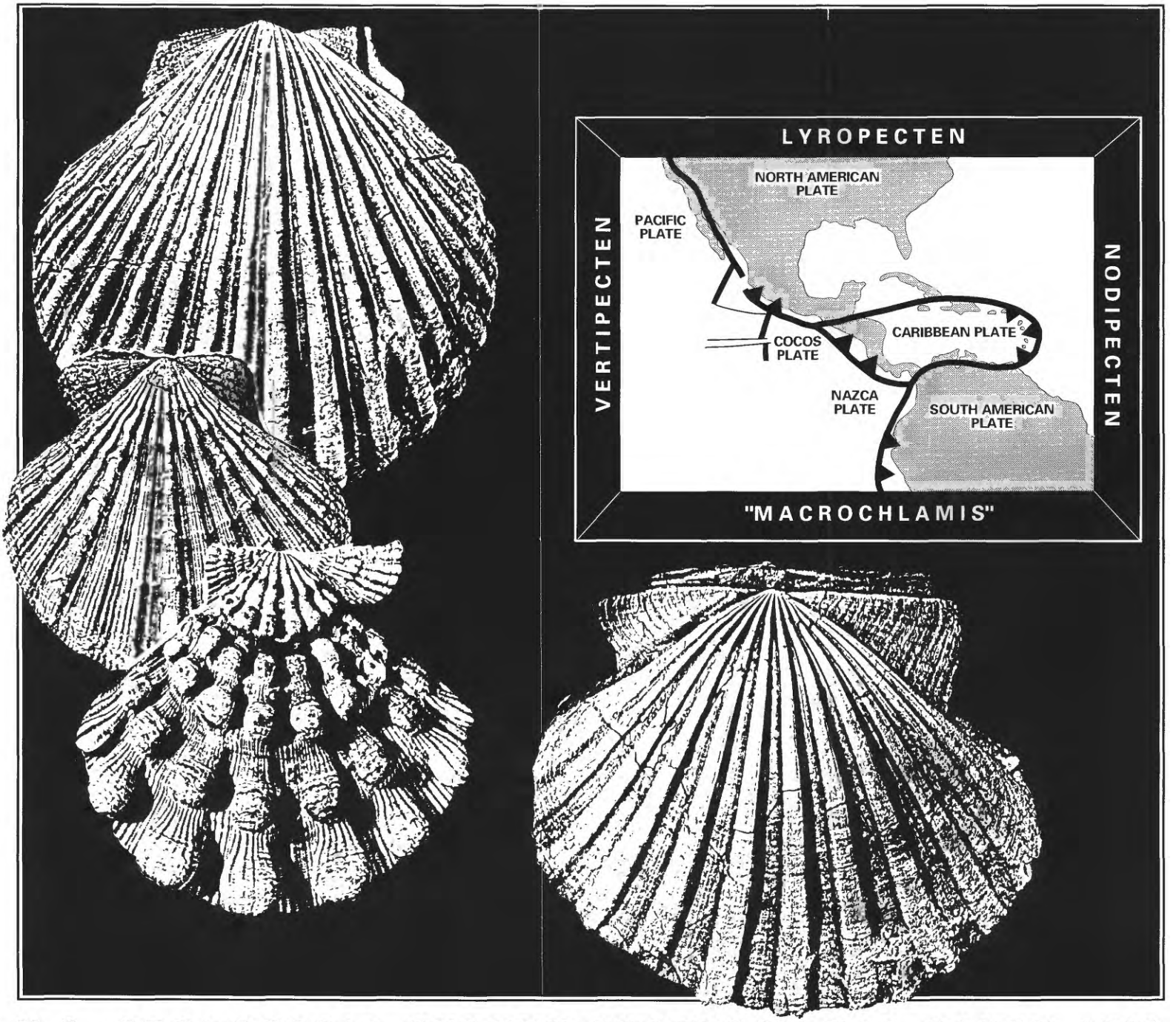
Cenozoic Giant Pectinids from California and the Tertiary Caribbean Province:

Lyropecten, "Macrochlamis," Vertipecten, and *Nodipecten* species



U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1391

Cover: Examples of giant pectinids, top left to bottom right: *Vertipecten bowersi* (Arnold), Miocene left valve from the Caliente Range, California [pl. 32, fig. 5]; *Lyropecten colinensis*, *s.s.* (F. & H. Hodson), Miocene left valve from La Vela, Colina District, Falcón, Venezuela [pl. 16, fig. 7]; *Nodipecten fragosus* (Conrad), Holocene right valve, from off St. George Island, Florida [pl. 7, fig. 5]; "*Macrochlamis*" *magnolia*, *s.s.* (Conrad), Oligocene or Miocene left valve from the Caliente Range, California [pl. 29, fig. 3]. Inset: Map shows plates on which giant pectinid species discussed in this paper are located. Heavy lines represent transform faults, subduction zones, and spreading ridge segments; light lines show fracture zones.

Cenozoic Giant Pectinids from California and the Tertiary Caribbean Province: *Lyropecten*, "*Macrochlamis*," *Vertipecten*, and *Nodipecten* species

By JUDITH TERRY SMITH

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Thirty-nine taxa, many of them index species, are described and illustrated; their biostratigraphic and chronostratigraphic significance are related to tectonostratigraphic settings

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CENOZOIC GIANT PECTINIDS FROM CALIFORNIA AND THE TERTIARY CARIBBEAN PROVINCE: *LYROPECTEN, "MACROCHLAMIS," VERTIPECTEN,* AND *NODIPECTEN* SPECIES

By JUDITH TERRY SMITH*

ABSTRACT

Tertiary pectinids recognized for more than 125 years by field geologists can now be used to date and correlate 3-4 m.y. increments of the geologic record and to determine faunal distributions in relation to tectonic terranes. Fossil pectinids are commonly preserved in shallow-marine clastic deposits that mostly lack microfossils. The stratigraphic ranges of *Lyropecten, "Macrochlamis," Vertipecten,* and *Nodipecten* can be used to subdivide provincial megafaunal stages in California and to correlate chronostratigraphic units in the Pacific Northwest and Atlantic Coastal Plain. One New World taxon, *"Macrochlamis" magnolia ojaiensis*, n. subsp., supports a direct correlation between the middle "Vaqueros" Stage of California (interpolated as 27-23 m.y. B.P.) and an Upper Chattian-Lower Aquitanian Stage section in southwestern Switzerland. Two lithologic units widespread in California, the Vaqueros Formation (spanning 12 m.y., from the late Oligocene into the early Miocene) and Temblor Formation (deposited over a period of 26 m.y., from the late Eocene or early Oligocene to the middle Miocene), transgress much longer periods of time than have been generally recognized.

Certain species pairs are identified as cognates, close relatives descended from a common ancestor. Close similarities are found between widely separated assemblages from the Salton Trough of California and the Caribbean, the Gulf Coastal Plain of eastern Mexico and the Sinu Valley of western Colombia, the Santa Rosalia area in Baja California Sur, Mexico, and the Paraguana Peninsula of Venezuela. Distribution patterns for relatively recently dispersed taxa have important implications for middle to late Cenozoic paleogeography and tectonic history, especially in west Mexico and the Caribbean. Speciation was concurrent with the closure of the Isthmus of Panama, the opening of the Gulf of California, and possibly with the northward translation of segments of the California Continental Borderland. Tertiary Caribbean and Pacific-Panamic Lyropectens and Nodipectens are plotted on a simplified tectonic map as an early step in considering Cenozoic molluscan distributions in relation to major plate boundaries. Taxa having unusual distributions are tabulated with the tectonic events that may have modified their observed geographic ranges. Southern California and the Baja California peninsula include tectonostratigraphic terranes and tectonic slivers that may have moved on the order of hundreds or thousands of kilometers in the Paleogene. Relations between recently dispersed faunas and tectonic terrane boundaries are further complicated by short-term variations in oceanographic phenomena such as currents, El Niño events, and shifts in areas of upwelling.

Lyropecten evolved in the late Oligocene or early Miocene, *Nodipecten* by the late middle Miocene. According to the classification used here, *Lyropecten* still lives in the Galapagos. Holocene Nodipectens divide the Pacific-Panamic and Caribbean provinces into two subprovinces each. Habitat, life history, dispersal, and growth data are summarized for living Nodipectens, whose distinctive shell features include ledges and hollow nodes. Phylogenetic lineages are based on progressive trends in node formation and rib schemes, some of which have biostratigraphic significance.

INTRODUCTION

From the time of the Pacific Railroad surveys (Conrad, 1856, 1857) to the present, geologists have used Pectens to identify and correlate Cenozoic marine clastic rocks in central and southern California. Ralph Arnold, newly graduated from Leland Stanford Junior University, undertook the first comprehensive study of living and fossil West Coast pectinids, basing his monograph on extensive collections and all available stratigraphic data.

Every decade or two since, other molluscan paleontologists have reexamined Arnold's original specimens, described new species, and added new insights to interpret pectinid evolution, distributions, and biostratigraphy. Individual problematic specimens from Arnold's collection have been discussed by four generations of Tertiary molluscan specialists, each pondering the phylogenetic importance of a particular structure or sculptural detail.

The aim of this paper is to revise the genera *Lyropecten, "Macrochlamis," Vertipecten,* and *Nodipecten* and to assemble published and unpublished biostratigraphic data for refined correlations based on old and newly established index species (fig. 1). Distributional data are considered in relation to paleogeography, currents, and tectonostratigraphic terranes. The report is based primarily on field checks in selected areas and the type and general collections as of 1972-1973 at the U.S. Geological Survey and in national institutions listed below under Locality Data.

Major systematic works that include eastern Pacific species referred to *Lyropecten, "Macrochlamis," Vertipecten,* and *Nodipecten* are the following:

Ralph Arnold[1] (1906). First comprehensive treatment

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Manuscript approved for publication June 15, 1988.

[1]Ralph Arnold's maps and 40 field notebooks are included in almost 200,000 of his papers in the Manuscript Department of the Huntington Library, San Marino, Calif.

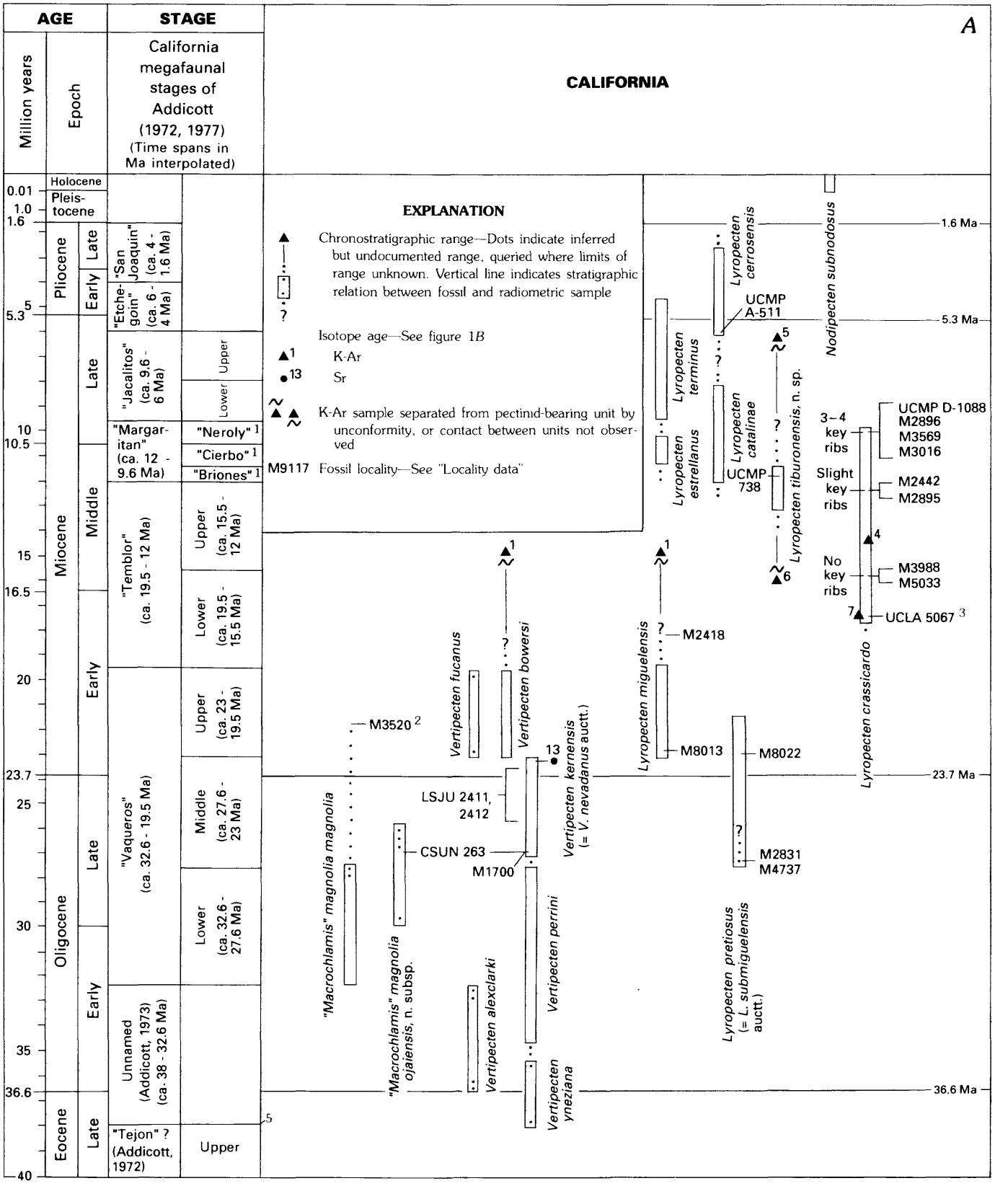
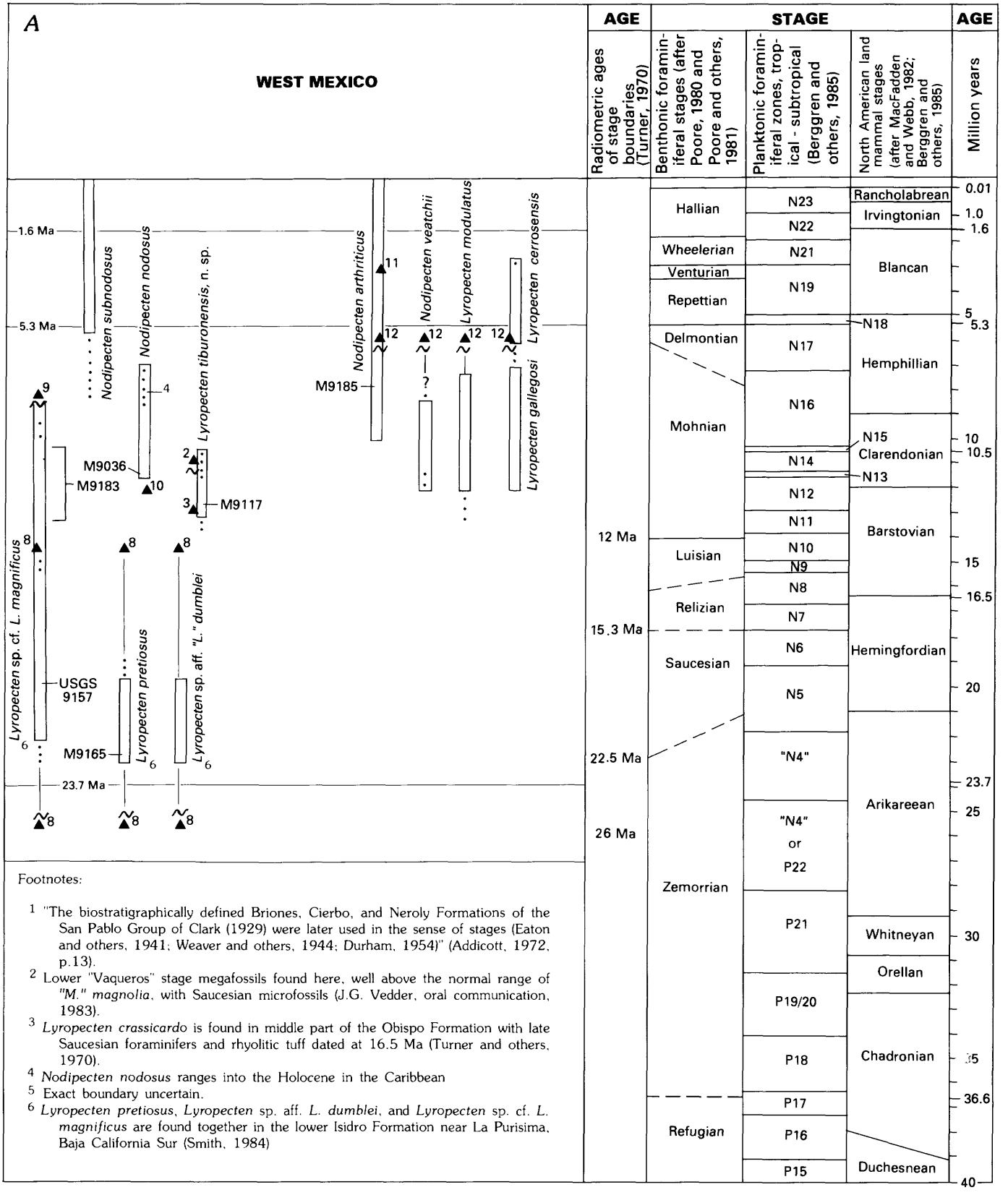


FIGURE 1.—Chronostratigraphic ranges of species from California and from Baja California and Sonora, Mexico. *A*, Chronostratigraphic ranges of *Vertipecten*, "*Macrochlamis*," *Lyropecten*, and *Nodipecten*. Radiometric data are shown on figure 1*B*; geologic time chart from Berggren and others (1985).



Footnotes:

1 "The biostratigraphically defined Briones, Cierbo, and Neroly Formations of the San Pablo Group of Clark (1929) were later used in the sense of stages (Eaton and others, 1941; Weaver and others, 1944; Durham, 1954)" (Addicott, 1972, p.13).

2 Lower "Vaqueros" stage megafossils found here, well above the normal range of *"M." magnolia*, with Saucesian microfossils (J.G. Vedder, oral communication, 1983).

3 *Lyropecten crassicardo* is found in middle part of the Obispo Formation with late Saucesian foraminifers and rhyolitic tuff dated at 16.5 Ma (Turner and others, 1970).

4 *Nodipecten nodosus* ranges into the Holocene in the Caribbean

5 Exact boundary uncertain.

6 *Lyropecten pretiosus*, *Lyropecten* sp. aff. *L. dumblei*, and *Lyropecten* sp. cf. *L. magnificus* are found together in the lower Isidro Formation near La Purisima, Baja California Sur (Smith, 1984)

FIGURE 1.—Chronostratigraphic ranges of species from California and from Baja California and Sonora, Mexico.

of 300 living and fossil taxa, many of them new; 53 plates illustrating new and earlier described type specimens. Material came mostly from San Francisco area institutions, Leland Stanford Junior University, the University of California at Berkeley, California Academy of Sciences, and Arnold's private collection.

B

Radiometric ages of units associated with pectinid-bearing strata

▲[1] Conejo Volcanics, 15.5±0.8 Ma near base, overlie Topanga Canyon Formation, Saddle Peak Member, Santa Monica Mountains (D.L. Turner and R.H. Campbell in Yerkes and Campbell, 1980a)

▲[2] Welded ash-flow tuff, 11.2±1.3 Ma, caps unnamed marine fossiliferous units with angular unconformity, southwestern Isla Tiburón, Sonora, Mexico (Gastil and Krummenacher, 1977)

▲[3] Monomict volcanic breccia, 12.9±0.4 Ma, interbedded with marine fossils, southwestern Isla Tiburón, Sonora, Mexico (Smith and others, 1985; Smith, in press)

▲[4] El Modeno Volcanics, 14.1±1.6 Ma, conformably overlie Topanga Formation, Santa Ana Mountains (Turner, 1970; Weigand, 1982)

▲[5] Basalt flow, 6.04±0.18 Ma and 5.94±0.18 Ma, in lower part of Painted Hill Formation overlies Imperial Formation in Whitewater River-Super Creek area, northern Salton Trough (Matti and others, 1985)

▲[6] Latrania Sand Member of Imperial Formation overlies Alverson Andesite of authors, which is 16±1.0 Ma (Eberly and Stanley, 1978)

▲[7] Rhyolitic tuff of Obispo Formation is 16.5±1.2 Ma (Turner and others, 1970)

▲[8] Basalt flow in lower part of Comondu Formation is 14.5±1.2 Ma, rhyolite in upper part of San Gregorio Formation is 25.3±0.3 Ma. Fossiliferous Isidro Formation is between them (Hausback, 1984; McLean and others, 1987)

▲[9] Tholeiitic basalt, 8.57±0.28 Ma, caps unconformably Miocene marine sediments in Arroyo Patrocinio, Baja California Sur, Mexico (J.G. Smith, unpublished data, 1984)

▲[10] Basaltic andesite, 12.3±0.4 Ma and 12.5±0.4 Ma, underlies marine fossils of Boleo Formation near Santa Rosalia, Baja California Sur, Mexico (Sawlan and Smith, 1984; and J.G. Smith, unpublished data, 1984)

▲[11] Tuff, 3.3±0.5 to 1.9±0.5 Ma, interbedded with Carmen-Marquer Formations, undifferentiated, north of Loreto, Baja California Sur, Mexico (McLean, 1987, 1988)

▲[12] Basalts cap Cerro del Elefante (6.48±0.23 Ma) and Mesa de las Auras (5.70±0.20 Ma) and are younger than abundantly fossiliferous Almejas Formation, Vizcaino Peninsula, Baja California Sur, Mexico (Sawlan and Smith, 1984)

•[13] *Vertipecten kernensis* specimens from Pyramid Hill Sand Member of basal Jewett Sand have $^{87}Sr/^{86}Sr$ values of 0.708208±0.000040 and 0.708193±0.000034, interpreted as 23±1 and 23.3±1 Ma, respectively (Hilary Olson, sample numbers HCO 1SrPH and HCO 2SrPH). Stratigraphic positions are shown in Olson (1988) in a measured section from Pyramid Hill, Calif. in Rio Bravo Ranch 7 1/2' quadrangle, sec. 14, T. 28 S., R. 29 E.

FIGURE 1.—Continued. *B*. Radiometric ages of units associated with pectinid-bearing strata.

L.G. Hertlein (1925a,b, 1928a,b, 1935, 1957, 1966). Described new material he collected from the northern Channel Islands and western Mexico. He named faunal zones and authored papers on the Miocene of the Baja California peninsula (Hertlein and Jordan, 1927), Pleistocene mollusks from the Galapagos Islands (Hertlein and Strong, 1939) and the geology and paleontology of the Pliocene San Diego Formation, California (Hertlein and Grant, 1972).

U.S. Grant, IV and H.R. Gale (1931). A large volume incorporating information from expanded collections at many national institutions and the paleontological literature. Despite the title, "Catalogue of Marine Pliocene and Pleistocene Mollusca," they treated Paleogene and Neogene species and included taxa from beyond California, illustrating many in 32 plates.

Wayne Loel and W.H. Corey (1932). Systematic treatment of about 200 invertebrate taxa, based on large numbers of specimens at the University of California, Berkeley, collected by them or for them with an emphasis on both chronologic and stratigraphic intervals. They emphasized faunas from the Vaqueros Formation, grouping localities by particular embayments. Loel and Corey covered a wide geographic area and used generalized stratigraphic data; their formation boundaries were faunal, not lithologic, and they used rock units in a chronostratigraphic sense.

Woodring (1957, 1977, 1982). Systematic studies of Paleogene and Neogene mollusks of Panama and the Tertiary Caribbean Province based on extensive U.S. Geological Survey collections at the U.S. National Museum and on holdings in West Coast museums. He included precise stratigraphic data and compared fossil species with Holocene taxa when feasible.

A. Myra Keen (1958, 1971). Holocene pectinids are listed and illustrated in two editions of "Sea Shells of Tropical West America." Her ecological and distributional data were based on the Stanford University and California Academy of Sciences' collections and from the literature.

Gilbert Grau (1959). Systematic treatment and illustrations of the pectinids of the eastern Pacific, based on his private collection, now in the U.S. National Museum of Natural History, and on national collections, the Allan Hancock Foundation holdings now at the Los Angeles County Museum of Natural History, and the literature.

E.J. Moore (1963, 1984b). Discussed and described marine Miocene mollusks from the Astoria Formation in Oregon, including *Vertipecten* (1963; Moore and Addicott, 1987). Primary source material on pectinid genera and species from California and Baja California, Mexico, are reviewed, and holotypes are illustrated in Moore (1984b).

F.S. MacNeil (1967). Described northern species of pectinids, including *Vertipecten* in Alaska.

W.O. Addicott (1965, 1973, 1974, 1976a,b). Pectinid

TABLE 1.—*Geographic, geologic, and chronostratigraphic ranges of the genera* Lyropecten, Vertipecten, Nodipecten, *and* Macrochlamis

	Lyropecten[1]	Vertipecten	Nodipecten	Macrochlamis
General geographic range	California, Mexico Panama, Galapagos, Colombia, Venezuela, Antilles	Alaska, Washington, Oregon, California; Kamchatka?	New and Old World; Pacific Panamic, eastern and western Atlantic	New World and Old World California and Europe
Province or geographic subregions defined by species distributions	Pacific and Tertiary Caribbean	North Pacific	Tertiary Caribbean; Holocene: tropical eastern Pacific, Caribbean and Gulf of Mexico	Tethyan, Mediterranean area; California
Geologic range	Oligocene to Holocene	Late Eocene to early Miocene	Miocene to Holocene	Oligocene to Pliocene (Aquitanian-Astian Stages of Europe)
Oldest known occurrence: Eastern Pacific	L. pretiosus (including L. submiguelensis auctt.) and Lyropecten sp. cf. L. magnificus, early Miocene	V. yneziana, late Eocene in California; several contemporary species reported from Washington and Alaska	N. nodosus, late middle or late Miocene	"M." magnolia magnolia middle Oligocene
Caribbean-southern Atlantic Coastal Plain	L. colinensis colinensis late early Miocene to late middle Miocene	---	N. collierensis, N. fragosus, late Miocene or early Pliocene	---
Megafaunal stages in California	Middle and upper "Vaqueros," "Temblor," "Margaritan," "Jacalitos"	"Tejon" stage of Weaver and others (1944), unnamed, "Vaqueros"	Not represented in the fossil record of California	Lower "Vaqueros" and lower middle "Vaqueros"
Number of New World species and subspecies, living and fossil, recognized in this paper	15	10	11	2

[1]"Lyropecten" is used for several Oligocene or Miocene Caribbean taxa not included in this chart; their relation to Lyropecten, s. s. of the eastern Pacific is uncertain.

biostratigraphy and geographic distributions were used for provincial zonation, regional correlation, defining and refining megafaunal stages, paleocology and paleoclimatology. Data gathered from U.S. Geological Survey field work and collections from national institutions. Mollusks were collected from critical biostratigraphic sequences from type areas of megafaunal stages in the Temblor and La Panza Ranges, the Cholame Hills, Kern River area, San Emigdio Mountains, and in the Pacific Northwest. U.S. Geological Survey collections are tied to precise geographic and stratigraphic localities on published maps.

T.E. Stump (1979, 1981). A study of Cenozoic pectinids from Baja California, the islands of the Gulf of California, and western Sonora, Mexico, including stratigraphic and geographic distributions. Illustrations of species referred to *Lyropecten, Argopecten, Chlamys, Nodipecten, Leptopecten, Euvola, Flabellipecten, Oppenheimopecten,* and *Leopecten.*

Other authors did not describe many new scallops but made important use of pectinid distributional data to solve regional correlation problems, measure amounts of offset along faults (Addicott, 1968), identify paleoclimatic trends (Addicott, 1970c), or trace paleogeographic boundaries. They include Woodring (1938), Hanna (1926), Vedder and Moore (1976), Weaver and Kleinpell (1963), and Mongin (1959).

OVERVIEW OF THE GENERA

These genera were studied together because many of their species co-occur as index fossils and are used to define megafaunal provinces (Addicott, 1974). All have members that have radial ribs and attain giant sizes (more than 9 cm in diameter, commonly more than 15 cm), and most are abundant; they are familiar and useful to many field geologists whether or not the mappers have a specialized knowledge of paleontology. Although the genera overlap in age and geographic and stratigraphic ranges, there are no direct evolutionary lines between "*Macrochlamis*" and *Vertipecten* and species referred to *Lyropecten* and *Nodipecten. Lyropecten* and *Nodipecten* are phylogenetically closer than the others, although their exact relation is unknown. The genera are compared in table 1.

LYROPECTEN

With the exceptions of *L. colinensis, s.l., Lyropecten* is an eastern Pacific genus. Dhondt (1972), in her system-

atic revision of the Chlamydinae, recognizes ten species of European Tertiary Lyropectens. Most seem closer to *Chlamys, s.l.* than to *Pecten estrellanus*, the type species of *Lyropecten*, although general characters such as radial ribs and byssal notch are the same for large numbers of pectinid taxa. Characteristic *Lyropecten* crura were absent in the European specimens that I saw.

The genus is distinguished by paired hinge teeth, subequal auricles, a hinge less than half the shell length, moderately deep byssal notch, and convex valves, some of which are ledged. Some lineages have key ribs or nodes of the scheme N 2r N_c 2r N or R 3r R_c 3r R (see fig. 15 for scheme code); others have regularly spaced ribs of equal prominence.

"LYROPECTEN"

"Lyropecten" dumblei, *"L." condylomatus*, and *"L." articulosus* are provisionally included here because they have hinge teeth, a tendency toward ledged growth forms, node formation in left valves, and costate, lirate macrosculpture. They may not be *Lyropecten, s.s.*, as it differs in adult size, geographic range, and place of origin; they may be closer to European pectinids, a relationship not investigated for this study. They are small compared to Pacific Lyropectens, and they are known from only a few isolated occurrences in Oligocene and lower middle Miocene rocks. *Lyropecten pyx* Gardner, here referred to *"Stralopecten,"* has the growth form and triangular auricles of *Stralopecten* but hinge teeth similar to those in the "Lyropectens" listed here. Tucker-Rowland (1938b) noted that hinge teeth are present in juveniles but obsolete in adults of the type species of *Stralopecten, S. ernestsmithi*. All of these taxa need further work.

"MACROCHLAMIS"

Macrochlamis is primarily a European, Miocene and Pliocene genus, now extinct, whose dispersal from France to the Vienna Basin and eastern Mediterranean (fig. 13*B*) has been traced by numerous workers, including Roger (1939) and Demarcq and Barbillat (1971). Although *M. latissimus*, the type species, has a circular outline and California representatives do not, both groups have proportionally large auricles, a reduced or absent byssal notch, and cardinal hinge teeth. California species are middle to late Oligocene in age; they are referred to *"Macrochlamis"* because not enough specimens were available for a detailed investigation of the genus and because there is no documented dispersal route between Europe and western North America. Other European species, such as *M.tournalii*, *M. terebratulaeformis*, and *M. nodosiformis* have outlines and overall proportions comparable to those of *"M." magnolia, s.l.* Specimens of *"M." magnolia ojaiensis*, n. subsp., from the Ojai Valley of California, suggest it is not merely convergent but morphologically very close to specimens from southwestern Switzerland referred herein to *M. terebratulaeformis*.

The genus is characterized by 0-3 pairs of hinge teeth, large, equal auricles, hinge greater than half the shell length, a shallow byssal notch, and large, equally convex valves. Ribs are commonly few in number, wider in the central parts of the shell, narrower toward the margins.

VERTIPECTEN

Vertipecten, unlike the other genera, is a cool water form, now extinct, known from the eastern Gulf of Alaska to California. Its presence during the late Eocene to early Miocene of California permits direct correlations between Addicott's (1972) Californian magafaunal stages ("Tejon"?, unnamed, "Vaqueros," and "Temblor") characterized by warm-water taxa and the more recently defined megafaunal stages of the Pacific Northwest (Addicott, 1977; Armentrout, 1983; Moore and Addicott, 1987). Left valves record a recognizable progression of morphologic changes that can be used to subdivide the "Vaqueros" Stage.

The genus is characterized by a smooth hinge area, equal to subequal auricles, deep byssal notch, a tendency toward planar right valve and convex left valve profiles; ribs vary in number, width, and macrosculpture.

NODIPECTEN

Nodipecten has a well-documented history in the Tertiary Caribbean Province, the Pacific-Panamic and western Atlantic areas. The oldest records are in Florida, Venezuela, Patagonia, and Baja California Sur, Mexico; they suggest it ranged through the Panamic seaway until its closure in the late early Pliocene. Endemic species of *Nodipecten* evolved in the late Miocene in the Gulf of California, the Gulf Coastal Plain, the southeastern Atlantic Coastal Plain, the Greater Antilles, and northern South America. The only old world, eastern Atlantic representative is *N. corallinoides* (d'Orbigny) living today off the Cape Verde and Canary Islands. Without knowledge of the Neogene African record, it is impossible to say whether the Cape Verde taxon is derived from the Caribbean via clockwise currents in the North Atlantic or whether old world fossil ancestors await recognition and systematic study.

The genus is characterized by paired hinge teeth, unequal auricles, hinge about half the shell length, a deep byssal notch, and equal valves with costate, lirate macrosculpture. Shells tend to have ledges and large, hollow nodes described by the node schemes N r N_c r N or N 2r N_c r N.

DIAGNOSING CONVERGENT PECTINIDS

Fragments of pectinids are commonly hard to identify; incomplete specimens of the four genera considered here have been referred in publications to a number of other pectinid taxa. Diagnostic characters, type species, and range data are summarized in table 2 to aid in distinguishing convergent (similar but unrelated), sometimes co-occurring forms from species of *Argopecten*, *Swiftopecten*, *Stralopecten*, *Chlamys*, *Patinopecten*, and *Chesapecten*. Representatives of these genera are illustrated in plates 1 and 2.

A number of species, originally described as *Lyropecten* or *Nodipecten*, are placed in other genera in this paper. Most are from the formations of the Chesapeake Group of the Atlantic Coastal Plain, two are from California, and one is from the Miocene Tumbez Formation at Zorritos, Peru. Original citations and the generic names used here are as follows:

Original name	*This paper*
Chlamys (*Lyropecten*) *acanikos* Gardner, 1926, U.S. Geological Survey Professional Paper 142-A, p. 46, pl. 11, figs. 1, 2	*Chlamys*
Chlamys (*Lyropecten*) *madisonius bassleri* Tucker-Rowland, 1938a, Institut royal des science naturelle de Belgique, ser. 2, fascicule 13, p. 13-14, pl. 5, fig. 1	*Chesapecten*
Pecten (*Nodipecten*) *caloosaensis* Dall, 1898, Wagner Free Institute of Science, Trans., v. 3, pt. 4, p. 731, pl. 29, fig. 12	*Stralopecten*
Chlamys (*Lyropecten*) *dysoni* Tucker-Rowland,1938a, Institut royal des science naturelle de Belgique, ser. 2, fascicule 13, p. 5, pl. 4, fig. 9	*Argopecten*?
Chlamys (*Lyropecten*) *planicosta* Gardner, 1943, U.S. Geological Survey Professional Paper 199-A, p. 34, pl. 9, fig. 1	*Argopecten eboreus* (Conrad) (*fide* Waller, 1969)
Chlamys (*Lyropecten*) *pontoni* Mansfield, 1932b, Florida State Geological Survey Bulletin 8, p. 59, pl. 10, figs. 1, 2	*Nodipecten collierensis* (Mansfield) or *Chesapecten*?
Lyropecten pyx Gardner, 1936, Florida Geological Survey Bulletin 14, p. 19, pl. 1. figs. 7-9	"*Stralopecten*"[2]
Chlamys (*Lyropecten*) *santamaria* Tucker, 1934, American Midland Naturalist, v. 15, no. 5, p. 615, pl. 26, fig. 2	*Chesapecten*
Pecten (*Lyropecten*) *tamiamiensis* Mansfield, 1932a, U.S. Geological Survey Professional Paper 170-D, p. 47, pl. 16, figs. 4, 6	*Chlamys*
Pecten (*Lyropecten*) *tucilla* Olsson, 1932, Bulletins of America Paleontology, v. 19, no. 68, p. 83, pl. 5, figs. 1, 4	*Aequipecten*
Pecten (*Lyropecten*) *bowersi* Arnold, 1906, U.S. Geological Survey Professional Paper 47, p. 70-71, pl. 12, figs. 1, 2; pl. 13, figs. 1, 1a	*Vertipecten*
Pecten (*Lyropecten*) *perrini* Arnold, 1906, U.S. Geological Survey Professional Paper 47, p. 80-81, pl. 14, figs. 1, 1a; pl. 15, fig. 1	*Vertipecten*

[2]Growth form and triangular auricles as in *Stralopecten ernestsmithi* and *S. caloosaensis*, although the species has hinge teeth and no ctenolium. Older than the other Stralopectens, "*S.*" *pyx* was described from the middle Miocene Shoal River Formation of northwestern Florida.

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Specimens studied for this paper came from many sources: museums, universities, U.S. Geological Survey geologists, and private individuals. Those in charge of collections were generous with their time and help, making even short visits to their institutions productive and informative. Many individuals contributed suggestions for literature and maps that provided the regional setting in which the taxa are considered. It was a pleasure to work with all of these people, to learn from them, and to assemble their data to make a composite study of pectinids in space and time.

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TABLE 2.—*Comparative data for convergent pectinid genera*

[See also plates 1 and 2]

Genera	Nodipecten Dall, 1898	Lyropecten Conrad, 1862	"Lyropecten" (this paper)	Macrochlamis Sacco, 1897a [= Gigantopecten Rovereto, 1899]	Argopecten Monterosato, 1899 [= Plagioctenium Dall, 1898 of authors]	Swiftopecten Hertlein, 1936
Type species	Ostrea nodosa Linnaeus, 1758	Pallium estrellanum Conrad, 1856	--	Ostrea latissima Brocchi, 1814	Pecten circularis Sowerby, 1835 [= P. solidulus Reeve, 1853]	Pecten swiftii Bernardi, 1858
Diagnostic morphologic characters of the genera						
Hinge	RV, 3 pairs, LV, 2 pairs of hinge teeth	RV, 3 pairs, LV, 2 pairs of hinge teeth	0-3 pairs, variable	Hinge teeth variable, 0-3 pairs	Teeth weak to moderately strong	1 pair of hinge teeth
Auricles	Subequal to equal, lirate, costate	Equal to subequal, radially costate	Equal to subequal, small; slight twist in RV A auricle	Very large, equal, smooth auricles, P auricle higher than A auricle	Equal; free margins of P auricle sigmoidal in plane of commissure; P sinus well developed (Waller, 1969)	Unequal, A auricle longer than P auricle
Byssal area	Byssal notch deep, ctenolium prominent	Byssal notch present	Byssal notch present	Byssal notch shallow	Byssal notch present, depth varies	Notch well developed
Valve profiles, outline	Equal convexity; ht=1th, circular outline	Equal to subequal, some with ledges ht=1th	Equal to subequal, commonly ledged; ht=1th	Equal; flat to convex; ht=1th	Equal; ht=1th	Equivalved; ht>1th
Beak or umbone in relation to the hinge line	Beaks project slightly beyond hinge line	Varies with species; beaks project beyond hinge in some, meet at the hinge line in others	Beaks project slightly beyond hinge line	Beaks meet at hinge line or RV projects slightly above it	Beaks meet at hinge line or umbones project slightly above it	Beaks meet at at hinge line
Sculpture	Radial ribs, some with hollow nodes; LV ribs alternate in width	Radial ribs; some left valves with key ribs; 1 species has hollow nodes	Radial ribs some left valves with nodes	Low, rectangular radial ribs become obsolete in some adults; nodes in some species	Radial ribs	Folded radial ribs, some have ledges and nodes
Fine macrosculpture	Concentric lirae and radial costae	Concentric lirae and radial costae	Concentric lirae, radial costae	Weak, mainly concentric growth lines	Radial costae; looped lamellar growth lines	Radial costae
Geographic distribution	North Carolina to Gulf of Mexico, Caribbean to Brazil; eastern Atlantic Ocean and tropical eastern Pacific; Patagonia	California; central America; Venezuela, Dominican Republic, Galapagos Islands	Mexico, Greater Antilles, Colombia, Florida; possibly from the Mediterranean Tertiary	Europe and California	Cosmopolitan, in tropical to warm temperate seas	California to Japan
Geologic range	Miocene to Holocene	Early Miocene to Holocene	Oligocene to Miocene	Middle Oligocene to Pliocene	Miocene to Holocene	Middle Miocene to Holocene

TABLE 2.—*Comparative data for convergent pectinid genera*—Continued

Genera----------	Stralopecten Tucker-Rowland, 1938b	Chlamys, s.s. Roding, 1798	Vertipecten Grant and Gale, 1931	Patinopecten, s.s. Dall, 1898	Chesapecten Ward and Blackwelder, 1975
Type species------	Pecten ernestsmithi Tucker, 1931	Pecten islandicus Muller, 1776	Pecten bowersi Arnold, 1906	Pecten caurinus Gould, 1850	Chesapecten nefrens Ward and Blackwelder, 1975
Diagnostic morphologic characters of the genera:					
Hinge	Teeth absent or obsolete in adults	Teeth weak to obsolete	Smooth, no teeth	Teeth weak to absent	Hinge area smooth
Auricles	Triangular, large, equal, radially costate	Unequal; A auricle longer than P auricle	Equal to subequal, hinge more than half the shell length	Unequal, proportionally small, less than half the the shell length	Equal to subequal, P auricle higher than than A auricle
Byssal area	Shallow byssal notch, prominent ctenolium	Deep, prominent notch	Deep, prominent notch	Notch deep, slightly flexed; ctenolium present in juveniles	Notch varies, deeper in older fossils, shallower in younger species
Valve profiles	Subequal, triangular; ht>lth	Equal ht>lth	RV flat, LV convex; lth>ht in older species, ht>lth in younger taxa	Equal, flat valves; RV longer than LV, ht=lth	Subequal, RV flatter than LV, lth >ht
Beak or umbone in relation to the hinge line	Beaks project equally, slightly beyond hinge line	Beaks project equally, slightly beyond hinge line	Beaks project equally, slightly beyond hinge line	Beaks project equally, slightly beyond hinge line	Beaks project equally, slightly beyond hinge line
Sculpture	5-7 strong radial ribs	Many fine radial ribs, commonly dichotomous and spinose	Radial ribs; riblets tend to split in RV. 1-3 key ribs develop in LVs of some species	Radial ribs low, rectangular sulcate in some species	Radial ribs
Fine macrosculpture	Strong radial cords to fine radial costae	Fine radial costae, concentric growth lines; spinose; shagreen microsculpture in some species	Imbricated lamellae or scales, shagreen microsculpture	Imbricated lamellar microsculpture, some with shagreen microsculpture	Scabrous lirae
Geographic distribution	Atlantic Coastal Plain, North Carolina to Florida	Cosmopolitan	California to Gulf of Alaska; Kamchatka?	California to Japan	Atlantic Coastal Plain, New Jersey to Florida; northeast Mexico; Colombia
Geologic range	Miocene(?) to Pliocene	Triassic to Holocene	Late Eocene to early Miocene	Oligocene(?) and middle Miocene to Holocene	Early or middle Miocene to early Pliocene

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LYROPECTEN AND *NODIPECTEN* DISTRIBUTIONS AND APPLICATIONS TO GEOLOGIC PROBLEMS

Lyropecten is Oligocene to Holocene in the Pacific and ranges in age from Miocene to early or middle Pliocene in Central America and the Caribbean. *Nodipecten* is known from the Miocene to Holocene in the Pacific-Panamic province, the Gulf of Mexico and the Caribbean, the Holocene in the eastern Atlantic and Brazil, and the Miocene of Patagonia.

More significant distribution patterns emerge for species and subspecies, some of which are very distant and discontinuous for such relatively recently dispersed middle and late Cenozoic taxa. In some cases, close relatives are geographically distant while taxa from intervening areas are not phylogenetically intermediate. Clues to their dispersal routes are obscured by the scarcity of known fossil occurrences and recent tectonic events. Taxa whose distributions contribute data on former faunal provinces or tectonic events include both living and fossil forms, many of which are cognates (close relatives descended from a common ancestor) that ranged widely in the Tertiary Caribbean sea before the emergence of the Central American land barrier. Most dispersed with the prevailing currents, but others went long distances in the opposite direction. The following groups of the Pacific-Panamic and Caribbean Nodipectens and Lyropectens have proved to be the most useful for paleogeographic reconstructions because of their phylogenetic relationships and spatial distributions:

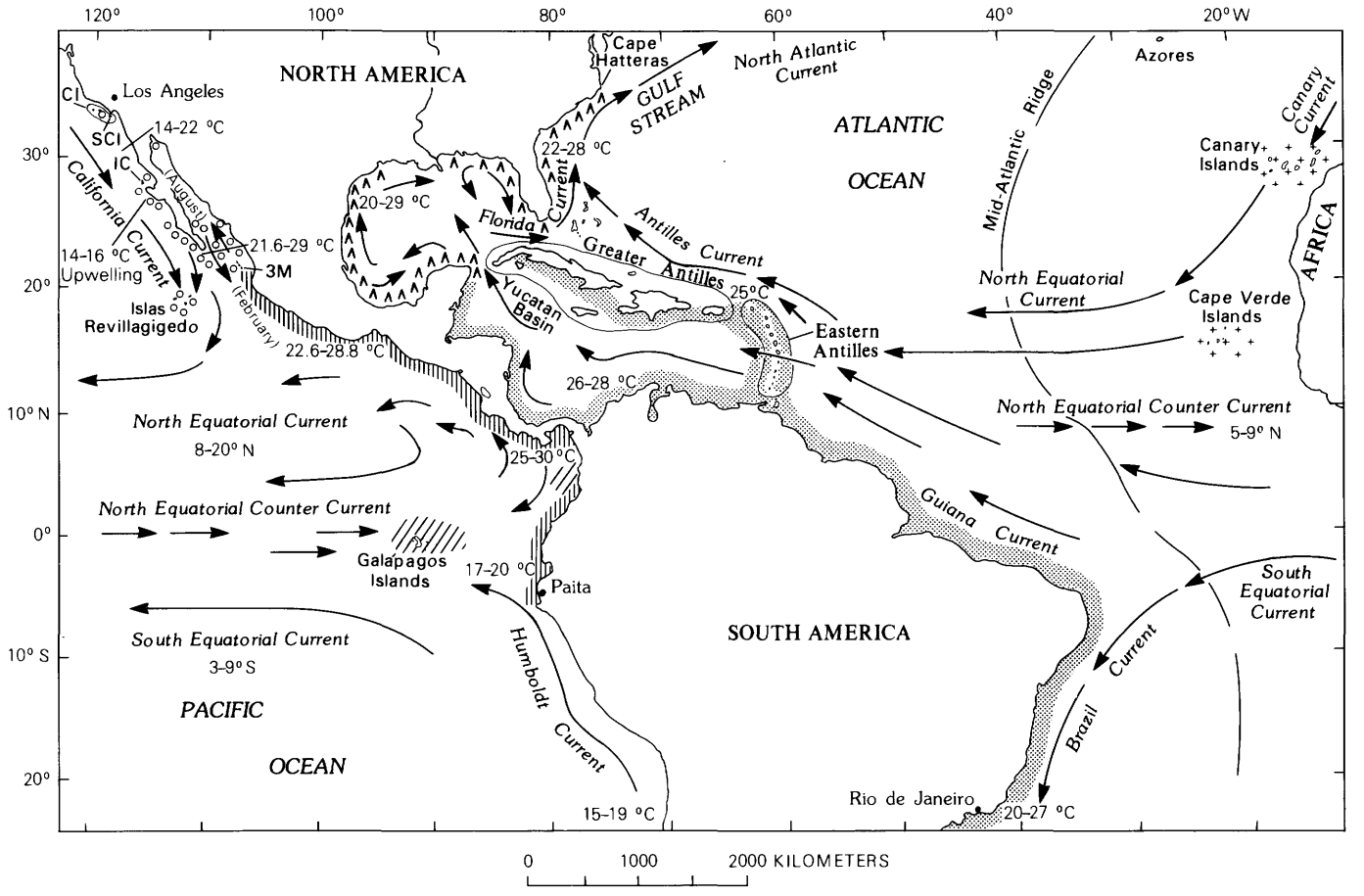
N. arthriticus and *N. subnodosus*
N. subnodosus and *N. nodosus*
N. collierensis, *N. pittieri*, and *N. nodosus*
N. veatchii, *N. peedeensis*, and *N. veracruzensis*, n. sp.
L. magnificus and *L. crassicardo*
L. colinensis colinensis and *L. colinensis vokesae*, n. subsp.
"L." dumblei

DISTRIBUTIONS, FAUNAL PROVINCES, AND SURFACE CURRENT PATTERNS

NODIPECTEN

The western Atlantic is divided into two provinces on the basis of living species or subspecies of *Nodipecten* (fig. 2). *Nodipecten fragosus* lives in the warm temperate Gulf of Mexico and north to Cape Hatteras (Gulf and Carolinian provinces of Briggs, 1974; the Caloosahatchian Province of Petuch, 1982); *N. nodosus* is found in the tropical Caribbean and as far south as Rio de Janeiro (Caribbean, West Indies, and Brazilian provinces of Briggs, 1974, in part the Gatunian province of Petuch, 1982). The Greater Antilles have probably been a barrier to *Nodipecten* dispersal since the early Pliocene, despite the existence of passageways such as the Yucatan Channel that permit Caribbean water masses to enter the Gulf of Mexico.

Of the two western Atlantic species, *Nodipecten nodosus*, the Caribbean form from the eastern Antilles,



EXPLANATION

Pacific Ocean species	Atlantic Ocean species
Nodipecten subnodosus	*Nodipecten nodosus**
Nodipecten arthriticus	*Nodipecten fragosus*
Lyropecten magnificus	*Nodipecten corallinoides*

* *Nodipecten nodosus* is the ancestor of *N. subnodosus* but they no longer live adjacent to each other.

CI Channel Islands
SCI Santa Catalina Island
IC Isla Cedros
3M Islas Tres Marias

FIGURE 2.—Distribution of living Nodipectens and Lyropectens related to surface current patterns. Surface currents and seasonal temperature ranges modified from Pickard (1979) and Hubbs and Roden (1964); seasonal upwelling and El Niño events can change provincial faunal boundaries by many degrees of latitude.

is closer to *N. corallinoides*, a dwarf form living around the islands off the continental shelf of northwest Africa. The distribution in time of *N. corallinoides* in the eastern Atlantic is unknown, as is the direction of dispersal by currents. The North Atlantic gyre accounts for west to east dispersal of some shallow tropical mollusks having eurythermal larvae (Scheltema, 1968), and the North Equatorial Current is available for east to west transport. *Nodipecten* is primarily a Tertiary Caribbean, tropical Pacific, and western Atlantic genus. Specimens of *N.*

corallinoides are reduced in size and limited in distribution; the taxon may represent an outpost island fauna from the west.

On the Pacific coast, *Nodipecten* species define two provinces: the Pacific-Panamic between the Tres Marias Islands, Mexico, and Peru, and the Gulf of California and western Baja California peninsula. The southern form, *N. arthriticus*, ranges through the Paita Buffer Zone of Olsson (1961) to Paita, Peru, as it has since at least Pliocene time. The northern species, *N. subnodosus*, migrated 800 km north against the California Current from the Vizcaino Peninsula, Mexico to Catalina Island off Los Angeles, Calif., during unusually warm periods from 1957-1959 (Radovich, 1961; Strachan and others, 1968), an example of dispersal during short-term favorable conditions produced during an El Niño event by an unusually strong countercurrent and an increase of 1-2°C in average sea-surface temperatures (Radovich, 1961).

The boundary between Holocene Pacific species of *Nodipecten* is at the Tres Marias Islands near the mouth of the Gulf of California; why these islands are the boundary is not well understood, because seasonal variations in temperature and currents produce similar conditions in water masses to the north and south. Pliocene records of *N. arthriticus*, the southern species, at Isla Cerralvo and Loreto, Baja California Sur, indicate that it ranged farther north at that time. Specimens of *N. arthriticus* 960 km south in Acapulco Bay, Mexico have aberrant ribbing and node schemes, characters that could result from pollution or other factors causing genetic variability within the population of a species that seems to have been morphologically constant for at least ten million years.

Of the four living New World *Nodipecten* species, adjacent forms are more distantly related than widely separated ones. The Caribbean *N. nodosus* is closer to the Gulf of California *N. subnodosus* than to the intervening Pacific-Panamic taxon, *N. arthriticus* (fig. 2).

LYROPECTEN

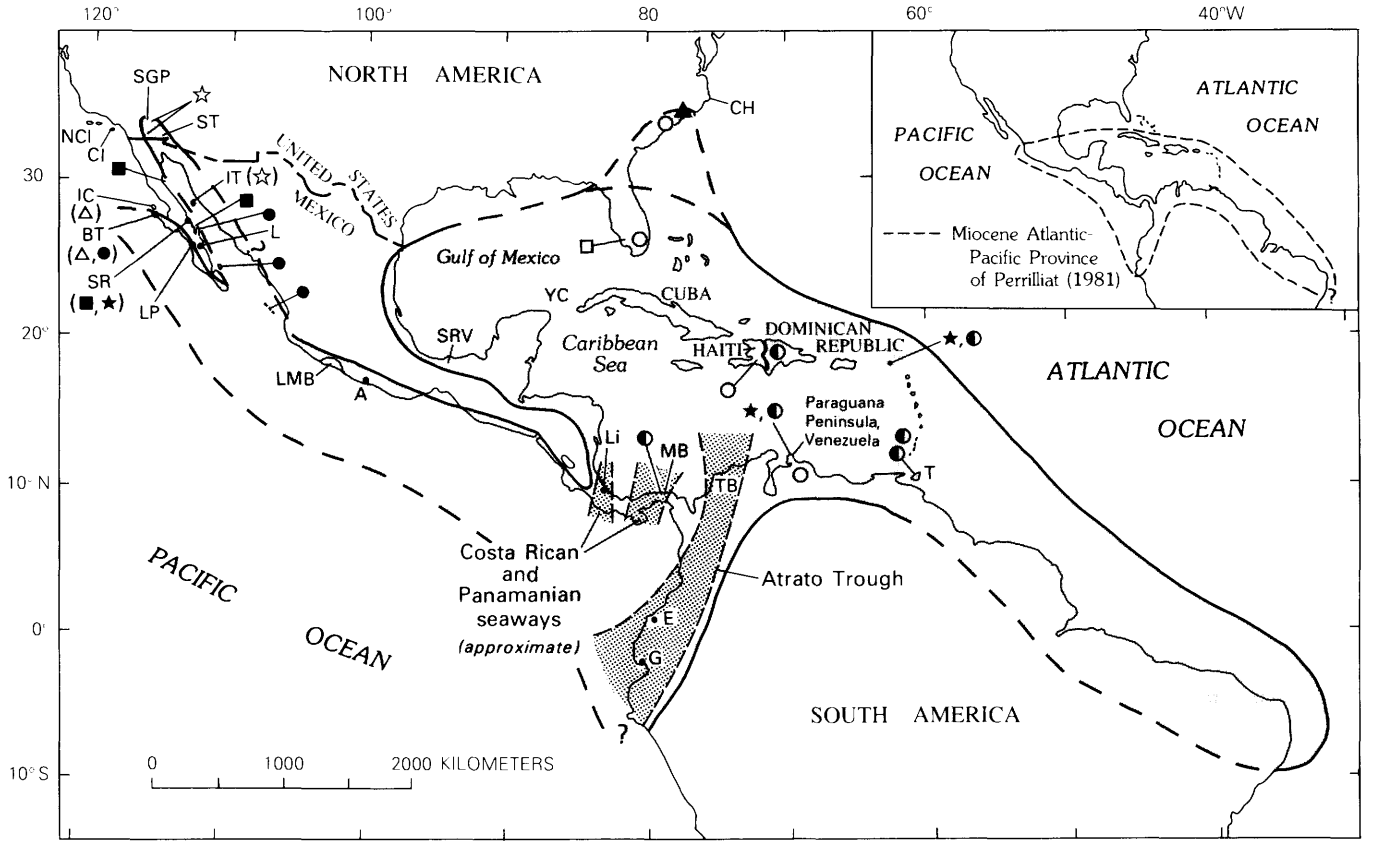
Lyropecten magnificus, the sole surviving *Lyropecten*, is found in the Galapagos, where it has lived since the middle or late Pliocene, and off Port Utria, Colombia (a single juvenile, USNM 765017, documents its presence near the mainland). Its closest relatives are the California late Miocene index fossil *L. crassicardo* and *Lyropecten* sp. cf. *L. magnificus* from the early to early middle Miocene of Baja California Sur, Mexico. The ancestor of *L. magnificus* presumably dispersed southeastward some 6,000 km across the North Equatorial Current during periods of weak westerly flow. Modern circulation, summarized in figure 2, shows that existing low latitude currents do not normally transport water masses from California as far south as the Galapagos, although the oldest islands were 200 km farther north and west at the time of dispersal (Cox, 1983), and temporary shifts in currents are part of El Niño phenomena. Dispersal of the *L. crassicardo-L. magnificus* stock may have occurred during periods of strong upwelling in the east Pacific waters off Panama, when associated currents moving south and west passed through the Galapagos (Abbott, 1966). Such a migration path is rare and probably of short duration, as suggested by the small percentage of Panamic marine mollusks living among the largely endemic fauna in the Galapagos (James, 1984). Growth of the eastern volcanic islands of the Galapagos to shallow depths provided an oceanic refuge at the time the ancestral taxon was dispersing in that direction.

PALEOGEOGRAPHY OF THE TERTIARY CARIBBEAN PROVINCE

The Tertiary Caribbean Province was recognized by Woodring (1966) as an extensive tropical sea extending between the present Caribbean and the eastern Pacific from the Eocene until the middle Pliocene, when the Isthmus of Panama rose above sea level. Western limits of the province now include southern Baja California and Tertiary marine basins in Guerrero and Michoacan, western Mexico (Durham and others, 1981; Perrilliat, 1981, 1987; Smith, in press). Southern limits may also be modified because of exotic occurrences of Tertiary Caribbean taxa in Patagonia (Smith and Zinsmeister, 1982).

Six Miocene subprovinces were recognized on the basis of molluscan genera and subgenera (Woodring, 1974): Mexican, West Indian, Central American to northern South America, Colombian-Venezuelan-Trinidad, Brasilian, and Ecuadorian-Peruvian. Different subdivisions were discussed by Petuch (1982): the Caloosahatchian for the southern Atlantic and Gulf Coastal Plains and the Gulf of Mexico, the Gatunian Province for the present Caribbean and Pacific-Panamic areas. Refinements of these ideas and subdivisions based on various invertebrate groups are discussed by Jones and Hasson (1985). A Miocene Atlantic-Pacific Province is preferred by Perrilliat (1981, 1987) to reflect the fauna of the Miocene Ferrotepec Formation of southwestern Michoacan, Mexico. Some of the younger Lyropectens and Nodipectens are restricted to these subdivisions, but late Miocene and older taxa range across provincial boundaries.

The Tertiary Caribbean faunal province, as defined by *Lyropecten* and *Nodipecten*, is shown in figure 3. The



EXPLANATION

Tertiary Caribbean province faunas—Dashed where approximate; queried where uncertain

Central American seaways modified from Woodring (1966)

LMB La Mira Basin, Michoacan, Mexico (Durham and others, 1981; Perrilliat, 1981, 1987)

Tertiary Caribbean cognates
(not necessarily the same age at all localities)

Pacific	Gulf of Mexico and Caribbean
△ *Nodipecten veatchii*	▲ *Nodipecten peedeensis*
■ *Nodipecten subnodosus*	□ *Nodipecten fragosus*
● *Nodipecten arthriticus*[1]	★ *Nodipecten nodosus*[2]
★ *Nodipecten nodosus*	○ *Nodipecten collierensis*
☆ *Lyropecten tiburonensis*, n. sp.	◐ *Lyropecten colinensis, s.l.*

[1] Also from Miocene at Valle Hermosa, Argentina (Smith and Zinsmeister, 1982).
[2] Late Miocene in the Pacific, Pliocene to Holocene in the Caribbean.

A	Acapulco, Guerrero
BT	Bahía Tortugas
CH	Cape Hatteras, North Carolina
CI	Catalina Island, California
E	Esmeraldas, Ecuador
G	Guayaquil, Ecuador
IC	Isla Cedros
IT	Isla Tiburón
L	Loreto
Li	Limón, Costa Rica
LMB	La Mira Basin, Mexico
LP	La Purisima and San Isidro
MB	Madden Basin, Panama
NCI	Northern Channel Islands, California: Santa Cruz, Santa Rosa
SGP	San Gorgonio Pass, California
SR	Santa Rosalía
SRV	Santa Rosa area, Veracruz, Mexico
ST	Salton Trough, California
T	Trinidad, B.W.I.
TB	Tubará area, Colombia
YC	Yucatan Channel

FIGURE 3.—The Tertiary Caribbean province and distribution of species of *Lyropecten* and *Nodipecten*. No correction for plate-tectonic movement.

northeastern boundary of the Tertiary Caribbean Province includes southern Florida, based on occurrences of *Nodipecten collierensis* there and in northern Venezuela. Neogene marine deposits of the southern Atlantic Coastal Plain as far north as Lake Waccamaw, North Carolina contain sparse records of *N. collierensis* and *N. peedeensis*, but this area, in part the Caloosahatchian Province of Petuch (1982), is considered peripheral to the main Tertiary Caribbean Province. The northwestern part of the province includes Tertiary marine basins from Michoacan to Oaxaca and southern Baja California Sur, Mexico; the relation of the northern Gulf of California and Salton Trough is under investigation.

PALEOCURRENTS IN THE TERTIARY CARIBBEAN SEA

Western Atlantic current systems have been generally the same since the Miocene (Berggren and Hollister, 1974), when one major component flowed east to west through Central American seaways and another deflected north along the east Mexican highlands as the Gulf Stream does today. Uplift of the Greater Antilles arc and the Panamanian land barrier changed the configuration of the larger Tertiary Caribbean basin but probably had little effect on the overall sense of major surface currents.

In the tropical eastern Pacific, pectinid distributions do not fit present or inferred late Cenozoic surface current patterns. As in the western Atlantic, current directions and amounts and variability of seasonal upwelling are probably largely unchanged since the Miocene. Observed fossil distributions are believed to reflect short-term circulation changes such as El Niño/Southern Oscillation phenomena, in some cases modified by tectonic events such as uplift of barriers or movement of tectonic microplates within faunal provinces.

CENTRAL AMERICAN SEAWAYS

In the absence of large-scale regional geologic maps, the Central American seaways are generally shown schematically as east-west straits aligned with the North Atlantic Equatorial Current. Their original locations may be obscured by considerable middle to late Cenozoic tectonic changes in the area (Case and Holcomb, 1980). Despite his exhaustive studies of Canal Zone mollusks, Woodring (1957-1982) noted that we do not know when or by what routes many species moved between the Pacific and western Atlantic sides of the Tertiary Caribbean Province. Neither *Nodipecten nodosus* nor *N. veatchii*, Tertiary Caribbean Nodipectens found in Baja California Sur, Mexico, is known from the Canal Zone fauna, although penecontemporaneous Lyropectens are found there.

Possible seaways cited by Woodring (1966) include the southern Nicaraguan depression and passages through central Costa Rica and central Panama. The Atrato Strait or Bolivar Trough of western Colombia, Ecuador and northern Peru was wider and may have remained open a long time. Although the fauna of the Atrato Strait has yet to be collected and studied in detail, the connection is indicated by "practically identical middle Miocene" (*sensu* Woodring, 1966) invertebrates from the Caribbean and Pacific coasts of Colombia. Geographic considerations to the contrary, there is no geological or faunal evidence of a seaway through the Gulf of Tehuantepec (Durham and others, 1955).

FINAL CLOSURE OF THE CENTRAL AMERICAN SEAWAYS

Separation of the eastern and western parts of the Tertiary Caribbean sea was complete by 3.5 to 3.1 m.y. ago, according to data from foraminifers (Saito, 1976; Keigwin, 1978), terrestrial vertebrates (Webb, 1978; Repenning and Tedford, 1977) and sedimentary studies (Mullins and Neumann, 1979). Closure may not have been accomplished by simple uplift of the area, as the Isthmus of Panama and adjacent areas are within a zone of deformation involved in faulting and east-west shortening in the area of convergence of the Nazca, Caribbean and South American plates (Pennington, 1981).

An important earlier shoaling in the middle Miocene is suggested by sedimentary and erosional records resulting from the origin of an accelerated Gulf Stream deflected northward from the South Equatorial Current (Mullins and Neumann, 1979) and supported by the presence of terrestrial vertebrates of North American affinities in Panama during the Miocene (Whitmore and Stewart, 1965). The Tertiary Caribbean Lyropectens and Nodipectens contribute little information on the age of final uplift of the Isthmus of Panama; their fossil records are scarce in the area of interchange and restricted to the Madden Basin. Holocene Nodipectens can live in shallow lagoons and their dispersal is less affected by shoaling than that of deeper water organisms.

PALEOBIOGEOGRAPHY OF TERTIARY CARIBBEAN COGNATES

Cognates are related taxa that are also called homologues if a close phylogenetic connection is documented. Many West Mexican and Caribbean forms are homologues, having descended from a common Tertiary Caribbean species, and their distributions and age ranges help to solve paleogeographic and biostratigraphic problems. Cognates commonly go unrecognized because regional specialists are rarely familiar with both living and fossil, Atlantic and Pacific organisms and the literature on them. Woodring (1966) compiled a list of cognate molluscan genera and Vermeij (1978) tabulated 279 pairs of Holocene molluscan species and subspecies; both references are points of departure for further detailed studies. This

investigation of *Nodipecten* and *Lyropecten* indicates that distributional details for species and subspecies highlight significant information that is masked by generic distributions; similar improved resolution is expected for other species pairs.

Of the three *Lyropecten* and *Nodipecten* cognate pairs known to have traversed Central America and northern South America, all seem to have crossed before the late Miocene or earliest Pliocene. Fossil records are insufficient for determining dispersal directions, although *Nodipecten* may have originated in the Pacific part of the Tertiary Caribbean Province and the oldest Lyropectens are from west Mexico and California. Only one pair, *Lyropecten colinensis colinensis* and *L. colinensis vokesae*, n. subsp., is represented in Panama, in the Alhajuela Formation, and all sets of cognates had reached the extreme ends of the Tertiary Caribbean Province by the early Pliocene, well before the final closure of the Central American seaways.

Although pectinid cognates are not found throughout the Tertiary Caribbean Province, they serve to correlate particular areas within it. *Lyropecten colinensis vokesae*, n. subsp. is found in the Gurabo and Cercado Formations of the Dominican Republic; *L. colinensis colinensis* is restricted to Venezuela, the Eastern Antilles and the lower member of the Alhajuela Formation of Panama. *Nodipecten veatchii* from the late Miocene of the Vizcaino Peninsula, Baja California Sur, corresponds to *N. peedeensis* from the Pliocene of the southern Atlantic Coastal Plain. *Nodipecten nodosus*, Pliocene to Holocene in the Paraguana Peninsula of Venezuela, is the closest relative of *N. subnodosus*, middle Pliocene to Holocene of the Gulf of California, a relation documented by the occurrence of *N. nodosus* in the upper Miocene Boleo Formation at Santa Rosalia, Baja California Sur. Should other species pairs have similar distributions, these data could have important paleogeographic implications for relating faunal provinces and tectonic terranes. Additional information can be expected from megafossiliferous Tertiary marine units from the Yucatan Peninsula (Butterlin, 1977) and numerous other known but unstudied invertebrate localities in the Tertiary Caribbean Province.

FAUNAL PROVINCES AND TECTONIC TERRANES

From the discussion of plate tectonic theory by Atwater (1970) until the discovery of marine Tertiary fossils in west Mexico (Durham and others, 1981; Perrilliat, 1981, 1987), the absence of an eastern Pacific Tertiary marine record north of Panama was explained by subduction beneath the Middle American Trench. Rapidly accumulating fossil and seismic data will require some years for thorough study and synthesis, but it is already clear that plates and microplates have moved far in the relatively recent past and that not all the records have been lost through subduction. Plate movements in the eastern Pacific and Caribbean require that paleontologists consider fossil assemblages not only as biocoenoses, thanatacoenoses, or reworked deposits but also as pieces of the geologic record preserved in tectonostratigraphic terranes that have been carried along by plate translation (Durham, 1985).

The relation between middle Tertiary to Holocene pectinid distributions and plate motion is complicated by the preliminary state of our knowledge of tectonic terranes, which may include plates, microplates, or flakes, many of whose boundaries are obscured. Rates of sea-floor spreading near the mouth of the Gulf of California, one of the cognate species boundaries, averages 6 cm per year (Drummond, 1981); this rate is very small compared to the rate of dispersal of planktonic larvae or free-swimming adult Pectens. Latitudinal displacement along faults combined with plate motion is more significant than plate movement alone, although total displacement is likely to fall within the geographic range of a particular taxon. For example, at the mouth of the Gulf of California, plate motion has moved the Baja California Peninsula 250 km away from the west Mexican mainland in the past 4-5 million years (Moore and Buffington, 1968), concurrent with *Nodipecten* speciation in that area. Such movement may partly explain anomalous distributions for which evidence of seaways or other avenues of dispersal is absent.

This section is a preliminary attempt to relate middle to late Cenozoic faunal distributions to tectonostratigraphic terranes, which are in the early stages of recognition. When details of stratigraphic and tectonic settings are known, the fossils will date the events and correlate terranes.

PACIFIC-PANAMIC AND CARIBBEAN *LYROPECTEN* AND *NODIPECTEN* OCCURRENCES AND TECTONIC PLATE BOUNDARIES

The locations of 22 taxa are plotted on a plate tectonic map (fig. 4). Most taxa are provincially restricted, but several are cognate pairs that dispersed to the extremes of the Tertiary Caribbean Province across present plate boundaries. Most are confined to shallow basins along the edges of continents or islands developed on folded Mesozoic rocks of the Caribbean within plate boundaries marked by major faults.

Several taxa have somewhat anomalous distributions that could have been affected significantly by plate movements. Further investigation of the distributions of these forms within their regional stratigraphic and tectonic settings will determine whether their faunal boundaries are merely coincidental with plate margins or related to translated or rotated blocks. A representative taxon for each region is cited in table 3. Within provincial areas,

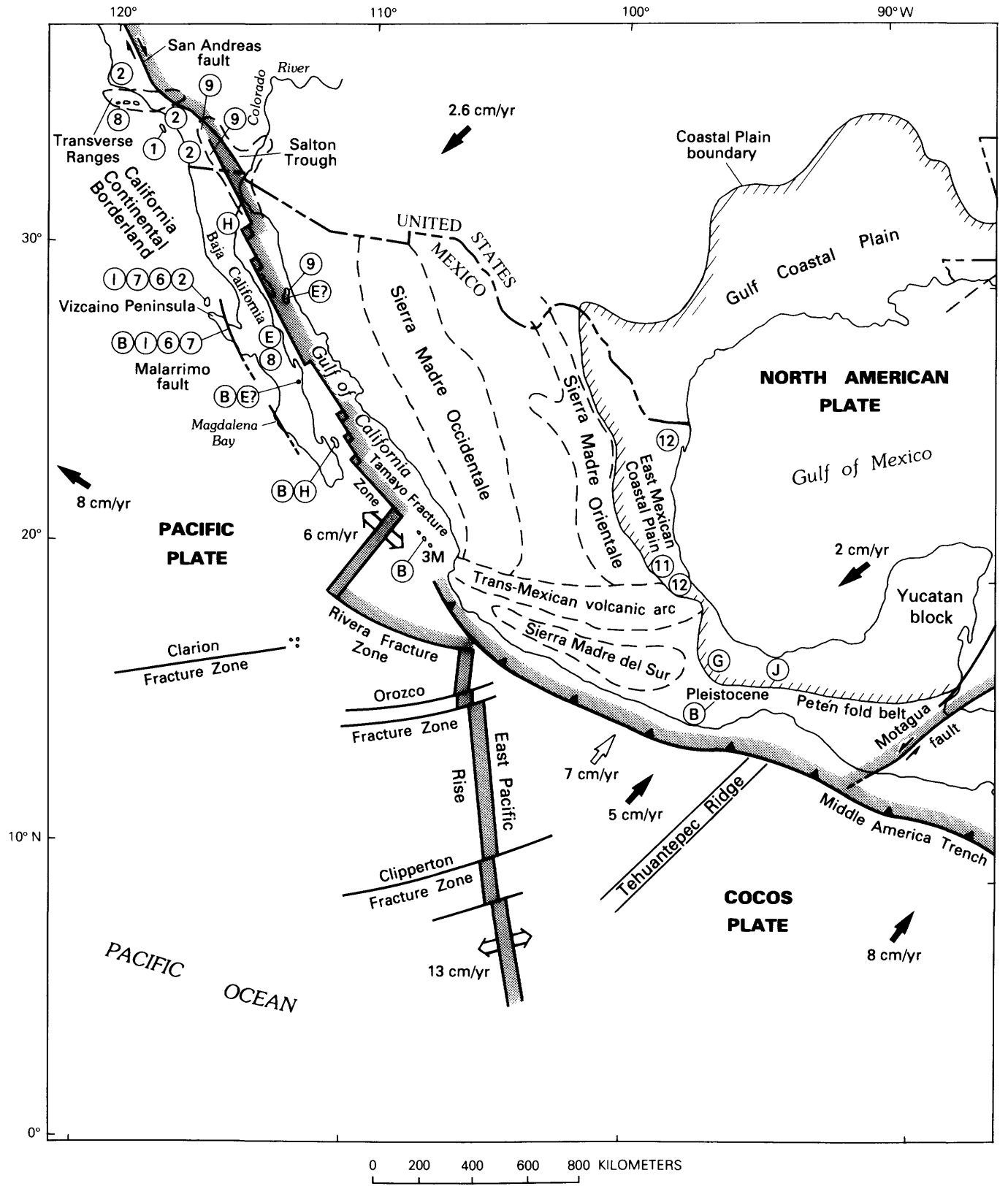


FIGURE 4.—Tertiary Lyropectens and Nodipectens from the Pacific-Panamic and Caribbean areas in relation to plate tectonic boundaries.

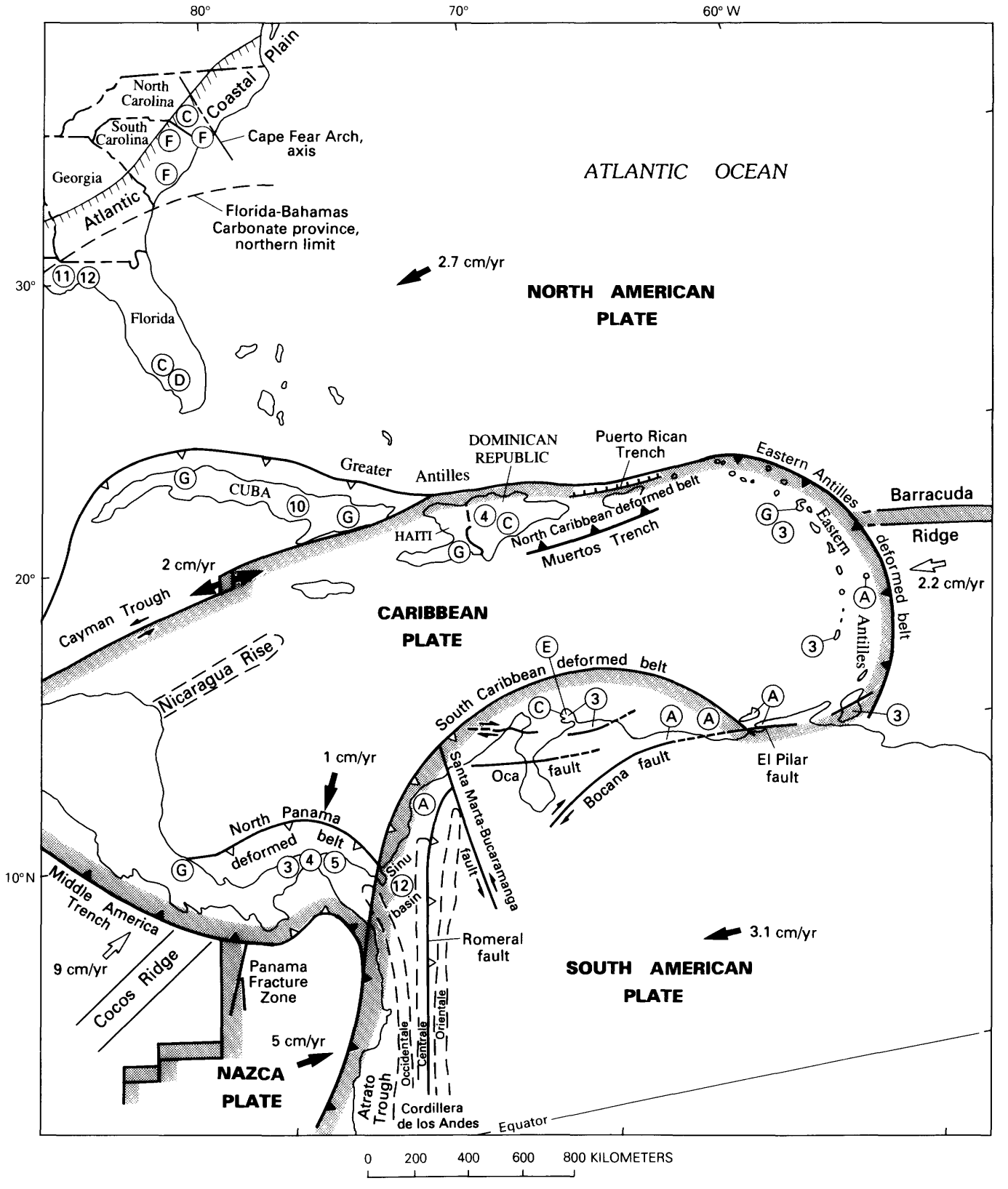


FIGURE 4.—Continued.

EXPLANATION

Active subduction zone—Sawteeth on upper plate

Thrust fault—Sawteeth on upper plate

Active transform fault—Dashed where approximately located. Arrows indicate direction of relative movement

Plate movement—Arrows indicate relative direction, number indicates movement in centimeters per year. Data from Drummond (1981)

Spreading ridge, diverging plate boundary

Absolute plate motion

Converging plate boundary; subduction rate

Plate boundaries (modified after Mattson, 1984)

Approximate boundary of selected mountain ranges, troughs, or terranes of significance in locating Tertiary marine fossils

3M Tres Marias Islands

① *Lyropecten* occurrence (numbers)

Ⓐ *Nodipecten* occurrence (letters)

Symbol	Lyropectens	Age	Tectonic setting
①	*Lyropecten catalinae*	Middle Miocene	Pacific plate, California Continental Borderland; related to Vizcaino species
②	*L. cerrosensis*	Early Pliocene	Pacific plate and Vizcaino Peninsula, in shallow basins
③	*L. colinensis colinensis*	Early Miocene to late middle Miocene	South Caribbean terrane and Eastern Antilles; North Panama deformed belt
④	*L. colinensis vokesae*, n. subsp.	Late Miocene to early Pliocene	Caribbean plate, Hispaniola terrane; North Panama deformed belt
⑤	*L. denaius*	Miocene	North Panama deformed belt
⑥	*L. gallegosi*	Late Miocene	Vizcaino Peninsula
⑦	*L. modulatus*	Late Miocene	Vizcaino Peninsula
⑧	*L. pretiosus*	Late Oligocene to early Miocene	La Purisima, Baja California; western Transverse Ranges, northern Channel Islands
⑨	*L. tiburonensis*, n. sp.	Late middle Miocene to early late Miocene	Gulf of California, Isla Tiburón and Salton Trough, California
⑩	*"L." articulosus*	Oligocene	Greater Antilles deformed belt; Cuba
⑪	*"L." condylomatus*	Early to middle Miocene	North American plate, southern Atlantic Coastal Plain and east Mexican Coastal Plain, Coahuila terrane
⑫	*"L." dumblei*	Late Oligocene to early Miocene	South Caribbean terrane; east Mexican Coastal Plain, Coahuila terrane; Baja California?

Symbol	Nodipectens	Age	Tectonic setting
Ⓐ	*N. arnoldi*	Late Pliocene to Pleistocene	South Caribbean terrane; southern Eastern Antilles
Ⓑ	*N. arthriticus*	Late Miocene to Holocene	Vizcaino terrane; Loreto and Isla Cerralvo, Gulf of California; terraces in Oaxaca, Ecuador, Peru; San Jorge Basin, Argentina
Ⓒ	*N. collierensis*	Late Miocene to early Pliocene	South Caribbean terrane; North American plate, South Atlantic Coastal Plain; descendant lives in Gulf of California
Ⓓ	*N. fragosus*	Late Miocene or early Pliocene to Holocene	North American plate, south Atlantic Coastal Plain
Ⓔ	*N. nodosus*	Late Miocene to Holocene	South Caribbean terrane; eastern Baja California
Ⓕ	*N. peedeensis*	Miocene(?), Pliocene, and Pleistocene(?)	North American plate, southeast Atlantic Coastal Plain
Ⓖ	*N. pittieri*	Miocene to Pliocene	North American plate, Petén and Greater Antilles fold belts; Caribbean plate, Hispaniola terrane; north Eastern Antilles
Ⓗ	*N. subnodosus*	Middle Pliocene to Holocene	Pacific plate, Gulf of California
Ⓘ	*N. veatchii*	Late Miocene	Vizcaino Peninsula
Ⓙ	*N. veracruzensis*, n. sp.	Middle Pliocene	Yucatan block, Maya terrane

FIGURE 4.—Continued.

TABLE 3.—*Geographic distributions of* Nodipecten *and* Lyropecten *taxa possibly related to plate tectonic movement*

Taxa	Age	Region	Tectonic events in area concurrent with speciation
N. arthriticus	Late Miocene to Holocene	Near Loreto, Isla Cerralvo, and Islas Tres Marias, Mexico (Pliocene); Oaxaca terraces (Pleistocene); Islas Tres Marias to Peru (Holocene); Vizcaino Peninsula (upper Miocene); Patagonia (middle or upper Miocene)	Tres Marias Islands lie at junction of East Pacific Rise and Middle America Trench; dispersal was concurrent with (1) opening of mouth of the Gulf of California (Karig and others, 1978), and (2) northward translation of Baja California Peninsula, possibly in slivers (Crouch, 1979; Beck and Plumley, 1979).
N. veatchii, cognate of Atlantic Coastal Plain species N. peedeensis; L. gallegosi and L. modulatus, endemic Vizcaino taxa	Late Miocene	Isla Cedros; Vizcaino Peninsula	Paleomagnetic data imply more than 1,000 km of northward translation (9° lateral displacement, 24° clockwise rotation) between late Cretaceous and early Oligocene; since then Baja California peninsula has undergone only only 250 km of translation (approx. 2° latitudinal displacement and 8° clockwise rotation) in rifting away from mainland Mexico (Hagstrum and others, 1985, 1987).
L. colinensis vokesae, n. subsp.	Late Miocene or Pliocene	Panama and Dominican Republic	Deformation of belts of rock in Dominican Republic and Panama (Moore and Buffington, 1968).
L. denalus	Miocene	Panama, La Boca Formation; eastern Costa Rica; North Panama deformed belt	Interaction of Nazca, South American, and Caribbean plates; formation of eastern Panama Basin (Case and others, 1984; Pennington, 1981).
L. pretiosus (including L. submiguelensis of authors)	Late Oligocene to early Miocene	Central Baja California Sur, Mexico, La Purisima area; northern Channel Islands, California	Pacific plate movement northwestward as much as 3,800 km since the Eocene in the California Continental Borderland, including clockwise rotation of Transverse Ranges in southern California, according to paleomagnetic data (Champion and others, 1981; Kamerling and Luyendyk, 1981; Crouch, 1979).
L. magnificus	Late Miocene or early Pliocene to Holocene	Santa Cruz Island, Galapagos	Santa Cruz Island, one of the oldest, easternmost islands of the Galapagos, was 200 km farther north and west of its present position in middle Pliocene (Cox, 1983). Sea-floor spreading south of the Galapagos Rift and eastward plate motion at 5 cm/yr brought Galapagos within dispersal path of L. magnificus.
Lyropecten sp. cf. L. magnificus	Early to early middle Miocene	La Purisima and Arroyo Patrocinio, Baja California Sur, Mexico; Wheeler Springs quadrangle, Calif.(?)	Northward translation of Baja California (Hagstrum and others (1985, 1987) and displacement along faults of the California Continental Borderland. Specimens from Transverse Ranges (LSJU loc. 2170) may represent this taxon.
"L." dumblei	Oligocene	Gulf Coastal Plain of east Mexico and northwest Florida; Sinu Basin, Colombia, South Caribbean deformed belt. Baja California Sur, Mexico(?)	Gulf Coastal Plain of east Mexico and northwest Florida is relatively undisturbed, but Sinu Basin is a deformed belt being affected by movement of Caribbean plate (Case and Holcomb, 1980) and by Nazca plate being thrust under South American plate between Panamanian-Colombian border and southern Ecuador (Pennington, 1981).

tectonic events have taken place concurrently with speciation and dispersal. In some cases Holocene species boundaries coincide with plate boundaries, with no apparent environmental restrictions to prevent the species from migrating from one terrane to another. Tectonic events are also given, with references to papers providing structural or paleomagnetic data relating to plate motion.

As relations between tectonic terranes and faunal provinces become clearer, paleontological data should be useful for dating or constricting events and tracing paleogeographic history. A recent study in the Gulf of California, for example, related molluscan distributions to associated radiometrically dated volcanic rocks (Smith, in press). Data showed that an early gulf similar in extent to the present one existed as early as 13 Ma (Smith and others, 1985), several million years prior to the tectonic "proto-gulf" attributed to late Neogene extensional tectonics and sea-floor spreading (Larson, 1972; Hagstrum and others, 1987). Faunas from Isla Tiburon, Sonora, San Felipe, Baja California, and the northern Salton Trough represent beach to deep water taxa of late middle and late Miocene age (Smith, in press; Boehm and Ingle, 1981; Kristin McDougall, unpublished data, 1987) and Caribbean and Pacific-Panamic affinities (Vaughan, 1917, Hanna, 1926, and others). These taxa underwent speciation and dispersal both before and during the time the boundary between the North American and Pacific plates changed from west of the Baja California peninsula to the Gulf of California.

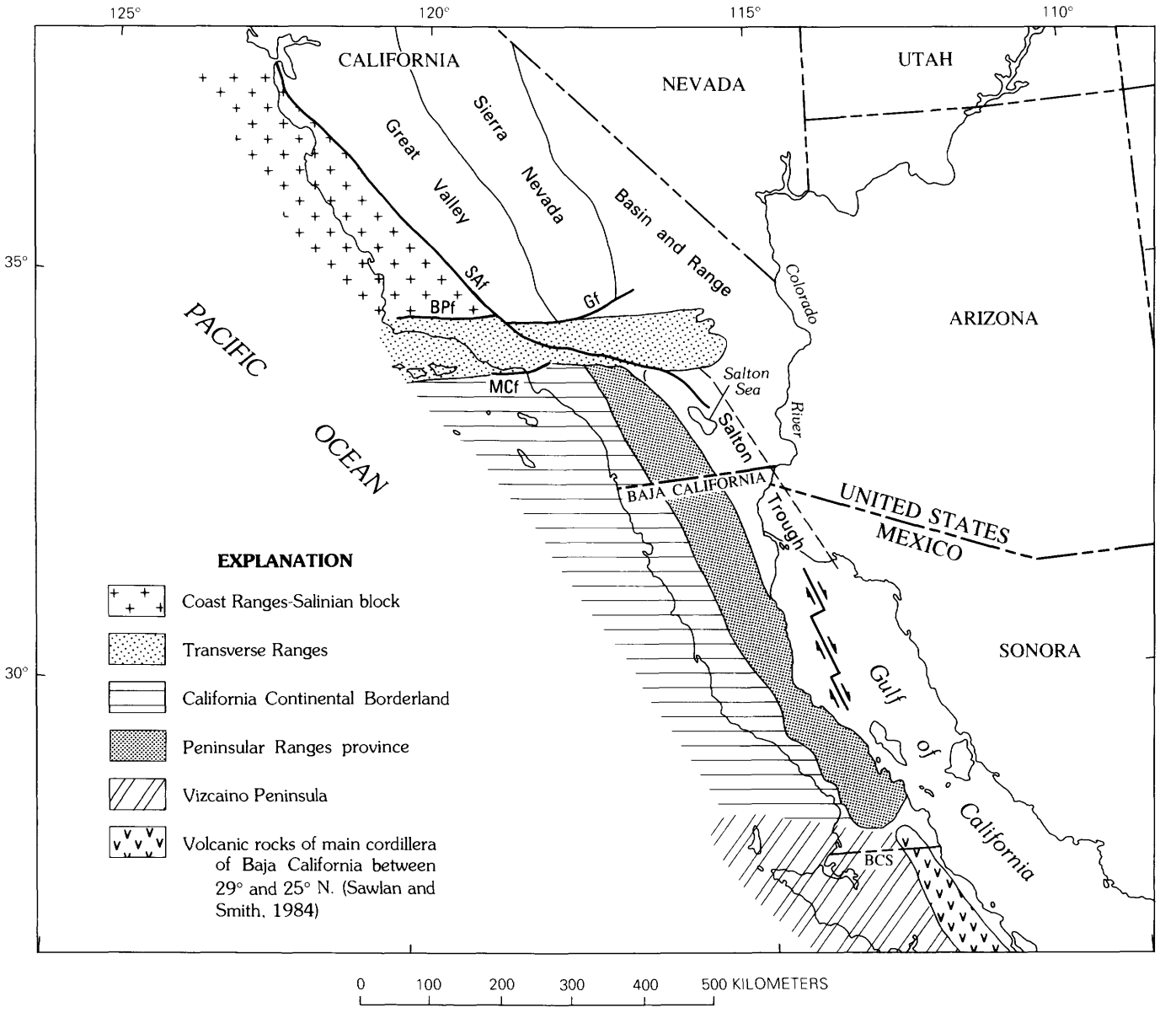


FIGURE 5.—Major provinces of California and northern Baja California. SAf, San Andreas fault; Gf, Garlock fault; MCf, Malibu Coast fault; BPf, Big Pine fault. En echelon faults in the Gulf of California shown schematically. Sources of map data: Case and Holcomb (1980); Case and others (1984); Mattson (1984); Howell and others (1983); Dickinson and Coney (1980); Moore and Buffington (1968); Karig and others (1978); Drummond (1981). Plate-tectonic map of Circum-Pacific region, northeast quadrant, scale 1:10,000,000.

Tertiary Pectens and other mollusks also divide the Baja California Peninsula longitudinally and suggest three subprovinces: the islands and margins of the Gulf, the area west of the Sierra La Giganta, and the Vizcaino Peninsula (see figure 6).

TERTIARY PECTINID DISTRIBUTIONS AND TECTONIC TERRANES IN CALIFORNIA

Since the time that the concept of suspect terranes was applied in California (Coney, and others, 1980), mainly pre-Tertiary faunal distributions have been considered with respect to tectonic plates and microplates. Earlier paleogeographic reconstructions used molluscan assemblages to match shorelines and measure cumulative amounts of offset since the Oligocene along the San Andreas fault (Addicott, 1968). Regional mapping and new paleomagnetic and tectonic data suggest that within the Pacific and North American plates in California there are smaller suspect terranes that need to be reinvestigated. As we learn how recent some large-scale plate movement has been, along with possible slivering,

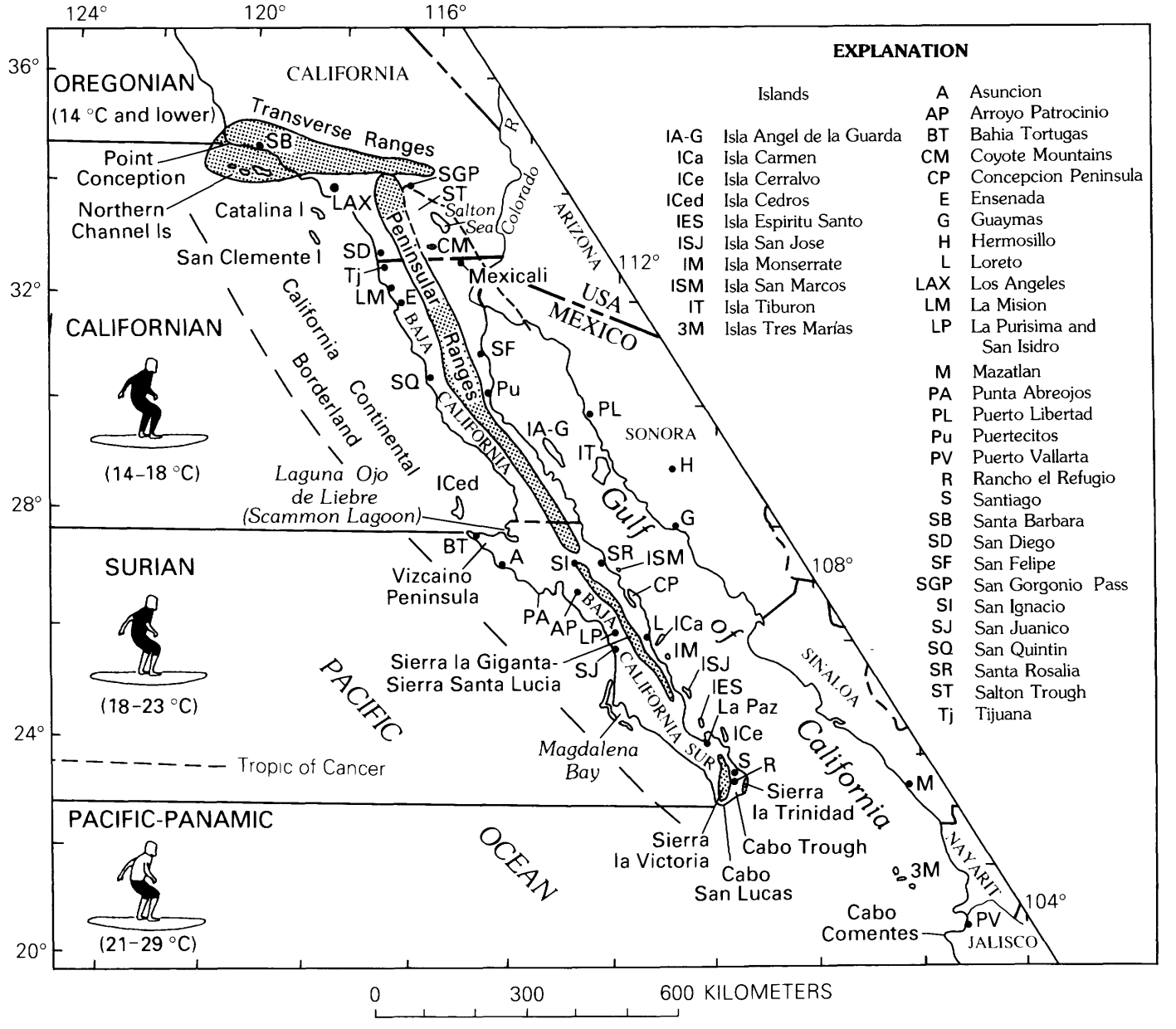


FIGURE 6.—West Mexican and California Continental Borderland localities and molluscan provinces of the eastern North Pacific Ocean. Modern shallow-water molluscan provinces and mean temperatures after Addicott (1970a).

splintering, and rotation of blocks, it becomes clear that geographically restricted Tertiary fossils are important clues to the origins and affinities of young suspect terranes. Major structural blocks of California and Baja California are shown in figure 5; certain pectinids and other index fossils from these blocks may have paleogeographic significance.

Studies such as this one identify species from exotic provinces and those whose distributions are not easily explained by continuous embayments between northern and southern California and southern Baja California Sur, Mexico. These taxa focus attention on suspect areas that can be expected to yield further data from other disciplines of geology.

California Lyropectens are potentially most useful for identifying suspect terranes in these areas: the California Continental Borderland, especially Oligocene to lower and middle Miocene strata, and the Transverse Ranges (figure 6).

"Macrochlamis" magnolia [= *Pecten magnolia* of many workers] has Mediterranean Tethyan affinities and first appears on the Pacific coast of North America in the middle Oligocene part of the Vaqueros Formation. The middle Oligocene form, *"M." magnolia magnolia*, is found

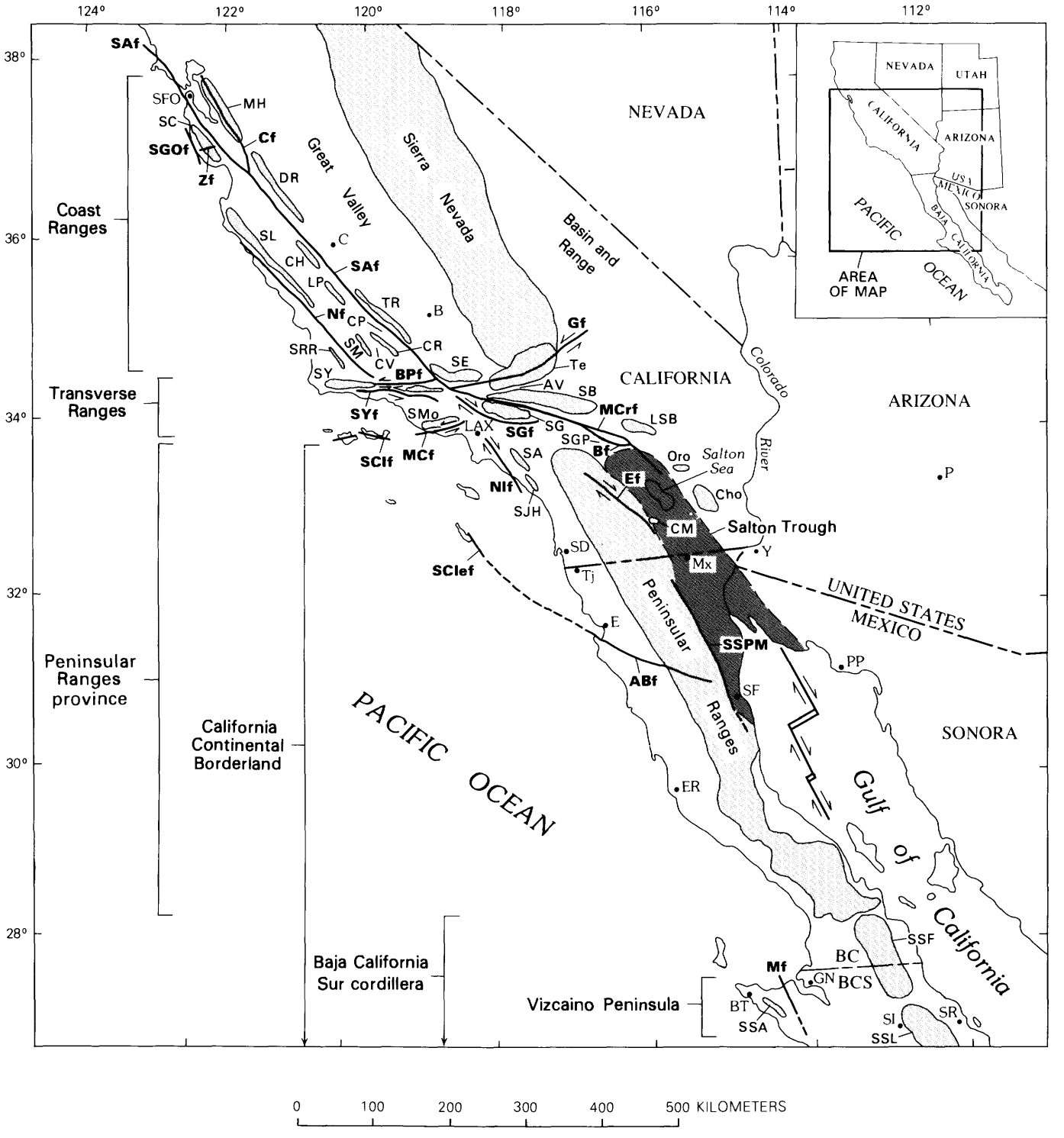


FIGURE 7.—Mountain ranges, faults, and provinces in California and Baja California relating to significant pectinid localities.

only on the present Pacific plate, in the southern Coast Ranges, La Panza Range, Caliente-Cuyama area, the Transverse Ranges, and the Santa Ana Mountains. The late Oligocene to early Miocene subspecies, "*M.*" *magnolia ojaiensis*, is found on both sides of the San Andreas fault, in the Pigeon Point block of the Santa Cruz Mountains, the Temblor and San Emigdio Ranges, Pyramid Hill area of Kern County, and the eastern Ventura Bay of Loel and Corey (1932). Intermediate forms are known from the Nipomo-Huasna Basin, northern side of the Santa Ynez Range, western Santa Susana Mountains, and the La Honda block of the Santa Cruz Mountains.

EXPLANATION

Faults—Dashed where inferred. Arrows indicate relative direction of movement. Note: spreading centers shown by parallel lines attached to fault; en echelon faults in the Gulf of California shown schematically

SAf, San Andreas; **Zf**, Zayante; **Cf**, Calaveras; **SGOf**, San Gregorio; **Nf**, Nacimiento; **BPf**, Big Pine; **SYf**, Santa Ynez; **Gf**, Garlock; **SGf**, San Gabriel; **SCIf**, Santa Cruz Island; **MCf**, Malibu Coast; **MCrf**, Mission Creek; **Bf**, Banning; **NIf**, Newport-Inglewood; **Ef**, Elsinore; **SCIef**, San Clemente Island; **ABf**, Agua Blanca; **SSPM**, east front of the Sierra San Pedro Martir; **Mf**, Malarrimo

Valleys—CV, Cuyama Valley; CP, Carrizo Plain; AV, Antelope Valley; SGP, San Gorgonio Pass

•SD Cities—SFO, San Francisco; C, Coalinga; B, Bakersfield; LAX, Los Angeles; SD, San Diego; Y, Yuma; P, Phoenix; Tj, Tijuana; Mx, Mexicali; E, Ensenada; SF, San Felipe; PP, Puerto Penasco; ER, El Rosario; BT, Bahia Tortugas; GN, Guerrero Negro; SI, San Ignacio; SR, Santa Rosalia

Mountains

West of San Andreas fault, north to south:

Coast Ranges

SC, Santa Cruz Mtns; SL, Santa Lucia Range; CH, Cholame Hills; LP, La Panza Range; CR, Caliente Range; SM, Sierra Madre Mtns; SRR, San Rafael Range

Transverse Ranges

SY, Santa Ynez Range; SMo, Santa Monica Mtns; SG, San Gabriel Mtns

California Continental Borderland

SA, Santa Ana Mtns, Puente Hills; SJH, San Joaquin Hills

Peninsular Range province

CM, Coyote Mtns

Baja California Sur cordillera

SSF, Sierra San Francisco; SSL, Sierra Santa Lucia

Vizcaino Peninsula

SSA, Sierra de San Andres

East of San Andreas fault, north to south

MH, Mount Hamilton Range; DR, Diablo Range; TR, Temblor Range; SE, San Emigdio Range; Te, Tehachapi Mtns; SB, San Bernardino Mtns; LSB, Little San Bernardino Mtns; Oro, Orocopia Mtns; Cho, Chocolate Mtns

Other—BC, Baja California; BCS, Baja California Sur

FIGURE 7.—Continued.

Many *Lyropecten* index species—*L. crassicardo, L. estrellanus, L. miguelensis,* and *L. terminus*—are endemic California taxa of biostratigraphic and chronostratigraphic significance (fig. 1). They are widespread and belong to species or phylogenetic series that lived and evolved in California during time intervals of 2 to 7 m.y. They are useful as index fossils for provincial correlation, not potential indicators of far-moving suspect terranes. Plate or microplate translation is suggested by such exotic species with Vizcaino affinities as *L. catalinae* and *L. pretiosus* [= *L. submiguelensis* auctt.]. *L. catalinae* from the Modelo Formation of the eastern Ventura basin and from Catalina Island is closely related to, or possibly the same as, *L. gallegosi* from the upper Miocene Almejas Formation of western Baja California Sur. *Lyropecten pretiosus* from the northern Channel Islands is a late Oligocene or early Miocene index fossil in the La Purisima area of Baja California Sur (Smith, 1984). *Lyropecten crassicardo,* a late Miocene, shallow-water California species, is present on San Miguel Island, westernmost of the Channel Islands; closer to the mainland, on southwest Santa Cruz Island, the west Mexican *L. pretiosus* has been collected from a diorite breccia facies of the Vaqueros Formation which interfingers with a younger sandstone facies bearing the California endemic taxon *L. miguelensis.*

Other areas where pectinid distributional data may be anomalous include the block between the Santa Ynez fault and the Santa Ynez River, the Cuyama Valley and Caliente Range, and Antelope Valley in the northwestern Mojave desert. Mountain ranges, faults, and provinces in California and Baja California relating to significant pectinid localities are shown in figure 7.

Fossils from the Salton Trough having Caribbean affinities indicate a more extensive Gulf of California in the late middle Miocene to Pliocene (Smith, in press), rather than an exotic terrane. Early Pliocene and younger Lyropectens are restricted to basins and embayments that formed locally; they do not suggest hundreds of kilometers of possible tectonic displacement as do some of the early Miocene fossils.

Considering Tertiary molluscan distributions in California in relation to tectonic setting is very new. Many other mollusks associated with the pectinids—*Turritella, Rapana, Cymia,* and *Solenosteira,* for example—offer similar possibilities for recognizing taxa that are not endemic to California. As in the Caribbean and west Mexico, terranes may have been rotated or translated within the geographic ranges of Tertiary species. Population studies of certain taxa within and between small suspect blocks may contribute useful insights on packages of rocks that were contiguous or more nearly aligned from 40-5 m.y. B.P.

NODIPECTEN LIFE HISTORY AND GROWTH PATTERNS

Living Nodipectens have rarely been observed; most of our suppositions about them are deduced from shell features or taken from studies of other pectinids. Growth

series provide ontogenetic details but do not indicate what factors account for intermittent structures such as constrictions or nodes. Clues are provided in monographs of other pectinids, most of them commercial shellfish. We know that important morphological and ecological differences exist within genera and within species, and that general biological facts cannot be assumed to be true for all pectinids.

Pectinid life history studies have been carried out for, among others, *Pecten [Argopecten] irradians* (Risser, 1901), *Pecten maximus* (Tang, 1941), *Notovola meridionalis* (Fairbridge, 1953), *Placopecten magellanicus* (Merrill and others, 1966; Schick and others, 1988), and *Argopecten gibbus* (Allen and Costello, 1972). Unlike *Nodipecten*, all these scallops are gregarious, congregating in commercially valuable beds. Except for *A. gibbus*, they are cold-water species whose life cycles and growth layers vary seasonally except in deep-water populations. Nodipectens are tropical to warm temperate shallow-water forms whose shells exhibit variable concentric features that could be explained by genetic variation or by ecological changes, except that environmental variations are unlikely in the tropics.

SHELL MORPHOLOGY

LARVAL SHELLS OF *NODIPECTEN SUBNODOSUS* (SOWERBY)

Juveniles as much as 2 cm high have been dredged from 36-64 m in the Gulf of California, but they have not been reported living in shallower water with adults. Comparisons with larval shells of other pectinids suggest that *N. subnodosus* is oviparous, the eggs being released to the sea for external fertilization. Scanning Electron Microscope photographs show the larval shell about 190 μm long, ornamented by concentric growth lines and resembling the prodissoconch of *Argopecten irradians* (T.R. Waller, written commun., 1981).

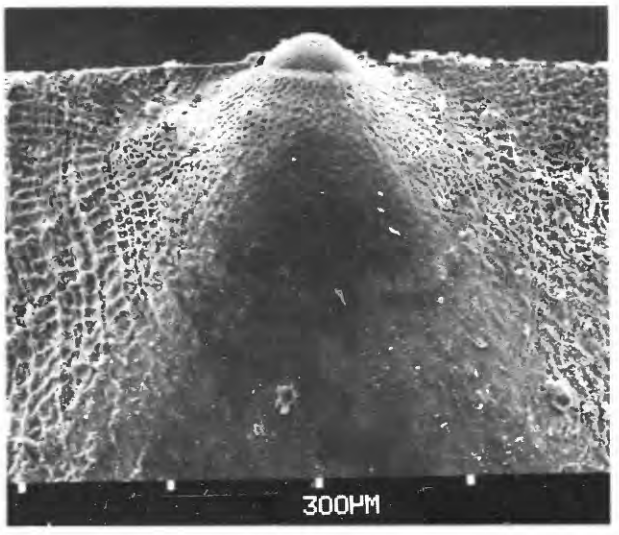
The larval shell has a small Prodissoconch I (length 84 μm) barely set off from the larger Prodissoconch II (185-190 μm), using the terminology of Jablonski and Lutz (1980). These characters, a relatively small Prodissoconch I and a large Prodissoconch II ornamented only by growth lines, distinguish species having a planktonic larval stage. *Argopecten irradians* larvae have shells of comparable size and spend 7-9 days as planktonic larvae (Waller, 1976), a reasonable estimate for the larval life of *N. subnodosus*. After metamorphosis and settling, the young bivalve becomes byssate and the postlarval shell or dissoconch abruptly develops a new surficial macrosculpture (fig. 8*D*,*F*).

In the right valve, the exterior shell layer from the prodissoconch margin to the earliest dissoconch stage is of prismatic calcite, which looks smooth or skinlike, even on the auricles. It changes to foliated calcite early in dissoconch growth, before the appearance of radial ribs and adult macrosculpture (fig. 8*B*,*E*). In contrast. the postlarval macrosculpture on left valves is coarser and irregular (fig. 8*A*,*C*), gradually giving way to the more organized costae and lirae characteristic of adults. This differentiation of shell macrosculpture between right and left valves is nearly universal in the families Pectinidae and Propeamussiidae (Waller, 1972, 1978). European examples were illustrated by Fatton and Bongrain (1980): *Chlamys (Aequipecten) opercularis* (Linnaeus), *Chlamys (C.) varia* (Linnaeus), *Pecten maximus* (Linnaeus), and the fossils *Chlamys (C.) multistriata* (Poli) and *Pecten subarcuatus* Tournouer.

The significance of different sculpture patterns in young Nodipectens is unknown, but from studies of bay scallops Waller (1976) reported that differences in microstructure of right and left valves in *Argopecten irradians* "allow the right valve to flex and nestle within the left during closure."

Studies made using SEM raise many questions beyond the scope of this paper. The two kinds of early juvenile microsculpture on right valves may be from a period of byssate attachment followed by a late juvenile to adult stage in which the animal can either cling by its byssus or recline on the substrate. Early juvenile left valves have only one kind of microsculpture, foliated calcite, in both early and later dissoconchs. In freely reclining adults, the right valve is always toward the substrate and has more uniform ribs than the left valve, which frequently develops nodes or ledges beginning at about 8 cm high. Further study of growth series is needed to relate morphologic

FIGURE 8.—Scanning electron microscope photographs of larval shell microsculpture in *Nodipecten subnodosus* (Sowerby). SEM photographs of a specimen of *Nodipecten subnodosus* (Sowerby), hypotype SDSNH T.S. 31222. The two-valved juvenile was taken live from 20 fms off Isla Carmen, Gulf of California by H.N. Lowe. It measures 8 mm high, 8 mm long; length of Prodissoconch I [PI] is 84 μm, Prodissoconch II [PII] 190 μm, D, dissoconch, eD, early dissoconch. Photographs by Robert Oscarson, U.S. Geological Survey. *A*, Left valve showing prodissoconch orientation with respect to dissoconch and marked change from smooth larval shell to foliated calcite in postlarval shell. *B*, Right valve showing prodissoconch (P). early dissoconch (eD), and later dissoconch (lD) sculpture patterns formed by prismatic calcite and foliated calcite. *C*, Left valve, dorsal view. Prodissoconchs I and II are smooth, in marked contrast to early dissoconch microsculpture. Note that the early dissoconch is foliated calcite in left valves, prismatic calcite in right valves. *D*, Right valve, view of Prodissoconch II and early dissoconch with skinlike microsculpture pattern formed by prismatic calcite. Byssal notch begins abruptly in postlarval stage, probably when animal settles on substrate. *E*, Right valve at lower magnification, showing three microsculptural types: Prodissoconch I and II are smooth, early dissoconch has prismatic calcite, and later dissoconch to adult stages have foliated calcite. Ctenolium is well developed from the beginning of the byssal notch. *F*, Right valve, higher magnification than figure 8*E*, showing how different magnifications emphasize microsculptural difference.



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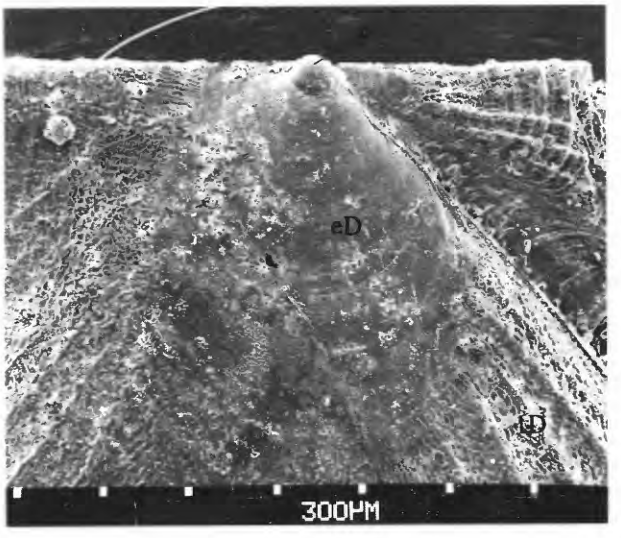

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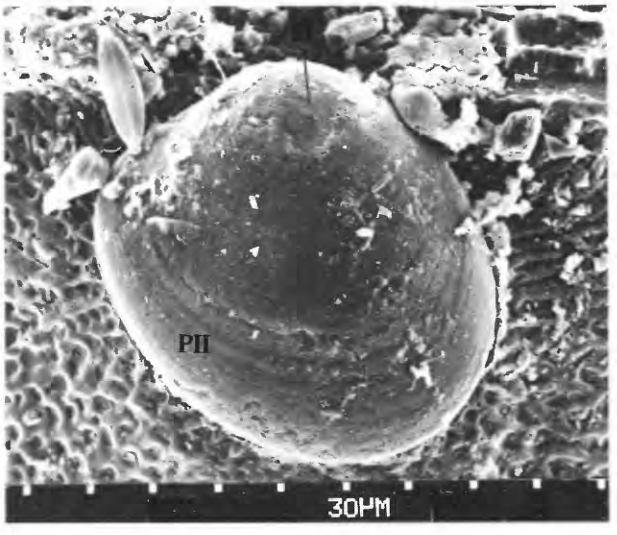

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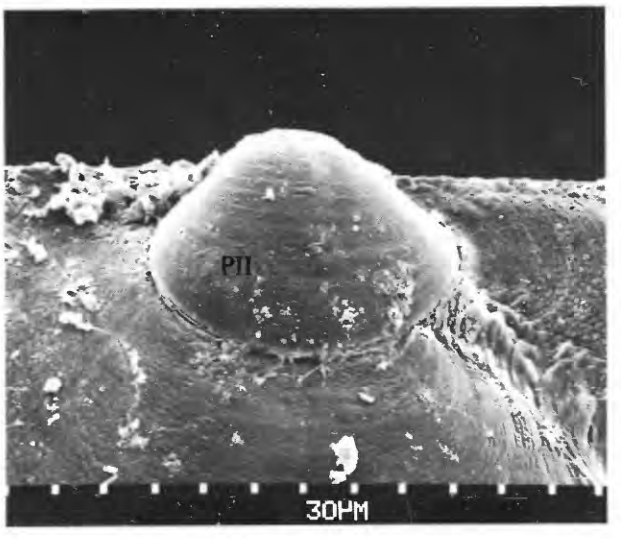

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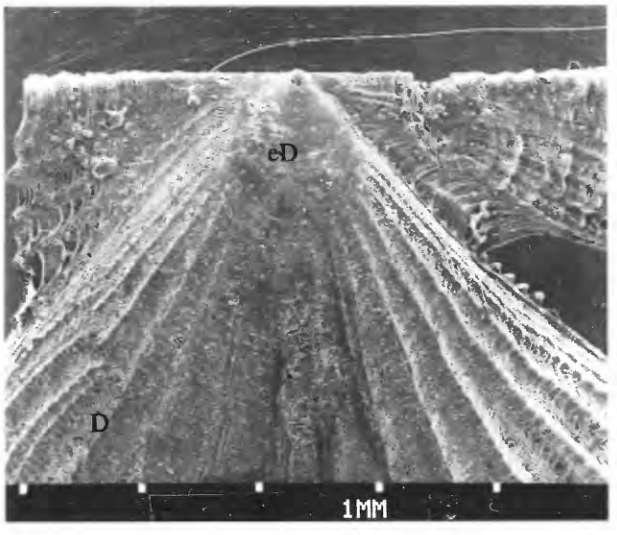

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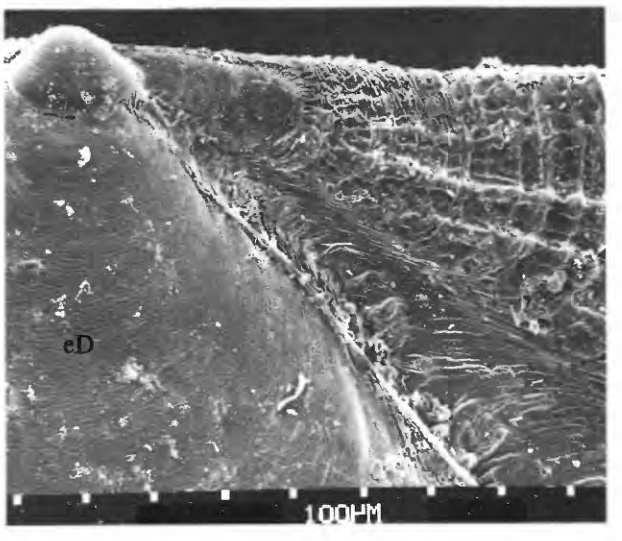

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details to biological events or ecological conditions, and ultimately to dispersal.

POSTLARVAL DEVELOPMENT

Nodipecten left valves commonly have three sets of evenly spaced nodes on alternating ribs when they reach a height of 2.4 cm. Valves may be flat or convex; some have constrictions. Nodes and ledges are more characteristic of shells as much as 8 cm high, although specimens reach more than 16 cm in height. Gerontic individuals may develop reinforcements in the internal hinge area (pl. 2, fig. 2) and their shells may be elongated posteriorly.

The largest living Nodipectens come from shallow lagoons in western Baja California Sur, Mexico. At lengths of 16 cm, they are small compared to fossil Nodipectens and Lyropectens from California and the Caribbean. Inferring from sizes of lagoonal specimens, this gigantism is generally attributed to optimal ecological and nutritional conditions.

No data are available for *Nodipecten* on spawning seasons, size of shell at sexual maturity, or average individual lifespan. Other bivalve studies indicate that these vary between and within species. *Pecten maximus* reaches reproductive maturity at 2.5 years (Tang, 1941) and spawns 8 months of the year. The maximum age reported for *Swiftopecten swifti* was 13 years for a shell 11.8 cm high (Ponurovskii and Silina, 1983).

SOFT PARTS

A monomyarian pelecypod, *Nodipecten* has a large adductor muscle posterior to its central axis and a reduced foot that points forward. Soft parts are shown in Abbott (1962); inside the mantle cavity gill filaments circle above and below the large, flat gonad, which curves from the posterior side of the nearly central adductor muscle. When the valves gape, small guard tentacles and eyes are visible along the striped mantle edges, and long, exploratory tentacles extend from the base of the velum.

ANIMAL BEHAVIOR

Individual Nodipectens have been observed anchored by a byssus to hard substrates, but they are commonest reclining on soft sands. They lie with the right side down, often in shallow depressions, and with the upper left valves obscured by encrusting algae and epifauna. If turned over they will right themselves. Scuba divers have observed that they swim awkwardly for only short distances. Thayer (1972), in comparing adaptive features of swimming Monomyarian bivalves, regarded *N. subnodosus* as sessile, the least competent swimmer of the *Chlamys* group; he based this conclusion on its nonoblique adductor muscle, heavy valves, asymmetric auricles and absence of a permanent gape.

BATHYMETRIC DATA

The animal filter feeds on micro-organisms in the water current; it is absent from turbid environments such as river deltas. Bathymetric data are few for specimens collected alive: *Nodipecten fragosus*, 15-82 m; *N. nodosus*, 10-15 m; *N. subnodosus*, 1-110 m; *N. arthriticus*, no records of live animals. *Lyropecten magnificus* has been collected alive from 10-30 m in the Galapagos; a juvenile (USNM 765017) was taken from 36 m (20 fms) off Port Utria, Colombia.

MEGASCOPIC GROWTH FEATURES

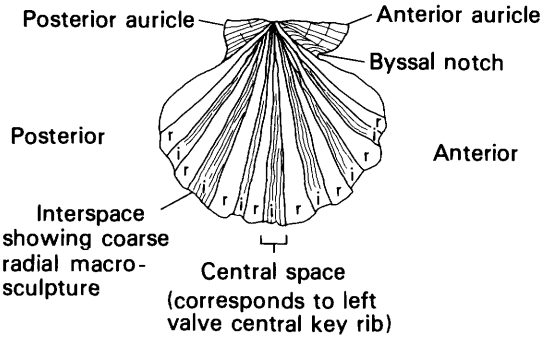
Ledges and nodes are the most distinctive growth features of Nodipectens and some Lyropectens. How they form has not been reported on by biologists, although studies of microgrowth increments suggest factors that may also apply to gross shell morphology.

LEDGING

Ledging is a steplike profile in a valve resulting from a period of growth, a resting stage, and resumption of growth at an angle to the shell edge. Ledges are sometimes called constrictions and are probably formed by the drawing in of the mantle. In profile they vary from angular to rounded, slight or pronounced (fig. 9). They commonly develop in late juvenile or young adult shells,

FIGURE 9.—Megascopic growth features of *Lyropecten*, *"Macrochlamis,"* *Vertipecten*, and *Nodipecten*. Details of ribs, nodes, ledging, and valve profiles. *A*, Right valve of *Nodipecten fragosus*, *B*, Left valve of *Nodipecten fragosus*, *C*, Characteristic shapes of nodes, *D*, Posterior views showing valve profiles. (See also fig. 15.) a, Valves equally convex. b, Angular ledging in the left valve, rounded ledging in the right valves; for example, *Lyropecten crassicardo*; ledged shells are also described as having constrictions (arrows). c, Swollen outline in juvenile right valve; for example, *Lyropecten miguelensis*. d, Juvenile left valves as much as 1 cm high, flattened (arrow); for example, *"Macrochlamis" magnolia ojaiensis*, n. subsp. e, Profile characteristic of *Lyropecten gallegosi*: left valve flat, until 6-7 cm high, then valves are equally convex. f, Left valve with single ledge and elongate thickenings in *"Lyropecten" dumblei*. g, Adult shells may become swollen, as is common in *Vertipecten bowersi*.

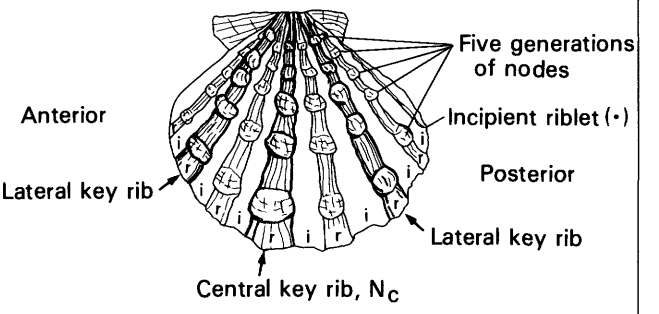
A Right valve, *Nodipecten fragosus*



EXPLANATION

i Interspace
r Rib of normal width
Rib count is 8

B Left valve, *Nodipecten fragosus*

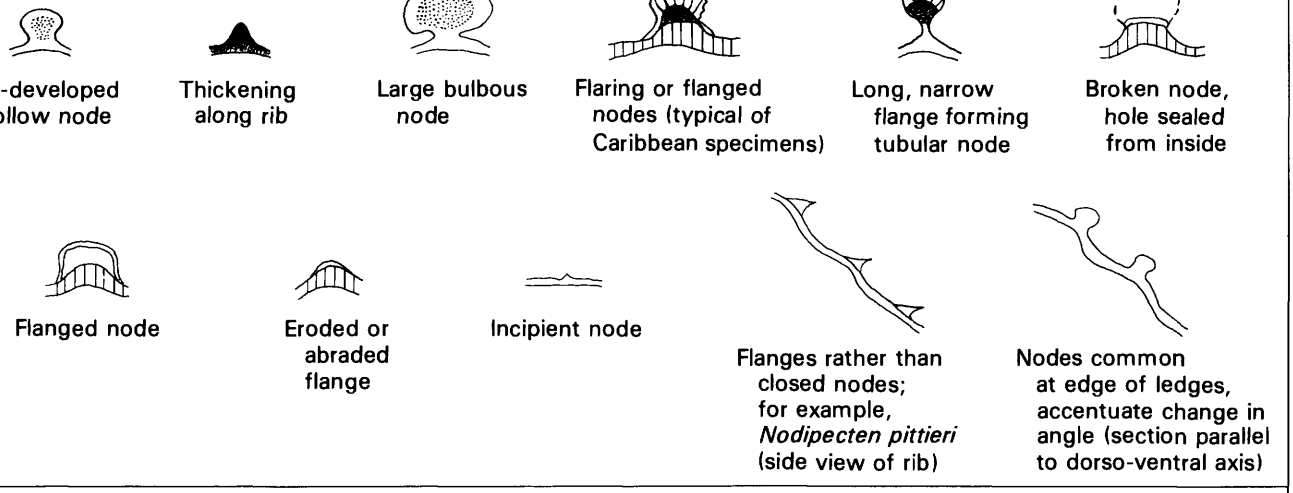


Rib or node scheme: r N r N_C r N r •
The central ribs define the diagnostic *Nodipecten* pattern

EXPLANATION

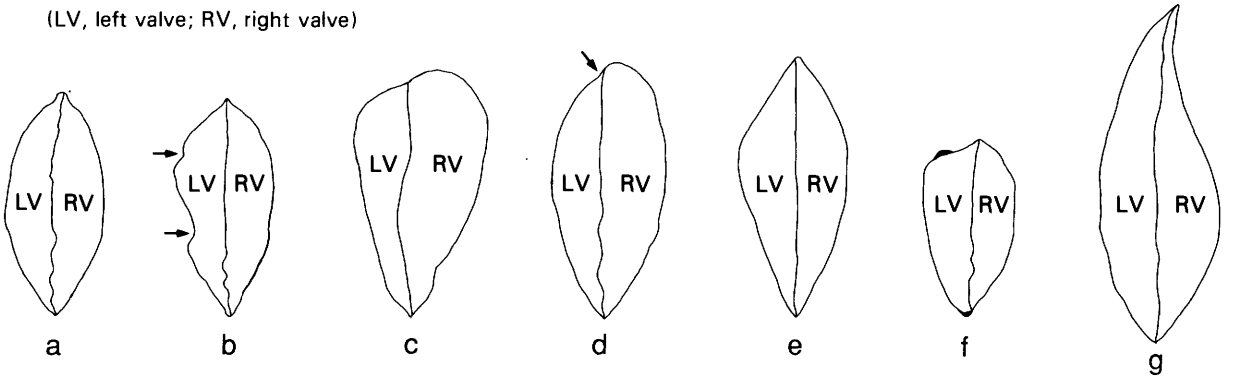
→ Indicates key ribs (wider, more prominent)
i Interspace
r Rib of normal width
Rib count is 7 •

C Nodes



D Posterior views showing profiles

(LV, left valve; RV, right valve)



and they are more pronounced in left valves. Certain species tend to have ledges of a particular profile: left valves of some specimens of *N. arthriticus*, *N. subnodosus*, *N. veatchii*, and *Lyropecten crassicardo* have angular profiles, right valves rounded ones. *L. estrellanus* and *L. miguelensis* have rounded profiles, highly convex in some juveniles. Left valves of *L. modulatus* are flat until about 5 cm high, then develop a pronounced change in shell angle. Juveniles of "*L.*" *dumblei* have a flat left valve with a single angular break in slope after the shell is 2 cm high, then a rounded adult form with no further ledging. All of these species have some individuals with no ledges at all, flat valved from juvenile through adult stages. Prominent angular ledging is also present in some species of *Swiftopecten*, *Stralopecten*, *Hinnites*, *Ostrea*, and in *Mytilus edulis*, where the process of forming ledges was first described (Moore, 1934). *Cryptopecten vesiculosus* has 1-3 conspicuous growth rings, the first one forming when the shell has an average height of 1.3-2.7 cm (Hayami, 1973).

HOW LEDGES FORM

Ledge development has not been studied in field or laboratory specimens of *Nodipecten*. It must be a rapid process because few living or fossil individuals are seen with partly formed ledges. Shelf edges are sometimes marked by a generation of hollow nodes or elongate thickenings.

Since the outer shell edge reflects the mantle, the shell-secreting layer must expand, change orientation, and draw in to form a ledge. In normal shell production, the valves are open and the mantle extends along the margins (Pannella and MacClintock, 1968). Clark (1970) used time-lapse photographs to watch *Pecten diegensis* produce daily growth increments by extending the mantle edge, secreting a thin layer, thickening and calcifying it. On a megascopic scale, this may be how Nodipectens produce new shell, including the big folds that are preserved as nodes.

PERIODIC GROWTH

Evidence for cyclic growth includes thick and thin increments, light and dark layers of finely grouped increments, and grooves or breaks in the shell (Barker, 1970). Experiments show that shell growth is very complicated, varying within a taxon or an individual according to the animal's physiology and environment.

Studies on pelecypods that deposit concentric rings show that growth rates are much faster in juveniles than in older individuals; they slow during spawning and accelerate afterward. Pannella and MacClintock (1968) report that growth is not continuous throughout 24 hours, that although shell increments are deposited every day, there may be interruptions or periods of very slow growth. Orton (1926) found that young cockles deposited 1-1.5 mm of new shell per week, the rate varying with any slight disturbance.

Megascopic concentric lines on shells have been attributed to changes associated with seasons, breeding, environment, shock, diurnal and subdaily growth, and tides and annual cycles. Rhoads and Pannella (1970) tabulate shell characters for these events, but none fit the random frequency of ledges in *Nodipecten*. Distinguishing the rings according to cause is difficult except in intertidal or marked experimental animals. Microscopic growth increments range from 10-100 μm in thickness and are visible in cross sections of the shell. They appear as concentric lines on shell surfaces, and in *Nodipecten* and *Lyropecten* they are wavy or lirate. In certain specimens of *Nodipecten* (pl. 7, figs. 1, 2), the lirae project perpendicularly to the shell surface and remain in interspaces as frilly laminae obscuring the radial costae. Megascopic inspection of Holocene *Nodipecten* shows no conspicuous clumping of growth lines, although Barker (1970) reported some *N. subnodosus* shells showing "an occasional distinct minor growth band comprised of 15 or 30 growth striae." Pannella and MacClintock (1968) attribute the constant thickness of microgrowth increments in subtidal shells to the absence of appreciable variation in temperature.

Experiments on *Swiftopecten swiftii* (Bernardi) from 2-50 m in coastal waters off Japan suggest seasonal growth cycles with the fastest rates during the first three years of life (Ponurovskii and Silina, 1983). During this time, annual accretions are 2.1-2.6 cm, later decreasing to 1 mm per year. For this species, ledges form annually but vary with summer warming periods and short-term environmental changes such as storms. Growth increments include elementary layers that represent 24-hr periods, broader growth layers that probably develop in a few days, and ledges that form every summer.

Observations on spawning or disturbance, rather than seasonal, rings are probably more relevant to understanding ledging in *Nodipecten*, since seasonal variation is slight for subtidal tropical and subtropical organisms having a wide geographic distribution. In his initial studies of ledging in cold-water Mytilids, Moore (1934) found that ledges formed in winter. Shell laid down during the summer continued in the same orientation as the preceding layers, but winter ledges formed at an angle to previous shell growth.

Pannella and MacClintock (1968) and Rhoads and Pannella (1970) note that spawning in *Mercenaria mercenaria* (Linnaeus) is marked by a sudden break in regular shell deposition followed by a slow recovery indicated by a series of thin daily growth lines. These differ from shock rings, such as those produced after a storm that show a sudden break in deposition followed by either death or a

fast recovery. Abrupt changes distinguish these from seasonal rings that are preceded by a gradual decrease in deposition. Rings from any cause are less sharply defined in subtidal and deeper water shells.

Data are not available on shell size at sexual maturity in *Nodipecten*. Juveniles commonly develop the first ledge at 2 cm high; later constrictions are at irregular intervals, usually before the shell is 8-10 cm high. The fact that some individuals have no ledges at all suggests that constrictions are not related to a regular reproductive cycle.

DISTURBANCE RINGS

Shock rings can result from injury or change in orientation as distinguished from environmental stress caused by variations in temperature, salinity, and turbidity. Molluscan growth experiments show that larger individuals tend not to record small disturbances. Minor grooves and narrow or erratic rings were reported by Barker (1970) for "comparatively short" interruptions of several days to two weeks, perhaps when a specimen was rolled about during a storm. He thought concentric grooves formed at the end of a slow growth period, not during it. In another study, 1-2 year old cockles showed megascopic rings 1 or 2 days after being removed from sea water for 15 minutes and stronger rings appeared in shells that were notched for experiments (Orton, 1926); *"L." condylomatus* valves have profiles similar to these.

NODES

Nodes are the most conspicuous feature of many left valves of living Nodipectens and Lyropectens. They form in generations of at least three large nodes each in *Nodipecten* and are usually more pronounced on alternating ribs (fig. 6). Node production has not been reported in laboratory specimens, and very few individuals died in the midst of forming them. We assume nodes form rapidly when the mantle edge flares in large ruffles at an angle to the shell edge. The largest flare coincides with the central rib, lesser ones with alternating lateral ribs. Mantle ruffles are reflected in thin shell material that is then calcified. The mantle then secretes shell material continuous with the former edge, sealing off the hollow nodes from the inside (MCZ 164873, pl. 3, fig. 3,). Shell flanges that become nodes are continuous with earlier shell material and probably secreted by the same mantle fold. One individual of *N. pernodosus* (hypotype USNM 334976, pl. 3, fig. 1) lost the capacity to form nodes in one section of mantle but was able to secrete ribs with normal fine macrosculpture.

Node shape and prominence varies, but within a taxon the node scheme or pattern of nodose ribs is the same. Nodes develop only in the left valves of most Nodipectens, but they can also form in right valves of *N. nodosus*, *N. pernodosus*, and *N. fragosus*. Holocene Nodipectens and *Lyropecten magnificus* have hollow nodes, but some fossil Lyropectens had filled nodes or elongate thickenings on corresponding left-valve ribs.

Nodes first form when the *Nodipecten* reaches 2-2.5 cm high. Subsequent sets may occur regularly at about 1-2 cm intervals or sporadically. Although they are commonest in young shells as much as 5-6 cm high, they are not unknown in larger adults.

Observations suggest that *Nodipecten* and *Lyropecten* form nodes in the same way. However, Caribbean specimens of these genera tend to produce ruffles or flares at a higher angle to the shell edge, and scaly flanges or former ruffles are commonly preserved. Erosion of flares often produces rounded bulbous nodes, but many specimens retain some evidence of the frilly edge. Such flanges are also characteristic of Caribbean fossils identified as *N. pittieri*, *N. arnoldi*, and *Lyropecten colinensis* subspecies, but they are unknown in Pacific forms. Holocene Pacific Nodipectens also have smaller, less bulbous nodes and less conspicuous ledges.

Node formation has not been explained by spawning, ecologic, or disturbance factors, although these may affect the shell. The sometimes rhythmic but other times irregular occurrences of generations of nodes suggest they are not related to regular cyclic phenomena. The present study disproves the contentions of Dall (1898, p. 729) and Hertlein (1972) that nodosity increases in deeper water or warmer, more southerly localities. *Nodipecten fragosus* from the Carolinas is commonly more nodose than *N. nodosus* from the Caribbean. Highly nodose shells came from open-ocean environments as well as from protected bays—the same environmental range as shells with no nodes.

The tendency of certain pectinids to have nodes in consistent patterns is a useful phylogenetic tool. *Lyropecten* and *Nodipecten* are distingished in this paper on the basis of node scheme (figs. 9 and 15), and several evolutionary progressions of species grouped according to node arrangement can be traced.

Two *"Lyropecten"* species, *"L." dumblei* and *"L." condylomatus*, have suitable characters for studying nodes and ledges. The former has a single distinctive ledge when the shell is about 2 cm high. Ribs on the shelf edge have a distinctive pattern of thickenings or "proto-nodes" (pl. 20, figs. 4a, 4b). *"Lyropecten" condylomatus* looks like a taxon experimenting with ledging and node possibilities, perhaps influenced by environmental factors. Node positions on *"L." condylomatus* are inconsistent, forming no single pattern. Other pectinid genera, including *Swiftopecten* and European species of *Macrochlamis*, may have nodes on left valves; most Lyropectens do not have them. Biological advantages of nodes, if any, are unknown.

BIOSTRATIGRAPHIC AND PALEOGEOGRAPHIC APPLICATIONS OF PECTINID DISTRIBUTIONAL DATA

VAQUEROS FORMATION AND "VAQUEROS" STAGE

"Vaqueros" is a name that has been used in reports and on maps and fossil labels since the early 1900's to denote lower Tertiary marine clastic rocks that are exposed over large areas in central and southern California. Outcrops commonly form prominent ledges bearing assemblages of shallow-water marine mollusks, especially pectinids, oysters, and turritellids. The Vaqueros Formation was originally named by Hamlin (1904) for a section in Monterey County in the Santa Lucia Mountains and was redefined by Thorup (1943). The term "Vaqueros Stage," based on megafossils, was introduced by Eaton and others (1941), but it has never been formally described with a designated type section. It should not be formalized because a time-stratigraphic unit should not be named for a cartographic one; a new name needs to be selected, in accordance with the Code of Stratigraphic Nomenclature (North American Commission on Stratigraphic Nomenclature, 1983).

Placing the formation name in quotations to indicate a time-stratigraphic sense is confusing enough without this unit's particular stratigraphic, paleontologic, and nomenclatural complications. Geographically, the formation is represented in a number of unconnected embayments and basins within which there are abrupt facies changes. The unit thickens and thins, intertongues with nonmarine deposits, and has different ages in successive onlaps, particularly in the San Joaquin Valley.

Megafossils show considerable morphologic evolution over the 10-12 m.y. between the oldest sections in the southern Santa Lucia Mountains and the youngest in the Santa Monica Mountains and northern Channel Islands, as well as in continuous thick sequences such as those in the central Sierra Madre and Caliente Ranges (table 4). The nearshore coarse clastic deposits contain some benthonic foraminifers from the Zemorrian and Saucesian Stages of Kleinpell (1938), but megafossils are more useful tools for correlation in the field.

Nomenclatural difficulties stem from using lithostratigraphic terms (formations) for chronostratigraphic or time-rock units (stages, or packages of time during which there was deposition of rocks and possibly periods of nondeposition or erosion). The problem is illustrated in figure 10 for two California megafaunal stages, the "Vaqueros" and "Temblor" Stages of Addicott (1972). The type section of the Vaqueros Formation represents only the middle part of the "Vaqueros" Stage, an interpretation based on index megafossils. The type Temblor Formation has two members in the lower half of the "Temblor" Stage, four members in the "Vaqueros" Stage, and one each in an unnamed stage (Addicott, 1972) and part of the upper "Tejon" Stage. Addicott (1965, 1970b) described the "Temblor" Stage fauna from the upper part of the Olcese Sand of the Barker's Ranch area northeast of Bakersfield[3]; either this area or the central Temblor Range could serve as type area for the stage that has never been formally described from a designated type section. Representative mollusks of the two stages are illustrated in Wiedey (1928), Hertlein (1928b), Loel and Corey (1932), and Addicott (1972).

Recognizing the importance of clarifying the two types of units, lithologic and chronostratigraphic, workers have already introduced new stage names for the Pacific Northwest (fig. 12). Revisions of California terminology are hampered by the lack of synthesized stratigraphic and faunal data required to formalize new stage names and by the scarcity of complete stratigraphic sequences.

The differences in how the Vaqueros Formation has been mapped in a number of key areas in California is documented in table 4; changes in thickness and age are construed from pectinid index species, which, when related to the radiometric ages of Turner (1970), show that deposition of the Vaqueros Formation was time transgressive over 10-12 m.y. The age of the formation does not vary in an orderly geographic progression; each embayment underwent its own depositional and tectonic history. In the current U.S. Geological Survey chronology, the "Vaqueros" Stage ranges in age from late early Oligocene to early Miocene.

Fossils from the central Sierra Madre Range collected from the Painted Rock Sandstone Member of the Vaqueros Formation as mapped by Fritsche (1969) represent all three subdivisions of the "Vaqueros" Stage. Sections from the Caliente Range and the Fox Mountain 7½-minute quadrangle west of Santa Barbara Canyon may represent the most complete megafaunal sequences for the lower, middle, and upper "Vaqueros" Stage, although the Vaqueros Formation is much thinner in the Fox Mountain area than in the Caliente Range.

The magnitude of time transgressed (late Oligocene and early Miocene) explains the long-standing controversy over the formation's age (Schenck, 1935, "What is The Vaqueros Formation of California and is it Oligocene?"; papers in Schenck and Childs, 1942). In the geochronologic scheme currently accepted by the U.S. Geological Survey (Berggren and others, 1985), the Oligocene/Miocene boundary is drawn within the middle "Vaqueros" Stage, at 23.7 Ma.

"VAQUEROS" STAGE EMBAYMENTS AND REPRESENTATIVE FAUNULES

The first comprehensive biostratigraphic study of the

[3]Barker's Ranch area, center sec. 5, T. 29 S., R. 29 E., south side of Kern River.

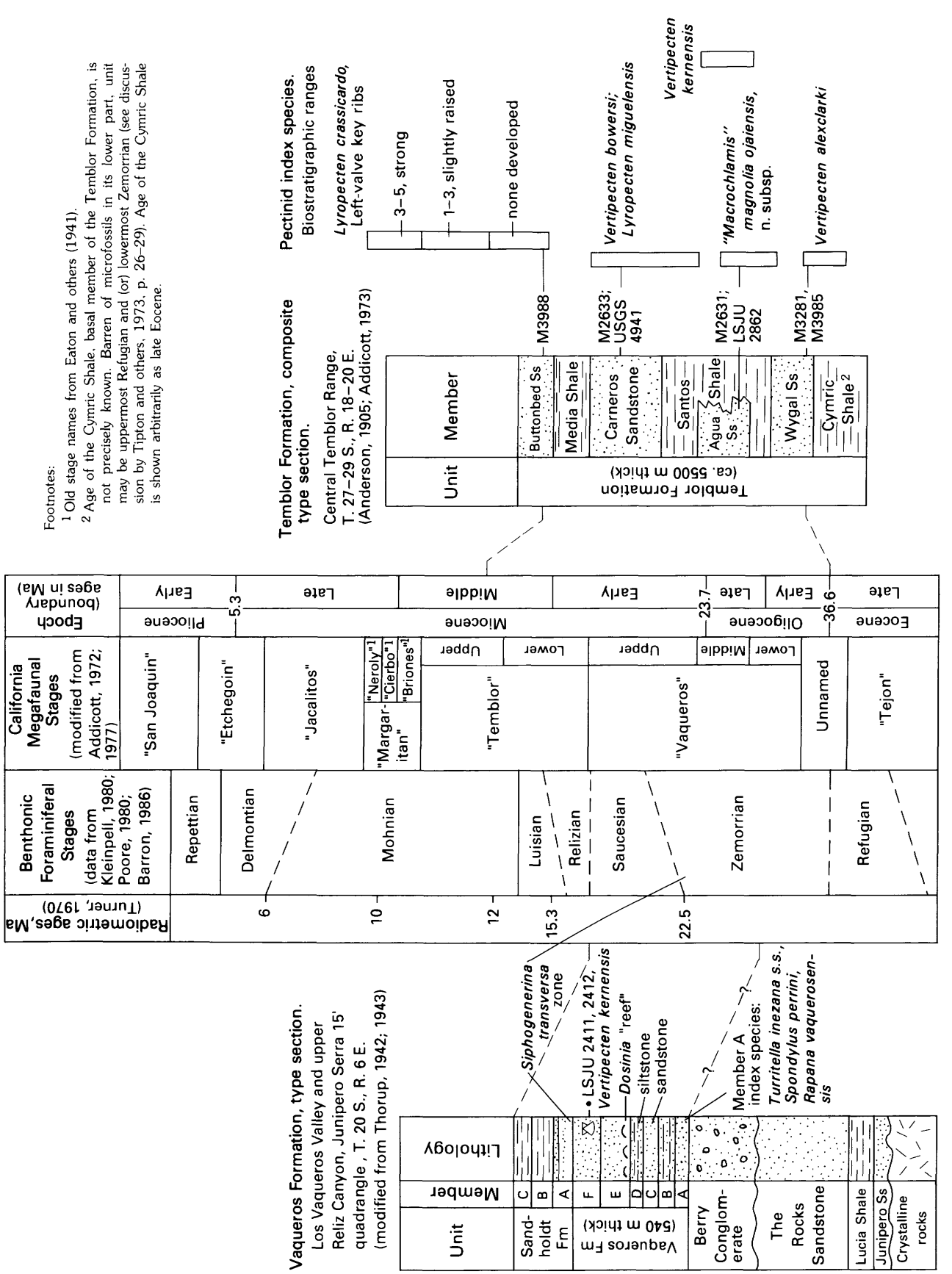


FIGURE 10.—Relations between the Vaqueros and Temblor Formations and the "Vaqueros" and "Temblor" stages. (Adapted from Addicott, 1977; Armentrout, 1975). Data plotted on the time scale of Berggren and others, 1985). The Vaqueros Formation spans 12 million years and the Temblor Formation may represent as much as 26 million years. M3281, U.S. Geological Survey fossil locality register; LSJU 2411, Stanford University fossil locality register.

TABLE 4.—*Local age ranges in the Vaqueros Formation construed from late early Oligocene to early Miocene pectinid index species from representative sections in California*

[Vaqueros Formation of authors transgresses 10-12 m.y. Species identifications verified or specimens redetermined for this study; —, no data]

Area	Unit terminology as shown on maps (source of data)	Thickness (m)	Lyropecten, Vertipecten, and "Macrochlamis" species	Megafaunal Stage	Comments
1. Santa Cruz Mountains					
i. Pescadero Beach, San Mateo County, Pigeon Point block	Vaqueros(?) Formation Isolated bed exposed at low-tide level (Clark and Brabb, 1978) LSJU accession No. 47625; CAS loc. 38686; M7157	135	"M." magnolia ojaiensis	Upper lower "Vaqueros" to lower middle "Vaqueros"	Minor outcrops in Pigeon Point block west of San Gregorio fault. Pectinids from La Honda block imply an older age than do do Upper Zemorrian microfossils and 23.1±0.7 Ma age for basalt flows (Turner, 1970)
ii. Zayante Creek area, La Honda block	Vaqueros Sandstone and intercalated basalt flows; M5049 (Clark and others, 1979)	350-440	V. perrini and link[1] between "M." magnolia magnolia and "M." magnolia ojaiensis	Lower "Vaqueros"	
iii. Twobar Creek, La Honda block	Vaqueros Sandstone; LSJU accession No. 4902 = R. Arnold 111; (Brabb and others, 1977; Burchfiel, 1964)	More than 740	V. alexclarki	Unnamed stage of Addicott (1972, 1973)	This is the type locality of Pecten sanctaecruzensis, which is also present at the Indians.
2. Santa Lucia Range, Salinian block					
i. Los Vaqueros Valley	Vaqueros Formation, member A (oldest) - F; LSJU loc. 2327 in member F (Thorup, 1943)	540-600 total; member F, 128	V. kernensis (= V. nevadanus of authors)	Middle "Vaqueros"	Type locality of Vaqueros Formation (Hamlin, 1904; Thorup, 1943).
ii. Lepidocyclina locality of Schenck and Childs (1942)	Vaqueros Formation, lower Saucesian conglomerate of Oligocene age. LSJU loc. 1155 (Schenck and Childs, 1942) [= M7895 of Brabb and others, 1983]	15	V. perrini or link between V. perrini and V. kernensis (= V. nevadanus of authors)	Upper lower "Vaqueros"	LSJU 1155 is about 64 km south of type locality.
iii. The Indians Ranch area	Vaqueros(?) Formation, upper sandstone member; M6494; LSJU 1758 (Addicott, 1979)	215	Link between V. perrini and V. alexclarki	Unnamed stage of Addicott (1972, 1973)	This member of the formation is 4-5 m.y. older than the strata of the type locality (LSJU 2327).
3. Morro/Toro Creek, Cypress Mountain quadrangle	Vaqueros Formation, poorly exposed and discontinuous; UCLA locs. 6203, 6205, 6206 (Prior, 1974)	1-75	"M." magnolia magnolia, V. perrini	Lower "Vaqueros"	Formation thickens to northwest; it may be older north of San Bernardo fault, younger to south.
4. Santa Ynez Mountains					
i. Santa Rosa Hills	Vaqueros Formation; UCMP loc. D-8794 (Dibblee, 1950, and oral commun., 1973)	60-90	Link between "M." magnolia ojaiensis and "M." magnolia magnolia	Upper lower "Vaqueros"	Both subspecies found south of Santa Ynez River on Alisal Ranch.
ii. San Julian Valley, Yridisis Creek to Tranquillon Mountain	--	60-90	"M." magnolia magnolia	Lower "Vaqueros"	Abundant in pebble bed, lower 25-30 m, near San Julian Ranch.

5. Northern Channel Islands					
i. Southwestern Santa Cruz Island	Vaqueros Formation, two members: Sandstone member (upper) with Saucesian microfossils: loc. M8013	--	L. miguelensis, V. bowersi	Upper "Vaqueros"	Members interfinger as lower diorite breccia unit grades southwest into upper unit. Vaqueros Formation fines upward and westward as seen from sections on Santa Rosa and San Miguel Islands.
	Diorite breccia member (lower) with Zemorrian microfossils: loc. M8022 (McLean and others, 1976)	240, est.	L. pretiosus (=L. submiguelensis of authors)	Middle "Vaqueros"	
ii. San Miguel Island	Vaqueros Formation, UCSB 4454, 4455, and Bremner (1933) localities 7/8 mile SW. of Bay Point and 1 mile N. of Crook Point	180	L. miguelensis	Upper "Vaqueros"	--
iii. Santa Rosa Island	Vaqueros Formation, sandstone member of McLean and others (1976) [= "Middle Kinton Point Formation" and "Lower Vaqueros Formation" of labels, Rincon Formation, lower member, of Weaver and others (1969).] Locs. CAS 1155, 1156, 2843, 12333; UCSB 4675, 1801, 1844; LSJU accession No. 45068	150, est.	L. miguelensis	Upper "Vaqueros"	--
	Vaqueros Formation, lower coarse-grained sandstone and conglomerate. Locs. UCMP A-311; UCSB SR64-11, SR67-57, SR67-53; CAS 1154, 1150.		L. pretiosus, including L. submiguelensis of authors	Middle "Vaqueros"	Type locality of L. submiguelensis (Loel and Corey, 1932).
6. Northern La Panza Range, Salinian block					
i. Hay Canyon section	Vaqueros Formation (Dibblee, 1962) loc. M2826	60-150	"M." magnolia magnolia V. perrini or link with V. kernensis	Upper lower "Vaqueros"	--
ii. La Panza section	CAS loc. 53	--	V. bowersi, L. miguelensis	Upper "Vaqueros"	--
7. Sierra Madre Range, including Fox Mountain area, Salinian block	Vaqueros Formation Painted Rock Sandstone Member, locs.				
	UCLA 5548, 5549	--	V. bowersi, L. miguelensis	Upper "Vaqueros"	East of Santa Barbara Canyon the stage is lower "Vaqueros"; to west formation ranges from lower to upper "Vaqueros" Stage.
	UCLA 5545, 5560	--	V. kernensis, L. pretiosus	Middle "Vaqueros"	
	UCLA 5564 (Fritsche, 1969)	--	"M." magnolia magnolia	Lower "Vaqueros"	
	Vaqueros Formation, basal part: loc. M2445 (Vedder, 1968)	127-168	"M." magnolia magnolia	Upper lower "Vaqueros"	
	Vaqueros Formation, undifferentiated: loc. M2446 (Hill and others, 1958)	--	L. miguelensis	Upper "Vaqueros"	
8. Caliente Range and Cuyama Valley, Salinian block	Vaqueros Formation, three members: Painted Rock Sandstone Member, Saucesian foraminifers, locs. M3519, M3520	4,650	"M." magnolia magnolia	--	Megafossils suggest lower "Vaqueros" but microfossils suggest upper "Vaqueros" (J.G. Vedder, oral commun., 1983). Differences between northwest and southeast Cuyama basin are summarized by Lagoe (1984).
	Soda Lake Shale Member	1,020	--	--	
	Quail Canyon Sandstone Member (Vedder and Repenning, 1965)	150	--	--	

TABLE 4.—*Local age ranges in the Vaqueros Formation construed from late early Oligocene to early Miocene pectinid index species from representative sections in California*—Continued

Area	Unit terminology as shown on maps (source of data)	Thickness (m)	Lyropecten, Vertipecten, and "Macrochlamis" species	Megafaunal Stage	Comments
9. Sespe Creek area	Vaqueros Formation, three members: Upper member: CSUN locs. 261, 263	40-165	V. kernensis (= V. nevadanus of authors), "M." magnolia ojaiensis	Lowermost middle "Vaqueros"	Co-occurrence of oldest known V. kernensis with youngest "M." magnolia ojaiensis is documented at these localities.
	Middle member	50-155	--	--	
	Lower member (Fritsche and Shmitka, 1978)	60-115	--	--	
10. Ojai area, Oak Ridge and South Mountain	Sandstone and siltstone of Vaqueros Formation overlying nonmarine redbeds. Locs. M8012; UCLA 8696, 8698; UCMP D-8792; UCR 7586; LSJU accession No. 22357 (Dibblee, oral commun., 1973)	90	"M." magnolia ojaiensis	Upper lower "Vaqueros" - lowest middle "Vaqueros"	-- --
11. Santa Monica Mountains	Vaqueros Formation, two members: San Nicholas Member, in Arroyo Sequit	400, inc.	V. bowersi, L. miguelensis	Upper "Vaqueros"	Overlying Saddle Peak Member of the Topanga Canyon Formation is also upper "Vaqueros" based on occurrence of V. bowersi.
	Danielson Member	--	--	--	--
	Members undivided in western Point Dume quadrangle, Solstice Canyon area (Yerkes and Campbell, 1980a, b);	800	--	--	--
	Newton Canyon at Zuma Canyon	--	"M." magnolia ojaiensis	Upper lower "Vaqueros" to lower middle "Vaqueros"	Rare specimens found in sandstone of the upper plate south of Malibu Bowl fault of Yerkes and Campbell (1980a).
12. Santa Ana Mountains, San Joaquin Hills	Vaqueros Formation and underlying Sespe Formation, undifferentiated: LSJU/SGS loc. 1949: 131-3A; relation between marine and nonmarine units undetermined.	190-275 (SGS 1949)	"M." magnolia magnolia	Lower "Vaqueros"	--
		914-975 (Truex, 1976)	V. bowersi, L. miguelensis	Upper "Vaqueros"	--

[1]Link = transitional form between two species.

"Vaqueros" Stage was made by Loel and Corey (1932), who studied assemblages from the major embayments (fig. 11). Distributions of two late early and late Oligocene lower "Vaqueros" index fossils, *"Macrochlamis" magnolia magnolia* and *"M." magnolia ojaiensis*, n. subsp., are plotted on figure 11, the former indicating the oldest sections and the latter upper lower "Vaqueros" to lowest middle "Vaqueros" Stage rocks where it co-occurs with the oldest specimens of *Vertipecten kernensis* (= *V. nevadanus* of authors).

"Macrochlamis" magnolia magnolia, the older subspecies, is restricted to basins west of the San Andreas fault, but the younger form, *"Macrochlamis" magnolia ojaiensis*, ranged widely across it. Known distribution patterns of these subspecies suggest tectonic displacement greater than the 320 km of offset along the San Andreas fault well documented by other stratigraphic, structural, and geophysical studies (Dickinson and Grantz, 1968).

In field notes and publications, fossils from the Vaqueros Formation have been informally called "a typical Vaqueros fauna," "a *Rapana* fauna" or the *"Turritella inezana* zone." Although useful within a given embayment, such assemblages mean different things to people working in different places. Several species of *Rapana* have been described that probably form a bioseries based on morphologic changes over time. *Turritella inezana*, which ranges from the lower "Vaqueros" to upper "Vaqueros" Stage, is potentially divisible into biostratigraphic subspecies. Schenck (1935) considered the whole Vaqueros Formation the *Turritella inezana* zone. Hertlein (1928b) recognized two lower Miocene zones on San Miguel and Santa Rosa Islands: the *Turritella inezana* zone of the Vaqueros Formation, overlain by the *Turritella ocoyana* zone of the Temblor Formation. He noted the occurrence of *Rapana vaquerosensis* Arnold "only in the *Turritella inezana* zone;" *R. imperialis* Hertlein and Jordan is more common with *T. ocoyana*. Loel and Corey (1932) suggest some overlap of zones defined by species of *Rapana* and *Turritella*, both of which need systematic and biostratigraphic revision within the current stratigraphic context. *Turritella ocoyana* is present well below the highest *T. inezana*; variants of the two species are found together in the Caliente Range and the San Joaquin Hills (J.G. Vedder, written commun., 1983). Loel and Corey (1932) and many others referred to "Transition zone" assemblages, which are here assigned to the upper "Vaqueros" Stage on the basis of *Lyropecten miguelensis* and associated taxa.

Another long-used reference point in correlations of the Vaqueros Formation is the *"Lepidocyclina* locality" of Schenck and Childs (1942) in the Adelaida quadrangle 65 km south of the type locality of the Vaqueros Formation. This outcrop represents the lower part of the section within the same depositional basin as the rocks of the type locality. Schenck regarded the locality (LSJU 1155 = M7895) as the equivalent of Thorup's member F, but Vertipectens from the type sections of members E and F (loc. LSJU 2412) are *V. kernensis* and the pectinids from loc. LSJU 1155 are more primitive, *V. perrini* or a transitional form between *V. perrini* and *V. kernensis* (LSJU accession no. 30935, and many other specimens from the vicinity of Lime Mountain). *Vertipecten perrini* is older than the lower Saucesian benthonic foraminiferal stage assignment of Schenck. Vertipectens and benthonic foraminifers support an Oligocene age for this part of the Vaqueros Formation, but the overlying shale beds contain latest early Miocene upper Saucesian planktonic microfossils (Brabb and others, 1983).

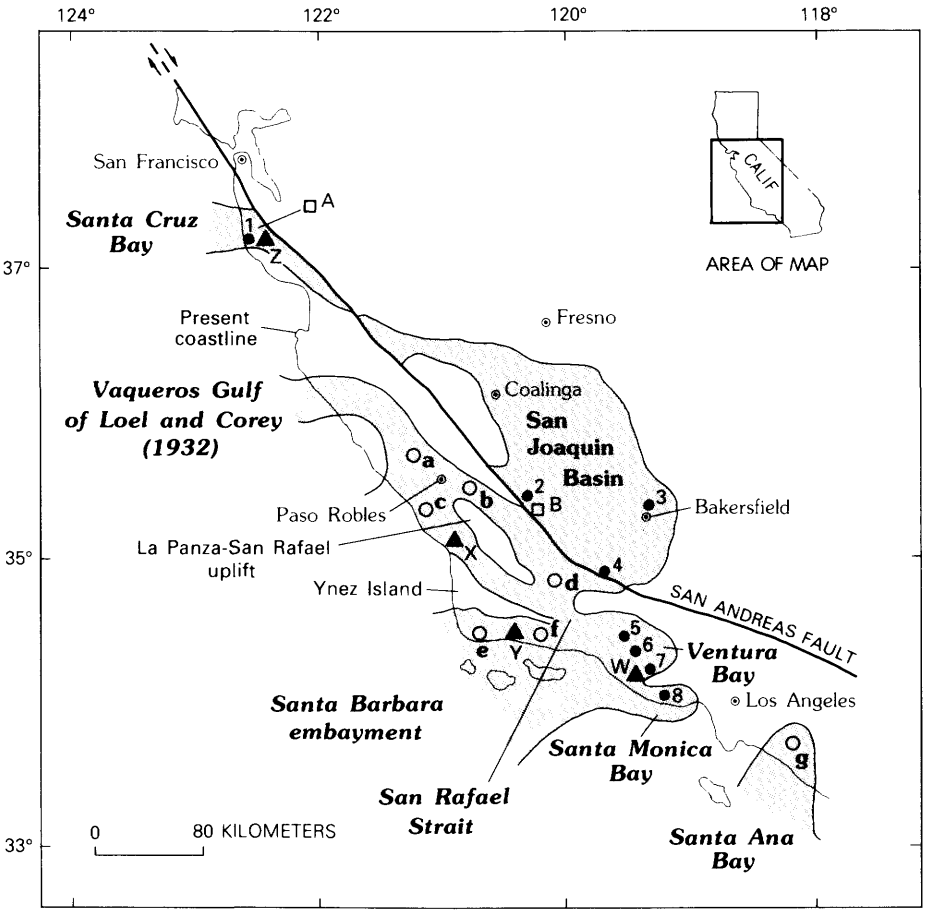
The Indians Ranch area, 11 km southwest of the type locality of the Vaqueros Formation, is another important reference section. *Vertipecten perrini*, or an older transition form between it and *V. alexclarki*, indicates an early Oligocene age for the Vaqueros Formation here; in time-rock terminology it represents the unnamed stage of Addicott (1972).

Given the changes in concepts of species and variability, identifications in faunal lists need to be redetermined and localities recollected for detailed biostratigraphic work. W.H. Corey once noted (J.G. Vedder, oral commun., 1973) that many of the Loel and Corey (1932) fossils were brought in by ranchers or amateur collectors from general localities. To be accurate, zonations based on such material require field checks and measured sections.

VERTIPECTEN BIOSERIES AND THE MEGAFAUNAL STAGES OF CALIFORNIA AND THE PACIFIC NORTHWEST

The chronostratigraphic ranges of six species of *Vertipecten* from California define 3-6 m.y. subdivisions of the upper "Tejon" stage of Clark and Vokes (1936) and the unnamed and "Vaqueros" Stages of Addicott (1972, 1973). They are shown in figure 12 in relation to equivalent units from Washington and Oregon described or refined by Armentrout (1975, 1977), Addicott (1977), Allison (1978), Moore (1984c), and Moore and Addicott (1987), after Weaver and others (1944) and Durham (1944). Formal descriptions of stage boundaries, type areas, and faunal assemblages are given in Addicott (1976a,b, 1977) and Armentrout (1975). As with the California megafaunal stages, the old stage names ("Keasey," "Lincoln," and "Blakeley") were those of formations, inappropriate and confusing when also used in a time-stratigraphic sense.

Vertipecten fucanus is the only *Vertipecten* found in both California and the Pacific Northwest, present in Kern County, Calif., in the Olcese Sand or the undivided Freeman Silt and Jewett Sand unit and at widely separated localities in the Pacific Northwest: the upper



EXPLANATION

(Specific localities and individuals shown in parentheses)

Indicates marine strata, Zemorrian and Saucesian Foraminiferal Stages (modified from Addicott, 1968), interpolated as 32–26 Ma

San Andreas fault—Arrows show relative direction of movement

● *"Macrochlamis" magnolia ojaiensis*, 5–6 ribbed subspecies

1 Pescadero Beach, Pigeon Point block (CAS 38686; LSJU acc. no. 47625; M7157)
2 Central Temblor Range (LSJU 2862; M2631)
3 Pyramid Hill (UCMP B-1605; M1700; UCR 1185; UCR 1154)
4 San Emigdio Range (USGS 13330)
5 Topa Topa Mountains (CSUN 263)
6 Ojai Valley, type area (UCMP D-8792, UCMP A-326, UCLA 8698, M8012)
7 Santa Susana Mountains (UCR 7586)
8 Santa Monica Mountains, Newton Canyon at Zuma Canyon

▲ *"Macrochlamis" magnolia*, intermediate rib counts

W Western Santa Susana Mountains (Society of Economic Paleontologists and Mineralogists fall field trip, 1983)
X Nipomo-Huasna basin (UCLA 4586)
Y Santa Ynez Range, south of Santa Ynez River (UCMP D-8794)
Z Santa Cruz Mountains, La Honda block (M5049; M2001)

○ *"Macrochlamis" magnolia magnolia*, 8 or 9–10 ribbed subspecies

a Southern Coast Ranges, Tierra Redonda Mountain (LSJU acc. no 53268)
b La Panza Range, Hay Canyon (M2831)
c Morro/Toro Creek area (UCLA 6203; UCLA 6208)
d Cuyama Valley, Caliente Range (M2445; M3520; UCLA 5564)
e Santa Ynez Range, Jalama Creek and San Julian Ranch, type area (LSJU acc no. 1710, UCMP A-315)
f South of Santa Ynez River, Alisal Ranch
g Santa Ana Mountains (Hypotype CAS 61039)

□ *Vertipecten alexclarki* Addicott

A Twobar Creek, Santa Cruz Mountains (LSJU acc. no 4902=Ralph Arnold loc. 111, Brabb and others, 1977, p 41)
B Central Temblor Range, type area (M3281), late early or early middle Oligocene; Temblor Formation, base of the Wygal Sand stone Member (Addicott, 1973)

FIGURE 11.—Distribution of *"Macrochlamis" magnolia* subspecies in the embayments of the lower "Vaqueros" stage of Addicott (1972, 1973) (after Loel and Corey, 1932) and occurrences of *Vertipecten alexclarki* Addicott.

part of the Poul Creek Formation of Alaska, Hoh rock assemblage of Rau (1973), the Clallam Formation (Addicott, 1976b), and the lower part of the Astoria Formation of Washington, and the Astoria Formation, upper part of the Yaquina Formation, and Nye Mudstone of Oregon. These records permit direct correlation between the lower Miocene Pillarian Stage of the Pacific Northwest and upper "Vaqueros" Stage of California, as discussed by Addicott (1976b) and Moore and Addicott (1987). Moore (1984c) recognized five molluscan zones equivalent to the five molluscan stages of the Pacific Northwest, the *Vertipecten fucanus* Molluscan Zone having the same chronostratigraphic range as the Pillarian Molluscan Stage.

The oldest Vertipectens are geographically more restricted: *V. yneziana* and *V. alexclarki* are present in upper Eocene and lower Oligocene rocks in the Santa Ynez Mountains and in the Temblor Range and Santa Cruz Mountains, respectively. *Vertipecten yneziana* evolved gradually through *V. perrini* to *V. kernensis* (= *V. nevadanus* auctt.), which dispersed north to the Santa Lucia and Diablo Ranges, east to the Kern River area and San Emigdio Range, and south to the Santa Ana Mountains. *Vertipecten bowersi* has a similar widespread distribution, overlapping the southernmost record of *V. fucanus* in Kern County.

Vertipecten is unknown in Japan, but it may be present in the Miocene and Pliocene of western Kamchatka. A specimen referred by Sinel'nikova (1975, p. 94-96, pl. 13, figs. 1a,b) to *Chlamys* (*Leochlamys*) *daishakaensis* Masuda and Sawada seems to be a *Vertipecten* close to *V. kernensis*.

The genus ranges from the Gulf of Alaska to Washington in the upper Eocene upper Galvinian (the old "Lincoln") Stage of Armentrout (1975). Two Alaskan species, *V. popofensis* and *V. lachenbruchi*, were described by MacNeil (1967) from the Eocene to Oligocene *Acila shumardi* zone of Schenck (1936). More recently refined chronozones, based on species of *Acila*, restrict the *A. shumardi* zone and its Vertipectens to the late Eocene Galvinian Stage (Addicott, 1976c). These species and *V. porterensis* (Weaver, 1912) from Washington and *V. yneziana* from California constitute the oldest known Vertipectens. They are included, with *V. columbianum* (Clark and Arnold, 1923) from the Sooke Formation, Vancouver Island, in figure 12 to summarize the range data currently known for *Vertipecten*.

Morphologically, the Alaskan species correspond less closely to the contemporaneous *V. yneziana* than to younger Vertipectens from California. *Vertipecten lachenbruchi* (MacNeil, 1967, pl. 1, figs. 3-8; pl. 2, figs. 4-7) is similar to *V. perrini* and *V. alexclarki*, and *Vertipecten popofensis* (MacNeil, 1967, pl. 2, figs. 1, 3, 5, 6) resembles *V. kernensis*.

NEW WORLD-OLD WORLD COGNATE SPECIES AND IMPLICATIONS FOR CORRELATION

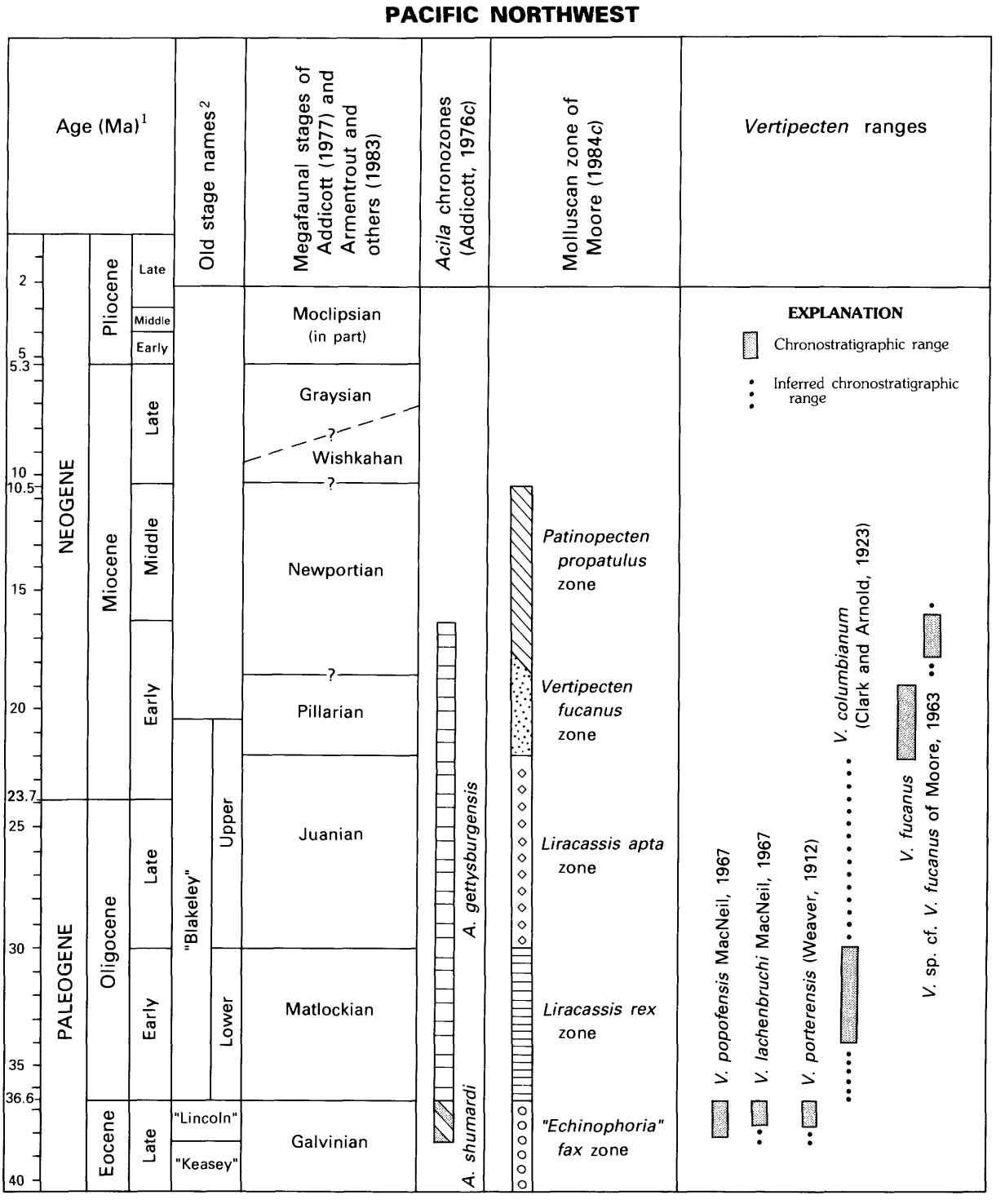
MACROCHLAMIS FROM CALIFORNIA AND SWITZERLAND

"Macrochlamis" magnolia from California and specimens referred here to *M. terebratulaeformis* (*M. tournalii* of authors, in part) from the Swiss Molasse near Sainte-Croix are almost identical cognate species long used in their respective provinces for zonation and correlation. If their relation is as close as their morphology implies, they permit direct correlation between upper Oligocene and lower Miocene California megafaunal stages and classic European divisions now related by planktonic foraminiferal zones (fig. 13*A*). In the continuous process of refining age and stage boundaries, resolution is improved by working out the detailed biostratigraphic ranges of well-known megafaunal reference species such as these.

The Swiss specimens are referred here to *M. terebratulaeformis*; this species also is present in the Burdigalian of the southwestern-most part of the Rhône Valley of France (Roger, 1939). It may be a facies controlled species, and its exact temporal relation to *M. tournalii* is as yet unknown. The section near Sainte-Croix from which the specimens came was considered Helvetian or Burdigalian by most workers (de Lapparent, 1885; Rittener, 1902; Leriche, 1927; Gignoux, 1950; Augustin Lombard, written commun., 1973), appreciably younger than the Upper Chattian and Lower Aquitanian Stages of Steininger (1977) suggested by California cognates in the equivalent upper lower to middle "Vaqueros" Stage. A geological map of the east end of the Auberson Tertiary basin refers the molasse in the area to the Burdigalian and Aquitanian (Renz and Jung, 1978).

Tertiary molasse near Sainte-Croix is located in several small synclinal basins detached from the main Swiss Molasse and surrounded by Cretaceous rocks that crop out between the Jura Mountains and the Alps. The sediments were deposited in shallow water in the perialpine trough that connected the Rhône Valley embayment of the western Mediterranean and the Vienna Basin to the east (fig. 13*B*). Eames and Savage (1975) noted that transgressive seas entered the Rhône Valley during the Aquitanian and lower Burdigalian stages but did not reach the Vienna Basin until the middle Miocene upper Burdigalian Stage. Because *M. terebratulaeformis* has been reported only from the western Mediterranean, it is probably no younger than the lower Burdigalian Stage of late early Miocene age.

The Tertiary molasse in the Auberson Valley northwest of Sainte-Croix is 50 m thick and poorly exposed; fossiliferous beds are rare along the road between La Chaux and Vraconne (Augustin Lombard, written commun., 1973). The section, which represents a very small ero-



[1] Time scale and planktonic foraminiferal zones from the standard time scale for the Cenozoic for the Decade of North American Geology (Berggren and others, 1985).
[2] Old stage names from Eaton and others (1941), Weaver and others (1944), and Durham (1954).
[3] Addicott (1972, 1973)
[4] From Weaver and others (1944).

FIGURE 12.—Chart showing *Vertipecten* and *Acila* ranges and megafaunal stage correlations between California and the Pacific Northwest. Megafaunal and microfaunal stages modified from Allison (1978), Addicott (1977), Armentrout (1975), Poore (1980), Armentrout and others (1983), and Moore (1984c). Molluscan zones of Moore (1984c). Pacific Northwest *Vertipecten* ranges from the literature.

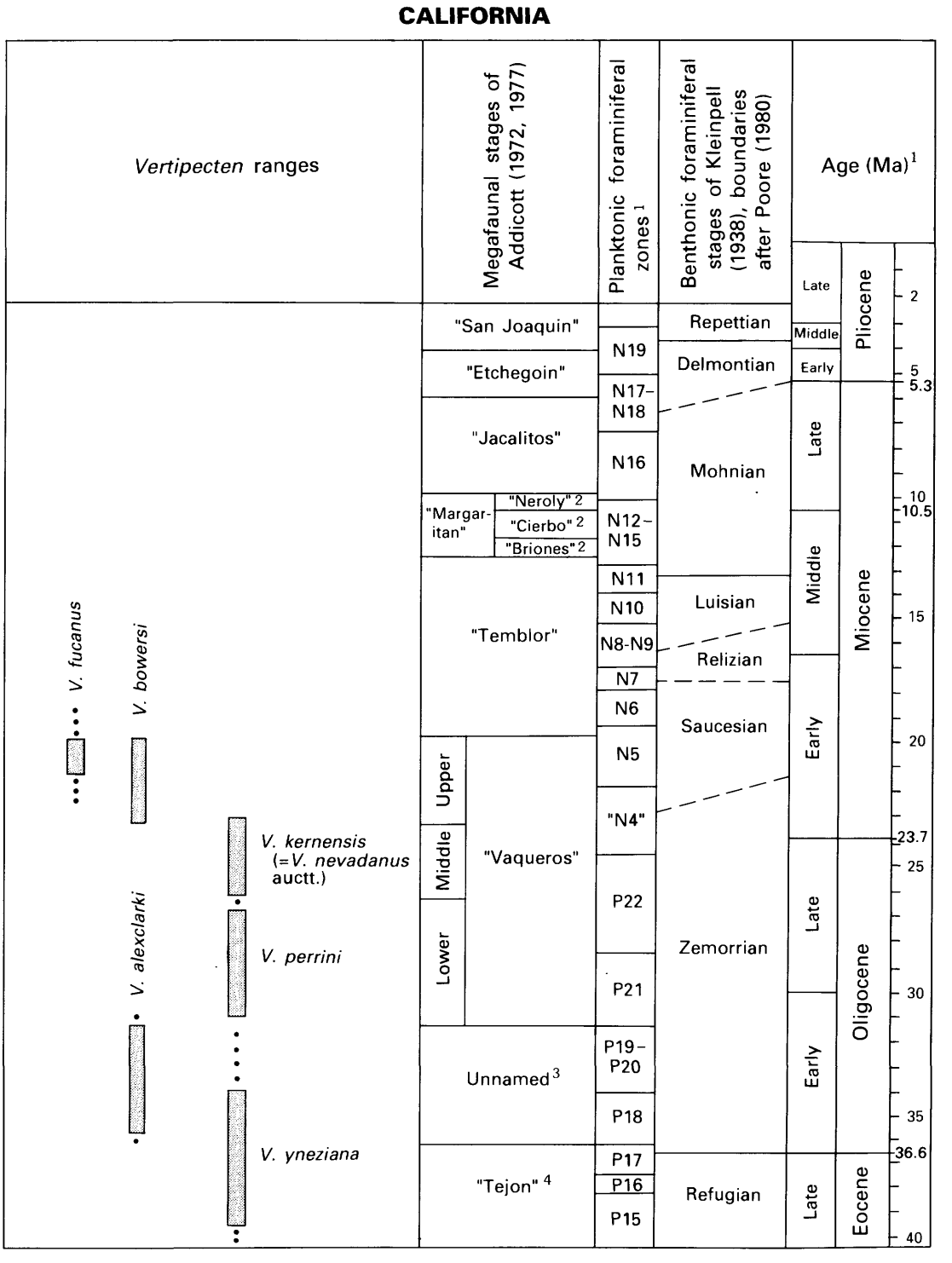
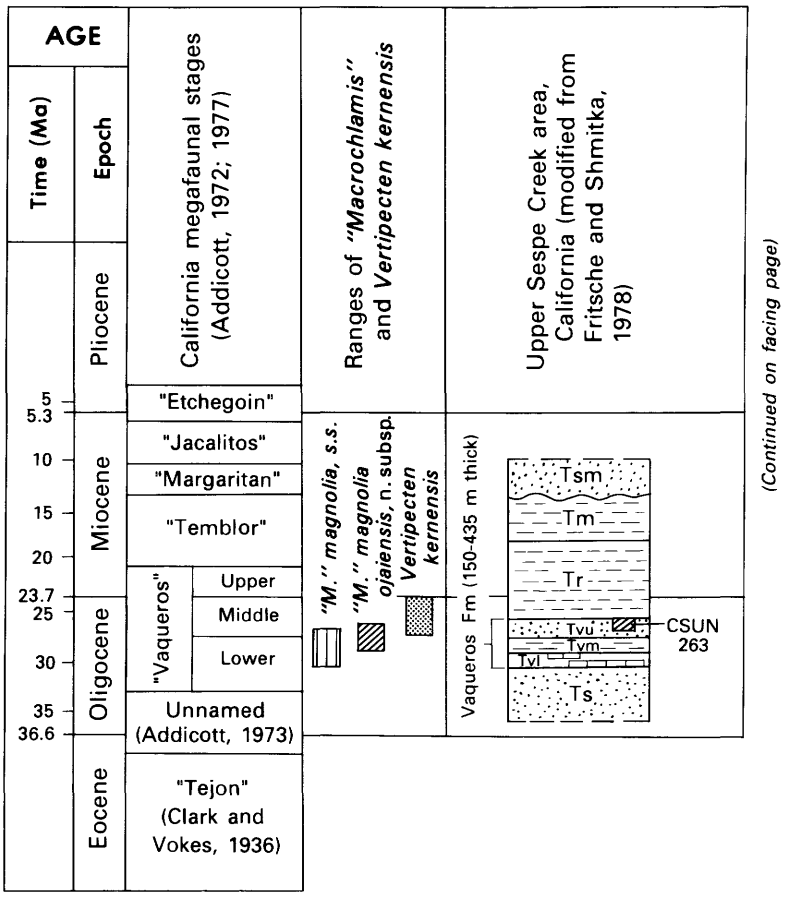


FIGURE 12.—Continued.

sional remnant of the Tertiary record, probably does not span the Aquitanian to Tortonian Stages as believed by Rittener (1902) and later workers. Lithologic subdivisions in the Swiss molasse in the Auberson Valley are shown in figure 13*A*; the upper few meters of conglomerate contain megafossils, including *Ostrea crassissima*. The macrochlamid suggests that most if not all of the section is in the Aquitanian Stage and of early Miocene age.

A



EXPLANATION

Tsm — Santa Margarita Formation (Miocene)—From oldest to youngest: Bioturbated white sandstone and basal pebble conglomerate; pellitic phosphate beds, mudstone and bentonite; thick beds of gypsum and coquina; mudstone and coarse-grained pebbly sandstone (Thor, 1978)

Tm — Monterey Formation (Miocene)—Grayish-yellow siliceous shale with a medial bedded sandstone

Tr — Rincon Formation of Weaver and Kleinpell (1969) (Miocene and Oligocene)—Thin-bedded fissile bentonite bed, uppermost Rincon Shale of Fritsche and Shmitka (1978); nonresistant dark-gray to dark-brown, mainly massive siltstone containing foraminifers

Vaqueros Formation (Oligocene–early Miocene)

Tvu — Upper member—Massive and bedded fossiliferous glauconitic sandstone

Tvm — Middle member—Brown claystone, mudstone, and siltstone

Tvl — Lower member—Sandstone, fossiliferous limestone, and mudstone (Reid, 1978)

Ts — Sespe Formation of Dibblee (1950) (Oligocene)—Nonmarine yellow-brown to red-brown crossbedded sandstone and conglomerate, red and green siltstone interbeds

Ranges of *"Macrochlamis"* and *Vertipecten kernensis*

Macrochlamis terebratulaeformis

"M." magnolia ojaiensis, n. subsp.

"M." magnolia, s.s.

Vertipecten kernensis

Fossil localities—See "Locality data"

CSUN 263; MCZ 18104, 18106

FIGURE 13.—New World-Old World megafaunal stage correlations. Compiled from Allison (1978), Steininger (1977), and Gignoux (1950) on the time scale of Berggren and others (1985). *A*, Megafaunal stage correlations based on species of *"Macrochlamis"* and *Macrochlamis*.

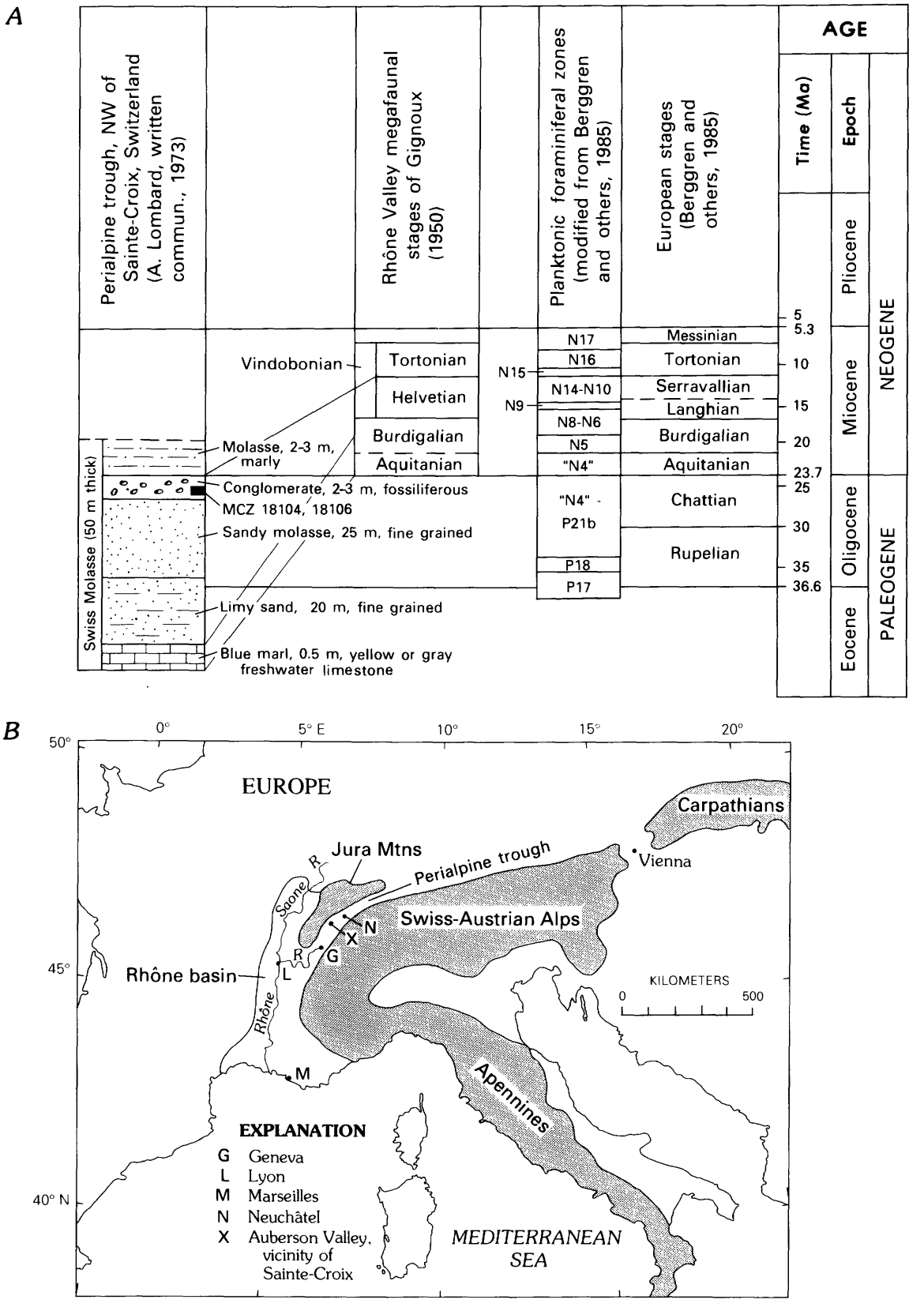


FIGURE 13.—*B*, Index map showing the Auberson Valley, Switzerland and the perialpine trough connecting the Rhône Valley and Vienna Basin in the middle Miocene. (Modified from Smith and Woodcock, 1982.)

EAST-WEST CORRELATIONS BETWEEN CALIFORNIA AND THE SOUTHEASTERN ATLANTIC COASTAL PLAIN

In 1854 Conrad identified a California macrochlamid, *Pecten magnolia*, as *Pecten jeffersonius* Say, 1824 from the Chesapeake area, leading early paleontologists to correlate Miocene marine beds from California with those of the coastal plain of Maryland and Virginia. The western forms are here referred to *"Macrochlamis" magnolia, s. l.*, the east coast complex to *Chesapecten*, the subject of a biostratigraphic study by Ward and Blackwelder (1975); both have been identified in the literature as *Lyropecten*. The *"Macrochlamis" magnolia* and *Chesapecten jeffersonius* bioseries, although unrelated to each other, are excellent provincial biostratigraphic markers: *"Macrochlamis"* for the Oligocene and early Miocene of California, *Chesapecten* for the middle Miocene to Pliocene of the Atlantic Coastal Plain.

Tertiary Caribbean Nodipectens are rare in the southern Atlantic Coastal Plain except in some south Florida Neogene formations. They are of limited use for provincial correlation because of the lack of precise biostratigraphic data for spoil-bank material and the difficulties of identifying formations in an area of thin, discontinuous units. Oaks and DuBar (1974) summarize the regional stratigraphic setting within which the *Nodipecten* species are considered here. California megafaunal stages are correlated with Atlantic Coastal Plain formations and stages in figure 14; occurrences of *Nodipecten* and *"Lyropecten"* are also shown. Neither *Nodipecten* nor *Lyropecten* is present in the Chesapeake Group (Choptank, Calvert, and Yorktown Formations) as noted by Tucker-Rowland (1938a) and Gardner (1943).

In many cases formations in the Atlantic and Gulf Coastal Plains are considerably younger than reported in the early molluscan literature. Revised ages have important implications for correlations between units in Florida and those of the Dominican Republic, Venezuela, Panama, and Baja California Sur, Mexico. Megafossiliferous clastic deposits are commonly coarse grained and devoid of microfossils; planktonic foraminiferal zones are included in figure 14 where available from the literature. The units from which many museum specimens were collected, generally without detailed stratigraphic data, are lithologically similar. Sediments were deposited in rapidly changing nearshore environments represented by facies that have been considered by authors or specimen labellers as formations, members, or informal beds. The Tamiami Formation, in which *Nodipecten* is abundant, and the Hawthorn Formation have undergone repeated revisions in stratigraphic nomenclature, as detailed by Peck and others (1979).

FOSSIL NODIPECTENS FROM THE SOUTHEASTERN ATLANTIC COASTAL PLAIN

Four *Nodipecten* taxa are recognized in the southern Atlantic Coastal Plain between Lake Waccamaw, N.C. and the Florida Keys. From oldest to youngest, they are *N. collierensis*, *N. peedeensis*, *N. pernodosus*, and the common Holocene form, *N. fragosus*. Transgressive-regressive marine cycles preclude tracing a complete phylogenetic series, as the marine record is broken by a number of emergent periods (Oaks and DuBar, 1974; Peck and others, 1979). All but *N. pernodosus* lived in open-marine nearshore environments; all but *N. collierensis* are restricted to the southeastern Atlantic and Gulf Coastal Plains.

Nodipecten collierensis is a Tertiary Caribbean Province species found in upper Miocene and lowermost Pliocene beds in Florida and Venezuela; its direct descendant, *N. nodosus*, is represented in the Boleo Formation in eastern Baja California Sur, Mexico. Abundant in the Pinecrest Sand Member of Puri and Vanstrum (1969) of the Tamiami Formation and the Buckingham Marl of former usage, the taxon is also present in beds at Lake Waccamaw, North Carolina, that are believed to be as young as late Pliocene in age (Lucy McCartan, written commun., 1981), although other occurrences of the species are older (late Miocene to early Pliocene). In the upper part of the Tamiami Formation of Florida and in the Paraguana Formation of Falcon, Venezuela, *N. collierensis* co-occurs with *Chlamys tamiamiensis* (Mansfield), an index fossil of a late Pliocene molluscan zone recognized by Hunter (1978).

Nodipecten peedeensis is the Atlantic Coastal Plain cognate of *N. veatchii*, an eastern Pacific late Miocene index fossil restricted to the Vizcaino Peninsula, western Baja California Sur, Mexico. *Nodipecten peedeensis* is very rare, known only from a few specimens from North and South Carolina; it may represent a relict of a wider ranging Tertiary Caribbean fauna, but it is too poorly known for use in correlation.

Nodipecten pernodosus (Heilprin) is endemic to the area around the type locality of the Caloosahatchee Formation in south Florida. It is closest to *N. collierensis*, from which it probably evolved in the late Pliocene; it has unique morphologic characters (a proportionally short hinge, nodes on all ribs of both valves, numerous constrictions or shell ledges) that may reflect an isolated lagoonal habitat that rapidly increased in salinity and dried up.

Nodipecten fragosus evolved in the late Miocene or early Pliocene after the Hispaniola Arc formed a barrier between the Caribbean and the Gulf of Mexico. It lives today from the Yucatan platform to Florida and North and

South Carolina, but it is too uncommon to be a useful Tertiary index fossil.

In contrast to Caribbean and west Mexican Nodipectens, those that lived in Florida occupied a relatively stable coastal plain that has undergone no major Neogene plate tectonic rearrangement. Distribution patterns probably reflect current patterns during periods of transgression and regression and extinctions owing to periods of emergence resulting from glacio-eustatic drops in sea level or lithospheric flexures that warped the coastal plain in the late Neogene (Cronin, 1981).

Megafaunal stages, widely used chronostratigraphic units in the Tertiary of California and the Pacific northwest, are not so useful for southeastern Atlantic Coastal Plain geology, where megafossiliferous marine formations tend to be thin and discontinuous. Provincial Pliocene stages were proposed by Blackwelder (1981) for type areas in the middle Atlantic Coastal Plain. The Miocene stages recognized by Puri and Vernon (1964) have formation or group names based on sections from northwest Florida; these stages have not been applied to formations in south Florida.

SYSTEMATIC PALEONTOLOGY

The classification scheme given here, modified from Waller (1978), is based on shell ultrastructure, ligament, mantle edges, and soft parts.

Phylum MOLLUSCA
Class PELECYPODA Goldfuss, 1820
Superorder PTERIOMORPHIA Beurlen, 1944
Order OSTREOIDA Férussac, 1822
Suborder PECTININA Waller, 1978
Superfamily PECTINACEA Rafinesque, 1815
Family PECTINIDAE, Rafinesque, 1815

Genera *Lyropecten* Conrad, 1856
***Macrochlamis* Sacco, 1897a**
***Vertipecten* Grant and Gale, 1931**
***Nodipecten* Dall, 1898**

In the Treatise of Invertebrate Paleontology, 1969, Part N, vol. 1, Hertlein arranged taxa below the family level in groups rather than in subfamilies that would imply established relations and distinctions. He listed *Lyropecten, Macrochlamis, Vertipecten,* and *Nodipecten,* and thirty other subgenera under *Chlamys,* on the basis of valve convexity, byssal notch, and radial sculpture. Of the four genera considered here, *Vertipecten* probably descended from *Chlamys* but the origins of the others are uncertain. Though some morphologic details suggest *Nodipecten* evolved from *Lyropecten,* the fossil record may eventually indicate separate origins. Extensive, unstudied Tertiary marine sequences in west Mexico, the Bolivar Trough, and the Yucatan Peninsula probably contain critical data for phylogenetic relations between *Lyropecten* and *Nodipecten.* The classification scheme that most accurately reflects present knowledge treats the four as genera of unspecified affinity to *Chlamys* or to each other.

COMMENTS ON TAXONOMIC ARRANGEMENT AND RANKING

Taxa are listed in alphabetical order by species, the lowest taxonomic unit for most Lyropectens and Vertipectens. The California macrochlamids are classified as subspecies of sequential geologic age and some geographic overlap. Ranking for Nodipectens reflects convenience and brevity, and for those taxa represented by few specimens, classification is typological. There are nine closely related Tertiary Caribbean Nodipectens with 2-3 m.y. geologic ranges within the period of late Miocene to Holocene time. Many have been referred to subspecies of one another; this practice has been confusing because a given taxon could have two valid names, one as a subspecies of a Holocene taxon, the other of a fossil species. In some instances systematic relations are more precisely known than the nomenclature suggests, but such degrees of closeness cannot be shown by names. A cladistic analysis was beyond the scope of this work but might offer a way of depicting relations for which the time of branching is not precisely known, although at the specific level there may be few recognizable branches or cladistic characters with which to work.

Morphologic terms used in this paper are defined in figure 15. Species descriptions include, in this order: valve profile and outline, height of beaks, auricle size and shape, byssal notch depth, hinge length, umbonal angle (varies with shell convexity), ribbing, macrosculpture (costae, lirae, not shell microsculpture); key rib and node patterns, color where present; size of the largest individual measured.

Lyropecten (Conrad, 1862)

Type species.—*Pallium estrellanus* Conrad, 1856 (subsequent designation, Dall, 1898).

Conrad (1867) reintroduced his new genus *Lyropecten* and listed one species, *L. crassicardo,* not recalling that in 1862 he had already described the genus and listed two species, *P. estrellanus* and *P. crassicardo.*

Diagnosis.—Valves circular in outline, equally convex in profile; moderately flat to gibbous, some species tending

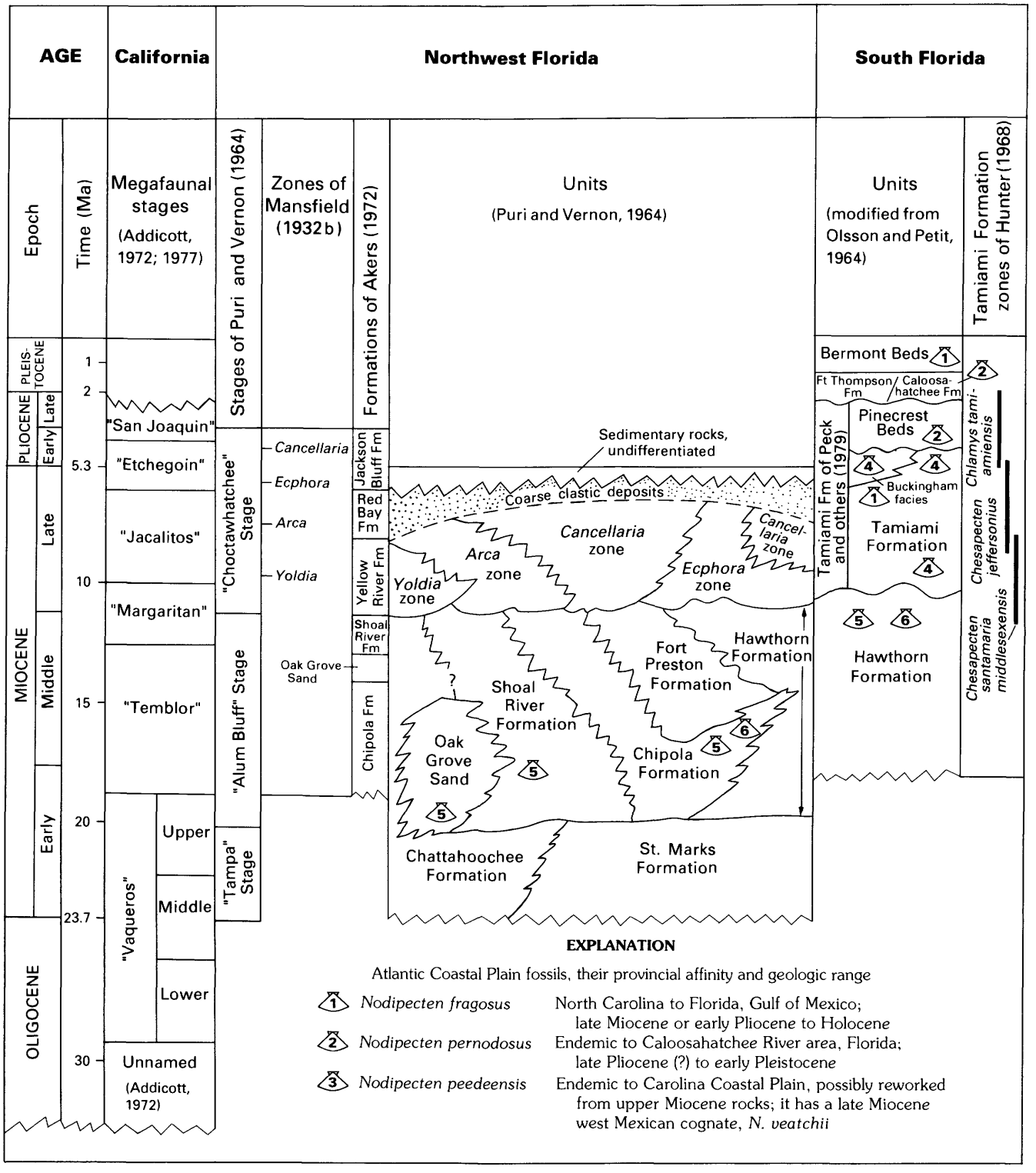
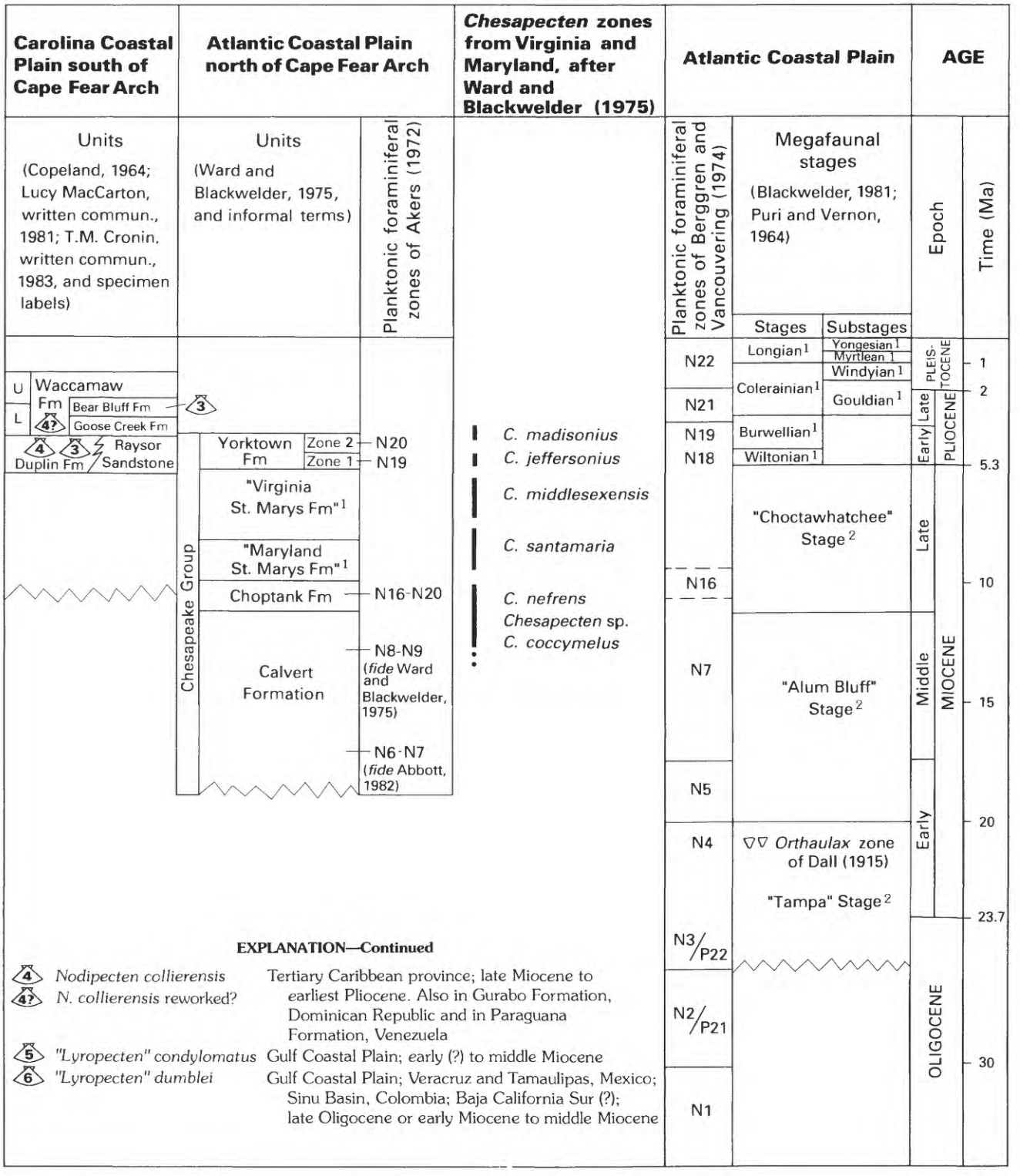


FIGURE 14.—East-West correlations between California megafaunal stages and Atlantic Coastal Plain formations. Geologic time scale is that of Berggren and others (1985).



[1] Of Blackwelder (1981)

[2] Of Puri and Vernon (1964)

FIGURE 14.—Continued.

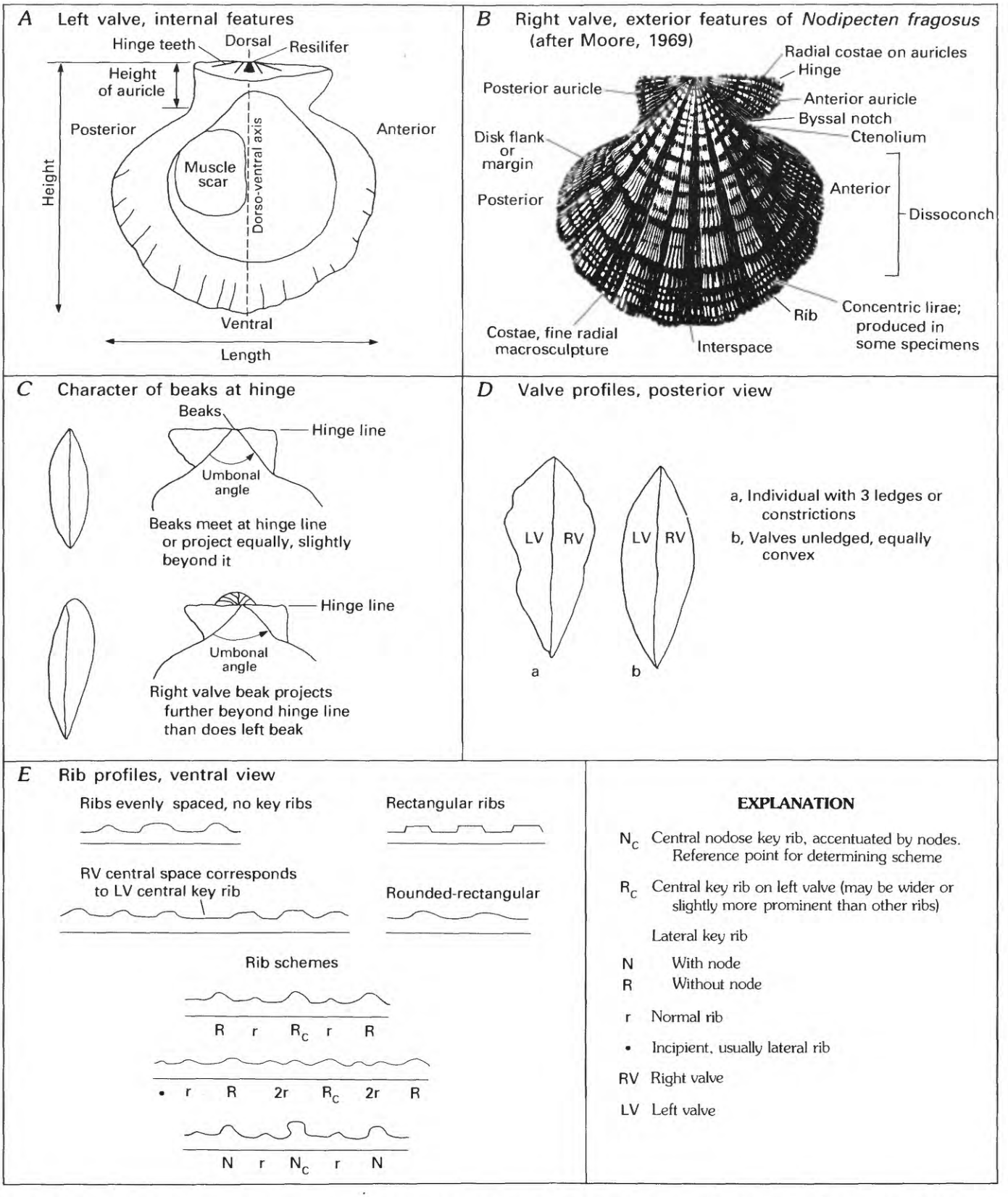
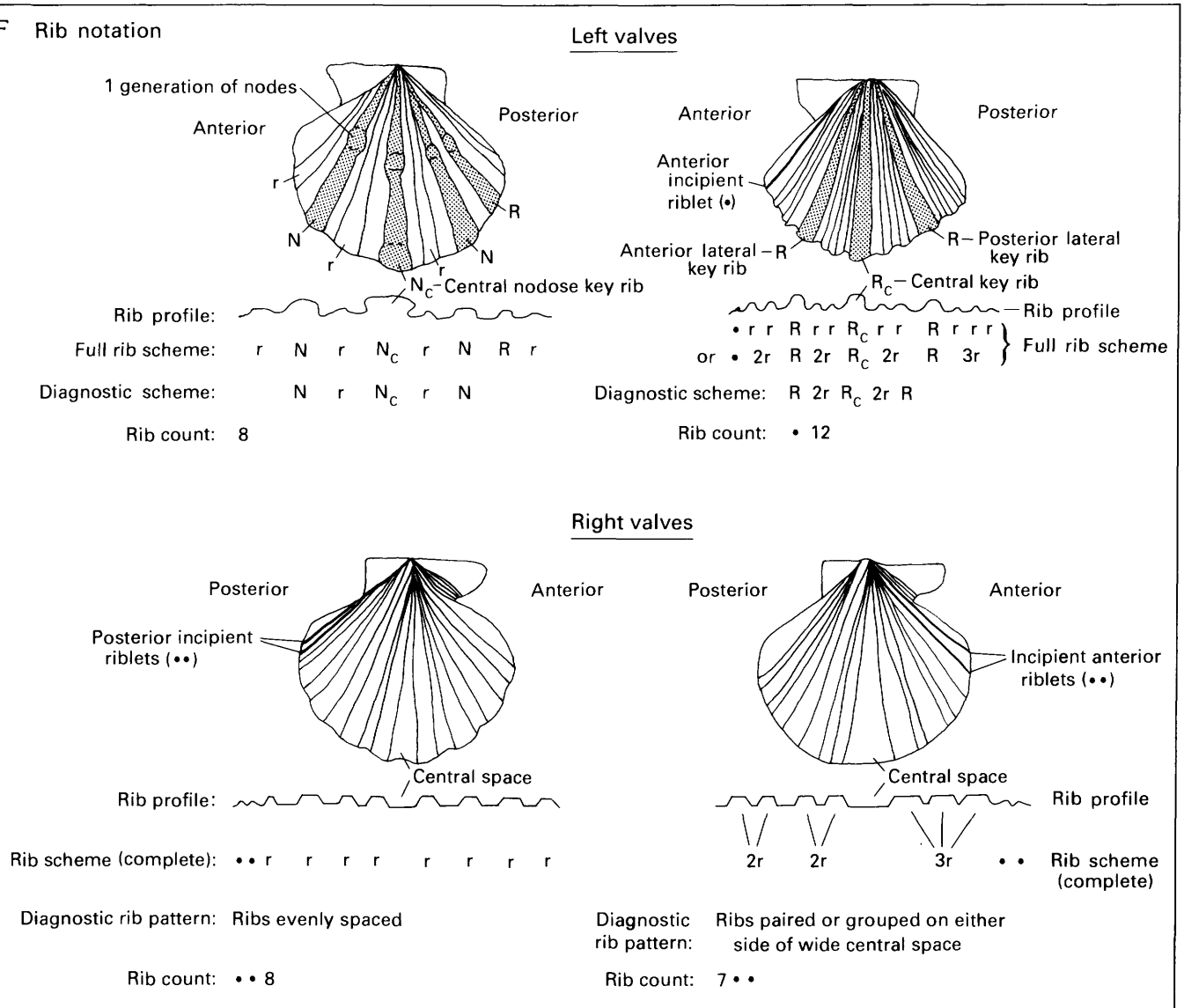


FIGURE 15.—Morphologic terms and definitions used in the species descriptions. (See also fig. 9.) *A*, Left valve, internal features. *B*, Right valve, exterior features of *Nodipecten fragosus* (after Moore, 1969). *C*, Character of beaks at hinge. *D*, Valve profiles, posterior view. *E*, Rib profiles, ventral view. *F*, Rib notation.

F Rib notation



Diagnostic rib or node schemes are determined with respect to the central space or central key rib; in left valves, the significant pattern shows up in the number of regular costae (r) between the central key rib (N_C or R_C) and the anterior and posterior lateral keys (N or R).

Key rib—any wider, raised or more prominent rib, commonly on left valves of Nodipectens and some Lyropectens. Taxa that have them usually have a central key rib (R_C) and one or more lateral ribs (R). Where nodes are developed, the central key rib is designated N_C, laterals as N.

Representative node or rib schemes for left valves of certain pectinids:

Vertipecten bowersi	R 2r R_C 2r R
Lyropecten crassicardo, L. magnificus, L. modulatus, L. colinensis, s.l.	R 2r R_C 2r R
L. catalinae, L. gallegosi, L. cerrosensis	R 3r R_C 3r R
Nodipecten arthriticus	N 2r N_C r N or R 2r R_C r R
N. subnodosus	N r N_C r N
N. nodosus, N. fragosus, N. arnoldi	N r N_C r N or R r R_C r R

FIGURE 15.—Continued.

to have rounded or angular ledges. Radiating ribs ornamented by radial costae in most taxa (but not the type species); interspaces with one or more radial riblets crossed by concentric lirae or growth lines. Auricles subequal, costate, and lirate, hinge line less than half shell length. Byssal notch moderately deep, ctenolium present in juveniles, preserved in some adults. Three pairs of hinge teeth in right valves, two pairs in left valves. Some species with regularly spaced ribs, others with prominent key ribs arranged in patterns characteristic of different phylogenetic lineages within the genus. Some of the species with key ribs also have nodes.

Similar to *Nodipecten* in valve outline and profile, hinge characters, ctenolium, and fine sculpture; unlike *Nodipecten* in having nearly equal auricles, a shallow byssal notch, and regularly spaced ribs rather than left valve ribs and right valve interspaces of alternating widths. Most species lack nodes, but in the group including *L. crassicardo* and *L. magnificus*, hollow nodes evolved over time from elongate thickenings along key ribs. *Nodipecten* nodes are commonly larger and bulbous. *Lyropecten* differs in growth form and proportions from "*Macrochlamis*," which is represented in California by taxa having large auricles, hinge lines greater than half the shell length, a shallow byssal notch, and no tendency to develop ledges, key ribs or nodes. *Vertipecten* has many characters that distinguish it from *Lyropecten*: a convex left valve and flat right valve, the number and character of imbricated ribs, shagreen microsculpture, deep byssal notch, and a smooth hinge area lacking crura.

Lyropecten catalinae (Arnold, 1906)

Plate 27, figures 2, 3, 7; plate 28, figures 1, 6

1906. *Pecten (Lyropecten) estrellanus* Conrad var. *catalinae* Arnold, U.S. Geological Survey Professional Paper 47, p. 76-77, pl. 20, figs. 3, 3a, 4.
1907. *Pecten Estrellanus* Trask, Southern California Academy of Sciences Bulletin, v. 3, no. 8, p. 140.
1931. *Pecten (Lyropecten) estrellanus* Conrad (in part). Grant and Gale, San Diego Society of Natural History Memoir, v. 1, p. 185, pl. 8, fig. 4.
1976. *Lyropecten estrellanus catalinae* (Arnold). Vedder and Howell, American Association Petroleum Geologists Miscellaneous Publication 24, p. 90.
1979. *Lyropecten catalinae* (Arnold). Vedder, Howell, and Forman, Society of Economic Paleontologists and Mineralogists, Pacific Section, Pacific Coast Paleogene Symposium no. 3, p. 249, 250, table 5.

Holotype.—LSJU 30, a right valve of a young adult 7.6 cm high, 7.4 cm long.

Type locality.—Santa Catalina Island, Calif. Arnold reported the type specimen "from a limy matrix near the Isthmus," but later work (Vedder and Howell, 1976, Vedder and others, 1979) suggests it came from the center of the island on the north side of the saddle between Mount Banning and Mount Orizaba (USGS loc. M6868).

Matrix material in the holotype is a hard, white, medium- to coarse-grained marly tuff. Megafossils associated with the species on Mount Banning (USGS loc. M6868) are represented mainly by external molds; Vedder and Howell (1976) also report rare specimens of *Hinnites* sp. cf. *H. giganteus* (Gray).

Age.—Late middle Miocene.

Paratype.—LSJU 561, internal shell of right valve.

Significant hypotypes.—UCMP 37385, a right-valve hinge fragment; UCMP 37386, a left valve; UCMP 16098.

Taxonomic comments.—*Lyropecten catalinae* is neither a subspecies nor a direct ancestor of *L. estrellanus*. It belongs to a more southern stock that includes *L. gallegosi* and *L. cerrosensis* and may be conspecific with the former.

Description.—Valve profiles flat to slightly convex, not ledged; height equals length. Beaks project slightly beyond hinge line. Auricles nearly equal, with costae crossed by concentric growth lines. Byssal notch deep, hinge line about half shell length. Umbonal angle wide, 105° in right valve, 110° in left valve. Adult right-valve ribs 17-19, flat topped, rectangular, separated by interspaces containing one midriblet. Left valves rare, poorly preserved, with 16-18 coarsely costate ribs, one midriblet per interspace. Diagnostic but barely developed key ribs in central and the fourth anterior and posterior lateral positions, a central rib scheme denoted R 3r R_c 3r R. Anterior and posterior dorsal shell margins radially costate. The species is known from about two dozen specimens, many fragmental and only one articulated (hypotype UCMP 16098). The largest individual measured 11.7 cm high, 12.5 cm long (incomplete and deformed, hypotype UCMP 37401).

Comparative notes.—*Lyropecten catalinae* has been confused with *L. estrellanus*, which has a similar rib count and interspace sculpture but differs in having convex valves and rounded ledges, and which is found in younger (late Miocene) rocks in northern and central California.

Phylogenetic affinities.—*Lyropecten catalinae*, *L. gallegosi*, and *L. cerrosensis* form a phylogenetic sequence based on morphologic characters and stratigraphic position. Rib counts are 16-18 in *L. catalinae* and *L. cerrosensis*, 20-21 in *L. gallegosi*, not a progressive increase in number from stratigraphically older to younger, although left-valve key ribs do increase in prominence in younger taxa.

The species is a warm-water form, and the lineage is best represented in upper Miocene and Pliocene rocks of the Vizcaino Peninsula, Baja California Sur, Mexico.

Geographic distribution and stratigraphic occurrence.—Santa Catalina Island and eastern Ventura Basin, California.

Santa Catalina Island (Vedder and others, 1979). North side of saddle between Mount Banning and Mount Orizaba (USGS M6868), in lenticular calcarenite and conglomer-

atic sandstone, where it is found with *Hinnites giganteus* (Gray). Cottonwood Canyon area (USGS M6873), in volcaniclastic sandstone and conglomerate containing barnacles, bryozoans, echinoid spines, and lower Mohnian Stage foraminifers (J.G. Vedder, oral commun., 1981).

Eastern Ventura Basin (Oakeshott, 1958), Modelo Formation (UCMP D-8261; UCMP A-4328). Towsley Formation (Kern, 1973), from Elsmere Canyon (SDSNH loc. 209; Grant and Gale, 1931, pl. 8, fig. 4; UCLA loc. 5800). Castaic Formation, basal transgressive facies in Ridge and Soledad basins (*L. estrellanus* of Stanton, 1967).

Geologic age.—Late middle Miocene to late Miocene.

Biostratigraphy.—"Margaritan" Stage. *Lyropecten crassicardo*, another "Margaritan" index fossil has been reported from Cactus Peak, Santa Catalina Island (M6869), but precise stratigraphic relations between rocks containing the two species have not been determined (J.G. Vedder, oral commun., 1976).

***Lyropecten cerrosensis* (Gabb, 1866)**

Plate 27, figures 5, 6; plate 28, figures 2, 3, 4

1866. *Pecten cerrosensis* Gabb, Paleontology of California, v. 2, p. 32; 1869, pl. 9, figs. 55, 55a.

1906. *Pecten* (*Lyropecten*) *ashleyi* Arnold, U.S. Geological Survey Professional Paper 47, p. 122-123, pl. 47, figs. 1, 1a; pl. 48, fig. 1.

not 1906. *Pecten* (*Plagioctenium*) *cerrosensis* Gabb. Arnold, U.S. Geological Survey Professional Paper 47, p. 123-124, pl. 44, fig. 5; pl. 49, figs. 1, 1a, 1b [=*Argopecten*].

1925b. *Pecten* (*Plagioctenium*) *cerrosensis* Gabb. Hertlein, California Academy of Sciences Proceedings, v. 14, no. 1, p. 15, pl. 6, fig. 1.

1926. *Pecten* (*Lyropecten*) *cerrosensis* Gabb. Jordan and Hertlein, California Academy of Sciences Proceedings, v. 15, no. 14, p. 432-433, pl. 32, fig. 4.

1931. *Pecten* (*Lyropecten*) *estrellanus* (Conrad) var. *cerrosensis* Gabb. Grant and Gale, San Diego Society of Natural History Memoir, v. 1, p. 187, pl. 8, figs. 1a, 1b, 2a, 2b; pl. 9, fig. 2.

1938. *Lyropecten cerrosensis* (Gabb). Woodring, U.S. Geological Survey Professional Paper 190, p. 21, 32-35, pl. 7.

1965. *Lyropecten cerrosensis* (Gabb). Durham and Addicott, U.S. Geological Survey Professional Paper 524-A, p. A13, pl. 3, fig. 8.

1972. *Chlamys* (*Lyropecten*) *cerrosensis* (Gabb, 1869). Hertlein and Grant, San Diego Society of Natural History Memoir 2B, pt. 2, p. 209, pl. 34, figs. 1-4; pl. 36, fig. 7.

Holotype.—UCMP 32669, a large two-valved individual from Cedros ("Cerros" of early authors) Island, off the west coast of Baja California Sur, Mexico. Height 21 cm, length 22.6 cm. After Gabb described *L. cerrosensis*, the holotype was misplaced for about 50 years. Presuming the type lost, authors used Arnold's name, *Pecten ashleyi*, until the Gabb type was recognized in the collections at UCMP (Joseph Peck, oral commun., 1973).

Type locality.—Cedros Island, Baja California Sur, Mexico. Subsequent mapping and collecting by Frank Kilmer restrict the type area to the southeast coast of the island, in cliffs below the town of Cedros. The sandstone, which has not been formally named, was considered "probably Miocene" by Gabb; field checking for this paper suggests it is Pliocene in age and possibly reworked.

Significant hypotypes.—UCMP 12082 (= holotype of *Pecten ashleyi* Arnold); UCMP 36469 (Durham and Addicott, 1965, pl. 3, fig. 8).

Taxonomic comments.—Arnold's referral of Gabb's species to the subgenus *Plagioctenium* [=*Argopecten*] led many later workers and curators to confuse argopectinid species with *Pecten cerrosensis*. Taxa misidentified as *L. cerrosensis* include *Pecten hakei* Hertlein, *P. subdolus* Hertlein, *P. callidus* Hertlein and *P. circularis* Sowerby (Jordan and Hertlein, 1926, p. 433).

Description.—Valves equally convex, not ledged; length slightly greater than height. Beaks project slightly beyond hinge line. Auricles subequal, small in proportion to adult shell size, with fine to obsolete costae. Byssal notch shallow to moderately deep. Hinge line about half shell length. Right valves with 16-18 unstriated, rectangular ribs; rib profiles high and narrow in juveniles, lower and flatter in adults. Juvenile interspaces with one midriblet, adult spaces with several fine threads. Left-valve ribs 16-18, anterior-most and posterior-most ribs commonly obsolete. Left valves with three or more slightly developed key ribs in a pattern described as R 3r R_c 2r r. Some individuals have a fourth incipient raised rib two positions in front of the anterior key rib, a scheme described, from anterior to posterior, as 2r R 2r R 3r R_c 3r R 4r (hypotype LACMIP 4505 from locality LACMIP 305-C). Key ribs are better developed in juvenile to young adult forms as much as 12-13 cm high (pl. 28, fig. 2); they are neither thickened, as in evolutionarily advanced forms of *L. crassicardo*, nor nodose, as in *Nodipecten* species. The largest individual is 20.5 cm high (incomplete), and 22.8 cm long (locality UCMP A-1360, Cedros Island).

Variability.—The largest specimens come from Cedros Island, where they are common; they become progressively smaller and rarer to the north. Rib number between juveniles and adults varies by one. Shells of mature specimens may have posterior elongation of no phylogenetic significance. Rib profiles are high and narrow in juveniles, lower and rounded near ventral edges of adult shells.

Comparative morphology.—*Lyropecten cerrosensis* differs from *L. catalinae* and *L. gallegosi* in having fewer ribs (16-17 rather than 17-19), rounder, less rectangular rib profiles and numerous fine striae in the interspaces. Single right valves of the three species are hard to distinguish.

Phylogenetic affinity.—*Lyropecten cerrosensis* is the youngest member of the phylogenetic series *L. catalinae-L. gallegosi-L. cerrosensis* and attains the largest adult size. The most distinctive morphologic clue to this series is the development of left-valve key ribs in the pattern R 3r R_c 3r R.

Geographic distribution and stratigraphic occurrence.—Neogene basins of Cedros Island and the Vizcaino Peninsula, Baja California Sur, Mexico to southern and central California: San Diego, Los Angeles, Ventura, Santa Maria, and the southern Salinas Valley. San Joaquin Valley, Panorama Hills 7½-minute quadrangle.

Representative localities.—Baja California Sur, Mexico: unnamed Pliocene strata, Cedros Island: CAS 946, 928; UCMP D-8795; UCMP A-1360; upper part of the Almejas Formation, Turtle Bay (LSJU loc. 807). Baja California, Mexico: La Cresta Formation, El Rosario Arriba (UCMP B-3269); San Diego Formation, Rosarito Beach, (U.C. Davis 248), from conglomerate 20 ft above base of formation (Rowland, 1972).

California Neogene basins: San Diego Formation (SDSNH 2287; LACMIP 305-C; SDSU 45; UCR 7583). Niguel Formation (M2098, M2099, and Vedder, 1960). Capistrano Formation, upper part (M2106), in a mixed assemblage of deep-water and displaced shallow-water organisms deposited by turbidity currents in 1,050-1,200 m (Kern and Wicander, 1974). Pico Formation (LSJU accession nos. 1639, 2938) and southeast of Pico Canyon (SDSNH 228). Santa Monica Mountains (Woodring, *in* Hoots, 1931, p. 116, 119). Careaga Formation, Santa Maria basin (Woodring and Bramlette, 1950) LSJU accession nos. 22360, 47622). Repetto Formation of former usage (LACMIP 291, USGS 3426; Oakeshott, 1958, as *L. estrellanus*). Fernando Formation, type section at north end of Los Angeles Aqueduct, San Fernando Valley (LSJU accession no. 53242) and Puente Hills (Durham and Yerkes, 1964); eastern Ventura Basin, Pico Formation, Camulos quadrangle (Winterer and Durham, 1962 and LSJU accession nos. 22373 and 22375) and Simi Valley (Woodring, 1930); Saugus Formation (UCLA 2535; UCR 7581; UCR 7585). Pancho Rico Formation (UCMP A-911, A-2939; USGS 3542; M952; M1341); rare, disarticulated specimens from these southern Salinas Valley localities are smaller than more southerly counterparts, as expected for a subtropical form at its northernmost range. *Lyropecten terminus* and *Forreria belcheri* (Hinds) are also found in the Pancho Rico Formation at these localities.

Geologic age.—Late Miocene to late Pliocene.

Biostratigraphy.—The species is found in rocks equivalent to the upper "Etchegoin" and "San Joaquin" Stages, although these may not be appropriate names for chronostratigraphic units in west Mexico. *Lyropecten cerrosensis* is not found in the San Joaquin Valley type sections of these stages. At Cedros Island the species is common in beach sections south of town, where it forms *Pecten*-coralline algae beds (locality UCMP D-8795).

Paleobiogeography.—The presence of *L. cerrosensis* in the western Cholame Hills is further evidence of the seaway connecting the Salinas Basin and the Santa Maria Basin (Addicott and Galehouse, 1973). It has not been found with *L. terminus* in the San Joaquin Valley near Coalinga, but a single right valve from unnamed marine sedimentary rocks in the Panorama Hills 7½-minute quadrangle (M7898) is tentatively referred to *L. cerrosensis*. Additional material including diagnostic left valves could have important biogeographic significance.

Lyropecten colinensis colinensis
(F. and H. Hodson, 1927)

Plate 16, figures 5-7; plate 19, figures 1, 3, 5

1927. *Pecten* aff. (*Nodipecten*) *colinensis* F. and H. Hodson, *in* Hodson, Hodson, and Harris, Bulletins of American Paleontology, v. 13, no. 49, p. 33-34, pl. 18, figs. 3, 6; pl. 19, fig. 4.
1964. *Lyropecten* (*Nodipecten*) sp. "b". Weisbord, Bulletins of American Paleontology, v. 45, no. 204, p. 162, pl. 17, figs. 4, 5 [fragment; probably the posterior part of a left valve].
1968. *Chlamys* (*Nodipecten*) *colinensis* (Hodson and Harris). Mongin, Bulletins of American Paleontology, v. 54, no. 245, p. 487, pl. 48, fig. 1.
1971. *Lyropecten* (*Nodipecten*) cf. *colinensis* (F. and H. Hodson). Jung, Bulletins of American Paleontology, v. 61, no. 269, p. 165, pl. 1, fig. 3.
1982. *Nodipecten clydonus* Woodring, U.S. Geological Survey Professional Paper 306-F, p. F599, pl. 101, figs. 5, 6.

Holotype.—PRI 21691, a two-valved individual, 8.3 cm high, 9.7 cm long.

Type locality.—Falcon, Venezuela, Colina District; Buena Vista structure at La Vela. From section running east-west beginning east of Taratara (Hodson field loc. 115). Outcrop of sandy yellow limestones 10 in. to 2 ft thick; hard, massive beds containing pectinids, large oysters, and very large echinoids.

Age.—Middle Miocene (Hodson); probably Caujarao Formation, Mataruca Limestone Member that is late middle Miocene in age (J. Gibson-Smith and W. Gibson-Smith, 1979).

Paratype.—PRI 21954 (Hodson field locality 125).

Description.—Valve profiles moderately convex, some with evenly spaced nodose ledges. Length slightly greater than height. Beaks project slightly beyond hinge line. Auricles subequal, lirate, the anterior auricle with 5-6 costae. Byssal notch moderately deep. Hinge line about half shell length. Umbonal angle 90°-92°. Right valve with 11-12, rounded-rectangular, evenly spaced ribs. Left-valve ribs 12-13; ledges and nodes prominent in juveniles as much as 2 cm in height, also common in adults. Hollow nodes on every third rib in a pattern described as N 2r N_c 2r N; additional anterior and posterior ribs may also have nodes. Anterior and posterior dorsal shell margins commonly striate, with numerous scaly ridges rather than fully developed riblets. Well-preserved material with prominent scales or frills where concentric growth lines cross radial riblets. Adults are as much as 10 cm high and 10.4 cm long (NMB G16551, locality 13117).

Comparative morphology.—Young right valves of *L. colinensis, s.s.* and *Nodipecten arnoldi* are similar, but left valves are easily separated by rib scheme and rib count (N r N_c r N, 9 ribs in *N. arnoldi*).

Phylogenetic affinities.—The left-valve node scheme (N 2r N_c 2r N) places *L. colinensis, s.l.* with the eastern Pacific *L. crassicardo-L. magnificus* stock of Miocene to Holocene age. *Lyropecten colinensis, s.l.* shares with the Caribbean Nodipectens the tendency toward coarse scaly macrosculpture and flanged nodes at former shell margins. The possibility that *L. colinensis* is a convergent *Nodipecten* that happened to develop a Lyropectinid node scheme is suggested by specimens from Guadeloupe, West Indies (Mongin, 1968). Present morphologic evidence and the Panamic fossil record favor grouping *L. colinensis, s.s.* with the Pacific Lyropectens rather than with the western Atlantic Nodipectens.

Lyropecten colinensis vokesae, n. subsp. is probably a direct descendant of *L. colinensis, s.s.*

Geographic distribution and stratigraphic occurrence.—Caribbean region: Panama, Venezuela, Trinidad, Guadeloupe.

Paraguana Peninsula, Falcon, Venezuela, Cantaure Formation (UCMP S-144), in soft yellow marl. Early Miocene foraminifers referable to the *Globigerinatella insueta* zone of Bolli (1957) were found at the type locality of the Cantaure Formation molluscan horizon, which is overlain by a middle or upper Miocene limestone (Hunter, 1978). The precise stratigraphic level of UCMP S-144 is unknown.

La Vela area. Caujarao Formation, Mataruca Limestone Member, a massive limestone (USGS 6296; UCMP S-305; NMB 13117). J. Gibson-Smith collected another specimen from the Cementerio de Carrizal outcrop near Mataruca, believed to be Hodson's locality 185 and considered late middle Miocene in age (J. Gibson-Smith and W. Gibson-Smith, 1979). San Gregorio Formation of L.W. Henry, specimen labels (UCMP S-284, S-287).

Trinidad. Tamana Formation, Guaracara Limestone Member (NMB 10636), lower or middle Miocene (Barr and Saunders, 1968).

Carriacou. Carriacou Formation, late early Miocene to early middle Miocene. Specimens from Trechmann (1935) were re-examined by Jung (1971), including a lot numbered BM(NH) Department of Paleontology, LL24528, top of Bretache Point, southeast part of the island.

Grand Terre, La Guadeloupe (Mongin, 1968, pl. 43).

Panama, Madden Basin. Alhajuela Formation, lower member (USGS 5906A, type locality of *Nodipecten clydonus* Woodring, 1982).

Geologic age.—Early Miocene to late middle Miocene.

Lyropecten colinensis vokesae, new subspecies

Plate 16, figures 1-3; plate 17, figure 3; plate 18, figures 2-4; plate 19, figures 2, 4

Holotype.—USNM 334988, a double-valved individual 6.5 cm. high, 7.2 cm long.

Type locality.—Dominican Republic, 2.9 km west of Los Quemados in roadcut on the Los Quemados-Sabaneta road; 0.3 km west of bridge over Rio Gurabo (TU 1338). Gurabo Formation, late Miocene or early Pliocene.

Description.—Valve outlines circular to slightly longer than high. Right valve slightly more convex than left valve. Beaks project slightly beyond hinge line. Auricles subequal, costate, and lirate, anterior auricle having about three coarse radials. Byssal notch moderately deep. Hinge line slightly shorter than half shell length. Right valves with 10-11 ribs sculptured by moderately coarse to coarse costae crossed by lirae; wide central space flanked by uniformly arranged to slightly grouped ribs and 1-3 coarse riblets in interspaces. Left valves flatter than right valves, with 9 ribs arranged in the scheme N 2r N_c 2r N; individuals over 1 cm high have hollow, flanged nodes on the three key ribs, 1-2 radials in interspaces. Nodes correspond to slight ledges or constrictions in the shells. Anterior and posterior shell margins have incipient radial ridges that confuse rib counts. The largest individual seen measured 9 cm high, 8.5 cm long (incomplete) (TU loc. 1209). Whole specimens tend to be longer than high.

Variability.—Juvenile parts of shells have one or two more ribs than adults, the earlier riblets becoming obsolete marginal ridges in later growth stages. Radial costae vary from coarse (four radials per rib) to very coarse (three radials per rib).

Comparative morphology.—*Lyropecten colinensis vokesae* differs from *L. colinensis, s.s.* in having one or two fewer ribs. Its rib count overlaps that of *L. modulatus*, from which it differs in having coarser fine sculpture and the flanged nodes characteristic of Caribbean Nodipectens and *L. colinensis, s.s.* The left-valve node scheme N 2r N_c 2r N separates *L. colinensis vokesae* from *Nodipecten collierensis* and *N. pittieri* (N r N_c r N), which are present in the Miocene and Pliocene of the Greater Antilles.

Phylogenetic affinities.—Juvenile rib counts and sculptural similarity indicate that *L. colinensis vokesae* evolved from *L. colinensis, s.s.* It is a Tertiary Caribbean taxon represented in Panama; its relation to *Lyropecten tiburonensis*, n. sp. from the northern Gulf of California and to *L. modulatus* of the Vizcaino Peninsula, Baja California Sur is uncertain.

Geographic distribution and stratigraphic occurrences.—Isolated occurrences within the Tertiary Caribbean Province in the Dominican Republic and Panama.

Dominican Republic, west of Los Quemados, near the Rio Gurabo. Gurabo Formation and in float from the Gurabo and Cercado Formations (TU 1209, 1210, 1231, 1338). W.H. Akers (oral commun., 1981) has identified early Pliocene N19 zone foraminifers from TU 1209, 1210; the Gurabo Formation is shown as late Miocene to early Pliocene by Saunders and others (1982).

Panama. Colon Province, Madden Basin. Alhajuela Formation(?) of collector T. Thompson (LSJU loc. 2659, about 1 mi below the Madden Dam on north bank of

Chagres River). Caimito Formation, upper part, and Alhajuela Sandstone of Woodring (1957, pl. 1).

Geologic age.—Late Miocene to early Pliocene.

***Lyropecten crassicardo* (Conrad, 1856)**

Plate 23, figures 1-4, 6; plate 24, figures 1, 3-9; plate 25, figures 1-7

1856. *Pallium crassicardo* Conrad, Academy of Natural Sciences of Philadelphia, Proceedings, v. 8, p. 313.
1867. *Lyropecten crassicardo* Conrad, American Journal of Conchology, new ser., v. 3, pt. 1, p. 6-7.
1906. *Pecten (Lyropecten) crassicardo* Conrad. Arnold, U.S. Geological Survey Professional Paper 47, p. 71-73, pl. 16, figs. 1, 1a; pl. 17, figs. 1, 1a, 1b; pl. 18, pls. 1, 2, 2a.
1906. *Pecten (Lyropecten) crassicardo* var. *hamiltoni* Arnold, U.S. Geological Survey Professional Paper 47, p. 73-74, pl. XI, figs. 5, 6.
1915. *Pecten (Pallium) holwayi* Clark, University of California Bulletin of the Department of Geology, v. 8, no. 22, p. 454, pl. 47, fig. 5.
1917b. *Pecten crassicardo biformatis* Nomland, University of California Bulletin of the Department of Geology, v. 10, no. 18, p. 307, pl. 18, figs. 1, 1a,b; pl. 19, fig. 4.
1922. *Pecten (Lyropecten) ricei* Trask, University of California Bulletin of the Department of Geological Sciences, v. 13, no. 5, p. 148, pl. 2, figs. 1, 2.
1922. *Pecten (Lyropecten) vickeryi* Trask, University of California Bulletin of the Department of Geological Sciences, v. 13, no. 5, p. 148, pl. 4, fig. 1.
1931. *Pecten (Lyropecten) magnificus* Sowerby, var. *crassicardo* (Conrad). Grant and Gale, San Diego Society of Natural History Memoir, v. 1, p. 183-184, pl. 9, figs. 4, 5.
1931. *Pecten crassicardo nomlandi* Hertlein, Journal of Paleontology, v. 5, no. 4, p. 369 [was *P. c. biformatis* Nomland, 1917b, a preoccupied name].
1969. *Lyropecten crassicardo* (Conrad) *nomlandi* (Hertlein). Adegoke, University of California Publications in Geological Sciences, v. 80, p. 100, pl. 2, fig. 8.
1969. *Swiftopecten adekunbiana* Adegoke, University of California Publications in Geological Sciences, v. 80, p. 104, pl. 6, figs. 3, 5 (= *Swiftopecten* sp. Adegoke, 1967, Veliger, v. 9, no. 3, p. 337-339, pl. 47). [It is a fragment of a much larger left valve of *L. crassicardo*].

Holotype.— Missing. Conrad described a double-valved specimen 5 in. high with 15-16 ribs that was collected by A.S. Taylor. Lectotype ANSP 30745a (pl. 23, fig. 4) designated by Moore (1984b) is a right valve, 13.8 cm high, 13.5 cm long.

Type locality.—Monterey County, Calif., from the northern La Panza Range. Subsequent work suggests the type area was near La Panza, a small settlement south of California Highway 58 between Creston and Simmler. Santa Margarita Formation, early late Miocene in age. Paratypes ANSP 30745 (given to Gabb and labelled by him as "Conrad paratypes," E.J. Moore, oral commun., 1974).

Taxonomic comments.—*Lyropecten crassicardo* varies in convexity and growth form, and juveniles and poorly preserved individuals are hard to identify. *Lyropecten crassicardo* has been described under at least nine different names; many of the holotypes of these synonymized species are figured herein and some are discussed in the sections on ledging and node formation.

Description.—Valves flat to moderately convex, left-valve profiles smooth or with one or more angular ledges producing a steplike profile in shells as much as 5 cm high (fig. 9). Beaks project equally, slightly, beyond hinge line. Auricles large, subequal, costate, lirate. Anterior auricle with five prominent radials crossed by fine imbricating lirae. Byssal notch moderately deep. Hinge line more than half shell length. Umbonal angle varies with convexity, 90°-110°. Right valves with 14-15 rectangular ribs. Left valves with 14 ribs; some specimens with prominent key ribs in the central and fourth lateral positions, as indicated by the scheme N 2r N_c 2r N. Ribs narrower, interspaces broader in left valves than in right valves. Nodes or thickenings common at ledge margins of juvenile parts of some shells (pl. 24, figs. 1, 3). Some specimens have no discernible key ribs; others three, four, or five, all separated by two normal ribs. Whether these additional key ribs appear anteriorly or posteriorly may have biostratigraphic significance, but precise stratigraphic data were lacking for much of the material available.

Fine costae and lirae on ribs and interspaces produce even, reticulate fine macrosculpture. Truly "giant pectinids," one specimen of *L. crassicardo* is 19.5 cm high and 20.0 cm long (CAS 503, Kimballs Wells, Coalinga).

Variability.—*Lyropecten crassicardo* varies considerably in valve convexity, presence and number of angular ledges, and prominence of key ribs on left valves. The node scheme (N 2r N_c 2r N) and lirate, striate fine macrosculpture are consistent features. Valves may be flat and thin, as in specimens from San Clemente Island (UCR 7597, LACMIP 1194), or moderately convex. Left valves may have 0-5 angular ledges. Incipient nodes or elongate thickenings (pl. 24, fig. 3) are common on geologically younger individuals. Some large adult shells are elongated posteriorly, a growth habit with no phylogenetic significance. There is some tendency to fewer ribs on the left valve (13-14) in material from southern California compared with 14-15 ribs in Transverse Range specimens.

Comparative notes.—*Lyropecten crassicardo* is found with *L. estrellanus* in many outcrops of the Santa Margarita Formation. *Lyropecten crassicardo* has fewer ribs, angular ledges, flat juvenile valves, radially striate, lirate fine macrosculpture, and incipient to prominent key ribs of the scheme N 2r N_c 2r N. *Lyropecten estrellanus* is rounded to gibbous in profile, especially in juveniles; it has 16-17 ribs, rounded ledges, no key ribs, and a single midriblet in each interspace.

Phylogenetic affinities.—*Lyropecten crassicardo* and the Holocene *L. magnificus* belong to a phylogenetic series that includes specimens from Baja California Sur referred here to *Lyropecten* sp. cf. *L. magnificus*. They are classified as a bioseries on the basis of rib counts, macrosculpture and left valves showing a progression of incipient key

ribs evolving to ribs bearing hollow nodes in the scheme N 2r N_c 2r N. The highest stratigraphic occurrences of *L. crassicardo* tend to be specimens having 3-5 ribs with elongate thickenings (pl. 24, figs. 1, 5) in the same positions occupied by hollow nodes in Lyropectens living in the Galapagos today (pl. 24, fig. 2). Right valves lack any obvious clues to phylogeny. *Lyropecten* sp. cf. *L. magnificus* from Baja California Sur is probably ancestral to *L. crassicardo*, and *Lyropecten pretiosus* (= *L. submiguelensis* of authors) is either a co-occurring species or a variant of the ancestral taxon.

Geographic distribution and stratigraphic occurrences.—California Coast Ranges, from the San Francisco Bay area to Orange County; the Channel Islands and Transverse Ranges; east of the San Andreas fault near Coalinga, Bakersfield, Tejon Hills, and Temblor Range; Caliente Range. Widespread in upper Miocene shallow-marine deposits. Reported from Baja California Sur, but much of the material is referable to *Lyropecten* sp. cf. *L. magnificus* or *L. pretiosus*. Not from the middle Miocene Rosarito Beach Formation near La Mision, Baja California as listed in Deméré and others (1984).

Representative localities.—Briones Sandstone, Mount Hamilton Range (UCMP B-4734; UCMP 3535; LSJU holotype 26, *L. vickeryi* from McGuire Peaks, Livermore 15-minute quadrangle; Stanford Geological Survey loc. 128, in *Scutella breweriana* beds); San Pablo Formation (UCMP B-4738; UCMP 1632, *Pecten* beds, upper part of San Pablo Group of Clark, 1915). Cholame area, UCMP A-3426. Specimens with 3-5 key ribs, slightly advanced to advanced evolutionary stage. Santa Margarita Formation, Carnaza Creek, northern La Panza Range (LSJU loc. 1080 N/SJR, slightly advanced evolutionary forms, but very worn shells. LSJU accession no. 22365). Type area between Huerhuero Creek on the west and Cammatta Creek on the east (Addicott and others, 1978). Santa Margarita Formation, upper part (USGS locs. M2895, M2896, M3569) in *Lyropecten crassicardo-Ostrea titan* biostrome at the base of a massive, coarse-grained sandstone on the western hillside of Shell Canyon. Specimens worn; most are slightly advanced, some highly advanced evolutionary forms, similar to material from USGS locs. M2879, M5028, M5033; found with abundant *L. estrellanus* at USGS locs. M2830, M5030; USGS 4930, 4944, 4945, 4950, 13098, 16853; LSJU Pz [Pozo] 51; LACMIP 484.

Obispo Formation, Nipomo Valley (Hall, 1973b); UCMP D-2426, external mold in rhyolitic beds on the east side of the valley, about 4.5 mi (7.2 km) northwest of Nipomo. Probably an early evolutionary form. UCLA 5068, evolutionary stage not determined. UCLA 5067, near middle part of the Obispo Formation. Found with late Saucesian foraminifers in rhyolitic tuff dated at 16.5 ± 1.2 Ma (Turner and others, 1970). These authors considered the top of the Obispo Formation to be near or at the boundary of the Saucesian and Relizian microfaunal stages; if this is so, then the specimens of *L. crassicardo* from the middle part of the Obispo Formation are some of its oldest records.

Coalinga area, western San Joaquin Valley. Santa Margarita Formation. Abundant in *Pecten-Ostrea* biostromes (CAS 2363); LSJU accession no. 46712; UCMP D-8791. Found with *L. estrellanus* at CAS 503, 504. Normal ribbing or slightly developed left-valve key ribs at many localities, such as UCMP D-1087. Some specimens of slightly advanced evolutionary stages; others less developed, as at UCMP B-7084, the sand dollar locality in the basal part of the Santa Margarita Formation just above the Big Blue Formation. Primitive form with no ledges or key ribs, LSJU accession no. 30702; advanced evolutionary form with four prominent key ribs at UCMP D-1088 (pl. 24, fig. 3), holotype of *Swiftopecten adekunbiana* Adegoke (1969). Monterey Formation, McLure Shale Member (Adegoke, 1969), UCMP D-1207, Reef Ridge quadrangle. Only right valves collected, of material similar to Comanche Point forms (M1619). Upper part of the Temblor Formation, Garza Peak quadrangle, USGS 14403, uniform ribbing on left valves, an early evolutionary form of the species.

Eastern San Joaquin Valley, Kern County. Santa Margarita Formation, Tejon Hills, Comanche Point (M1619); worn, disarticulated specimens, evolutionary stage indeterminate, from *Pecten-Ostrea* conglomerate. Some specimens have aberrant rib counts, none have key ribs; CAS 1677 and UCMP 3029, type locality of *Pecten crassicardo biformatis* Nomland. USGS 6071, one specimen of slightly advanced evolutionary stage but with some aberrant ribs. UCMP A9417, A9419, left valves with uniform ribbing to very slightly developed key ribs. Olcese Sand, Oil Center 7½-minute quadrangle, UCLA 8271, a single juvenile left valve with uniform ribbing.

Temblor Range, Santa Margarita Formation, M3784, M3786, M3787, some left valves with no or very slightly developed key ribs; abundant juveniles and adults at these localities. Buttonbed Sandstone Member, upper part of the Temblor Formation. M3988, basal part of the Buttonbed Sandstone Member, here 5 feet thick; LSJU loc. 2846 (Heikkila and MacLeod, 1951), specimens with very slightly developed key ribs on left valves, interpreted as early forms of the species. Temblor Formation, M3580, 10 ft above unconformity between Temblor Formation and Cretaceous rocks; early forms of *L. crassicardo* with uniform ribbing on left valves.

Northern Channel Islands, San Onofre Breccia (McLean and others, 1976), Southwest Santa Cruz Island. UCSB loc. JW Byer 65-5, upper Canada Posa, "Kinton Point C Member" of specimens labels; disarticulated specimens, evolutionary stage indeterminate, UCMP A-8698, in *Pecten* bed 1-2 ft thick. San Miguel Island, Beechers Bay Member, upper part, of Monterey Formation or a local

calcareous reef in the overlying shale member (Weaver and others, 1969): M3016, advanced evolutionary stage, with five prominent key ribs. Southwest Santa Lucia Range, Morro Bay area (Prior, 1974; Hall 1973a); Pismo Formation, lower member: UCLA 6199, with *Ostrea titan* and *Balanus gregarius*, forming a shell breccia in basal conglomerate. *Lyropecten crassicardo* occurs in the lower third of the lower member and the base of the upper member. Foraminifers are "possibly lower Upper Mohnian" (Prior, 1974).

Transverse Ranges, Wheeler Springs 7½-minute quadrangle, Santa Margarita Formation: LSJU/SGS loc. 64-8, gypsiferous member, upper part of the Santa Margarita Formation, just below gypsum beds. Specimens of advanced evolutionary stage, in very coarse grained lithic sandstone with shell fragments. Monterey Formation, sandy middle member: LSJU 2170; left valves have uniform ribbing and may be referable to *Lyropecten* sp. cf. *L. magnificus*; silty interbeds contain Relizian Foraminifera (Dickinson, 1969; Vedder and others, 1973). Warm Springs Mountain 7½-minute quadrangle, Los Angeles County, Castaic Formation: UCR 7569, abundant specimens of advanced evolutionary stage in basal conglomerate on east side of Castaic Canyon and in basal pebbly sandstone east of Cordova Ranch (Stanton, 1967).

San Joaquin Hills area, Orange County. Monterey Shale (Vedder and others, 1957): M3188, M3225, sandy facies of basal part of the Monterey Shale; *L. crassicardo* is a slightly advanced evolutionary form with three key ribs and an incipient anterior key rib found with Luisian foraminifers (J.G. Vedder, oral commun., 1973). Corona 7½-minute quadrangle, UCMP 1910; UCLA 45108, labeled "Temblor Formation" from field loc. 411, up ravine east-northeast of Bee Canyon (= Topanga Formation localities of Schoellhamer and others, 1981). UCMP 1912, and UCLA 635 (hypotype UCLA 45105, pl. 25, fig. 5), advanced evolutionary forms with well-developed key ribs. San Onofre Breccia (Vedder and others, 1957): M3179, San Juan Capistrano quadrangle, from sandstone lens within breccia; left-valve ribs uniform, suggesting an early form of *L. crassicardo*. Topanga Formation, near top, just below contact with the Monterey Shale: M3222, mostly right valves of *L. crassicardo* (evolutionary stage indeterminate), found with oysters. Monterey Formation, sandstone member (J.G. Vedder, oral commun., 1983), mostly unconsolidated: LACMIP 1189, Moulton Parkway roadcut near Rossmore Leisure World. Abundant articulated *L. crassicardo* with oysters, barnacles, sharkteeth, and porpoise vertebrae (E.C. Wilson, oral commun., 1973). *Lyropecten crassicardo* represented by juveniles to adults, all of which are abnormally flat valved and mostly unledged. Ribs are uniform and low in profile (pl. 25, fig. 1); no discernible key ribs in many, but 3-4 ribs are slightly raised in some juveniles.

Similar thin, flat-valved specimens (pl. 25, fig. 7) are found at some San Clemente Island localities (LACMIP 1193, 1194) and at USGS 4132, Aliso Creek, southeast of El Toro, in leached, diatomaceous marly sandstones. Specimens with flat right valves having 13 ribs and left-valve key ribs indicate a slightly advanced evolutionary stage.

Southern Channel Islands. Santa Catalina Island (Vedder and others, 1979): M6869, about 1.5 km northwest of Cactus Peak, in calcareous sandstone with bryozoans, calcareous algae, echinoid spines, and barnacles. Foraminifers from near the base of section (Mf3323) are lower or middle Mohnian from shallow water. Evolutionary stage of *L. crassicardo* not determined.

San Clemente Island (Vedder and Moore, 1976). Lemon Tank Reservoir, in sandy lenses in poorly consolidated to concretionary sand and silt beds exposed in quarry faces in east-central part of the island. Specimens are of a slightly advanced evolutionary stage, with incipient to marked key ribs. *Lyropecten crassicardo* is thin and flat valved with a low rib count (12-13) at some horizons (UCLA 5899, UCR 7957, LACMIP 1193, 1194), and of normal thickness and convexity at others (for example, M3734a, the lowest fossil zone exposed here, according to Vedder and Moore, 1976). Because *L. crassicardo* is represented in collections by right valves only, evolutionary stage is indeterminate. Specimens were collected by different people at different times and cannot be related stratigraphically, although available material suggests the reservoir sections contain more detailed information than is presently known.

The fact that specimens from LACMIP 1193, 1194, UCLA 5899, and UCR 7957 match material from Moulton Parkway (LACMIP 1189) and Aliso Creek (USGS 4132) suggests that similar environmental conditions affected these late Miocene populations.

The China Canyon area (USGS M6505) has Monterey-like sedimentary rocks, fine- to coarse-grained calcarenite facies overlying andesites dated about 15 Ma. Associated microfossils from USGS loc. Mf2974, which is adjacent to loc. USGS M6505, are shallow water (less than 100 m), Saucesian to Relizian foraminifers (Vedder and Moore, 1976). *Lyropecten crassicardo* is represented by fragments of indeterminate evolutionary stage. They are found with fragments of *Amussiopecten* sp. cf. *A. vanvlecki*, a provincial middle Miocene index species also represented at Moulton Parkway (LACMIP 1189).

Cuyama Valley area (Vedder, 1968). Branch Canyon Formation of Hill and others (1958), upper member. *Lyropecten crassicardo* is abundant in the upper part of this coarse, sandy, well-indurated unit, found with oysters, barnacles, and echinoids (USGS locs. M2361, M2417, M2321, M2337). Abundant material, all with left valves having slightly developed key ribs indicating a slightly advanced evolutionary form. Some material has four key ribs and incipient nodes, even more advanced morphologic characters.

Upper Sespe Creek area, upper part of the Branch Canyon Sandstone (UCLA 5683, CSUN 62). *Lyropecten crassicardo* of advanced evolutionary stage (left valves with five well-developed key ribs, elongate thickenings at ledge edges) occurs with *Astrodapsis whitneyi* (Remond) (A.E. Fritsche, oral commun. 1978). Specimens from CSUN 92 correspond to the Moulton Parkway assemblage (LACMIP 1189). Worn, disarticulated, and deformed specimens of a slightly advanced to advanced evolutionary stage are found in the Salisbury Potrero 7½-minute quadrangle (UCLA 5611, 5648, 5649).

Santa Ana Mountains. LSJU specimen from LSJU/SGS 1949, loc. 131-3A (insufficent stratigraphic and locality data, but the species is found there, represented by a two-valved specimen with no well-developed key ribs). Miocene Topanga Formation near the head of Round Canyon and Bee Canyon, El Toro quadrangle (loc. F172 of Schoellhamer and others, 1981).

Antelope Valley, western Mojave Desert. Specimens from the Quail Lake Formation (Dibblee, 1967) [= Santa Margarita Formation of Crowell (1952) and other authors] not seen for this study.

Geologic age.—Middle Miocene to late Miocene.

Biostratigraphy.—Middle "Temblor" to upper "Margaritan" Stages. Advanced forms of *L. crassicardo* and *L. estrellanus* are important "Margaritan" Stage index fossils. The stratigraphically youngest specimens of *L. crassicardo* have left valves with key ribs defined by elongate solid thickenings, ancestral expressions of the hollow nodes of Pliocene to Holocene specimens of *L. magnificus*.

Within the *L. crassicardo* lineage, several evolutionary forms are defined by left-valve ribbing. The oldest specimens have uniform ribbing; slightly advanced forms have more prominent key ribs (. . R 2r R_c 2r R. .), and advanced forms have three to five conspicuous key ribs, usually with elongate thickenings or incipient nodes (fig. 15). No single geographic area has a complete stratigraphic section with specimens showing all the evolutionary stages in biostratigraphic order.

Paleoecology.—*Lyropecten crassicardo*, especially the advanced evolutionary stage, is a prominent member of the *Ostrea-Pecten* community represented by biostromes in the upper part of the Santa Margarita Formation in Shell Canyon, northern La Panza Range, and the Coalinga area (USGS loc. M2896; UCMP D-1088).

Lyropecten denaius
(Woodring, 1982)

Plate 18, figure 1; plate 23, figure 5

1961. *Lyropecten*? (*Nodipecten*?) sp. cf. *L.* (*N.*) *nodosus* (Linne). Woodring and Malavassi, Journal of Paleontology, v. 35, no. 3, p. 495.
1982. *Nodipecten denaius* Woodring, U.S. Geological Survey Professional Paper 306-F, p. F598-599, pl. 92, fig. 11; pl. 98, figs. 8, 9.

Holotype.—USNM 647126, a double-valved specimen, but the shells are rotated 40° with respect to one another; 4.9 cm high, 4.75 cm long.

Type locality.—Panama Canal, Gaillard Cut area, west side of Las Cascadas Reach, canal station 1767 plus 15 m (USGS 23654 = field loc. 101g). La Boca Formation, upper limestone in upper part of formation. Miocene.

Description.—Type specimen incomplete, valves moderately flat. Beaks project equally, slightly, beyond hinge line. Auricles incomplete, costate. Byssal notch deep. Right valve with about 14 evenly spaced, narrow rectangular ribs; juvenile interspaces with strong concentric fine sculpture, adult spaces with 1-3 fine costae. Left valve incomplete, only 11 ribs preserved; node scheme described as . . N 2r N_c 3r N. . . Nodes are small, more like early *L. crassicardo* thickenings than large nodes of *Nodipecten nodosus*. Node scheme may be aberrant, differing from the typical *Lyropecten crassicardo-L. magnificus* pattern in having one extra rib between central and posterior key ribs. Anterior shell margin with fine radials rather than ribs. Few specimens known from the Panama area, all relatively small (3-5 cm high).

Phylogenetic affinities.—The taxon is probably related to *L. pretiosus* and the *L. crassicardo-L. magnificus* stock, on the basis of the fine macrosculpture and node scheme. It is older than *L. colinensis, s.l.*, a coarsely sculptured Caribbean lyropectinid, and is possibly ancestral to it.

Geographic distribution and stratigraphic occurrence.—Panama; probably from Costa Rica; possibly from Baja California Sur, Mexico. It is probably a Tertiary Caribbean species but few specimens have been collected.

Panama Canal area, La Boca Formation, upper limestone of upper part of the formation (USGS 23654). Possibly from Emperador Limestone Member of La Boca Formation in the Madden basin.

Costa Rica, Valle Central, San Antonio de Desamparados (USGS 7291). Left-valve fragment having the lyropectinid rib scheme defined by small nodes or thickening on the nine remaining ribs. Another poorly preserved internal mold (USGS 6469) has 10-11 ribs and remnants of fine striae and lirae.

Geologic age.—Early Miocene.

Lyropecten estrellanus
(Conrad, 1856)

Plate 1, figures 4, 5; plate 22, figures 1, 4, 7

1855a. *Pallium heermanni* Conrad, Academy of Natural Sciences of Philadelphia, Proceedings, v. 7, p. 267 [a *nomen nudum*, insufficient diagnosis, no illustration].
1856. *Pallium estrellanum* Conrad, Academy of Natural Sciences of Philadelphia, Proceedings, v. 8, p. 313.
1857. *Pallium estrellanum* Conrad, "Report on the Paleontology of the Survey," p. 191, pl. 3, figs. 3, 4 *in* Parke, John G., Report of Explorations for Railroad Routes***, v. 7, pt. 2.
1862. *Lyropecten volaeformis* Conrad, Academy of Natural Sciences of Philadelphia, Proceedings, v. 14, p. 291 [*nomen nudum*].
1898. *Pecten* (*Lyropecten*) *heermanni* Conrad. Dall, Wagner Free Institute of Sciences of Philadelphia, Transactions, v. 3,

pt. 4, p. 701.

1906. *Pecten (Lyropecten) estrellanus* Conrad. Arnold, U.S. Geological Survey Professional Paper 47, p. 74-76, pl. 20, figs. 1, 2, 2a; v. 21, figs. 1, 1a, 1b. Not pl. 19, figs. 1, 1a [= *L. terminus*]. Not pl. 21, figs. 2a, 2b, 2c; Arnold (1906, p. 76) called it "flat form grading into var. catalinae***" [= *Argopecten*].

Not 1931. *Pecten (Lyropecten) estrellanus*. Grant and Gale, San Diego Society of Natural History Memoir, v. 1, p. 185-186, pl. 8, fig. 4 [= *L. catalinae*].

Holotype.—Missing. Conrad (1856) refers to a double-valved specimen and to a single-valved individual (Conrad, 1857). Lectotype, USNM 13317, designated by Woodring (1938), is an incomplete right valve about 9 cm high, with 16 ribs.

Type locality.—San Luis Obispo County, Calif. The type area was originally given as "Estrella Valley." Although Angel (1883, p. 241) included the species in a list of Conrad's fossils from "the Estrella River at Panza," subsequent work suggests it came from the San Juan River Valley from the Santa Margarita Formation. The poor preservation and hard calcareous matrix of the *L. estrellanus* lectotype is matched in specimens washing out of Carnaza Creek (LSJU 1080), eastern tributary to the San Juan River. Late Miocene.

Description.—Juvenile valves flat, adults convex. Left valves usually more inflated than right valves, commonly with rounded ledges. Beaks project equally beyond hinge line. Auricles equal to subequal, the anterior one with 4-5 radial riblets and a deep byssal notch. Hinge length greater than half of shell length. Right-valve ribs 16-17, interspaces with a single radial riblet crossed by fine, distantly spaced lirae. Growth lines more prominent and interspace furrows more numerous in gerontic specimens. Left-valve ribs 16, with 0-5 irregularly spaced round ledges produced by periodic growth. Growth series well represented in collections from Kimballs Wells (CAS 503). Adults commonly 10 cm in height; the largest individual is 14.8 high and 14.5 cm long; it has five ledges (CAS loc. 503, near Coalinga, Calif.).

Variability.—Valve profiles vary in convexity from juveniles (flatter) to adults and in number of constrictions or ledges. Rib counts vary from 15-18, but only a few individuals have as few as 15.

Comparative notes.—*Lyropecten estrellanus* is more restricted in geologic and geographic range than *L. crassicardo*, but they commonly occur together in the upper Miocene sandstones of the Santa Margarita Formation of central California. *Lyropecten estrellanus* is distinguished by more convex valves, rounded rather than angular ledges, and 16-17 ribs compared to 14-15 in *L. crassicardo*. *Lyropecten estrellanus* has one midriblet in each interspace, no raised or "key" ribs on the left valve.

At the few localities where *L. estrellanus* is found with *L. terminus*, the former is probably reworked. At these localities *L. terminus* is distinguished by low rib counts (12-14) and multiple striae in left-valve interspaces. Single valves or fragments of *L. cerrosensis* and *L. catalinae* have been confused with *L. estrellanus* but both have higher rib counts, incipient key ribs on left valves (R 3r R_c 3r R), and no tendency to form ledges.

Transitional morphologic forms between *L. miguelensis* and *L. estrellanus* from the Cuyama area (USGS M2418) are difficult to separate, although older forms of *L. miguelensis, s.s.* have a more convex right valve and narrower umbonal angle, the beak projecting higher above the hinge line. Both taxa have a radial riblet in each interspace, but the riblet almost fills the space in *L. miguelensis*. After an inflated juvenile stage, *L. miguelensis* valves are flatter in comparison to the profile of *L. estrellanus*, which may have as many as 3-4 rounded ledges. Rib counts differ, 14-15 in *L. miguelensis*, 16-17 in *L. estrellanus*.

Arnold's "flat form grading into *catalinae*" (pl. 22, figs. 5, 6) is a flat, short-hinged scallop from the Vineyard Canyon-Indian Valley area of the Stockdale Mountain 7½-minute quadrangle (localities USGS M3995, USGS 12922 = 16833, CAS 28473). It is a convergent *Argopecten* sp. related to but different from undescribed forms from eastern Baja California Sur (CAS localities 56493, 56499); in the Cholame Hills it is restricted to a hard sandy facies of the Monterey Formation (T.W. Dibblee, Jr., oral commun. 1973, and field map of the San Miguel 15-minute quadrangle).

This form is an *Argopecten* that has been identified as both *L. estrellanus* and *L. catalinae*. It differs from both of them in hinge crura and a proportionally shorter hinge line that is not perfectly straight. Beaks meet at the hinge line, auricles are not rectangular, and valves are flat and unledged. Looped lamellar growth lines are distantly spaced. Despite all of these *Argopecten* features, the species is easily confused with *L. estrellanus*; it also has 17-18 ribs and a single midriblet in each interspace.

Phylogenetic affinities.—*Lyropecten estrellanus* belongs in the bioseries *L. miguelensis-L. estrellanus-L. terminus*; this classification is based on overall morphologic similarity, fine macrosculpture, and growth forms that have rounded ledges and beaks standing above the hinge line. The bioseries constitutes a biostratigraphic succession in middle and upper Miocene shallow-marine units and becomes progressively more restricted in geographic distribution toward the end of the Miocene.

Geographic distribution and stratigraphic occurrences.—Central California, southern Coast Ranges, La Panza and Temblor Ranges; western foothills of the San Joaquin Valley near Coalinga, and east of the Caliente Range, and in Cuyama Valley (J.G. Vedder, oral commun., 1983). Not from Elsmere Canyon (Kern, 1973) in the San Fernando quadrangle [= *L. catalinae*]. Arnold (1906) gave its range as "nearly every county from Napa to Orange,"

but the northern and southern limits established by this study are the southern Santa Lucia Range and Cuyama Valley.

Santa Margarita Formation, western San Joaquin Valley, north of Coalinga, Fresno County. Domengine Ranch localities in T. 18 S., R. 15 E., sec. 29 (CAS 29395, UCMP B-4350), especially abundant in *Pecten-Ostrea* titan reef in N¼ sec. 33. USGS M956, specimens slightly to considerably tectonically deformed; some are ledged and others not, but most tend to be flat and have pronounced concentric growth lines. UCMP A-6724, all growth stages abundant. *Lyropecten estrellanus* is found with *L. crassicardo* at CAS 2363, UCMP D-702, CAS 2037, and CAS 504. Abundant at Anticline Ridge (CAS 507) and at Kimballs Wells, the locality yielding the largest specimens of *L. estrellanus*. Also from UCMP A-6724; UCMP D-117, which is near Skunk Hollow, in the second oyster reef above the Big Blue Formation. *Lyropecten estrellanus* is rare south of Coalinga but present north of Warthan Creek Road (LSJU accession no. 53259), northeast of Alcalde (USGS 4807); in an oyster bed at Mont Jack Gulch, east of Oil City (USGS 3864).

Santa Lucia Range, Bryson and Bradley 15-minute quadrangles. Tierra Redonda Mountain area, along San Antonio River (M2308, M2305, M1678) in a white, coarse sandy matrix containing unledged specimens of *L. estrellanus* with 16-17 flat-topped ribs. Material corresponds to forms from the knoll east of San Lucas (M903) and from the Nipomo quadrangle (UCLA 4157). Also from M1936, M2046, M1678, and M1936. Abundant specimens from USGS 4140, 3 mi west of San Ardo. Present at the Arroyo Seco area (LSJU accession no. 33227) and Paraiso Spring (LSJU 4043).

Santa Margarita Formation, Cholame Hills and Santa Lucia Mountains, east and west, respectively, of the Salinas Valley. Stockdale Mountain 7½-minute quadrangle, at the top of an oyster bioherm; *L. estrellanus* is found with flatter convergent forms here referred to *Argopecten* sp. (USGS M1968, M1969). Dibblee (1972) shows the rocks as a fossiliferous sandstone older than the Santa Margarita Formation, (M3955, M4002, M4071, M3992, M4086, and LSJU accession no. 1989, from east of Vineyard Canyon). "Priest Valley" localities of old labels yielded forms equivalent to unledged, flat-ribbed specimens at the knoll east of San Lucas (M903).

Pancho Rico Formation, M2050, near base of formation (Durham and Addicott, 1965). Mostly disarticulated valves, possibly reworked with younger forms in beach deposits, as at the knoll east of San Lucas (M903). The rocks here are sandstones replete with shell fragments, echinoid and barnacle plates; the sediments represent an isolated, high-energy beach deposit surrounded by younger sandstones of the Pancho Rico Formation, whose age was revised to late Miocene by Addicott (1978). The fauna is a mixed assemblage that includes older *Lyropecten estrellanus* and *Balanus gregarius* but not the Pancho Rico index species *L. terminus*. *Lyropecten estrellanus* here is the typical 16-18 ribbed form, unledged and flatter valved than most of the older "Margaritan" specimens. Many disarticulated juveniles and adults from M903 match those from M2305 west of the Salinas Valley.

Santa Margarita Formation. Northern La Panza Range, west of Shell Canyon (M2897, just above the intraformational diatomaceous shale bed of Dibblee map, 1972). Many juveniles and adults, most disarticulated, are common with *L. crassicardo* at M5030 and in Camatta Canyon (M5031) and Quailwater Creek (uppermost part of the Santa Margarita Formation at M3735; M2872, from *Saxidomus* bed; USGS 16851).

Nipomo quadrangle, Santa Margarita Formation, lower part of the Saucelito Member of Hall (1962). UCLA 4157, 4159, 4160. Specimens have 17-18 flat-topped rectangular ribs, typical for the species. Most have swollen juvenile forms, but not with repeated ledges as are common in material from Coalinga. Mode of preservation as in M903 and Bradley localities. Lower upper Delmontian foraminiferal stage reported from here, but the lyropectinids are older, uppermost "Margaritan" stage.

Santa Margarita Formation, Phoenix Member of Hall (1962), submember 4, with upper lower Delmontian foraminifers, from UCLA 4177, 4178 (Hall and Corbato, 1967). UCLA 4550, Nipomo quadrangle. Hall (1962) also reports finding *Astrodapsis antiselli* Conrad, 1856.

Southwestern Temblor Range. Santa Margarita Formation, Panorama Hills 7½-minute quadrangle (USGS 12984, associated with *Ostrea titan* Conrad and *Astrodapsis* sp. cf. *A. antiselli*; M7868).

Northeast side of the Sierra Madre Range and western Cuyama Valley, Miranda Pine Mountain 7½-minute quadrangle (M3794, Santa Margarita Formation is correlative with the uppermost part of the Branch Canyon Sandstone in the South Cuyama Oil Field, (J.G. Vedder, oral commun., 1973). Santa Margarita Formation, member B of Fritsche (1969). Very worn specimens are found with *Crassostrea titan* in New Cuyama quadrangle (UCLA 5697, 5699, 5702); tectonically deformed, disarticulated individuals at UCLA 5708, New Cuyama and Salisbury Potrero 7½-minute quadrangles.

Geologic age.—Late middle to early late Miocene. Worn, disarticulated valves in the upper Miocene Pancho Rico Formation are probably reworked.

Biostratigraphy.—Lyropecten estrellanus is an upper "Margaritan" Stage index fossil, found with the youngest forms of *L. crassicardo*. It is commonly associated with *Ostrea titan* Conrad, *Astrodapsis*, and barnacles in biostromes near Coalinga (UCMP B-4350) and in a small knoll representing a beach deposit east of San Lucas in the Cholame Hills (M903).

Lyropecten gallegosi
(Jordan and Hertlein, 1926)
Plate 27, figures 1, 4; plate 28, figure 5

1926. *Pecten* (*Lyropecten*) *gallegosi* Jordan and Hertlein, California Academy of Sciences Proceedings, ser. 4, v. 15, no. 14, p. 434-435, pl. 29, fig. 1.

1931. *Pecten* (*Lyropecten*) *estrellanus* (Conrad) var. *cerrosensis* Gabb. Grant and Gale, San Diego Society of Natural History Memoir, v. 1, p. 187 (in part).

Holotype.—CAS 2096, an adult right valve 12.5 cm high, 13.8 cm long with 21-22 ribs.

Type locality.—Cedros Island, western Baja California Sur, "9 miles [14.5 km] north of Bernstein's abalone camp" [= village of Cedros], near Arroyo Choyal, north of Gran Canon (CAS 946). Collected by Hanna and Jordan, who regarded it as late Pliocene. Holotype matrix is a well-indurated, yellow-brown, medium-grained sandstone and pebble conglomerate.

Giant specimens of *L. gallegosi* are randomly oriented in coarse conglomerate at the type locality and the strata may represent a turbidite or heavily reworked channel deposit (fig. 16). These unnamed beds, which are correlative with the Almejas Formation southeast of Turtle Bay on the Vizcaino Peninsula, Baja California Sur, are considered late Miocene in age (Smith, 1984).

Paratypes.—CAS 2096, 2097, 2098, 2099, 2100.

Hypotype.—UCMP 16107 (pl. 28, fig. 5), a well-preserved adult 14.1 cm high, 14.3 cm long. (loc. UCMP B-3059).

Description.—Valves moderately flat, height equal to length. Left valves commonly with one slight ledge when the individual measures 6 cm high (pl. 28, fig. 5). Beaks project equally, slightly, beyond hinge line. Auricles subequal, costate; right valve anterior auricle with about seven coarse radials. Byssal notch deep. Hinge line about half of shell length. Umbonal angle 105°-110°, varying with convexity. Right-valve ribs 19-20. Left-valve ribs 20-21, high and narrowly rectangular in juveniles, 18-20 broad, flat-topped in adults. The left-valve central rib most prominent; left-valve key ribs separated by three regular ribs in a scheme described R 3r R_c 3r R.. Key ribs 3-5, anterior and posterior ones usually less prominent. Interspaces with a single midriblet; unusually well preserved

FIGURE 16.—Photograph showing *Lyropecten gallegosi* in random orientations within channel deposit or turbidite. In small canyon just south of Arroyo Choyal, Isla Cedros, Baja California Sur, Mexico (CAS946).

specimens, such as hypotype UCMP 16107, with fine costae and scaly, distantly spaced lirae. Anterior and posterior shell margins costate, without fully developed ribs. Adults exceed 16 cm high but are not so gigantic as *L. cerrosensis*.

Variability.—The rib count ranges to 23 in some left valves, because of extra posterior riblets. Although most left valves have the key rib pattern . . R 3r R_c 3r R. . , some have four riblets between the central and anterior key ribs. Ranges in variation in rib counts and profiles overlap for *L. gallegosi* and *L. cerrosensis*, and right valves are hard to distinguish.

Comparative notes.—*Lyropecten gallegosi*, which grades morphologically into *L. cerrosensis*, is distinguished from it by subtle differences in rib profiles, auricle shape and proportions, fine sculpture, and the tendency toward flatter valves. Key ribs are more prominent in left valves of *L. cerrosensis*; all ribs are more rectangular in *L. gallegosi*, more rounded in *L. cerrosensis*. The tendency to have one ledge or a change in shell angle is common in *L. gallegosi*, unknown in *L. cerrosensis*.

The two species are found with *Lyropecten modulatus* and *Nodipecten veatchii* on Cedros Island in reworked marine sandstone and conglomerate. *Lyropecten modulatus* has fewer ribs and a left-valve scheme of N 2r N_c 2r N, whereas *N. veatchii* has 6-7 very broad ribs alternating on left valves in the pattern N r N_c r N.

Phylogenetic affinities.—*Lyropecten gallegosi* overlaps *L. catalinae* in morphologic characters, but it has not been identified north of the Vizcaino Peninsula. It may be conspecific with *L. catalinae*, a middle to late Miocene form, or it may be a direct descendant of it. *Lyropecten gallegosi* gave rise to *L. cerrosensis* by the early Pliocene. The three taxa *L. catalinae-L. gallegosi-L. cerrosensis* are recognized as a phylogenetic series on the basis of left-valve key rib pattern, gradational morphology, and stratigraphic position.

Geographic distribution and stratigraphic occurrences.—Baja California Sur, Mexico: Cedros Island and the Vizcaino Peninsula near Turtle Bay. Beds containing *L. gallegosi* have been assigned to the Salada Formation (E.C. Allison and earlier collectors, field notes) but are now referred to the Almejas Formation and considered late Miocene in age (Smith, 1984).

Representative localities.—Cedros Island: common in canyon south of Arroyo Choyal, about 9 mi north of town of Cedros (CAS 946), where it is found with *Nodipecten veatchii* and *Lyropecten modulatus*. In Almejas Formation at Turtle Bay, from San Bartolome Point, north side of the bay (CAS 37626); east end of bay, in canyon, in a matrix of fine-grained diatomaceous sandstone (LSJU 807); near a prominent monadnock about 5 mi southeast of Turtle Bay (CAS 945; M9185). *Lyropecten gallegosi* is found with *L. modulatus* in the Almejas Formation at LACMIP 926, LSJU 49, and UCMP B-3049, where it was collected by E.C. Allison in 1956 with an associated "lower *Merriamaster israelskyi* fauna." One right valve from Pacific Beach, La Jolla quadrangle (CAS 1413), is possibly transitional between *L. gallegosi* and *L. cerrosensis*.

Geologic age.—Late Miocene, possibly reworked in Pliocene deposits on Cedros Island.

Biostratigraphy.—Upper Miocene, endemic to the western Vizcaino Peninsula.

Lyropecten magnificus
(Sowerby, 1835)

Plate 21, figures 1, 2, 4, 5; plate 24, figure 2

1835. *Pecten magnificus* Sowerby, Zoological Society of London Proceedings, v. 3, p. 109 (partem) [variety A from the Galapagos, not variety B from "eastern Colombia," [= Isla La Plata, Ecuador, off western Colombia] which was probably *Nodipecten arthriticus* (Reeve)].

1847. *Pecten magnificus*. Sowerby, Thesaurus Conchyliorum, v. 1, Monograph of Genus *Pecten*, p. 65.

1852. *Pecten magnificus*. Reeve, Conchologica Iconica, *Pecten*, pl. 2, fig. 9.

Not 1873. *Pecten magnificus* Gabb, American Philosophical Society Transactions, new ser. v. 15, p. 256.

1931. *Pecten (Lyropecten) magnificus* Sowerby. Grant and Gale, San Diego Society of Natural History Memoir, v. 1, p. 182-183, pl. 9, fig. 1; pl. 10, fig. 6.

1939. *Pecten (Lyropecten) magnificus* Sowerby. Hertlein and Strong, California Academy Sciences Proceedings, ser. 4, v. 23, p. 369.

1959. *Nodipecten magnificus* (Sowerby). Grau, Allan Hancock Pacific Expeditions, v. 23, p. 132-133, pl. 44.

1961. *Lyropecten (Nodipecten) magnificus* (Sowerby). Olsson, Mollusks of the tropical eastern Pacific, p. 161-162, pl. 22, fig. 1 [copied from Reeve, 1852].

1971. *Lyropecten (Nodipecten) magnificus* (Sowerby). Keen, 1971, Sea shells of tropical west America, 2d ed., p. 93, fig. 201.

1972. *Chlamys (Nodipecten) magnifica* Sowerby. Hertlein, California Academy of Sciences, Proceedings, ser. 4, v. 39, no. 3, p. 31, figs. 5, 15, 25.

Lectotype, here designated.—British Museum (Natural History) 1950.11.14.43-44 (Sowerby's variety A), a two-valved specimen 13.8 cm high, 14.3 cm long. Holocene, the Galapagos Islands.

Description.—Valves moderately flat, circular. Beaks project equally, slightly, beyond hinge line. Auricles unequal, rectangular in shape. Anterior auricle one third longer than posterior auricle, both with scaly costae. Byssal notch deep, ctenolium prominent. Hinge length more than half shell length. Right-valve ribs 12-13, costate, lirate, lacking nodes. Left-valve ribs 12-14, of which 3-5 are raised key ribs with hollow nodes. Rib scheme is N 2r N_c 2r N. . . , matching that of the California Miocene *L. crassicardo* (Conrad). Some individuals (such as CAS hypotype 13676 of Hertlein, 1972) have hollow nodes of the scheme N r N 2r N_c 2r N r N, but several had an additional riblet between the posteriormost

key ribs. The three central key ribs are phylogenetically most significant, and additional lateral riblets are less consistent. None of the 18 or so specimens seen had the strong angular ledges of *L. crassicardo*. The largest individuals measured 16.5 cm high, 17.8 cm long (hypotype LSJU 440, a Holocene right valve) and UCMP hypotype 16106, 16.8 cm high (incomplete), 18.6 cm long (UCMP B-3612, a fossil). Holocene specimens red or purple on exterior, white with red-purple edge on interior.

Comparative notes.—Lyropecten magnificus is almost indistinguishable from the middle to late Miocene California index species *L. crassicardo*. Characters in common are rib counts, node scheme, fine sculpture, overall size and proportions. Differences include a more rectangular anterior auricle in *L. magnificus* and hollow nodes in positions occupied by elongate thickenings on left-valve ribs of *L. crassicardo*. *Nodipecten arthriticus* (Reeve), the common *Nodipecten* from coastal Peru to the Tres Marias Islands, Mexico, has fewer ribs (9-10) and a different left-valve node scheme, N 2r N_c r N. Two Holocene disarticulated valves from Isla San Jose, Panama (USNM 603323) and Acapulco, Mexico (J.T. Smith, private collection) share the node scheme of *L. magnificus*, but they differ from it in ledged growth form, fewer ribs (9 or 10), and coarser radial sculpture on the auricles, whose shape is more like that of *N. arthriticus* (Reeve) than the rectangular outline of *L. magnificus*. Until more material becomes available, these specimens are regarded as aberrant *N. arthriticus* or a relict *L. modulatus*.

Phylogenetic affinities.—Lyropecten magnificus is the only living *Lyropecten*, a direct descendant of *L. crassicardo* and early Miocene specimens identified herein as *L.* sp. cf. *magnificus* (pl. 21, fig. 3). Other species in the *L. crassicardo-L. magnificus* stock include those sharing the left-valve node scheme N 2r N_c 2r N: *L. modulatus*, *L. pretiosus*, *L. colinensis*, *s.l.*, *L. vaughani*, *L. denaius*, and *L. tiburonensis*, n. sp. *Lyropecten* sp. cf. *magnificus* and *L. pretiosus* are found together in the lower Miocene Isidro Formation near La Purisima, Baja California Sur, Mexico, but available specimens are insufficient to determine whether they could be variants of a single species.

Geographic distribution and stratigraphic occurrences.—Galapagos Islands; Port Utria, Colombia (one juvenile). Baja California Sur, Mexico? Possibly in the Wheeler Springs quadrangle of California.

Holocene, Santa Cruz Island, Academy Bay. Fernandina, at Punta Espinosa (AMNH 164521, AMNH 169826, taken live from 35-100 ft [10-30 m] in protected bays). Beach drift from the islands of Santa Cruz, Fernandina, Baltra, San Salvador (Sullivan Bay, James Bay TU R-145), Isabela (Tagus Cove), Rabida, and Santa Fe (Barrington). Port Utria, Colombia (USNM 765017).

Thomas R. Waller recently recognized the first positively identified occurrence of *L. magnificus* from mainland South America, from Port Utria, Departamento Choco, Colombia. One juvenile from the Grau Collection (now USNM 765017) was taken live from 20 fathoms January 25, 1935.

Pleistocene and Holocene terraces at San Salvador Island (CAS 27255, James Bay), from raised beach 5-10 m above sea level. Baltra Island (CAS 27249, considered Pliocene by Hertlein, 1972); west side of island, south side of bay in white and yellowish tuffaceous strata interbedded with lava.

Local uplifts of Holocene beaches are common in the Galapagos, as in 1954 when a seven-mile limestone reef at Urvina Bay, Isabela Island was raised 15 ft (Bowman, 1966, p. 68). Such occurrences require reconsideration of terraces dated by early workers as Pliocene and Pleistocene.

Pliocene, Santa Cruz Island (UCMP B-3608, UCMP B-3612) in Cerro Colorado area northeast of Academy Bay. The matrix is very hard limestone. Younger lavas unconformably overlying the limestone were radiometrically dated at 1.03 ± 0.78 Ma (sample H70-130, Cox, 1983). Durham (1979) considered this locality late Miocene in age; he based his conclusion on the similarity of the fossil *L. magnificus* (pl. 20, fig. 2) to *L. crassicardo* and on the unconformable relation of the dated pillow basalt to the fossiliferous limestone. The more diagnostic left valve of *L. magnificus* could not be extricated entirely from the matrix, but the specimens seem to be the same as the living species, distinguishable but barely, from *L. crassicardo*. More recent radiometric and paleomagnetic data from volcanic rocks associated with the marine deposits suggest an age of 2 Ma (Hickman and Lipps, 1985).

Miocene specimens of *Lyropecten* sp. cf. *L. magnificus* (pl. 21, fig. 3) from several localities in Baja California Sur, Mexico approach *L. magnificus* in rib counts, profile, and fine sculpture. Localities include CAS 38792, LSJU 57, and USGS 9157, from the lower part (lower Miocene) of the Isidro Formation, Arroyo La Purisima (M9180) and Arroyo San Gregorio (Smith, 1984) and from white sandstone overlain unconformably by basalt dated at 8.1 ± 0.4 Ma (McLean and others, 1985, 1987) in Arroyo Patrocinio (M9183). Specimens from the Wheeler Springs quadrangle, California (LSJU loc. 2170) may also be this taxon.

Ecology: Sowerby listed *L. magnificus* from a depth of 6 fathoms in coral sand. Subsequent live specimens came from 10-30 m in protected bays.

Geologic age.—Latest Miocene or early Pliocene to Holocene. *Lyropecten* sp. cf. *L. magnificus* is early Miocene to middle Miocene.

Biostratigraphy.—Fossil record insufficient to determine.

Lyropecten miguelensis (Arnold, 1906)

Plate 34, figures 1-6; plate 35, figures 1, 5, 6

1903. *Liropecten estrellanus* Conrad. Yates, Southern California Academy of Sciences Bulletin, v. 2, no. 7, p. 89, pl. 8, fig. 23; footnote to pl. 6.
1906. *Pecten (Lyropecten) miguelensis* Arnold, U.S. Geological Survey, Professional Paper 47, p. 79-80, pl. 22, figs. 1, 1a, 1b; pl. 23, fig. 1.
1928b. *Pecten (Lyropecten) miguelensis* Arnold. Hertlein, Journal of Paleontology, v. 2, no. 2, p. 151; pl. 24, fig. 1.
1932. *Pecten (Lyropecten) miguelensis* Arnold. Loel and Corey, University of California Publications, Department of Geological Sciences Bulletin, v. 22, no. 3, p. 199-200, pl. 29, figs. 2, 3 [typical form], pl. 30, fig. 2 ["super-variant" form, "***the most highly developed variant," *fide* Loel and Corey, p. 340].
1969. *Pecten miguelensis* (supervariant) Arnold. Weaver, American Association of Petroleum Geologists and Society of Economic Paleontologists and Mineralogists, Pacific Section, Special Publication, pl. 32, figs. 8a, 8b).
Not 1969. *Pecten miguelensis* Arnold. Weaver, ibid., pl. 34, fig. 9 [= *L. submiguelensis* = *L. pretiosus*].

Holotype.—UCMP 12079, a double-valved, slightly deformed specimen, height 11.0 cm, length 11.0 cm. Right valve deformed, looking more convex, the umbonal area seeming narrower than it actually is.

Type locality.—San Miguel Island, one of the northern Channel Islands, Santa Barbara County, Calif. Vaqueros Formation "***confined to the Miocene (probably lower) horizon" (Arnold, 1906). The present study determined that it is early Miocene in age, from the upper "Vaqueros" Stage.

Significant hypotype.—CAS 4143, an undeformed specimen (pl. 34, fig. 5, from CAS loc. 1156, Santa Rosa Island) with better preserved fine macrosculpture than the holotype.

Description.—Valves strongly inflated, especially in juveniles; right valves more convex than left. Right-valve beak projects farther beyond hinge line than left beak. Auricles equal, costate, lirate. Byssal notch moderately deep. Right-valve ribs 15, evenly spaced and broadly rectangular. Each interspace nearly filled by a single riblet, which in large, worn adult shells may be furrowed, resembling the radial costae in mature specimens of *L. estrellanus*. Left-valve ribs 15, costate, lirate, and evenly spaced. In his original description, Arnold listed 17 or 18 rounded ribs, but my determinations for many of the same specimens are 15. Ribs and spaces with prominent growth lines (pl. 34, fig. 3). Large individuals measure 13.8 cm high, 14.6 cm long (CAS hypotype 4143).

Varibility.—Preservation accounts for some variation in fine sculpture. No trace of radial striae remains on very worn individuals. Convexity varies with growth stage, as seen in the posterior profile view (pl. 35, fig. 1).

Lyropecten miguelensis, supervariant form

Loel and Corey (1932) referred to large, broad-ribbed specimens as "supervariant forms" (pl. 34, fig. 4). They are *L. miguelensis* specimens with extremely broad, flat-topped ribs with scaly concentric growth lines. They are found at many localities and throughout the stratigraphic range of *L. miguelensis, s.s.*, although Loel and Corey regarded them as "***probably Temblor Transitional or upper Vaqueros," younger than the "type form."

The present study found no geographic, ecologic, facies, or chronostratigraphic basis for separating the forms. Many good specimens come from southwestern Santa Cruz Island, between Kinton Point and Morse Point.

Comparative notes.—Lyropecten miguelensis differs from *L. estrellanus* in valve profile and growth form, the former having strongly inflated valves, the right more convex than the left. In *L. miguelensis* the right beak projects farther beyond the hinge line. *Lyropecten estrellanus* has equally convex valves, beaks projecting equally beyond the hinge line, and a tendency to develop rounded ledges in left valves. The single interspace midriblet is coarser in *L. miguelensis* than in *L. estrellanus*, and the former has costae on the ribs. Juveniles of the two species are hard to differentiate, especially specimens from middle Miocene strata in the Cuyama Valley (loc. M2418). *Lyropecten miguelensis* is commonly found with another large pectinid, *Vertipecten bowersi*; *V. bowersi* differs in having a flat right-valve, convex left-valve, and large, well-defined byssal area. The internal hinge lacks crura; ribbing and fine sculpture distinguish fragments of the two taxa.

On southwestern Santa Cruz Island, *L. miguelensis* is found in rocks that interfinger with a conglomeratic facies bearing *L. pretiosus* (= *L. submiguelensis* auctt.). *Lyropecten pretiosus* belongs to the *L. crassicardo* stock, with a left-valve rib scheme of N 2r N_c 2r N; it has 13-14 ribs that are low in profile and more subdued microsculpture. Specimens of *L. miguelensis* are distinguished from *L. estrellanus* by macrosculptural details and growth forms.

Phylogenetic affinity.—Lyropecten miguelensis has growth habits and interspace macrosculpture similar to those of *L. estrellanus*, which is stratigraphically younger. Neither taxon has left-valve key ribs that would group them with one of the other *Lyropecten* stocks. They are regarded as a bioseries although a complete phylogenetic succession has not been collected.

Loel and Corey recognized a potentially useful evolutionary series within the species, one end member a thin-shelled, low-ribbed form, the other a heavy, rugose, more convex "superform." They considered the holotype and Hertlein's hypotype (pl. 34, fig. 5) intermediate members of the series. The present work did not substantiate their

zonal scheme. They also saw a complete gradation between *L. miguelensis* and *L. m. submiguelensis*, but this continuum is not borne out by this research. *Lyropecten miguelensis* is probably ancestral to *L. estrellanus*.

Geographic distribution and stratigraphic occurrences.—Santa Lucia Mountains, La Panza Range to Orange County; the northern Channel Islands, Transverse Ranges, Temblor and Sierra Madre Ranges; Cuyama Valley.

Representative localities.—Santa Lucia Mountains (UCMP A-581); La Panza Range (M2826, CAS 53, UCMP A-494), in the Painted Rock Sandstone Member, Vaqueros Formation; UCMP A-499, in an oyster reef; UCMP A-505; M3396 has some specimens that look transitional to *L. estrellanus*. Temblor Range, Carneros Sandstone Member of the Temblor Formation (USGS 4941, with *Vertipecten bowersi*).

Northern Channel Islands-San Miguel Island. Vaqueros Formation (UCSB 4454, 4455); from about 1 mi northeast of Crook Point (Bremner, 1933) with *Spondylus perrini*, also about 0.9 mi southwest of Bay Point (Bremner loc. 16). The latter may represent an area of interfingering facies comparable to southwestern Santa Cruz Island, as Bremner reports both *L. miguelensis* and "*L. crassicardo*" [= *L. pretiosus*] from this locality.

Santa Rosa Island. "Lower Vaqueros Formation" of labels, and Rincon Formation, lower member, of Weaver (1969). (UCSB SR-67-28 = UCSB 4675; UCSB 1801, 1844; LSJU acc. no. 45068, CAS 1155, CAS 1156; CAS 2843; CAS 12333). Most specimens from a hard, gray fine sandy matrix, the Vaqueros Formation, sandstone member (McLean and others, 1976) or "Middle Kinton Point Formation" of labels.

Santa Cruz Island. Rincon Formation of Weaver (1969) (UCSB 4372 = E-8). Vaqueros Formation, upper sandstone member (UCSB E-5, 1844, 1846; UCSB 1847, *Pecten-Balanus* reef; UCR 5227). On southwest Santa Cruz Island, *L. miguelensis* is abundant in the upper sandstone member of the Vaqueros Formation at USGS M8013. Its lowest occurrence is at the top of the interfingering, underlying breccia; its highest occurrence is in the Rincon Formation (UCSB 4372, 4397).

Western San Joaquin Valley, Reef Ridge area, Garza Peak 7½-minute quadrangle. Temblor Formation, "near top of lower part" (USGS 14393, *Pecten* zone in well indurated pebble conglomerate; USGS 14403).

Cuyama Valley, Caliente Range, and central Sierra Madre Range, Saltos Shale Member of the Monterey Formation (Vedder, 1970). Abundant juveniles showing variations in fine macrosculpture, growth forms, and preservation (M3403, M3409); from basal part of the Saltos Shale Member, with *Vertipecten bowersi* (M3448, M3371); M2418, very coarse sandstone, including some tectonically deformed specimens transitional to *Lyropecten estrellanus*; M3382, "supervariant" form from just below the Branch Canyon Sandstone M3344; M3341; lower part of the Saltos Shale Member near contact with underlying Painted Rock Sandstone Member (M3358); Temblor Formation of early labels (UCR 1273 and UCR 1257, 235 feet above UCR 1273); Branch Canyon Sandstone, Fox Mountain quadrangle, (M2424, lower member). Painted Rock Sandstone Member, Vaqueros Formation (Vedder, 1970; Fritsche, 1969); M2446; M3365, juveniles occurring with Saucesian foraminifers in a fine-grained sandstone; UCLA 5543, 5558, 5559. *Lyropecten miguelensis*, disarticulated and tectonically deformed, occurs at UCLA 5542, 5548, 5549; at M3904 and CSUN 91 with *V. bowersi*. Below Saltos Shale Member with abundant *Spondylus* (M2446).

Vaqueros Formation, Santa Ynez Range (UCSB 3766); Topanga Formation, Santa Monica Mountains [may be Vaqueros Formation, San Nicholas Member of Yerkes and Campbell, 1980a,b] (UCLA 2735; LSJU acc. no. 45093 from Tuna Creek; UCLA 3448).

Vaqueros Formation, San Joaquin Hills, Orange County (Vedder and others, 1957). Abundant at M3166, M3161, UCMP A-527 and UCMP A-6729; poorly preserved at M3168; at UCLA 6959, Crystal Cove Canyon, San Joaquin Hills, "***from top of the transition between Vaqueros and Temblor Formation;" LSJU acc. no. 45071.

Geologic age.—Early to middle Miocene.

Biostratigraphy.—Upper "Vaqueros" Stage index species, commonly with *Vertipecten bowersi*; lower "Temblor" Stage in the Cuyama Valley?

Its earliest records overlap the youngest occurrences of *Lyropecten pretiosus* (= *L. submiguelensis* of authors) on southwest Santa Cruz Island. Studies there by McLean and others (1976) show that the two Lyropectens come from interfingering facies of the Vaqueros Formation: *L. pretiosus* in the lower, diorite breccia and *L. miguelensis* in the finer sandstone member.

Further work may show that *L. miguelensis* ranges high into the lower "Temblor" Stage (as reported in Addicott, 1972), although data are incomplete for its youngest occurrences. The species is common in the Cuyama area where it may have evolved to *L. estrellanus*.

Lyropecten modulatus (Hertlein, 1925)

Plate 16, figure 4; plate 17, figures 1, 2, 4; plate 18, figures 6, 7

1925b. *Pecten (Lyropecten) modulatus* Hertlein, California Academy of Sciences Proceedings, ser. 4, v. 14, no. 1, p. 11-12, pl. 3, fig. 6.

1932a. *Pecten subnodosus* Sowerby. Mansfield, U.S. Geological Survey Professional Paper 170-D, pl. 16, fig. 1.

Not 1950. *Lyropecten modulatus* (Hertlein). Durham, Geological Society of America Memoir 43, p. 65, pl. 11, fig. 7 [= *Nodipecten arthriticus* (Reeve)].

Holotype.—LSJU 39, a worn right valve, late juvenile or early adult stage. 5.8 cm high, 6.0 cm long.

Type locality.—Vizcaino Peninsula, Baja California Sur, Mexico. From the mesa west of Mesa de las Auras [= Cerro Elefante, northwest of Asuncion]; collected by Marland Oil Company geologist B.F. Hake, who regarded the outcrop as Salada Formation and Pliocene in age. Subsequent collecting in the area suggests that it is late Miocene, from the Almejas Formation, and probably from "Arroyo Elefante", northwest of Cerro Elefante.

Significant hypotypes.—LACM 5879, UCMP 37396; left valves show diagnostic rib pattern.

Description.—Valves flat to moderately convex; a slight angular ledge common in left valves. Height less than length. Beaks project equally, slightly, beyond hinge line. Auricles unequal, rectangular, costate, lirate. Anterior auricle two to three times longer than posterior auricle. Byssal notch deep. Hinge line longer than half shell length. Right-valve ribs 10-11, rounded-rectangular in profile, grouped in a distinctive pattern of three ribs on either side of a wide central space: 2 ribs-3 ribs-central space-3 ribs-2 ribs. Interspaces wider between groups than within them; incipient costae affect rib counts in different growth stages, 10-11 in juveniles, 9-10 in adults. Interspace fine sculpture varies, 1-2 costae in flat juvenile spaces, 4-6 in adult interspaces. Left-valve ribs 10-11, higher and narrower in profile than in right valves, including three wider or raised key ribs with 3 or 4 generations of incipient nodes in young growth stages as much as 5-6 cm high. Key ribs correspond to wider spaces on right valves; the left valve rib scheme is . . N 2r N_c 2r N. Slight angular ledging may accompany each generation of nodes. The largest individual seen (loc. UCMP D-8801, from Cedros Island) measured 12.3 cm high (incomplete), 13.8 cm long, 6.9 cm in hinge length.

Variability.—*Lyropecten modulatus* varies in convexity and number of slightly angular ledges. Juvenile valves are commonly flat; nodes and ledges form after the individual is 3 cm high. Preservation affects fine macrosculpture; the sculpture ranges from few to many radial striae in juvenile and adult interspaces, respectively.

Comparative morphology.—Right valves of *Lyropecten modulatus* and *Nodipecten arthriticus* (Reeve) [= *Nodipecten subnodosus, s.s.* auctt.] differ only in the number and arrangement of ribs; the ribs are grouped symmetrically about the central space in the former, unequally on either side of the central space in the latter. The taxa occur together in the upper Miocene Almejas Formation at Turtle Bay on the Vizcaino Peninsula, Baja California Sur (Smith, 1984). *Lyropecten modulatus* differs from specimens of *L. gallegosi*, which are commonly found with it, in having a lower rib count, fine sculpture, and left-valve key ribs of a distinctive pattern. It is distinguished from *Nodipecten veatchii* by rib count and profile, and left-valve node scheme (*N. veatchii* has N r N_c r N, *L. modulatus* has N 2r N_c 2r N). Right-valve ribs are grouped in two's and three's about the central space; ribs are not grouped in *L. gallegosi*. *Lyropecten modulatus* differs from *L. magnificus* in rib count, a tendency toward ledged growth form, and fewer nodes per generation (only 3 in *L. modulatus*, 3-5 in *L. magnificus*). Like *L. magnificus*, *L. modulatus* has fine radial costae on the auricles, and the auricles are more rectangular than those of *Nodipecten arthriticus*.

Two Holocene specimens, disarticulated left valves from Isla San Jose, Gulf of Panama (USNM 603323) and Acapulco (J.T. Smith, private collection) have similar growth form, fine sculpture, rib count, and node scheme to those of *L. modulatus*. Morphologically, they could be aberrant specimens of *Nodipecten arthriticus* because of an extra rib between the central and anterior lateral nodose ribs. They may also represent rare relicts of *L. modulatus*, although this interpretation cannot be documented by only two specimens.

Phylogenetic affinities.—The left-valve rib scheme places *L. modulatus* with the *L. crassicardo-L. magnificus* stock; it is also close morphologically to the Tertiary Caribbean taxon *L. colinensis vokesae* n. subsp. from the Dominican Republic and Panama. It has the finer fine sculpture and node formation characteristic of eastern Pacific Lyropectens.

Geographic distribution and stratigraphic occurrences.—Vizcaino Peninsula, western Baja California Sur; Cedros Island to San Juanico.

Cedros Island, near Arroyo Choyal. About 3 mi north of Gran Cañon (CAS 946) in coarse pebble conglomerate exposed along the shore, where it is found with *L. gallegosi* and *Nodipecten veatchii*. Late Miocene to early Pliocene in age, probably a turbidite. South of the town of Cedros (UCMP D-8800), float from main ridge parallel to the shoreline, in a coarse pebble conglomerate matrix up section from a diatomite (Frank Kilmer, oral commun., 1973).

Vizcaino Peninsula, Baja California Sur, Mexico: Turtle Bay area, bluffs of Almejas Formation, fossiliferous sandstone to the southeast, east and north of Turtle Bay. Potentially an important area for biostratigraphically controlled sections, but Lyropectens in museum collections lack detailed stratigraphic data. (LSJU acc. 53269, LSJU loc. 807; CAS 37626; CAS 945, with *L. gallegosi*; LACMIP 962). Fine-grained, well-indurated sandstone at these localities assigned to the Salada Formation by early workers are now considered part of the Almejas Formation (Smith, 1984).

Cerro Elefante area, west of Mesa de las Auras, north of Asuncion. Almejas Formation (Troughton, 1974). Asuncion, along the beach, in yellowish-brown sand, where it is found with *Turritella ocoyana*. Twenty kilometers

south of San Juanico (UNAM collection, occurring with Miocene sharks, S.P. Applegate, oral commun., 1980).

Though poorly preserved specimens from the Carrizo Formation and Imperial Formation were referred to this species in the past (Smith, 1977), they are now included in *L. tiburonensis*, n. sp.

Geologic age.—Late Miocene.

Lyropecten pretiosus (Hertlein, 1925)

[= *L. submiguelensis* (Loel and Corey, 1932) auctt.]

Plate 26, figures 1-9, 12-14; plate 37, figure 3

?1906. *Pecten (Lyropecten) vaughani* Arnold, U.S. Geological Survey Professional Paper 47, p. 81-82, pl. 23, figs. 3a-3c (see taxonomic comments under *L. vaughani*).

1925b. *Pecten (Lyropecten) pretiosus* Hertlein, Proceedings California Academy of Sciences, ser. 4, v. 14, no. 1, p. 12, pl. 2, fig. 6; pl. 3, fig. 4.

1932. *Pecten (Lyropecten) miguelensis* (Arnold) *submiguelensis* Loel and Corey, University of California Publications, Department of Geological Sciences Bulletin, v. 22, no. 3, p. 200-201, pl. 29, fig. 1; pl. 31, figs. 1a-1c.

1933. *Pecten crassicardo* Conrad. Bremner, Santa Barbara Museum of Natural History Occasional Papers no. 2, p. 16, pl. 3, fig. 2.

1948. *Pecten* cf. *P. crassicardo* Conrad. Beal, Geological Society of America Memoir 31, p. 55. [Listed as *Pecten crassicardo* and as *P. condylomatus*].

1969. *Pecten miguelensis* Arnold. Weaver, American Association of Petroleum Geologists and Society of Economic Paleontologists and Mineralogists, Pacific Sections, Special Publication 200, pl. 34, fig. 9.

Not 1969. *Pecten miguelensis submiguelensis* Loel and Corey. Weaver, ibid., pl. 32, fig. 7 [= *Vertipecten bowersi* (Arnold)].

1969. *Pecten crassicardo* Conrad. Weaver, ibid., pl. 32, fig. 9.

Holotype.—LSJU 38, juvenile right valve 2.6 cm high, 2.9 cm long.

Paratype.—CAS 1770, juvenile right valve.

Type locality.—Baja California Sur, Mexico, on trail from Arroyo Mesquital to La Purisima, in a turritellid bed [= *Turritella wittichi* Hertlein and Jordan, 1927] above San Gregorio Lagoon (LSJU loc. 59). Collected by E. Call Brown from the Isidro Formation, early to early middle Miocene.

Paratypes and significant hypotypes.—"Paratypes" LSJU 89, CAS 1771, juvenile left valves from LSJU loc. 57, "La Purisima cliffs along the San Ramon River." UCMP 31737, holotype of *Pecten (Lyropecten) miguelensis submiguelensis* Loel and Corey, 1932 (UCMP loc. A-311, Santa Rosa Island off Santa Barbara, Calif.), 6.9 cm high, 7.2 cm long. UCMP 37393, from UCMP B-5016, a two-valved young adult specimen, 4.7 cm high, 4.7 cm long.

Taxonomic comments.—A suite of specimens from the La Purisima area of Baja California Sur (UCMP B-5016), collected in 1957 by F.H. Kilmer and E.C. Allison, provided the first evidence of adult form and variability in *L. pretiosus*. Rib counts, ledging, growth form, and fine sculpture matched those of rare individuals formerly identified as *L. submiguelensis* from the northern Channel Islands. Morphologic similarity suggests conspecificity, not convergence. The closest morphologic correspondence is between specimens from loc. UCMP B-5016 and hypotypes of *L. submiguelensis* from Santa Rosa Island (UCMP 10136; UCSB hypotype M15, UCSB 4698 from SR 67-53). Some specimens from the La Purisima area that are identified in the literature as *L. crassicardo* (Beal, 1948) are *L. pretiosus*, others are *L.* sp. cf. *L. magnificus*.

Description.—Valves equally convex with 0-3 rounded ledges. Beaks stand slightly above the hinge line. Auricles relatively small, radially costate. Byssal notch moderately deep. Hinge line about half shell length. Umbonal angle 87°, varying with shell convexity. Right valves with 14-15 ribs (not 17-18 as originally described), weaker in anterior and posterior parts of the shell. Left valves with 14-15 ribs of which three are incipient key ribs separated by two ribs of normal strength. Rib scheme is that of the *L. crassicardo-L. magnificus* stock, R 2r R_c 2r R. Several individuals have slight thickenings, almost incipient nodes, where the shell forms a slight ledge. Fine macrosculpture delicate; few well-preserved left valves have been collected. The largest specimens from San Isidro (UCMP B-5012) measured 7 cm high, the largest from the Channel Islands of California 11.8 cm high (UCSB 5197 = hypotype M-18).

Variability.—(Pl. 26, figs. 1-9, 12-14) Valves are moderately flat to convex with 0-3 rounded ledges. Juvenile interspaces with one fine riblet, adults with multiple striae. Some have 12-13 narrow, rectangular ribs, and a square right-valve anterior auricle similar to that of *L. magnificus* (pl. 21, figs. 1, 2). These may be variants of *L. pretiosus* or younger descendants of the forms common at San Isidro (UCMP B-5051, B-5016). Individuals with higher rib profiles have been collected from USGS 9157, CAS 38792, and LSJU 57; some are similar to "*L.*" *dumblei* (pl. 20, fig. 9), others to *L. pretiosus* and *L. magnificus*. Precise locality and stratigraphic data are needed to evaluate their relationships. USGS 9157, collected by W.S.W. Kew in 1920, is in Arroyo San Gregorio, from outcrops along an old trail; it is probably downstream from where it was reported ("between Paso Hondo and Purisima Vieja," about 15 mi northwest of San Isidro). Specimens from CAS 38792 and LSJU 57 are found with forms like those from UCMP B-5016.

Comparative notes.—*Lyropecten pretiosus* never attains the large size of *L. miguelensis* or *L. crassicardo*. It has finer macrosculpture and lower rib profiles than the others and tends to form slightly angular ledges in left valves. *Lyropecten miguelensis* has one coarse midriblet

in each interspace, highly convex juvenile shells, and the right-valve umbone projecting above the hinge line. *Lyropecten pretiosus* has a higher rib count, 17-18, than *L. miguelensis*, which has 15.

Phylogenetic affinities.—The left-valve rib scheme, R 2r R_c 2r R, tendency toward angular ledging and fine macrosculpture place *L. pretiosus* in the *L. crassicardo-L. magnificus* bioseries. Growth form, valve profiles, and fine sculpture differentiate *L. pretiosus* from *L. miguelensis* and *L. estrellanus*.

Geographic distribution and stratigraphic occurrences.—Baja California Sur, Mexico, vicinity of La Purisima and arroyos to north; northern Channel Islands off Santa Barbara, Calif. Poorly preserved specimens from the northern La Panza Range may be this species. Reported occurrences in the Temblor Formation are unverified.

La Purisima and San Isidro, from the lower part of the Isidro Formation, early Miocene. Specimens collected from "cliffs along the San Ramon River" (LSJU 59; M8648; M9165). The best material is from a low, white knoll about 100 yd east of the center of the town of San Isidro (UCMP B-5015, UCMP B-5016). Outcrops of flat-lying, hard, gray, limy sandstone have abundant *Ostrea* and *Lyropecten pretiosus* in low cliffs along the river between San Isidro and La Purisima (Smith, 1984). Some exposures had many turritellids, mostly internal molds; others had concentrations of echinoids and *Spondylus scotti* Brown and Pilsbry or of *Rapana imperialis* Hertlein and Jordan. Loel and Corey (1932) mentioned two Pectens from Purisima Nueva Cliffs (UCMP A-600, east of the river at Purisima, probably = LSJU 57) that are very similar to *L. submiguelensis* from San Miguel Island.

Arroyo Patrocinio, Baja California Sur, from white sandy coquina overlain unconformably by a basalt dated at 8.1 ± 0.4 Ma (McLean and others, 1985, 1987).

Northern Channel Islands, Calif. Santa Rosa Island, type locality of *Lyropecten submiguelensis* (Loel and Corey); at UCMP A-311 "***the taxon occurs with *Ostrea vespertina loeli, Spondylus perrini, Turritella inezana,* and *Rapana vaquerosensis imperialis* in massive yellowish shaley sandstone in the canyon east of the pass between the two high peaks on the crest of the island" (W.S.W. Kew, collector, 1926; detailed locality data from Joseph H. Peck). Santa Rosa Island localities include UCSB SR64-11, in the Vaqueros Formation, lower coarse-grained sandstone and conglomerate member; UCSB SR67-57 "with *Rapana,*" UCSB SR67-53; CAS 1154, from San Augustine Canyon, matrix a hard, gray mudstone. CAS 1150, with many Rapanas, poorly preserved.

Southwest Santa Cruz Island. Vaqueros Formation, diorite breccia member ("Lower Kinton Point" unit of UCSB labels). (M8022, UCSB 1668; UCSB 1651). The diorite breccia member interfingers with an overlying sandstone member; McLean and others (1976) consider these fossiliferous units correlative with upper Zemorrian or lower Saucesian microfaunal stages.

San Miguel Island, Bremner (1933) localities: specimen SBMNH 32.7 = CAS plastotype 6125, labeled *P. crassicardo*, came from about 0.9 mi southwest of Bay Point (Bremner's loc. 16), where it is found with *L. miguelensis* in a unit he mapped as upper part of the Temblor Formation. These species were also listed from beach localities about a mile east of Crook Point and from a mile to the north (Bremner loc. 14). Weaver and Doerner (in Weaver, 1969) correlate Bremner's Temblor Formation with their lower member of the Rincon Formation, characterized by *Rapana vaquerosensis, L. miguelensis,* and *L. submiguelensis* [= *L. pretiosus*], the same assemblages as on southwestern Santa Cruz Island. They note distinctive beds of chert-pebble conglomerate in the lower part of this lower member, which also includes fine- to coarse-grained mollusk-bearing sandstone. *Lyropecten pretiosus* occurs in interfingering members of the Vaqueros Formation on southwest Santa Cruz Island (McLean and others, 1976), where the fossils may be facies controlled. Unfortunately a fire at the Santa Barbara Museum of Natural History in 1962 destroyed the collections; the fossils, together with Bremner's locality map, would have yielded further important biostratigraphic data.

Uncertain occurrence, northern La Panza Range, Hay Canyon section: Painted Rock Sandstone Member (M2831, M4737), in very coarse pebbly sandstone bed. Most specimens very poorly preserved; some were large for the species, 8 cm high, 8 cm long. They are found there with *"Macrochlamis" magnolia, s.s.* and fragments of *Vertipecten perrini*, lower "Vaqueros" Stage index species. Loel and Corey's hypotype UCMP 31738 from this general area (UCMP A-494) is also associated with *"M." magnolia, s.s.* Some of their other specimens from the Santa Monica Mountains, the San Joaquin Hills in Orange County, and the Santa Ynez Range are redetermined here as *L. miguelensis*.

Central Sierra Madre Range, Fox Mountain 7½-minute quadrangle, Vaqueros Formation, Painted Rock Sandstone Member (Fritsche, 1969). Worn, tectonically deformed specimens, many fragmental but similar to the holotype of *L. submiguelensis* and material from Baja California Sur, Mexico (UCMP B-5016; M9165). Localities include UCLA 5542 and 5560.

Geologic age.—Late Oligocene(?) to early Miocene.

Biostratigraphy.—Upper lower "Vaqueros" and middle "Vaqueros" Stages in California; the equivalent of upper "Vaqueros" Stage in La Purisima and Arroyo San Gregorio, Baja California Sur, is based on radiometrically dated volcanic rocks stratigraphically below and above the marine Isidro Formation (Smith, 1984 and in press).

***Lyropecten terminus* (Arnold, 1906)**

Plate 2, figure 1; plate 22, figures 2, 3

1906. *Pecten* (*Lyropecten*) *estrellanus* Conrad var. *terminus* Arnold, U.S. Geological Survey Professional Paper 47, p. 77, pl. 23, figs. 2, 2a.
1906. *Pecten* (*Lyropecten*) *estrellanus* Conrad. Arnold, ibid., pl. 19, figs, 1, 1a.
1915. *Pecten estrellanus* Conrad. Waring, California State Mining Bureau map folio accompanying Bulletin 69, fig. 38 [hypotype SU 5186].
1917a. *Pecten terminus*. Nomland, University of California Department of Geology Bulletin, v. 10, no. 14, p. 219 (list), pl. 6, fig. 4.
1965. *Lyropecten terminus* (Arnold). Durham and Addicott, U.S. Geological Survey Professional Paper 524-A, p. A13, A15, pl. 1, figs. 1, 10,; pl. 2, figs. 1, 10.

Holotype.—UCMP 11622, a single right valve of a young adult 7.0 cm high, 7.5 cm long.

Type locality.—Monterey County, Calif. Subsequent work by Durham and Addicott (1965) restricts the type area to terraces along the east side of the Salinas Valley or in tributary canyons between King City and San Ardo. Pancho Rico Formation. Originally described as "Upper Miocene or San Pablo Horizon," *L. terminus* is late Miocene to early Pliocene in age, "Jacalitos" Stage.

Significant hypotypes.—UCMP 36249, thin section described by Oberling (1964) showing overlapping foliations producing an interlocking shell microstructure. UCMP 37391, an individual with articulated valves.

Description.—Valves equal, flat to moderately convex. Beaks project slightly, equally, beyond hinge line. Auricles unequal, costate, and lirate. Byssal notch deep. Hinge length about half shell length. Right-valve rectangular ribs 14-15, one riblet in juvenile interspaces, four or more costae in adults. Left-valve ribs 13-14 (a few 12), rectangular in profile, of equal prominence and spacing. Left-valve interspaces wide, with four to five or more costae, as in *L. crassicardo*; *L. terminus* has no key or raised ribs, no nodes. Large specimens commonly measure 12-14 cm high; one individual from the Salinas Valley is 16 cm high, 17.6 cm long.

Variability.—Fine sculpture varies between juveniles and adults, right and left valves; rib counts vary by one, rarely two ribs. Juvenile right valves have one prominent riblet per interspace (as in *L. estrellanus*), adults have four or more radial striae. Rib widths and moderately convex valve profiles are consistent characters.

Comparative notes.—Articulated specimens are rare; single, worn specimens are hard to distinguish from *L. estrellanus* except by their lower rib count and left-valve fine sculpture.

Phylogenetic affinities.—*Lyropecten terminus* is morphologically closest to *L. estrellanus* and probably its direct descendant. Disarticulated valves of both species are found in beach deposits that may be reworked. *Lyropecten terminus* is relatively rare and restricted geographically to the southern Salinas Valley and San Joaquin Valley near Coalinga. It may be an abnormally low-ribbed variant of *L. estrellanus* that lived later than *L. estrellanus s.s.* in progressively shallower basins in central California.

Geographic distributions and stratigraphic occurrence.—Southern Salinas Valley and eastern tributary canyons; San Benito-Waltham Trough (Flynn, 1963) and the Jacalitos Hills and canyons south of Coalinga, western San Joaquin Valley.

Pancho Rico Formation in Wildhorse, Sweetwater, Pancho Rico, and Hamilton Canyons, Lynch Creek, and Long Valley (CAS 467, LSJU accession nos. 2757, 30142; LSJU loc. 1159). Canyons are shown in Durham and Addicott (1965). The best material came from the San Ardo 15-minute quadrangle: M2283; M1341; USGS 7898; M2280; M2295; M2275; M913; M920; USGS 3542; M912; LSJU acc. no. 1883; UCMP D-4612. A few localities yielded mixed assemblages including *L. terminus*, *L. estrellanus*, and *L. cerrosensis*. These represent float collections from the north side of Wildhorse Canyon (M2279) and river terraces along the eastern Salinas Valley (M912); *L. terminus* and *L. cerrosensis* are found at UCMP A-2939. *Lyropecten terminus* is also from west of the Salinas River (M1935, M1676). Priest Valley 15-minute quadrangle localities: UCMP A-3046, A-3295, A-3324, D-4612.

Coalinga area, western San Joaquin Valley. Jacalitos Formation (lower part of the Etchegoin Formation of some authors), Jacalitos and Zapato Chino Canyons (UCMP 2520; 2523; 2526; at 2533 with *Patinopecten lohri*; UCMP 2646), labelled "in *Chione elsmerensis* zone". Etchegoin Formation (Adegoke, 1969 localities in Reef Ridge area, south of Coalinga (UCMP B-6528, B-6529, B6535; D-1147, D-1148; UCMP A-628, from Kreyenhagen Hills 7½-minute quadrangle).

Geologic age.—Late Miocene to early Pliocene. Although the Pancho Rico Formation was originally considered early Pliocene in age by Durham and Addicott (1965), its revised age is late Miocene on the basis of recalibration of Pacific Coast marine chronology with European standards (Addicott, 1978).

Biostratigraphy.—"Jacalitos" Stage index fossil. Stanton and Dodd (1976) found its highest occurrences overlapping the lowest ones of *Patinopecten lohri*, guide fossil of the upper "Jacalitos"-lower "San Joaquin" Stages (for example, UCMP 2533, in Waltham Creek). They point out that *L. terminus* is the pectinid of the "*Pecten estrellanus* zone" of Arnold and Anderson (1910), more or less equivalent to the *Chione elsmerensis* zone of Nomland (1917a).

Paleoecology.—The Pancho Rico Formation includes coarse-textured sedimentary rocks and worn shell fragments of robust, shallow-water organisms such as bar-

nacles and oysters. Durham and Addicott (1965) interpret the environment of deposition as a high-energy zone along a constantly shifting shoreline. Stanton and Dodd (1976) cite crossbedding, channelling, and facies changes as evidence for a similar nearshore, constantly shifting environment "***near an inlet***" in Jacalitos and Zapato Chino Canyons, where fluvial processes intermittently affected nearshore, marine-basin deposition. In this unstable environment, *L. terminus* became extinct long before the disappearance of the broad inland sea occupying the western San Joaquin Valley.

***Lyropecten tiburonensis*, n. sp.**

Figure 17A; plate 16, figure 2; plate 18, figure 5

1926. *Pecten subnodosus* Sowerby. Hanna, California Academy of Sciences Proceedings, ser. 4, v. 14, no. 18, p. 474, pl. 25, fig. 6.
1977. *Lyropecten modulatus* (Hertlein). Smith, Society of Economic Paleontologists and Mineralogists, Pacific Section, Abstracts, p. 16-17.
1979. ?*Lyropecten* sp. indet. Stump, The evolutionary biogeography of the west Mexican Pectinidae, Davis, University of California, Ph.D. dissertation, p. 420, pl. 16, figs. 4, 5.
1981. ?*Lyropecten* sp. indet. Stump, Geological Society of America, Cordilleran Section Guidebook, p. 107.

Holotype.—CAS 61215.01, fragment of an adult right valve, height 4.5 cm, length 8.7 cm (incomplete), hinge length 4.6 cm (figure 17*A*, ii, iii).

Type locality.—Southwestern Isla Tiburon, Sonora, Mexico (M9117 = CAS 61215 = Gordon Gastil field nos. S2G-8 and S2G-18), about 4 km northwest of Punta Willard. Unnamed marine conglomerate in "Arroyo 4," about ½ km from the beach where the arroyo forms a prominent delta near the center of Bahía Vaporeta (fig. 17*B*). Late middle Miocene, based on associated volcanic rocks having a radiometric age of 12.9 ± 0.4 Ma (Smith and others, 1985; Smith, in press).

Paratype.—CAS 61974.01, an incomplete left valve measuring 7.1 cm high, 3.3 cm long (locality M9117 = CAS 61215). Significant hypotypes include UCR 7267/3 and UCMP 32291 (pl. 18, fig. 5) from the basal part of the Imperial Formation, Coyote Mountains, Calif. and UCR 5042/4 from the Whitewater River area, Riverside County, Calif.

Taxonomic comment.—Although the new species shares the rib scheme of the *L. crassicardo-L. magnificus* stock, it differs from those species in anterior and posterior disc sculpture and fine macrosculpture. Right valves are very similar to those of *Nodipecten subnodosus*, with which it was confused for many years until diagnostic left valves were collected.

Description.—Valves moderately convex. Beaks project slightly above the hinge line; auricles unequal, the anterior one rectangular, twice as long as the posterior, and radially ribbed with 5 or 6 costae. Byssal notch moderately deep; umbonal angle 100°. Right valves with striae on anterior and posterior dorsal parts of the disc, 11-12 rounded rectangular striate ribs grouped in threes about a narrow central space bearing a single medial thread. Left valves with 9-10 ribs having a scheme of (r) r R 2r R_c 2r R r; interspaces bear one medial thread in juveniles, up to three in later growth stages; worn adult specimens may have no striae preserved in interspaces. Adult specimens from the southeastern Coyote Mountains could not be collected whole; specimens measured 12 or more cm in height.

Comparative morphology.—Specimens are similar to *L. colinensis, s.s.* in having striate dorsal margins of the shell; they share the left-valve rib and node scheme common to *L. colinensis, s.l.*, *L. modulatus*, *Lyropecten* sp. cf. *L. magnificus*, and *L. crassicardo*, but differ from these in fine macrosculpture, anterior and posterior striae, and slightly differentiated rather than nodose key ribs. Some individuals have ledges (fig. 17*A*iv), most do not.

Phylogenetic affinities.—Specimens of this taxon have been known from the Imperial Formation for many years, but available material is still insufficient or too poorly preserved for determining close phylogenetic relations. In rib scheme the taxon belongs with the *L. crassicardo-L. magnificus* stock.

Geographic distribution and stratigraphic occurrence.—Isla Tiburon, Sonora, Gulf of California and the Salton Trough of California.

Southwestern Isla Tiburon. Fragments from unnamed boulder and cobble conglomerate exposed in "Arroyo 4" (M9117 in fig. 17*B* and Smith, in press). The unit is interbedded with a volcanic debris flow of 12.9 ± 0.4 Ma and overlain with an angular unconformity by an ash flow cap of 11.2 ± 1.3 Ma (Gastil and Krummenacher, 1977).

Salton Trough of California. Southern and southeastern part of the Coyote Mountains (UCR 7267, UCMP 738, UCMP A-1273, CAS 683), in the Latrania Sand Member of the Imperial Formation. Present in Alverson (= Fossil) Canyon and abundant as stacks of shells in the Painted Gorge 7½-minute quadrangle, SW¼ sec. 5 and S½ sec. 6, T. 16 S., R. 10 E. Also from the northernmost Salton Trough, in the Whitewater River area, Riverside County (UCR 5042), between the Banning and Mission Creek strands of the San Andreas fault; rocks mapped as Imperial Formation are overlain by the nonmarine Painted Hill Formation, which contains a basalt flow of 5.94 ± 0.18-6.04 ± 0.18 Ma (Matti and others, 1985).

Geologic age.—Late middle Miocene to late(?) Miocene. Although the Imperial Formation was deposited over an irregular surface, possibly over a span of 8 to 10 million years, faunal and radiometric evidence suggest that the sections containing *L. tiburonensis*, n. sp. are late middle to late Miocene in age.

Lyropecten vaughani
(Arnold, 1906)
Plate 26, figures 10, 11

1906. *Pecten (Lyropecten) vaughani* Arnold, U.S. Geological Survey Professional Paper 47, p. 81-82, pl. 23, figs. 3a-3c.

1931. *Pecten (Lyropecten) nodosus* (Linnaeus) var. *vaughani* Arnold. Grant and Gale, San Diego Society of Natural History Memoir, v. 1, p. 180-181.

1972. *Lyropecten crassicardo vaughni* (Arnold). Addicott, Society of

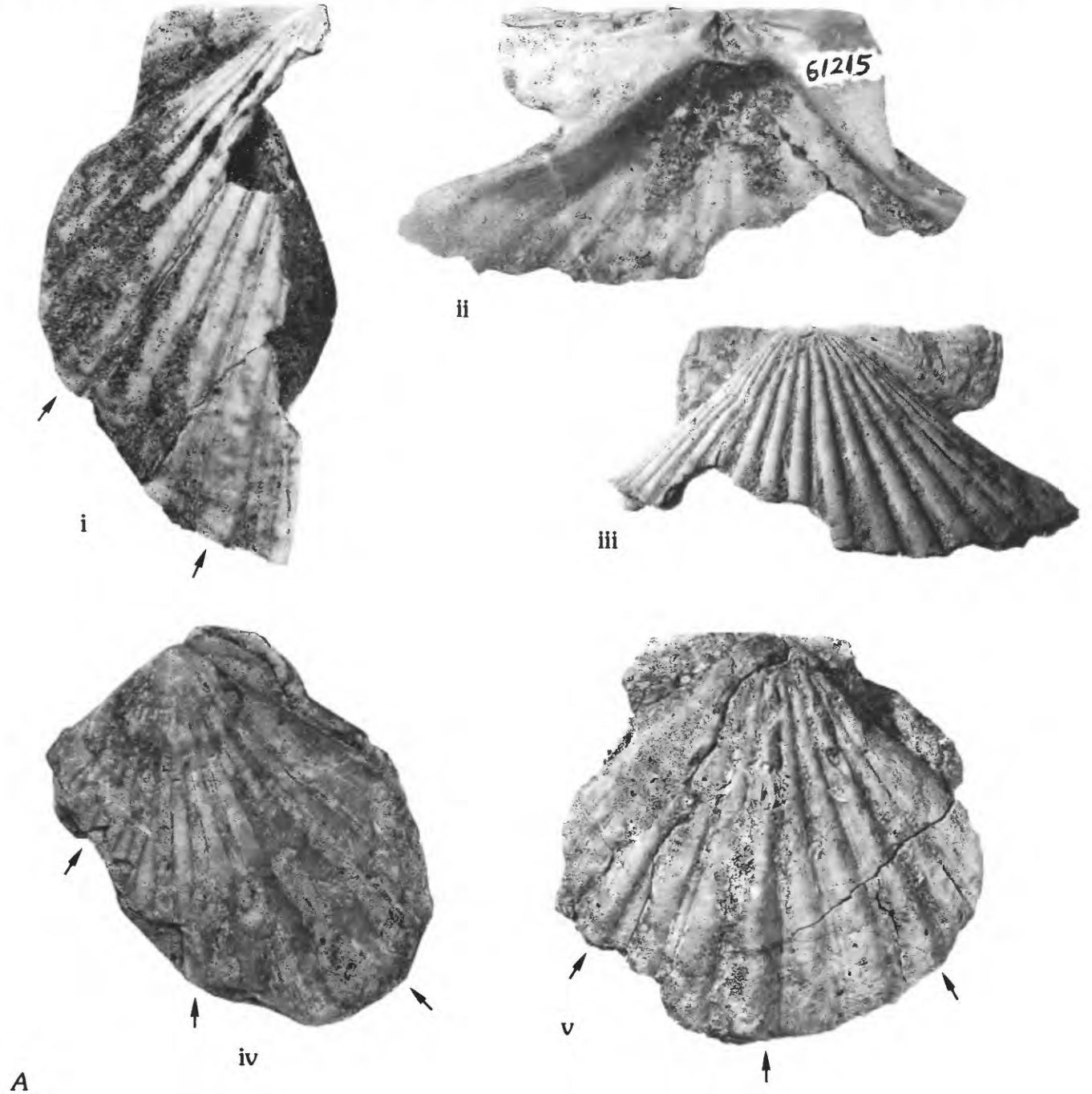


FIGURE 17.—Photographs of *Lyropecten tiburonensis*, n. sp., type specimens and map of type locality. *A*, Type specimens of *Lyropecten tiburonensis* Smith, n. sp. Arrows indicate key ribs. (i) Paratype CAS 61974.01, left valve fragment from southwestern Isla Tiburon (M9117); measuring 7.1 cm in height, 3.3 cm in length. (ii, iii) Hinge area, exterior view, holotype CAS 61215.01, right valve fragment from southwestern Isla Tiburon (M9117); 4.5 cm in height, 8.7 cm in length. (iv) Hypotype UCR 7267/3, a two-valved young adult specimen from the Imperial Formation, Latrania Sand Member, Coyote Mountains, Calif. Height 5.6 cm, length 6 cm (incomplete). Specimen has a ledge or constriction at 1.5 cm height. (v) Hypotype UCR 5042/4, left valve from the Whitewater River area, northern Salton Trough, Calif. Height 7 cm, length 7 cm.

Economic Paleontologists and Mineralogists, Pacific Section, Miocene Biostratigraphic Symposium, Proceedings, p. 7, 10, pl. 2, fig. 6.

Holotype.—LSJU 9, a worn, double-valved late juvenile specimen, 3.7 cm high, 4.0 cm long.

Type locality.—Ojai Valley, Ventura County, Calif. Exact locality not known. Collected by Stephen Bowers. "Miocene, probably lower." Subsequent collecting has recovered no additional material from the type area, although master's thesis work by John Byrd, University of California, Santa Barbara, turned up fragmentary specimens from south of Solvang and the Santa Ynez River, near the well downstream from the Alisal Bridge.

The taxon cannot be evaluated yet because it is represented by only two specimens, a juvenile holotype lacking stratigraphic data and an internal mold from the Temblor Formation, Carneros Sandstone Member (USGS loc. 4941).

Description.—The type specimen has equally convex valves, a single constriction or incipient ledge, and beaks that project equally, slightly, above the hinge line. Auricles unequal, costate, lirate. Byssal notch deep. Hinge length greater than half the shell length. Right valve has 11 ribs, left valve 11 ribs with incipient nodes on every third rib. Rib scheme is N 2r N_c 2r N. Fine macrosculpture not preserved.

Phylogenetic affinities.—The holotype belongs with the *L. crassicardo-L. magnificus* stock on the basis of left-valve key-rib scheme. It is possibly the same as *L. pretiosus* (= *L. submiguelensis* authors), which it resembles in growth form and ribbing.

"Lyropecten"

Several species from the Paleogene of the Caribbean region are referred to *"Lyropecten"* on the basis of morphologic similarity to eastern Pacific taxa. No Caribbean specimens attain the large size of the California species and none are known from intermediate, contemporaneous formations in Panama.

Diagnosis.—Valves equally convex, some with angular ledges. Radial ribs and interspaces costate and lirate; some left valves with nodes in varying positions. Auricles small, subequal to unequal. Byssal notch moderately deep. Hinge area has two pairs of crura on each valve.

Similar to *Lyropecten*, except smaller in size, species referred to *"Lyropecten"* need further study and comparison with European taxa to verify the generic assignment.

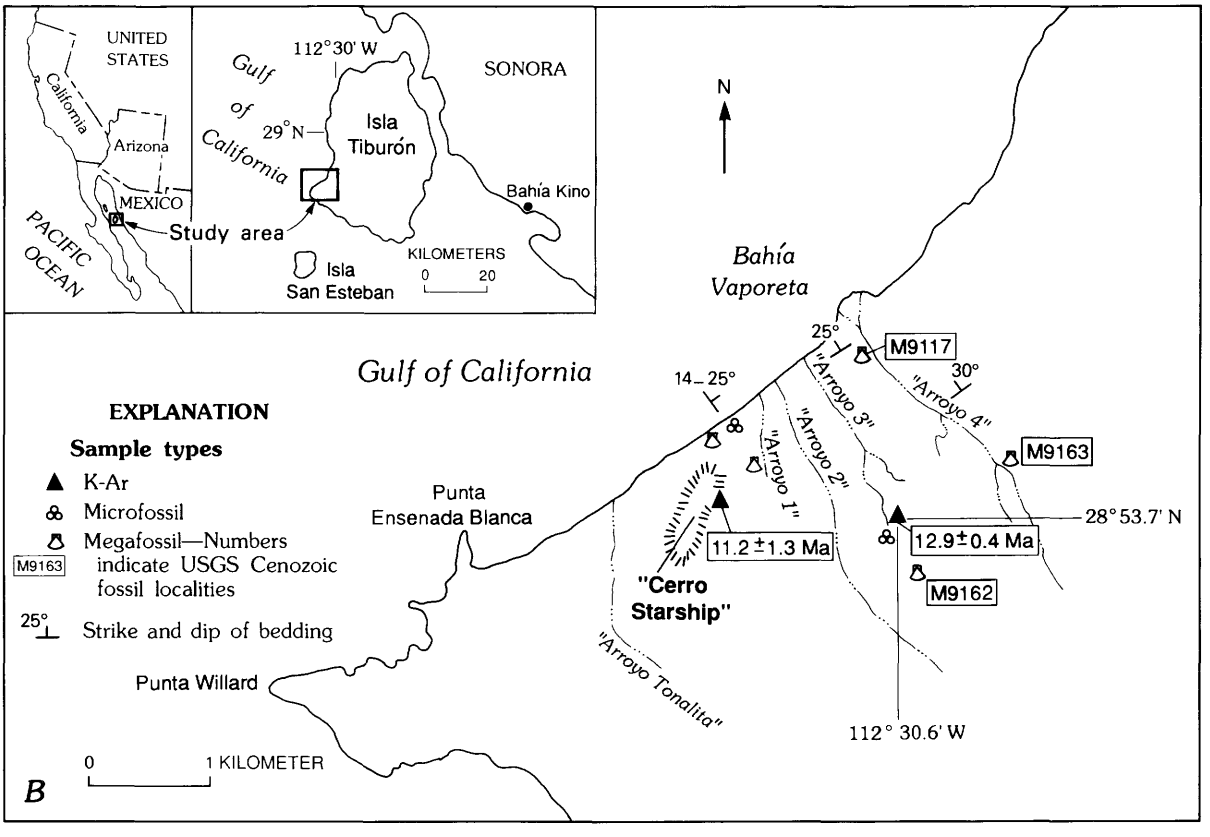


FIGURE 17.—**B**, Type locality of *L. tiburonensis* Smith, n. sp., southwestern Isla Tiburón, Sonora, Mexico.

"Lyropecten" articulosus (Cooke, 1919)

Plate 20, figures 1, 2

1919. *Pecten (Nodipecten) articulosus* Cooke, Geology and Paleontology of the West Indies, Carnegie Institution of Washington Publication 291, p. 136, pl. 7, figs. 7, 8.

Holotype.—AMNH 25025, a right valve, white in color, 5.5 cm high, 6.2 cm long, 2.2 cm in hinge length. Collected by Barnum Brown.

Type locality.—Guajay, Cuba, 15 mi southwest of Havana. Oligocene, "Disintegrated limestone in a quarry near asylum***."

Taxonomic comment.—The species is grouped with *"Lyropecten"* because of general growth form, hinge, shape of auricles, and similarity to *L. estrellanus*, type of the genus. *Nodipecten* is here restricted to those species having hollow, bulbous nodes on alternating ribs of left valves, as typified by *N. nodosus* (scheme N r N_c r N. . .). *"Lyropecten" articulosus* belongs with *"L." dumblei* and *"L." condylomatus*, two other species which develop variable numbers of nodes in varying positions.

Description.—(Based only on the type specimens and original description.) Valves convex, the right more rounded and the left more angular in profile, with 14 ledges. Beaks project equally, slightly, beyond hinge line. Auricles small, subequal; byssal notch moderately deep. Right-valve ribs seven, high and narrow in juvenile part of the shell, lower and flatter in adult. Nodes lacking, fine sculpture except for growth lines not preserved. Left-valve ribs 6-7, evenly spaced; at 2 cm high, late juvenile shell has a prominent node on the central rib and an incipient node on the anterior lateral in a scheme described as r R r N_c 3r. Originally described as having 8-11 ribs, but the types have only 7 (juvenile) or 8 (adult).

Comparative notes.—*"Lyropecten" articulosus* shares hinge characters, growth form, and size and shape of auricles with two other Caribbean "early Lyropectens." Adult shells are 5-6 cm high with a marked ledge in juveniles 2 cm high. *"Lyropecten" articulosus* has the fewest and widest ribs: 7-8. *"Lyropecten" condylomatus*, represented abundantly in collections at USNM and Tulane University, has greater variation in valve profile and 10-11 ribs. *"Lyropecten" dumblei* has thinner ribs and some nodes on left valves. Cooke (1919, p. 136) notes *P. articulosus* is "***more nearly equivalve, has larger and fewer ribs, and lacks the secondary sculpture [of *P. condylomatus* Dall]."

Phylogenetic affinity.—*"Lyropecten" articulosus* is grouped with *"L." dumblei* and *"L." condylomatus* on the basis of morphology, adult size, and geographic distribution. It may have a European ancestor.

Geographic distribution and stratigraphic occurrence.—Guajay, Cuba; 15 mi southwest of Havana, in quarry.

Geologic age.—Oligocene. Cooke (1919) correlated the faunule with that of the Tampa Limestone.

"Lyropecten" condylomatus (Dall, 1898)

Plate 20, figures 6, 7

1898. *Pecten (Nodipecten) condylomatus* Dall, Wagner Free Institute of Sciences of Philadelphia Transactions, v. 3, pt. 4, p. 729-730, pl. 34, figs. 14, 15.

1926. *Chlamys (Nodipecten) condylomatus* (Dall). Gardner, U.S. Geological Survey Professional Paper 142-A, p. 46-47, pl. 12, figs. 3, 4.

1959. *Chlamys condylomata* (Dall): Mongin, Bulletins of American Paleontology, v. 39, no. 180, p. 305-306, pl. 25, figs. 3a-3d.

Holotype.—USNM 114776, a juvenile left valve 2.4 cm high, 2.4 cm long, with two prominent angular ledges.

Type locality.—Ten Mile Creek, 1 mi west of Bailey's Ferry, Calhoun County, Florida (USGS 2212). Lower Miocene (Oligocene of early workers), Chipola Formation.

Paratype.—USNM 334994, a right valve 3.2 cm high, 3.3 cm long.

Taxonomic comment.—The original type lot, USNM 114776, included more than one taxon, even allowing for the high degree of variability in *"L." condylomatus*. A right valve that may be another species of pectinid from the same lot is shown on plate 20, figure 3.

Description.—Valve profiles variable, commonly with 1-3 ledges, rounded in right valves, angular in left. Beaks project equally, slightly, beyond hinge line. Auricles small and subequal, costate, lirate. Byssal notch moderately deep. Hinge length about half of shell length. Right-valve ribs 10-12 or 13, costate, lirate; anterior and posterior ribs tend to become obsolete. Left-valve ribs 12-13. Ledge margins usually have elongate nodes, the noded ribs in varying positions in shells from the same lot. Commonest pattern is nodes on the central rib and on laterals separated from it by 1 or 2 regular ribs. Large individuals (4 cm high) may be elongated posteriorly. Different modes of preservation produce stronger, distantly spaced concentric fine sculpture. Shells have not been found articulated. The largest specimen measured 5 cm high, 5.7 cm long (TU 951). Abundant specimens in the USNM and Tulane collections are available for detailed biometric studies.

Comparative notes.—Fewer ribs (10-13) than in *"L." dumblei* (13-15), smaller in maximum size. Left valves have one or more angular ledges, not the single break in slope of most *"L." dumblei* left valves; three elongate thickenings or incipient nodes commonly develop on the central and two lateral ribs, although the spacing of noded ribs varies. The two species share similar growth habits, shell outlines, and the tendency toward posterior elongation. *"Lyropecten" condylomatus* is geographically more restricted, and there are only a few localities in Florida

where the taxa occur together. Juvenile valves are distinguished with difficulty.

Phylogenetic affinities.—Of the New World pectinids, "*L.*" *condylomatus* is closest in size and growth form to "*L.*" *dumblei*.

Geographic distribution and stratigraphic occurrences.—Florida panhandle, from the Alum Bluff Group, and Tuxpan, Veracruz, Mexico.

Northwest Florida, Chipola Formation, lower Miocene: TU 1098, 1050; 998; 951; 831; 830; 825; 810; 655; 546; 457; USGS 2212, 2213, 2564, 3419, 9994. Shoal River Formation, Oak Grove Sand Member, middle Miocene: USGS 9961 [with *Chesapecten sayanus* (Dall)] and Shoal River Formation, USGS 9957 (*fide* Gardner, 1926).

Sarasota County, Fla., Hawthorn Formation, middle Miocene: USGS 23598 (with "*L.*" *dumblei*).

The original description listed the taxon from the "lower bed at Hawkinsville, Georgia," but the specimen was misidentified (Gardner, 1926). That specimen is from the Guajalote Formation, northeastern Mexico, as given in early lists of San Fernando and Tuxpan faunas [= "*L.*" *dumblei*]. Emily H. Vokes found a single specimen of "*L.*" *condylomatus* at Tuxpan, Veracruz, in the top of the type section of the Tuxpan Formation, planktonic foraminiferal zone N 7-8 (E.H. Vokes, written commun., 1975).

Geologic age.—Early to middle Miocene. Microfossils from the Chipola Formation are N zones 7 and 8 (Akers, 1972).

"*Lyropecten*" *dumblei* (Gardner, 1945)

Plate 1, figures 6, 7; plate 20, figures 4a, 4b, 5, 8

Pecten condylomatus Dall? of the checklists of Dumble and others (*fide* Gardner, 1945, p. 69). (Not 1898 *Pecten (Nodipecten) condylomatus* Dall, Wagner Free Institute of Sciences of Philadelphia Transactions, v. 3, pt. 4, p. 729, pl. 34, figs. 14, 15.)

1945. *Chlamys (Nodipecten) dumblei* Gardner, Geological Society of America Memoir 11, p. 69, pl. 11, figs. 4 [paratype 49456], 6 [paratype 494955, = 7712-A]

Syntypes.—USNM 494994 a right valve, 4.5 cm high, 5.0 cm long. USNM 494995, a left valve with one prominent ledge or change in shell profile at 1.8 cm high, emphasized by three hollow nodes or thickenings. 5.1 cm high, 5.9 cm long.

Type locality.—Tamaulipas, Mexico, east bank of Rio Conchos, near town of San Fernando (USGS 13455, USGS 13585). Lower Miocene, Guajalote Formation.

Paratypes.—USNM 494955, a left valve measuring 4.5 cm high, 4.9 cm long (USGS loc. 13455). USNM 494956, an atypical left valve with three rounded ledges and broken anterior auricles, 3.5 cm high, 3.7 cm long (USGS loc. 13587).

Significant hypotype.—UCMP 37395, a double-valved specimen from the type area (UCMP D-8799).

Description.—Adult valves equally convex, juvenile left valves flatter than right valves. Profile variable; right valve rounded, left valve commonly with a single angular ledge at about 2 cm high (but some specimens have two or three ledges). Valves circular in juvenile stages, longer than high in adults. Posterior elongation is common in larger individuals. Beaks project equally, slightly, beyond hinge line. Auricles small, unequal, costate, and lirate. Byssal notch moderately deep. Hinge length less than half shell length. Right-valve ribs 14-15 or 16, ribs and spaces costate and lirate. Rib profiles narrow, rectangular, and moderately high. Left-valve ribs 14-15, with two or more elongate nodes on the central and fourth posterior ribs. The central rib and one or two others usually bear elongate hollow swellings or incipient nodes before the break in shell slope. The node scheme can be described as 3r N 2r N_c 3r N 2r.

The largest individuals measured 8 cm high (TU 1071). The fact that many specimens had repaired shells suggests that the single prominent ledge may be related to injury. However, uninjured specimens from other localities are also ledged and shell growth seems to be continuous. The ledge is a normal character. Only one individual has been found with two articulated valves (hypotype UCMP 37395).

Variability.—Variation among specimens from the type area is low. Specimens from Baja California Sur here referred to "*Lyropecten*" sp. aff. "*L.*" *dumblei*, differ in lacking the pronounced left-valve ledge and well-developed elongate thickenings. Individuals from northwestern Florida are scarce and poorly preserved, occurring at a few localities with "*L.*" *condylomatus*; the Chipola Formation specimens have one or two fewer ribs than those from eastern Mexico. Gardner (1945) noted the early confusion between *L. dumblei* and *L. condylomatus* and the misidentification of the Mexican species as "*L.*" *condylomatus*. "*Lyropecten*" *condylomatus* varies in rib count and node scheme; some specimens overlap "*L.*" *dumblei* in rib count, but none have its single angular ledge and node scheme.

Comparative notes.—"*Lyropecten*" *dumblei* is distinguished from "*L.*" *condylomatus* in having evenly spaced ribs and a consistent left-valve node scheme, 7r N_c 3r N 3r. It has 13-15 ribs; "*L.*" *condylomatus* has 10-11, a few individuals as many as 13. Disarticulated juvenile right valves of the two species are hard to distinguish.

Phylogenetic affinities.—"*Lyropecten*" *dumblei* seems to be ancestral to "*L.*" *condylomatus*, although records for the taxa are meager outside their respective type areas, and foraminifers from the two areas suggest that the species could be penecontemporaneous.

Lyropecten sp. aff. "*L.*" *dumblei* (pl. 20, figs. 9-11) occurs in the lower Miocene Isidro Formation near La Purisima, Baja California Sur, Mexico (locations USGS 9157, 9160; CAS 36409; M9165). It resembles "*L.*"

dumblei in internal hinge, size, and growth form but lacks the characteristic left-valve ledge and elongate nodes. It may also be ancestral to *L. pretiosus*, the oldest Pacific *Lyropecten*.

Geographic distribution and stratigraphic occurrences.—Coastal plain of northeastern Mexico, states of Tamaulipas and Veracruz; Sinu Basin, northwestern Colombia. Florida panhandle along the Chipola River, co-occurring with *"L." condylomatus*.

Northeastern Mexico, Guajalote Formation [San Fernando and San Rafael Formation of early workers], near San Fernando, Tamaulipas: USGS 13455, 13585, 13587, 13588; 3419; CAS 40508, 40274; 41034, 41053; UCMP S-8293 (occurs with a *Chesapecten*); TU 430.

Veracruz, Mexico. Tuxpan Formation, Papantla region (CAS 41039, 41040; TU 1071). Planktonic foraminifers from TU 1071, which are from zones N 10 or N 11, are interpreted as indicating 30 m in depth (W.H. Akers, oral commun., 1981). Rio Las Playas (UCMP S-8219).

Northern Colombia, Departamento Cordoba, Sinu River basin. Hatachica, above Maria Magdalena [= La Risa] (UCMP S-7331). Rio San Juan area, Quebrada Pajuil (USGS 1625, 1626).

Uncertain occurrence, Baja California Sur, Mexico (Smith, 1984). La Purisima area (USGS 9157, 9160; CAS 36409; M9165).

Northwestern Florida. Oak Grove Formation, Sand Member, Shoal River Formation (USGS 659 = 11659, very worn material). Chipola Formation (USGS 3419; 2564).

Sarasota County, Fla., with *"L." condylomatus* at USGS 23596, 23598, South Point Drive, Hawthorn Formation.

Geologic age.—Late Oligocene or early Miocene to middle Miocene.

Macrochlamis Sacco, 1897a

Type species (original designation).— *Ostrea latissima* Brocchi, 1814. The holotype was illustrated in Ronchetti, 1952, p. 26-29, figs. 8a, 8b.

Diagnosis.—Valves equally convex, auricles equal, large, and smooth. Byssal notch present, hinge teeth variable, 0-3 weak pairs, hinge greater than half shell length. Beaks project slightly. equally beyond hinge. Radial ribs tend to be few, low in profile, and wider in the central part of the shell. Fine macrosculpture mainly concentric growth lines in California taxa.

The correct spelling of the generic name is *Macrochlamis*, as published by Sacco (1897a) in a synopsis preceding his major monograph of the same title (1897b). In the second publication, which contained complete descriptions of his new taxa, he spelled the genus *Macrochlamys*, a name preoccupied by a gastropod (Benson, 1832). This led later workers to reject the name as a primary homonym and to propose new names such as *Gigantopecten* Rovereto, 1899 and *Grandipecten* Cossmann, 1914. The difference of one letter and designation of a type species in Sacco's first publication distinguishes it from the gastropod *Macrochlamys* and qualifies it as a valid name rather than a junior homonym.

"Macrochlamis" is used here for an important California index species, because thorough revisions of European genera are beyond the scope of this paper. A European cognate species here referred to *Macrochlamis terebratulaeformis* (de Serres) is included for comparison.

"Macrochlamis" magnolia magnolia (Conrad, 1857)

Plate 29, figures 3, 4; plate 31, figures 1, 5; plate 37, figures 2, 4

1857. *Pecten magnolia* Conrad, Report of Explorations for Railroad Routes..., v. 7, pt. 2, p. 191, pl. 1, fig. 2.

1906. *Pecten (Lyropecten) magnolia* Conrad. Arnold, U.S. Geological Survey Professional Paper 47, p. 77-78, pl. 24, fig. 1 [fig. 2 is *"M." magnolia ojaiensis*, n. subsp.]; not pl. 25, fig. 1 [= fragment of *Lyropecten crassicardo*; probably not from the Vaqueros Formation].

1931. *Pecten (Lyropecten) jeffersonius* Say. Grant and Gale, San Diego Society of Natural History Memoir, v. 1, p. 176-177 (in part).

1932. *Pecten (Lyropecten) magnolia* Conrad. Loel and Corey, University of California Publications, Department of Geological Sciences, v. 22, no. 3, p. 198-199 (in part), pl. 25, figs. 1, 2, 4; pl. 27, fig. 2.

Not 1942. *Pecten (Lyropecten) magnolia* Conrad. Haas, Journal of Paleontology, v. 16, no. 3, p. 309, 313 [a poorly preserved internal mold of a pectinid having 8 or 9 ribs].

Taxonomic comments.—*Pecten magnolia* Conrad has long been classified as a *Lyropecten* because of its interior hinge crura, large size, and morphologic similarity to a large number of species referred to that genus. Addicott (1972) noted that the shell proportions and giant size of auricles resemble those of European pectinids of the *Macrochlamis latissimus-M. holgeri* group; he considered *P. magnolia* the first representative of that stock in western North America. The genus is unknown in the Eastern United States, but it ranged widely during Miocene and Pliocene time in the eastern and western Tethys of Europe.

Two subspecies are recognized here: the 9-10 ribbed *"M." magnolia, s.s.* and a fewer ribbed form, *"M." magnolia ojaiensis*, n. subsp. They are separable biostratigraphically, the former occurring in the lower lower "Vaqueros" Stage, the latter in the upper lower "Vaqueros" to lower middle "Vaqueros" Stage. Ranges of *"M." magnolia, s.s.* and *"M." magnolia ojaiensis* overlap those of *Vertipecten perrini* and *V. kernensis*, respectively. Gradational specimens occur in upper Oligocene rocks of the Santa Cruz Mountains, the Santa Ynez Range, the Nipomo-Huasna basin, and the western Santa Susana Mountains (fig. 11).

Neotype.—UCMP 31729, here selected, illustrated by Loel and Corey (1932, pl. 27, fig. 2).

Conrad designated no holotype, although the original description mentioned 11 ribs and very large size. His illustration does not match his description; it seems to be a valve of *Pecten meekii* Conrad. Arnold (1906) referred to type specimens at the U.S. National Museum (USNM 13311 and 13325), but they are fragments of *L. crassicardo* and not Conrad types.

Type locality.—Santa Ynez ("Inez") Mountains, Santa Barbara County, Calif. Subsequent field work suggests it is on the north side of the range and in the Santa Ynez Valley, probably in the vicinity of the San Julian Ranch (Lompoc 15-minute quadrangle), in T. 5 N., R. 30 W. (Keen and Bentson, 1944). Neotype locality: about 0.5 mi north of Jalama Creek, near Escondido Creek, Santa Ynez Mountains (loc. UCMP A-315). Oligocene, Vaqueros Formation, basal part (Loel and Corey, 1932, p. 91).

Significant hypotype.—UCMP 37387 (loc. UCMP D-8794).

Description.—Valves massive, subcircular; juvenile right valves more convex, left valves flat. Right-valve beak projects farther beyond hinge line than left beak (pl. 31, fig. 1). Auricles very large, sculptured by fine growth lines, a few faint radials near the hinge. Posterior auricle higher than anterior. Byssal notch weak. Hinge has three pairs of strong cardinal crura; hinge length about half shell length. Right-valve ribs 9-10, wider than interspaces. Fine macrosculpture obsolete, mainly concentric growth lines. Left-valve ribs 9-10, narrower than interspaces. The fine sculpture, rarely preserved, consists of several fine radial striae crossed by concentric growth lines (hypotype UCMP 37387, pl. 31, fig. 5). Many large specimens from Cuyama Valley (for example, locality M3519) are extremely swollen. One giant measured 25 cm high, 28-30 cm long, 14.5 cm in hinge length (J.G. Vedder, oral commun., 1973).

Variability.—Juveniles have 10 high, narrow ribs, adults 8-9 lower rectangular ribs, lateral riblets becoming incipient in some cases. Loel and Corey (1932) noted rib counts of 10-12 in many specimens, as low as 6 in others. Stratigraphic and geographic data support the subdivision into two subspecies differentiated by rib count. Within each subspecies, ribs vary by one or two.

Comparative notes.—Subspecific differences are as follows:

"M." magnolia s.s., *"many ribbed form"*	"M." magnolia ojaiensis *"few-ribbed form"*
Rib count 9-10	Rib count 6-7
Right-valve beak projects slightly above straight hinge line	Right-valve beak projects higher above hinge line
Left-valve juvenile normal convexity	Flat-concave profile until 1.5-2 cm high; may have one slight ledge
Maximum adult size 25 cm high; most 20 cm	Maximum adult size 14-15 cm high

Phylogenetic affinities.—Biostratigraphic data indicate that the many ribbed *"M." magnolia s.s.* is the older subspecies and direct ancestor of *"M." magnolia ojaiensis*. There is no other representative of *"Macrochlamis"* in North America; a comprehensive systematic revision of European pectinid genera may indicate that *"M." magnolia, s.l.* and the close European cognate identified here as *M. terebratulaeformis* belong in another genus. Arnold (1906) considered *Pecten magnolia* ancestral to *L. crassicardo*, but that lineage is not borne out by the morphologic progression and fossil record of *Lyropecten* sp. cf. *L. magnificus* and *L. pretiosus* (including *L. submiguelensis* auctt.)-*L. crassicardo-L. magnificus*. The phylogenetic relation, if any, between *"Macrochlamis"* and *Lyropecten* is unknown.

Geographic distribution and stratigraphic occurrences.—In figure 11 the distributions of *"M." magnolia* subspecies are compared.

Western Transverse Ranges, southern Santa Lucia and northern La Panza Ranges; Cuyama Valley and Caliente Range; Santa Ana Mountains. Not from the type locality of the Vaqueros Formation, as listed by Thorup (1943). Not from Central America as reported in the literature. Reports by reconnaissance geology mappers of occurrences on the northern Channel Islands could not be verified from museum collections.

Representative localities.—Vaqueros Formation, southern Coast Ranges: LSJU accession no. 53268, Bradley 15-minute quadrangle, near Tierra Redonda Mountain north of Nacimiento Reservoir. Lompoc 15-minute quadrangle; San Julian Ranch, Ytias Canyon, and Jalama Creek (LSJU accession Nos. 1710, 1821; UCMP D-8794, A-315, A-319). Also from south of the Santa Ynez River, on the Alisal Ranch.

Cayucos 15-minute quadrangle, near Morro and Toro Creeks (UCLA 6205, with *V. perrini*; LSJU acc. no. 20058, 22362); Cypress Mountain quadrangle (UCLA 6068, 6069; 6073); Nipomo quadrangle (UCLA 4586, 4584); Pismo Beach quadrangle (UCLA 5840, fragments).

La Panza Range, Hay Canyon (USGS M2831) Vaqueros Formation, Painted Rock Sandstone Member. Large individuals are found with internal molds of *Amusium* and *Lyropecten pretiosus* (= *L. submiguelensis* auctt.).

Caliente Range and central Sierra Madre Range. Abundant large specimens as well as juveniles occur at USGS M3519, M3520; UCLA 5564 (Fritsche, 1969); UCMP B-4064, in the Fox Mountain quadrangle. Vaqueros Formation, basal part, Cuyama Valley (abundant at M2445). Fieldwork was not undertaken to investigate the relation of lower "Vaqueros" Stage megafossils and Saucesian microfossils reported from some localities (J.G. Vedder, oral commun., 1973).

Forms having rib counts intermediate between *"M." magnolia, s.s.* and *"M." magnolia ojaiensis* include a worn individual from the San Emigdio Mountains (UCR 4021)

and specimens from the Huasna Basin (UCLA 4586) and Big Mountain, western Santa Susana Mountains (Pacific Section Society of Economic Paleontologists and Mineralogists field trip, Oct. 8, 1983).

Vaqueros Formation, western Santa Ana Mountains, Irvine Ranch area (LSJU summer geology collections, 1949 and 1950, including SGS 1949 131-3A, pl. 37, fig. 4). This specimen, hypotype CAS 61039, is closest to material from the Santa Ynez Mountains (locs. UCMP A-543, D-8794).

Geologic age.—Middle Oligocene. Specimens from the Salisbury Canyon 15-minute quadrangle (USGS loc. M3520) are regarded as early Miocene by J.G. Vedder (oral commun., 1973).

Biostratigraphic data.—Lower "Vaqueros" Stage. "One of the most characteristic of the lower Miocene, or Vaqueros Formation fossils," according to Arnold (1906), who was referring to the formation in the Morro-Toro Creek area, Cayucos 15-minute quadrangle, rather than at its type locality farther north. It commonly occurs with *Vertipecten perrini.*

Paleoecology.—*"M." magnolia, s.l.* is known only from shallow-water deposits, especially well indurated coarse-grained pebbly sandstones and sandy conglomerates. The majority of specimens collected have two valves intact but most of the outer shell layer is gone; this kind of preservation implies a turbulent beach environment.

"Macrochlamis" magnolia ojaiensis
n. subsp.

Plate 29, figures 1, 2; plate 30, figure 3; plate 31, figures 2, 3, 6

1906. *Pecten (Lyropecten) magnolia* Conrad. Arnold, U.S. Geological Survey Professional Paper 47, p. 77-78, pl. 24, fig. 2.

?1923. *Pecten (Lyropecten) vaughani emigdioensis* Wagner and Schilling, University of California Publications, Department of Geological Sciences, v. 14, no. 6, p. 253, pl. 45, fig. 2 [a juvenile left valve].

1932. *Pecten (Lyropecten) magnolia* Conrad. Loel and Corey, University of California Publications, Department of Geological Sciences Bulletin, v. 22, no. 3, p. 198-199 (in part), pl. 25, fig. 3; pl. 26, figs. 1a, 1b; pl. 27, fig. 1; pl. 28, fig. 1.

1972. *Macrochlamis magnolia* (Conrad). Addicott, Society of Economic Paleontologists and Mineralogists, Pacific Section, Proceedings, p. 8.

1974. *Macrochlamis magnolia* (Conrad). Addicott, Journal of Paleontology, v. 48, no. 1, pl. 2, fig. 3.

Holotype.—USNM 335004, formerly LSJU accession no. 22366, a double-valved adult 13.2 cm high, 14.5 cm long, is designated as type. It is named for the Ojai Valley, a Chumash Indian name pronounced ō' high, meaning "moon."

Paratype.—UCMP 37383.

Type locality.—Ventura County, Calif., Ojai 7½-minute quadrangle "East end of Ojai Valley near the abandoned oil well" according to notes from Stanford Summer Geology, 1931 (field loc. 20-Z, = UCMP D-8792). Vaqueros Formation, upper Oligocene (lower Miocene of many authors).

Taxonomic comment.—The "few-ribbed Ojai form" can be separated morphologically and stratigraphically from *"M." magnolia, s.s. Pecten emigdioensis* Wagner and Schilling, based on a juvenile left valve from the San Emigdio Range, is possibly a juvenile of this taxon, although the name is rejected because it is not certain that the single immature specimen is the same species as the abundant adult "machrochlamids" in the Ojai Valley.

Description.—Valves longer than high, convex in adults. Juvenile right valves convex; left valves flat to concave, many with a slight ledge at 1.5 cm height. Right-valve beak projects farther above hinge line than left valve. Auricles large, equal, the posterior auricle higher than the anterior one; auricles smooth except for growth lines and 2-3 obsolete radials near hinge line. Byssal notch shallow. Hinge length greater than three-fourths shell length. Umbonal angle about 90°. Right valves with 6-7 rectangular ribs that are highest and widest in center of shell; lateral ribs progressively narrower and commonly obsolete in adults. Left valves 6-7 ribs, which are narrower than interspaces. Fine macrosculpture of radial costae and concentric growth lines; coarse radial costae rarely preserved in interspaces of a few individuals (loc. USGS 13330). The largest individual studied was incomplete at 14.7 cm high (LSJU accession no. 22367).

Variability.—Ribs usually 6-7, 8 in some specimens (UCR loc. 7586). Juveniles may have one rib more than adults. Left-valve umbonal area slightly concave, flat, or normal.

Comparative notes.—*"Macrochlamis" magnolia ojaiensis* has fewer ribs than *"M." magnolia, s.s.*; the right-valve beak projects farther above the hinge line. Middle to late Oligocene forms have rib counts intermediate between the two subspecies.

In a broader framework, *"M." magnolia, s.l.* from California may be related to *M. tournalii, s.l., M. terebratulaeformis* (pl. 30, figs. 1, 2; pl. 31, fig. 4), and European taxa referred to *M. subholgeri* (Fontannes, 1878) and *M. restitutensis* (Fontannes, 1881). Shared morphologic characters include shape and size of auricles, juvenile growth forms, and comparable rib counts, profiles, and fine sculpture. Of the two California subspecies, *"M." magnolia ojaiensis* is closer to European specimens referred here to *M. terebratulaeformis* (de Serres, 1829). California localities yielding cognate material most like the European specimens include UCR 1154 and UCLA 1311.

Geographic distribution and stratigraphic occurrences.—Transverse Ranges, from the Sespe Creek area to the Santa Susana Mountains; present but not common as far north as San Mateo County, south to the San Emigdio Mountains. Very rare in the Santa Monica Moun-

tains, Point Dume quadrangle, south of the Malibu Bowl fault. Also from Pyramid Hill, Kern County, and the eastern Temblor Range.

Not from the type locality of the Vaqueros Formation, member E or F as indicated in faunal lists (Thorup, 1942). Specimens that are intermediate in rib count between "*M.*" *magnolia s.s.* and "*M.*" *magnolia ojaiensis* come from the Huasna Basin, the western Santa Susana Mountains, and south of the Santa Ynez River in the Los Olivos 15-minute quadrangle.

Distributions are plotted for comparison with occurrences of "*M.*" *magnolia, s.s.* on figure 11. The map demonstrates the problem of interpreting paleogeography from species distributions: localities of "*M.*" *magnolia, s.l.* alone suggest simple basins, but zoogeographic data from larger faunal assemblages demonstrate 150-200 mi of lateral offset along the San Andreas fault since the Oligocene (Addicott, 1968). This amount of displacement is also supported by data from studies of sedimentary basins, Tertiary volcanic rocks, structural relationships, and geomorphology.

Representative localities for "*M.*" *magnolia ojaiensis*:

Ojai Valley and east along Oak Ridge, Vaqueros Formation: USGS M8012 = UCMP D-8792; LSJU accession no. 22367, 143, 33535; UCLA 1311; UCMP A-326, A-330). Ridgetops on the Alisal Ranch, south of Solvang and the Santa Ynez River, Santa Ynez 7½-minute quadrangle. Santa Susana Mountains (UCR 7586). Topatopa Mountains, Lion Canyon 7½-minute quadrangle, with *Vertipecten kernensis* (CSUN 263). South of Huasna Peak, Nipomo 15-minute quadrangle (UCLA 4586) and in isolated outcrops in the northwestern part of Vaquero Flat (UCLA 4584, 4583 of Hall and Corbato, 1967).

Temblor Range, from the lower part of the Temblor Formation, Santos Shale Member, Agua Sandstone Bed in the Packwood Creek 7½-minute quadrangle: LSJU loc. 2862; USGS M2631; at UCR 1269 specimens are intermediate in rib count between "*M.*" *magnolia, s.s.* and "*M.*" *ojaiensis*. "*Macrochlamis*" *magnolia ojaiensis* forms a biostrome in the basal conglomerate of the Agua Sandstone Bed, where it is found with *Vertipecten* fragments of a form transitional between *V. perrini* and *V. kernensis*.

San Emigdio Mountains (UCR 4021; USGS 13330); in the Temblor Formation near Pleito Creek (Nilsen and others, 1973). Material from USGS 13330 (east side of Pleitito Creek) has a hard pebble and sand matrix; specimens match material from Ojai Valley.

Santa Monica Mountains, north of the Malibu Coast fault, south of the Malibu Bowl fault, near the junction of Newton Canyon with Zuma Canyon; Vaqueros Formation, undifferentiated, of Yerkes and Campbell (1980a) (field check for this paper).

Pyramid Hill, Kern County (UCR 1152, 1154, 1185; UCMP B-6205; USGS M1700), from the Jewett Sand, basal grit. Pescadero Beach, San Mateo County, in the Vaqueros Formation exposed at low tide (CAS 38386; LSJU accession no. 47625).

Geologic age.—Late Oligocene.

Biostratigraphic data.—Upper lower "Vaqueros" to lower middle "Vaqueros" Stage. Its highest occurrences are with *Vertipecten kernensis* (= *V. nevadanus* auctt.) in the basal grit zone of the Jewett Sand near Pyramid Hill (USGS M-1700) and in the Vaqueros Formation in the Lion Canyon 7½-minute quadrangle (CSUN 263).

Paleoecology.—Heavy, articulated shells are found with neritic organisms in coarse conglomerates. In the eastern Temblor Range near Cedar Canyon (USGS M2631), concentrations of "*M.*" *magnolia ojaiensis* form a biostrome in basal conglomerates of the Agua Sandstone Bed, Santos Shale Member, Temblor Formation.

Macrochlamis terebratulaeformis (de Serres, 1829)

Plate 30, figures 1, 2; plate 31, figure 4

1829. *Pecten terebratulaeformis* de Serres, Géognosie des terrains tertiares du Midi de la France, p. 132, corrections p. 273; pl. IV, fig. 1.

1939. *Chlamys tournali* de Serres. Roger, Société géologique de France, nouvelle serie, Mémoire 40, p. 21 (in part); pl. IX, figs. 1, 1a [specimen in collection at the Université de Lyon].

Taxonomic comment.—Described from the Midi, France, this species is referred by most European workers to *M. tournalii* (de Serres, 1829, p. 263-4, pl. IV, fig. 1), an early Miocene Burdigalian index fossil in the western Mediterranean region (Roger, 1939; Demarq and Barbillat, 1971). De Serres' original illustrations show *M. tournalii* as a 14-ribbed specimen with a plano-concave juvenile left valve, and *M. terebratulaeformis* with only 8 ribs. Although *M. terebratulaeformis* was described first in de Serres' paper, later authors synonymized it with *M. tournalii* (Roger, 1939).

Type information.—The holotype illustrated in the original reference is a double-valved individual with a distinctive hole broken through the shell where the beaks meet. Left valve with 8 ribs. About 14-15 cm high.

Type locality.—Île Sainte-Lucie, France, "Calcaire moellon, marnes argileuses bleues Italie." Burdigalian Stage (Roger, 1939).

Hypotypes.—MCZ 18104, 18105, 18106 from the Auberson Valley about 2 km northwest of Sainte-Croix, Switzerland. Collected by Dr. Gustave Campiche, an amateur whose collections went to the Musée Géologique at the Université de Lausanne and to Harvard College in the 1860's. Modern maps show the area within the perialpine trough connecting the Rhône Valley and Vienna Basin. The rocks are referred to the Swiss Molasse, and by the early 1900's, the fossiliferous beds collected by Dr. Campiche had been exhausted (Rittener, 1902).

Description.—The *Macrochlamis terebratulaeformis* illustrated by Roger (1939) has 7-8 (the original description said 9-10) ribs and a slightly concave juvenile left valve that becomes gibbose in adult specimens. Right valve convex, projecting above the hinge line. Height about 11 cm. Auricles equal, large and smooth. Specimens here identified as *M. terebratulaeformis* from the Auberson Valley of southwestern Switzerland (MCZ 18104, 18105, 18106) have rectangular, flat-topped ribs that become lower and wider in adults. Lateral ribs very reduced in width and prominence. Fine macrosculpture is limited to concentric growth lines.

Comparison between two European macrochlamids:

M. terebratulaeformis	*M. tournalii*
Ribs 7-8	Ribs 11-14
Right-valve beak projects high above hinge line	Right-valve beak projects slightly above hinge line

Variability.—The apical depression in the left valve of *M. terebratulaeformis* varies from slight to marked.

Roger (1939), who regarded the two taxa as extremes of one variable species, based his interpretation on overlapping morphological characters in material from three geographic areas and on the occurrence of both forms in the type area of Sainte-Lucie. He noted that specimens from Montpellier are closer to *M. tournalii s.s.*, those from Béziers are *M. terebratulaeformis*, and those from Narbonne intermediate in rib count and convexity. Although detailed biostratigraphic data are not available, he implied that they were contemporaneous.

Phylogenetic affinities.—Macrochlamis terebratulaeformis and *M. tournalii* approach "*M.*" *magnolia, s.l.* in size, shape, and valve profiles as well as in number and arrangement of ribs and fine sculpture.

If the relation between European and California macrochlamids is as close as suggested by the limited material from this study, there are two important implications for future biostratigraphic work. The first is a means of correlating megafaunal stages directly on the basis of macrochlamid cognates. The second is the potential subdivision of European stages using detailed stratigraphic data and the phylogenetic series referred here to *M. tournalii, s.l.*

Geographic and biostratigraphic distribution.—Macrochlamis terebratulaeformis, s.s: Béziers, Sainte Lucie; Béziers (Hérault, about 61 km southwest of Montpellier; Mus (Gard); northwest of Sainte-Croix, Switzerland (MCZ hypotypes 18104-18106).—*Macrochlamis tournalii s.l.*, including *M. terebratulaeformis*, (from the literature): Burdigalian in the western Mediterranean: Nîmes, Bouche-du-Rhône (plan d'Aren), Vence (Alpes-Maritimes); rare in the Rhône Valley (Roger, 1939; Demarcq and Barbillat, 1971); Vindobonian, middle Miocene, in the eastern Mediterranean and eastern Italian embayment (Roger, 1939); upper Miocene in the Vienna Basin and Poland (Roger, 1939).

Geologic age.—Late Oligocene to early Miocene.

Stratigraphic comment.—Roger (1939) noted that forms referred to *M. tournalii, s.s.* are commonly found in a fine sandy molassic facies, while very convex, bulging forms identified as *M. terebratulaeformis* occur in coarser, limier molasse. For many specimens cited in the literature, matrix material is unspecified.

Biostratigraphic data.—Aquitanian to lower Burdigalian Stage.

The pectinids here identified as *M. terebratulaeformis* came from an area including the Auberson and Noirvaux valleys described in papers and on maps by Pictet, Campiche, and de Tribolet (Pictet and Campiche, 1858) and also shown in Renz and Jung (1978). They were not listed[4] or illustrated with other Falunien Stage mollusks, although each specimen bears a printed label "Falunien de Sainte-Croix." The term "Falunien" was probably introduced by d'Orbigny prior to volume III of his *Prodrome* (1852), in which he considered it a substage younger than Tongrian and older than Subapennine. D'Orbigny did not list *Pecten tournalii* or *P. terebratulaeformis* among the Falunien Stage fossils, although he mentioned some of the pectinids (*Pecten jeffersonius, P. clintonius, P. madisonius, P. decemnarius*) referred by Ward and Blackwelder (1975) to *Chesapecten*.

Vertipecten Grant and Gale, 1931

Type species (original designation): *Pecten nevadanus* Conrad (+ *Pecten bowersi* Arnold) [= *Pecten bowersi* Arnold, 1906; see taxonomic comments under *Vertipecten bowersi*].

Diagnosis.—Valves equal in height and length in most species, but height exceeds length in the youngest taxon. Profiles variable, from equally convex to planoconvex right valves and strongly convex left valves. Ribs or costae and interspaces numerous, of varying widths, with imbricated or scaly fine sculpture in most taxa. Shagreen or screenlike microsculpture preserved in some species. Rib profiles vary with time (see table 5). Auricles equal, with scaly radial riblets. Byssal notch deep; hinge area smooth, lacking crura.

Vertipecten differs from *Lyropecten* and "*Macrochlamis*" in valve profiles, scaliness of ribs and auricles, hinge, and byssal area; ribs and costae are irregularly spaced. *Vertipecten* has the deep byssal notch of *Chlamys* but differs from it in having more equal auricles, no hinge crura, coarser imbricated sculpture, and unequal valve profiles, a planar left valve and convex right valve.

[4]Pictet and Campiche (1858) noted that Falunien mollusks were rare and, except for *Pecten scabrellus*, poorly preserved.

Vertipecten alexclarki
Addicott, 1973

Plate 38, figures 1-4

1905. *Pecten* sp. Anderson, California Academy Sciences Proceedings, 3d ser, v. 2, no. 2, p. 170.
1906. *Pecten (Chlamys) branneri* Arnold, U.S. Geological Survey Professional Paper 47, p. 55-56 (in part), not pl. 3, figs. 9-11 [specimen from upper Oligocene Vaqueros Sandstone at Twobar Creek, near Boulder Creek, Santa Cruz County, collected by Newsom and Arnold is *V. alexclarki*, LSJU accession no. 4902].
1972. *Vertipecten* n. sp. Addicott, Society of Economic Paleontologists and Mineralogists, Pacific Section, Biostratigraphic symposium, Bakersfield, Calif., 1972, Proceedings, pl. 1, figs. 16, 18.
1973. *Vertipecten alexclarki* Addicott, U.S. Geological Survey Professional Paper 791, p. 26-27, pl. 1, figs. 9, 10, 13; pl. 2, figs. 1, 3, 5, 8, 9; pl. 3, figs. 1, 4.

Lectotype.—USNM 646531, a right valve, height 6.9 cm, length 6.6 cm (subsequent designation, Moore (1984b).

Type locality.—Central Temblor Range, Kern County, Calif. Las Yeguas Ranch 7½-minute quadrangle, on south side of hill 2259 just below summit; 2,200 feet north, 1,000 ft west of southeast corner sec. 22, T. 28 S., R. 19 E. (USGS M3281). Temblor Formation, base of the Wygal Sandstone Member (Addicott, 1973) [= Phacoides sand of local usage; see Stinemeyer and others, 1959] late early or middle Oligocene in age.

Paratypes.—USNM 646538, 646539.

Hypotypes.—USNM 646528, 646529, 646530, 646532 CAS 60862.

Description.—Right valve flat, left valve convex, nearly equal; height exceeds length. Beaks do not project above hinge line. Right auricle square, with 4-5 radials; no complete left auricles seen. Byssal notch deep. Umbonal angle narrow, about 70°. Ribs 24-34, hard to count because they are narrow, sometimes split, and barely distinguishable from interriblets; left-valve ribs of several sizes, as in *V. perrini* and *V. kernensis* (= *V. nevadanus* auctt.), but with no single key rib. Fine sculpture consists of many fine radial ribs and interspace riblets with very fine imbrications. Adults small compared to other Vertipectens, the largest measuring 11.5 cm.

Morphologic variability seems low, although there are no complete individuals known and only a dozen or two fragmental specimens have been collected.

Comparative notes.—*Vertipecten alexclarki* is typical of the oldest Vertipectens in having small, nearly equally convex valves and numerous scaly ribs of several strengths. It has the narrowest umbonal angle of any *Vertipecten*. *Vertipecten yneziana* is more circular in outline, with flatter valves and coarser ribs. *Vertipecten perrini* has many coarser ribs, a convex left valve and wide umbonal angle.

Addicott (1973) compared *V. alexclarki* to *Chlamys branneri* (Arnold, 1906); he found the latter equivalved with auricles having 6 to 10 radials. Fine macrosculpture is similar. *Vertipecten alexclarki* is early to early middle Oligocene in age; *C. branneri* is middle Miocene.

Phylogenetic affinities.—*Vertipecten alexclarki* is isolated geographically from the phylogenetic series *V. yneziana-V. perrini*, although its chronostratigraphic range falls within the transition zone between them. Its relationship to contemporaneous Vertipectens is uncertain.

Geographic distribution and stratigraphic occurrences.—Central Temblor Range, between Media Agua Creek, Las Yeguas Ranch 7½-minute quadrangle and outcrops between Zemorra Creek and Temblor Creek, Carneros Rocks 7½-minute quadrangle, (T. 28-29 S., R. 19-20 E.). Wygal Sandstone Member, Temblor Formation (USGS M3280, M3281, M3579, M3636, M3772, M3984, M3985, M4466, M4468, M4470, M4472; CAS 27625). Santa Cruz Mountains: Twobar Creek, Big Basin 7½-minute quadrangle, Vaqueros Sandstone at the type locality of *Pecten sanctaecruzensis* (Ralph Arnold field loc. 111, LSJU accession no. 4902). The distribution in the central Temblor Range and the La Honda block of the Santa Cruz Mountains (fig. 11) supports the figure of about 300 km of post-Eocene right-slip motion along the San Andreas fault in central California (Graham and others, 1986).

Reported from Junipero Serra Peak, Santa Cruz Mountains, but specimens were not seen.

Geologic age.—Early to early middle Oligocene.

Biostratigraphy.—*Vertipecten alexclarki* is restricted to the unnamed molluscan stage between the lower "Vaqueros" and upper "Refugian" Stages (Addicott, 1973). The unnamed stage is equivalent to the lower (but not lowest) part of the Zemorrian Stage at its type section in the Zemorra Creek-Chico Martinez Creek area.

Paleoecology.—The Wygal Sandstone Member contains mollusks indicating shallow water to 20 fathoms, inner sublittoral conditions. The genera suggest warm temperate to subtropical temperatures; Addicott (1973) noted the occurrence of the unique eastern Pacific hermatypic coral *Favosites* at the type locality of *V. alexclarki* (M3280).

Vertipecten bowersi
(Arnold, 1906)

Plate 32, figures 4, 5; plate 35, figures 2-4

?1855. *Pecten nevadanus* Conrad, Report of Explorations in California for Railroad Routes***, v. 5, p. 329, pl. 8, fig. 77 [not *Pecten nevadanus* auctt.].
1906. *Pecten (Lyropecten) bowersi* Arnold, U.S. Geological Survey Professional Paper 47, p. 70-71, pl. 12, figs. 1, 2; pl. 13, figs. 1, 1a.
1931. *Pecten (Vertipecten) nevadanus* Conrad. Grant and Gale, San Diego Society of Natural History Memoir, v. 1, p. 189-190 (in part); pl. 7, figs. 2a, 2b, 2c [Neotype LSJU 431].
1932. *Pecten (Lyropecten) bowersi* Arnold. Loel and Corey, University of California Publications, Department of Geological Sciences Bulletin, v. 22, p. 198, pl. 22, fig. 1.
1941. *Pecten (Vertipecten) bowersi* Arnold. Hanna and Hertlein, California Division of Mines Bulletin 118, p. 176, fig. 64-20.

1969. *Pecten miguelensis submiguelensis* Loel and Corey. Weaver, American Association of Petroleum Geologists and Society of Economic Paleontologists and Mineralogists, Pacific Sections, Special Publication 200, pl. 32, fig. 7.

1972. *Vertipecten nevadanus* (Conrad). Addicott, Society of Economic Paleontologists and Mineralogists, Pacific Sections, Pacific Coast Miocene Biostratigraphic Symposium, p. 9, 10, pl. 2, fig. 9.

Holotype.—UCMP 12075, a large, double-valved, worn adult specimen 15.0 cm high, 14.7 cm long; hinge line (restored) 9.0 cm.

Paratype.—LSJU 432.

Type locality.—Santa Inez [= Ynez] Canyon, Santa Barbara County, Calif., western Transverse Ranges, north flanks of Santa Ynez Mountains. Arnold (1906) considered it "***lower to possibly the middle Miocene;" subsequent work restricts the range to late early Miocene to early middle Miocene, upper "Vaqueros" Stage.

It is not, as originally cited (Conrad, 1855b), associated with an older index fossil, *Pecten magnolia.*

Taxonomic comment.—Two early Miocene *Vertipecten* species are confused by many workers because of morphologic similarity and misinformation about the type material. *Vertipecten bowersi* (Arnold) and *V. nevadanus* (Conrad) of authors form a phylogenetic series documented by gradational shell characters and stratigraphic succession.

Specimens referred by authors to *V. nevadanus* are older than the incompletely diagnosed, poorly sketched external mold described as *Pecten nevadanus* by Conrad, who designated no holotype. Subsequent field work in Conrad's type area near Ocoya (now Poso) Creek has yielded a few poorly preserved fragments (USGS M1698) of the younger Miocene taxon widely known as *V. bowersi* (Arnold). None of this very poor material could serve as lectotype for *Pecten nevadanus* Conrad. In any case, it is preferable not to reinstate the name after its use for almost 75 years for another, older species of *Vertipecten*, referred to herein as *V. kernensis* (Hertlein). *Vertipecten bowersi* is based on a reasonably well preserved holotype from the western Transverse Ranges of southern California.

Arnold (1906) noted that Conrad's brief description and drawing of a right valve closely matched his own *Pecten bowersi* with respect to shell size, byssal area, and ribbing, although he hesitated to synonymize his taxon on the basis of few specific characters. Later workers thought Conrad's *Pecten nevadanus* was the same as the abundant, well-preserved pectinid [*V. kernensis* (Hertlein) of this report] from Pyramid Hill, about 4 mi southeast of the type Ocoya Creek area (M1698). Regional mapping and biostratigraphic studies by Addicott (1970) and Bartow and Doukas (1976) established significant chronostratigraphic differences between the Freeman Silt-Jewett Sand sequence at Pyramid Hill and the younger Olcese Sand that crops out to the southeast, west, and northwest. Disarticulated right valves or poorly preserved material of the two *Vertipecten* species from these units are hard to separate.

Grant and Gale synonymized *Pecten bowersi* and *P. nevadanus*, designating the type of *Vertipecten* as "*Pecten nevadanus* Conrad (+ *Pecten bowersi* Arnold)." The present study differentiates two species based on rib count, fine macrosculpture, and left-valve rib patterns. In the currently accepted geochronologic scheme, *V. bowersi* is a late early Miocene index species of the upper "Vaqueros" Stage; *V. kernensis* (= *V. nevadanus* auctt.) is latest Oligocene to early Miocene, indicative of the middle "Vaqueros" Stage. The stratigraphic ranges of Vertipectens from California and the Pacific Northwest are shown in figure 12.

Description.—Right valves flat, left valves highly convex; height equal to or slightly greater than length. Beaks meet at hinge line. Auricles equal, radially ribbed; byssal notch deep; umbonal angle about 95°. Adult right valves with 15-16 rounded-rectangular ribs (15-17 in juveniles); left valves with 14-15 rounded, narrow rectangular ribs, higher than those on right valves. Several prominent key ribs on left valves, including the central rib and anterior and posterior laterals separated from it by two lesser ribs. Fine macrosculpture of concentric growth lines and a single midriblet in each interspace. Small flanges rarely preserved on lateral ribs or over whole shell. Specimens rarely show the shagreen microsculpture[5] that is present in interspaces on both valves of UCSB hypotype M17 (= UCSB 1806, from Santa Cruz Island).

Adults measure more than 20 cm high, 22 cm long (UCR 7232, from Saddle Peak, Santa Monica Mountains). One shell measured 0.9-1 cm thick at its margin.

Morphologic variability.—Valve profiles vary between juvenile and adult stages, from flat to slightly convex in most individuals. Very large specimens, including many examples from the Caliente Range (USGS loc. M3439), become swollen in outline (fig. 9).

Right-valve rib width and spacing variable, as in *V. kernensis* (= *V. nevadanus* auctt.), *V. fucanus*, and *V. perrini*. Anterior and posterior parts of the shell may have narrow, incipient riblets which complicate the rib count. Left-valve key ribs may number one (in the central position), two (central and anterior) or three, of which the posterior rib may be less prominent than the others.

[5]Shagreen microsculpture is "a screenlike pattern of openings between projecting lamellae on the shell exterior," (Waller, 1972, fig. 12); it has been called metal-lathe or tesselate by some authors. It is preserved on some Holocene specimens of *Mizuhopecten yessoensis* (Jay), but rarely seen on fossils except in small patches, commonest on left valves.

Comparative morphology.—*Vertipecten bowersi* commonly occurs with *Lyropecten miguelensis*, another giant pectinid index species of the lower Miocene upper "Vaqueros" Stage. *Lyropecten miguelensis* is distinguished by a typical *Lyropecten* hinge having two pairs of crura in the left valve, three pairs on the right valve, and by radial ribs sculptured with radial lines and concentric lirae. Valve profiles both convex in *L. miguelensis*, one planar and one convex in *V. bowersi*. Byssal notch in *Vertipecten* is deeper, more set off than in *Lyropecten*.

Vertipecten kernensis has more ribs, scalier fine sculpture, and more equal valve proportions than the younger species of *Vertipecten*. *Vertipecten fucanus* has flat-topped, rectangular ribs, a single key rib with imbrications on left valves, and shagreen microsculpture rather than a well-defined midriblet in each interspace.

Phylogenetic affinities.—Overlapping morphologic characters and stratigraphic succession document the phylogenetic series *V. yneziana-V. perrini-V. kernensis* (= *V. nevadanus* auctt.)-*V. bowersi*. All are known only from California south of the Mount Hamilton Range; geographic distributions are wider for *V. bowersi*. *Vertipecten bowersi* and *V. kernensis* are possible ancestors to *V. fucanus*, although the latter species is common in the lower Miocene of Washington and Oregon and may represent a separate lineage.

Morphologic evidence of phylogenetic relations is marked in left valves, more obscure in right valves.

Geographic distribution and stratigraphic occurrences.—Central and southern California, from the northern La Panza Range, Caliente Range, Transverse Ranges and Santa Cruz Island; Orange County. East of the San Andreas fault in the northern Temblor Range and in canyons north of Poso Creek, Kern County. Erroneously reported from Vaqueros Creek, Monterey County (Loel and Corey, 1932, p. 198).

Representative stratigraphic occurrences.—Vaqueros Formation, sandstone member: La Panza 7½-minute quadrangle (M4670; CAS 53; found with *L. miguelensis*); southwest Santa Cruz Island (UCSB 1806 = M17); found with *L. miguelensis* in a fine-grained sandstone that interfingers with the upper part of the coarse diorite breccia member (McLean and others, 1976). Vaqueros Formation, Painted Rock Sandstone Member: Caliente Range, Carrizo Plain area (M5199, west of Soda Lake, Chimineas 7½-minute quadrangle, Vaqueros Formation, Painted Rock Sandstone Member: central Sierra Madre Range (Fritsche, 1969), at UCLA 5554, and with *L. miguelensis* at UCLA 5548, 5549, CSUN 91.

Temblor Formation, Carneros Sandstone Member: northern Temblor Range (M2633 = USGS 4941, Packwood Creek 7½-minute quadrangle; very large specimens more than 20 cm high found with *L. miguelensis*). Monterey Formation, Saltos Shale Member: Caliente Range, Sierra Madre and San Rafael Mountains, and Cuyama Valley (abundant specimens of *V. bowersi* and *L. miguelensis* throughout the Saltos Shale Member at M3430, M3448, M3771, M3320). Abundant *V. bowersi* at M3446, M3436 (basal part of Saltos Shale Member), M3439, M2416. Tectonically deformed specimens from M2418, just below contact with the overlying Branch Canyon Sandstone; San Rafael Mountains, UCR 1285, calcareous sandstones between Zaca and Corral Canyons.

Santa Monica Mountains; Calabasas, Point Dume, and Malibu Beach 7½-minute quadrangles (Yerkes and Campbell, 1980a,b), in the Topanga Group and the undivided Vaqueros Formation and Topanga Group: M4027, very thick shelled specimens in sedimentary breccia of upper part of the Topanga Group; UCR 7232, a large individual from upper Las Flores Canyon, possibly a link between *V. kernensis* and *V. bowersi*. Topanga Canyon Formation, Saddle Peak Member: M1953; M4018; CSUN 24; SGS, 1910 localities. Ten cm thick basal conglomerate bed with abundant *V. bowersi* [identified as *V. nevadanus* by authors] can be traced along southwest shoulder of Saddle Peak, Malibu Beach 7½-minute quadrangle in T. 1 S., R. 17 W. (Yerkes and Campbell, 1980a,b). Unit is denoted by the symbol Tn_2, below the Conejo Volcanics, in preliminary maps of Campbell and others (1970). Vaqueros Formation, San Nicholas Member: Triumpho Pass 7½-minute quadrangle; very poorly preserved specimens, some external molds.

Santa Ana Mountains (*fide* Arnold, 1906; Dickerson, 1914). Elesor Creek, 2.5 miles southeast of El Toro (USGS 4132). Very large specimens from the Vaqueros Formation in Laguna Canyon, Orange County, (UCMP A-527), and west of Laguna Canyon in the Topanga Formation (J.G. Vedder, written commun., 1983).

Poso (formerly Ocoya) Creek area, Knob Hill 7½-minute quadrangle, Olcese Sand: USGS 6627, poorly preserved fragment from concretionary sands that Addicott regards as lower part of the Olcese Sand (material is transitional between *V. kernensis* and *V. bowersi*).

Geologic age.—Early Miocene.

Biostratigraphic range.—Upper "Vaqueros" Stage. Loel and Corey (1932) noted its "***wide distribution in the Vaqueros horizon," which they considered early Miocene, and in what they called the middle Miocene Temblor Formation. Vedder and others (1973) reported that the species [identified as *V. nevadanus*] ranges into lowest Relizian in the Caliente Range. After several shifts in age-stage correlations, the taxon is currently considered early Miocene in age.

Paleoecology.—The species is most abundant in nearshore clastic facies. Specimens can be seen at Point Mugu in random orientations in a turbidite deposit.

Vertipecten fucanus
(Dall, 1898)

Plate 33, figures 2-4

1898. *Pecten (Chlamys) fucanus* Dall, Wagner Free Institute of Sciences of Philadelphia Transactions, v. 3, pt. 4, p. 704, pl. 26, fig. 7.

1906. *Pecten (Patinopecten) propatulus* Conrad. Arnold, U.S. Geological Survey Professional Paper 47, pl. 9, figs. 1, 1a, 2, 2a; not pl. 7, fig. 1.

1906. *Pecten (Chlamys) fucanus* Dall. Arnold, ibid., p. 66-67, pl. 10, figs. 1-2a.

1909. *Pecten (Patinopecten) propatulus* Conrad. Dall, U.S. Geological Survey Professional Paper 59, p. 64-65, pl. 9, figs. 1, 1a, 2, 2a; not pl. 7, fig. 1.

Not 1931. *Pecten (Vertipecten) nevadanus* Conrad, var. *fucanus* Dall. Grant and Gale, San Diego Society of Natural History Memoir, v. 1, p. 190, pl. 7, figs. 1a, 1b [= *V. kernensis* (= *V. nevadanus* auctt.)].

1963. *Vertipecten fucanus* (Dall). Moore, U.S. Geological Survey Professional Paper 419, p. 66, pl. 19, figs. 1, 2; pl. 20, fig. 8; pl. 21, figs. 1, 3; pl. 22, figs. 1, 4.

1963. *Vertipecten*? cf. *V. fucanus* (Dall). Moore, ibid., pl. 19, fig. 3; pl. 21, fig. 4.

1976b. *Vertipecten fucanus* (Dall). Addicott, U.S. Geological Survey Professional Paper 976, p. 29-30, pl. 4, figs. 1, 2, 5, 7, 10, 12.

Holotype.—USNM 107790, external mold of a cracked young adult left valve, 8.4 cm high, 8.9 cm long, hinge 5.2 cm, with a single imbricated key rib.

Plastotypes.—UCMP 14525; USNM 107790.

Type locality.—Clallam County, Wash., south shore of Strait of Juan de Fuca (USGS loc. 2464). Type found in concretion in sandstones at Clallam Bay, 25 mi east of Cape Flattery. Miocene. Weaver (1942) refined the locality (Univ. Washington 490) to NE¼, SE¼ sec. 22, T. 32 N., R. 12 W. and referred the sandstones to the Astoria Formation, middle Miocene. Addicott (1976b) revised the biostratigraphy and recognized the unit as the Clallam Formation of late early Miocene age, the type section of the Pillarian Stage, whose index species are figured in Moore and Addicott (1987).

Significant hypotypes.—CAS 60984, from the Olcese Sand, Poso Creek area, Kern County, Calif. (loc. CAS 1452). USNM 563294 from the Astoria Formation, Astoria, Oreg. (loc. CAS 2275) (Moore, 1984b, pl. 27, fig. 1).

Description (based on California specimen).—Valves relatively flat, left valve more convex than right valve. Height equals length; auricles equal, radially costate. Byssal notch deep. Hinge length greater than half shell length. Right valve with 16-17 flat-topped ribs of varying width flanking a wide central space opposite the raised key rib of the left valve. Left valve with 15-16 narrow ribs, more rounded than in right valve, a central raised "key rib" ornamented with imbricated flanges. Ribbing more irregular in lateral areas. Fine sculpture obsolete to fine, right valves with a medial groove on ribs, radial thread in spaces. Left valve interspaces smooth or with as many as three fine radials in addition to the fine shagreen microsculpture preserved in some specimens.

Specimens from southwestern Washington tend to be larger, 12-13 cm high, than those from California. Hypotype CAS 60984 from Kern County, Calif., measured 10.5 cm high, 10 cm long (incomplete).

Comparative morphology.—Right valves of *V. fucanus* are distinguished with difficulty from right valves of *V. bowersi*; *V. bowersi* has rounded, higher ribs and wider interspaces. *Vertipecten kernensis* has more ribs than *V. fucanus*, imbricated fine sculpture, and interribs. Patinopectens (for example, *P. propatulus*) usually have thinner shells, flatter ribs, smaller auricles, and a shallower byssal sinus than do Vertipectens. Addicott (1976b) noted that *V. fucanus* has relatively larger auricles (longer than half the shell length), a flat to slightly concave profile in juvenile right valves, and more irregular ribbing, especially in lateral areas, than *Patinopecten propatulus*.

Left valves of *V. fucanus* from California have a single central key rib, (Moore, 1984b, reported 1-3 key ribs in specimens from Oregon), whereas *V. bowersi* has 1-3 key ribs, none with the imbrications of *V. fucanus*. *Vertipecten kernensis* (= *V. nevadanus* auctt.), which is morphologically closest to *V. fucanus* in rib profiles and spacing, has 17-19 imbricated ribs of two or three strengths.

Phylogenetic affinities.—Primarily from western Washington and Oregon, *V. fucanus* may have evolved from *V. kernensis* in Kern County, Calif. Morphologic and chronostratigraphic evidence for this bioseries comes from specimens of *V. fucanus* in the Olcese Sand exposed after rare flash floods in tributary canyons north of Poso Creek (localities CAS 1452, UCMP B-1673).

Vertipecten may be ancestral to *Patinopecten*, a relation supported by biostratigraphic ranges and right valve morphologic characters of California taxa but not verified for taxa from the Pacific Northwest. A transitional form examined for this study was described as *Pecten (Patinopecten) haywardensis calaverasensis* Hall, 1958, middle Miocene "Temblor" Stage fossil from the Diablo Range east of San Francisco, Calif. Left-valve fragments have *Patinopecten* ribbing and no trace of the raised key ribs found in the youngest Vertipectens, but right valves resemble *Vertipecten* in rib number, profile, and arrangement.

Geographic and stratigraphic distributions.—Gulf of Alaska; Clallam County, northern Olympic Peninsula, and southwestern Wash.; western Oregon near Astoria and Newport; Kern County, Calif.

Poul Creek Formation, upper part, from the Gulf of Alaska Yakataga District (Kanno, 1971; Addicott, 1976b).

Northwestern Washington, along the Strait of Juan de Fuca: Clallam Formation, type section of the Pillarian Stage [uppermost part of the Clallam Formation of Arnold (1906)]. Representative localities include M4049, M4675,

and M6029. Addicott called *Vertipecten fucanus* the most characteristic mollusk found throughout the 600-800 m section of the Clallam Formation exposed in sea cliffs and the intertidal zone between Slip Point at Clallam Bay and Pillar Point, north of the Pysht River. Hoh rock assemblage, western Olympic Mountains (M4146, M4415).

Astoria Formation of western Oregon, Nye Mudstone, as mapped by Snavely and others (1976), Newport Embayment, coastal Oregon (Addicott, 1976b), and upper part of the Yaquina Formation south of Newport, Oreg. (E.J. Moore, written commun., 1984).

Olcese Sand, Knob Hill 7½-minute quadrangle, Kern County, Calif. Locality CAS 1452, west of Borel Canyon and about 4 mi north of Poso Creek. This important specimen was collected in 1928 by G D. Hanna, who noted that *Aturia* was also found in the same unit, and who referred the outcrop to "zone B" of Anderson (1911). A field check for this project in 1974 turned up no trace of fossils in the gray siltstone and sandstone covered by soil and grass, but material may be buried in stream beds. Considered the middle Miocene Temblor Formation by early workers, the locality probably falls in the upper part of the Olcese Sand in the Kern River area that was discussed in detail by Addicott (1970b). The locality, originally plotted on the old Woody quadrangle (1952 ed.), is about 7 mi northwest of the Barker's ranch locality and type section of Anderson's B zone (north side of the Kern River between Hart Memorial Park and the south end of Round Mountain). Until more specimens are collected and the stratigraphic unit confirmed, the possibility remains that the strata in which *V. fucanus* is found are part of the undivided Freeman Silt-Jewett Sand unit.

The species was misidentified from the middle Miocene Temblor Formation near Coalinga, Calif. (Adegoke, 1969).

Geologic age.—Early Miocene.

Biostratigraphic range.—Upper "Vaqueros" Stage in California; Pillarian Stage of the Pacific Northwest (Addicott, 1976b, 1977; Moore, 1984a; Moore and Addicott, 1987). *Vertipecten fucanus* is a good zonal index fossil correlating the lower Miocene Clallam Formation and Nye Mudstone, the lower part of the Astoria Formation, and the upper part of the Yaquina Formation of Oregon (E.J. Moore, written commun., 1984); these units are equivalent to the upper "Vaqueros" Stage formations of California and "***presumably, the uppermost part of the Poul Creek Formation in the Gulf of Alaska" (Addicott, 1976b). Moore (1984c) showed the *Vertipecten fucanus* Molluscan Zone equivalent to the Pillarian Stage; it is underlain by the *Liracassis apta* Molluscan Zone of late Oligocene to early Miocene age, and overlain by the *Patinopecten propatulus* Molluscan Zone of late early Miocene to middle Miocene age.

Paleoecology.—Associated molluscan taxa in Washington and Oregon indicate a nearshore environment of shallow to moderate depths with both cool and warm water forms. Addicott (1976b) considered the Clallam Formation assemblages to be inner sublittoral, less than 100 m deep and shallower during the later depositional stages.

***Vertipecten kernensis* (Hertlein, 1925)**

[= *V. nevadanus* (Conrad) of authors]

Plate 2, figures 6, 7; plate 32, figure 3; plate 33, figures 1, 5, 6; plate 36, figures 1-5

1855b. *Pecten nevadanus* Conrad, Reports of Explorations and Surveys, v. 5, p. 329, pl. 8, fig. 77 [external mold of a right valve].

?1855. *Pecten catelliformis* Conrad, ibid., p. 329, pl. 9, fig. 83 [indeterminate: internal shell of a large pectinid, probably a *Vertipecten*].

1906. *Pecten nevadanus* Conrad. Arnold, U.S. Geological Survey Professional Paper 47, p. 141.

?1918. *Pecten (Lyropecten) gabbi* Clark, University of California Publications Bulletin of the Department of Geology, v. 11, no. 2, p. 131-132, pl. 15, figs. 1, 2 (a homonym, *fide* Keen and Bentson, 1944, p. 84).

?1924. *Pecten diabloensis* Clark, *in* Hanna, California Academy of Sciences Proceedings, ser. 4, v. 13, p. 176 (new name for *Pecten gabbi* Clark, preoccupied).

1925a. *Pecten (Patinopecten) kernensis* Hertlein, Southern California Academy of Sciences Bulletin, v. 24, pt. 2, p. 40-41, pl. 4, fig. 3.

Not 1931. *Pecten (Vertipecten) nevadanus* Conrad. Grant and Gale, San Diego Society of Natural History Memoir, v. 1, p. 189-190, pl. 7, figs. 2a, 2b, 2c [= *V. bowersi* Arnold].

Not 1972. *Vertipecten nevadanus* (Conrad). Addicott, Provincial stages, Temblor Range, Pacific Coast Miocene Biostratigraphic Symposium, Proceedings, p. 9, 10, pl. 2, fig. 9 [= *V. bowersi*].

1974. *Vertipecten perrini* (Arnold). Addicott, Journal of Paleontology, v. 48, no. 1, p. 184, pl. 1, figs. 3, 4.

Holotype.—LSJU 128, a right valve 9.3 cm high, 9.3 cm long. An excellent specimen showing diagnostic characters of both valves is hypotype USNM 647085 (pl. 2, fig. 7, pl. 36. fig. 4).

Type locality.—Pyramid Hill, Kern County, northeast of Bakersfield, Calif., (LSJU loc. 150). Rio Bravo Ranch 7½-minute quadrangle, sec. 14, T. 28 S., R. 29 E. Rocks mapped as the "Freeman Silt-Jewett Sand, undifferentiated" unit (Bartow and Doukas, 1976). Miocene.

Taxonomic comment.—*Vertipecten kernensis* (Hertlein) is the oldest valid name for the taxon known as *V. nevadanus* Conrad of authors. For 75 years it was assumed that the external mold described by Conrad as *Pecten nevadanus* from Ocoya (now Poso) Creek was the same as the well-preserved form occurring in abundance in basal ledges at Pyramid Hill several miles to the southeast. Subsequent stratigraphic and systematic studies distinguished an older *Vertipecten* in the undivided Freeman Silt and Jewett Sand unit at Pyramid Hill and two younger species, *V. fucanus* and *V. bowersi*, in the overlying Olcese Sand that crops out to the north of Poso Creek. Conrad's name probably referred to one of the younger

species (see discussion under *V. bowersi*) and the next available name for *V. nevadanus* auctt. is *V. kernensis* (Hertlein).

Pecten gabbi Clark, 1918 (a homonym renamed *P. diabloensis* Clark by Hanna, 1924) from the Diablo Range of northern California, is probably the same species. It is known from a few poorly preserved specimens that lack the detailed locality and biostratigraphic data of *V. kernensis.*

Description.—Right valves flat to slightly convex, left valves convex. Height and length nearly equal. Auricles equal, radially ribbed; byssal notch deep. Hinge line greater than half shell length. Umbonal angle 98-108°, varying with convexity. Right valves with 21-23 narrow, rounded ribs, some furrowed and some incipient. Left valves with 17-19 narrower, higher ribs that vary in width, prominence, and spacing. One to three ribs may be more prominent imbricated key ribs, as in *V. fucanus*. Fine flanges commonly preserved on anterior- and posterior-most ribs, auricles and interspace riblets. Left valves generally scalier than right valves, interspaces having 2-4 scaly riblets that complicate accurate rib counts. Adults range as much as 15.4 cm high, 15.8 cm long, 7.5 cm hinge length (LACMIP loc. 462), and one slightly deformed individual measured 18 cm high, 15 cm long (USGS loc. M2826, from the La Panza Range).

Variability.—Rib profiles are higher, more rectangular in juveniles, lower in adults. State of preservation affects microsculpture, especially the shagreen pattern in interspaces. There is some evidence that stratigraphically higher specimens (for example, hypotype UCMP 36554) have two prominent key ribs on left valves and a slightly lower rib count (17-18) than in stratigraphically lower specimens (for example, hypotype USNM 647085, left valve 19-20).

Comparative morphology.—Stratigraphic successions of Vertipectens trace the gradual evolution of *V. perrini* to *V. kernensis*, intermediate forms being referable to either species. Right valves are hard to distinguish but left valve proportions, rib counts, and fine macrosculpture separate end members of the series. Morphologic differences and evolutionary trends in California Vertipectens are summarized in table 5.

Phylogenetic affinities.—*Vertipecten kernensis* is intermediate in morphologic characters and stratigraphic occurrence between *V. perrini* and *V. bowersi*. It is probably the immediate ancestor of *V. fucanus*. Morphologically similar late Eocene or early Oligocene species from the Pacific Northwest include *V. popofensis* MacNeil, 1967 from an unnamed formation equivalent to the *Acila shumardi* zone in the Shumagin Islands (USGS 3563, 5037) and Chichagof Bay (USGS 3373), and from the Tokun Formation in the Katalla district, Alaska (USGS 4323). *Vertipecten porterensis* (Weaver) from the Lincoln Formation of Weaver (1912) (= Lincoln Creek Formation) (Moore, 1976) and *V. columbianum* (Clark and Arnold) from the Sooke Formation, Vancouver Island, may also be closely related.

Geographic and stratigraphic distribution.—Northern California, from the Diablo Range and the Santa Lucia Mountains, including the type locality of the Vaqueros Formation; Pyramid Hill area, Kern County; San Emigdio Range, southern San Joaquin Valley; Santa Ana Mountains, Orange County. Morphologic links between *V. perrini* and *V. kernensis* are found in the Santa Lucia Range.

Representative occurrences.—San Lorenzo Series of Clark (1918), Mount Diablo Range, type specimens of *Pecten gabbi* Clark (UCMP loc. 1311).

Vaqueros Formation, Junipero Serra 15-minute quadrangle, southern Coast Ranges. Los Vaqueros Valley and east of Vaqueros Creek, type section, members E, F of Thorup (1943): LSJU 2412; LSJU 2411, specimens tectonically deformed, misidentified on old labels as *Pecten perrini*; CAS 31524. Adelaida 15-minute quadrangle, southern Santa Lucia Mountains; the *Lepidocyclina* (*L.*) *californica* locality of Schenck and Childs (1942). Vertipectens from here (LSJU 1155) are intermediate between *V. kernensis* and *V. perrini.*

Agua Sandstone Bed, Santos Shale Member, Temblor Formation, Temblor Range: LSJU 2862, USGS M2631. Poorly preserved fragments of a form transitional between *V. perrini* and *V. kernensis* are found with "*Macrochlamis*" *magnolia ojaiensis.*

Painted Rock Sandstone Member, Vaqueros Formation, La Panza Range: M2826, in lower of two *Crepidula* biostromes.

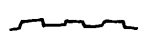
Monterey Formation, near base of the Saltos Shale Member, northwest Caliente Range; Chimineas Ranch 7½-minute quadrangle, from *Crepidula-Antigona* bed (M3781).

Vaqueros Formation, Santa Susana Mountains (LSJU accession no. 22358, from Oak Ridge, east of Grimes Canyon, Ventura County). Vaqueros Formation, Painted Rock Sandstone Member, Sierra Madre Range, (Fritsche, 1969). Fox Mountain quadrangle, near head of Olive Canyon; specimens tectonically distorted (UCLA 5539) and abundant (UCLA 5545).

Undivided Freeman Silt and Jewett Sand, Pyramid Hill area, Kern County. Rio Bravo Ranch, Knob Hill, and Pine Mountain 7½-minute quadrangles. At Pyramid Hill, basal part of the Jewett Sand (M1591), friable sandstone with concretions, including "grit zone" of Addicott (1970b). The species was abundant in ledges along the southwest flank of Pyramid Hill (secs. 14, 15, T. 28 S., R. 29 E.), but by the mid-1970's localities were essentially quarried out by avid collectors. LACMIP 462, large lots of articulated specimens representing juveniles to adults; M5211, lowest stratigraphic occurrence, in the Pyramid

TABLE 5.—*Evolutionary trends in California Vertipectens*

[See also plates 32 and 33; ht, height; lth, length; RV, right valve; LV, left valve]

Morphologic character	*V. yneziana*	*V. alexclarki*	*V. perrini*	*V. kernensis*	*V. fucanus*	*V. bowersi*
Valves						
Proportions	ht=lth	ht=lth	ht=lth or lth>ht	lth=ht	lth=ht	ht>lth
Profiles	equally convex	RV flat, LV convex	RV flat, LV convex	RV planoconvex, LV convex	RV planoconcave-planoconvex, LV convex	RV planoconvex, LV strongly convex
Ribs						
Number (count is complicated by macrosculpture)	RV 30-40, LV 24+	Variable, 20-34	RV 28, LV 22+	RV 21-23 LV 17-19	RV 16-17 LV 15-16	RV 15-16 LV 14-15
Coarseness	Fine	Very fine	Fine	Moderate	Moderate	Coarse
Differentiation (all one width or 2 or 3 widths)	1-2	2-3	2-3, irregularly spaced	2-3, irregularly spaced	1-2; one scaly key rib on LV	2-3; LV with 1-3 key ribs
Tendency to bifurcate (RV)	Commonly split	Commonly split	Commonly split	Commonly split	Few if any ribs split	Ribs not split
Profiles	Low, rounded	Narrowly rectangular	Rectangular	Rectangular, flanged	Low, rectangular	High, smooth, rectangular
LV rib profiles						
Interspaces						
Macrosculpture	1 radial riblet	Radial riblet	1-3 scaly riblets per space	1-2 riblets, commonly scaly	0-1 fine radial riblets	1 radial riblet
Shell surface	Scaly	Fine, scaly	Coarse flanges	Scales on lateral ribs	Smooth or shagreen microsculpture	Concentric growth lines
Maximum adult height	9.7 cm	11.5 cm	19.7+ cm	15.4 cm	12-13 cm	20+ cm
Megafaunal Stage	Upper "Tejon" Stage of Weaver and others (1944) to unnamed stage of Addicott (1973)	Unnamed (Addicott, 1973)	Lower "Vaqueros"	Middle "Vaqueros"	Upper "Vaqueros" of California; Pillarian of the Pacific Northwest	Upper "Vaqueros"

Hill Sand Member of the Jewett Sand. In basal part of the Jewett Sand at CAS 69; M1590, M1591; UCMP B-1662, UCR 1149, all large lots from the southwest side of Pyramid Hill. LSJU accession no. 2945 from "top of Pyramid Hill Sand."

Hypotype UCMP 36554 (pl. 33, figs. 1,5) is an evolutionarily advanced form from UCMP B-1673, about 40 ft above base of the Jewett Sand (Addicott, 1965). UCMP B-1656, from Knob Hill 7½-minute quadrangle, is near the top of a lower sandy facies of the undivided Freeman Silt and Jewett Sand unit, 230-240 ft stratigraphically above its base (Addicott, 1965). An *Ostrea-Pecten* biostrome in concretionary silty sandstone has evolutionarily advanced forms with fewer ribs and a better developed left-valve key rib. Fossils are very scarce in this area, leached and poorly preserved.

Vaqueros Formation, upper member, from upper Sespe Creek (CSUN 263); *V. kernensis* occurs with *"Macrochlamis" magnolia ojaiensis* at its highest stratigraphic position.

San Lorenzo Formation, Mount Diablo Range (UCMP 1311), type locality of *Pecten (Lyropecten) gabbi* Clark, 1918.

Pleito Formation, San Emigdio Mountains, southern San Joaquin Valley, USGS 4448; M3750, from *Balanus-Vertipecten* reef in Pleito Hills quadrangle, 150 ft stratigraphically below base of basalt; USGS loc. M3751.

Vaqueros Formation, Santa Ana Mountains, Orange County: AMNH collection, material from E.W. Warth, good specimens with no further locality data; LACMIP 1373, Santa Ana Canyon, "Topanga Formation" of label.

Geologic age.—Late Oligocene to early early Miocene.

Biostratigraphic data.—Index species of the middle "Vaqueros" Stage. Found with *"Macrochlamis" magnolia ojaiensis*, n. subsp., in the Upper Sespe Creek area and near Pyramid Hill, Kern County, Calif.

Vertipecten perrini (Arnold, 1906)

Plate 32, figure 2; plate 37, figures 1, 5, 6

1906. *Pecten (Lyropecten) perrini* Arnold, U.S. Geological Survey Professional Paper 47, p. 80-81, pl. 14, figs. 1, 1a; pl. 15, fig. 1.
1931. *Pecten (Vertipecten) nevadanus* Conrad var. *perrini* Arnold. Grant and Gale, San Diego Society of Natural History Memoir, v. 1, p. 190.
1932. *Pecten (Lyropecten) perrini* Arnold. Loel and Corey, University of California Publications, Department of Geological Sciences Bulletin, v. 22, no. 3, p. 201, pl. 23, fig. 1; pl. 24, fig. 1.
1942. *Lyropecten bowersi* (Arnold). Schenck and Childs, Stanford University Publications in the Geological Sciences, v. 3, no. 2, p. 28.
1963. *Pecten (Chlamys) sespeensis* Arnold. Weaver and Kleinpell, University of California Publications in the Geological Sciences, v. 43, p. 197-198 (in part).

Holotype.—LSJU 13, two-valved adult specimen, 15.0 cm high, 16.0 cm long (restored) left valve deformed.

Type locality.—Southern Santa Lucia Mountains, San Luis Obispo County, Calif. North of Morro Bay, "***between Morro and Toro Creeks." Associated with *Pecten* [= *"Macrochlamis"*] *magnolia*. Early Miocene.

The type area was not rediscovered until Hall and Prior (1975) mapped the Cayucos 15-minute quadrangle and worked out the regional stratigraphy. They considered the type locality to be in the Morro Bay North 7½-minute quadrangle at the knob just south of hill 1017 in sec. 4, T. 29 S., R. 11 E. (UCLA loc. 6204), in a lithic sandstone facies of the Vaqueros Formation; here the formation is 20-40 ft thick and older than at its type locality in Los Vaqueros Valley to the north. Lower "Vaqueros" Stage.

Arnold named the species in honor of James Perrin Smith, Professor of Paleontology at Stanford University from 1892-1931, mentor and well-loved teacher of several generations of students.

Description.—Right-valve flat, left-valve convex; length exceeds height. Left-valve beak projects slightly beyond hinge line. Auricles subequal, with flanged radial riblets. Byssal notch deep. Umbonal angle wide, 92-103°, varying with shell convexity. Ribs numerous, commonly bifurcated, and variable in widths and spacing. Right valves with about 28 ribs and riblets of at least three widths. Left valves with 22-23 coarsely imbricated ribs, interspaces with 1-3 scaly riblets. Juvenile shells commonly worn, ribs and riblets undifferentiated. Relatively few articulated specimens are present in collections; the best preserved specimen is the holotype. The largest specimen seen was incomplete; it is 19.7 cm high, 21.3 cm long (USGS loc. M4200, west of Paso Robles).

Variability.—Too few specimens are available to evaluate variability, either between individuals or growth stages. Arnold (1906) noted considerable variation in "over 50 specimens examined," but this is more than twice the number of specimens I found in all the museum collections combined. Most specimens are very worn and incomplete. One specimen from the northern La Panza Range has unusually fine ribbing (USGS loc. M4737).

Comparative notes.—Evolutionary trends of the California Vertipectens, two of which are closely related to *V. perrini* in a continuous phylogenetic progression, are shown in table 5. Transitional forms between *V. yneziana* and *V. perrini* and between *V. perrini* and *V. kernensis* (= *V. nevadanus* auctt.) cannot be separated from either end member. *Vertipecten perrini* is the first *Vertipecten* to attain a very large adult size, and to have a flat right valve and convex left valve typical of the genus.

Vertipecten perrini commonly occurs with another giant pectinid, *"Macrochlamis" magnolia, s.s.*, from which it differs in having a smooth hinge, valves unequal in profile, and more numerous, imbricated, rectangular ribs.

Phylogenetic affinities.—*Vertipecten perrini* is a member of a well-documented phylogenetic series; it evolved by the middle Oligocene from *V. yneziana* and gave rise in the late Oligocene to *V. kernensis* (= *V. nevadanus* auctt.) (pl. 32).

Vertipecten perrini is similar to the Pacific Northwest species *Vertipecten lachenbruchi* MacNeil, 1967 from the upper *Acila shumardi* zone of the Alaskan Peninsula (M1025) and the Shumagin Islands (USGS 5037). *Vertipecten perrini* from the La Panza Range (M4737) is perhaps closest in morphology to Alaskan specimens of *V. lachenbruchi*.

Geographic distribution and stratigraphic occurrences.—Central and southern California, from the Santa Lucia and La Panza Ranges, central Temblor Range, San Emigdio Mountains, and Transverse Ranges.

Representative occurrences:

Vaqueros Formation, Junipero Serra Peak quadrangle. "The Indians," (LSJU accession no. 1758), 7 mi southwest of the type locality of the Vaqueros Formation in sec. 16, T. 21 S., S. 5 E. *Vertipecten perrini* from here has the proportions, profiles, and ribbing of the holotype, LSJU-13, but specimens are poorly preserved; they are external molds lacking outer shell material. The Vaqueros Formation here is older than at the type locality. Addicott re-collected the locality (M6494) in 1975 and regarded the associated fossils as the same as those in the Wygal Sandstone Member of the Temblor Formation in the Temblor Range. They represent the unnamed stage of Addicott (1972), older than lower "Vaqueros" Stage.

Vaqueros Formation, Santa Lucia Range, Adelaida 15-minute quadrangle. The "*Lepidocyclina* locality" of Schenck and Childs, 1942 (LSJU loc. 1155, specimen linking *V. perrini* and *V. kernensis*). Specimens collected singly in the 1890's from ranches west and southwest of Paso Robles. They lack detailed locality and stratigraphic data (for example, Gillis Ranch, LSJU accession no. 47629; G.W. Michaels Ranch, AMNH 11730; Lenton Ranch, between Morro and Old Creeks, CAS accession no. 9365).

On modern geologic maps these localities are in lower beds of the Vaqueros Formation.

Vaqueros Formation, Cypress Mountain 7½-minute quadrangle. *V. perrini* is common in rocks north of Santa Rosa Creek along the old highway between Cambria and Paso Robles. Near Oceanie Mine (Hall, oral commun., 1973); UCLA 6069 and 6070; San Simeon 15-minute quadrangle (LSJU accession no. 30261, between Carroll and McLoughlin Canyons).

Vaqueros Formation, Morro Bay North 7½-minute quadrangle (Prior, 1974). Type locality of *V. perrini*, between Morro and Toro Creek (UCLA 6204) and in canyons to the north (abundant at UCLA 6205, 6206). It is present in a lithic and calcareous sandstone facies about 5 m above the base of the formation in this area. Outcrops are discontinuous; they contain numerous specimens of *V. perrini* and "*Macrochlamis*" *magnolia*, *s.s.*

Between San Bernardo Creek and Little Morro Creek in sec. 14, T. 29 S., R. 11 E. (UCLA 6191, 6192). Specimens of *V. perrini* are worn but are similar to *V. kernensis* in rib sizes and spacing. The Vaqueros Formation may be slightly younger than at UCLA 6204, but the upper age limit is unknown because all of the Saucesian and part of the Zemorrian benthic foraminiferal stages are missing (Prior, 1974).

Alegria Formation (Dibblee, 1950), Transverse Ranges. Transitional forms between *V. perrini* and *V. yneziana*: at UCMP B-7015, LSJU acc. no. 53256 (Hawley loc. 93, west-southwest of Las Cruces); also in Gaviota Canyon and Canada del Agua Caliente [Hawley label says "*Turritella variata* zone"]; LSJU accession no. 53251 (Hawley loc. 76, west of Cuarta Canyon), and UCSB 1561, Cañada de Santa Anita.

Middle part of the Gaviota Formation, Transverse Ranges. (Dibblee, 1950): LSJU specimen, Hawley loc. 68; poorly preserved transitional form between *V. perrini* and *V. yneziana*; UCMP A-4646, uppermost part of middle member of the Gaviota Formation, the *Vertipecten* is *V. perrini* with some features of *V. yneziana*. The foraminifers from here belong to the Refugian Stage, tropical to subtropical, neritic to upper bathyal taxa (Wilson, 1954).

San Emigdio Region, Grapevine 7½-minute quadrangle (USGS 13080, 13084; localities 0.5-2 mi up Salt Creek from its mouth; west side of creek, in sandstone immediately below a basalt. Specimens collected in 1912 by R.G. Davies from strata referred to the Temblor Formation by Nilsen and others (1973) and placed near the Saucesian-Zemorrian boundary. *Vertipecten perrini* from here is similar to the La Panza specimens (M4737) and is indicative of the lower "Vaqueros" Stage.

Geologic age.—Middle Oligocene to late Oligocene.

Biostratigraphic data.—Unnamed stage to lower "Vaqueros" Stage. It is found at many localities with "*Macrochlamis*" *magnolia s.s.*, another lower "Vaqueros" Stage index fossil. Transitional forms between *V. yneziana* or *V. alexclarki* and *V. perrini* are from the unnamed megafaunal stage of Addicott (1972).

***Vertipecten yneziana* (Arnold, 1907)**

Plate 32, figure 1; plate 38, figures 6-8

1907. *Pecten (Chlamys?) yneziana* Arnold, Smithsonian Miscellaneous Collections, v. 50, pt. 4, p. 426-427, pl. 50, fig. 4; pl. 51, figs. 6a, 6b.

1907. *Pecten (Chlamys?) yneziana* Arnold. Arnold and Anderson, U.S. Geological Survey Bulletin 322, pl. 12, fig. 4; pl. 13, figs. 6a, 6b.

1931. *Pecten (Vertipecten) yneziana* Arnold. Grant and Gale, San Diego Society of Natural History Memoir, v. 1, p. 191.

1954. *Pecten (Chlamys)* cf. *P. (C.) sespeensis* Arnold. Wilson, University of California Publications, Department of Geological Sciences Bulletin, v. 30, no. 2, p. 147, pl. 18, figs. 1, 2.
1963. *Pecten (Vertipecten) yneziana yneziana*. Weaver and Kleinpell, University of California Publications in Geological Sciences, v. 43, p. 198, pl. 30, figs. 6, 7; pl. 31, figs. 1, 4.
1963. *Pecten (Chlamys) sespeensis* Arnold. Weaver and Kleinpell, ibid., p. 197-198, pl. 29, fig. 10; pl. 30, fig. 1.
?1963. *Pecten (Vertipecten) yneziana subyneziana* Weaver and Kleinpell. Weaver and Kleinpell, ibid., p. 198 (in part); pl. 31, figs. 3, 5, 7 (internal molds); not pl. 31, fig. 2.

Holotype.—USNM 165313, an incomplete right valve 6.4 cm high (Arnold, 1907, gave restored height as 7.5 cm).

Paratypes.—USNM 165313, an incomplete right valve with auricles, byssal area, 5 cm high (incomplete), hinge line 2.5 cm. USNM 165313, juvenile left-valve fragment, 5.2 cm high.

West Coast plastotypes: UCMP 33448, 33449.

Type locality.—Santa Ynez Mountains, Santa Barbara County, Calif.; Lompoc 15-minute quadrangle, San Julian Ranch, 10 mi southeast of Lompoc (USGS loc. 4507). Wilson (1954) elaborated, "Locality 4507 is just above the San Julian Ranch House about 1 mi southeast of B.M. 603 [not shown on recent maps, but it is on El Jaro Creek about 0.5 mi southeast of mouth of Ytias Creek]." Arnold (1907) called it the Tejon Formation, Eocene in age, but later maps show it as the Gaviota Formation, late Eocene in age (Dibblee, 1950, pl. 1).

Significant hypotypes.—LSJU 9262, two-valved specimen collected by Weaver and Kleinpell (pl. 32, fig. 1). 9.7 cm high, 9.8 cm long; LSJU 9263, right-valve fragment showing complete anterior auricle and byssal area (pl. 38, fig. 6).

Description.—Valves equally, slightly convex; outlines nearly circular, although adult shells commonly flare anteriorly and posteriorly. Auricles subequal, anterior auricle with three or more radial costae; byssal notch deep. Hinge line shorter than half shell length. Left-valve umbo more convex than right valve; umbonal angle 94-100° in right valves, 88° in left valves. Right valves with 30-40 low rounded ribs that tend to bifurcate in later growth stages. Rib counts complicated by interspace riblets that approach ribs in width and prominence. Widest ribs in center of shell; narrower and scalier ribs near anterior and posterior margins. Left valves with 24-25 or more ribs of equal prominence. The largest individual seen was incomplete, and it measured 9.7 cm high, 9.8 cm long (LSJU 9262).

Comparative morphology.—Adults are smaller, fewer ribbed than those of *V. perrini*. Umbonal angle smaller than in *V. perrini*, greater than in *V. alexclarki*. The types of *Pecten (Vertipecten) yneziana subyneziana* Weaver and Kleinpell (1963) are internal molds of small right valves having 20 or more ribs, but they are not well enough preserved to identify with certainty (pl. 38, fig. 5).

Phylogenetic affinities.—This species, oldest of the California Vertipectens, grades into *V. alexclarki* by the late early Oligocene and into *V. perrini* by the early late Oligocene. The first link is not well documented, because specimens are rare, but the progression of *V. yneziana* to *V. perrini* in the western Transverse Ranges is recorded by a number of transitional forms from intermediate strata.

The internal molds serving as types of *Pecten yneziana subyneziana* are from the undivided Sacate and Gaviota Formations (UCMP B-6963) or "Coldwater" sandstone of Weaver and Kleinpell (UCMP B-6940). These and other small Paleogene *Chlamys*, such as those referred by authors to *Chlamys sespeensis* (Arnold), are possibly ancestral to *V. yneziana* but they were not considered in this study.

Geographic distribution and stratigraphic occurrences.—Western Transverse Ranges, especially Lompoc and Los Olivos 15-minute quadrangles, Santa Ynez Mountains, southern California. Arnold (1907) reported it as far east as Ojai Valley, but this could not be verified from specimens. Santa Ynez Mountains, in canyons cut by south-flowing streams east and west of Gaviota Canyon.

Gaviota Formation, middle member (common in friable sandstones near the contact between middle and upper members of the Gaviota Formation, according to Wilson, 1954). Undivided Sacate and Gaviota Formations, (UCMP B-6955); Stanford Summer Geology, 1948; collections by H.J. Hawley; UCMP B-7033. Gaviota Formation, upper part, transitional forms between *V. yneziana* and *V. perrini* (UCMP B-7015, juvenile; UCMP A-4646).

Geologic age.—Late Eocene to early Oligocene.

Biostratigraphic data.—Equivalent to the Refugian Stage. *Vertipecten yneziana* is neither as abundant nor as widely dispersed as the other *Vertipecten* index species.

Nodipecten Dall, 1898

Type species.—(original designation): *Ostrea nodosa* Linnaeus, 1758 [here taken to be the southern Caribbean form *N. nodosus* exemplified by specimens from Margarita Island, Venezuela, pl. 8, fig. 4; pl. 9, fig. 2].

Diagnosis.—Valve outline circular in most species; profiles equally convex, moderately flat to moderately convex, commonly with angular ledges. Radial ribs and interspaces costate and lirate. Right-valve interspaces correspond to left-valve ribs of alternating widths; left-valve ribs commonly nodose, as expressed by the scheme N r N_c r N. Auricles subequal to equal, costate and lirate. Hinge length about half shell length in most species. Byssal notch deep, ctenolium prominent. Three pairs of hinge teeth in right valve, two pairs in left valve. Hollow nodes more prominent on wider key ribs of left valves, present in right valves of some species, and commonly flanged in western Atlantic taxa.

Nodipecten is similar to the Holocene representative of *Lyropecten*, *L. magnificus*, from the Galapagos Islands. Both have costate, lirate ribs and interspaces, a deep byssal notch, and the same hinge teeth. They differ in arrangement of left-valve nodose ribs: *Nodipecten* is characterized by the scheme N r N_c r N and *Lyropecten* by N 2r N_c 2r N. These schemes can be traced through separate, distinct ancestral lineages despite the convergence of Holocene forms. *Lyropecten magnificus* has more rectangular auricles than *Nodipecten*, and as far as is known, no tendency toward ledging.

One taxon, *N. arthriticus* (Reeve) [= *N. subnodosus*, *s.s.* auctt.], is referred here to *Nodipecten* although its rib scheme differs from the others. Holocene left valves look most like those of *N. subnodosus* [= *N. intermedius* of Conrad (1867)] except for the rib scheme of N 2r N_c r N. It is classified as a *Nodipecten* although it evolved by the late Miocene, possibly by a genetic mutation from a Pacific Panamic *Lyropecten*.

Nodipecten arnoldi
(Aguerrevere, 1925)

Plate 11, figures 3, 4; plate 13, figures 2, 3

1886. *"Pecten gigas"* Karsten, Geologie de l'ancienne Colombie bolivarienne, Venezuela, Nouvelle Grenade et Ecuador, p. 9 [a *nomen nudum*, *fide* Weisbord, 1964, p. 161, for specimen from Cabo Blanco, Venezuela].

1925. *Pecten* (*Lyropecten*) *arnoldi* Aguerrevere, Southern California Academy of Sciences Bulletin, v. 24, pt. 2, p. 51-53, pl. 5.

1937. *Pecten* cf. *pittieri* Dall. Trechmann, Geological Magazine, v. 74, no. 878, p. 352-353, pl. 12, fig. 23.

1964. *Lyropecten* (*Nodipecten*) *arnoldi* (Aguerrevere). Weisbord, Bulletins of American Palentology, v. 45, no. 204, p. 159, pl. 18, fig. 1; pl. 19, fig. 1.

1964. *Lyropecten* (*Nodipecten*) species "a" Weisbord, *ibid.*, p. 162, pl. 17, figs. 2, 3 [fragment].

Holotype.—LSJU 364, a large two-valved adult measuring 21 cm high, 21.8 cm long.

Type locality.—State of Sucre, Venezuela, Araya Peninsula, 1.75 mi east of the Castle of Cumana. Named in honor of Ralph Arnold for his extensive work with Pectens. Aguerrevere (1925) considered it "probably Miocene;" Weisbord (1964) referred the unit to the Playa Grande Formation, Catia Member, "***tentatively, Pliocene in age." One lot of specimens labelled "topotypes" comes from "the Cumana beds" (USGS 18408). Cumana Formation, upper Pliocene (Hunter, 1978).

Description.—Valves equally convex, height equals length; beaks project slightly, equally beyond hinge line. Auricles large, with heavy growth lines; anterior auricle with strong radial costae. Byssal notch moderately deep. Hinge line straight, about half shell length. Umbonal angle 95-110°, varying with shell convexity. Right valves have 9-10 evenly spaced, flat-topped rectangular ribs. Left valves with 8-9 ribs; juveniles to young adults 10 cm high have nodes on alternate ribs in a pattern described as N r N_c r N. Nodes may be incipient or prominent and flanged; none develop in gerontic growth stages. Fine macrosculpture coarse in juveniles to young adults, obsolete in large individuals that have prominent undulating growth lines (pl. 11, fig. 3; pl. 13, fig. 2). Right-valve ribs have 4-5 fine costae, interspaces with 1-3 midriblets; the central interspaces have fewer radials than later interspaces have.

Variability.—Rib profiles are high and rounded in juveniles, low and rectangular in adults. Ribs and fine macrosculpture become obsolete in gerontic individuals. Juveniles may have one more rib than adults. Left valves have alternating key ribs, and four or more generations of nodes, but some specimens (for example, the holotype) do not.

Comparative notes.—Nodipecten arnoldi is common in Neogene marine collections from the Venezuelan Coast Ranges. Its occurrence in the field with *Lyropecten colinensis*, *s.s.* and *Nodipecten collierensis* has not been documented by careful biostratigraphic work, so the three species have been confused in museum collections. *Lyropecten colinensis s.s.* has more ribs, 11-13, and a lyropectinid left-valve node scheme of N 2r N_c 2r N, but its fine macrosculpture and flanged nodes are similar to those of *N. arnoldi*.

Nodipecten collierensis, *N. pittieri*, and *N. arnoldi* have the same number of ribs, 9-10, and overlapping morphologic characters. They differ in rib profiles and fine sculpture. The profile of *Nodipecten pittieri* is flatter than in the other two species, its dimensions longer than high; *N. collierensis* and *N. arnoldi* are equally convex and have a lower umbonal angle than *N. pittieri*.

Phylogenetic affinities.—Nodipecten arnoldi belongs in the *N. nodosus* stock with other species having a left-valve node scheme of N r N_c r N. It is closest to *N. collierensis* and may be a gigantic-size, tropical, lagoonal descendant of it. Juvenile valves of the two are hard to distinguish.

Geographic distribution and stratigraphic occurrence.—Venezuelan Coast Ranges, Sucre and Distrito Federal; Cubagua, Margarita and Tortuga Islands; Barbados, B.W. Indies; Caribbean coast of Colombia between Cartagena and Puerto Colombia.

Sucre, Cumana beds near Castle of Cumana (USGS 6295; 18408); Cabo Blanco area, Distrito Federal (USGS 18246-18247; LSJU accession no. 53241), yellowish-brown marl, about 30 ft thick. Late Pliocene (Hunter, 1978). Araya Peninsula (UCMP S-115; S-116, USGS 24704). Yellow limy sand 2 m thick, called by some the Barrigon Formation (invalid name, J. Gibson-Smith, written commun., 1981), is the Cumana Formation. The contact between the Cumana beds and underlying middle Pliocene Cubagua Formation is marked by abundant *N. arnoldi*.

Offshore islands, Pleistocene terrace deposits: *N.*

arnoldi is present in lower Pleistocene beds on the following: Cubagua Island, lower Pleistocene (Vignali, 1972), and Margarita Island, from terrace deposits at Macanao and Loma de Parate Bueno. *Nodipecten arnoldi* is abundant on the oldest or 30 m terrace, which is early Pleistocene N zone 22 (Graf, 1972); it is present but possibly reworked on the 18-21 m and 10-12 m terraces. Tortuga Island, Tortuga Formation, upper Pleistocene (AMNH 765; Graf, 1972). Specimens possibly reworked.

Cabo Blanco area, D.F., 15 km northwest of Caracas and north of the Bruscas fault. Playa Grande Formation, Catia Member (UCMP S-141) and Lower Mare Member (Weisbord, 1957, 1964, localities W 13, abundant at W 15, W 21). The Mare Formation, which is considered late Pliocene in age, is older than the Playa Grande Formation according to J.G. Gibson-Smith and W. Gibson-Smith (1979).

Barbados, British West Indies, Coral Rock Formation Pliocene-Holocene (2d Latinamerican Geological Congress, Caracas, 1975, guidebook); USGS 18372, "***from the deeper or basal strata of the high level limestone road cut near the Police Station, St. Thomas. Alt. approx. 500 ft." Trechmann (1937) noted a fragment of *N. arnoldi* from "***near the base of the old coral-sand rock in the Consett railroad cutting" and believed the basal coral-rock faunule had Miocene or Pliocene affinities.

Northern Colombia, Popa Formation. 4,000-m-thick reefal limestone and basal mudstone containing *Globorotalia truncatulinoides*, Pleistocene age, N zone 22 (Hermann Duque-Caro, written commun., 1979): UCMP S-69, 3 mi north of Cartagena, at Cerros Moritos, from coral limestone matrix collected by T.J. Etherington, who considered the rocks Pliocene. Some specimens may come from Miocene and Pliocene marine turbidites (Hermann Duque-Caro, 1978). Also from 800 m southwest of Puerto Colombia in limestone marls (UCMP S-8064).

Geologic age.—Late Pliocene to early Pleistocene. J. Gibson-Smith (1981) considers its oldest record as late Pliocene.

Paleoecology.—The occurrence of gigantic specimens of *N. arnoldi* in Pliocene and lower Pleistocene neritic deposits in coastal Colombia and Venezuela suggests that environmental conditions were optimal at that time. The largest modern Nodipectens live in lagoons along western Baja California Sur where specimens attain twice the size of normal adults in the Gulf of California. Weisbord (1957) described a similar environment in the Cabo Blanco area where sediments were deposited in an east-west trough north of the Coast Ranges "***and separated from the sea by a barrier on the north." From Miocene and Pliocene to Holocene time, marine and nonmarine sediments filled the trough, regression beginning in the late Pliocene (Graf, 1972). Repeated Quaternary uplifts are represented by at least four terraces on which *N. arnoldi* is found.

Nodipecten arthriticus
(Reeve, 1853)

[= *N. subnodosus* (Sowerby) auctt., in part]

Plate 2, figure 5; plate 4, figures 1, 5-7; plate 5, figure 1; plate 6, figures 1, 3-7

1835. *Pecten subnodosus* Sowerby, Zoological Society of London, Proceedings, v. 3 for 1835, p. 109, in part (not Variety α).
1852. *Pecten subnodosus* Sowerby. Reeve, Conchologica Iconica, v. 8, pl. 4, fig. 20.
1853. *Pecten arthriticus* Reeve, Conchologica Iconica, v. 8, pl. 28, fig. 119.
1898. *Pecten (Nodipecten) subnodosus* Sowerby. Dall, Wagner Free Institute of Science of Philadelphia, Transactions, v. 3, pt. 4, p. 710.
Not 1926. *Pecten subnodosus* Sowerby. Hanna, California Academy of Sciences, Proceedings, ser. 4, v. 14, no. 18, p. 474, pl. 25, fig. 6 [= *Lyropecten tiburonensis*, n. sp. from the Salton Trough; refigured in Mansfield, 932a, U.S. Geological Survey Professional Paper 170-D, pl. 16, fig. 1].
1931. *Pecten (Lyropecten) nodosus* (Linnaeus) var. *subnodosus* Sowerby. Grant and Gale, San Diego Society of Natural History Memoir, v. 1, p. 180.
1959. *Nodipecten subnodosus* (Sowerby). Grau, Allan Hancock Pacific Expeditions, v. 23, p. 128, 132 (in part).
1961. *Lyropecten (Nodipecten) subnodosus* (Sowerby). Olsson, Mollusks of the tropical eastern Pacific, p. 161, pl. 20, figs. 1-1b; pl. 21, figs. 5, 5*a*.
1982. *Nodipecten subnodosus* (Sowerby). Smith and Zinsmeister, Geological Society of America Abstracts with Programs, v. 14, no. 4, p. 235.
1984b. *Nodipecten subnodosus subnodosus* (Sowerby). Moore, U.S. Geological Survey Professional Paper 1228-B, p. B57-B58, pl. 6, figs. 4, 8.

Holotype.—BM(NH) 1950.11.14.10. Type by monotypy, specimen identified and photographed by Thomas R. Waller (written commun., 1983). The original illustration does not show the left-valve rib scheme as clearly as the photograph (pl. 4, figs. 1, 5). The holotype is a late juvenile with two valves measuring 2.4 cm high, 2.4 cm long.

Type locality.—No locality given. Holotype is a Pacific-Panamic form common from the Tres Marias Islands, Mexico to Peru.

Significant hypotype.—SDSNH 78669, a two-valved specimen 8.5 cm high, 9.1 cm long, from San Juan del Sur, Nicaragua (pl. 5, fig. 1; pl. 6, fig. 1).

Taxonomic comments.—When he first described *Pecten subnodosus*, Sowerby (1835) had before him several specimens that are here referred to two species, *Nodipecten subnodosus* and *N. arthriticus*. The species are distinguished by rib count and arrangement and by geographic distribution. *Nodipecten subnodosus* is retained for Sowerby's variety α, the *Nodipecten* common today in the Gulf of California and Pacific side of Baja California, Mexico. The first available name for Sowerby's varieties β and γ from western Colombia and the Gulf of Tehuantepec is *Pecten arthriticus* Reeve, 1853.

Description.—Valves equally convex, height equal to length. Auricles unequal, radially costate; byssal notch

deep. Right valves with 10-11 ribs, a wide central space flanked by five or six anterior and posterior ribs that in some specimens are slightly grouped on either side of the central space (posterior to anterior: 2 or 3 - 2 - central space - 3 - 3); nodes lacking. Left valves with 10 ribs, the central and lateral key ribs commonly nodose as described by the notation (anterior to posterior) 2r-N-2r-N_c-r-N-2r. The central nodose rib (N_c) separated from the anterior key rib by two lesser ribs and from the posterior key by only one lesser rib. Key ribs correspond to the wider spaces on right valves; they have 0-5 generations of hollow nodes. Macrosculpture consists of fine lirae and striae; adult interspaces contain three to five radials each. Holocene specimens vary from red to purple or may be mottled. The largest individual seen measured 10 cm high, 10.2 cm long (CAS 17943A from Port Culebra, Costa Rica).

Variability.—Individuals vary in the number of generations (0-5) and prominence of nodes. Juveniles may have one fewer ribs than adults. Left-valve rib counts, spacing and key-rib scheme (N 2r N_c r N) are consistent except in a few cases. Three or four aberrant individuals were collected from Port Culebra, Costa Rica (CAS 17943A) and Acapulco Bay (SDSNH 31247), where ecological or other factors may affect the rare specimens occurring there. Two disarticulated left valves from Isla San Jose, Panama (USNM 603323) and Acapulco, Mexico (J.T. Smith, private collection) have 10 or 11 ribs with the scheme (N 2r N_c 2r N) seen in *Lyropecten magnificus* from the Galapagos and *L. modulatus* (late Miocene, from the Vizcaino Peninsula). These individuals agree in ledged growth form, auricle shape, fine macrosculpture, and color with other specimens of *N. arthriticus*; they are referred here to *N. arthriticus*, although more specimens may indicate a relict population of *L. modulatus*.

Comparative morphology.—Nodipecten arthriticus differs from the northern Pacific-Panamic species, *N. subnodosus*, and from the southern Caribbean cognate, *N. nodosus*, in rib count, rib spacing, and left-valve node scheme. It has more ribs (10-11 compared with 8-9), a tendency toward grouping about the central space in right valves, and an atypical left-valve node scheme: N 2r N_c r N in *N. arthriticus*, compared to N r N_c r N in other Nodipectens. It differs from left valves of *Lyropecten modulatus* and *L. magnificus* that have 10-11 and 12-14 ribs, respectively, and the node scheme N 2r N_c 2r N.

Except for the node arrangement, specimens look most like *N. subnodosus* in color, macrosculpture, and growth form. The southern Pacific-Panamic species never attains the large proportions of *N. subnodosus* from lagoons in western Baja California.

Phylogenetic affinities.—Nodipecten arthriticus is classified with the Nodipectens on the basis of general similarity, even though the node scheme (N 2r N_c r N) could derive from either *Nodipecten* (N r N_c r N) or *Lyropecten* (N 2r N_c 2r N). Unlike the other Nodipectens and many fossil Lyropectens, its phylogenetic origin cannot yet be traced through the fossil record. The node scheme is set in the first dissoconch ribs and probably resulted from a genetic mutation. It seems to have originated in the Pacific Panamic province where it ranges from Miocene to Holocene in age; its most likely ancestor is *L. modulatus*, with which it occurs in the Almejas Formation at Turtle Bay, Baja California Sur, Mexico.

Geographic distribution and stratigraphic occurrences.—Nodipecten arthriticus is the "southern species" of the Pacific-Panama province; it lives from the Tres Marias Islands near the mouth of the Gulf of California to Paita, Peru. Fossils are present in the Vizcaino Peninsula, Baja California Sur, and in the Gulf of California north of Loreto, at Cerralvo and Maria Madre Islands; in raised terraces in Oaxaca, Mexico, and Talara, Peru. Also from Chubut Province, Argentina. Not, as recorded in earlier literature, from the Galapagos.

Holocene: Pacific-Panamic province south of the Gulf of California through the Paita Buffer zone. Tres Marias Islands, San Juanito Island (CAS 27578; 24108, all disarticulated) and Maria Madre Island (CAS 23779). Los Arcos, south of Puerto Vallarta (CAS 42693). Several specimens from Acapulco Bay, all aberrant (SDSNH 31248); common in collections from Panama Bay (SDSNH 31247) and Manta, Ecuador (CAS 36679, 36667). A lot of 15 double-valved individuals (USNM 765008) from Angel de la Guarda Island, Gulf of California, includes two left valves having the rib scheme of *N. arthriticus* but other morphologic features as in *N. subnodosus*; these specimens, which are discussed under variability in *N. subnodosus*, are not regarded as extending the geographic range of *N. arthriticus*.

Beach drift from Peru: Caleta Mero (CAS 36661), Cabo Blanco (CAS 36660), Mancora (CAS 36666), Paita (CAS 36679), Puerto Pizarro, (ANSP 234848, very worn). Olsson (1961) also lists it from Isla la Plata, Ecuador and Negritos, Peru.

Pleistocene to Holocene: Ecuador, from Santa Elena, (LSJU 3159) and Manta (CAS 36667); Talara, Peru, in tablazos, raised beach deposits (LSJU 3158 accession no. 53254).

Upper Pleistocene, Colotepec Formation (Palmer, 1928): Oaxaca coast, 16 km west of the mouth of Rio Colotepec (LSJU loc. 3692, CAS 1299; LSJU accession no. 47606). Raised beaches about 5-15 m above sea level are capped by coarse beach sand. Palmer (1928) referred to patchy deposits for 30 mi from Rio Potrero on the east to beyond Puerto Escondido. The sediments are gently warped soft gray or buff, locally indurated sandstones with low coastward dips. In some places they are exposed only at low tide, elsewhere at 75 ft elevation.

Pliocene, Cerralvo Island, about 125 mi north of Cabo San Lucas, southern Gulf of California (CAS 38543; CAS 39408, west side of the island, south of "Farallones Blancos," in coarse-grained sandy rocks exposed in sea cliffs 125 ft above base of the section). Pliocene, Maria Madre Island, Tres Marias: CAS 937, locality near northeast end of the island, collected by Eric Knight Jordan; along south shore (CAS 27577; Hertlein, 1935).

Pliocene, north of Loreto, B.C.S., in Arroyo de Arce in the Carmen and Marquer Formations, undifferentiated (M9045) (Smith, in press).

Upper Miocene, Almejas Formation near Turtle Bay, Baja California Sur, Mexico (Smith, 1984).

Miocene, from Valle Hermosa, about 82 km west of Comodoro Rivadavia, Argentina (Smith and Zinsmeister, 1982). The specimens are small but otherwise identical to Pacific-Panamic forms.

Geologic age.—Miocene of Patagonia; late Miocene on the Vizcaino Peninsula, Baja California Sur, Mexico; Pliocene to Holocene in the Pacific-Panamic province.

Ecology.—No adult specimens seen in museum collections were taken alive. Beach-drift occurrences suggest it is an offshore neritic form.

Nodipecten collierensis
(Mansfield, 1932)

Plate 8, figures 5, 6; plate 9, figures 3, 4; plate 10, figures 1-6; plate 11, figure 1

1932a. *Pecten (Nodipecten) pittieri collierensis* Mansfield, U.S. Geological Survey Professional Paper 170-D, p. D47, pl. 16, figs. 3, 5.

?1932b. *Chlamys (Lyropecten) pontoni* Mansfield, Florida State Geological Survey Bulletin 8, p. 59, pl. 10, figs. 1, 2.

1964. *Lyropecten (Nodipecten)* sp. B. Weisbord, Bulletins of American Paleontology, v. 45, no. 204, p. 162, pl. 11, figs. 4, 5. [right-valve fragment; transitional between *N. collierensis* and *N. nodosus*, or maybe is *N. nodosus*].

Holotype.—USNM 371326, a poorly preserved left valve 12.5 cm high, 14.3 cm long (fine sculptural details were added to the original illustration).

Type locality.—Collier County, Fla., on the Tamiami Trail [Florida State 41], about 11 mi east by north of Marco (USGS 1176). Matrix of white to gray, hard limestone called the Caloosahatchee Marl by Mansfield (1932a), now referred to the Tamiami Formation, which is here considered to be late Miocene in age but which is regarded as early Pliocene by Hazel (1983).

Paratype.—USNM 371327, a right valve.

Description.—Valves equally, moderately convex, height equals or slightly exceeds length. Beaks project slightly beyond hinge line. Auricles unequal, anterior auricle longer than posterior, both with coarse radial costae. Byssal notch moderately deep. Hinge line slightly longer than half shell length. Umbonal angle varies with convexity. Right valves with 7-8 ribs, slightly paired about a central interspace. Posterior margin finely costate, not ribbed. Right valves lack nodes. Left valves have 8-9 ribs, wide interspaces containing 2-3 coarse costae and finer radials. Alternate ribs wider or nodose, following the scheme N r N_c r N. Juveniles commonly with five or six generations of nodes by the time they reach 6.5 cm high. Fine sculpture of radial costae crossed by concentric lirae. The largest specimen seen measured 14.7 cm high, 13.5 cm long.

Variability.—Large suites of specimens from the Tamiami Formation (USGS localities 21067, 22587, 22882) in south Florida showed considerable variation in rib profiles (high rectangular to low and rounded), fine macrosculpture (2-3 coarse radials to numerous fine radials per interspace), and shell proportions, depending upon convexity. Umbonal angles are as low as 90° in juveniles, as much as 138° in adults. Left valves have incipient to well-developed nodes, mostly in juvenile to young adult stages. Preservation affected rib profiles and fine sculpture. Many Tamiami limestone samples have dissolution effects that those from the sandier Buckingham facies do not have. Variation in shell characters is illustrated in plate 10.

The holotype of *Chlamys (Lyropecten) pontoni* Mansfield (USNM 371613) is a poorly preserved left valve with an incomplete hinge and 10-11 ribs, possibly with incipient nodes; it resembles a specimen of *N. collierensis* (pl. 10, fig. 4) from North Carolina, although it could be *Chesapecten jeffersonius* (Say).

Comparative notes.—Nodipecten collierensis differs slightly from *N. pittieri* from the Greater Antilles and from *N. nodosus*, the Holocene Caribbean form. *Nodipecten pittieri* is longer than high, flatter valved, and sculptured by coarse radials and scalier, flanged nodes than *N. nodosus*; ribs are lower and rounded, whereas they are high and rectangular in *N. collierensis*. The two forms may eventually be recognized as morphologic variants of a single Caribbean-wide taxon. *Nodipecten nodosus* is almost indistinguishable from *N. collierensis*, although the Holocene species tends to have more prominent hollow nodes. *Nodipecten collierensis* has one to three more ribs than the Holocene *N. fragosus* that lives off Florida and that is identified by its fewer ribs, bulbous nodes commonly developed on both valves, and narrower umbonal angle.

Phylogenetic affinities.—Nodipecten collierensis is the immediate ancestor of *N. nodosus*, the Holocene Caribbean form that ranges from south of the Hispaniola arc to coastal Colombia and Venezuela and south to Brazil. It is closely related to *N. arnoldi*, which reaches gigantic proportions in coastal northern South America, and to *N. pittieri*. *Nodipecten collierensis* seems to have ranged widely in the late Miocene but *N. arnoldi* and *N. pittieri* are known only from restricted geographic areas. In

recognition of its similarities, Mansfield originally described *N. collierensis* as a subspecies of *N. pittieri*.

Geographic distribution and stratigraphic occurrences.—Southern Atlantic Coastal Plain, from Lake Waccamaw, N.C. to southern Florida; specimens from Haiti and the Dominican Republic are transitional between *N. collierensis* and *N. pittieri*; northern Venezuela on the Paraguana Peninsula and coastal Falcon.

Lake Waccamaw (hypotype USNM 334980, pl. 10, fig. 2), Duplin Formation of former usage or Waccamaw Formation. Cooper River, across from Etiwan Iron works, South Carolina (Charleston Museum 30. 112. 2), formation unknown.

Southern Florida, along Tamiami Trail (Florida Route 41), collected by Mansfield in the 1930's, and later workers. Tamiami Formation, Sunniland area (USGS 1176, 1180, 21091), in well-indurated, heavily leached limestone with molluscan internal molds. Many specimens are from spoil banks or quarries and lack precise stratigraphic data. Abundant in collections from the Sunniland Rock and Lime Quarry (USGS 21057, 22587, 22882; TU 204) and from 10 mi (16 km) south of Immokalee, Fla. (USGS 195297).

Buckingham Facies, Tamiami Formation, near Buckingham, Lee County, Fla. Matrix is a soft, white limy marl. USGS 13927; at USGS 22598 it is found with *Chlamys tamiamiensis*; 22601, 22602; also from Telegraph Park, (USGS 21045, in canal banks); Baucom Ranch (USGS 21128) and Pinellas Park, Pinellas County, in soft white marl (USGS 25276). Left valves are almost identical to Holocene specimens of *N. nodosus* from Venezuela and Brazil.

If the specimen described as *Chlamys* (*Lyropecten*) *pontoni* Mansfield is *N. collierensis*, it is the only record of the species from the *Arca* zone of the Choctawhatchee Stage of Puri (1953) or Red Bay Formation of Walton County, Fla. Subsequent workers have not re-collected the species.

?Dominican Republic, Gurabo Formation. Juveniles and fragments from TU1209, 1210, and 1215 are either *N. collierensis* or *N. pittieri*.

Venezuela, from the Paraguana Peninsula and coastal Falcon. Paraguana Formation, lower Pliocene (Hunter and Bartok, 1976; Hunter 1978). Las Piedras, western Paraguana Peninsula: UCMP S-254; USGS 24705, with specimens of *Chlamys tamiamiensis* as much as 11.5 cm high in well-indurated marl. UCMP S-8362, specimens very close to *N. nodosus*, including occurrences of that species in eastern Baja California Sur (USGS 16054).

San Gregorio Formation (Stratigraphic Lexicon of Venezuela, 1956): Urumaco; Rio Seco anticline area (La Vela Formation, lower Pliocene, of Hunter and Bartok, 1976); UCMP S-148, S-17, S-18 ("San Gregorio Formation" of collectors); CAS 32038.

Geologic age.—Late Miocene to earliest Pliocene; may be late Pliocene at Lake Waccamaw.

Paleoecology.—Puri and Vernon (1964) regarded the Tamiami Formation of south Florida as an open-marine, inner-neritic deposit, similar to the Caribbean units containing *N. collierensis*.

Nodipecten corallinoides
(d'Orbigny, 1839)
Plate 7, figures 3, 4

1839. *Pecten corallinoides* d'Orbigny, *in* Webb and Berthelot, Mollusques***aux Iles Canaries, p. 102, pl. 7, figs. 20-22.
1852. *Pecten corallinoides*. Reeve, Conchologica Iconica, v. 8, pl. 6, fig. 27.
1956. *Chlamys nodosa* var. *corallinoides* d'Orbigny. Soares, Conferencia d'internat. dos Africanistas occidentais, 6 sessao, v. 2, p. 284, pl. 2, figs. 2-5.

Nodipecten corallinoides from the Canary Islands and St. Vincent, Cape Verdes, is a lesser known relative of the Caribbean *N. nodosus*. Its presence in the eastern Atlantic Ocean implies dispersal from the Caribbean, an old world fossil record, or both. No fossils are known.

Material in United States museums is limited to a few lots of shells no larger than 5.2 cm high, mottled to coral red in color. Valves are circular to slightly longer than high, rib counts and node scheme are as in specimens of *N. nodosus* from Venezuela and Brazil. Right valves have 7-8 ribs, paired on either side of a very wide central space. Left valves have 8-9 ribs, with nodes on alternating costae. Radial fine macrosculpture is finer and scalier than in Caribbean forms. Shells are much smaller than, but similar in proportion to, the fossil species *N. pittieri* from Guadeloupe Island, the Greater Antilles, and eastern Costa Rica.

Occurrences of *N. corallinoides* in the Canary Islands at Santa Cruz de Tenerife (type locality) and in the Cape Verde Islands at St. Vincent (SDSNH13201) are within the water mass that becomes the west-flowing North Equatorial Current (fig. 2). An east to west migration cannot be assumed without further information on Holocene and fossil records for West Africa. Scheltema (1977) documents the dispersal of certain larvae from west to east via the North Atlantic gyre, aided, perhaps, by recently formed islands along the mid-Atlantic Ridge.

The oldest known Nodipectens are middle or late Miocene forms represented by *N. veatchii* and *N. nodosus* from Baja California Sur, Mexico, *N. collierensis* in Venezuela and Florida, and *N. arthriticus* [reported as *N. subnodosus, s.s.* by Smith and Zinsmeister (1982)] from Patagonia. Present knowledge of the fossil record suggests that *Nodipecten* is a new world genus of the Tertiary Caribbean Province and that populations in the eastern Atlantic are newly dispersed since the closure of Panama.

Nodipecten fragosus
(Conrad, 1849)

Plate 2, figures 3, 4; plate 3, figure 5; plate 7, figures 1, 2, 5; plate 14, figure 5

1849. *Pecten fragosus* Conrad, Academy of Natural Sciences of Philadelphia, Journal, new ser., v. 1, pt. 3, art. 16, p. 214; Pt. 4, (Jan., 1850), pl.39, fig. 11.

1898. *Pecten (Nodipecten) nodosus* Linné. Dall, Wagner Free Institute of Science of Philadelphia, p. 728-729 (in part).

1932. *Pecten (Lyropecten) pittieri floridensis* Tucker and Wilson, Bulletins of American Paleontology, v. 18, no. 65, p. 43-44, pl. 4, fig. 6.

Holotype.—Missing. Conrad (1849) illustrated a right valve 2 in. high, 2 in. long, with unequal auricles and eight slightly nodose ribs. He noted the differences from *Pecten nodosus*: "***fewer, sulcated, and much larger ribs***" Color deep orange.

Type locality.—"Inhabits the West Indies" does not fit the specimen Conrad described and illustrated. That taxon is the common form that lives off Florida today.

Neotype.—USNM 818272, here designated, is an individual having four generations of nodes on alternate ribs of the left valve, no nodes on the right valve but well-preserved concentric lirae that coincide with the original figure. Height 8.3 cm, length 8.5 cm.

Neotype locality.—Southern Florida, Tarpon Springs. Collected by sponge divers (loc. CAS 41794). From same lot: Voucher Specimen CAS 029017.

Description.—The scallop popularly known as the "Lion's Paw." Valves equally convex, height equal to length. Beaks project slightly above hinge line; auricles unequal, sculptured by five or six heavy radials; anterior auricle twice as long as posterior auricle. Byssal notch deep; hinge line greater than half the shell length; umbonal angle 86-94°. Right valves with eight strongly paired ribs, a prominent central space between them. Anterior- and posterior-most riblets narrow to incipient ridges. Ribs may be straight or nodose, with knobs on each rib. Some individuals develop prominent concentric frills that in some cases completely mask the fine radial striae. Left valves with seven ribs alternating in width on either side of a wide central rib; ribs nodose or not, alternating key ribs wider or more prominent in a scheme described as r N r N_c r N r. Concentric laminae are sometimes preserved in interspaces of newly added adult shell; the laminae are very thin and brittle, and that is probably why they are not commonly seen. Exterior colors range from orange to reddish brown, sometimes mottled; interior margins commonly outlined by a yellow-orange band. The largest specimens measure more than 14 cm high, 15 cm long (MCZ collections, from Tarpon Springs, and ANSP 227762 from Bradenton, Fla).

Variability.—Considerable variation in prominence of nodes. Some individuals have transverse laminae instead of concentric lirae in juvenile parts of shells and in anterior and posterior interspaces (for example, USNM 715050, from off Campeche Bank, Yucatan Peninsula). Holocene specimens from off the Carolinas, Fla. (pl. 7, fig. 5), and from eastern Mexico commonly have large bulbous nodes on both valves; they develop after the shell is 4.5-5 cm high. Juveniles may have one rib more than adults, commonly a posterior incipient rib.

Comparative notes.—The "Florida form," *N. fragosus*, is distinguished from the Caribbean form, *N. nodosus*, by its fewer ribs (7 or 8 instead of 9 or 10), finer macrosculpture and greater tendency to develop nodes on both valves. Some specimens of *N. fragosus* have concentric laminae instead of lirae crossing the radial costae. Right valves are more difficult to distinguish, as marginal ribs may be incipient in some specimens of *N. nodosus* and more prominent in some Florida specimens. Heavily nodose right valves of *N. fragosus* from the Pleistocene of South Bay, Fla. are similar to *N. pernodosus*, but that species is distinguished by an extra rib and shorter hinge line. Fossil specimens of *N. fragosus* have fewer ribs and finer reticulate macrosculpture than specimens of *N. collierensis*.

Phylogenetic affinities.—*Nodipecten fragosus* is close in rib count and arrangement, proportions, and fine sculpture to the Gulf and Atlantic Coastal Plain taxa *N. peedeensis* and *N. veracruzensis*, n. sp. and to *N. veatchii* from western Baja California Sur. The oldest records of *N. fragosus* are from the Buckingham facies of the Tamiami Formation; described as *Pecten pittieri floridensis* by Tucker and Wilson (1932), those specimens occur at some localities (USGS 22597) with *N. collierensis*, ancestor of the Holocene Caribbean species *N. nodosus*.

Geographic distribution and stratigraphic occurrences.—Holocene: Living offshore from Cape Hatteras, North Carolina to Florida; common in the Florida keys and the panhandle; western Gulf of Mexico from Matagorda, Mustang, and Padre Islands, and the Flower Garden Banks off Texas (MCZ 194599, USNM 465304, and H. Odé, written commun., 1973). The Yucatan Peninsula near Rio Lagartos and off Campeche Bank, Mexico. Rare as dredged empty valves from deep water off Bermuda (Russell Jensen, written commun., 1980).

Beach drift from eastern Mexico: Tampico, Tamaulipas (MCZ 194601, ANSP 301859), Tuxpan (MCZ 194619, AMNH 105476), Barra Cazones, Veracruz (MCZ 194929), and Yucatan (ANSP 139643, MCZ 218218). Off Campeche Bank, in 55 m, 22°23′ N. 89°52′ W. (USNM 715050) and as drift from Isla Contoy (TU R-124). Holocene, from middens in the Yucatan Peninsula (Andrews, 1970). Some shells were perforated for use as pendants, and at least one [BM (NH) 1946 Am 1921], had gold nuggets set in the broken nodes (Cox, 1957).

Fossil: Bermont Formation, Pleistocene, South Bay, Fla. (loc. USGS 25657). Pinecrest Beds of Olsson and Petit

(1964), upper Pliocene (USGS 22298, TU 1000). San Diego Society of Natural History collections from Warrens Pit, Sarasota, Fla. include fragments and juveniles with seven to eight rectangular ribs and fine sculpture as in Holocene specimens. Right-valve ribs strongly paired. Tamiami Formation, Buckingham facies, from Buckingham, Fla. (USGS 22597, 22598); transitional from or found with *N. collierensis* at USGS 21045.

Geologic range.—Late Miocene or early Pliocene to Holocene.

Ecologic data.—Offshore, outer neritic; away from turbid, fresh-water streams such as the Mississippi River. Individuals are not gregarious, rarely more than two or three living near each other. Of hundreds of specimens examined, only about 20 lots were taken alive, from depths of 15-82 m. Byssate or reclining with left valves up.

Large suites of specimens taken alive were collected by sponge divers at Tarpon Springs southwestern Florida (AMNH 169243; ANSP 242657; USNM 487610; CAS 41794) and from 50-102 ft off the Florida panhandle (AMNH 129779; M/V *Oregon* station 898; TU R-283). Many individuals were collected alive from 10 mi south of Alligator Point, Franklin County (AMNH 47692, 158478); one was byssate on Buoy no. 26 at 70 ft, others reclined on sandy coral substrates.

Large specimens live on algal reefs off the Texas coast (27°53¼′ N., 93°19′ W.) at 25-28 fathoms. Collected alive at Seven and One-Half Fathom Reef, east of Padre Island (Tunnell and Chaney, 1970); less common on coral reefs and sandy shell substrates (Helmer Odé, written commun., 1973).

Northeastern records include specimens from depths of 54 ft and 80-85 ft off Cape Fear (AMNH 323053) and Drum Inlet, Carteret County, N.C. (AMNH 166816, ANSP 323053; south-southwest of Cape Lookout, USNM 544129). An individual byssally attached to a wreck was collected by Warren Blow east of Wrightsville Beach, N.C. from 80-85 ft. One juvenile (USNM 54002) came from 54 ft 37 mi southeast of Bulls Island, S.C. (*Pelican* Sta. 194-10). Adults and juveniles clung to an ocean buoy 5 miles off Cape Romain (UCLA 23796) and one lot came from 270 ft depth, 62 mi southeast of Charleston, S.C. (USNM 544029, *Pelican* station 195-7).

Beach drift records from North Panama City; beaches in the western Gulf of Mexico, Isla Contoy (TU R-164), and Isla Cerrito, mouth of Rio Lagartos, Yucatan (USNM 715050, TU R-84). Sanibel Island (MCZ 111880) and Florida beaches and keys.

Nodipecten nodosus (Linnaeus, 1758)

Plate 3, figures 3, 4, 6; plate 4, figures 3, 4; plate 7, figures 6, 7; plate 8, figures 1, 3, 4; plate 9, figures 1, 2

1758. *O.* [*Ostrea*] *nodosa* Linnaeus, Systema Naturae, 10th ed., Tomus 1, p. 697, no. 164.

1764. *O.* [*Ostrea*] *nodosa* Linnaeus, Museum Reginae Ludovicae Ulricae Holmiae, p. 527, no. 108.

1767. *O.* [*Ostrea*] *nodosa* Linnaeus, Systema Naturae, 12th ed., p. 1145, no. 194.

1847. *Pecten nodosus* (Linnaeus). Sowerby, Thesaurus Conchyliorum, v. 1, p. 66, pl. 15, fig. 115.

1852. *Pecten nodosus*. Reeve, Conchologica Iconica, v. 8, *Pecten*, sp. 15, pl. 3, fig. 15 ["hab. Gulf of Mexico" is incorrect; fig. 15 is the southern Caribbean form].

1898. *Pecten* (*Nodipecten*) *nodosus* Linnaeus. Dall, Wagner Free Institute of Science of Philadelphia, Transactions, v. 3, pt. 4, p. 728-729.

1964. *Lyropecten* (*Nodipecten*) *nodosus*? (Linnaeus). Weisbord, Bulletins of American Paleontology, v. 45, no. 204, p. 156-159, pl. 17, fig. 1.

1968. *Chlamys* (*Nodipecten*) *nodosa* (Linné). Mongin, Bulletins of American Paleontology, v. 54, no. 245, p. 489, pl. 48, fig. 2.

Lectotype, here designated.—Museum Ludovicae Ulricae no. 106 of the Linnaean collection, University of Uppsala, Uppsala, Sweden (Lars Wallin, Zoologiska Museet, written commun., 1981). The specimen has two valves, the left has nine nodose ribs; it measures 9.6 cm high, 9.5 cm long. Neither of the two worn right valves of *Nodipecten nodosus* in the Linnean Shell Collection at the British Museum (Natural History) can be identified with certainty as Linnean specimens (Solene Morris, written commun., 1981).

Type locality.—"In O. Africano and Indico" (Linnaeus, 1758) is erroneous. The holotype matches material from the southern Caribbean, especially specimens from Margarita Island, Venezuela (for example, hypotypes UCMP 37389, 37390).

Description.—Valves equally convex; beaks project equally, slightly beyond hinge line. Auricles unequal, radially costate; byssal notch deep. Umbonal angle about 95° in juveniles, 105° in adults. Right valves with 9-10 ribs, slightly paired on either side of the central space in some juveniles, 3-4 riblets in each interspace. Right valves lack nodes. Left valves with nine nodose ribs with more prominent hollow nodes or scaly flanges on alternating key ribs. Nodes commonest in juveniles but develop at irregular intervals in some adults. Ribs and interspaces bear coarse riblets and scaly lirae; this kind of fine macrosculpture is characteristic of the Caribbean Nodipectens. Holocene specimens red, orange, brown, purplish, or mottled; interiors white or reddish brown. The largest specimen measured 11.9 cm high, 12.9 cm long (USNM 708187).

Variability.—Individuals vary in the number and spacing of generations of nodes. Adults commonly have lower rib counts than juveniles, owing to incipient anterior and posterior riblets that become obsolete in later growth stages. Some right valves from Brazil and Tobago Island have slightly paired ribs. Adequate population samples were not available to study relations between geographic distributions and slight differences in ribbing. Color varies

within populations from the same bay.

Comparative morphology.—*Nodipecten nodosus* has 1-2 ribs more than *N. fragosus* from Florida and the Gulf of Mexico; it also has coarser macrosculpture and less tendency to develop large bulbous nodes. Right valves of *N. fragosus* have more strongly paired ribs; nodes are common on all ribs of both valves.

Fossil *N. nodosus* and *N. collierensis* have overlapping rib counts (9-10 in the former, 8-9 in the latter) but differ in amounts of variation. *Nodipecten nodosus* is less variable in rib profiles (rounded-rectangular) and has fewer, coarser radials in interspaces than in *N. collierensis*. They overlap in geographic and geologic ranges: *N. nodosus* is mainly Pliocene to Holocene in age in the Caribbean; *N. collierensis* is Miocene to Pliocene in age in the Caribbean and southeastern Atlantic Coastal Plain. *Nodipecten pittieri* differs from *N. nodosus* in proportions (length exceeds height, umbonal angle very wide), rib profile, and more restricted geographic distribution, mainly in the Greater Antilles. *Nodipecten arnoldi* may represent gigantic specimens of *N. nodosus* that flourished in the late Pliocene in an especially favorable environment.

Phylogenetic affinities.—*Nodipecten nodosus* evolved directly from *N. collierensis* in the late Miocene or early Pliocene. It is closely related to *N. arnoldi* and *N. pittieri* from the Caribbean, although insufficient specimens are available to determine at what time these taxa evolved from the *N. collierensis-N. nodosus* lineage. *Nodipecten nodosus* is slightly more removed from the Gulf of Mexico taxa, *N. fragosus*, *N. peedeensis*, and *N. veracruzensis*, n. sp., all of which have fewer (7-8) ribs. *Nodipecten nodosus* dispersed by the late Miocene as far as the central Gulf of California, where it evolved to *N. subnodosus* by the middle Pliocene.

Geographic distribution and stratigraphic occurrences.—Holocene: widespread in shallow tropical water in the Caribbean, south of the Greater Antilles, the Virgin Islands, Eastern Antilles, eastern Central America south of the Yucatan Peninsula; eastern Panama to Colombia and Venezuela, and discontinuously as far south as Rio de Janeiro, Brazil.

Fossil occurrences.—Northern Venezuela, Guadeloupe, and eastern Baja California Sur. Specimens from Las Piedras, Paraguana Peninsula, Venezuela transitional between *N. collierensis* and *N. nodosus*.

Representative Holocene localities.—Greater Antilles: Cuba, from Tunas de Zaca, Santa Clara (SDSNH 31345); Dominican Republic, Samana Bay (USNM 430645); Puerto Rico, beach drift from Punta Guarajibo to Punta Arena, Mayagueza; (USNM 681801); Bahía Bramaduo (MCZ 225932, 225930).

Virgin Islands, St. Thomas (SDSNH 18397); St. John, Flannegan Passage, in 27 fms; St. Croix (MCZ 74068; 218217).

Tobago (AMNH 130171); Bahamas (ANSP 320933); Barbados (MCZ 164711, drift); Trinidad, beach drift (MCZ 148520, 148510).

Honduras (USNM 714967, M/V *Oregon* sta. 1938, 24 fathoms; eastern Panama (USNM 589589); Curaçao (AMNH 114027); off Cartagena, Colombia (CAS 19000, USNM 364250).

Margarita Island, Venezuela. Near Pompatac: USNM hypotype 252608; UCMP hypotypes 37389, 37390; MCZ 219534; ANSP 225229; ANSP 240092, in 40-50 ft, off Morro de Punta Moreno.

Brazil, Rio de Janeiro, Bahía de Todos Santos (ANSP 263473, MCZ 246135, juveniles in 10 m); Ilha Grande (Haas, 1953).

Representative fossil localities.—Pleistocene or Pliocene and Pleistocene: Venezuela, Cabo Blanco, D. F. (Weisbord, 1964, loc. N322*a*). Float from near outcrops of Playa Grande Formation, but possibly from the Mare Formation. The specimen, a right valve, could be *N. collierensis* or *N. nodosus*; the bulging right-valve ribs are more characteristic of the Holocene form. From Paraguana and Tortuga (Weisbord, 1964), also Cubagua (UCMP S-146). Eastern Antilles, St. Kitts and St. Eustasias (*fide* Weisbord, 1964); Bowden, Jamaica (USGS 369625).

Baja California Sur, Mexico: Santa Rosalia area, upper Miocene Boleo Formation (USGS 16054 and M9036). The closest morphologic forms from Venezuela are in the western Paraguana Peninsula (UCMP S-8362). Monserrate Island, algal sandstone and *Pecten* beds at southeast end of the island (UCMP A-3568). North of Loreto, "between Arroyo de Arce and Arroyo de Gua" (UCMP A-3556, A-3356, Carmen and Marquer Formations, undifferentiated), transitional forms between *N. nodosus* and *N. subnodosus*, and from Arroyo de Arce (CAS 56568, 56569).

Geologic age.—Late Miocene to Holocene.

Nodipecten peedeensis (Tuomey and Holmes, 1855)

Plate 15, figures 1, 2, 3, 4

1848. *Pecten peedeensis* Tuomey, Report on the geology of South Carolina. [*nomen nudum*].

1855. *Pecten peedeensis* Tuomey and Holmes, Pleiocene fossils of South Carolina, South Carolina Geologic and Natural History Survey, Nos. 5-6, p. 30, pl. 12, figs. 1-5.

1898. *Pecten* (*Nodipecten*?) *peedeensis* Tuomey and Holmes. Dall, Wagner Free Institute of Science of Philadelphia, Transactions, v. 3, pt. 4, p. 729.

1914. *Pecten* (*Nodopecten* [sic]) *vaccamavensis* Olsson, Bulletins of American Paleontology, v. 5, no. 24, p. 11-12, pl. 1, fig. 1 [or p. 49-50, pl. 8, fig. 1].

Not 1938*a*. *Chlamys* (*Lyropecten*) *peedeensis* (Tuomey and Holmes). Tucker-Rowland, Brussels Institut Royal des Sciences Naturelles de Belgique, ser. 2, fasc. 13, p. 23-24, pl. I, fig. 8. [a hypotype USNM 9526 designated as neotype of *N. peedeensis*, but it is a European specimen having

affinities with *Chlamys latissimus nodosiformis* de Serres, 1837 or *C. melii* Ugolini, 1905].

Holotype.—AMNH 5504, a double-valved specimen measuring 10.2 cm high, 11.6 cm long. Type lot also includes two disarticulated right valves and a left valve.

Type locality.—Darlington District, S.C., on the Pee-Dee River, labelled "Pleiocene" (AMNH loc. 10822). This area is in northeastern South Carolina in Darlington and Florence Counties on the Atlantic Coastal Plain. The species has not been re-collected from rocks in place, but best estimates are that it occurs in the Duplin Marl of former usage of late Miocene or early Pliocene age.

Description.—Valves moderately convex, beaks project equally, slightly above hinge line. Auricles unequal, faintly costate. Byssal notch shallow. Hinge line about half shell length in the holotype, incomplete in other specimens. Right valves with six to seven rectangular ribs paired about a wide central space; ribs wider than spaces. Left valves with six to seven high, narrow rounded ribs of alternating width and prominence; interspaces wider than ribs. Umbonal angle 90°, umbonal areas worn in available material; remnants of hollow nodes appear on alternate ribs of juveniles. Reticulate fine sculpture present in juveniles, scaly concentric lirae in adult interspaces. The largest individual measured was a pathologic, gerontic specimen 16.9 cm high, 17.6 cm long from Fetteressa, South Carolina (Charleston Museum no. 43. 28. 9186).

Variability.—The taxon is known from the type lot of four specimens, several individuals from the Charleston Museum, and the holotype of *Pecten vaccamavensis* Olsson. Within this limited sample, variation is observed between juvenile and adult microsculpture and rib profiles. Auricle proportions and shapes of type-lot specimens differ more than in contemporaneous specimens of other Nodipectens. Differences in fine macrosculpture are related to amount of abrasion, as seen on Holocene specimens of *Nodipecten fragosus* and from mode of preservation.

Comparative notes.—Nodipecten peedeensis differs from *N. collierensis* in its lower rib count, right-valve rib spacing, and fine, even macrosculpture. Although very similar in proportions, rib count, and rib spacing to Holocene *N. fragosus* from Florida and the Gulf of Mexico, *N. peedeensis* has finer lirae and striae as in the eastern Pacific forms *N. subnodosus*, *N. arthriticus*, and *N. veatchii*. Morphologic differences from *N. veatchii* include lower, rounded ribs of more uniform sizes, more highly developed or better preserved concentric microsculpture, and weakly ornamented auricles. The angular ledges and prominent left-valve nodes of most specimens of *N. veatchii* are not present in available *N. peedeensis* specimens, but they are probably within the limits of its variability.

Phylogenetic affinities.—Rib counts, rib spacing, and macrosculpture suggest that *N. peedeensis* and *N. veatchii* from the tropical eastern Pacific are end members of a wide ranging Tertiary Caribbean taxon. They are morphologically close but geographically isolated from *N. veracruzensis*, n. sp. from the Agueguexite Formation of the Mexican Gulf Coastal Plain.

Nodipecten peedeensis is probably ancestral to *N. fragosus*, the early Pliocene to Holocene *Nodipecten* living in the Gulf of Mexico and southern Atlantic Coastal Plain. Tuomey and Holmes (1855) considered it "***very closely related to, if not identical with *P. nodosus* of the Gulf of Mexico."

Geographic distribution and stratigraphic occurrences.—Isolated occurrences from North Carolina, south of Cape Fear near Lake Waccamaw, and several localities in northeastern South Carolina. Not from the "Miocene ***of Virginia" as indicated by Dall (1898). Many of the localities are now unknown except to historical scholars of South Carolina. Mr. Albert E. Sanders of the Charleston Museum kindly relocated many of the sites on current maps for this study.

Representative localities.—Lake Waccamaw, along the north shore, N.C., Bear Bluff(?) Formation, probably latest Pliocene (Lucy McCartan, written commun., 1981); the lower, indurated layer may be the Duplin Formation of former usage, lower Pliocene, and the friable upper one may be the Waccamaw Formation (here early Pleistocene in age, *fide* Lucy McCartan, written commun.,1981). Elsewhere the Waccamaw Formation is considered by some workers to be Pliocene (Waller, 1969) or Miocene in age, on the basis of ostracods, mollusks, and foraminifers (Swain, 1968). PRI 3483, holotype of *Pecten vaccamavensis* Olsson, 1914, (pl. 15, fig. 2), in a sandy matrix.

Darlington and Marion Districts, S.C., including parts of present Darlington, Lee, Marion, and Florence Counties; along the Great Peedee River and the Little Peedee River. AMNH 10822, type locality "on the Peedee River." Godfrey's Ferry, S.C., in bluff along Great Peedee River, 2.4 mi southwest of Gresham via Route 378 (Johnsonville quadrangle). *Nodipecten peedeensis* was listed from here by Tuomey (1848) from an indurated *Pecten* bed in a Pliocene marl; probably early Pliocene in age (T.M. Cronin, written commun., 1983).

Fetteressa, S.C., collected by the Rev. A.E. Cornish, 1897. Charleston Museum 43.28. 9186, John's Island 7½-minute quadrangle, Trailwood Trailer Park pit, Pleistocene (Lucy McCartan, written commun., 1981). The taxon is represented by a large pathologic right valve, perhaps reworked. (Fetteressa was a plantation, later a small community in the late 19th century; it was located on the north bank of the Ashley River, about 4 mi west of North Charleston, around Cohen Hill.)

Geologic age.—Miocene(?), Pliocene, and early Pleistocene(?) Searches in museum collections and inquiries of geologists and private collectors who have worked in the

Carolina Coastal Plain have yielded no new specimens or clues to localities where they can be found. Most of the recorded locality and stratigraphic data do not permit certain rock-unit assignments among the Duplin Formation, the Waccamaw or Bear Bluff Formations. Stratigraphic assignments are further complicated by lithologic similarities, facies changes within relatively thin units, and nomenclatural confusion stemming from the use of formational names in a time-rock sense.

Without precise locality and stratigraphic data, age and chronostratigraphic range can only be estimated. Dall (1898) considered *N. peedeensis* Miocene in age, and Copeland (1964) identified Miocene foraminifers from the Duplin Formation of former usage, one of the units in which the pectinid may occur. The now-abandoned Duplin Formation in the Darlington District is no older than early Pliocene, according to Lucy McCartan (written commun., 1981); morphologically, *N. peedeensis* has strong affinities with the late Miocene Tertiary Caribbean species *N. veatchii* from Baja California Sur, Mexico.

Paleoecology.—Outcrops at *N. peedeensis* localities are neritic clastic deposits. Copeland (1964) found inner sublittoral foraminiferal assemblages typical of 30-60 ft depths in Duplin County, N.C.

Nodipecten pernodosus
(Heilprin, 1887)

Plate 3, figures 1, 2

1887. *Pecten pernodosus* Heilprin, Exploration on the west coast of Florida, Wagner Free Institute of Science of Philadelphia, p. 131, pl. 16b, figs. 69a, 69b [reprinted 1964, Paleontographica Americana, v. IV, no. 33, p. 503, pl. 71, figs. 69a, 69b].

1898. *Pecten (Nodipecten) nodosus* Linné. Dall, Wagner Free Institute of Science of Philadelphia, Transactions, v. 3, pt. 4, p. 728-729, in part [Dall considered this species from the Caloosahatchee Marl the same as Pleistocene and Holocene forms of *N. nodosus* from the Antilles, South America, the Gulf of Mexico, and "***probably also (as *P. subnodosus*) on the Pacific shores of middle America."].

Holotype.—WFIS 938, a two-valved adult 10.3 cm high, 10.5 cm long.

Type locality.—Lee County, Fla., along the Caloosahatchee River between Labelle and Olga. From sandy marls referred to the Caloosahatchee Formation or Marl of Pliocene and Pleistocene age.

Description.—Valves moderately convex, height equals length. Beaks project slightly, equally beyond hinge line; auricles unequal, anterior auricle twice as long as posterior auricle, both with furrowed radial riblets. Byssal notch shallow. Hinge line relatively short, less than half shell length. Umbonal angle 92-96° in young shells as much as 2 cm high, 120-130° in later growth stages. Almost all specimens have many ledges (seven or more in adults), commonly accentuated by large bulbous nodes on each rib. Right valves with 8-9 ribs, plus incipient anterior and posterior ridges that raise juvenile rib counts to 8-10. Nodes and rib widths decrease in size away from the central space. Left valves with 8-9 ribs, all bearing hollow nodes. Alternating ribs, including the central one, more prominent than the rest, following the scheme. . N r N_c r N. . The first nodes develop when late juveniles are about 4.5 cm high and have four or five ledges. Later growth stages have 5-8 ledges, each coinciding with a generation of nodes. Macrosculpture consists of radial striae and wavy or scaly concentric lirae, commonly abraded from nodes. Interspaces have one to four, thick radial riblets, producing a herringbone pattern with concentric lirae in young stages. The largest shell measured 11.1 cm high, 11.5 cm long (WFIS 2646).

Variability.—In the two dozen specimens examined, diagnostic features such as shell proportions, ribbing, and ledging never varied.

Comparative notes.—*Nodipecten pernodosus* differs from *N. fragosus*, the Holocene species from Florida and the Gulf of Mexico, in having a higher rib count (eight to nine ribs instead of seven to eight), shorter hinge, and coarser macrosculpture. *Nodipecten pernodosus* tends to have more ledges and develops bulbous nodes on both valves, unlike longer hinged fossils referred to *N. collierensis* that have nodes only on left valves. *Nodipecten nodosus* from the Holocene of the Caribbean has the same rib count as *N. pernodosus* but not the short hinge line or the tendency to develop nodes on right valves. Some individuals of *N. fragosus* from the Carolinas (USNM 54429) and the Yucatan Peninsula (MCZ 218218) have the same bulbous nodes, coarse macrosculpture, and flared adult shells as *N. pernodosus*, but they are not the exclusive morphologic forms in these areas. *Nodipecten pernodosus* is remarkable for its consistency throughout the Caloosahatchee Formation.

Phylogenetic affinities.—A member of the *Nodipecten nodosus* stock defined by the left-valve node scheme, *N. pernodosus* may be an ecological variant that became isolated from the wider ranging *N. collierensis* or its descendant, *N. nodosus*, during the early Pliocene. Available evidence suggests that *N. collierensis* is geographically and morphologically likely to have given rise to *N. pernodosus*.

Morphologic evidence suggesting *N. pernodosus* is environmentally controlled include the numerous, closely spaced ledges in all individuals, enlarged nodes on both valves, and absence of morphologic variation observed in Holocene relatives from widespread localities and habitats. *Nodipecten pernodosus* seems to be a genetically isolated form from a stenotypic ecologic setting.

Geographic distribution and stratigraphic occurrences.—Lee and Hendry Counties, Florida, along banks of the Caloosahatchee River.

Caloosahatchee Formation: TU 203, east of Fort Denaud; TU 726; TU 792, southwest of La Belle; USGS 4880, type locality of the formation; TU 529, same as DuBar loc. 30-31, *Cyrtopleura* zone (DuBar, 1958).

Geologic age.—Early Pleistocene (T.M. Cronin, written commun., 1983).

Paleoecology.—The Caloosahatchee Formation was deposited in an isolated basin that shoaled and dried up by middle Pleistocene time.

Nodipecten pittieri
(Dall, 1912)

Plate 2, figure 2; plate 11, figure 2; plate 12, figures 1-4; plate 13, figure 1; plate 14, figure 1

1912. *Pecten (Lyropecten) pittieri* Dall, Smithsonian Miscellaneous Collections, v. 59, no. 2, p. 10. Illustrated in Dall, 1925, U.S. National Museum, Proceedings, v. 66, art. 17, p. 23, pl. 17, fig. 6.

1919. *Pecten (Lyropecten) pittieri*. Cooke, Carnegie Institution Publication, 291, p. 135-136, pl. 13, fig. 5.

1968. *Chlamys (Nodipecten) colinensis* (Hodson and Harris) forma *guadeloupensis* Mongin, Bulletins of American Paleontology, v. 54, no. 245, p. 487-490 [in part]; pl. 44, figs. 1, 2; pl. 45, fig. 1.

1968. *Gigantopecten pittieri* (Dall). Mongin, ibid., p. 491-492, pl. 46, fig. 1; pl. 47, fig. 1; pl. 50, figs. 1, 2.

Holotype.—USNM 214368, a two-valved, very fragile specimen measuring 13.2 cm high, 15.2 cm long, hinge length 8.2 cm.

Type locality.—Costa Rica, near Limon, in later Tertiary niveau *a* of Moin Hill; from deposits a few feet in elevation, in the swamps around Limon Bay. Later workers include these beds in the Moin Formation, of late Pliocene age (Weisbord, 1964; Woodring, 1977).

Description.—Valves flat, height equal to length. Beaks project slightly, equally beyond hinge line; auricles costate, equal to or slightly less than half shell length. Byssal notch shallow, ctenolium prominent. Umbonal angle wide, 115°. Anterior and posterior shell margins with radial striae, no incipient ribs. Right valves with 10-11 ribs; left valves with 9-10 ribs bearing scaly hollow flanges on alternating ribs (. . N r N_c r N. .). Macrosculpture consists of moderately coarse radial riblets and fine concentric growth lines. The largest individual is 19 cm high, hinge length 9.6 cm, shell length incomplete (hypotype USNM 334975 from Cuba, USGS loc. 7533).

Variability.—The treatment of this species is highly typological because specimens are very rare and are represented mainly by adults. The specific name is used here for specimens that closely match the holotype. Variations in ribbing and shell convexity are probably similar to those of *Nodipecten nodosus*.

Comparative notes.—Nodipecten pittieri resembles *N. nodosus* in having open flanges rather than nodes on left-valve ribs. It is flatter valved than *N. nodosus*, commonly longer than high, and has very low rib profiles. *Nodipecten arnoldi* has similar macrosculpture but higher, more rectangular ribs and hollow flanged nodes; its height usually exceeds its length. *Lyropecten colinensis, s.l.* has a lyropectinid node scheme, N 2r N_c 2r N. In some individuals of *N. pittieri*, including the holotype of *Chlamys (Nodipecten) colinensis* forma *guadeloupensis* Mongin, former shell edges are preserved as low flanges, producing forms convergent with *L. colinensis, s.l.*

Nodipecten collierensis is abundant in Florida and Venezuela, where sizeable populations show considerable variation; some forms resemble *N. pittieri*. *Nodipecten collierensis* has one or two fewer ribs and a variable profile; left valves have either no nodes or hollow nodes, not the low flanges of *N. pittieri*.

Phylogenetic affinities.—N. pittieri is a Caribbean *Nodipecten* most closely related to the phylogenetic series *N. collierensis-N. nodosus*. Biostratigraphic data are inadequate; it is probably a geographic form contemporaneous with the earliest specimens of *N. nodosus*. Its evolution and distribution may be related to the uplift of the Hispaniola arc.

Geographic distribution and stratigraphic occurrences.—Sparse records from Costa Rica, the Greater Antilles, and Guadeloupe Island; Oaxaca, Mexico.

Representative localities.—Costa Rica: Limon area, upper Pliocene deposits referred to the Moin Formation (type locality).

Northeastern Oaxaca, Mexico, near Tuxtepec, on Rio Santo Domingo (TU loc. 1030), from the Concepcion Superieur Formation, middle Pliocene, Zone N 20 (Akers, 1979). Van den Bold (in Ferrusquia-Villafranca, 1977) shows it as in upper Miocene strata, below the Aqueguexite Formation.

Dominican Republic, bluffs along Rio Gurabo (TU 1209, 1210, 1215 = USGS 8539-8543) Gurabo Formation, Maury (1917) zones B and D (E. Vokes, written commun., 1981), lower Pliocene. Juveniles are transitional between *N. pittieri* and *N. collierensis*. Haiti; Jacmel, about 25.1 km from the north shore of Grand Coave (NMB accession no. G-16554). Riviere Gauche Formation. Cuba: Matanzas Province, gorge of Yumuri River, below Iglesia Mont Serrato (USGS 3468); near mouth of Macambo River (USGS 7533), from hard, marly sand with shell fragments (Cooke, 1919); Oriente Province, Santiago de Cuba USGS 5255. Guadeloupe, Grande Terre, in algal limestones and reefal deposits, "calcaires de Grande-Terre" of L. Barrabe. Localities are in the southwest corner of La Guadeloupe Island, north of Pointe à Pitre at Aerodrome Hill and south near Poucet ravine and Sainte-Anne (NMB loc. 10115). Also from beds near a factory at Gardel and Le Moule, on the southeast part of the island. Middle and upper Miocene (Mongin, 1968).

Geologic age.—Miocene to Pliocene.

Nodipecten subnodosus
(Sowerby, 1835)

Plate 4, figure 2; plate 5, figures 2-5; plate 6, figure 2; plate 8, figure 2

1835. *Pecten subnodosus* Sowerby, Zoological Society of London, Proceedings, v. 3 for 1835, p. 109, var. A.
1847. *Pecten sub-nodosus* Sowerby. Sowerby, Thesaurus Conchyliorum, v. 1, p. 65-66, pl. 15, figs. 97, 112 [varieties 2 and 3, not variety 1].
1867. *Lyropecten intermedius* Conrad, American Journal of Conchology, new ser., v. 3, pt. 1, p. 7.
1906. *Pecten (Nodipecten) subnodosus* Sowerby. Arnold, U.S. Geological Survey Professional Paper 47, p. 128-129, pl. 52, fig. 1; pl. 53, figs. 1, 1a.
Not 1926. *Pecten subnodosus* Sowerby. Hanna, California Academy of Sciences Proceedings, ser. 4, v. 14, no. 18, p. 474, pl. 25, fig. 6 [= *Lyropecten tiburonensis*, n. sp.].
1931. *Pecten (Lyropecten) nodosus* (Linnaeus) var. *intermedius* (Conrad). Grant and Gale, San Diego Society of Natural History Memoir, v. 1, p. 181.
1959. *Nodipecten subnodosus* (Sowerby). Grau, Allan Hancock Pacific Expeditions, v. 23, p. 128, pl. 43 (in part).
1971. *Lyropecten (Nodipecten) subnodosus* (Sowerby). Keen, Sea shells of tropical west America, 2d ed., p. 93, fig. 202.
1984. *Nodipecten subnodosus intermedius* (Conrad). Moore, 1984b, U.S. Geological Survey Professional Paper 1228-B, p. B58, pl. 22, fig. 1; pl. 23, fig. 5.

Lectotype, here designated.—BM (NH) 1950.11.44.77. The specimen is selected on the basis of notes and photographs from Thomas R. Waller (written commun., 1983), who suggests that the lectotype is one of the several syntypes Sowerby originally described. The lectotype has two valves and measures 11.4 cm high, 11.7 cm long.

Type locality.—Gulf of California, Mexico. Holocene.

Description.—Valves equal, flat to moderately convex. Auricles subequal; hinge more than half shell length. Byssal notch deep. Umbonal angle 96-98°. Anterior and posterior shell margin are sculptured by radial striae which also cover ribs and interspaces. Right valves with 8-9 rounded-rectangular ribs that are evenly spaced, not paired as in *N. fragosus* from the Gulf of Mexico. Right valves lack nodes. Left valves have nine ribs, alternate ones have one or more generations of hollow nodes in a scheme described . . . N r N_c r N. . Nodes tend to be more numerous and regularly spaced in juveniles more than 5-6 cm high; they are associated with changes in shell profile similar to the ledges of fossil Lyropectens. Individuals from Scammon Lagoon have as many as seven generations of nodes. Rib profiles high and narrow in juveniles that have flat valves, low and rounded rectangular in adults. Macrosculpture consists of costae and lirae that project as concentric frills in unworn material. Color in Quaternary shells varies from reddish purple to drab or mottled. The largest specimens seen measured 17.3 cm high, 18.5 cm long (MCZ 225857, from Guerrero Negro [Black Warrior Lagoon]) and 17.1 cm high, 17.5 cm long (CAS 34614, from El Pulpito, Gulf of California).

Variability.—Valve profiles vary with size; juveniles are flatter than adults. One lot of 15 two-valved specimens from 25 fathoms off Angel de la Guarda Island (USNM 765008) includes three exceptions to the normal node scheme. The atypical left valves have the following patterns: N r N 2r N_c r N r N, N 2r N 2r N_c r N r N, and N r N r N_c 2r N r N. Such a large amount of variability in node scheme is unknown in other lots of this species. The three atypical specimens are similar in proportions, color, and morphologic details other than rib scheme to normal *N. subnodosus*; they are considered here as genetic mutations of *N. subnodosus* rather than a northern population of *N. arthriticus*.

Comparative morphology.—Except in the lot noted above, the northern or Gulf of California species differs from *N. arthriticus* in having one less rib and a different left-valve node scheme: . . N r N_c r N. . in *N. subnodosus* and . . N 2r N_c r N. . in *N. arthriticus*. Right valves of *N. arthriticus* have ribs in groups, four or five posterior to the widest central interspace and five anterior to it. In *N. subnodosus* ribs are evenly distributed in right valves.

Holocene *N. nodosus* from Margarita Island, Venezuela, have more bulbous or flared nodes and coarser striate, lirate macrosculpture. Differences are slight between less nodose individuals of the two species, as would be expected for two closely related taxa.

Fossil specimens of *N. subnodosus* are separated from *Lyropecten modulatus* by left-valve node scheme and rib count (10 ribs, N 2r N_c 2r N in *L. modulatus*). Poorly preserved right valves are harder to separate, but *L. modulatus* has 11-12 ribs grouped around a wider central space and the ribs of *N. subnodosus* are arranged evenly.

Phylogenetic affinities.—*Nodipecten subnodosus* is directly descended from the Caribbean cognate *N. nodosus* or its immediate ancestor, *N. collierensis*.

The relation of *N. subnodosus* to *N. arthriticus* is unclear. Holocene specimens of *N. arthriticus* and *N. subnodosus* are identical except for a slight but consistent difference in all but a few individuals in left-valve node schemes and rib counts differing by one. Intermediate morphologic forms document the evolution of *N. subnodosus* from the Caribbean *N. collierensis-N. nodosus* lineage; morphologic and distributional data suggest *N. arthriticus* may have evolved by genetic mutation from *Lyropecten modulatus*.

Geographic distribution and stratigraphic records.—Gulf of California and west coast of Baja California Sur as far north as Guerrero Negro and Cedros Island. Anomalous occurrences in 1963 and 1967 off Santa Catalina Island, Calif.; also from Clarion Island and Cocos Island.

Holocene.—Off the east coast of Cedros Island in 30-90 ft on sandy bottoms (J.H. McLean, written commun., 1972) and from bays and lagoons in western Baja Califor-

nia Sur (SDSNH 10493). Common as beach drift off islands in the western Gulf of California; especially abundant at La Paz. Juveniles from San Jose Island (SDMNH 31245); Angel de la Guarda Island (SDMNH 31251; CAS 49009). One juvenile taken live from 3 mi off Clarion Rock in 55 fathoms (CAS 17789). Two disarticulated valves from 66 fathoms near Cocos Island (USNM 122863). Not from the Tres Marias Islands to Negritos, Peru (= *N. arthriticus*). Old museum collections contain some mixed lots that confuse true distributions.

Holocene middens: Amortajada Bay, San Jose Island, abundant in 20 ft thick shell middens (Emerson, 1960b). Along west end of San Luis Gonzaga Bay (Coan, 1965). Early reconnaissance workers (Beal, 1948, among others) noted middens from sea level to elevations as much as 1,200-2,300 ft. Formerly interpreted as Pleistocene terraces, many are now considered middens from at least 1,000 years B.P. (Emerson, 1960b).

Holocene to Pleistocene: El Pulpito (CAS 34614; LSJU accession nos. 53263, 52250).

Representative fossil localities.—Not from Pleistocene upper part of the San Pedro Formation of Deadmans Island, San Pedro, Calif. as noted by Arnold (1906) and Grant and Gale (1931). Not from the Pliocene of Imperial County, Calif. [= *Lyropecten tiburonensis*, n. sp.].

Pleistocene, mainly terrace deposits:

Pacific Coast of Baja California Sur: Cedros Island (Dall, 1898), Magdalena Bay (Jordan, 1924), Punta Conejo (CAS 38742).

Northern Gulf of California: Isla Angel de la Guarda, in terrace deposits overlain by lava flow (UCMP A-3591); Isla Salsipuedes (SDSNH 631); Punta Libertad, Sonora (CAS 28185, CAS 54534, CAS 60566); Isla Tiburon, southeast side (CAS 55066).

Southern Gulf of California: Santa Rosalia (LSJU accession no. 53284); Isla San Marcos (UCMP A-3571); near Mulege (CAS 38856, from 10 m terrace; LSJU 805, UCMP A-3582); Isla Coronado (CAS 796, CAS 27273, from tuff on beach); Isla Carmen, Ballandra Bay (CAS 34165); Isla Monserrate (CAS 38554); Isla San Jose, many disarticulated valves from 122 m terrace; La Paz area, 17 km northeast of town (CAS 32944).

Middle and upper Pliocene, western Gulf of California:

San Felipe, Baja California, 12 mi west of town in the eastern Sierra San Felipe (San Diego State University loc. SD 29-BGG) and west of the northern Sierra Santa Rosa (M9040).

Santa Rosalia area (Wilson, 1948; Wilson and Rocha, 1955), Infierno Formation, upper Pliocene. Tirabuzon Formation (=Gloria Formation of Wilson, 1948), middle Pliocene, Arroyo de la Soledad (abundant from CAS 56503), Arroyo del Boleo, (CAS 56507, near top of claystone member). Present at Loma del Tirabuzon (Corkscrew Hill, seacliff north of the mouth of Arroyo de Purgatorio, = LACMIP loc. 4828; M9035), which is lower Pliocene to middle Pliocene in the basal and middle sections, upper Pliocene to Pleistocene at the top, found with planktonic foraminifers indicating an open-marine environment and depths of 200-500 m (Carreño, 1981, 1982; Smith, 1989). Arroyo de Santiago (CAS 56524, Dowlan locality B 2D-6, specimens large for Gulf material, 12.3 cm high); north of Loreto (CAS 56564; M9065).

Isla Carmen and Arroyo de Arce (M9045), near Loreto, Baja California Sur, Carmen and Marquer Formations, undifferentiated, Pliocene (Durham, 1950); Marquer Bay, in calcareous sands (UCMP A-3517, A-3521; in *Pecten*-oyster bed at UCMP A-3524; CAS 38963).

Isla San Jose, Pliocene at Arroyo Aguada (CAS 27274, 38548, 38967). Isla Cerralvo (CAS 39408, found with *N. arthriticus*).

Uncertain occurrence, Rancho El Refugio (CAS 39411, a right valve).

Geologic age.—Middle Pliocene to Holocene.

Ecology.—Low tide-110 m, mostly offshore, taken by Scuba divers or shrimp trawlers.

Juveniles taken live from 36 m off Carmen Island (SDSNH 31222). Elsewhere in the Gulf of California from 5-10 m near Mulege (collected by J.G. Vedder) and at 6 m in shallow depressions at Punta Colorado, Guaymas (UCLA 23795). Intertidal to 3 m at Bahía de Los Angeles (LACM 60-12) at the village and small offshore islands. From 25 fathoms off Angel de la Guarda Island (USNM 765008).

Observations by Scuba divers at Cedros village indicate that the species reclines, left valve upwards, in circular depressions on sand in 30-90 ft depths. They are not gregarious and were spaced no closer than 6 m apart (James H. McLean, oral commun., 1973).

Although they are not sufficiently abundant for commercial fishing, they have always been collected and eaten when available, as seen from the middens. Leo Pinkus collected many large individuals from Guerrero Negro and Ojo de Liebre (Scammon) lagoons in 0.5-15 ft of water, some very large specimens from 1-3 ft at very low tide.

Strachan and others (1968) of the California Fish and Game Department reported anomalous occurrences of live adults far north of their normal range, off Santa Catalina Island, Calif. in 6-9 m on open sand (1967) and in 37 m off Long Point (1963).

Nodipecten veatchii (Gabb, 1866)

Plate 14, figure 8; plate 15, figures 5, 6

1866. *Pecten veatchii* Gabb, Paleontology of California, v. 2, p. 32-33; 1869, pl. 10, fig. 56.

1931. *Pecten* (*Lyropecten*) *nodosus* (Linnaeus) var. *veatchii* Gabb. Grant and Gale, San Diego Society of Natural History Memoir, v. 1, p. 182.

Holotype.—UCMP 12078, a two-valved adult, 12.8 cm high, 14 cm long from a hard matrix of limy sandstone with rounded pebbles.

Type locality.—East side of Cedros Island, off western Baja California Sur, Mexico. Holotype and matrix resemble material collected by subsequent workers from pebble conglomerate near Arroyo Choyal, about 9 mi north of the village of Cedros. Age given as "probably Miocene" (Gabb, 1866); field checks for this study suggest it is late Miocene in age but in places it is reworked in Pliocene deposits.

Description.—Valves equally convex, length slightly greater than height; almost always with four or five ledges. Beaks project equally above hinge line. Auricles subequal, with seven or eight costae; byssal notch moderately deep. Hinge line equal to half shell length. Umbonal angle 96-100°. Right valves with six ribs, four strongly paired and one or two marginal riblets arranged on either side of a very wide central space. Four to five ledges common in individuals as much as 6 cm high, zero to several more in later growth stages. Ledges are rounded in right valves, angular and steplike in left valves. Left valves with 6-7 unpaired ribs that alternate between narrow and wide, the broadest rib in the central position. Wider left-valve ribs with prominent hollow nodes in the pattern r N r N_c r N r. Adults range as large as 13.5 cm high, 14.5 cm long, and 8 cm in hinge length.

Variability.—Rib counts vary with prominence of incipient marginal ribs. Development of nodes and ledges vary as in Holocene specimens of *N. nodosus*, *N. arthriticus*, and *N. subnodosus*.

Comparative notes.—Nodipecten veatchii has the same fine lirate striate macrosculpture but a lower rib count than *N. subnodosus*; the latter lives today in western Baja California and in the Gulf of California. Flat, rectangular ribs and spaces are very wide in *N. veatchii*; right-valve ribs are strongly paired. Its characteristic *Nodipecten* left-valve scheme, . . N r N_c r N . . , low rib count and presence of hollow nodes distinguish it from *Lyropecten gallegosi* and *L. modulatus* which are found with it.

Phylogenetic affinities.—Nodipecten veatchii is a cognate of *N. peedeensis* from the Carolina coastal plain. It is morphologically closest to Nodipectens from the Gulf of Mexico and Florida, forms referred here to *N. fragosus*. It may represent a relict of the Tertiary Caribbean Province, although it is unknown from Panama and the Caribbean islands.

Geographic distribution and stratigraphic occurrence.—Restricted to Cedros Island and the Vizcaino Peninsula, Baja California Sur, from the Almejas Formation and younger reworked deposits on Cedros Island. Not from the Saugus Formation (Kew, 1924; Woodring, 1930).

Cedros Island, east coast. Northern section: from small canyon south of Arroyo Choyal, about 9 mi north of the town of Cedros (CAS 946) where it is found with *Lyropecten gallegosi* and *L. modulatus* in coarse pebble to cobble conglomerate. Southern section: abundant in conglomerate exposed in canyon south of main part of town of Cedros ("Arroyo de los Puercos," LSJU 806, CAS 928, FK-53). It occurs with *Swiftopecten parmeelei*, a Pliocene index species that is also in the Jacalitos Hills, Fresno County, Calif. (Stanton and Dodd, 1976). Also in *Pecten*-algal beds (UCMP D-795) and in the "*Laqueus* zone" cropping out at mouth of "Brachiopod Canyon" (Frank Kilmer, oral commun., 1973). Tertiary marine strata at Cedros Island have not been assigned a formal name, but the conglomeratic facies is probably a turbidite or channel deposit; it has many of the pectinids found in the Almejas Formation at Turtle Bay. The fossils are oriented randomly in the very coarse, loosely consolidated matrix (fig. 16). On the basis of mollusks, the northern section is considered slightly older than the southern section.

Turtle Bay, Vizcaino Peninsula. North of town (CAS 27258; UCMP B-3014). The Pliocene rocks of Jordan and Hertlein (1926) are now considered to be the upper Miocene Almejas Formation (Smith, 1984). Also from Asuncion, in coarse-grained yellowish sandstones with *Turritella*, barnacles, and pectinid fragments (Smith field check, 1979).

Geologic age.—Late Miocene to earliest Pliocene (probably reworked in the Pliocene).

Biostratigraphy.—Equivalent to the upper "Margaritan" and "Jacalitos" Stages of California; age is based upon contemporaneous Lyropectens.

***Nodipecten veracruzensis* n. sp.**

Plate 14, figures 2, 3, 4, 6, 7

Holotype.—USNM 334986, a left valve measuring 6.9 cm high, 7 cm long.

Paratypes.—Universidad Nacional Autonoma de Mexico, a right valve of a late juvenile 4.6 cm high, 4.7 cm long; USNM 334985, a right valve 5.3 cm high, 5.6 cm long; UCMP 37398, 334985; also in the collections at CAS and LACMIP, all disarticulated valves.

Type locality.—Veracruz, Mexico, southeast of Coatzocoalcos. Along Mexican Highway 180, 14 mi east of junction with side road into Coatzocoalcos. Third cut on north side of road, in very coarse quartz yellow-brown sandstone (TU 638, collectors, Harold and Emily Vokes). Agueguexite Formation, middle Pliocene, zone N 20 (Akers, 1974, 1979).

Description.—Valves flat to slightly convex, nearly circular in outline; beaks do not project beyond hinge line. Anterior auricles twice as long as posterior auricles, both with five or more radials. Byssal notch shallow; hinge line slightly less than shell length. Umbonal angle 88-93°, varying with shell convexity. Right valves with 6-8 strongly paired ribs ornamented by fine radials and concentric

growth lines. Some individuals with transverse laminae that obscure the radial macrosculpture. Concentric growth lines in juvenile interspaces give way to radial threads in adults. Left valves with six or seven very low, rounded-rectangular ribs of alternating widths described by the *Nodipecten* scheme N r N_c r N. Juveniles as much as 2 cm high commonly have incipient nodes on alternate ribs; most specimens have 0-2 generations of nodes. The largest individual measured 9.4 cm high, 10 cm long (USNM 334984, from loc. TU 1046).

Variability.—The species is known from about 75 disarticulated individuals from two localities in Veracruz; they do not show significant morphologic variation. Most specimens are 5 cm high, inferred to be late juveniles or young adults. Juvenile rib profiles are higher than in adults. Ctenolia are not preserved in right valves over 5 cm high.

Comparative morphology.—The taxon approaches *N. veatchii* and *N. peedeensis* in rib count, macrosculpture, and rib spacing, but differs in lower rib profiles, lack of ledges and nodes, and smaller size. The morphologic characters of *N. veracruzensis* are seen in some variants of the Holocene Florida *Nodipecten, N. fragosus*, which is rare off the Yucatan Peninsula (USNM 715050, TU R-84). One of these, USNM 715050, has similar paired ribs and transverse laminae in juvenile interspaces, but it is distinguished by rib count: *N. veracruzensis* has 6 ribs, *N. fragosus* has 6-8, the anterior- and posterior-most riblets being narrow. Anterior and posterior edges of *N. veracruzensis* have underdeveloped or incipient riblets, if any.

Phylogenetic affinities.—Nodipecten veracruzensis is younger than the oldest Gulf of Mexico *Nodipecten fragosus*. Valve proportions, small number of ribs, and fine reticulate microsculpture ally it with the Tertiary Caribbean cognates *N. veatchii* from Baja California Sur, Mexico and *N. peedeensis* from the Carolinas. The central space on right valves has transverse laminae as in *N. peedeensis* and *N. fragosus*.

Geographic distribution and stratigraphic occurrences.—Southern Mexican Coastal Plain, southeastern Veracruz (TU 638, 1046), in a lower yellow facies and also in an upper grey facies at TU 638. It was unknown at the time other Agueguexite Formation mollusks were described by Perrilliat (1963), who regarded those assemblages as late middle Miocene in age.

Geologic age.—Middle Pliocene; planktonic foraminiferal zone upper N 20 at TU 638 and TU 1046 (W.H. Akers, written commun., 1981).

LOCALITY DATA

Institutions are arranged alphabetically by their abbreviations, localities in numerical order by institution. Since many collections are old, modern quadrangles and landmarks are added for clarity and ease in relocating. Formation names are updated for localities in remapped areas; sources of these data are shown in parenthesis.

Numbering systems changed over the years at several repositories. U.S. National Museum localities and U.S. Geological Survey, Washington, D.C. numbers were once recorded separately, some as USGS, others as USNM localities; they are combined in this list. Stanford University (LSJU) maintained several numbering systems, listed here separately as localities, Stanford Geological Survey numbers (from summer geology classes), and accession numbers assigned to particular specimens in the general collection. The Stanford material is now at the Department of Invertebrate Biology and Paleontology, California Academy of Sciences, San Francisco, and the old numbers are kept to avoid further confusion.

California counties, mountain ranges, and other geographic features referred to in the locality data are shown in figure 18; California and Baja California quadrangles are listed in table 6.

ABBREVIATIONS OF INSTITUTIONS

AMNH	American Museum of Natural History, New York
ANSP	Academy of Natural Sciences of Philadelphia
BM(NH)	British Museum (Natural History)
CAS	California Academy of Sciences, San Francisco
CSUN	California State University, Northridge
FMNH	Field Museum of Natural History, formerly Chicago Natural History Museum
LACMIP	Los Angeles County Museum of Natural History, Department of Invertebrate Paleontology
LSJU	Leland Stanford Junior University (Stanford University)
MCZ	Museum of Comparative Zoology, Harvard University
NMB	Naturhistoriches Museum, Basel, Switzerland
PRI	Paleontological Research Institution, Ithaca, New York
SDSNH	San Diego Society of Natural History
TU	Tulane University, New Orleans, Louisiana
UCLA	University of California, Los Angeles
UCMP	University of California, Berkeley, Museum of Paleontology
UCR	University of California, Riverside
UCSB	University of California, Santa Barbara
UNAM	Universidad Nacional Autónoma de México, Instituto de Geología, México, Distrito Federal
USNM	U.S. National Museum of Natural History, Washington, D.C.
USGS	U.S. Geological Survey, Washington, D.C. register
USGS M	U.S. Geological Survey, Menlo Park, California, Cenozoic register
WFIS	Wagner Free Institute of Science, Philadelphia

CAS LOCALITIES, CALIFORNIA ACADEMY OF SCIENCES, GOLDEN GATE PARK, SAN FRANCISCO, CALIF.

CAS 53 San Luis Obispo County, Calif., La Panza 15-minute quadrangle. About ½ mi southeast of the La Panza Post Office. Along west side of SE¼ sec. 36, T. 29 S., R. 16 E,. near top of a small hill. Miocene, Vaqueros Formation, Painted Rock Sandstone Member.

CAS 69 Kern County, Calif., Rio Bravo Ranch 7½-minute quadrangle. South and west slopes of Pyramid Hill, 4 or 5 mi north of powerplant on the Kern River; 15 mi northeast of Bakersfield. Miocene.

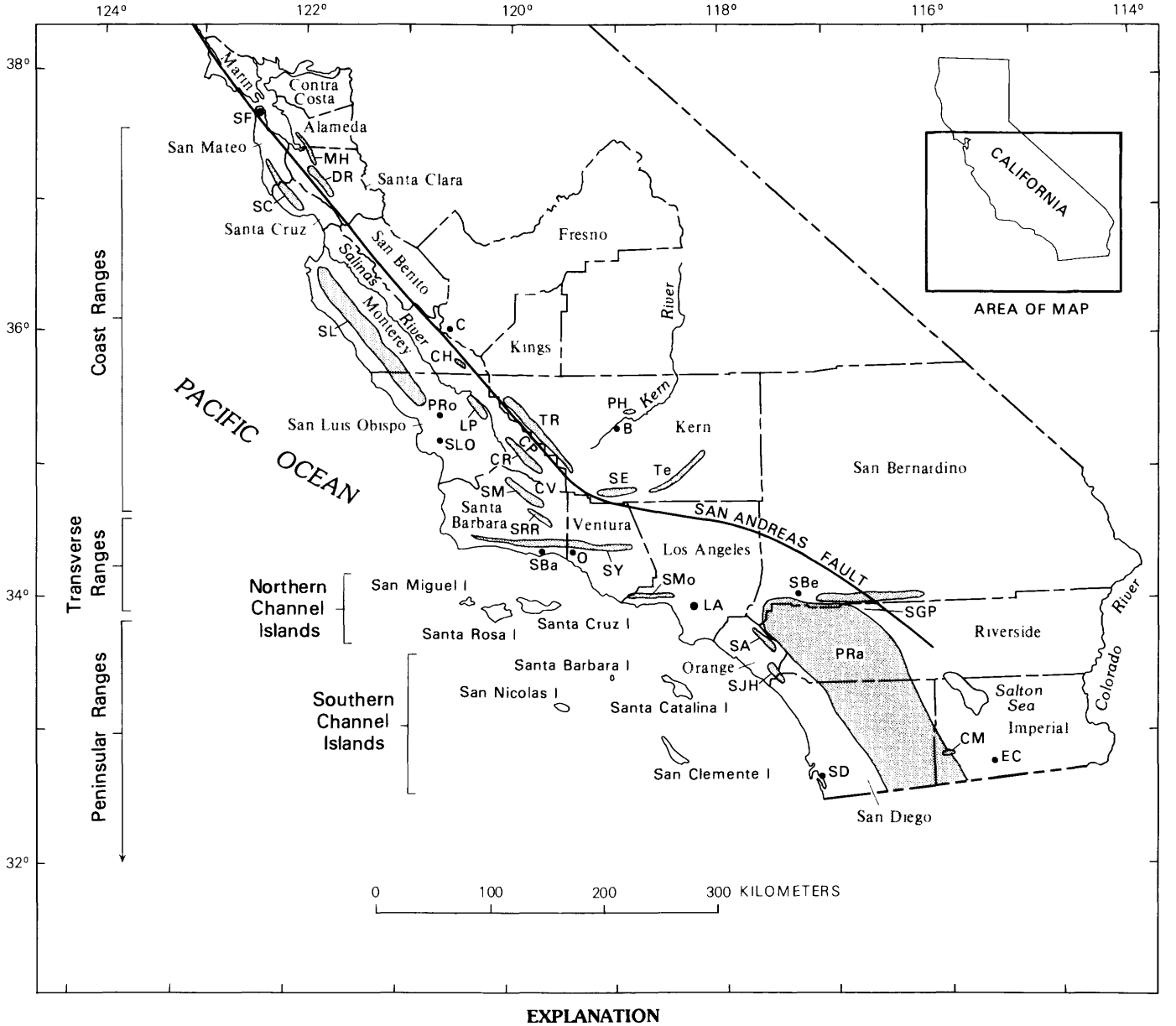
CAS 467 Monterey County, Calif., San Ardo 15-minute quadrangle. 1½ mi north of San Ardo. Miocene, Pancho Rico Formation.

CAS 503 Fresno County, Calif., Joaquin Rocks 15-minute quadrangle. Near Kimball's Wells, Coalinga. NW¼ sec. 20, T. 18 S., R. 14 E. Miocene, Santa Margarita Formation.

CAS 504 Fresno County, Calif., Domengine Ranch 7½-minute quadrangle. West side of sec. 29, T. 18 S., R. 15 E. Miocene, Santa Margarita Formation.

CAS 507 Fresno County, Calif., Domengine Ranch 7½-minute quadrangle. Anticline Ridge, northeast of Coalinga. Sec. 34, T. 19 S., R. 15 E. Miocene, Santa Margarita Formation.

CAS 683 Imperial County, Calif., Carrizo Mountain 7½-minute quadrangle. Coyote Mountain, "Gypsum Canyon," second



EXPLANATION

B	Bakersfield	LA	Los Angeles	SBa	Santa Barbara	SL	Santa Lucia Range
C	Coalinga	LP	La Panza Range	SBe	San Bernardino	SLO	San Luis Obispo
CH	Cholame Hills	MH	Mount Hamilton Range	SC	Santa Cruz Mountains	SM	Sierra Madre Mountains
CM	Coyote Mountains	O	Ojai	SD	San Diego	SMo	Santa Monica Mountains
CP	Carrizo Plain	PH	Pyramid Hill	SE	San Emigdio Range	SRR	San Rafael Range
CR	Caliente Range	PRa	Peninsular Ranges	SF	San Francisco	SY	Santa Ynez Range
CV	Cuyama Valley	PRo	Paso Robles	SGP	San Gorgonio Pass	Te	Tehachapi Mountains
DR	Diablo Range	SA	Santa Ana Mountains	SJH	San Joaquin Hills	TR	Temblor Range
EC	El Centro						

FIGURE 18.—Map showing California counties, mountain ranges, and islands cited in locality data.

TABLE 6.—*California and Baja California quadrangles cited in locality data*

[Coordinates are given for the southeast corner of each map. Out of print quadrangles are available on microfiche from the U.S. Geological Survey; field notebooks containing old locality data are on file at the California Academy of Sciences and Stanford University]

California	
Adelaida 15′	35°30′00″ N., 120°45′00″ W.
Arvin 7½′	35°07′00″ N., 118°45′00″ W.
Big Basin 7½′	37°07′30″ N., 122°07′30″ W.
Big Pine Mountain	34°37′30″ N., 119°37′30″ W.
Bradley 15′	35°45′00″ N., 120°45′00″ W.
Briones Valley	37°52′30″ N., 122°07′30″ W.
Bryson 15′	35°45′00″ N., 121°00′00″ W.
Calabasas 7½′	34°07′30″ N., 118°37′30″ W.
California Valley	35°15′00″ N., 120°00′00″ W.
Camatta Ranch 7½′	35°22′30″ N., 120°15′00″ W.
Camulos 30′ of SGS 1920	34°00′00″ N., 118°30′00″ W.
[SGS 1920 locality A24 is in present Santa Susana 7½′ quadrangle, 34°15′00″ N., 118°37′30″ W.]	
Carneros Rocks 7½′	35°22′30″ N., 119°45′00″ W.
Carrizo Mountain 7½′	32°45′00″ N., 116°00′00″ W.
Cayucos 15′	35°15′00″ N., 120°07′30″ W.
Chimineas Ranch 7½′	35°07′30″ N., 119°52′30″ W.
Cholame 7½′	35°37′30″ N., 120°15′00″ W.
Cholame Valley 7½′	35°45′00″ N., 120°15′00″ W.
Coalinga 15′	35°00′00″ N., 120°15′00″ W.
Concord 15′	37°45′00″ N., 122°00′00″ W.
Cone Peak 7½′	36°00′00″ N., 121°22′30″ W.
Corona South 7½′	33°45′00″ N., 117°30′00″ W.
Cuyama Ranch 7½′	34°52′30″ N., 119°37′30″ W. [= present New Cuyama 7½′]′
Cypress Mountain	35°30′00″ N., 120°52′00″ W.
Dana Point 7½′	33°22′30″ N., 117°37′30″ W.
Domengine Ranch 7½′	36°15′00″ N., 120°15′00″ W.
Eagle Rest Peak 7½′	34°52′30″ N., 119°07′30″ W.
El Toro 7½′	33°37′30″ N., 117°37′30″ W.
Fellows 7½′	35°07′30″ N., 119°30′00″ W.
Felton 7½′	37°00′00″ N., 122°00′00″ W.
Fox Mountain 7½′	34°45′00″ N., 119°30′00″ W.
Garza Peak 7½′	35°52′30″ N., 120°07′30″ W.
Gaviota 7½′	34°22′00″ N., 120°07′30″ W.
Grapevine 7½′	34°52′30″ N., 118°52′30″ W.
Greenfield 15′	36°15′00″ N., 121°00′00″ W.
Hernandez Valley 15′	36°15′00″ N., 120°45′00″ W.
Imperial Beach, Calif.—Baja California Norte	32°30′00″ N., 117°00′00″ W.
Joaquin Rocks 15′	36°15′00″ N., 120°15′00″ W.
Junipero Serra 15′	36°00′00″ N., 121°15′00″ W.
King City 15′	36°00′00″ N., 121°00′00″ W.
Knob Hill 7½′	35°30′00″ N., 118°52′30″ W.
La Costa Valley 7½′	37°30′00″ N., 121°45′00″ W.
La Jolla	32°45′00″ N., 117°07′30″ W.
La Panza 15′	35°15′00″ N., 120°00′00″ W.
Laguna Beach 7½′	33°30′00″ N., 117°45′00″ W.
Las Yeguas Ranch 7½′	35°22′30″ N., 119°52′30″ W.
Lime Mountain 7½′	35°37′30″ N., 120°52′30″ W.
Lion Canyon 7½′	34°20′00″ N., 119°07′30″ W.
Livermore 15′	37°30′00″ N., 121°45′00″ W.
Lompoc 15′	34°30′00″ N., 120°15′00″ W.
Los Olivos 15′	34°30′00″ N., 120°00′00″ W.
Malibu Beach 7½′	34°00′00″ N., 118°37′30″ W.
Mare Island 7½′	38°00′00″ N., 112°15′30″ W.
Matilija 7½′	34°22′30″ N., 119°15′00″ W.
Mint Canyon 7½′	34°22′30″ N., 118°22′30″ W.
Miranda Pine Mountain 7½′	35°00′00″ N., 120°00′00″ W.
Moorpark 7½′	34°15′00″ N., 118°52′30″ W.
Morro Bay North 7½′	35°22′30″ N., 120°45′00″ W.
Mount Hamilton 15′	37°15′00″ N., 121°30′00″ W.
National City	32°37′30″ N., 117°00′00″ W.
New Cuyama 7½′	34°52′30″ N., 119°37′30″ W.
Newhall 7½′	34°22′30″ N., 118°30′00″ W.
Nipomo 15′	35°00′00″ N., 120°15′00″ W.
Oil Center 7½′	35°22′30″ N., 118°52′30″ W.
Ojai 7½′	34°22′30″ N., 119°07′30″ W.
Orchard Peak 15′	35°30′00″ N., 120°00′00″ W.
Packwood Creek 7½′	35°30′00″ N., 120°00′00″ W.
Painted Gorge 7½′	32°45′00″ N., 115°52′30″ W.
Panorama Hills 7½′	35°07′30″ N., 119°37′30″ W.
Paraiso Springs 7½′	36°15′00″ N., 121°15′00″ W.
Pico 7½′	34°18′00″ N., 118°36′00″ W. [= E½ present Santa Susana 7½′]
Pismo Beach 7½′	35°07′30″ N., 120°37′30″ W.
Plaster City 15′	32°45′00″ N., 115°45′00″ W.
Pleito Hills 7½′	34°52′30″ N., 119°00′00″ W.
Point Dume 7½′	34°00′00″ N., 118°45′00″ W.
Pozo 15′	35°15′00″ N., 120°15′00″ W.
Priest Valley 15′	36°00′00″ N., 120°30′00″ W.
Rio Bravo Ranch 7½′	35°22′30″ N., 118°45′00″ W.
Sacate 7½′	34°22′30″ N., 120°15′00″ W.
Salisbury Potrero 7½′	34°45′00″ N., 119°37′30″ W.
San Ardo 15′	36°00′00″ N., 120°45′00″ W.
San Clemente Island Central 7½′	32°50′00″ N., 118°27′30″ W.
San Clemente Island North 7½′	32°57′30″ N., 118°30′00″ W.
San Clemente Island South 7½′	32°47′30″ N., 118°20′00″ W.
San Fernando 7½′	34°15′00″ N., 118°22′30″ W.
San Gregorio 7½′	37°15′00″ N., 122°45′00″ W.
San Juan Capistrano 7½′	33°30′00″ N., 117°37′30″ W.
San Lucas 7½′	36°07′30″ N., 121°00′00″ W.
San Miguel 15′	35°45′00″ N., 120°30′00″ W.
San Simeon 15′	35°30′00″ N., 121°00′00″ W.
Santa Catalina Island North 7½′	33°30′00″ N., 118°22′30″ W.
Santa Catalina Island South 7½′	33°15′00″ N., 118°22′30″ W.
Santa Cruz Island A 7½′	33°57′30″ N., 119°50′00″ W.
Santa Rosa Island East 7½′	33°53′30″ N., 119°55′00″ W.
Santa Rosa Island West 7½′	33°53′30″ N., 120°10′00″ W.
Santa Susana 7½′	34°15′00″ N., 118°37′30″ W.
Shale Point 7½′	35°30′00″ N., 119°52′30″ W.
Shandon 15′	35°30′00″ N., 120°15′00″ W.
Shedd Canyon 7½′	35°30′00″ N., 120°22′30″ W.
Simi 7½′	34°15′00″ N., 118°45′00″ W.
Stockdale Mountain 7½′	35°52′30″ N., 120°30′00″ W.
Tejon Ranch 7½′	35°00′00″ N., 118°37′30″ W.
Tesla 15′	37°30′00″ N., 121°30′00″ W.
Tierra Redonda Mountain 7½′	35°45′00″ N., 120°52′30″ W.
Topanga 7½′	34°00′00″ N., 118°30′00″ W.
Warm Springs Mountain 7½′	34°30′00″ N., 118°30′00″ W.
Wells Ranch 7½′	35°00′00″ N., 119°37′30″ W.
Wheeler Springs 7½′	34°30′00″ N., 119°15′00″ W.
Whitewater 7½′	33°52′30″ N., 116°37′30″ W.
Zaca Lake 7½′	34°45′00″ N., 120°00′00″ W.

Baja California, Mexico	
Bahía Tortugas, G11G27, 1:50,000	27°30′00″ N., 114°40′00″ W.
Jesus Maria, G12A54, 1,50,000	26°45′00″ N., 112°40′00″ W.
Loreto, G12A88, 1:50,000	26°00′00″ N., 111°20′00″ W.
San Isidro, G12A86, 1:50,000	26°00′00″ N., 112°00′00″ W.
Santa Agueda, G12A35, 1:50,000	27°15′00″ N., 112°20′00″ W.
Santa Clara, H11B46, 1:50,000	31°00′00″ N., 115°00′00″ W.
Santa Rosalía, G12A36, 1:50,000	27°15′00″ N., 112°00′00″ W.

canyon east of Alverson Canyon. Miocene, Imperial Formation, Latrania Sands Member of Keen and Bentson (1944) (Collector, G D. Hanna, 1921).

CAS 796 Gulf of California, Mexico. Coronado Island, just north of Loreto, Baja California Sur; from southwest point of island in 40-50 ft fossiliferous section. Pliocene (Hanna and Hertlein, 1927).

CAS 928 Baja California Sur, Mexico. Cedros Island, southeast shore near Bernstein's abalone camp [= town of Cedros]. Pliocene, possibly includes reworked Miocene. (Collector, G D. Hanna, 1922; = CAS 753).

CAS 937 Tres Marias Islands, east of Cabo Corrientes, Mexico. Northeast end of Maria Madre Island, in Arroyo Hondo. First exposure upstream from mouth of arroyo. Pliocene, unnamed beds (collector, E.K. Jordan, Revillagigedo expedition, 1925).

CAS 943 Baja California Sur, Mexico. Turtle Bay area, 1-2 mi southeast of bay at prominent monadnock. Miocene (Tortugas Formation of collectors Hanna and Jordan; = Almejas Formation).

CAS 946 Baja California Sur, Mexico. Cedros Island, east side. 9 mi north of Bernstein's abalone camp [= town of Cedros], near Arroyo Choyal. About 3 mi north of Gran Cañon. Miocene, turbidites or reworked beds with fossils equivalent to those of the Almejas Formation at Turtle Bay.

CAS 1150 Santa Rosa Island, Calif., Santa Rosa Island West 7½-minute quadrangle. North side of island, on beach 900 ft west of mouth of Arlington Canyon just northeast of mouth of Tecolote Canyon. Oligocene or Miocene, Vaqueros Formation, sandstone and shale facies (near UCSB loc. 67-57, FX 25-64).

CAS 1154 Santa Rosa Island, Calif. Oyster bed on slope of ridge down to San Augustine Canyon, between spring on top of ridge and *Turritella inezana* bed about 6 mi south of ranch house. Miocene, Vaqueros Formation.

CAS 1155 Santa Rosa Island, Calif. North-northwest of Ford Point, north and northwest of mouth of San Augustine Canyon. Top of ridge above San Augustine Canyon, east side about 6 mi south of ranch house. Miocene, Vaqueros Formation (collectors, L.G. Hertlein and E.L. Rixford, 1927).

CAS 1156 Santa Rosa Island, Calif. Southeast coast of Santa Rosa Island, west of East Point, east of Ford Point. About ¼ mi southeast of spring at CAS 1154. Miocene, Vaqueros Formation.

CAS 1413 San Diego County, Calif., La Jolla quadrangle. Pacific Beach, north of San Diego. Pliocene, lower beds exposed along beach.

CAS 1452 Kern County, Calif., Knob Hill 7½-minute quadrangle. North of Poso (= Ocoya) Creek, between Borel and Granite Canyons. 1,650 ft E., 660 ft N. of SW cor. sec. 13, T. 27 S., R. 28 E., in north-trending canyon. "Excellent exposure of zone B" and *Aturia* found here by collector, G D. Hanna, Nov., 1928, but no fossils found subsequently. Fossils exposed only rarely, after severe storms and erosion in the canyon. Miocene, Olcese Sand, upper part (Addicott, 1970b).

CAS 1677 Kern County, Calif., Tejon Ranch 7½-minute quadrangle. Comanche Point, at old water well. NW¼ sec. 25, T. 32 S., R. 30 E. Miocene, white fossiliferous sandstone with shells and bones (collectors, G D. Hanna and F.A. Menken, July, 1929).

CAS 2037 Fresno County, Calif., Joaquin Rocks 15-minute quadrangle. North of Coalinga, at Domengine Ranch. Sec. 29, T. 18 S., R. 14 E. Miocene, Santa Margarita Formation.

CAS 2363 Fresno County, Calif., Joaquin Rocks 15-minute quadrangle. Domengine Ranch 7½-minute quadrangle. Sec. 29, T. 18 S., R. 15 E. Miocene, Santa Margarita Formation.

CAS 12139 Sucre, Venezuela. 1¾ mi east of Castle Cumana. Pliocene or Pleistocene. (collector, Caribbean Petroleum Co., loc. 1185).

CAS 17789 Clarion Island, off West Mexico. 3 mi off Pyramid Rock, at 55 fathoms depth. Holocene.

CAS 26257 Santa Barbara County, Calif., Los Olivos 15-minute quadrangle. Ridge ¼ mi northeast of Las Cruces. Eocene, Sacate or Gaviota Formations of Dibblee (1950).

CAS 27255 Galapagos Islands. James Island, James Bay, about 15-20 ft above base of cliffs, on black lava flow. Pleistocene, raised beach (collector, L.G. Hertlein, 1932).

CAS 27258 Baja California Sur, Mexico. North side of Turtle Bay. Miocene, Almejas Formation.

CAS 27273 Gulf of California, Mexico. Coronado Island, north of Loreto. In tuff on beach, south side of island (collector, S.A. Glassell, Dec., 1931).

CAS 27274 Gulf of California, Mexico. San Jose Island. Pliocene or Pleistocene, strata at 400 ft elevation.

CAS 27625 Kern County, Calif., Carneros Rocks 7½-minute quadrangle. Temblor Range, near mouth of Carneros Creek. SE cor. sec. 31, T. 28 S., R. 20 E. Oligocene, Temblor Formation, Wygal Sandstone Member [= Phacoides sand of local usage].

CAS 27773 Kern County, Calif., Las Yeguas Ranch 7½-minute quadrangle. Temblor Range, east of Devilwater Creek. N sec. 16, T. 28 S., R. 19 E. Miocene, Temblor Formation, Buttonbed Sandstone Member.

CAS 28030 Los Angeles County, Calif., Pico quadrangle, 1934 ed. 1,925 ft N. 56° E. of SW cor. sec. 25, T. 3 N., R. 17 W. Pliocene, Pico Formation.

CAS 28185 Sonora, Mexico. Punta [= Puerto] Libertad, east of Cabo Lobos, about 120 mi northwest of Hermosillo. Pleistocene, coarse-grained pebble conglomerate.

CAS 28473 Monterey County, Calif., Stockdale Mountain 7½-minute quadrangle. Cholame Hills, between Indian Valley and Portuguese Canyon. West central part of SW¼SE¼ sec. 6, T. 23 S., R. 13 E. Miocene, Santa Margarita Formation.

CAS 29395 Fresno County, Calif., Domengine Ranch 7½-minute quadrangle. South bank of Domengine Creek near N¼ cor. sec. 33, T. 18 S., R. 15 E. Miocene, Santa Margarita Formation, *Pecten-Ostrea titan* reef.

CAS 31524 Monterey County, Calif., Junipero Serra 15-minute quadrangle. Los Vaqueros Valley, 800 ft W., 1,750 ft N. of SE cor. sec. 4, T. 20 S., R. 6 E. Late Oligocene or early Miocene. Vaqueros Formation (type locality) (collector, R. Thorup, July, 1941).

CAS 32038 Falcon, Venezuela. Near Río Seco, about 4 km southeast of Río Seco-La Montanita uplift. Some fossils from near Urumaco, about 18 km S., 4 km W. of Río Seco. Late Miocene.

CAS 32944 Baja California Sur, Mexico. La Paz peninsula, 11 mi northeast of La Paz, in low sea cliffs 30 ft above high tide. ½ mi east of mouth of Arroyo del Coyote, southeast of Punta Coyote. Pliocene or Pleistocene.

CAS 32946 Baja California Sur, Mexico. East of Santiago, west of Punta Colorado. About 2 mi southeast of La Rivera, 1 mi from the coast. Pliocene, limy sandstone in side of *calera* [= lime kiln] (collector, E.H. Hammond, 1949).

CAS 34165 Gulf of California, Mexico. Carmen Island, Ballandra Bay. Pleistocene.

CAS 34614 Baja California Sur, Mexico. Punta Púlpito, south of San Ildefonso Island. Pleistocene or Holocene.

CAS 36409 Baja California Sur, Mexico. La Purisima area. 1½ mi N. 60° W. of La Purisima, from river level to 70 ft above. Early or early middle Miocene. White marly sandstone of Isidro Formation (collectors, Ira Wiggins and others, Dec. 27, 1958).

CAS 37626 Baja California Sur, Mexico. North end of Turtle Bay, San Bartholome Point. Miocene, Almejas Formation (collector, Anatole Loukashkin, 1961).

CAS 37630 Baja California Sur, Mexico. Punta Púlpito, between Bahía San Nicholas and Bahía San Basilio. Pleistocene, thick fossiliferous layer extending ¼ mi along beach.

CAS 38543 Gulf of California. Cerralvo [Ceralbo of old labels] Island, west side. Pliocene (collector, Ira Wiggins, 1962).

CAS 38548 Gulf of California, Mexico. San Jose Island. Arroyo de la Aguada, elevation 530 ft. Pliocene (collector, Ira Wiggins, 1962).

CAS 38554 Gulf of California, Mexico. Monserrate Island, west side. Pleistocene.

CAS 38686 San Mateo County, Calif., San Gregorio 7½-minute quadrangle. Pescadero Beach, about 1.4 mi south of mouth of Pescadero Creek. Miocene, Vaqueros Formation.

CAS 38742 Pacific coast, Baja California Sur, Mexico. Cliffs halfway between Punta Conejo and Arroyo Conejo, nearly due west of La Paz. Pleistocene.

CAS 38792 Baja California Sur, Mexico. La Purisima area. On road 7.4 mi northeast of La Purisima (collector, Oliver Bowen, 1963).

CAS 38856 Gulf of California, Mexico. North end of Concepción Peninsula between Punta Aguja and Punta Concepción, from terrace 35 ft above sea level. Pleistocene.

CAS 38963 Gulf of California, Mexico. Carmen Island, near south end. Pliocene, Marquer Formation.

CAS 38967 Gulf of California, Mexico. San Jose Island, east shore, Arroyo Aguada. Pliocene or Pleistocene.

CAS 39408 Gulf of California, Mexico. Cerralvo [= Ceralbo of some workers] Island. West side of island, in sea cliffs south of arroyo and south of "Farallones Blancos," 125 ft above base of section. Pliocene, coarse-grained sandy matrix (collectors, G D. Hanna and J. Wyatt Durham, April 26, 1965).

CAS 39411 Baja California Sur, Mexico. Rancho El Refugio, about 17 km S. 30° E. from village of Santiago. On ridge top about 200 m east of ranch house. Silty and sandy beds striking N. 30° E., dipping 20-25° SE. (collector, J. Wyatt Durham, 1965, field loc. 1163).

CAS 40274 Tamaulipas, Mexico. San Fernando, in Río Conchos. Oligocene, Guajalote Formation (Gardner, 1945) [= San Rafael Formation or San Fernando Formation of early workers] (collector, T.F. Stipp, 1926).

CAS 40508 Tamaulipas, Mexico. San Fernando. Oligocene, Guajalote Formation (San Rafael Formation of collector, T.F. Stipp, 1926).

CAS 41034 Tamaulipas, Mexico. Near San Fernando, on the river. Oligocene, Guajalote Formation.

CAS 41039 Veracruz, Mexico. Hills north of Tuxpan. Oligocene, Tuxpan Formation (collectors, W.F. Cummins and Mr. [sic] Sands, 1909).

CAS 41040 Veracruz, Mexico. Papantla area, near Cazones River. Kilometer 32, "Cobos-Furbero Railroad" (C.F.R.R.). Oligocene, Tuxpan Formation.

CAS 41053 Tamaulipas, Mexico. San Fernando. Oligocene, Guajalote Formation (collector, W.F. Cummins, 1907).

CAS 41794 Tarpon Springs, Fla. Holocene specimens collected by sponge divers.

CAS 55066 Gulf of California, Mexico. Tiburon Island, Pleistocene.

CAS 56503 Baja California Sur, Mexico. Santa Rosalia area. South side of Arroyo de la Soledad. Middle Pliocene, Tirabuzon Formation (= Gloria Formation of early workers). In claystone beds, *fide* collector, T.E. Stump, 1976.

CAS 56507 Baja California Sur, Mexico. Santa Rosalia area. Arroyo del Boleo, road up canyon and about 3 km west, on a road leading to road-materials quarry. Up small hill immediately south of center of quarry, near hill's crest. Pliocene, Tirabuzon Formation exposed 250 yd west of hill. (Gloria Formation of collector T.E. Stump; = field No. B4S-138).

CAS 56524 Baja California Sur, Mexico. Santa Rosalia area, Cañada de Santiago. Pliocene, fossiliferous sandstone about 25 ft thick (collector, R. Dowlen, 1972, field No. B2D-6).

CAS 56564 Baja California Sur, Mexico. Loreto quadrangle, 1:50,000, G12A88. Arroyo San Juan [not Arroyo de Arce], about 100 yd north of northern wall of the arroyo and 70 ft up section. Up a side canyon. Pliocene, brown bioclastic sandstone, many internal molds (collector, T.E. Stump, field No. B4S-114).

CAS 56568 Baja California Sur, Mexico. Loreto quadrangle, 1:50,000, G12A88. North of Loreto, Arroyo San Juan [not Arroyo de Arce], about 1.4 mi north of northern wall of arroyo. Pliocene, sandstone interbed with abundant pectinids. (Collector, T.E. Stump, field No. B4S-119, shown in Stump, 1979, fig. 4).

CAS 56569 Baja California Sur, Mexico. North of Loreto on Mexican Highway 1. Arroyo San Juan [not Arroyo de Arce]. Over crest of small hill and about 50 ft above top of 30-ft-thick pectinid "reef." Up a side canyon off main branch of arroyo. (Collector, T.E. Stump, loc. B4S-116, shown in Stump, 1979, fig. 4).

CAS 60566 Sonora, Mexico. Sea cliff ¾ mi west of Puerto Libertad. Holocene.

CAS 61215 Gulf of California, Mexico. Tiburon Island, in northwest-trending arroyo about 5 km northeast of Punta Willard (collector, Gordon Gastil, 1973). [= USGS locality M9117.]

CALIFORNIA STATE UNIVERSITY, NORTHRIDGE LOCALITIES

CSUN 24 Los Angeles County, Calif., Malibu Beach 7½-minute quadrangle. Santa Monica Mountains; southwest of Saddle Peak, north side of Piuma Road. 2,400 ft E., 2,200 ft S. of NW cor. sec. 21, T. 1 S., R. 17 W.; elevation 1,925 ft. Miocene, Topanga Canyon Formation, Saddle Peak Member.

CSUN 62 Santa Barbara County, Calif., New Cuyama 7½-minute quadrangle. 3,200 ft W., 1,000 ft N. of SE cor. sec. 1, T. 9 N., R. 27 W. Miocene, hard white sandstone (collector, A.E. Fritsche, 1969).

CSUN 91 Santa Barbara County, Calif., Fox Mountain 7½-minute quadrangle. Sierra Madre Range, west of Santa Barbara Canyon; hill north of Rainbow Canyon. Miocene, Vaqueros Formation, Painted Rock Sandstone Member.

CSUN 92 Santa Barbara County, Calif., Fox Mountain 7½-minute quadrangle. Sierra Madre Range, west of Santa Barbara Canyon. Elevation 3,200 ft. Miocene, Branch Canyon Sandstone.

CSUN 261 Ventura County, Calif., Lion Canyon 7½-minute quadrangle. Upper Sespe Creek area, NW¼ sec. 36, T. 6 N., R. 22 W. Miocene, Vaqueros Formation, upper member (collector, A.E. Fritsche).

CSUN 263 Ventura County, Calif., Lion Canyon 7½-minute quadrangle. Los Padres National Forest, upper Sespe Creek area. NW¼NE¼ sec. 26, T. 6 N., R. 22 W. North of Sespe

Creek, west of Piedra Blanca Creek. Miocene, Vaqueros Formation, upper member (Squires and Fritsche, 1978).

LOS ANGELES COUNTY MUSEUM OF NATURAL HISTORY, INVERTEBRATE PALEONTOLOGY LOCALITIES

LACMIP 291 Los Angeles County, Calif., San Fernando 7½-minute quadrangle. Sand Canyon, center of S½ sec. 27, T. 4 N., R. 15 W. ½ mi S of Humphreys railroad station. Pliocene, Repetto Formation of former usage (Oakeshott, 1958, map).

LACMIP 305-C San Diego County, Calif., Imperial Beach quadrangle. Hills south of Tijuana River at Palm City, Calif. "K" Ranch, exactly 290 ft from the U.S.-Mexican border fence. Southwest of Goat Canyon, at base of hill 100 ft W., 440 ft S. of NE cor. sec. 8. Pliocene, San Diego Formation.

LACMIP 462 Kern County, Calif., Rio Bravo Ranch 7½-minute quadrangle. Southwest flank of Pyramid Hill. 200 ft N., 500 ft E. of SW cor. sec. 14, T. 28 S., R. 29 E. Miocene, Jewett Sand, basal part.

LACMIP 484 San Luis Obispo County, Calif., Shandon 15-minute quadrangle. Northern La Panza Range, SE cor. sec. 23, T. 27 S., R. 15 E. Miocene, Santa Margarita Formation.

LACMIP 962 Baja California Sur, Mexico. South end of Turtle Bay. Miocene, Almejas Formation (collector, H.E. Childs, 1968).

LACMIP 1189 Orange County, Calif., San Juan Capistrano 7½-minute quadrangle. Near Rossmore, Leisure World, Laguna Hills. Road cut on Moulton Parkway, 2 mi south of intersection with El Toro Road. W½ unsurveyed sec. 10, T. 7 S., R. 8 W. Miocene, Monterey Formation, sandy facies (J.G. Vedder oral commun., 1983).

LACMIP 1193 Los Angeles County, Calif., San Clemente Island. San Clemente Central 7½-minute quadrangle. Lemon Tank reservoir section. From south end of west side of pit 0.3 mi east of hill marked "1185" on crest of the island. Miocene.

LACMIP 1194 Los Angeles County, Calif., San Clemente Island 7½-minute quadrangle. Lemon Tank reservoir section. Same as 1193 except from the east side of the pit. Miocene.

LACMIP 1373 Orange County, Calif. Santa Ana Canyon. Miocene, "Topanga Formation" of label.

LACMIP 4828 Baja California Sur, Mexico. North of Santa Rosalía on Mexican Highway 1. Loma del Tirabuzón or "Corkscrew Hill," sea cliff north of mouth of Arroyo del Purgatorio. Middle Pliocene, Tirabuzón Formation (= Gloria Formation of Wilson, 1948, preoccupied).

LELAND STANFORD JUNIOR UNIVERSITY LOCALITIES
[Collections housed at California Academy of Sciences, San Francisco as of March 9, 1977 (Smith, 1978)]

LSJU loc. 43 Baja California Sur, Mexico. Vizcaino desert, north of Asuncion. Northwest of Cerro Elefante, the mesa west of Mesa de las Auras; off road between San José del Castro and Asuncion. Miocene, Almejas Formation (collector, B.F. Hake, Marland Oil Co., who referred the rocks to the Salada Formation, which he regarded as Pliocene).

LSJU loc. 48 Baja California Sur, Mexico. Puerto Nuevo quadrangle, 1:50,000, G11B38. Vizcaino Peninsula, arroyo northwest of Cerro Elefante. Miocene or Pliocene. Almejas Formation.

LSJU loc. 57 Baja California Sur, Mexico. San Isidro quadrangle, 1:50,000, G12A86. La Purisima, cliffs in San Ramon River [Arroyo de la Purisima]. Miocene (collector, E. Call Brown).

LSJU loc. 59 Baja California Sur, Mexico. On trail from Arroyo Mesquital to La Purisima, in turritellid beds. Above San Gregorio Lagoon. Lower Miocene, Isidro Formation.

LSJU loc. 150 Kern County, Calif., Rio Bravo Ranch 7½-minute quadrangle. Southwest of Pyramid Hill, 3 mi northwest of mouth of Kern River canyon. Sec. 14, T. 28 S., R. 29 E. Miocene, Freeman Silt-Jewett Sand, undifferentiated.

LSJU loc. 805 Baja California Sur, Mexico. San José de Magdalena quadrangle, 1:50,000, G12A46. 10 mi north of Mulege, about ⅛ mi southwest of eastern tip of Punta Santa Inez (south side of Punta Chivato). Pliocene and Pleistocene deposits (collector, W.W. Valentine; equivalent to UCMP A-3582, A-3583, *fide* Durham, 1950).

LSJU loc. 806 Baja California Sur, Mexico. Cedros Island, east side. Canyon south of Bernstein's abalone camp [= town of Cedros], "Arroyo de los Puercos" of later workers. Pliocene and reworked Miocene limy sandstone and conglomerate (collector, W.W. Valentine).

LSJU loc. 807 Baja California Sur, Mexico. Bahía Tortugas quadrangle, 1:50,000, G11B27. Turtle Bay [= Bahía Tortugas or San Bartolome Bay]. Canyons at east end of Turtle Bay. Miocene, Almejas Formation (collector, W.W. Valentine, Stanford expedition, 1929).

LSJU loc. 1080 San Luis Obispo County, Calif., La Panza 15-minute quadrangle. East of San Juan River, Carnaza Creek. South line of sec. 14, T. 29 S., R. 17 E. Miocene, Santa Margarita Formation. Type area of *Lyropecten estrellanus* (Conrad). (Collectors, S.W. Muller, G. Richards, 1931).

LSJU loc. 1155 San Luis Obispo County, Calif., Adelaida 15-minute quadrangle. Santa Lucia Mountains. Center of sec. 7, T. 26 S., R. 10 E., near B.M. 836. On west slope of low hill, just above Las Tablas Creek and 3 ft above base of Vaqueros Formation. *Lepidocyclina* locality of Schenck and Childs (1942) is at north end of exposed reef. Miocene, Vaqueros Formation (collector, T.S. Childs; equivalent of USGS M7895).

LSJU loc. 1758 Monterey County, Calif., Junipero Serra 15-minute quadrangle. 1,250 ft E., 2,400 ft S. of NW cor. sec. 16, T. 21 S., R. 5 E. "The Indians." Miocene, Vaqueros Formation (collector, K. Edwards, 1939; = LSJU accession no. 3165).

LSJU loc. 2170 Ventura County, Calif., Wheeler Springs 7½-minute quadrangle. 2,500 ft N., 1,450 ft E. of SW cor. sec. 14, T. 6 N., R. 23 W. Hillside southeast of waterfall. Miocene, Monterey Formation, upper part of sandstone member, with Relizian foraminifers (Dickinson, 1969; Vedder and others, 1973).

LSJU loc. 2236 Monterey County, Calif., Cholame Valley 7½-minute quadrangle. Sec. 17, T. 24 S., R. 16 E. Miocene, Santa Margarita Formation.

LSJU loc. 2411 Monterey County, Calif., Junipero Serra 15-minute quadrangle, Reliz Canyon 7½-minute quadrangle. Vaqueros Creek drainage, 1,600 ft N., 1,450 ft W. of SE cor. sec. 4, T. 20 S., R. 6 E. Miocene, Vaqueros Formation, members E and F. Type locality of Vaqueros Formation (collector, R.R. Thorup).

LSJU loc. 2412 Monterey County, Calif., Junipero Serra 15-minute quadrangle. Reliz Canyon 7½-minute quadrangle. Type locality of the Vaqueros Formation, 400 ft E., 650 ft N. of SE cor. sec. 4, T. 20 S., R. 6 E. In sec. 3 in bottom of brushy, steep, narrow canyon. Miocene, Vaqueros Formation, member E (collector, R.R. Thorup, R. Smith, July, 1941).

LSJU loc. 2659 Republic of Panama, Colon Province. Madden Basin, north bank of Chagres River at point where "Emperador Formation" cuts across river. About 1 mi below Madden Dam. Lat 9°12′+ 1,980 ft, long 79°37′+ 3,960 ft. Miocene, "Alhajuela Formation" of Reeves and Ross (1932, U.S. Geological Survey Bull. 821B) (collector, T. Thompson, field Nos. E-1, E-2).

LSJU loc. 2846 Kern County, Calif., Shale Point 7½-minute quadrangle. Eastern Temblor Range, Bitterwater-Packwood Creek area. Southwest of center sec. 25, T. 27 S., R. 18 E., on north bank of creek flowing northeast. Just above junction with north-flowing stream. Miocene, Temblor Formation, Buttonbed Sandstone Member (collector, H.H. Heikkila, 1947).

LSJU loc. 2862 Kern County, Calif., Packwood Creek 7½-minute quadrangle. Eastern Temblor Range, center of sec. 28, T. 27 S., R. 18 E. Miocene, Temblor Formation, Agua Sandstone Member (collector, H.H. Heikkila, 1947).

LSJU loc. 3158 Talara, Peru. Tablazos deposits. Pleistocene (collector, T.F. Thompson).

LSJU loc. 3159 Santa Elena Peninsula, Ecuador. Beach drift or terrace deposit 100-150 ft above sea level. Pleistocene. (Collector, W.A. Williams, 1912).

LSJU loc. 3245 Alameda County, Calif., La Costa Valley 7½-minute quadrangle. NW¼NW¼ sec. 11, T. 5 S., R. 1 E. Middle Miocene, Oursan Sandstone.

LSJU loc. 3692 Oaxaca, Mexico. About 16 km west of mouth of Río Colotepec, along beach and inland about 1½ mi. From low cliffs of loosely consolidated beach material and beaches raised 5-16 m above sea level. Pleistocene, Colotepec Formation (collector, Robert H. Palmer; = CAS loc. 1299).

LSJU loc. 4043 Monterey County, Calif., Paraiso Springs 7½-minute quadrangle. Arroyo Seco area, west of Greenfield. Sec. 5, T. 19 S., R. 6 E. Miocene, Santa Margarita Formation (collector, Stanford Geological Survey, 1940).

LELAND STANFORD JUNIOR UNIVERSITY STANFORD GEOLOGICAL SURVEY LOCALITIES

[Year and field No. refer to Summer Geology notebooks on file in the Department of Geology, Stanford University]

LSJU/SGS year?: 128 Alameda County, Calif., old Tesla quadrangle. 2 mi southeast of Midway, low hills ½ mi south of 805 ft hill. Sec. 32, T. 2 S.-T. 3 S., R. 4 E. Miocene, Briones Sandstone, in *Scutella breweriana* beds.

LSJU/SGS 1910: 12-u Los Angeles County, Calif., Malibu Beach 7½-minute quadrangle. Santa Monica Mountains, south slope of Calabasas Peak. Miocene. (= LSJU accession No. 47627).

LSJU/SGS 1910: 13x Los Angeles County, Calif., Malibu Beach 7½-minute quadrangle. Santa Monica Mountains, near Saddle Peak. (collectors, Boyd and Templeton).

LSJU/SGS 1920: A-24 Ventura County, Calif., Camulos quadrangle. West of Tapo Canyon, 1½ mi northwest of BM 2231. Pliocene, Pico or Fernando Formations (collector, L.G. Hertlein; = LSJU accession No. 22373).

LSJU/SGS 1925: Pz-51 San Luis Obispo County, Calif., Pozo 15-minute quadrangle. West fork of Cammatti Creek, elevation 1,700 ft. NE¼NW¼ sec. 27, T. 28 S., R. 15 E. Miocene, Santa Margarita Formation (= LSJU accession No. 22369).

LSJU/SGS 1931: 20-Z Ventura Country, Calif., Ojai 7½-minute quadrangle. East end of Ojai Valley, near abandoned oil well. Miocene, Vaqueros Formation (= LSJU accession No. 22366, 22367; = UCMP D-8792; = USGS loc. M8012).

LSJU/SGS 1949: 131-3A Orange County, Calif., western Santa Ana Mountains. East side of Santiago Canyon, Irvine Lake area. Oligocene, Vaqueros Formation (= specimen No. 82).

LSJU/SGS 1964: 64-8 Ventura County, Calif., Wheeler Springs 7½-minute quadrangle. 700 ft S., 2,000 ft W. of NE cor. sec. 15, T. 6 N., R. 23 W. North side of small hill between Burro and Munson Creeks. Miocene, Santa Margarita Formation, basal part of gypsiferous member. (Collector, J. Terry, field No. 6-2).

LELAND STANFORD JUNIOR UNIVERSITY H.J. HAWLEY LOCALITIES

[Samples collected in 1916]

LSJU/Hawley 4 Santa Barbara County, Calif., Gaviota 7½-minute quadrangle. Santa Ynez Mountains, east side of Gaviota Canyon about 1 mi north of Gaviota. Elevation about 200 ft. Eocene or Oligocene, Gaviota or Alegria Formations.

LSJU/Hawley 46 Santa Barbara County, Calif., Los Olivos 15-minute quadrangle. Santa Ynez Mountains, south of Santa Ynez River, west of junction with Nojoqui Creek. South of Santa Rosa Road, sec. 13, T. 6 N., R. 32 W., elevation 400 ft. Oligocene, Vaqueros Formation (= loc. UCMP D-8794).

LSJU/Hawley 64 Santa Barbara County, Calif., Lompoc 15-minute quadrangle. Santa Ynez Mountains, between Alegria Canyon and Cañada del Agua Caliente, northeast of Las Cruces. T. 5 N., R. 32 W. Elevation about 1,000 ft. Eocene, middle part of the Gaviota Formation.

LSJU/Hawley 65 Santa Barbara County, Calif., Gaviota 7½-minute quadrangle. Between Gaviota Canyon and Cañada del Agua Caliente, west southwest of Las Cruces. About 1 mi north of Hawley loc. 93; elevation about 900 ft. Eocene, middle part of the Gaviota Formation.

LSJU/Hawley 68 Santa Barbara County, Calif., Lompoc 15-minute quadrangle. Cañada del Agua Caliente, north of lat 34°30′, T. 5 N., R. 32 W. Elevation about 850 ft. Eocene or Oligocene, Gaviota Formation.

LSJU/Hawley 76 Santa Barbara County, Calif., Sacate 7½-minute quadrangle. Santa Ynez Mountains, T. 5 N., R. 33 W. Ridge between main western branches of Cuarta Creek. Eocene or Oligocene, Gaviota or Alegria Formations (= loc. UCMP B-7033; LSJU accession No. 53251).

LSJU/Hawley 93 Santa Barbara County, Calif., Gaviota 7½-minute quadrangle. T. 5 N., R. 32 W. Between Gaviota Canyon and Cañada del Agua Caliente on west; southwest of Las Cruces. Elevation about 100 ft. Oligocene, Alegria Formation (Dibblee, 1950, map), in "*Turritella variata* zone" according to Hawley (= LSJU accession No. 53256).

LELAND STANFORD JUNIOR UNIVERSITY
[LSJU accession numbers]

143 Ventura County, Calif., Ojai 7½-minute quadrangle. Divide between Ojai Valley and Upper Ojai Valley, on old road 1,000 ft northeast of abandoned well; 5 mi E. of the town of Ojai. Oligocene, Vaqueros Formation.

1639 Ventura County, Calif., Camulos 7½-minute quadrangle. ½ mi north of Fairview, Las Posas. Pliocene, Pico Formation (= Stanford Geological Survey, 1920 field No. Ca-161).

1710 Santa Barbara County, Calif., Lompoc 15-minute quadrangle. Santa Ynez Mountains, Ytias Canyon; 2 mi north-northeast of San Julian ranch house. T. 6 N., R. 33 W. Oligocene, Vaqueros Formation (collector, T. Dibblee, 1930).

1821 Santa Barbara County, Calif., Los Olivos 15-minute quadrangle. Santa Ynez Mountains, east of Buellton, south of the Santa Ynez River. 5¼ mi S. 60° E. of Santa Ynez Mission. Oligocene, Vaqueros Formation.

1883 Monterey County, Calif., Priest Valley 15-minute quadrangle. West side of upper part of Indian Valley in sec. 23, T. 22 S., R. 12 E. Northeast bank of canyon in which road trends northwest. Fossil ledge 50 ft above the road. Pliocene, Pancho Rico Formation (collector, N.L. Taliafero, 1935, field loc. I-CC).

1989 Monterey County, Calif., San Miguel 15-minute quadrangle. Cholame Hills, east of Vineyard Canyon. NE¼SW¼ sec. 35, T. 23 S., R. 13 E. East bank of stream, east of house. Miocene, Santa Margarita Formation (collector, N.L. Taliaferro, 1935).

2945 Kern County, Calif., Knob Hill 7½-minute quadrangle. 1,000 ft S., 1,150 ft E. of northwest cor. sec. 19, T. 27 S., R. 29 E.; west side of small gully, 15 ft above bottom, about 350 ft above the Vedder Sand. Miocene, Jewett Sand, uppermost part of the Pyramid Hill Sand Member.

4902 Santa Cruz Co., Calif., Big Basin 7½-minute quadrangle. SW¼ sec. 18, T. 9 S., R. 2 W. Oligocene, Vaqueros Sandstone. [= Ralph Arnold's locality 111, "1/4 mi up Twobar Creek," shown in Brabb and others, 1977].

20058 San Luis Obispo County, Calif., Cayucos 15-minute quadrangle. Top of hills between Morro and Toro Creeks. Oligocene, Vaqueros Formation.

22358 Ventura County, Calif., Moorpark 7½-minute quadrangle. Santa Susana Mountains, Oak Ridge. East of Grimes Canyon. Miocene, Vaqueros Formation.

22362 San Luis Obispo County, Calif., Cayucos 15-minute quadrangle. Southern Santa Lucia Range, between Toro and Old Creeks. Oligocene, Vaqueros Formation.

22367 Ventura County, Calif., Ojai 7½-minute quadrangle. East end of Ojai Valley, near the abandoned oil well. Oligocene, Vaqueros Formation [= SGS 1931: 20 Z]

22373 Ventura County, Calif., Camulos 7½-minute quadrangle. Eastern Ventura Basin, ½ mi N. of Fairview, Las Posas. Pliocene, Pico Formation [= SGS 1920: field No. Ca.-161]

30261 San Luis Obispo County, Calif., San Simeon 15-minute quadrangle. NE cor. SW¼SW¼ sec. 9, T. 26 S., R. 9 E. Northwest of Town Spring and Town Creek, between Carroll and McLaughlin canyons. Oligocene, Vaqueros Formation (collector, N.L. Taliaferro, 1939).

30702 Fresno County, Calif., Coalinga 15-minute quadrangle. 2,600 ft W., 1,700 ft S. of NE cor. sec. 29, T. 18 S., R. 15 E., on top of 1,200 ft small hill. Miocene, Santa Margarita Formation (collector, R.T. White).

45068 Santa Rosa Island, Calif. On beach about 2 mi west of East Point. Miocene, Vaqueros Formation or lower member of the Rincon Shale (collector, T.W. Dibblee).

45093 Los Angeles County, Calif., Topanga 7½-minute quadrangle. Santa Monica Mountains, midway between Las Flores and Tuna Canyons. T. 1 S., R. 16-17 W. Miocene, Topanga Formation (collector, Stanford Geological Survey, 1910, Templeton and Boyd, field No. C-634).

46708 San Luis Obispo County, Calif., Fellows 7½-minute quadrangle. Southeastern Temblor Range, McKittrick area, Carrizo Plain. Sec. 22, T. 32 S., R. 22 E. Miocene, Santa Margarita Formation (collector, R.N. Ferguson, 1909).

47625 San Mateo County, Calif., San Gregorio 7½-minute quadrangle. Beach west of town of Pescadero, 1½ mi north of Pescadero Point, on small island. Miocene, Vaqueros Formation (collector, D.W. Buchan, 1936).

47629 San Luis Obispo County, Calif., southern Santa Cruz Mountains. 4 mi west of Roblar, southwest of Paso Robles. On Gillis Ranch. Oligocene, Vaqueros Formation (collector, James Perrin Smith, 1894).

52250 = 53263

53242 Los Angeles County, Calif., San Fernando 15-minute quadrangle. Top of hill at north end of Los Angeles Aqueduct. Reservoir dam at San Fernando. Pliocene, Fernando Formation, type section (= field No. C-513).

53259 Fresno County, Calif., Coalinga 15-minute quadrangle. NE¼ sec. 13, T. 21 S., R. 14 E. North of road along Warthan Creek, southwest of Coalinga. Miocene, Santa Margarita Formation (collector, R.N. Ferguson).

53263 Baja California Sur, Mexico. El Púlpito or Punta Púlpito, north-northwest of Loreto, between Bahía San Nicholas and Bahía San Basilio. Pliocene or Pleistocene.

53268 Border between Monterey and San Luis Obispo Counties, Bryson 15-minute quadrangle. Southern Santa Lucia Mountains, west of Pleyto. Probably in or near Harris Valley, north of Nacimiento Reservoir and near Tierra Redonda Mountain. Oligocene, Vaqueros Formation.

NATURHISTORISCHES MUSEUM,
BASEL, SWITZERLAND

NMB 10636 Trinidad, Concord Quarry at Pointe à Pierre. Middle Miocene, Tamana Formation, Guaracara Limestone Member.

NMB 13117 Falcon, Venezuela. Highway east of La Vela, near Mataruca turnoff; about 100 m north of road. Upper middle Miocene, Caujarao Formation, Mataruca Limestone Member (J. and W. Gibson-Smith, 1979) (collector, H.G. Kugler, 1949).

NMB 10115 Grande Terre, French Antilles. Southwest La Guadelupe Island. Near Poucet Ravine, cliff along Sainte-Anne road. Miocene, limestones and reef deposits (Mongin, 1968).

NMB G-16554 (accession no.) Haiti; Jacmel, about 25.1 km from north shore of Grande Coave crossroads, along road. Upper Miocene or lower Pliocene, Riviere Gauche Formation (collector, E. Lehner, 1934, field No. E.L.-1496).

SAN DIEGO SOCIETY OF
NATURAL HISTORY LOCALITIES

SDSNH 228 Los Angeles County, Calif., southeast of Pico Canyon. Pliocene, Pico Formation.

SDSNH 612 Gulf of California, Mexico. San Jose Island. Pliocene.

SDSNH 631 Gulf of California, Mexico. Salsipuedes Island. Pleistocene.

SDSNH 2287 San Diego County, Calif., National City quadrangle. Chula Vista, Telegraph Canyon. Pliocene, San Diego Formation.

TULANE UNIVERSITY, NEW ORLEANS, LA., DEPARTMENT OF GEOLOGY LOCALITIES

TU 204 Collier County, Fla. Sunniland Rock and Lime Quarry, west side of Fla. Route 29, about 30 mi south of La Belle. Miocene, Tamiami Formation.

TU 430 Tamaulipas, Mexico. South side of San Fernando. Road cut on Mexican Highway 101, just north of bridge over the river. Oligocene, Guajalote Formation.

TU 457 Calhoun County, Fla. About ½ mi below Ten Mile Creek, west bank of Chipola River. SW¼ sec. 17, T. 1 N., R. 9 W. Early Miocene, Chipola Formation, lower part [locations of this and other TU localities in the type area of the Chipola Formation are shown in Tulane Studies in Geology and Paleontology, vol. 10, no. 1, p. 28]

TU 546 Calhoun County, Fla. Ten Mile Creek, about 1½ mi west of Chipola River. NW¼ sec. 29, T. 1 N., R. 9 W. Miocene, Chipola Formation [= USGS loc. 2212]

TU 638 Veracruz, Mexico. Road cut and quarry on Mexico Highway 180; 14 mi east of junction with side road into Coatzocoalcos. Third cut on north side of road. Gray silt with scattered fossils overlies yellowish gravel containing abundant Pectens. Middle Pliocene, Agueguexite Formation (collectors, H. and E. Vokes).

TU 810 Calhoun County, Fla. East side of Chipola River, just upstream from TU 547, which is 1 mi below Bailey's Ferry. Miocene, Chipola Formation, basal part (collectors, H. and E. Vokes).

TU 830 Calhoun County, Fla. Ten Mile Creek at powerline crossing, about 1 mi west of Chipola River. SE¼ sec. 12, T. 1 N., R. 10 W. Miocene, Chipola Formation.

TU 951 Calhoun County, Fla. Ten Mile Creek, about 1¼ mi west of Chipola River. South bank just under footbridge on property of Mr. A. Sexton. SE¼ sec. 12, T. 1 N., R. 10 W. Miocene, Chipola Formation (collectors, H. and E. Vokes).

TU 998 Calhoun County, Fla. Ten Mile Creek, about 1¼ mi west of the Chipola River. SE¼ sec. 12, T. 1 N., R. 10 W. North bank at west end of long straight stretch. Miocene, Chipola Formation (collectors, H and E. Vokes).

TU 1000 Sarasota County, Fla. Sarasota, about 8 mi east of U.S. Route 301. Borrow pit at east end of 17th Street, 3.2 mi east of Tuttle Road. Pliocene or Pleistocene, Pinecrest Beds of labels.

TU 1030 Oaxaca, Mexico. North of Tuxtepec, northeast Oaxaca. Hill on west bank of Río Santo Domingo just before its junction with Río Tonto to form Río Papoloapan. About 20 ft above river level, in upper beds. Pliocene, Concepción Superieur Formation (collectors, H. and E. Vokes).

TU 1046 Veracruz, Mexico. Road cuts on both sides of Mexican Highway 180, 7.5 mi east of junction with side road into Coatzocoalcos. Pliocene, Agueguexite Formation (collectors, H. and E. Vokes).

TU 1071 Veracruz, Mexico. Near Papantla, 7.2 mi north of junction of road to Gutierrez Zamora and side road over bridge over Río Tecolutla. Miocene, Tuxpan Formation (collectors, H. and E. Vokes; zone N10 or N11, W. Akers, written commun., 1981).

TU 1209 Dominican Republic. 2 km west of Los Quemados, in road cuts along road between Los Quemados and Sabaneta. 0.6 km east of Río Gurabo bridge. Pliocene, Gurabo Formation (collectors, H. and E. Vokes).

TU 1210 Dominican Republic. East bank and first bluff downstream from bridge over Río Gurabo, Los Quemados-Sabaneta road. About 2.6 km west of Los Quemados. Miocene and Pliocene float, Cercado and Gurabo Formations (collectors, H. and E. Vokes) [= loc. UCMP D-8790]

TU 1231 Dominican Republic. Río Gurabo, float found in river gravel above and below ford on Los Quemados-Sabaneta Road. Collectors, H. and E. Vokes.

TU 1279 Dominican Republic. Road cut 0.3 km west of the bridge over Río Gurabo. 2.9 km west of Los Quemados on road to Sabaneta. Pliocene, Gurabo Formation.

TU 1338 Dominican Republic. 2.3 km west of Los Quemados; 0.3 km west of bridge over Río Gurabo. Road cut along Los Quemados-Sabaneta Road. Pliocene, Gurabo Formation (collectors, H. and E. Vokes).

UNIVERSITY OF CALIFORNIA, LOS ANGELES LOCALITIES

[Collections housed at Los Angeles County Museum of Natural History as of 1986 (Wilson and Saul, 1986)]

UCLA 438 San Luis Obispo County, Calif., La Panza 15-minute quadrangle. Northern La Panza Range, west side of San Juan River. Sec. 13, T. 28 S., R. 16 E. Miocene, Santa Margarita Formation.

UCLA 635 Orange County, Calif., San Juan Capistrano 7½-minute quadrangle. Eastern tributary to Wood Canyon, in Aliso Creek drainage. 1.85 mi S., 1.25 mi W. of NE cor. sec. 4, T. 7 S., R. 8 W. Miocene, Monterey Shale, sandstone lens or facies (Vedder and others, 1957, OM 193).

UCLA 806 Baja California Sur, Mexico. Cedros Island, east coast. Just south of Bernstein's abalone camp [= town of Cedros] in "Arroyo de los Puercos." Miocene or Pliocene, possibly reworked sediments (collector, W.W. Valentine).

UCLA 1084 Los Angeles County, Calif., Newhall 7½-minute quadrangle. North of Towsley Canyon, near top of south side of first saddle west of peak 1,730 ft, Pico Anticline area. Pliocene, Repetto Formation of former usage, near top.

UCLA 1311 Ventura County, Calif., Ojai 7½-minute quadrangle. East end of Ojai Valley, south of Reeves Creek. At end of road on north side of small canyon, across from abandoned C.T. Well. SE¼ sec. 3, T. 4 N., R. 22 W. Oligocene, Vaqueros Formation (collectors, Durrell, Putnam, and others, 1941).

UCLA 2535 Los Angeles County, Calif., Santa Susana 7½-minute quadrangle. East side of Devil's Canyon in sec. 25, T. 3 N., R. 17 W. Pliocene, Saugus Formation, basal part.

UCLA 3315 Santa Barbara County, Calif., Los Olivos 15-minute quadrangle. Up Nojoqui Creek from old state highway bridge. Eocene, Gaviota Formation.

UCLA 3448 Los Angeles County, Calif., Malibu Beach 7½-minute quadrangle. Santa Monica Mountains, between north ridge of Calabasas Peak and scout camp. Miocene, Vaqueros Formation, San Nicholas Member (Yerkes and Campbell, 1980a,b).

UCLA 4157 San Luis Obispo County, Calif., Nipomo 15-minute quadrangle. 1,800 ft S., 1,000 ft E. of NW cor. sec. 6, T. 32 S., R. 15 E., east of Tar Springs, southwest of La Panza. Miocene, Santa Margarita Formation, Saucelito Member of Hall (1962); white siltstone and pebble beds (Hall and Corbato, 1967).

UCLA 4159 San Luis Obispo County, Calif., Nipomo 15-minute quadrangle. Huasna basin area, 800 ft W., about 1,000 ft S. of NW cor. sec. 5, T. 32 S., R. 15 E. Miocene, Santa Margarita Formation, lower part of the Saucelito Member of Hall (1962) (Hall and Corbato, 1967).

UCLA 4160 San Luis Obispo County, Calif., Nipomo 15-minute quadrangle. Huasna basin, 4,100 ft S., 1,400 ft E. of NW cor. sec. 6, T. 32 S., R. 15 E. Miocene, Santa Margarita Formation, lower part of the Saucelito Member of Hall

(1962); with Upper Delmontian foraminifers (Hall and Corbato, 1967).

UCLA 4586 San Luis Obispo County, Calif., Nipomo 15-minute quadrangle. Northwest of San Rafael Mountains, south of Huasna Peak. 850 ft E., 8,100 ft S. of NE cor. sec. 16, T. 11 N., R. 33 W. Miocene, Vaqueros Formation (collector, C.A. Hall, 1960).

UCLA 5067 San Luis Obispo County, Calif., Nipomo 15-minute quadrangle. Southern Coast Ranges, northwest of Nipomo and Mehlscaw Creek, about 500 ft N. of B.M. 431 on Los Berros Road. Quarry near center of sec. 31 (projected), T. 12 N., R. 14 E. Miocene, Obispo Formation. Sample from this locality dated radiometrically as 16.5 ± 1.2 m.y. (D.L. Turner and others, 1970).

UCLA 5068 San Luis Obispo County, Calif., Nipomo 15-minute quadrangle. North of Nipomo Valley, on side of hill, about 200 ft from top. 31,600 ft N., 1,200 ft E. of SW cor. of Nipomo quadrangle. Miocene, Obispo Formation, pebbly conglomerate or breccia with tuffaceous matrix, mostly internal molds (collector, C.A. Hall).

UCLA 5539 Santa Barbara County, Calif., Fox Mountain 7½-minute quadrangle. Near head of Olive Canyon, 0.9 mi south of Olive Spring and ¼ mi southeast of Honolulu Oil Co. well H-O #1. 5,380 ft W., 2,200 ft N. of lat 34°50′ N., long 119°35′ W. Elevation 3,470 ft, on small ridge on west side of Olive Canyon. Miocene, Vaqueros Formation, hard shelly sand (collector, A.E. Fritsche, field No. 671).

UCLA 5542 Santa Barbara County, Calif., Fox Mountain 7½-minute quadrangle. South side of divide between Olive and Castro Canyon drainage areas, slope immediately south of saddle at head of Olive Canyon. 4,890 ft W., 1,260 ft N. of lat 34°50′ N., long 119°35′ W.; elevation 3,730 ft. 0.45 mi southeast of Honolulu Oil Co. well Honolulu-Oceanic #1. Miocene, Vaqueros Formation, Painted Rock Sandstone Member (collector, A.E. Fritsche, loc. F852).

UCLA 5543 Santa Barbara County, Calif., Fox Mountain 7½-minute quadrangle. First canyon south of Olive and Castro Canyon drainage divide, about 0.6 mi south and a little east of Honolulu Oil Co. well Honolulu-Oceanic #1. About 0.3 mi east of the firebreak trail to Fox Mountain. 5,590 ft W., 140′ N. of lat 34°50′ N., long 119°35′ W.; elevation 3,520 ft. Miocene, Vaqueros Formation, Painted Rock Sandstone Member (collector, A.E. Fritsche, loc. 855).

UCLA 5545 Santa Barbara County, Calif., Fox Mountain 7½-minute quadrangle. Small canyon just south of the first canyon south of Olive and Castro Canyon drainage divide; about 0.65 mi south, a little east of Honolulu Oil Co. well Honolulu-Oceanic #1 and about 0.3 mi east of the firebreak trail to Fox Mountain. 5,580 ft W., 10 ft N. of lat. 34°50′N, long. 119°35′W; elevation 3,550 ft. Miocene, Vaqueros Formation, Painted Rock Sandstone Member (collector, A.E. Fritsche, loc. 856).

UCLA 5548 Santa Barbara County, Calif., Fox Mountain 7½-minute quadrangle. 5,860 ft E., 1,230 ft N. of lat 34°50′ N., long 119°35′ W., elevation 3,320 ft. East slope of fifth major canyon east of Tennison Spring, about 0.8 mi southeast of Tennison Spring and 0.55 mi northwest of spring in Rainbow Canyon. Miocene, Vaqueros Formation, Painted Rock Sandstone Member (collector, A.E. Fritsche, 1963, loc. 1188).

UCLA 5549 Santa Barbara County, Calif., Fox Mountain 7½-minute quadrangle. 1 mi southeast of Tennison Spring, 0.4 mi northwest of spring in Rainbow Canyon. 5,660 ft W., 600 ft N. of lat 34°50′ N., long 119°32′30″ W., elevation 3,350′. Miocene, Vaqueros Formation, Painted Rock Sandstone Member (collector, A.E. Fritsche, field No. 815).

UCLA 5554 Santa Barbara County, Calif., Fox Mountain 7½-minute quadrangle. Top of ridge on north side of Rainbow Canyon, about 6 mi northwest of spring in canyon and 0.7 mi southeast of Tennison Spring. 4,800 ft E., 490 ft N. of lat 34°50′ N., long 119°35′ W., elevation 3,460 ft. Miocene, Vaqueros Formation, Painted Rock Sandstone Member (collector, A.E. Fritsche, loc. 818).

UCLA 5558 Santa Barbara County, Calif., Fox Mountain 7½-minute quadrangle. Top of first ridge to south of the Olive and Castro Canyon drainage divide, about 0.8 mi southeast of Honolulu Oil Co. well Honolulu-Oceanic #1. About 0.6 mi east of firebreak trail to Fox Mountain. 4,210 ft W., 320 ft S. of lat 34°50′ N., long 119°35′ W., elevation 3,840 ft. Miocene, Vaqueros Formation, Painted Rock Sandstone Member (collector, A.E. Fritsche, loc. 857).

UCLA 5559 Santa Barbara County, Calif., Fox Mountain 7½-minute quadrangle. Top of ridge forming Tennison and Castro Canyon drainage divide, about 0.8 mi southeast of Honolulu Oil Co. well Honolulu-Oceanic #1; about 0.75 mi east of firebreak trail to Fox Mountain. 3,550 ft W., 290 ft S. of lat 34°50′ N., long 119°35′ W., elevation 3,970 ft. Miocene, Vaqueros Formation, Painted Rock Sandstone Member (collector, A.E. Fritsche, loc. 858).

UCLA 5560 Santa Barbara County, Calif., Fox Mountain 7½-minute quadrangle. Sierra Madre Range, south of Goode Springs. Top of ridge forming the Tennison and Castro Canyon drainage divide, about 0.75 mi southeast of Honolulu Oil Co. well Honolulu-Oceanic #1, and about 0.7 mi east of firebreak trail to Fox Mountain. 100 N., 3,670 ft W. of lat 34°50′ N., long 119°35′ W., elevation 3,870 ft. Miocene, Vaqueros Formation, Painted Rock Sandstone Member (collector, A.E. Fritsche, loc. 676).

UCLA 5564 Santa Barbara County, Calif., Fox Mountain 7½-minute quadrangle. Sierra Madre Range, west of Santa Barbara Canyon Ranch and about 0.95 mi southwest of the spring in Rainbow Canyon. 4,820 ft E., 5,710 ft S. of lat 34°50′ N., long 119°35′ W., elevation 3,560 ft. Miocene, Vaqueros Formation, Painted Rock Sandstone Member (Fritsche, 1969).

UCLA 5611 Santa Barbara County, Calif., Salisbury Potrero 7½-minute quadrangle. Sierra Madre Range, about 0.6 mi northwest of Lower Newsome Spring. 0.4 mi east, slightly north of La Jolla spring. 750 ft E., 3,550 ft S. of lat 34°52′ N., long 119°42′30″ W., elevation 2,820 ft. Coarse-grained calcareous sandstone in streambed of major south-flowing tributary of Lion Canyon. Miocene, Branch Canyon Sandstone, upper member (collector, A.E. Fritsche, 1962, loc. 462).

UCLA 5648 Santa Barbara County, Calif., Salisbury Potrero 7½-minute quadrangle. Sierra Madre Range, north side of Lion Canyon. Less than 0.1 mi W., 840 ft S. of lat 34°52′30″ N., long 119°42′30″ W., elevation 2,650 ft. Miocene, Branch Canyon Sandstone (collector, A.E. Fritsche, 1961, loc. 322).

UCLA 5649 Santa Barbara County, Calif., Salisbury Potrero 7½-minute quadrangle. Sierra Madre Range, northeast slope of first canyon west of junction of Lion and Newsome Canyons. 40 ft E., 1,400 ft S. of lat 34°52′30″ N., long 119°42′30″ W., elevation 2,690 ft. Miocene, Branch Canyon Sandstone, upper part (collector, A.E. Fritsche, 1962, loc. 460).

UCLA 5661 Santa Barbara County, Calif., Salisbury Potrero 7½-minute quadrangle. Sierra Madre Range. West side of Branch Canyon road in Castro Canyon, just after road leaves the canyon. 570 ft W., 7,020 ft S. of lat 34°52′30″ N., long 119°37′30″ W., elevation 2,980 ft. Miocene, Branch Canyon Sandstone, upper member (collector, A.E. Fritsche, 1962, loc. 756).

UCLA 5683 Santa Barbara County, Calif., Fox Mountain 7½-minute quadrangle. Sierra Madre Range, small canyon on east side of major eastward tributary to Goode Canyon. 1 mi southwest of ranch in Tennison Canyon, about 0.5 mi east, a little south of water tank at end of road in Goode Canyon. 1,040 ft E., 6,610 ft S. of lat 34°52′30″ N., long 119°35′ W., elevation 2,960 ft. Miocene, Branch Canyon Sandstone, upper member (collector, A.E. Fritsche, 1963, loc. 1093).

UCLA 5697 Santa Barbara County, Calif., New Cuyama 7½-minute quadrangle. 1,910 ft W., 4,000 ft N. of lat 34°52′30″ N., long 119°42′30″ W., elevation 2,670 ft. North side of small canyon tributary to larger one about 0.2 mi southwest of Bell Petroleum Co. well Johnston 76-1. Miocene, Santa Margarita Formation, member B of collector A.E. Fritsche, loc. 848.

UCLA 5699 Santa Barbara County, Calif., New Cuyama 7½-minute quadrangle. 0.7 mi southwest of Forest Service gate in Newsome Canyon, on north slope of major westerly tributary to Newsome Canyon. 2,060 ft W., 1,650 ft N. of lat 34°52′30″ N., long 119°42′30″ W., elevation 2,810 ft. Miocene, Santa Margarita Formation (collector, A.E. Fritsche, 1961, loc. 383).

UCLA 5702 Santa Barbara County, Calif., New Cuyama 7½-minute quadrangle. 2,730 ft W., 1,800 ft N. of lat 34°52′30″ N., long 119°40′ W., elevation 2,900 ft. At head of small canyon 0.75 mi north of Richfield Oil Co. well. S.C.U. 77-6. Miocene, Santa Margarita Formation, member B (collector, A.E. Fritsche, 1962, loc. 505).

UCLA 5708 Santa Barbara County, Calif., Salisbury Potrero 7½-minute quadrangle. 4,690 ft W., 2,400 ft S. of lat 34°52′30″ N., long 119°40′ W., elevation 3,030 ft. East side of canyon, just south of the George J. Greer well Bandini 51-17. Miocene, Santa Margarita Formation, member B, with very deformed fossils (collector, A.E. Fritsche, loc. 638).

UCLA 5800 Los Angeles County, Calif., San Fernando 7½-minute quadrangle. 640 ft E., 1,910 ft N. of SW cor. sec. 8, T. 3 N., R. 15 W. Calcareous sandy siltstone exposed on crest of ridge. Pliocene, Towsley Formation (Kern, 1973).

UCLA 5840 San Luis Obispo County, Calif., Pismo Beach 7½-minute quadrangle. 9,100 ft E., 7,450 ft S. of northwest cor. of quadrangle, in sec. 18, T. 31 S., R. 12 E. Oligocene, Vaqueros Formation.

UCLA 5899 Los Angeles County, Calif., San Clemente Island Central 7½-minute quadrangle. Northeast shore of Lemon Tank reservoir, elevation 1,075 ft. Miocene, sandy to silty sedimentary rocks (collector, D.L. Wiede, 1969).

UCLA 6069 San Luis Obispo County, Calif., Cypress Mountain 7½-minute quadrangle. sec. 4, T. 28 S., R. 10 E. Oligocene, Vaqueros Formation.

UCLA 6191 San Luis Obispo County, Calif., Morro Bay North 7½-minute quadrangle. 500 m E., 806 m S. of northwest cor. sec. 14, T. 29 S., R. 11 E. Oligocene, Vaqueros Formation (Prior, 1974).

UCLA 6192 San Luis Obispo County, Calif., Morro Bay North 7½-minute quadrangle. Between San Bernardo and Little Morro Creeks, 793 m W., 470 m N. of southeast cor. sec. 14, T. 29 S., R. 11 E. Oligocene, Vaqueros Formation (Prior, 1974).

UCLA 6194 San Luis Obispo County, Calif., Morro Bay North 7½-minute quadrangle. 500 m W., 334 m S. of northeast cor. sec. 20, T. 29 S., R. 11 E. Miocene, Pismo Formation, lower member (Prior, 1974).

UCLA 6196 San Luis Obispo County, Calif., Morro Bay North 7½-minute quadrangle. 442 m W., 412 m N. of southeast cor. sec. 17, T. 29 S., R. 11 E. Miocene, Pismo Formation, lower member (Prior, 1974).

UCLA 6199 San Luis Obispo County, Calif., Morro Bay North 7½-minute quadrangle. Miocene, Pismo Formation, lower member (Prior, 1974).

UCLA 6200 San Luis Obispo County, Calif., Morro Bay North 7½-minute quadrangle. In creek bed 2,110 m W., 216 m S. of northeast cor. sec. 17, T. 29 S., R. 11 E. Miocene, Pismo Formation, lower member, resistant shell bed about 1 m thick, 16.5 m above base of formation (Prior, 1974).

UCLA 6203 San Luis Obispo County, Calif., Morro Bay North 7½-minute quadrangle. 605 m E., 197 m S. of northwest cor. sec. 4, T. 29 S., R. 11 E. North side of hill 1017. Oligocene, Vaqueros Formation (Prior, 1974).

UCLA 6204 San Luis Obispo County, Calif., Morro Bay North 7½-minute quadrangle. Just south of hill 1017, on knob southeast of hill. 698 m W., 410 m S. of northwest cor. sec. 4, T. 29 S., R. 11 E. Oligocene, Vaqueros Formation (Prior, 1974).

UCLA 6205 San Luis Obispo County, Calif., Morro Bay North 7½-minute quadrangle. North side of Toro Creek, between Toro and Smith Creeks, 157 m E., 1,902 m S. of northeast cor. sec. 32, T. 28 S., R. 11 E. Oligocene, Vaqueros Formation (Prior, 1974).

UCLA 6206 San Luis Obispo County, Calif., Morro Bay North 7½-minute quadrangle. 74 m E., 1,920 m S. of northwest cor. sec. 32, T. 28 S., R. 11 E. Oligocene, Vaqueros Formation (Prior, 1974).

UCLA 6959 Orange County, Calif., Laguna Beach 7½-minute quadrangle. San Joaquin Hills, Crystal Cove Canyon. Miocene, "from top of transition from Vaqueros to Temblor Formation" of label (collector, W.H. Corey).

UCLA 8271 Kern County, Calif., Oil Center 7½-minute quadrangle. Northeast of Bakersfield. About ¼ mi west of Barker Ranch locality, from prominent calcified outcrop. NE¼ sec. 5, T. 29 S., R. 29 E. Miocene, Olcese Sand, at top of section (W.O. Addicott, oral commun., 1973).

UCLA 45108 Orange County, Calif., Corona 7½-minute quadrangle. Up prominent ravine east-northeast from Bee Canyon. Miocene.

UNIVERSITY OF CALIFORNIA, BERKELEY

[Museum of Paleontology localities]

UCMP 738 Imperial County, Calif., Carrizo Mountain 15-minute and Plaster City 15-minute quadrangles. Base of Coyote Mountain (sometimes called Carrizo Mountain), west of road from Coyote Wells to Carrizo Spring; about 7 mi north of the U.S.-Mexican border. About 3 mi north of Coyote Wells, 25 mi west of El Centro on U.S. Route 80. From two small washes on west side of stream cut heading northwest from road near the base of the formation. Miocene, Imperial Formation, "Latrania Sands" of Hanna (1926).

UCMP 1311 Contra Costa County, Calif., Concord 15-minute quadrangle. Walnut Creek, lat 37°59′14″ N., long

122°6′8″ W. 1.5 mi southeast of Muir station, on a direct line between Muir Station and Pacheco. Elevation 200 ft. Miocene(?), San Ramon Sandstone.

UCMP 1632 Contra Costa County, Calif., Mare Island 7½-minute quadrangle. On shore of San Pablo Bay to south or west of town of Rodeo, just south of Lone Tree Point. Miocene, San Pablo Formation, *Pecten* beds (Clark, 1915).

UCMP 1910 Orange County, Calif., El Toro 7½-minute quadrangle. 3 mi southwest of El Toro, near junction of two branches of road down Aliso Creek. Miocene.

UCMP 2520 Fresno County, Calif., Coalinga 15-minute quadrangle. Northern Jacalitos Hills, south side of Warthan Creek. Near center of SE¼NW¼ sec. 24, T. 21 S., R. 14 E., about 200 yd east of Alcalde-Jacalitos Ranch road. Pliocene, Jacalitos Formation of former usage (Dibblee, 1973b), *Chione elsmerensis* zone (collector, J.O. Nomland).

UCMP 2523 Fresno County, Calif., Coalinga 15-minute quadrangle. North of Jacalitos Canyon, west of Alcalde-Jacalitos Ranch road around Curry Mountain. Center of SE¼SE¼ sec. 27, T. 21 S., R. 14 E., about 15 yd above road and west of its southernmost curve. Pliocene, Jacalitos Formation of former usage.

UCMP 2526 Fresno County, Calif., Coalinga 15-minute quadrangle. At junction of Jacalitos and Jasper Creeks, near SW cor. of sec. 6, T. 22 S., R. 15 E. Pliocene, Jacalitos Formation of former usage, *Chione elsmerensis* zone of Nomland (1917a).

UCMP 2533 Fresno County, Calif., Coalinga 15-minute quadrangle. Middle of south boundary of NW¼NE¼ sec. 29, T. 21 S., R. 14 E., in north bank of Waltham Creek. Pliocene, Jacalitos Formation of former usage, *Turritella nova* zone of Nomland.

UCMP 3029 Kern County, Calif., Arvin 7½-minute quadrangle. Western Tejon Hills, southeast of Bakersfield. Near west edge of sec. 13, T. 32 S., R. 29 E. Miocene, Santa Margarita Formation.

UCMP 3234 Kern County, Calif., San Emigdio Mountains, Oligocene.

UCMP 3535 Alameda County, Calif., Livermore 15-minute quadrangle. Reef beds in the vicinity of Verona, near Pleasanton (*fide* Trask, 1922). Miocene, Briones Sandstone.

UCMP 3670 Monterey County, Calif., Junipero Serra 15-minute quadrangle. Santa Lucia Range, near head of San Antonio Creek. Miocene, Vaqueros Formation.

UCMP A-311 Santa Rosa Island, Calif. In canyon east of pass between the two high peaks on crest of island, 1,500 ft south of "a" of "Rosa" in "Santa Rosa" on U.S. Coast and Geodetic Survey map #5202. Oligocene or Miocene, massive yellowish shaley sandstone (collector, W.S.W. Kew, Jan., 1926, as described in Kew, 1927, p. 645-654).

UCMP A-312 Santa Barbara County, Calif., Lompoc 15-minute quadrangle. Santa Ynez Mountains, east side of Atascaso Creek. San Julian Ranch, on east side of small canyon back of hairpin turn on new road between second and third canyons west of Yridisis Creek. Eocene, Gaviota Formation, upper part (Dibblee, 1950).

UCMP A-315 Santa Barbara County, Calif., Lompoc 15-minute quadrangle. Santa Ynez Mountains, about ½ mi north of Jalama Creek at cut through rocky spur on west side of road from Lompoc. Near junction of Jalama and Escondido Creeks. Oligocene, Vaqueros Formation.

UCMP A-319 Santa Barbara County, Calif., Lompoc 15-minute quadrangle. Santa Ynez Mountains. Along high east-west ridge as far as canyon west of Yridisis Creek. Oligocene, Vaqueros Formation, calcareous bed and sandstone 50 ft stratigraphically above conglomerate.

UCMP A-326 Ventura County, Calif., Matilija 7½-minute quadrangle. Southwest of Ojai, upper end of San Antonio Creek Canyon and northwest of mouth of Lion Canyon. Oligocene or Miocene, Vaqueros Formation; Loel and Corey (1932) considered it equivalent to their lower Oak Ridge and South Mountain zones.

UCMP A-494 San Luis Obispo County, Calif., La Panza 15-minute quadrangle. Eastern La Panza Range, southeast fork of Hay Canyon, southwest of San Juan River. Elevation about 1,700 ft; 0.15 mi W., 0.35 mi S. of northeast cor. sec. 21, T. 30 S., R. 17 E. Oligocene or Miocene, Vaqueros Formation.

UCMP A-499 San Luis Obispo County, Calif., La Panza 15-minute quadrangle. Eastern La Panza Range. Northwest cor. sec. 9, T. 31 S., R. 18 E., across knoll which is just west of sharp "v" in Carrizo Creek, exactly on S line of La Panza 15-minute quadrangle. Miocene, Vaqueros Formation, Painted Rock Sandstone Member, *Ostrea* reef.

UCMP A-505 San Luis Obispo County, Calif., California Valley 7½-minute quadrangle. East of San Juan River and Big Spring fault. Just east of midpoint on west line of sec. 7, T. 30 S., R. 18 E., at head of west branch of Anderson Creek. Miocene, Vaqueros Formation, fossiliferous zone at top of white sandstone bed.

UCMP A-527 Orange County, Calif., Laguna Beach 7½-minute quadrangle. 2 mi north of Laguna Beach in road cut on highway at end of spur in big bend in Laguna Canyon. Miocene, Vaqueros Formation, shaley sandstone facies (probably correlative with the Topanga Formation, *fide* J.G. Vedder, written commun., 1983).

UCMP A-581 San Luis Obispo County, Calif., Bryson 15-minute quadrangle. Santa Lucia Range, east side of north Grizzly Bend Creek. North of Nacimiento Reservoir, southwest of Harris Valley, approximately 0.2 mi S., 0.4 mi W. of southeast cor. sec. 1, T. 25 S., R. 8 E. Miocene, Vaqueros Formation.

UCMP A-628 Fresno County, Calif., Coalinga 15-minute quadrangle. Kreyenhagen Hills 7½-minute quadrangle. West central part of sec. 22, T. 21 S., R. 15 E. Pliocene, Etchegoin Formation [*fide* label].

UCMP A-911 Monterey County, Calif., San Ardo 15-minute quadrangle. Bluffs along east side of Salinas River between Long Valley and Pine Valley. 500 ft N. of W¼ sec. 14, T. 21 S., R. 9 E., in steep hill slope 150 ft north of state highway. Miocene, Pancho Rico Formation (Durham and Addicott, 1965; Addicott, 1978).

UCMP A-1273 Imperial County, Calif., Carrizo Mountain 7½-minute quadrangle. Southeast side of Carrizo Mountain, about 200 ft southwest of most northerly point of crest of dip slope. Miocene or Pliocene, Imperial Formation.

UCMP A-1275 Imperial County, Calif., Carrizo Mountain 7½-minute quadrangle. Southeast side of Carrizo Mountain, from isolated outcrop of marine sedimentary rocks about 600 ft west of most westerly projection of big dip slope. On divide between streams running to the two sides of the dip slope. Miocene or Pliocene, Imperial Formation.

UCMP A-1360 Baja California Sur, Mexico. Cedros Island, lat 28° N., long 115.2° W. Pliocene, unnamed sedimentary rocks.

UCMP A-2937 Monterey County, Calif., Greenfield 15-minute quadrangle. East of Salinas Valley, ½ mi southeast of

Burchard's ranch house. NE¼ sec. 26, T. 19 S., R. 8 E. Miocene, Pancho Rico Formation (collector, N. Sander, 1937).

UCMP A-2939 Monterey County, Calif., San Ardo 15-minute quadrangle. North central ¼ sec. 2, T. 20 S., R. 9 E., in valley head 100 ft below section fence. Left branch of 3-headed canyon. Miocene, Pancho Rico Formation.

UCMP A-3046 Monterey County, Calif., Priest Valley 15-minute quadrangle. West side of Slack Canyon, south boundary of NW¼ sec. 27, T. 21 S., R. 12 E., in head of box canyon. Miocene, Pancho Rico Formation.

UCMP A-3295 San Benito County, Calif., Priest Valley 15-minute quadrangle. North of Lewis Creek in SW¼ sec. 36, T. 19 S., R. 11 E. Pliocene, Etchegoin Formation.

UCMP A-3324 Fresno County, Calif., Priest Valley 15-minute quadrangle. Center of SE¼ sec. 11, T. 21 S., R. 13 E., in reef. Pliocene, Etchegoin Formation.

UCMP A-3426 San Luis Obispo County, Calif., Cholame 7½-minute quadrangle. Red Hills east of Shandon. Miocene, Santa Margarita Formation.

UCMP A-3517 Gulf of California, Mexico. Carmen Island, Marquer Bay. Along sea cliff in center of bay, 100 yd south of small south-central arroyo. Pliocene, Marquer Formation, calcareous sands above gravel beds.

UCMP A-3524 Gulf of California Sur, Mexico. Carmen Island, Marquer Bay. Sea cliff just inside mouth of small arroyo, south end of the bay. Pliocene Marquer Formation, from *Pecten* and oyster bed.

UCMP A-3556 Baja California Sur, Mexico. Loreto quadrangle, 1:50,000, G12A88. Along the Gulf north of Loreto, east side of Mexican Highway 1 between Arroyo de Gua and Arroyo de Arce. North side of arroyo. [Details of this locality in relation to others nearby given in Durham, 1950] Pliocene, unnamed sandstone.

UCMP A-3568 Gulf of California, Mexico. Monserrate Island, south-central end at about 500 ft elevation. Pliocene, algal sandstone and *Pecten* beds, possibly a terrace block raised by faulting.

UCMP A-3576 Gulf of California, Mexico. San Marcos Island. East side of island in northeast corner of gypsum bed outcrop. From cliff in mesalike hill. Lower Pliocene, San Marcos Formation, 150-200 ft stratigraphically above gypsum.

UCMP A-3591 Gulf of California, Mexico. Ángel de la Guarda Island, from southeast of south point of the island. Pliocene, terracelike deposits unconformable on "Comondú" and overlain by lava flows.

UCMP A-4328 Los Angeles County, Calif., Mint Canyon 7½-minute quadrangle. Santa Clara Valley north of Newhall, S45°W, 3,600 ft from Humphrey's Station, on ridge at 1,710 ft elevation. NW¼,SW¼ sec. 27, T. 4 N., R. 15 W. Miocene, Modelo Formation (= USGS loc. 1929).

UCMP A-4646 Santa Barbara County, Calif., Gaviota 7½-minute quadrangle. In tributary at west fork of Canada Omentero drainage. Eocene, Gaviota Formation, middle member (Wilson, 1954).

UCMP A-6724 Fresno County, Calif., Joaquin Rocks 15-minute quadrangle. Approximately center NE¼, just above oil seep on northeast stream cut on outer edge of loop, where dirt road crosses Domengine Creek twice on northeast. Miocene, Santa Margarita Formation, sandstone interbedded with limy sandstone reefs.

UCMP A-6729 Orange County, Calif., Laguna Beach 7½-minute quadrangle. Road cut in easternmost part of big bend in Laguna Canyon Road, 300 yd north along base of west canyon wall. Fossils scattered in horizons through limy to silty yellow sandstone. Miocene, Vaqueros Formation.

UCMP B-1605 Kern County, Calif., Pine Mountain 7½-minute quadrangle. West flank of northernmost knob on north-south ridge and 25 ft below top, SW¼NW sec. 10, T. 28 S., R. 29 E. Calcareous, very coarse grained conglomeratic sandstone [= "Grit zone"], about 5 ft thick. Lower Miocene, basal part of the Jewett Sand.

UCMP B-1655 Kern County, Calif., Knob Hill 7½-minute quadrangle. Near center of W½,NE¼ sec. 32, T. 27 S., R. 29 E. Miocene, Freeman Sand and Jewett Silt, undivided, float and concretions from 250 ft interval above basal "Grit Zone" and below UCMP B-1656.

UCMP B-1656 Kern County, Calif., Knob Hill 7½-minute quadrangle. Near center of W½NE¼ sec. 32, T. 27 S., R. 29 E. Miocene, Freeman Sand and Jewett Silt, undivided, *Ostrea-Pecten* biostrome in concretionary silty sandstone 115 ft stratigraphically above B-1654, 230-240 ft stratigraphically above base of formation.

UCMP B-1673 Kern County, Calif., Pine Mountain 7½-minute quadrangle. Poso Creek, north of Coffee Canyon. SW¼ sec. 33, T. 27 S., R. 29 E. On southeast slope of southwest shoulder of hill 1778, near head of canyon. Miocene, Freeman Sand and Jewett Silt, undivided, about 40 ft above "Grit Zone." Fossils in gray, calcareous, very fine sandstone concretions.

UCMP B-3014 Baja California Sur, Mexico. Bahía Tortugas quadrangle, 1:50,000, G11B27. Turtle Bay, on northeast side of landing field north of town. Miocene, Almejas Formation.

UCMP B-3049 Baja California Sur, Mexico. Bahía Tortugas quadrangle, 1:50,000, G11B27. About 6 mi southeast of town of Turtle Bay. 100-150 ft high bluffs inland from beach. Miocene, Almejas Formation. Flat-lying sands and silts with *Patinopecten*, *Forraria*, and *Merriamaster* in basal part (E.C. Allison, field notes, July 2, 1956).

UCMP B-3059 Baja California Sur, Mexico. Near Turtle Bay, east side of "Peak A" of Ward and others, [field party of Pomona College students, July, 1956]. Miocene, Almejas Formation, about 50 ft stratigraphically below capping coquina (collector, E.C. Allison, July 5, 1956).

UCMP B-3269 Baja California Norte, Mexico. About 1¾ mi northwest of El Rosario Arriba and about 500 ft east of main road near summit of west-pointing spur. Pliocene, La Cresta or Cantil Costero Formation, white calcareous marine conglomerate which forms crest of west-pointing spur.

UCMP B-3607 Galapagos Islands. Santa Cruz Island [= Indefatigable Island]. Cerro Colorado area, outcrops in sea cliffs. Pliocene, from 10 ft thick very hard limestone that is unconformable on an irregular surface cut into red-brown lapilli tuffs. Area cut by faults, has older and younger lavas (collector, J. Wyatt Durham, Feb. 9, 1964).

UCMP B-3612 Galapagos Islands. Santa Cruz Island [= Indefatigable Island] Northeast of Academy Bay, near Cerro Colorado. Pliocene, apparently same limestone as at B-3607, in sea cliffs 75 yd to north and on north side of a fault. Limestone thins to 2-3 ft, rests directly on surface cut in lavas. (collector, J. Wyatt Durham, Feb. 10, 1964).

UCMP B-4350 Fresno County, Calif., Domengine Ranch 7½-minute quadrangle. SE¼NW¼NE¼ sec. 33, T. 18 S., R. 15 E. In Domengine Creek, downstream from the *Merychippus* quarry. Oyster-*Pecten* bank. Miocene, Santa Margarita Formation.

UCMP B-4734 Contra Costa County, Calif., Briones Valley 7½-minute quadrangle. Near Lafayette Reservoir, 1.7 mi north of northwest end of spillway 456. 1,660 ft north of junction of Happy Valley Road and Panorama Drive. Miocene, San Pablo Formation. Two-ft fossil bed in fine-grained, crumbly sandstone.

UCMP B-4738 Contra Costa County, Calif., Briones Valley 7½-minute quadrangle. Near Lafayette Reservoir, 1.7 mi north of northwest end of spillway 456. 1,698 ft north of junction of Happy Valley Road and Panorama Drive. Elevation 925 ft. Miocene, San Pablo Formation, a 9-in. bed containing almost exclusively *Lyropecten crassicardo* and serpulid worm tubes in a hard, fine-grained, greenish-gray matrix.

UCMP B-5012 Baja California Sur, Mexico. La Purisima area. Northwest of La Purisima, 10 mi by road via San Isidro, across arroyo at large pool and waterfall at downstream edge of narrow, deep stream channel. Early to early middle Miocene, about 20 ft of flat-lying, hard, limy bluish-brown sandstone with abundant invertebrates and bone fragments (collectors, E.C. Allison and F. Kilmer, July, 1957).

UCMP B-5015 Baja California Sur, Mexico. San Isidro quadrangle, 1:50,000, G12A86. San Isidro, in La Purisima area. Low, white knoll about 100 yd east of center of San Isidro, near the cemetery. Early to early middle Miocene, flat-lying, limy, fossiliferous sandstone with abundant oysters (collectors, E.C. Allison and F. Kilmer, July, 1957).

UCMP B-5016 Baja California Sur, Mexico. San Isidro quadrangle, 1:50,000, G12A86. La Purisima area, about ¾ mi north of town in cliffs forming north bank of stream. Also 100 yd downstream from abandoned crossing at road end, 1.4 mi by road from La Purisima. Early to early middle Miocene, 50 ft of gently arched gray, brown, and yellow limy sandstones. Abundant marine invertebrates and bone fragments (= UCMP vertebrate locality V-5734; collectors, E.C. Allison and F. Kilmer, July 22, 1957).

UCMP B-6955 Santa Barbara County, Calif., Los Olivos 15-minute quadrangle. Santa Ynez Mountains. 300 ft N., 500 ft E. of U.S. Highway 101 bridge over Nojoqui Creek. Eocene, Sacate and Gaviota Formations, undifferentiated (= UCMP loc. A-948).

UCMP B-6985 Santa Barbara County, Calif., Los Olivos 15-minute quadrangle. Santa Ynez Mountains. In Nojoqui Creek, 3,000 ft above junction with Gaviota Canyon. Eocene, Gaviota Formation (= LSJU loc. 2908a).

UCMP B-7015 Santa Barbara County, Calif., Lompoc 15-minute quadrangle. Santa Ynez Mountains. Northeast of old San Julian school in small gully. Elevation 975 ft. Eocene, upper part of the Gaviota Formation, oyster reef at the contact between the Gaviota and Sespe Formations.

UCMP B-7033 Santa Barbara County, Calif., Sacate 7½-minute quadrangle. Santa Ynez Mountains. North of Sacate, east of Cañada de Santa Anita, on ridge between main western branches of Cuarta Creek. T. 5 N., R. 33 W. Eocene, Alegria Formation (Dibblee, 1950) [= LSJU loc. 2058; collector, H.J. Hawley, field loc. 76; also LSJU accession No. 53251].

UCMP B-7084 Fresno County, Calif., Domengine Ranch 7½-minute quadrangle. SE¼SE¼ sec. 16, T. 19 S., R. 15 E. Several ledges capping high hill and extending southeast down ridge to the 1,600 ft contour. Miocene, Santa Margarita Formation. Sand dollars abundant in the highest ledge.

UCMP D-117 Fresno County, Calif., Domengine Ranch 7½-minute quadrangle. Skunk Hollow area, north of Coalinga. NE¼SE¼ sec. 10, T. 19 S., R. 15 E. Second ledge in the bottom of a draw draining south to road to Skunk hollow. Ledge at same elevation as and 50 ft north of a well site on north sidewall of canyon. Miocene, Santa Margarita Formation, oyster reefs lying above the Big Blue Formation.

UCMP D-702 Fresno County, Calif., Domengine Ranch 7½-minute quadrangle. North of Coalinga, 1,090 ft S., 500 ft E. of northwest cor. sec. 22, T. 19 S., R. 15 E. In road cut about 25 ft east of Shell Oil Co. well no. 254-15. Miocene, Santa Margarita Formation, from 8 ft oyster bed 4-5 ft above a prominent oyster and *Pecten* reef [= UCMP D-701 = D-1098].

UCMP D-1088 Fresno County, Calif., Coalinga 15-minute quadrangle. West side of Anticline Ridge. 3,630 ft N., 500 ft E. of southwest cor. sec. 28, T. 19 S., R. 15 E. Oyster-*Pecten* bed on hill slope about 120 ft north of Standard Oil well 184. Miocene, Santa Margarita Formation, about 40 ft stratigraphically below unconformity at base of the overlying Etchegoin Formation (Adegoke, 1969).

UCMP D-1147, D-1148 Kings County, Calif., Garza Peak 7½-minute quadrangle. Sec. 34, T. 22 S., R. 16 E.; fossil bed traceable for 2,300 ft, thickest in SW¼ sec. 27. Pliocene, Etchegoin Formation (collector, O.S. Adegoke, 1963).

UCMP D-1207 Kings County, Calif., Garza Peak 7½-minute quadrangle. 40 ft N., 2,450 ft E. of southwest cor. sec. 7, T. 23 S., R. 17 E. Miocene, silty sandstones that grade upward into the McLure Shale Member of the Monterey Formation (O.S. Adegoke, 1969).

UCMP D-2332 Santa Clara County, Calif., Mount Hamilton 15-minute quadrangle. Near Mount Hamilton. Miocene.

UCMP D-2426 San Luis Obispo County, Calif., Nipomo 15-minute quadrangle. East side of Nipomo Valley, about 4½ mi northwest of Nipomo. About 1,000 yd north, slightly west of B.M. 431 in T. 12 N., R. 35 W., just east of Los Berros Road, north and west of Mehlscaw Creek. Miocene, Obispo Formation, rhyolitic beds with mostly external molds (mapped by Hall, 1973b).

UCMP D-3176 Monterey County, Calif., San Ardo 15-minute quadrangle. Near Lonoak, Calif., probably in sec. 5, T. 20 S., R. 9 E., in Sweetwater Canyon. Miocene, Santa Margarita Formation.

UCMP D-4612 Monterey County, Calif., Priest Valley 15-minute quadrangle. N½SE¼ sec. 22, T. 22 S., R. 12 E. Ledge in Meyer's Canyon. Miocene, Pancho Rico Formation.

UCMP D-8261 Los Angeles County, Calif., Mint Canyon 7½-minute quadrangle. Santa Clara Valley north of Newhall and the Santa Susana Mountains. Center of west side NW¼SW¼ sec. 27, T. 4 N., R. 15 W. Miocene, Modelo Formation, from float.

UCMP D-8790 Dominican Republic, on Los Quemados-Sabaneta Road. About 2.6 km west of Los Quemados, above and below the bridge over Rio Gurabo. Miocene or Pliocene, float from Cercado and Gurabo Formations (collectors, H. and E. Vokes; = TU 1231).

UCMP D-8791 Fresno County, Calif., Domengine Ranch 7½-minute quadrangle. North of Coalinga, on Domengine Creek. Sec. 20, T. 18 S., R. 15 E., Miocene, Santa Margarita Formation (locality for LSJU accession No. 46712).

UCMP D-8792 Ventura County, Calif., Ojai 7½-minute quadrangle. East end of Ojai Valley, near abandoned oil well. 1,100

ft E., 650 ft N. of southeast cor. sec. 3, T. 4 N., R. 22 W. Oligocene or Miocene, Vaqueros Formation. (collector, Stanford Geological Survey, 1931, loc. 20-Z, on old Santa Paula quadrangle. Locality for LSJU accession nos. 22363, 22366; = USGS loc. M8012).

UCMP D-8793 Los Angeles County, Calif., Santa Catalina Island South 7½-minute quadrangle. In saddle northeast of Mount Banning and Mount Orizaba, from calcarenite overlain and underlain by dacitic flow breccia. Miocene, unnamed calcarenite (collectors, J.T. and J.G. Smith, 1975; = USGS loc. M6868).

UCMP D-8794 Santa Barbara County, Calif., Los Olivos 15-minute quadrangle. Santa Ynez Mountains, south of Santa Ynez River, west of its junction with Nojoqui Creek. sec. 13, T. 6 N., R. 32 W. Oligocene, Vaqueros Formation (collector, H.J. Hawley, loc. 46; loc. for LSJU accession No. 47624).

UCMP D-8795 Baja California Sur, Mexico. Cedros Island. South of Cedros Village, between Valle Blanca and "Arroyo de los Puercos," where coarse-grained algal conglomerate crops out at beach. *Pecten*-rich bed that separates lower richly mammaliferous unit from overlying brown, friable sand that is poorer in mammals. Pliocene, unnamed strata (collector, F. Kilmer, July, 1965, = Kilmer loc. 25).

UCMP D-8796 Margarita Island, Nueva España, Venezuela. Near Pompatac, beach shells and specimens from dunes just above beach. Holocene (= LSJU loc. 36/1).

UCMP D-8797 Monterey County, Calif., San Lucas 7½-minute quadrangle. Near Wildhorse Canyon, 3 mi east of San Lucas. Miocene, Pancho Rico Formation (= LSJU accession No. 1159, R.B. Moran field loc. C-1001).

UCMP D-8798 Along the York River, Va. Miocene, St. Marys Formation.

UCMP D-8799 Tamaulipas, Mexico. Oligocene, Guajalote Formation (= LSJU accession No. 22378).

UCMP D-8800 Baja California Sur, Mexico. Cedros Island, airport road south of town. Float from east side of main ridge, about ¾ mi from airport road. Pliocene or reworked Miocene sediments, well indurated pebble conglomerate (collector, F. Kilmer, field loc. FK-19).

UCMP D-8801 Baja California Sur, Mexico. Cedros Island, east coast. Miocene or Pliocene (collector, F. Kilmer, 1966, loc. FK-15).

UCMP D-8802 Veracruz, Mexico. Road cut and quarry on Mexico Highway 180, 14 mi east of junction with side road into Coatzacoalcos. Pliocene, Agueguexite Formation (collectors, H. and E. Vokes; = TU loc. 638).

UCMP D-8804 Los Angeles County, Calif., Santa Catalina Island. About 1.5 mi southeast of Mount Orizaba. Miocene (collector, E. Bailey; = LSJU accession No. 1988).

Note: coordinates copied from old locality records may not be accurate.

UCMP S-17 Falcon, Venezuela. 11.1° N., 69.2° W. About 2.5 km S. 10° W. of Rio Seco well #2. Pliocene, San Gregorio Formation, *Schizaster redondo* bed IV (collectors L.W. Henry and C.M. Carson, Standard Oil of California, 1931).

UCMP S-18 Falcon, Venezuela. 11.1° N., 69.2° W. About 2 km north of Río Seco Road of Creole Petroleum Co. Pliocene, San Gregorio Formation (collectors, J.O. Nomland and L.W. Henry, Standard Oil of California, 1931).

UCMP S-69 Departamento Bolivar, Colombia. 10.1° N., 75.2° W. 3 mi north of Cartagena at Cerros Morritos. Pliocene or Pleistocene, in coral limestone, Popa(?) Formation (collector, T.J. Etherington, field loc. C-134).

UCMP S-116 Sucre, Venezuela. Near Manicuare, Araya Peninsula. Pliocene or Pleistocene, Cumana Beds.

UCMP S-141 Distrito Federal, Venezuela. 10.2° N., 66.2° W. Cabo Blanco area, near Playa Grande. ½ km east of Karsten's *Lithothamnion* bed [H. Karston, 1886, Geologie de l'ancienne Colombie bolivarienne, Venezuela, Nouvelle Grenada et Ecuador. Berlin, 32 p.]. Pliocene or Pleistocene, Playa Grande Formation, *"Pecten gigas"* [= *Nodipecten arnoldi*] bed of Karsten (collector, L.W. Henry, 1929).

UCMP S-144 Falcon, Venezuela. Paraguana Peninsula, 11.2° N., 69.2° W. Hilltop above Casa la Vigia, 5 km S. 58° W. of Pueblo Nuevo. Miocene, soft yellowish marl, probably Cantaure Formation (Hunter and Bartok, 1976).

UCMP S-146 Cubagua Island, Nueva Esparta, Venezuela. Holocene specimens.

UCMP S-148 Falcon, Venezuela. 11.1° N., 69.2° W. South flank of Río Seco anticline, about 3.75 km S. 47° E. of Río Seco. Miocene or lower Pliocene, probably La Vela Formation (Hunter and Bartok, 1976) (collectors L.W. Henry and W.E. Heater, Standard Oil of California, 1928).

UCMP S-254 Falcon, Venezuela. 11.2° N., 70.1° W. Western Paraguana Peninsula. Cliff at Las Piedras, about 350 m S. 10° E. of village of Carirubana. Lower Pliocene, Paraguana Formation, from large oyster bed underlying limestone that caps the tableland (collectors L.W. Henry and C.M. Carson, Standard Oil of California, 1930).

UCMP S-284 Falcon, Venezuela. 1 km southeast of Cucurucho.

UCMP S-287 Miller La Vela Sheet 2. Miocene, probably Caujarao Formation.

UCMP S-305 Falcon, Venezuela. 11.1° N., 69.2° W. Mataruca, 1.6 km east of La Vela de Coro. La Vela Sheet 2. Upper middle Miocene (J. and W. Gibson-Smith, 1979), Caujarao Formation, Mataruca Member.

UCMP S-7331 Departamento Cordoba, Colombia. 8.1° N., 76.1° W.. Hatachica on Río Sinu, above Marta Magdalena [= modern town of La Risa]. Oligocene, formation unknown (collectors Rohwer and Steineke, Standard Oil of California; = field loc. 1280).

UCMP S-8064 Departamento Atlantico, Colombia. 800 m southwest of Puerto Colombia, near Barranquilla. Pliocene or Pleistocene, limestone marl, probably Popa Formation (H. Duque-Caro, written commun., 1979).

UCMP S-8219 Veracruz, Mexico. Isthmus of Tehuantepec, Río Las Playas. ½ mi southeast of Buena Vista. Oligocene or Miocene (collector, E. Böse, field loc. 526E).

UCMP S-8362 Falcon, Venezuela. Distrito Democracia, Paraguana Peninsula, about ½ km north of Pueblo Amuay. Just west of Los Tagues-Amuay road. Upper Miocene or lower Pliocene marl, probably Paraguana Formation (collectors, S.B. Henry and J.P. Bailey, Standard Oil of California, 1927).

UCMP S-8293 Tamaulipas, Mexico. 2.7 mi upstream from town of San Fernando. In riverbed, El Salto de Río Conchos. Oligocene or Miocene, Guajalote Formation (collectors, E. Böse and O.A. Cavins, 1923, field no. 526D).

UNIVERSITY OF CALIFORNIA, RIVERSIDE LOCALITIES

UCR 1149 Kern County, Calif., Rio Bravo Ranch 7½-minute quadrangle. Southwest flank of Pyramid Hill, 2,200 ft N., 600 ft

E. of southwest cor. sec. 14, T. 28 S., R. 29 E. Miocene, Jewett Sand (collector, William Rau, 1928).

UCR 1152 Kern County, Calif., Rio Bravo Ranch 7½-minute quadrangle. Southwest flank of Pyramid Hill, SW¼ sec. 14, T. 28 S., R. 29 E. Miocene, Jewett Sand.

UCR 1154 Kern County, Calif., Pine Mountain 7½-minute quadrangle. Northwest of Pyramid Hill, southeast of Coffee Canyon-Poso Creek. 2,045 ft N., 2,195 ft E. of northwest cor. sec. 15, T. 28 S., R. 29 E. [Rio Bravo Ranch 7½-minute quadrangle], in sec. 10. Miocene, Jewett Sand, 35 ft above its base (collector, William Rau, 1928).

UCR 1178 Kern County, Calif., Pine Mountain 7½-minute quadrangle. West side of Coffee Canyon, 2,200 ft E. of northwest cor. sec. 4, T. 28 S., R. 29 E. Miocene, Jewett Sand (collector, M. Birkhauser).

UCR 1185 Kern County, Calif., Pine Mountain 7½-minute quadrangle. North of Poso Creek-Coffee Canyon. Center of sec. 4, T. 28 S., R. 29 E. Miocene, Jewett Sand, Pyramid Hill Sand Member (W.O. Addicott, 1972).

UCR 1257 San Luis Obispo County, Calif., on boundary of Salisbury Canyon and Wells Ranch quadrangles. South slope of Caliente Range, in small canyon 3 mi northwest of Cuyama Ranch house. NW¼ sec. 32, T. 11 N., R. 26 W. 235 ft stratigraphically above UCR 1273. Miocene, Temblor Formation of field labels (collector, W.H. Whittier, 1930).

UCR 1258 San Luis Obispo County, Calif. South slope of Caliente Range, in small canyon 3 mi northwest of Cuyama Ranch house. NW¼ sec. 32, T. 11 N., R. 26 W. 735 ft stratigraphically above UCR 1273. Miocene, Temblor Formation.

UCR 1269 Kern County, Calif., Orchard Peak 15-minute quadrangle. Temblor Range, east side of mouth of Cedar Canyon. Central part of NW¼ sec. 28, T. 27 S., R. 18 E. Oligocene or Miocene, Vaqueros Formation of collector, E.K. Craig, 1932.

UCR 1273 San Luis Obispo County, Calif. South slope of Caliente Range, in small canyon about 3 mi northwest of Cuyama Ranch house. NW¼ sec. 32, T. 11 N., R. 26 W. Miocene, Temblor Formation (collector, W.H. Whittier, 1930).

UCR 1285 Santa Barbara County, Calif., Zaca Lake 7½-minute quadrangle. San Rafael Mountains. In syncline between Zaca Creek and Round Corral Canyon. Miocene, calcareous sandstone.

UCR 4021 Kern County, Calif., Pleito Hills 7½-minute quadrangle. San Emigdio Mountains, east side of Pleitito Creek, east corner of San Emigdio grant. Northwest corner of fractional sec. 16, T. 10 N., R. 21 W. Oligocene, about 150 ft above the Vaqueros Formation, *fide* collector, E.K. Craig, 1931.

UCR 5042 Riverside County, Calif., Whitewater 7½-minute quadrangle. Southeast San Bernardino Mountains, west side of west branch of Super Creek. 1,400 ft E., 520 ft N. of southwest cor. sec. 36, T. 2 S., R. 3 E., elevation 1,930 ft. Miocene, Imperial Formation, basal breccia ["Bramkampf's locality"].

UCR 5227 Northern Channel Islands, Calif., Santa Cruz Island A 7½-minute quadrangle. Southwest part of island, in low sea cliff 1,000 ft west of mouth of Canada del Posa. Miocene, Vaqueros Formation, sandstone member (collector, J. Suppe and J. Swinehart, 1964).

UCR 7232 Los Angeles County, Calif., Malibu Beach 7½-minute quadrangle. Santa Monica Mountains. Southeast slope of Saddle Peak, upper end of Las Flores Canyon. Miocene, Vaqueros and Topanga Formations, undifferentiated, of collector, Soper, 1938.

UCR 7267 Imperial County, Calif., Carrizo Mountain 7½-minute quadrangle. Mouth of Fossil or Alverson Canyon, on east saddle between Fossil Canyon and first canyon to the east. Miocene, Imperial Formation, Latrania Sand Member.

UCR 7583 San Diego County, Calif., La Jolla quadrangle. Pacific Beach, middle of cliff 25 ft south of west end of Loring Street. In lower beds of exposed section. Pliocene, San Diego Formation (collector, J. Mount, 1969, 1974).

UCR 7585 Ventura County, Calif., Santa Susana 7½-minute quadrangle. Santa Susana Mountains, east side of Chivo Canyon. 1,980 ft W., 100 ft S. of northeast cor. sec. 29, T. 3 N., R. 17 W. Pliocene, Saugus Formation, 400 ft stratigraphically above its base (collector, J. Mount, 1968).

UCR 7586 Ventura County, Calif., Simi 7½-minute quadrangle. Oak Ridge, east side of east branch of Wiley Canyon. SW¼NE¼ sec. 1, T. 3 N., R. 9 W. Miocene, Vaqueros Formation, "lower third." (collector, J. Mount, 1963).

UCR 7596 Los Angeles County, Calif., Warm Springs Mountain 7½-minute quadrangle. East side of Castaic Canyon, NW¼SW¼ sec. 31, T. 6 N., R. 17 W. Miocene, Castaic Formation, basal conglomerate.

UCR 7957 San Clemente Island, Calif.

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[Some numbers are locality numbers, some are accession numbers]

UCSB 1561 Santa Barbara County, Calif., Sacate 7½-minute quadrangle. Cañada de Santa Anita, west of Sacate. Oligocene, Alegria Formation.

UCSB 1651 Santa Cruz Island, Calif., southwest part between Posa and Johnston Canyons, on upper part of ridge south of Posa Canyon. Northeast of Paleocene deposits. Miocene, Vaqueros Formation, diorite breccia member ["Lower Kinton Point" or "Kinton Point A" unit of specimen labels].

UCSB 1668 Santa Cruz Island, Calif. West side, just south of mouth of Alegria Canyon, on beach in conglomerate bed. Miocene, Vaqueros Formation, diorite breccia member [= "Lower Kinton Point Formation" of specimen labels].

UCSB 1801 Santa Cruz Island, Calif. Southwest coast, on beach north of Posa anticline, next to the road. At contact between lower and middle members of the "Kinton Point Formation" of field notes. Miocene, Vaqueros Formation, sandstone facies (= field No. JK-FA 65-102).

UCSB 1806 Santa Cruz Island, Calif. Southwest coast, southeast of Near Point on beach near mouth of a small canyon about 950 ft northwest of the stream in Cañada Posa. Miocene, Vaqueros Formation, sandstone member of McLean and others (1976) (= field No. DWW-16).

UCSB 1844 Santa Cruz Island, Calif. Southwest coast, south of Posa Anchorage, on the beach in extensive *Pecten-Balanus* bed. Miocene, Vaqueros Formation, sandstone member.

UCSB 1846 Santa Cruz Island, Calif. Southwest coast, south of Morse Point. On beach in *Pecten-Balanus* reef within a massive conglomerate. Miocene, Vaqueros Formation, sandstone member.

UCSB 1847 Santa Cruz Island, Calif. Southwest coast, south of Posa Anchorage, on beach in extensive *Pecten-Balanus* reef. Miocene, Vaqueros Formation, sandstone member (same horizon as UCSB 1846).

UCSB 1904 Santa Cruz Island, Calif. West side, in sea cliff between Christi and Los Sauces Canyons, just north of Kinton Point. In second short, unnamed canyon south of Christi Ranch, about 700 ft from the beach on north side of canyon; immediately below the 150 ft contour and just east of where it changes from a north-south to an east-west trending line. Miocene, Vaqueros Formation, sandstone

member (collector L. Edwards, 1964, field No. E-8).

UCSB 1912 Santa Cruz Island, Calif. Southwest part of island, on beach at mouth of first canyon west of Posa Canyon. Miocene, Vaqueros Formation, sandstone member [= "Kinton Point B" member of specimen labels] (= L. Edwards, 1964 field No. E-5).

UCSB 4313, 4346, 4351 Fresno County, Calif. Joaquin Rocks 15-minute quadrangle, north of Coalinga. SE¼SE¼NW¼NE¼ sec. 33, T. 18 S., R. 15 E. In stream bank and overhanging cliff about 300 ft northwest of where Mack Pump Road crosses Domengine Creek. 1.7 mi west of Mack Pumping Station, on old road that follows north side of Domengine Creek. Miocene, Santa Margarita Formation.

UCSB 4372 Santa Cruz Island, Calif. West coast, north of Kinton Point, third canyon south of Christi Ranch canyon. Miocene, Vaqueros Formation, sandstone member (= field No. FX SC5-64).

UCSB 4382 Santa Cruz Island, Calif. Southwest corner, along beach east of Morse Point, west of mouth of Johnston Canyon. Miocene, Vaqueros Formation, sandstone member (collector, H. Sonneman, 1964, field No. FX SC4-64).

UCSB 4397 Santa Cruz Island, Calif. Southwest part, near beach between Morse Point and Johnston Canyon, at foot of hill. Immediately below and at west end of a broad U-shaped bend in the 50 ft contour. Miocene, Vaqueros Formation, sandstone member (= field No. DM JB 65-43).

UCSB 4675 Santa Rosa Island, Calif. Santa Rosa Island East 7½-minute quadrangle. Southeast coast, west of East Point, on beach (= field No. SR67-28, on D.W. Weaver and others, 1969 map). Miocene, Vaqueros Formation.

UCSB 4698 Santa Rosa Island, Calif. North coast, mouth of Canada Garanon. Miocene, Vaqueros Formation (field No. SR67-53).

UCSB 5192 Santa Rosa Island, Calif. Santa Rosa Island West 7½-minute quadrangle. Southwest coast, east southeast of Pemberton corehole 1. Miocene, Vaqueros Formation, coarse-grained sandstone and conglomerate (collector, W. Poponoe, field No. SR64-11P; also = UCSB 5749).

U.S GEOLOGICAL SURVEY (USGS), MENLO PARK, CENOZOIC REGISTER

M903 Monterey County, Calif., San Lucas 7½-minute quadrangle. 425 ft S., 425 ft W. of northeast cor. sec. 5, T. 21 S., R. 9 E. Sandstone and shell knoll on west side of Highway 198. Miocene, Pancho Rico Formation or slightly older beach deposit.

M912 Monterey County, Calif., San Lucas 7½-minute quadrangle. 2,200 ft N. of southwest cor. sec. 29, T. 20 S., R. 9 E. Worn, mixed Miocene and Pliocene fossils from terraces between Salinas River and Cholame Hills. Miocene, Pancho Rico Formation.

M913 Monterey County, Calif., San Lucas 7½-minute quadrangle. North side of Wildhorse Canyon, 2,650 ft N., 1,075 ft E. of southwest cor. sec. 8, T. 20 S., R. 9 E. Miocene, Pancho Rico Formation.

M952 Monterey County, Calif., San Lucas 7½-minute quadrangle. 800 ft N., 2,250 ft E. of southwest cor. sec. 32, T. 19 S., R. 9 E. Miocene, Pancho Rico Formation.

M956 Fresno County, Calif., Domengine Ranch 7½-minute quadrangle. North of Coalinga, from both sides of lower Domengine Creek near end of road. 0.7 mi N., 0.25 mi W. of southeast cor. sec. 33, T. 18 S., R 15 E. Upper Miocene, Santa Margarita Formation.

M980 = M1929

M1025 Port Moller 1:250,000 quadrangle, Alaska. North tributary to Mud Bay, in flats. 15.8″ E., 13.2″ N. of southwest cor. of quadrangle. Upper Eocene, unnamed strata, *Acila shumardi* zone (MacNeil, 1967).

M1341 Monterey County, Calif., San Lucas 7½-minute quadrangle. North side of Wildhorse Canyon, NW¼SE¼ sec. 8, T. 20 S., R. 9 E. Miocene, Pancho Rico Formation. Mixed beach assemblage of late Miocene and early Pliocene fossils.

M1345 Monterey County, Calif., San Lucas 7½-minute quadrangle. South side of Wildhorse Canyon, SE¼SE¼ sec. 8, T. 20 S., R. 9 E. and NE¼NE¼ sec. 17, T. 20 S., R. 9 E. Miocene, Pancho Rico Formation. Mixed beach assemblage of late Miocene and early Pliocene fossils.

M1590 Kern County, Calif., Rio Bravo Ranch 7½-minute quadrangle. Large fossil quarry southwest of Pyramid Hill in small gully on south side of southwest-trending ridge through SE¼ sec. 15, T. 28 S., R. 29 E.; 1,450 ft N., 1,500 ft W. of southeast cor. sec. 15. Miocene, basal part of the Jewett Sand.

M1591 (= UCMP B-1662) Kern County, Calif., Rio Bravo Ranch 7½-minute quadrangle. Southwest flank of Pyramid Hill, north side of west-trending gully in NW¼ sec. 14, T. 28 S., R. 29 E.; 2,150 ft N., 500 ft E. of southwest cor. sec. 14. Miocene, conglomeratic sandstone in basal part of the Jewett Sand.

M1619 Kern County, Calif., Arvin 7½-minute quadrangle. Tejon Hills, Comanche Point area, near head of second east-trending gully due north of Hill 1039; NW¼SW¼ sec. 24, T. 32 S., R. 29 E. Miocene, *Pecten*-oyster conglomerate bed, Santa Margarita Formation.

M1678 Monterey County, Calif., Tierra Redonda Mountain 7½-minute quadrangle. 4,100 ft S., 1,300 ft E. of northwest cor. sec. 20, T. 24 S., R. 10 E. Miocene.

M1698 Kern County, Calif., Knob Hill 7½-minute quadrangle. 150 ft S., 50 ft E. of northwest cor. sec. 7, T. 28 S., R 29 E. 350 ft S. of bridge across Poso Creek, near base of cliff. Miocene, Olcese Sand. [Probably = the Ocoya Creek locality collected by Blake in August, 1853]

M1700 Kern Co., Calif., Pine Mountain 7½-minute quadrangle. 2,300 ft S., 2,000 ft E. of northwest cor. sec. 10, T. 28 S., R. 29 E. Early Miocene. Jewett Sand, Pyramid Hill Sand Member or basal conglomeratic sandstone.

M1929 (= M980) Monterey County, Calif., San Ardo 15-minute quadrangle. South side of Pancho Rico Creek, base of bluff; 1,600 ft N., 1,400 ft W. of southeast cor. sec. 11, T. 22 S., R. 10 E. Miocene, Pancho Rico Formation.

M1936 Monterey County, Calif., Tierra Redonda Mountain 7½-minute quadrangle. 975 ft N., 2,150 ft E. of projected southwest cor. sec. 29, T. 24 S., R. 10 E. Upper Miocene, Santa Margarita Formation.

M1953 Los Angeles County, Calif., Malibu Beach 7½-minute quadrangle. Central Santa Monica Mountains, 2,830 ft E., 730 ft S. of southwest cor. sec. 28, T. 1 S., R. 17 W. Miocene, *Vertipecten* bed in the Topanga Canyon Formation, Saddle Peak Member (Yerkes and Campbell, 1980a).

M1969 Monterey County, Calif., Stockdale Mountain 7½-minute quadrangle. 2,625 ft N., 1,850 ft E. of southwest cor. sec. 34, T. 23 S., R. 13 E. Upper Miocene, Santa Margarita Formation, from leached, limonitized fine sand.

M2001 Santa Cruz County, Calif., Felton 7½-minute quadrangle. 1,450 ft N., 100 ft W. of southeast cor. sec. 25, T. 9 S., R. 2 W., 800 ft W. of Zayante Creek. Oligocene, Vaqueros Sandstone.

M2046 San Luis Obispo County, Calif., Bradley 15-minute quadrangle. North bank of Nacimiento River, near center of north-south line, sec. 11, T. 25 S., R. 10 E. Upper Miocene, Santa Margarita Formation.

M2049 San Luis Obispo County, Calif., Adelaida 7½-minute quadrangle. Just south of Sulphur Spring Road, 2,300 ft S., 500 ft

E. of northwest cor. sec. 19, T. 25 S., R. 11 E. Upper Miocene, Santa Margarita Formation.

M2097 Orange County, Calif., San Juan Capistrano 7½-minute quadrangle. About ½ mi northwest of Galivan Siding. 3,775 ft S., 675 ft W. of northeast cor. sec. 11, T. 7 S., R. 8 W. Pliocene, Niguel Formation.

M2098 Orange County, Calif., San Juan Capistrano 7½-minute quadrangle. About 3 mi north of San Juan Capistrano. 1,650 ft S., 2,550 ft W. of northeast cor. sec. 24, T. 7 S., R. 8 W. Elevation about 340 ft. Pliocene, Niguel Formation.

M2099 Orange County, Calif., San Juan Capistrano 7½-minute quadrangle. Approximately 2½ mi north of San Juan Capistrano, between Arroyo Trabuco and Horno Creek. 1,425 ft S., 3,450 ft W. of northeast cor. sec. 30, T. 7 S., R. 7 W. Elevation about 530 ft. Pliocene, Niguel Formation.

M2106 Orange County, Calif., Dana Point 7½-minute quadrangle. Northeast of Capistrano Beach. In artificial cut, north side of Deep Canyon. 4,400 ft S., 2,400 ft W. of northeast cor. projected sec. 13, T. 8 S., R. 8 W. Outcrop destroyed by excavation in 1968; it contained mixed deepwater and shallow water forms and was a turbidity deposit. Pliocene, Capistrano Formation, upper part (collector, J.G. Vedder, 1964, field No. SA 248A).

M2275 Monterey County, Calif., Hernandez Valley 15-minute quadrangle. Road cut, north side of Bull Canyon Road; 100 ft S., 2,400 ft E. of northwest cor. sec. 26, T. 19 S., R. 9 E. Miocene, Pancho Rico Formation.

M2279 Monterey County, Calif., King City 15-minute quadrangle. North side of Wildhorse Canyon, near head of small gully; 2,500 ft N., 300 ft W. of southeast cor. sec. 8, T. 20 S., R. 9 E. Float from Miocene Pancho Rico Formation and reworked Miocene deposits.

M2280 Monterey County, Calif., Greenfield 15-minute quadrangle. West of Eagle Mountain in southwest-trending canyon near center of SW¼ sec. 29, T. 18 S., R. 9 E. Elevation about 1,350 ft. Miocene, Pancho Rico Formation.

M2283 Monterey County, Calif., San Ardo 15-minute quadrangle. East side of road from Lynch Canyon to abandoned well in southwest cor. sec. 8; 2,300 ft S., 2,200 ft E. of northwest cor. sec. 8, T. 22 S., R. 11 E. Miocene, Pancho Rico Formation.

M2295 Monterey County, Calif., San Ardo 15-minute quadrangle. Two mi south of San Lucas, in bluffs east of Highway 101. Miocene, Pancho Rico Formation.

M2305 San Luis Obispo County, Calif., Bradley 15-minute quadrangle. On top of ridge northwest of Nacimiento River; 1,925 ft S., 350 ft W. of northeast cor. sec. 11, T. 25 S., R. 10 E. Upper Miocene, Santa Margarita Formation.

M2308 Monterey County, Calif., Tierra Redonda Mountain 7½-minute quadrangle. On top of bluff south of San Antonio River; 4,500 ft N., 1,575 ft E. of southwest cor. sec. 32, T. 24 S., R. 10 E. Upper Miocene, Santa Margarita Formation.

M2314 Santa Barbara County, Calif., New Cuyama 7½-minute quadrangle. South side of Cuyama Valley, west side of ridge crest; 450 ft N., 2,100 ft W. of southeast cor. sec. 1, T. 9 N., R. 27 W. Elevation about 2,800 ft. Miocene, Branch Canyon Formation of Hill and others (1958), upper part.

M2321 Santa Barbara County, Calif., New Cuyama 7½-minute quadrangle. North side of canyon just west of fence line, 100 ft N., 2,500 ft W. of southeast cor. sec. 1, T. 9 N., R. 27 W. Elevation about 2,770 ft. Miocene, Branch Canyon Formation of Hill and others (1958), in sandstone bed near top.

M2337 Santa Barbara County, Calif., New Cuyama 7½-minute quadrangle. West side of gully, 2,875 ft N., 1,050 ft E. of southwest cor. sec. 35, T. 10 N., R. 27 W. Elevation about 2,600 ft. Miocene, Branch Canyon Formation of Hill and others (1958), resistant limy sandstone bed at top of section.

M2361 Santa Barbara County, Calif., Fox Mountain 7½-minute quadrangle. North side of canyon, 325 ft E., 4,950 ft S. of northwest cor. of quadrangle. Elevation about 2,940 ft Upper Miocene, Branch Canyon Formation of Hill and others (1958), limy sandstone in upper part.

M2416 Santa Barbara County, Calif., Fox Mountain 7½-minute quadrangle. 1,850 ft N., 5,550 ft E. of lat 34°50′00″ N., long 119°35′00″ W. Elevation about 3,370 ft. Miocene, Saltos Shale Member, Monterey Shale of Hill and others (1958) (Vedder, 1968).

M2417 Santa Barbara County, Calif., Fox Mountain 7½-minute quadrangle. West of Santa Barbara Canyon, 2,950 ft N., 2,775 ft W. of lat 34°50′ N., long 119°32′30″ W.. Elevation about 3,120 ft Miocene, Branch Canyon Formation of Hill and others (1958), basal part.

M2418 Santa Barbara County, Calif., Fox Mountain 7½-minute quadrangle. West of Santa Barbara Canyon, 1,800 ft N., 4,650 ft W. of lat 34°50′00″ N., long 119°32′30″ W. Elevation 3,280′. Miocene, Saltos Shale Member, Monterey Shale of Hill and others (1958) (Vedder, 1968).

M2424 Santa Barbara County, Calif., Fox Mountain 7½-minute quadrangle. West of Santa Barbara Canyon, 6,450 ft E., 200 ft S. of lat 34°50′ N., long 119°37′30″ W. Elevation about 3,530 ft. Miocene, Branch Canyon Formation of Hill and others (1958), lower member (Vedder, 1968).

M2442 Santa Barbara County, Calif., Fox Mountain 7½-minute quadrangle. 6,650 ft S., 1,100 ft E. of lat 34°52′30″ N., long 119°35′00″ W. Elevation about 2,980 ft. Miocene, Branch Canyon Formation of Hill and others (1958).

M2445 Santa Barbara County, Calif., Fox Mountain 7½-minute quadrangle. West of Santa Barbara Canyon, 8,850 ft E., 1,490 ft N. of lat 34°50′00″ N., long 119°37′30″ W., in T. 9 N., R. 25 W. Oligocene, Vaqueros Formation, basal part of section.

M2446 Santa Barbara County, Calif., Fox Mountain 7½-minute quadrangle. West of Santa Barbara Canyon. 7,500 ft E., 1,225 ft N. of lat 34°50 ft N., 119°37′30″ W. Elevation about 3,730 . Miocene, Vaqueros Formation.

M2631 Kern County, Calif., Packwood Creek 7½-minute quadrangle. Eastern Temblor Range. 1,800 ft S., 1,550 ft E. of northwest cor. sec. 28, T. 27 S., R. 18 E. About ¼ mi south of mouth of Cedar Canyon, on east side of road. Oligocene, Temblor Formation, Santos Shale Member, Agua Sandstone bed. *"Macrochlamis" magnolia ojaiensis* biostrome in basal conglomerate (collector, W.O. Addicott, 1965).

M2755 Los Angeles County, Calif., Point Dume 7½-minute quadrangle. Santa Monica Mountains, Zuma Canyon, north of Malibu Coast fault. 4,050 ft N. 47° E. of southwest cor. sec. 13, T. 1 S., R. 19 W. Miocene, Vaqueros Formation, uppermost part of San Nicholas Member (Yerkes and Campbell, 1980a).

M2826 San Luis Obispo County, Calif., La Panza 15-minute quadrangle. Near Hay Canyon, 50 ft S., 2,100 ft W. of northeast cor. sec. 21, T. 30 S., R. 17 E. Miocene, Vaqueros Formation, Painted Rock Sandstone Member, lower *Crepidula princeps* biostrome, a few feet above base of unit.

M2831 San Luis Obispo County, Calif., La Panza 15-minute quadrangle. 1,900 ft S., 700 ft W. of northeast cor. sec. 21, T. 30 S., R. 17 E., on west side of small gully near spring. Miocene, Vaqueros Formation, Painted Rock Sandstone Member, basal 10 ft of section that unconformably overlies boulder conglomerate.

M2872 San Luis Obispo County, Calif., Pozo 15-minute quadrangle. Northern La Panza Range, 1,700 ft N., 2,450 ft W. of southeast cor. sec. 13, T. 28 S., R. 14 E.. Upper Miocene, Santa Margarita Formation, from *Saxidomus* bed on east side of Quailwater Creek.

M2879 San Luis Obispo County, Calif., Pozo 15-minute quadrangle. 900 ft W. of northeast cor. sec. 27, T. 28 S., R. 15 E. Float from ridge top. Miocene, Santa Margarita Formation.

M2895 San Luis Obispo County, Calif., Pozo 15-minute quadrangle. Shell Creek Canyon, northern La Panza Range. 250 ft S., 500 ft E. of northwest cor. sec. 26, T. 28 S., R. 15 E.; hills on west side of the road. *Lyropecten crassicardo-Ostrea titan* biostrome in massive sandstone. Upper Miocene, Santa Margarita Formation.

M2896 San Luis Obispo County, Calif., Pozo 15-minute quadrangle. 900 ft N., 50 ft W. of southeast cor. sec. 22, T. 28 S., R. 15 E. *Lyropecten crassicardo-Ostrea titan* biostrome near top of the Santa Margarita Formation, Upper Miocene.

M2897 San Luis Obispo County, Calif., Pozo 15-minute quadrangle. 900 ft N., 50 ft E. of southwest cor. sec. 23, T. 28 S., R. 15 E. Stratigraphically above M2895 and a diatomaceous shale bed, a few feet below the base of the Paso Robles Formation. Upper Miocene, Santa Margarita Formation.

M3016 San Miguel Island, Calif. East end of the island between Bay Point and Cardwell Point. North-trending canyon 600 ft N., 2,900 ft W. of triangulation station "Fish," elevation about 200 ft. Miocene, Beechers Bay Member of Avila and Weaver (1969), Monterey Formation (Weaver and others, 1969). Upper Relizian, just below basal Luisian foraminiferal stage.

M3161 Orange County, Calif., Laguna Beach 7½-minute quadrangle. Northwest of Laguna Canyon-Niguel Road junction. Elevation about 605 ft. 2,580 ft S., 1,100 ft W. of junction of T. 7 S., R. 8 W. Miocene, Vaqueros Formation.

M3166 Orange County, Calif., Laguna Beach 7½-minute quadrangle. 3,400 ft N., 540 ft W. of southwest cor. sec. 7, T. 7 S., R. 8 W., in tributary west of Laguna Canyon, 380 ft elevation. Miocene, Vaqueros Formation.

M3168 Orange County, Calif., Laguna Beach 7½-minute quadrangle. In San Joaquin Hills, 8,290 ft N., 260 ft N. of southwest cor. sec. 7, T. 7 S., R. 8 W. West side of Nigger Canyon, elevation about 530 ft. Miocene, Vaqueros Formation.

M3179 Orange County, Calif., San Juan Capistrano 7½-minute quadrangle. East of Trabuco Canyon, 2,500 ft S., 4,350 ft E. of northwest cor. sec. 8, T. 7 S., R. 7 W. Elevation about 800 ft. Upper middle Miocene sandstone lens within the San Onofre Breccia (Vedder and others, 1957).

M3188 Orange County, Calif., San Juan Capistrano 7½-minute quadrangle. North of Sheep Hills, in stream bed 1,150 ft W., 12,250 ft S. of northeast cor. sec. 5, T. 7 S., R. 8 W., elevation about 360 ft. Miocene, basal sandy facies of the Monterey Shale with Luisian foraminifers (J.G. Vedder, oral commun., 1983).

M3222 Orange County, Calif., San Juan Capistrano 7½-minute quadrangle, 1949 ed. San Joaquin Hills, 250 ft S., 200 ft W. of northeast cor. of quadrangle; elevation about 960 ft. Miocene, uppermost part of the Topanga Formation.

M3225 Orange County, Calif., El Toro quadrangle, 1950 ed. 525 ft W., 1,200 ft N. of southeast cor. sec. 21, T. 6 S., R. 8 W. At west end of dam for small reservoir, elevation about 320 ft. Miocene, Monterey Shale, with Luisian foraminifers (J.G. Vedder, oral commun., 1983).

M3241 Monterey County, Calif., Bryson 15-minute quadrangle. 700 ft N., 1,850 ft W. of northeast cor. sec. 18, T. 24 S., R. 9 E., in bed of Copperhead Creek. Miocene, Santa Margarita Formation or fossils reworked in Miocene Pancho Rico Formation.

M3280 Kern County, Calif., Las Yeguas Ranch 7½-minute quadrangle. South side of Media Agua Creek, minor saddle in northeast-trending ridge; 900 ft S., 500 ft E., of northwest cor. sec. 23, T. 28 S., R. 19 E. Oligocene, Temblor Formation, Wygal Sandstone Member.

M3281 Kern County, Calif., Las Yeguas Ranch 7½-minute quadrangle. South side of hill 2259, south of Media Agua Creek. 2,200 ft N., 1,000 ft W. of southeast cor. sec. 22, T. 28 S., R. 19 E. Oligocene, Temblor Formation, basal part of Wygal Sandstone Member.

M3320 San Luis Obispo County, Calif., Wells Ranch 7½-minute quadrangle. 6,440 ft N., 4,525 ft E. of lat 35°00′00″ N., long 119°42′30″ W., in sec. 30, T. 11 N., R. 26 W.; elevation about 2,875 ft. Miocene, Monterey Shale, Saltos Shale Member.

M3341 San Luis Obispo County, Calif., Wells Ranch 7½-minute quadrangle. 6,800 ft S., 4,850 ft W. of intersection of 35°12′30″ N., 119°42′30″ W.; elevation 3,110 ft. Miocene, Monterey Shale, lower part of the Saltos Shale Member.

M3344 San Luis Obispo County, Calif., Wells Ranch 7½-minute quadrangle. Northeast Caliente Range, 6,975 ft N., 4,080 ft W. of lat 35°00′00″ N., long 119°42′30″ W., elevation about 3,250 ft. NW¼ sec. 26, T. 11 N., R. 27 W. Miocene, Monterey Shale, basal part of Saltos Shale Member.

M3351 San Luis Obispo County, Calif., Wells Ranch 7½-minute quadrangle. 2,775 ft N., 5,275 ft E. of intersection of lat 35°00′00″ N., long 119°45′00″ W. Elevation about 2,910 ft (collector, J.G. Vedder, 1961).

M3358 San Luis Obispo County, Calif., Cuyama Ranch 7½-minute quadrangle. 2,750 ft S., 2,990 ft E. of lat 35°00′00″ N., long 119°45′00″ W., elevation 2,300 ft. Miocene.

M3365 San Luis Obispo County, Calif., New Cuyama 7½-minute quadrangle. Southeast Caliente Range. 2,120 ft S., 1,785 ft E. of lat 35°00′00″ N., long 119°45′00″ W.; elevation about 2,545′. Miocene, Vaqueros Formation, upper part of the Painted Rock Sandstone Member.

M3371 San Luis Obispo County, Calif., Wells Ranch 7½-minute quadrangle. 2,550 ft N., 4,275 ft W. of lat 35°00′00″ N., long 119°40′00″ W., elevation 2,800 ft. West sec. 29, T. 11 N., R. 26 W. Miocene, Monterey Shale, Saltos Shale Member (Dibblee, 1973b).

M3382 San Luis Obispo County, Calif., Wells Ranch 7½-minute quadrangle. 5,250 ft E., 4,450 ft N. of lat 35°00′00″ N., long 119°42′30″ W.; elevation 2,690 ft. Miocene, Monterey Shale, Saltos Shale Member.

M3396 San Luis Obispo County, Calif., New Cuyama 7½-minute quadrangle. 3,000 ft S., 390 ft W. of lat 35°00′00″ N., long 119°42′30″ W., in sec. 36, T. 11 N., R. 27 W.; elevation about 2,650 ft. Miocene, Vaqueros Formation, Painted Rock Sandstone Member.

M3403 San Luis Obispo County, Calif., Wells Ranch 7½-minute quadrangle. Caliente Range, 3,875 ft N., 4,700 ft W. of intersection of lat 35°00′00″ N., long 119°40′00″ W.. Elevation about 2,550 ft. Miocene, Monterey Shale, Saltos Shale Member.

M3409 San Luis Obispo County, Calif., New Cuyama 7½-minute quadrangle. Southwest Caliente Range. 2,475 ft S., 3,150 ft W. of intersection of lat 35°00′00″ N., long 119°40′00″ W.; elevation about 2,275 ft. Miocene, Monterey Shale, basal part of the Saltos Shale Member or Vaqueros Formation, Painted Rock Sandstone Member.

M3436 San Luis Obispo County, Calif., Salisbury Canyon 15-minute quadrangle. Caliente Range, 4,675 ft S., 5,725 ft E. of intersection of lat 35°00′00″ N., long 119°42′30″ W., from sec. 31, T. 11 N., R. 26 W. Elevation about 2,250 ft. Miocene, Monterey Shale, Saltos Shale Member.

M3439 San Luis Obispo County, Calif., New Cuyama 7½-minute quadrangle. Caliente Range, 7,075 ft S., 2,050 ft E. of intersection of lat 35°00′00″ N., long 119°42′30″ W., in sec. 6, T. 10 N., R. 26 W. Elevation 2,450 ft. Miocene, Monterey Shale, Saltos Shale Member.

M3446 San Luis Obispo County, Calif., Wells Ranch 7½-minute quadrangle. 4,400 ft N., 1,300 ft E. of intersection of lat 35°00′00″

N., long 119°40′00″ W., in sec. 29, T. 11 N., R. 26 W. Elevation about 3,050 ft. Miocene, Monterey Shale, Saltos Shale Member.

M3448 San Luis Obispo County, Calif., Wells Ranch 7½-minute quadrangle. Northeast Caliente Range, 1,075 ft E., 4,300 ft N. of intersection of lat 35°00′00″ N., long 119°40′00″ W. Elevation about 2,650 ft. Miocene, Monterey Shale Formation, Saltos Shale Member.

M3519 San Luis Obispo County, Calif., Cuyama 7½-minute quadrangle. 7,950 ft N., 4,270 ft W. of lat 34°57′30″ N., long 119°30′00″ W. Elevation about 3,000 ft. Oligocene or Miocene, Vaqueros Formation.

M3520 San Luis Obispo County, Calif., Salisbury Canyon 15-minute quadrangle. 5,950 ft N., 2,120 ft W. of lat 34°57′30″ N., long 119°30′00″ W. Elevation about 3,225 ft. Oligocene, Vaqueros Formation.

M3569 San Luis Obispo County, Calif., Pozo 15-minute quadrangle. East of Shell Creek, on northwest flank of hill 1790 in sec. 25, T. 28 S., R. 16 E.; elevation of hill 1,803 ft. Upper Miocene, Santa Margarita Formation.

M3579 Kern County, Calif., Carneros Rocks 7½-minute quadrangle. 2,200 ft S., 850 ft E. of northwest cor. sec. 15, T. 29 S., R. 20 E.; northeast bank of southeast-flowing stream. Oligocene, Temblor Formation, Wygal Sandstone Member.

M3580 Kern County, Calif., Orchard Peak 7½-minute quadrangle. At bend of southeast-trending canyon between U.S. Highway 466 and Jack Canyon, 3,100 ft N., 2,600 ft E. of southwest cor. sec. 31, T. 25 S., R. 17 E. Miocene, Temblor Formation, Carneros Sandstone Member; below buttonbed.

M3636 Kern County, Calif., Carneros Rocks 7½-minute quadrangle. North side of Chico-Martinez Creek, approximately 2,100 ft W., 250 ft S. of northeast cor. sec. 8, T. 29 S., R. 20 E. Oligocene, Temblor Formation, Wygal Sandstone Member.

M3735 San Luis Obispo County, Calif., Shedd Canyon 7½-minute quadrangle. Quailwater Creek, near southeast cor. sec. 12, T. 28 S., R. 14 E. Upper Miocene, uppermost part of the Santa Margarita Formation.

M3743 San Clemente Island, Calif., Central 7½-minute quadrangle. Lemon Tank reservoir area, 1,375 ft due east of hill 1185, in quarry face. Lat 32°55.8′ N., long 118°30.3′ W. Miocene.

M3750 Kern County, Calif., Pleito Hills 7½-minute quadrangle. 1,800 ft N., 3,250 ft W. of southeast cor. sec. 19, T. 10 N., R. 20 W. *Balanus-Vertipecten* bed, about 150 ft stratigraphically below base of basalt. Miocene, upper part of the Pleito(?) Formation.

M3751 Kern County, Calif., Pleito Hills 7½-minute quadrangle. SW¼SW¼,SE¼ sec. 19, T. 10 N., R. 20 W. From conglomerate overlying basalt flow, southwest side of prominent WNW-trending ridge. 800 ft exposure. Miocene, Temblor Formation (collector, W.O. Addicott, 1961).

M3769 San Luis Obispo County, Calif., La Panza 7½-minute quadrangle. Northern La Panza Range, north side of Hay Canyon. 400 ft S., 1,300 ft W. of northeast corner sec. 21, T. 30 S., R. 17 E. *Amiantis* bed, Miocene.

M3772 Kern County, Calif., Las Yeguas Ranch 7½-minute quadrangle. Temblor Range, 1,025 ft S., 200 ft E. of northwest cor. sec. 23, T. 28 S., R. 19 E. Southeast side of ridge paralleling Media Agua Creek, about 200 ft above dirt road. Oligocene, Temblor Formation, Wygal Sandstone Member.

M3781 San Luis Obispo County, Calif., Chimineas Ranch 7½-minute quadrangle. Northwest slope of low ridge northeast of dam on Barret Creek, 1,950 ft N., 2,500 ft E. of southwest cor. sec. 31, T. 31 S., R. 19 E. Miocene, Monterey Shale, *Crepidula-Antigona* bed near base of the Saltos Shale Member.

M3784 San Luis Obispo County, Calif., Fellows 7½-minute quadrangle. Eastern Temblor Range, 10,110 ft E., 790 ft N. of southwest cor. of Fellows quadrangle. Elevation about 2,975 ft. Miocene, Santa Margarita Formation, white sandstone beds at bend in creek on northwest side.

M3786 San Luis Obispo County, Calif., Fellows 7½-minute quadrangle. Eastern Temblor Range, 8,890 ft E., 2,700 ft N. of southwest cor. of Fellows quadrangle. Elevation about 3,075 ft. Miocene, Santa Margarita Formation.

M3787 San Luis Obispo County, Calif., Fellows 7½-minute quadrangle. Eastern Temblor Range, 9,125 ft E., 2,430 ft N. of southwest corner of quadrangle. Near ridge crest, about 2,995 ft elevation. Miocene, Santa Margarita Formation.

M3794 Santa Barbara County, Calif., Miranda Pine Mountain 7½-minute quadrangle. Cuyama Valley area, NW¼ sec. 11, T. 11 N., R. 30 W. 3,280 ft N., 4,300 ft W. of lat 35°02′30″ N., long. 120°00′00″ W. Elevation about 2,040 ft, in stream bank. Miocene, Santa Margarita Formation.

M3904 Santa Barbara County, Calif., New Cuyama 7½-minute quadrangle. Cuyama oilfield area, 680 ft S., 490 ft E. of northwest cor. sec. 35, T. 10 N., R. 27 W. North of Windmill Canyon, tributary to Bitter Creek. Elevation about 2,630 ft. Miocene, Vaqueros Formation, Painted Rock Sandstone Member, with many tectonically deformed fossils.

M3948 San Luis Obispo County, Calif., Lime Mountain 7½-minute quadrangle. West side of Lime Mountain, 2,700 ft N., 800 ft E. of southwest cor. sec. 15, T. 26 S., R. 9 E. Miocene, Vaqueros Formation.

M3955 Monterey County, Calif., Stockdale Mountain 7½-minute quadrangle. Cholame Hills, west-northwest-flowing tributary to Vineyard Canyon. 650 ft E., 650 ft S. of northwest cor. sec. 26, T. 23 S., R. 13 E. Elevation about 2,220 ft, 20-50 ft below base of prominent cliff. Miocene, Santa Margarita Formation.

M3982 Kern County, Calif., Carneros Rocks 7½-minute quadrangle. Temblor Range, 1,300 ft N., 300 ft W. of southeast cor. sec. 25, T. 28 S., R. 19 E., in bottom of north fork of Santos Creek. Elevation about 1,300 ft. Fossils in concretions in the Temblor Formation, Santos Shale Member, Agua Sandstone Bed. Miocene.

M3984 Kern County, Calif., Las Yeguas Ranch 7½-minute quadrangle. Southwest side of small knoll encircled by 1,400 ft contour. 1,600 ft N. of southeast cor. sec. 23, T. 28 S., R. 19 E. Elevation about 1,330 ft. Oligocene, Temblor Formation, Phacoides sand of local usage, basal 10 ft (collector, W.O. Addicott, 1968).

M3985 Kern County, Calif., Las Yeguas Ranch 7½-minute quadrangle. Temblor Range, south side of Stone Corral Creek. 600 ft S., 1,900 ft E. of northwest cor. sec. 25, T. 28 S., R. 19 E. Elevation about 1,330 ft. Oligocene, Temblor Formation, basal 6-10 ft of Wygal Sandstone Member.

M3988 Kern County, Calif., Shale Point 7½-minute quadrangle. Temblor Range, 550 ft N., 2,600 ft E. of southwest cor. sec. 30, T. 27 S., R. 19 E. Miocene, Temblor Formation, basal part of the Buttonbed Sandstone Member (Dibblee, 1973b). Coarse sandstone with abundant *Lyropecten crassicardo* and *Balanus*.

M3992 Monterey County, Calif., Stockdale Mountain 7½-minute quadrangle. East of Portuguese Canyon, 1,150 ft N., 2,550 ft W. of southeast cor. sec. 8, T. 23 S., R. 13 E. Miocene, Santa Margarita Formation.

M4002 Monterey County, Calif., Stockdale Mountain 7½-minute quadrangle. East of Vineyard Canyon, 1,050 ft N., 650 ft E. of southwest cor. sec. 35, T. 23 S., R. 13 E. Miocene, Santa Margarita Formation or a sandy facies of the Monterey Formation (Dibblee, San Miguel 15-minute quadrangle.)

M4004 Monterey County, Calif., Stockdale Mountain 7½-minute quadrangle. 2,150 ft N., 2,900 ft W. of southeast cor. sec. 31, T. 22 S., R. 13 E. Miocene, marine sandstone.

M4018 Los Angeles County, Calif., Malibu Beach 7½-minute quad-

rangle. Santa Monica Mountains, south of Saddle Peak. 1,400 ft S. 76° E. of northwest cor. sec. 22, T. 1 S., R. 17 W. At or near UCMP A-546 (Loel and Corey, 1932, Vaqueros Formation). Miocene, Topanga Canyon Formation, Saddle Peak Member.

M4027 Los Angeles County, Calif., Calabasas 7½-minute quadrangle. Santa Monica Mountains. 450 ft S. 29° W. of northeast cor. sec. 28, T. 1 N., R. 17 W. North side of McCoy Canyon. Miocene, sedimentary breccia overlying the Conejo Volcanics, dated at 13±0.9-15.1 Ma (Turner, 1970).

M4049 Clallam County, Wash. Pysht 15-minute quadrangle. Sea cliff and intertidal zone exposures near center of E½ sec. 32, T. 32 N., R. 11 W. Lower Miocene, Clallam Formation. Collectors, W. O. Addicott and J. W. Miller, 1974.

M4071 Monterey Formation, Calif., Stockdale Mountain 7½-minute quadrangle. 50 ft N., 1,125 ft E. of southwest cor. sec. 5, T. 23 S., R. 13 E. Miocene, Santa Margarita Formation or sandy facies of the Monterey Formation (Dibblee, 1972).

M4086 Monterey County, Calif., Stockdale Mountain 7½-minute quadrangle. 1,100 ft S., 2,000 ft E. of northwest cor. sec. 26, T. 23 S., R. 13 E. Miocene, marine sandstone facies of the Monterey Formation (Dibblee, 1972).

M4146 Jefferson County, Wash. Destruction Island 15-minute quadrangle. Center of NE¼ NE¼ sec. 20, T. 26 N., R. 13 W. Approximately 4,400 ft N., 600 ft W. from southeast corner of the section. Miocene, Hoh rock assemblage. Collectors, R. Yeats, R. Tallyn, and R. Stewart, 1969.

M4200 San Luis Obispo County, Calif., SW¼ Adelaida 15-minute quadrangle. Santa Lucia Mountains. 100 ft S., 3,500 ft E. of northwest cor. sec. 29, T. 27 S., R. 11 E. Oligocene, Vaqueros Formation.

M4415 Jefferson County, Wash. Forks 15-minute quadrangle. Fletchers Ranch fossil locality. Road cut on north side of road, center of NE¼NE¼ sec. 20, T. 26 N., R. 13 W. (= M4146). Lower Miocene, Hoh Rock assemblage. Collectors, W.O. Addicott, R. Tallyn, and W. Rau, 1970.

M4670 San Luis Obispo County, Calif., La Panza 7½-minute quadrangle. Northern La Panza Range, in small gully near top of hill ½ mi southeast of old La Panza. 1,650 ft N., 2,050 ft W. of southeast cor. sec. 36, T. 29 S., R. 16 E. Miocene, Vaqueros Formation, Painted Rock Sandstone Member (collector, J.A. Bartow, 1971).

M4675 Clallam County, Wash. Pysht 15-minute quadrangle. Sea cliff and intertidal exposures about ⅔ km W. of Pillar Point, 100 ft N., 500 ft E. of northwest cor. sec. 3, T. 31 N., R. 11 W. Lower Miocene, Clallam Formation. Collectors, W.O. Addicott and J.E. Pearl, 1971.

M4737 San Luis Obispo County, Calif., La Panza 7½-minute quadrangle. Northern La Panza Range, in bottom of north-trending tributary to Hay Canyon. In sec. 21, 2,150 ft S., 500 ft W. of southwest cor. sec. 15, T. 30 S., R. 17 E. Oligocene or Miocene, Vaqueros Formation.

M5028 San Luis Obispo County, Calif., Camatta Ranch 7½-minute quadrangle. Northern La Panza Range, 1,200 ft N., 1,250 ft W. of southeast cor. sec. 22, T. 28 S., R. 15 E., just west of ridge crest. Upper Miocene, Santa Margarita Formation.

M5030 San Luis Obispo County, Calif., Camatta Ranch 7½-minute quadrangle. Northern La Panza Range. 1,775 ft N., 1,250 ft W. of southeast cor. sec. 22, T. 28 S., R. 15 E., west side of road through Shell Creek Canyon. Upper Miocene, Santa Margarita Formation.

M5031 San Luis Obispo County, Calif. Camatta Ranch 7½-minute quadrangle. Northern La Panza Range. 1,600 ft S., 2,750 ft W. of northeast cor. sec. 30, T. 28 S., R. 16 E. On small ridge east of Camatta Creek. Miocene, Santa Margarita Formation.

M5033 San Luis Obispo County, Calif., Camatta Ranch 7½-minute quadrangle. Top of steep bluff on hill west of Shell Creek. 1,000 ft S., 1,750 ft W. of northeast cor. sec. 27, T. 28 S., R. 15 E. Upper Miocene, Santa Margarita Formation.

M5049 Santa Cruz County, Calif., Felton 7½-minute quadrangle. Santa Cruz Mountains, La Honda Block. 1,350 ft N., 200 ft E. of southwest cor. sec. 30, T. 9 S., R. 1 W. North of the Zayante Fault, about 700 ft W. of Zayante Road; elevation 800 ft. Oligocene, Vaqueros Sandstone of Clark and others (1979).

M5199 San Luis Obispo County, Calif., Chimineas 7½-minute quadrangle. 1,300 ft N., 1,450 ft W. of southeast cor. sec. 16, T. 31 S., R. 19 E. Carrizo Plain, west of Soda Lake. Miocene, Vaqueros Formation, Painted Rock Sandstone Member (collector, J.A. Bartow, 1972).

M5211 Kern County, Calif., Rio Bravo Ranch 7½-minute quadrangle. Southwest flank of Pyramid Hill. 1,900 ft N., 1,875 ft E. of southwest cor. sec. 14, T. 28 S., R. 29 E. Miocene, Jewett Sand, Pyramid Hill Sand Member, from friable sandstone between concretions.

M6029 Clallam Co., Wash. Clallam Bay 15-minute quadrangle. Intertidal exposure of massive *Vertipecten*-bearing sandstone at base of gravel beach at Slip Point Lighthouse compound, 300 ft W., 4,250 ft N. of southeast corner of Clallam Bay 15-minute quadrangle. Lower Miocene, approximately 130 m above base of the Clallam Formation. Collector, W.O. Addicott, 1973.

M6494 Monterey County, Calif., Cone Peak 7½-minute quadrangle. Central Santa Lucia Range, The Indians area. About 50 ft stratigraphically below the top of the upper sandstone member of the Vaqueros(?) Formation on hillside east of The Indians ranch house, 7,750 ft N., 3,700 ft W. of lat 36°05′ N., long 121°25′ W.

M6505 San Clemente Island, Calif., San Clemente Island South 7½-minute quadrangle. China Canyon section, west side of canyon about 15 ft above streambed at west-pointing oxbow. About 3.1 km northwest of China Point. Miocene, Monterey Formation, coarse clastic facies (Vedder and Moore, 1976).

M6868 Santa Catalina Island, Calif., Santa Catalina North 7½-minute quadrangle. In saddle northeast of Mount Banning and Mount Orizaba. Elevation about 1,250 ft. Middle Miocene, calcarenite overlain and underlain by dacite flow breccia (Vedder and others, 1979) (= field loc. JGV S Ca. I-5 = UCMP loc. D-8793).

M6869 Los Angeles County, Calif., Santa Catalina Island South 7½-minute quadrangle. On ridge about 3,600 ft W., 3,350 ft N. of Cactus Peak. Elevation about 1,350 ft. About 1.3 mi south of Middle Ranch. Miocene, calcarenite and conglomeratic sandstone, 20-30 m section (collector, J.G. Vedder, 1975 = field loc. S Ca I-6A).

M6873 Santa Catalina Island, Calif., Santa Catalina North 7½-minute quadrangle. About 1.2 mi east of mouth of Cottonwood Canyon. About 2,850 ft S., 900 ft W. of B.M. 665 (near Wrigley Ranch house). About 475 ft elevation. Middle or upper Miocene (collector, J.G. Vedder, 1975, 1976; field No. S Ca I-18).

M7157 San Mateo County, Calif., San Gregorio 7½-minute quadrangle. Pescadero Point, along beach opposite the stop sign on terrace; about 500 ft northwest of Pescadero Road-U.S. Highway 1 intersection. Upper Oligocene or Lower Miocene, Vaqueros Formation.

M7868 San Luis Obispo County, Calif., Panorama Hills 7½-minute quadrangle. NE¼SW¼SE¼ sec. 6, T. 32 S., R. 22 E. Miocene, Santa Margarita Formation.

M7895 San Luis Obispo County, Calif., Lime Mountain 7½-minute quadrangle. Sec. 7, T. 26 S., R. 10 E. 5-ft-thick conglomerate ledge exposed near crest of hill. Fossils from the part of the ledge nearest road cut with horizontal Cretaceous(?) rocks. Miocene, Vaqueros Formation, basal conglomerate. (Collector,

E.E. Brabb, 1981; = LSJU 1155, the "*Lepidocyclina* locality" of Schenck and Childs, 1942).

M7898 San Luis Obispo County, Calif., Panorama Hills 7½-minute quadrangle. East of Caliente Mountains, in San Joaquin Valley. NW¼SE¼NW¼ sec. 7, T. 32 S., R. 22 E. Lower Pliocene, unnamed marine sedimentary unit of Dibblee (1973a, U.S.G.S. Miscellaneous Geologic Investigations Map I-757).

M8012 Ventura County, Calif., Ojai 7½-minute quadrangle. East end of Ojai Valley, near abandoned oil well. 1,100 ft E., 650 ft N. of southeast cor. sec. 3, T. 4 N., R. 22 W. Oligocene or Miocene, Vaqueros Formation (collector, Stanford Geological Survey, 1931, loc. 20-Z; = UCMP loc. D-8792).

M8013 Santa Cruz Island "A" 7½-minute quadrangle, southwestern Santa Cruz Island, Calif. About 1 mi up Cañada Posa from beach. Miocene, Vaqueros Formation, sandstone facies near base of section (McLean and others, 1976; = field loc. S Cr I-5 = 575-7-1).

M8022 Santa Cruz Island, Calif., southwestern part. 7800 ft upstream from mouth of Cañada Posa. Oligocene or Miocene, Vaqueros Formation, diorite breccia member, near top of section (collector, J.G. Vedder, field No. 575-7-1 = S C I-21).

M8648 Baja California Sur, Mexico. San Isidro quadrangle, 1:50,000, G12A86. Arroyo La Purisima, north bank of stream at junction of the river with road from San Isidro to Paso Hondo. White limy sandstone facies of the Isidro Formation, lower Miocene. (Collectors, J.T. and J.G. Smith, field No. 81JTS8.)

M9035 Baja California Sur, Mexico. Santa Rosalia quadrangle, 1:50,000, G12A36. Loma del Tirabuzon ("Corkscrew Hill"), 3-4 km north of Santa Rosalia, along west side of Mexican Highway 1 between mouths of Arroyo Purgatorio and Arroyo de la Soledad. Pliocene, Tirabuzon Formation (= Gloria Formation of authors). [= LACMIP loc. 4828]

M9036 Baja California Sur, Mexico. Santa Agueda quadrangle, 1:50,000, G12A35. North of Santa Rosalia, about 2 km SE of abandoned Lucifer Mine. Hill near drainage divide between Arroyo del Boleo and Cañada de la Gloria. Late middle or late Miocene, Boleo Formation, basal part, deposited on volcanic rocks dated at 12.3 ± 0.4 and 12.5 ± 0.4 Ma (Smith, in press).

M9040 Baja California, Mexico. Santa Clara quadrangle, 1:50,000, H11B46. West of San Felipe, about 22-24 km by road from Km 178 on Mexican Highway 3. West side of southern Sierra San Felipe and northern Sierra Santa Rosa, west of road that branches south from old San Felipe-Ensenada road that runs through Buenavista Pass. Unnamed coarse-grained, locally derived beach deposit, probably Pliocene in age. SDSU 29-BGG is about 5 km to the northeast, on the east side of the Sierra San Felipe. Collectors, J.T. Smith and Joyce Gemmel, April 26, 1986. (= field loc. 86JS24 and locs. CAS 40666, LACMIP 6286, SDSNH 3270.)

M9045 Baja California Sur, Mexico. Loreto quadrangle, 1:50,000, G12A88. North side of Arroyo de Arce about 500 m upstream from cliffs constricting canyon before it opens onto plain north of Loreto. Pliocene, Carmen and Marquer Formations, undifferentiated (McLean, 1988). [= UCMP A-3565]

M9065 Baja California Sur, Mexico. Loreto quadrangle, 1:50,000, G12A88. North of Loreto on west side of Mexican Highway 1 near Km 21. Dipslopes of white, coarse-grained coquina referred to the Carmen and Marquer Formations, undifferentiated (McLean, 1988). Pliocene.

M9117 Southwestern Isla Tiburón, Sonora, Mexico. South side of "Arroyo 4", 3-4 km northeast of Punta Willard and about ½ km from the beach where arroyo forms a large delta near the center of Bahía Vaporeta (fig. 17*B* herein). Unnamed marine conglomerate. Late middle Miocene, based on associated radiometrically dated rocks of 12.9 ± 0.4 Ma. (Smith and others, 1985; Smith, in press).

M9165 Baja California Sur, Mexico. San Isidro quadrangle, 1:50,000, G12A86. Arroyo La Purisima. North side opposite downstream end of San Isidro at base of el Pilon. Lower Miocene, Isidro Formation (McLean and others, 1985, 1987). (Collectors, J.T. Smith and T.M. Cronin, field No. 84JS9.)

M9180 Baja California Sur, Mexico. San Isidro quadrangle, 1:50,000, G12A86. San Isidro, upstream from junction of road from San Isidro to Paso Hondo. Lower Miocene, Isidro Formation (Smith, 1984, 1986, in press; McLean and others, 1985, 1987). (Collectors, J.T. Smith and T.M. Cronin, field No. 84JS10)

M9183 Baja California Sur, Mexico. Jesús Maria quadrangle, 1:50,000, G12A54. Arroyo Patrocinio, 7.5 mi by road upstream from mouth of arroyo. North side of arroyo in white sandstone and siltstone capped unconformably by a basalt flow dated at 8.57 ± 0.28 Ma and 8.6 ± 0.7 Ma (McLean and others, 1985, 1987). (Collectors, J.T. Smith, J.R. Ashby, Hugh McLean, J.H. Knapp) [= field Nos. 85JS2 and McLean and Knapp 384-5-3]

M9185 Baja California Sur, Mexico. Vizcaino Peninsula, about 3 km south-southeast of town of Bahía Tortugas. Prominent monadnock of loosely consolidated, coquina-capped yellow sandstone. Upper Miocene, Almejas Formation (Smith, 1984). [= CAS 945; J.T. Smith field Nos. 682-28-1, 682-29-1]

U.S. GEOLOGICAL SURVEY AND UNITED STATES NATIONAL MUSEUM LOCALITIES, WASHINGTON, D.C. REGISTER

USGS 1176 Collier County, Fla. Along Tamiami Trail, about 11 mi northeast of Marco. Miocene, Tamiami Formation, gray-white limestone with many fossils whose shells are leached.

USGS 1178 Collier County, Fla. Tamiami Trail, about 6 mi west of crossroad to Everglades. Miocene, Tamiami Formation.

USGS 1179 Monroe County, Fla. Tamiami Trail, 9 mi west of Pinecrest in sec. 13, T. 54 S., R. 32 E. Miocene, Tamiami Formation.

USGS 1180 Collier County, Fla. Tamiami Trail at Carnestown, 4 mi north of Everglades. Miocene, Tamiami Formation.

USGS 1208 Denaud, Fla. Pliocene and Pleistocene, Caloosahatchee Formation.

USGS 1625 Bolivar, Colombia. Sinu River area. Quebrada Pajuil, west of Sinu River. Oligocene or Miocene (= Sta. 176 of A.K. McGill).

USGS 1626 Departamento Cordoba [formerly Bolivar], Colombia. Quebrada Pajuil, west of Río Sinu (= Sta. 169 of A.K. McGill).

USGS 2212 Calhoun County, Fla. Tenmile Creek, 1 mi west of Baileys Ferry. Early Miocene, Chipola Formation [type locality of *Pecten condylomatus, fide* Gardner, 1926].

USGS 2213 Calhoun County, Fla. 1 mi below Baileys Ferry. Early Miocene, Chipola Formation.

USGS 2564 Calhoun County, Fla. McClelland farm, 1 mi below Baileys Ferry. Early Miocene, Chipola Formation.

USGS 3419 Calhoun County, Fla. McClelland farm, 1 mi below Baileys Ferry. Oligocene or Miocene, Chipola Formation.

USGS 3426 Los Angeles County, Calif., Beverly Hills 7½-minute quadrangle. Third Street Tunnel, Los Angeles. Pliocene, Repetto Formation of former usage.

USGS 3468 Matanzas Province, Cuba. Gorge of Yumuri River, below Iglesia Mont Serrato (= Sta. 3468 of T.W. Vaughan).

USGS 3542, 3546 Monterey County, Calif., San Ardo 15-minute quadrangle. Salinas Valley, along railroad between San Lucas and San Ardo. NE¼ sec. 23, T. 21 S., R. 9 E. Miocene,

Pancho Rico Formation (collector, H. Hamlin, 1904 = USGS 7898).

USGS 3864 Fresno County, Calif., Domengine Ranch 7½-minute quadrangle. Coalinga area, Mont Jack Gulch, east of Oil City. Miocene, Santa Margarita Formation.

USGS 3907 Los Angeles County, Calif., Puente Hills. Lat 34°00′ N., long 118° W. Olinda Hill, south of western wells of Fullerton Consolidated Oil Co. Pliocene.

USGS 4132 Orange County, Calif., San Juan Capistrano 7½-minute quadrangle. Aliso Creek, 2½ mi southeast of El Toro. Miocene, hard marly sandstone.

USGS 4140 Monterey County, Calif., San Ardo 7½-minute quadrangle. 3 mi west of San Ardo, second ridge south of Earl ranch house. Miocene, Santa Margarita Formation.

USGS 4448 Kern County, Calif., Eagle Rest Peak 7½-minute quadrangle. Southern San Joaquin Valley, east side of San Emigdio Canyon, 3½ mi south of San Emigdio ranch house. Oligocene, Pleito Formation (Nilsen and others, 1973).

USGS 4766 Fresno County, Calif., Coalinga 15-minute quadrangle. 9 mi north of Coalinga, from NE¼ sec. 21, T. 19 S., R. 15 E., west of Peerless Oil property. Miocene, Santa Margarita Formation, from the *Tamiosoma* zone or "big oyster bed" above the sand and clay of the Big Blue Formation (Arnold, 1909; Adegoke, 1969).

USGS 4918 San Luis Obispo County, Calif., Bradley 7½-minute quadrangle. 6 mi southwest of Bradley, ½ mi south of Monterey County line, in Cavanough's canyon (Ralph Arnold's field notes, 6/8/1905). Miocene, Santa Margarita Formation.

USGS 4941 Kern County, Calif., Orchard Peak 15-minute quadrangle. Northeast Temblor Range, beside road about ¾ mi north of Miller ranch house. 600 ft N., 1,000 ft E. of southwest cor. sec. 36, T. 26 S., R. 17 E. Miocene, Temblor Formation, Carneros Sandstone Member (Addicott, 1972; = loc. M2633).

USGS 4944 San Luis Obispo County, Calif., Pozo 15-minute quadrangle. Northern La Panza Range, 1½ mi north of Camatta ranch house. Miocene, Santa Margarita Formation.

USGS 4945 San Luis Obispo, Calif., Pozo 15-minute quadrangle. ¾ mi north of Camatta ranch house. Miocene, Santa Margarita Formation, with *Balanus*.

USGS 4950 San Luis Obispo County, Calif., Pozo 15-minute quadrangle. 4 mi northwest of Camatta ranch house. Miocene, Santa Margarita Formation.

USGS 5037 Northeast part of Unga Island, Alaska, from bed about 70 ft above mean tide. Collector, Attwood, 1908.

USGS 5255 Oriente Province, Cuba. Santiago de Cuba. Miocene or Pliocene, fossiliferous at "***one horizon at numerous localities in Santiago" (Cooke, 1919).

USGS 5906a Panama, Madden Basin. Río Chagres, about 1.5 mi above Alhajuela, submerged under water. Miocene, Alhajuela Formation, lower member (Woodring, 1973).

USGS 6071 Kern County, Calif., Tejon Hills 7½-minute quadrangle. Comanche Point area, near Tejon Ranch, 1 mi southwest of spring at mouth of Comanche Creek. About ¼ mi northwest of 1,100 ft hill with signal. Near top of ridge at head of northernmost northeast-southwest trending canyon. Miocene, Santa Margarita Formation.

USGS 6293 Sucre, Venezuela. 1¾ mi east of Castle Cumana.

USGS 6295 Sucre, Venezuela. East of Cumana. Upper Pliocene, Cumana Beds.

USGS 6296 Falcon, Venezuela. Near La Vela. Upper middle Miocene, Caujarao Formation, Mataruca Limestone Member, the upper limestone capping hills (J. Gibson-Smith and W. Gibson-Smith, 1979).

USGS 6627 Kern County, Calif., Knob Hill 7½-minute quadrangle. 12 mi northeast of Bakersfield, in W½ sec. 36, T. 27 S., R. 28 E. One mi north of junction of Poso Creek and Adobe Canyon, elevation about 850 ft. Small arroyo tributary to Adobe Canyon, first arroyo upstream from 1,070 ft hill. Miocene, Olcese Sand, lower part (Addicott, 1970a).

USGS 7291 Costa Rica, Valle Central. San Antonio do Desamparados, about 4-5 km south-southeast of San José. Western foothills of Cerros de Candelaria, at boundary between Valle Central Occidental and Valle Central Oriental. Miocene, limestone (collector, A. Alfaro, 1910; = loc. 6469).

USGS 7533 Cuba. Oriente Province. Near mouth of Macambo River. Cliff on west side, elevation about 150 ft. Miocene or Pliocene, limestone conglomerate (collector, O.E. Meinzer, 1915).

USGS 7898 Monterey County, Calif., San Ardo 15-minute quadrangle. Salinas Valley, between San Ardo and San Lucas. ¼ sec. 23, T. 21 S., R. 9 E., near mouth of Coyote Canyon. Miocene, Pancho Rico Formation.

USGS 9157 Baja California Sur, Mexico. "Between Posa [Paso] Hondo and Purisima Vieja," about 15 mi northwest of San Isidro, "where trail cuts hill in turn at stream" (collector, W.S.W. Kew, July 19, 1920). Lower Miocene, Isidro Formation. Subsequent field work (Smith, 1984) suggests the locality is in the lower Miocene part of the formation, downstream from the palm grove at Purisima Vieja.

USGS 9160 Baja California Sur, Mexico. La Purisima. Upper Oligocene or lower Miocene, Isidro Formation (collector, W.S.W. Kew, July 19, 1920).

USGS 9424 Monterey County, Calif., San Ardo 15-minute quadrangle. Salinas Valley, gulch near center south line of NE¼NE¼ sec. 4, T. 22 S., R. 10 E. Miocene, Pancho Rico Formation.

USGS 9957 Walton County, Fla. On road from Eucheeanna to Knox Hill, 6.7 mi south of Argyle, 1.7 mi southeast of Eucheeanna. Gully south of road and east of bridge over White's Creek. Miocene, Shoal River Formation.

USGS 9961 Oakaloosa County, Fla. Horse Creek, 1½ mi south of Oak Grove. Miocene, Oak Grove Sand Member, Shoal River Formation.

USGS 10603 Walton County, Fla. Gully south of road and east of bridge over White's Creek, on road from Eucheeanna to Knox Hill, 6.7 mi south of Argyle, 1.7 mi southeast of Eucheeanna. Miocene, Shoal River Formation, Alum Bluff Group.

USGS 12922 Monterey County, Calif., San Miguel 15-minute quadrangle. SW¼SE¼ sec. 16, T. 23 S., R. 13 E., in creek bed, near Vineyard Canyon. Miocene (= USGS 16833).

USGS 12984 San Luis Obispo County, Calif., Panorama Hills 7½-minute quadrangle. Southwestern Temblor Range, SW¼ sec. 6, T. 32 S., R. 22 E., in saddle just north of 3,000 ft hill. Miocene, Santa Margarita Formation.

USGS 13080 Kern County, Calif., Grapevine 7½-minute quadrangle. North of San Emigdio Mountains, west of Grapevine Creek. About 2 mi up from the point where Salt Creek empties into the San Joaquin Valley. West side of the creek near contact with basalt. Oligocene, Temblor Formation.

USGS 13084 Kern County, Calif., Grapevine 7½-minute quadrangle. San Emigdio Mountains. West side of Salt Creek, about

2 mi above its mouth. Oligocene, sandstone immediately below basalt.

USGS 13098 San Luis Obispo County, Calif., Pozo 15-minute quadrangle. Northern La Panza Range. Highland Monocline section "Cushman Canyon." Miocene, Santa Margarita Formation (collectors, R.M. Kleinpell and M.N. Bramlette, Sept. 26, 1931).

USGS 13104 San Luis Obispo County, Calif., Pozo 15-minute quadrangle. Northern La Panza Range. Highland Monocline section. Miocene, Santa Margarita Formation, horizon B, *Pecten*-barnacle reef. (Near Sta. 35, collector, R.M. Kleinpell, Sept. 13, 1931).

USGS 13105 San Luis Obispo County, Calif., Pozo 15-minute quadrangle. Northern La Panza Range. Sec. 24, T. 28 S., R. 14 E. Highland Monocline section. Miocene, Santa Margarita Formation, horizon C, top of *Pecten* reef.

USGS 13330 Kern County, Calif., Pleito Hills 7½-minute quadrangle. Sec. 9, T. 10 N., R. 21 W. ⅛ mi east of point where the first creek west of Pleito Creek turns sharply to the southwest. Elevation 2,300 ft. Oligocene or Miocene, Temblor Formation, basal sandstone (Nilson and others, 1973).

USGS 13455 Tamaulipas, Mexico, San Fernando. 3,950 m N. 24½° W. from church tower. Oligocene or Miocene, Guajalote Formation (= loc. W-29 of Gardner, 1945).

USGS 13585 Tamaulipas, Mexico. San Fernando, 8,600 m N. 40° W. from town. Oligocene or Miocene, Guajalote Formation (= V-29 of Gardner, 1945; = lot 7710).

USGS 13587 Tamaulipas, Mexico. San Fernando, 3,250 m south of the church tower. Oligocene or Miocene, Guajalote Formation (= W-30 of Gardner, 1945).

USGS 13588 Tamaulipas, Mexico. San Fernando, 620 m N. 55° W. from church tower. Oligocene or Miocene, Guajalote Formation (= W-30 of Gardner, 1945; lot 7723C = Sta. 997c).

USGS 13927 Lee County, Fla. About ½ mi west of Buckingham, in quarry at roadside. Miocene, Tamiami Formation, type area of the Buckingham facies.

USGS 14393 Kings County, Calif., Garza Peak 7½-minute quadrangle. Flanks of Roundtop, a peak on Reef Ridge. Sec. 12, T. 23 S., R. 16 E. Miocene, Temblor Formation, pebble beds and *Pecten* zone near top of the lower part of the formation.

USGS 14403 Kings County, Calif., Garza Peak 7½-minute quadrangle. Dirty Spring, southeast of Canoas Creek. Sec. 33, T. 22 S., R. 16 E., 480 ft N., 1,740 ft W. Miocene, near top of the Temblor Formation.

USGS 16054 Baja California Sur, Mexico. Santa Rosalía, Boleo Copper District. South side of Arroyo Purgatorio, south of San Roberto shaft. Upper Miocene, Boleo Formation (= F-12, collector, Ivan Wilson, March 26, 1946).

USGS 16082 Monterey County, Calif., San Ardo 15-minute quadrangle. Northwest of Bradley, west of Salinas River. Garriseri Gulch area. 1,000 ft E., 2,000 ft N. of southwest cor. sec. 12, T. 28 S., R. 9 E. Miocene, Santa Margarita Formation.

USGS 16833 Monterey County, Calif., San Miguel 15-minute quadrangle. Middle fork of Vineyard Canyon, SW¼SE¼ sec. 16, T. 23 S., R. 13 E. 700 ft down canyon from fault. Miocene (= field No. SM4).

USGS 16837 Monterey County, Calif., San Ardo 15-minute quadrangle. Salinas Valley, near mouth of Long Valley. 2,000 ft W., 2,500 ft S. of northeast cor. sec. 33, T. 20 S., R. 9 E. Miocene, sandstone similar to that of the Santa Margarita Formation (collectors, M.N. Bramlette and S.N. Davies, April, 1944; = field No. SA-24).

USGS 16849 Monterey County, Calif., Bradley 15-minute quadrangle. West end of Swain Valley, 1,500 ft E., 800 ft S. of northwest cor. sec. 28, T. 32 S., R. 10 E. South end of northwest trending ridge with three knobs. Miocene, Santa Margarita Formation.

USGS 16851 San Luis Obispo County, Calif., Pozo 15-minute quadrangle. Highland Monocline, "Cushman Canyon." Miocene, Santa Margarita Formation (= Sta. 41 of Bramlette's Monterey section; collector, M.N. Bramlette, 1944).

USGS 16853 San Luis Obispo County, Calif., Pozo 15-minute quadrangle. Northern La Panza Range, tributary on west side of Quailwater Creek. Highland Monocline, "Cushman Canyon." 3,300 ft W., 900 ft S. of northeast cor. sec. 13, T. 28 S., R. 14 E. First canyon west of Indian Creek, at approximately 1,450-ft contour in third draw south of north section line. Miocene, Santa Margarita Formation.

USGS 18246, 18247 Distrito federal, Venezuela. Cabo Blanco area. In short quebrada about 15 m south of La Guira-Playa Grande road and about 3 km west-northwest of triangulation station and airport beacon. Pliocene or Pleistocene, Cabo Blanco Formation; medium-grained, partly consolidated sandstone (collectors, O. Renz, G. Dengo, E. Mencher, W.P. Woodring, 1951).

USGS 18408 Sucre, Venezuela. Near Cumana, 2.5 km N. 80° E. of Cumana castle and S. 30° W. of village of Caiguire Abajo. Pliocene or Pleistocene, Cumana Beds, 30 ft of yellow-brown marl (collectors, P. Henry and J.A. Tong, Sept. 1931).

USGS 21045 Lee County, Fla. Just north of Florida Route 78, east and south of Telegraph Creek. Telegraph Park Estates, spoil banks along canal. Upper Miocene, Buckingham facies, Tamiami Formation (collectors, Double and D. Wilson, 1957).

USGS 21091 Collier County, Fla. One mi north of Tamiami Trail (= U.S. 41), 4.7 mi east of Ochopee post office. In pit 27 ft deep. Miocene, Tamiami Formation.

USGS 21128 Lee County, Fla. South of Fort Myers Shores and Florida Route 80; spoil bank of 40-ft-deep pit in Baucom Ranch. Upper Miocene Buckingham facies, Tamiami Formation.

USGS 22298 Charlotte County, Fla. Acline. Sec. 29, T. 41 S., R. 23 E., deep pit dug pre-1931 (= pit C of Schroeder and Hoy, 1952). Pliocene, Pinecrest Beds of labels (collectors, D. Wilson and others, Dec. 11, 1958).

USGS 22587 Collier County, Fla. Sunniland. Float from pits on west side of Florida Route 29. Miocene, Tamiami Formation (= USGS loc. 21067).

USGS 22597 Lee County, Fla. Buckingham. Near Florida Route 25, ½ mi west of Orange River. Miocene, type locality of Buckingham facies, Tamiami Formation (collectors, D. Wilson and H.E. Vokes, 1952).

USGS 22598 Lee County, Fla. Just west of Buckingham. Borrow pit, south side of Florida Route 26. Miocene, Tamiami Formation.

USGS 22601, 22602 Lee County, Fla. Near Buckingham. Quarry near Florida Route 25, ½ mi west of Orange River, in sec. 5, T. 44 S., R. 26 E. Miocene, Tamiami Formation, type locality of the Buckingham facies.

USGS 22882 Collier County, Fla. Sunniland. Float from pit on Sunniland Rock Co. property, about 0.1 mi S., 0.5 mi W. of Florida Route 29. Miocene, Tamiami Formation.

USGS 23596 Sarasota County, Fla. Little Sarasota Bay, Coral Cove, at foot of Peninsula Terrace. Middle Miocene, Hawthorn Formation.

USGS 23598 Sarasota County, Fla. Little Sarasota Bay. Middle Miocene, Hawthorn Formation.

USGS 23654 Panama, Gaillard Cut area, west side of Las Cascadas Reach. Canal Station 1767 ± 15 m. Miocene, La Boca Formation, upper part of upper limestone (= field loc. 101g, Woodring, 1982).

USGS 24704 Sucre, Venezuela. Manicuare, south coast of Araya Peninsula. Pliocene, Cumana Beds (collector, J.A. Tong).

USGS 24705 Falcon, Venezuela. Las Piedras, west coast of Paraguana Peninsula. Upper Miocene or lower Pliocene, Paraguana Formation (Hunter and Bartok, 1976; Hunter, 1978).

USGS 25276 Pinellas County, Fla. St. Petersburg quadrangle. Pinellas Park, 5 mi north of St. Petersburg. Outcrop in pit near 102d Avenue and 63d Street, interpreted as NE¼NE¼ sec. 20, T. 30 S., R. 16 E. Pliocene, facies of the Tamiami Formation.

USGS 25657 Palm Beach County, Florida. South Bay. Pleistocene, Bermont Beds of labels. Collector, Druid Wilson.

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[Main references indicated by italic page numbers]

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PLATES 1-38

Photographs are by Kenji Sakomoto, U.S. Geological Survey, Menlo Park, Calif., except where noted. Many of the fossils were coated with black opaque, allowed to dry, and sprayed with a thin film of ammonium chloride, a procedure described in Sakomoto (1973). This technique was especially effective in emphasizing macrosculpture and subtle differences in concentric lirae, although its use has been discontinued for primary types and unique specimens.

Giant pectinids cannot be illustrated at natural size, because many single individuals exceed the plate boundaries. It is important to note measurements and to distinguish figures of young individuals from substantially reduced pictures of adult specimens.

In the plate explanations which follow, RV denotes right valve, LV is left valve.

[Contact photographs of the plates in this report are available from the
U.S. Geological Survey Library, Federal Center, Denver, Colorado 80225]

PLATE 1

Comparative genera, part I
Hinges and diagnostic shell morphology
[All specimens except figures 1 and 12 were coated for photographing]

FIGURES 1. *Chlamys islandicus* (Muller) (p. 9).
RV, hypotype UCMP 37378 of the type species of *Chlamys*. Newfoundland. Height 8.7 cm, length 8.5 cm.

2. *Chlamys tamiamiensis* (Mansfield) (p. 91).
LV hinge, hypotype USNM 334972. Miocene, Tamiami Formation, Buckingham marl facies, just west of Buckingham, Fla. (loc. USGS 22598). Hinge length 4 cm; specimen height and length 6.6 cm.

3. *Macrochlamis latissimus restitutensis* (Fontannes) (p. 74).
RV, hypotype MCZ 18107. Europe, specific locality unknown. Height 12.5 cm, length 13.5 cm.

4, 5. *Lyropecten estrellanus* (Conrad) (p. 55).
4. LV hinge of hypotype USNM 647533. Miocene, Santa Margarita Formation northern La Panza Range, Calif. Hinge length 5 cm.
5. RV, hypotype CAS 60983. Miocene, Santa Margarita Formation, *Pecten-Ostrea titan* reef on Domengine Creek, near Coalinga, Calif. (CAS 29395). Height 10.4 cm, length 10.2 cm.

6, 7. *"Lyropecten" dumblei* (Gardner) (p. 71).
RV hinge, RV cotype USNM 494994. Early Miocene. Guajalote Formation, near San Fernando, Tamaulipas, Mexico (loc. USGS 13455). Height 4.5 cm, length 5.0 cm.

8. *Stralopecten ernestsmithi* (Tucker) (p. 9).
RV hinge, holotype Chicago Natural History Museum 57203 of *Chlamys* (*Lyropecten*) *ernestsmithi* Tucker, 1931. Pliocene, Waccamaw(?) Formation, Acme, N.C. Hinge length 4.2 cm.

9, 10. *"Stralopecten" pyx* (Gardner) (p. 7).
9. LV, hypotype USNM 334974. Miocene, Shoal River Formation, near Eucheeanna, Fla. (loc. USGS 10603). Height 2.6 cm, length 2.5 cm. Specimen has complete auricles with typical winglike outline.
10. RV hinge, hypotype USNM 334973. Miocene, Shoal River Formation, near Eucheeanna, Fla. (loc. USGS 10603). Hinge length 3.1 cm. Specimen has paired hinge teeth and lacks a ctenolium but auricles and RV ribs are more like those of *Stralopecten* than *Nodipecten*.

11, 12. *Chesapecten edgecombensis* (Conrad) (p. 7).
11. LV hinge, hypotype Charleston Museum 13352a. Miocene, Chesapeake Group (part), Maryland. Hinge length 6.8 cm.
12. RV, hypotype Charleston Museum 13352b. Miocene, Chesapeake Group (part), Maryland. Height 11 cm, length 11.3 cm.

13. *Chesapecten middlesexensis* (Mansfield) (p. 7).
RV, hypotype UCMP 37392. Middle and upper(?) Miocene, St. Marys Formation, Chesapeake Group, York River, Va. (loc. UCMP D-8798). Height 13.4 cm, length 15 cm.

14, 15. *Swiftopecten swiftii* (Bernardi) (p. 28).
LV hinge, LV, hypotype UCMP 37400. Holocene, Teshwo, Japan. Hinge length 4.2 cm, height 8.7 cm, length 7.5 cm.

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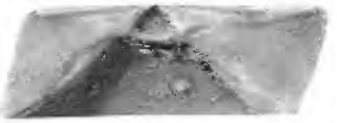

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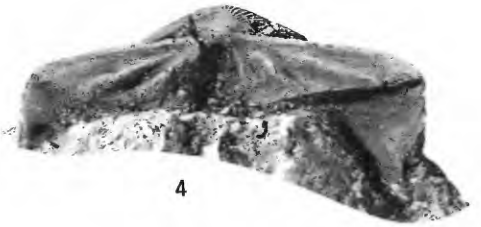

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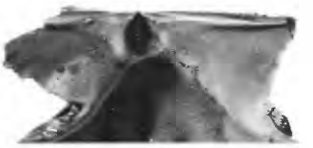

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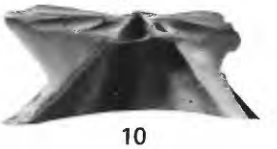

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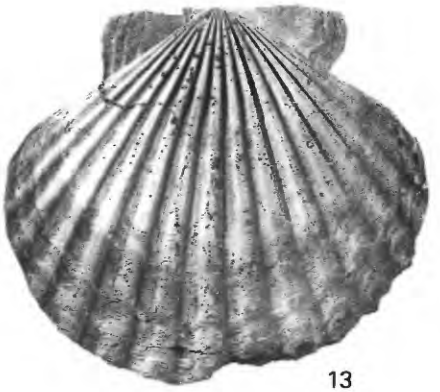

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PECTINID GENERA

PLATE 2

Comparative genera, part II
Hinges and diagnostic shell morphology
[All except figures 3, 4, and 6 coated for photographing]

FIGURES 1. *Lyropecten terminus* (Arnold) (p. 66).
RV hinge, holotype UCMP 11622 of *Pecten* (*Lyropecten*) *estrellanus* Conrad var. *terminus* Arnold, 1906. Late Miocene or early Pliocene. Pancho Rico Formation, Salinas Valley, Calif. Hinge length 3.7 cm.

2. *Nodipecten pittieri* (Dall) (p. 97).
LV hinge reinforced by vertical ridges in a gerontic individual. Hypotype USNM 334975, from sand near mouth of Macambo River, Cuba (loc. USGS 7533). Hinge length 9.9 cm.

3, 4. *Nodipecten fragosus* (Conrad) (p. 92).
RV hinge, LV, voucher specimen CAS 029017. Holocene, Tarpon Springs, Fla. (loc. CAS 41794). Hinge length 5.9 cm, height 10.3 cm, length 11 cm.

5. *Nodipecten arthriticus* (Reeve) (p. 88).
Juvenile RV, voucher specimen CAS 029018. Holocene, Mancora, Peru (loc. CAS 36666). Height 1.8 cm, length 1.9 cm.

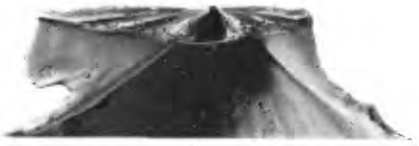
6, 7. *Vertipecten kernensis* (Hertlein) [= *V. nevadanus* auctt.] (p. 81).
6. RV hinge, hypotype USNM 335002. Miocene, Jewett Sand, Pyramid Hill, Kern County, Calif. (loc. USGS M1590). Hinge length 6.7 cm (incomplete).
7. RV, hypotype USNM 647085 of *Vertipecten perrini* (Arnold) of Addicott, 1974. Miocene, Jewett Sand, Pyramid Hill, Kern County, Calif. (loc. USGS M5211). Height 12.3 cm, length 12.2 cm.

8. *Patinopecten caurinus* (Gould) (p. 9).
RV, hinge area, hypotype UCMP 37379. Holocene, locality unknown. Hinge length 4.6 cm.

9. *Patinopecten lohri* (Hertlein) (p. 9).
LV, holotype UCMP 12081 of *Pecten (Patinopecten) lohri* Hertlein, 1928. Early Pliocene, Santa Barbara County, Calif. Height 9.9 cm, length 8.9 cm (incomplete). Left valve anterior auricle is higher than posterior auricle.

10, 11. *Argopecten percarus* (Hertlein) (p. 8).
RV, LV, holotype LSJU 42 of *Pecten* (*Aequipecten*) *percarus* Hertlein, 1925b. Pliocene, from arroyo northwest of Cerro Elefante, Baja California Sur, Mexico (loc. LSJU 48). Height 8.2 cm, length 9.1 cm. Looped lamellar growth lines distinguish *Argopecten* from *Lyropecten*.

12. *Argopecten subventricosus* (Dall) (p. 8).
LV hinge, holotype USNM 61246 of *Pecten* (*Plagioctenium*) *subventricosus* Dall, 1898. Pliocene, Ventura County, Calif. Hinge length 4.3 cm.



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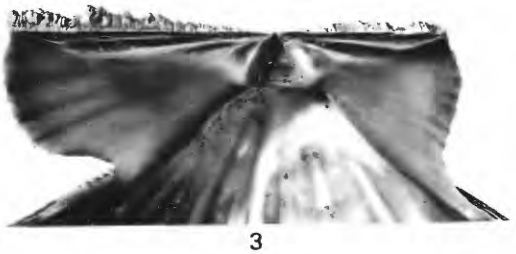

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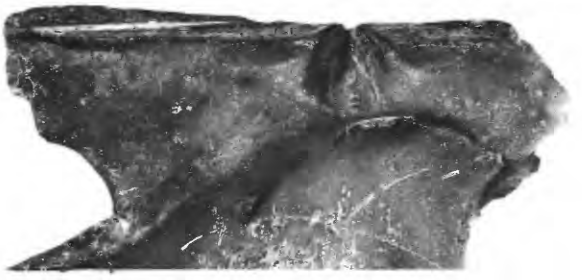

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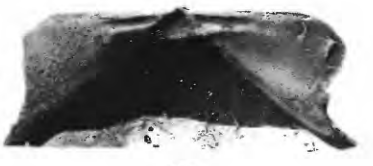

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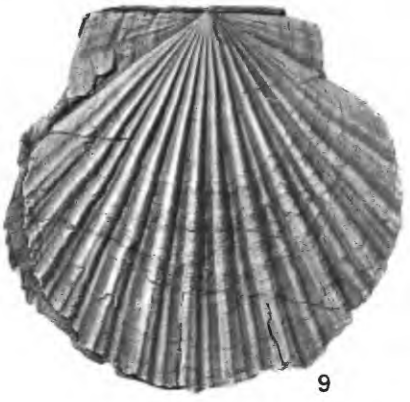

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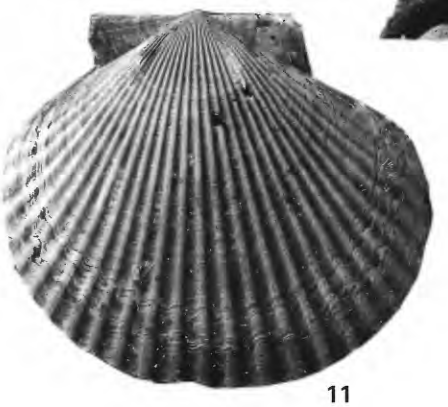

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PECTINID GENERA

PLATE 3

Node formation in *Nodipecten*

FIGURES 1, 2. *Nodipecten pernodosus* (Heilprin) (p. 96).

1. LV, hypotype USNM 334976. Pliocene and Pleistocene, Caloosahatchee Formation, Denaud, Florida (loc. USGS 1208). Height 10.2 cm, length 11.1 cm. After the fifth generation of nodes formed, the shell-secreting part of the mantle lost the capacity to form nodes, although it continued to lay down the central rib and macrosculpture.
2. RV, holotype Wagner Free Institute of Science 938 of *Pecten pernodosus* Heilprin, 1887. Pliocene and Pleistocene, Caloosahatchee Formation, along the Caloosahatchee River between Labelle and Olga, Fla. Height 10.3 cm, length 10.5 cm. The species is distinguished by a relatively short hinge line and nodes on both valves.

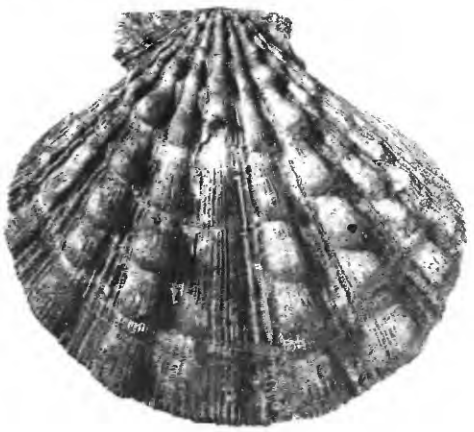
3, 4, 6. *Nodipecten nodosus* (Linnaeus) (p. 93).

3. LV and interior view of same valve, hypotype MCZ 164873. Holocene, Praia do Leste, Ilha Guaiba, Río de Janeiro, Brazil. Height 7.8 cm, length 8.1 cm. Specimen shows how nodes form by flaring along the ribs, then sealing them off from the inside.

4, 6. Antero-ventral view, LV, hypotype AMNH 47391. Holocene. Erroneous location, "Gulf of Mexico," for the southern Caribbean form. Height 8.7 cm, length 9 cm. Extreme development of long, tubular nodes.

5. *Nodipecten fragosus* (Conrad) (p. 92).

Ventral view, neotype USNM 818272. Holocene, Tarpon Springs, Fla. (loc. CAS 41794). Height 8.3 cm, length 8.5 cm.



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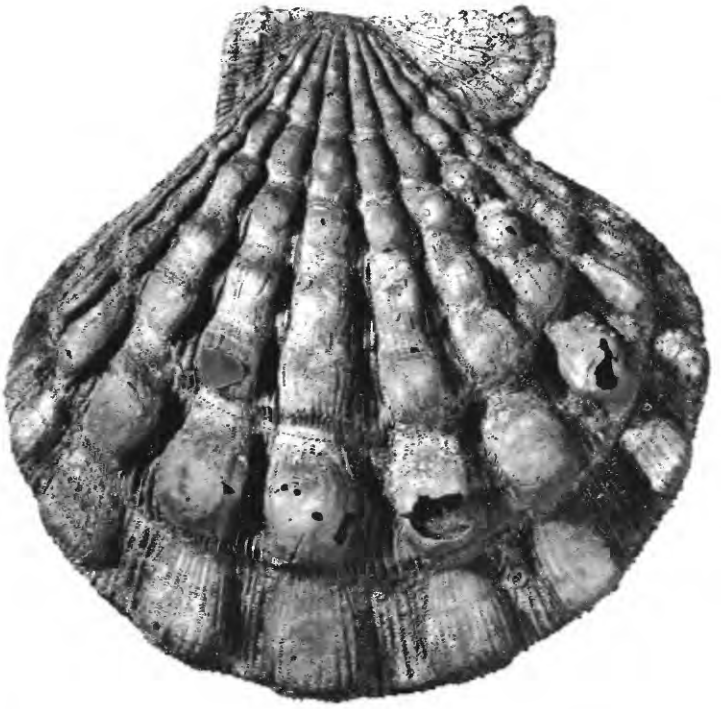

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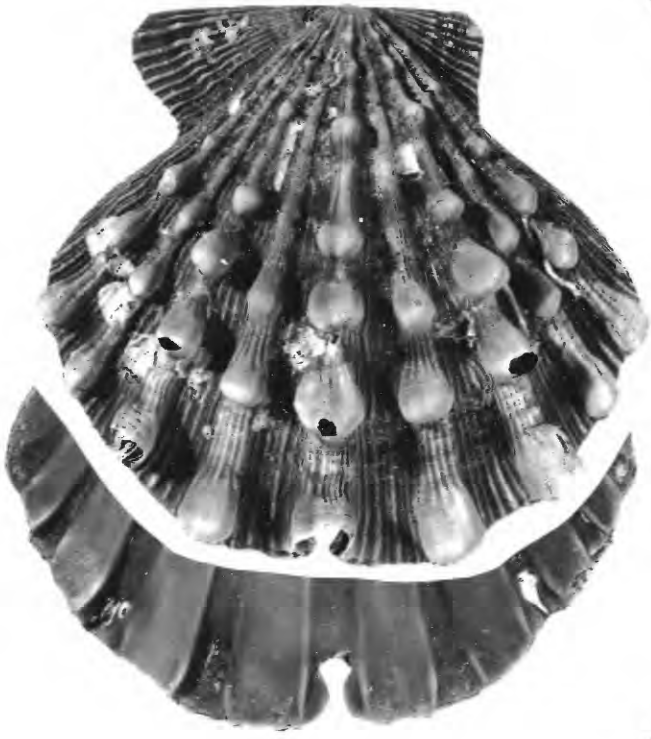

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NODIPECTEN

PLATE 4

Holocene type specimens of *Nodipecten* species and two Tertiary fossils from Argentina

[Arrows indicate key ribs]

FIGURES 1, 5-7. *Nodipecten arthriticus* (Reeve) [= *N. subnodosus* auctt., in part] (p. 88).

1, 5. LV, RV, holotype BM(NH) 1950.11.14.10. Juvenile shell, very worn and bleached. Holocene; no locality given, but is the Pacific-Panamic *Nodipecten* common from the Tres Marias Islands, Mexico to Peru. Height 2.4 cm, length 2.4 cm, hinge 1.6 cm. Photographs by Thomas R. Waller, U.S. National Museum.

6. RV fragment, hypotype USNM 387584. Middle and upper Miocene, unnamed sedimentary rocks from Valle Hermosa, 82 km W of Comodoro Rivadavia, Argentina. Height 5.5 cm, length 5 cm (incomplete). [= *N. subnodosus* s.s. of Smith and Zinsmeister, 1982].

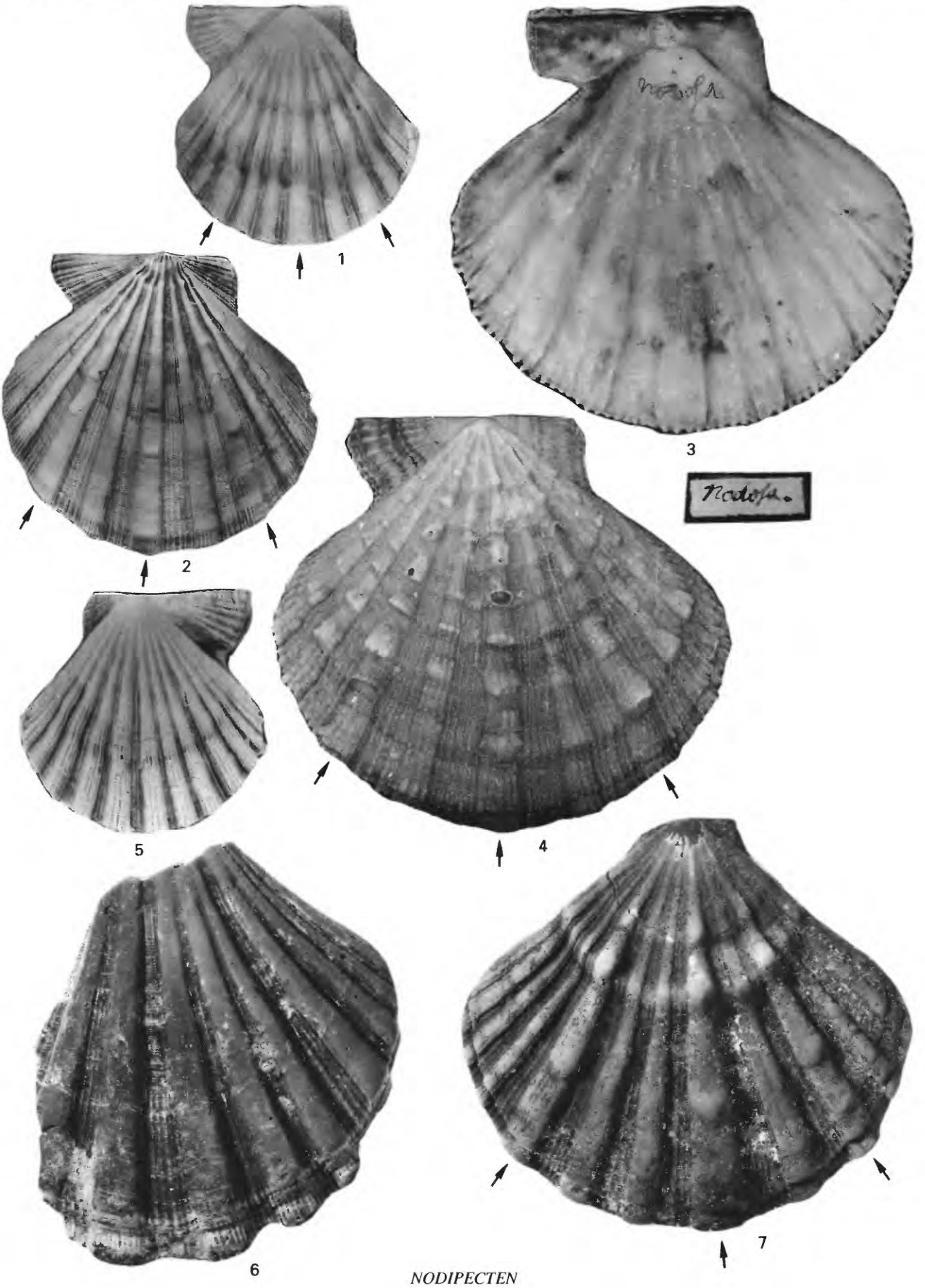
7. LV, hypotype USNM 387585. Data as for figure 6. Height 5.7 cm, length 6 cm.

2. *Nodipecten subnodosus* (Sowerby) (p. 98).

LV, lectotype BM (NH) 1950.11.14.77. Holocene, no locality given, but is the *Nodipecten* common in the Gulf of California, Mexico. Height 11.4 cm, length 11.7 cm, hinge length 3.6 cm. Photograph by Thomas R. Waller, U.S. National Museum.

3, 4. *Nodipecten nodosus* (Linnaeus) (p. 93).

RV, LV lectotype no. 106, and label, Zoologiska Museet, Uppsala Universitet, Uppsala, Sweden. Holocene, no locality given, but the specimen matches the Caribbean forms from Margarita Island, Venezuela. Height 9.6 cm, length 9.5 cm, hinge length 4.7 cm. Photographs courtesy of Lars Wallin, Uppsala Universitet.



NODIPECTEN

PLATE 5

Pacific-Panamic species of *Nodipecten*

[Arrows indicate key ribs]

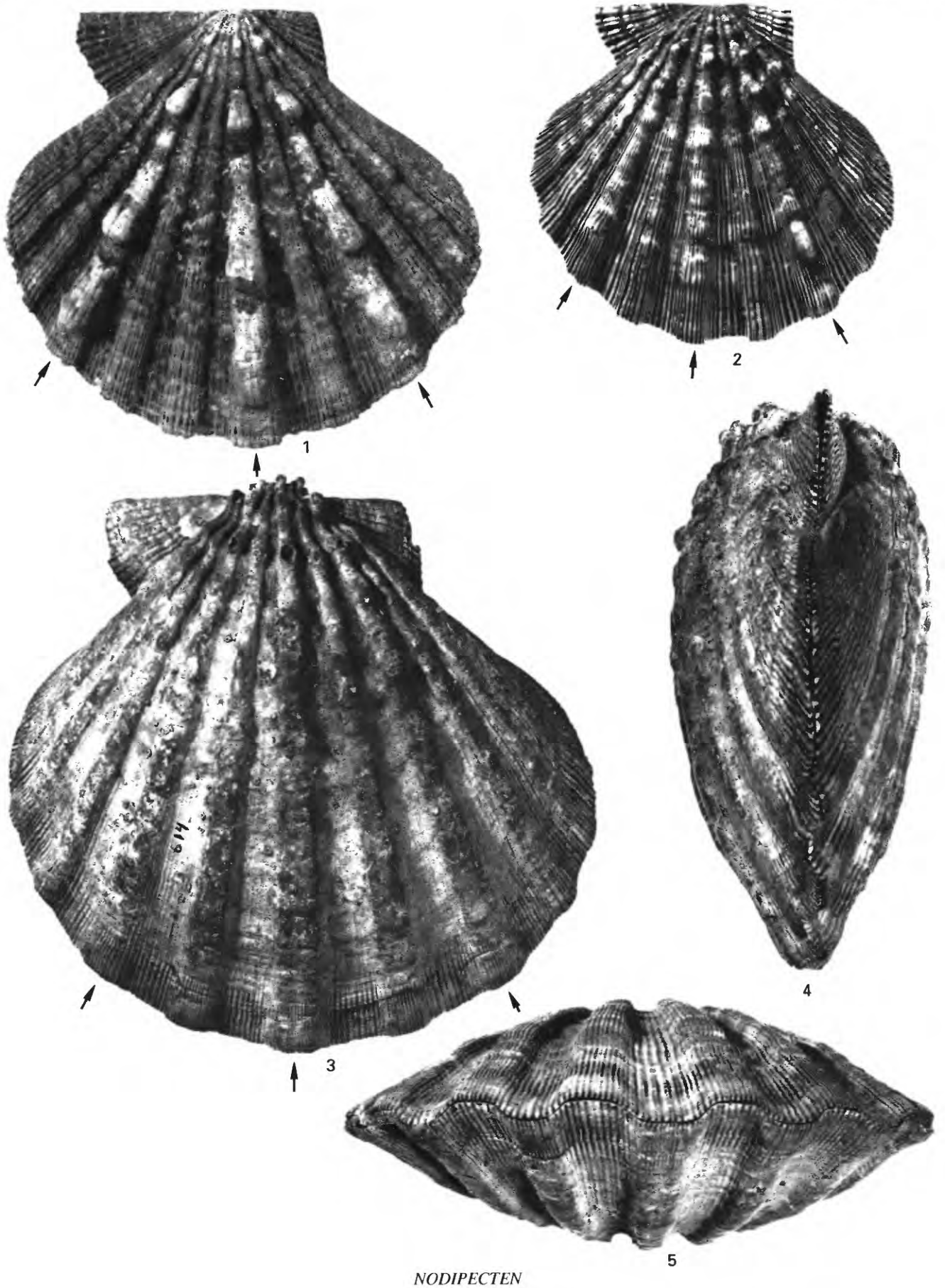
FIGURES 1. *Nodipecten arthriticus* (Reeve) (p. 88).

LV, hypotype SDSNH 78669. Holocene, San Juan del Sur, Nicaragua. Height 8.5 cm, length 9.1 cm. Prominent nodes emphasize rib-scheme characteristic of the southern species. It has 10 ribs.

2-5. *Nodipecten subnodosus* (Sowerby) (p. 98).

2. LV, hypotype AMNH 167572. Holocene, dredged off Guaymas, Sonora, Mexico. Height 9.3 cm, length 10 cm. Alternating nodose ribs characterize the Gulf of California subspecies, which has 9 ribs.

3, 4, 5. LV, posterior and ventral views, hypotype USNM 818270. Holocene, Magdalena Bay, west coast of Baja California Sur, Mexico (LSJU no. 614). Height 16 cm, length 16.5 cm Typical large lagoonal specimen.



NODIPECTEN

PLATE 6

Nodipectens from the Pacific-Panamic province

[Arrows indicate central key ribs on left valves; open arrows point to corresponding central spaces on right valves]

FIGURES 1, 3-7. *Nodipecten arthriticus* (Reeve) (p. 88).

1. RV, hypotype SDSNH 78669. Holocene, San Juan del Sur, Nicaragua. Height 8.5 cm, length 9.1 cm. Posterior ribs are paired, anterior ribs grouped in three and two in the southern species.

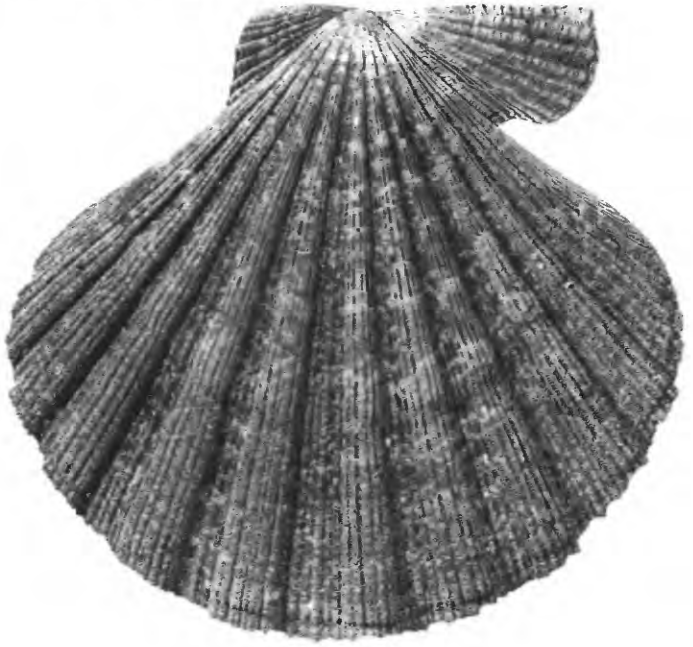
3, 4, 5. LV, RV, posterior views, hypotype MCZ 233063. Holocene, Guanecasta, Costa Rica. Height 5.2 cm, length 5.5 cm. Angular ledging in the left valve and a more rounded profile in the right valve are illustrated in figure 8.

6. LV, hypotype CAS 60985. Pliocene, Cerralvo Island, southwestern Gulf of California, Mexico (loc. CAS 38543). Height 7 cm, length 7.6 cm.

7. LV, hypotype MCZ 233063. Holocene, Guanecasta, Costa Rica. Height 9.3 cm, length 9.7 cm.

2. *Nodipecten submodosus* (Sowerby) (p. 98).

RV, hypotype USNM 818270. Holocene, Magdalena Bay, Baja California Sur, Mexico. Height 16.1 cm, length 16.5 cm. The northern species has equally spaced ribs.



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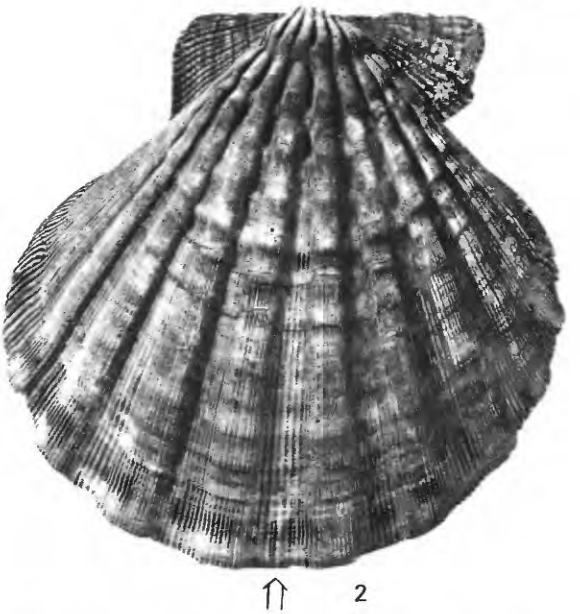

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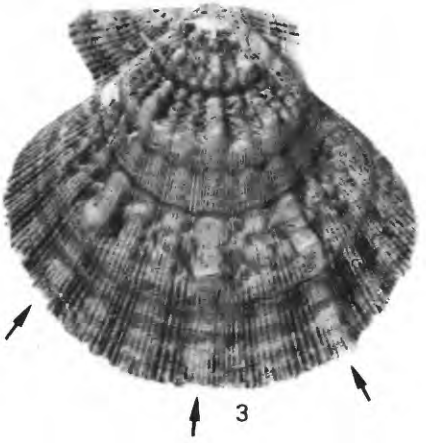

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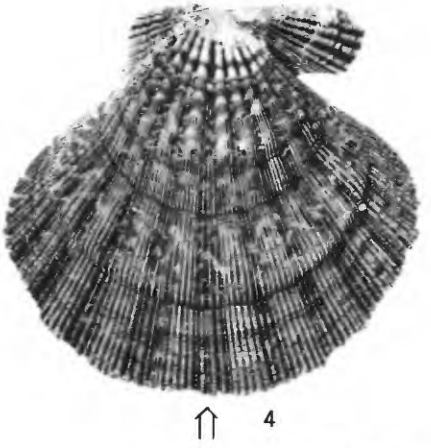

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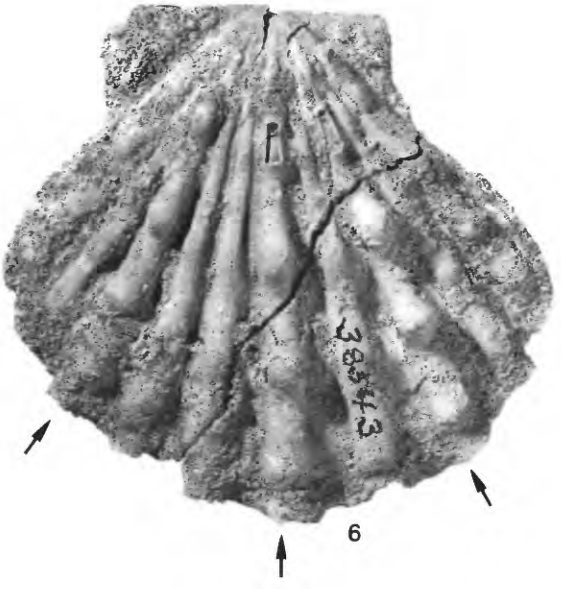

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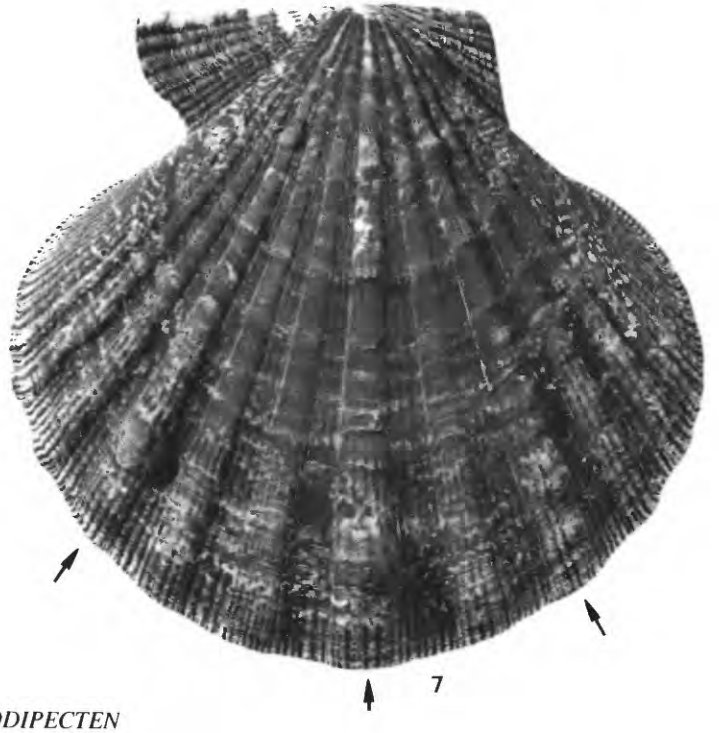


7

NODIPECTEN

PLATE 7

Holocene Atlantic Nodipectens

FIGURES 1, 2, 5. *Nodipecten fragosus* (Conrad) (p. 92).

1, 2. RV, LV, neotype USNM 818272. Holocene, Tarpon Springs, Fla. (loc. CAS 41794). Height 8.3 cm, length 8.5 cm. Specimen is coated for photographing and shows unusually well preserved frilly laminae.

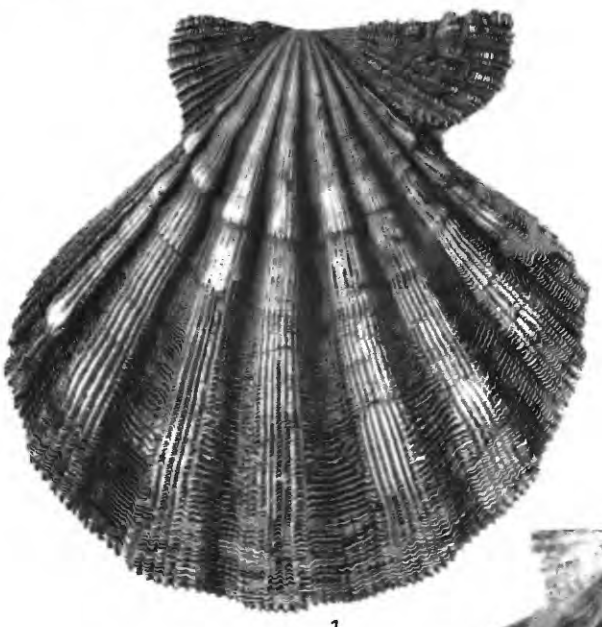
5. RV, hypotype USNM 714872. Holocene, off St. George Island, Fla. (M/V *Oregon* station 898). Height 7.9 cm, length 8.4 cm.

3, 4. *Nodipecten corallinoides* (d'Orbigny) (p. 91).

RV, LV, hypotype SDSNH 13201. Holocene, St. Vincent, Cape Verde, off West Africa. Height 4.1 cm, length 4.2 cm.

6, 7. *Nodipecten nodosus* (Linnaeus) (p. 93).

RV, LV, hypotype MCZ 151768. Holocene, Río de Janeiro, Brazil. Height 8.4 cm, length 8.7 cm. LV illustrates the difficulty in counting ribs; juvenile shell has 10 ribs, adult has 9-10, the posterior-most ribs being incipient.



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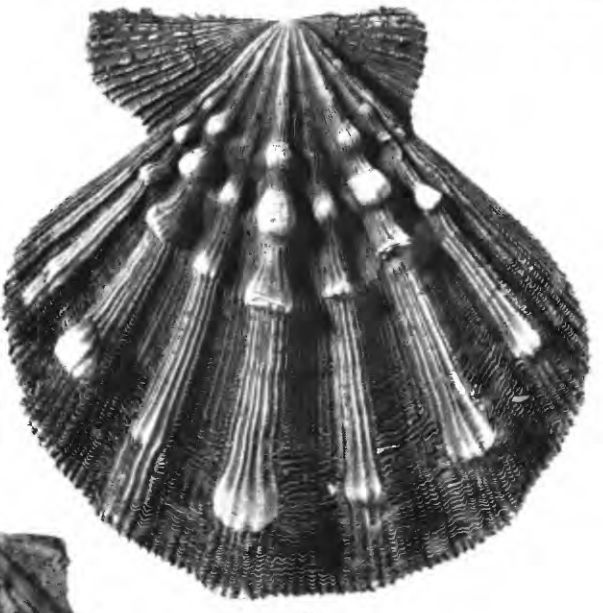

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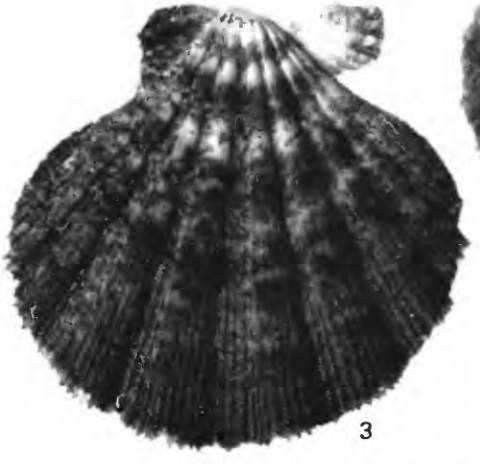

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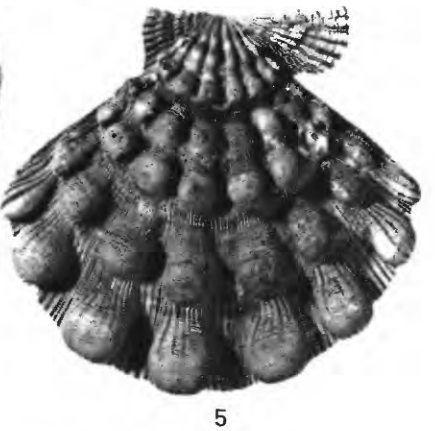

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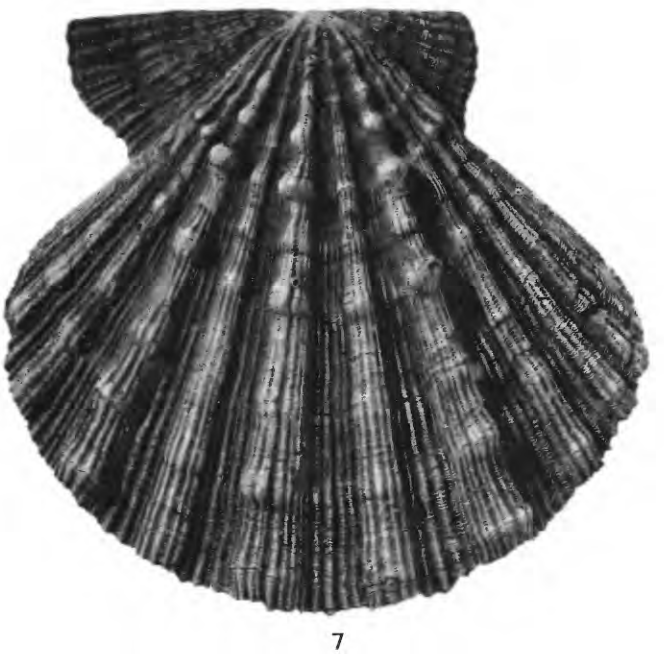

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NODIPECTEN

PLATE 8

Nodipecten phylogeny

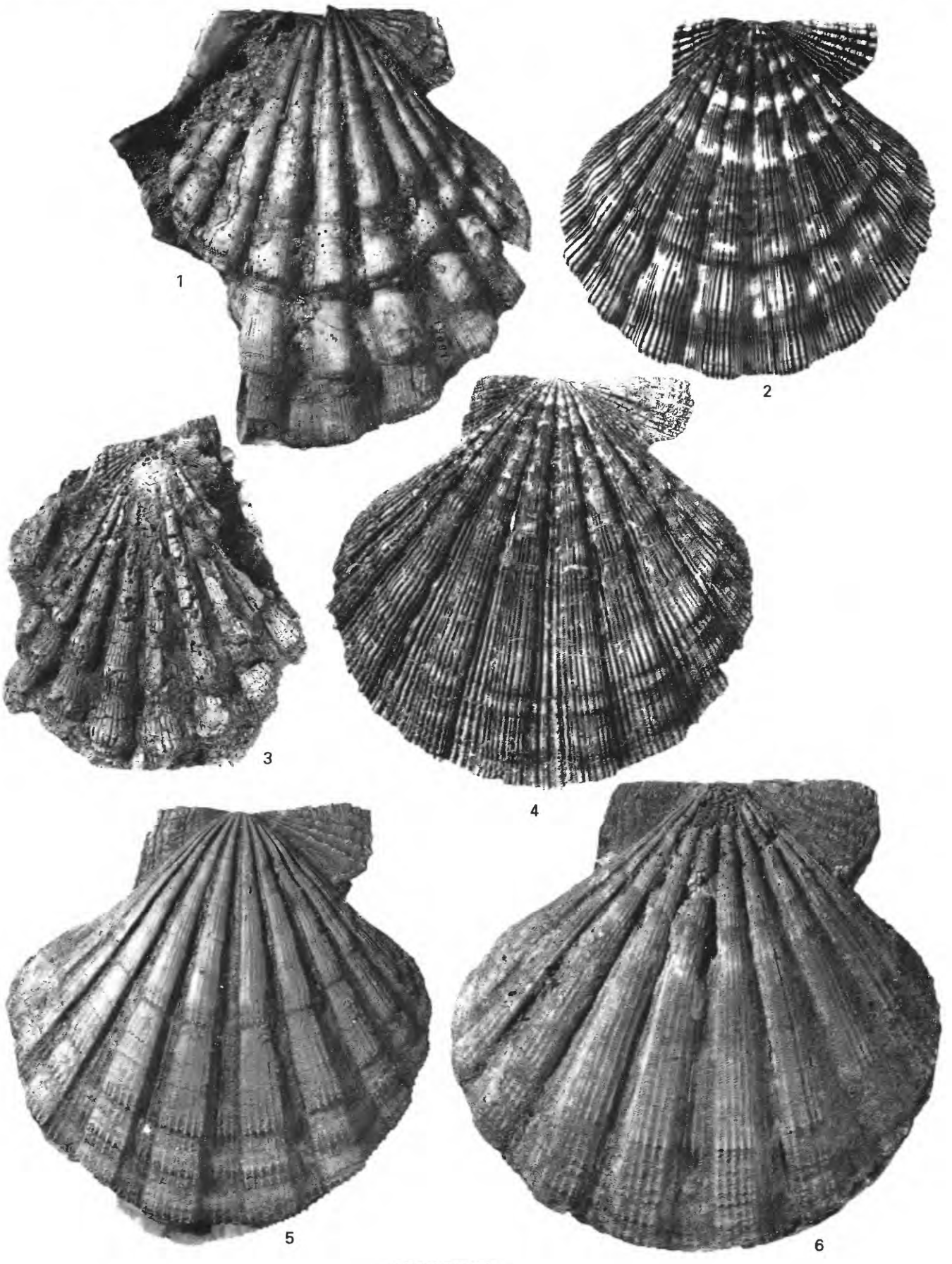
FIGURES 1, 3, 4. *Nodipecten nodosus* (Linnaeus) (p. 93).

1. RV, hypotype USNM 334977, Late Miocene or early Pliocene, probably the Boleo Formation, near Santa Rosalía, Baja California Sur, Mexico (loc. USGS 16054). Height 10.8 cm, length 10 cm (incomplete).
3. RV, hypotype PRI 26577 of *Lyropecten* (*Nodipecten*) *nodosus*? Weisbord, 1964. Pliocene and Pleistocene, Playa Grande Formation (float) or Mare Formation, Cabo Blanco, D.F., Venezuela (Weisbord locality N322a). Height 10.3 cm, length 8.7 cm (incomplete).
4. RV, hypotype UCMP 37389. Holocene, Margarita Island, Venezuela. Height 10.4 cm, length 10.5 cm.

2. *Nodipecten subnodosus* (Sowerby) (p. 98).
RV, hypotype AMNH 167572. Holocene, dredged off Guaymas, Sonora, Mexico. Height 9.3 cm, length 10 cm.

5, 6. *Nodipecten collierensis* (Mansfield) (p. 90).

5. RV, hypotype USNM 334978, Late Miocene. Tamiami Formation, Pinellas Park, Fla. (loc. USGS 25276). Height 11 cm, length 11.4 cm.
6. RV, hypotype UCMP 16104, Late Miocene or Early Pliocene. La Vela Formation of Hunter and Bartok (1976), Rio Seco area, Falcon, Venezuela (loc. UCMP S-148). Height 12 cm, length 12.2 cm.



NODIPECTEN

PLATE 9

Nodipecten phylogeny: morphologic progression from *N. collierensis* to *N. nodosus*

FIGURES 1, 2. *Nodipecten nodosus* (Linnaeus) (p. 93).

1. LV, hypotype USNM 334977. Late Miocene or early Pliocene. Probably the Boleo Formation, near Santa Rosalía, Baja California Sur, Mexico (loc. USGS 16054). Height 10.8 cm, length 10 cm (incomplete). LV coated for photograph. Coarse radial macrosculpture matches that of the modern Caribbean species, not the finer striae of the late Neogene Gulf of California *Nodipecten*.
2. LV, hypotype UCMP 37390. Holocene, Margarita Island, Venezuela. Height 10.6 cm, length 11.4 cm.

3, 4. *Nodipecten collierensis* (Mansfield) (p. 90).

3. LV, hypotype UCMP 16102. Upper Miocene or lower Pliocene, Paraguana Formation of Hunter and Bartok (1976), from Las Piedras, western Paraguana Peninsula, Venezuela (loc. UCMP S-254). Height 10 cm, length 10.2 cm.
4. RV, hypotype UCMP 16101. Upper Miocene or lower Pliocene, Paraguana Formation, Las Piedras, Venezuela (loc. UCMP S-254). Height 9.4 cm, length 10.4 cm.

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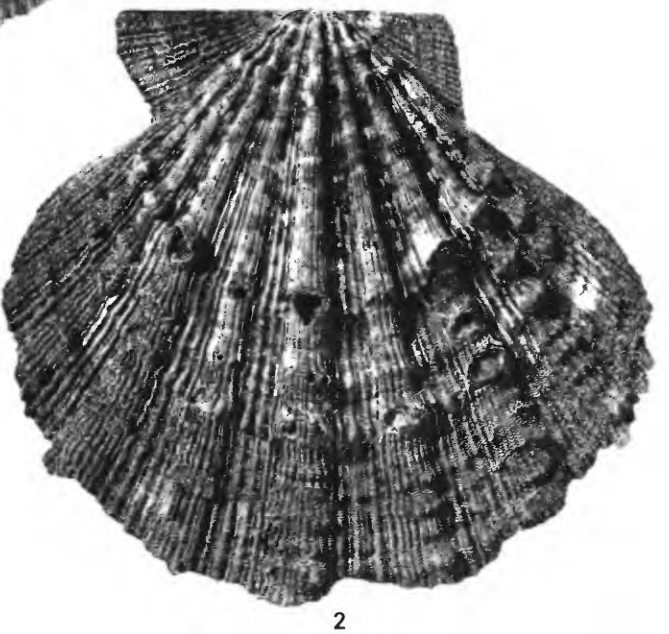

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NODIPECTEN

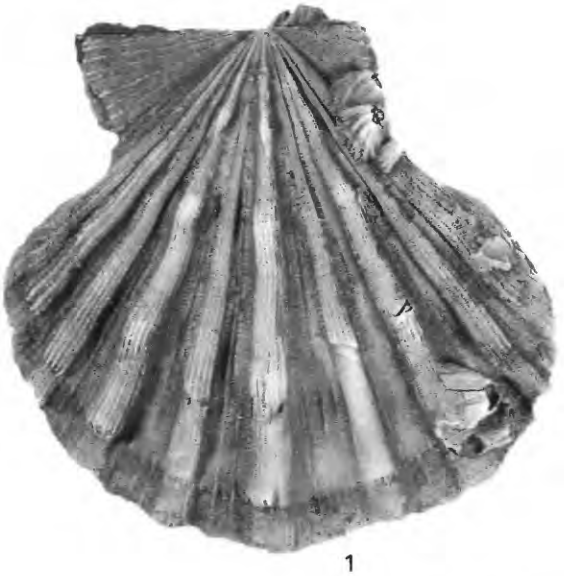
PLATE 10

Nodipecten collierensis, morphologic variation in left valves

[Specimens except for figures 2 and 6 coated for photographing]

FIGURES 1-6. *Nodipecten collierensis* (Mansfield) (p. 90).

1. LV, hypotype 334979. Upper Miocene, Tamiami Formation, Buckingham facies, from Telegraph Park, Lee County, Fla. (loc. USGS 21045). Height 7 cm, length 7.3 cm.
2. LV, hypotype USNM 334980. Pliocene, high bluff on the north shore of Lake Waccamaw, N.C. Height 12.5 cm, length 12.9 cm.
3. LV, hypotype USNM 334978. Upper Miocene, Tamiami Formation, Pinellas Park, Fla. (loc. USGS 25276). Height 11 cm, length 11.4 cm.
4. LV, hypotype Charleston Museum 30.112.2. Pliocene, from Cooper River, across from Etiwan Iron Works, S.C. Height 12.2 cm, length 12.3 cm.
5. LV, holotype USNM 371326 of *Pecten* (*Nodipecten*) *pittieri collierensis* Mansfield, 1932a. Upper Miocene, Tamiami Formation, Collier County, Fla. (loc. USGS 1176). Height 12.5 cm, length 14.3 cm.
6. LV, hypotype UCMP 16104. Upper Miocene or lower Pliocene, La Vela Formation of Hunter and Bartok (1976), Rio Seco area, Falcon, Venezuela (loc. UCMP S-148). Height 12 cm, length 12.2 cm.



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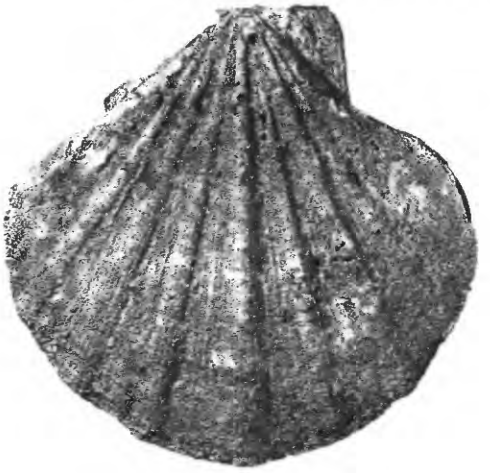

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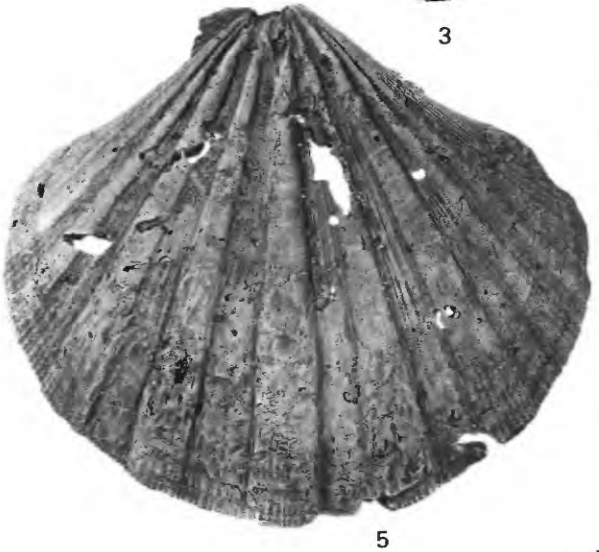

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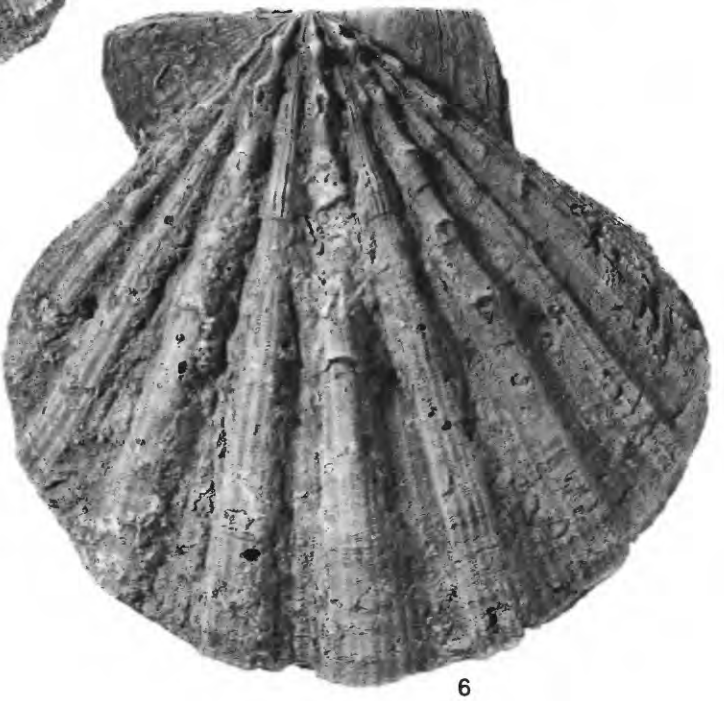

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NODIPECTEN

PLATE 11

Nodipectens from Florida, the Greater Antilles, and Venezuela

[Specimens in figures 1 and 2 coated for photographing]

FIGURES 1. *Nodipecten collierensis* (Mansfield) (p. 90).

LV, hypotype USNM 334981, upper Miocene, Tamiami Formation, near Sunniland, Collier County, Fla. (loc. USGS 22587). Height 9.7 cm, length 10 cm. Rib profiles low, macrosculpture unusually fine for the species; form approaches *N. pittieri* from the Greater Antilles.

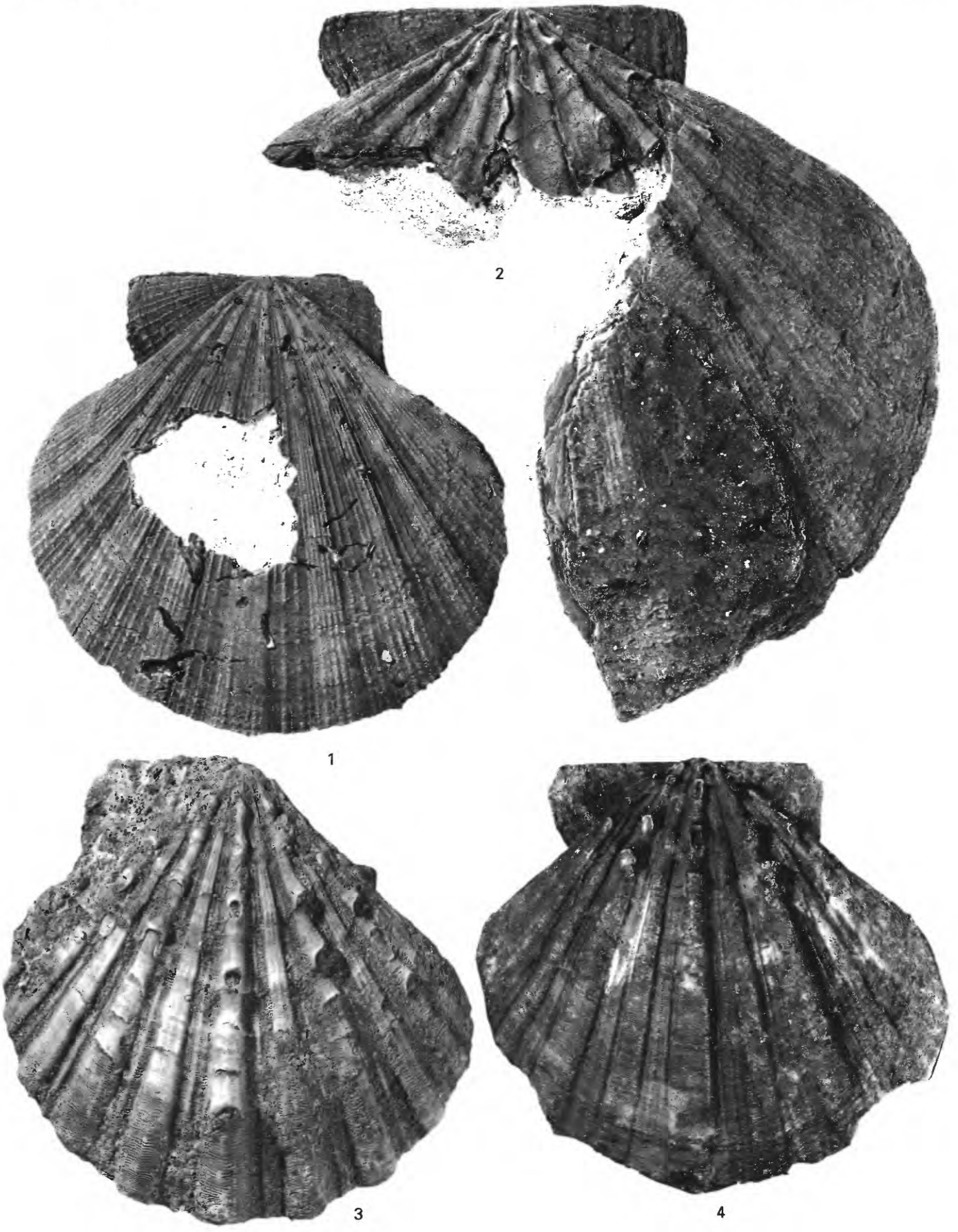
2. *Nodipecten pittieri* (Dall) (p. 97).

LV, hypotype USNM 334975, from marly sand near the mouth of the Macambo River, Cuba (loc. USGS 7533). Height 19 cm (incomplete), hinge length 9.6 cm. Wide umbonal angle and lower-rib profiles near the margins distinguish this species from *N. arnoldi*.

3, 4. *Nodipecten arnoldi* (Aguerrevere) (p. 87).

3. LV, hypotype USNM 334982, upper Pliocene, Cumana Beds near Cumana Castle, Sucre, Venezuela (loc. USGS 18408). Height 9.5 cm, length 9.4 cm.

4. LV, hypotype UCMP 16105. Upper Pliocene or Pleistocene, Cumana Beds near Manicuare, Araya Peninsula, Sucre, Venezuela (loc. UCMP S-116). Height 14.5 cm, length 16.2 cm.



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NODIPECTEN

PLATE 12

Nodipecten pittieri from Mexico and the Greater Antilles

[Specimens in figures 2 and 4 coated for photographing]

FIGURES 1-4. *Nodipecten pittieri* (Dall) (p. 97).

1. LV, holotype USNM 214368 of *Pecten (Lyropecten) pittieri* Dall, 1912. Late Pliocene. Limon Bay, Costa Rica. Height 13.2 cm, length 15.2 cm. Specimen has "Caribbean type" flared nodes on alternating ribs. Photograph courtesy U.S. National Museum.
2. LV, hypotype USNM 334983. Middle Pliocene, Concepción Superieur Formation, near Tuxtepec, Oaxaca, Mexico (loc. TU 1030). Height 9.6 cm, length 10.2 cm.
3. LV, hypotype of *Chlamys (Nodipecten) colinensis* forma *guadeloupensis* of Mongin (1968), collection of A. de Reynal, Institut Catholique de Paris. Miocene or Pliocene, colline de l'Aerodrome, southwest La Guadeloupe Island, French Antilles. Height 9.3 cm (incomplete), length 9.9 cm (incomplete).
4. LV, hypotype NMB G-16554. Miocene or Pliocene, Jacmel, Haiti; Riviere Gauche, about 25.1 km from Grand Coave junction. Height 13 cm, length 13.5 cm. Specimen is transitional between *N. pittieri* and *N. collierensis* (Mansfield).

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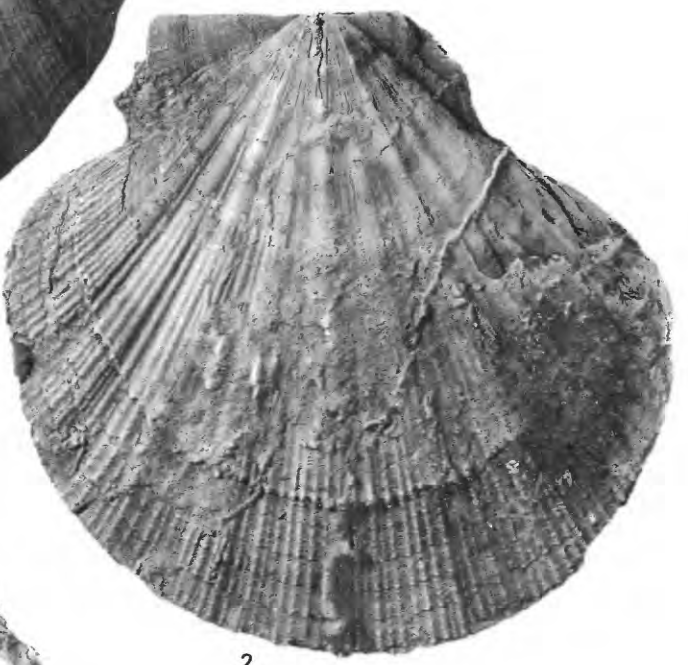

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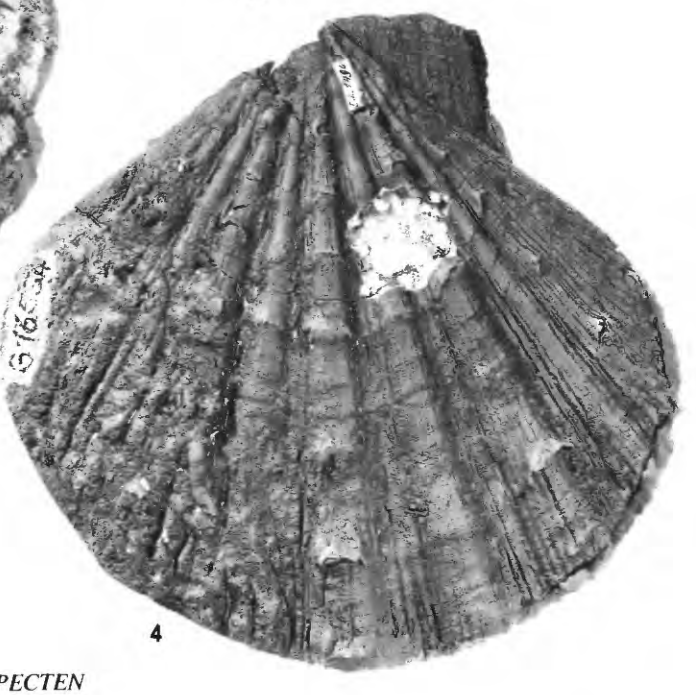

4

NODIPECTEN

PLATE 13

Giant fossil Caribbean Nodipectens

FIGURES 1. *Nodipecten pittieri* (Dall) (p. 97).
RV, holotype USNM 214368 of *Pecten* (*Lyropecten*) *pittieri* Dall, 1912. Late Pliocene. Limon Bay, Costa Rica. Height 13.2 cm, length 15.2 cm. Shell large and flat, rib profiles lower toward margins. Photograph courtesy U.S. National Museum.

2, 3. *Nodipecten arnoldi* (Aguerrevere) (p. 87).

2. RV anterior fragment, hypotype PRI 26578 of *Lyropecten* (*Nodipecten*) sp. "a" of Weisbord, 1964. Pliocene, Lower Mare Formation, Cabo Blanco, D.F., Venezuela (Weisbord loc. W13). Height of fragment 6.6 cm. Good example of coarse, scaly macrosculpture.
3. RV, holotype LSJU 364 of *Pecten* (*Lyropecten*) *arnoldi* Aguerrevere, 1925. Upper Pliocene, Cumana Formation, Araya Peninsula, Sucre, Venezuela. Height 21 cm, length 21.8 cm. Shell large, convex, higher than long, with coarser macrosculpture than in *N. pittieri*.

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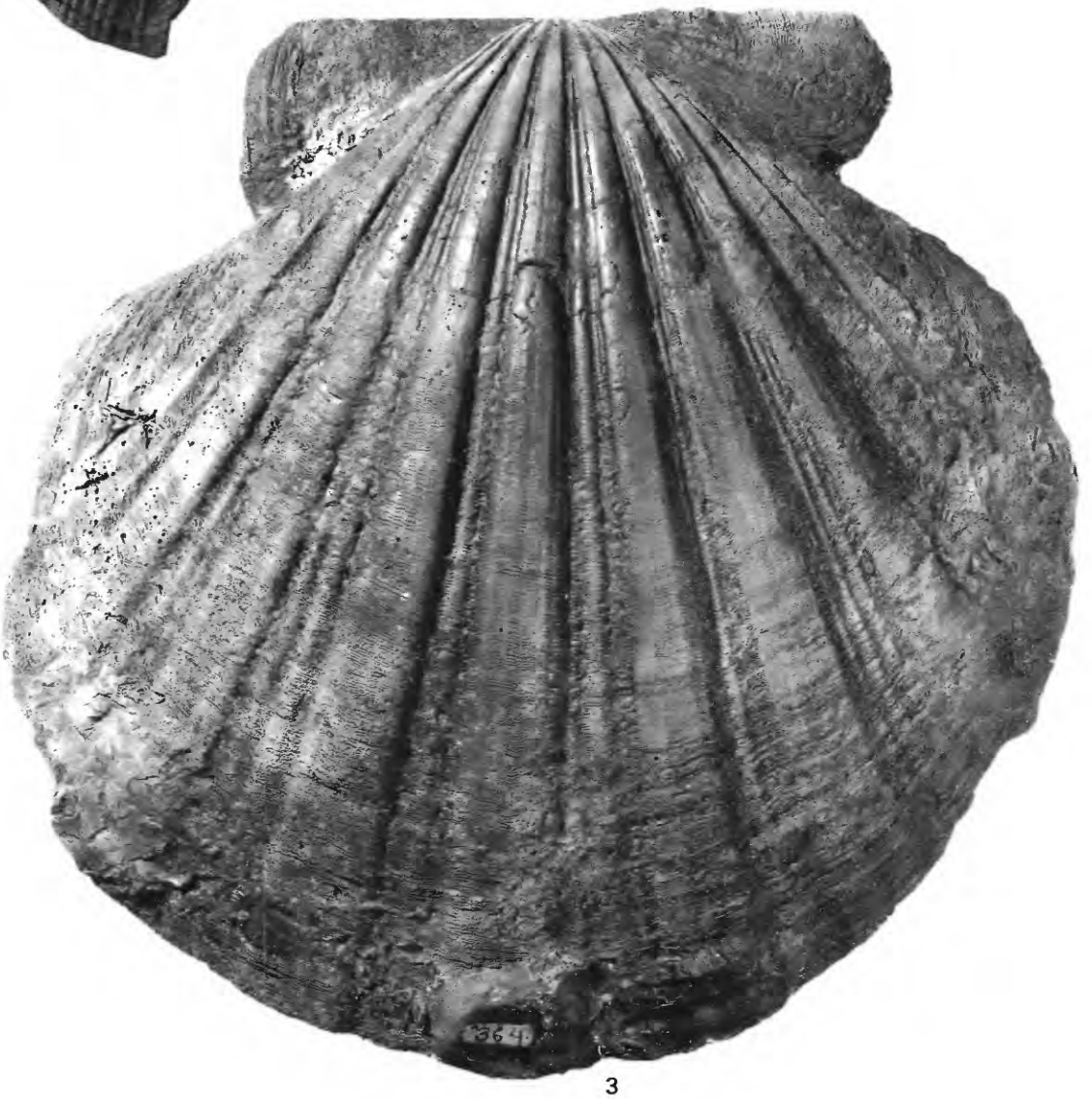

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NODIPECTEN

PLATE 14

Nodipectens from eastern Mexico and Cedros Island, Baja California Sur

[All specimens except for figures 2 and 5 coated for photographing.]

FIGURES 1. *Nodipecten pittieri* (Dall) (p. 97).

RV, hypotype USNM 334983. Middle Pliocene, Concepción Superieur Formation, near Tuxtepec, Oaxaca, Mexico (loc. TU 1030). Height 9.6 cm, length 10.2 cm.

2-4, 6, 7. *Nodipecten veracruzensis*, n. sp. (p. 100).

2. RV, hypotype USNM 334984. Middle Pliocene, Agueguexite Formation, near Coatzocoalcos, Veracruz, Mexico (loc. TU 1046). Height 9.4 cm, length 10 cm.
3. RV, paratype USNM 334985. Middle Pliocene, Agueguexite Formation, near Coatzocoalcos, Veracruz, Mexico (loc. TU 638). Height 5.3 cm, length 5.6 cm; auricles incomplete, ribs strongly paired on either side of a wide central space.
4. LV, holotype USNM 334986. Middle Pliocene, Agueguexite Formation, near Coatzocoalcos, Veracruz, Mexico (loc. TU 638). Height 6.9 cm, length 7 cm.
6. Juvenile RV, paratype at UNAM. Middle Pliocene, Agueguexite Formation, near Coatzocoalcos, Veracruz, Mexico (loc. TU 638). Height 4.2 cm, length 4.6 cm.
7. LV, paratype UCMP 37398. Middle Pliocene, Agueguexite Formation, near Coatzocoalcos, Veracruz, Mexico (loc. TU 638). Height 7.8 cm, length 8.4 cm (largest specimen known).

5. *Nodipecten fragosus* (Conrad) (p. 92).

RV, hypotype AMNH 171479. Holocene, west Florida. Height 7.1 cm, length 7 cm. Right-valve ribs are paired as in *N. veracruzensis*, but proportions tend to be higher than long.

8. *Nodipecten veatchii* (Gabb) (p. 99).

LV, hypotype USNM 334987. Late Miocene. Cedros Island, western Baja California Sur, Mexico. Height 9.6 cm (incomplete), length 10.6 cm. Pacific cognate of *N. peedeensis* and *N. veracruzensis*.

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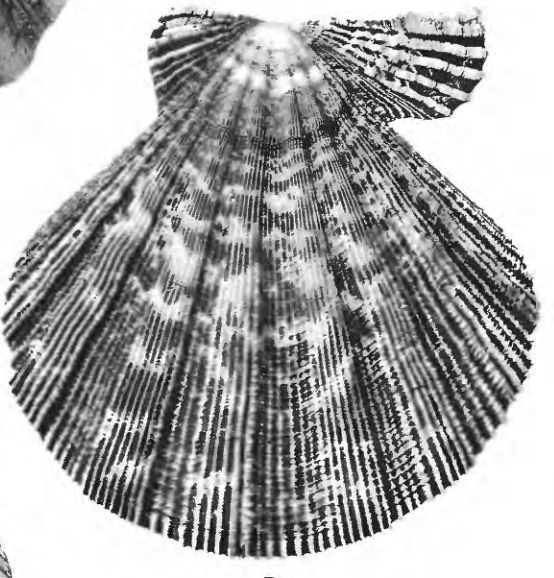

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NODIPECTEN

PLATE 15

Tertiary *Nodipecten* cognates

[All specimens coated for photographing]

FIGURES 1-4. *Nodipecten peedeensis* (Tuomey and Holmes) (p. 94).

1. LV, hypotype from type lot, AMNH 10822. Pliocene, Darlington District, S.C., "on the PeeDee River." Height 9.3 cm, length 9 cm. Unusually well preserved macrosculpture.
2. LV, holotype PRI 3483 of *Pecten (Nodipecten) vaccamavensis* Olsson, 1914. Pliocene, formation uncertain, from Lake Waccamaw, N.C. Height 7.3 cm, length 6.9 cm.

3, 4. LV, RV, holotype AMNH 5504 of *Pecten peedeensis* Tuomey and Holmes, 1855. Late Miocene or early Pliocene. Darlington District, "on the PeeDee River," S.C. (loc. AMNH 10822). Height 10.2 cm, length 11.6 cm.

5, 6. *Nodipecten veatchii* (Gabb) (p. 99).

LV, RV, holotype UCMP 12078 of *Pecten veatchii* Gabb, 1866. Cedros Island, western Baja California Sur, Mexico. Height 12.8 cm, length 14 cm.

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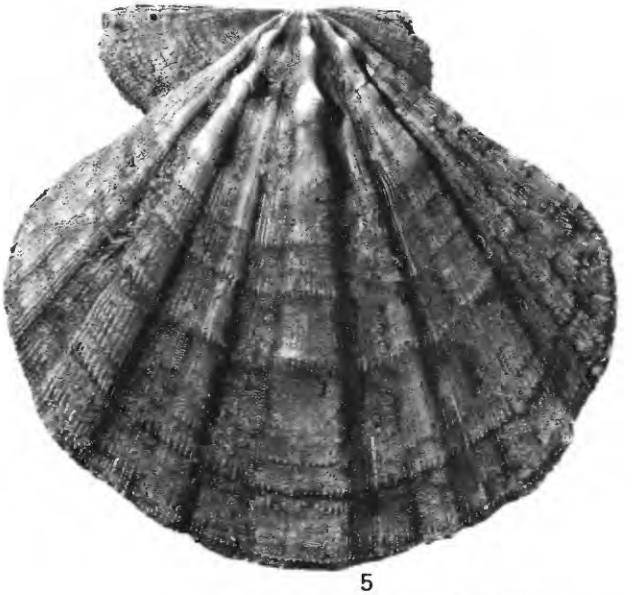

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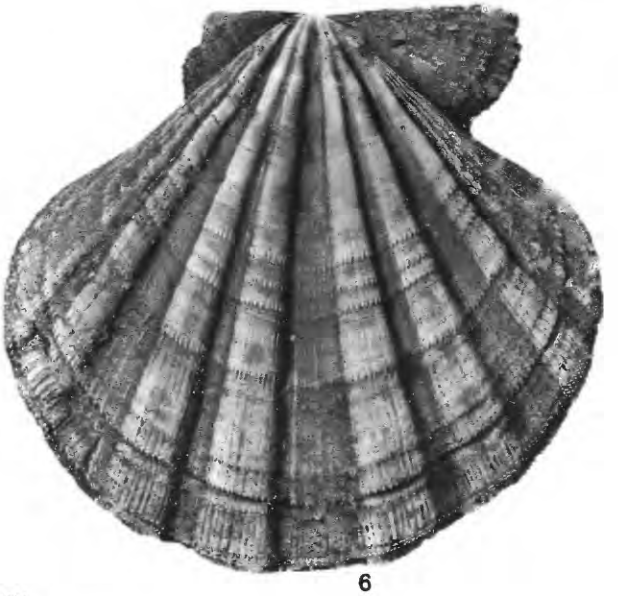

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NODIPECTEN

PLATE 16

Tertiary Caribbean cognates, *Lyropecten colinensis, s.l.*, *Lyropecten tiburonensis*, n. sp., and *Lyropecten modulatus*

[Specimens for figures 4-7 coated for photographing. Arrows indicate key ribs]

FIGURES 1, 3. *Lyropecten colinensis vokesae*, n. subsp. (p. 51).

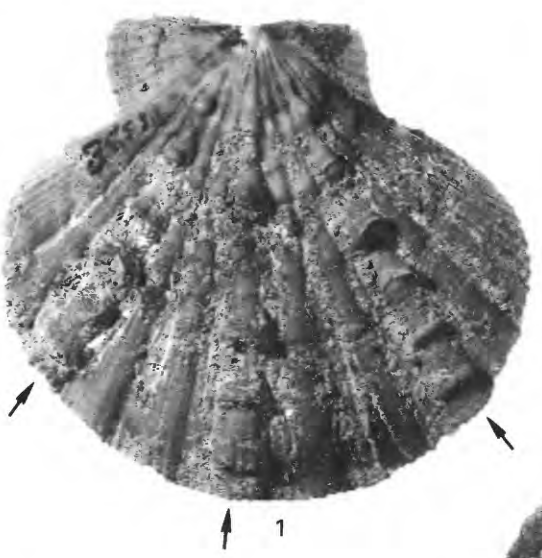
1. LV, holotype USNM 334988. Pliocene, Gurabo Formation, Dominican Republic, west of Los Quemados (loc. TU 1338). Height 6.5 cm, length 7.2 cm. Specimen has the coarse radial macrosculpture and flanged nodes characteristic of Caribbean Nodipectens and Lyropectens. Anterior and posterior margins are striate.
3. LV, hypotype USNM 334989. Miocene or Pliocene, Gurabo Formation, Dominican Republic, west of Los Quemados (loc. TU 1231). Height 5 cm (incomplete), length 6 cm.

2. *Lyropecten tiburonensis*, n. sp. (p. 67).
   LV, hypotype UCR 5042/4. Miocene, from the northern Salton Trough, near Whitewater, Calif. Height 7 cm, length 7 cm.
4. *Lyropecten modulatus* (Hertlein) (p. 62).
   LV, hypotype UCMP 37396. Cedros Island, Baja California Sur, Mexico (loc. UCMP D-8800). Pliocene conglomerate, probably reworked from upper Miocene deposits. Height 9.8 cm, length 10.8 cm.

5-7. *Lyropecten colinensis, s.s.* (F. and H. Hodson) (p. 50).

5, 7. Posterior view, LV, holotype PRI 21691 of *Pecten* aff. (*Nodipecten*) *colinensis* of F. and H. Hodson in Hodson and others, 1927. Miocene, probably the Caujarao Formation, Mataruca Member, from La Vela, Colina District, Falcon, Venezuela (Hodson field loc. 115). Height 8.3 cm, length 9.7 cm.

6. RV, paratype PRI 21954 of *Pecten* aff. (*Nodipecten*) *colinensis* F. and H. Hodson, 1927. Miocene, probably the Caujarao Formation, Mataruca Member, from La Vela, Colina District, Falcon, Venezuela (Hodson loc. 125). Height 6.1 cm (incomplete), length 7.4 cm (incomplete).



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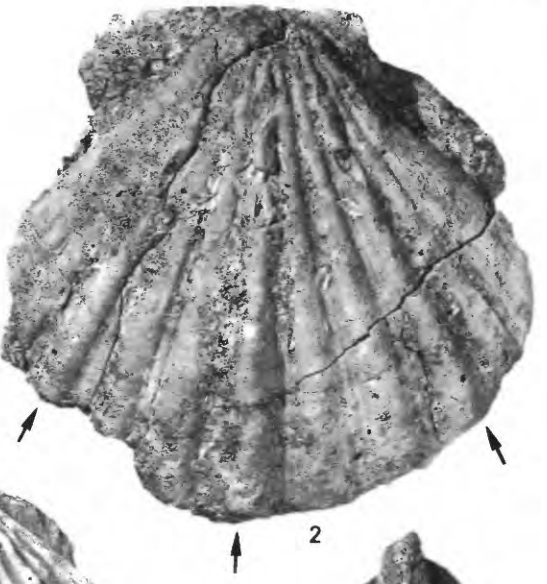

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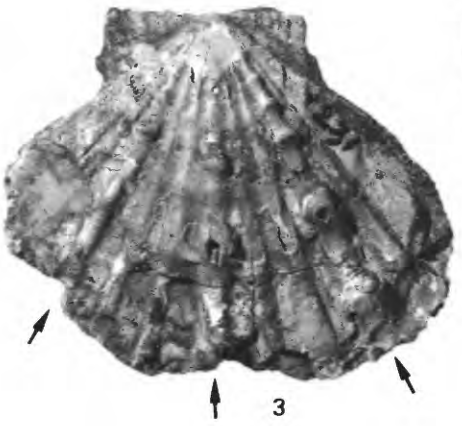

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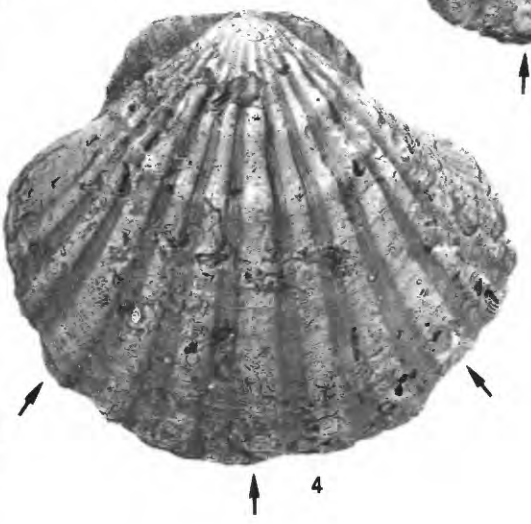

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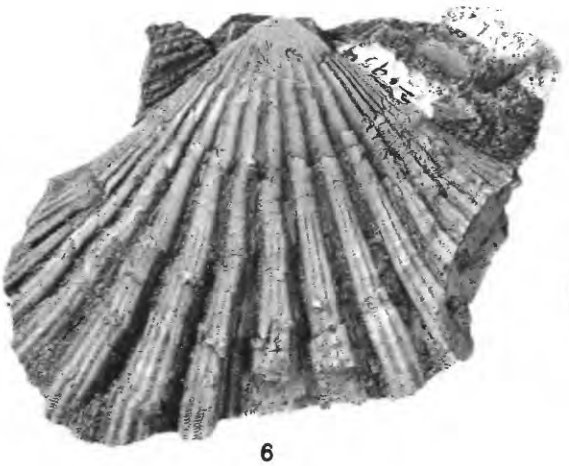

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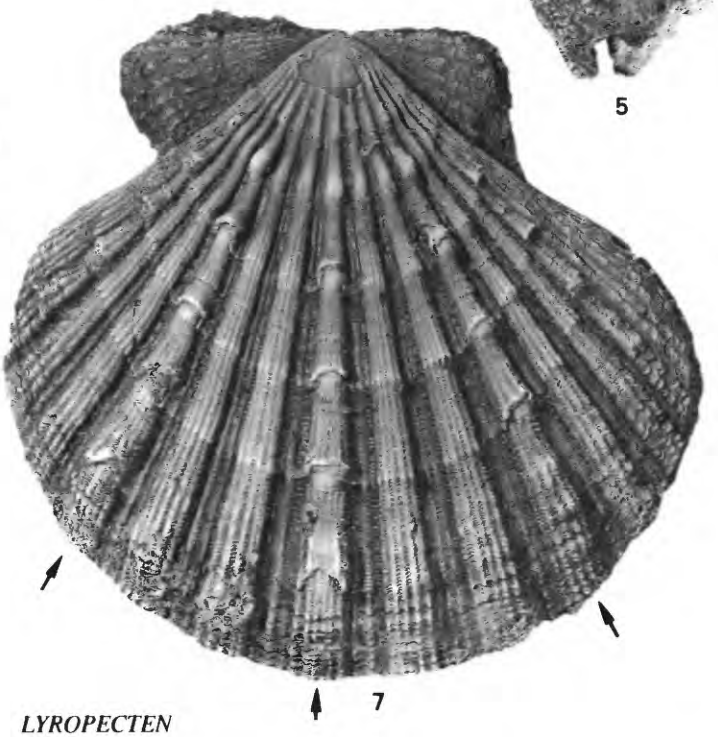

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LYROPECTEN

PLATE 17

Tertiary Caribbean *Lyropecten* cognates

[Specimens for all but figure 3 coated for photographing]

FIGURES 1, 2, 4. *Lyropecten modulatus* (Hertlein) (p. 62).

1. RV, holotype LSJU 39 of *Pecten* (*Lyropecten*) *modulatus* Hertlein, 1925. Miocene, Vizcaíno Peninsula near Cerro Elefante, Baja California Sur, Mexico. Height 5.8 cm, length 6.0 cm. Late juvenile or young adult individual.
2. RV, hypotype LACMIP 5878. Upper Miocene, Almejas Formation, Turtle Bay, Baja California Sur, Mexico (loc. LACMIP 962). Height 9.7 cm, length 10.2 cm. Open arrows indicate major interspaces, the central one of which separates groups of three ribs.
4. RV, hypotype UCMP 37397. Miocene or Pliocene, Cedros Island, Baja California Sur, Mexico (loc. UCMP D-8801). Height 12.3 cm, length 14.2 cm, the maximum size known for the species.

3. *Lyropecten colinensis vokesae*, n. subsp. (p. 51).
   RV, hypotype USNM 334989. Pliocene, Gurabo Formation, Dominican Republic, west of Los Quemados (loc. TU 1231). Height 5 cm (incomplete), length 6 cm. Poorly preserved and lacking outer shell material, this specimen has groups of three ribs flanking the central space.

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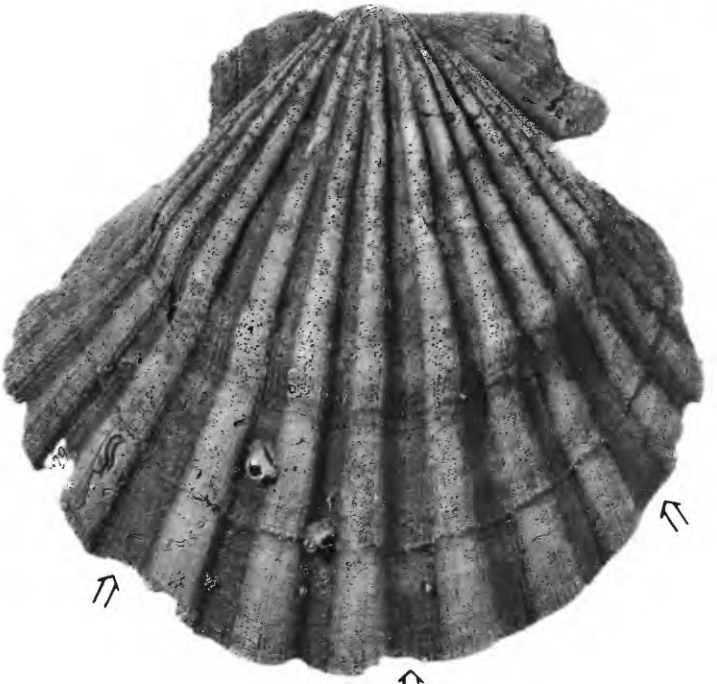

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LYROPECTEN

PLATE 18

Tertiary Caribbean *Lyropecten* cognates

[Specimens in figures 3, 5, 6, and 7 were coated for photographing]

FIGURES 1. *Lyropecten denaius* (Woodring) (p. 55).
RV, holotype USNM 647126 of *Nodipecten denaius* Woodring, 1982. Miocene, La Boca Formation, upper limestone in upper part, from Gaillard Cut area, Panama Canal (loc. USGS 23654). Height 4.9 cm, length 4.75 cm.

2-4. *Lyropecten colinensis vokesae*, n. subsp. (p. 51).
2, 4. RV, LV, hypotype UCMP 37380. Pliocene float from Cercado and Gurabo Formations, near Los Quemados, Dominican Republic (loc. TU 1231). Height 5.5 cm, length 5.8 cm.
3. LV, hypotype USNM 334990, Miocene or Pliocene, Alhajuela(?) Formation of collector T. Thompson, north bank of Chagres River, Colon Province, Panama (loc. LSJU 2659). Height 4.5 cm, length 3.8 cm. Outer shell material is missing; left valve has 11 ribs.

5. *Lyropecten tiburonensis*, n. sp. (p. 67).
LV, hypotype UCMP 32291 of *Pecten subnodosus* Sowerby of Hanna, 1926. Miocene. Latrania Sands of Hanna (1926) overlying the type section of the Imperial Formation, Coyote Mountains, southwestern Salton Trough, Calif. Height 8.5 cm, length 9.8 cm.

6, 7. *Lyropecten modulatus* (Hertlein) (p. 62).
6. LV, hypotype LACM 5879. Upper Miocene, Almejas Formation, Turtle Bay, Baja California Sur, Mexico (loc. LACMIP 962). Height 8.3 cm, length 9.1 cm. Outstanding specimen showing well-preserved macrosculpture.
7. RV, hypotype USNM 334991. Upper Miocene, Almejas Formation, Vizcaino Peninsula near Turtle Bay, Baja California Sur, Mexico. Height 7.4 cm, length 7.5 cm. Open arrow indicates characteristic central interspace; ribs are grouped in twos and threes on either side of it.

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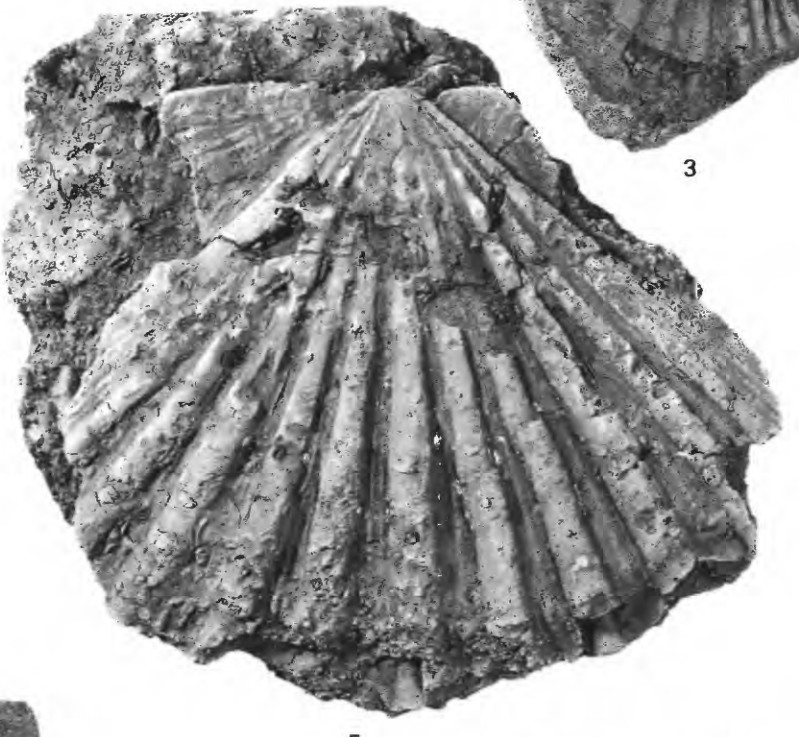

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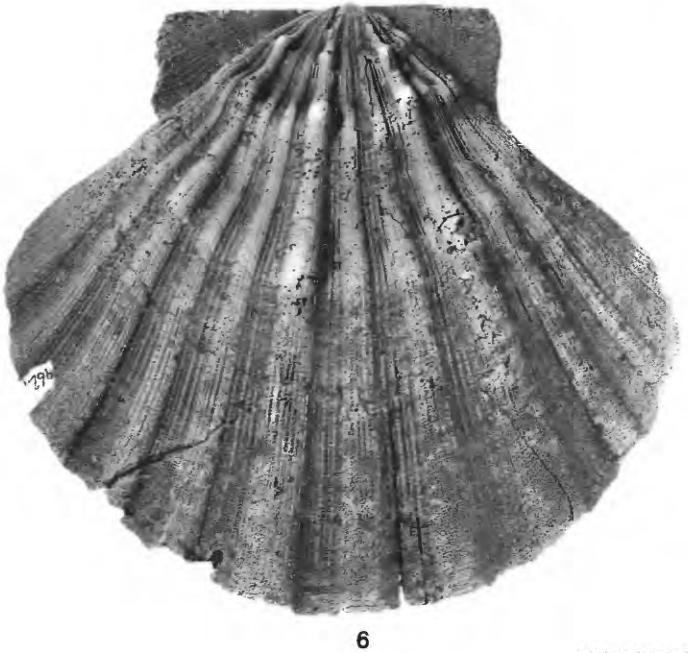

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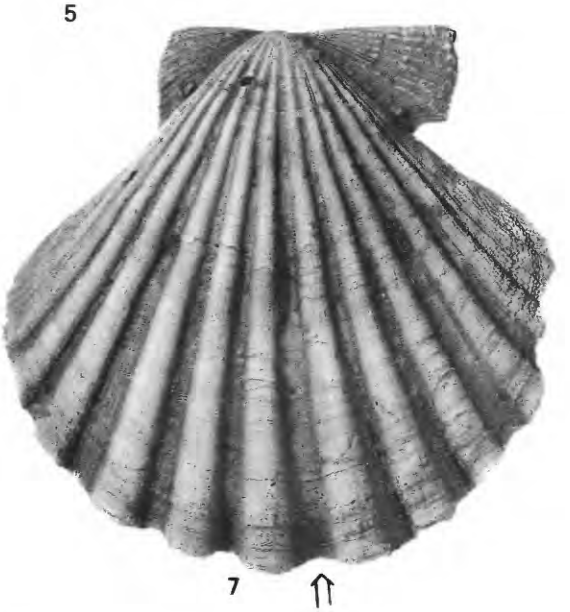

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LYROPECTEN

PLATE 19

Lyropecten colinensis subspecies from Panama, Venezuela, and the Dominican Republic

[Specimen 4 coated for photographing]

FIGURES 1, 3, 5. *Lyropecten colinensis colinensis* (F. and H. Hodson) (p. 50).

1, 3. LV, RV of holotype USNM 647127 of *Nodipecten clydonus* Woodring, 1982. Miocene, Alhajuela Formation, lower member, from Madden Basin, Panama (loc. USGS 5906a). Height 8.8 cm, length 9.8 cm.

5. RV, hypotype UCMP 16100. Miocene, Cantaure Formation or overlying limestone unit, Paraguana Peninsula, Falcón, Venezuela (loc. UCMP S-144). Height 8.4 cm, length 9.3 cm.

2, 4. *Lyropecten colinensis vokesae*, n. subsp. (p. 51).

2. RV, holotype USNM 334988. Late Miocene or early Pliocene, Gurabo Formation, near Los Quemados, Dominican Republic (locality TU 1338). Height 6.5 cm, length 7.2 cm.

4. RV, hypotype USNM 334992. Miocene, Alhajuela(?) Formation, bank of Chagres River, Colon Province, Panama (loc. LSJU 2659). Height 6 cm, length 6.2 cm (incomplete). Most of outer shell layer is missing.

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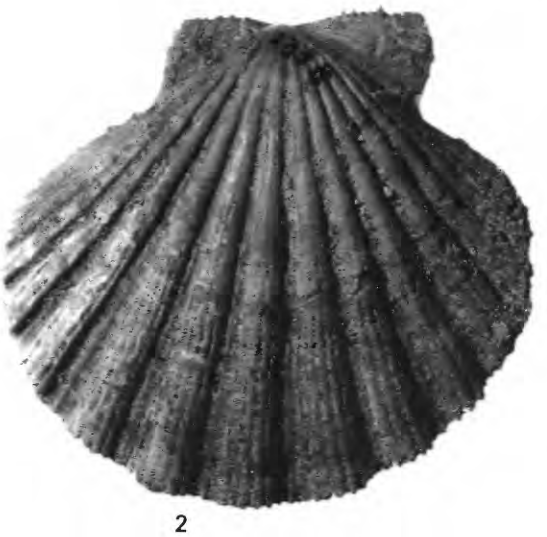

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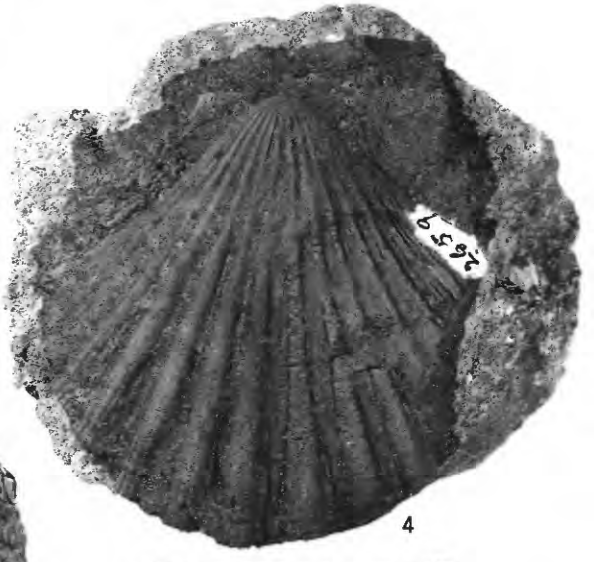

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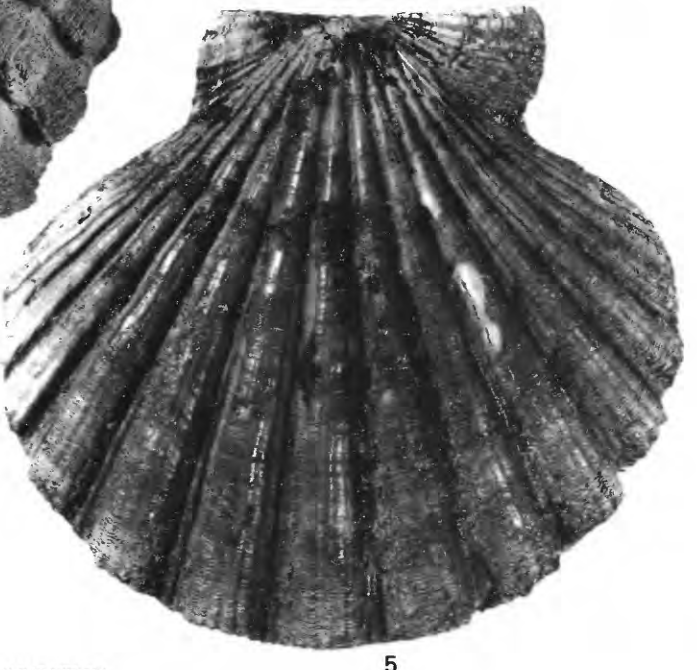

5

LYROPECTEN

PLATE 20

Early "Lyropectens" of uncertain affinities from the Caribbean and Baja California Sur, Mexico

[All specimens except in figures 1 and 2 coated for photographing]

FIGURES 1, 2. *"Lyropecten" articulosus* (Cooke) (p. 70).

1. RV, holotype AMNH 25025 of *Pecten (Nodipecten) articulosus* Cooke, 1919. Oligocene, in limestone from Guajay, Cuba, about 15 miles southwest of Havana. Height 5.5 cm, length 6.2 cm.
2. LV, hypotype AMNH 25026 of *Pecten (Nodipecten) articulosus* Cooke, 1919. Oligocene, in limestone from Guajay, Cuba. Height 5.2 cm, length 5.5 cm.

3. *"Lyropecten" condylomatus* (Dall)? (p. 70).
LV, hypotype USNM 334993. Miocene. Chipola Formation, from the type lot of *"L." condylomatus*, USNM 114776 (loc. USGS 2212) but possibly representing a different species. Height 4 cm, length 5 cm.

4a, 4b, 5, 8. *"Lyropecten" dumblei* (Gardner) (p. 71).

4a, 4b. LV, cotype USNM 494995 of *Chlamys (Nodipecten) dumblei* Gardner, 1945. Oligocene or Miocene. Guajalote Formation, from Tamaulipas, Mexico, east bank of Rio Conchos near San Fernando (loc. USGS 13585). Height 5.1 cm, length 5.9 cm. Reflected light emphasizes the single angular ledge developed when the shell was 2 cm high. Arrows indicate key ribs, typically arranged with the central key rib separated by two normal ribs from the anterior key rib and by three normal ribs from the posterior key rib.

5, 8. Posterior view, RV, of hypotype UCMP 37395. Oligocene, Guajalote Formation, Tamaulipas, Mexico (loc. UCMP D-8799). Height 6.2 cm, length 6.4 cm. Only known specimen having two valves intact, showing the more angular profile of the left valve and development of a single ledge.

6, 7a, 7b. *"Lyropecten" condylomatus* (Dall) (p. 70).

6. RV, paratype USNM 334994. Miocene. Chipola Formation, western Florida (loc. USGS 2212). Height 3.2 cm, length 3.3 cm.

7a, 7b. Juvenile LV, posterior view, holotype USNM 114776 of *Pecten (Nodipecten) condylomatus* Dall, 1898. Miocene, Chipola Formation, from the Chipola River, Calhoun Co., western Florida (loc. USGS 2212). Height 2.4 cm, length 2.4 cm. The holotype has two angular ledges and a rib scheme described as . .N 2r N_c r N. .; other left valves in the type lot vary in the number of normal ribs between key ribs. Arrows indicate key ribs.

9-11. *Lyropecten* sp. aff. *"L." dumblei* (Gardner) (p. 64, 71).

9. RV, hypotype USNM 334995. Miocene, about 15 mi northwest of San Isidro, Baja California Sur, Mexico, in Arroyo San Gregorio (loc. USGS 9157). Early Miocene. Isidro Formation. Height 5 cm, length 5.7 cm. Specimen poorly preserved but has distinctive wavy concentric lamellae on the ribs, deep rectangular interspaces.

10, 11. LV, RV, hypotype USNM 334996. Early Miocene. Near La Purisima, Baja California Sur, Mexico (loc. USGS 9160). Growth form and ribbing are reminiscent of *"L." dumblei*, although there is no pronounced ledge. The specimen is from an unknown stratigraphic level in the lower Miocene Isidro Formation in the same general area as *L. pretiosus* and a specimen identified as *Lyropecten* sp. cf. *L. magnificus* (pl. 21, fig. 3). Height 6.9 cm, length 7.8 cm.


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4a


4b


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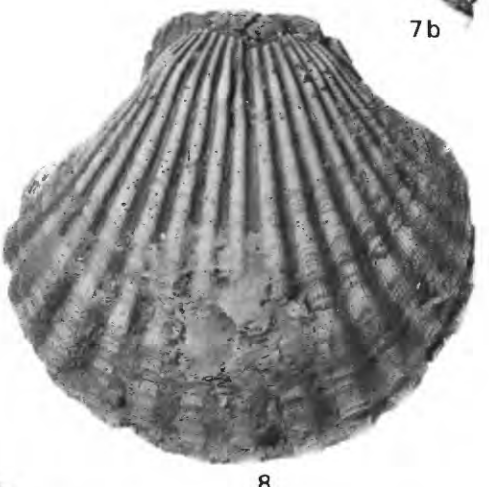
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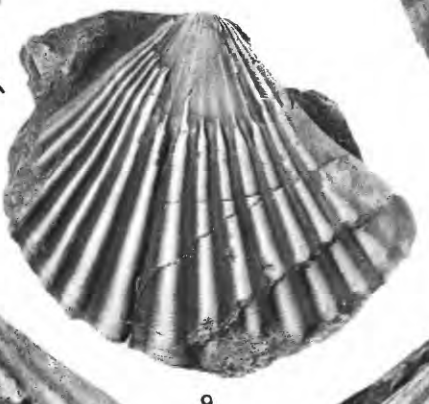
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LYROPECTEN

PLATE 21

Lyropecten magnificus (Sowerby), Holocene and fossil specimens

[Specimens in figures 2 and 3 coated for photographing]

FIGURES 1, 2, 4, 5. *Lyropecten magnificus* (Sowerby) (p. 59).

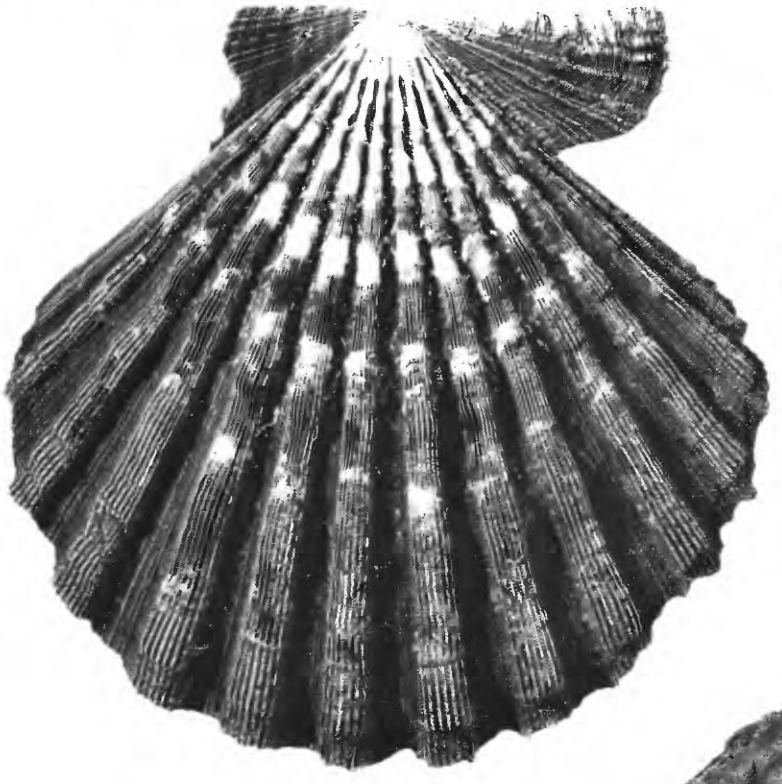
1, 4. RV, LV hypotype AMNH 169826. Holocene, Fernandina Island, Galapagos, off Punta Espinosa at 35 ft depth. Height 10.1 cm, length 10.5 cm. Arrows indicate key ribs.

2. RV, hypotype UCMP 16106. Pliocene or late Miocene. Santa Cruz Island, Galapagos (loc. UCMP B-3612). Height 16.8 cm (incomplete), length 18.6 cm.

5. LV, hypotype 440 of *Pecten* (*Lyropecten*) *magnificus* Sowerby of Grant and Gale, 1931. Holocene, Galapagos. Height 16.5 cm, length 17.8 cm.

3. *Lyropecten* sp. cf. *L. magnificus* (Sowerby) (p. 60).

RV, hypotype USNM 334997. Early Miocene. Isidro Formation, Arroyo San Gregorio, Baja California Sur, Mexico (loc. USGS 9157). Height 10 cm, length 10 cm (incomplete).



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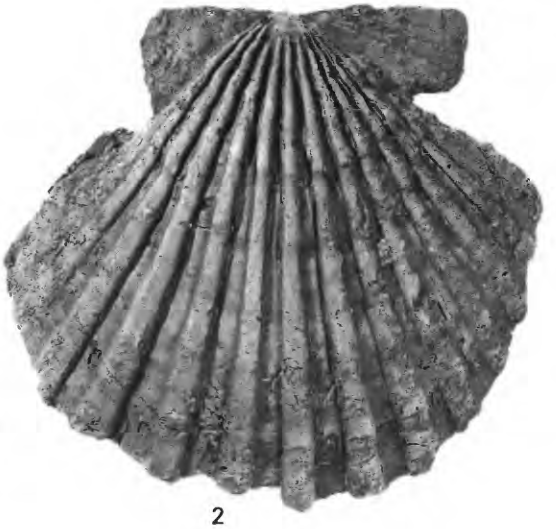

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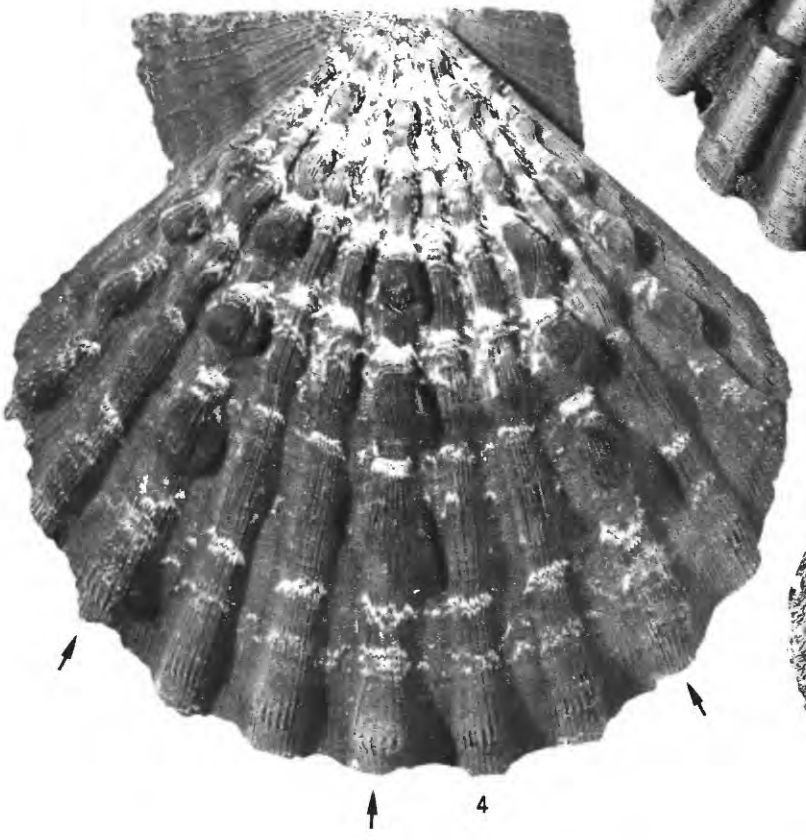

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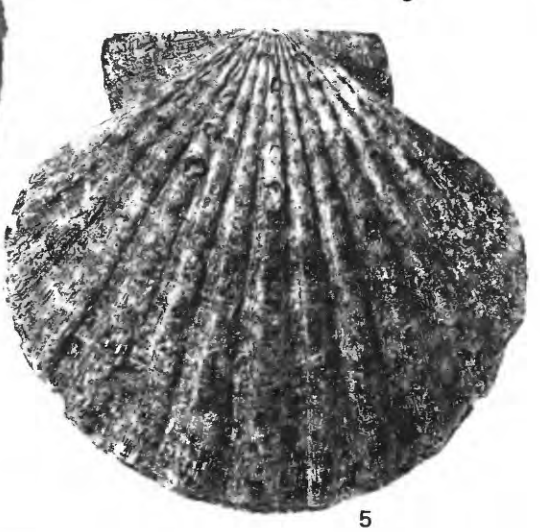

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LYROPECTEN

PLATE 22

Pectinids from Coalinga and the Cholame Hills, California

[Specimens except for figure 2 coated for photographing]

FIGURES 1, 4, 7. *Lyropecten estrellanus* (Conrad) (p. 55).

1, 7. LV, posterior view hypotype CAS 60983. Miocene, Santa Margarita Formation, in *Pecten*-oyster reef from Domengine Creek, north of Coalinga, Calif. (loc. CAS 29395). Height 10.4 cm, length 10.2 cm.

4. RV, hypotype USNM 165616 of *Pecten estrellanus* (Conrad) of Arnold, 1909. Miocene, Santa Margarita Formation, *Tamiosoma* zone, from 9 mi north of Coalinga, Calif. (loc. USGS 4766). Height 11.1 cm, length 12 cm.

2, 3. *Lyropecten terminus* (Arnold) (p. 66).

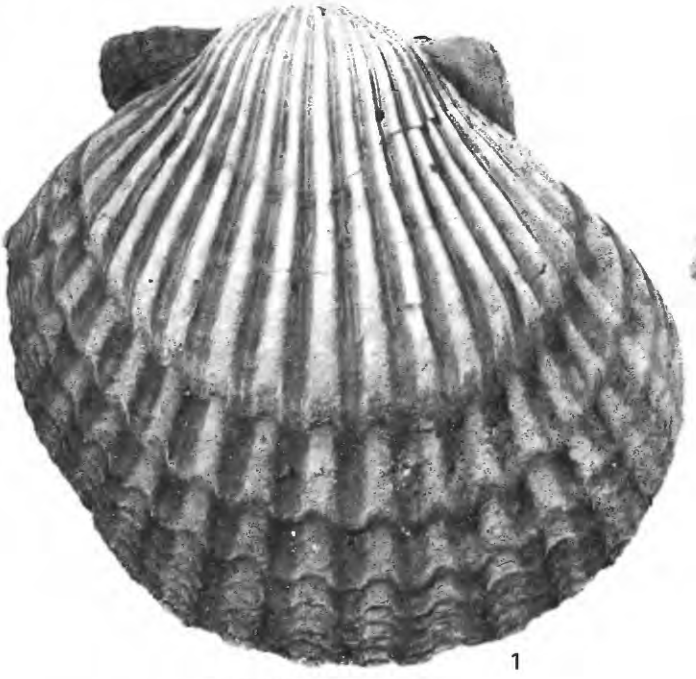
2. LV, hypotype UCMP 37391. Late Miocene. Pancho Rico Formation, east of San Lucas, Cholame Hills, Monterey County, Calif. (loc. UCMP D-8797). Height 8 cm, length 8 cm.

3. RV, holotype UCMP 11622 of *Pecten* (*Lyropecten*) *estrellanus* var. *terminus* Arnold, 1906. Late Miocene. Pancho Rico Formation, from terraces or a canyon in the Cholame Hills, east side of the Salinas Valley, Calif. Height 7.0 cm, length 7.5 cm.

5, 6. *Argopecten* sp. (p. 56).

5. Posterior view, hypotype USNM 334998. Miocene, Vineyard Canyon, Monterey County, Calif. (loc. USGS 16833). Height 6.3 cm, length 6.8 cm.

6. RV, hypotype CAS 5900 of *Pecten* (*Lyropecten*) *estrellanus* of Hanna and Hertlein, 1941. Miocene, from the Cholame Hills, Calif., between Indian Valley and Portuguese Canyon (loc. CAS 28473). Height 8.4 cm, length 8.5 cm. Arnold regarded this taxon as a flat form of *L. estrellanus* grading into *L. catalinae*, but the hinge characters and looped growth lamellae place it in *Argopecten*.



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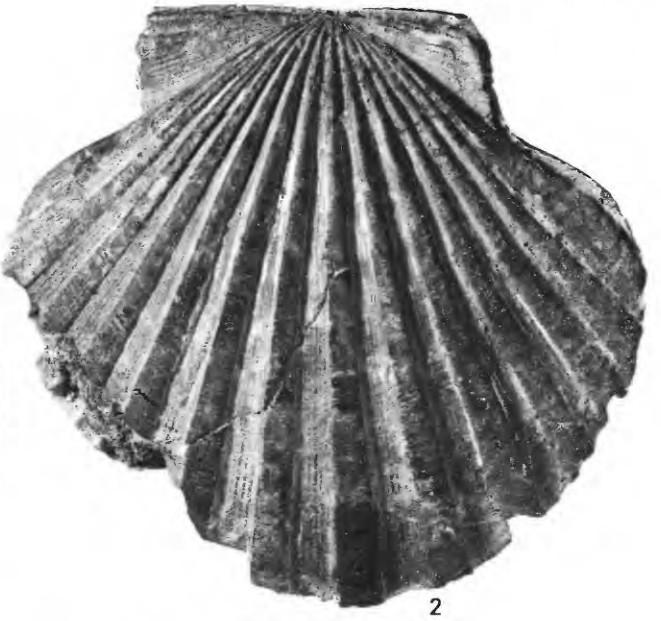

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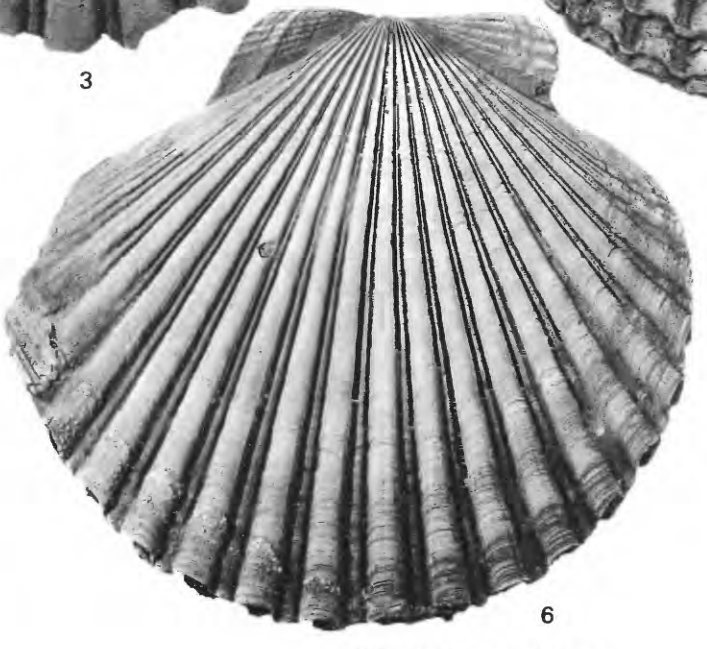

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LYROPECTEN, ARGOPECTEN

PLATE 23

Lyropecten crassicardo (Conrad) and *L. denaius* (Woodring)

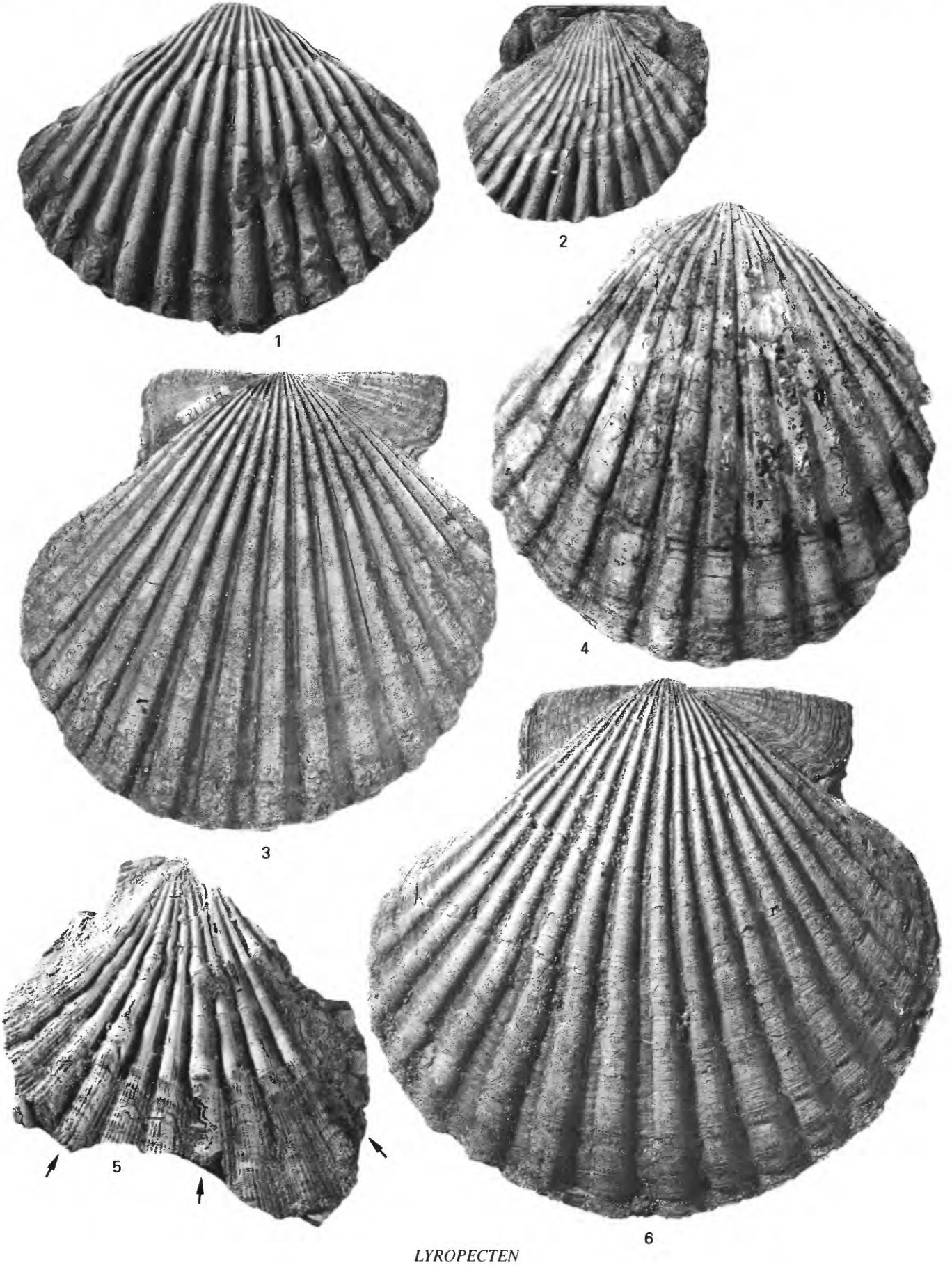
[Specimens in figures 1, 2, 3, and 6 coated for photographing]

FIGURES 1-4, 6. *Lyropecten crassicardo* (Conrad) (p. 52).

1. LV, deformed, paratype USNM 164845 of *Pecten* (*Lyropecten*) *crassicardo* var. *hamiltoni* of Arnold, 1906. Miocene, Briones Sandstone, Alum Rock Canyon, Santa Clara County, Calif. Height 6.4 cm, length 8 cm.
2. RV, holotype USNM 164845 of *Pecten* (*Lyropecten*) *crassicardo* var. *hamiltoni* Arnold, 1906. Miocene, Briones Sandstone, Alum Rock Canyon, Santa Clara County, Calif. Height 4.0 cm, length 4.7 cm.
3. RV, hypotype UCMP 37381. Miocene, Santa Margarita Formation, in *Pecten*-oyster biostrome along Domengine Creek near Coalinga, Calif. (formerly LSJU accession no. 46712). Height 16 cm, length 17.3 cm.
4. RV, lectotype ANSP 30745a of *Pallium crassicardo* Conrad, 1856. Miocene, northern La Panza Range, Monterey County, Calif. Height 13.8 cm, length 13.5 cm.
6. RV of hypotype USNM 646812 of Addicott, 1972. Miocene, Santa Margarita Formation, eastern Temblor Range, Fellows 7½-minute quadrangle, Calif. (loc. M3786). Height 13.8 cm, length 14.6 cm.

5. *Lyropecten denaius* (Woodring) (p. 55).

LV, holotype USNM 647126 of *Nodipecten denaius* Woodring, 1982. Miocene, La Boca Formation, upper limestone in upper part, from Gaillard Cut area, Panama Canal (loc. USGS 23654). Height 4.9 cm, length 4.75 cm. Arrows indicate key ribs.



LYROPECTEN

PLATE 24

Key rib evolution in left valves of *Lyropecten crassicardo* (Conrad) and *L. magnificus* (Sowerby)

[Specimens in figures 1, 3-7, and 9 were coated for photographing. Arrows indicate key ribs]

FIGURES 1, 3-9. *Lyropecten crassicardo* (Conrad) (p. 52).

1. LV, hypotype USNM 334999. Miocene, Santa Margarita Formation, from biostrome east of Shell Canyon, northern La Panza Range, Calif. (loc. M3569). Height of fragment 4.8 cm, length 7.5 cm. Arrows indicate four well-developed key ribs, which are more pronounced in the juvenile stage.

3. LV, holotype UCMP 36639 of *Swiftopecten adekunbiana* Adegoke, 1969. Miocene, Santa Margarita Formation, from Coalinga area, western San Joaquin Valley, Calif. (loc. UCMP D-1088). Height 4.3 cm, length 4.1 cm (incomplete). Fragment has four highly developed key ribs, representing the most advanced evolutionary form for the species.

4. LV, holotype UCMP 12364 of *Pecten* (*Lyropecten*) *ricei* Trask, 1922. Miocene, Briones Sandstone, near Pleasanton, Calif. (loc. UCMP 3535). Height 6.3 cm, length 5.3 cm. Outer shell material has been removed.

5, 6. LV, posterior view hypotype LSJU 442 of *Pecten* (*Lyropecten*) *magnificus* Sowerby of Grant and Gale, 1931. Miocene, Santa Margarita Formation, from Cammatta Ranch, northern La Panza Range, Calif. Height 10.7 cm, length 10.7 cm. Specimen shows angular ledging and four fairly well developed key ribs.

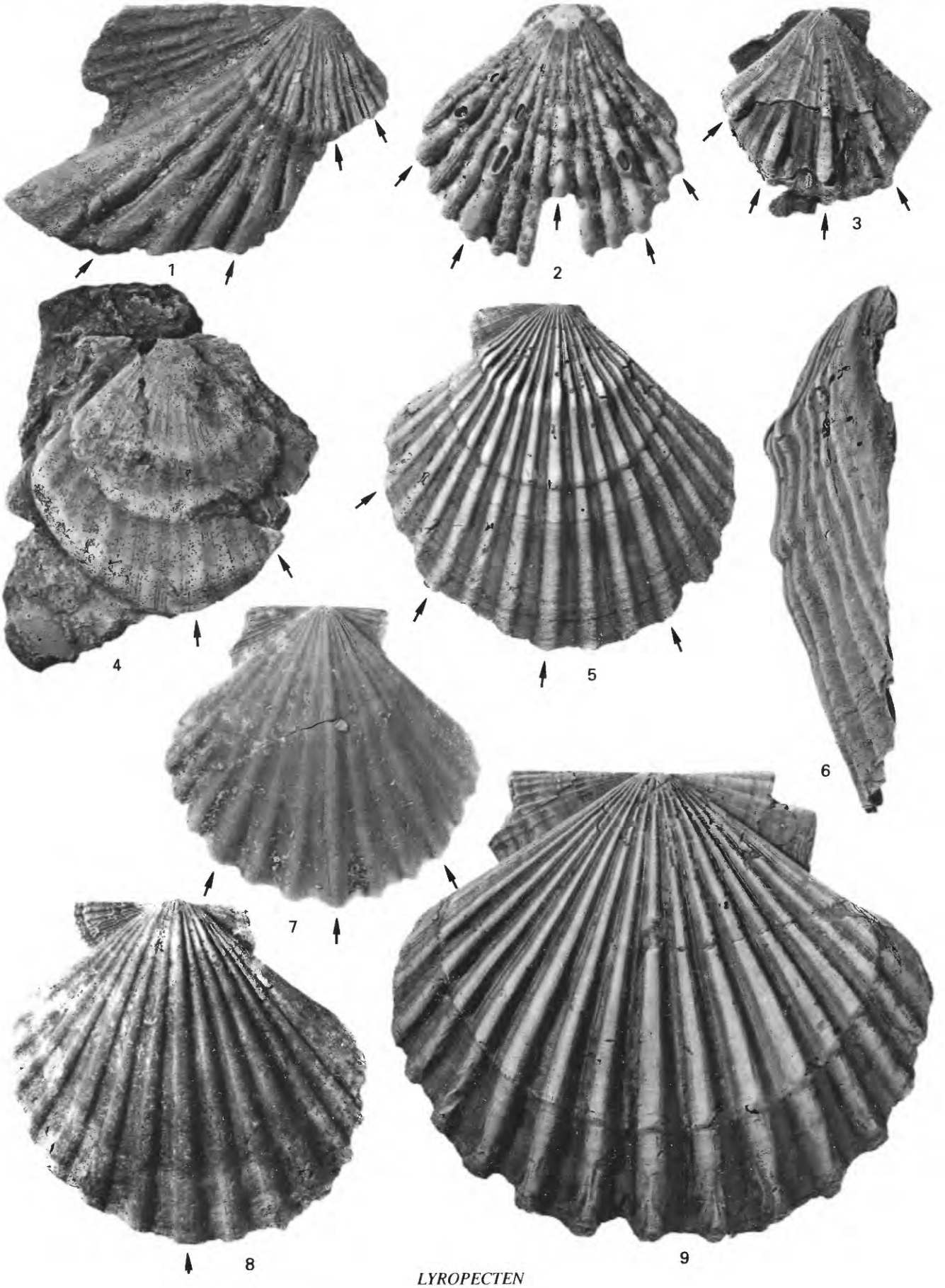
7. LV, hypotype UCLA 59266. Miocene, sandstones from Lemon Tank Reservoir, San Clemente Island (loc. UCLA 5899). Height 5.8 cm, length 6.0 cm. Specimen, which has three slightly developed key ribs, is a moderately advanced evolutionary form.

8. LV, hypotype LACMIP 5877. Miocene, Lemon Tank Reservoir, San Clemente Island, Calif. (loc. LACMIP 1194). Height 9.8 cm, length 10.2 cm.

9. LV, holotype UCMP 11318 of *Pecten crassicardo biformatis* Nomland, 1917 [preoccupied] = *Pecten crassicardo nomlandi* Hertlein, 1931. Miocene, Santa Margarita Formation, Tejon Hills, Kern County, Calif. (loc. UCMP 3029). Height 9.2 cm, length 11.4 cm.

2. *Lyropecten magnificus* (Sowerby) (p. 59).

LV, hypotype UCMP 37382. Holocene, Sullivan Bay, James Island, Galapagos (loc. UCMP B-3621). Height 5 cm, length 5 cm. Left-valve key ribs bear hollow nodes.



LYROPECTEN

PLATE 25

Lyropecten crassicardo (Conrad), index species of the "Margaritan" and Upper "Temblor" Stages

[Specimens in figures 2, 4, and 6 coated for photographing. Arrows indicate key ribs on left valves, a scheme described as R 2r R_c 2r R (see text figs. 6, 12)]

FIGURES 1-7. *Lyropecten crassicardo* (Conrad) (p. 52).

1, 3. LV, posterior view, hypotype LACMIP 5876. Miocene, Monterey Formation, sandstone facies from Moulton Parkway road cut, Orange County, Calif. (loc. LACMIP 1189). Height 8.4 cm, length 9 cm.

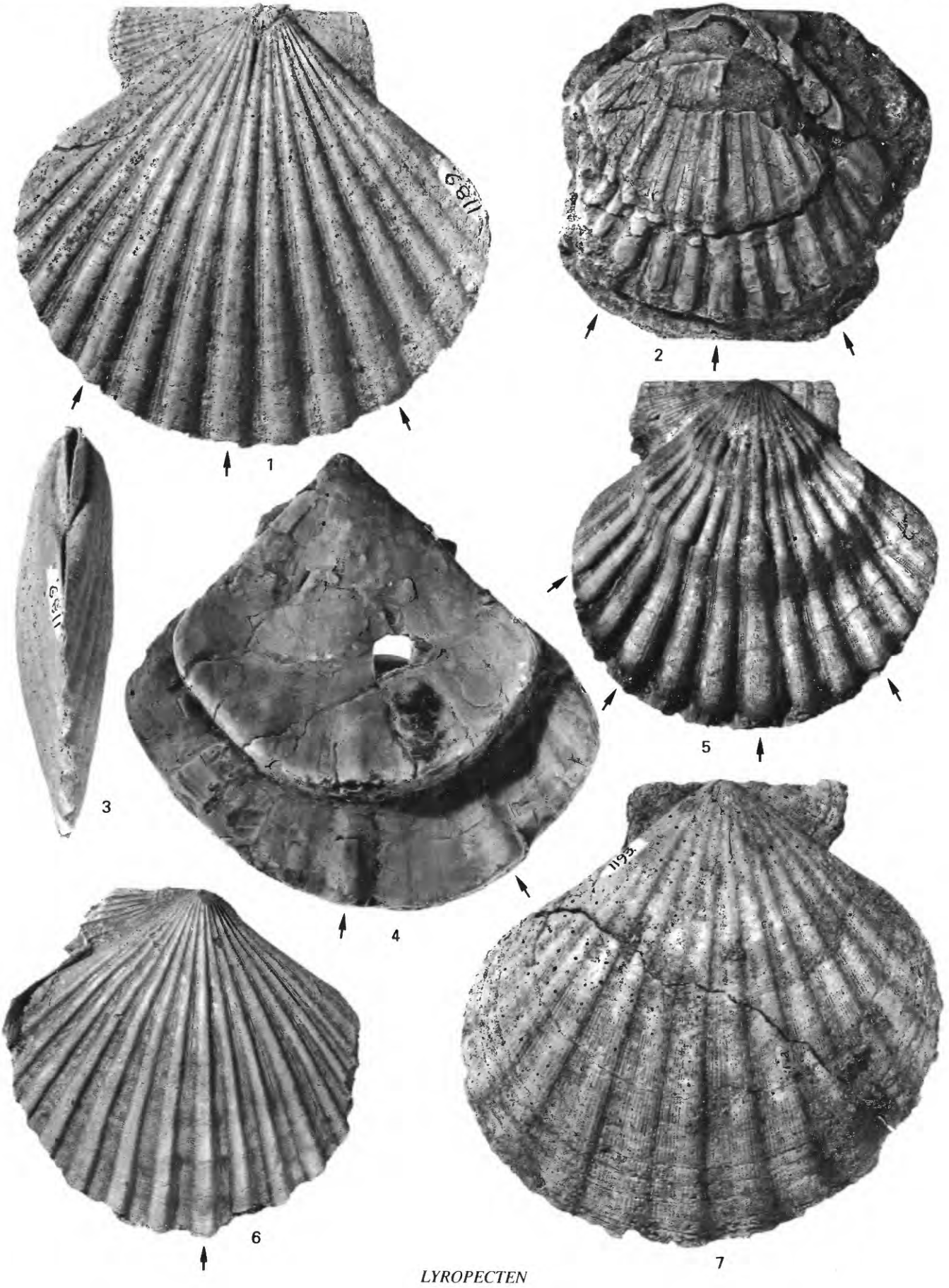
2. LV, holotype LSJU 26 of *Pecten* (*Lyropecten*) *vickeryi* Trask, 1922. Miocene, Briones Sandstone, near McGuire Peaks, Mount Hamilton Range, Calif. Height 9.9 cm, length 10.6 cm.

4. LV, holotype UCMP 11580 of *Pecten* (*Pallium*) *holwayi* Clark, 1915. Miocene, San Pablo Formation, Contra Costa County, Calif. (loc. UCMP 1632). Height 8.6 cm, length 9 cm. Auricles and outer shell material missing, but two or three key ribs and angular ledge are preserved.

5. LV, hypotype UCLA 45105. Miocene, Monterey Formation, San Juan Capistrano Quadrangle, Orange County, Calif. (loc. UCLA 635). A young adult specimen, fairly advanced evolutionary form.

6. LV, hypotype UCMP 16099. Miocene, Corona Quadrangle, Calif. (loc. UCMP 1910). Height 13 cm, length 13.5 cm. Key ribs barely distinguishable.

7. RV, hypotype LACMIP 5875. Miocene, Lemon Tank Reservoir, San Clemente Island, Calif. (loc. LACMIP 1193). Height 13 cm, length 13.4 cm.



LYROPECTEN

PLATE 26

Lyropecten pretiosus (Hertlein), including *L. submiguelensis* of authors,
from Baja California Sur, Mexico and the northern Channel Islands, California

[Specimens in figures 10, 11, 12, and 13 coated for photographing]

FIGURES 1-7. *Lyropecten pretiosus* (Hertlein) (p. 64).

1a, 1b. Hinge, juvenile RV, holotype LSJU 38 of *Pecten* (*Lyropecten*) *pretiosus* Hertlein, 1925. Miocene, Baja California Sur, Mexico, from "*Turritella* beds" along the trail from Arroyo Mesquital to La Purisima. Early Miocene. Isidro Formation. Height 2.6 cm, length 2.9 cm.

2, 3, 4. RV, posterior view, LV, hypotype UCMP 37393. Early Miocene. From limy sandstone facies of the Isidro Formation near La Purisima, Baja California Sur, Mexico (loc. UCMP B-5016). Height 4.7 cm, length 4.7 cm (incomplete). Best and largest specimen showing characters of the left valve. Arrows indicate key ribs.

5. RV, hypotype UCMP 37394. Early Miocene. From limy sandstone facies, Isidro Formation, near La Purisima, Baja California Sur, Mexico (loc. UCMP B-5016). Height 5.2 cm, length 5.4 cm. Individual has two ledges.

6. RV, hypotype CAS 61038. Early Miocene. White marly sandstone facies, Isidro Formation, northwest of La Purisima, Baja California Sur, Mexico (loc. CAS 36409). Height 4.9 cm, length 5.2 cm. An unledged specimen.

7. RV, hypotype UNAM type collection. Early Miocene. Limy sandstone facies, Isidro Formation, northwest of La Purisima, Baja California Sur, Mexico (loc. UCMP B-5012). Height 4.8 cm, length 5 cm. Specimen has several ledges.

8, 9, 12-14. *Lyropecten pretiosus* (Hertlein) (p. 64). [= *L. submiguelensis* auctt.]

8. Juvenile RV, hypotype USNM 335000. Miocene, Vaqueros Formation, diorite breccia facies, southwest Santa Cruz Island, Calif. (loc. USGS M8022). Height 2.7 cm, length 3.1 cm.

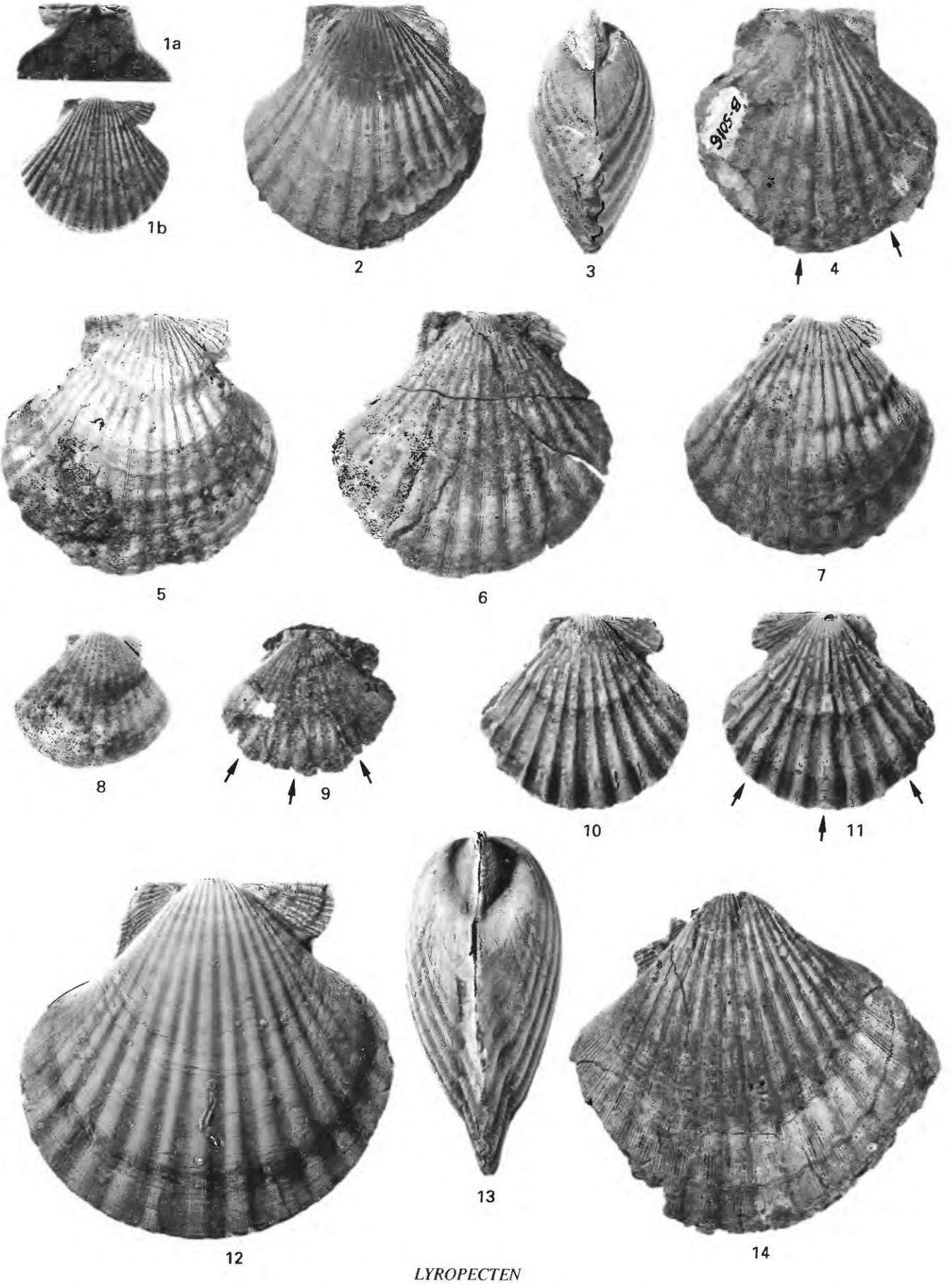
9. Juvenile LV, hypotype USNM 335001. Miocene, Vaqueros Formation, diorite breccia facies, southwest Santa Cruz Island, Calif. (loc. USGS M8022). Height 2.8 cm, length 3.4 cm. Arrows indicate key ribs.

12, 13. RV, posterior view, holotype UCMP 31737 of *Pecten* (*Lyropecten*) *miguelensis submiguelensis* Loel and Corey, 1932. Miocene, Vaqueros Formation, Santa Rosa Island, Calif. (loc. UCMP A-311). Height 6.9 cm, length 7.2 cm.

14. RV, hypotype UCSB M15 of *Pecten miguelensis* of Weaver and others, 1969. Miocene, Rincon Formation of Weaver and others, 1969, north coast of Santa Rosa Island, Calif. (loc. UCSB SR67-53). Height 6.4 cm, length 7 cm (incomplete).

10, 11. *Lyropecten vaughani* (Arnold) (? = *L. pretiosus*) (p. 68).

RV, LV, holotype LSJU 9 of *Pecten* (*Lyropecten*) *vaughani* Arnold, 1906. Miocene, Ojai Valley, Ventura County, Calif. (exact locality unknown). Height 3.7 cm, length 4 cm. Outer shell layer removed. Arrows indicate key ribs.



LYROPECTEN

PLATE 27

Lyropecten phylogeny: *L. catalinae, L. gallegosi, L. cerrosensis*

[Specimens in figures 1-4, 7 coated for photographing]

FIGURES 1, 4. *Lyropecten gallegosi* (Jordan and Hertlein) (p. 58).

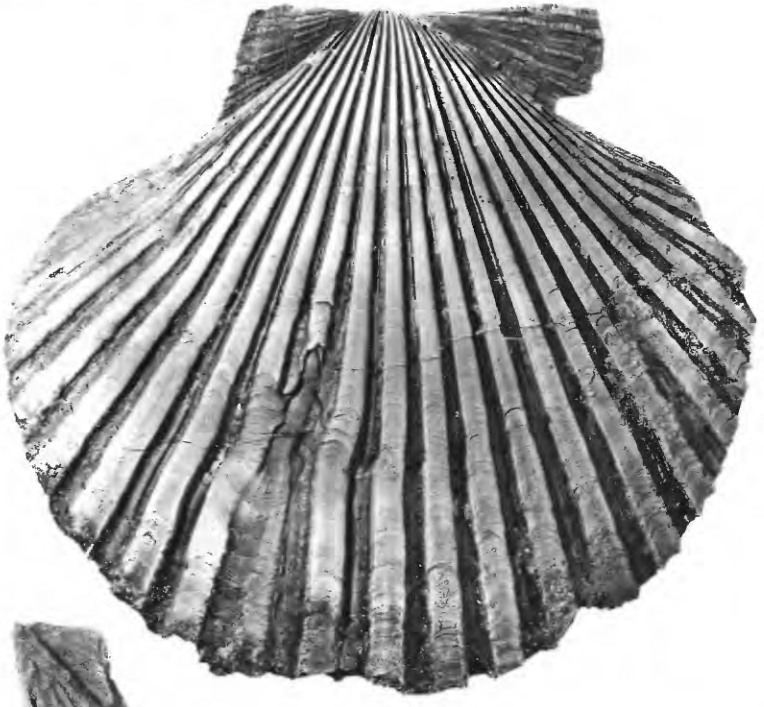
1. RV, holotype CAS 2096, of *Pecten* (*Lyropecten*) *gallegosi* Jordan and Hertlein, 1926. Late Miocene or reworked early Pliocene. Cedros Island, Baja California Sur, Mexico (loc. CAS 946). Height 12.5 cm, length 13.8 cm.
4. Ventral view, paratype CAS 2097, showing regular rectangular ribbing and coarse radial riblets in interspaces. Miocene or reworked early Pliocene. Cedros Island, western Baja California Sur, Mexico (loc. CAS 946). Specimen shown x1.

2, 3, 7. *Lyropecten catalinae* (Arnold) (p. 48).

2. RV, holotype LSJU 30 of *Pecten* (*Lyropecten*) *estrellanus* Conrad var. *catalinae* Arnold, 1906. Miocene, Santa Catalina Island, Calif. Height 7.6 cm, length 7.4 cm.
3. LV fragment, hypotype UCMP 37384, showing marginal radial striae characteristic of the species. Miocene, Santa Catalina Island, Calif. (loc. UCMP D-8793).
7. *Lyropecten catalinae* (Arnold) (p. 48).
   RV, hypotype UCMP 37385. Miocene, Santa Catalina Island, Calif. (loc. UCMP D-8793). Hinge length 5.6 cm. Fragment shows marginal striae on posterior slope and auricular macrosculpture.

5, 6. *Lyropecten cerrosensis* (Gabb) (p. 49).

5. RV, hypotype UCMP 36469 of Durham and Addicott, 1965. Late Miocene or early Pliocene. Pancho Rico Formation, Salinas Valley near San Lucas, Calif. (loc. UCMP A-911). Height 11.2 cm, length 12.3 cm.
6. RV, holotype UCMP 32669 of *Pecten cerrosensis* Gabb, 1866. Pliocene, Cedros Island, western Baja California Sur, Mexico. Height 21 cm, length 22.6 cm.



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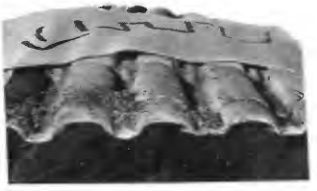

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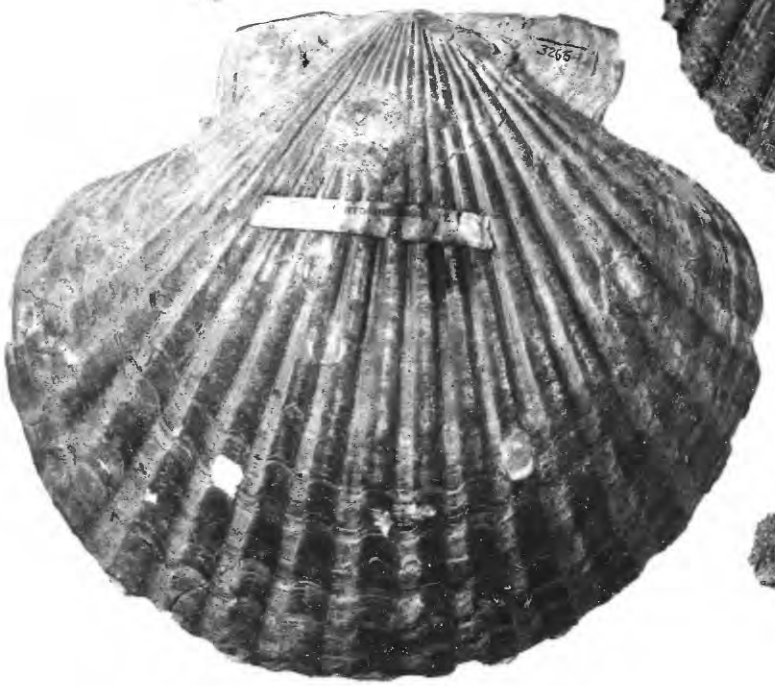

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LYROPECTEN

PLATE 28

Lyropecten phylogeny: *L. catalinae*, *L. gallegosi*, *L. cerrosensis* (left valves)

[All except for figure 1 coated for photographing. Arrows point to slightly raised key ribs]

FIGURES 1, 6. *Lyropecten catalinae* (Arnold) (p. 48).

1. LV, hypotype UCMP 16098. Miocene, Modelo Formation, north of the Santa Susana Mountains, Mint Canyon 7½-minute quadrangle (loc. UCMP D-8261). Height 5 cm, length 5.6 cm (incomplete).
6. LV, hypotype UCMP 37386. Miocene, Santa Catalina Island, from saddle between Mt. Banning and Mt. Orizaba (loc. UCMP D-8793). Height 10.5 cm, length 11 cm.

2-4. *Lyropecten cerrosensis* (Gabb) (p. 49).

2. LV, holotype UCMP 12082 of *Pecten* (*Lyropecten*) *ashleyi* Arnold, 1906. Early Pliocene. Cedros Island, western Baja California Sur, Mexico. Hinge length 8.5 cm. Arrows indicate slightly raised key ribs in the central and fourth positions in young stages of the left valve. Beaks meet at the hinge line; they do not project above it.
3. LV, hypotype UCMP 37388. Pliocene, Cedros Island, western Baja California Sur, Mexico (loc. UCMP D-8795). Height 5.3 cm, length 7.6 cm (incomplete). Arrows indicate slightly raised key ribs.
4. LV, hypotype LACMIP 4505 of *Chlamys* (*Lyropecten*) *cerrosensis* Gabb of Hertlein and Grant, 1972. Pliocene, San Diego Formation, near Palm City, Calif. (loc. LACMIP 305-C). Height 14.5 cm, length 15.6 cm. Specimen shows well-preserved radial macrosculpture, barely discernible key ribs.

5. *Lyropecten gallegosi* (Jordan and Hertlein) (p. 58).

LV, hypotype UCMP 16107. Late Miocene. Near Turtle Bay, Baja California Sur, Mexico (loc. UCMP B-3059). Height 14.1 cm, length 14.3 cm. Good example of well-preserved macrosculpture, rectangular ribs, and slightly developed key ribs (arrows).

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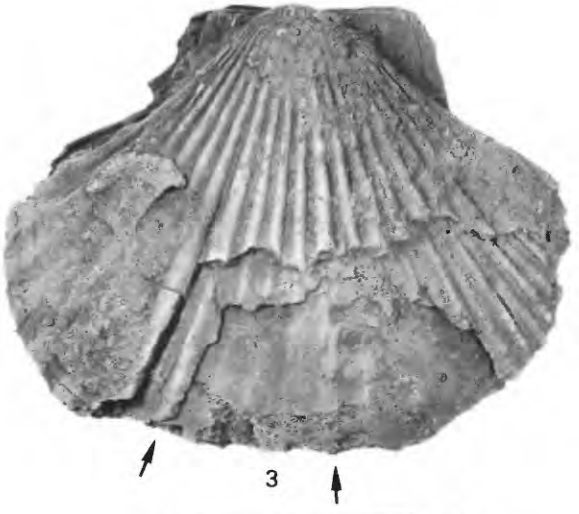

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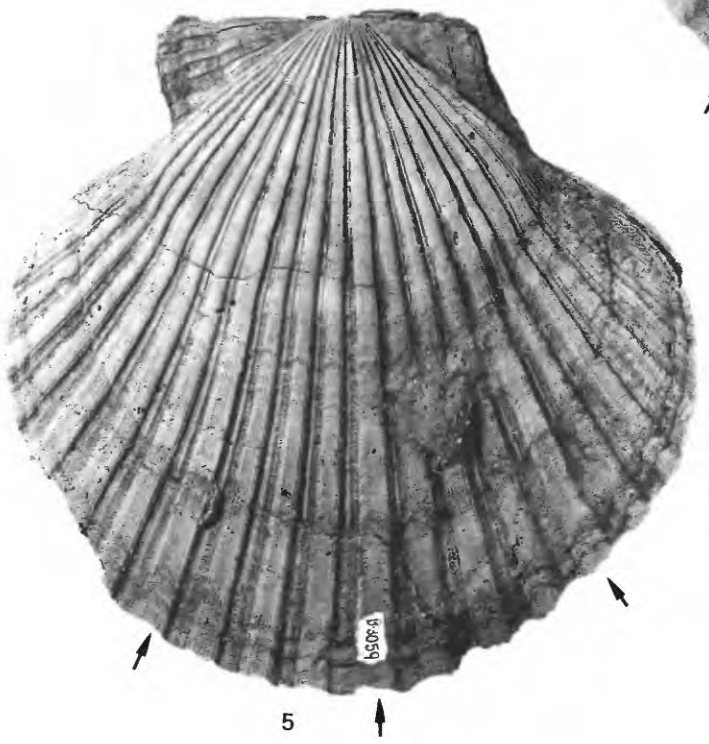

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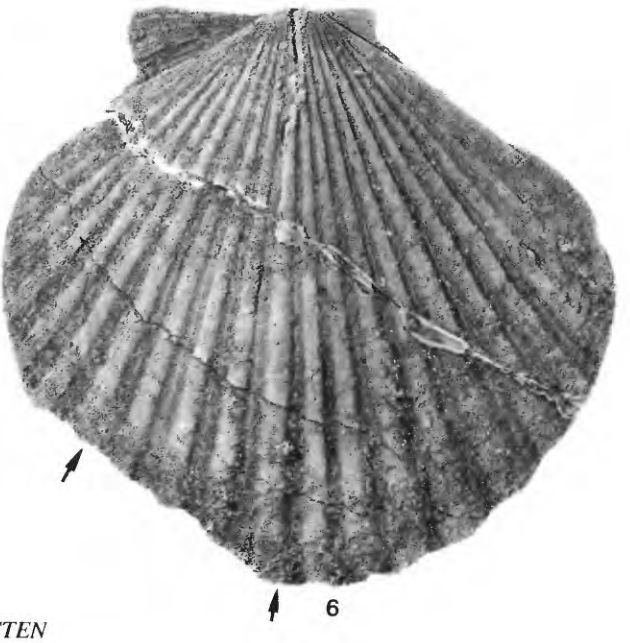

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LYROPECTEN

PLATE 29

"Macrochlamis" magnolia subspecies, index fossils of the lower and middle "Vaqueros" Stage

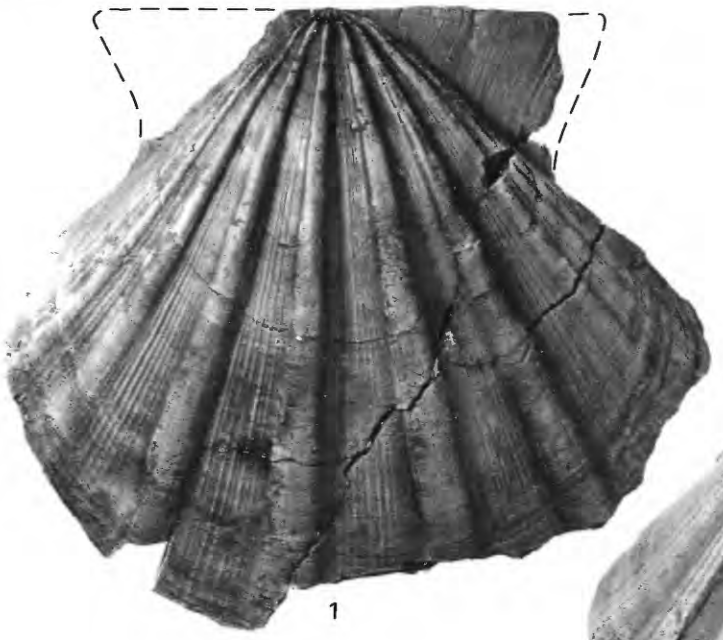
[All specimens coated for photographing]

FIGURES 1, 2. *"Macrochlamis" magnolia ojaiensis*, n. subsp. (p. 74).

1. LV, hypotype UCR 1185/6 of *Macrochlamis magnolia* (Conrad) of Addicott, 1974. Miocene, Jewett Sand, from Pyramid Hill area, Kern Co., Calif. Height 10.8 cm, (incomplete), length 14 cm.
2. RV, hypotype UCMP 31734 of *Pecten (Lyropecten) magnolia* Conrad of Loel and Corey, 1932. Oligocene, Vaqueros Formation, from San Antonio Creek Canyon, southwest of Ojai, Calif. (loc. UCMP A-326). Height 9.7 cm, (incomplete), length 10.9 cm.

3, 4. *"Macrochlamis" magnolia magnolia* (Conrad) (p. 72).

3. LV, hypotype USNM 647534. Oligocene or Miocene, Vaqueros Formation, Caliente Range, Calif. (loc. USGS M3520). Height 14.5 cm, length 17 cm, hinge 12.5 cm.
4. RV, hypotype USNM 335003. Oligocene or Miocene, Vaqueros Formation, Caliente Range, Calif. (loc. USGS M3520). Height 19.5 cm, length 19.6 cm.



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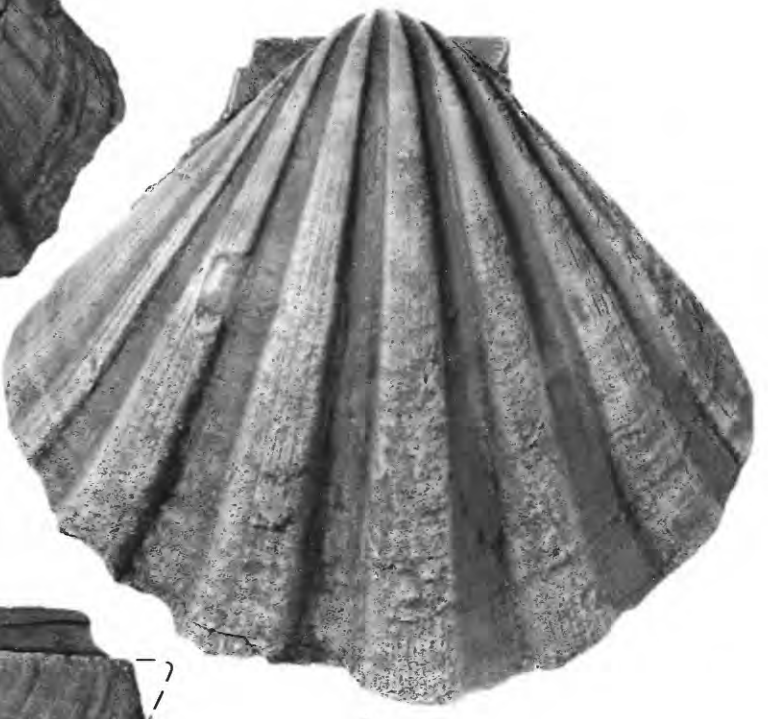

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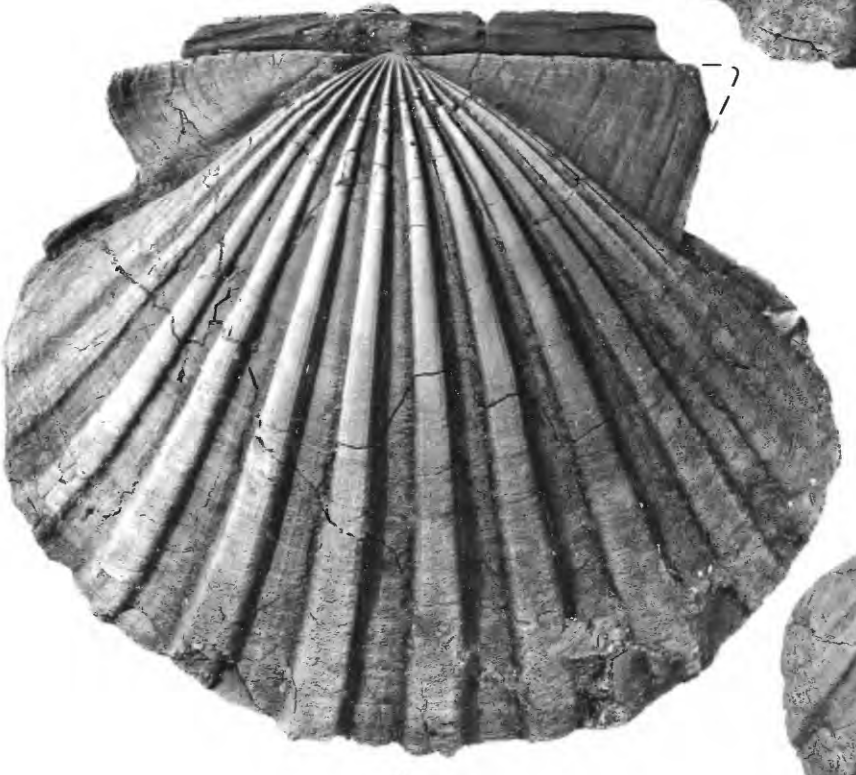

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4

"MACROCHLAMIS"

PLATE 30

Macrochlamis and "*Macrochlamis*" right valves

[All specimens coated for photographing]

FIGURES 1, 2. *Macrochlamis terebratulaeformis* (de Serres) (p. 75).

1. RV, hypotype MCZ 18106. "Falunien de Sainte-Croix," Auberson Valley, Switzerland. Height 13.7 cm, length 15.5 cm (incomplete).
2. RV, hypotype MCZ 18104. "Falunien de Sainte-Croix," Auberson Valley, Switzerland. Height 12 cm (incomplete), length 10 cm (incomplete).

3. "*Macrochlamis*" *magnolia ojaiensis*, n. subsp. (p. 74).
RV, paratype UCMP 37383 (formerly LSJU accession no. 22363). Oligocene, Vaqueros Formation, from the east end of Ojai Valley, Ventura County, Calif. (loc. UCMP D-8792 = USGS M8012). Height 13 cm, length 14.7 cm.

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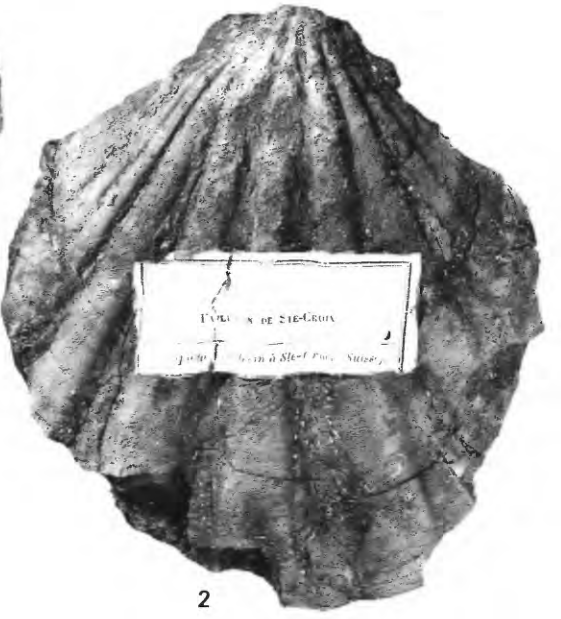

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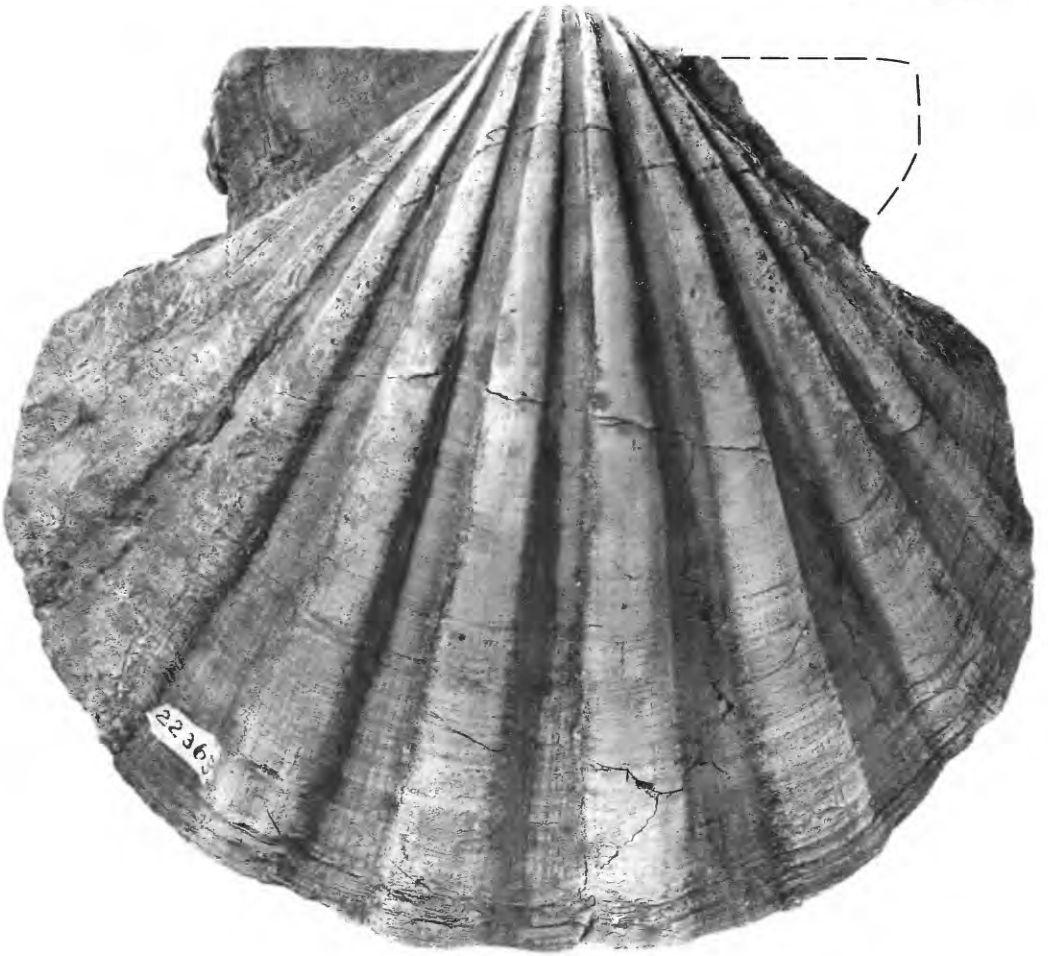

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MACROCHLAMIS, "MACROCHLAMIS"

PLATE 31

"Macrochlamis" and *Macrochlamis* left valves

[All specimens coated for photographing]

FIGURES 1, 5. *"Macrochlamis" magnolia magnolia* (Conrad) (p. 72).
LV, hypotype UCMP 37387. Oligocene, Vaqueros Formation, Santa Ynez Mountains, Calif. (loc. UCMP D-8794 = Hawley loc. 46). Height 11.3 cm (incomplete), length 9 cm (incomplete). Specimen shows the RV beak projecting above the hinge line; adult macrosculpture is unusually well preserved.

2, 6. *"Macrochlamis" magnolia ojaiensis*, n. subsp. (p. 74).

2. LV, hypotype UCLA 59265. Oligocene, Vaqueros Formation, eastern Ojai Valley, Calif. (loc. UCLA 1311). Height of whole specimen, 12 cm, length 14 cm. Umbonal area is partly concave; outer shell layer removed.
6. LV, holotype USNM 335004 (formerly LSJU accession no. 22366). Oligocene, Vaqueros Formation, from the eastern Ojai Valley, Calif. (loc. USGS M8012). Height 13.2 cm, length 14.5 cm. Outer shell layer has been removed, but relict macrosculpture remains.

3. ?*"Macrochlamis" magnolia ojaiensis*, n. subsp. (p. 74).
Juvenile LV, holotype UCMP 11417 of *Pecten* (*Lyropecten*) *vaughani emigdioensis* Wagner and Schilling, 1923. Oligocene, San Emigdio Mountains, Calif. (loc. UCMP 3234). Height 2.1 cm, length 2.3 cm.

4. *Macrochlamis terebratulaeformis* (de Serres) (p. 75).
LV, hypotype MCZ 18106. "Falunien de Sainte-Croix," Auberson Valley, Switzerland. Height 13.7 cm (incomplete), length 15.5 cm (incomplete). Umbonal area is concave but also worn.

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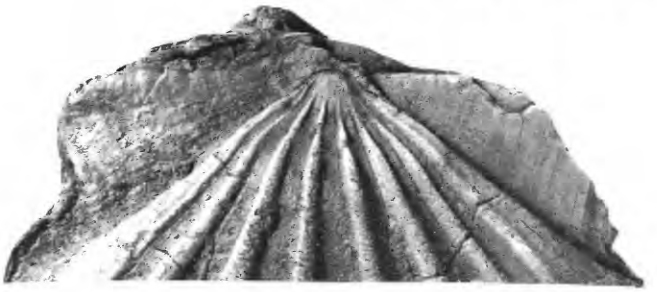

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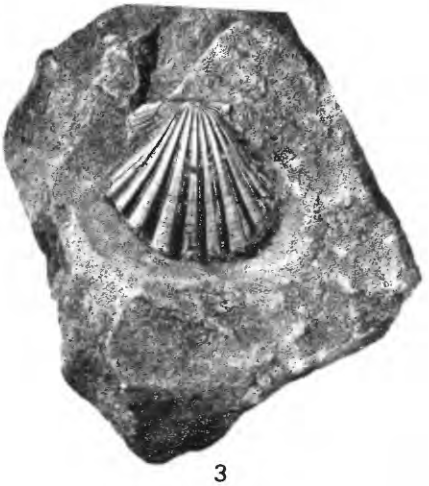

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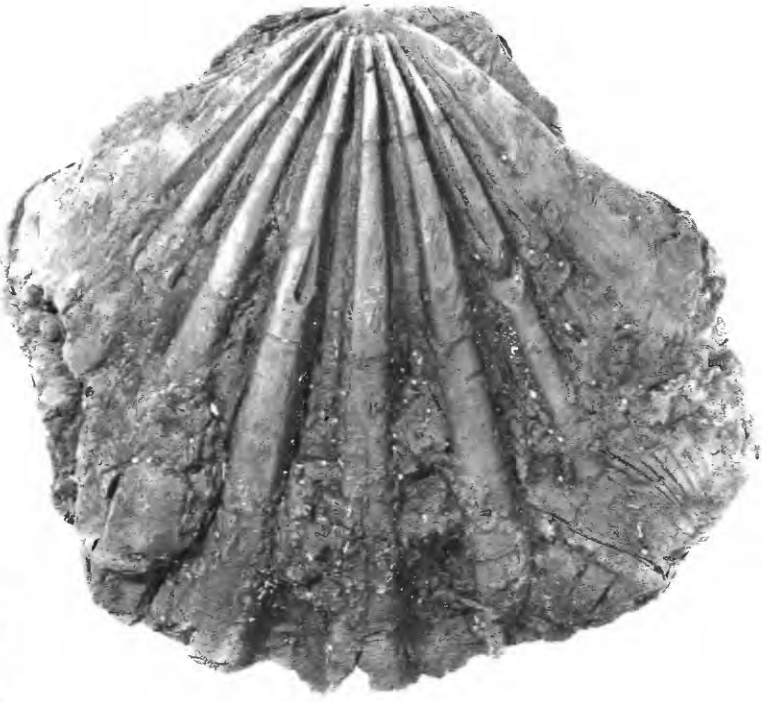

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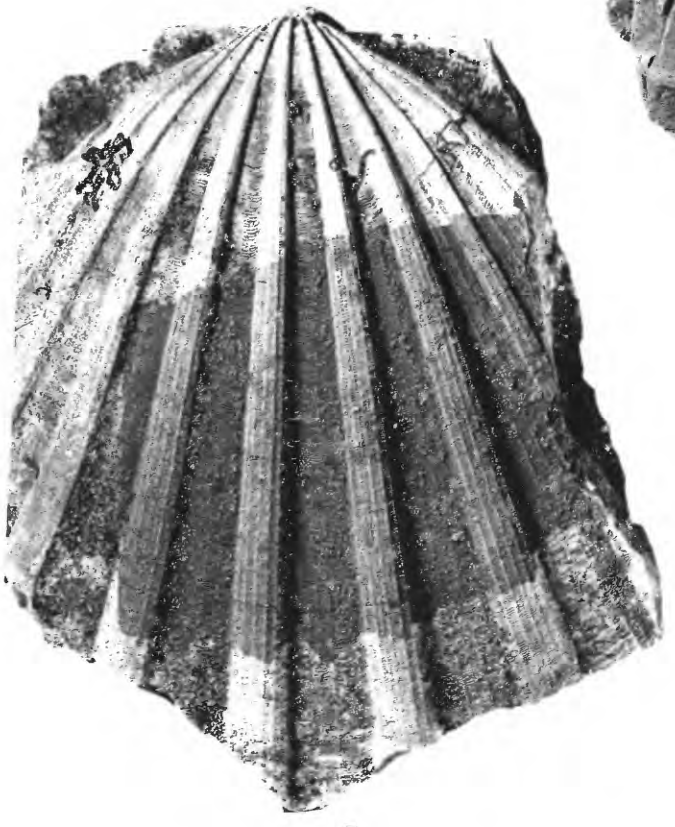

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MACROCHLAMIS, "MACROCHLAMIS"

PLATE 32

Vertipecten phylogeny

[Oldest to youngest, top to bottom. Specimens in figures 1, 3, and 5 coated for photographing]

FIGURES 1. *Vertipecten yneziana* (Arnold) (p. 85).
LV, hypotype LSJU 9262 of *Pecten* (*Vertipecten*) *yneziana yneziana* of Weaver and Kleinpell, 1963. Eocene, Gaviota Formation of Dibblee (1950), middle member, from the Santa Ynez Mountains above junction of Nojoqui Creek and Gaviota Canyon (loc. UCMP B-6985 = LSJU 2908a). Height 9.7 cm, length 9.8 cm (incomplete).

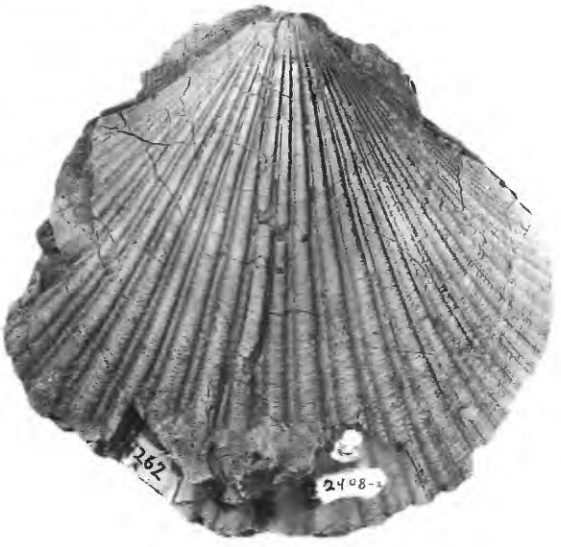
2. *Vertipecten perrini* (Arnold) (p. 84).
LV, holotype LSJU 13 of *Pecten* (*Lyropecten*) *perrini* Arnold, 1906. Oligocene, Vaqueros Formation, southern Santa Lucia Range, between Morro and Toro Creeks, San Luis Obispo Co., Calif. Height 15 cm, length 16 cm. The individual was injured as a young adult; ribs are offset in the repaired shell.

3. *Vertipecten kernensis* (Hertlein) (= *V. nevadanus* auctt.) (p. 81).
LV, hypotype LACMIP 5874. Miocene, Jewett Sand, near Pyramid Hill, Kern Co., Calif. (loc. LACMIP 462). Height 8.7 cm, length 8.1 cm. A fairly advanced evolutionary form with two well-developed key ribs (arrows).

4, 5. *Vertipecten bowersi* (Arnold) (p. 77).

4. LV, holotype UCMP 12075 of *Pecten* (*Lyropecten*) *bowersi* Arnold, 1906. Miocene, Vaqueros Formation, north flank of Santa Ynez Mountains, Santa Barbara County, Calif. Height 15 cm, length 14.7 cm. Arrows indicate key ribs.

5. LV, hypotype USNM 335951. Miocene, Saltos Shale Member, Monterey Shale, basal part, Caliente Range, Calif. (loc. USGS M3436). Height 13.3 cm, length 13.1 cm. Arrows indicate well-developed key ribs.



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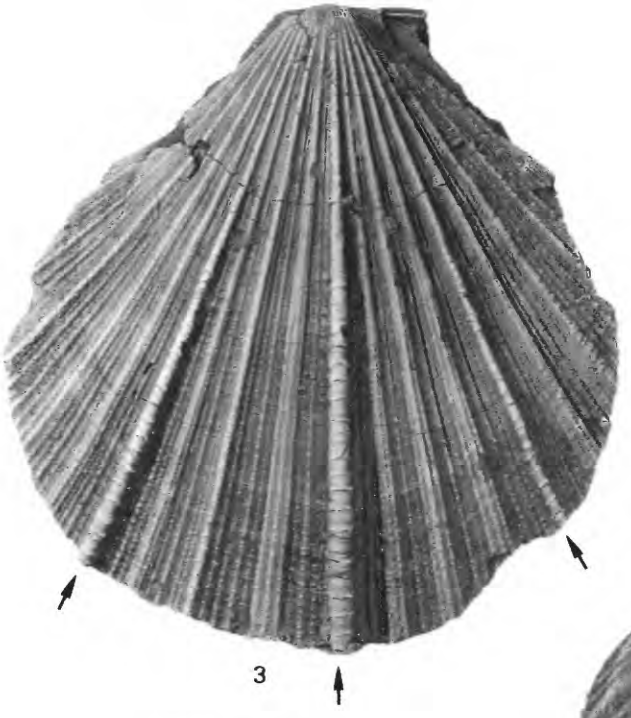

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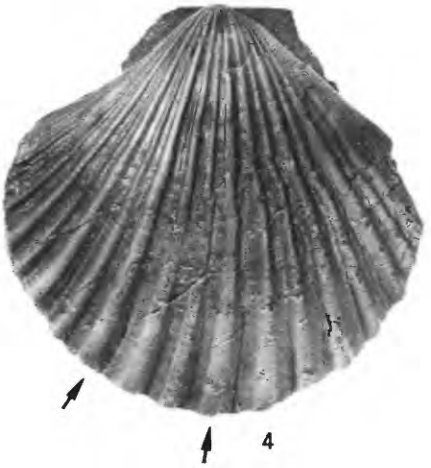

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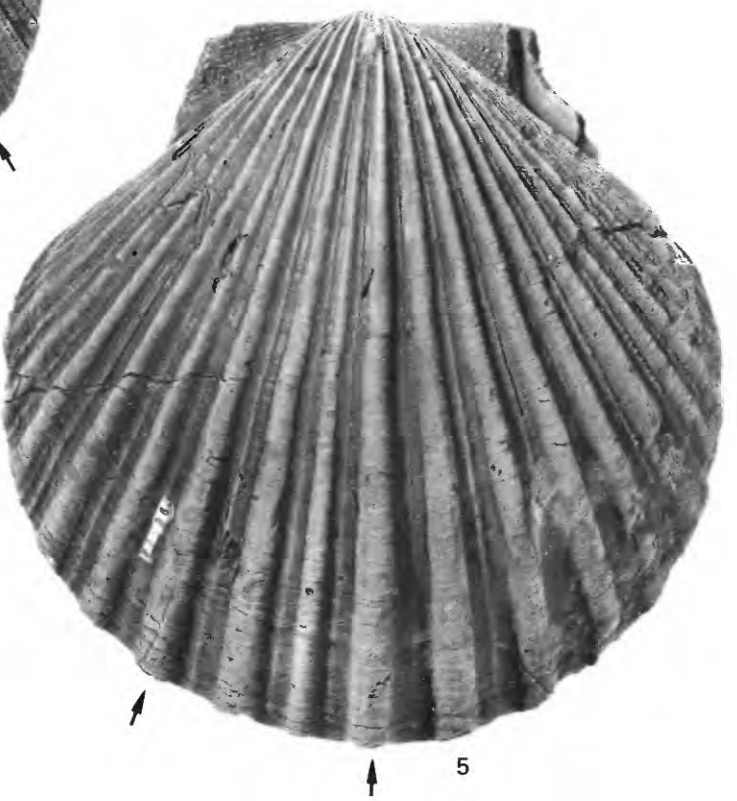

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VERTIPECTEN

PLATE 33

Vertipecten bioseries

[Specimens coated for photographing except for figure 6]

FIGURES 1, 5, 6. *Vertipecten kernensis* (Hertlein) (= *V. nevadanus* auctt.) (p. 81).

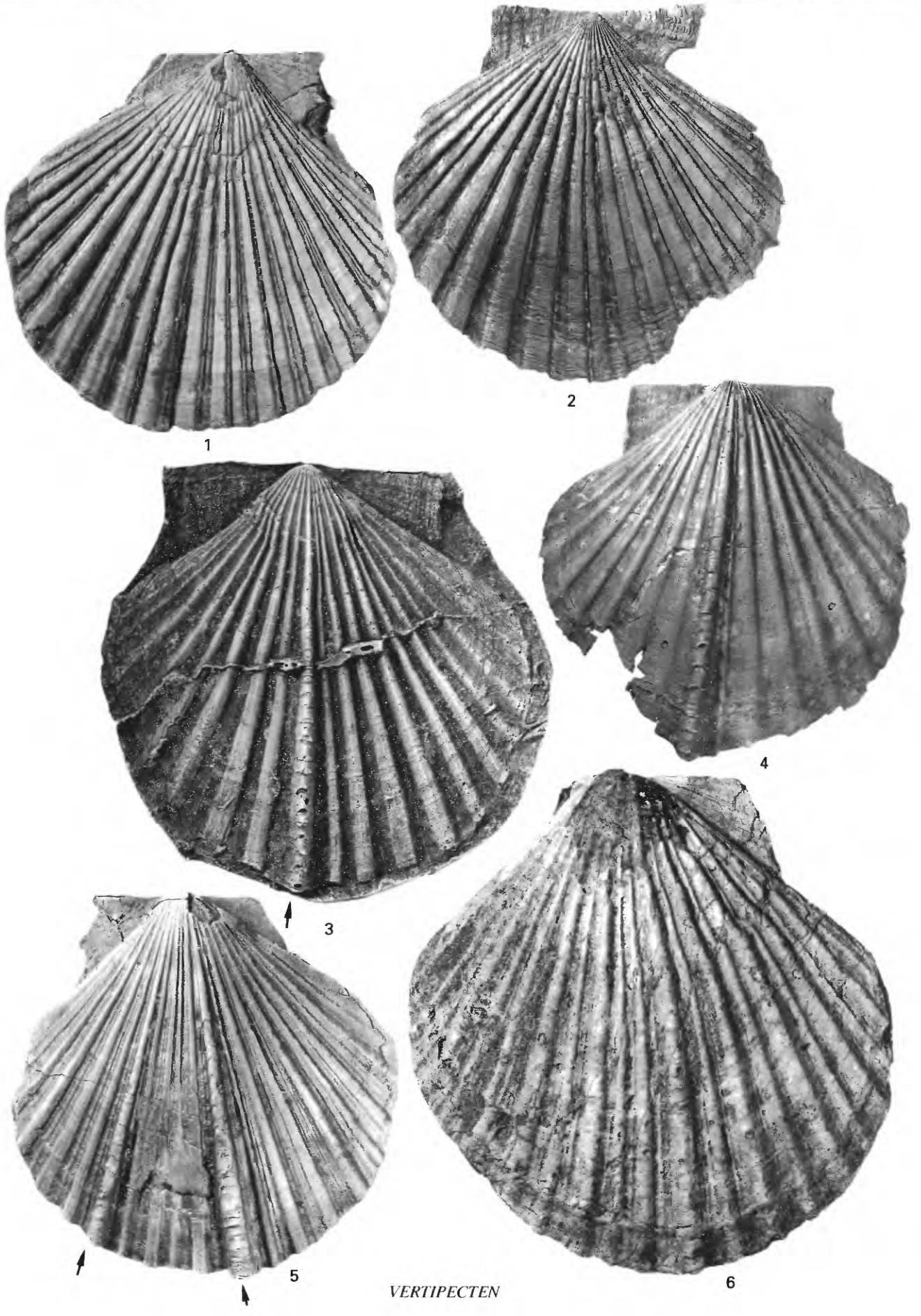
1, 5. RV, LV, hypotype UCMP 36554 of *Vertipecten nevadanus* (Conrad) of Addicott, 1965. Miocene, Freeman Silt and Jewett Sand, undivided, Coffee Canyon area, Pine Mountain 7½-minute quadrangle, Kern Co., Calif. (loc. UCMP B-1673). From 40 ft stratigraphically above the "Grit Zone," this young adult specimen is an advanced evolutionary form with two prominent key ribs (arrows) and well-preserved metal-lathe microsculpture in the interspaces. It is morphologically transitional between *V. kernensis* and *V. fucanus* (figs. 2, 4). Height 7.5 cm, length 7.3 cm.

6. LV, hypotype CAS 60986. Late Oligocene or early Miocene. Vaqueros Formation, type locality, Vaqueros Canyon, Monterey County, Calif. (loc. CAS 31524). Height 10.4 cm, length 10 cm.

2-4. *Vertipecten fucanus* (Dall) (p. 80).

2, 4. RV, LV, hypotype CAS 60984. Miocene, Olcese Sand, Kern Co., Calif. (loc. CAS 1452). Height 11.4 cm, length 11.6 cm.

3. LV, plastoholotype UCMP 14525 of holotype USNM 107790 of *Pecten fucanus* Dall, 1889. Miocene, Clallam Bay, Wash. Height 8.4 cm, length 8.9 cm. Arrow indicates key rib. Cast by John Miller, U.S. Geological Survey.



VERTIPECTEN

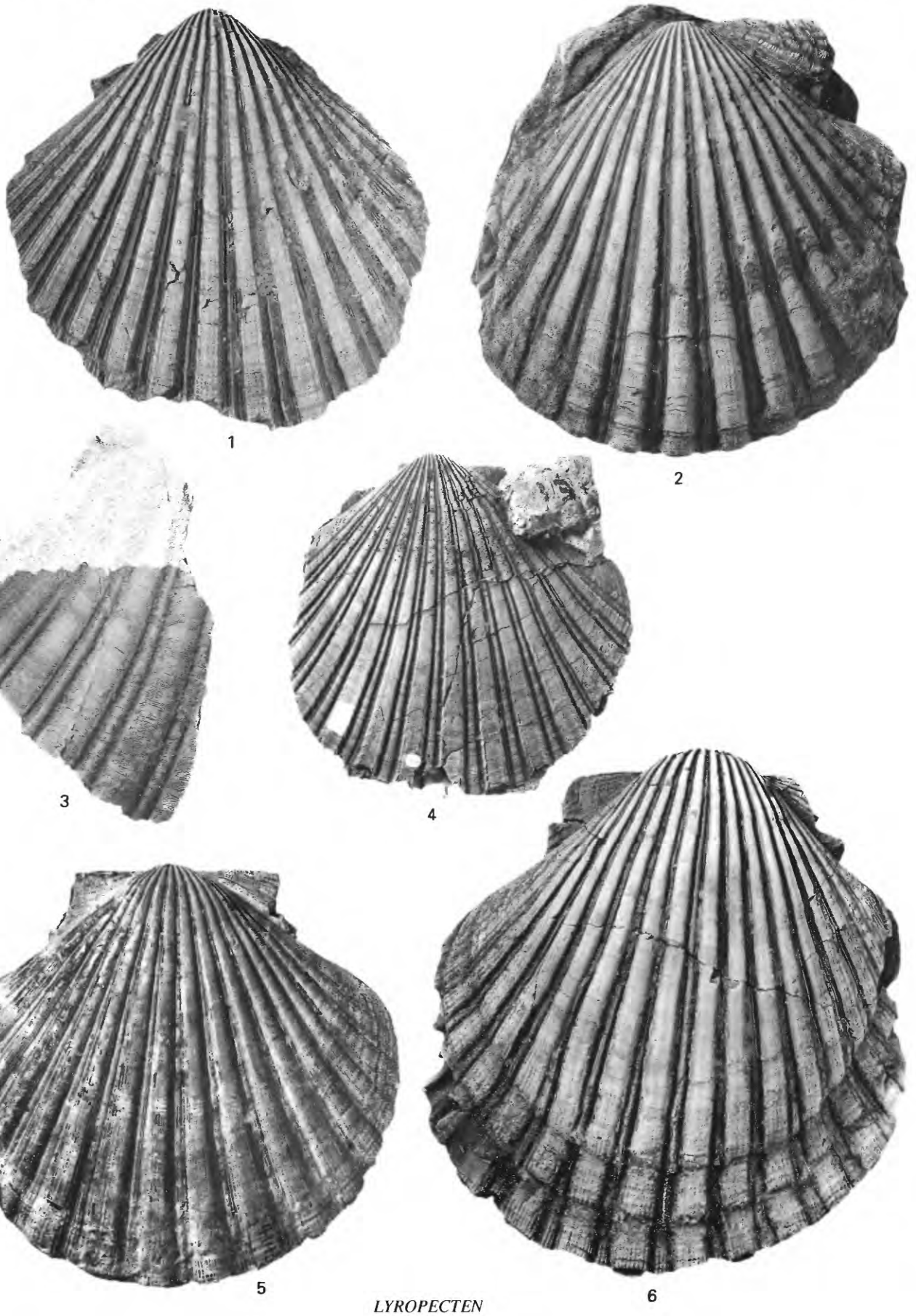
PLATE 34

Lyropecten miguelensis (Arnold), intraspecific variation of an index species of the upper "Vaqueros" Stage

[Except for figure 5, all specimens coated for photographing]

FIGURES 1-6. *Lyropecten miguelensis* (Arnold) (p. 61).

1. RV, hypotype USNM 335952. Miocene, Branch Canyon Sandstone, lower member, from Fox Mountain 7½-minute Quadrangle, Calif. (loc. USGS M2424). Height 11 cm (incomplete), length 10.7 cm (incomplete). Specimen has finer riblets than the holotype and incised radial striae.
2. RV, hypotype UCSB 4675. Miocene, Rincon Formation of Weaver and others (1969), along beach west of East Point, southeastern Santa Rosa Island, Calif. (loc. UCSB SR67-28). Height 8.3 cm, length 8.4 cm.
3. RV, posterior fragment, hypotype UCSB 1844. Miocene, Vaqueros Formation, from southwestern Santa Cruz Island, Calif. Fragment is 6.5 cm across, has "supervariant" macrosculpture.
4. LV, hypotype UCSB M16 of *Pecten miguelensis* (supervariant) Arnold of Weaver and others, 1969. Miocene, Vaqueros Formation, sandstone facies, from north of Kinton Point, Santa Cruz Island, Calif. (loc. UCSB E-8). Height 12.7 cm, length 14.4 cm (incomplete). Typical "supervariant" form, with broad rectangular ribs and coarse midriblets.
5. RV, hypotype CAS 4143 of *Pecten* (*Lyropecten*) *miguelensis* Arnold of Hertlein, 1928b. Miocene, Vaqueros Formation, Santa Rosa Island, Calif. (loc. CAS 1156). Height 13.8 cm, length 14.6 cm. Best known specimen of an undeformed adult shell (cf. holotype, fig. 6).
6. RV, holotype UCMP 12079 of *Pecten* (*Lyropecten*) *miguelensis* Arnold, 1906. Miocene, San Miguel Island, Calif. Height 11 cm, length 11 cm. Specimen slightly compressed from anterior and posterior ends.



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LYROPECTEN

PLATE 35

Index species of the upper "Vaqueros" Stage

[All specimens coated for photographing]

FIGURES 1, 5, 6. *Lyropecten miguelensis* (Arnold) (p. 61).

1, 6. Posterior view, LV, holotype UCMP 12079 of *Pecten* (*Lyropecten*) *miguelensis* Arnold, 1906. Miocene, San Miguel Island, Calif. Height 11 cm, length 11 cm. Specimen is slightly compressed.

5. LV, hypotype UCSB 1912. Miocene, Vaqueros Formation, sandstone member, southwestern Santa Cruz Island, Calif. (loc. UCSB E-5). Height 7.5 cm, length 7.5 cm. Specimen is the "supervariant form," having broad, flat ribs and a single thick interriblet.

2, 3, 4. *Vertipecten bowersi* (Arnold) (p. 77).

Posterior view, RV, ventral view of hypotype USNM 335951. Miocene, Monterey Shale, Saltos Shale Member, from the Caliente Range, Salisbury Canyon 15-minute Quadrangle, Calif. (loc. USGS M3436). Height 13 cm, length 12.5 cm.

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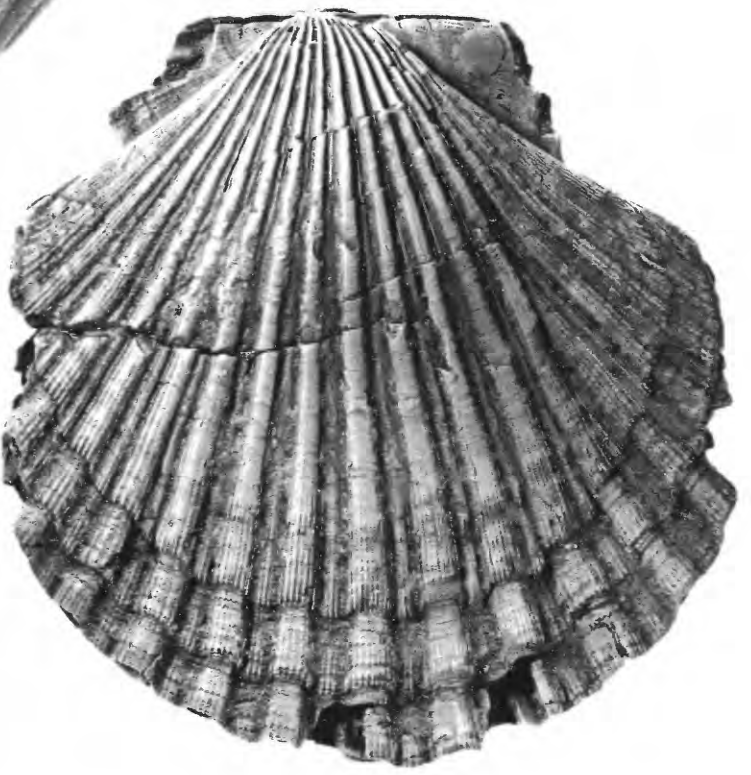

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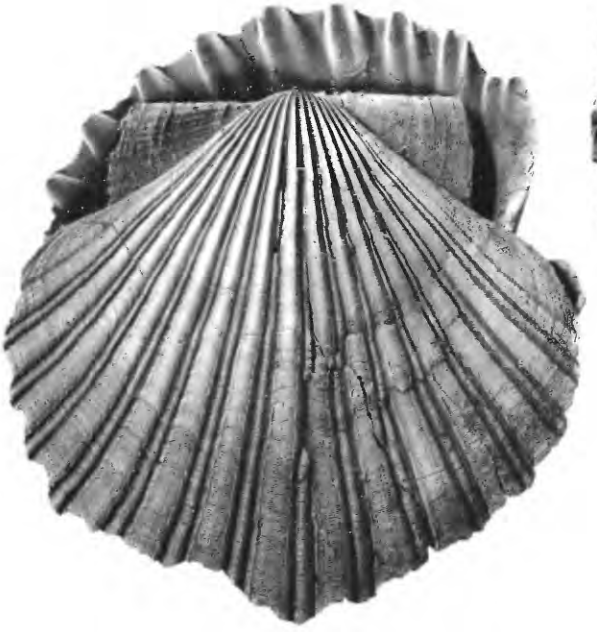

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LYROPECTEN, VERTIPECTEN

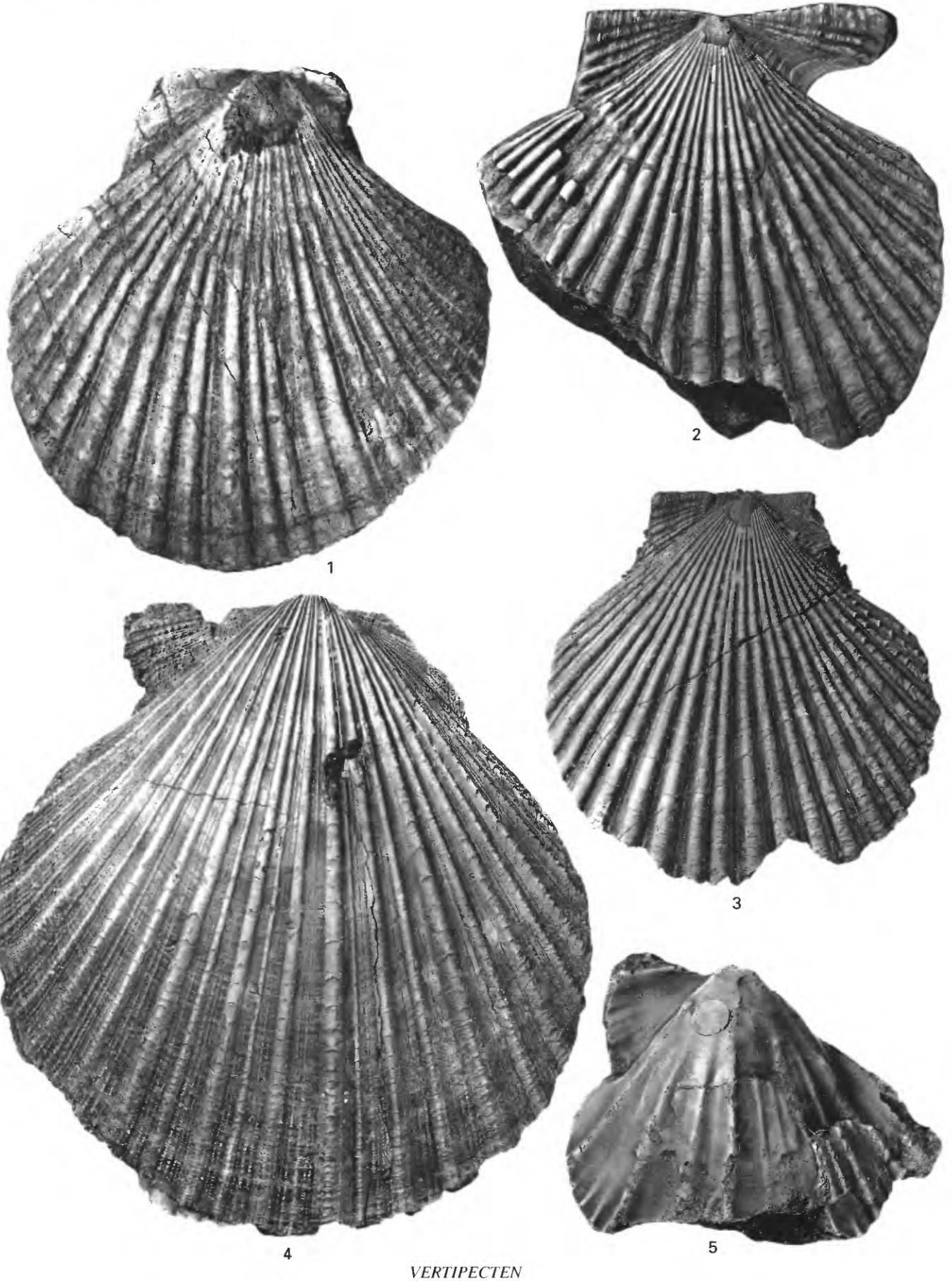
PLATE 36

Vertipecten kernensis (= *V. nevadanus* auctt.), index species of the middle "Vaqueros" Stage

[Except for figure 1, all specimens coated for photographing]

FIGURES 1-5. *Vertipecten kernensis* (Hertlein) (p. 81).

1. RV, hypotype CAS 60986. Late Oligocene or early Miocene. Vaqueros Formation, member E, type locality, Vaqueros Canyon, Monterey County, Calif. (loc. CAS 31524, collected by R. Thorup, 1941). Height 10.4 cm, length 10 cm.
2. RV, holotype LSJU 128 of *Pecten* (*Patinopecten*) *kernensis* Hertlein, 1925a. Miocene, Freeman Silt and Jewett Sand, undivided, from Pyramid Hill, Kern County, Calif. (loc. LSJU 150). Height 9.3 cm, length 9.3 cm (incomplete). Specimen shown without matrix.
3. RV, hypotype LACMIP 5873. Miocene, Jewett Sand, from Pyramid Hill, Kern County, Calif. (loc. LACMIP 462). Height 7.5 cm, length 7.4 cm. Young adult specimen with well preserved anterior macrosculpture.
4. LV, hypotype USNM 647085 of *Vertipecten perrini* (Arnold) of Addicott, 1974. Miocene, Pyramid Hill Sand Member, Jewett Sand, Kern River area northeast of Bakersfield, Calif. (loc. USGS M5211). Height 12.3 cm, length 12.2 cm.
5. LV, holotype UCMP 11138 of *Pecten* (*Lyropecten*) *gabbi* Clark, 1918 and of *Pecten diabloensis* Clark in Hanna, 1924. Miocene, San Lorenzo Series of Clark (1918), Mount Diablo Range, Contra Costa County, Calif. (loc. UCMP 1311). Height 5.5 cm. Most of outer shell is missing.



VERTIPECTEN

PLATE 37

Index species of the lower "Vaqueros" Stage

[Specimens in figures 3, 5, and 6 coated for photographing]

FIGURES 1, 5, 6. *Vertipecten perrini* (Arnold) (p. 84).

1. LV, hypotype UCLA 38065. Oligocene, Vaqueros Formation, between Smith and Toro Creeks, Morro Bay North 7½-minute Quadrangle, Calif. (loc. UCLA 6205). Height 9.5 cm, length 8.6 cm (incomplete). Outer shell layer removed. Photograph courtesy of Scott Prior.

5, 6. RV, posterior view, holotype LSJU 13 of *Pecten* (*Lyropecten*) *perrini* Arnold, 1906. Oligocene, Vaqueros Formation, between Morro and Toro Creeks, Cayucos 7½-minute Quadrangles, Calif. Height 15 cm, length 16 cm.

2, 4. *"Macrochlamis" magnolia magnolia* (Conrad) (p. 72).

2. LV, hypotype UCLA 59264. Oligocene, Vaqueros Formation, Morro Bay North 7½-minute Quadrangle, Calif. (loc. UCLA 6203). Photograph courtesy of Scott Prior.

4. LV, hypotype CAS 61039. Oligocene, Vaqueros Formation, western Santa Ana Mountains, Calif. (loc. LSJU SGS 1949, 131-3A). Height 13.2 cm, length 14.6 cm. Photograph courtesy of George Moore, U.S. Geological Survey.

3. *Lyropecten pretiosus* (Hertlein) [= *L. submiguelensis* Loel and Corey] (p. 64).
LV, holotype UCMP 31737 of *Pecten* (*Lyropecten*) *miguelensis* var. *submiguelensis* Loel and Corey, 1932. Early Miocene. Vaqueros Formation, near crest of Santa Rosa Island, Calif. (loc. UCMP A-311). Height 6.9 cm, length 7.2 cm. An upper lower to middle "Vaqueros" stage index fossil.

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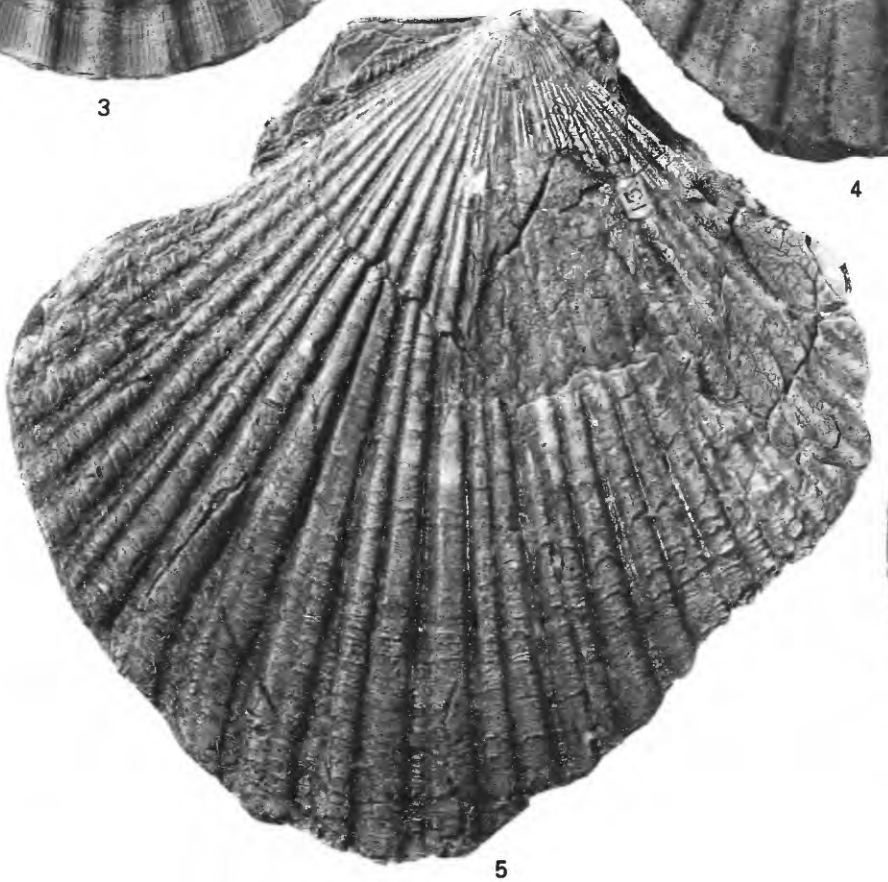

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VERTIPECTEN, "MACROCHLAMIS", LYROPECTEN

PLATE 38

Eocene and Oligocene Vertipectens

[Specimens except for figure 6 coated for photographing]

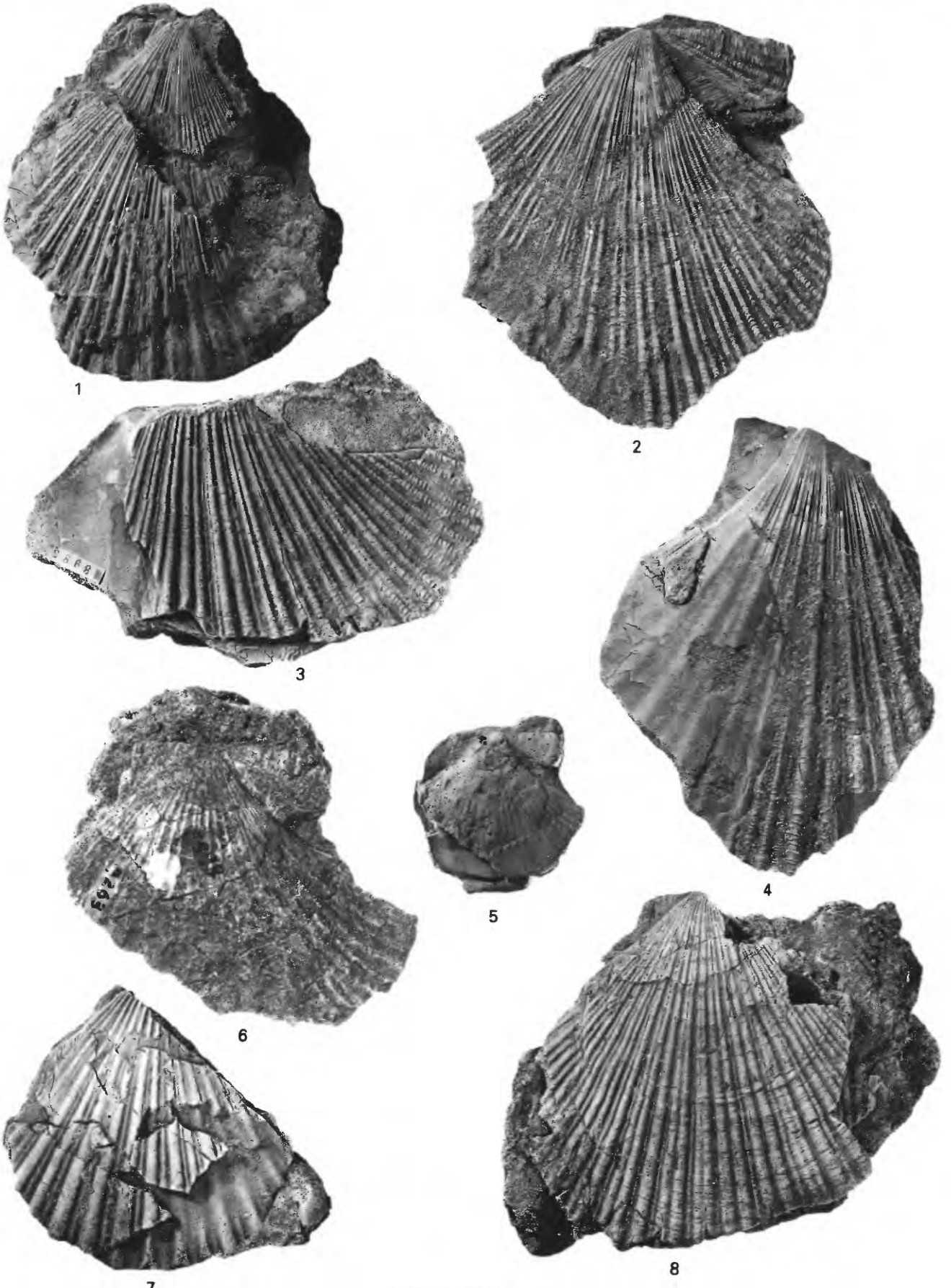
FIGURES 1-4. *Vertipecten alexclarki* Addicott (p. 77).

1. RV, lectotype USNM 646531. Oligocene. Temblor Formation, Wygal Sandstone Member. Central Temblor Range, Kern County, Calif. (loc. USGS M3281). Height 6.9 cm, length 6.6 cm.
2. RV, hypotype CAS 60862. Oligocene. Temblor Formation, Wygal Sandstone Member. Carneros Canyon, Temblor Range, Calif. (loc. CAS 27625). Height 7.5 cm (incomplete), length 6.8 cm (incomplete).
3. RV fragment, hypotype USNM 646539. Oligocene. Temblor Formation, Wygal Sandstone Member. Central Temblor Range, Calif. (loc. USGS M3985). Length 6.6 cm. Fragment has well preserved fine, scaly macrosculpture.
4. LV, hypotype USNM 646529. Oligocene. Temblor Formation, Wygal Sandstone Member. Central Temblor Range, Calif. (loc. USGS M3772). Height 8.2 cm, length 6.3 cm.

5. *Pecten yneziana subyneziana* Weaver and Kleinpell (p. 86).
   RV, internal mold, cast of holotype LSJU 9265. Eocene, "Coldwater" Sandstone of Weaver and Kleinpell (1963). San Rafael Mountain, Calif. (loc. UCMP B-6940). Height 3.1 cm, length 3.2 cm.

6-8. *Vertipecten yneziana* (Arnold) (p. 85).

6. RV, hypotype LSJU 9263 of *Pecten* (*Vertipecten*) *yneziana yneziana* Arnold of Weaver and Kleinpell, 1963. Eocene, Sacate and Gaviota Formations of Dibblee (1950). Nojoqui Creek, Santa Barbara County, Calif. (loc. UCMP B-6955). Height 5 cm, length 6.8 cm (incomplete).
7. LV fragment, paratype USNM 165313 of *Pecten* (*Chlamys*?) *yneziana* Arnold, 1907. Eocene, Gaviota Formation of Dibblee (1950). San Julian Ranch, Santa Ynez Mountains, Santa Barbara County, Calif. (loc. USGS 4507). Height of juvenile LV fragment, 5.2 cm.
8. RV, fragment, holotype USNM 165313 of *Pecten* (*Chlamys*?) *yneziana* Arnold, 1907. Eocene, Gaviota Formation of Dibblee (1950). San Julian Ranch, Santa Ynez Mountains, Santa Barbara County, Calif. (loc. USGS 4507). Height 6.4 cm.



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VERTIPECTEN

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