen., n. sp.	Shallow water or intermediate.
Calyptogena n. sp	Do.
Periploma cryphia Woodring, n. sp., and var. stenopa Woodring, n. var.	Deep water.
Cassidulid	(?).

Fossils of shallow-water facies have so far been found at localities along the northern margin of the basin and nearby, and in the Playa del Rey field, at the western margin of the basin. The fossils of intermediate-depth facies have a wider distribution in Los Angeles and in the Montebello, Whittier, Santa Fe Springs, Inglewood, Dominguez, and Torrance fields. *Fusitriton* aff. *F. oregonensis* is the most widely distributed species of this group. The fossils of deep-water facies have an extensive distribution within the basin and on the northern and southern borders.

PALEOGEOGRAPHIC IMPLICATIONS

Paired pelecypods that do not have a closely interlocking hinge suggest burial close to the places where they lived. The following fossils of deep-water facies are represented by paired specimens: *Solemya* aff. *S. johnsoni*, from the Montebello field; *Limposis phrear*, from the Dominguez field; and *Lima hamlini*, from Los Angeles, the Rosecrans field, and a locality near the Lawndale field. *Limoposis* has a closely interlocking hinge; *Solemya* and *Lima* have virtually no hinge.

The widespread distribution of fossils of deep-water facies indicates considerable depths over the greater part of the basin. According to Wissler's age assignments, the fossils of deep-water facies have a stratigraphic distribution at intervals throughout the greater part of the formation. The localization of the shallow-water fossils is probably to be attributed to proximity to areas of shallow water near the margins of the basin rather than to movements that changed the depth of the water over a large part of the basin. The occurrence of land and fresh-water fossils near the northern margin of the basin, in addition to the shallow-water, intermediate, and deep-water fossils, points to proximity to land. The mollusks of shallow-water facies from the Third Street tunnel in Los Angeles consist of broken and worn specimens, suggesting transportation by some unknown agency. A core that yielded two forms of shallow-water fossils constitutes the only record for the East Coyote field. One of these fossils (*Corbula gibbiformis*) is a paired pelecypod that does not have a closely interlocking hinge. Additional records are needed from the East Coyote field to support the suggestion that an area of shallow water lay in this part of the basin or nearby.[61]

Land-plant debris appears to be abundant in the northern part of the basin. The *Albatross* dredged great quantities of decomposed land-plant debris in deep water off the Pacific coast of Central America.[62] Perhaps the occurrence of the echinothuriid *Araeosoma* in the West Coyote field is to be correlated with the abundance of plant debris. Mortensen[63] found that echinothuriids dredged in deep water off the Philippine and Kei Islands have their intestines more or less filled with finely divided land-plant debris, and he commented on the paradox of deep-sea animals feeding on land plants.

The source of the big, thick-shelled, shallow-water *Anadara* from the Playa del Rey field is not known. It shows signs of transportation, for part of the shell well within the core is broken and worn. It might be argued that the schist ridge that underlies the Playa del Rey field[64] formed an area of shallow water during at least part of Repetto time. However, the occurrence of the deep-water *Lima* in another well in this field at about the same horizon as the *Anadara* is opposed to this view. Shallow water or land, part of Reed's Catalinia,[65]

[61] Collections from two additional wells in the East Coyote field submitted by Wissler too late to be included in this report do not include any forms of deep-water facies.

[62] Agassiz, Alexander, General sketch of the expedition of the *Albatross* from February to May, 1891: Harvard College Mus. Comp. Zoology Bull., vol. 23, pp. 11–12, 1892. I am indebted to Dr. T. Wayland Vaughan for pointing out this description.

[63] Mortensen, Th., A monograph of the Echinoidea, II, pp. 112–113, 255, Copenhagen, 1935.

[64] Hoots, H. W., Blount, A. L., and Jones, P. H., Marine oil shale, source of oil in Playa del Rey field, California: Am. Assoc. Petroleum Geologists Bull., vol. 19, fig. 2 (opp. p. 177), 1935.

[65] Reed, R. D., Geology of California, fig. 51 (opp. p. 253), Tulsa, 1933. (See also fig. 20, opp. p. 117.)

may have lain not far south of the northern border of the Palos Verdes Hills. Though the Repetto along the northern border of the Palos Verdes Hills contains the deep-water *Lima*, it also contains scattered small pebbles of schist and basaltic rock.

A fossil of intermediate-depth facies (*Katherinella* aff. *K. subdiaphana*) is known from the Torrance field, and one (*Acila semirostrata*) probably of the same facies from the Wilmington field. Both records are the only ones for these areas.

The fossils of deep-water facies suggest that during Repetto time the Los Angeles Basin sea had depths of 300 to 600 fathoms (roughly 2,000 to 4,000 feet). Part of the basin doubtless contained deep water before the beginning of the Pliocene epoch. Kleinpell estimated that the Foraminifera of the Malaga mudstone member of the Monterey shale, underlying the Repetto in the Palos Verdes Hills, indicate a depth of 500 fathoms or more.[66] Evidence that the upper part of the subsurface Miocene in the basin carries larger fossils of deep-water facies is afforded by material in the Standard collection from horizons assigned by Driver and Wissler to the Miocene. In addition to the specimens of *Hyalopecten* aff. *H. randolphi*, *H.* cf. *H. pedroanus*, *Lima hamlini*, and *Lucinoma* aff. *L. aequizonata* cited under the description of species, this material includes part of a large *Propeamussium* (Bradford Oil Co. B. & B. No. 1, southest of Huntington Beach field, depth 3,810 feet, U. S. G. S. locality 13910) unlike any known modern species in the eastern Pacific, but allied to deep-water species in other parts of the world.

BEARING ON GEOLOGIC HISTORY OF LOS ANGELES BASIN

At outcrop localities in Los Angeles and at Potrero Canyon—localities considered under the heading "Age relations of larger fossils"—the Pico formation, which overlies the Repetto formation and is assigned to the upper Pliocene, contains larger fossils of intermediate-depth facies. According to age assignments by Driver and Wissler, the lower part of the Pico in the subsurface section contains the following larger fossils of deep-water facies: *Hyalopecten* aff. *H. randolphi*, *H.* aff. *H. randolphi tillamookensis* (records cited under descriptions of species), and *Nuculana* aff. *N. leonina* (Dall) (Standard Oil Co. Vickers No. 1 lease, No. 28, Inglewood field, depth 1,256 feet, U. S. G. S. locality 13889; Southern California Drilling Co. Matteson No. 1, El Segundo field, depth 2,599 feet, U. S. G. S. locality 13912a). A species apparently of shallow-water facies, *Sinum?* cf. *S. californicum* Oldroyd (Pan American Petroleum Co. Pacific Southwest No. 2, El Segundo field, depth 1,149 feet, U. S. G. S. locality 13913), and one of uncertain-depth facies, *Phreagena lasia* (cited under descriptions of species) also are assigned to the Pico formation.

In general terms the Repetto formation has a deep-water facies over a large part of the basin; the Pico formation has a moderately deep-water and intermediate-depth facies; and the Pleistocene has a shallow-water facies. This succession suggests that the deposition of sediments of decreasing-depth facies during Pliocene and Pleistocene time was a factor in the accumulation of the 6,000 to 10,000 feet of Pliocene and Pleistocene sediments in the Los Angeles Basin. But unless the Repetto sea was much deeper than now appears probable, subsidence also was a factor in the accumulation of these sediments.

Stratigraphic data for the larger fossils may yield information to test the implication that, possible subsidence disregarded, the Repetto formation itself represents decreasing depth facies. Two collections of fossils at horizons assigned by micropaleontologists to the transition zone between the Repetto and Pico formations in the Repetto Hills are listed under the heading "Age relations of larger fossils." One of the collections consists of species of shallow-water facies and others of uncertain-depth facies. Most of the specimens in this collection are incomplete, but their condition is due principally to difficulties in extracting them from the hard limy matrix; and none of the pelecypods are paired. The other collection includes one species (*Yoldia* aff. *Y. thraciaeformis*) that, if correctly identified, is of cool-water, possibly deep-water facies. A form similar to the Arctic and Aleutian *Y. thraciaeformis* is represented in the collections of the National Museum by specimens dredged at depths of 152 to 1,006 fathoms along the California coast. Another species (*Acila semirostrata*) is classified in the group of intermediate-depth facies, and others are of shallow-water or uncertain facies. In preservation and matrix this collection is similar to the one just mentioned. One specimen of *Acila*, which has a closely interlocking hinge, is a paired mold. These two collections may represent accidental-death associations, but they indicate a shallower facies than the Third Street tunnel locality in Los Angeles and most of the subsurface localities.

This interpretation of the history of the Los Angeles Basin is not new. It is implied in Natland's analysis of the succession of foraminiferal faunas in the Ventura Basin, where the succession is essentially the same as in the Los Angeles Basin. Reed, who used Natland's data and suggested that the water generally was too deep for bottom-dwelling mollusks, presented this interpretation.[67] Natland [68] found that the succession of associations of Foraminifera with increasing depth in a profile across the channel between San Pedro Bay and Santa Catalina Island closely resembles the downward succession of foraminiferal faunas in the Pleistocene and

[66] Kleinpell, R. M., in Woodring, W. P., Bramlette, M. N., and Kleinpell, R. M., Miocene stratigraphy and paleontology of Palos Verdes Hills, California: Am. Assoc. Petroleum Geologists Bull., vol. 20, p. 148, 1936.

[67] Reed, R. D., Oil-bearing Pliocene beds of southern California [abstract]: Pan-Am. Geologist, vol. 59, p. 231, 1933.

[68] Natland, M. L., The temperature and depth distribution of some Recent and fossil Foraminifera in the southern California region: California Univ., Scripps Inst. Oceanography, Bull., Tech. ser., vol. 3, pp. 225–230, 1 table, 1933.

Pliocene of the Ventura Basin. The possibility that the different temperature facies of the fossil faunas is due to change in climate or other changes not correlated with depth is not excluded in Natland's discussion.[69]

COMPARISON BETWEEN LOS ANGELES BASIN DURING REPETTO TIME AND MODERN DEEP-WATER BASINS ON CONTINENTAL SHELF OF SOUTHERN CALIFORNIA

The conception of the Los Angeles Basin as a deep-water basin during Repetto time invites comparison of the Los Angeles Basin with the basins on the Continental Shelf of southern California shown in figure 1. Despite their location on the Continental Shelf, these basins have depths of 300, 500, 700, and 1,000 fathoms. They may fairly be claimed to have had a tectonic origin, as they are exceptional features in a region of marked crustal instability. Apparently some of the deformation took place recently, for Pleistocene elephants are found on Santa Cruz, Santa Rosa, and San Miguel Islands.[70]

The morphologic similarity between the basins on the Continental Shelf of southern California and the Pliocene Los Angeles and Ventura Basins on the adjoining mainland has been pointed out by Trask[71] and Reed.[72] Trask[73] found that sand is being deposited on ridges between the basins regardless of depth and that the organic content of the fine-grained sediments in the basins is exceptionally high for modern sediments. Many California geologists have been loath to think, however, that the depth of the water in the Pliocene basins was nearly as great as in the modern basins. According to the interpretation of the depth facies of the larger Repetto fossils from the Los Angeles Basin here offered, there is a reasonable probability that the depth was as great as in some of the basins on the Continental Shelf.

Geologists would be under a great debt to oceanographers for a detailed survey of the physical and biologic features of this part of the Continental Shelf of southern California. The Pliocene and modern basins appear to be similar in general features. A detailed survey might yield results of great value in interpreting the geologic history and the conditions during the accumulation of the sediments that are regarded as the source beds of petroleum in the Los Angeles and Ventura Basins.

It may be worth while for sedimentary petrologists to study the Repetto sediments with the probable deep-water origin of the formation in mind. These studies combined with comparison with the sediments in the modern California deep-water basins may yield criteria for the recognition of deep-water sediments that superficially resemble shallow-water sediments. Such criteria would be particularly useful in attempts to evaluate the depth facies of older sediments, for with greater age the decreasing similarity to modern faunas renders paleontologic data of doubtful value. If, on the other hand, it is found that the Repetto sediments are not comparable with those being deposited in the modern deep-water basins, some explanation for the fossils of deep-water facies other than a deep-water habitat may be preferred.

AGE RELATIONS OF LARGER FOSSILS

The Repetto formation is currently assigned to the lower Pliocene, as it overlies strata considered of upper Miocene age and constitutes the lower part of the section referred to the Pliocene. The designation lower Pliocene is a relative one for this region. The age relations with reference to the European Miocene and Pliocene are not directly known. Direct comparison with the time scale adopted for the continental Tertiary of the Pacific coast and Great Basin also is impracticable, with the following exception. A tooth referred to *Hipparion mohavense* has been found in an area of diatomaceous shale assigned to the upper part of the Puente formation in the San Jose Hills, north of the Los Angeles Basin.[74] The Puente formation is considered of upper Miocene age. This species of *Hipparion* was described from the Ricardo formation of the Mojave Desert, north of the San Gabriel Range. The Ricardo formation is generally assigned to the lower Pliocene but by some workers is considered late Miocene or transitional Miocene-Pliocene. English[75] realized that units mapped as the upper part of the Puente might at places be of Pliocene age, and since then Repetto Foraminifera have been found in an area mapped as Puente.[76] According to a communication from Wissler, however, the diatomaceous shale in the area where the tooth was collected is of Miocene age in terms of the time scale used for the marine section.

FOSSILS OF DEEP-WATER FACIES

Some of the fossils of deep-water facies in the Repetto formation of the Los Angeles Basin represent genera or subgenera that so far have not been found elsewhere in the California Pliocene. These unusual fossils give the Repetto fauna a distinctive character, which so far as known has a chronologic value in the Los Angeles Basin. But inasmuch as the deep-water forms are

[69] Natland, M. L., op. cit., p. 230.

[70] The data for the three islands are summarized in the most recent account: Stock, Chester, Exiled elephants on the Channel Islands, California: Sci. Monthly, vol. 41, pp. 205-214, 10 figs., 1935.

[71] Trask, P. D., Origin and environment of source sediments of petroleum, p. 119, Houston, 1932.

[72] Reed, R. D., Geology of California, pp. 3-5, Tulsa, 1933; Oil-bearing Pliocene beds of southern California [abstract]: Pan-Am. Geologist, vol. 59, p. 231, 1933.

[73] Trask, P. D., Sedimentation in the Channel Islands region, California: Econ. Geology, vol. 26, pp. 24-43, 6 figs., 1931; op. cit. (1932), pp. 88-90, 119-124, 237-238.

[74] Stock, Chester, A tooth of *Hipparion mohavense* from the Puente formation, California: Carnegie Inst. Washington Pub. 393, pp. 49-53, 1 fig., 1928.

[75] English, W. A., Geology and oil resources of the Puente Hills region, southern California: U. S. Geol. Survey Bull. 768, pp. 36-38, 1926.

[76] Stewart, R. E., and Stewart, K. C., "Lower Pliocene" in eastern end of Puente Hills, San Bernardino County, California: Am. Assoc. Petroleum Geologists Bull., vol. 14, pp. 1445-1450, 1 fig., 1930.

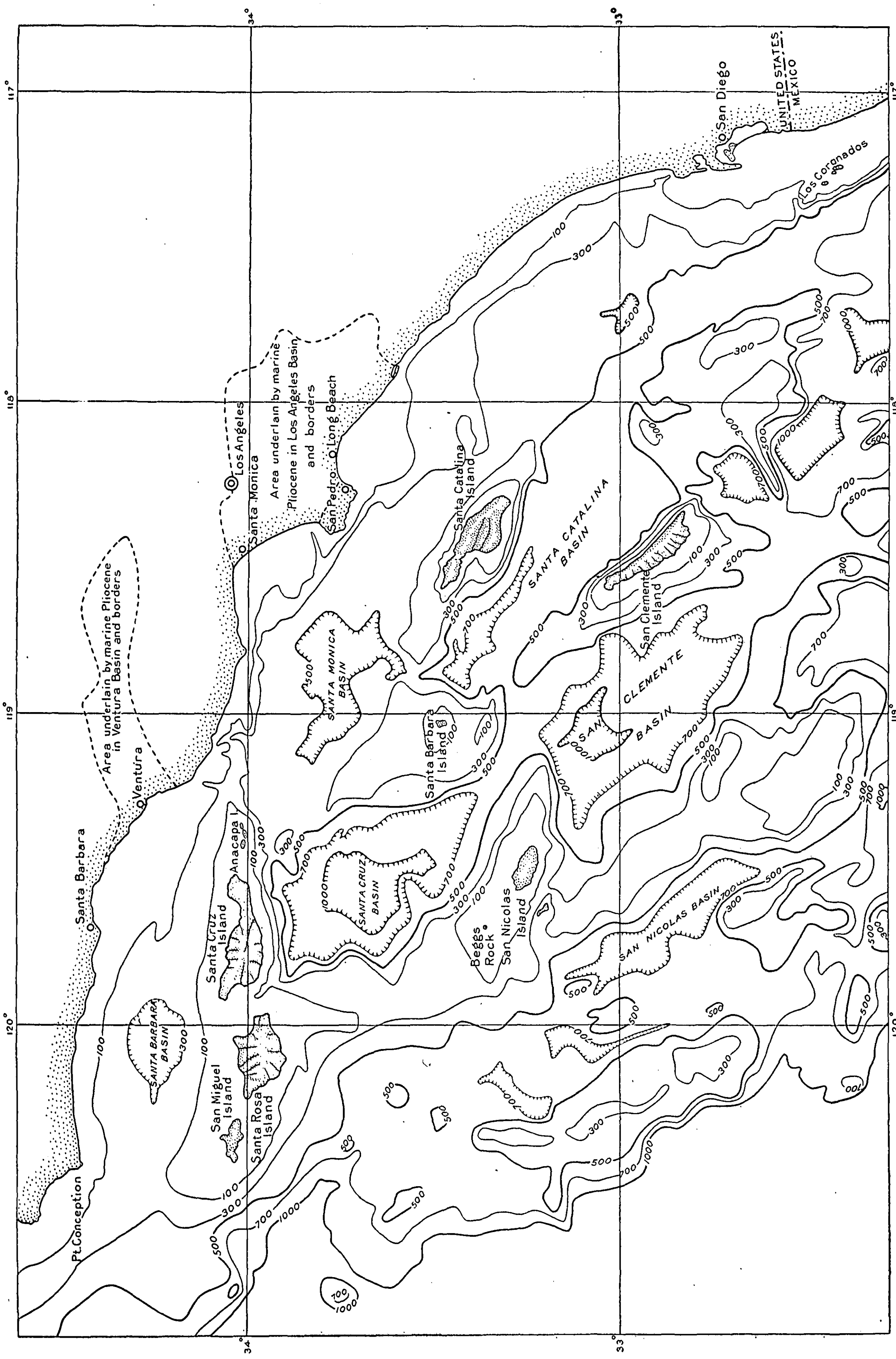


FIGURE 1.—Bathymetric map of Continental Shelf along part of coast of southern California. After U. S. Navy, Hydrographic Office, chart 5194. Contours represent 100, 300, 500, 700, and 1,000 fathoms. Depression contours hachured. A more detailed bathymetric chart of the California coast has recently been compiled by F. P. Shepard in collaboration with the U. S. Coast and Geodetic Survey but has not been published.

facies fossils, and inasmuch as most of them are closely allied to modern species and many are allied to older forms, a similar fauna might be expected at other horizons. Indeed, some of the species of deep-water facies are now known in the Los Angeles Basin at horizons assigned to the underlying Miocene and to the overlying Pico formation.

Though most of the fossils of deep-water facies closely resemble species living in the eastern Pacific, related forms have not been found in the California Pleistocene, presumably owing to the absence of a similar facies. That a similar facies is represented in formations older than the Repetto is indicated by the occurrence of similar forms. In fact, *Limopsis phrear*, *Araeosoma* sp., and the sponge are the only species of deep-water facies still unrepresented by similar forms in older formations. *Hyalopecten* is abundant in the Miocene Monterey shale and in the Eocene and Oligocene Kreyenhagen shale. The Miocene Astoria formation of Oregon contains *Stephanocyathus?*, *Solemya*, *Hyalopecten*, and a form of the *Lucinoma aequizonata* group. Weaver's Blakeley formation of Washington, which is generally considered of Oligocene age, contains *Solemya*, *Hyalopecten*, and possibly a *Periploma* similar to *P. cryphia*. A giant *Lima* is represented in strata assigned to the Oligocene on the south shore of the Strait of Juan de Fuca, Washington, and also in the Oregon Oligocene. Tegland estimated that the fine-grained sediments of the Blakeley formation were deposited at depths of at least 1,000 fathoms.[77]

FOSSILS OF INTERMEDIATE AND SHALLOW-WATER FACIES

The number of species of intermediate and shallow-water facies is too small to justify an attempt to make a detailed analysis of their age relations. Also the faunal relations of the Pliocene formations in different parts of southern California are uncertain, owing to the lack of stratigraphically controlled successions of faunas in many areas and to the possibility that facies differentiation is more significant than age differentiation.

Comparison with other Pliocene faunas from Los Angeles Basin.—Other Pliocene faunas from the Los Angeles Basin are briefly considered for comparison with the Repetto fauna.

The following fossils, represented by poorly preserved material, were collected in the type region of the Repetto formation in the Repetto Hills at localities pointed out by Alex Clark. Though these localities appear to fall in the Repetto formation as originally defined, they are, according to Clark, assigned by micropaleontologists to the transition zone between the Repetto and Pico formations.

[77] Tegland, N. M., The fauna of the type Blakeley upper Oligocene of Washington: California Univ., Dept. Geol. Sci., Bull., vol. 23, p. 102, 1933.

Fossils from transition zone between Repetto and Pico formations in Repetto Hills

U. S. G. S. locality 13614. Repetto Hills, road cut near top of slope west of Atlantic Boulevard, 0.33 mile S. 32° E. from 735-foot triangulation station between Atlantic Boulevard and Garvey Avenue. Limy concretion in siltstone. W. P. Woodring and Alex Clark, August 1935:

Gastropods:
- Astraea cf. A. gradata Grant and Gale.
- Neverita aff. N. reclusiana (Deshayes).
- Calyptraea aff. C. mamillaris Broderip.
- Calyptraea aff. C. radians (Lamarck).
- Crepidula cf. C. onyx Sowerby.
- Turritella cf. T. goniostoma Valenciennes.
- Aletes? cf. A. squamigerus Carpenter.
- "Nassa" hamlini Arnold.
- "Nassa" cf. "N." californiana (Conrad).
- "Nassa" sp.
- "Neptunea"? cf. "N." humerosa Gabb.
- "Cancellaria" hemphilli Dall.

Pelecypods:
- Yoldia cf. Y. cooperi Gabb.
- Anadara aff. A. trilineata (Conrad).
- Volsella? sp.
- Pecten sp.
- Ostrea sp.
- Trachycardium cf. T. quadragenarium (Conrad).
- "Protocardia" cf. "P." centifilosa (Carpenter).
- Macrocallista? sp.
- Callithaca aff. C. tenerrima (Carpenter).
- Katherinella aff. K. subdiaphana (Carpenter).
- Chione cf. C. fernandoensis English.
- Macoma? sp.
- Solen cf. S. sicarius Gould.
- Panomya? sp.

U. S. G. S. locality 13616. Repetto Hills, west branch of ravine between Atlantic Boulevard and Garvey Avenue, 0.32 mile S. 30° W. from 735-foot triangulation station. Hard limy layer in sandstone. W. P. Woodring and Alex Clark, August 1935:

Gastropods:
- Neverita? sp.
- Calyptraea aff. C. mamillaris Broderip.
- Turritella cf. T. cooperi Carpenter.
- "Neptunea"? cf. "N." humerosa Gabb.

Pelecypods:
- Acila semirostrata (Grant and Gale).
- Yoldia aff. Y. thraciaeformis (Storer).
- Anadara? sp.
- Patinopecten? sp.
- Lucinoma sp.

"Nassa" hamlini, *Acila semirostrata*, and forms similar to *Astraea* cf. *A. gradata* and *Katherinella* aff. *K. subdiaphana* occur in the Repetto formation. *"Neptunea"*? cf. *"N." humerosa* and *Chione* cf. *C. fernandoensis* suggest forms found at the base of the Pliocene section in Elsmere Canyon, at the east end of the Ventura Basin, where Pliocene strata overlap the granitic rocks of the San Gabriel Range. The Elsmere Canyon fauna is generally considered of lower Pliocene age. *"Cancellaria" hemphilli* occurs at San Diego in the San Diego formation, which is currently considered middle Pliocene.

The relative stratigraphic position of the Pliocene larger fossils from the Puente Hills with reference to the Repetto and Pico formations is unknown or has not been recorded. English [78] found fossils in a zone about 3,000 feet above the base of the 5,000-foot section assigned to the Pliocene. Eldridge's collections from localities 3907 (Olinda Hill, south of western wells of Fullerton Consolidated Oil Co.) and 3909 (face of ridge north of Brea Canyon opposite wells of Brea Canyon Oil Co.) are the only ones in the National Museum. Two of Eldridge's collections appear to be lost (3908, 3910). Many of the species listed by Arnold [79] from the Puente Hills are not in the two collections extant. *Lyropecten cerrosensis* (locality 3907) and *Ostrea vespertina* (locality 3909 [80]) occur in the Repetto formation. A form of *Fusitriton oregonensis* (locality 3907) and *Anadara* aff. *A. multicostata* (locality 3909) appear to be more closely similar to modern forms than to forms from the Repetto formation. *Lyropecten cerrosensis* and *Chlamys* aff. *C. etchegoini* (locality 3907) have been considered characteristic species of the San Diego formation. Other fossils from the Puente Hills were described or recorded by Carson,[81] including *Cantharus breaensis* and *Solenosteira angelensis*, which are considered forms of *"Neptunea" humerosa*, and *Chione elsmerensis* and *Chione fernandoensis*. All these species occur in the Elsmere Canyon fauna of the Ventura Basin.

A small Pliocene fauna characterized by the abundance of Pectinidae and brachiopods is found in sandstone at Temescal Canyon, near Santa Monica (third canyon northwest of Santa Monica on pl. 2).[82] Virtually every species in this fauna is recorded from the San Diego formation at Pacific Beach, near San Diego. The same Pliocene fauna is recorded from the south slope of the Santa Susana Mountains, between the Ventura Basin and the Los Angeles Basin.[83] The sandstone carrying these fossils, referred to the Saugus formation by Kew, appears to represent an extension of the sea from the Ventura Basin. At the time when it was laid down the sea may have extended from the Ventura Basin to the Los Angeles Basin across San Fernando Valley. At the localities where this fauna is found it occurs in sandstone that overlaps rocks ranging in age at different places from Miocene to Cretaceous. Essential faunal identity would ordinarily be considered as indicating essential synchroneity for the Pliocene transgression at these localities, as I formerly assumed.[84] The chronologic value of the fauna is not yet established, however, by its position in stratigraphically controlled successions of faunas.

A large fauna from the upper part of the Pico formation in Los Angeles has been listed and discussed by Moody[85] and Grant.[86] The Recent species *Trachycardium quadragenarium* and *Katherinella subdiaphana* are the only species in this fauna that suggest Repetto forms. This fauna appears to represent water of moderate depth. At all events, the shallow-water genera *Anadara*, *Ostrea*, and *Dendraster* are absent. Essentially the same fauna occurs in the Pico formation in Potrero Canyon[87] (the second canyon northwest of Santa Monica shown on pl. 2). *Lyropecten cerrosensis*, which occurs in the Repetto formation, is recorded from this locality. Though Potrero Canyon is only half a mile east of the adjoining Temescal Canyon, where the sandstone containing Pliocene fossils just mentioned is exposed, the field relation between the two Pliocene sections is undeterminable owing to the cover of the Santa Monica Plain. My attempt to fit this fauna into a chronologic climatic scheme [88] should be disregarded, as it was based on an assumption unsupported by independent evidence, and some of the faunal evidence is opposed to it.

Comparison with Pliocene faunas from Ventura Basin and San Diego region.—The Pliocene mollusks of the Ventura Basin and San Diego region have recently been described or recorded by Grant and Gale,[89] and the stratigraphy and faunal zones have been described by Gale.[90] The following Repetto fossils from the Los Angeles Basin are found in strata in the eastern part of the Ventura Basin assigned by Gale to the middle Pliocene: *Acila semirostrata*, *Anadara camuloensis*, *Lyropecten cerrosensis*, *Ostrea vespertina*, and *Corbula gibbiformis*. *Astraea* cf. *A. gradata*, from the Repetto formation, resembles *A. gradata* from strata in the eastern part of the Ventura Basin assigned to the middle Pliocene. *Lyropecten cerrosensis* and *Ostrea vespertina* occur in the San Diego formation, which was considered of middle Pliocene age by Gale.

In terms of Gale's age assignments, the few shallow-water fossils from the Repetto formation have a middle

[78] English, W. A., Geology and oil resources of the Puente Hills region, southern California: U. S. Geol. Survey Bull. 768, p. 42, 1926.

[79] Arnold, Ralph, in Eldridge, G. H., and Arnold, Ralph, The Santa Clara Valley, Puente Hills, and Los Angeles oil districts, southern California: U. S. Geol. Survey Bull. 309, p. 107, 1907.

[80] The locality number 3809 on the specimens of this species appears to be an error for 3909.

[81] Carson, C. M., Some new species from the Pliocene of southern California: Southern California Acad. Sci. Bull., vol. 24, pp. 31–35, p. 1, 1925. Carson, C. M., New molluscan species from the Californian Pliocene: Idem, vol. 25, pp. 49–62, pls. 1–4, 1926.

[82] Arnold, Ralph, New and characteristic species of fossil mollusks from the oil-bearing Tertiary formations of southern California: U. S. Nat. Mus. Proc., vol. 32, p. 527, 1907. Arnold, Ralph, in Eldridge, G. H., and Arnold, Ralph, op. cit. (Bull. 309), p. 153. Woodring, W. P., in Hoots, H. W., Geology of the eastern part of the Santa Monica Mountains, Los Angeles County, Calif.: U. S. Geol. Survey Prof. Paper 165, p. 119, 1931.

[83] Kew, W. S. W., Geology and oil resources of a part of Los Angeles and Ventura Counties, Calif.: U. S. Geol. Survey Bull. 753, pp. 84–85, 88 (localities 8139, 8144, 8145, 8151, 8153, 8154, 8157, 8159), 1924. Woodring, W. P., Pliocene deposits north of Simi Valley, Calif.: California Acad. Sci. Proc., 4th ser., vol. 19, pp. 57–64, 1930.

[84] Woodring, W. P., op. cit. (1930), pp. 61–63. Woodring, W. P., in Hoots, H. W., op. cit. (1931), p. 119.

[85] Moody, C. L., Fauna of the Fernando of Los Angeles: California Univ., Dept. Geology, Bull., vol. 10, pp. 39–62, pls. 1–2, 1916.

[86] Grant, U. S., in Soper, E. K., and Grant, U. S., Geology and paleontology of a portion of Los Angeles, Calif.: Geol. Soc. America Bull., vol. 43, pp. 1058–1067, 1932 [1933].

[87] Woodring, W. P., in Hoots, H. W., op. cit. (1931), p. 116.

[88] Idem, p. 117.

[89] Grant, U. S., IV, and Gale, H. R., Catalogue of the marine Pliocene and Pleistocene Mollusca of California: San Diego Soc. Nat. History Mem., vol. 1, 1931.

[90] Idem, pp. 26–39, 46–49. Faunal lists for the localities discussed may be assembled from the records in the systematic part of the memoir.

Pliocene aspect. If it is found that the shallow-water fossils represent horizons in the upper part of the Repetto formation, their assignment to the middle Pliocene is not in conflict with their occurrence in the Repetto formation, though a twofold subdivision of the Los Angeles Basin Pliocene appears preferable to a threefold subdivision. Larger fossils appear to be rare in the thick Pliocene section in the western part of the Ventura Basin. The stratigraphic position of Gale's middle Pliocene zone of the eastern part of the basin is not known in the western part of the basin, where the Repetto formation is recognized on the basis of its foraminiferal fauna.

DESCRIPTIONS OF SPECIES

MOLLUSKS

Family TURBINIDAE

Genus ASTRAEA ("Bolten") Röding

Subgenus POMAULAX M. E. Gray

Astraea (Pomaulax) cf. A. gradata Grant and Gale

Plate 5, figure 17

A large, poorly preserved and deformed *Astraea* in the Third Street tunnel collection was not mentioned by Arnold. It has a double undulated but not noded basal keel; and a wide band on the middle of the whorl has coarse nodes. Length (incomplete) 65.5 millimeters, greatest width (exaggerated by compression) 90.5 millimeters. The sculpture suggets *A. gradata* Grant and Gale,[91] expecially the form shown in their figures 3*a*, *b*. *A. gradata* was described from beds on both the north and south sides of Santa Clara Valley assigned to the middle Pliocene. This species was compared with the Recent *A. turbanica* (Dall), from Magdalena Bay, Lower California. The operculum in the aperture of the type and only specimen of *A. turbanica* in the collections of the National Museum has three narrow ribs, as compared with the broad ribs of opercula associated with shells of *A. gradata*, which more closely resemble opercula of the Recent Californian *A. undosa* (Wood). An incomplete operculum in the Elsmere Canyon collection (locality 4401) resembles, so far as it goes, the operculum associated with *A. gradata* figured by Grant and Gale. *A. breaensis* Carson,[92] from the Pliocene of the Puente Hills, is strongly sculptured and may be allied to *A. turbanica*, but the type and apparently only specimen has nodes elongated in a protractive pattern.

A. gradata and apparently also the Third Street tunnel form seem to be referable to *Pomaulax* M. E. Gray,[93] which is assigned subgeneric rank under *Astraea*.[94]

Family NATICIDAE

Genus LUNATIA Gray

Lunatia cf. L. caurina (Gould)

Plate 5, figure 19

A small high-spired naticid from Standard Oil Co. Baldwin-Cienega No. 105, Inglewood field, depth 2,221 feet (U. S. G. S. locality 13890), has a length of 8.4 millimeters and a width of 6.8 millimeters. The outer lip and basal margin are broken back. The umbilicus is almost completely filled with callus, but a narrow space is not covered. Very faint microscopic spiral markings are visible on the shell. This little shell resembles small Recent shells arranged under *L. caurina* (Gould).[95] Specimens from the type region of *L. caurina* are larger and stouter than the fossil, and the umbilicus is a little more open; on some the callus has a slight depression. Lots arranged under this species represent a range from Alaska to San Diego, and along the coast from Washington to California they represent a depth range of 20 to 822 fathoms. The umbilicus of *Euspira acosmita* Dall,[96] dredged at depths of 34 to 822 fathoms off the coast of southern California, is completely filled with callus in a manner strikingly suggestive of *Cryptonatica*. *E. acosmita* seems to have been described from a single specimen, and Dall thought that when the operculum was known it might turn out to be a *Cryptonatica*. The type may be a *Cryptonatica*, but this seems improbable, as smaller shells in several lots have the same kind of callus pad, and some shells in these lots have a horny operculum. On unworn shells the callus fills the umbilicus regardless of shell size; and inasmuch as the callus edge shows no signs of wear on the fossil from the Los Angeles Basin, it probably is not allied to this Recent form. The Recent shells include both low-spired and high-spired forms, the latter resembling the fossil in outline.

[91] Grant, U. S., IV, and Gale, H. R., Catalogue of the marine Pliocene and Pleistocene Mollusca of California: San Diego Soc. Nat. History Mem., vol. 1, pp. 818–819, pl. 31, figs. 1*a*, *b*, 3*a*, *b*, 5, 8, 9, 1931.

[92] Carson, C. M., New molluscan species from the Californian Pliocene: Southern California Acad. Sci. Bull., vol. 25, pp. 57, 59, pl. 4, figs. 3, 4, 1926.

[93] Gray, M. E., Figures of molluscous animals, vol. 4, p. 87, 1850. Subsequently designated type (Cossmann, Essais de paléoconchologie comparée, pt. 11, p. 149, 1918), *Trochus japonicus* Dunker, Recent, Japan. I have not seen any specimens of this species nor any description of the operculum. A more exhaustive search may reveal an earlier type designation of the Californian *Trochus undosus* Wood, which was Mrs. Gray's first species under *Pomaulax*. Stoliczka's claim that *Trochus undosus* Wood is the only species of *Pomaulax* (Cretaceous fauna of southern India, vol. 2, p. 357, 1868) is not considered a type designation.

[94] Röding, P. F., in Bolten, J. F., Museum Boltenianum, pt. 2, p. 79, 1798. Subsequently designated type (Suter, Manual of New Zealand Mollusca, p. 166, 1913), *Trochus imperialis* Gmelin, Recent, New Zealand.

[95] Gould, A. A., [Descriptions of shells from collection of Exploring Expedition]: Boston Soc. Nat. History Proc., vol. 2, p. 239, 1847 (as *Natica*, Straits of De Fuca); Mollusca and shells: U. S. Expl. Exped., vol. 12, pp. 212–213, figs. 254, 254*a*, 1852 (as *Natica*).

[96] Dall, W. H., Descriptions of new species of Mollusca from the north Pacific Ocean in the collection of the United States National Museum: U. S. Nat. Mus. Proc., vol. 56, p. 352, 1919.

The fossil is assigned to the genus *Lunatia* Gray,[97] the type of which has an open umbilicus. The type of *Natica ampullaria*, the type species of *Lunatia*, was figured by Delessert.[98] Deshayes,[99] following Reclus, considered *N. ampullaria* a high-spired form of *N. monilifera*. The Arctic and temperate Naticidae characterized by a horny operculum appear to be generically removed from the tropical *Polinices* Montfort;[1] it is improbable that they are allied to the Eocene *Euspira* Agassiz.[2]

An undetermined naticid—Arnold's "*Neverita recluziana* Petit"[3]—is represented by an imperfect poorly preserved specimen in the Third Street tunnel collection. Another undetermined naticid, possibly *Lunatia*, was obtained from a core in Union Oil Co. Hellman No. 10, Dominguez field, at a depth of 4,193 feet.

Family CYMATIIDAE

Genus FUSITRITON Cossmann

Fusitriton aff. F. oregonensis (Redfield)

Plate 5, figures 21–23

Priene oregonensis Redfield var. *angelensis* Arnold, U. S. Nat. Mus. Proc., vol. 32, pp. 527 (list), 536–537, pl. 50, fig. 11, 1907. Third Street tunnel, Los Angeles; probably equivalent of middle Fernando formation, lower Pliocene.

Grant, in Soper and Grant, Geol. Soc. America Bull., vol. 43, p. 1058 (Arnold's list), 1932 (1933). Third Street tunnel, Los Angeles; middle Pliocene.

Priene oregonensis Redfield var.? *angelensis* Arnold. Arnold, in Eldridge and Arnold, U. S. Geol. Survey Bull. 309, pp. 152 (list), 252, pl. 40, fig. 11, 1907. Third Street tunnel, Los Angeles; Fernando formation, lower Pliocene.

Ranella (*Priene*) *oregonensis* (Redfield) variety *angelensis* (Arnold) Grant and Gale, San Diego Soc. Nat. History Mem., vol. 1, pp. 40 (discussion), 738, 1931.

?*Argobuccinum* n. sp. (an uncited worker in) Reed, Geology of California, p. 230, 1933. Repetto formation; Pliocene.

A *Fusitriton* closely resembling *F. oregonensis*. Varices weak or absent. Ribs generally subdued and generally relatively closely spaced on later whorls of large shells.

Length (incomplete) 73 millimeters, width (crushed) 42 millimeters (holotype of *angelensis*). Length of body whorl about 75.8 millimeters, width (crushed) 65.5 millimeters (fragment of large specimen from Third Street tunnel). Length (incomplete) about 70 millimeters, width (crushed) 37.5 millimeters (largest core specimen, pl. 5, fig. 21).

This *Fusitriton* is the most abundant gastropod in the collection of core fossils and is represented by 11 specimens in the collection from the Third Street tunnel. The thin shells are broken and deformed, and the characters are not entirely clear. Arnold's claim that the canal is longer and less recurved than in the modern *F. oregonensis* (Redfield)[4] cannot be confirmed. On most of the fossils the ribs on the later whorls of large shells are more subdued and more closely spaced than on Recent shells of the same size; but this character is not uniform, and the variation apparently is not determined by the condition of the material. On the holotype of *angelensis* and on other specimens from the Third Street tunnel the ribs are hardly more closely spaced than on some modern shells (pl. 5, fig. 22); on others from this lot they are more subdued and more closely spaced (pl. 5, fig. 23). A moderately large specimen from Union Oil Co. Callender No. 22, Dominguez field, depth 4,146 feet, has exceptionally subdued ribs (pl. 5, fig. 21); a fragment of a moderately large shell from Standard Oil Co. Baldwin No. 74, Montebello field, depth 1,955 to 1,975 feet, had strong widely spaced ribs. Small shells have strong ribs of varying spacing. Relatively strong varices are absent on the fossils, a condition possibly due to poor preservation, for the relative prominence of a varix may be altered by flattening along the varix. Better material may show characters to differentiate *angelensis*, or it may show that different forms are represented at different horizons. It is doubtful, however, whether better material will be forthcoming, as these thin shells are almost certain to be deformed by compaction of the sediments. Some specimens that are compressed in a plane at right angles to the long axis have assumed a grotesque outline.

F. oregonensis is recorded from many Pliocene localities,[5] including the Ventura Basin[6] and the Puente Hills.[7] Arnold cited *Priene oregonensis* var. *angelensis* from the Pliocene of Elsmere Canyon,[8] near Camulos,[9] and the Puente Hills.[10] No specimens of *Fusitriton* are now recognized in the collection from Elsmere Canyon. Seven poorly preserved specimens collected

[97] Gray, J. E., A list of the genera of Recent Mollusca, their synonyma and types: Zool. Soc. London Proc., 1847, p. 149. Originally designated type, *N*[*atica*] *ampullaria* Lamarck (considered a form of *Natica monilifera* Lamarck), Recent, Europe.

[98] Delessert, B., Recueil de coquilles décrites par Lamarck, pl. 32, figs. 11*a*, *b*. 1841.

[99] Deshayes, G. D., Lamarck's Histoire naturelle des animaux sans vertèbres, 2d ed., vol. 8, p. 625, 1838. See also Bucquoy, E., Dautzenberg, Ph., and Dollfus, G., Les mollusques marins du Roussillon, vol. 1, pp. 146–148, 1883.

[1] Montfort, Denys de, Conchyliologie systématique, vol. 2, pp. 222–223, 1810. Originally designated type, *Polinices albus* Montfort (=*Natica mammillaris* Lamarck =*Natica brunnea* Link), Recent, West Indies.

[2] Agassiz, L., in James Sowerby's Mineral-Conchologie Grossbrittaniens, pp. 14, 15, 17, 1839. [For date see Sherborn, Index animalium, 1801–50, p. cxviii, 1922.] Subsequently designated type (Dall, U. S. Geol. Survey Prof. Paper 59, p. 87, 1909), *Natica glaucinoides* Sowerby, Eocene, England. [Dall designated *Natica labellata* Lamarck as the type, but in the preceding synonymy he stated that *Natica glaucinoides*=*Natica labellata*.]

[3] Arnold, Ralph, New and characteristic species of fossil mollusks from the oil-bearing Tertiary formations of southern California: U. S. Nat. Mus. Proc., vol. 32, p. 527 (list), 1907. Arnold, Ralph, in Eldridge, G. H., and Arnold, Ralph, The Santa Clara Valley, Puente Hills, and Los Angeles oil districts, southern California: U. S. Geol. Survey Bull. 309, p. 152 (list), 1907. (The figured specimen is from Elsmere Canyon.)

[4] Redfield, J. H., Description of some new species of shells: New York Lyceum Nat. History Annals, vol. 4, pp. 165–166, pl. 11, figs. 2*a*, *b*, 1848 (as *Triton;* Straits of St. Juan de Fuca, Oregon).

[5] See Grant, U. S., IV, and Gale, H. R., op. cit., p. 737.

[6] Merriam, J. C., in Watts, W. L., Oil and gas yielding formations of California: California State Min. Bur. Bull. 19, p. 222 (list), 1901 (as *Priene*, Piru Creek and vicinity). For other Ventura Basin records see Grant and Gale, op. cit., p. 737, who figured a specimen with relatively strong varices from the upper Pliocene of Sulphur Canyon.

[7] Merriam, J. C., in Watts, W. L., idem, p. 222 (list, as *Priene* aff. *P. oregonensis*).

[8] Arnold, Ralph, op. cit., p. 526 (list). Arnold, Ralph, in Eldridge, G. H., and Arnold, Ralph, op. cit., p. 25 (list).

[9] Idem, p. 24 (list).

[10] Idem, p. 107 (list).

by Eldridge in the Puente Hills (locality 3907, Olinda Hill, south of western wells of Fullerton Consolidated Oil Co.) seem to be more uniformly similar to the Recent *oregonensis* in strength and spacing of ribs, and one has two strong varices near the outer lip. It is not known whether this collection represents the Repetto formation or a higher Pliocene horizon. According to Martin's figure, some specimens from the Los Angeles Basin resemble the incomplete shell from Lawson's Wildcat series of the Eel River Basin in northern California (Pliocene) that served as the type of *Argobuccinum scotiaensis* Martin.[11]

F. oregonensis is represented in the collections of the National Museum from localities extending from Bering Sea to San Nicolas Island, California. Dall [12] gave the range as "from the line of floating ice in winter in Bering Sea near the Pribiloff Islands, south on the west to the Okhotsk Sea and Japan, and on the east to San Nicolas Island, California; San Diego in deeper water (Raymond)." There are no large shells in the National Museum from localities south of Puget Sound; the largest one south of that region was dredged at a depth of 1,081 to 1,100 fathoms off San Nicolas Island (no. 210537; length (tip broken) 72 millimeters, width 41 millimeters). A fragment from the Third Street tunnel indicates a size about as large as the largest Recent shells. Of the 50 lots from Alaskan waters, 31 have depth records ranging from 6 to 230 fathoms. Southward along the coast of Washington, Oregon, and California the shells were dredged at depths of 40 to 1,081 (to 1,100) fathoms, with the exception of two young shells from Monterey that have no depth record.

Grant and Gale [13] stated that *Ranella* (*Priene*) *cancellata* (Lamarck)[14] may be the proper name for *oregonensis*. This matter was discussed many years ago by Von Martens,[15] Lischke,[16] and Dall,[17] all of whom considered the two species well differentiated. Dall pointed out that Lamarck cited South America for *Triton cancellatum* and that a species agreeing with his figure is represented in the National Museum by specimens from Patagonia (Cape Horn and vicinity).

Triton cancellatum is the originally designated type of *Fusitriton* Cossmann,[18] characterized by a relatively long canal, heavy parietal denticle, and relatively weak varices. *F. cancellatus* and *F. oregonensis* are closely allied, though separated by a gap of several thousand miles. In California paleontologic literature *oregonensis* is generally assigned to *Argobuccinum* or *Priene*. *Argobuccinum* dates from Herrmannsen's usage [19] and need not be compared with *Fusitriton; Argobuccinum* Mörch,[20] the usage followed in many accounts of California fossils, is a homonym. *Priene* H. and A. Adams [21] has a short canal, denticulate inner lip, and lirate outer lip. *Cryotritonium* Von Martens [22] appears to be the same genus as *Fusitriton*. Von Martens' publication bears the date 1903 on the title page, but according to a notation by Dall on his separate, Thiele received his copy January 30, 1904, and the publication was issued in the later part of January 1904. It was included in the 1903 issue of the Zoological Record, and the date 1903 is assigned to *Cryotritonium* in the Index zoologicus, No. II. Cossmann's publication bears the date December 1903.

F. oregonensis is recorded as a Pliocene and Recent species in Japan,[23] and the genus is recognized in New Zealand.[24]

[11] Martin, Bruce, Descriptions of new species of fossil Mollusca from the later marine Neocene of California: California Univ., Dept. Geology, Bull., vol. 8, pp. 192-193, pl. 21, fig. 3, 1914.

[12] Dall, W. H., Summary of the marine shell-bearing mollusks of the northwest coast of America: U. S. Nat. Mus. Bull. 112, p. 141, 1921.

[13] Grant, U. S., IV, and Gale, H. R., op. cit., p. 737.

[14] Lamarck, Tableau encyclopédique et méthodique, Mollusques et polypes divers, pl. 415, fig. 1 (unnamed; Liste, p. 4, 1816 (as *Triton*)). [I have not seen the "Liste" cited by Sherborn (Index animalium, 1801-50, p. 1034, 1924). The "Liste des objects représentés dans les planches de cette livraison" (Sherborn, C. D., and Woodward, B. B., On the dates of the 'Encyclopédie méthodique' (Zoology): Zool. Soc. London Proc., 1893, p. 584) is not in either of two copies of this part of the Encyclopédie at the National Museum. Perhaps it was issued with some other part published at about the same time.] Lamarck, Histoire naturelle des animaux sans vertèbres, vol. 7, p. 187, 1822 (as *Triton;* mers de l'Amérique méridionale).

[15] Von Martens, E., Conchylien aus Alaska: Malakozool. Blätter, vol. 19, pp. 80-82, 1872.

[16] Lischke, C. E., Japanische Meers-Conchylien, pt. 2, pp. 166-167, 1871; pt. 3, pp. 31-32, 1874.

[17] Dall, W. H., Report on Bering Island Mollusca collected by Mr. Nicholas Grebnitzki: U. S. Nat. Mus. Proc., vol. 9, pp. 212-214, 1886.

[18] Cossmann, M., Essais de paléoconchologie comparée, pt. 5, p. 109, 1903.

[19] Hermannsen, A. N., Indicis generum malacozoorum, pt. 1, p. 77, 1846 (cited as of Klein). Originally designated type, *Ranella argus* Linné [*Murex argus* Gmelin], Recent, "India."

[20] Mörch, O. A. L., Yoldi catalog, p. 105, 1852 (cited as of Klein).

[21] Adams, Henry, and Adams, Arthur, The genera of Recent Mollusca, vol. 2, p. 654, 1858. Subsequently designated type (Cossmann, op. cit., p. 109), *Triton scaber* King, Recent, Chile.

[22] Von Martens, in Von Martens and Thiele, Die beschalten Gastropoden der deutschen Tiefsee-Expedition, pt. A, pp. 38, 40, 1903 [1904?]. Monotype, *Tritonium* (*Cryotritonium*) *murrayi* (E. Smith) (*Lampusia* (*Priene*) *murrayi* Smith), Recent, Cape of Good Hope.

[23] For citations see Grant, U. S., IV, and Gale, H. R., op. cit., pp. 737-738.

[24] Finlay, H. J., A further commentary on New Zealand molluscan systematics: New Zealand Inst. Trans., vol. 57, p. 399, 1926.

Specimens of Fusitriton aff. F. oregonensis (Redfield) from Repetto formation examined

Locality	Specimens	Locality	Specimens
Third Street tunnel, Los Angeles; Homer Hamlin. U. S. G. S. locality 3426.	Holotype of *oregonensis angelensis* and 10 other broken and deformed specimens, 2 of which are figured.	Union Oil Co. Sansinena No. 11, SE¼ sec. 30, T. 2 S., R. 10 W., Puente Hills, depth 818 feet. Collection of Union Oil Co.	3 broken, crushed specimens of medium size.
100 feet northeast and 90 feet northwest from northeast corner of Second and Hill Streets, Los Angeles; about 4 feet above level of Hill Street; W. H. Holman. U. S. G. S. locality 13862.	Broken, crushed specimen of medium size, sculptured with strong, widely spaced ribs.	Standard Oil Co. Emery No. 52, West Coyote field, depth 3,625 to 3,626 feet. U. S. G. S. locality 13878.	Small, poorly preserved, slender (crushed?) specimen; fragment of small specimen.
Standard Oil Co. Temple No. 19, Montebello field, depth 1,265 feet. U. S. G. S. locality 13869.	Broken, crushed, slender specimen of medium size, sculptured with strong ribs. Apparent sutural collar probably due to telescoping.	Same well, depth 3,653 feet. U. S. G. S. locality 13878*b*.	Small, broken, slender specimen with sculptured widely spaced ribs.
Standard Oil Co. Baldwin No. 74, Montebello field, depth 1,955 to 1,975 feet. U. S. G. S. locality 13865.	Fragment of large specimen sculptured with moderately strong ribs; fragment of canal.	Same well, depth 3,663 feet. U. S. G. S. locality 13878*c*.	Fragment of specimen of medium size.
		Union Oil Co. Callender No. 22, Dominguez field, depth 4,146 feet. U. S. G. S. locality 13895.	Incomplete large crushed specimen sculptured with exceptionally subdued ribs (figured).

Family "NASSIDAE"

Genus "NASSA Lamarck"

"Nassa" hamlini Arnold

Plate 5, figure 16

Nassa hamlini Arnold, U. S. Nat. Mus. Proc., vol. 32, pp. 527 (list), 537–538, pl. 50, fig. 9, 1907. Third Street tunnel, Los Angeles; probably middle Fernando formation, lower Pliocene.

Arnold, in Eldridge and Arnold, U. S. Geol. Survey Bull. 309, pp. 152 (list), 252, pl. 40, fig. 9, 1907. Third Street tunnel, Los Angeles; Fernando formation, lower Pliocene.

Grant, in Soper and Grant, Geol. Soc. America Bull., vol. 43, p. 1058 (Arnold's list), 1932 (1933). Third Street tunnel, Los Angeles; middle Pliocene.

Nassarius (Uzita) hamlini (Arnold) Grant and Gale, San Diego Soc. Nat. History Mem., vol. 1, p. 678, 1931.

Nassarius (?Uzita) hamlini (Arnold) Grant, in Soper and Grant, Geol. Soc. America Bull., vol. 43, p. 1058 (list), 1932 [1933]. Third Street tunnel, Los Angeles; middle Pliocene (Arnold's record).

A moderately slender *"Nassa"* of medium size. Apex blunt. Sculpture consisting of narrow widely spaced ribs (11 on body whorl of holotype, not including varix at outer lip) and narrow weak spiral threads (4 on penultimate whorl of holotype) that override the ribs in subdued form. Outer lip varicose, the interior smooth. Canal not known. Parietal wall bearing a denticle. Siphonal fasciole bordered by a shallow groove. Length (incomplete) 15.4 millimeters, width 8.7 millimeters (holotype).

This species is readily recognized by its sculpture. The type is the only specimen in the Third Street tunnel collection. A young shell from the Hollenbeck well in Los Angeles (in Hollenbeck Park approximately on Boyle Avenue, according to Hamlin's manuscript map) was identified by Arnold as *hamlini*. Inasmuch as this shell has retractive ribs, the identification is considered doubtful. The core specimens are poorly preserved. In addition to this material, four imperfect specimens collected from the transition zone between the Repetto and Pico formations in the Repetto Hills at locality 13614 are identified as *hamlini*. They show 12 or 13 ribs on the body whorl and 4 or 5 spirals on the penultimate whorl and are a little larger than the type (incomplete length 18.3 millimeters, width 10.5 millimeters). Eight other specimens from this locality, mostly molds that have a little shell material, may represent this species.

"Nassa" hamlini is characterized by subdued sculpture, varicose outer lip, and by the absence of lirations or wrinkles on the inner lip and on the interior of the outer lip. Though the type appears to be an adult shell, the interior of the outer lip is quite smooth. No fossil or living species similar to *hamlini* has been found in California, and this species may be a useful indicator of the Repetto or the transition zone between the Repetto and Pico. Perhaps *hamlini* is most closely allied to *Nassa townsendi* Dall,[25] the type and only specimen of which was dredged near the Galapagos Islands at a depth of 812 fathoms. The edge of the

[25] Dall, W. H., Preliminary report on the collection of Mollusca and Brachiopoda obtained in 1887–88 [*Albatross* Rept.]: U. S. Nat. Mus. Proc., vol. 12, pp. 326–327, pl. 12, fig. 9, 1889.

outer lip is broken on this specimen, but the interior is smooth; the inner lip is smooth; and the posteriormost two spirals are stronger than in *hamlini*. *Alectrion goniopleura* Dall,[26] from a depth of 633 fathoms near the Galapagos Islands, evidently is closely allied to *townsendi*, but the only specimen is a small defective shell that differs in sculpture from that species.

Nassarius Duméril is of doubtful validity as a substitute name for the Lamarckian *Nassa*, as was recognized when it was recently used.[28] But it is to be regretted that *Nassarius* was used, as Pilsbry and Lowe's claim that it is to be used for the group of *Buccinum arcularia* Linné appears to be well founded.[29] It is not known to what genus of nassid gastropods "*N.*" *hamlini* belongs.

Specimens of "Nassa" hamlini from Repetto formation examined

Locality	Specimens
Third Street tunnel, Los Angeles; Homer Hamlin. U. S. G. S. locality 3426.	Holotype.
Standard Oil Co. Emery No. 52, West Coyote field, depth 3,695 feet. U. S. G. S. locality 13878d.	A poorly preserved crushed specimen (figured).
Union Oil Co. Bell No. 69, Santa Fe Springs field, depth 3,642 feet. Collection of Union Oil Co.	2 poorly preserved specimens.
Ohio Oil Co. Recreation No. 1, Playa del Rey field, depth 3,821 feet. Collection of Union Oil Co.	A poorly preserved specimen.

Specimens of "Nassa" hamlini from other horizons examined

Repetto Hills, slope on west side of Atlantic Boulevard, 0.33 mile S. 32° E. from 735-foot triangulation station between Garvey Avenue and Atlantic Boulevard; W. P. Woodring and Alex Clark. U. S. G. S. locality 13614. Transition zone between Repetto formation and Pico formation.	4 incomplete specimens and 8 poorly preserved specimens (identification of latter doubtful).

Family NEPTUNEIDAE?

Genus PLICIFUSUS Dall?

Plicifusus? sp.

Plate 5, figure 18

Pleurotoma sp. undet., Arnold, U. S. Nat. Mus. Proc., vol. 32, p. 527 (list), 1907. Third Street tunnel, Los Angeles; middle Fernando formation, lower Pliocene.

Grant, in Soper and Grant, Geol. Soc. America Bull., vol. 43, p. 1058 (Arnold's list), 1932 [1933]. Third Street tunnel, Los Angeles; middle Pliocene.

Pleurotoma sp. indet., Arnold, in Eldridge and Arnold, U. S. Geol. Survey Bull. 309, p. 152 (list), 1907. Third Street tunnel, Los Angeles; Fernando formation, lower Pliocene.

An incomplete crushed specimen in the Third Street tunnel collection, evidently Arnold's *Pleurotoma*, has a length (incomplete) of 47.2 millimeters, and a width (modified by compression) of 29.9 millimeters. The growth lines are misleading in the figured view, as the part of the body whorl adjoining the suture is telescoped and broken. A small area on the opposite side shows that the lines bend forward near the suture. Faint ribs are visible on the penultimate whorl. This shell is probably neptuneid and may represent the genus *Plicifusus* Dall,[27] a few species of which reach the California coast in deep water.

A poorly preserved crushed shell from Union Oil Co. Callender No. 17, Dominguez field, depth 5,463 feet, may represent another neptuneid form. It shows some indication of spiral sculpture.

Family BUCCINIDAE?

Genus BUCCINUM Linné?

Buccinum? sp.

Plate 5, figure 15

Buccinum sp. undet., Arnold, U. S. Nat. Mus. Proc., vol. 32, p. 527 (list), 1907. Third Street tunnel, Los Angeles; middle Fernando formation, lower Pliocene.

Grant, in Soper and Grant, Geol. Soc. America Bull., vol. 43, p. 1058 (Arnold's list), 1932 [1933]. Third Street tunnel, Los Angeles; middle Pliocene.

Buccinum sp. indet., Arnold, in Eldridge and Arnold, U. S. Geol. Survey Bull. 309, p. 152 (list) 1907. Third Street tunnel, Los Angeles; Fernando formation, lower Pliocene.

Buccinum sp., Gale, in Grant and Gale, San Diego Soc. Nat. History Mem., vol. 1, p. 40 (discussion), 1931.

The incomplete deformed specimen from the Third Street tunnel identified by Arnold as *Buccinum* probably represents that genus. The length (incomplete) is 42.8 millimeters, and the width (modified by deformation) 25.6 millimeters. The whorls have a strong sutural constriction. In outline this specimen resembles the round-shouldered form of *Buccinum viridum* Dall,[30]

[26] Dall, W. H., The Mollusca and the Brachiopoda [*Albatross* Rept.]: Harvard College Mus. Comp. Zoology Bull., vol. 43, pp. 308-309, 1908.

[27] Dall, W. H., Illustrations and descriptions of new, unfigured, or imperfectly known shells, chiefly American, in the U. S. National Museum: U. S. Nat. Mus. Proc., vol. 24, p. 523, 1902 (as subgenus of *Tritonofusus*). Originally designated type, *Fusus kroyeri* Moller, Recent, north Atlantic, circumboreal.

[28] Woodring, W. P., Miocene mollusks from Bowden, Jamaica; pt. 2, Gastropods and discussion of results: Carnegie Inst. Washington Pub. 385, pp. 264-265, 1928. See this discussion for citations.

[29] Pilsbry, H. A., and Lowe, H. N., West American and Central American mollusks collected by H. N. Lowe, 1929-31: Philadelphia Acad. Nat. Sci. Proc., vol. 84, p. 68, 1932.

[30] Dall, W. H., Preliminary report on the collection of Mollusca and Brachiopoda obtained in 1887-88 [*Albatross* Rept.]: U. S. Nat. Mus. Proc., vol. 12, p. 320, pl. 6, fig. 9, 1889.

which ranges down the coast from Alaska and has been dredged at depths of 236 to 795 fathoms off California. The fossil apparently is more slender, and no spiral sculpture is discernible.

Family SOLEMYACIDAE

Genus SOLEMYA Lamarck

Subgenus ACHARAX Dall

Solemya (Acharax) aff. S. johnsoni Dall

Plate 5, figure 14

An *Acharax* of medium size with the opisthodetic ligament preserved. Posterior part of shell sculptured with weak, closely spaced radial ribs and shallow grooves; part extending down from umbonal region sculptured with very weak ribs and grooves; anterior part sculptured with an indeterminate number (4 on preserved part of left valve) of strong grooves bearing a midrib. On the left valve the first groove from the umbonal region is relatively weak and the midrib is faint; on the others the groove and midrib are strong. On the right valve the first groove is relatively weak and the midrib is wide and low; on the second groove the midrib is not quite so strong as on the left valve; and the other grooves are not preserved. Posterior end bearing coarse irregular concentric ripples.

Restored length about 45 millimeters, height 15.8 millimeters.

The genus *Solemya* is represented by the greater part of a paired gaping shell. The valves are slightly sheared except where they are held together by the ligament. This specimen was obtained from Standard Oil Co. Baldwin No. 73, Montebello field, at a depth of 3,340 to 3,358 feet (U. S. G. S. locality 13864). The upper edge of the proximal part of the thick ligament is broken, and part of the right valve is broken away.

The type lot of *Solemya johnsoni* Dall [31] is from *Albatross* station 3010 (off California, 1,005 fathoms), the only locality mentioned in the original description. I am indebted to Dr. J. P. E. Morrison for searching the alcoholic collection in the National Museum for the material from this locality, which was not included in the catalog of the alcoholic collection. The material from locality 3010, labeled *johnsoni* in Dall's writing, consists of four paired shells that have a virtually intact periostracum. One that appears to agree with the figure is regarded as the holotype. The valves of this specimen are cracked, and a small part of the anterior end of the periostracum is missing. This shell has a length including the periostracum of about 112 millimeters. A lot of three paired shells, two of which have the periostracum intact, from *Albatross* station 3399 (off northern Ecuador, depth 1,740 fathoms) is labeled "types" of *johnsoni* in Dall's writing (alcholic collection No. 3175). The largest of these shells has a length including the periostracum of about 73 millimeters. Later it was claimed that *S. johnsoni* was described from a specimen collected off the coast of Oregon.[32] *Solemya agassizi* Dall,[33] which was given a range from the Gulf of California to Peru, was differentiated from *johnsoni* on the grounds that it has 6 or 7 anterior radial channels, as compared with 9 to 12 on *S. johnsoni*, and that the periostracum of *johnsoni* has a subtriangular outline. The type of *agassizi* is a large shell (U. S. Nat. Mus. 106885) that has a length exclusive of the periostracum of about 143 millimeters and was dredged off Panama at a depth of 1,672 fathoms. The basal part has been broken since the drawing was made, or the drawing is a restoration. The anterior part of the shell has six grooves; some sculpture on the umbonal part of the shell is not shown on the drawing. It appears doubtful whether two species are represented in the National Museum collections. All the specimens in the dried collection, representing localities from Oregon to Ecuador, are labeled *agassizi* in Dall's writing, or were so labeled under his direction. They have five or six grooves bordered by flat or slightly raised edges, but on some there is a transition from deep grooves to shallow grooves and ribs, and the number of grooves is a matter of individual judgment. No specimen has the entire periostracum preserved. The specimens in the type lot of *johnsoni* have seven distinct grooves; those from station 3399 have seven to nine.

In some of the specimens labeled *agassizi* the central part of the groove is inflated but does not form a distinct midrib as on the fossil from the Los Angeles Basin. More specimens are needed to determine the significance of the midrib; it apparently is not so strong on the right valve.

Solemya has been recorded from the Pliocene of the Eel River Basin, in northern California,[34] but this is the first record in the southern California Pliocene. *Solemya ventricosa* Conrad [35] was described at an early date from the Miocene of Astoria, Oreg. Figure 7 appears to have been based on a large, paired, gaping specimen (U. S. Nat. Mus. 3567) on which the greater part of the right valve has a thin layer of shell material. The mineralized ligament is preserved. The specimen does not entirely agree with the figure, as the extreme posterior end is missing and more of the lower part

[31] Dall, W. H., On some new or interesting West American shells obtained from the dredgings of the U. S. Fish Commission steamer *Albatross* in 1888, and from other sources: U. S. Nat. Mus. Proc., vol. 14, p. 189, 1891; Report on Mollusca and Brachiopoda dredged in deep water, chiefly near the Hawaiian Islands, with illustrations of hitherto unfigured species from Northwest America: U. S. Nat. Mus. Proc., vol. 17, pp. 712-713, 731, pl. 25, fig. 1, 1895.

[32] Dall, W. H., The Mollusca and the Brachiopoda [*Albatross* Rept.]: Harvard College Mus. Comp. Zoology Bull., vol. 43, pp. 365-366, 1908.

[33] Idem, pp. 365-366, pl. 16, fig. 10.

[34] Martin, Bruce, The Pliocene of middle and northern California: California Univ., Dept. Geology, Bull., vol. 9, pp. 238 (list), 240 (list), 254 (list), 1916 (as *Solemya ventricosa* Conrad).

[35] Conrad, T. A., in Dana, J. D., U. S. Exploring Expedition, Geology, p. 723, pl. 17, figs. 7, 8, 1849.

below the umbonal region is preserved. The whole rock mass has been broken up and part of it glued together. The sculpture on the anterior part of the shell is not so strong as on the figure, and the number of grooves is indeterminable. The specimen under U. S. Nat. Mus. 3486 closely agrees with figure 8, aside from a small upper posterior part that is missing. *Donax? protexta* Conrad [36] (U. S. Nat. Mus. 3613) is probably a mold of a small *Solemya*, as Woodward,[37] Meek,[38] and Dall [39] concluded, probably a small *S. ventricosa*. Tegland [40] identified as *ventricosa* a relatively high form, higher than Conrad's specimens, from the Miocene of Washington. A *Solemya* from the upper Oligocene of Washington has been described as *S. dalli* Clark,[41] and the genus has been recognized in the California Eocene.[42]

The relations of the subgenera of *Solemya* were discussed by Dall. In *Solemya* s. s.[43] a narrow internal arm of the ligament extends in front of the chondrophore; in the subgenus *Acharax* [44] the ligament is thicker and wholly external, and the sculpture is stronger.

Family NUCULIDAE

Genus ACILA H. and A. Adams

Subgenus ACILA s. s.

Acila (Acila) semirostrata (Grant and Gale)

Plate 5, figures 10, 11

Nucula (*Acila*) *semirostrata* Grant and Gale, San Diego Soc. Nat. History Mem., vol. 1, pp. 113–115, figs. 2a, 2b, 3a, 3b, 1931. Near San Martinez Grande Canyon; middle Pliocene.

Acila (*Acila*) *semirostrata* (Grant and Gale) Schenck, Mus. royale histoire nat. Belgique, vol. 11, no. 14, p. 4, table, 1935; Geol. Soc. America Special Paper 4, p. 94, pl. 13, figs. 2, 8, 10, text fig. 8, 1936.

A moderately large, short *Acila*. Posterior end truncated, slightly prolonged at the ventral margin. Posterior sinus moderately strong. The apex of the main chevron extends downward in an arc from the umbo. An inverted chevron lies in the posterior sinus, and a minor chevron on the rostrum back of the sinus.

Length 22 millimeters, height 18.5 millimeters.

A flattened right valve from Wilmington Terminal Oil Co. Banning No. 1, Wilmington field, depth 3,265 feet (U. S. G. S. locality 13916), has the outline of *semirostrata*. Most of the shell is on the impression. The inverted chevron in the sinus and the minor chevron behind it are not mentioned in the original description and do not show on the figure, but Schenck described "secondary bifurcation especially noticeable on disk posterior to sinus." The Recent Japanese *A. mirabilis* (Adams and Reeve)[45] has an inverted chevron and minor chevron, but large specimens have a double or multiple main chevron. This species also is larger, more elongate, and more strongly rostrate than *semirostrata*.

Acila s. s.[46] appears in the Oligocene of the Pacific coast, and *semirostrata* is the latest species known there. This species appears to range from the Repetto formation into the Pico formation. Poorly preserved specimens agreeing in outline with *semirostrata* occur in the transition zone between the Repetto and Pico formations in the Repetto Hills (locality 13616, west side of valley between Atlantic Boulevard and Garvey Avenue, 0.32 mile S. 30° W. from 735-foot triangulation station). Specimens collected from a concretion in the Pliocene sandy silt unconformably underlying Pleistocene foraminiferal sand on the east side of Newport Lagoon are similar to *semirostrata*, as I remember them, but the collection has been mislaid. The Pliocene silt at this locality carries a meager foraminiferal fauna of Pico aspect, according to a communication from Mr. D. D. Hughes.

There appears to be no reasonable doubt that *Nucula divaricata* Hinds belongs in the rostrate division of *Acila*. Hinds' figure represents a small shell with an indistinct rostrum and sinus. Schenck and other workers considered *mirabilis* conspecific with *divaricata*, but apparently small shells from the type region of *divaricata* have not been available for comparison with young shells of *mirabilis*. The smallest specimen of *mirabilis* in the collections of the National Museum (length 15 millimeters) is larger than Hinds' figure and has a more extended posterior end. On the ground that *divaricata* was described as having 22 to 24 posterior [anterior] teeth, Hanley [47] considered the two forms distinct.

[36] Conrad, T. A., in Dana, J. D., op. cit., pp. 723–724, pl. 17, fig. 9.

[37] Woodward, S. P., in Carpenter, P. P., Report on the present state of our knowledge with regard to the Mollusca of the west coast of North America; British Assoc. Adv. Sci. Rept. for 1856, p. 367, 1857.

[38] Meek, F. B., Check list of the invertebrate fossils of North America; Miocene: Smithsonian Misc. Coll., no. 183, p. 30, 1864.

[39] Dall, W. H., The Miocene of Astoria and Coos Bay, Oregon: U. S. Geol. Survey Prof. Paper 59, p. 101, 1909.

[40] Tegland, N. M., The fauna of the type Blakeley upper Oligocene of Washington: California Univ., Dept. Geol. Sci., Bull., vol. 23, pp. 102–103, pl. 4, figs. 11, 12, 1933.

[41] Clark, B. L., Pelecypoda from the marine Oligocene of western North America: California Univ., Dept. Geol. Sci., Bull., vol. 15, p. 73, pl. 22, fig. 3, 1925. Tegland, N. M., op. cit., pp. 103–104, pl. 4, figs. 1–10.

[42] Clark, B. L., and Woodford, A. O., The geology and paleontology of the type section of the Meganos formation (lower middle Eocene) of California: California Univ., Dept. Geol. Sci., Bull., vol. 17, p. 85, pl. 14, fig. 1, 1927. According to Clark and Woodford, there is an earlier record of the genus from the Eocene of the Pacific coast, which I have not found.

[43] Lamarck, Histoire naturelle des animaux sans vertèbres, vol. 5, pp. 488–489, 1818. Subsequently designated type (Children, J. G., Lamarck's genera of shells: Quart. Jour. Sci., vol. 14, p. 300, 1823; quoted from Kennard, A. S., Salisbury, A. E., and Woodward, B. B., The types of Lamarck's genera of shells as selected by J. G. Children in 1823: Smithsonian Misc. Coll., vol. 82, no. 17, p. 7, 1931), *Solenomya mediterranea* Lamarck [emendation for *Solemya*] [= *Tellina togata* Poli, fide Bucquoy, E., Dautzenberg, Ph., and Dollfus, G., Mollusques marins du Roussilon, vol. 2, p. 718, 1898; = *Mytilus solen* von Salis Marschlins, fide Dall, W. H., op. cit., p. 362, 1908], Recent, Mediterranean.

[44] Dall, W. H., A revision of the Solenomyacidae: Nautilus, vol. 22, p. 2, 1908; The Mollusca and the Brachiopoda [*Albatross* Rept.]: Harvard College Mus. Comp. Zoology Bull., vol. 43, p. 364, 1908. Originally designated type, *S. johnsoni* Dall.

[45] Adams, A., and Reeve, L., Zoology of the voyage of H. M. S. *Samarang;* Mollusca, p. 75, pl. 21, fig. 8, 1850 (as *Nucula*).

[46] Adams, H. and A., The genera of Recent Mollusca, vol. 2, p. 545, 1858. Subsequently designated type (Stoliczka, Cretaceous fauna of southern India, vol. 3, p. 325, 1871), *Nucula divaricata* Hinds, Recent, China Sea.

[47] Hanley, Sylvanus, Monograph of the family Nuculidae (Sowerby's Thesaurus conchyliorum), p. 155, 1860.

Subgenus TRUNCACILA Schenck?

Acila? (Truncacila?) cf. A. castrensis (Hinds)

Plate 5, figure 20

A right valve from Union Oil Co. Farwell No. 17, Santa Fe Springs field, depth 5,631 feet (U. S. G. S. locality 13885), appears to be similar to *Acila castrensis*. The abrupt posterior truncation and the rather pointed anterior end may be due to deformation. The inner shell material is preserved. The corresponding impression, which should show the sculpture, apparently was not available. A shallow groove extending downward in an arc from the umbo probably marks the apex of the chevron. Indistinct, almost vertical markings are visible at one place behind the groove, but it is improbable that they represent sculpture. The length is 13 millimeters; the height 9.7 millimeters.

A. castrensis has been identified in the Pliocene beds at Elsmere Canyon and Pico Canyon [48] and in the beds near Holser Canyon assigned by Grant and Gale to the middle Pliocene; [49] and a form similar to *castrensis* has been described from the lower Pliocene on the south slope of Sulphur Mountain.[50] *A. castrensis* now ranges from Bering Sea to San Diego, and the lots in the National Museum have depth records of 8 to 688 fathoms. This species is the type of the subgenus *Truncacila*,[51] which lacks the posterior sinus and rostrum of *Acila* s. s. The differentiation is not well marked in some fossil species.

Family ARCIDAE

Genus ANADARA Gray

Anadara camuloensis (Osmont)

Plate 6, figures 10, 13–16

Arca n. sp. (a) Merriam, in Watts, California State Min. Bur. Bull. 19, p. 220 (list), 1900 (fide Osmont). Puente Hills, Piru Creek and vicinity; middle Neocene.

Arca camuloensis Osmont, California Univ., Dept. Geology, Bull., vol. 4, p. 98, pl. 10, pl. 11, figs. 6b, 6c, 1905. Near Camulos and in foothills of Santa Ana Mountains; probably Pliocene (p. 100).

Arnold, U. S. Nat. Mus. Proc., vol. 32, p. 543, pl. 47, figs. 1, 1a, 1b (after Osmont; said to be holotype), 1907. Near Camulos; Fernando formation, lower Pliocene or upper Miocene.

Arnold, in Eldridge and Arnold, U. S. Geol. Survey Bull. 309, pp. 24, 246, pl. 37, figs. 1, 1a, 1b (after Osmont; said to be type), 1907. Near Camulos; lower part of Fernando formation.

English, California Univ., Dept. Geology, Bull., vol. 8, p. 209 (list), 1914. Holser Canyon; lower Fernando, Pliocene.

Smith, California Acad. Sci. Proc., 4th ser., vol. 9, pp. 150 (list), 152 (list), 155 (list), 1919. Fernando, Pliocene.

Kew, U. S. Geol. Survey Bull. 753, p. 77 (list), 1924. Holser Canyon, between Holser Canyon and San Martinez Grande Canyon; Pico formation, Pliocene.

Arca (Arca) multicostata variety *camuloensis* Osmont. Grant and Gale, San Diego Soc. Nat. History Mem., vol. 1, pp. 30 (discussion), 34 (discussion), 139, pl. 2, figs. 5a–c, 1931. Holser Canyon and southeast of Pico Canyon (figured specimen); middle Pico, Pliocene.

Arca multicostata Sowerby. Arnold, U. S. Geol. Survey Prof. Paper 47, pp. 91 (list), 95 (list, "?"), 116 (list), 123 (list), 1906. Third Street tunnel, Los Angeles; Pliocene, probably lower. Puente Hills; lower Pliocene.

Arnold, U. S. Nat. Mus. Proc., vol. 32, p. 527 (list), 1907. Third Street tunnel, Los Angeles; middle Fernando formation, lower Pliocene.

Arnold, in Eldridge and Arnold, U. S. Geol. Survey Bull. 309, pp. 107 (list, "?"), 152 (list), 1907. Puente Hills; Fernando formation. Third Street tunnel, Los Angeles; Fernando formation, lower Pliocene.

Smith, California Acad. Sci. Proc., 4th ser., vol. 9, pp. 152 (list), 155 (list), 1919. Fernando, Pliocene.

English, U. S. Geol. Survey Bull. 768, p. 43 (Arnold's list), 1926. Puente Hills; Fernando group, Pliocene.

Grant, in Soper and Grant, Geol. Soc. America Bull., vol. 43, p. 1057 (Arnold's list) 1932 [1933]. Third Street tunnel, Los Angeles; middle Pliocene.

Arca (Arca) multicostata Sowerby. Grant, in Soper and Grant, idem (Arnold's record).

Not *Arca multicostata* Sowerby, Zool. Soc. London Proc., 1833, p. 21. Gulf of Tehuantepec; Recent.

A large, thick-shelled, moderately short *Anadara*. Sculpture consisting of strong ribs bearing heavy concentric ridges ("beads") that appear to be strongest on the anterior part of the shell and are not uniformly developed. Ribs and interspaces show indistinct radial threads. Cardinal area wide (from umbo to lower margin).

Restored length about 85 millimeters, restored height about 81 millimeters, diameter (right valve) about 45 millimeters.

An incomplete right valve from the Third Street tunnel (pl. 5, figs. 14–16) and part of a right valve from A. T. Jergins Trust Robertson No. 1, Playa del Rey field, depth 3,830 feet (U. S. G. S. locality 13911; pl. 5, figs. 10, 13) are identified as *Anadara camuloensis*. The shell of the outcrop specimen has a thickness of 17 millimeters in the anterior-ventral region. The ribs over the greater part of the central region are worn, and the posterior half of the cardinal area also is worn, revealing the trace of the teeth. The core specimen is not so thick (12 millimeters) and is less inflated. The shell is bored and corroded, and the upper part is greatly worn. A thin layer of inner shell material covers the mold, which extends to the edge of the core in the lower posterior region, indicating that more of the

[48] English, W. A., The Fernando group near Newhall, Calif.: California Univ., Dept. Geology, Bull., vol. 8, p. 210, 1918 (as *Nucula*). Grant, U. S., IV, and Gale, H. R., Catalogue of the marine Pliocene and Pleistocene Mollusca of California: San Diego Soc. Nat. History Mem., vol. 1, p. 116, 1931.

[49] Osmont, V. C., Arcas of the California Neocene: California Univ., Dept. Geology, Bull., vol. 4, p. 98, 1905. Grant, U. S., IV, and Gale, H. R., op. cit., p. 116.

[50] Schenck, H. G., op. cit. (1936), p. 98, pl. 14, figs. 2, 3.

[51] Schenck, H. G., in Grant, U. S., IV, and Gale, H. R., op. cit., p. 115. Originally designated type.

lower posterior part of the shell was present but was cut off by the core bit.

The Third Street tunnel specimen was identified by Arnold as *Arca multicostata*, but the specimen of *multicostata* that Arnold figured, as stated in the explanation of the plate, is a Recent shell from San Diego (U. S. Nat. Mus. 12574). *Anadara multicostata*, which has a range from Balboa, Calif., to the Gulf of California,[52] is not so thick-shelled and is more elongate (according to Osmont's figures); lacks the heavy ridges on the ribs; and generally has concentric grooves in the interspaces. The anterior ribs have ridges, or "beads", which are weaker than in *camuloensis*. They generally are confined to the umbonal part of the shell but may continue toward the margin of moderately large specimens. *A. camuloensis* may be a form of *multicostata*, as treated by Grant and Gale, but *multicostata* proper has not been certainly identified in the California Pliocene. There are no complete specimens of *camuloensis* in the National Museum. A well-preserved fragment of the lower anterior part of a left valve collected by Kew in the type region (locality 8140, 2,223-foot hill on divide between Holser Canyon and San Martinez Grande Canyon) has heavy ridges on the ribs, relatively strong radial threads on the ribs and weak ones in the interspaces. The only specimens available from the Puente Hills (locality 3909, face of ridge north of Brea Canyon, opposite wells of Brea Canyon Oil Co.) are incomplete impressions of small ones (length about 35 millimeters), the most complete of which appears to be relatively elongate and therefore similar in outline to *multicostata*. It has in at least parts of the shell well-defined concentric grooves in the interspaces, as in *multicostata*, but the ridges on the ribs of the anterior half of the shell are stronger than in *multicostata*. This presumably is the material that Arnold identified as *multicostata?*, and it may be more similar to that form than to *camuloensis*. It is not known whether this collection represents the Repetto formation or a higher horizon.

Specimens of *camuloensis* that show the character of the umbo at an early stage are not available. Young shells of *multicostata* have a depression on the umbo, indicating a median byssal gape at an early stage. This depression, which may continue to a late stage, is found on every species of *Anadara* examined. *Arca grandis* Broderip and Sowerby is a thick-shelled species that lives on the Pacific coast of Central America and northern South America and tolerates brackish water. *A. grandis*[53] and its allies in the Miocene of the West Indies, Central America, and northern South America[54] have been referred to *Senilia* Gray.[55] Reinhart's objection to this arrangement[56] appears to be well founded. Young valves of *grandis* have a depression on the umbo, whereas on young valves of *senilis* a depression is absent on the strongly prosogyrate umbo. *Senilia* is considered a separate genus. Reinhart adopted the arrangement of placing *Senilia* as a subgenus under *Anadara*, though *Senilia* was proposed 5 years earlier, and claimed that there is nothing in the International Rules of Zoological Nomenclature to prevent such action. Article 7 of the rules states that generic and subgeneric names "are coordinate—that is, they are of the same value." *Larkinia* Reinhart[57] was proposed for the American so-called *Senilia*. The type species is represented by fragments and one poorly preserved paired shell, part of Nelson's original material and labeled by him "cotypes", in the collections of the National Museum. It has an angular posterior ridge, a virtually central umbo, and a very wide cardinal area. The characters of the umbo at an early stage are undeterminable, and they have not been described. *A. multicostata* and *camuloensis* may belong to this minor division of *Anadara*, where they were placed by Reinhart.

The type designation of *Arca* Linné[58] has recently been considered by several writers.[59] Schumacher's designation[60] ("pour le type du genre j'ai donné la fig. 2, Pl. XIX, de la charnière de l'*Arca antiquata* Lin. qu'on trouve figurée dans Chemn. 7, p. 201, Tab. 55, fig. 548") is not entirely satisfactory. As contrasted with the use of the term "type" on pages 20, 148, and 173, it is doubtful whether the usage on pages 107, 108, 118, and 172 is to be regarded as a type designation. According to Schumacher's descriptions and figures, his advanced classification of pelecypods was based principally on the hinge, and he may have intended to figure the type of hinge in *Arca*, not the type species of the genus. *Arca antiquata* is not cited under any of the

[52] Grant, U. S., IV, and Gale, H. R., op. cit., p. 139. The type locality is cited by Sowerby as the Gulf of Tehuantepec.

[53] Mörch, O. A. L., Beiträge zur Molluskenfauna Central-Amerika's: Malakol. Blätter, vol. 7, p. 205, 1861. Lamy, Édouard, Révision des *Arca* vivants du Muséum d'histoire naturelle de Paris: Jour. Conchyliologie, vol. 55, pp. 262–263, 1907.

[54] Woodring, W. P., Miocene mollusks from Bowden, Jamaica; pt. 2, Gastropods and discussion of results: Carnegie Inst. Washington Pub. 385, pp. 58, 70, 71, 79–80, 84, 87, 1928. Olsson, A. A., Contributions to the Tertiary paleontology of northern Peru; pt. 5, The Peruvian Miocene: Bull. Am. Paleontology, vol. 19, no. 68, pp. 71–76, 1932.

[55] Gray, J. E., Synopsis of the contents of the British Museum, ed. 44, p. 81, 1842 (genus without species). (Quoted from Iredale, Malacol. Soc. London Proc., vol. 10, p. 308, 1913.) Tautonymic type designated by Gray (Zool. Soc. London Proc., 1847, p. 198) *Arca senilis* [Linné], Recent, West Africa.

[56] Reinhart, P. W., Classification of the pelecypod family Arcidae: Mus. royale histoire nat. Belgique Bull., vol. 11, no. 13, pp. 41–43, 1935.

[57] Idem, pp. 41–42. Originally designated type, *Anadara larkinii* (Nelson), Miocene, Peru.

[58] Linné, C., Systema naturae, ed. 10, pp. 693–695, 1758.

[59] Stewart, R. B., Gabb's California Cretaceous and Tertiary type lamellibranchs: Acad. Nat. Sci. Philadelphia Special Pub. 3, pp. 83–86, 1930. Grant, U. S., IV, and Gale, H. R., op. cit., pp. 137–138, 1931. Arkell, W. J., Monograph of British corallian Lamellibranchia, pt. 8, Pal. Soc. (vol. 88), pp. ii–iii, 1935. Reinhart, P. W., op. cit., pp. 14–17, 1935.

[60] Schumacher, C. F., Essai d'un nouveau système des habitations des vers testacées, p. 172, 1817.

subdivisions of *Arca* according to the method which, as pointed out by Stewart,[61] Schumacher used to cite types, but perhaps the typical subdivision was not included. Even if Schumacher's designation is accepted, perhaps the International Commission on Zoological Nomenclature may waive the designation in view of the long-continued usage of *Arca noae* Linné as the type of *Arca*. My proposal of *Diluvarca*,[62] which was based on a misconception of the characters of *Arca antiquata* Linné, the type species of *Anadara*,[63] and on ignorance of the availability of other names, has been justly criticized.[64] I soon abandoned *Diluvarca* as a synonym of *Anadara*,[65] but it has been used by a few workers, and it will always remain an unnecessary burden.

The type of *Arca microdonta* Conrad [66] is a well-preserved right valve in the National Museum (no. 1844), said to be from the "Tulare Valley(?)." Blake (op. cit., p. 188) cited the locality as "the hills of the Coast Mountains near the Tulares." The Kettleman Hills fit this description, and in these hills an *Anadara* that corresponds to Conrad's figure of *Arca trilineata* [67] is abundant. *Arca trilineata* was said to have been collected by Newberry at Santa Barbara, but according to Newberry's itinerary he was nowhere near Santa Barbara, and this species has never been found near Santa Barbara. *Arca trilineata*, *Arca canalis*, and *Mulinia densata*, described at the same time and said to have been collected at Santa Barbara by Newberry, may have been collected at some locality farther north in the coastal region of California. It is possible but unlikely that they were collected by Blake in the Kettleman Hills or nearby; Blake mentioned only the *Arca*. The types of all three are lost, and, inasmuch as they have not been found at the alleged type locality, they are on an unsatisfactory footing. California fossils have been identified as *Arca microdonta*, but no fossil or living species now known from California agrees with it, and whether it came from California is very doubtful. It shows no characters to differentiate it from "non-winged" specimens of the Recent West Indian species identified by Dall as *Arca auriculata* Lamarck. Perhaps Blake collected it from Pleistocene deposits on the Atlantic coast of Panama near Colon (Aspinwall of Blake's time), where the species identified as *A. auriculata* is known to occur. Blake collected from the Miocene Gatun formation, but nothing is mentioned about other localities in Panama.

[61] Stewart, R. B., op. cit., p. 33.

[62] Woodring, W. P., Miocene mollusks from Bowden, Jamaica; Pelecypods and scaphopods: Carnegie Inst. Washington Pub. 366, pp. 40–41, 1925. Originally designated type, *Arca diluvii* Lamarck, Miocene to Recent, Mediterranean.

[63] Gray, J. E., A list of the genera of Recent Mollusca, their synonyms and types: Zool. Soc. London Proc., 1847, p. 198. Originally designated type, *Arca antiquata* [Linné].

[64] Cox, L. R., Neogene and Quaternary Mollusca from the Zanzibar Protectorate: Paleontology of Zanzibar Protectorate, p. 95, 1927. Stewart, R. B., op. cit., p. 86. Grant, U. S., IV, and Gale, H. R., op. cit., pp. 137–138.

[65] Woodring, W. P., Miocene mollusks from Bowden, Jamaica, pt. 2: Carnegie Inst. Washington Pub. 385, p. 18, footnote, 1928.

[66] Conrad, T. A., in Blake, W. P., Preliminary geological report [Williamson's Reconnaissance in California], pp. 7 (list), 13, 1857. Conrad, T. A., Descriptions of the fossil shells: U. S. Pacific R. R. Expl., vol. 5, pt. 2, pp. 319 (list), 323–324, 352 (list), pl. 3, fig. 29, 1857.

[67] Conrad, T. A., Descriptions of three new genera, twenty-three new species middle Tertiary fossils from California, and one from Texas: Acad. Nat. Sci. Philadelphia Proc., vol. 8, p. 314, 1857; Description of the Tertiary fossils collected on the survey: U. S. Pacific R. R. Expl., vol. 6, pt. 2, p. 70, pl. 2, fig. 8, p. 85 (list), 1856 (?).

Family LIMOPSIDAE

Genus LIMOPSIS Sassi

Subgenus FELICIA Mabille and Rochebrune

Limopsis (Felicia) phrear Woodring, n. sp.

Plate 5, figures 7–9, 12, 13

A large *Limopsis* allied to *dalli* and other deep-water species from the west coast of Central America and southern Chile. Obliquely elongate; some specimens, probably distorted, are short. Sculpture consisting of radial pits, between some of which faint or distinct narrow radial grooves extend. Near the upper posterior margin the grooves are generally replaced by narrow faint threads. Growth lines interrupt the grooves. Cardinal area and hinge plate moderately narrow. Hinge apparently symmetrical.

Length 17.8 millimeters, height 15.4 millimeters, diameter (left valve) 4 millimeters (gaping paired shell, holotype). Length 20.5 millimeters, height 14.7 millimeters, diameter 3 millimeters (left valve, paratype). Length 18.4 millimeters, height 21.5 millimeters, diameter 6 millimeters (short, probably deformed left valve).

Holotype, U. S. Nat. Mus. 496077; paratype, U. S. Nat. Mus. 496078.

L. phrear has not been found at outcrop localities but has been obtained from widely distributed wells in the basin. Two of the specimens are short (pl. 5, figs. 8, 13) and have a greater diameter than elongate ones; and the one short specimen on which the cardinal area and hinge are exposed has a wider cardinal area and hinge plate than the one elongate specimen on which these features are exposed. It is improbable that two forms similar in most features are represented in this material; and inasmuch as the allied modern species are elongate, it is assumed that the short specimens are deformed. The elongate paratype is somewhat crushed. The radial grooves and pits are more closely spaced on the paratype than on other specimens of comparable size. In the modern species long hairs forming part of a thick periostracal pelage are inserted in the pits and grooves. The hinge is exposed on two specimens, but most of the teeth are broken, probably having been damaged during preparation.

This species is closely allied to three large deep-water species from the west coast of Central America and southern Chile—"*compressus*" Dall [68] (=*dalli* Lamy; southern Mexico, Panama), *zonalis* Dall [69] (Panama); and *jousseaumi* (Mabille and Rochebrune [70]) (Strait of Magellan), which as shown in the table under the heading "Inferred depth range of larger fossils" were dredged by the *Albatross* at depths of 122 to 2,232 fathoms. These three species were differentiated by Dall principally on characters of the periostracum. *L. phrear* is so far as now known smaller than these three species, elongate specimens are more elongate, and the radial grooves and pits are more widely spaced, except on the holotype. *L. zonalis* generally has a wider ligament area and hinge plate, and *jousseaumi* has slightly fainter sculpture. The fossils appear to be most closely allied to *dalli*.

Several subdivisions have been proposed under *Limopsis*,[71] based principally on characters of the inner margin of the shell and sculpture,[72] but there is no agreement as to the value of these characters. *Felicia* [73] was proposed on the grounds that it has no ligament pit and that the muscle scars differ from those of *Limopsis*. Bernard,[74] Dall,[75] and Lamy,[76] the last of whom examined the type material, showed that *jousseaumi* has a ligament pit. Numerous specimens dredged by the *Albatross* in the type region are similar to the figure of *jousseaumi*. They have a ligament pit, and the muscle scars are essentially like those of *L. aurita*. Nevertheless *Felicia* appears to be useful for a minor group of large deep-water western American and southern South American species that have a smooth inner margin, relatively widely spaced radial grooves and conspicuous pits, and a more symmetrical hinge than *Limopsis* s. s.

Specimens of Limopsis phrear from Repetto formation examined.

Locality	Specimens	Locality	Specimens
Standard Oil Co. Emery No. 57, West Coyote field, depth 5,265 feet. U. S. G. S. locality 13882.	Elongate left valve.	Union Oil Co. Hellman No. 19, Dominguez field, depth 4,292 feet. Collection of Union Oil Co.	Incomplete left valve.
Taylor Oil Co. Uharriet No. 1, near Culver City, depth 3,221 feet. U. S. G. S. locality 13887.	Short right valve.	Shell Oil Co. Reyes No. 43, Dominguez field, depth 5,128 feet. Collection of Union Oil Co.	Incomplete paired specimen.
Pacific Western Oil Corporation Cone No. 16, Inglewood field, depth 2,926 to 2,945 feet. U. S. G. S. locality 13892.	Virtually complete short left valve (figured).	Shell Oil Co. Reyes No. 101, Dominguez field, depth 5,245 feet. U. S. G. S. locality 13900.	Elongate paired gaping specimen (figured holotype).
Western Consolidated Oil Co. Smith No. 1, Inglewood field, depth 3,941 feet. U. S. G. S. locality 13924.	Incomplete short left valve and impression of part of a valve.	Signal Finance Corporation Woods No. 1, southwestern part of sec. 10, T. 3 S., R. 14 W., depth 5,100 feet. Collection of Union Oil Co.	Elongate right valve and impression; part of shell on impression.
Union Oil Co. Callender No. 27, Dominguez field, depth 4,998 feet. U. S. G. S. locality 13896.	Elongate left valve (figured paratype).	Standard Oil Co. Bolsa No. 38, Huntington Beach field, depth 3,874 to 3,894 feet. U. S. G. S. locality 13974.	Incomplete elongate deformed right valve.

Family PECTINIDAE

Genus LYROPECTEN Conrad

Lyropecten cerrosensis (Gabb)

Plate 7

Pecten cerrosensis Gabb, California Geol. Survey, Paleontology, vol. 2, p. 32, 1866; p. 103 (list), pl. 9, figs. 55, 55*a*, 1869. Cerros Island, Lower California; probably Miocene (p. 32), post-Pliocene (p. 103).

Watts, California State Min. Bur. Bull. 19, p. 222 (list, "?"), 1900. Piru Creek and vicinity; middle Neocene.

English, California Univ., Dept. Geology, Bull., vol. 8, p. 210 (list), 1914. Elsmere Canyon, Holser Canyon; lower Fernando, Pliocene.

Kew, U. S. Geol. Survey Bull. 753, p. 78 (list), 1924. Elsmere Canyon, Holser Canyon; Pico formation, lower Pliocene.

Stewart, Acad. Nat. Sci. Philadelphia Special Pub. 3, p. 118, 1930.

Pecten (*Lyropecten*) *ashleyi* Arnold, U. S. Geol. Survey Prof. Paper 47, pp. 122–123, pl. 47, figs. 1, 1a, pl. 48, fig. 1, 1906. Cerros Island, Lower California (type locality), San Diego, Third Street tunnel, Los Angeles; Pliocene.

[68] Dall, W. H., Diagnoses of new species of mollusks from the west coast of America: U. S. Nat. Mus. Proc., vol. 18, p. 16, 1896; The Mollusca and the Brachiopoda [*Albatross* Rept.]: Harvard College Mus. Comp. Zoology Bull., vol. 43, no. 6, p. 394, pl. 7, figs. 7, 8, 1908. Lamy, E., Revision des *Limopsis* vivants du Muséum d'histoire naturelle de Paris: Jour. Conchyliologie, vol. 60, p. 137, footnote, 1912 (*L. dalli*, new name for *L. compressus* Dall, 1896, not *L. compressa* G. and H. Nevill, 1874). Finlay, H. J., Invalid molluscan names, no. 1: New Zealand Inst. Trans., vol. 61, p. 67, 1930 (*L. solicola*, new name for *L. compressus* Dall, 1895 [1896], not L. *compressa* G. and H. Nevill, 1874).

[69] Dall, W. H., op. cit. (1908), pp. 393–394, pl. 7, figs. 6, 9.

[70] Rochebrune, A. T. de, and Mabille, J., Mollusques: Miss. Sci. Cap Horn, Zoologie, vol. 6, p. H116, pl. 7, fig 9, 1889 (as *Felicia*).

[71] Sassi, A., Giorn. ligustico, vol. 1, p. 476, 1827 (cited from Sherborn, Index animalium, sec. 2, 1801–1850, p. 3572, 1927). Type (fide Sacco, Molluschi dei terreni terziarii del Piemonte e della Liguria, pt. 26, p. 39, 1898), *Arca aurita* Brocchi, Miocene to Recent, Mediterranean.

[72] See Dall, W. H., Harvard College Mus. Comp. Zoology Bull., vol. 43, p. 393, 1908; Lamy, E., op. cit., pp. 110–112, 1912. The generic names *Loringella*, *Phrynelima*, and *Aspalima* (Iredale, Tom, Mollusca from the continental shelf of eastern Australia, no. 2: Australian Mus. Rec., vol. 17, p. 160, 1929) and *Versipella* and *Senectidens* (Iredale, Tom, Australian molluscan notes, no. 1: Idem, vol. 18, pp. 203–204, 1931) have been proposed for Australian species.

[73] Rochebrune, A. T. de, and Mabille, J., op. cit., pp. H115–116, 1889. Monotype, *Felicia jousseaumi* Mabille and Rochebrune.

[74] Bernard, Félix, Recherches ontogéniques et morphologiques sur la coquille des lamellibranchs: Annales sci. nat., Zoologie, 8th ser., vol. 8, p. 107, 1898.

[75] Dall, W. H., op. cit., pp. 393, 395, 1908.

[76] Lamy, E., Mission dans l'Antarctique dirigée par M. le Dr. Charcot; Pélécypodes: Mus. nat. histoire nat. (Paris) Bull., vol. 7, p. 392, 1910; Revision des *Limopsis* vivants du Muséum d'histoire naturelle de Paris: Jour. Conchyliologie, vol. 60, p. 111, 1912.

Arnold, in Eldridge and Arnold, U. S. Geol. Survey Bull. 309, p. 240, pl. 34, fig. 2 (type), 1907. Cerros Island, Pliocene.

Pecten ashleyi Arnold. Arnold (part), U. S. Geol. Survey Prof. Paper 47, pp. 28 (list), 91 (list), 95 (list), 116 (list), 121 (list), 1906. San Diego, Puente Hills, Third Street tunnel, Los Angeles; Pliocene.

Arnold, U. S. Nat. Mus. Proc., vol. 32, p. 527 (two lists), 1907. Third Street tunnel, Los Angeles, Temescal Canyon; middle Fernando formation, lower Pliocene.

Arnold, in Eldridge and Arnold, U. S. Geol. Survey Bull. 309, pp. 107, 152 (lists), 1907. Puente Hills; Fernando formation. Third Street tunnel, Los Angeles; Fernando formation, lower Pliocene.

English, California Univ., Dept. Geology, Bull., vol. 8, p. 210 (list), 1914. Elsmere Canyon; lower Fernando, Pliocene.

Kew, U. S. Geol. Survey Bull. 753, p. 78 (list), 1924. Elsmere Canyon, between Holser Canyon and San Martinez Grande Canyon; Pico formation, lower Pliocene.

English, U. S. Geol. Survey Bull. 768, p. 43 (list, from Arnold's list), 1926. Puente Hills; Fernando group, Pliocene.

Grant, in Soper and Grant, Geol. Soc. America Bull., vol. 43, p. 1058 (Arnold's list), 1932 [1933]. Third Street tunnel, Los Angeles; middle Pliocene.

Pecten (*Plagioctenium*) *cerrosensis* Gabb. Hertlein, California Acad. Sci. Proc., 4th ser., vol. 14, pp. 15–16, pl. 6, fig. 1 (type), 1925. Cedros Island, Lower California; Pliocene (see p. 6).

Pecten (*Lyropecten*) *cerrosensis* Gabb. Jordan and Hertlein, California Acad. Sci. Proc., 4th ser., vol. 15, pp. 418, 432–433, pl. 32, fig. 4, 1926. Cedros Island, Lower California; Pliocene.

Grant, in Soper and Grant, Geol. Soc. America Bull., vol. 43, p. 1058 (list), 1932 (1933). Third Street tunnel, Los Angeles; middle Pliocene (Arnold's record of *P. ashleyi*).

"*Pecten*" *cerrosensis* Gabb. Woodring, California Acad. Sci. Proc., 4th ser., vol. 19, pp. 59, 62 (lists), 1930. North of Simi Valley, Temescal Canyon; Pliocene.

Woodring, in Hoots, U. S. Geol. Survey Prof. Paper 165, p. 116 (list). Potrero Canyon; upper Pliocene. Idem, p. 119 (list), 1931. Temescal Canyon; San Diego formation, middle or upper Pliocene.

Pecten (*Lyropecten*) *estrellanus* (Conrad) var. *cerrosensis* Gabb. Grant and Gale, San Diego Soc. Nat. History Mem., vol. 1, pp. 21 (discussion), 33 (discussion), 34 (discussion), 40 (discussion), 46 (discussion), 187, pl. 8, figs. 1a, 1b, 2a, 2b, pl. 9, fig. 2, 1931. Figured specimens from Holser Canyon, Pico Canyon, and a locality between San Fernando Pass and Pico Canyon; middle Pliocene.

Not *Pecten* (*Plagioctenium*) *cerrosensis* Gabb. Arnold, U. S. Geol. Survey Prof. Paper 47, pp. 123–124, pl. 44, fig. 5, pl. 49, figs. 1, 1a, 1b.

A large *Lyropecten* sculptured with 16 or 17 ribs. Ribs and interspaces bearing riblets. Ears (of left valve) sculptured with numerous riblets.

Restored length about 125 millimeters; restored height about 120 millimeters, length of cardinal margin about 60 millimeters (figured left valve). Length about 132 millimeters, restored height about 130 millimeters (mold, identification doubtful).

An incomplete left valve (pl. 5, fig. 2), backed by a mold of another valve, and parts of an apparently different valve (pl. 5, fig. 1) in Hamlin's Third Street tunnel collection are referred to *L. cerrosensis*. A mold of a valve, which has some inner shell material, of comparable size and ribbing, and the interior of the lower part of a large valve from the same locality are doubtfully referred to it. A midrib is absent in the interspaces in the umbonal part of the left valve. Fragments from the Puente Hills (locality 3907, Olinda Hill, south of western wells of Fullerton Consolidated Oil Co.) also fail to show a strong midrib near the lower margin of the valve, but in some interspaces one riblet is a little stronger than others. Fragments of an exceptionally large valve from San Diego mentioned by Arnold [77] (locality 2474, second bench back on mesa, three-fourths of a mile northeast from Pacific Beach, near San Diego; associated with *Patinopecten healeyi*) have a riblet stronger than the others in the interspaces some distance from the margin of the valve, in the middle of the interspaces or a short distance from the middle. Hertlein's figure of the type of *cerrosensis* shows a riblet slightly stronger than others in interspaces on the middle of the right valve about halfway between the umbo and lower margin; Arnold's figures of the type of *ashleyi* apparently do not show a stronger riblet on either valve. The figure of a young right valve of *P. cerrosensis* from the type locality, published by Jordan and Hertlein, shows a relatively strong midrib in at least some of the interspaces.

Lyropecten cerrosensis was considered a variety of *estrellanus* by Grant and Gale. It was compared with *crassicardo* by Arnold and appears to be allied to *crassicardo*. A lot of seven imperfect specimens from the Estrella Valley (U. S. Nat. Mus. 13317) is regarded as the type lot of *L. estrellanus* (Conrad),[78] unless the type is found at the Philadelphia Academy of Natural Sciences. The specimen figured by Conrad is not recognized,[79] and the right valve figured by Arnold [80] is taken as the lectotype. These valves are strongly inflated; the lectotype and two others, on which the number of ribs is discernible, have 17 ribs; the interspaces are occupied by a strong midrib, which is split toward the margin, and the two branches may be flanked by a riblet. The anterior ear of a right valve has four relatively strong ribs. *L. estrellanus* has been recognized in the Santa Margarita sandstone of the type region, but the horizon of the Santa Margarita, generally assigned to the upper Miocene, in this region is not recorded. Arnold's figured right valve from the Santa Margarita sandstone of the Coalinga region [81]

[77] Arnold, Ralph, Tertiary and Quaternary Pectens of California: U. S. Geol. Survey Prof. Paper 47, p. 123, 1906.

[78] Conrad, T. A., Descriptions of three new genera, twenty-three new species middle Tertiary fossils from California, and one from Texas: Acad. Nat. Sci. Philadelphia Proc., 1856, p. 313, 1857 (as *Pallium*); Description of the Tertiary fossils collected on the survey: U. S. Pacific R. R. Expl., vol. 6, pt. 2, p. 71, pl. 3, fig. 15, 1856 (?), as (*Pallium*).

[79] The figured specimen was not recognized by Marcou (U. S. Nat. Mus. Proc., vol. 8, p. 341, 1885).

[80] Arnold, Ralph, op. cit. (Prof. Paper 47), pl. 20, fig. 1, 1906.

[81] Arnold, Ralph, Paleontology of the Coalinga district, California: U. S. Geol. Survey Bull. 396, pl. 10, fig. 3, 1909 [1910] (as *Pecten*).

is strongly inflated; is sculptured with 17 ribs; has a strong midrib that is not split toward the margin but in some interspaces is not stronger than riblets added near the margin; and has four relatively strong ribs on both ears. Strongly marked "resting stages", possibly induced by unfavorable conditions, produce humps in the profile. Arnold [82] figured another specimen from the Santa Margarita (San Pablo of Professional Paper 47) of the Coalinga region that closely resembles the typical form aside from the strong "resting stages." Arnold's figured left valve from locality 3586, in the Salinas Valley,[83] is not so strongly inflated and has 15 ribs and a narrow midrib that does not split but is a little heavier (or of about the same strength) than riblets added near the margin. This is not the typical form of *estrellanus;* it is probably *estrellanus terminus* (Arnold),[84] the type of which, from an indefinite locality in Monterey County, is in the collections of the University of California. Arnold thought that this form that has fewer ribs is at a higher horizon than the typical form.[85] Nomland's "*Pecten terminus* Arnold," from the *Chione elsmerensis* zone (Jacalitos formation) and *Turritella nova* zone (lower part of Etchegoin formation or upper part of Jacalitos formation) of the Coalinga region,[86] is larger, relatively longer, and more inflated and has squarer ribs. If the interpretation of *estrellanus terminus* here offered is confirmed, the Jacalitos form is an unnamed species allied to *estrellanus.* Perhaps the Jacalitos form is the one that occurs in the Pliocene at Elsmere Canyon, recorded by Ashley [87] as *Liropecten estrellanum* (Conrad), by Arnold [88] as *Pecten estrellanus* (Conrad) var. *catalinae* Arnold, and by Grant and Gale [89] as *Pecten* (*Lyropecten*) *estrellanus* (Conrad) s. s. The only specimen in the National Museum from Elsmere Canyon is part of a large flat (crushed?) valve showing wide, rather square ribs. The flatness probably led Arnold to identify it as *estrellanus* var. *catalinae.* According to the figure,[90] the type of *catalinae* from Santa Catalina Island has a strong midrib filling the interspaces, as in *estrellanus* s. s. Material from the Pliocene at Temescal Canyon mentioned by Arnold [91] as representing *catalinae* is not recognized in the National Museum collection. This record is probably an error, as *catalinae* is not mentioned in Arnold's later lists from this locality. The strong midrib indicates that *Pecten* (*Lyropecten*) *gallegosi* Jordan and Hertlein,[92] from Cedros Island, where it is associated with *cerrosensis,* is allied to *estrellanus.* It was considered the same as *cerrosensis* by Grant and Gale.[93] Two fragments from the Puente Hills (locality 3907, already mentioned), associated with fragments of *cerrosensis,* have more closely spaced and squarer ribs than *cerrosensis* and may represent *gallegosi.* The larger fragment, representing an area near the lower margin of a valve, does not have a strong midrib; the other, from the region near an ear, is poorly preserved but also does not show a strong midrib.

L. cerrosensis is larger than *L. estrellanus, estrellanus catalinae,* and *estrellanus terminus* but is not much larger than the Jacalitos form and *gallegosi;* it also lacks the strong midrib of *estrellanus* and its allies, those on the young shell figured by Jordan and Hertlein being weaker than in *estrellanus.* It is almost as large as the Miocene *L. crassicardo* (Conrad),[94] which has similar ribs and riblets, but the ribs of *crassicardo* are squarer near the margin of large valves, and the ears are sculptured with fewer riblets. On some specimens of *crassicardo* a riblet in some of the interspaces is stronger than the others. A fragment of a large valve from locality 3586 in the same tray with Arnold's figured "*estrellanus*" is indistinguishable from fragments of *crassicardo* and *cerrosensis.* Arnold identified and figured a specimen, from an unknown California locality, in the collections of the Philadelphia Academy of Natural Sciences as the type of *crassicardo.* This species is widely distributed in the upper Miocene and is recorded from horizons assigned to the middle Miocene.

Lyropecten [95] is characterized by its large, heavy shell, approximately equal inflation of the valves and equal size of the ears, strong undivided radial ribs, and strong cardinal lamellae. At an early date Meek [96] pointed out the principal characters, and Verrill [97] indicated that it should be given generic rank. Verrill

[82] Arnold, Ralph, op. cit. (Prof. Paper 47), pl. 21, figs. 1, 1a, 1b, 1906.

[83] Idem, pl. 19, figs. 1, 1a.

[84] Idem, p. 77, pl. 23, figs. 2, 2a [as *Pecten* (*Lyropecten*)].

[85] Idem, p. 76.

[86] Nomland, J. O., The Etchegoin Pliocene of middle California: California Univ., Dept. Geology, Bull., vol. 10, pp. 212, 213, 219, table opp. p. 230, pl. 6, fig. 4, 1917.

[87] Ashley, G. H., The Neocene stratigraphy of the Santa Cruz Mountains of California: California Acad. Sci. Proc., 2d ser., vol. 5, p. 338, 1895.

[88] Arnold, Ralph, New and characteristic species of fossil mollusks from the oil-bearing Tertiary formations of southern California: U. S. Nat. Mus. Proc., vol. 32, p. 527, 1907.

[89] Grant, U. S., IV, and Gale, H. R., op. cit., pp. 185–186, pl. 8, fig. 4, 1931.

[90] Arnold, Ralph, op. cit. (Prof. Paper 47), pp. 76–77, pl. 20, figs. 3, 3a, 4, 1906.

[91] Idem, p. 77.

[92] Jordan, E. K., and Hertlein, L. G., Contribution to the geology and paleontology of the Tertiary of Cedros Island and adjacent parts of Lower California: California Acad. Sci. Proc., 4th ser., vol. 15, pp. 434–435, pl. 29, fig. 1, 1926.

[93] Grant, U. S., IV, and Gale, H. R., op. cit., p. 187.

[94] Conrad, T. A., Descriptions of three new genera, twenty-three new species middle Tertiary fossils from California, and one from Texas: Acad. Nat. Sci. Philadelphia Proc., 1856, p. 313, 1857 (as *Pallium*). Arnold, Ralph, op. cit. (Prof. Paper 47), pp. 71–73, pl. 16, figs. 1, 1a, pl. 17, figs, 1, 1a, 1b, pl. 18, figs. 1, 2, 2a, 1906 [as *Pecten* (*Lyropecten*)]. Arnold, Ralph, Paleontology of the Coalinga district, California: U. S. Geol. Survey Bull. 396, pl. 12, fig. 1, 1909 [1910] (as *Pecten*). Grant, U. S., IV, and Gale, H. R., op. cit., pp. 183–184, pl. 9, figs. 4, 5, 1931 (as *Pecten* (*Lyropecten*) *magnificus* Sowerby variety *crassicardo*).

[95] Conrad, T. A., Descriptions of new genera, subgenera, and species of Tertiary and Recent shells: Acad. Nat. Sci. Philadelphia Proc., 1862, p. 291. Subsequently designated type (Dall, Wagner Inst. Sci. Philadelphia Trans., vol. 3, pt. 4, pp. 695, 701, 1898), *Pallium estrellanum* Conrad, Miocene, California.

[96] Meek, F. B., Check list of the invertebrate fossils of North America; Miocene: Smithsonian Misc. Coll., no. 183, p. 27, 1864.

[97] Verrill, A. E., A study of the family Pectinidae, with a revision of the genera and subgenera: Connecticut Acad. Sci. Trans., vol. 10, pp. 63–64, 1897.

and also Stoliczka [98] cited *Pecten nodosus* (Linné) as the type of *Lyropecten*, probably following Fischer's citation [99] of that species as an example. In a later account Conrad [1] included *nodosus* under this genus. *P. nodosus* is the type of *Nodipecten* Dall,[2] which has hollow nodes on the ribs and is regarded as a subgenus of *Lyropecten* that also appeared in the Miocene, *nodosus* itself being identified in the Miocene of the West Indies. Species of *Lyropecten* that have humps on the shell are not properly assignable to *Nodipecten*. *Lyropecten* appears on the Pacific coast in the lower Miocene (Vaqueros formation), and the large shells of this genus are used by field geologists as a readily recognized aid in distinguishing the late Tertiary from the early Tertiary. There are large Pectens in the late Eocene and Oligocene of the Pacific coast (*ynezianus* Arnold, *porterensis* Weaver), but they belong to an endemic genus, *Vertipecten*,[3] which became extinct in the Miocene and is not directly related to *Lyropecten*, as pointed out by Grant and Gale. On the Atlantic coast *Lyropecten* appears in the Oak Grove sand of Florida and the Calvert formation of the Chesapeake embayment. These formations are now considered of about the same age and are assigned to the middle Miocene,[4] as that term is used in a relative sense. *Lyropecten* proper is unknown in the Tampa limestone (basal Miocene) of Florida but may occur in beds correlated with the Chipola formation of Florida (lower Miocene).[5] Facies control may affect this distribution, for *Lyropecten* is not known in the Shoal River formation, which is younger than the Chipola formation and Oak Grove sand. In the Miocene of the Atlantic and Gulf coasts *Lyropecten* is associated with faunas of cool-water aspect. The Pacific coast *Lyropecten* has been considered a migrant from the West Indies and Central America,[6] or from the Atlantic coast through Central America,[7] but *Lyropecten* proper has not certainly been recognized in the West Indian and Central American Miocene. *Nodipecten*, however, is widely distributed in the Miocene of that region. Young valves from the type locality of *Pecten* (*Lyropecten*) *arnoldi* Aguerrevere,[8] a Pliocene (?) species from Venezuela, indicate that it is a *Nodipecten*, probably an exceptionally large form of *nodosus*. In the Peruvian Miocene *Lyropecten* is recognized by Olsson[9] in the Tumbez formation, which is assigned to the upper Miocene. At the present time the predecessors of *Lyropecten* and its route of migration between the two coasts of America are unknown.

Similar large Pectens with strong undivided ribs and heavy cardinal lamellae, assigned to *Gigantopecten*,[10] are found in the European Miocene and Pliocene. Cossmann and Peyrot claimed that *Gigantopecten* lacks a byssal sinus, but illustrations support Sacco's and Philippi's statement[11] that young valves have a shallow sinus that disappears, or virtually disappears, on adults. *Lyropecten* and *Gigantopecten* apparently are closely related. American species that have a few wide ribs (*jeffersonius* Say and *magnolia* Conrad) appear to be very similar to *latissima*. *Gigantopecten* was recognized by Sacco in the Oligocene (Tongrian).

Genus HYALOPECTEN Verrill

Subgenus DELECTOPECTEN Stewart

Hyalopecten (Delectopecten) aff. H. randolphi (Dall)

Plate 6, figures 5–7, 11

Pecten (*Pseudamusium*) *pedroanus* (Trask) Arnold (part), U. S. Geol. Survey Prof. Paper 47, pp. 90–91, pl. 28, figs. 4, 5, 1906. Figured specimens from Third Street tunnel, Los Angeles; Pliocene, probably lower.

Arnold, in Eldridge and Arnold, U. S. Geol. Survey Bull. 309, p. 244, pl. 36, figs. 5, 6, 1907. Third Street tunnel, Los Angeles; lower Pliocene. (Same illustrations as in Prof. Paper 47, but considerably reduced.)

Pecten pedroanus (Trask) Arnold, U. S. Geol. Survey Prof. Paper 47, pp. 116 (list), 123 (list), 1906. Third Street tunnel, Los Angeles; Pliocene.

Arnold, U. S. Nat. Mus. Proc., vol. 32, p. 527 (list), 1907. Third Street tunnel, Los Angeles; middle Fernando formation, lower Pliocene.

Arnold, in Eldridge and Arnold, U. S. Geol. Survey Bull. 309, p. 152 (list), 1907. Third Street tunnel, Los Angeles; Fernando formation, lower Pliocene.

?Arnold, idem, p. 153 (list). Normal School and Clark estate, Los Angeles; Pliocene.

Grant, in Soper and Grant, Geol. Soc. America Bull., vol. 43, p. 1058 (Arnold's list), 1932 (1933). Third Street tunnel, Los Angeles; middle Pliocene.

[98] Stoliczka, F., Cretaceous fauna of southern India, vol. 3, p. 425, 1871 (as *Liropecten*).

[99] Fischer, P., Manuel de conchyliologie, p. 944, 1886 (as *Liropecten*).

[1] Conrad, T. A., Paleontological miscellanies: Am. Jour. Conchology, vol. 3, p. 6, 1867.

[2] Dall, W. H., Wagner Inst. Sci. Philadelphia Trans., vol. 3, pt. 4, p. 695, 1898.

[3] Grant, U. S., IV, and Gale, H. R., op. cit., p. 188. Originally designated type, *Pecten nevadanus* Conrad, Miocene, California. Grant and Gale's designation of a specimen of uncertain provenance as the neotype of *nevadanus* (p. 190) is to be ignored.

[4] Mansfield, W. C., Stratigraphic significance of Miocene, Pliocene, and Pleistocene Pectinidae in the southeastern United States: Jour. Paleontology, vol. 10, p. 173, 1936.

[5] Gardner, J. A., The molluscan fauna of the Alum Bluff group of Florida: U. S. Geol. Survey Prof. Paper 142–A, p. 46, 1926 (*Chlamys* (*Lyropecten*) *acanikos* Gardner).

[6] Smith, J. P., Climatic relations of the Tertiary and Quaternary faunas of the California region: California Acad. Sci. Proc., 4th ser., vol. 9, p. 161, 1919.

[7] Grant, U. S., IV, and Gale, H. R., op. cit., p. 176.

[8] Aguerrevere, P. I., Description of a new pecten from Venezuela, S. A.: Southern California Acad. Sci. Bull., vol. 24, pp. 51–53, pl. 5, 1925.

[9] Olsson, A. A., Contributions to the Tertiary paleontology of northern Peru, pt. 5, The Peruvian Miocene: Bull. Am. Paleontology, vol. 19, no. 68, p. 83, pl. 5, figs. 1, 4, 1932 (*Pecten* (*Lyropecten*) *hopkinsi*, renamed *Pecten tucilla* on p. 226).

[10] Roverto, G., Rectifications de nomenclature: Rev. crit. paléozoologie, year 3, p. 90, 1899; new name for *Macrochlamys* Sacco, 1897, not Benson, 1832; type (see under *Macrochlamys*), *Ostrea latissima* Brocchi, Miocene, Italy. *Macrochlamys* Sacco, Molluschi dei terreni terziarii del Piemonte e della Liguria, pt. 24, p. 32, 1897 (as subgenus of *Chlamys*); originally designated type, *M. latissima* (Brocchi). *Grandipecten* Cossmann and Peyrot, Conchologie néogénique de l'Aquitaine, vol. 2, pt. 2, p. 273, 1914; new name for *Macrochlamys* Sacco, 1897, not Benson, 1832 (as section of *Amussiopecten*, subgenus of *Pecten*). Cossmann overlooked Roverto's name issued in his own publication.

[11] Philippi, E., Beiträge zur Morphologie und Phylogenie der Lamellibranchier, II, Zur Stammesgeschichte der Pectinidae: Deutsche geol. Gesell. Zeitschr., vol. 52, p. 105, 1900.

Pecten (*Pseudamussium*) *pedroanus* (Trask) Grant and Gale (part), San Diego Soc. Nat. Hist. Mem., vol. 1, pp. 236–237, 1931.

Grant, in Soper and Grant, Geol. Soc. America Bull., vol. 43, p. 1058 (list), 1932 (1933). Third Street tunnel, Los Angeles; middle Pliocene (Arnold's record).

?*Pecten pedroanus* (Trask) Cooper, in Watts, California State Min. Bur., Bull. 11, p. 4 (mentioned), 1897. Clark estate [between Los Angeles River and Arroyo Seco, see fig. 30]; Miocene. Idem, p. 80 (list). Normal School, Clark estate, Los Angeles.

Not *Plagiostoma pedroana* Trask, California Acad. Sci. Proc., vol. 1, p. 86, figs. 1, 1a, 1856 (*pedrona* in text). San Pedro; Cretaceous [Miocene].

A large *Delectopecten* allied to *randolphi*. Concentric undulations strong on some specimens; moderately strong or weak on others. Radial sculpture absent except on right anterior ear, the upper part of which is sculptured with 5 or 6 radial ribs. Growth lines conspicuous on right anterior ear, forming low scales on the radial ribs. Entire shell bearing microscopic, somewhat pustular radial threads that bend upward near anterior and posterior ends of shell (camptonectes sculpture).

Length 25 millimeters, height 22.8 millimeters (right valve figured by Arnold). Length 32.5 millimeters, height 30.6 millimeters (distorted left valve figured by Arnold). Length 34.5 millimeters, height 33.5 millimeters (left valve, largest in core material; from a horizon assigned to Pico formation).

Exteriors generally have only part of the inner shell preserved. The camptonectes sculpture is visible on small patches of shell, on some impressions (pl. 6, fig. 11), and shows through the thin shell on some interiors.

The fossils from the Los Angeles Basin identified as *H.* aff. *H. randolphi* represent horizons ranging from upper Miocene to upper Pliocene. Large specimens are somewhat larger than the largest shells of *randolphi*. The concentric undulations on upper Miocene and Repetto specimens (pl. 6, fig. 7) are stronger than on most specimens of *randolphi*. The undulations are exceptionally strong on Third Street tunnel fossils, including those figured by Arnold. Perhaps these strongly undulated fossils are to be regarded as a variety of *pedroanus* that lacks radial ribs except on the right anterior ear. Fossils from the Pico formation have moderately strong to weak undulations, and specimens that have undulations of varying strength occur together (pl. 6, figs. 5, 6). Those that have weak undulations appear to be indistinguishable from *randolphi*.

The Third Street tunnel is the only outcrop locality for this *Delectopecten* in the collections at hand. The specimens figured by Arnold and others in the lot from which they were selected have the locality number 3428 (Broadway tunnel, Los Angeles), which appears to be an error for 3426, as the label reads Third Street tunnel. Additional specimens are under a Third Street tunnel number (3432). Watts and later Arnold recorded *pedroanus* from other localities in Los Angeles—the Clark estate and the Normal School. According to Watts' map, the Clark estate was in a region where strata now assigned to the Miocene crop out. The Normal School was on the site of the present Los Angeles Public Library, which is underlain by the Pico formation. Arnold also recorded *pedroanus* from the Pliocene of the Puente Hills.[12] The only specimen from the Puente Hills now in the collections of the National Museum that may represent *Delectopecten* is a valve which lacks shell material and in which the ears are not exposed. It has weak undulations, is 16 millimeters long, and may represent a form of *peckhami*. The matrix is dense diatom-bearing limestone, possibly from the Miocene Puente formation. Limestone of coarser grain under the same locality number (3909, face of ridge north of Brea Canyon, opposite wells of Brea Canyon Oil Co.) contains molds and impressions of Pliocene fossils. McLaughlin and Waring's figure of a pecten, identified as "*pedroanus* Arnold", from the Miocene near Eastlake [now Lincoln] Park, Los Angeles,[13] shows the posterior ear set off from the main part of the shell and radial lines on the main part of the shell.

Delectopecten is represented on the Pacific coast from the Eocene to the Recent. The following names have been proposed:

[12] Arnold, Ralph, op. cit. (Prof. Paper 47), p. 91.

[13] McLaughlin, R. P., and Waring, C. A., Petroleum industry of California: California State Min. Bur. Bull. 69, map folio, pl. 1, fig. 35, 1914.

Names proposed for Tertiary and Recent forms of Delectopecten from Pacific coast

Name	Type locality	Characters	Remarks
Plagiostoma pedroana Trask.[1]	San Pedro [east coast of Palos Verdes Hills], Calif. Cretaceous [Miocene].	Large; length about 35 mm [apparently exaggerated by deformation]. Concentric undulations strong. Right anterior ear sculptured with about 13 radial ribs. (Fide Trask.)	Large number of ribs on right anterior ear needs confirmation.
Plagiostoma annulatus Trask.[2]	-----do------------------	Large; length about 32 mm [apparently exaggerated by deformation]. Concentric undulations strong. Left anterior ear sculptured with about 12 radial ribs. (Fide Trask.)	Considered same as *pedroanus*. Radial ribs on left anterior ear suggest that well-preserved specimens may show radial ribs on main part of shell.
Plagiostoma truncata Trask.[3]	-----do------------------	Large; length about 28 mm [apparently slightly exaggerated by deformation]. Concentric undulations strong. (Fide Trask.)	Considered same as *pedroanus*.
Pecten peckhami Gabb[4] ---	Ojai ranch, Santa Barbara [now Ventura] County, Calif. Bituminous shale of upper Miocene [Monterey shale of some geologists and Modelo formation of others].	Small; length of 3 specimens in lectotype lot 12 to 14.8 mm. Concentric undulations weak. Lectotype sculptured with weak, relatively widely spaced radial ribs on main part of shell. Right anterior ear sculptured with a few radial ribs (6 or 7; fide Arnold).	On many specimens that appear to represent *peckhami* radial ribs are not discernible, except on right anterior ear. Forms resembling *peckhami* have been recorded from horizons ranging from Eocene to Miocene.
Pecten (Pseudamusium) vancouverensis Whiteaves.[5]	Forward Inlet, Quatsino Sound, Vancouver Island; depth 10 to 20 fathoms.	Small; length 8.5 to 10 mm. Concentric undulations weak or absent. Main part of shell sculptured with weak to strong radial ribs; absent on some specimens. Right anterior ear sculptured with 5 to 7 radial ribs.	Radial sculpture very variable in lots assigned to this form. Apparently ranges from southern Alaska to San Diego in shallow to moderately deep water (12 to 200 fathoms).
Pecten randolphi Dall[6] ---	Off Destruction Island, Wash.; depth 516 fathoms.	Large; length 28 to 30.8 mm. Concentric undulations moderately strong or weak. Right anterior ear sculptured with 5 to 8 radial ribs.	Apparently ranges from Bering Sea to Cape Blanco, Oreg., in deep water (225 to 1,064 fathoms).
Pecten (Pseudamusium) randolphi var. *tillamookensis* Arnold.[7]	Off Tillamook Bay, Oreg.; depth 786 fathoms.	Large; length 29 to 32.5 mm. Concentric undulations moderately strong or weak. Type sculptured with weak radial ribs on main part of shell. In other specimens this radial sculpture varies from a few faint ribs to strong ribs covering entire shell. Some left valves that lack radial sculpture are paired with faintly sculptured right valves. Right anterior ear sculptured with 5 to 8 radial ribs.	Considered a sculptured variety of *randolphi*, as described by Arnold. Radial sculpture very variable in suites of shells assigned to this variety. Apparently ranges from Bering Sea to San Diego, generally in deep water (30 to 1,084 fathoms).
Pecten (Pseudamusium) polyleptus Dall.[8]	Off Hood Island, Galapagos; depth 300 fathoms.	Small; length 9.6 to 10 mm. Concentric undulations weak or absent. Main part of shell sculptured with weak radial ribs, mainly in form of vaulted scales. Right anterior ear sculptured with 4 or 5 radial ribs.	Represented in two lots from depths of 300 and 392 fathoms near Galapagos. Apparently closely allied to *H. gelatinosus* (Mabille and Rochebrune), a larger form from southern South America.
Pecten (Pseudamusium) arces Dall.[9]	Santa Barbara Channel, Calif., off Santa Cruz Island; depth 534 fathoms.	Moderately large; length 19.5 to 23 mm (type lot). Concentric undulations moderately strong or weak. Main part of shell sculptured with strong radial ribs. Right anterior ear sculptured with 5 to 7 radial ribs.	Considered a synonym of *tillamookensis;* strongly sculptured form.

[1] Trask, J. B., Description of three new species of the genus *Plagiostoma* from the Cretaceous rocks of Los Angeles: California Acad. Sci. Proc., vol. 1, p. 86, figs. 1, 1a, 1856 (*pedrona* in text).
[2] Idem, p. 86, fig. 2.
[3] Idem, p. 86, fig. 3.
[4] Gabb, W. M., California Geol. Survey, Paleontology, vol. 2, pp. 59–60, pl. 16, figs. 19, 19a, 1869. Stewart, R. B., Gabb's Cretaceous and Tertiary type lamellibranchs: Acad. Nat. Sci., Philadelphia Special Pub. 3, pp. 119–120, pl. 13, fig. 4, 1930.
[5] Whiteaves, J. F., Notes on some marine Invertebrata from the coast of British Columbia: Ottawa Naturalist, vol. 7, no. 9, pp. 133–134, pl. 1, figs. 1, 1a, 1893. Illustrations reproduced by Arnold, Ralph, op. cit. (Prof. Paper 47), p. 140, pl. 52, figs. 3, 3a, 1906.
[6] Dall, W. H., New west American shells: Nautilus, vol. 11, p. 86, 1897; Illustrations and descriptions of new, unfigured, or imperfectly known shells, chiefly American, in the U. S. National Museum: U. S. Nat. Mus. Proc., vol. 24, p. 559, pl. 40, fig. 2, 1902. Arnold, Ralph, Tertiary and Quaternary pectens of California: U. S. Geol. Survey Prof. Paper 47, pp. 138–139, pl. 48, figs. 2, 2a, 1906.
[7] Arnold, Ralph, op. cit. (Prof. Paper 47), p. 139, pl. 48, figs. 3, 3a, 1906.
[8] Dall, W. H., The Mollusca and the Brachiopoda [*Albatross* Rept.]: Harvard College Mus. Comp. Zoology Bull., vol. 43, p. 403, pl. 10, fig. 9, 1908.
[9] Dall, W. H., Diagnoses of new shells from the Pacific Ocean: U. S. Nat. Mus. Proc., vol. 45, pp. 592–593, 1913; Illustrations of unfigured types of shells in the collection of the U. S. National Museum: U. S. Nat. Mus. Proc., vol. 66, p. 24, pl. 27, fig. 4, 1925.

Names proposed for Tertiary and Recent forms of Delectopecten from Pacific coast—Continued

Name	Type locality	Characters	Remarks
Pecten (*Pseudamusium*) *alternilineatus* Clark.[10]	Presumably a locality near Walnut Creek, Contra Costa County, Calif. (see Clark, table opp. p. 80). San Ramon sandstone, assigned to Oligocene.	Small; length 5 to 5.5 mm. [Concentric undulations apparently weak or absent.] Main part of shell sculptured with radial ribs. Right anterior ear sculptured with about 5 radial ribs. (Fide Clark.)	Apparently allied to *vancouverensis*.
Pecten (*Pseudamusium*) *vancouverensis sanjuanensis* Clark and Arnold.[11]	Vancouver Island, British Columbia. Sooke formation, assigned to Oligocene.	Small; length 7 mm. Concentric undulations moderately strong. Main part of shell sculptured with radial ribs. (Fide Clark and Arnold.)	Apparently allied to *vancouverensis*.
Pecten (*Pseudamusium*) *vancouverensis fernandoensis* Hertlein.[12]	Ventura River, ¼ mile south of Taylor well no. 1 and 1½ miles north of Ventura, Calif. Fernando, Pliocene [upper Pliocene].	Of medium size to moderately large; length 12.5 to 22.7 mm. Concentric undulations moderately strong to weak; main part of shell sculptured with radial ribs of varying strength. Right anterior ear sculptured with 5 to 7 radial ribs.	Apparently closely allied to *tillamookensis*. Pliocene specimens from Los Angeles Basin are smaller than *tillamookensis*, and some have stronger concentric undulations.
Pecten (*Pseudamusium*) *lillisi* Hertlein.[13]	Crow Creek road, Stanislaus County, Calif. Kreyenhagen shale, upper Eocene or lower Oligocene [apparently from part of Kreyenhagen shale now assigned to Eocene].	Small; length 9 to 15.6 mm. Concentric undulations weak or moderately strong. Main part of shell sculptured with a few or many radial ribs, especially on right valves. Right anterior ear sculptured with 4 to 8 radial ribs.	Relations to *peckhami*, to which this form was formerly assigned, not determined. Some specimens have stronger concentric undulations than *peckhami*.
Pecten (*Delectopecten*) *zacae* Hertlein.[14]	Gulf of Panama; depth 322 fathoms.	Moderately large; length 19 to 22 mm. Concentric undulations weak. Main part of shell sculptured with a few or many weak radial ribs. Right anterior ear sculptured with 4 to 6 radial ribs.	Specimens in collection of U. S. National Museum more obliquely elongate than those of other recent species of comparable size.

[10] Clark, B. L., The San Lorenzo series of middle California: California Univ., Dept. Geology, Bull., vol. 11, pp. 132–133, pl. 13, figs. 14, 15, 1918.
[11] Clark, B.L., and Arnold, Ralph, Fauna of the Sooke formation, Vancouver Island: Idem, vol. 14, pp. 140–141, pl. 16, figs. 5, 6, 1923.
[12] Hertlein, L. G., New species of marine fossil Mollusca from western North America: Southern California Acad. Sci. Bull., vol. 24, p. 43, pl. 4, figs. 6, 7, 1925.
[13] Hertlein, L. G., New oysters and a new pecten from the Tertiary of southern California: Idem, vol. 33, pp. 5–6, pl. 1, fig. 1; pl. 2, figs. 2, 3, 1934.
[14] Hertlein, L.G., The Recent Pectinidae [Templeton Crocker Expedition Rept.]: California Acad. Sci. Proc., vol. 21, pp. 321–322, pl. 18, figs. 3–6, 9, 10, 1935. (New name for *Pecten* (*Pseudamusium*) *panamensis* Dall, Harvard College Mus. Comp. Zoology Bull., vol. 43, p. 404, pl. 6, figs. 8, 10, 1908; not *Pecten panamensis* Dall, 1898.)

These little pectens apparently do not have many characters to serve as a basis for differentiation. Those that have been adequately described have the same kind of camptonectes sculpture and a few (4 to 8, generally 5 to 7) radial ribs on the right anterior ear, with the apparent exception of *pedroanus*. According to Trask's description and figure, *pedroanus* has 13 radial ribs on the right anterior ear. Nevertheless, as has recently been suggested,[14] it appears desirable to attempt some differentiation in this large group embracing small to relatively large forms, weakly to strongly sculptured forms, and forms having weak to strong concentric undulations.

The presence or absence of radial ribs on parts of the shell other than the right anterior ear appears to be of doubtful value for specific differentiation. Large suites of specimens agreeing in other characters show gradations from strong sculpture to none. This gradation is well shown in the modern forms (*vancouverensis*, *randolphi*, and *tillamookensis*), in the Oligocene and Miocene forms assigned to *peckhami*, and in the form from the Eocene part of the Kreyenhagen shale formerly assigned to *peckhami* and recently named *lillisi*. The radial ribs vary from strong beaded or scaly ribs covering the entire shell to weak ribs confined to a small part or parts of the shell. Many right valves that elsewhere lack radial ribs, aside from those on the anterior ear, have a few at the anterior margin of the shell. Some left valves that are paired with weakly sculptured right valves lack radial ribs entirely or they are restricted to the anterior ear. The presence or absence of radial ribs is considered of varietal rank, and perhaps this rank is open to question.

[14] Slodkewitsch, W. S., Stratigraphy and fauna of the Tertiary deposits of the western coast of Kamchatka, pt. 1: Geol. Oil Inst. Trans., ser. A, fasc. 79, pp. 171–173 (English summary), 1936.

The size of the shell and the strength of the concentric undulations appear to offer grounds for specific differentiation. The possible value of these characters, however, is undetermined in many of the forms. The outline of the shell may be a characteristic feature in some Recent forms, but many fossil specimens are deformed.

The three forms named by Trask have been regarded since Gabb's time as specimens of the same species representing varying degrees of deformation. According to a communication from L. G. Hertlein, Trask's material is not in the collections of the California Academy of Sciences. Trask's descriptions and illustrations evidently represent a large species that has strong concentric undulations. He described and showed "about 13" radial ribs on the right anterior ear of *pedroanus* and "about 12" on the left anterior ear of *annulatus*. The sculpture on the left anterior ear suggests that well-preserved specimens of this species may show radial ribs on the main part of the shell.

The large number of ribs on the right anterior ear needs confirmation. Other radially sculptured forms have 10 to 13 ribs on the left anterior ear, but only 4 to 8 on the right anterior ear, the lower part of which lacks radial ribs. Trask's specimens were examined by Gabb,[15] who stated that they were casts and that the sculpture is unknown. Trask's specimens evidently came from the lower part of the Valmonte diatomite member of the Monterey shale or the upper part of the underlying Altamira shale member exposed near the breakwater at Cabrillo Beach, for this is the only locality on the east coast of the Palos Verdes Hills where the beds dip as steeply as recorded by Trask ("about 50°"). Through the kindness of Hertlein a collection of pectens from the Valmonte diatomite about 220 yards northwest from the breakwater is available (California Acad. Sci. no. 1894). These specimens have weak or moderately strong concentric undulations, and the largest (length 15 millimeters, height 14.7 millimeters) is about half as large as Trask's. Impressions of two incomplete right valves show a few radial ribs near the anterior margin of the shell; impressions of two left valves show weak radial ribs on the anterior ear, and one of these shows indistinct traces of radial ribs at the margin of the shell near the anterior ear. This material appears to be similar to *peckhami*. No trace of radial ribs on the left anterior ear or on the main part of the shell can be seen on the specimens from the Valmonte diatomite collected a few miles from the type locality of *pedroanus* and recently cited as that species [16] (locality 13837). They have a maximum length of 15 to 16 millimeters, weak concentric undulations, and 4 to 7 ribs on the right anterior ear and apparently represent a form of *peckhami*.

A large *Delectopecten* (length 30 to 36 millimeters) from the Monterey shale in the Temblor Range at locality 3881, 4 miles southwest of McKittrick, was identified by Arnold [17] as *pedroanus*. It has moderately strong concentric undulations. An impression of a left valve shows numerous fine radial ribs. The number of ribs on the right anterior ear is undeterminable. Incomplete impressions of a large *Delectopecten* (length 25+ millimeters) are represented in a collection from the Monterey shale at locality 8136, in Las Virgenes Canyon, on the south slope of the Simi Hills, in southeastern Ventura County. These impressions show numerous fine radial ribs. The right anterior ear is not preserved. The concentric undulations are weaker than in Trask's illustrations and in most of the impressions from locality 3881.

Gabb failed to compare *peckhami* with *pedroanus*. A squeeze of the lectotype of *peckhami* is available through the courtesy of W. E. Schevill, of the Museum of Comparative Zoology. It is a left valve that has a length of about 12 millimeters, weak concentric undulations, and weak, relatively widely spaced radial ribs, which are absent in most of the area extending downward from the umbo. These ribs are not well shown on the photograph of the lectotype, the radial lines of which appear to have been added by retouching. The other two specimens in the lectotype lot also are available through the kindness of Schevill. One—a left valve exposed in interior view—has a length of 13 millimeters; the other—a right valve that lacks the shell aside from small patches of inner layers—has a length of 14.8 millimeters. Both specimens have weak concentric undulations, and neither shows radial ribs, with the exception of traces on the right anterior ear.

H. peckhami seems to be a small species that has weak concentric undulations and weak, relatively widely spaced radial ribs. In many specimens the ribs are apparently absent. They are absent on the specimens from the Monterey group of the San Francisco Bay region figured by Arnold.[18] On some specimens the apparent absence of ribs may be a matter of preservation, as the shell itself is generally not preserved, and preservation in the form of impressions is generally needed to show such weak ribs. *H. peckhami* is recorded from the Monterey shale and from other formations ranging in age from Eocene to Miocene.

A moderately large *Delectopecten* (length 20 millimeters) that has weak or moderately strong undulations is abundant in collections from the Miocene of Astoria, Oreg. (localities 2263, 5314, 5315, 5317, 5318, 5319, 5322, 5332, 5379), where *peckhami* has been recorded.[19] Impressions of a right valve from locality 5315 (loose concretion on river bank, lower part of Astoria) and of another right valve from locality 5332 (bridge on Youngs River 2 miles from Astoria on road to Portland, NW¼ sec. 21, T. 8 N., R. 9 W.) show a few radial ribs at the anterior end of the valve.

A small strongly undulated *Delectopecten* (length 11.5 millimeters) is represented in the Whepley shale (of drillers), assigned to the lower Miocene, of the subsurface section in the Kettleman Hills, on the west side of the San Joaquin Valley. The specimens available (Petroleum Securities Felix No. 3, depth 8,495 to 9,516 feet; Kettleman North Dome Association No. 61–2–P, depth 8,312 to 8,328 feet) retain some shell material replaced by pyrite showing the camptonectes sculpture. Some show obscure indications of radial ribs, but this may be a matter of preservation.

A right valve (length 18 millimeters) that lacks shell material and shows radial ribs only on the anterior ear was collected at the south end of the San Joaquin

[15] Gabb, W. M., California Geol. Survey, Paleontology, vol. 2, p. 60, 1869.

[16] Woodring, W. P., in Woodring, W. P., Bramlette, M. N., and Kleinpell, R. M., Miocene stratigraphy and paleontology of Palos Verdes Hills, California: Am. Assoc. Petroleum Geologists Bull., vol. 20, p. 146, 1936.

[17] Arnold, Ralph, op. cit. (Prof. Paper 47), p. 91, 1906.

[18] Idem, pp. 56–57, pl. 3, fig. 8.

[19] Howe, H. V., Astoria; mid-Tertic type of Pacific coast: Pan-Am. Geologist, vol. 45, pp. 298, 304, 1926.

Valley in an area mapped as underlain by the Vaqueros formation[20] (locality 13315, canyon draining eastward into Santiago Creek about 2 miles below San Andreas rift).

The material from Weaver's Blakeley formation of Washington (Oligocene) and strata of equivalent age on the south shore of the Strait of Juan de Fuca cited by Arnold [21] as *peckhami* is poorly preserved. An impression of a left valve from locality 4112a, on Bainbridge Island, has radial ribs; and impressions of two right valves from locality 4114, near Gettysburg, have a few radial ribs at the anterior end of the valve.

Radial ribs are not discernible on imperfect specimens of a small form (length 9 millimeters) from the Oligocene of Columbia and Clatsop Counties, Oreg. (localities 2712, 5382, 5387).

The *Delectopecten* from the part of the Kreyenhagen shale now assigned to the Eocene was identified by Arnold [22] as *peckhami* and has recently been named *lillisi* by Hertlein. This form is represented in collections at the National Museum from localities extending from the north limb of the Coalinga anticline northward to the type region near Crow Creek, in Stanislaus County (localities 205, 4616, 5745, 5747, 5752, 5760, 5762, 5787). A few right valves have ribs over the entire valve; others have ribs on the greater part of the anterior half of the valve; and on many, as on the one from which the squeeze figured by Arnold was prepared, only one or two ribs, or rows of knobs, are discernible at the anterior margin. Ribs were observed on only one left valve. This form appears to resemble *peckhami* closely; some specimens have stronger concentric undulations than *peckhami*. The *Delectopecten* from the Eocene part of the Kreyenhagen shale is associated with *Propeamussium interradiatum* (Gabb) at localities 4616 (north limb of Coalinga anticline) and 205 (Big Panoche Creek).

A strongly undulated right valve (length 12.5 millimeters) that lacks radial ribs is in a collection from the Oligocene part of the Kreyenhagen—Atwill's "Tumey formation"—at locality 5756, on Arroyo Ciervo.[23]

Pecten vanwinkleae,[24] from the Oligocene of Washington, was described as having the right posterior ear differentiated from the main part of the shell, and the illustration shows this feature in a form that otherwise appears to resemble forms of *peckhami*.

Delectopecten,[25] proposed as a subgenus of *Palliolum*, may not be closely allied to *Hyalopecten*,[26] a deep-water North Atlantic genus that has a notched posterior ear, weaker ctenolium, concentric undulations, fine radial sculpture, and no camptonectes sculpture. It appears, however, to be more closely related to *Hyalopecten*, with which Stewart compared it, than to *Palliolum*,[27] which has a heavier shell, differentiated posterior ear, and camptonectes sculpture of minute pustules.

Specimens of Hyalopecten aff. H. randolphi from Repetto formation examined

Locality	Specimens	Locality	Specimens
Third Street tunnel, Los Angeles; Homer Hamlin. U. S. G. S. locality 3426. Specimens figured by Arnold and others have the locality number 3428 (Broadway tunnel, Los Angeles), which apparently is an error for 3426.	7 right and 5 left valves of various size, 3 of which were figured by Arnold. Undulations strong.	Standard Oil Co. Baldwin No. 41, Montebello field, depth 3,600 feet. U. S. G. S. locality 13907.	Incomplete large valve and impression (figured); part of left valve and impression. Undulations strong.
Third Street tunnel, Los Angeles; Homer Hamlin. U. S. G. S. locality 3432.	Right and 2 left valves. Undulations strong.	Union Oil Co. Bell No. 43, Santa Fe Springs field, depth 5,518 feet. Collection of Union Oil Co.	Parts of small right (?) valve and impression. Undulations strong.

[20] Pack, R. W., The Sunset-Midway oil field, California, pt. 1: U. S. Geol. Survey Prof. Paper 116, pl. 2, 1920.

[21] Arnold, Ralph, op. cit. (Prof. Paper 47), p. 57, 1906.

[22] Arnold, Ralph, Paleontology of the Coalinga district, California: U. S. Geol. Survey Bull. 396, p. 13, pl. 3, figs. 2, 2*a*, 1909 [1910].

[23] For records of a *peckhami*-like form in this part of the Kreyenhagen see Anderson, F. M., A stratigraphic study in the Mount Diablo Range of California: California Acad. Sci. Proc., 3d ser., vol. 2, p. 173, 1905; A further stratigraphic study in the Mount Diablo Range of California: Idem, 4th ser., vol. 3, p. 16, 1908. Woodring, W. P., in Condit, D. D., Age of the Kreyenhagen shale in the Cantua Creek-Panoche district, California: Jour. Paleontology, vol. 4, p. 261, 1930. Atwill, E. R., Oligocene Tumey formation of California: Am. Assoc. Petroleum Geologists Bull., vol. 19, p. 1200, 1935.

[24] Clark, B. L., Pelecypoda from the marine Oligocene of western North America: California Univ., Dept. Geol. Sci., Bull., vol. 15, pp. 82–83, pl. 15, fig. 2, 1925.

[25] Stewart, R. B., Gabb's California Cretaceous and Tertiary type lamellibranchs: Acad. Nat. Sci. Philadelphia Special Pub. 3, p. 118, 1930. Originally designated type, *Pecten (Pseudamusium) vancouverensis* Whiteaves.

[26] Verrill, A. E., A study of the family Pectinidae, with a revision of the genera and subgenera: Connecticut Acad. Sci. Trans., vol. 10, p. 71, 1897. Originally designated type, *Hyalopecten undatus* Verrill, Recent, off Maryland (cf. *Pecten fragilis* Jeffreys, 1876, North Atlantic).

[27] Monterosato, Marchese di, Nomenclatura generica e specificà di alcune conchiglie mediterranee, p. 5, 1884. Subsequently designated type (Crosse, Jour. Conchyliologie, vol. 33, p. 140, 1885), *Pecten incomparabilis* Risso, Recent, Mediterranean (frequently cited as *P. testae* Bivona).

Specimens of Hyalopecten aff. H. randolphi from other horizons examined

Locality	Specimens	Locality	Specimens
Standard Oil Co. Bolsa No. 31, Huntington Beach field, depth 3,086 to 3,092 feet. U. S. G. S. locality 13905. Miocene.	Right and left valves of medium size and corresponding impressions. Undulations strong.	Marine Oil Co. Strong No. 1, near Norwalk, depth 3,535 feet. U. S. G. S. locality 13886. Pico formation.	Imperfect large right valve. Undulations moderately strong.
Standard Oil Co. Schumacher No. 1, Huntington Beach field, depth 4,430 to 4,440 feet. U. S. G. S. locality 13902. Miocene.	Right valve of medium size superimposed on interior of left valve of medium size (probably sheared paired specimen). Undulations strong.	Southern California Drilling Co. Matteson No. 1, near El Segundo, depth 2,081 feet. U. S. G. S. locality 13912. Pico formation.	Large left valve (figured). Impression of part of right valve showing sculpture on anterior ear (figured). Incomplete right valve (figured). Impression of part of right valve. Undulations moderately strong to weak.
Same well, depth 4,440 to 4,453 feet. U. S. G. S. locality 13902b. Miocene.	Part of large left valve; parts of right and 2 left valves and impressions. Undulations strong.		

Hyalopecten (Delectopecten) aff. H. randolphi tillamookensis (Arnold)

Plate 6, figures 3, 4

Pecten (Pseudamusium) vancouverensis fernandoensis Hertlein, Southern California Acad. Sci. Bull., vol. 24, pp. 43, 44, pl. 4, figs. 6, 7, 1925. Ventura River; Fernando, Pliocene (type). Well at Signal Hill; lower Fernando, lower Pliocene (paratype).

Pecten (Pseudamussium) pedroanus (Trask) variety *vancouverensis* Whiteaves. Grant and Gale (part), San Diego Soc. Nat. History Mem., vol. 1, p. 238, 1931.

A *Delectopecten*, allied to *tillamookensis*, of medium size or moderately large. Concentric undulations moderately strong to weak. Sculpture consisting of fine radial ribs and concentric threads; minute knobs at the intersections. Right anterior ear sculptured with 5 to 7 radial ribs and concentric threads. Camptonectes sculpture as in *Hyalopecten* aff. *H. randolphi*.

Length 22.7 millimeters, estimated height 22 millimeters (left valve; from a horizon assigned to Pico formation). Length 12.5 millimeters, height about 7 millimeters (left valve).

Exteriors generally have only a thin veneer of inner shell substance preserved. Parts of the entire shell are preserved on some specimens, and the sculpture shows through the thin translucent shell.

It has not been determined whether *fernandoensis* is differentiated from *tillamookensis*. The fossils from the Los Angeles Basin are considerably smaller than large shells of *tillamookensis*. Some of the fossils have stronger concentric undulations than Recent shells, but the strength of the undulations is variable in both fossil and Recent specimens.

The type locality of *fernandoensis*, on the south flank of the Ventura anticline, represents strata of upper Pliocene age. The specimens from the Los Angeles Basin are from core material representing horizons in the Repetto and Pico formations. Hertlein recorded *fernandoensis* from a well in the Long Beach field at a depth determined by Wissler as representing a horizon near the top of the Repetto formation. In the material at hand specimens from the Repetto formation are smaller (length 9.2 to 12.5 millimeters) than those from the Pico formation (length 14.3 to 22.5 millimeters).

Two specimens from the upper Miocene, or a horizon near the contact between Miocene and Pliocene, have exceptionally strong concentric undulations and are identified as *H.* cf. *H. pedroanus*. One (pl. 6, fig. 1; St. Helen's Petroleum Co. P. & B. No. 6, Montebello field, depth 5,704 feet; U. S. G. S. locality 13870; from a horizon near contact between Miocene and Pliocene) has a length of 30.5 millimeters and is much larger than the specimens from the Repetto and Pico formations. It has faint radial ribs near the lower margin of part of the shell. The other (pl. 6, fig. 2; Graham & Loftus Oil Co. No. 1, East Coyote field, depth 5,592 to 5,615 feet; U. S. G. S. locality 13872; Miocene) has a length of 17 millimeters and strong radial ribs. Right anterior ears are not preserved in the material from either well.

In addition to the Repetto records in the following table, Wissler has identified *H.* aff. *H. randolphi tillamookensis* in a core from A. N. Macrate Gray No. 1, Rosecrans field, depth 5,620 feet.

Specimens of Hyalopecten aff. H. randolphi tillamookensis from Repetto formation examined

Locality	Specimens	Locality	Specimens
Julian Oil Co. Farnsworth No. 2, Huntington Beach field, depth 2,081 feet. U. S. G. S. locality 13908.	Left valve of medium size and impression (figured); most of shell on impression.	Huntington Signal Oil Co. Hand No. 2, Huntington Beach field, depth 3,454 feet. U. S. G. S. locality 13909.	Interior of small right valve; most of shell preserved.
Same well, depth 2,135 feet. U. S. G. S. locality 13908a.	Interior of small right valve; most of shell preserved.		

Specimens of Hyalopecten aff. H. randolphi tillamookensis from other horizons examined

Locality	Specimens	Locality	Specimens
Standard Oil Co. Vickers No. 1 lease, well No. 27, Inglewood field, depth 1,240–1,253 feet. U. S. G. S. locality 13888. Pico formation.	Interior of valve of medium size (figured). Exterior of parts of 2 other valves; shell not preserved.	Union Oil Co. Mosier No. 1, Rosecrans field, depth 3,000 feet. U. S. G. S. locality 13894. Pico formation.	Left valve of medium size and impression; most of the shell on the impression. Greater part of distorted left valve of medium size. Strongly sculptured left valve of medium size; shell not preserved.
Standard Oil Co. Los Angeles Investment No. 71, Inglewood field, depth 1,323–1,324 feet. U. S. G. S. locality 13891. Pico formation.	Interiors and impressions of 4 incomplete valves of medium size or moderately large.		

Family OSTREIDAE

Genus OSTREA Linné

Ostrea vespertina Conrad

Plate 9, figure 5

Localities in coastal region of California and San Joaquin Valley

Ostrea vespertina Conrad, Gabb (part), California Geol. Survey, Paleontology, vol. 2, p. 107 (list), 1869. Santa Barbara; Pliocene.

Cooper (part), California State Min. Bur. 7th Ann. Rept., p. 256 (list), 1888. Santa Barbara, San Fernando; Pliocene.

Cooper, in Watts, California State Min. Bur. Bull. 11, p. 80 (list), 1897. Los Angeles oil wells.

Arnold, U. S. Geol. Survey Bull. 396, pp. 31 (list), 35 (list), 39 (list), 42 (discussion), 43 (discussion), 44 (discussion), 77–79, pl. 24, figs. 4, 5, 1909 [1910]. Coalinga district; Etchegoin formation, uppermost Miocene. [Figured specimens from *Pecten coalingaensis* zone, now referred to San Joaquin formation; Pliocene.]

Arnold, in Arnold and Anderson, U. S. Geol. Survey Bull. 398, pp. 126 (list), 129 (list), 132 (list), 137 (discussion), 138 (discussion), 139 (discussion), pl. 46, figs. 4, 5, 1910. Coalinga district; Etchegoin formation, uppermost Miocene. [Figured specimens from *Pecten coalingaensis* zone, now referred to San Joaquin formation; Pliocene.

Smith, California Acad. Sci. Proc., 4th ser., vol. 3, pp. 167 (list), 172 (list), 1912. Etchegoin, upper Miocene.

Nomland, California Univ., Dept. Geology, Bull., vol. 10, p. 219 (list), table opposite p. 230 (list), 1917. Coalinga district; Etchegoin, Pliocene.

Nomland, California Univ., Dept. Geology, Bull., vol. 10, pp. 299 (list), 300 (list), 302 (list, "cf."), 1917. Coalinga district; Santa Margarita, Miocene.

Gester, 1917, California Acad. Sci. Proc., 4th ser., vol. 7, p. 224 (mentioned), 1917. Blown out of well at McKittrick; Pliocene.

Smith (part), California Acad. Sci. Proc., 4th ser., vol. 9, p. 147 (list), 1919. Etchegoin-Jacalitos; Pliocene.

Woodring, California Acad. Sci. Proc., 4th ser., vol. 19, pp. 59 (list), 62 (list), 1930. North of Simi Valley, Temescal Canyon; Pliocene.

Woodring, in Hoots, U. S. Geol. Survey Prof. Paper 165, p. 119 (list), 1931. Temescal Canyon; San Diego formation, middle or upper Pliocene.

Grant and Gale (part), San Diego Soc. Nat. History Mem., vol. 1, pp. 30 (discussion), 34 (discussion), 152–153, pl. 12, figs. 1*a*, 1*b*, 1931. Figured specimen from Holser Canyon; San Diego zone, middle Pliocene.

Grant, in Soper and Grant, Geol. Soc. America Bull., vol. 43, p. 1057 (list), 1932 (1933). Third Street tunnel, Los Angeles; middle Pliocene [Arnold's record of *O. veatchii*].

Ostrea veatchii Gabb. Dall, U. S. Nat. Mus. Proc., vol. 1, p. 11 (list), 1879. San Diego.

Dall, U. S. Nat. Mus. Proc., vol. 1, p. 29 (list), 1879. 10 miles north of San Diego.

Ashley, California Acad. Sci. Proc., 2d ser., vol. 5, p. 338 (list), 1895. San Fernando Pass; Merced series.

Watts, California State Min. Bur. Bull. 19, p. 222 (list, "?"), 1900. Piru Creek and vicinity; middle Neocene.

Arnold, California Acad. Sci. Mem., vol. 3, p. 63 (list) ("*veatchi* ?"), 1903. San Diego; Pliocene.

Osmont, California Univ., Dept. Geology, Bull., vol. 4, p. 94 (Ashley's list), 98 (list), 1905. 5 miles northeast of Camulos; probably Pliocene (p. 100).

Arnold (part), U. S. Geol. Survey Prof. Paper 47, pp. 28 (list), 91 (list), 116 (list), 123 (list), 1906. Pacific Beach, near San Diego; Pliocene. Third Street tunnel, Los Angeles; Pliocene.

Arnold, U. S. Nat. Mus. Proc., vol. 32, p. 527 (list), p. 544, pl. 49, fig. 1, 1907. Third Street tunnel, Los Angeles; middle Fernando formation, lower Pliocene. [Figured specimen from San Diego.]

Arnold, in Eldridge and Arnold, U. S. Geol. Survey Bull. 309, pp. 24 (list), 107 (list), 152 (list), 153 (list), 250, pl. 39, fig. 1, 1907. Near Camulos; Fernando formation, Pliocene. Puente Hills; Fernando formation, Pliocene. Third Street tunnel, Los Angeles; Fernando formation, lower Pliocene. Los Angeles oil wells; Pliocene. [Figured specimen from San Diego.]

Arnold, Smithsonian Misc. Coll., vol. 50, no. 1781, pp. 423 (list), 445, pl. 56, fig. 10, 1907. Santa Maria district; Fernando, upper Miocene-Pliocene-Peleistocene.

Arnold, in Arnold and Anderson, U. S. Geol. Survey Bull. 322, pp. 58 (list), 148, pl. 23, fig. 10, 1907. Santa Maria district; Fernando, base of Pliocene.

Smith, California Acad. Sci. Proc., 4th ser., vol. 3, pp. 167 (list), 172 (list), 1912. Upper Miocene to Pliocene.

English, California Univ., Dept. Geology, Bull., vol. 8, p. 210 (list), 1914. Holser Canyon; lower Fernando, Pliocene.

Dievendorff, in Collom, California State Min. Bur. Bull. 82, pp. 212 (list), 213 (list) ("*veatchi*"), 1918. Santa Maria district; Fernando, Pliocene.

Smith (part), California Acad. Sci. Proc., 4th ser., vol. 9 ("*veatchi*"), pp. 146 (list), 147 (list), 150 (list, part), 151 (list), 152 (list), 166 (discussion), 1919. Pliocene.

Kew, U. S. Geol. Survey Bull. 753, pp. 78 (list), 88 (list), 1924. Holser Canyon; Pico formation, Pliocene. Browns Canyon; Saugus formation, Pliocene.

Carson, Southern California Acad. Sci. Bull., vol. 24, pp. 31 (list), 32 (2 lists), 1925. Brea Canyon, Puente Hills, Holser Canyon, Gavin Canyon; Fernando formation, lower Pliocene.

English, U. S. Geol. Survey Bull. 768, p. 43 (Arnold's list), 1926. Puente Hills; Fernando group, Pliocene.

Carson, Southern California Acad. Sci. Bull., vol. 25, pp. 49 (list), 51 (2 lists), 55 (list), 56 (list), 57 (list), 1926. Fugler's Point, half a mile north of Schuman, Elsmere Canyon; Fernando formation, lower Pliocene.

Grant, in Soper and Grant, Geol. Soc. America Bull., vol. 43, p. 1057 (Arnold's list), 1932 (1933). Third Street tunnel, Los Angeles; middle Pliocene.

Localities in Colorado Desert

Ostrea vespertina Conrad, Acad. Nat. Sci. Philadelphia Jour., 2d ser., vol. 2, p. 300, 1854. Near San Diego; Miocene.

Meek, Smithsonian Misc. Coll., no. 183, p. 3 (list), 1864. "Con." [? error for Calif.]

Conrad, in Blake, Preliminary report, U. S. Pacific R. R. Expl., app., pp. 7 (list), 15, 1855. Carrizo Creek; Miocene.

Blake, U. S. Pacific R. R. Expl., vol. 5, pt. 2, pp. 108 (mentioned), 122 (mentioned), 175 (mentioned), 176 (mentioned), 235 (mentioned), 351 (list), 352 (list), 1857. Carrizo Creek.

Conrad, idem, pp. 317 (mentioned), 319 (list, "nov. sp."), 325–326, pl. 5, figs. 36–38, 1857. Carrizo Creek; Miocene.

Conrad, in Emory, Report on the United States and Mexican boundary survey, vol. 1, pt. 2, p. 160, pl. 17, figs. 1a–1d, 1857. Carriso Creek and near San Diego; Miocene.

Carpenter, British Assoc. Adv. Sci. Rept. for 1863, p. 590 ("resembles *O. lurida* var."), 1864. Colorado Desert; Miocene.

Gabb (part), California Geol. Survey, Paleontology, vol. 2, p. 107 (list), 1869. Colorado Desert; Pliocene.

Heilprin, in White, U. S. Geol. Survey 4th Ann. Rept., p. 315, pl. 71, figs. 2–4, 1884. Carrizo Creek; Miocene (Conrad), Pliocene (Gabb).

Marcou, U. S. Nat. Mus. Proc., vol. 8, p. 341 (list, "types, U. S. Nat. Mus. no. 9832"), 1885.

Cooper (part), California State Min. Bur. 7th Ann. Rept., p. 256 (list), 1888. West of Colorado Desert, San Diego County; Pliocene.

Orcutt, California State Min. Bur. 10th Ann. Rept., p. 917 ("described from Carrizo Creek"), 1890.

Dall, Wagner Inst. Sci. Philadelphia Trans., vol. 3, pt. 4, p. 685 ("types in Nat. Mus."), 1898.

Schuchert, U. S. Nat. Mus. Bull. 53, pt. 1, p. 475 (list, "cotypes U. S. Nat. Mus. no. 9832"), 1905. Carrizo Creek and near San Diego; Miocene.

Arnold, U. S. Geol. Survey Prof. Paper 47, pp. 22 (list), 61 (mentioned), 1906. Carrizo Creek; Miocene.

Kew, California Univ., Dept. Geology, Bull., vol. 8, pp. 44 (mentioned), 45 (mentioned), 46 (list), 1914. Carrizo Creek region; Carrizo formation, age not definitely determined.

Smith (part), California Acad. Sci. Proc., 4th ser., vol. 9, p. 153 (list), 1919. Carrizo; Pliocene.

Hanna, California Acad. Sci. Proc., 4th ser., vol. 14, pp. 468–469, pl. 26, figs. 4–7, 1926. Coyote Mountain; Pliocene.

Woodring, Carnegie Inst. Washington Pub. 418, pp. 9 ("probably different species"), 11 ("*vespertina*"), 1931. Imperial formation; Miocene.

Localities in Lower California

Ostrea veatchii Gabb, California Geol. Survey, Paleontology, vol. 2, pp. 34–35, 1866; pp. 60–61, 106 (list), pl. 11, fig. 59, pl. 17, fig. 21, 21a, 1869. Cerros Island; probably Miocene (p. 32), post-Pliocene (p. 106). Near Loreto; post-Pliocene (pp. 61, 106).

Ostrea vespertina Conrad. Jordan and Hertlein, California Acad. Sci. Proc., 4th ser., vol. 15, p. 212 (list), 1926. Maria Madre Island; Pliocene.

Jordan and Hertlein, California Acad. Sci. Proc., 4th ser., vol. 15, pp. 417 (list), 420 (list), 428–429, 1926. Cedros Island; Pliocene.

Hanna and Hertlein, California Acad. Sci. Proc., 4th ser., vol. 16, pp. 141 (list), 145 (list), 146 (list), 149 (list), 1927. Localities bordering Gulf of California; Pliocene.

Ostrea haitensis Sowerby subsp. *vespertina* Conrad. Stewart, Acad. Nat. Sci. Philadelphia Special Pub. 3, pp. 128–129, pl. 14, fig. 4, 1930. Cedros Island; Pliocene.

A broken strongly plicate left valve in Hamlin's collection from the Third Street tunnel represents an apparently elongate-ovate oyster (height 66.6 millimeters, restored length about 50 millimeters). It closely resembles strongly plicate left valves from San Diego referred to *O. vespertina* or *veatchii*.

Ostrea vespertina was one of the first fossils to be described from California. It was described in 1854 on the basis of material collected "near San Diego" by Le Conte. The locality record is equivocal, and both San Diego and Carrizo Creek, which lies in the Colorado Desert 65 miles east of San Diego in a direct line, have been claimed as the type locality. Through the kindness of Dr. H. A. Pilsbry a lot of nine specimens in the collections of the Philadelphia Academy of Natural Sciences (no. 13366), which is regarded as the type lot, is available for examination. The locality and collector are not recorded on the label, which doubtless was written after Conrad's time. The largest specimen, an incomplete right valve riddled by a boring sponge (?) shown on plate 8, figures 3, 8, agrees with Conrad's dimensions ("from beak to base 1⅞; transversely 1½" [inches]) and is selected as the lectotype. The type lot represents a small ovate or ovate-falcate oyster that agrees in characters with the oyster found at Carrizo Creek, and the specimens have the brown color and vitreous luster of Carrizo Creek specimens. The collector presumably was John L. Le Conte, who traveled down Carrizo Creek in 1850 to examine the mud volcanoes at Salton Sea and in his account mentioned oyster shells observed along Carrizo Creek but left no record of having collected specimens.[28] "Near San Diego" would not be an unreasonable description for Carrizo Creek at the time when this oyster was described. Conrad's later citation "Carriso Creek and near San Diego" indicates that he thought he had this species from two localities, and this citation has sup-

[28] Le Conte, J. L., Account of some volcanic springs in the Desert of the Colorado in southern California: Am. Jour. Sci., 2d ser., vol. 19, p. 3, 1855.

ported the literal interpretation of "near San Diego" that is the current one.

The plicate oysters in the Miocene and Pliocene of California and Lower California appear to represent two closely related poorly defined groups—(1) large circular-ovate oysters; (2) ovate, ovate-falcate, or elongate oysters of small or medium size. A satisfactory nomenclature for these oysters has not been worked out. Large circular-ovate oysters are not recorded from the Pliocene of the coastal region of California and the San Joaquin Valley, but aside from the difference in size some specimens resemble the large circular-ovate form. The plicate oysters from the coastal region and the San Joaquin Valley appear to resemble *vespertina*, and that name is used for them.

The coastal *vespertina* is of medium size, and almost any collection of fair size includes elongate specimens. A collection from locality 2474 (second bench back on mesa, three-fourths mile northeast of Pacific Beach, near San Diego) consists of 38 valves, associated with *Pecten stearnsii*, *Lyropecten cerrosensis*, and *Patinopecten healeyi*. In outline they range from ovate to ovate-falcate; a few are markedly elongate. The largest has a length of 66.4 millimeters and a height of 84.4 millimeters. Left valves have relatively few (5 to 7) plications; right valves are strongly to weakly plicate, and a few are only undulate. The inner margin below the ligament area is strongly fluted, weakly fluted, or smooth. Three corresponding right and left valves from locality 2272 (mesa between San Diego and National City) have stronger and more numerous plications, and right valves are as strongly plicate as left valves. The left valve from this locality figured by Arnold [29] is more elongate and larger than the others, except the corresponding right valve. The inner margin below the ligament area is smooth or weakly fluted. Despite the outline the lower margin of the shell figured by Arnold is not broken. An elongate left valve and a paired small ovate shell from locality 2661 (Crystal Springs) are strongly plicate. A small left valve from Pacific Beach (locality 2458) is ovate and moderately plicate; three ovate right valves from the same locality but under a different locality number (2657) are undulate.

In addition to localities near San Diego representing the Pliocene San Diego formation, the coastal oyster is recorded as *vespertina* or *veatchii* from Pliocene localities in the Puente Hills, Los Angeles, and Temescal Canyon (all around the borders of the Los Angeles Basin), in the hills north of Simi Valley in Ventura County, in the Ventura Basin, in the Santa Maria Basin, and in San Joaquin Valley. A right valve from an indefinite locality near Newhall, in the eastern part of the Ventura Basin close to San Fernando Pass (locality 3514), has a circular-ovate outline and exceptionally deep plications (incomplete length 59 millimeters, height 67 millimeters). It closely resembles the Lower California form (*veatchii*). An elongate paired shell in the same collection also has very deep plications. Arnold [30] figured a relatively large ovate, moderately plicate left valve from locality 4474, in the Santa Maria Basin (railroad cut 1 mile north of Schumann), where this species is represented by numerous specimens, most of which are strongly fluted on the inner margin below the ligament area. A few valves are elongate, and some right valves are undulate. Arnold received from Orlando Barton a fine lot of 83 valves from the *Pecten coalingaensis* zone, now assigned to the San Joaquin formation, on the east side of South Dome, at the south end of the Kettleman Hills (locality 4715),[31] in San Joaquin Valley, a left valve and a right valve of which were figured. Most of these shells are ovate, like the figured right valve; the figured left valve, which is not correctly oriented, is about as strongly ovate-falcate as any other; and a few are markedly elongate. Left valves are strongly plicate, and all except two or three right valves are as strongly plicate as left valves. Fluted margins were not observed on any of the 25 left valves, and 17 of 52 right valves that show the inner margin are clearly fluted. Of these 17 only 5 are fluted on the anterior margin. These shells resemble strongly plicate shells from San Diego but are a little smaller, the largest having a length of 56.3 millimeters and a height of 71.7 millimeters. A smaller, generally less plicate oyster, most right valves of which are undulate rather than plicate, occurs in the uppermost part of the San Joaquin formation. It was named *Ostrea vespertina* var. *sequens* by Arnold [32] and appears to be a variety or subspecies of the oyster found at lower horizons in this region. No character aside from smaller size is apparent to distinguish elongate, weakly plicate left valves and most right valves of *vespertina sequens* from moderately elongate shells of the modern *O. lurida* Carpenter,[33] some left valves of which are weakly plicate or strongly undulate, and perhaps *lurida* is derived from this form. Modern shells from the Gulf of California, Lower California, and Puget Sound, labeled *O. palmula* Carpenter,[34] resemble ovate or ovate-falcate

[29] Arnold, Ralph, U. S. Nat. Mus. Proc., vol. 32, pl. 49, fig. 1, 1907 (as *Ostrea veatchii* Gabb). Eldridge, G. H., and Arnold, Ralph, U. S. Geol. Survey Bull. 309, pl. 39, fig. 1, 1907 (as *Ostrea veatchii* Gabb).

[30] Arnold, Ralph, Smithsonian Misc. Coll., vol. 50, no. 1781, pl. 56, fig. 10, 1907 (as *Ostrea veatchii* Gabb). Arnold, Ralph, and Anderson, Robert, U. S. Geol. Survey Bull. 322, pl. 23, fig. 10, 1907 (as *Ostrea veatchii* Gabb).

[31] This locality is listed in Bull. 396 (pp. 34–36, 47) and Bull. 398 (pp. 135, 153) under both the Etchegoin and Tulare formations, presumably on account of the occurrence of fresh-water shells, which were mistaken for Tulare fossils.

[32] Arnold, Ralph, Paleontology of the Coalinga district, California: U. S. Geol. Survey Bull. 396, pp. 79–80, pl. 29, figs. 5, 6, 1909 [1910].

[33] Carpenter, P. P., Supplementary report on the present state of our knowledge with regard to the Mollusca of the west coast of North America: British Assoc. Adv. Sci. Rept. for 1863, p. 645, 1864.

[34] Carpenter, P. P., Catalogue of the collection of Mazatlan shells in the British Museum, pp. 163 ("*Ostrea?? conchaphilla* var. *palmula*"), 550 ("the examination of additional specimens confirms the opinion that *Ostrea palmula* is a distinct species"), 1857.

specimens of the coastal *vespertina* of medium size, but they have an exceptionally long strongly fluted area on the inner margin.

The small ovate-falcate oyster from Carrizo Creek and other localities around the borders of Carrizo Mountain and nearby regions in the Colorado Desert was described by Conrad as *vespertina*, which was again treated as a new species in 1857 but not in 1855. Two left valves figured by Conrad in volume 5 of the Pacific Railroad reports (pl. 5, figs. 37, 38) are in the U. S. National Museum (no. 1854). According to a later label they were identified by Meek, which probably means that Meek recognized them as Conrad's figured specimens. Five less satisfactory specimens, labeled "identified by Conrad", are under the number 8397. Dall added "types" to the label; therefore, these specimens were claimed by Dall as the "types" of *vespertina* and were identified as *O. haitensis* Sowerby.[35] The well-executed drawings by Meek in Emory's report on the geology of the Mexican boundary survey are based on a left and a right valve also in the National Museum (no. 9832). They were listed by Marcou as "types" and by Schuchert as "cotypes" of *vespertina*. Another drawing of the same left valve was published by Heilprin. This oyster is a little smaller than the coastal *vespertina*. It also is generally more distinctly ovate-falcate. Ovate specimens that show no suggestion of a falcate outline are rare, and the few elongate specimens are more distinctly falcate than elongate coastal specimens. The posterior margin of the lectotype (pl. 8, figs. 3, 8) is broken and it may have had a more ovate-falcate outline than is apparent. Two complete right valves from Carrizo Creek (locality 3921; Barrett's oil well [on south side of Carrizo Creek], about 20 miles north of Mexican boundary) are shown in plate 8, figures 1, 2, 4, 9. Left valves are strongly plicate, and with few exceptions right valves also are plicate, aside from an undulate or smooth area extending downward from the umbonal region, but generally are not so strongly plicate as left valves. Most specimens from Carrizo Creek and the coastal region are twisted clockwise when viewed in attached position; a few are counterclockwise. The largest valve in a lot of 40 from locality 3921 has a length of 48.7 millimeters and a height of 61.7 millimeters, being thus exceptionally large for this form. Left and right valves from this locality are strongly fluted on the inner margin below the ligament area, but this character is not uniform; some lots consist of weakly fluted or smooth specimens. Of the shells at hand from the coast and San Joaquin Valley the Carrizo Creek form is most similar to the one from the *Pecten coalingaensis* zone of the Kettleman Hills, one of the similarities that led Arnold to consider the formations at these localities to be of about the same age.[36] Some specimens from the Kettleman Hills are as distinctly ovate-falcate as those from Carrizo Creek, but an ovate outline is general, and a few specimens are elongate-ovate. The Carrizo Creek oyster is abundant in the upper part of the Imperial formation associated with *Aequipecten circularis deserti* and *Anomia subcostata*, an association indicating brackish water. It is more similar to the coastal and San Joaquin *vespertina* than to any described Miocene or Pliocene oyster from the Pacific coast.

O. veatchii was considered identical with *vespertina* by Dall, by Jordan and Hertlein, who had topotype material from Cedros Island, and by Stewart. Gabb's specimens of *veatchii* are available through the kindness of Dr. Pilsbry. The left valve from Cedros Island (or Cerros Island), off Lower California, identified by Stewart as the holotype, agrees in outline and dimensions with Gabb's figure; differences in details of sculpture probably are due to free drawing. This left valve is strongly plicate and of medium size (length about 69 millimeters, height 75.5 millimeters). As noted by Stewart, the upper anterior margin is broken. Gabb's drawing of this part of the shell may be a reconstruction. The corresponding right valve, which also is strongly plicate, is more complete (length 67 millimeters, height 73 millimeters). A smaller left valve also is circular-ovate and strongly plicate. An exceptionally deep right valve is irregularly undulate and probably represents some other form. The much larger circular-ovate left valve later figured by Gabb is in the same tray, but whether it came from Cedros Island or is one of the large specimens from the gulf side of Lower California described at the time when it was figured is not clear. The shell is very thick, and the plications are not so deep as on the holotype and corresponding right valve (length 123 millimeters, height 131 millimeters, maximum thickness about 42 millimeters). The characters of large suites of specimens from Cedros Island have not been described. If the holotype and corresponding right valve are representative, *veatchii* has deeper plications than most specimens of the coastal *vespertina* and has a more circular-ovate outline than most coastal specimens; and if the large left valve is conspecific, *veatchii* reaches a much larger size than the coastal *vespertina*. Some strongly plicate coastal specimens, however, such as those from localities near San Diego (2272) and Newhall (3514), closely resemble small specimens of *veatchii*.

O. veatchii apparently belongs in the group of large, circular-ovate plicate oysters that was widespread in the Miocene. This group of oysters is found in the Miocene of the Caribbean region, where it is represented

[35] Dall, W. H., Contributions to the Tertiary fauna of Florida: Wagner Inst. Sci. Philadelphia Trans., vol. 3, pt. 4, p. 685, 1898.

[36] Arnold, Ralph, Paleontology of the Coalinga district, California: U. S. Geol. Survey Bull. 396, pp. 44, 78, 1909 [1910].

by *O. haitensis* Sowerby,[37] from the Dominican Republic, and *O. gatunensis* Brown and Pilsbry,[38] from the Gatun formation of the Canal Zone. Gabb considered *veatchii* identical with *haitensis* when he became acquainted with *haitensis* as a result of his explorations in the Dominican Republic.[39] Dall also considered *veatchii* identical with *haitensis*, and Stewart cited *vespertina* (+ *veatchii*) as a subspecies of *haitensis*. Though now extinct in the Caribbean region, this group of oysters is still living in the Gulf of California, where it is represented by the oyster that Dall named *O. fisheri*.[40] For no apparent reason several small shells and a large one from the Gulf of California were differentiated by Dall as *O. veatchii*.[41]

O. heermanni Conrad,[42] from the Imperial formation of the Colorado Desert, is another representative of this group of large circular-ovate plicate oysters. The type of *heermanni*, according to a communication and photograph from Dr. Pilsbry, is a large, thick, weakly plicate right valve (Acad. Nat. Sci. Philadelphia no. 13367). The large oyster figured by Gabb as *veatchii* appears to be indistinguishable from the strongly plicate form of *heermanni*, which is the usual form. *O. heermanni* is found in sandstone and limestone near the base of the Imperial formation and at places in the upper part of the formation in association with the abundant small ovate-falcate *vespertina*. These two forms are under the same locality number in one of Bower's early collections (locality 3921, Barrett's oil well, about 20 miles north of Mexican boundary, on south side of Carrizo Creek), and in another of his collections (locality 3919, east end of Carrizo Mountain) *vespertina* is under the same number as species characteristic of the lower part of the Imperial formation. Small shells varying in outline from circular-ovate to ovate-falcate are associated with large specimens of *heermanni* and some of intermediate size in another of Bower's collections (locality 3922, head of Garnet Canyon [on north slope of Carrizo Mountain]) from the lower part of the Imperial formation. Some of these small specimens (length 37.8 to 44.4 millimeters) have fewer and broader plications than *vespertina*, but some ovate-falcate specimens (length 27.3 to 40.7 millimeters) are indistinguishable from that form in outline, plication, fluting of the inner margin, and character of the ligament area. The possibility that two species of plicate oysters are represented at this locality seems to be remote. These small specimens indicate that *vespertina* from the upper part of the Imperial formation is a form of *heermanni* and that *heermanni* should be treated as a nomenclatural variety of *vespertina*. Nevertheless, it does not seem desirable to unite *heermanni* with *vespertina*, for typical *heermanni* is readily distinguishable from any lot of small oysters from the upper part of the Imperial formation. Dall considered *veatchii*, *heermanni*, and *vespertina* identical with *haitensis*, and Stewart suggested that the small Carrizo Creek form is the young of *heermanni*. Though a satisfactory nomenclature has not been worked out for the plicate oysters named *haitensis*, *vespertina*, *heermanni*, *veatchii*, *fisheri*, and *gatunensis*, it may be advantageous to differentiate the coastal *vespertina*, for large circular-ovate, plicate oysters are not recorded in the coastal and San Joaquin Valley Pliocene. Loel and Corey considered a large plicate Vaqueros oyster a variety of *vespertina*.[43]

The distribution of *O. virleti* Deshayes and similar species in the Mediterranean region and in the Orient has been discussed by Davies,[44] who included *vespertina* in the *virleti* group, and by Cox,[45] who pointed out the similarity of *haitensis* to *virleti*.

The type of *Ostrea* [46] is the Recent European *O. edulis* Linné. Oysters with strong plications on both valves are generally assigned to the subgenus *Lopha*.[47]

The Imperial formation of the Colorado Desert is considered Miocene by some workers [48] and Pliocene by others.[49] Mansfield [50] has called attention to the similarity of fossils considered of Pliocene age, recovered from limestone dug up along the Tamiami Trail, in

[37] Sowerby, G. B., Description of new species of fossil shells found by J. S. Heniker, Esq.: Geol. Soc. London Quart. Jour., vol. 6, p. 53, 1850.

[38] Brown, A. P., and Pilsbry, H. A., Fauna of the Gatun formation, Isthmus of Panama: Acad. Nat. Sci. Philadelphia Proc., vol. 63, p. 366, pl. 29, figs. 1, 2, 1911. The type is more ovate than a paired shell at Washington.

[39] Gabb, W. M., On the topography and geology of Santo Domingo: Am. Philos. Soc. Trans., new ser., vol. 15, pp. 257–258, 1873.

[40] Dall, W. H., Notes on West American oysters: Nautilus, vol. 28, p. 1, 1914; new name for *O. jacobaea* Rochebrune, 1895 (Mus. hist. nat. Paris Bull., vol. 1, p. 241), not Linné, 1758. Lamy (Jour. Conchyliologie, vol. 57, pp. 218–219, 1909) considered *jacobaea* identical with *O. cumingiana* Dunker (Zeitschr. Malakozoologie, year 3, p. 48, 1846; Philippi, Abbildung und Beschreibungen neuer oder wenig gekannter Conchylien, vol. 2, p. 81, *Ostrea*, pl. 1, figs. 1–4, 1847), which he cited as a variety of the oriental *O. sinensis* Gmelin. *O. cumingiana* was originally described from an unknown locality.

[41] Dall, W. H., idem, pp. 1–2; Summary of the marine shell-bearing mollusks of the northwest coast of America: U. S. Nat. Mus. Bull. 112, p. 17, 1921.

[42] Conrad, T. A., Description of eighteen new Cretaceous and Tertiary fossils: Acad. Nat. Sci. Philadelphia Proc., vol. 7, p. 267, 1855. Hanna, G. D., Paleontology of Coyote Mountain, Imperial County, Calif.: California Acad. Sci. Proc., 4th ser., vol. 14, p. 467, pl. 22, figs. 7, 8, pl. 23, figs. 1, 2, 1926.

[43] *Ostrea vespertina* Conrad *loeli* Hertlein. Loel and Corey, California Univ., Dept. Geol. Sci., Bull., vol. 22, pp. 193–194, pl. 16, figs. 1a, 1b, 2, pl. 17, 1932.

[44] Davies, A. M., in Wayland, E. J., and Davies, A. M., The Miocene of Ceylon: Geol. Soc. London Quart. Jour., vol. 79, pp. 588–589, 1923. Davies, A. M., Tertiary faunas, vol. 2, pp. 160–161, London, 1934.

[45] Cox, L. R., Neogene and Quaternary Mollusca from the Zanzibar Protectorate: Report on the paleontology of the Zanzibar Protectorate, pp. 67–69, London, 1927.

[46] Linné, C., Systema naturae, ed. 10, p. 696, 1758. Subsequently designated type (Children, Lamarck's genera of shells: Quart. Jour. Sci., vol. 15, p. 43, 1823; cited from Kennard, Salisbury, and Woodward, Smithsonian Misc. Coll., vol. 82, no. 17, p. 15, 1931).

[47] Röding, P. F., in Bolten, J. F., Museum Boltenianum, pt. 2, p. 168, 1798. Subsequently designated type (Dall, Wagner Inst. Sci. Philadelphia Trans., vol. 3, pt. 4, p. 672, 1898), *Ostrea crista-galli* (Linné) (cited by Röding as *crista galli* Gmelin), Recent, Indian Ocean.

[48] Dickerson, R. E., Ancient Panama Canals: California Acad. Sci. Proc., 4th ser., vol. 7, pp. 200–201, 1917. Woodring, W. P., Distribution and age of the marine Tertiary deposits of the Colorado Desert: Carnegie Inst. Washington Pub. 418, pp. 14–25, 1931. Bramkamp, R. A., Molluscan fauna of the Imperial formation of San Gorgonio Pass [abstract]: Geol. Soc. America Proc., 1934, p. 385, 1935.

[49] Vaughan, T. W., The reef-coral fauna of Carrizo Creek, Imperial County, Calif., and its significance: U. S. Geol. Survey Prof. Paper 98, p. 368, 1917. Kew, W. S. W., Cretaceous and Cenozoic Echinoidea of the Pacific coast of North America: California Univ., Dept. Geology, Bull., vol. 12, pp. 32, 33, 56, 59, 60, 61, 137, 1920. Hanna, G. D., Paleontology of Coyote Mountain, Imperial County, Calif.: California Acad. Sci. Proc., 4th ser., vol. 14, p. 434, 1926. Strong, A. M., Hanna, G. D., and Hertlein, L. G., Marine Mollusca from Acapulco, Mexico, with notes on other species: California Acad. Sci. Proc., 4th ser., vol. 21, p. 125, 1933.

[50] Mansfield, W. C., Pliocene fossils from limestone in southern Florida: U. S. Geol. Survey Prof. Paper 170, p. 46, 1932.

southern Florida, with species from the Imperial formation. Of the mollusks compared with Imperial species all except *Pecten* (*Lyropecten*) *tamiamiensis* compare favorably with West Indian and Central American Miocene species (*Ostrea tamiamiensis* with *O. haitensis* Sowerby and allies, *Pecten* (*Nodipecten*) *pittieri* with *Lyropecten* (*Nodipecten*) *nodosus* (Linné), *Pecten* (*Plagioctenium*) *evergladensis* with *Aequipecten* (*Plagioctenium*) *levicostatus* (Toula) and allies).[51] The hinge of *Pecten tamiamiensis* is not exposed, but it appears to be a moderately inflated *Lyropecten*. The strong midrib filling the interspaces points to alliance with the California Miocene *L. estrellanus* (Conrad). (See discussion under *L. cerrosensis*.) The Imperial *L. mediacostatus* (Hanna),[52] with which *tamiamiensis* was compared, is a species of the *estrellanus* stock, as Hanna recognized; and it has been considered the same as *L. estrellanus catalinae* (Arnold),[53] described from beds on Santa Catalina Island referred to the Miocene. There is no record of a pecten similar to *tamiamiensis* in the Miocene of Central America, the West Indies, or the Atlantic coast. *Pecten interlineatus* Gabb,[54] a Miocene species from the Dominican Republic that has a moderately strong midrib, is probably an *Aequipecten*. Inasmuch as *estrellanus* and its allies occur in the California Miocene, *tamiamiensis* is a migrant from California, if it is allied to *estrellanus* and if it is of Pliocene age. The Florida species may not have any bearing on the age of the Imperial formation, but it opens an interesting paleogeographic problem. This species or its unknown predecessor may have reached the Gulf of Mexico through an interoceanic passage across Tehuantepec, postulated by some workers.[55]

Family LIMIDAE

Genus LIMA Bruguière

Subgenus ACESTA H, and A. Adams

Lima (Acesta) hamlini Dall

Plate 8, figures 5, 7, 10, 11

Lima hamlini Dall, Nautilus, vol. 14, pp. 15–16, 1900. Third Street tunnel, Los Angeles; probably Pliocene.

Arnold, U. S. Geol. Survey Prof. Paper 47, pp. 91 (list), 116 (list), 123 (list), 1906. Third Street tunnel, Los Angeles; Pliocene.

Arnold, U. S. Nat. Mus. Proc., vol. 32, p. 527 (list), 1907. Third Street tunnel, Los Angeles; middle Fernando formation, lower Pliocene.

Arnold, in Eldridge and Arnold, U. S. Geol. Survey Bull. 309, p. 152 (list), 1907. Third Street tunnel, Los Angeles; Fernando formation, lower Pliocene.

Dall, U. S. Nat. Mus. Proc., vol. 66, art. 17, p. 18, pl. 29, fig. 6, 1925. Pliocene clays of Los Angeles.

Grant and Gale, San Diego Soc. Nat. History Mem., vol. 1, p. 239 (Dall's and Arnold's records), 1931. Pliocene clays of Los Angeles.

Grant, in Soper and Grant, Geol. Soc. America Bull., vol. 43, p. 1057 (Arnold's list), 1932 [1933]. Third Street tunnel, Los Angeles; middle Pliocene.

A giant *Lima* allied to the modern Panamanian *agassizii*. Depressed area at anterior end and posterior auricle sculptured with relatively strong radial ribs that are more closely spaced toward the center of the shell, the interspaces being gradually transformed into narrow grooves, microscopically punctated by concentric threads. On some specimens (pl. 8, fig. 10) subdued grooves continue over the central part of the shell, except in the umbonal region, but in most specimens (pl. 8, figs. 5, 7, 11) they are absent on a central area of varying width. Ligament area not exposed.

Greatest length about 52 millimeters, height 37 millimeters, diameter of both valves 15.8 millimeters (holotype). Restored greatest length about 110 millimeters, height (crushed) about 95 millimeters, diameter of both valves (crushed) about 31 millimeters (largest outcrop specimen). Greatest length about 100 millimeters, height 79 millimeters, diameter (right valve) about 20 millimeters (largest virtually complete outcrop specimen). Restored greatest length about 110 millimeters, height 94.5 millimeters (largest specimen from well cores).

Holotype, U. S. Nat. Mus. 495186; 4 paratypes, U. S. Nat. Mus. 495187.

This giant *Lima* has been recorded heretofore only from the Third Street tunnel in Los Angeles, a locality now inaccessible. Two poorly preserved small specimens were recently collected by W. H. Holman, of the Standard Oil Co. of California about two blocks east of the type locality; and a large specimen from the excavation for the Los Angeles Times Building is in the collection of Alex Clark, of the Shell Oil Co. Outcrop specimens have also been collected at Malaga Cove, on the west coast of the Palos Verdes Hills, on the south side of the Los Angeles Basin, and fragmentary remains too imperfect to collect were recognized in a small outcrop of siltstone of the Repetto formation at the head of the fourth ravine west of Walteria, at the north edge of the Palos Verdes Hills. This species is the most widely distributed fossil in the core collections. It probably has a considerable stratigraphic range in the Repetto formation, and a small crushed right valve from the Huntington Beach field (Standard Oil Co. Schumacher No. 1, depth 4,400 feet, U. S. G. S. locality 13902a) is assigned to the upper Miocene. In two wells (Emery No. 53, in the West Coyote field, and Reyes No. 43, in the Dominguez field) it was recovered at two horizons, which, dip disregarded, are 921 feet apart in the Emery well and 706 feet in the Reyes well.

[51] *Thracia* (*Cyathodonta*) *tristana* Olsson, doubtfully identified in the Tamiami collection, is a Costa Rican Miocene species.

[52] Hanna, G. D., op. cit., p. 472, pl. 22, fig. 6, pl. 24, fig. 2.

[53] Grant, U. S., IV, and Gale, H. R., op. cit., p. 186, 1931.

[54] See Pilsbry, H. A., Revision of W. M. Gabb's Tertiary Mollusca of Santo Domingo: Acad. Nat. Sci. Philadelphia Proc., vol. 73 (1921), p. 411, pl. 45, fig. 3, 1922.

[55] Schuchert, Charles, Historical geology of the Antillean-Caribbean region, pp. 29, 375, 378–379, pl. 15, New York, 1935.

The holotype, selected by Dall for figuring, is the smallest of five specimens in the type lot but has more of the outer shell layer preserved than the others. Part of the shell has evidently been broken off since the drawing was made, and the drawing is somewhat misleading, as there are no grooves or ripples on the central part of the shell. The type lot, which bears the locality number 3322, was received at an earlier date (1900) than the larger lot under locality no. 3426, though both lots were collected by Homer Hamlin in the Third Street tunnel.

The thin shells of this species are generally crushed and distorted, and paired specimens are generally sheared. The brown translucent outer shell layer, composed of calcite, readily peels from the inner chalky layers, consisting of aragonite,[56] and generally is absent on part or all of the shell. The 17 specimens from the type locality show more or less clearly the central part of the shell. On four of these specimens the radial grooves extend in subdued form over the central part except in the umbonal region; on the others they are absent, and the smooth area is exceptionally wide on some specimens. On the shells that have a smooth central part the grooves gradually disappear or stop abruptly. Outcrop specimens from Malaga Cove and also core specimens that show the sculpture have a generally wide, smooth central area.

Lima hamlini belongs in a group of thin-shelled deep-water Limas that are widely distributed in the modern seas, as shown in the table under the heading "Inferred depth range of larger fossils." It closely resembles *L. agassizii* Dall [57] but has stronger ribs at the anterior and posterior ends and more symmetrical grooves on the posterior part. The only specimen of *agassizii* is a right valve dredged by the *Albatross* at a depth of 322 fathoms in the Gulf of Panama. Part of the anterior depressed area is pathologically infolded on this specimen. These deep-water Limas represent the subgenus *Acesta*,[58] which has a larger, thinner shell than *Lima* s. s.,[58a] a narrower cardinal area, a more oblique ligament pit, and weak ribs instead of strong scaly ribs. *Callolima* [59] was proposed for Philippine species that are weakly sculptured and have a narrow oblique ligament pit even on large adults. The shape of the ligament pit appears to depend on the width (distance from umbo to lower edge of chondrophore) of the cardinal area, and the species that have a narrow cardinal area also have a narrow anterior impressed area. The sculpture of the type species, *rathbuni*, is very weak, but in *bartschi* it is variable though still relatively weak The Japanese *goliath* has a ligament pit that is less oblique than in *excavata* and weak sculpture; *agassizii* has a narrow oblique ligament pit and moderately strong sculpture. It appears that *Callolima* does not differ essentially from *Acesta*, as Thiele claimed.[60] Some writers cite the modern deep-water Limas under the subgenus *Plagiostoma* J. Sowerby,[61] the type of which is a giant Jurassic species. This Jurassic species and its allies may not have a closer relation to *Acesta* than one of family or generic resemblance and large size. Arkell [62] rated *Acesta* and *Plagiostoma* as subgenera and compared their characters.

No living species of *Acesta* is known along the Pacific coast north of Panama, and *hamlini* is the only species recorded from the Pliocene of the Pacific coast. *Lima* (*Plagiostoma*) *oregonensis* Clark,[63] from the Oligocene of Oregon, is the only other described form from the Tertiary of this region. It evidently needs comparison with *hamlini;* according to the illustrations, it resembles *hamlini* in outline and sculpture. A giant *Lima* is represented in the Oligocene of Washington by an incomplete, poorly preserved specimen from locality 4092 (Strait of Juan de Fuca, 4¼ miles west of Gettysburg). Tegland [64] recorded a giant *Lima* from this region and also from Weaver's Lincoln formation. *L. goliath* has been found in the later Tertiary of Japan.[65]

[56] For the shell composition of *Lima* see Bøggild, O. B., The shell structure of the mollusks: Danemark Acad. roy. sci. let., Sec. sci., 9th ser., vol. 11, p. 263, 1930.

[57] Dall, W. H., Notes on the giant Limas: Nautilus, vol. 16, p. 16, 1902; The Mollusca and the Brachiopoda [*Albatross* Rept.]: Harvard College Mus. Comp. Zoology Bull., vol. 43, no. 6, p. 407, pl. 16, fig. 1, 1908.

[58] Adams, H. and A., The genera of Recent Mollusca, vol. 2, p. 558, 1858. Monotype, [*Ostrea*] *excavata* [etc.] Chemnitz (= *Ostrea excavata* Fabricius), Recent, Norway.

[58a] Bruguière, J. G., Tableau encyclopédique et méthodique, Vers testacées, vol. 2, p. 206, 1797 (genus without named species). Tautonymic type, *Lima squamosa* Lamarck. Système des animaux sans vertèbres, p. 136, 1801 (= *Ostrea lima* Linné, cited in synonymy), Recent, Mediterranean.

[59] Bartsch, Paul, The giant species of the molluscan genus *Lima* obtained in Philippine and adjacent waters: U. S. Nat. Mus. Proc., vol. 45, p. 235, 1913. Originally designated type, *Lima* (*Callolima*) *rathbuni* Bartsch, Recent, Philippines.

[60] Thiele, J., Familia Limidae: Systematisches Conchylien-Cabinet, vol. 7, pt. 2a, p. 5, 1918.

[61] Sowerby, James, Mineral conchology of Great Britain, vol. 1, pp. 175-176, 1814. Tautonymic type, *Pectinites plagiostomus* [etc.] Lhuyd (= *Plagiostoma gigantea* J. Sowerby), Lias, England.

[62] Arkell, W. J., Monograph of British corallian Lamellibranchia, pt. 3: Paleont. Soc., vol. 83, pp. 128-129, 1931.

[63] Clark, B. L., Pelecypoda from the marine Oligocene of western North America: California Univ., Dept. Geol. Sci., Bull., vol. 15, p. 84, pl. 14, figs. 3, 4, 1925. Schenck, H. G., Nuculid bivalves of the genus *Acila:* Geol. Soc. America Special Paper 4, p. 62 (list), 1936.

[64] Tegland, N. M., The gastropod genus *Galeodea* in the Oligocene of Washington: California Univ., Dept. Geol. Sci., Bull., vol. 19, p. 399, footnote, 1931.

[65] Yokoyama, Matajiro, Tertiary fossils from western Hizen: Tokyo Imp. Univ., Fac. Sci., Jour., sec. 2, vol. 2, p. 188, pl. 50, fig. 1, 1927. (Includes earlier citations of fossil records.)

Specimens of Lima hamlini from Repetto formation examined

Locality	Specimens	Locality	Specimens
Third Street tunnel, Los Angeles; Homer Hamlin. U. S. G. S. locality 3322.	Holotype (small sheared paired specimen) and 4 paratypes (2 paired shells, 1 right valve), 1 left valve), all of medium size.	Standard Oil Co. Emery No. 59, West Coyote field, depth 4,304 feet. U. S. G. S. locality 13883a.	Greater part of right valve of medium size and impression.
		Union Oil Co. Bell No. 45, Santa Fe Springs field, depth 5,564 feet. Collection of Union Oil Co.	Part of distorted right valve of medium size.
Third Street tunnel, Los Angeles; Homer Hamlin. U. S. G. S. locality 3426.	12 specimens, of medium to large size, 3 of which are figured (4 paired, 4 right valves, 4 left valves.	Union Oil Co. Bell No. 53, Santa Fe Springs field, depth 6,237 feet. U. S. G. S. locality 14012.	Part of moderately large right valve and impression.
		Standard Oil Co. Baldwin-Cienega No. 105, Inglewood field, depth 5,713 feet. U. S. G. S. locality 13890a.	Small crushed left valve and fragment.
100 feet northeast and 100 feet northwest from northeast corner of Second and Hill Streets, Los Angeles; about 4 feet above level of Hill Street; H. W. Holman. U. S. G. S. locality 13862a.	Part of distorted small left valve; very small right valve.	Union Oil Co. Rosecrans No. 15, Rosecrans field, depth 5,686 feet. U. S. G. S. locality 14013.	Part of distorted paired specimen and impression of right side.
		Barnsdall Oil Co. Trust No. 1, Rosecrans field, depth 5,760 feet. Collection of Union Oil Co.	Small crushed paired specimen.
Excavation for Times Building, First and Spring Streets, Los Angeles. Collection of Alex Clark, Shell, Oil Co.	Crushed, broken large paired specimen.	Union Oil Co. Hellman No. 17, Dominguez field, depth 4,216 feet. Collection of Union Oil Co.	Part of right valve of medium size.
Malaga Cove, west coast of Palos Verdes Hills north limb of northern syncline near trough, 5 to 10 feet below lower bed of volcanic ash in Repetto formation; W. P. Woodring. U. S. G. S. locality 13838.	Small distorted right valve; part of right valve of medium size; fragment of large right valve.	Shell Oil Co. Reyes No. 43, Dominguez field, depth 4,135 feet. U. S. G. S. locality 14014.	Part of right valve of medium size and impression.
		Same well, depth 4,841 feet. Collection of Union Oil Co.	Part of right valve of medium size.
		Standard Oil Co. San Gabriel No. 25, Seal Beach field, depth 4,929 feet. U. S. G. S. locality 13901.	Part of large left valve.
Malaga Cove, west coast of Palos Verdes Hills, north limb of syncline near trough and not more than 10 feet below lower bed of volcanic ash. Collection of Union Oil Co.	Part of large distorted, very weakly sculptured right valve.	Standard Oil Co. Bolsa No. 7, Huntington Beach field, depth 3,720 feet. U. S. G. S. locality 13904.	Part of right valve of medium size.
Standard Oil Co. Murphy Coyote No. 117, West Coyote field, depth 5,910 feet. U. S. G. S. locality 13875a.	Large crushed right valve (figured).	Ohio Oil Co. Del Rey No. 2, Playa del Rey field, depth 4,001 feet. U. S. G. S. locality 14015.	Greater part of large left valve and impression.
Standard Oil Co. Emery No. 53, West Coyote field, depth 4,273 feet. U. S. G. S. locality 13879.	Impression and part of shell of distorted right valve of medium size.	Shell Oil Co. Barkdall No. 1, Lawndale field, depth 5,346 feet. Collection of Union Oil Co.	Part of crushed right valve of medium size; greater part of shell preserved.
Same well, depth 6,194 feet. U. S. G. S. locality 13879a.	Part of distorted right valve and impression.	Standard Oil Co. Bodger No. 1, southeast of Lawndale field, sec. 22, T. 3 S., R. 14 W., depth 5,398 feet. U. S. G. S. locality 14002.	Large gaping paired specimen exposed in anterior (?) view and impression.

Through the kindness of S. G. Wissler the following additional records of *Lima hamlini* are available, based on specimens collected under his direction and deposited in the collection of the Union Oil Co.'s micropaleontology laboratory:

Additional specimens of Lima hamlini in collection of Union Oil Co.

Union Oil Co. Bell No. 88, Santa Fe Springs field, depth 4,491 feet.

Pacific Gulf Oil Co. Rosecrans No. 1, Rosecrans field, depth 5,401 and 5,407 feet.

A. N. Macrate Gray No. 1, Rosecrans field, depth 6,025 and 6,122 feet.

Union Oil Co. Hellman No. 16, Dominguez field, depth 5,072 feet.

Union Oil Co. Callendar No. 32, Dominguez field, depth 5,450 feet.

Shell Oil Co. Peck No. 1, center of sec. 20, T. 3 S., R. 14 W., near Hermosa Beach, depth 5,656 feet.

Genus LIMATULA S. V. Wood

Limatula aff. L. "subauriculata (Montagu)"

Plate 8, figure 6

A small moderately elongate valve (height 7.6 millimeters, length 4.4 millimeters) from Universal Consolidated Oil Co. Nutt No. 2, Montebello field, depth 3,627 to 3,655 feet (U. S. G. S. locality 13871), represents a species of *Limatula*. Part of the shell is missing. The sculpture consists of fine radial ribs, slightly roughened by microscopic concentric threads. Two median ribs are heavier than the others and modify the interior outline. On the interior of the lower part of the shell, where the exterior is missing, a narrow midrib lies between the heavy ribs.

This species is probably the Recent form that ranges from Alaska to Lower California at depths of 14 to 984 fathoms and is known as *Lima* (*Limatula*) *subauriculata*

(Montagu).[66] Recent shells attain a height of 16.4 millimeters and a length of 10.4 millimeters. They have one to three relatively heavy median ribs that are differentiated by strong interspaces on the interior, even though the ribs are not conspicuously differentiated on the exterior, a characteristic feature of *Limatula* shown by the fossil. This Recent form probably needs a new name, as it does not appear to be conspecific with the North Atlantic *Limatula subauriculata* (Montagu),[67] which is smaller and narrower. The small, narrow Alaskan *Limatula attenuata* Dall [68] appears to be more closely allied to *subauriculata*. The only Alaskan lot of "*subauriculata*" in the collections of the National Museum was dredged by George Willett at Forrester Island, west of Prince of Wales Island, at a depth of 40 fathoms.

Limatula,[69] characterized by small, closed, virtually equilateral shells that have strong median ribs or interspaces, is considered generically removed from *Lima*. The modern species have a wide distribution.[70] On the Pacific coast of America they are found from Alaska to Panama and the Galapagos Islands and along the coast of Chile. No species has heretofore been recorded from the California Pliocene.

Family VESICOMYACIDAE?

Genus PHREAGENA Woodring, n. gen.

Phreagena lasia Woodring, n. sp.

Plate 5, figures 3, 4

?*Cypricardia pedroana* (Conrad) Cooper, California State Min. Bur. Bull. 4, p. 25 (list), 1894. Los Angeles, about 20–30 feet below surface, Mrs. N. B. Williamson.

Cooper (part?), in Watts, California State Min. Bur. Bull. 11, p. 79 (list), 1897. Well on Green Meadow ranch, Shatto estate, West Los Angeles; Normal School, Los Angeles.

Dall, Wagner Inst. Sci. Philadelphia Trans., vol. 3, pt. 6, p. 1500, 1903. "The *Cypricardia pedroana* of Cooper probably is a *Calyptogena*."

?*Petricola carditoides* (Conrad) Arnold (part?), in Eldridge and Arnold, U. S. Geol. Survey Bull. 396, p. 153 (list), 1907. Well on Greenmeadow ranch, Shatto estate, West Los Angeles; Normal School, Los Angeles; Pliocene.

?*Calyptogena pacifica* Dall (part), op. cit., pp. 1435–1436, 1903. Los Angeles; Pliocene.

Carditoid. Arnold, U. S. Nat. Mus. Proc., vol. 32, p. 527 (list), 1907. Third Street tunnel, Los Angeles; middle Fernando formation, lower Pliocene.

Grant, in Soper and Grant, Geol. Soc. America Bull., vol. 43, p. 1057 (Arnold's list), 1932 [1933]. Third Street tunnel, Los Angeles; middle Pliocene.

[66] Dall, W. H., Summary of the marine shell-bearing mollusks of the northwest coast of America: U. S. Nat. Mus. Bull. 112, p. 20, 1921.

[67] Montagu, George, Testacea Britannica, supplement, p. 63, pl. 29, fig. 2, 1808 (as *Pecten*).

[68] Dall, W. H., Diagnoses of new species of marine bivalve mollusks from the northwest coast of America in the collection of the United States National Museum: U. S. Nat. Mus. Proc., vol. 52, p. 404, 1916.

[69] Wood, S. V., Descriptions of the species of the genus *Lima*, from the Coralline Crag, in the cabinet of Searles Valentine Wood, Esq.: Mag. Nat. Hist., new ser., vol. 3, pp. 233, 235–236, 1839 (as subgenus of *Lima*). Subsequently designated type (Gray, Zool. Soc. London Proc., 1847, p. 200), *Pecten subauriculata* Montagu, Recent, northeastern Atlantic.

[70] See Thiele, J., op. cit., pp. 38–56, 1918.

Moderately large, elongate, thick-shelled. Lunule absent; escutcheon long, abruptly angulated and flattened. Sculpture consisting of strongly defined growth lines. Hinge of right valve consisting of a short, weak anterior cardinal, a heavy bifid middle cardinal, and a bifid posterior cardinal. Hinge of left valve consisting of a heavy anterior cardinal, joined to a heavy bifid middle cardinal, and a posterior cardinal. Adductor and pedal muscle scars deeply sunk. Pallial line apparently simple.

Length about 41.5 millimeters, height 22 millimeters (holotype). Length about 39 millimeters, height about 24 millimeters.

Holotype, U. S. Nat. Mus. 496097.

This species is the type of the genus *Phreagena*. It has a hinge of venerid type, but the same structural

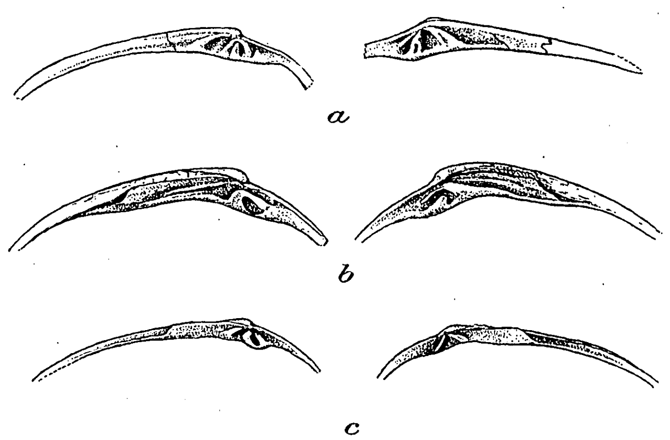


FIGURE 2.—Hinge of *Phreagena*, *Calyptogena*, and *Ectenagena*. *a*, *Phreagena lasia*, U. S. Nat. Mus. 496097; *b*, *Calyptogena pacifica*, U. S. Nat. Mus. 222323; *c*, *Ectenagena elongata*, U. S. Nat. Mus. 205888.

elements modified and arranged differently appear to be recognizable in the genus *Calyptogena* Dall.[71] *Calyptogena* was placed in the family Carditidae by Dall. Its hinge seems to be vesicomyacid and it is assigned to the family Vesicomyacidae. In *Calyptogena pacifica* the right anterior cardinal is thin, virtually parallels the margin of the valve, and is joined to the anterior part of the broad bifid posterior cardinal; the middle cardinal lies under the anterior cardinal and almost parallels the margin of the hinge plate. The left anterior cardinal joins the broad bifid middle cardinal and makes a right angle with it; the posterior cardinal is long and slender. (See fig. 2.) The hinge of *Phreagena* might be converted into that of *Calyptogena* by rotation of the anterior and middle cardinals, by shortening of the middle cardinals, and by elongation of the posterior cardinals. These two genera are similar in texture, sculpture, escutcheon, ligament area, and insertion of pedal muscle. *Calyptogena* lacks a pallial sinus, and *Phreagena* apparently has none. The hinge of *Calyptogena pacifica* resembles that of *Vesicomya lepta*

[71] Dall, W. H., On some new or interesting west American shells obtained from the dredgings of the U. S. Fish Commission steamer *Albatross* in 1888, and from other sources [*Albatross* Rept.]: U. S. Nat. Mus. Proc., vol. 14, pp. 189–190, 1891. Monotype, *Calyptogena pacifica* Dall, Recent, Alaska.

(Dall),[72] dredged off Oregon at a depth of 786 fathoms and in the Gulf of California at depths of 857 and 1,005 fathoms. In other species from the Pacific coast assigned to *Vesicomya*, all from deep water, further hinge modifications are apparent. Though it is not certain that *Vesicomya lepta* and other species from the Pacific coast represent *Vesicomya* [73] proper, they probably are allied to it.

Calyptogena elongata Dall,[74] from depths of 270 fathoms off Santa Rosa Island and 183 and 275 fathoms off Point Loma, is the only other Recent species that has been assigned to *Calyptogena*. It has a thinner and more elongate shell than *pacifica;* the right anterior cardinal is suppressed, the middle cardinal swings up to the umbo, and the posterior cardinal is shorter and narrower than in *pacifica;* the left anterior cardinal is not so strongly joined to the middle one and is not parallel to the margin of the valve, and the posterior cardinal is short. In many respects the hinge of *elongata* resembles that of *lasia*, aside from the suppression of the right anterior cardinal. The generic name *Ectenagena* is proposed for *Calyptogena elongata*.

Phreagena may possibly be related to the larger Peruvian Oligocene shells assigned by Olsson [75] to the genus *Pleurophopsis* Van Winkle.[76] The hinge of the Peruvian shells is not known. The fossils associated with the Peruvian *Pleurophopsis* include *Solemya* and species assigned to *Vesicomya*. The Trinidad *Pleurophopsis* was described as having two cardinals in each valve. The peculiar fauna that includes *Pleurophopsis* has been recognized by Olsson in Peru, Ecuador, Colombia, and Trinidad.

Phreagena lasia is represented by material from the Third Street tunnel and from wells in the Montebello and West Coyote fields, near the north edge of the basin, but much of it is imperfect and in a poor state of preservation. Three imperfect valves and doubtful fragments from the Inglewood field are assigned to the Pico formation. An umbonal fragment of a small left valve from the Third Street tunnel has a hinge like the left valve of the holotype. The gaping valves of the holotype are held together by a remnant of the ligament. The shell has a thickness of about 1.7 millimeters. Molds of paired valves with some shell attached in old collections from Los Angeles probably represent this species, including specimens received from J. G. Cooper and Mrs. M. B. Williamson in 1893. A search through Dall's letters from Cooper and Mrs. Williamson covering the period 1891 to 1893 fails to reveal any information about these fossils. The Cooper and Williamson lots are labeled *Cypricardia pedroana* Conrad. They show no trace of a pallial sinus and therefore are not *Petricola pedroana* (Conrad), which was based on a Pleistocene fossil from San Pedro and is considered a synonym of *P. carditoides* (Conrad).

Calyptogena pacifica is recorded by Grant and Gale [77] as a Pliocene fossil blown out of a well in the Salt Lake field in Los Angeles. *C. gibbera* Crickmay [78] was described from the early Pleistocene silt on Deadman Island (Arnold's Pliocene; Alex Clark's Timms Point formation) and was compared with *pacifica*. The hinge was not described and apparently was inaccessible.

The thick shell of *C. pacifica* belies its depth range. The type lot, consisting of 42 shells (still paired or corresponding valves) and an extra left valve, was dredged at a depth of 322 fathoms in Clarence Strait, Alaska; a paired shell is from a depth of 506 to 680 fathoms off Santa Cruz; and a pair of corroded valves from a depth of 30 to 41 fathoms off Santa Rosa Island. The probable depth significance of *Phreagena lasia* is unknown, as its living counterpart has not been found.

Dall [79] claimed that the gills of *Vesicomya stearnsii* are foliobranch or at least intermediate between foliobranch and eulamellibranch, but Ridewood [80] found them to be eulamellibranch. The anatomy of *Calyptogena* and *Ectenegena* is unknown.

Specimens of Phreagena lasia from Repetto formation examined

Locality	Specimens
Third Street tunnel, Los Angeles; Homer Hamlin. U. S. G. S. locality 3426.	4 imperfect paired specimens (3 gaping), 5 imperfect valves (1 of which is figured) and fragments, including umbonal part of a small left valve that shows the hinge; a high (deformed?) right valve (identification doubtful).
Los Angeles; J. G. Cooper. U. S. Nat. Mus. 115368. [Repetto formation (?).]	3 paired molds, 2 of which have some shell attached (identification doubtful).
Los Angeles: Mrs. N. B. Williamson. U. S. Nat. Mus. 115367. [Repetto formation (?).]	2 paired molds; some inner shell attached (identification doubtful).
Sixth and Lucas Streets, Los Angeles, altitude 370 feet; R. E. C. Sterns. U. S. G. S. locality 2483. [Repetto formation (?).]	3 paired molds, 1 of which has some inner shell attached (identification doubtful).

[72] Dall, W. H., Diagnoses of new species of mollusks from the west coast of America: U. S. Nat. Mus. Proc., vol. 18, pp. 17-18, 1895 [1896] (as *Callocardia*). Dall, W. H., The Mollusca and the Brachiopoda [*Albatross* Rept.]: Harvard College Mus. Comp. Zoology Bull., vol. 43, p. 416, pl. 18, figs. 13, 14, 1908.

[73] Dall, W. H., Report on the Mollusca, pt. I, Brachiopoda and Pelecypoda [*Blake* Rept.]: Harvard College Mus. Comp. Zoology Bull., vol. 12, pp. 272-273, 1886 (as subgenus of *Callocardia*). Originally designated type, *Callocardia atlantica* Smith [*Callocardia? atlantica* Smith], Recent, eastern Atlantic and West Indies in deep water.

[74] Dall, W. H., Diagnoses of new species of marine bivalve mollusks from the northwest coast of America in the collection of the United States National Museum: U. S. Nat. Mus. Proc., vol. 52, p. 408, 1916; Summary of the marine shell-bearing mollusks of the northwest coast of America: U. S. Nat. Mus. Bull. 112, p. 32, pl. 3, fig. 3, 1921.

[75] Olsson, A. A., Contributions to the Tertiary paleontology of northern Peru, pt. 4, The Peruvian Oligocene: Bull. Am. Paleontology, vol. 17, no. 63, pp. 43-44, pl. 4, figs. 1, 2, 4, 5, 7, 9, 1931.

[76] Van Winkle, Katherine, Remarks on some new species from Trinidad: Idem, vol. 8, no. 33, pp. 23-25, pl. 3, figs. 12-14, 1919. Monotype, *Pleurophopsis unionoides* Van Winkle, probably middle Tertiary [Oligocene, fide Olsson], Trinidad.

[77] Grant, U. S., IV, and Gale, H. R., op. cit., p. 279.

[78] Crickmay, C. H., On a new pelecypod, *Calyptogena gibbera*: Canadian Field-Naturalist, vol. 43, p. 93, 1 fig., 1929.

[79] Dall, W. H., Report on Mollusca and Brachiopoda dredged in deep water, chiefly near the Hawaiian Islands, with illustrations of hitherto unfigured species from northwest America: U. S. Nat. Mus. Proc., vol. 17, pp. 696-697, fig. 1 (p. 693), 1895 (as *Callocardia*).

[80] Ridewood, W. G., On the structure of the gills of the Lamellibranchia: Roy. Soc. London Philos. Trans., ser. B, vol. 195, pp. 224-226, 1903.

Specimens of Phreagena losia from Repetto formation examined—Continued

Locality	Specimens
Standard Oil Co. Baldwin No. 73, Montebello field, depth 3,340–3,358 feet. U. S. G. S. locality 13864.	An imperfect paired gaping specimen exposed in interior view (figured holotype); 2 imperfect paired specimens.
Standard Oil Co. Baldwin No. 77, Montebello field, depth 4,500 feet. U. S. G. S. locality 13867.	2 imperfect paired specimens; ligament preserved.
Standard Oil Co. Temple No. 18, Montebello field, depth 3,044 feet. U. S. G. S. locality 13868.	Imperfect left valve.
Standard Oil Co. Temple No. 19, Montebello field, depth 4,811–4,825 feet. U. S. G. S. locality 13869a.	Doubtful fragments.
Standard Oil Co. Emery No. 54, West Coyote field, depth 5,900 feet. U. S. G. S. locality 13880a.	Incomplete left valve (identification doubtful).

Specimens of Phreagena lasia from other horizons examined

Locality	Specimens
Standard Oil Co. Los Angeles Investment No. 71, Inglewood field, depth 1,323–1,324 feet. U. S. G. S. locality 13891. Pico formation.	3 imperfect valves and doubtful fragments.

Family VESICOMYACIDAE

Genus CALYPTOGENA Dall

Calyptogena n. sp.

Plate 5, figures 5, 6

An incomplete, thick-shelled, short left valve, on which the umbonal part is corroded, from Standard Oil Co. Emery No. 54, West Coyote field, depth 4,230 feet (U. S. G. S. locality 13880), is identified as a new species of *Calyptogena*. It is less elongate than *C. pacifica* and has stronger sculpture consisting of low concentric lamellae. The escutcheon is abruptly angulated and flattened, as in *pacifica*. Part of the ligament is preserved. The hinge is imperfect but resembles the hinge of *pacifica*, as the anterior cardinal parallels the margin of the valve and forms a right angle with the bifid middle cardinal, and a wide socket lies between the middle and posterior cardinals. Both the anterior and posterior cardinals are closer to the dorsal edge of the hinge plate than in *pacifica*. An imperfect left valve, doubtfully determined as *Phreagena lasia*, was recovered at a lower horizon in the same well at a depth of 5,900 feet.

This species has the outline of *Vesicomya ovalis* (Dall).[81] Perhaps an imperfect left valve from Standard Oil Co. Temple No. 19, Montebello field, depth 4,811 to 4,825 feet (U. S. G. S. locality 13869a), associated with *Phreagena lasia*, represents the same form. It has stronger sculpture than the specimen from the Emery well, and the hinge is not exposed.

[81] Dall, W. H., Diagnoses of new species of mollusks from the west coast of America: U. S. Nat. Mus. Proc., vol. 18, p. 18, 1895 (1896) (as *Callocardia*); The Mollusca and the Brachiopoda [*Albatross* Rept.]: Harvard College Mus. Comp. Zoology Bull., vol. 43, p. 417, 1908.

Family LUCINIDAE

Genus LUCINOMA Dall

Lucinoma aff. L. aequizonata (Stearns)

Plate 5, figures 1, 2

An incomplete small right valve (height 20 millimeters) in the collection from the Third Street tunnel represents a *Lucinoma* characterized by a strongly truncated posterior margin (pl. 5, fig. 1). In view of its outline it is improbable that this is the specimen identified by Arnold[82] as "*Astarte* species"; no specimen comparable to *Astarte* is now in the collection. The specimen from the Third Street tunnel appears to represent the same species as a moderately large right valve from a horizon in the East Coyote field assigned to the Miocene (Graham & Loftus Oil Co. No. 1, depth 5,957 to 5,980 feet, U. S. G. S. locality 13872a). The core specimen has the relatively elongate outline, strongly depressed posterior area and correspondingly strong posterior truncation, and heavy primary lamellae of the modern *aequizonata* (pl. 5, fig. 2). It has a length of 43.7 millimeters and a height of 41.5 millimeters. Parts of the outer shell layer and at places the entire shell are missing.

The genus *Lucinoma*,[83] characterized by suppressed or weak lateral teeth and strong lamellar sculpture, is represented on the Pacific coast in beds assigned to the Oligocene and is now found from Alaska southward to California and in deep water to Lower California and along the coast of Chile. *Lucina acutilineata* Conrad,[84] from the Miocene of Astoria, Oreg., was the first species to be described from the Pacific coast. The type material is in the National Museum (no. 3519). The specimen shown in figure 2, said to be natural size, is not recognized. A paired specimen having most of the shell on the left valve and part of the shell on the right one, evidently the specimen shown in figures 2a, 2b, is designated the lectotype (length 36.8 millimeters, height 33.9 millimeters). Two other specimens now under this number are molds of paired specimens. The holotype of *Pectunculus patulus* Conrad[85] (no. 3605) was recog-

[82] Arnold, Ralph, New and characteristic species of fossil mollusks from the oil-bearing Tertiary formations of southern California: U. S. Nat. Mus. Proc., vol. 32, p. 527 (list), 1907. Arnold, Ralph, in Eldridge, G. H., and Arnold, Ralph, The Santa Clara Valley, Puente Hills, and Los Angeles oil districts, southern California: U. S. Geol. Survey Bull. 309, p. 152 (list), 1907.

[83] Dall, W. H., Synopsis of the Lucinacea and of the American species: U. S. Nat. Mus. Proc., vol. 23, p. 806, 1901 (as subgenus of *Phacoides*). Originally designated type *Lucina filosa* Simpson, Recent, Maine to Florida.

[84] Conrad, T. A., in Dana, J. D., Geology, U. S. Expl. Exped., p. 725, pl. 18, figs. 2, 2a, 2b, 1849.

[85] Idem, p. 726, pl. 18, figs. 8, 8a.

nized as a mold of *acutilineata* by Meek.[86] The impression of the elongate anterior muscle scar is clearly visible on the mold; the puckers near the lower anterior margin are too strong on the drawing. A specimen of *acutilineata* somewhat larger than the lectotype (length 47.4 millimeters, height 42.8 millimeters) has been figured from the Miocene of southern Washington,[87] and this species has been recognized in the Miocene Vaqueros[88] and Temblor[89] formations of California. It has been pointed out that the type of *acutilineata* has a shorter posterior dorsal margin than the modern *annulata*.[90] This difference also holds for the Miocene specimen from the Coalinga region figured by Arnold, but other specimens from the same locality (4803, Coalinga anticline) have a longer posterior dorsal margin than the one figured. Miocene representatives so far figured are relatively small; an incomplete one from locality 4860 (Wagonwheel Mountain, Devil's Den district) has a length of about 57 millimeters. The range of variation in outline and size of the Miocene *Lucinoma* has not yet been determined, and the hinge is still unknown. *L. annulata* (Reeve)[91] attains a length of 70 millimeters and a height of 64 millimeters in Puget Sound and surrounding waters. Shells from Alaska are considerably smaller, and those from California, dredged at depths of 10 to 414 fathoms, are smaller still. Small shells from California resemble the figure published by Reeve, who cited the locality as "California?". A large shell labeled "San Pedro" (U. S. Nat. Mus. 151726), which has some sand matrix adhering to it, evidently is a fossil from the lower Pleistocene San Pedro sand; it agrees with fossils collected from that formation on Deadman Island (locality 12530). *L. annulata densilirata* Dall,[92] based on a pair of valves from Sitka, Alaska, is larger than other Alaskan specimens and has a more steeply sloping posterior dorsal margin and more closely and more irregularly spaced primary lamellae. A relatively well-preserved shell from the Jacalitos formation (locality 4644), fossils from Elsmere Canyon (locality 4401) where *Lucinoma* is abundant, and a flattened left valve from Ring Oil Co. More No. 1, near Goleta, Santa Barbara County, depth 4,957 feet, received from W. S. W. Kew, resemble modern shells. Most specimens from the Etchegoin formation (localities 4664, White Creek syncline; 12817, Kettleman Hills) have a strongly concave anterior dorsal margin. *Phacoides columbianum* Clark and Arnold,[93] from the Sooke formation of Vancouver Island, considered of Oligocene age by Clark, belongs in the *acutilineata-annulata* group. It was described as having an anterior lateral; the figures closely resemble the Miocene *acutilineata*.

L. aequizonata[94] has been dredged at depths of 183 to 405 fathoms from the Channel Islands southward to Lower California. It has an elongate shell, strongly depressed posterior area and correspondingly strong posterior truncation, and relatively strong laterals. Adult shells are corroded in the umbonal region. The posterior truncation of *Phacoides hannibali* Clark,[95] from the Washington Oligocene, suggests that it is allied to *aequizonata*, but not all the specimens figured by Tegland are strongly truncated. The presence of a species of the *aequizonata* group in the Miocene at Astoria is indicated by material from locality 5318 (northwest corner of 10th Street and Harrison Avenue). *L. heroica* (Dall),[96] known only from a lot of fine shells dredged off Lower California at a depth of 1,005 fathoms, has strongly sloping dorsal margins. The Chilean *L. lamellata* (Smith)[97] has a long anterior end, which, however, is not well developed on some young shells. The pair of young valves from Chile, listed by Dall[98] under *aequizonata*, apparently represent *lamellata*.

Family CARDIIDAE

Genus TRACHYCARDIUM Mörch

Subgenus DALLOCARDIA Stewart

Trachycardium (Dallocardia) cf. T. quadragenarium (Conrad)

Plate 9, figure 1

The collection from the Third Street tunnel contains a small fragment of the lower part of the right valve of a large thick-shelled *Trachycardium* not mentioned by Arnold. According to the curvature of the ribs it represents the region lying in front of the middle of the shell. The shell has a thickness of about 7 millimeters. The ribs are more or less eroded. Where the ornamentation is preserved it consists of heavy oblique ridges extending from the posterior edge of a rib forward to or beyond the middle. In the corresponding region large Recent specimens of *quadragenarium* have broad-based blunt spines, the base of which extends forward

[86] Meek, F. B., Check list of the invertebrate fossils of North America; Miocene: Smithsonian Misc. Coll., no. 183, p. 29, 1864. Meek erroneously cited *Lucina acutilineata* as *Lucina occidentalis*.

[87] Etherington, T. J., Stratigraphy and fauna of the Astoria Miocene of southwest Washington: California Univ., Dept. Geol. Sci., Bull., vol. 20, pp. 76–77, pl. 4, fig. 5, 1931 [as *Phacoides (Lucinoma)*].

[88] Loel, Wayne, and Corey, W. H., The Vaqueros formation, lower Miocene of California, 1, Paleontology: Idem, vol. 22, p. 211, pl. 36, fig. 3, 1932 [as *Phacoides (Lucinoma)*].

[89] Arnold, Ralph, Paleontology of the Coalinga district, California: U. S. Geol. Survey Bull. 396, p. 17 (list), pl. 8, fig. 4, 1909 [1910] (as *Phacoides*, Vaqueros formation).

[90] Stewart, R. B., in Tegland, N. M., The fauna of the type Blakeley upper Oligocene of Washington: California Univ., Dept. Geol. Sci., Bull., vol. 23, p. 116, 1933.

[91] Reeve, L. A., Conchologica iconica; *Lucina*, species 17, pl. 4, fig. 17, 1850 (as *Lucina*).

[92] Dall, W. H., New shells from the northwest coast: Biol. Soc. Washington Proc., vol. 32, p. 249, 1919.

[93] Clark, B. L., and Arnold, Ralph, Fauna of the Sooke formation, Vancouver Island: California Univ., Dept. Geol. Sci., Bull., vol. 14, pp. 144–145, pl. 25, figs. 2a, 2b, 1923. Clark, B. L., Pelecypoda from the marine Oligocene of western North America: Idem, vol. 15, p. 89, pl. 22, fig. 9, 1925.

[94] Stearns, R. E. C., Descriptions of new west American land, fresh-water, and marine shells, with notes and comments [*Albatross* Rept.]: U. S. Nat. Mus. Proc., vol. 13, pp. 220–221, pl. 17, figs. 3, 4, 1890 (as *Lucina*).

[95] Clark, B. L., op. cit., p. 89, pl. 22, figs. 2, 4, 1925. Tegland, N. M., op. cit., pp. 115–116, pl. 8, figs. 5–13.

[96] Dall, W. H., U. S. Nat. Mus. Proc., vol. 23, pp. 812, 828, pl. 41, fig. 1, 1901.

[97] Smith, E. A., Mollusca and Molluscoidea [*Alert* Rept.]: Zool. Soc. London Proc., 1881, pp. 38–39, pl. 5, figs. 1–1c (as *Diplodonta*).

[98] Dall, W. H., Summary of the marine shell-bearing mollusks of the northwest coast of America: U. S. Nat. Mus. Bull. 112, p. 35, 1921.

not farther than about the middle of a rib. With the proper amount of wear the spines of *quadragenarium* probably would be converted into ornamentation like that seen on the fossil.

Arnold described as *Cardium quadrigenarium* [error for *quadragenarium*] Conrad var. *fernandoensis* a form from the Pliocene of Elsmere Canyon,[99] differentiated by being smaller, more oblique, and less inflated and by having a narrower umbo and fewer (36 as against more than 40) and less spinose ribs. In addition to the type two imperfect specimens are represented in the collection from Elsmere Canyon (locality 4401). The type and the one other specimen that shows the outline are more elongate than young Recent shells of *quadragenarium*. The difference in inflation and in the width of the umbones appears to be negligible. The character of the ornamentation depends on the amount of wear; where it is preserved it resembles that of Recent shells. The type is the only specimen on which the number of ribs is discernible. There appear to be 37 or 38, the number depending on what is included at the ends of the shell. On four modern shells of comparable size the count is 41 to 45. This may be a recognizable variety or subspecies, but more material is desirable. It was recognized by English [1] at Elsmere Canyon and Pico Canyon. *Cardium quadragenarium* has been identified in formations as old as the upper Miocene San Pablo [2] and is now found along the coast from Santa Barbara to Lower California. It is the type of *Dallocardia*,[3] proposed as a subgenus of *Trachycardium*.[4]

Family VENERIDAE

Genus KATHERINELLA Tegland

Subgenus COMPSOMYAX Stewart

Katherinella (Compsomyax) aff. K. subdiaphana (Carpenter)

Plate 6, figure 12

Several imperfect valves from Chanslor-Canfield Midway Oil Co. Torrance No. 71, Torrance field, depth 3,245 feet (U. S. G. S. locality 13915), appear to be similar to the modern "*Clementia*" *subdiaphana* Carpenter [5] and to the Miocene Oregon "*Venus*" *angustifrons* Conrad.[6] The most nearly complete specimen, which has a restored length of about 33 millimeters and a height of 28 millimeters and probably is flattened, is figured. An attempt was made to expose the hinge of this specimen. The middle cardinal was broken off at the base, and the distal part of the anterior cardinal also was damaged. The posterior cardinal is not so deeply bifid as in fresh modern specimens of *subdiaphana*. This apparent difference is probably a matter of wear, as in one worn right valve dredged off Oregon at a depth of 61 fathoms (U. S. Nat. Mus. 210964) the posterior cardinal is not more deeply bifid. *K. subdiaphana* ranges from Alaska to San Pedro, Calif. Two small corresponding valves (length 18.5 millimeters, height 15 millimeters) in the National Museum collected by Kennerly in Puget Sound are labeled "types" (no. 4541). As the dimensions do not agree exactly with those given by Carpenter, this pair of valves is considered the lectotype. A small, badly broken left valve under the same number, also collected in Puget Sound by Kennerly, may have been the one measured by Carpenter. Large specimens from localities between Alaska and northern California attain a length of 58 millimeters and a height of 46.9 millimeters. No large shells are in the National Museum from localities south of Drakes Bay, Calif. Shells dredged off the Channel Islands are small or of medium size and relatively short.

The relations of *subdiaphana* to the Miocene *angustifrons* are still unknown, but the two forms appear to be closely allied, and the Recent one may eventually take the name *angustifrons*. The specimen figured by Conrad may be one of two under National Museum no. 3492, but the posterior part is higher than shown in the figure, and only a small part of the outer shell is preserved; at all events this specimen is taken as the lectotype. Ten other specimens, some of which were labeled "*Marcia oregonensis*" by Dall, are in the Dana Astoria collection. In outline and sculpture many of these specimens resemble short shells of *subdiaphana*. The hinge of the Miocene fossil has not yet been described. Dall [7] considered *angustifrons* the same as *Cytherea oregonensis* Conrad,[8] also described from Astoria. A Miocene species from southern Washington that appears to agree reasonably well with Conrad's figure has been identified as *oregonensis* and assigned to "*Pitaria*." [9] Dall's *Marcia oregonensis* (Conrad) [10] from the Pliocene of Coos Bay, Oregon, closely resembles in outline the modern *subdiaphana*, with which he compared it. The holotype of "*Venus*" *brevilineata* Conrad,[11] a paired mold, is under no. 3606. It has a short

[99] Arnold, Ralph, New and characteristic species of fossil mollusks from the oil-bearing Tertiary formations of southern California: U. S. Nat. Mus. Proc., vol. 32, p. 535, pl. 48, figs. 2, 2*a*, 1907.

[1] English, W. A., The Fernando group near Newhall, Calif.: California Univ., Dept. Geology, Bull., vol. 8, p. 209, 1914.

[2] Clark, B. L., Fauna of the San Pablo group of middle California: Idem, vol. 8, p. 417, 1915 (as *quadrigenarium*).

[3] Stewart, R. B., Gabb's California Cretaceous and Tertiary type lamellibranchs: Acad. Nat. Sci. Philadelphia Special Pub. 3, p. 264, 1930. Originally designated type, *Cardium quadrigenarium* Conrad [error for *quadragenarium*].

[4] Mörch, O. A. L., Yoldi catalog, pt. 2, p. 34, 1853. Subsequently designated type (Von Martens, Zool. Record, 1869, p. 586, 1870), *Cardium isocardia* Linné, Recent, West Indies.

[5] Carpenter, P. P., Supplementary report on the present state of our knowledge with regard to the Mollusca of the west coast of America: British Assoc. Adv. Sci. Rept. for 1863, pp. 602, 640, 1864; Diagnoses specierum et varietatum novarum molluscorum, prope Sinum Pugetianum a Kennerlio Doctore, nuper decesso, collectorum: Acad. Nat. Sci. Philadelphia Proc., 1865, p. 56 (as ?*Clementia*).

[6] Conrad, T. A., in Dana, J. D., Geology, U. S. Expl. Exped., p. 724, pl. 17, fig. 11, 1849.

[7] Dall, W. H., The Miocene of Astoria and Coos Bay, Oregon: U. S. Geol. Survey Prof. Paper 59, p. 123, 1909.

[8] Conrad, T. A., Fossil shells from Tertiary deposits on the Columbia River, near Astoria: Am. Jour. Sci., 2d ser., vol. 5, p. 432, fig. 8, 1848.

[9] Etherington, T. J., Stratigraphy and fauna of the Astoria Miocene of southwest Washington: California Univ., Dept. Geol. Sci., Bull., vol. 20, pp. 78–79, pl. 6, figs. 1–3, 1931.

[10] Dall, W. H., op. cit. (Prof. Paper 59), pp. 123–124, pl. 2, fig. 12, pl. 11, fig. 9, pl. 12, fig. 3, 1909.

[11] Conrad, T. A., op. cit. (U. S. Expl. Exped.), p. 724, pl. 17, fig. 13, 1849.

anterior end and appears to be a variety of *angustifrons*, as treated by Etherington.[12] It is not clear what Etherington meant in differentiating *angustifrons* from *subdiaphana* by "the absence of the sunken area just anterior to the beak" in *angustifrons*. *K. subdiaphana* is found in the Pliocene of Elsmere Canyon and Holser Canyon [13] and is recorded from Los Angeles.[14]

Compsomyax [15] is considered a subgenus of *Katherinella*,[16] which apparently is its predecessor. According to Tegland's figures, *Katherinella* has a weak anterior lateral that is absent in *Compsomyax*, and the right posterior cardinal is not so strongly bifid as in *Compsomyax*. In outline and sculpture *Compsomyax* closely resembles *Katherinella*. The strong anterior lateral of the Recent species, said to be from Alaska, described by Tegland as *Pitaria ida*,[17] indicates that it is not allied to *Katherinella*.

Genus MACROCALLISTA Meek

Macrocallista sp.

A mold of a right valve (length about 54 millimeters, restored height about 34.5 millimeters), on which the umbonal part is missing, is identified as a *Macrocallista*.[18] It was obtained from Great American Petroleum Co. Tuffree No. 2, East Coyote field, at a depth of 3,351 to 3,356 feet (U. S. G. S. locality 13873). Part of the smooth shell originally adhered to the mold, but peeled off when the core was split. Enough of the hinge is preserved to reveal the anterior laterals and the almost vertical and closely spaced anterior and middle cardinals. The lower lateral, which is broken, appears to lie in front of and to overlap the upper one instead of lying directly under it. This species is more elongate than any known to be living on the Pacific coast and in outline seems to resemble more closely the Miocene to Recent West Indian *M. maculata* (Linné). A similar but smaller elongate *Macrocallista* has been recognized in the Miocene of the Palos Verdes Hills.[19]

Family CORBULIDAE

Genus CORBULA Bruguière

Subgenus VARICORBULA Grant and Gale

Corbula (Varicorbula) gibbiformis Grant and Gale

Plate 6, figures 8, 9

Corbula (*Corbula*) *gibbiformis* Grant and Gale, San Diego Soc. Nat. History Mem., vol. 1, pp. 420–421, pl. 19, figs. 4–6, 1931. Type from well in San Joaquin Valley (Southern California Gas Co. No. 1–4, sec. 4, T. 28 S., R. 23 E., depth 3,951 to 3,952 feet); upper Etchegoin formation [San Joaquin formation?], upper Pliocene.

A relatively large *Varicorbula* with a short posterior rostrum. Right valve sculptured with strong concentric undulations; left valve sculptured with at least 12 radial riblets which, except at the ends of the shell, are arranged in pairs or triplets.

Length 11.3 millimeters, height (not quite complete) 9.8 millimeters, diameter (both valves) 8.3 millimeters.

A paired, not quite complete specimen from Great American Petroleum Co. Tuffree No. 2, East Coyote field, depth 3,351 to 3,356 feet (U. S. G. S. locality 13873), associated with *Macrocallista* sp., is assigned to *Corbula gibbiformis*. According to Grant and Gale's figures, the right valve is a little smaller and more elongate than the holotype of *gibbiformis* but is not more elongate than a paratype from the same core (fig. 4); and the left valve has more numerous radial riblets than the paratype of *gibbiformis*, but this apparent difference may be a matter of preservation. With more material it may be possible to differentiate the coastal form from the San Joaquin Valley form. In addition to the type locality, Grant and Gale recorded *gibbiformis* from the *Pecten coalingaenis* zone, now assigned to the San Joaquin formation, of the Kettleman Hills in San Joaquin Valley, and in association with *Acila semirostrata* from a locality near Camulos, in the Ventura Basin, that they assigned to the middle Pliocene. Two poorly preserved worn right valves, collected by Ralph Stewart from gravel in the *Pecten coalingaensis* zone on the west side of the northern Middle Dome of the Kettleman Hills (locality 12384), are larger and less elongate than the specimen from the Los Angeles Basin.

Varicorbula is not represented in the collection of Recent mollusks from the west coast of America in the

[12] Etherington, T. J., op. cit., pp. 81–82, pl. 6, figs. 6, 7 [as *Marcia* (*Mercimonia*)].

[13] Ashley, G. H., The Neocene stratigraphy of the Santa Cruz Mountains of California: California Acad. Sci. Proc., 2d ser., vol. 5, p. 238, 1895 (as *Saxidomus gibbosus* Gabb?, ridge over San Fernando tunnel). Arnold, Ralph, New and characteristic species of fossil mollusks from the oil-bearing Tertiary formations of southern California: U. S. Nat. Mus. Proc., vol. 32, pp. 526 (list), 544, pl. 49, fig. 3, 1907 (as *Callista*, Elsmere Canyon). Arnold, Ralph, in Eldridge, G. H., and Arnold, Ralph, The Santa Clara Valley, Puente Hills, and Los Angeles oil districts, southern California: U. S. Geol. Survey Bull. 309, pp. 25 (list), 250, pl. 39, fig. 3, 1907 (as *Callista*, Elsmere Canyon). English, W. A., The Fernando group near Newhall, Calif.: California Univ., Dept. Geology, Bull., vol. 8, p. 210 (list), 1914 (as *Marcia*, Elsmere Canyon and Holser Canyon). Kew, W. S. W., Geology and oil resources of a part of Los Angeles and Ventura Counties, Calif.: U. S. Geol. Survey Bull. 753, p. 78 (list), 1924 (as *Marcia*, Elsmere Canyon, Holser Canyon, near Pico Canyon).

[14] Cooper, J. G., in Watts, W. L., Oil and gas yielding formations of Los Angeles, Ventura, and Santa Barbara Counties: California State Min. Bur. Bull. 11, p. 80, 1897 (as *Saxidomus gibbosus* Gabb; Shatto estate, West Los Angeles). Arnold, Ralph, in Eldridge, G. H., and Arnold, Ralph, op. cit., p. 153, 1907 (as *Saxidomus gibbosus* Gabb; Shatto estate, West Los Angeles).

[15] Stewart, R. B., Gabb's California Cretaceous and Tertiary type lamellibranchs: Acad. Nat. Sci. Philadelphia Special Pub. 3, p. 224, 1930 (as subgenus of *Venerella*). Originally designated type, *Saxidomas gibbosus* Gabb (= *V. subdiaphana* (Carpenter), Pliocene to Recent, Pacific coast.

[16] Tegland, N. M., Correlation and affinities of certain species of *Pitaria:* California Univ., Dept. Geol. Sci., Bull., vol. 18, pp. 280–282, 1929. Originally designated type, *Callocallista arnoldi* Weaver, Oligocene, Washington.

[17] Tegland, N. M., *Pitaria ida*, a new Recent species from Alaska: Nautilus, vol. 42, pp. 4–6, 1928; Correlation and affinities of certain species of *Pitaria:* California Univ., Dept. Geol. Sci., Bull., vol. 18, pp. 283–284, pl. 22, figs. 7–10, 1929.

[18] Meek, F. B., A report on the invertebrate Cretaceous and Tertiary fossils of the upper Missouri country: U. S. Geol. Survey Terr. Rept., vol. 9, p. 179, 1876. Monotype, *Venus gigantea* Gmelin (= *Venus nimbosa* Solander, fide Dall), Recent, West Indies.

[19] Woodring, W. P., in Woodring, W. P., Bramlette, M. N., and Kleinpell, R. M., Miocene stratigraphy and paleontology of Palos Verdes Hills, California: Am. Assoc. Petroleum Geologists Bull., vol. 20, p. 138 (list, *Macrocallista* cf. *M. maculata* (Linné)), 1936.

National Museum, and no species are recorded from the Miocene of the west coast of North America. It is represented in the Peruvian Miocene [20] and is widespread in the Miocene of the West Indian region, where it is now represented by *C. disparilis* D'Orbigny,[21] but is not known earlier than the lower Miocene in this region and Florida. The status of *Corbula binominata* Hanna,[22] from the upper Pliocene of Los Angeles, is uncertain.

The nomenclature of the subdivisions of *Corbula* [23] has recently been discussed by Gardner,[24] Stewart,[25] and Grant and Gale.[26] If Schmidt's designation of *C. sulcata* is accepted, the provisionally proposed *Varicorbula* [27] appears to be the name to use for American and European Corbulas with dissimilarly sculptured valves. Perhaps this name will be supplanted by *Notocorbula* Iredale,[28] proposed for an Australian species that has a long rostrum and is said to have a keeled cardinal tooth. Iredale claimed that specific names were first assigned to *Corbula* in the Museum Boltenianum.[29] As there are no citations to Bruguière's figures and as it has not been shown that any of the valid species are the same as Bruguière's unnamed ones, the *Corbula* of this publication is considered a homonym of *Corbula* Bruguière, a conclusion reached by Stewart.

Family PERIPLOMIDAE

Genus PERIPLOMA Schumacher

Periploma cryphia Woodring, n. sp.

Plate 9, figures 4, 6

A short, slightly elongate, thin-shelled *Periploma* of medium size. Posterior end rounded. Sculpture over greater part of shell consisting of regular fine concentric undulations that disappear toward ventral and posterior margins. Chondrophore buttress thin and long.

Length 35.2 millimeters, height about 29.5 millimeters (holotype). Length 26.9 millimeters, height 19.5 millimeters.

Holotype, U. S. Nat. Mus. 496104.

The holotype (pl. 9, fig. 6) is a left valve from Union Oil Co. Hellman No. 17, Dominguez field, depth 3,939 feet (U. S. G. S. locality 13898). A more elongate right valve (pl. 9, fig. 4) from Union Oil Co. Hellman No. 14, Dominguez field, depth 5,102 feet (U. S. G. S. locality 13897), is referred to this form. Part of the outer shell layer is missing on the holotype, and the insertion of the long, thin chondrophore buttress shows through the shell. Much of the shell is missing on the specimen from Hellman No. 14; the insertion of the buttress is visible; the umbo appears to be fissured; and at the posterior end, where an area of shell is preserved, the concentric undulations are replaced by strong growth threads.

This species may be allied to one from Weaver's Blakeley formation of Washington (Oligocene) described as *Cochlodesma bainbridgensis* Clark,[30] which according to the figures has strong concentric undulations. Whether *bainbridgensis* has a long, thin buttress is not known. *Cochlodesma* [31] has a broad, blunt buttress and a thin, low supplementary one under it; Dall [32] treated it as a subgenus of *Periploma*. *P. cryphia* is not similar to any Recent species now known on the Pacific coast. *P. stearnsii* Dall,[33] a shallow-water species from the head of the Gulf of California, and *P. carpenteri* Dall,[34] dredged at a depth of 210 fathoms off Panama, are somewhat similar in outline but have granular sculpture and a short blunt buttress. A small unnamed Japanese species in the collections of the National Museum (Suruga Gulf, 503 fathoms; Japan Sea, 325 fathoms) has a long, thin triangular buttress but lacks the strong sculpture. A deep-water species ranging from Nova Scotia to Chesapeake Bay (depth 101 to 300 fathoms), labeled "*P. abyssorum* Verrill, 1893", has a similar buttress but lacks the strong sculpture. I have not discovered where this name was published. *P. fragilis* (Totten) and *P. papyratia* (Say), two small species from the Atlantic coast, also have a thin buttress. Perhaps these species with a long, thin triangular chondrophore buttress strongly diverging from the umbo deserve subgeneric rank.

[20] Spieker, E. M., The paleontology of the Zorritos formation of the north Peruvian oil fields: Johns Hopkins Univ. Studies in Geology, no. 3, pp. 170-172, 1922 (as *Aloidis*). Olsson, A. A., Contributions to the Tertiary paleontology of northern Peru, pt. 5. The Peruvian Miocene: Bull. Am. Paleontology, vol. 19, no. 68, p. 135, 1932 (as undesignated subgenus).

[21] See Woodring, W. P., Miocene mollusks from Bowden, Jamaica, Pelecypods and scaphopods: Carnegie Inst. Washington Pub. 366, pp. 188-189, 1925 (as *Corbula* s. s.).

[22] Hanna, G. D., Rectifications of nomenclature: California Acad. Sci. Proc., 4th ser., vol. 13, p. 163, 1924. New name for *Corbula tenuis* Moody, 1916 (California Univ., Dept. Geology, Bull., vol. 10, p. 59, pl. 2, figs. 4a, 4b): not Sowerby, 1833.

[23] Bruguière, J. G., Tableau encyclopédique et méthodique, Vers testacées, vol. 2, pl. 230, 1797 (genus without named species). Subsequently designated type (Schmidt, Versuch * * * der Conchylien-Sammlungen, p. 77, 1818, fide Stewart), *Corbula sulcata* Lamarck, Recent, West Africa.

[24] Gardner, Julia, The nomenclature of the superspecific groups of *Corbula* in the lower Miocene of Florida: Nautilus, vol. 40, pp. 41-47, 1926; The molluscan fauna of the Alum Bluff group of Florida: U. S. Geol. Survey Prof. Paper 142-E, pp. 226-228, 1928.

[25] Stewart, R. B., Gabb's California Cretaceous and Tertiary type lamellibranchs: Acad. Nat. Sci. Philadelphia Special Pub. 3, pp. 286-287, 1930.

[26] Grant, U. S., IV, and Gale, H. R., op. cit., pp. 420-421.

[27] Idem, p. 420, footnote. Originally designated type *Corbula gibba* (Olivi), Recent, Mediterranean.

[28] Iredale, Tom, More notes on the marine Mollusca of New South Wales: Australian Mus. Rec., vol. 17, p. 404, 1930. Originally designated type, *N. vicaria* Iredale, Recent, New South Wales.

[29] Röding, P. F., in Bolten, J. F., Museum Boltenianum, pt. 2, p. 184, 1798.

[30] Clark, B. L., Pelecypoda from the marine Oligocene of western North America: California Univ., Dept. Geol. Sci., Bull., vol. 15, p. 86, pl. 13, figs. 3, 4, 1925. Tegland, N. M., The fauna of the type Blakeley upper Oligocene of Washington: Idem, vol. 23, p. 112, pl. 6, figs. 3, 4, 1933.

[31] Couthouy, J. P., Monograph of the family Osteodesmacea: Boston Soc. Nat. History, Jour. Nat. History, vol. 2, p. 170, 1839. Monotype, *Cochlodesma leana* (Conrad) (=*Anatina leana* Conrad), Recent, Atlantic coast of United States.

[32] Dall, W. H., Tertiary fauna of Florida: Wagner Inst. Sci. Philadelphia Trans., vol. 3, pt. 6, p. 1528, 1903.

[33] Dall, W. H., Diagnoses of new species of mollusks from the west coast of America: U. S. Nat. Mus. Proc., vol. 18, p. 19, 1895 [1896]. Dall, W. H., The Mollusca and the Brachiopoda [*Albatross* Rept.]: Harvard College Mus. Comp. Zoology Bull., vol. 43, pp. 426-427, pl. 16, fig. 5, 1908.

[34] Dall, W. H., op. cit. (1895 [1896]), p. 20; op. cit. (1908), p. 426, pl. 16, fig. 8.

Periploma[35] proper has a relatively thick shell, a short posterior end, weak granular sculpture, and a thick, blunt buttress inserted parallel to the margin of the valve. *Halistrepta*,[36] proposed as a subdivision of *Periploma*, is characterized by heavy undulations that do not conform to the growth lines and by a broad low buttress.

Periploma discus Stearns has been recorded from a Los Angeles locality (First and Olive Streets)[37] that may represent the Repetto formation.

Periploma cryphia stenopa Woodring, n. var.

Plate 9, figure 7

Larger and more elongate than *cryphia* proper and having a more pointed posterior end.

Length 45.2 millimeters, height 33.9 millimeters (holotype).

Holotype, U. S. Nat. Mus. 496106.

Inasmuch as it is improbable that the difference in outline is due to deformation, the large elongate left valve from Union Oil Co. Hellman No. 18, Dominguez field, depth 4,076 feet (U. S. G. S. locality 13899) is considered a variety of *cryphia*. Almost all the outer shell material is missing on this specimen; the umbo seems to be fissured; and the insertion of the long, thin chondrophore buttress is visible. An incomplete elongate left valve from Standard Oil Co. Baldwin No. 73, Montebello field, depth 4,745 feet (U. S. G. S. locality 13864a), probably represents this elongate *Periploma*. The upper posterior margin is slightly truncated. *Cochlodesma bainbridgensis* is more similar in outline to this elongate form but appears to have a narrower posterior end.

ECHINOIDS

Family ECHINOTHURIIDAE

Genus ARAEOSOMA Mortensen

Araeosoma sp.

[Identification by Th. Mortensen]

Plate 9, figures 2, 3

Two poorly preserved incomplete echinoids from Standard Oil Co. Murphy Coyote No. 117, West Coyote field, depth 4,400 feet (U. S. G. S. locality 13875), were recognized by Dr. A. H. Clark, of the United States National Museum, as echinothuriids. They were examined by Dr. H. L. Clark, of the Harvard Museum of Comparative Zoology, who concurred in this identification, and on his recommendation were forwarded to Dr. Th. Mortensen, of the Zoological Museum of the University of Copenhagen. Dr. Mortensen identified them as an undeterminable species of *Araeosoma*, probably more closely allied to the West Indian *A. fenestratum* (Thomson) and *A. belli* Mortensen than to the eastern Pacific *A. eurypatum* A. Agassiz and H. L. Clark and *A. leptaleum* A. Agassiz and H. L. Clark, but stated that the material is too incomplete to be certain of the affinities.

One specimen (pl. 9, fig. 2) consists of part of the inner side of the oral surface with the lantern in place and includes an ambulacrum and interambulacrum, half of another interambulacrum, and part of another ambulacrum. The distance from the center to the edge, which may be some distance from the ambitus, is 25.5 to 33.5 millimeters. The interambulacrum has a width at the distal edge of 24.5 millimeters, the half ambulacrum 15.7 millimeters; and the ambulacrum about 19 millimeters. The pores are not clearly discernible. The interambulacra have an adradial series of primary tubercles, usually one on each plate, an admedian series, and a few scattered tubercles between the two series toward the ambitus. The ambulacra have an admedian series. The preserved part of the peristome shows numerous narrow imbricating plates. The other specimen (pl. 9, fig. 2) from the same core consists of part of the aboral surface telescoped onto the inner side of the oral surface, which has the lantern in place. The outer edge at the place of maximum diameter appears to be the ambitus, indicating a horizontal diameter of 82 millimeters. Only the greater part of an aboral ambulacrum and interambulacrum in exterior view and the peristome, seen from the inside, are clearly shown. The incomplete interambulacrum has a maximum width of 23 millimeters. The interambulacral adradial series of tubercles adjoining the preserved ambulacrum appear to be present only near the ambitus.

These specimens, incomplete as they are, are of exceptional interest, inasmuch as they are the first fossil representatives of the family Echinothuriidae to be found in America and apparently the first Tertiary specimens from any region represented by more than isolated spines. The Echinothuriidae have recently been monographed by Mortensen,[38] who recognized 13 Recent species of *Araeosoma*. No echinothuriids have been dredged along the California coast. The *Albatross* dredged *A. eurypatum* A. Agassiz and H. L. Clark[39] off the Galapagos Islands at a depth of 671 fathoms and *A. leptaleum* A. Agassiz and H. L. Clark[40] off Panama at a depth of 581 fathoms.

[35] Schumacher, C. F., Essai d'un nouveau système des habitations des vers testacés, pp. 115-116, 1817. Monotype, *Periploma inaequivalvis* Schumacher, Recent, West Indies.

[36] Dall, W. H., A new species of *Periploma* from California: Nautilus, vol. 17, pp. 122-123, 1904. Originally designated type, *Periploma sulcata* Dall, Recent, California.

[37] Cooper, J. G., in Watts, W. L., Oil and gas yielding formations of Los Angeles, Ventura, and Santa Barbara Counties: California State Min. Bur. Bull. 11, p. 80 (list), 1897. Arnold, Ralph, in Eldridge, G. H., and Arnold, Ralph, op. cit. (Bull. 309), p. 153 (list), 1907.

[38] Mortensen, Th., A monograph of the Echinoidea, II, pp. 80-292, pls. 1-65, 74-83, Copenhagen, 1935.

[39] Agassiz, A., and Clark, H. L., Hawaiian and other Pacific Echini: Harvard College Mus. Comp. Zoology Mem., vol. 34, pp. 181-183, pl. 66, figs. 18, 19; pls. 73-75, 1909.

[40] Idem, pp. 183-185, pls. 76, 77.

Numerous slender spines, represented principally by vertical sections in which the structure is obscure, are in a core from Standard Oil Co. Bastanchury Ranch No. 1, West Coyote field, depth 6,414 feet (U. S. G. S. locality 13884). They have a length of about 4 to 7 millimeters and a diameter of about 0.1 to 0.2 millimeter. Those that show the exterior have fine roughened ribs. A few show the enlarged base, which has a diameter of about 0.3 millimeter and a length of about 0.35 millimeter. Horizontal sections showing the same diameter probably represent the base. One spine shown in vertical section terminates in a swelling that has a length of 0.7 millimeter and widens near the end to a diameter of 0.35 millimeter. These may be spines of an echinothuriid. According to Mortensen's illustrations, they are relatively small for primary spines and none clearly show the characteristic hoof. Part of a test probably was in this core, but the substance now present is too powdery to make out any plates. An imperfect imprint of a curled leaf is in the same core.

The occurrence of another echinoid in the Repetto formation is indicated by poorly preserved material, too imperfect for identification. A mold (length about 73 millimeters, height about 39 millimeters) of almost half an echinoid, collected by W. H. Holman, of the Standard Oil Co. of California, on the north side of Wilshire Boulevard 200 feet east of the center line of Bixel Street (U. S. G. S. locality 13923), is identified by A. H. Clark as a cassidulid. Fragments from a horizon in the Huntington Beach field assigned to the Miocene (Standard Oil Co. Pacific Electric No. 15, depth 3,174 to 3,180 feet, U. S. G. S. locality 13903) are considered by Clark as a spatangid, possibly one of the Hemiasteridae. A few strongly ribbed spines are associated with these fragments.

PLATES 5–9

145569—38——6

PLATE 5

[Figures natural size unless otherwise designated]

FIGURE 1. *Lucinoma* aff. *L. aequizonata* (Stearns). Small incomplete right valve. Height 20 millimeters. Third Street tunnel, Los Angeles; U. S. G. S. locality 3426. U. S. Nat. Mus. 496331.

2. *Lucinoma* aff. *L. aequizonata* (Stearns). Right valve. Length 43.7 millimeters, height 41.5 millimeters. Graham & Loftus Oil Co. No. 1, East Coyote field, depth 5,957 to 5,980 feet; U. S. G. S. locality 13872*a*. Miocene. U. S. Nat. Mus. 496100.

3. *Phreagena lasia* Woodring, n. gen., n. sp. Holotype; gaping valves held together by remnant of ligament. Length about 41.5 milimeters, height 22 millimeters. Standard Oil Co. Baldwin No. 73, Montebello field, depth 3,340 to 3,358 feet; U. S. G. S. locality 13864. U. S. Nat. Mus. 496097.

4. *Phreagena lasia* Woodring, n. gen., n. sp. Imperfect right valve. Length (incomplete) 40 millimeters, height (incomplete) 25.5 millimeters. Third Street tunnel, Los Angeles; U. S. G. S. locality 3426. U. S. Nat. Mus. 496098.

5, 6. *Calyptogena* n. sp. Exterior and hinge of imperfect left valve. Length (incomplete) 26.5 millimeters. Standard Oil Co. Emery No. 54, West Coyote field, depth 4,230 feet; U. S. G. S. locality 13880. U. S. Nat. Mus. 496099.

7, 12. *Limopsis* (*Felicia*) *phrear* Woodring, n. sp. Hinge and exterior of paratype, an elongate left valve. Length 20.5 millimeters, height 14.7 millimeters. Union Oil Co. Callender No. 27, Dominguez field, depth 4,998 feet; U. S. G. S. locality 13896. U. S. Nat. Mus. 496078.

8, 13. *Limopsis* (*Felicia*) *phrear* Woodring, n. sp. Hinge and exterior of short (deformed?) left valve. Length 18.4 millimeters, height 21.5 millimeters. Pacific Western Oil Corporation Cone No. 16, Inglewood field, depth 2,926 to 2,945 feet; U. S. G. S. locality 13892. U. S. Nat. Mus. 496079.

9. *Limopsis* (*Felicia*) *phrear* Woodring, n. sp. Left valve of holotype, an elongate gaping paired shell. Length 17.8 millimeters, height 15.4 millimeters. Shell Oil Co. Reyes No. 101, Dominguez field, depth 5,245 feet; U. S. G. S. locality 13900. U. S. Nat. Mus. 496077.

10, 11. *Acila* (*Acila*) *semirostrata* (Grant and Gale). Flattened right valve (fig. 10) and impression (fig. 11). Length 22 millimeters, height 18.5 millimeters. Wilmington Terminal Oil Co. Banning No. 1, Wilmington field, depth 3,265 feet; U. S. G. S. locality 13916. U. S. Nat. Mus. 496071.

14. *Solemya* (*Acharax*) aff. *S. johnsoni* Dall. Right valve of imperfect paired shell. Length (incomplete) 30.8 millimeters, height 15.8 millimeters. Standard Oil Co. Baldwin No. 73, Montebello field, depth 3,340 to 3,358 feet; U. S. G. S. locality 13864. U. S. Nat. Mus. 496070.

15. *Buccinum?* sp. Rear view of imperfect crushed specimen. Length (incomplete) 42.8 millimeters, width (crushed) 25.6 millimeters. Third Street tunnel, Los Angeles; U. S. G. S. locality 3426. U. S. Nat. Mus. 496069.

16. "*Nassa*" *hamlini* Arnold, × 2. Side view of imperfect specimen. Length (incomplete) 13.8 millimeters, width (crushed) 6 millimeters. Standard Oil Co. Emery No. 52, West Coyote field, depth 3,695 feet; U. S. G. S. locality 13878d. U. S. Nat. Mus. 496067.

17. *Astraea* (*Pomaulax*) cf. *A. gradata* Grant and Gale. Rear view of imperfect deformed specimen. Length (incomplete) 65.5 millimeters, greatest width (exaggerated by compression) 90.5 millimeters. Third Street tunnel, Los Angeles; U. S. G. S. locality 3426. U. S. Nat. Mus. 496061.

18. *Plicifusus?* sp. Rear view of imperfect deformed specimen. Length (incomplete) 47.2 millimeters, width (crushed) 29.9 millimeters. Third Street tunnel, Los Angeles; U. S. G. S. locality 3426. U. S. Nat. Mus. 496068.

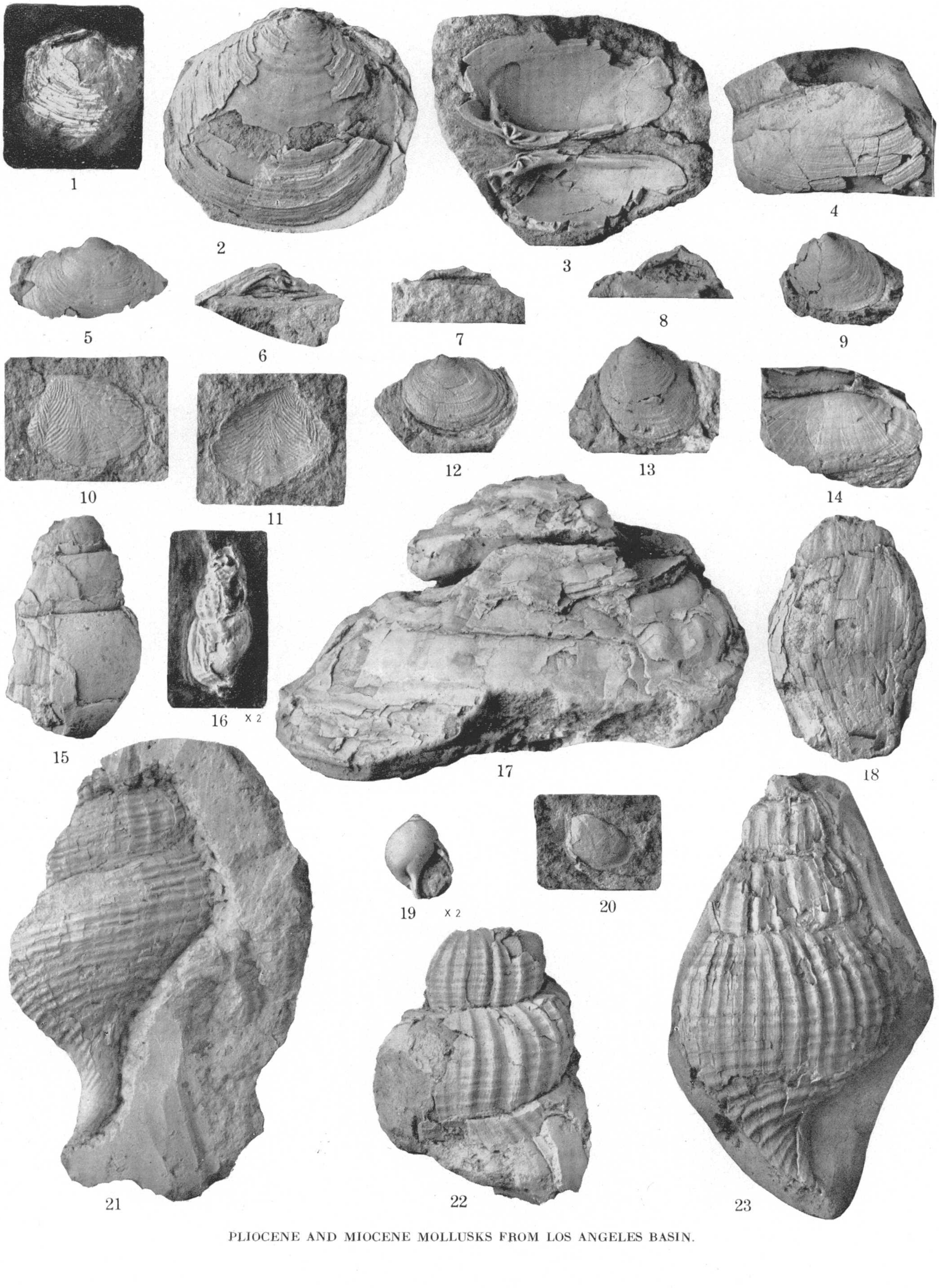
19. *Lunatia* cf. *L. caurina* (Gould), × 2. Length 8.4 millimeters, width 6.8 millimeters. Standard Oil Co. Baldwin-Cienega No. 105, Inglewood field, depth 2,221 feet; U. S. G. S. locality 13890. U. S. Nat. Mus. 496062.

20. *Acila?* (*Truncacila?*) cf. *A. castrensis* (Hinds). Right valve; outer shell layer missing. Length 13 millimeters, height 9.7 millimeters. Union Oil Co. Farwell No. 17, Santa Fe Springs field, depth 5,631 feet; U. S. G. S. locality 13885. U. S. Nat. Mus. 496072.

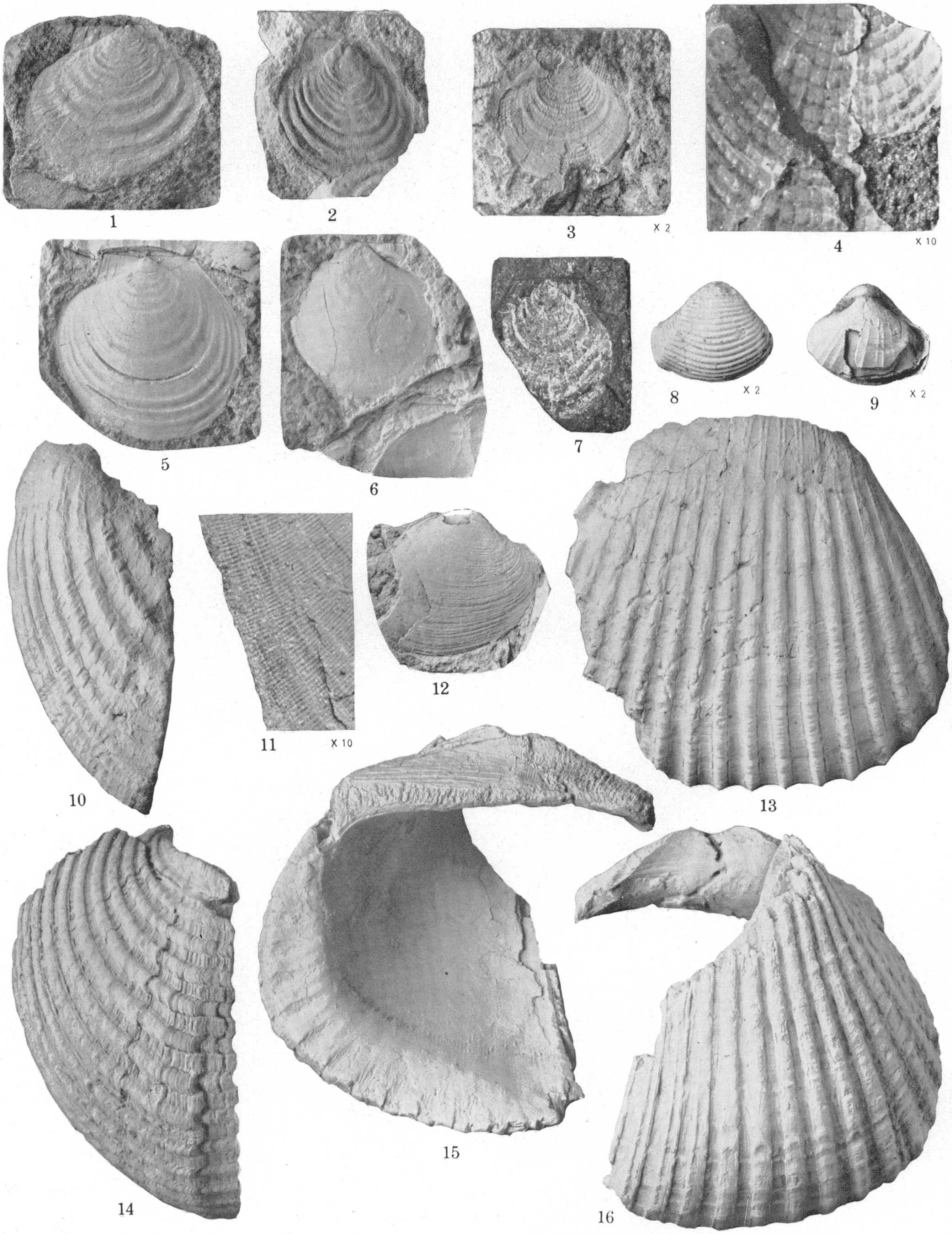
21. *Fusitriton* aff. *F. oregonensis* (Redfield). Incomplete specimen having exceptionally subdued ribs. Length (incomplete) about 70 millimeters, width (crushed) 37.5 millimeters. Union Oil Co. Callender No. 22, Dominguez field, depth 4,146 feet; U. S. G. S. locality 13895. U. S. Nat. Mus. 496066.

22. *Fusitriton* aff. *F. oregonensis* (Redfield). Incomplete specimen having strong, relatively widely spaced ribs. Length (incomplete) 53 millimeters, width (crushed) 44 millimeters. Third Street tunnel, Los Angeles; U. S. G. S. locality 3426. U. S. Nat. Mus. 496065.

23. *Fusitriton* aff. *F. oregonensis* (Redfield). Incomplete specimen having subdued, closely spaced ribs. Length (incomplete) 77 millimeters, width (crushed) 66.5 millimeters. Third Street tunnel, Los Angeles; U. S. G. S. locality 3426. U. S. Nat. Mus. 496064.



PLIOCENE AND MIOCENE MOLLUSKS FROM LOS ANGELES BASIN.



PLIOCENE AND MIOCENE MOLLUSKS FROM LOS ANGELES BASIN.

PLATE 6

[Figures natural size unless otherwise designated]

FIGURE 1. *Hyalopecten* (*Delectopecten*) cf. *H. pedroanus* (Trask). Faintly sculptured left valve. Length 30.5 millimeters, height 26.7 millimeters. St. Helen's Petroleum Co. P. & B. No. 6, Montebello field, depth 5,704 feet; U. S. G. S. locality 13870. From a horizon close to contact between Miocene and Pliocene. U. S. Nat. Mus. 496082.

2. *Hyalopecten* (*Delectopecten*) cf. *H. pedroanus* (Trask). Strongly sculptured left valve. Length 17 millimeters, height about 17 millimeters. Graham & Loftus Oil Co. No. 1, East Coyote field, depth 5,592 to 5,615 feet; U. S. G. S. locality 13872. Miocene. U. S. Nat. Mus. 496083.

3. *Hyalopecten* (*Delectopecten*) aff. *H. randolphi tillamookensis* (Arnold), × 2. Interior of left valve of medium size; part of shell missing. Length 12.5 millimeters, height about 12 millimeters. Julian Oil Co. Farnsworth No. 2, Huntington Beach field, depth 2,081 feet; U. S. G. S. locality 13908. U. S. Nat. Mus. 496085.

4. *Hyalopecten* (*Delectopecten*) aff. *H. randolphi tillamookensis* (Arnold), × 10. Interior view of part of valve of medium size, showing sculpture. Standard Oil Co. Vickers No. 1 lease, well 27, Inglewood field, depth 1,240 to 1,253 feet; U. S. G. S. locality 13888. Pico formation. U. S. Nat. Mus. 496084.

5. *Hyalopecten* (*Delectopecten*) aff. *H. randolphi* (Dall). Large left valve; concentric undulations moderately strong; most of shell material missing except on anterior ear. Length 34.5 millimeters, height 33.5 millimeters. Southern California Drilling Co. Matteson No. 1, near El Segundo, depth 2,081 feet; U. S. G. S. locality 13912. Pico formation. U. S. Nat. Mus. 496086.

6. *Hyalopecten* (*Delectopecten*) aff. *H. randolphi* (Dall). Upper part: Right valve; concentric undulations weak; shell missing except inner layer on ears and nearby. Length about 27 millimeters, height 28.7 millimeters. Lower part: Impression of incomplete right valve; concentric undulations weak; shell preserved in interior view on part of anterior ear, showing sculpture of anterior ear. Southern California Drilling Co. Matteson No. 1, near El Segundo, depth 2,081 feet; U. S. G. S. locality 13912. Pico formation. U. S. Nat. Mus. 496087.

7. *Hyalopecten* (*Delectopecten*) aff. *H. randolphi* (Dall). Impression of incomplete left valve; concentric undulations strong; some shell material preserved. Length (incomplete) 22.2 millimeters, height 26.2 millimeters. Standard Oil Co. Baldwin No. 41, Montebello field, depth 3,600 feet; U. S. G. S. locality 13907. U. S. Nat. Mus. 496328.

8, 9. *Corbula* (*Varicorbula*) *gibbiformis* Grant and Gale, × 2. Right (fig. 8) and left (fig. 9) valves of paired shell. Length 11.3 millimeters, height (not quite complete) 9.8 millimeters. Great American Petroleum Co. Tuffree No. 2, East Coyote field, depth 3,351 to 3,356 feet; U. S. G. S. locality 13873. U. S. Nat. Mus. 496103.

10, 13. *Anadara camuloensis* (Osmont). Anterior end (fig. 10) and exterior (fig. 13) of imperfect worn right valve. Length (incomplete) 78.5 millimeters, height (incomplete) 72.5 millimeters. A. T. Jergins Trust Robertson No. 1, Playa del Rey field, depth 3,830 feet; U. S. G. S. locality 13911. U. S. Nat. Mus. 496076.

11. *Hyalopecten* (*Delectopecten*) aff. *H. randolphi* (Dall), × 10. Impression showing camptonectes sculpture. Anterior part of specimen shown in lower part of figure 6.

12. *Katherinella* (*Compsomyax*) aff. *K. subdiaphana* (Carpenter). Imperfect right valve. Length (incomplete) 31 millimeters, height 28 millimeters. Chanslor-Canfield Midway Oil Co. Torrance No. 71, Torrance field, depth 3,245 feet; U. S. G. S. locality 13915. U. S. Nat. Mus. 496102.

14–16. *Anadara camuloensis* (Osmont). Anterior end (fig. 14), interior (fig. 15), and exterior (fig. 16) of imperfect worn right valve. Length (incomplete) 69.5 millimeters, height (not quite complete) 75.5 millimeters, diameter about 45 millimeters. Third Street tunnel, Los Angeles; U. S. G. S. locality 3426. U. S. Nat. Mus. 496075.

PLATE 7

[Figures natural size]

FIGURE 1. *Lyropecten cerrosensis* (Gabb). Four fragments mounted on plaster of paris model in form of a complete valve. Third Street tunnel, Los Angeles; U. S. G. S. locality 3426. U. S. Nat. Mus. 496081.

2. *Lyropecten cerrosensis* (Gabb). Imperfect left valve. Length (incomplete) 100 millimeters, height 117 millimeters, length of cardinal margin about 60 millimeters. Third Street tunnel, Los Angeles; U. S. G. S. locality 3426. U. S. Nat. Mus. 496080.

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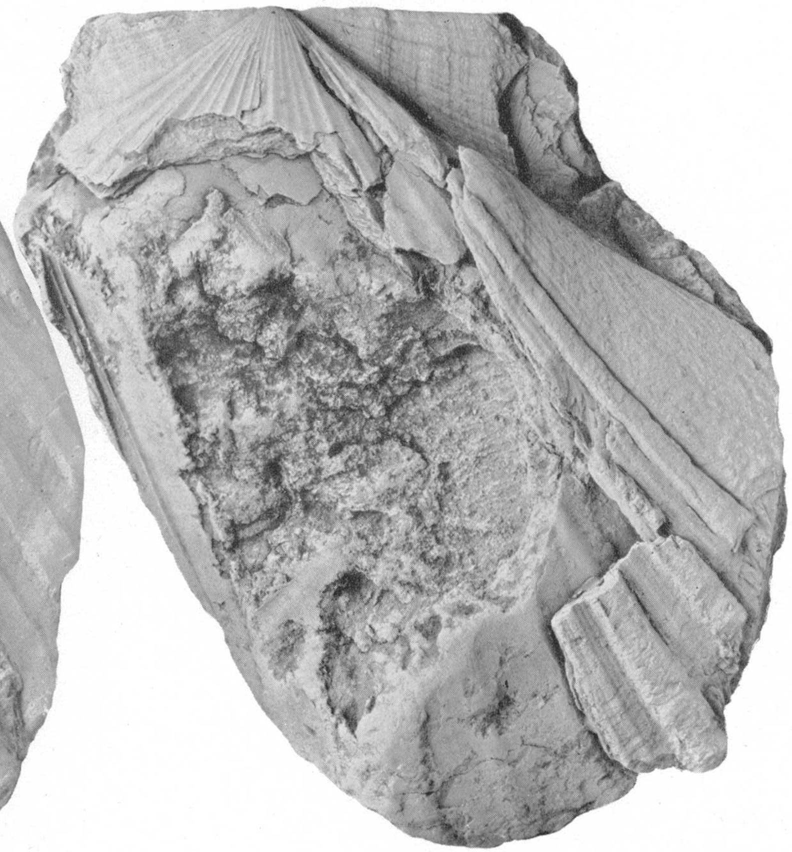

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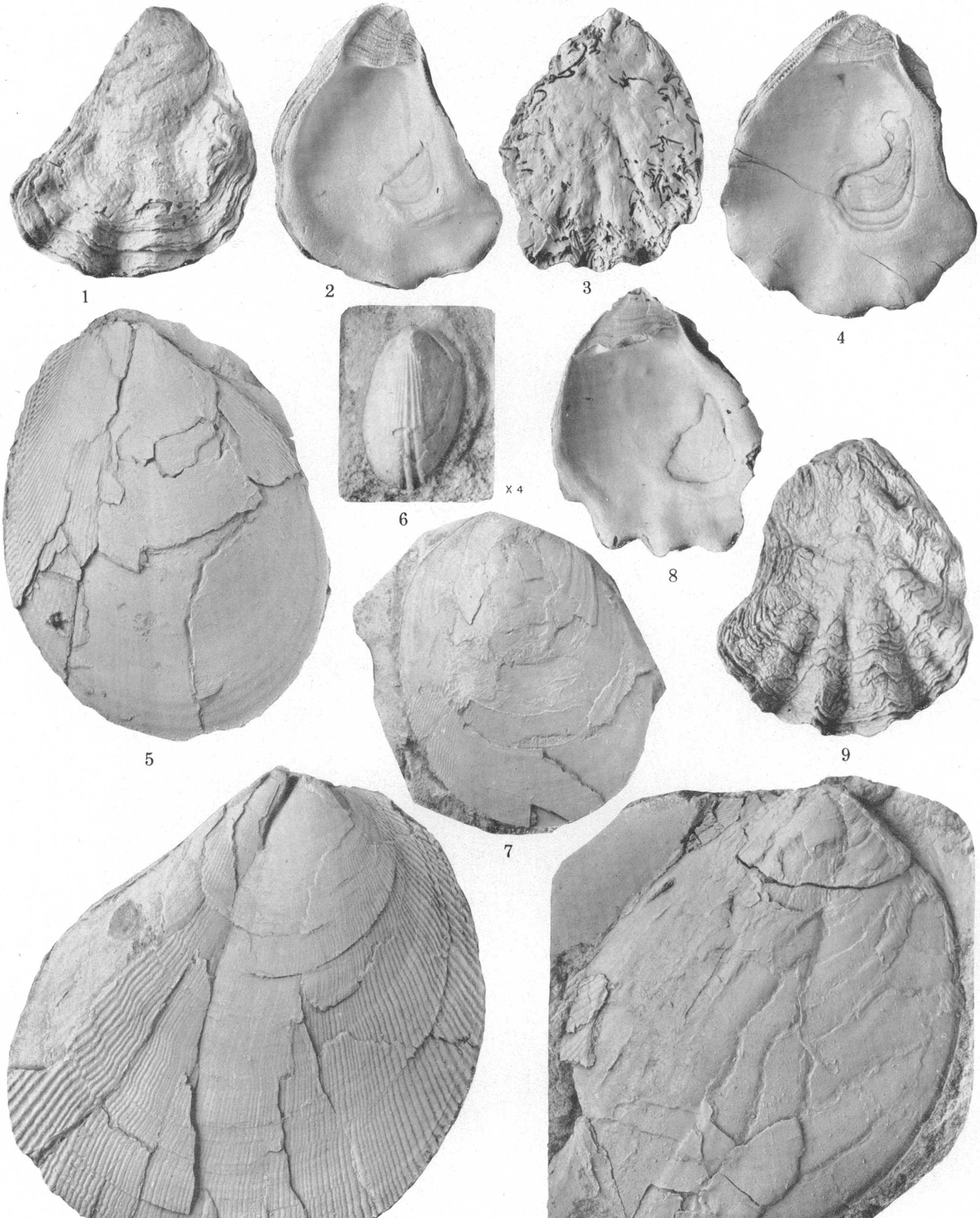
PLIOCENE MOLLUSKS FROM LOS ANGELES BASIN



PLIOCENE MOLLUSKS FROM LOS ANGELES BASIN AND MIOCENE MOLLUSKS FROM COLORADO DESERT

PLATE 8

[Figures natural size unless otherwise designated]

FIGURES 1, 2. *Ostrea vespertina* Conrad. Weakly plicate right valve from type region. Barrett's oil well [on south side of Carrizo Creek], Imperial County, Calif.; U. S. G. S. locality 3921. Imperial formation, Miocene. Length 42.8 millimeters, height 49.7 millimeters. U. S. Nat. Mus. 496329.

3, 8. *Ostrea vespertina* Conrad. Lectotype, an incomplete right valve. Length (incomplete) 37.7 millimeters, height 48.6 millimeters. "Near San Diego" [evidently Carrizo Creek]. Acad. Nat. Sci., Philadelphia, 13366.

4, 9. *Ostrea vespertina* Conrad. Strongly plicate right valve from type region. Barrett's oil well [on south side of Carrizo Creek], Imperial County, Calif.; U. S. G. S. locality 3921. Imperial formation, Miocene. Length 46.6 millimeters, height 53.3 millimeters. U. S. Nat. Mus. 496330.

5. *Lima (Acesta) hamlini* Dall. Left valve of medium size having smooth central area; lower part of shell missing. Length 58.5 millimeters, height 75 millimeters. Third Street tunnel, Los Angeles; U. S. G. S. locality 3426. U. S. Nat. Mus. 496093.

6. *Limatula* aff. *L. "subauriculata* (Montagu)", × 4. Shell partly missing. Height 7.6 millimeters, length 4.4 millimeters. Universal Consolidated Oil Co. Nutt. No. 2, Montebello field, depth 3,627 to 3,655 feet; U. S. G. S. locality 13871. U. S. Nat. Mus. 496096.

7. *Lima (Acesta) hamlini* Dall. Small left valve having smooth central area; large part of shell missing. Length 46 millimeters, height 56.5 millimeters. Third Street tunnel, Los Angeles; U. S. G. S. locality 3426. U. S. Nat. Mus. 496094.

10. *Lima (Acesta) hamlini* Dall. Large, almost complete, crushed right valve having subdued sculpture in central area. Length 82 millimeters, height 90 millimeters. Third Street tunnel, Los Angeles; U. S. G. S. locality 3426. U. S. Nat. Mus. 496092.

11. *Lima (Acesta) hamlini* Dall. Large crushed right valve having smooth central area; most of shell missing. Length 70.5 millimeters, height 85.5 millimeters. Standard Oil Co. Murphy Coyote No. 117, West Coyote field, depth 5,910 feet; U. S. G. S. locality 13875a. U. S. Nat. Mus. 496095.

PLATE 9

[Figures natural size unless otherwise designated]

FIGURE 1. *Trachycardium* (*Dallocardia*) cf. *T. quadragenarium* (Conrad). Fragment from lower anterior-median part of large right valve. Length 47.5 millimeters. Third Street tunnel, Los Angeles; U. S. G. S. locality 3426. U. S. Nat. Mus. 496101.

2. *Araeosoma* sp., × 2. Part of inner side of oral surface; lantern in place. Distance from center to edge 25.5 to 33.5 millimeters. Standard Oil Co. Murphy Coyote No. 117, West Coyote field, depth 4,400 feet; U. S. G. S. locality 13875. U. S. Nat. Mus. 496107.

3. *Araeosoma* sp., × 2. Part of aboral surface telescoped onto inner side of oral surface, which has lantern in place. Maximum distance from center to edge 41 millimeters. Standard Oil Co. Murphy Coyote No. 117, West Coyote field, depth 4,400 feet; U. S. G. S. locality 13875. U. S. Nat. Mus. 496108.

4. *Periploma cryphia* Woodring, n. sp. Elongate right valve; most of shell missing. Length 26.9 millimeters, height 19.5 millimeters. Union Oil Co. Hellman No. 14, Dominguez field, depth 5,102 feet; U. S. G. S. locality 13897. U. S. Nat. Mus. 496105.

5. *Ostrea vespertina* Conrad. Imperfect, elongate, strongly plicate left valve. Height 66.6 millimeters. Third Street tunnel, Los Angeles; U. S. G. S. locality 3426. U. S. Nat. Mus. 496089.

6. *Periploma cryphia* Woodring, n. sp. Holotype, left valve; part of outer shell missing. Length 35.2 millimeters, height about 29.5 millimeters. Union Oil Co. Hellman No. 17, Dominguez field, depth 3,939 feet; U. S. G. S. locality 13898. U. S. Nat. Mus. 496104.

7. *Periploma cryphia stenopa* Woodring, n. var. Holotype, left valve; part of outer shell missing. Length 45.2 millimeters, height 33.9 millimeters. Union Oil Co. Hellman No. 18, Dominguez field, depth 4,076 feet; U. S. G. S. locality 13899. U. S. Nat. Mus. 496106.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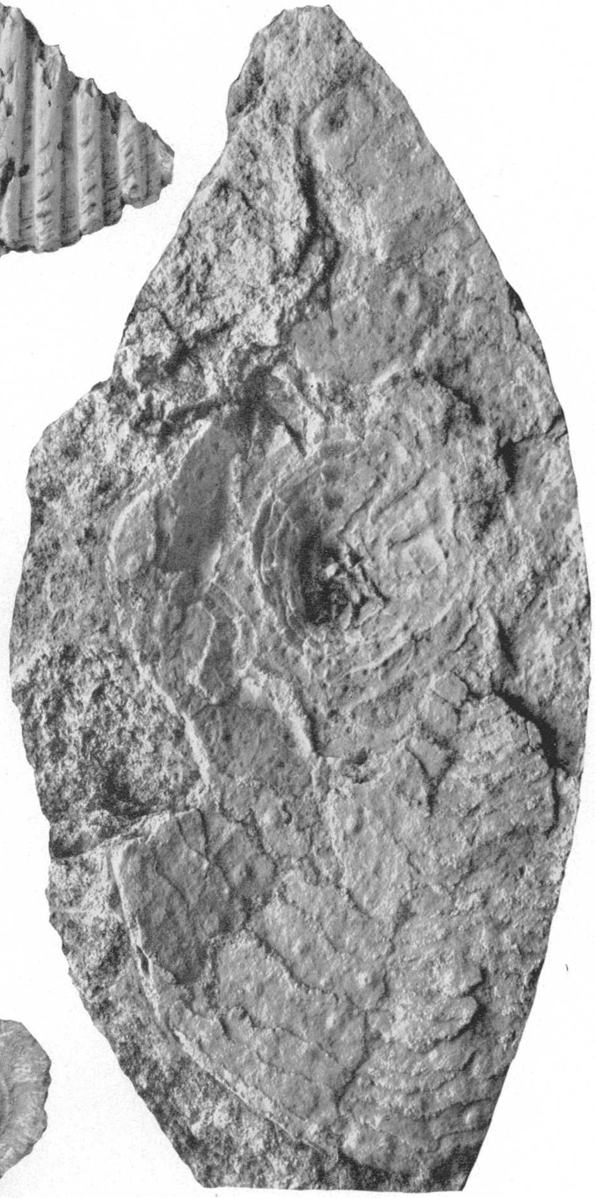
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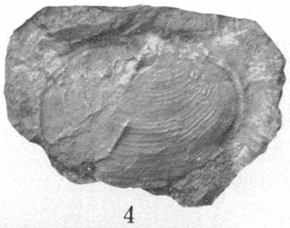
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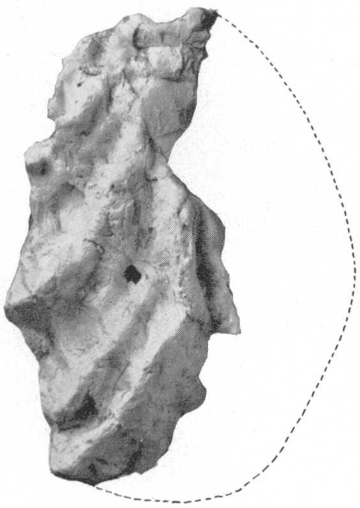
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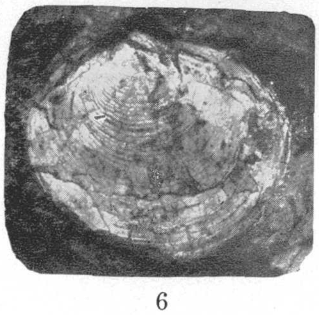
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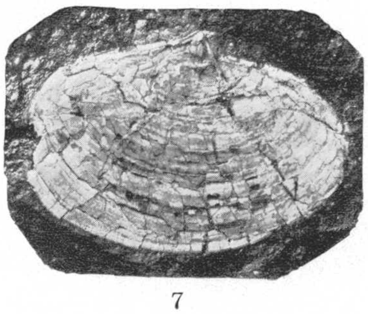
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