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XIV

EXPEDITION TO THE REVILLAGIGEDO ISLANDS,
MEXICO, IN 1925, VII¹

CONTRIBUTION TO THE GEOLOGY AND PALEON-
TOLOGY OF THE TERTIARY OF CEDROS
ISLAND AND ADJACENT PARTS
OF LOWER CALIFORNIA¹

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¹ This paper is No. 7 of the Revillagigedo Islands Expedition of 1925. Previous papers dealing with the scientific results of that expedition are to be found in preceding papers of Vol. XV of these Proceedings, No. 1, pp. 1-113, being the General Report with itinerary.

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INTRODUCTION

The following paper is a report on all available collections of fossils from the Pliocene beds of Cedros Island², off the west coast of Lower California, and of the general region about Turtle Bay³, opposite the island in the central part of the west coast of the peninsula. No extensive list of fossils of any of the Tertiary formations of Lower California has heretofore been published, and the fauna herein described extends our knowledge of the Pliocene of western North America southward.

The greater part of the material upon which this report is based was obtained by the expedition of the California Academy of Sciences to the Revillagigedo and Tres Marias Islands, Mexico, in the early summer of 1925. The party spent three days on Cedros Island, and two days at Turtle Bay. During that time Dr. G. Dallas Hanna and the present senior author made collections as complete as possible from the Pliocene sediments that are exposed at these places.

The writers have also examined a small collection made on Cedros Island and at Turtle Bay by Dr. Hanna in the course of the expedition to Guadalupe Island in 1922.

During a recent geological investigation of Lower California by the Marland Oil Company of California, Mr. B. F. Hake made collections from the Pliocene beds in the general region about Turtle Bay. Most of the material was deposited at Leland Stanford Junior University by Mr. Carl H. Beal, Chief Geologist of the company, and through his courtesy and that of Dr. J. P. Smith, Professor of Paleontology at the Leland Stanford Junior University, it has been available for the present study⁴. Finally, in the collections of the California Academy of Sciences, Leland Stanford Junior University, and the University of California, there are a few specimens collected on Cedros Island by Mr. Henry Hemphill and others. These have been examined in the course of the work.

A few species have already been described or listed on the basis of this material. From the fossils secured by Hanna on

² Cedros Island has been sometimes called "Cerros" Island.

³ Also known as San Bartolome Bay, Bahia San Bartolo, and Bahia Tortuga.

⁴ See *Boletin del Petroleo*, Vol. 17, No. 6, 1924, pp. 417-453; Vol. 18, No. 1, 1924, pp. 14-53, for an account of the observations of the Marland Oil Company's geologists.

Cedros Island in 1922, Israelsky⁵ described three new species of echinoids; Hertlein⁶ has already described or listed the pectens from the collections made by Hake and Hanna in 1922. Except for the information found in these two papers, and for descriptions of a few species from Cedros Island by early writers, the fauna of the Pliocene of this region has remained unknown.

The geologic occurrence of the deposits at Cedros Island and at Turtle Bay is briefly discussed in the present paper and the known fossils are listed. The relations of the fauna to those of Pliocene formations elsewhere are considered. Finally, notes are included on many of the definitely recognized species, and 10 new species are described.

The writers wish to acknowledge their indebtedness to Dr. G. Dallas Hanna, Curator of Paleontology in the California Academy of Sciences, for the collection of much of the material upon which this report is based, for advice and assistance in various ways during the preparation of the manuscript, and for preparation of the illustrations. Acknowledgment is due Mr. T. F. Stipp for assistance in the preparation of the sketch map. They also wish to thank Mr. Carl H. Beal, of the Marland Oil Company of California, for permission to publish upon the collections made by geologists of that company; and Dr. J. P. Smith, of Leland Stanford Junior University, for permission to borrow these collections and for helpful suggestions and criticism during the course of this study; acknowledgment is due Dr. B. L. Clark, of the University of California, for opportunity to examine type specimens in the collections of that institution.

OCCURRENCE AND GEOLOGY

The approximate position of the localities from which the fossils described in this report were obtained is shown on the accompanying sketch map (fig. 1). Limitation of time precluded any careful geological investigation by the senior author at either Cedros Island or at Turtle Bay. It was for the same reason impossible to cover any large area in collect-

⁵ Univ. Cal. Pub. Geol., Vol. 14, No. 11, 1923, pp. 377-396.

⁶ Proc. Calif. Acad. Sci., 4th Ser., Vol. 14, No. 1, 1925, pp. 1-35.

ing, and the large number of specimens obtained may be attributed to the extreme abundance of fossils. Members of the expedition did not visit the localities at Elephant Mesa⁷ nor at the Mesa west of Mesa de las Auras⁸, where Mr. Hake

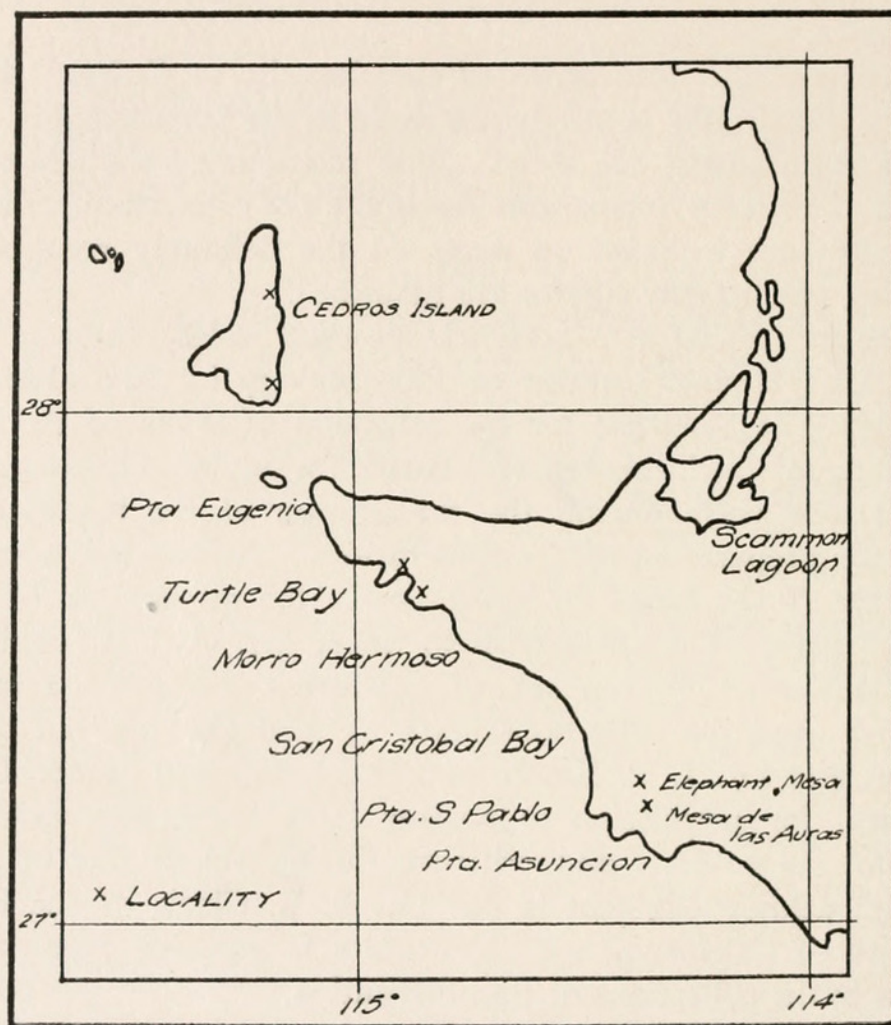


Fig. 1. Map showing collecting stations.
(Tracing from map by Rand McNally.)

made collections for the Marland Oil Company, and no information was secured as to the geology at those places.

At Bernstein's Abalone Camp, on the southeast side of Cedros Island, a tilted block of Tertiary sediments is exposed, apparently a fault block, downthrown relative to the complex

⁷ Localities 48 (L. S. J. U.), 76 (L. S. J. U.), and 77 (L. S. J. U.).

⁸ Locality 43 (L. S. J. U.)

of older sediments, and metamorphic rocks that compose the core of the island.

The Tertiary strata dip in a general northerly direction directly toward the older rocks. On the south side of the block, beneath the Tertiary beds, sandstones, conglomerates and shales⁹ are exposed; these dip northward at a high angle. Hanna has recorded the occurrence of Foraminifera, *Inoceramus* and *Ammonites* in the shale.

Unconformably overlying the older beds are several hundred feet of sediments probably of Miocene age. At the base is a layer containing bones of whales and other marine mammals and sharks' teeth which can be identified with species from the Miocene of California. A thin bed of gray siliceous shale overlies the bed containing the vertebrate fossils. The greater part of the Miocene which overlies the two beds just described, consists of strata of nearly uniform, fine grained, rather soft white sandstone, in all several hundred feet thick, and as far as known, barren of recognizable megascopic fossils.

Several hundred feet of Pliocene sediments overlie the Miocene series, probably unconformably¹⁰. These consist of fairly well consolidated sandstones and gravels in alternating layers of varying thickness. The Pliocene series is extraordinarily fossiliferous throughout, and, the preservation of certain groups of fossils is everywhere excellent. The Pliocene sediments are more resistant to erosion than are the soft Miocene beds. The higher parts of the area of Tertiary rocks are occupied by Pliocene and the Miocene-Pliocene contact is marked by a steep escarpment.

About nine miles north of Bernstein's Camp, on and close to the shore, and almost surrounded by older rocks, a small area of Pliocene beds is exposed, similar to those at Bernstein's camp. They are nearly flat lying and their occurrence at this point may or may not be ascribed to faulting.

The stratigraphy at Turtle Bay is essentially similar to that on Cedros Island. The oldest rocks exposed close to the bay are conglomerates accompanied by less abundant sandstones and shales, and the series may be several thousand feet in

⁹ Proc. Calif. Acad. Sci., 4th Ser., Vol. 15, No. 1, 1926, p. 86.

¹⁰ Locality 928 (C. A. S.).

thickness. These beds stand at high angles and were mapped by the Marland Oil Company geologists¹¹ as Eocene, the equivalent of the Tepe Tate formation of the southern part of the peninsula, but may be in part or all Cretaceous on the basis of similarity of lithology and stratigraphic position to the Cretaceous beds on Cedros Island, as considered by Hanna¹². Miocene and Pliocene sediments occupy old embayments of small size between low ranges of hills composed of Cretaceous or Eocene rocks. The base of the Miocene series is a layer containing bones and sharks' teeth, belonging to the species *Aetobatus smithii* Jordan & Beal, *Carcharocles rectus* Ag., *Carcharhinus antiquus* Ag., *Carcharodon* sp., *Hemipristis heteropleurus* Ag., and *Isurus hastalis* Ag., and pectens which are poorly preserved, but resemble *P. andersoni* Arnold. A bed of white siliceous shale about 30 feet thick, overlies the bone bed. The remainder of the series is soft fine grained white sandstone, ash, and impure diatomite rich in fish scales and in casts of foraminifera. The whole Miocene series is several hundred feet thick, and the beds dip in a general westerly direction at about 20°.

The Pliocene series at Turtle Bay¹³ overlies the Miocene unconformably. The beds are almost horizontal, the prevailing dip being very gently seaward. They consist of soft to moderately indurated sandstones, abundantly fossiliferous throughout. At the time of deposition these beds apparently contained a large and varied molluscan fauna, but leaching, presumably a result, in part at least, of the desert conditions of the region, has removed the shells of all but a few genera leaving of the others only casts seldom specifically determinable. As on Cedros Island the Pliocene sediments are generally more resistant to erosion than is the Miocene material, and the Pliocene stands up in prominent small mesas and hills.

The areal extent of neither the Miocene nor Pliocene beds was determined in the Turtle Bay region. East of the bay, mountains composed of conglomerates and sandstones of either Cretaceous or Eocene age rise rather abruptly above the younger sediments.

¹¹ Boletín del Petróleo, Vol. 18, No. 1, 1924. Map opposite p. 53.

¹² Proc. Calif. Acad. Sci., 4th Ser., Vol. 15, No. 1, 1926, p. 86.

¹³ Localities 944 (C.A.S.), 945 (C.A.S.), 47 (L.S.J.U.), 49 (L.S.J.U.), 80 (L.S.J.U.).

A thin veneer of Pleistocene sands and gravels, containing a marine fauna, overlies the Tertiary beds, some places nearly a hundred feet above the sea.

LIST OF COLLECTING STATIONS

California Academy of Sciences localities:

928 (C.A.S.). Cedros Island, off Lower California. Pliocene beds at Bernstein's Abalone Camp on southeast side of island. G. D. Hanna and E. K. Jordan collectors. This is the same as Locality 753 (C.A.S.)¹⁴.

944 (C.A.S.). Turtle Bay, Lower California. Pliocene beds exposed on shore at north end of Bay, beneath the Pleistocene. G. D. Hanna and E. K. Jordan, collectors. Locality 930 (C.A.S.)¹⁵, is in part the same as this locality.

945 (C.A.S.). Turtle Bay, Lower California. Pliocene beds exposed about a prominent monadnock, from one to two miles to southeast of bay. G. D. Hanna and E. K. Jordan collectors.

946 (C.A.S.). Cedros Island, off Lower California. Pliocene beds exposed near the shore on east side of island about nine miles north of Bernstein's Abalone Camp. G. D. Hanna and E. K. Jordan collectors.

Leland Stanford Junior University localities:

43 (L.S.J.U.). "Mesa west of Mesa de las Auras, Scammon Lagoon Quadrangle, Lower California; 27° 15' N. Lat., 114° 20' W. Long". Pliocene; B. F. Hake, collector.

47 (L.S.J.U.). "Turtle Bay, Lower California". Pliocene; B. F. Hake, collector.

48 (L.S.J.U.) "Mouth of large Arroyo, northwest of Elephant Mesa, Scammon Lagoon Quadrangle, Lower California". Pliocene; B. F. Hake, collector.

49 (L.S.J.U.). "Slopes of Salada, three miles southeast of Turtle Bay, uppermost beds"; B. F. Hake, collector.

76 (L.S.J.U.). "Pliocene beds on white clay northwest of Elephant Mesa and west of Arroyo, Scammon Lagoon Quadrangle, Lower California"; B. F. Hake, collector.

77 (L.S.J.U.). "Pliocene beds on west side of Elephant Mesa, Scammon Lagoon Quadrangle, Lower California"; B. F. Hake, collector.

¹⁴ Israelsky, M. C., Univ. Cal. Pub. Geol., Vol. 14, No. 11, 1923, pp. 378, 379, 381.

¹⁵ Hertlein, L. G., Proc. Calif. Acad. Sci., 4th Ser., Vol. 14, No. 1, 1925, p. 3.

80 (L.S.J.U.). "Pliocene exposed in Cañon southeast of Turtle Bay, Lower California"; B. F. Hake, collector.

116 (L.S.J.U.). "Cedros Island, Lower California; Pliocene;" Henry Hemphill and other collectors.

LIST OF SPECIES

Echinoidea

1. *Astrodapsis israelskyi* E. K. Jordan & Hertlein, new species, Cedros Island, Loc. 928 (C.A.S.).
2. *Astrodapsis kewi* E. K. Jordan & Hertlein, new species, Cedros Island, Loc. 928 (C.A.S.).
3. *Clypeaster deserti* Kew, Cedros Island, Loc. 946 (C.A.S.).
4. *Cælopleurus corona-formis* Israelsky, Cedros Island, Loc. 928 (C.A.S.).
5. *Dendraster cedrosensis* Israelsky, Cedros Island, Loc. 928 (C.A.S.); Turtle Bay, Loc. 945 (C.A.S.); Elephant Mesa, Loc. 76 (L.S.J.U.); Mesa west of Mesa de las Auras, Loc. 43 (L.S.J.U.).
6. *Dendraster diegoensis* Kew, Cedros Island, Loc. 928 (C.A.S.).
7. *Dendraster gibbsii humilis* Kew, Cedros Island, Loc. 928 (C.A.S.).
8. *Dendraster pacificus* Kew, Cedros Island, Loc. 928 (C.A.S.).
9. *Dendraster pentagonalis* Israelsky, Cedros Island, Loc. 928 (C.A.S.); Turtle Bay, Loc. 945 (C.A.S.); Elephant Mesa, Locs. 48 (L.S.J.U.); 76 (L.S.J.U.).
10. *Strongylocentrotus franciscanus* A. Agassiz, Cedros Island, Loc. 928 (C.A.S.).
11. *Strongylocentrotus purpuratus* Stimpson, Cedros Island, Loc. 928 (C.A.S.).

Brachiopoda

12. *Laqueus californicus vancouveriensis* Davidson, Cedros Island, Loc. 928 (C.A.S.).
13. *Terebratalia transversa caurina* Gould, Cedros Island, Loc. 928 (C.A.S.).
14. *Waldheimia kennedyi* Dall, Cedros Island (Dall)¹⁶.

¹⁶ Proc. Calif. Acad. Sci., 1st Ser., Vol. 5, 1874, p. 299. Not recognized in the present collection.

Pelecypoda

15. *Anomia peruviana* Orbigny, Turtle Bay, Loc. 945 (C.A.S.).
16. *Arca* sp.¹⁷, Turtle Bay, Loc. 945 (C.A.S.).
17. *Arca* sp., Turtle Bay, Loc. 945 (C.A.S.).
18. *Arca* sp., Turtle Bay, Loc. 945 (C.A.S.).
19. *Arca* sp., Turtle Bay, Loc. 945 (C.A.S.).
20. *Chama frondosa* Broderip, Cedros Island, Loc. 946 (C.A.S.); Turtle Bay, Loc. 945 (C.A.S.).
21. *Chione* sp., Elephant Mesa, Loc. 77 (L.S.J.U.).
22. *Macoma kelseyi* Dall, Turtle Bay, Loc. 945 (C.A.S.).
23. *Mactra* sp., Turtle Bay, Loc. 945 (C.A.S.).
24. *Metis* cf. *M. alta* Conrad, Cedros Island, Loc. 928 (C.A.S.).
25. *Ostrea lurida* Carpenter, Cedros Island, Loc. 946 (C.A.S.); Turtle Bay, Locs. 944 (C.A.S.), 945 (C.A.S.).
26. *Ostrea megodon* Hanley, Cedros Island, Loc. 928 (C.A.S.); Turtle Bay, Loc. 945 (C.A.S.); Elephant Mesa, Loc. 48 (L.S.J.U.).
27. *Ostrea tayloriana* Gabb, Elephant Mesa, Loc. 48 (L.S.J.U.).
28. *Ostrea vespertina* Conrad, Cedros Island, Locs. 928 (C.A.S.), 946 (C.A.S.); Turtle Bay, Locs. 944 (C.A.S.), 945 (C.A.S.); Elephant Mesa, Locs. 48 (L.S.J.U.), 76 (L.S.J.U.).
29. *Pecten (Pecten) bellus* Conrad, Cedros Island, Loc. 928 (C.A.S.); Turtle Bay, Loc. 49 (L.S.J.U.); Elephant Mesa, Loc. 48 (L.S.J.U.).
30. *Pecten (Pecten)* cf. *P. heimi* Hertlein, Cedros Island, Loc. 928 (C.A.S.).
31. *Pecten (Pecten) lecontei* Arnold, Cedros Island, Loc. 928 (C.A.S.); Turtle Bay, Loc. 945 (C.A.S.); Elephant Mesa, Loc. 48 (L.S.J.U.).
32. *Pecten (Pecten) stearnsi* Dall, Cedros Island, Locs. 928 (C.A.S.), 946 (C.A.S.).
33. *Pecten (Patinopecten)* cf. *P. coosensis* Shumard, Elephant Mesa, Loc. 48 (L.S.J.U.).
34. *Pecten (Patinopecten) dilleri* Dall, Elephant Mesa, Loc. 48 (L.S.J.U.).
35. *Pecten (Patinopecten) healeyi* Arnold, Cedros Island, Loc. 928 (C.A.S.).

¹⁷ The inclusion in the list of generic determinations of casts seems in this case to be desirable, as indicating the presence in the fauna of representatives of other than the few abnormally predominant groups.

36. *Pecten (Chlamys) opuntia* Dall, Turtle Bay, Loc. 944 (C.A.S.).
37. *Pecten (Lyropecten) cerrosensis* Gabb, Cedros Island, Locs. 928 (C.A.S.), 946 (C.A.S.); Turtle Bay, Loc. 945 (C.A.S.).
38. *Pecten (Lyropecten) gallegosi* E. K. Jordan & Hertlein, new species, Cedros Island, Loc. 946 (C.A.S.).
39. *Pecten (Lyropecten) modulatus* Hertlein, Mesa west of Mesa de las Auras, Loc. 43 (L.S.J.U.).
40. *Pecten (Lyropecten) subnodosus* Sowerby, Cedros Island, Locs. 928 (C.A.S.), 946 (C.A.S.); Turtle Bay, Loc. 945 (C.A.S.).
41. *Pecten (Lyropecten) veatchii* Gabb, Cedros Island, Locs. 928 (C.A.S.), 946 (C.A.S.).
42. *Pecten (Aequipecten) percarus* Hertlein, Cedros Island, Loc. 928 (C.A.S.); Turtle Bay, Loc. 944 (C.A.S.); Elephant Mesa, Locs. 48 (L.S.J.U.), 76 (L.S.J.U.).
43. *Pecten (Leptopecten) bellilamellatus* Arnold, Cedros Island, Loc. 928 (C.A.S.); Turtle Bay, Loc. 945 (C.A.S.); Elephant Mesa, Loc. 48 (L.S.J.U.).
44. *Pecten (Leptopecten) latiauritus* Conrad, Cedros Island, Loc. 928 (C.A.S.); Turtle Bay, Loc. 945 (C.A.S.).
45. *Pecten (Leptopecten) praevalidus* E. K. Jordan & Hertlein, new species, Turtle Bay, Loc. 945 (C.A.S.).
46. *Pecten (Plagiectenium) calli* Hertlein, Cedros Island, Loc. 928 (C.A.S.); Turtle Bay, Locs. 944 (C.A.S.), 945 (C.A.S.).
47. *Pecten (Plagiectenium) callidus* Hertlein, Cedros Island, Locs. 928 (C.A.S.), 946 (C.A.S.), 116 (L.S.J.U.); Turtle Bay, Locs. 944 (C.A.S.), 945 (C.A.S.).
48. *Pecten (Plagiectenium) circularis* Sowerby, Cedros Island, Locs. 928 (C.A.S.), 946 (C.A.S.); Turtle Bay, Locs. 945 (C.A.S.), 47 (L.S.J.U.); Elephant Mesa, Loc. 48 (L.S.J.U.).
49. *Pecten (Plagiectenium) cristobalensis* Hertlein, Cedros Island, Loc. 928 (C.A.S.); Turtle Bay; Locs. 944 (C.A.S.), 945 (C.A.S.), 49 (L.S.J.U.); Elephant Mesa, Loc. 48 (L.S.J.U.).
50. *Pecten (Plagiectenium) evermanni* E. K. Jordan & Hertlein, new species, Cedros Island, Loc. 928 (C.A.S.).
51. *Pecten (Plagiectenium) hakei* Hertlein, Cedros Island, Loc. 928 (C.A.S.); Turtle Bay, Locs. 944 (C.A.S.), 945 (C.A.S.), 47 (L.S.J.U.).

- 52. *Pecten (Plagiectenium) invalidus* Hanna, Cedros Island, Loc. 928 (C.A.S.), Turtle Bay, Locs. 944 (C.A.S.), 945 (C.A.S.).
- 53. *Pecten (Plagiectenium) mendenhalli* Arnold, Cedros Island, Locs. 928 (C.A.S.), 946 (C.A.S.); Turtle Bay, Loc. 944 (C.A.S.).
- 54. *Pecten (Plagiectenium)* cf. *P. purpuratus* Lamarck, Cedros Island, Locs. 928 (C.A.S.), 116 (L.S.J.U.).
- 55. *Pecten (Plagiectenium) subdolos* Hertlein, Cedros Island, Locs. 928 (C.A.S.), 946 (C.A.S.).
- 56. *Pecten (Amusium)* sp., Turtle Bay, Loc. 945 (C.A.S.).
- 56a. *Phacoides californica* Conrad, Cedros Island, Loc. 928 (C.A.S.).
- 57. *Placunanomia hannibali* E. K. Jordan & Hertlein, new species, Cedros Island, Loc. 928 (C.A.S.); Turtle Bay, Loc. 945 (C.A.S.).
- 58. *Sanguinolaria* sp. Turtle Bay, Loc. 945 (C.A.S.).
- 59. *Spondylus calcifer* Carpenter, Cedros Island, Loc. 946 (C.A.S.).
- 60. *Spondylus crassisquama* Lamarck, Cedros Island, Loc. 928 (C.A.S.).

Gastropoda

- 61. *Conus* aff. *C. regularis* Sowerby, Elephant Mesa, Loc. 48 (L.S.J.U.).
- 62. *Epitonium cedrosensis* E. K. Jordan & Hertlein, new species, Cedros Island, Loc. 928 (C.A.S.); Turtle Bay, Loc. 945 (C.A.S.).
- 63. *Epitonium contrerasi* E. K. Jordan & Hertlein, new species, Turtle Bay, Loc. 945 (C.A.S.).
- 64. *Epitonium dallasi* E. K. Jordan & Hertlein, new species, Turtle Bay, Loc. 945 (C.A.S.).
- 65. *Epitonium* sp., Turtle Bay, Loc. 945 (C.A.S.).
- 66. *Epitonium* sp., Turtle Bay, Loc. 49 (L.S.J.U.).
- 67. *Forreria belcheri* Hinds, Turtle Bay, Loc. 944 (C.A.S.).
- 68. *Forreria wrighti* E. K. Jordan & Hertlein, new species, Turtle Bay, Loc. 945 (C.A.S.).
- 69. *Forreria* sp. Turtle Bay, Loc. 945 (C.A.S.).
- 70. *Forreria* sp., Turtle Bay, Loc. 80 (L.S.J.U.).
- 71. *Gyrineum* sp., Turtle Bay, Loc. 945 (C.A.S.).
- 72. *Haliotis* cf. *H. rufescens* Swainson, Cedros Island, Loc. 928 (C.A.S.).
- 73. *Natica* sp., Turtle Bay, Loc. 945 (C.A.S.).
- 74. *Turritella* sp., Turtle Bay; Loc. 945 (C.A.S.).

Cirripedia

75. *Balanus* cf. *B. concavus* Bronn, Turtle Bay, Locs. 944 (C.A.S.), 945 (C.A.S.).
76. *Balanus tintinnabulum* cf. *B. t. californicus* Pilsbry, Turtle Bay, Loc. 944 (C.A.S.).
77. *Balanus tintinnabulum coccopoma* Darwin, Turtle Bay, Loc. 945 (C.A.S.).

CORRELATION

The inadequacy of previous collections from these deposits until recently has prevented any definite correlation or determination of their age. Veatch¹⁸ in 1860 gave a brief account of the general geology of Cedros Island and referred to "fossiliferous sandstones of a late Tertiary age". The first account of Tertiary fossils from Cedros Island is in the original descriptions of *Pecten cerrosensis*, *P. veatchii*, *Ostrea cerrosensis* (= *O. megodon*), and *O. veatchii* (= *O. vespertina*), by Gabb¹⁹ in 1869. He considered the deposits to be of Miocene age. Dall²⁰ in 1874, described *Waldheimia kennedyi* from "beds of Miocene age, Cerros Island, Lower California", and in 1898²¹ referred to the beds on Cedros Island as of either Miocene or Pliocene age. Arnold²² in 1906 considered the beds on Cedros Island to be of Pliocene age, and equivalent to the Purisima formation of central California. In 1919, J. P. Smith²³ correlated the Pliocene of Cedros Island with the Carrizo formation of Imperial County, California, and considered both to be equivalent to the Etchegoin formation of the San Joaquin valley. Kew²⁴, in 1920, described *Dendraster pacificus* from the Pliocene of Pacific Beach, California, and of Cedros Island, and apparently considered the deposits at these two localities to be equivalent, and of upper Pliocene age. Darton²⁵ in 1921 in a paper on the Geology of Lower California, described marine post-Miocene deposits exposed in the Arroyo

¹⁸ The Hesperian, Vol. 3, No. 6, 1860, pp. 531-534. See also J. A. Veatch, in J. Ross Brown. Resources of the Pacific Slope, 1869, p. 143.

¹⁹ Pal. Cal., Vol. 2, 1869, pp. 32, 34, 35.

²⁰ Dall, W. H., Proc. Calif. Acad. Sci., 1st Ser., Vol. 5, 1874, p. 299.

²¹ Dall, W. H., Trans. Wagner Inst. Sci., Vol. 3, pt. 4, 1898, p. 705.

²² Arnold, R., Prof. Paper U. S. Geol. Surv., No. 47, 1906, p. 26.

²³ Proc. Calif. Acad. Sci., 4th Ser., Vol. 9, No. 4, 1919, p. 153.

²⁴ Univ. Cal. Pub. Geol., Vol. 12, No. 2, 1920, p. 129.

²⁵ Journ. Geol., Vol. 29, No. 8, 1921, pp. 746-747.

La Salada, some distance to the south of the present region, and listed a few species found there. In 1922 Heim²⁶ published an account of the Tertiary of the southern part of Lower California in which he gave the name Salada to the beds exposed at the Cattle Ranch, La Salada. He gave no faunal list and made no mention of the occurrence of Pliocene on Cedros Island but stated that the Salada formation extended some distance to the north of the type locality. Israelsky²⁷, in 1923 described three species of echinoids from the beds on Cedros Island, and referred them to the Pliocene.

The first statement of the occurrence of Pliocene beds in the Turtle Bay region appeared in 1924²⁸, on a geological map of Lower California compiled from the results of the Marland Oil Company. On this map and in the accompanying report, all the Marine Pliocene of the peninsula was referred to the Salada formation. Hertlein²⁹ in 1925, writing on pectens from Lower California chiefly collected by the geologists of the Marland Oil Company, correlated the beds on Cedros Island with the San Diego formation of Pacific Beach; he applied Heim's name Salada to the deposits at Turtle Bay and at Elephant Mesa, and suggested the equivalence of those beds to those on Cedros Island. The writers concur entirely with Hertlein's conclusions, except that they do not accept extension of the name Salada to regions remote from the type locality of that formation, until the fauna of the type locality is more fully known. Hanna³⁰ in 1925 and in 1926, referred to the Pliocene beds on Cedros Island and at Turtle Bay.

The present study of collections far larger than those before available to Hertlein, while little altering the general correlation of these beds, furnishes a basis for a fuller discussion of the character and relations of the fauna.

In the preceding list of species the records from Cedros Island, Turtle Bay and from Elephant Mesa are combined. The deposits at these points are approximately equivalent in

²⁶ Geol. Mag., Vol. 59, No. 702, 1922, p. 529-548.

²⁷ Univ. Cal. Pub. Geol., Vol. 14, No. 11, 1923, pp. 378-380.

²⁸ Boletín del Petróleo, Vol. 18, No. 1, 1924, opposite p. 52; M. Bustamente in 1921 mapped the sedimentary rocks in the immediate region of Turtle Bay as Tertiary and Quaternary in age. Bol. del Petróleo, Vol. 11, No. 6, 1921, map opposite p. 532.

²⁹ Proc. Calif. Acad. Sci., 4th Ser., Vol. 14, No. 1, 1925, p. 6.

³⁰ Proc. Calif. Acad. Sci., 4th Ser., Vol. 14, No. 12, 1925, pp. 262, 264, 268 also Vol. 15, No. 1, 1926, pp. 85, 86.

age and in fauna. Community of species between the various localities is most striking and the collecting stations are in no case separated by any very great distances. In the following discussion the whole assemblage is treated as a unit.

This fauna is peculiar in that it consists of little more than echinoderms, pectens and oysters; it contains few other pelecypods and few gastropods. Pectens were evidently excessively abundant in Lower Californian waters in Pliocene time, but the extreme predominance of that genus in the present fauna may be to a considerable extent attributed to the destruction of the shells of many other forms by weathering in a desert climate. In attempting a correlation of a fauna such as this its incomplete nature must not be forgotten. It is an assemblage in which species of short range in geologic time, abnormally predominate, and the percentage of living species found is unreliable as an exact criterion for age determination. Correlation rests chiefly on community of diagnostic species with other known Pliocene formations.

The affinity of this fauna is wholly western North American. More than half of the species are common to the Pliocene of southern California; the remainder are slightly more tropical forms, still living in western Mexican waters or known only from the Pliocene of Lower California. No pronounced similarity is shown to the Tertiary of the Caribbean or Peruvian provinces.

About 40 per cent of the species in the present list are known to occur in the San Diego formation, as exposed in Pliocene sands at Pacific Beach, near San Diego, California, which lie upon the harder Eocene sandstones, shales and conglomerate with no evident discordance of dip and are unconformably overlain by nearly horizontal soft Pleistocene sand, boulders and shells.

The beds at Pacific Beach probably approximate in age the lower part of the upper Pliocene, as has been stated by J. P. Smith³¹. Fewer species of the Lower California fauna are found in the Saugus (Saugus of Hershey³², and of Kew³³, Ventura of Carson³⁴, upper Fernando of various authors) and

³¹ Proc. Calif. Acad. Sci., 4th Ser., Vol. 9, No. 4, 1919, pp. 149, 151, 152.

³² Am. Geologist, Vol. 29, No. 6, 1902, pp. 359-362.

³³ Bull. U. S. Geol. Surv., No. 753, 1924, pp. 81-89.

³⁴ Pan-American Geologist, Vol. 43, No. 4, 1925, pp. 269, 270.

Santa Barbara³⁵ formations of southern California, which are of upper Pliocene age but are a little younger than the Pliocene of Pacific Beach. Many species in the present list are found in the Pico formation (Lower Fernando of English³⁶, and of various authors, Fernando of J. P. Smith³⁷, Pico of Kew³⁸), Lower Pliocene, in southern California. The similarity of the present fauna to that of the beds at Pacific Beach is, however, more striking than to that of the Pico. Beyond community of a few wide ranging and non-diagnostic species, the present fauna is not related to that of the Jacalitos or Etchegoin formations of the San Joaquin valley region, nor similar in aspect to that of the Pliocene of Coyote Mountain, in Imperial County, California³⁹.

The writers, therefore, consider the Pliocene beds of Cedros Island and of the Turtle Bay region to be approximately equivalent to the San Diego formation of Pacific Beach, and to represent either approximately the middle of the Pliocene or the lower part of the upper Pliocene.

Considered as to climatic relations, the present fauna presents a mixture of warm and cool water types, with warm water forms in the majority, a condition similar to that today prevailing in the waters about Cedros Island and Turtle Bay. The presence of abundant *Lyropecten*, *Plagioctenium*, *Amusium*, *Pecten* ss., *Placunanomia*, *Arca*, *Spondylus*, fluted *Ostrea*, *Astrodapsis*, and *Clypeaster* indicates that when these beds were deposited the waters were at least as warm as they are at present in the region. On the other hand the effect of gradual cooling in Pliocene time in western North America, described by J. P. Smith⁴⁰, is shown by the occurrence here of many central and southern California upper Pliocene forms, particularly *Patinopectens* and such species as *Laqueus californicus vancouveriensis*. Probably at the time of deposition of these beds the climate in the region did not differ greatly from that of the present.

It is yet impossible to draw any conclusions as to distribution or relationship of Pliocene faunas in Lower California as

³⁵ J. P. Smith, Proc. Calif. Acad. Sci., 4th Ser., Vol. 9, No. 4, 1919, pp. 150-151.

³⁶ Univ. Cal. Pub. Geol., Vol. 8, No. 8, 1914, pp. 203-214.

³⁷ Proc. Calif. Acad. Sci., 4th Ser., Vol. 9, No. 4, 1919, pp. 149, 151, 152.

³⁸ Bull. U. S. Geol. Surv., No. 753, 1924, pp. 70-81.

³⁹ Hanna, Proc. Calif. Acad. Sci., 4th Ser., Vol. 14, No. 18, 1926, pp. 427-503.

⁴⁰ Proc. Calif. Acad. Sci., 4th Ser., Vol. 9, No. 4, 1919, pp. 123-173.

a whole. Hertlein⁴¹ has listed pectens, probably of Pliocene age, from various localities on the peninsula outside of the present region. Deposits of this age are known to occur at Santa Rosalia and at other points near the shores of the Gulf of California; their fauna as far as known is somewhat different from that found in the beds on Cedros Island and Turtle Bay. E. K. Jordan & Hertlein⁴² recently described a small Pliocene fauna from Maria Madre Island, far to the south and that assemblage shows affinities with the present one; it is not older and may be slightly younger in age than the present fauna. The Pliocene of Maria Madre Island is apparently more closely related to the Pliocene of the Gulf of California region.

NOTES AND DESCRIPTIONS OF SPECIES

1. *Astrodapsis israelskyi* E. K. Jordan & Hertlein, new species

Plate XXVII, figures 4 and 6

Test small; subcircular to suboval in outline, not greatly elevated, the upper surface rather flat; margin thick, evenly rounded and entire; apical system central, or slightly posterior, the apex of the test slightly anterior to the center of the madreporic area; madreporic area pentagonal, with four genital pores; petals narrow, slightly elevated, widely open, and extending nearly to the margin; rows of pores at first diverge, then at about half the distance to the margin they converge slightly, after which they continue toward the margin parallel or very slightly divergent; outer row of pores more pronouncedly sinuous than inner; interambulacral areas relatively broad, little depressed, flat, sloping gently from the apex toward the margin; inferior surface concave toward the center; mouth central, large, subpentagonal in outline; ambulacral furrows not distinct, but branching close to their origin at the peristome and extending nearly to the margin; periproct fairly large, situated on ventral surface and a little less than its own diameter from the margin; tuberculation prominent, the tubercles rather large and distantly spaced,

⁴¹ Proc. Calif. Acad. Sci., 4th Ser., Vol. 14, No. 1, 1925, pp. 1-35.

⁴² Proc. Calif. Acad. Sci., 4th Ser., Vol. 15, No. 4, 1926, pp. 209-217.

those on the inferior surface perhaps even more prominent than those above. Anteroposterior diameter 37.5 mm.; transverse diameter 35.3 mm.; greatest elevation 7.9 mm.

Type: No. 2086, *paratypes*, Nos. 2087, 2088, and 2089, Mus. Calif. Acad. Sci., from Loc. 928, **Bernstein's abalone camp, Cedros Island, Lower California**; upper Pliocene; G. D. Hanna and E. K. Jordan collectors.

Four other specimens of this species were examined from the same locality.

Astrodapsis israelskyi somewhat resembles *A. fernandoensis* Pack, but lacks the very large tubercles that are characteristic of Pack's species. It is close to *Dendraster perrini* Weaver, but the apical system of the present species is central in the type, and nearly central in all the other specimens, while in *D. perrini* it is moderately eccentric.

The species is named in honor of Mr. Merle C. Israelsky, in recognition of his work on echinoids.

2. *Astrodapsis kewi* E. K. Jordan & Hertlein, new species

Plate XXVII, figures 2 and 3

Test small, subcircular in outline, considerably elevated, the margin thick, evenly rounded, and entire; apex distinctly anterior to and higher than center of apical system; petals strongly elevated, and extending about two-thirds of the distance to the edge of the test, their extremities wide open; interambulacral areas deeply sunken, depressed in a distinct median trough; apical system nearly central; madreporic area pentagonal, with four genital pores, the one opposite the posterior interambulacral area absent; pores of petals conjugate, the inner rows not converging very rapidly outward, the outer rows converging more rapidly; anterior a little longer and narrower than others; inferior surface evenly concave; mouth subcentral, large, subpentagonal in outline; ambulacral furrows distinct, broad, branching at somewhat less than half the distance outward to the margin, becoming obsolete as the margin is approached, periproct of moderate size, situated on the under surface and distant from the margin about one and a

half times its own diameter; tuberculation prominent, the tubercles elevated, of several orders of magnitude, and the same on both surfaces, except that the ambulacral furrows on the lower surface are smooth. Anteroposterior diameter 31.6 mm.; transverse diameter 31.1 mm.; greatest elevation 8.3 mm.

Type: No. 2090, Mus. Calif. Acad. Sci., from Loc. 928 (C. A. S. Coll.), **Bernstein's abalone camp, Cedros Island, Lower California**; upper Pliocene; G. D. Hanna and E. K. Jordan collectors.

Astrodapsis kewi is distinguished from what is apparently its nearest relative, *A. tumidus* Rémond of the upper San Pablo Miocene of central California by the following characters: the petals in the present species do not extend to the margin of the test as they do in *A. tumidus* and the relief between the crest of the petals and the bottom of the interambulacral areas is greater in *A. kewi*; the summit of *A. kewi* is considerably anterior to the madreporite, rather than almost coinciding as in *A. tumidus*; margins in *A. kewi* are thicker than in *A. tumidus* and are entire, rather than notched by the ends of the ambulacral furrows. *A. kewi* as a whole has a thicker and more tumid test than has *A. tumidus*. *Dendraster arnoldi* Twitchell in some degree resembles this species, but it is distinguished by the excentricity of the apical system. *A. kewi* bears little resemblance to *A. fernandoensis* Pack, from the lower Pliocene of southern California.

This species is named in honor of Dr. W. S. W. Kew, in recognition of his masterly work on the fossil echinoids of western North America.

3. *Laqueus californicus vancouveriensis* Davidson

Plate XXVII, figure 7

Megerlia jeffreysi DALL, Sci. Res. Expl. Alaska, 1877, p. 48; Living, Vancouver, Id., B. C.

Not *Frenula jeffreysi* DALL, Am. Nat., Vol. 5, 1871, p. 55; Living, northeast Atlantic (= *Macandrevia cranium* Müller 1776).

Laqueus californicus var. *vancouveriensis* DAVIDSON, Trans. Linn. Soc. Lond., 2nd Ser., Vol. 4, 1887, p. 113, pl. 18, figs. 10, 11, 12, 13, 13a, 13b; Living, off Lopez Id., Wash.

Laqueus jeffreysi DALL, ARNOLD, Mem. Calif. Acad. Sci., Vol. 3, 1903, p. 93.

Laqueus californicus vancouveriensis DAVIDSON, DALL, Proc. U. S. Nat. Mus., Vol. 57, 1920, p. 348.

Laqueus californicus jeffreysi DALL, OLDROYD, Pub. Puget Sound Biol. Sta. Univ. Wash., Vol. 4, 1924, p. 205.

Laqueus californicus vancouverensis DAVIDSON, OLDROYD, Pub. Puget Sound Biol. Sta. Univ. Wash., Vol. 4, 1924, p. 206.

This wholly west American form has been confused with the *Frenula*, *Ismenia* or *Megerlia jeffreysi* of Dall, originally described from the northeast Atlantic, and now considered by Dall to be the young of *Macandrevia cranium*.

There is no basis for records of both *Laqueus californicus vancouveriensis* and *Laqueus californicus jeffreysi* from the Puget Sound region, and, as Dall has pointed out, the name *jeffreysi* is not tenable for either the Atlantic or Pacific species.

This form was found abundantly in small lenses near Bernstein's abalone camp, on Cedros Island. It is known living from southeastern Alaska to the Washington Coast, and occurs in the Santa Barbara and San Diego Pliocene formations of southern California.

4. *Chama frondosa* Broderip

Plate XXXIV, figure 1

Chama frondosa BRODERIP, Proc. Zool. Soc. Lond., 1834, p. 148; living, Id. Plata, "Western Colombia."

Chama frondosa BRODERIP, Trans. Zool. Soc., Vol. 1, p. 302, pl. 38, figs. 1, 2.

Chama frondosa BRODERIP, REEVE, Conch. Icon. Vol. 4, 1846, Chama, pl. 1, figs. 1a, 1b.

This species occurs on Cedros Island and at Turtle Bay. It is known living from San Diego, Calif., south to Peru.

5. *Ostrea megodon* Hanley

Plate XXVIII, figure 1

Ostrea megodon HANLEY, Proc. Zool. Soc. Lond., 1845, p. 106; living, Peru.

Ostrea gallus VALENCIENNES, Plates of Voy. Venus, Coq., pl. 21, 1846. According to Dall.

Ostrea cerrosensis GABB, Geol. Surv. Cal., Pal., Vol. 2, 1869, p. 35, pl. 11, fig. 61; Pliocene, Cedros Island.

Ostrea megodon HANLEY, SOWERBY, Conch. Icon., Vol. 18, Ostrea, 1871, pl. 12, fig. 24.

Ostrea megodon HANLEY, MAURY, Bull. Amer. Paleo., Vol. 5, No. 29, p. 183, pl. 34, fig. 3.

This species is found very abundantly on Cedros Island, and also near Turtle Bay and Elephant Mesa. The fossils are unquestionably identical with the living species, and examples from the Caribbean Miocene appear in no way different. *O. megodon* has also been reported from the Pleistocene of Lower California, from the Pliocene of Maria Madre Island, Mexico, and occurs in the Saugus, upper Pliocene, near Piru, California.

6. *Ostrea tayloriana* Gabb

Plate XXXIII, figure 3

Ostrea tayloriana GABB, Geol. Surv. Cal., Pal., Vol. 2, 1869, p. 34, pl. 12, figs. 60, 60a; "Miocene", San Marcos Pass, Calif.

Ostrea georgiana CONRAD, DALL, Trans. Wagner Inst. Sci., Vol. 3, pt. 4, 1898, p. 683. In part; not of Conrad.

Ostrea megodon HANLEY, DALL, Nautilus, Vol. 28, No. 1, 1914, p. 1. In part; not of Hanley.

This species, apparently not recognized in California since the discovery of the original specimens, has been recorded under various names in the literature. Our examples agree almost exactly with the figure of the type of *O. tayloriana*. They are in no wise related to *O. georgiana*, which is similar to the well known west American *O. titan* Conrad, nor do they resemble *O. megodon*. *O. tayloriana* does not differ greatly from *O. chilensis* Philippi.

7. *Ostrea vespertina* Conrad

Ostrea vespertina CONRAD, Journ. Acad. Nat. Sci. Phila., 2nd Ser., Vol. 2, 1854, p. 300; "Miocene?", near San Diego, Calif.

Ostrea vespertina CONRAD, House Doc. 129, Proj. Vol. 3, 33rd Congress, 1st Sess. 1855, p. 15, App. to Rep. of W. P. Blake.

Ostrea vespertina CONRAD, Pac. R. R. Rept., Vol. 5, 1857, p. 325, pl. 5, figs. 36, 37, 38.

?*Ostrea amara* CARPENTER, Proc. Zool. Soc. Lond., 1863, p. 363; living, Panama.

Ostrea veatchii GABB, Geol. Surv. Cal., Pal., Vol. 2, 1869, p. 34, pl. 11, fig. 60.

Ostrea haitensis SOWERBY, DALL, Trans. Wagner Inst. Sci., Vol. 3, pt. 4, 1898, p. 685. In part; not of Sowerby.

Ostrea veatchii GABB, ARNOLD, Bull. U. S. Geol. Surv. No. 322, 1907, p. 148, pl. 23, fig. 10.

Ostrea vespertina CONRAD, ARNOLD, Bull. U. S. Geol. Surv. No. 396, 1909, p. 77, pl. 24, figs. 4, 5.

Ostrea veatchii GABB, DALL, Nautilus, Vol. 28, 1914, p. 1.

Ostrea vespertina CONRAD, HANNA, Proc. Calif. Acad. Sci., 4th Ser., Vol. 14, No. 18, 1926, p. 468, pl. 26, figs. 1, 2, 3.

As first pointed out by Arnold there can be little question that the *O. veatchii* of Gabb, originally described from the Pliocene of Cedros Island, and generally common in the Pliocene of southern California, is identical with *O. vespertina* Conrad. It has not generally been recognized that the types of Conrad's species came from San Diego, where the form commonly known as *O. veatchii* is abundant.

O. amara Carpenter is also probably identical with *O. vespertina*, but absolute proof of identity cannot be given. The name was applied by Carpenter to specimens in the C. B. Adams collection of living Panama shells, and referred to other examples from Mazatlan sketchily described by Carpenter⁴³, under the title "*Ostrea* sp." As nearly as can be made out from this description, without figure, *O. amara* was meant to represent a fairly large, plicate oyster, similar in general characteristics to the present species.

O. haitensis, a species of the Caribbean Miocene is quite similar to *O. vespertina*, but not certainly identical.

O. vespertina was found abundantly on Cedros Island, around Turtle Bay, and near Elephant Mesa. It has previously been reported in the Gulf of California, from the Pleistocene of Lower California, from the Saugus, the San Diego and the Pico of southern California, from the upper Pliocene of Maria Madre Island, Mexico, and the Pliocene of Coyote Mtn., Imperial County, California.

⁴³ Maz. Cat., 1857, p. 164.

8. *Pecten (Pecten) bellus* Conrad

Plate XXXII, fig. 2; Plate XXXIII, figs. 1, 2; Plate XXXIV, figs. 2, 3, 4

Janira bella CONRAD, Proc. Acad. Nat. Sci. Phila., 1857, p. 312; "Middle Tertiary", Santa Barbara, Calif.

Janira bella CONRAD, Pac. R. R. Rept., Vol. 6, 1857, p. 71, pl. 3, fig. 16.

Janira bella CONRAD, GABB, Geol. Surv. Calif., Pal., Vol. 2, 1869, p. 105, pl. 16, fig. 20.

Pecten hemphillii DALL, Proc. U. S. Nat. Mus., Vol. 1, 1879, p. 15; San Diego formation (Pliocene); San Diego, Calif.

Pecten (Pecten) bellus CONRAD, DALL, Trans. Wagner Inst. Sci., Vol. 3, pt. 4, 1898, p. 704.

Pecten (Pecten) hemphillii DALL, Trans. Wagner Inst. Sci., Vol. 3, pt. 4, 1898, p. 706.

Pecten (Pecten) bellus CONRAD, ARNOLD, Mem. Calif. Acad. Sci., Vol. 3, 1903, p. 103, pl. 21, figs. 1, 2.

Pecten (Pecten) hemphilli DALL, ARNOLD, Mem. Calif. Acad. Sci., Vol. 3, 1903, p. 105.

Pecten (Pecten) bellus CONRAD, ARNOLD, Prof. Paper U. S. Geol. Surv. 47, 1906, p. 95.

Pecten (Pecten) hemphilli DALL, ARNOLD, Prof. Paper U. S. Geol. Surv. 47, 1906, p. 97, pl. 33, figs. 3, 3a, 3b.

Examination of a large number of specimens of both typical *Pecten bellus* Conrad and *P. hemphillii* Dall, from both Upper and Lower California, has convinced the authors that these two forms are merely extremes of an unbroken series, and belong to but one very variable species. The name *bellus* takes precedence by right of priority.

P. hemphillii has been said to differ from *P. bellus* in that the left valve is flat or concave in the former, rather than somewhat convex as in typical *P. bellus*, and in that the radiating ribs on both valves of Dall's species are more numerous and more highly elevated. In the series examined by us we find great variation in the combinations of these characters; no two adult specimens are exactly alike in appearance, and the extremes are perfectly united by intermediate forms. The number of ribs on the right valve varies from 14 to 18; the ribs vary greatly in width, elevation and prominence, and the convexity of the two valves is in no wise constant. Young examples, up to an altitude of 20 mm., are all very similar in appearance.

Six paratypes of *P. hemphillii*, out of the original lot from Pacific Beach, near San Diego, have been examined in the course of this work. On the basis of the previously enumerated distinctions, certain of these specimens can be referred to Dall's species, while others are unquestionably the *P. bellus* of Conrad. One of the latter is herewith figured, together with illustrations of two of our specimens from Cedros Island. The type of *P. hemphillii*, as indicated by the illustration furnished by Arnold, is an intermediate form not exactly similar to either extreme of the series, although it inclines toward the narrow-ribbed variants. In the original description of *P. hemphillii* no reference was made to *P. bellus*, but a comparison was drawn with *Pecten stearnsii* Dall, a quite different form. There is, furthermore, neither stratigraphic nor geographic difference in the occurrence of the two extremes of the series, and there is no doubt that they are specifically identical.

This species is excessively abundant in the Pliocene beds near Bernstein's abalone camp on Cedros Island, and it also occurs near Turtle Bay and Elephant Mesa. It is known from the Santa Barbara, Saugus and San Diego upper Pliocene formations, and from the Pico lower Pliocene formation of southern California.

9. *Pecten (Patinopecten) dilleri* Dall

Plate XXX, figure 1

Pecten (Lyropecten) dilleri DALL, Nautilus, Vol. 14, No. 10, 1901, p. 117.

Pecten (Patinopecten) dilleri DALL, ARNOLD, Prof. Paper U. S. Geol. Surv. 47, 1906, p. 62, pl. 5, fig. 2.

The left valve of this species has hitherto not been illustrated but the discovery of several in these collections enables us to supply this deficiency. We have compared our specimens with left valves from the lower Pliocene of the Santa Maria district in California, where they are associated with right valves which agree exactly with specimens from the type locality.

The left valve of *P. dilleri* is large, subcircular in outline, and slightly arched. The anterior ear is rather sharply truncated at the anterior margin, and is ornamented by about six to eight radiating ribs which are crossed by concentric lines of

growth and are roughened by raised scaly imbrications. The posterior ear slopes slightly from the posterior dorsal margin to the base; it bears about six radiating ribs and is otherwise sculptured similar to the anterior ear.

The left valve bears about 27 or 28 slightly rounded, high, prominent radiating ribs separated by interspaces that are a little wider than the ribs. The tops of the ribs are ornamented by strong, raised scaly concentric imbrications; the sides of the ribs and the interspaces are marked only by faint traces of rather widely spaced concentric lamellæ.

P. dilleri Dall is distinguished from *P. purisimænsis* Arnold and from *P. coosensis* Shumard by having a larger number of ribs which, in the left valve of Dall's species, are fairly large, slightly rounded, and more distant than in the others. The great prominence of the raised scaly imbrications on the ribs is also characteristic of *P. dilleri*.

This species was found near Elephant Mesa, and has previously been known from the Wildcat lower Pliocene of northern California, and from the lower Pliocene of the Santa Maria District, southern California.

10. *Pecten* (*Lyropecten*) *cerrosensis* Gabb

Plate XXXII, figure 4

Pecten cerrosensis GABB, Geol. Surv. Cal. Pal., Vol. 2, 1869, p. 32, pl. 9, figs. 55, 55a; "Miocene", Cerros Id.

Pecten (*Lyropecten*) *ashleyi* ARNOLD, Prof. Paper U. S. Geol. Surv. 47, 1906, p. 122, pl. 47, figs. 1, 1a, pl. 48, fig. 1; Pliocene, Cerros Id.

Not *Pecten* (*Plagiectenium*) *cerrosensis* GABB, ARNOLD, Prof. Paper U. S. Geol. Surv. 47, 1906, p. 123, pl. 44, fig. 5, pl. 49, figs. 1, 1a, 1b.

Pecten (*Plagiectenium*) *cerrosensis* GABB, HERTLEIN, Proc. Calif. Acad. Sci., 4th Ser., Vol. 14, No. 1, 1925, p. 15, pl. 6, fig. 1.

A comparison of the type specimens of *P. cerrosensis* Gabb and *P. ashleyi* Arnold, both taken from the Pliocene beds on Cedros Island, together with examination of a large number of specimens in the present collection, leads the authors to the conclusion that the two so-called species both clearly belong to

the section *Lyropecten* and are identical. The name *P. cerrosensis* takes precedence by priority. The type of *P. ashleyi* is slightly less globose than the type of *P. cerrosensis*, the latter has much less pronounced radial striations than those that ornament the radial ribs of *P. ashleyi* and it lacks also the pronounced sculpture present on the ears of *P. ashleyi*; but the type of *P. cerrosensis* is an exceptionally large and old specimen, and weathering apparently has obliterated much of the finer ornamentation. The number of ribs on the two specimens is the same. A study of other *Lyropectens* such as *P. estrellanus* Conrad, which the young of *P. cerrosensis* closely resemble, shows that species of the subgenus *Lyropecten* vary greatly in globosity of valves, and in prominence of secondary radial sculpture.

The fact that the type of *P. cerrosensis* has not until recently been available for study, has, as pointed out by Hertlein, led to considerable misunderstanding of the species. The type specimen was not available at the time that Arnold described *P. ashleyi*, and the concept arose that *P. cerrosensis* Gabb belonged to the section *Plagiectenium* rather than to *Lyropecten*. As a result various species have been referred to *P. cerrosensis* in literature and in collections, particularly *P. hakei* Hertlein, *P. subdolus* Hertlein, *P. callidus* Hertlein, *P. circularis* Sowerby (= *P. subventricosus* Dall). Most of the records of *P. cerrosensis* from the Pliocene of southern California are erroneous, but *P. cerrosensis* does occur in southern California in some cases, in the form hitherto known as *P. ashleyi* Arnold.

The original description of *P. cerrosensis* Gabb, together with the description and figure of *P. ashleyi* Arnold fully define the characters of the former. A young specimen of *P. cerrosensis* which resembles *P. estrellanus* Conrad, is herewith figured.

P. cerrosensis has been found on Cedros Island at Locality 928 (C.A.S.), abundantly at Locality 946 (C.A.S.), and a single valve was also discovered at Turtle Bay. It also occurs in the San Diego formation of southern California.

July 22, 1926

11. *Pecten (Lyropecten) gallegosi* E. K. Jordan & Hertlein,
new species

Plate XXIX, figure 1

Shell large, and of the same general outline as *P. cerrosensis* Gabb, but flatter. Right valve ornamented by 21 to 23, narrow, square, flat-topped and often T-rail shaped radiating ribs; interspaces flat-bottomed, with a well defined midrib, their bottoms and walls also finely, radially striate; ribs and interspaces crossed by concentric lines of growth; anterior dorsal and posterior dorsal margins of the valve bearing several sharp, radiating riblets; anterior ear large, with a well defined byssal notch, the ear ornamented by six to eight strong, radiating riblets which are crossed by lines of growth; posterior ear smaller than anterior, and sloping obliquely, posteriorly and downward from posterior termination of hinge line to edge of disk, the ear sculptured by 10 to 12 sharp, strong, radiating riblets crossed by growth lines. Height 125 mm.; length 138 mm.; apical angle 116° . Left valve more highly arched than right, and similarly sculptured; at intervals every fifth rib is slightly raised, as is the case on occasional specimens of *P. cerrosensis* Gabb.

Type: Right valve, No. 2096, *paratypes* No. 2097, 2098, 2099 and 2100, Mus. Calif. Acad. Sci., from Loc. 946 (C.A.S. coll.), on shore nine miles north of Bernstein's abalone camp, Cedros Island, Lower California; upper Pliocene; G. D. Hanna and E. K. Jordan collectors.

Two other specimens from the same locality were examined; all agree substantially with the type.

It is recognized that intergradation may ultimately be proved with *P. cerrosensis* Gabb, which itself is rather variable, but the type and paratypes of *P. gallegosi* present such striking characters as to merit a separate designation. From *P. cerrosensis*, the present form is distinguished mainly by having a much flatter shell, and by a greater intensity of sculpture. The slightly greater number of ribs, which are in nowise rounded, the sharp riblets on the anterior dorsal and posterior dorsal margins of the shell, and the strong sculpture on the ears are distinguishing characters. From *P. hakei* Hertlein,

P. gallegosi differs in having the strong hinge teeth characteristic of a *Lyropecten*, in the presence of a midrib between the major radial ribs, and in other less important particulars.

This shell is named in honor of the late Professor José Maria Gallegos, Explorer for the Departamento de Agricultura y Fomento, Mexico, in recognition of his work so unfortunately terminated, on the preservation of the wild life of Lower California.

12. *Pecten* (*Aequipecten*) *percarus* Hertlein

Pecten (*Aequipecten*) *percarus* HERTLEIN, Proc. Calif. Acad. Sci., 4th Ser., Vol. 14, No. 1, 1925, p. 13, pl. 2, figs. 2, 5; Pliocene, Elephant Mesa, Lower Calif.

The large size, subcircular form, flatness of the right valve, and the number and even roundness of the radiating ribs crossed by concentric growth lines distinguish adults of this species from related forms. Very young examples are not easily differentiated from the young of several species of *Plagi-octenium*. Specimens of this species have been found on Cedros Island, at Turtle Bay, and near Elephant Mesa.

13. *Pecten* (*Leptopecten*) *praevalidus* E. K. Jordan & Hertlein, new species

Plate XXIX, figures 2, 3

Shell of moderate size, somewhat inflated, elongated posteriorly giving an oblique outline, the hinge line four-fifths the length of the shell. Right valve nearly flat, ornamented by about 13 or 14 flat-topped radiating ribs which are often longitudinally sculptured by one or two slight sulci; ribs separated by interspaces about as wide as the ribs, the bottoms of some of the interspaces lightly, longitudinally striate; anterior ear large, cut by a large byssal notch, and ornamented by four or five radiating ribs crossed by concentric lines of growth; left ear larger than right, sloping acutely from hinge line to posterior margin of shell, ornamented by six to nine unequal radiating riblets. Left valve somewhat more arched than right, ornamented by 15 or 16 moderately rounded radiating ribs some

of which show a fairly well defined medial sulcus; interspaces as wide as ribs; both ribs and interspaces finely longitudinally striate, and crossed by concentric lines of growth; ears much as those of right valve, and similarly ornamented, except that the anterior ear of the left, carries six or seven radiating riblets between which are intercalated minute raised lines. Length 50 mm.; height 48 mm.; diameter approximately 15 mm.; length of hinge line approximately 40 mm.; apical angle 103° .

Type: No. 2101, *paratypes* Nos. 2102, 2103, 2104, 2105, and 2106, Mus. Calif. Acad. Sci., from Loc. 945, **Southeast of Turtle Bay, Lower California**; upper Pliocene; G. D. Hanna and E. K. Jordan, collectors.

30 other specimens were examined from the same locality.

The large size, the flattish right valve, the flat-topped ribs of the right valve and the striations of the ribs of both valves characterize this large *Leptopecten*. Some specimens attain a length of about 70 mm., and a height of about 60 mm., or more.

14. *Pecten* (*Plagiectenium*) *calli* Hertlein

Plate XXVII, figure 5

Pecten (*Plagiectenium*) *calli* HERTLEIN, Proc. Calif. Acad. Sci., 4th Ser., Vol. 14, No. 1, 1925, p. 16, in part, pl. 4, fig. 6; Pliocene, Santiago, Lower Calif.; not figs. 5, 7.

Pecten calli is especially abundant in the Pliocene of Turtle Bay, and after examination of a large series of specimens, certain characteristics of the species are better known than previously.

The type specimen of the species is a left valve. The writers are now convinced that the Miocene shell figured by Hertlein⁴⁴ as a paratype of *P. calli*, and from which a description of the right valve was drawn, does not belong to this species. A right valve, undoubtedly of *P. calli*, is figured in this paper.

Right valves of this species vary considerably in convexity; usually they are moderately convex, and markedly so at the umbo. The hinge line is about two-thirds as long as the shell. They bear 18-21 ribs, which are rather high and prominent,

⁴⁴ Proc. Calif. Acad. Sci., 4th Ser., Vol. 14, No. 1, 1925, pl. 4, figs. 5, 7.

squarish in early stages of growth and usually square in the adult forms, but in a few individuals later becoming slightly rounded. The ribs are separated by interspaces that are not quite as wide as the ribs and, in unweathered specimens their sides are ornamented by fine concentric lamellæ. The posterior ear is well developed, and shows a very faint, broad notch. The ear is ornamented by five or six faint radiating riblets crossed by concentric lines of growth. The anterior ear is well developed, and is cut by a well defined byssal notch; the anterior margin of the ear is rounded, and the surface is ornamented by four to six radiating riblets crossed by incremental lines.

In size, our specimens range from 5 mm. up to an altitude of 50 mm., the average is probably between 25 and 35 mm.

Pecten calli is a variable species, but it may be distinguished from its near allies *P. deserti* Con., *P. impostor* Hanna, and *P. invalidus* Hanna, by peculiarities of the left valve, with its high and sharp ribbing, subangular shape at the umbo, and distinctly notched ears slightly turned up at the umbo. The ribbing and high umbo of the right valve are also characteristic.

This species occurs in the Pliocene beds on Cedros Island, as well as at Turtle Bay, in the Pliocene of the Cape region of Lower California and the San Diego Pliocene of Pacific Beach near San Diego, California.

15. *Pecten (Plagiectenium) callidus* Hertlein

Pecten (Plagiectenium) callidus HERTLEIN, Proc. Calif. Acad. Sci., 4th Ser., Vol. 14, 1925, No. 1, p. 22, pl. 5, figs. 1, 3, 5, 6; Pliocene, Cedros Island.

From *P. subdolus* Hertlein, this species is distinguished by having higher, squarer, flat-topped ribs. The shell of *P. callidus* is usually somewhat thicker than that of *P. subdolus*. The right valve in *P. callidus* varies somewhat in convexity, but usually has a tendency to become flattish, with the posterior ventral margin slightly attenuated. A short hinge line, the character of the ribbing, a greater relative height of shell and a usually slight, posterior ventral attenuation distinguish this species from *P. mendenhalli* Arnold. The character of the

ribbing, a generally larger size, a tendency toward flattening of the right valve and slight posterior attenuation distinguish *P. callidus* from *P. invalidus* Hanna.

In the case of immature individuals, the above criteria are not always effective, and the young of these closely related species of *Plagiectenium* can not always be identified with certainty.

P. callidus was found generally distributed in the Pliocene beds on Cedros Island and about Turtle Bay. It is also known to occur in the Pico formation of southern California, from which it has been listed as *P. cerrosensis*. *P. callidus* also occurs in the San Diego Pliocene of Pacific Beach near San Diego, California.

16. *Pecten* (*Plagiectenium*) *circularis* Sowerby

Pecten tumidus SOWERBY, Proc. Zool. Soc. Lond., 1835, p. 109; Living, Santa Elena, Ecuador. Not Turton 1822, nor Zeilen 1830.

Pecten circularis SOWERBY, Proc. Zool. Soc. Lond., 1835, p. 110; Living, Guaymas, Mexico.

Pecten ventricosus SOWERBY, Thes. Conch., Vol. 1, 1843, *Pecten*, p. 51, pl. 12, figs. 18, 19, 26; Living, St. Elena, Ecuador.

Pecten circularis SOWERBY, Thes. Conch., Vol. 1, 1843, *Pecten*, p. 51, pl. 12, fig. 23.

Pecten (*Pecten*) *compactus* DALL, Trans. Wagner Inst. Sci., Vol. 3, pt. 4, 1898, p. 707, pl. 34, fig. 5; "Pliocene", Ventura Co., Calif.

Pecten (*Plagiectenium*) *subventricosus* DALL, Trans. Wagner Inst. Sci., Vol. 3, pt. 4, 1898, p. 707, pl. 29, fig. 8; "Pliocene", Ventura Co., Calif.

Pecten (*Plagiectenium*) *ventricosus* SOWERBY, DALL, Trans. Wagner Inst. Sci., Vol. 3, pt. 4, 1898, p. 710.

Pecten (*Plagiectenium*) *newsomi* ARNOLD, Mem. Calif. Acad. Sci., Vol. 3, 1903, p. 113, pl. 11, figs. 1, 1a; Pleistocene, San Pedro, Calif.

Pecten (*Plagiectenium*) *ventricosus* SOWERBY, ARNOLD, Mem. Calif. Acad. Sci., Vol. 3, 1903, p. 114, pl. 11, figs. 3, 3a, 6, 6a.

Pecten (*Plagiectenium*) *cerrosensis* GABB, ARNOLD, Prof. Paper U. S. Geol. Surv. 47, 1906, p. 123, pl. 44, fig. 5. In part; not *P. cerrosensis* Gabb.

Pecten (*Plagiectenium*) *circularis* SOWERBY, ARNOLD, Prof. Paper U. S. Geol. Surv. 47, 1906, p. 125, pl. 42, figs. 3, 4, 5, 6, pl. 44, figs. 6, 6a, 6b, 7.

Pecten (*Plagiectenium*) *circularis* SOWERBY, E. K. Jordan & Hertlein, Proc. Calif. Acad. Sci., 4th Ser., Vol. 15, No. 4, 1926, p. 214, pl. 23, fig. 9.

The considerable inflation of the valves, and the rounded ribs separated by fairly wide interspaces distinguish this species. It occurs on Cedros Island, at Turtle Bay, and near Elephant Mesa, and has previously been found living from Monterey, Calif., to Payta, Peru, in the Pleistocene of southern and Lower California, the San Diego Pliocene at Pacific Beach, near San Diego, California, and has been reported in the Saugus, upper Pliocene formation in southern California.

17. **Pecten (Plagiectenium) cristobalensis** Hertlein

Pecten (Plagiectenium) cristobalensis HERTLEIN, Proc. Calif. Acad. Sci., 4th Ser., Vol. 14, 1925, p. 19, pl. 3, figs. 1, 2, 5; Pliocene, Turtle Bay.

P. cristobalensis is easily recognized by its numerous, high, rather narrow, square ribs, separated by deep, square interspaces, and by the presence of unusually strong, sharp concentric lamellæ ornamenting the bottoms of the interspaces and the sides of the ribs. This species has been found on Cedros Island, at Turtle Bay, and near Elephant Mesa.

18. **Pecten (Plagiectenium) evermanni** E. K. Jordan & Hertlein, new species

Plate XXVII, figure 1

Shell large, thick, moderately inflated. Right valve ornamented by 30 or 31, flattish topped, equal, radiating ribs, separated by narrow, slightly rounded interspaces, both the ribs and interspaces crossed by concentric lines of growth and the sides of ribs fringed by concentric lamellæ; anterior ear sculptured by about four radiating ribs, a very prominent thickening at base of ear; posterior ear somewhat similar to anterior in ornamentation, but without any large ridge at base. Length about 125 mm.; height 115 mm.; apical angle 108°.

Type: Right valve, No. 2108, *paratype*, No. 2109, Mus. Calif. Acad. Sci., from Loc. 928, **Bernstein's abalone camp, Cedros Island**; upper Pliocene; G. D. Hanna and E. K. Jordan, collectors.

P. evermanni differs from *P. hakei* Hertlein in possessing more numerous ribs which are flatter and much closer together. From *P. purpuratus* Lamarck, *P. evermanni* can be distinguished by the much greater number of ribs in the new species.

This species is named in honor of Dr. Barton Warren Evermann, Director of the California Academy of Sciences, in recognition of his notable scientific and executive accomplishments.

19. *Pecten* (*Plagiectenium*) *hakei* Hertlein

Plate XXXI, figures 1 and 2

Pecten (*Plagiectenium*) *cerrosensis* GABB, ARNOLD, Prof. Paper U. S. Geol. Surv. 47, 1906, p. 123, in part, pl. 49, figs. 1, 1a, 1b; not pl. 44, fig. 5; not *P. cerrosensis* Gabb.

Pecten (*Plagiectenium*) *purpuratus* LAMARCK, HERTLEIN, Proc. Calif. Acad. Sci., 4th Ser., Vol. 14, No. 1, 1925, p. 14, in part, pl. 4, fig. 2. Not Pl. 4, fig. 5; Pl. 1, fig. 1.

Pecten (*Plagiectenium*) *hakei* HERTLEIN, Proc. Calif. Acad. Sci., 4th Ser., Vol. 14, No. 1, 1925, p. 18, pl. 4, figs. 1, 3; Pliocene, Turtle Bay.

A large number of specimens of *P. hakei*, in a much better state of preservation than the original lot, has shown that this species is closely related to *P. purpuratus* Lamarck, yet the two species are clearly distinct.

P. hakei reaches a much larger size than does *P. purpuratus*. The shell of *P. hakei* appears to be uniformly thicker than that of *P. purpuratus* of equal size, and it is neither as distinctly suborbicular nor as flattish on the umbo as are typical examples of Lamarck's species. *P. hakei* shows considerable variation in globosity. The specimen here figured tends to be flattish while the young specimen figured by the junior author (These Proceedings, Vol. 14, No. 1, pl. 4, fig. 2), is a much more globose form. Furthermore, the anterior ear of the right valve of *P. hakei* is apparently larger than it is on *P. purpuratus*; on some young individuals of *P. hakei* the anterior ear of the right valve bears only three radiating ribs, as do many of the young of *P. purpuratus*, but differences in the ribbing on

the disk serve to separate the two species; adults of both often have more than three ribs on the ear.

The ribs ornamenting the right valve of *P. hakei* vary in number from 24 to 27. These are rounded and are separated by interspaces nearly as wide as the ribs, while in *P. purpuratus* the ribs are flat-topped or almost T-rail shaped, and are set close together, with narrow and deep interspaces. On unweathered specimens of *P. hakei* the ribs are seen to be laterally fringed by fine lamellæ, but these are not as pronounced as in *P. purpuratus*.

This species was found on Cedros Island, at Turtle Bay, and is known from other Pliocene localities to the south of the present region in Lower California.

20. *Pecten (Plagiocentrum) invalidus* Hanna

Pecten (Plagiocentrum) cooperi ARNOLD, Prof. Paper 47, U. S. Geol. Surv., 1906, p. 124, pl. 49, figs. 2-4. Pliocene, San Diego, Calif. Not *Pecten cooperi* E. A. Smith, 1903.

Pecten invalidus HANNA, Proc. Calif. Acad. Sci., 4th Ser., Vol. 13, No. 10, 1924, p. 177.

This species is distinguished from *P. callidus* Hertlein and *P. mendenhalli* Arnold by its smaller size, usually moderately arched umbo, and by its square ribs. In some of the specimens referred to *P. invalidus* the ribs show a tendency to become rounded in later stages of growth, while *P. callidus* always possesses square ribs. The right valve of *P. invalidus* is more symmetrical and not slightly attenuated toward the posterior ventral margin as is usually shown in typical examples of *P. callidus*. Young of *P. invalidus* show few positive characters to differentiate them from several other forms; the adults, however, can be recognized.

P. invalidus was found on Cedros Island, and at Turtle Bay. It had previously been known from the San Diego upper Pliocene of southern California, the Pliocene of Maria Madre Island, Mexico, and from the Pliocene of the Cape and Gulf of California regions of Lower California.

21. *Pecten* (*Plagiectenium*) *mendenhalli* Arnold

Pecten (*Plagiectenium*) *cerrosensis* GABB var.? *mendenhalli* ARNOLD, Prof. Paper, U. S. Geol. Surv., No. 47, 1906, p. 84, pl. 25, figs. 2, 2a, 2b; Pliocene, Santa Rosalia, Lower Calif.

Pecten (*Plagiectenium*) *cerrosensis mendenhalli* ARNOLD, HERTLEIN, Proc. Calif. Acad. Sci., Vol. 14, No. 1, 1925, p. 16, pl. 1, fig. 5.

Pecten mendenhalli ARNOLD, HANNA, Proc. Calif. Acad. Sci., 4th Ser., Vol. 14, No. 18, 1926, p. 473, pl. 25, figs. 4, 5.

A few specimens in the collection appear to belong to this species. They agree with Arnold's figure of the type of *P. mendenhalli* in possessing an unusually long hinge line, valves which are little inflated and are unusually long in proportion to their height and right valves which are evenly rounded at the umbo, and broadly rounded on the ventral margin. They can be distinguished from *P. invalidus* and *P. callidus* by these characters. None of our specimens has quite as broadly rounded ribs as is shown by Arnold's figure of the type of *P. mendenhalli*.

Examination of many specimens of true *P. cerrosensis* Gabb proves that *P. mendenhalli* is not related to that species, but it is far closer to *P. invalidus*, *P. callidus*, *P. subdulus*, and *P. circularis*.

This species was found at Cedros Island and at Turtle Bay. It has previously been known from the Imperial Pliocene formation of Imperial County, California, from Santa Rosalia, Lower California, and from the San Diego Pliocene of Pacific Beach near San Diego, California.

22. *Pecten* (*Plagiectenium*) cf. *purpuratus* Lamarck

Pecten purpuratus LAMARCK, Hist. des Animaux sans Vertèbres (edition by Deshayes and Edwards), Vol. 7, 1836, p. 134; Recent, "Mers orientales et australes".

Pecten purpuratus LAMARCK, Dall, Proc. U. S. Nat. Mus. Vol. 37, 1910, p. 149, pl. 26, figs. 5, 6.

Pecten (*Plagiectenium*) *purpuratus* LAMARCK, HERTLEIN, Proc. Calif. Acad. Sci. 4th Ser., Vol. 14, No. 1, 1925, p. 14, in part, pl. 1, fig. 1, pl. 4, fig. 4; not fig. 2.

In the collection from Cedros Island there are a few specimens which are very similar to *P. purpuratus* Lamarck, al-

though none is exactly typical of that species. The writers are convinced that the right valve figured by Hertlein as *P. purpuratus* from Turtle Bay is *P. hakei* Hertlein (Vol. 14, No. 1, Pl. 4, fig. 2).

A suborbicular disk, moderately small anterior ear on the right valve, ornamented with three or four radiating ribs, and numerous closely spaced flat-topped or T-rail shaped ribs which are laterally fringed with lamellæ, are characteristic features of *P. purpuratus*.

P. purpuratus is now living from Coquimbo, Chile, northward to Ecuador, and is also known from the Pliocene and Pleistocene of Coquimbo.

23. *Pecten* (*Plagiectenium*) *subdolus* Hertlein

Pecten (*Plagiectenium*) *subdolus* HERTLEIN, Proc. Calif. Acad. Sci., 4th Ser., Vol. 14, No. 1, p. 20, pl. 5, figs. 2, 4, 7; Pliocene, Pacific Beach near San Diego, Calif.

Pecten subdolus is distinguished by having usually a rather thin shell, with somewhat low rounded ribs, and rounded interspaces; both the ribs and interspaces in perfect specimens are usually ornamented by fine radial striæ. These characteristics easily distinguish the species from *P. callidus* Hertlein.

The specimen figured for *P. cerrosensis* by Arnold⁴⁵, but later referred to *P. subdolus* by Hertlein, can not be identified with this species and is not *P. cerrosensis* Gabb; it is apparently a variant of *P. hakei* Hertlein.

P. subdolus was found on Cedros Island, and near Turtle Bay. It is abundant in the San Diego upper Pliocene of Pacific Beach, Calif.

24. *Placunanomia hannibali* E. K. Jordan & Hertlein, new species

Plate XXVIII, figures 2, 3, and 4

Shell large, thin, subcircular to suboval in outline, usually very flat, compressed and more or less regular in growth; most specimens with no evidence of radial plication but a few

⁴⁵ Prof. Paper U. S. Geol. Surv., No. 47, 1906, pl. 49, figs. 1, 1a, 1b.

more or less profoundly, radially plicate; surface sculptured by concentric growth lines, and by very fine, wavy, minutely prickly, radial striations. Right valve slightly arched; byssal foramen closed or nearly so, but leaving an elongate oblique semi-triangular pit near the beak, which almost communicates with the interior; auricular crura very strong, diverging from the beak at an acute angle varying somewhat in different specimens. Left valve flat or concave, never convex as is the right; without byssal foramen, but usually broken slightly at the beak; interiorly with two strong ribs radiating from the umbo, but fitting outside of the auricular crura, and hence diverging at a somewhat greater angle. Length 114 mm.; width 95 mm.; thickness 15 mm.

Type: No. 2110, *paratypes*, Nos. 2111, 2112, 2113, 2114, and 2115, Mus. Calif. Acad. Sci., from Loc. 945 (C.A.S. coll.), **southeast of Turtle Bay, Lower California**; upper Pliocene.

Fourteen other specimens of this species were examined from the same locality, and one was found at Loc. 928 (C.A.S. Coll.), Bernstein's abalone camp, Cedros Island, Lower California; upper Pliocene.

Placunanomia hannibali is related to *P. californica* Arnold, from the Etchegoin lower Pliocene of central California, but is distinguished by having a generally flatter and more regular shell with very fine rather than heavy radial sculpture. *P. cumingii* Broderip, from the recent fauna of western Mexico and the upper Pliocene of Maria Madre Island is very strongly radially plicate, and lacks all radial sculpture. *P. hannibali* is most nearly related to *P. lithobleta* Dall, of the Miocene of the Caribbean region, but seems to attain a larger size than that species, and to be fitted with larger and heavier auricular crura.

This species is named in honor of Mr. Harold Hannibal, in recognition of his work on the paleontology and stratigraphy of western North America.

25. *Spondylus crassisquama* Lamarck

Spondylus crassi-squama LAMARCK, Hist. des Animaux sans Vertèbres, Vol. 6, 1819, p. 191; Living, "les mers de l'Inde",—"fossile a Carthagène d'Amerique".

Spondylus princeps BRODERIP, Proc. Zool. Soc. Lond., 1833, p. 4; Living, "Insulam Platom Columbiae Occidentalis".

Spondylus dubius BRODERIP, Proc. Zool. Soc. Lond., 1833, p. 4; Living, Gulf of Tehuantepec.

Spondylus leucacantha BRODERIP, Proc. Zool. Soc. Lond., 1833, p. 5; Living "ad Insulam Platom".

Spondylus limbatus SOWERBY, Proc. Zool. Soc. Lond., 1847, p. 87; Recent, "Persian Gulf".

Spondylus pictorum SOWERBY (as of CHEMNITZ), Thes. Conch., Vol. 1, 1847, p. 422, pl. 85, fig. 17, pl. 86, fig. 28; Living, Island of Plata, Colombia.

Spondylus leucacantha BRODERIP, SOWERBY, Thes. Conch., Vol. 1, 1847, p. 423, pl. 87, figs. 35, 36.

Spondylus limbatus SOWERBY, Thes. Conch., Vol. 1, 1847, p. 427, pl. 88, fig. 51.

Spondylus leucacantha BRODERIP, REEVE, Conch. Icon., Vol. 9, 1856, *Spondylus*, pl. 2, fig. 6.

Spondylus princeps BRODERIP, REEVE, Conch. Icon., Vol. 9, 1856, *Spondylus*, pl. 2, fig. 9.

Spondylus pictorum CHEMNITZ, REEVE, Conch. Icon., Vol. 9, 1856, *Spondylus*, pl. 6, fig. 24.

Spondylus limbatus SOWERBY, REEVE, Conch. Icon., Vol. 9, 1856, pl. 6, fig. 34.

Spondylus crassisquama LAMARCK, DALL, Proc. U. S. Nat. Mus., Vol. 37, 1909, p. 256.

This species, of which many fragments but no complete specimens were found on Cedros Island, is the large, spiny, brilliantly colored *Spondylus* well known from the recent fauna of western Mexico. There can be no question that all of the so-called species enumerated above are specifically identical, although the range of variation shown is considerable.

S. calcifer Carpenter reaches a much larger size than this species, has a relatively heavier, longer and narrower shell at all stages of growth, and never bears as long and prominent spines as *S. crassisquama*.

26. ***Epitonium cedrosensis*** E. K. Jordan & Hertlein,
new species

Plate XXX, figure 3

Shell small, broadly conic, solid; spire turritid, of five, strongly convex, post nuclear whorls, the tip lost; sutures deeply marked; varices 13 to 15, somewhat unequal, generally strong, the terminal varix and occasional scattered varices on earlier whorls much stronger and thicker than others; all varices reflected, rounded on top, and thin edged, continuous across the suture and encircling about half of the spire, each bearing a small, broad but sharp spine at the shoulder; intercostal spaces averaging one and one-third times as wide as the varices, ornamented by about 30 subequal, rounded spiral threads that are separated by rounded grooves about as wide as the threads; no basal disk, the base of the last whorl evenly rounded, sculptured as are the whorls of the spire, the varices continuous to the umbilical area; umbilicus narrowly perforate; aperture ovate. Length 8.2 mm.; width 4.34 mm.

Type: No. 2116, *paratypes* Nos. 2117, 2118, 2119, and 2120, Mus. Calif. Acad. Sci., from Loc. 928 (C.A.S. coll.), **Bernstein's abalone camp, Cedros Island, Lower California**, upper Pliocene; G. D. Hanna and E. K. Jordan collectors.

Seventeen other specimens of this species were examined from the type locality and one from locality 945.

This species belongs to the group of *E. bellastriata* Carpenter, to which has been given the subgeneric designation of *Asperiscala* De Boury⁴⁶. From the several previously known species of the group, it is apparently well distinguished by the number and character of the varices.

27. ***Epitonium contrerasi*** E. K. Jordan & Hertlein,
new species

Plate XXX, figure 4

Shell rather elongate conic, of moderate size, not very thick; spire of five moderately convex and slightly shouldered whorls, the tip lost; varices about ten, nearly equal, subequally spaced,

⁴⁶ See Dall, Proc. U. S. Nat. Mus., Vol. 53, 1917, p. 475.

thin, sharp, hardly recurved, rarely directly continuous across the suture, each varix with a small, sharp spine at the shoulder; intercostal spaces perfectly smooth, about five times as wide as the varices; no basal disk, the varices continuous to the umbilical area; umbilicus imperforate. Length 21.3 mm.; width 8.6 mm.

Type: No. 2121, Mus. Calif. Acad. Sci., from Loc. 945 (C.A.S. Coll.), **one mile southeast of Turtle Bay, Lower California**; upper Pliocene; G. D. Hanna, and E. K. Jordan, collectors.

While we are unable to state that this is, without question, distinct from any of the previously described, but so far unfigured species of the genus, from western America, we have, at the same time been unable to identify it with any described species.

This species is named in honor of Prof. Francisco Contreras Assistant Director of the Museo Nacional de Mexico, conchologist and member of the expedition to Lower California, 1925.

28. ***Epitonium dallasi*** E. K. Jordan & Hertlein, new species

Plate XXX, figure 2

Shell small, conic, quite thick and solid; spire of four strongly convex post nuclear whorls, the tip lost; sutures sharp; varices 18 or 19, of which all except the terminal and next to terminal are moderately strong, round topped, not reflected nor much overhanging, having more the appearance of axial ribs than of true varices; terminal and next to terminal varices very wide, thick, and heavy, together occupying about one-third of the perimeter of the body whorl, fused posteriorly at the suture and anteriorly on the base, elsewhere separated by an intercostal space of a little greater than normal width; other varices partly fused at the suture but not directly continuous across it, nor in any wise produced or spiny at the shoulder; intercostal spaces about twice as wide as a normal varix, ornamented by about 20 subequal and subequally spaced impressed spiral grooves, which extend part way up on the sides of the varices but end abruptly and do not pass over the

tops; no true basal disk, the umbilical area, however, covered by a thick irregular patch of callus that is fused with the anterior ends of the last few varices; remainder of base evenly rounded, sculptured as the whorls of the spire, the varices and spiral grooves extending to the edge of the patch of callus; aperture sub-circular. Length 5-9 mm.; width 4.0 mm.

Type: No. 2122, Mus. Calif. Acad. Sci., from Loc. 945 (C.A.S. Coll.), **one mile southeast of Turtle Bay, Lower California**; upper Pliocene; G. D. Hanna and E. K. Jordan, collectors.

This species is named in honor of Dr. G. Dallas Hanna, curator of Paleontology in the California Academy of Sciences.

29. ***Forreria wrighti*** E. K. Jordan & Hertlein, new species

Plate XXXII, figures 1 and 3

Shell of moderate size, fairly thick and solid; spire moderately elevated, about five whorls, the tip lost, the whorls enlarging rapidly, and strongly shouldered near the summit; axial sculpture of ten to thirteen sharp varices, produced into short, sharp slightly reflexed spines at the shoulder; spiral sculpture of few to many strong and distantly spaced, or fine and closely spaced ridges, which are most intense on the earlier whorls and become less marked later; all the sculpture varying greatly in different individuals; aperture ovate; outer lip anteriorly bearing a tooth of greater or less prominence; canal moderately long, broadly open. Altitude of type with tip of spire lost 45.1 mm.; width 32.2 mm.

Type: No. 2123, *paratypes*, Nos. 2124, 2125, 2126, 2127, 2128, 2129, and 2130, Mus. Calif. Acad. Sci., from Loc. 945, **southeast of Turtle Bay, Lower California**; Pliocene; G. D. Hanna and E. K. Jordan, collectors.

Sixty other specimens have been examined from the same locality.

This species is extremely variable in form and sculpture and resembles various forms from the Miocene and Pliocene of western North America, but none of our examples agrees exactly with any other described species. From *F. coalingensis*

Arnold it is distinguished by the presence of more spiral ridges on the whorls. From *F. perelegans* Nomland, *F. wrighti* is distinguished by possessing somewhat stronger sculpture and a less recurved canal and a less prominent siphonal fasciole. From *F. carisaënsis* Anderson, it is distinguished by a more elongate outline of the shell. The prominent spiral sculpture on the early whorls distinguish *F. wrighti* from the young of *F. belcheri* Hinds, *F. magister* Nomland, and *F. ponderosum* Gabb.

This species is named for Mr. John T. Wright, collector of birds and mammals on the expedition of 1925, who frequently and generously assisted in the collection of fossils.

30. *Haliotis* cf. *rufescens* Swainson

A specimen of an abalone shell was found in the Pliocene of Cedros Island, in place and associated with Pliocene fossils. Unfortunately the friable condition of the matrix and brittleness of the shell makes complete cleaning of the specimen impossible.

The shell is a little thinner than that of typical *H. rufescens* from the recent west American fauna, and the spiral sculpture is more regular. It is not *H. fulgens* Philippi, for in that species the holes are small, more numerous, and their margins are little elevated, while on our specimen the holes are few, large, with elevated margins, and very similar to those of *H. rufescens*. The known recent range of *H. rufescens* is from Bodega Bay, California, southward to La Paz, Lower California.

PLATE 27

- Fig. 1. *Pecten (Plagiectenium) evermanni* E. K. Jordan & Hertlein, new species; natural size; type, right valve, No. 2108 (C. A. S. Type Coll.), from Loc. 928 (C. A. S.), Pliocene beds at Bernstein's abalone camp on east side of Cedros Island. Pliocene; p. 439.
- Fig. 2. *Astrodapsis kewi* E. K. Jordan & Hertlein, new species; natural size; type, upper surface of test, No. 2090 (C. A. S. Type Coll.), Loc. same as Fig. 1; p. 425.
- Fig. 3. *Astrodapsis kewi* E. K. Jordan & Hertlein, new species; natural size; type, lower surface of test. Same specimen as Fig. 2; p. 425.
- Fig. 4. *Astrodapsis israelskyi* E. K. Jordan & Hertlein, new species; natural size; type, lower surface of test, No. 2086 (C. A. S. Type Coll.), Loc. same as Fig. 2; p. 424.
- Fig. 5. *Pecten (Plagiectenium) calli* Hertlein; natural size; plesiotype, right valve, No. 2107 (C. A. S. Type Coll.), from Loc. 945 (C. A. S.), Pliocene beds exposed about a prominent monadnock, from one to two miles to southeast of Turtle Bay. Upper Pliocene; p. 436.
- Fig. 6. *Astrodapsis israelskyi* E. K. Jordan & Hertlein, new species; natural size; type, upper surface of test. Same specimen as Fig. 4; p. 424.
- Fig. 7. *Laqueus californicus vancouveriensis* Davidson; natural size; plesiotype, No. 2091 (C. A. S. Type Coll.), Loc. same as Fig. 1; p. 426.

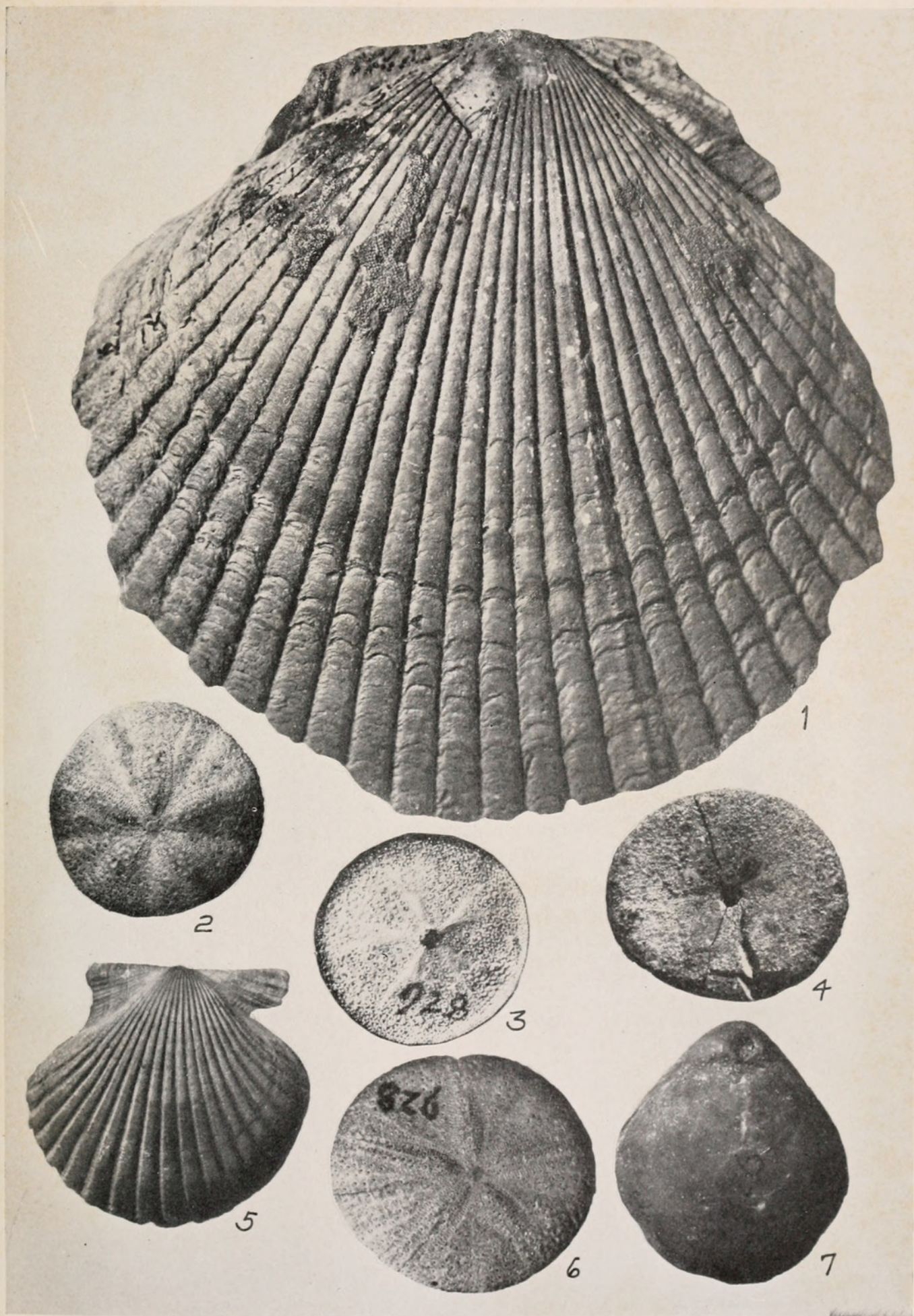


Plate 28

- Fig. 1. *Ostrea megodon* Hanley; natural size; plesiotype, No. 2093 (C.A.S. Type Coll.), from Loc. 928 (C.A.S.), Pliocene beds at Bernstein's abalone camp on southeast side of Cedros Island. Pliocene; p. 427.
- Fig. 2. *Placunanomia hannibali* E. K. Jordan & Hertlein, new species; natural size; type, right valve, No. 2110 (C.A.S. Type Coll.), from Loc. 945 (C.A.S.), Pliocene beds exposed about a prominent monadnock, from one to two miles southeast of Turtle Bay. Upper Pliocene; p. 443.
- Fig. 3. *Placunanomia hannibali* E. K. Jordan & Hertlein, new species; natural size; paratype, right valve showing interior of valve, No. 2112 (C.A.S. Type Coll.), Loc. same as Fig. 2; p. 443.
- Fig. 4. *Placunanomia hannibali* E. K. Jordan & Hertlein, new species; natural size; paratype, right valve, No. 2111 (C.A.S. Type Coll.), Loc. same as Fig. 2. Figure shows tendency of some forms to become plicate; p. 443.

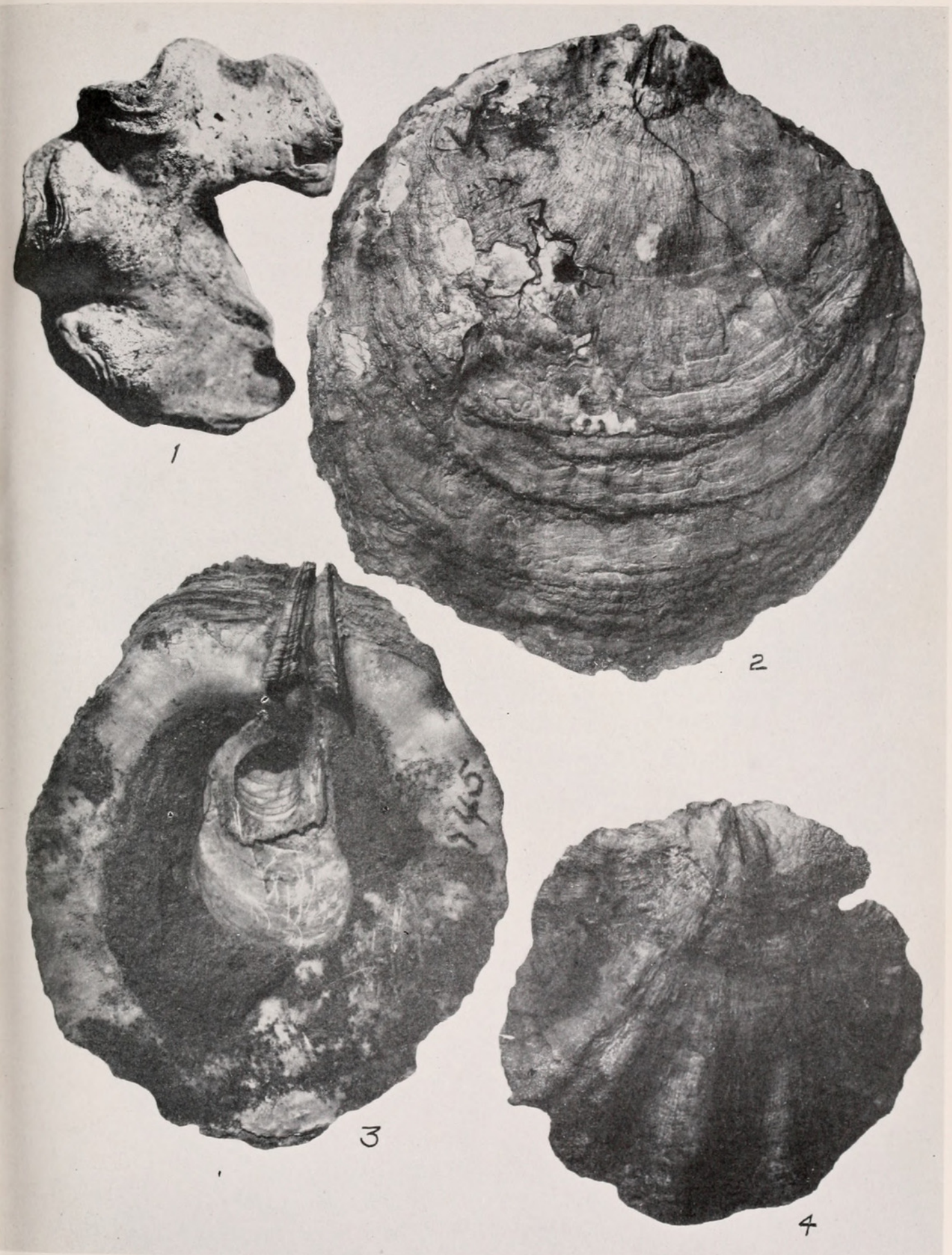


Plate 29

- Fig. 1. *Pecten (Lyropecten) gallegosi* E. K. Jordan & Hertlein, new species; natural size; type, right valve, No. 2096 (C.A.S. Type Coll.), from Loc. 946 (C.A.S.), Pliocene beds exposed near the shore on east side of Cedros Island about nine miles north of Bernstein's abalone camp. Upper Pliocene; p. 434.
- Fig. 2. *Pecten (Leptopecten) prævalidus* E. K. Jordan & Hertlein, new species; natural size; paratype, left valve, No. 2102 (C.A.S. Type Coll.), from Loc. 945 (C.A.S.), Pliocene beds exposed about a prominent monadnock, from one to two miles southeast of Turtle Bay. Upper Pliocene; p. 435.
- Fig. 3. *Pecten (Leptopecten) prævalidus* E. K. Jordan & Hertlein, new species; natural size; type, right valve, No. 2101 (C.A.S. Type Coll.), Loc. same as Fig. 2; p. 435.

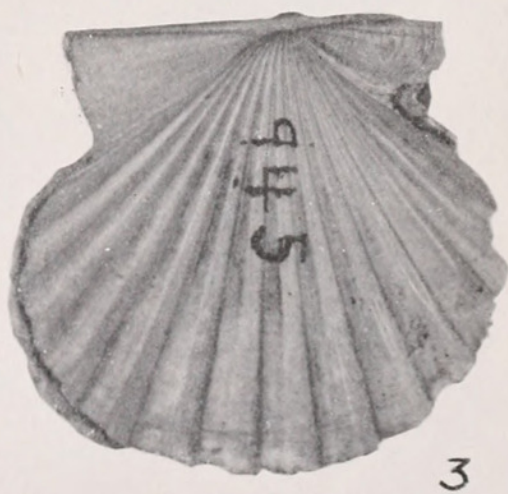
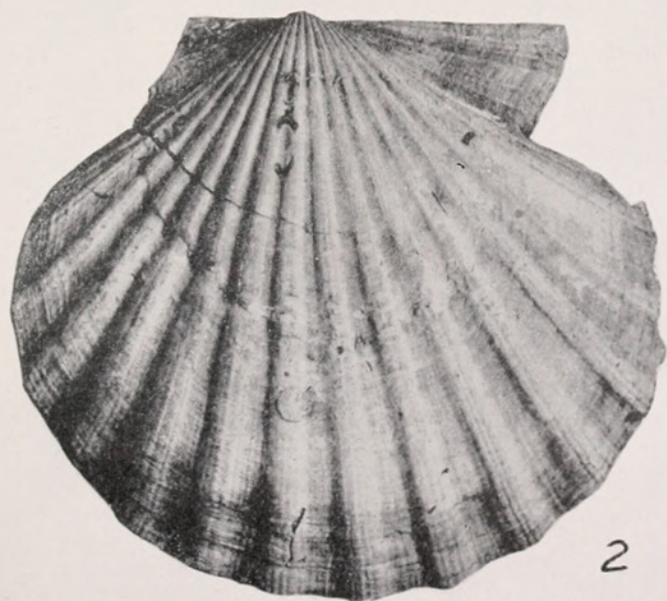
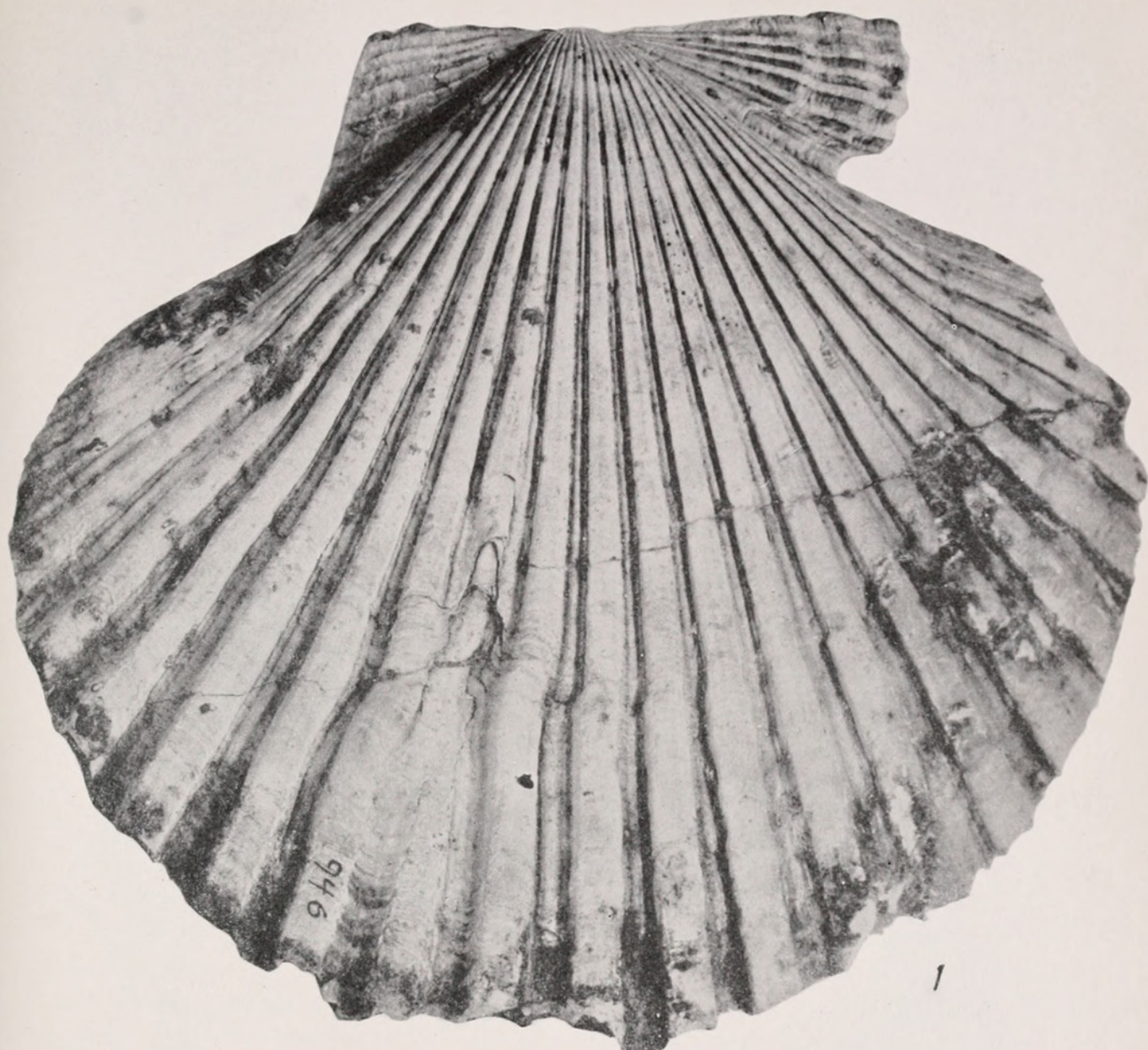


Plate 30

- Fig. 1. *Pecten (Patinopecten) dilleri* Dall; natural size; plesiotype, left valve, No. 2095 (C.A.S. Type Coll.), from Loc. 48 (L.S.J.U.), mouth of big arroyo northwest of Elephant Mesa, Scammon Lagoon Quadrangle, Lower California. Pliocene; p. 431.
- Fig. 2. *Epitonium dallasi* E. K. Jordan & Hertlein, new species; true length of figured specimen approximately 8 mm.; width 4 mm.; type No. 2122 (C.A.S. Type Coll.), from Loc. 945 (C.A.S.), one mile southeast of Turtle Bay. Pliocene; p. 447.
- Fig. 3. *Epitonium cedrosensis* E. K. Jordan & Hertlein, new species; true length of figured specimen 8.2 mm.; width 4.34 mm.; type, No. 2116 (C.A.S. Type Coll.), from Loc. 928 (C.A.S.), Pliocene beds at Bernstein's abalone camp on southeast side of Cedros Island. Pliocene; p. 446.
- Fig. 4. *Epitonium contrerasi* E. K. Jordan & Hertlein, new species; true length of figured specimen 21.3 mm.; width 8.6 mm.; type, No. 2121 (C.A.S. Type Coll.), from Loc. 945 (C.A.S.), one mile southeast of Turtle Bay. Pliocene; p. 446.

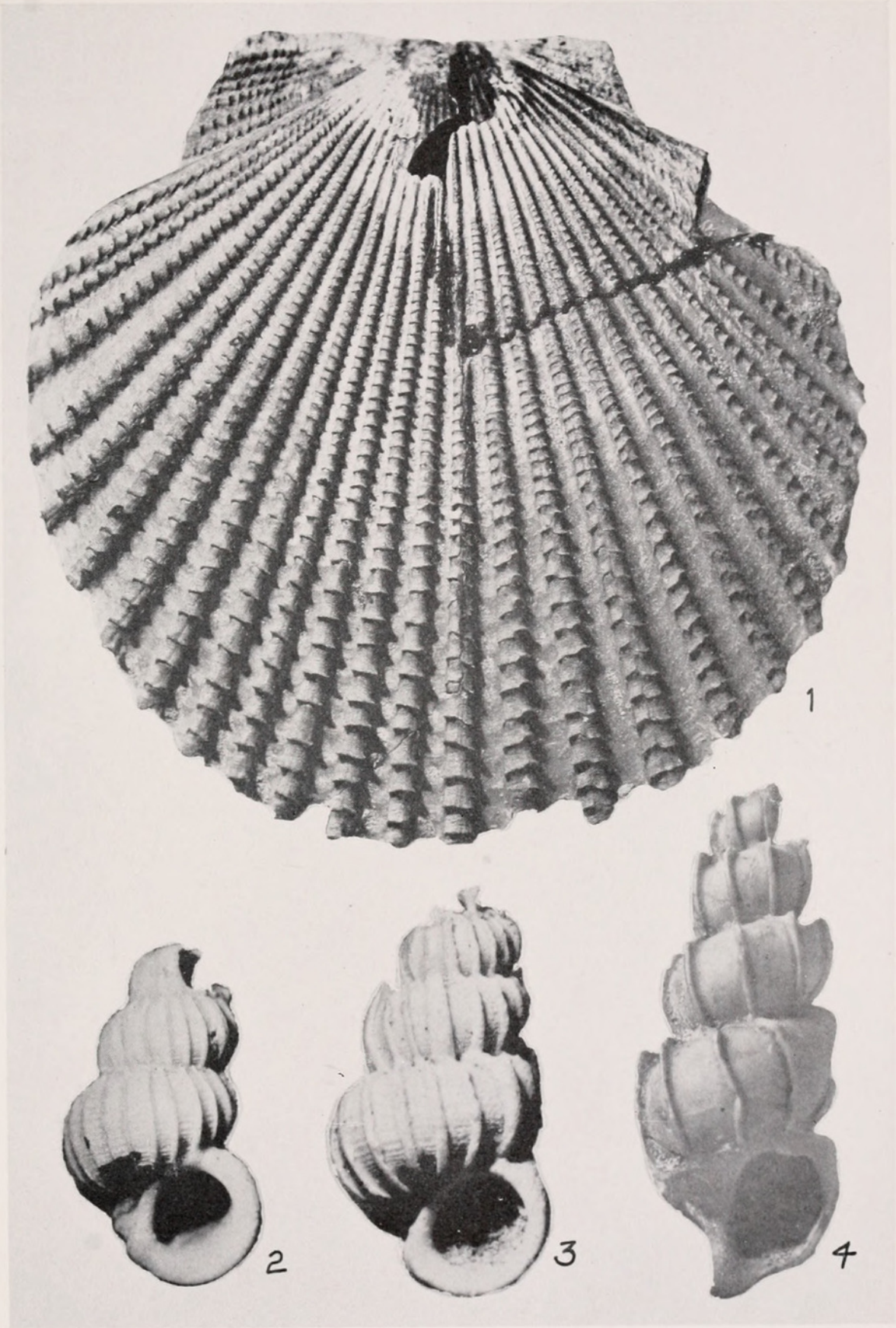


Plate 31

Fig. 1. *Pecten (Plagiectenium) hakei* Hertlein; natural size; plesiotype, right valve, No. 2131 (C.A.S. Type Coll.), from Loc. 928 (C.A.S.), Pliocene beds at Bernstein's abalone camp on south-east side of Cedros Island. Pliocene; p. 440.

Fig. 2. *Pecten (Plagiectenium) hakei* Hertlein; natural size; plesiotype, left valve; same specimen as Fig. 1; p. 440.

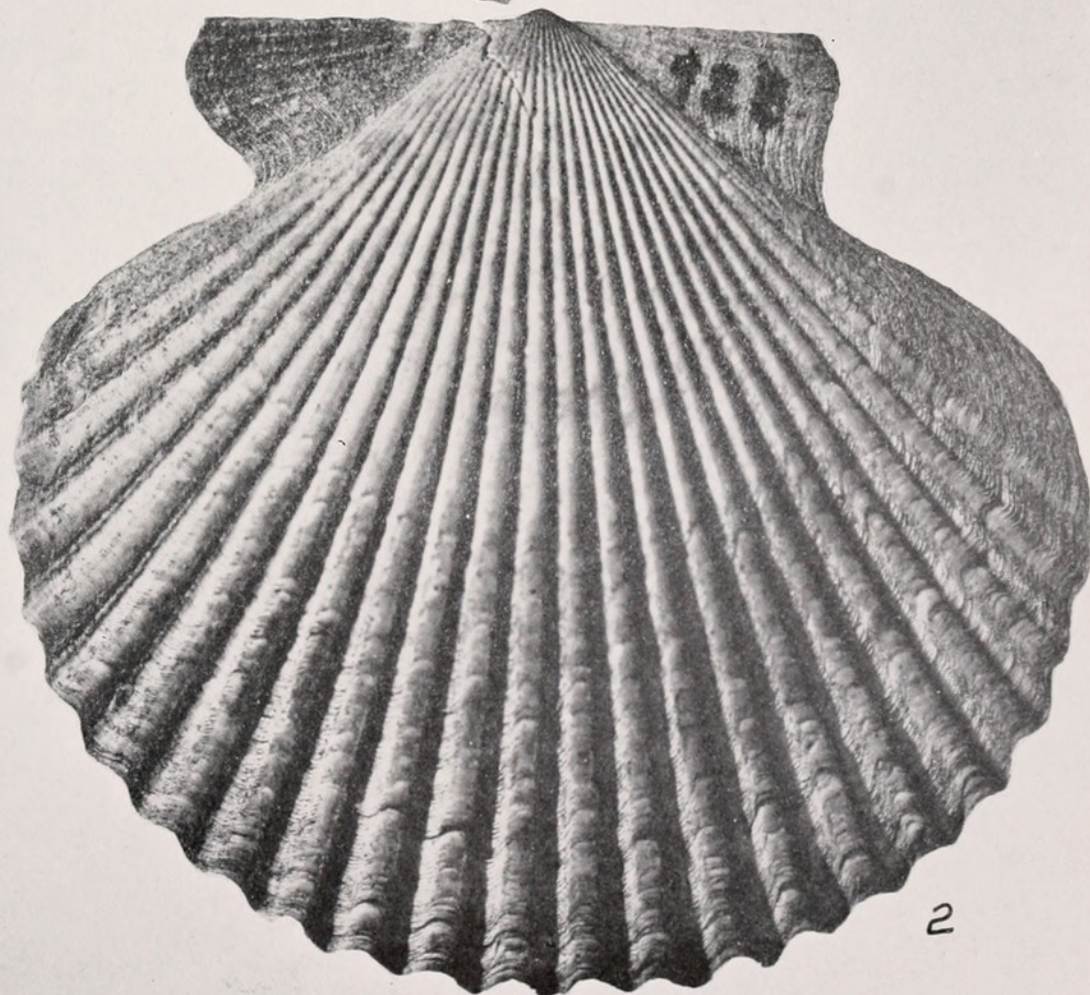
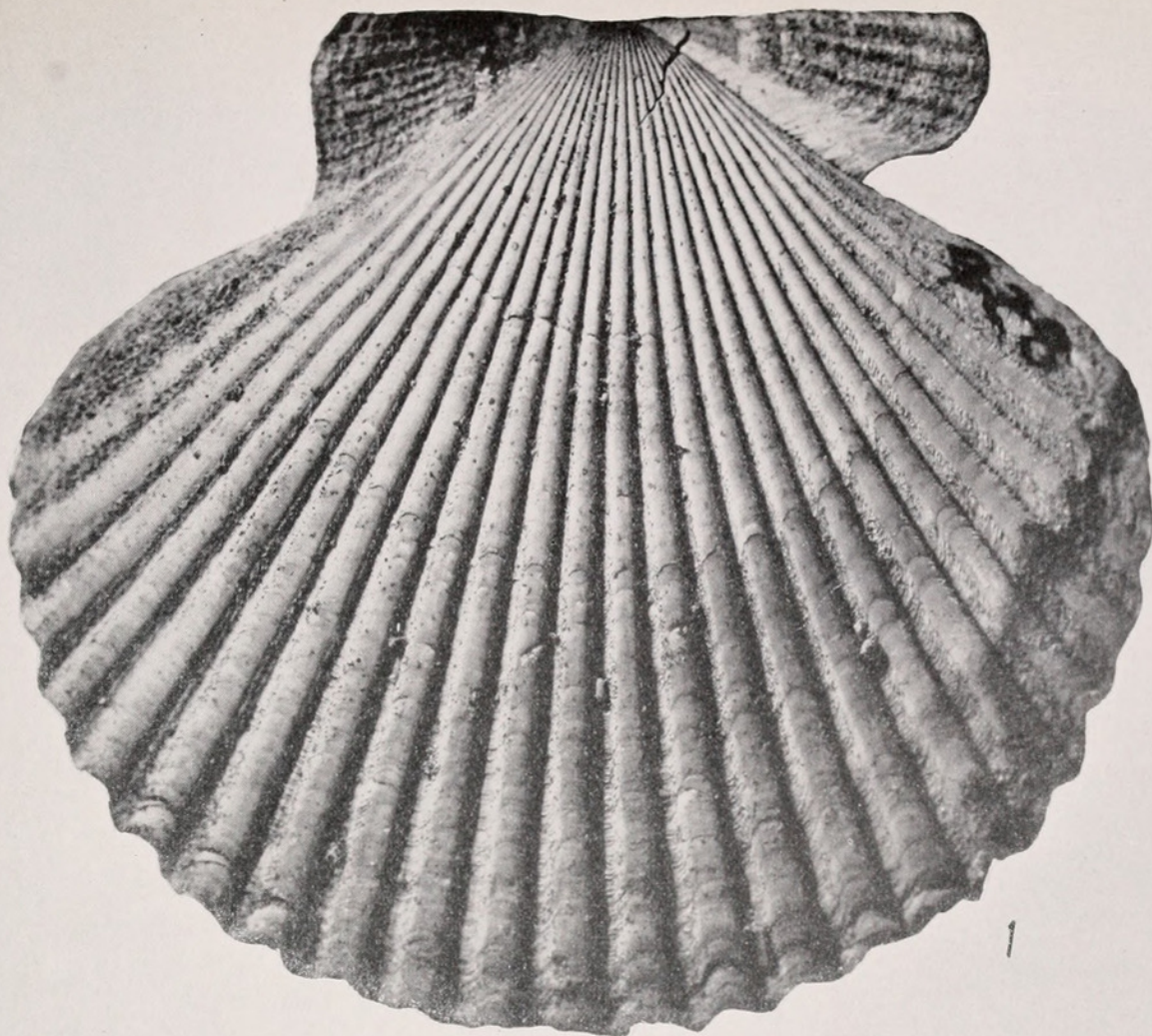


Plate 32

- Fig. 1. *Forreria wrighti* E. K. Jordan & Hertlein, new species; natural size; type, No. 2123 (C.A.S. Type Coll.), from Loc. 945 (C.A.S.), Pliocene beds exposed about a prominent monadnock, from one to two miles to southeast of Turtle Bay. Pliocene; p. 448.
- Fig. 2. *Pecten (Pecten) bellus* Conrad; natural size; paratype, right valve (of *P. hemphillii* Dall), No. 526a (C.A.S. Type Coll.), from Pacific Beach near San Diego, California. San Diego Pliocene; p. 430.
- Fig. 3. *Forreria wrighti* E. K. Jordan & Hertlein, new species; natural size; paratype, No. 2124 (C.A.S. Type Coll.), Loc. same as Fig. 1; p. 448.
- Fig. 4. *Pecten (Lyropecten) cerrosensis* Gabb; natural size; plesiotype, right valve, No. 2134 (C.A.S. Type Coll.), young form, from Loc. 928 (C.A.S.), Pliocene beds at Bernstein's abalone camp on southeast side of Cedros Island. Pliocene; p. 432.

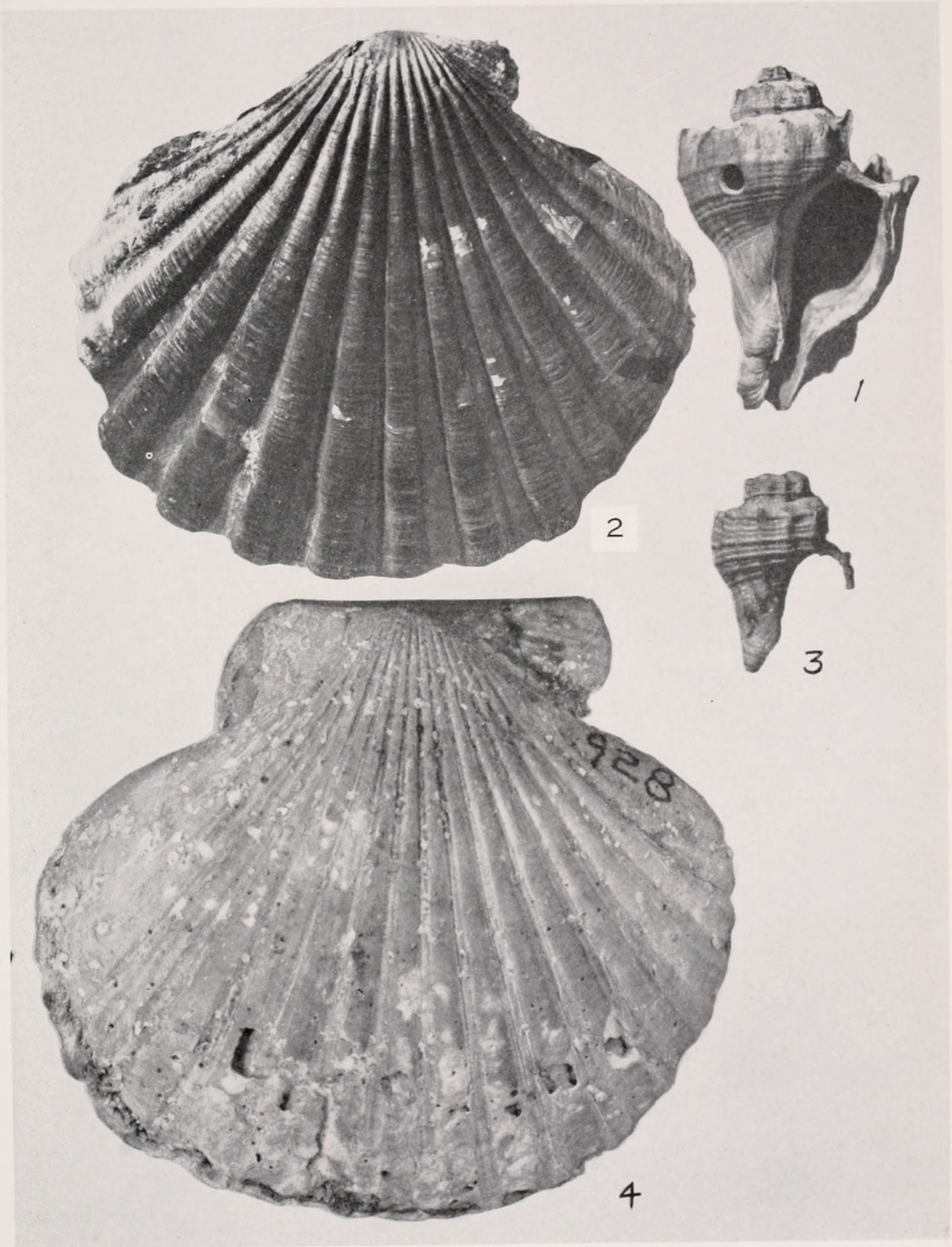
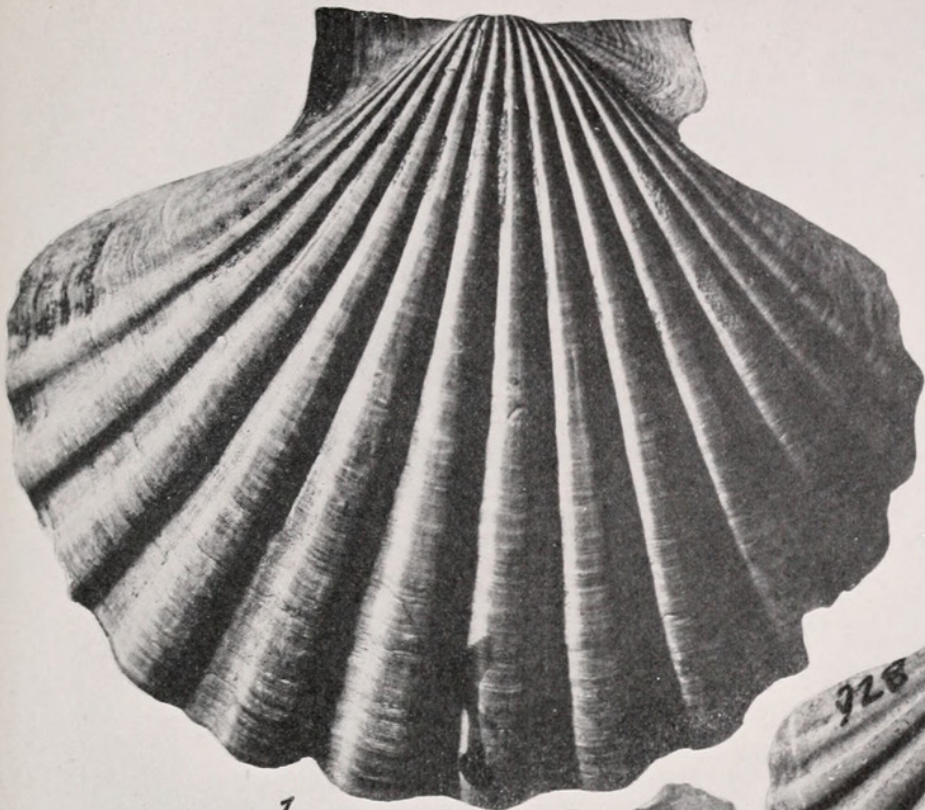
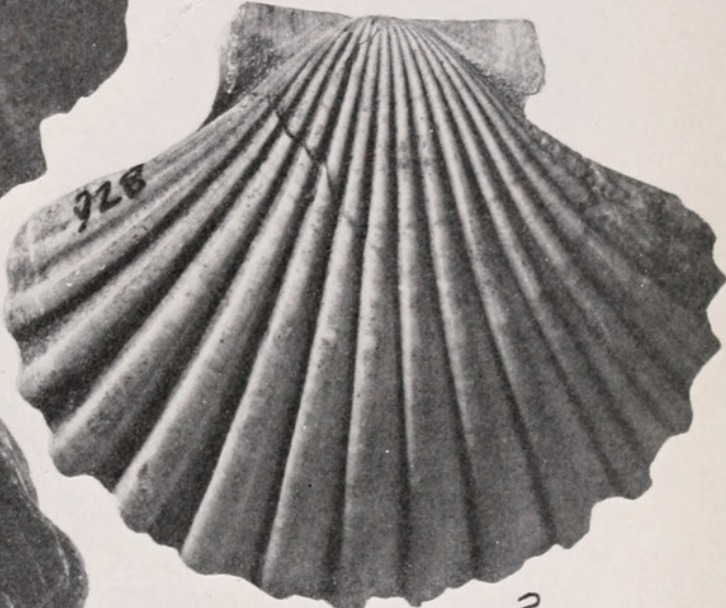


Plate 33

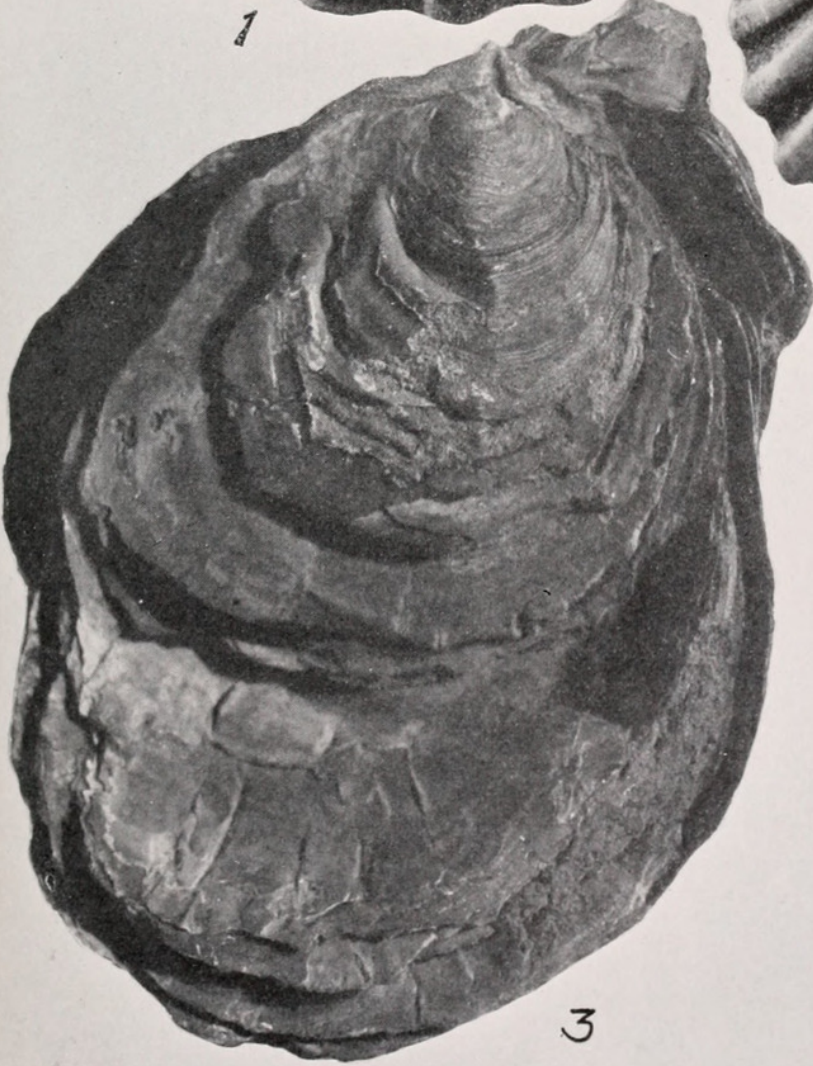
- Fig. 1. *Pecten (Pecten) bellus* Conrad; natural size; plesiotype, right valve, No. 2132 (C.A.S. Type Coll.), from Loc. 928 (C.A.S.), Pliocene beds at Bernstein's abalone camp on southeast side of Cedros Island. Pliocene; p. 430.
- Fig. 2. *Pecten (Pecten) bellus* Conrad; natural size; plesiotype, right valve, No. 2133 (C.A.S. Type Coll.), from same Loc. as Fig. 1; p. 430.
- Fig. 3. *Ostrea tayloriana* Gabb; natural size; plesiotype, right valve, No. 2094 (C.A.S. Type Coll.), from Loc. 48 (L.S.J.U.), mouth of big arroyo northwest of Elephant Mesa, Scammon Lagoon Quadrangle, Lower California. Pliocene; p. 428.



1



2



3

Plate 34

- Fig. 1. *Chama frondosa* Broderip; natural size; plesiotype, right valve, No. 2092 (C.A.S. Type Coll.), from Loc. 946 (C.A.S.), Pliocene beds exposed near the shore on east side of Cedros Island about nine miles north of Bernstein's abalone camp. Pliocene; p. 427.
- Fig. 2. *Pecten (Pecten) bellus* Conrad; natural size; paratype, left valve (of *P. hemphillii* Dall) No. 526a (C.A.S. Type Coll.). Same specimen as Plate 32, Fig. 2; p. 430.
- Fig. 3. *Pecten (Pecten) bellus* Conrad; natural size; plesiotype, left valve, No. 2132 (C.A.S. Type Coll.). Same specimen as Plate 33, Fig. 1. Pliocene; p. 430.
- Fig. 4. *Pecten (Pecten) bellus* Conrad; natural size; plesiotype, left valve, No. 2133 (C.A.S. Type Coll.). Same specimen as Plate 33, Fig. 2. Pliocene; p. 430.



Jordan, Eric Knight and Hertlein, Leo George. 1926. "Expedition to the Revillagigedo Islands, Mexico, in 1925, VII. Contribution to the geology and paleontology of the Tertiary of Cedros Island and adjacent parts of Lower California." *Proceedings of the California Academy of Sciences, 4th series* 15, 409–464.

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