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NEW INFORMATION ON MOLLUSCAN PALEONTOLOGY AND DEPOSITIONAL ENVIRONMENTS OF THE UPPER PLIOCENE PICO FORMATION, VALENCIA AREA, LOS ANGELES COUNTY, SOUTHERN CALIFORNIA

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Natural History Museum
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New Information on Molluscan Paleontology and Depositional Environments of the Upper Pliocene Pico Formation, Valencia Area, Los Angeles County, Southern California

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ABSTRACT. The lower 304 m of the Pico Formation, in the Valencia area of Los Angeles County, Southern California, consist of muddy siltstone, with the upper part of the siltstone locally incised by vertically stacked sequences interpreted as delta-influenced channelized conglomerates in a prodelta (middle to upper bathyal) environment. The upper 152 m consist of a silty sandstone combination, interpreted as transition-zone deposits, grading vertically into sandstone containing hummocky cross stratification, amalgamated beds, and, in the lower part, a few storm beds rich in invertebrates, especially mollusks. The sandstone was deposited in the shoreface environment within a prograding (regressive) wave-dominated deltaic system. The shoreface sandstone interfingers with overlying braided-river deposits of the Pleistocene Saugus Formation.

Sixty-six species of marine invertebrates, mostly mollusks, were collected in the shoreface deposits and are indicative of normal marine salinities. Sixty-two species are found throughout central and Southern California and are indicative of warm-temperate conditions. Four species have only been previously found either in the southern part of Southern California and/or in Baja California, Mexico, where they are associated with subtropical paleoenvironments: the bivalves *Argopecten invalidus* (Hanna, 1924), *Lyropecten catalinae* (Arnold, 1906), and *Placunanomia hannibali* Jordan and Hertlein, 1926, and the gastropod *Acanthinucella emersoni* (Hertlein and Allison, 1959). In addition, the oyster *Myrakeena veatchii* (Gabb, 1866), which is an especially common component of warm-water fossil assemblages in Baja California, even though it can be found as far north as central California, is the most common mollusk in the Valencia area.

"*Ostrea*" *veatchii* is here reassigned to genus *Myrakeena* Harry, 1985. *Lyropecten gallegosi* Jordan and Hertlein, 1926, is here regarded as a junior synonym of *L. catalinae*.

The age of the Pico Formation in the Valencia area is late Pliocene, based on benthic foraminifera and mollusks.

INTRODUCTION

The Pico Formation in the Ventura Basin (Fig. 1) consists mainly of an extremely thick, approximately 5,500 m, deep-marine sequence containing abundant foraminifera and some megafossils. In the shallow-water interval, near the top of the formation exposed in the eastern part of the basin, megafossils are locally abundant, but foraminifera are scarce (Durham, 1954). Faunal lists were provided by Kew (1924) and Winterer and Durham (1962). Detailed work on the megafossils was done by Squires et al. (1977), Squires and White (1983), Groves and Squires (1988), and Groves (1991a, 1991b), but these studies concentrate in the area between Browns Canyon and Gillibrand Canyon, along the southern flank of the Santa Susana Mountains and approximately 13 km southwest of the Valencia area (Fig. 1).

This is the first detailed stratigraphic, megapaleontologic, and depositional-environmental study of the upper part of the Pico Formation exposed near Valencia (Fig. 1). Until a fire in October 2004, the outcrops were inaccessible for at least 50 years because of very dense brush. These strata represent the youngest marine deposits in the eastern Ventura Basin. During the middle Pleistocene, the region experienced considerable uplift, forming the Santa Susana Mountains (Levi and Yeats, 1983; Treiman and Saul, 1986).

We present here new morphologic, paleobiogeographic, and/or systematic information derived from four bivalves and one gastropod. It was not a purpose of this paper to provide

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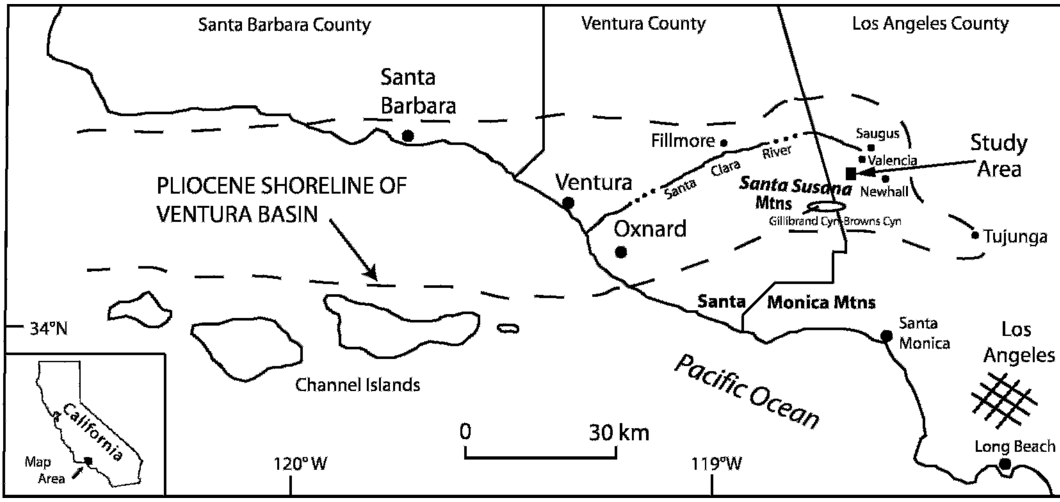


Figure 1 Index map showing generalized location of the Valencia area and the maximum extent of Pliocene seas in the Ventura Basin (modified from Corey, 1954, fig. 8)

a detailed account of every species found. These can be found in Hertlein and Grant (1972), Moore (1984, 1987), Groves (1991a), and Davis (1998).

Abbreviations for locality and/or catalog numbers are ANSP (Academy of Natural Sciences of Philadelphia), CAS (California Academy of Sciences, San Francisco; includes the Stanford University collection), CSUN (California State University, Northridge, collection now housed at LACMIP), LACMIP (Natural History Museum of Los Angeles County, Invertebrate Paleontology Section), and UCMP (University of California, Museum of Paleontology, Berkeley, California).

All the megafossils collected in the course of this study, including figured specimens, have been deposited in LACMIP collection. Comparative fossils from Baja California are housed in LACMIP stratigraphic collection and UCMP's type collection.

PREVIOUS WORK

Generalized geologic maps of the Valencia area were prepared by Eldridge and Arnold (1907) and Kew (1924). More detailed maps were prepared by Winterer and Durham (1962) and Dibblee (1992). Winterer and Durham (1962) also provided localities and faunal lists of the megafossils and benthic foraminifera found in and near the Valencia area but did not illustrate any specimens.

The history of formation names used by major investigators in the Valencia area and vicinity is summarized in Figure 2. The type section area for the Pico Formation, named by Kew (1924), is approximately 6 km northwest of the Valencia area. He defined this formation as consisting of fine and coarse sandstone with a few interbedded conglomerates and being entirely of marine origin. The type section of the Saugus Formation, named by Hershey (1902), is approximately 6.4 km northeast of the Valencia area. He defined this formation as consisting of sand, gravel, and clay and being entirely of alluvial origin. Dibblee (1992) applied the name "Sunshine Ranch Member" for lowermost Saugus Formation strata in the Valencia area, but this member, whose name was coined by Hazzard in Oakeshott (1950), does not crop out in the Valencia area.

Groves (1991a) did a detailed megafossil investigation of the Pliocene to Pleistocene lower Saugus Formation mainly along the south side of the Santa Susana Mountains, and one of his fossil localities (CSUN 1165 = LACMIP locality 15719) is in the Valencia area.

Treiman and Saul (1986), Stitt (1986), Davis et al. (1996), and Tsutsumi and Yeats (1999) included the Valencia area in their tectonic history investigations of the Santa Susana Mountains. Levi and Yeats (1982, 1983) and Levi et al. (1986) reported on the magnetostratigraphy of the Saugus Formation just west of the Valencia area. Treiman (1982) reported on the occurrence of an ash bed, the age of which is approximately 0.73 Ma, in the upper Saugus Formation just northeast of the Valencia area.

MEGAFOSSIL OVERVIEW

A total of 66 species of megafossils were collected from 11 localities, whose locations are shown in Figure 3. These species are listed in Table 1. Preservation is generally good to excellent, but collection of complete specimens of the large

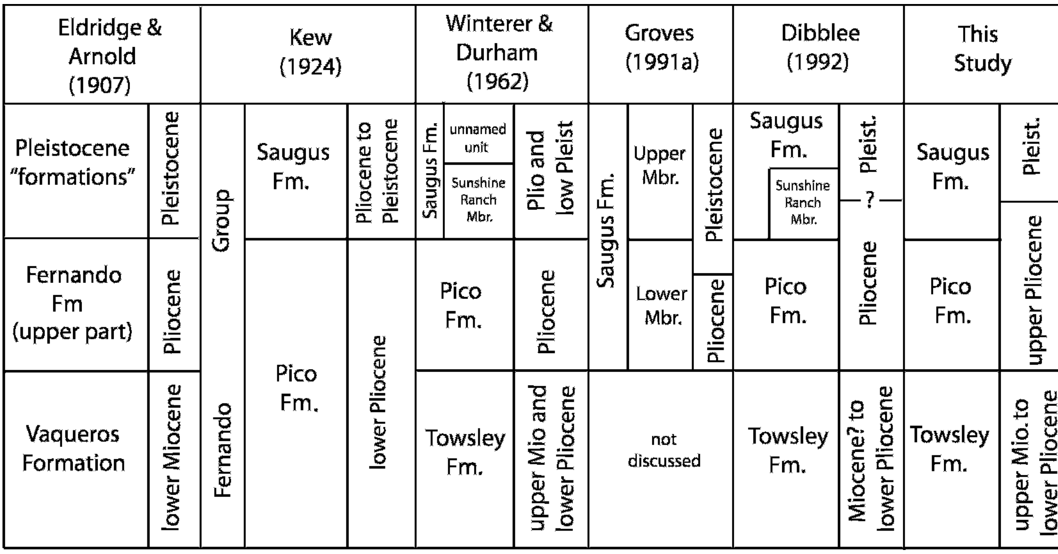


Figure 2 History of pertinent stratigraphic nomenclature and chronostratigraphic assignments for the Valencia area and vicinity

bivalve *Lyropecten catalinae* is difficult because they are commonly badly fractured.

Winterer and Durham (1962) reported a meager fauna of poorly preserved bivalves in the siltstone in the lower part of the Pico Formation in the general region of the eastern Ventura Basin. They also reported that localities high in the Pico Formation commonly contain oysters, pectens, sand dollars and that the uppermost 30 m or so can be very fossiliferous. In the Valencia area, however, the uppermost 20 m of this formation lacks megafossils.

Winterer and Durham (1962) listed 48 species from the Valencia area in their faunal list (table 4, localities F 77–F 81). None of the specimens, however, was illustrated or assigned a museum catalog number, and their present location is unknown. We collected approximately one-third of their reported species. We suggest, furthermore, that the strongly plicate oyster *Myrakeena veatchii* was incorrectly identified by them as "*Ostrea vespertina*," the large pectinid *L. catalinae* was incorrectly identified by them as *Lyropecten cerrosensis*, and the small pectinid *Argopecten invalidus* was incorrectly identified by them as *Aequipecten circularis*.

DEPOSITIONAL ENVIRONMENTS

Depositional environments represented by the 456-m-thick Pico Formation in the Valencia area were determined by means of lithology, sedimentary structures, fossil content, and taphonomy. Depositional-environment terminology follows Reineck and Singh (1980).

PRODELTA DEPOSITS

The lower three-fourths of the Pico Formation consists of approximately 350 m of muddy siltstone (Fig. 4), and the upper part of this muddy siltstone package is locally incised by vertically stacked and mappable channels filled with cobble conglomerate or pebbly conglomeratic sandstone. The channels increase upsection in number, thickness (maximum thickness 10 m), lateral extent, and coarseness of the contained material. The cobbles are well rounded, up to 20 cm in diameter, and consist largely of igneous rocks and quartzite. Some of the channelized sandstone beds contain horizontal laminations and low-angle cross bedding.

The muddy siltstone surrounding the channels contain benthic foraminifera, especially *Uvigerina peregrina* and *Epistominella pacifica*, which are indicative of deposition at middle to upper bathyal water depths (approximately 90–1000 m), with shallowing upsection (Winterer and Durham, 1962; Blake, 1991). The channelized conglomerates and sandstones strongly resemble fluvial deposits, and, therefore, we conclude that they indicate initiation of the progradation of a high-energy deltaic system whose fluvial-influenced storm-generated currents carried coarse debris seaward into the upper bathyal part of the prodelta.

Directly overlying the eastern edge of the stratigraphically uppermost and laterally most extensive of the channels is a localized terebratulid brachiopod-rich sandstone bed (LACMIP locality 17774), which is the stratigraphically

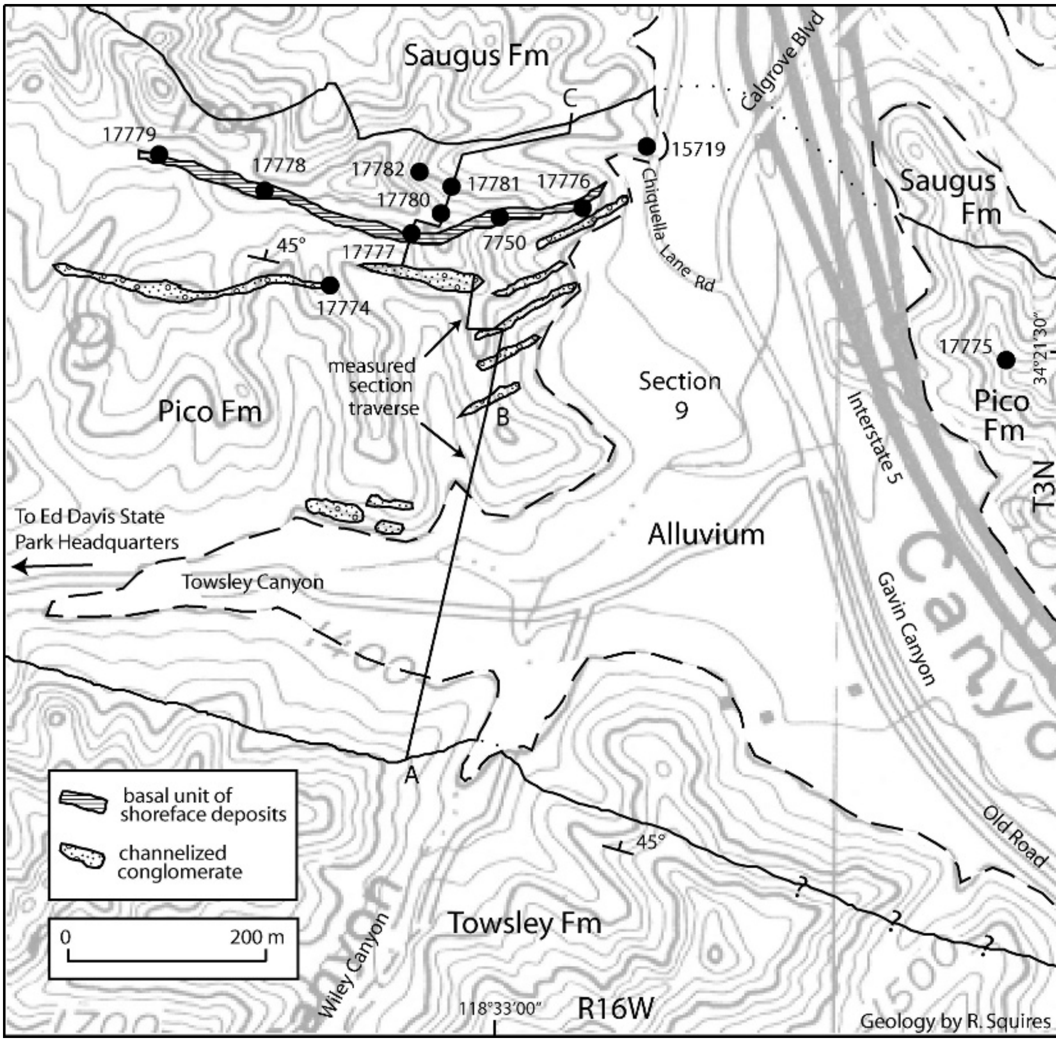


Figure 3 Geologic map of the Valencia area. Geology by R.L. Squires. Base map from U.S. Geological Survey 7.5 minute Oat Mountain Quadrangle (1952 [photo revised 1969])

lowest bed with megafossils. Some of the brachiopods have paired valves, but others are unabraded single valves. Brachiopods are rare elsewhere in the Valencia area. The only other megafossils collected from this particular bed were a few broken but unabraded valves of *Lyropecten catalinae*.

DELTAIC DEPOSITS

Transition Zone

These deposits, which consist of siltstone grading upsection into silty very fine sandstone, represent the transition zone between the muddy deposits of the upper bathyal part of the prodelta environment and the sandy deposits of the more proximal parts of the delta. No megafossils were found in these transition-zone deposits.

Shoreface

The shoreface deposits make up the remaining part of the Pico Formation and are subdivided into three parts: basal unit, middle unit, and upper unit. The stratigraphic distribution of fossil-bearing beds in these units is shown in Figure 4.

BASAL UNIT

This unit (Figs. 3–5) is a 3-m-thick, lens-shaped bed of silty very fine sandstone with scattered small cobbles and oysters with paired valves, pectinids, and rare anomid bivalves. Fossils were recovered from several localities along strike in this richly fossiliferous unit, which is, at least, 1.6 km in lateral extent and most likely a complex of channel-fill deposits. To the west, it grades into thin parallel-laminated beds of fossil hash; to the east, near Interstate Highway 5, it is covered but appears to be the same unit as at LACMIP locality 17775. The bivalves in the basal unit are well preserved; equal numbers have paired valves or are broken but unabraded, and the gastropods also seem to be unabraded. Locally, the fossils are jumbled together in small concentrations (Fig. 6); it is evident that the shells were transported a short distance by the storm waves that affected the shoaling bottom (shoreface environment) associated with the prograding delta. This basal unit grades vertically into the overlying beds.

MIDDLE UNIT

This unit is approximately 50 m thick and consists mostly of very fine sandstone with intervals that are either massive (bioturbated), hummocky cross stratified (Fig. 7) and amalgamated, or horizontally laminated. According to Dott and Bourgeois (1982), hummocky cross stratification is formed on the shoreface by waves and is a major characteristic of a wave-dominated coastline. The most common variant of hummocky cross stratification is amalgamation, which is caused by the stacking of successive hummocky deposits or by intense bioturbation that obliterates original boundaries between depositional units. Amalgamation units commonly form when one event follows another with nearly the same intensity and the second event strips off the fine-grained top of the first bed and subsequently deposits sand on top of the truncated first bed (Thorne et al., 1991:67). Beds therefore tend to be multiple-event beds, and the amalgamation of these multiple-event beds results in a characteristic condensed section (Swift et al., 1991:100).

Although most of the sandstone of the middle unit is barren of megafossils, a few channelized fossil beds are present. They are approximately 30-cm-thick lenses containing fossils (some complete bivalves) and localized cobbles. At least three of these fossil beds are laterally persistent, and the upper two are mappable for at least 1 km. Sandstone at LACMIP locality 15719 is unusual because it contains several fossiliferous lentils. Compared to the basal unit mentioned above, the fossils at LACMIP locality 15719 are more diverse, especially the small-sized species, and more concentrated. Bivalve shells, especially *Myrakeena veatchii*, *Argopecten invalidus*, and *Lyropecten catalinae*, are more broken but show no abrasion. A few of the bivalves, especially *Here excavata*, have paired valves, but only rare specimens of *M. veatchii* and *L. catalinae* have paired valves.

Toward the top of the fossil-bearing zone at LACMIP locality 15719, the number of specimens with paired valves of the large bivalves *Dosinia ponderosa* and *Tresus nuttallii* increases to the point that the uppermost bed consists almost exclusively of these two species. *Dosinia ponderosa* is a shallow, subtidal burrower (Meldahl et al., 1997), commonly found today in areas of constant water movement (Baqueiro and Stuardo, 1977). *Tresus nuttallii* commonly lives on sandy bottoms at low tide and in sheltered bottoms offshore to depths of 30 m, and it burrows 30 cm to 1 m beneath the surface (McLean, 1978). Neither of these burrowing bivalves was found in living position in the Valencia area. They show random orientation, even though they occur as paired valves. These specimens were most likely displaced from their burrows by severe storm waves and transported short distances while alive.

UPPER UNIT

The unit consists of very fine sandstone very similar to the underlying shoreface sandstone, except the upper unit has more abundant and better-developed hummocky cross stratification and lacks megafossils. This cliff-forming unit in outcrop appears to be massively bedded (structureless) when viewed from a distance because of the amalgamation bedding. The uppermost beds contain well-developed and very thin, parallel laminae, as well as a few small, vertical and nearly vertical burrows, up to approximately 6 cm in length and 1 cm in diameter.

BRAIDED RIVER

The uppermost part of the shoreface deposits interfingers with two unfossiliferous beds consisting of rounded boulder conglomerate that grade upward into conglomeratic sandstone. The stratigraphically lowermost of these two beds is 2 m thick and is overlain by a 1.5-m-thick very fine sandstone bed that is poorly laminated and contains a few poorly developed burrows. The upper contact of this sandstone bed is irregular and represents local erosion prior to the deposition of the overlying 4-m-thick complex of boulder beds that grades laterally into sandstone containing large-scale cross beds. This interval of interfingering lithologies corresponds to the "gradation" between the Pico Formation and the overlying Saugus Formation (Fig. 8) and represents the initiation of the braided-river environment associated with the prograding high-energy deltaic system. We place the contact between these two stratigraphic units at the base of the stratigraphically lowermost boulder conglomerate bed (Fig. 4).

The interval of interfingering lithologies between the two formations can be mapped only by physically walking the contact. It is not easy to differentiate the contact from afar because both the uppermost part of the Pico Formation and the basal part of the Saugus Formation form cliffs and have the same brown color. The interfingering nature of the two formations is well exposed in

Table 1 Megafossils of the Valencia area Pico Formation listed systematically. Localities arranged stratigraphically.

Taxa	17774	7750	17775	17776	17777	17778	17779	17780	15719	17781	17782
Monera (encrusting calcareous algae)									R		
Porifera: Demospongiae											
Cliona? sp. (on *M. veatchii* and *C. humerosus*)		F	C				R				
Bryozoa: Cheilostomata											
Microporella sp.		R			R	F	R		F		
Unidentifiable encrusting bryozoan						F					
Brachiopoda: Articulata											
Terebratalia hemphilli Dall, 1902	A		R								
Terebratalia occidentalis (Dall, 1871)	C		R	R							R
Annelida: Polychaeta											
Serpula? sp.		R		R		F			R	R	
Serpulid tube, minute and ribbed, on *M. veatchii*					F	R					
Mollusca: Scaphopoda											
Dentalium sp.									R		
Mollusca: Bivalvia											
Anadara (*Larkinia*) *multicostata* (Sowerby, 1833)		R									
Anadara sp.									R	R	
Argopecten invalidus (Hanna, 1924)		R	R			A	R	A	A	C	R
Lyropecten catalinae (Arnold, 1906)	?	R	A	F	R	A	R		F		F
Patinopecten healeyi (Arnold, 1906)						C					
Placunanomia hannibali Jordan & Hertlein, 1926						R					
Myrakeena veatchii (Gabb, 1866)	F	A	A	A	A	A	C	F	A	R	
Lucinoma annulatum (Reeve, 1850)					R						
Here excavata (Carpenter, 1857)			R						A	R	
Trachycardium (*Dallocardia*) *quadragenarium* (Conrad, 1837)		R	F		R	R					
Tresus nuttallii (Conrad, 1837)		R	R					R	F	F	C
Solen (*Ensisolen*) *sicarius*? Gould, 1850		R	F		R			R	R	R	
Leporimetis obesa (Deshayes, 1855)			R		R				R		
Tellina (*Tellinella*) *idae* Dall, 1891		R									
Saxidomus nuttalli Conrad, 1837		R									R
Dosinia ponderosa (Gray, 1838)		R			R	R		R	A	R	C
Chione (*Chione*) *californiensis* (Broderip in Broderip & Sowerby, 1835)										R	
Chione (*Securella*) *kanakoffi* Hertlein & Grant, 1972					R				R		
Juliacorbula luteola (Carpenter, 1864)									R		
Panopea abrupta (Conrad, 1849)		R			R				R	R	
Cyathodonta pedroana Dall, 1915			R								
Thracia (*Homoeodesma*) *trapezoides* Conrad, 1849						R					
Mollusca: Gastropoda											
Megastraea undosa (Wood, 1829)									R		
Tegula (*Chlorostoma*) *gallina* (Forbes, 1852)									R	R	
Bittium (*Semibittium*) *quadrifiliatum* Carpenter, 1864									F	C	
Turritella cooperi Carpenter, 1864		A	F		A	C		R	A	R	R
Calyptraea (*Trochita*) sp. cf. *C.* (*T.*) *spirata* (Forbes, 1852)			R						R		
Crepidula (*Grandicrepidula*) *princeps* Conrad, 1856			R						F		
Nitidiscala tincta (Carpenter, 1864)									R	R	
Asperiscala sp. cf. *A. minuticosta* (DeBoury, 1912)							R				
Zonaria (*Neobernaya*) *spadicea* (Swainson, 1823)			R								
Sinum scopulosum (Conrad, 1849)									R		
Glossaulax reclusiana (Deshayes, 1839)		R		R	F	F			A	R	
Euspira lewisi (Gould, 1847)			R								

Table 1 Continued.

Taxa	17774	7750	17775	17776	17777	17778	17779	17780	15719	17781	17782
Maxwellia eldridgei (Arnold, 1907a)									R		
Forreria belcheri (Hinds, 1844)		R								R	
Acanthinucella emersoni (Hertlein & Allison, 1959)									F	R	
Calicantharus humerosus (Gabb, 1869)		C	F		A	R		R	C		
?*Calicantharus kettlemenensis* (Arnold, 1909)			R					R			
Fusinus cf. *F. barbarensis* (Trask, 1855)		R							R		
Nassarius (*Demondia*) *californicus* (Conrad, 1856)					C	R			A	C	
Olivella (*Callianax*) *baetica* Carpenter, 1864									R		
Admete gracilior (Carpenter in Gabb, 1869)									R		
Cancellaria hemphilli Dall, 1909									C		
Cancellaria tritonidea Gabb, 1866					R						
Crassispira (*Burchia*) *semiinflata* (Grant & Gale, 1931)									F		
Terebra (*Strioterebrum*) *martini* English, 1914									R		
Tornastra culcitella (Gould, 1853)					R				R		
Arthropoda: Crustacea: Decapoda (crabs)									R		
Arthropoda: Crustacea: Cirripedia (barnacles)											
Megabalanus (*Megabalanus*) *californicus* (Pilsbry, 1916)						R		R	F	C	
Balanus gregarius (Conrad, 1857)					R						
Chthamalus sp. on *M. veatchii*					R						
Echinodermata: Echinoidea (sea urchins)											
Eucidaris sp. (spine)						R					
Echinodermata: Echinoidea (sand dollars)											
Dendraster ashleyi (Arnold in Arnold and Anderson, 1907)		R							F		
Merriamaster? sp.									F		
Vertebrata: Mammalia											
Marine mammal bone							R				
Plantae: Fagaceae											
Quercus sp. (California live oak leaf)									R		

A = abundant (>10 specimens); C = common (5–9 specimens); F = few (3–4 specimens); R = rare (<2 specimens)

the small canyon just west of LACMIP locality 15719 (Fig. 3). This canyon is readily observable from Interstate Highway 5 or from the service road along its west side. The contact in this canyon was especially well exposed after mudslides removed some of the talus during rainfalls in the winter of 2004 and spring of 2005.

SYSTEMATICS

Phylum Mollusca Linnaeus, 1758
Class Bivalvia Linnaeus, 1758
Family Ostreidae Rafinesque, 1815
Subfamily Lophinae Vyalov, 1936
Genus *Myrakeena* Harry, 1985

TYPE SPECIES. *Ostrea angelica* Rochebrune, 1895, by original designation; Miocene to recent. Fossil from Southern California and Baja California, Mexico; recent or Holocene from San Ignacio Lagoon to San Felipe, Baja California and south to Mazatlan, Sinaloa, Mexico (Hertlein and Grant, 1972), to Ecuador (Keen, 1971).

Myrakeena veatchii (Gabb, 1866)
Figures 9–14

O[*strea*]. *veatchii* Gabb, 1866:34–35, pl. 11, fig. 59.

Ostrea veatchii Gabb. Eldridge and Arnold, 1907:153, pl. 39, fig. 1 (refigured in Arnold, 1907a:527, 544, pl. 49, fig. 1, and refigured in Clark, 1929:28, pl. 46, fig. 3 as *Ostrea vespertina*); Arnold, 1907b:423, 445, pl. 56, fig. 10 (refigured in Arnold and Anderson, 1907:59, 148, pl. 23, fig. 10; Hertlein and Grant, 1972: 219–221, pl. 39, fig. 4, pl. 40, figs. 1, 4, 5, 6; Carreño et al., 1989:343, fig. 129i).

Ostrea vespertina Conrad, 1854. Arnold, 1909 [1910]:77–79, pl. 24, figs. 4, 5 (refigured in Arnold and Anderson, 1910:129, pl. 46, figs. 4, 5); Grant and Gale, 1931:152–153, pl. 12,

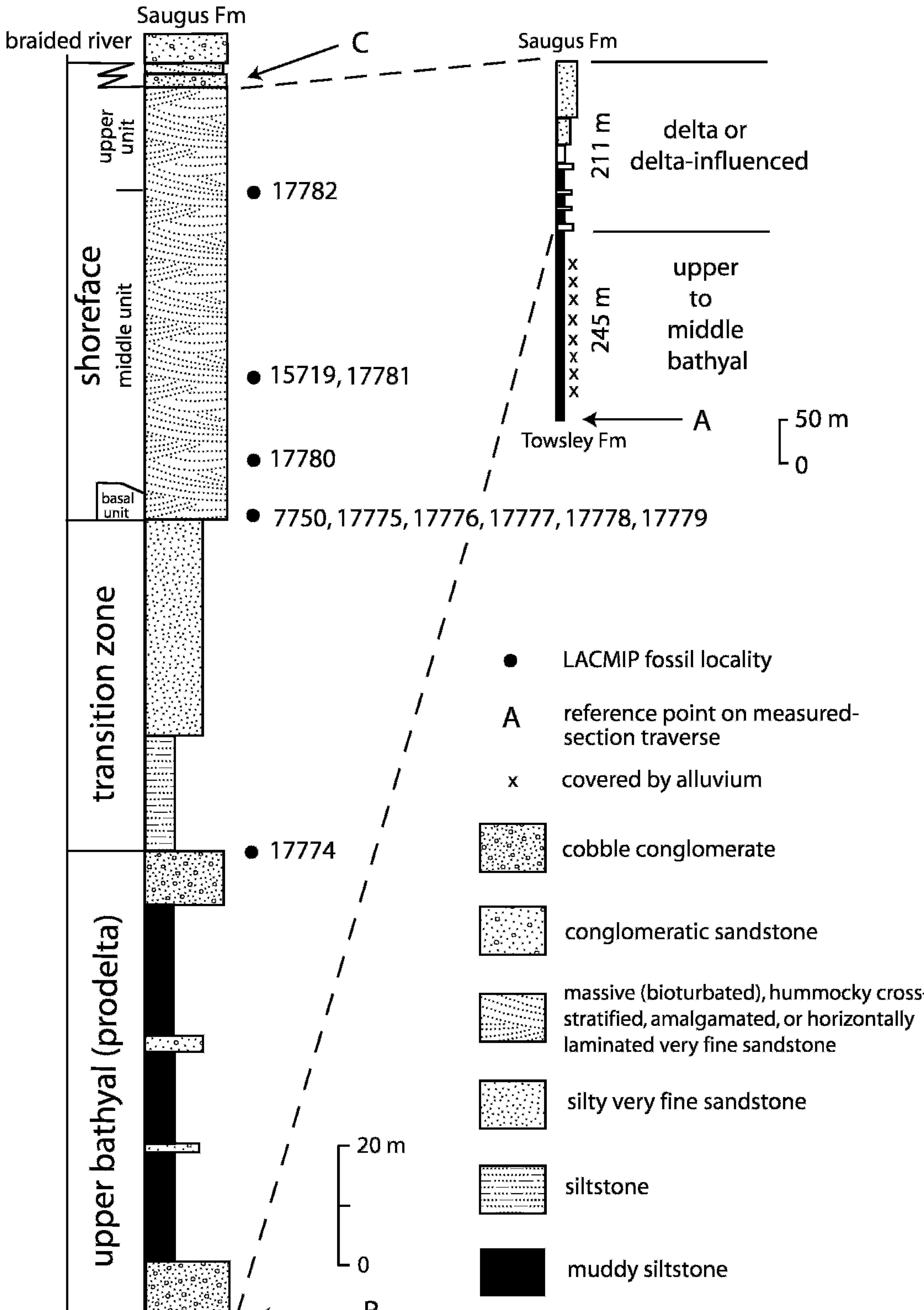
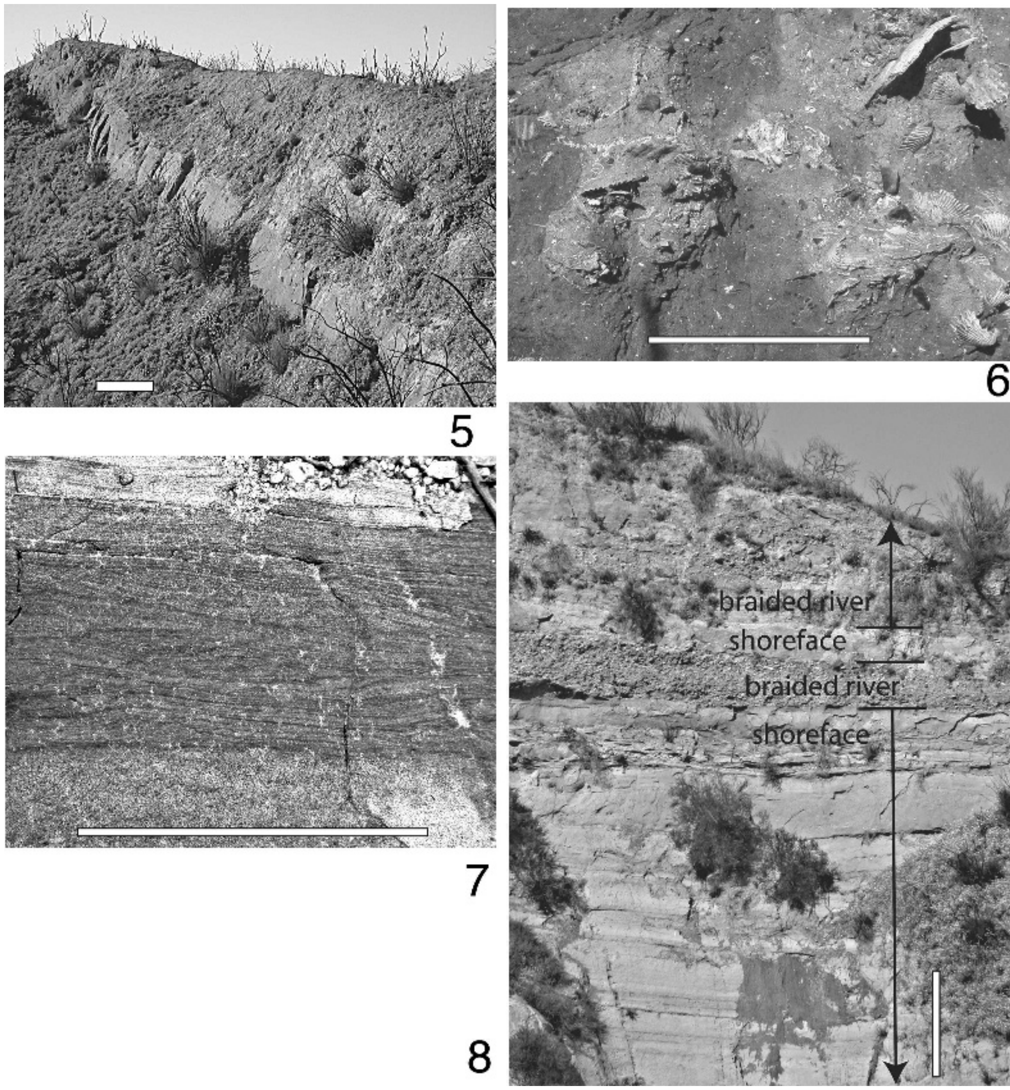


Figure 4 Columnar section showing stratigraphy, depositional environments, and stratigraphic positions of megafossil localities. The left column is an expanded version of the upper part of the complete column on the right



Figures 5–8 Photographs of selected outcrops of the Pico Formation in the Valencia area. **5.** Basal unit of shoreface sandstones forming a small cliff at LACMIP locality 17778, view to the west; scale bar represents 3 m. **6.** Close-up view of basal unit of shoreface sandstones at LACMIP locality 17778, where fossils occur in small concentrations; scale bar represents 15 cm. **7.** Close-up of hummocky cross stratification in upper part of shoreface deposits in small canyon due west of LACMIP locality 15719; scale bar represents 10 cm. **8.** Interfingering contact between shoreface deposits of the Pico Formation and the braided-river deposits of the overlying Saugus Formation in small canyon due west of LACMIP locality 15719; scale bar represents 5 m

figs. 1a–b (refigured, in part, in Shimer and Shrock, 1944:397, pl. 155, fig. 3); Woodring et al., 1940 [1941]:92, pl. 14, fig. 9; Hanna and Hertlein, 1943:174, fig. 64-4; Woodring and Bramlette, 1950 [1951]:85, pl. 16, figs. 4, 17; Frazier, 1968:15, fig. 8; Hertlein and Grant, 1972:218–219, pl. 39, figs. 1–9; Addicott and Galehouse, 1973:511, 513; figs. 3a–c, h, l, m, n; Stadum, 1973:pl. 6, fig. 1; Stadum, 1984:80, pl. 1, fig. 20.

Ostrea vespertina Conrad var. *sequens* Arnold, 1909 [1910]:79–80, pl. 29, figs. 5, 6 (refigured in Arnold and Anderson, 1910:132, pl. 51, figs. 5, 6).

Ostrea haitensis Sowerby subsp. *vespertina* Conrad. Stewart, 1930:128–130, pl. 14, fig. 4 [holotype of O. *veatchii* Gabb].

Ostrea vespertina sequens Arnold. Woodring et al., 1940 [1941]:pl. 8, figs. 10–14; pl. 10, figs. 1–5; Edinger, 1961:6, 18, 4 unnumbered figs.

Ostera [*sic*] *vespertina* Conrad. Squires and White, 1983:222, pl. 1, fig. 4 (refigured in Squires, 1997:301, fig. 6g as *Dendostrea vespertina* (Conrad)).

"*Ostrea*" *veatchii* Gabb. Smith, 1984:26, pl. 4, fig. 6.

Lopha? ("*Lopha*") *veatchii* (Gabb). Moore, 1987:C24–C25, pl. 17, figs. 1–5 [figs. 2 and 4 = holotype of *veatchii*].

Dendostrea? *vespertina* (Conrad). Moore, 1987: C25, pl. 15, figs. 2, 3.

Lopha veatchii (Gabb). Groves, 1991a:120–121, pl. 4, fig. 3.

Dendostrea vespertina (Conrad). Groves, 1991a: 117–119, pl. 4, fig. 2.

? *Ostrea vespertina* Conrad. Woodring, 1938:pl. 9, fig. 5.

not *Ostrea veatchii* Gabb. Gabb, 1869:60–61, pl. 17, figs. 21, 21a (refigured, in part, by Heilprin in White, 1884:316, pl. 72, fig. 1) [= *Ostrea heermanni* Conrad, 1855 [1856] *fide* Moore, 1987:C24]; Yates, 1903:pl. 7, fig. 6, pl. 8, figs. 18–20.

TYPE MATERIAL. Holotype ANSP 4502.

TYPE LOCALITY. Eastern Cedros Island, Baja California Sur, Mexico; Almejas Formation, Pliocene.

GEOLOGIC AGE. Pliocene.

STRATIGRAPHIC DISTRIBUTION. UNDIFFERENTIATED UPPER MIOCENE TO PLIOCENE: "Purisima" Formation, La Honda area west of Santa Clara, San Mateo County, California (Powell, 2000). LOWER PLIOCENE: Fernando Formation, northern Los Angeles County, California (Eldridge and Arnold, 1907; Kew, 1918); Pico Formation, northern Los Angeles County, California (Kew, 1924); upper Almejas Formation, eastern Cedros Island (Gabb, 1866; Jordan and Hertlein, 1926; Hertlein and Grant, 1972; Carreño et al., 1989); Tortugas Bay area, Vizcaino Peninsula, Baja California Sur, Mexico (Jordan and Hertlein, 1926; Hertlein and Grant, 1972; Smith, 1984; also see LACMIP localities 962, 963, 4687). UPPER PLIOCENE: Upper San Joaquin Formation, Kettleman Hills area, San Joaquin Valley, Fresno and Kings counties, California (Arnold 1909 [1910] as "Etchegoin" Formation; Woodring et al., 1940 [1941]); Careaga Sandstone and probably Foxen Mudstone, Santa Maria district, Santa Barbara County (Woodring and Bramlette, 1950 [1951]); formation undesignated (=Pico Formation?), northeastern Ventura County (Hanna and Hertlein, 1943); Saugus Formation, lower part, northern Los Angeles County, California (Stadum, 1973; Squires and White, 1983; Groves, 1991a); Pico Formation, near Valencia, northern Los Angeles County, California (new information); Niguel Formation, Orange County (Stadum, 1984); San Diego Formation, San Diego County, California (Frazier, 1968; Hertlein and Grant, 1972); San Diego Formation, northwestern Baja California, Mexico (Rowland, 1972); Cantil Costero Formation (see Santillán and Barrera, 1930), near San Quintin, northwestern Baja California, Mexico (Hertlein and Allison, 1959, as formation undesignated). PLIOCENE UNDIFFERENTIATED: Paso Robles Formation, near Atascadero, San Luis Obispo County, California (Addicott and Galehouse, 1973); Fernando Formation, northern Los Angeles County, California (Woodring, 1930; Grant and Gale, 1931).

REMARKS. *Myrakeena veatchii* is the most common megafossil in the Valencia area. Specimens range in height from 28 mm to 95 mm and are locally abundant in the basal unit of the shoreface deposits (e.g., localities 7750, 17777, and 17778). Preservation is excellent, and specimens show no evidence of abrasion. Ninety-five specimens were collected from this basal unit: 24 with paired valves, 25 single left valves, and 46 single right valves. Many of the specimens with paired valves were collected from float. Most of the single valves are complete. Upsection from the basal shoreface unit, *M. veatchii* specimens with paired valves become uncommon and most are small single valves or fragments (e.g., LACMIP locality 15719).

Myrakeena veatchii is characterized by its coarse radial plicae. The left valve, which is more convex than the right valve, has a pit-like resilifer, whereas the right valve has a slightly overhanging tooth-like resilium that fits into the resilifer.

Some left valves are cemented to other oyster specimens; rarely, they are cemented to pectinids or to shells of the gastropod *Calicantharus humerosus*. Left valves vary in shape, ranging from teardrop to sickle, because they conform to the substrate. Right valves are more likely to be collected because they were not cemented. The matrix surrounding nearly all the collected *M. veatchii* specimens is usually easy to remove, allowing valve margins to be studied. One left valve had its ligament preserved. Approximately 10 percent of the oysters found in the basal unit have epibionts attached, namely, bryozoans and serpulid worm tubes. Most of these epibionts are attached to the valve exteriors, but some are attached to the valve interiors. Pholad boreholes are uncommon, and sponge boreholes are rare.

Ostreine chomata are present on 40 percent of the right valves of *M. veatchii* and are rarely seen on the left valves. The chomata are weak, few in number, and almost always restricted to the hinge area. When chomata are present on the right valves, they are almost always located posteriorly (e.g., Fig. 12). Only two right valves (heights 55 mm and 70 mm) show chomata both anteriorly and posteriorly, and only one specimen (height 75 mm) shows chomata posteriorly. Gerontic specimens (i.e., height >85 mm) show chomata on older shell layers but none on the youngest layer. When chomata are present on the left valves, they are located only posteriorly and are very weak. It is possible that as *M. veatchii* became gerontic, the chomata were no longer functional. Hertlein and Grant (1972) also reported variability in the occurrence of chomata on specimens of *M. veatchii*.

"*Ostrea*" *veatchii* is assigned here for the first time to the genus *Myrakeena*. It is similar to *M. angelica*, the type species of the genus, but *M. veatchii* differs from it by having a thinner shell, plicae extending to the beaks (in *M. angelica*, they usually do not extend beyond the pallial line on the interior of the valves), chomata poorly developed on left valve (in *M. angelica*, they are equally developed on both valves), biconvex valves (in *M. angelica*, only the upper valve is convex), and a suboval to subquadrate muscle scar (in *M. angelica*, the muscle scar is trapezoidal).

Several workers (e.g., Arnold, 1909 [1910]:77–78; Jordan and Hertlein, 1926:429; Woodring, 1938; Durham, 1950) regarded "*Ostrea*" *veatchii* as conspecific with "*Ostrea*" *vespertina*, which is reported from Miocene and Pliocene strata in California and the Baja California Peninsula, Mexico (Moore, 1987). Moore (1987) tentatively assigned Conrad's species to genus *Dendostrea*. Conrad (1854) did not provide precise information regarding the type locality of his "*Ostrea*" *vespertina*, but, based on a detailed analysis by Woodring (1938:43–45), the type locality is now generally believed to be in the northern part of the ancient Gulf of California in the Imperial Formation, San Diego County, California. Woodring (1938:43) selected a lectotype (ANSP 13366) of "*O.*" *vespertina* from the Imperial Formation, and, according to Moore (1987:C26), this type specimen, which is figured in Moore (1987:pl. 16, figs. 6, 7), establishes a basis for separating *D.*? *vespertina* from *M. veatchii*.

Using LACMIP collection specimens of *D.*? *vespertina* from the Imperial Formation for comparison, *M. veatchii* is the larger of the two species. The left valve of *M. veatchii* is more strongly plicate, more convex (never flat as in some *D.*? *vespertina* specimens), and with much fewer ostreine chomata that never extend to the ventral margin and are not supplemented by lophine (minutely pustulate) chomata. If chomata are present on the left valve of *M. veatchii*, they are less well developed and fewer in number than those on the left valve of *D.*? *vespertina*. Right valves of *M. veatchii* have stronger and more numerous plicae. *Myrakeena veatchii* only rarely has the inflated smooth beak area that is characteristic of *D.*? *vespertina*; if present on *M. veatchii*, it is delineated by a groove from the rest of the valve surface. Woodring (1938) reported that some small right valves of "*O.*" *vespertina* can be weakly plicate.

In summary, we do not follow the concept that *M. veatchii* and *D.*? *vespertina* are conspecific. We acknowledge, however, that if only exterior morphology is considered, especially for the left valve, the two taxa are easily confused because the left valves can be similar.

Some workers (e.g., Moore, 1987:C25) put "*O.*" *vespertina* var. *sequens* Arnold, (1909 [1910]:79–80, pl. 29, figs. 5, 6) into synonymy with *D.*? *vespertina*. *Ostrea vespertina sequens* is smaller, thinner, and less plicate (right valve can be smooth) than *D.*? *vespertina*. We put "*O.*" *vespertina sequens* into synonymy with *M. veatchii* because we can find no morphologic criteria to separate them. Illustrated specimens of "*O.*" *vespertina sequens* are juvenile specimens of *M. veatchii*.

Winterer and Durham (1962) reported "*O.*" *v. sequens* from the type section of the Sunshine Ranch Member of the Saugus Formation near Van Norman Dam, southeastern Ventura Basin, Los Angeles County, but they did not illustrate any specimens, nor they did give any catalog numbers of any museum specimens.

Woodring (1938:42–47) commented that plicate oysters of the Miocene and Pliocene age of California and Baja California, Mexico belong to "*Ostrea vespertina*," and their localities can be segregated into the following three areas: 1) coastal region of California and San Joaquin Valley, 2) Colorado Desert of southeastern California, and 3) Baja California.

Based on specimens collected from the Valencia area, comparative material from other formations in California and Baja California, and illustrated specimens in the literature, we conclude that *M. veatchii* occurs in the San Joaquin Valley, the coastal region of California, and the eastern Cedros Island/Vizcaino Peninsula areas in Mexico. *Dendostrea*? *vespertina* is restricted to southeastern California (e.g., Imperial County) and the ancient Gulf of California.

Family Pectinidae Rafinesque, 1815
Genus *Argopecten* Monterosato, 1899

TYPE SPECIES. *Pecten solidulus* Reeve, 1853, by original designation; recent, eastern Pacific (Coan et al., 2000).

Argopecten invalidus (Hanna, 1924)
Figures 15, 16

Pecten (*Plagioctenium*) *cooperi* Arnold, 1906: 124, pl. 49, figs. 2–4. Not *Pecten cooperi* Smith, 1903.

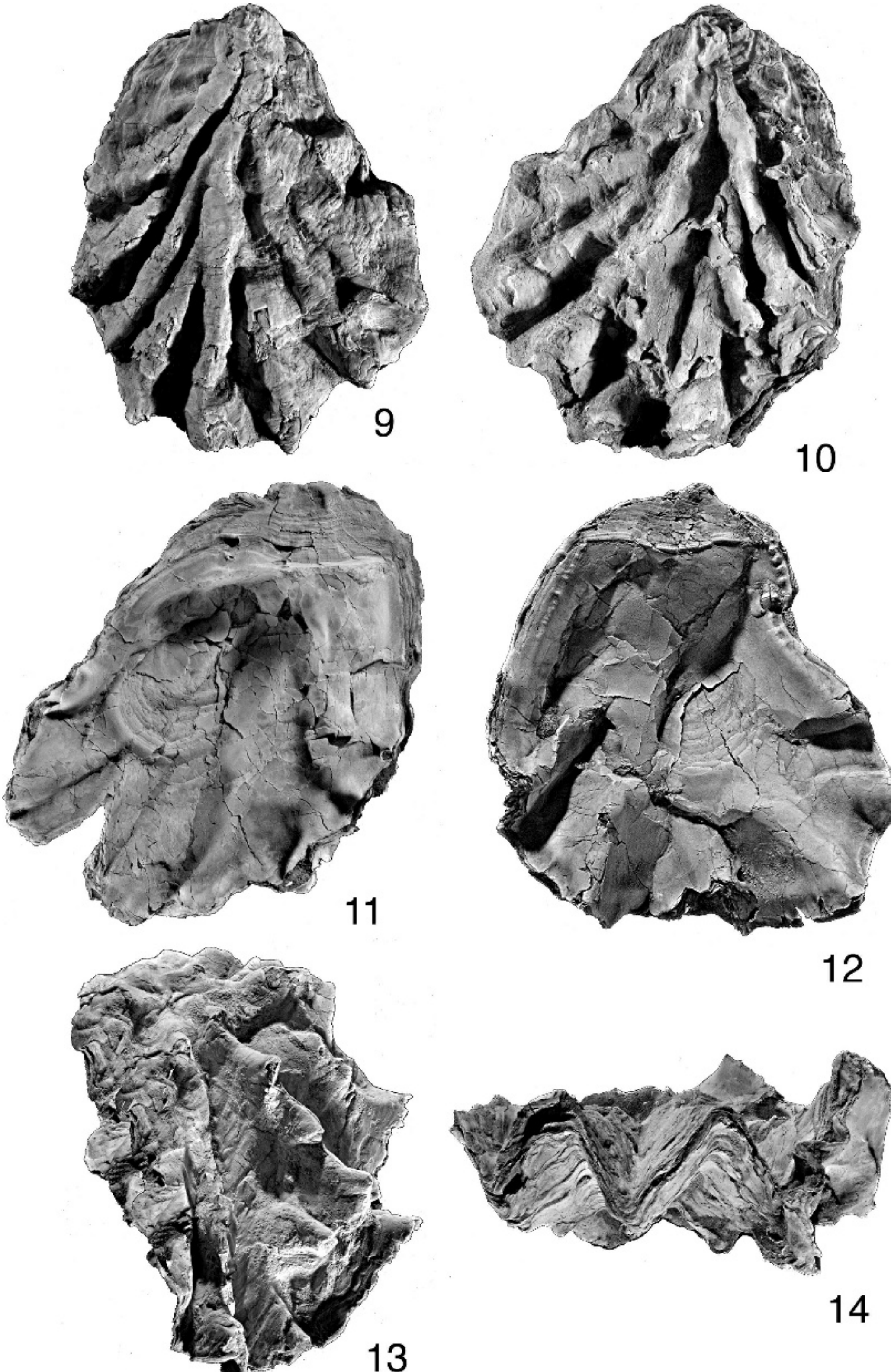
Pecten invalidus Hanna, 1924:177, new name for *P. cooperi* Arnold, 1906.

Pecten (*Plagioctenium*) *invalidus* Hanna. Jordan and Hertlein, 1926:441; Minch et al., 1976: table 15.

Pecten (*Aequipecten*) *deserti* Conrad variety *invalidus* Hanna. Grant and Gale, 1931:213–214, pl. 5, figs. 5a–c, 6a–c.

Argopecten invalidus (Hanna). Vedder, 1960:table 151.1; Moore, 1984:B37, pl. 10, fig. 5.

Chlamys (*Argopecten*) *invalida* Hanna. Hertlein and Grant, 1972:200–201, pl. 33, figs. 1, 3, 8.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TYPE MATERIAL. Holotype (of *Pecten* (*Plagioctenium*) *cooperi* Arnold, 1906) CAS 61855.01 (*ex* CAS 8).

TYPE LOCALITY. Pacific Beach, San Diego, San Diego County, California; San Diego Formation, Pliocene.

GEOLOGIC AGE. Pliocene.

STRATIGRAPHIC DISTRIBUTION. LOWER PLIOCENE: Almejas Formation, eastern Cedros Island and Tortugas Bay, Baja California Sur, Mexico (Jordan and Hertlein, 1926; Minch et al., 1976). UPPER PLIOCENE: Pico Formation, Valencia area, northern Los Angeles County, California (new information); Niguel Formation, San Juan Capistrano, Orange County, California (Vedder, 1960); San Diego Formation, lower member, San Diego County, California (Hertlein and Grant, 1972; Deméré, 1983). PLIOCENE UNDIFFERENTIATED: Pico Formation, northern Los Angeles County, California (Grant and Gale, 1931); formation undesignated, Pacific Beach, San Diego County, California (Arnold, 1906; Grant and Gale, 1931).

REMARKS. *Argopecten invalidus* is one of the most common megafossils in the Valencia area, and its preservation is generally excellent. Specimens range from 3 mm to 50 mm in height. They appear to be unabraded, and many have their fragile auricles intact. The species is especially abundant at LACMIP locality 17778, where a total of 40 specimens were collected, four of which have paired valves. Upsection at LACMIP locality 17779, 10 specimens were collected (three with paired valves); at LACMIP locality 15719, 23 specimens were collected (three with paired valves).

This species is characterized by having, on both valves, 18 to 20 flat-topped, squarish ribs, separated by U-shaped interspaces. The ribs tend to flatten out and become more convex in the later stages of growth. The shells of this species are slightly longer than high and moderately convex.

Arnold (1906:125) reported that his species occurs only in the Pliocene San Diego Formation. He also listed it in a table of taxa from the Pliocene Purisima and Merced formations, but he used the occurrence in a chronostratigraphic sense, not a lithostratigraphic sense, which has led to many species being misrepresented (C.L. Powell, II, personal communication). Hertlein and Grant (1972) restricted *A. invalidus* to the Pliocene of Southern California and Baja California. The occurrence of *A. invalidus* in the Pico Formation in the Valencia area represents the northernmost known limit of this species.

Genus *Lyropecten* Conrad, 1862

TYPE SPECIES. *Pallium estrellanus* Conrad, 1856, by subsequent designation (Dall, 1898); early late Miocene, central California (Smith, 1991).

Lyropecten catalinae (Arnold, 1906)
Figures 17–19

Pecten (*Lyropecten*) *estrellanus* Conrad var. *catalinae* Arnold, 1906:76–77, pl. 20, figs. 3, 3a, 4.
Pecten (*Lyropecten*) *gallegosi* Jordan and Hertlein, 1926:434–435, pl. 29, fig. 1; Carreño et al., 1989:348, fig. 132b.
Pecten (*Lyropecten*) *estrellanus* Conrad (in part). Grant and Gale, 1931:185, pl. 8, fig. 4.
Lyropecten gallegosi (Jordan and Hertlein). Hertlein, 1933:440; Minch et al., 1976:table 15; Moore, 1987:B54–B55, pl. 19, fig. 3; Smith, 1984:pl. 3, figs. 4, 7; Smith, 1991:58–59, pl. 27, figs. 1, 4; pl. 28, fig. 5.
Lyropecten estrellanus (Conrad). Stanton, 1966: text-fig. 2; Stanton, 1967:table 1; Kern, 1973:73–74 (*fide* Smith, 1991:56).
Lyropecten catalinae (Arnold). Moore, 1987:B53, pl. 18, figs. 4, 6; Vedder et al., 1979:249–250, table 5; Smith, 1991:48–49, pl. 27, figs. 2, 3, 7; pl. 28, figs. 1, 6.
Lyropecten cerrosensis (Gabb 1866). Groves, 1991a:93–95, pl. 2, fig. 9.

TYPE MATERIAL. Holotype CAS 61825 (ex SU 30), incomplete right valve.

TYPE LOCALITY. Near center of Santa Catalina Island, California; San Onofre(?) Breccia, Miocene (Moore, 1984).

GEOLOGIC AGE. Late Miocene to late Pliocene.

STRATIGRAPHIC DISTRIBUTION. UPPER MIOCENE: Unnamed limy sandstone beds [= San Onofre (?) Breccia (Moore, 1984)] near center of Santa Catalina Island, California (Vedder et al., 1979; Smith, 1991); Castaic Formation,

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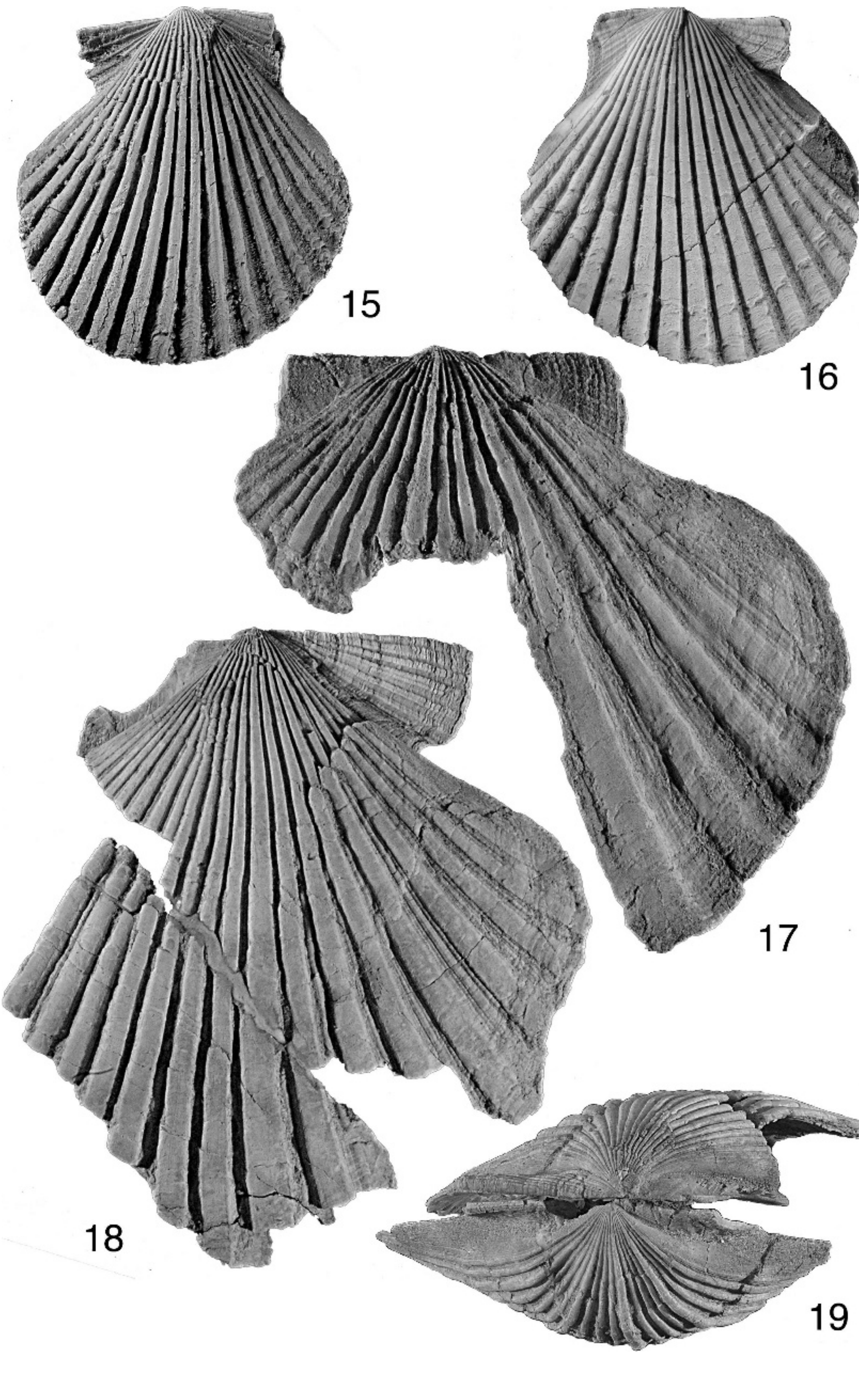
Figures 9–14 *Myrakeena veatchii* (Gabb, 1866) from the Valencia area. All specimens coated with ammonium chloride. **9, 10.** LACMIP hypotype 13339, height 77.4 mm, diameter 61.3 mm, ×0.9, LACMIP locality 17777. **9.** Left valve. **10.** Right valve. **11.** Left-valve interior, height 78.5 mm, diameter 65.4 mm, ×0.8, LACMIP hypotype 13340, LACMIP locality 17778. **12.** Right-valve interior, height 55.2 mm, diameter 49.5 mm, ×1, LACMIP hypotype 13341, LACMIP locality 17777. **13.** Oblique view of right valve, height 65.9 mm, diameter 58.7 mm, ×0.9, LACMIP hypotype 13342, LACMIP locality 17777. **14.** Specimen with paired valves (left valve on bottom) showing zigzag commissure, height 31.7 mm, width 7.5 mm, ×1, LACMIP hypotype 13343, LACMIP locality 17777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basal transgressive facies, Ridge basin, northern Los Angeles County, California (Stanton, 1967; Smith, 1991). UPPER MIOCENE AND LOWER PLIOCENE: Almejas Formation, eastern Cedros Island, Mexico (Jordan and Hertlein, 1926; Hertlein, 1933; Minch et al., 1976; Carreño et al., 1989; Smith, 1991), north and south of Tortugas Bay, Vizcaino Peninsula, Mexico (Hertlein, 1933; Smith, 1991), and north of Abreojos Point (its southernmost occurrence), north of Scammons Lagoon (=Laguna Ojo de Liebre), Vizcaino Peninsula, Baja California Sur, Mexico (Carreño and Smith, in press). LOWER PLIOCENE: Towsley Formation, Elsmere Canyon, northern Los Angeles County, California (Grant and Gale, 1931; Kern, 1973; Smith, 1991:56). UPPER PLIOCENE: Pico Formation, Valencia area, northern Los Angeles County, Southern California (new information); Cantil Costero Formation (see Santillán and Barrera, 1930), vicinity of San Quintin, Baja California, Mexico (Hertlein and Allison, 1959, formation undesignated).

REMARKS. This pectinid is common in the Valencia area. Fourteen specimens were collected: two paired valves, 10 left valves, and two right valves. Most of the specimens are very fragile and break easily when attempts are made to extract them from the outcrop. Complete specimens were found at LACMIP locality 17774 and especially at locality 17778.

Smith (1991:23) reported that *L. catalinae* is closely related to, or possibly conspecific with, *L. gallegosi*. Our observations indicate that they are conspecific. Smith (1991) provided detailed morphologic descriptions and illustrations of both *L. catalinae* and *L. gallegosi*. Both have flat-topped rectangular ribs, straight-sided auricles with costae, and adult right valves with 17 to 20 ribs and one midriblet per interspace. The rectangular right auricle has coarse costae crossed by growth lines. Adult left valves have 16 to 20 ribs and one midriblet per interspace. Left-valve raised ribs are separated by three regular ribs in a scheme described as R 3r Rc 3r R (see Smith, 1991:fig. 15).

Vedder et al. (1979:249) reported the geologic age of *L. catalinae* found at its type locality on Santa Catalina Island as possibly late middle Miocene to late Miocene, but in their faunal list (table 5) they indicate that the specimens are of late Miocene in age. Smith (1991) restricted *L. catalinae* to Southern California and to the late middle Miocene to late Miocene, but these reports were made before it was recognized that *L. catalinae* and *L. gallegosi* are the same species. Smith (1991), furthermore, reported that the geologic age of *L. gallegosi* at its type locality on eastern Cedros Island was late Miocene, but she stated that these beds are correlative with the Almejas Formation, now known to range in age from late Miocene to early Pliocene (Carreño and Smith, in press). More work is needed to establish which mollusks come from which part of the Almejas Formation because there is a distinct possibility that float material from several horizons was collected by early workers.

Smith (1991:49) reported *L. catalinae* from the Modelo Formation in the Ventura Basin, but the unit was mapped by Dibblee (1996) as the upper Miocene Castaic Formation.

Winterer and Durham (1962) reported *L. cerrosensis* from the Pico Formation. However, their specimens were never given museum catalog numbers; thus, their identification cannot be verified. We restudied Groves's (1991a) lower Saugus specimen of "*Lyropecten cerrosensis*," which is deposited in the LACMIP collection (LACMIP locality 12599), and determined that it is *L. catalinae*.

This report is the first confirmed report of *L. catalinae* from the Pico Formation of the eastern Ventura Basin, and this occurrence represents the northernmost known limit of this species.

Family Anomiidae Rafinesque, 1815
Genus *Placunanomia* Broderip, 1832

TYPE SPECIES. *Placunanomia cumingii* Broderip, 1832, by monotypy; recent, Gulf of California to Ecuador (Keen, 1971).

Placunanomia hannibali Jordan and Hertlein, 1926
Figures 20, 21

Placunanomia hannibali Jordan and Hertlein, 1926:443–444, pl. 28, figs. 2–4; Hertlein, 1933:440; Minch et al., 1976:table 15; Moore,

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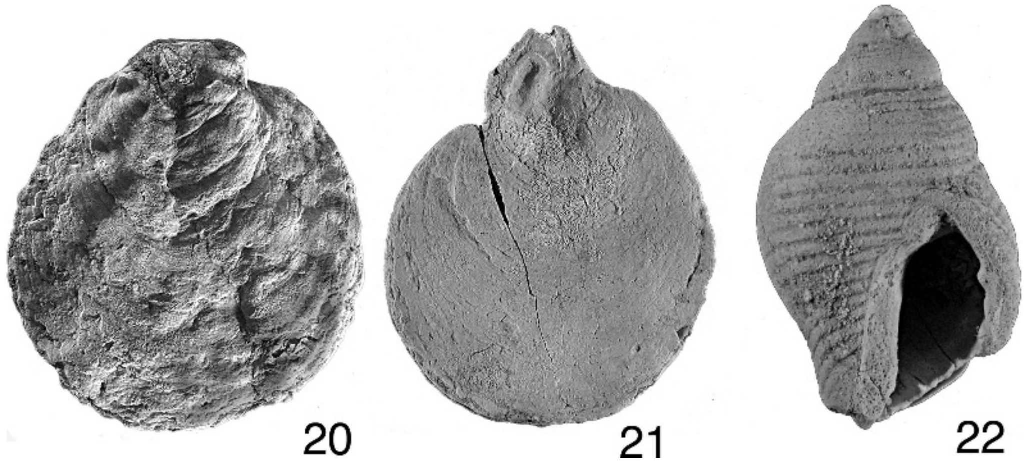
Figures 15–19 Pectinids from the Valencia area. All specimens coated with ammonium chloride. **15, 16.** *Argopecten invalidus* (Hanna, 1924). **15.** Left valve, height 38.6 mm, diameter 35.4 mm, ×1.3, LACMIP hypotype 13344, LACMIP locality 15719. **16.** Right valve, height 38.8 mm, diameter 36.8 mm, ×1.3, LACMIP hypotype 13345, LACMIP locality 17778. **17–19.** *Lyropecten catalinae* (Arnold, 1906). **17.** Left valve (incomplete), height 110 mm, partial diameter 100 mm, ×0.9, LACMIP hypotype 13346, LACMIP locality 17778. **18.** Right valve, height 142 mm, partial diameter 130 mm, ×0.7, LACMIP hypotype 13347, LACMIP locality 17778. **19.** Two valves of approximately same size placed together to simulate hinge-line view of a specimen with paired valves: left valve on bottom, partial diameter 140 mm, ×0.5, LACMIP hypotype 13348, LACMIP locality 17778; right valve on top, ×0.5, same specimen illustrated in Fig. 19



Figures 20–22 Anomiid bivalve and muricid gastropod from the Valencia area. All specimens coated with ammonium chloride. **20, 21.** *Placunanomia hannibali* Jordan and Hertlein, 1926. **20.** Left valve, height 60.4 mm, diameter 54.5 mm, ×0.9, LACMIP hypotype 13349, LACMIP locality 17777. **21.** Right valve, height 84.2 mm, diameter 69.8 mm, ×0.6, LACMIP hypotype 13350, LACMIP locality 17777. **22.** *Acanthinucella emersoni* (Hertlein and Allison, 1959), apertural view, height 23.3 mm, diameter 14.7 mm, ×2.4, LACMIP hypotype 13351, LACMIP locality 15719

1987:C12, pl. 7, figs. 2, 6, 7; pl. 8, figs. 2, 5; Smith, 1984:pl. 3, figs. 2, 3, table 1; Carreño et al., 1989:355, fig. 134h.

TYPE MATERIAL. Holotype CAS 2110; paratypes CAS 2111–2115.

TYPE LOCALITY. Prominent monadnock 3 km southeast of Tortugas Bay, Baja California Sur, Mexico; Almejas Formation, Pliocene, CAS locality 945.

GEOLOGIC AGE. Pliocene.

STRATIGRAPHIC DISTRIBUTION. LOWER PLIOCENE: Upper Almejas Formation, Cedros Island (Jordan and Hertlein, 1926) and Tortugas Bay area, Vizcaino Peninsula, Baja California Sur, Mexico (Minch et al., 1976; Smith, 1984). LOWER PLIOCENE TO POSSIBLY UPPER PLIOCENE: Imperial Formation, Imperial County, California (Powell, 1988). UPPER PLIOCENE: Pico Formation, Valencia area, northern Los Angeles County, Southern California (new information).

REMARKS. This flattish anomiid bivalve is rare in the Valencia area. Only two specimens were found at LACMIP locality 17777. Preservation is moderately good, but the specimens appear to be somewhat worn. Both have paired valves and range in height from 6 cm to 8.5 cm.

Placunanomia hannibali tends to be large (height 8 cm to 11 cm), subcircular to suboval in outline. Left valves are flat to concave with no byssal opening, and two strong internal ribs radiate from the umbo. Right valves are slightly convex, commonly with an elongate opening near the beak. Interior right valves have auricular crura that diverge strongly from the beak. The record of *P. hannibali* in the Valencia area is the northernmost occurrence of this bivalve. Although *P. hannibali* was listed by Wilson and Rocha (1955:tables 7, 8) from the Gloria and Infierno formations, near Santa Rosalía, Baja California Sur, Mexico, their species is actually *Placunanomia panamensis*, an ancient Gulf of California (i.e., Caribbean-Panamic) species.

Class Gastropoda Cuvier, 1797
Family Muricidae Rafinesque, 1815
Subfamily Ocenebrinae Cossmann, 1903
Genus *Acanthinucella* Cooke, 1918

TYPE SPECIES. *Monoceros punctulatum* Sowerby, 1835, by original designation; recent, Bolinas Bay and Monterey Bay, northern California south to Baja California, Mexico (McLean, 1978).

Acanthinucella emersoni
(Hertlein and Allison, 1959)
Figure 22

Acanthina n. sp. Santillán and Barrera, 1930:25.

Acanthina emersoni Hertlein and Allison, 1959:22–23, pl. 8, fig. 1; Deméré, 1983:193; Ashby and Minch, 1984:table 1, pl. 2, figs. 2, 3; Carreño et al., 1989:117, fig. 47a; Carreño and Smith, in press.

Acanthinucella emersoni (Hertlein and Allison). Marko and Vermeij, 1999:282.

TYPE MATERIAL. Holotype UCMP 37729, paratype UCMP 37730; paratype CAS 61694 (*ex* CAS 12120A).

TYPE LOCALITY. Marine terrace north of Agua Chiquita, northeast of San Quintin, northwestern Baja, California, Mexico; Cantil Costero Formation, Pliocene, UCMP locality A-459.

GEOLOGIC AGE. Late Pliocene.

STRATIGRAPHIC DISTRIBUTION. Pico Formation, Valencia area, northern Los Angeles County, California (new information); San Diego Formation, both "upper" and "lower" members at Pacific Beach, San Diego County, California (Deméré, 1983:193) and including upper Pliocene section at La Joya, approximately 5.5 km south of Tijuana, Baja California, Mexico (Ashby and Minch, 1984); Cantil Costero Formation, northeast of San Quintin, Baja California, Mexico (Santillán and Barrera, 1930; Hertlein and Allison, 1959, as formation undesignated); Cantil Costero Formation, between San Quintin and El Rosario, Baja California, Mexico (Carreño and Smith, in press).

REMARKS. Three specimens were found, and they are generally well preserved, although the labial tooth on the outer lip is broken on all of them. The species has a thick shell, rounded whorls, apex commonly broken, and a labial tooth on the outer lip (also commonly broken). Broad spiral bands separated by narrow grooves ornament the shell, which has a deep anterior notch and well-developed siphonal fasciole.

This gastropod was originally assigned to *Acanthina*, but Marko and Vermeij (1999) restricted the genus to South America. They reassigned "*Acanthina*" *emersoni* to the genus *Acanthinucella*.

In the vicinity of its type locality, *Acanthinucella emersoni* is found with the following taxa: *Lyropecten* cf. *L. catalinae* [identified by Hertlein and Allison (1959) as *Pecten* cf. *P. gallegosi*], *Myrakeena veatchii* [identified by Hertlein and Allison (1959) as *Ostrea vespertina* and *Ostrea vespertina veatchii*], the barnacle *Megabalanus californicus* [identified by Hertlein and Allison (1959) as *Balanus tintinnabulum*], the sand dollar *Dendraster ashleyi*, and *Pecten* (*Pecten*) *bellus*. All but the last species are found in the Pico Formation in the Valencia area.

The occurrence of *Acanthinucella emersoni* from the Valencia area represents the northernmost known limit of this species.

PALEOTEMPERATURE IMPLICATIONS OF THE MEGAFAUNA

Biogeographic distribution data for nearly all the species that occur in the Valencia area have been tabulated by Groves (1991a) in a detailed faunal analysis of Pliocene to Pleistocene megafauna from the southern part of the Santa Susana Mountains. Most of the species from the Valencia area were also found in central California during the Pliocene and represent warm-temperate paleoenvironmental conditions. Some of these species are extant and live in warm-temperate waters off Southern California. Only one species, *Dosinia ponderosa*, is presently found in more southerly, warmer waters between 28°N and 5°S (Keen, 1971; Bernard, 1983) and is not found today north of Scammon's Lagoon (=Laguna Ojo de Liebre), Baja California Sur, Mexico (Keen, 1971; Rowland, 1972).

Four of the extinct mollusks from the Valencia area, however, are unexpected because all available data limit their paleobiogeographic distribution to subtropical areas to the south. They are *Argopecten invalidus*, *Lyropecten catalinae*, and *Placunanomia hannibali* and *Acanthinucella emersoni*. Their occurrence, reported here for the first time in the Ventura Basin, represents their northernmost records. They otherwise occur only in fossil deposits in Southern California and Baja California, as far south as the Vizcaino embayment. Extant species of these three genera, furthermore, are indicative of the Pacific-Panamic Province. *Argopecten* is represented by numerous extant species, and most argopectinids live in tropical to subtropical regions (Hertlein, 1969; Waller, 1995). Extant species of *Placunanomia* are found in warm waters in the Gulf of California, Mexico, and/or farther south to either Panama or Ecuador (Keen, 1971). The gastropod *Acanthinucella emersoni* occurs elsewhere only in San Diego and northern Baja California, Mexico. *Lyropecten magnificus*, the sole surviving species of this genus, occurs in tropical waters in the Galapagos Islands and in western Colombia (Smith, 1991).

Although the northern occurrence of *Myrakeena veatchii* is in the La Honda area west of Santa Clara, San Mateo County, California (Powell, 2000), its occurrence in the Valencia area is noteworthy because it is a common component of warm-water assemblages in Baja California. The LACMIP collection contains many specimens of this oyster from the Almejas Formation at the south end of Tortugas Bay (LACMIP locality 962), Baja California Sur, Mexico. In addition, *Myrakeena angelica*, the sole surviving species of this genus, occurs in warm-water embayments and warm waters from San Ignacio Lagoon, Baja California Sur, to Mazatlan, Sinaloa, Mexico (Hertlein and Grant, 1972; Harry, 1985).

According to Addicott (1970), in response to the progressive climatic cooling during the Pliocene, by the late Pliocene, extralimital mollusks of tropical and subtropical affinities had almost entirely disappeared from California. The Ventura Basin, however, was a narrow east-to-west reentrant along the Pacific coast during the Pliocene (Corey, 1954) (Fig. 1); its shallower waters, especially those associated with the shoaling areas of the deltaic environment, could have been relatively warm, thereby supporting the local conditions needed for *A. invalidus*, *L. catalinae*, *P. hannibali*, *A. emersoni*, as well as *M. veatchii*.

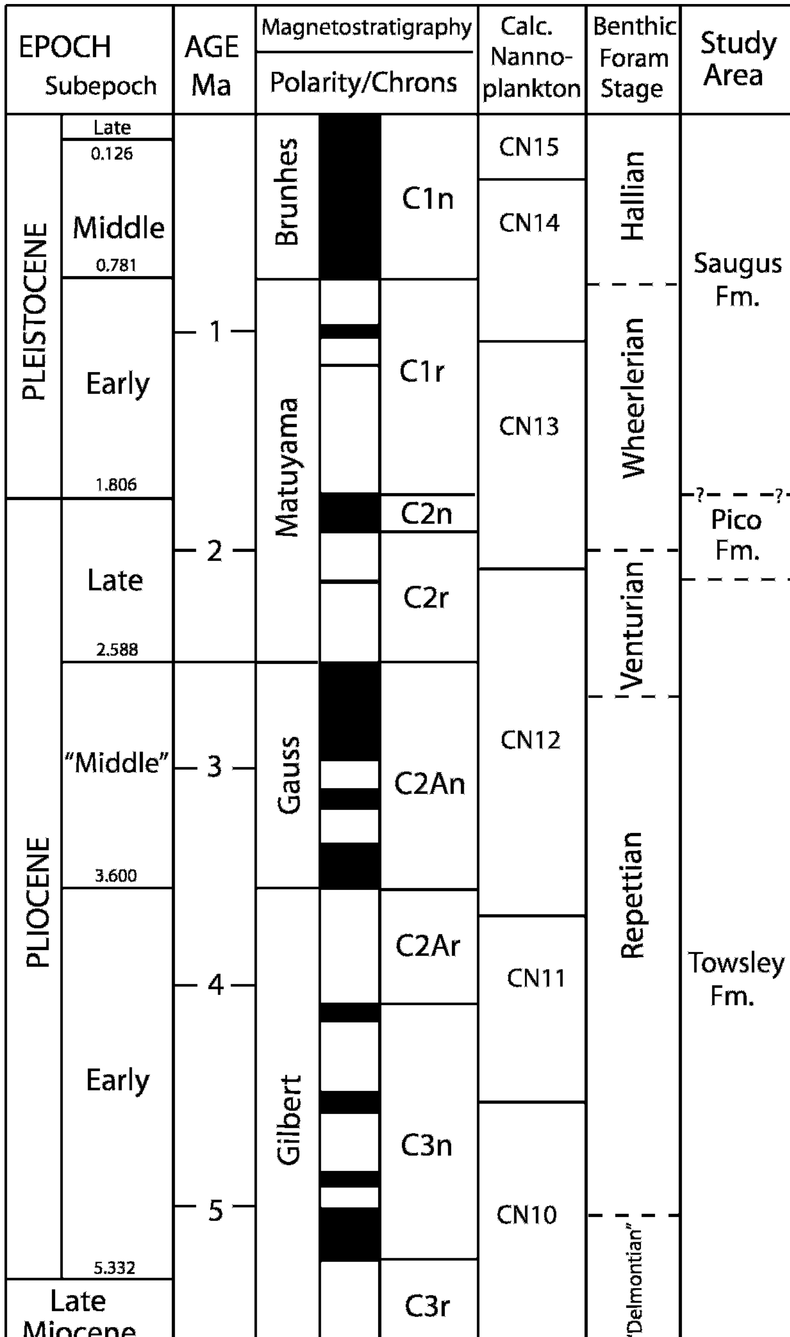


Figure 23 Chronostratigraphic framework for the Pliocene and Pleistocene showing correlation of magnetostratigraphic units to eastern equatorial Pacific calcareous nannoplankton zones (from Gradstein et al., 2004) and Californian benthic foraminiferal stages (from Natland, 1952; Blake, 1991)

AGE

Most of the molluscan species found in the Valencia area basal and middle units of the shoreface sandstones have relatively long chronologic ranges; hence, these species have limited biochronologic utility. Eight species, however, are confined to the Pliocene and are listed in Table 2. In addition, the pectinid *Patinopecten healeyi* is most likely restricted to the Pliocene (Moore,

Table 2 Study area species whose geologic range has been reported as confined to the Pliocene. Asterisk denotes probable restriction to the Pliocene.

Taxon	Source of information
Myrakeena veatchii	See "Systematics"
Argopecten invalidus	See "Systematics"
**Patinopecten healeyi*	Hertlein and Grant, 1972
Placunanomia hannibali	See "Systematics"
Chione (*Securella*) *kanakoffi*	Hertlein and Grant, 1972
**Maxwellia elridgei*	Powell and Stevens, 2000
Acanthinucella emersoni	Hertlein and Allison, 1959
Nassarius (*Demondia*) *californicus*	Addicott, 1965
Cancellaria hemphilli	Grant and Gale, 1931
Terebra (*Strioterebrum*) *martini*	Woodring and Bramlette, 1950 [1951]

1984; C.L. Powell, II, personal communication), as is, according to Powell and Stevens (2000), the gastropod *Maxwellia eldridgei*. Because the upper unit of the shoreface sandstones of the Pico Formation in the Valencia area as well as the interfingering basal part of the overlying Saugus Formation are unfossiliferous, their ages are equivocal.

Although there are provincial molluscan stages for Pliocene strata in California, correlation of the Valencia area to any of these stages is tenuous. The framework for these provincial "stages" stems from the early work by Arnold (1906) on pectinids. Neogene mega-invertebrate "stages" were eventually informally named by Weaver et al. (1944), who relied heavily on Woodring et al.'s (1940 [1941]) tripartite chronostratigraphic subdivision of marine Pliocene strata in California based on large invertebrates from the Jacalitos, Etchegoin, and San Joaquin formations in the Coalinga area, Fresno County, central California. Recognition of these three biochronologic subdivisions in other California basins has proved difficult (Durham and Addicott, 1965; Addicott, 1977), and this is also true for the Valencia area. Stanton and Dodd (1976) recognized that a formalized biostratigraphic zonation of the marine Pliocene of the Pacific slope is much needed. To date, this zonation is still informal and not very useful.

The benthic foraminifera found by Winterer and Durham (1962) in the muddy siltstone parts of the Pico Formation in the immediate vicinity of the Valencia area represent a relatively diverse assemblage, characterized by *Bulimina subacuminata* in the siltstone in the lower part of the Pico Formation (i.e., the upper to middle bathyal siltstone depicted in Fig. 4), and *Uvigerina peregrina* and *Epistominella pacifica* in the siltstone upsection in the Pico Formation (i.e., the delta or delta-influenced siltstone depicted in Fig. 4). Winterer and Durham (1962) did not base any geologic age(s) on these foraminifera because all three of them live today off the California coast (Bandy, 1953). *Bulimina subacuminata* characterizes the benthic foraminifera-based Venturian Stage of Natland (1952), which was assigned by Blake (1991) to the late Pliocene (Fig. 23). *Uvigerina peregrina* and *Epistominella pacifica* characterize Natland's Wheelerian Stage, which Blake (1991) assigned to the uppermost Pliocene to early Pleistocene (Fig. 23).

Paleomagnetic studies (Levi and Yeats, 1982, 1983; Levi et al., 1986) of the Saugus Formation revealed that the base of this formation at the "Transmission Line Section," 6.3 km northwest of the Valencia area, is roughly equivalent to the base of the Pleistocene in the Matuyama paleomagnetic zone (Fig. 23). These workers, however, did not discuss how they determined the base of the Saugus Formation. Assuming their age is correct, it cannot be uniformly applied everywhere to the top of the Pico Formation or the base of the Saugus Formation because the prograding deltaic paleoenvironment associated with these beds is time transgressive, becoming younger to the west. In fact, the deltaic deposits that accumulate today at the mouth of the Santa Clara River at Ventura, California, represent modern counterparts of this same prograding delta (Winterer and Durham, 1962:315).

In summary, the age of the lower part of the Pico Formation in the Valencia area is late Pliocene, based on benthic foraminifera (Venturian). The foraminifera (Wheelerian) in the upsection muddy siltstone indicate either a late Pliocene or early Pleistocene age, but the overlying shoreface sandstones contain several species of mollusks (San Joaquin) that are known to be confined to the Pliocene; therefore, we interpret the upper part of the muddy siltstone and the overlying shoreface sediments to be of late Pliocene age (Fig. 23).

Based on its presence in the Pico Formation in the Valencia area, the geologic age range of the gastropod *Crassispira* (*Burchia*) *semiinflata* (Grant and Gale, 1931) is extended back to the late Pliocene. This species was known previously only from the Santa Monica Mountains, Southern California, in a terrace of late Pleistocene age (Grant and Gale, 1931). We also report this species, for the first time, from the Niguel

Formation (LACMIP locality 5610), of late Pliocene age (Vedder, 1960), in Orange County, California.

Relative to other molluscan faunas in the southeastern Ventura Basin, the Valencia area fauna is younger than the early Pliocene megafauna (Kern, 1973) in the Towsley Formation east of Newhall (Fig. 1) in Elsmere Canyon, 6.5 km east of the Valencia area. The two faunas share at least 20 species. The megafauna in the Valencia area is approximately the same age as the latest Pliocene to earliest Pleistocene megafauna in the lower Saugus Formation between Browns Canyon and Gillibrand Canyon along the south flank of the Santa Susana Mountains, 8 km to 19 km southwest of the Valencia area (Fig. 1). The two faunas share at least 31 species, including *Lyropecten catalinae* and abundant *Myrakeena veatchi*.

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