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Late Pliocene Megafossils of the Pico Formation, Newhall Area, Los Angeles County, Southern California[1]

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ABSTRACT. Taxonomic composition and stratigraphic distribution of megafossils in the Pico Formation south of Newhall, northern Los Angeles County, Southern California, are described in detail. Eighty-three taxa, from 15 localities, were found: one brachiopod, 36 bivalves, 40 gastropods, one scaphopod, one crab, one barnacle, one sea urchin, one shark, and one land plant. All are illustrated here. The pectinid bivalve *Argopecten invalidus* (Hanna, 1924) is put into synonymy with *A. subdolus* (Hertlein, 1925) and *A. callidus* (Hertlein, 1925). Rare specimens of the gastropods *Calliostoma* and *Ocinebrina* might be new species.

The mollusks, which are indicative of a late Pliocene age, lived in waters of inner sublittoral depths and normal marine salinity. Most of the 41 extant species indicate warm-temperate waters similar to those occurring today off the adjacent coast, although a few species, both extant and extinct, indicate a southerly warmer water component. The fauna lived predominantly in, or on, soft sands, but a few lived on other shells or possibly on large rock clasts.

Geologic field mapping done as part of this present study revealed that the Pico Formation south of Newhall was deposited at the site where a braided river entered the marine environment (i.e., braid delta). Initially, the river gravel and coarse sand interfingered with relatively deep offshore silts, barren of megafauna, in the lower and middle parts of the formation. Eventually, the delta built up, and the resulting shoaling conditions in the upper part of the formation were conducive for the megafauna to live in, or immediately adjacent to, the deltaic shoreface fine sands. Storm waves raked the delta and concentrated the shells of the megafauna, along with cobbles of igneous and metamorphic basement rocks, into channelized deposits. Postmortem transport distance was short, as evidenced by many paired-valved bivalve shells.

INTRODUCTION

During the Pliocene, the Pico Formation was deposited for a distance of approximately 92 km along the axis of the Ventura Basin, which trends parallel to the present course of the modern Santa Clara River in Southern California (Fig. 1). The formation has its broadest extent of outcrops in the Ventura area, and the outcrop pattern narrows significantly eastward toward the Newhall area. The Pico Formation represents the youngest marine deposits in the eastern Ventura Basin. Throughout most of this basin, the Pico Formation is an offshore-marine sequence consisting of siltstone, mudstone, and claystone with some minor amounts of sandstone and conglomerate. Megafossils are sparse, but relatively deep-water benthic foraminifera are common. To the east, toward Val Verde and Valencia (Fig. 1), the formation becomes increasingly sandier and conglomeratic, and shallow-marine gastropods and bivalves are locally common in the upper part (Grant and Gale, 1931; Squires et al., 2006). The purposes of this present study are to 1) determine how far east the shallow-marine megafossiliferous beds continue beyond the Valencia area into the stratigraphically and structurally complex Newhall area, 2) tabulate and illustrate the taxonomic composition of the megafauna, and 3) establish its age, depositional environment, and zoogeographic implications.

All preexisting geologic maps (e.g., Winterer and Durham, 1958, 1962; Dibblee, 1991a, 1992a) of the Newhall area are inconsistent in regard to 1) the differentiation of the Pico Formation from the other Neogene stratigraphic units in the area (i.e., Towsley Formation, Saugus Formation, and Sunshine Ranch Member of the Saugus Formation), 2) the structural geology of the area, and 3) the depositional environments the Pico Formation. Also, no previous detailed megafossil investigations were done. It was necessary, therefore, to do my own geologic mapping in order to understand the fundamental geologic relationships of the easternmost Pico Formation in the Ventura Basin. The outcome is that the Pico Formation in the Newhall area is recognized for the first time as having been deposited in a braid-delta environment. This study is important because it affords the unusual opportunity to observe the complex interfingering between the fluvial and marine components of a Tertiary-age, predominantly marine formation in Southern California. The study area encompasses where the two environments interfinger for a lateral distance of approximately 5 km, and the lateral-fluvial component extends eastward for an additional 3 km (Fig. 2).

There might be a few small outcrops of the Pico formation just south and southeast of the study area in the San Fernando Valley (e.g., Lopez Canyon) (Chen, 1988) and, possibly, a fault-bounded, small outcrop approximately 22 km southeast of Newhall (Berry et al., 2009) in Gold Creek, a tributary of Big Tujunga Canyon.

PREVIOUS WORK

The earliest work on fossils from the study area was by Gabb (1869:49), who described a few species of Pliocene mollusks from an area originally referred to as Fremont Pass, later known as San Fernando Pass, and now known as Newhall Pass, located just north of the junction of U.S. Interstate 5 and California State Highway 14. Ashley (1895:338) listed some mollusks from the same general area. None of his specimens were illustrated nor were they assigned a museum catalog number; they could not be located.

Eldridge and Arnold (1907:22) used the name "Fernando" for an enormous section of siliciclastics, largely of Pliocene age, that crops out over a considerable area of Southern California, including the study area. Instead of basing the section on lithology, they improperly based it on three megafossil zones (collectively of Pliocene age). They erroneously lumped fossils found in Newhall Pass and Elsmere Canyon, but they listed only the fossils from Elsmere Canyon. The former beds belong to the

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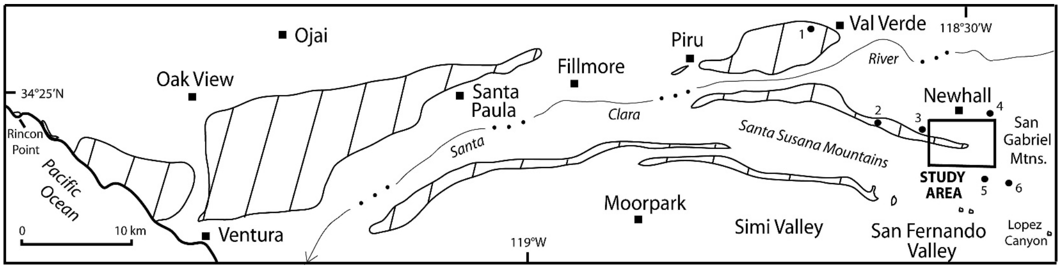


Figure 1 Index map showing outcrop-distribution map of the Pico Formation (slanted lines) in the Ventura Basin. Newhall-area outcrops (shown in box) based on this present report; remaining map area based on Dibblee (1987a, b, c; 1988; 1990a, b; 1991a, b; 1992a, b, c, d, e, f; 1993; 1996a, b). Specific locales: 1 = Holser Canyon; 2 = Pico Canyon, the type section of the Pico Formation; 3 = Valencia; 4 = Running Horse area; 5 = Los Angeles County Aqueduct (the "cascades"); and 6 = Stetson Ranch Park area.

Pico Formation, and the latter beds are now referred to as the Towsley Formation of early Pliocene age (Winterer and Durham, 1962; Kern, 1973). English (1914) and Kew (1918) used "Fernando Group" and "Fernando formation," respectively, for outcrops in the eastern Ventura Basin, but these units are vague, ambiguous, and should not be used.

Kew (1923) was the first worker to use the name "Pico" (following Clark's 1921 informal use of this name) for the lower part of the "Fernando Group." Kew (1924) formally defined the Pico Formation by designating a type section area in the vicinity of Pico Canyon, 11 km northwest of Newhall Pass (Fig. 1). Although he listed megafossils found in the Pico Formation, none of his localities are from the Newhall area. Kew (1924) incorrectly correlated beds in Elsmere Canyon to his Pico Formation. Grant and Gale (1931) over-applied Kew's (1924) name "Pico" to include all the Pliocene marine beds in the Ventura Basin. They failed to recognize that the beds, now referred to as the Towsley Formation, are lithologically different from the overlying Pico Formation. They subdivided the so-called "Pico" unit into three zones and correlated the fossiliferous beds in the Newhall area just west of Newhall Pass to their "San Diego Zone." They mistakenly referred any molluscan species found in the Newhall area to a "middle" Pliocene age. They mentioned and illustrated a few fossils from four localities just west of Newhall Pass (see "Localities" for equivalency to Natural History Museum of Los Angeles County Invertebrate Paleontology Section [LACMIP] localities).

Detailed geologic maps of all or part of the Newhall area were prepared by Rynearson (1938), Oakeshott (1958), Winterer and Durham (1958, 1962), Kern (1973), Barrows et al. (1975), Nelligan (1978), Dibblee (1991a, 1992a, 1996a), and Yerkes and Campbell (2005). No two maps are in agreement with regard to the outcrop distribution of the Pico Formation, and there are also inconsistencies as to which stratigraphic name(s) should be used.

Rynearson (1938), Winterer and Durham (1962:table 4), and Dibblee (1992a) mentioned a few fossil localities. They are in the central part of the study area and were recollected by the author (see "Localities" for equivalency to LACMIP localities). Rynearson was a student at Caltech, and his senior-thesis fossil collections became part of the LACMIP collection when Caltech donated its collections to LACMIP. Winterer and Durham (1962:table 4) provided a faunal list of some species they collected, but none of their specimens were illustrated or assigned a museum catalog number and they could not be located. Winterer and Durham (1962) also studied the benthic foraminifera fauna of Pico Formation just north of Gavin Canyon in the southwestern part of the Newhall area.

Dibblee (1991a) reported exposures of the Pico Formation just south of the study area in 1) a prominent cliff where the Los Angeles Aqueduct is aboveground at the "cascades" and 2) in another prominent cliff approximately 1.8 km to the east, in the Stetson Ranch area of Sylmar (Fig. 1). Both areas were examined by the author, and the exposures were placed in the Towsley Formation because they include greenish-gray sandstones like those of the Towsley Formation.

Oakeshott (1958:81), Ehlig (1975:14), and Powell (1993:43) reported that there are outcrops of the Pico Formation along the trend of the San Gabriel Fault just north of Placerita Canyon and approximately 1.5 km northeast of the northeastern corner of the Newhall area. Dibblee (1996b) mapped these same outcrops as the Saugus Formation. In order to resolve the issue, the area of Running Horse Road (Fig. 1), just north of the Placerita Nature Center, was examined, and these exposures possibly belong to the Sunshine Ranch Member? of the Saugus Formation.

Squires (2008) studied the geology of the Eocene Juncal Formation east of Newhall and provided a generalized geologic map that included the Pico and Saugus formations. Squires et al. (2006) studied the Pico Formation immediately west of the western border of the Newhall area. The term "Pico Formation" is used in this present report because of the historic usage of the term, thereby reducing further stratigraphic nomenclature confusion. A more appropriate term would be "marine facies of the Saugus Formation."

MATERIALS AND METHODS

Field work was begun in March 2006 but most of field time occurred during the last half of 2011. The geology was mapped at a scale of 1:12,000, and megafossils and rock samples were collected. Every available road and trail was hiked, and a considerable amount of cross-country traversing was done. The field area comprises steep terrain, and 30-m-high or higher vertical cliffs are common, as is dense vegetation that is impenetrable in many places. The shoreface deposits in the uppermost part of the formation are especially difficult to access because of these problems. There is no continuous stratigraphic section to measure the formation from its base to its top because of faults and local incisement by overlying stratigraphic units. Thicknesses were derived by means of graphical techniques: the Elsmere Ridge area was used for the fluvial part of the formation, and the Gavin Ridge area was used for the marine part of the formation (Fig. 2).

Fossils were studied from 15 localities: eight previously known and seven new localities. Some of the previously known localities have been assigned, over the years, to different but equivalent or approximately equivalent locality numbers. Approximations had to be made for some of the previous localities because their word descriptions are inexact and the localities were never precisely plotted on a map but are in close proximity to where the present collections were made. In those cases, new locality numbers based on personal mapping (e.g., LACMIP locs. 17917 and 17918) were assigned.

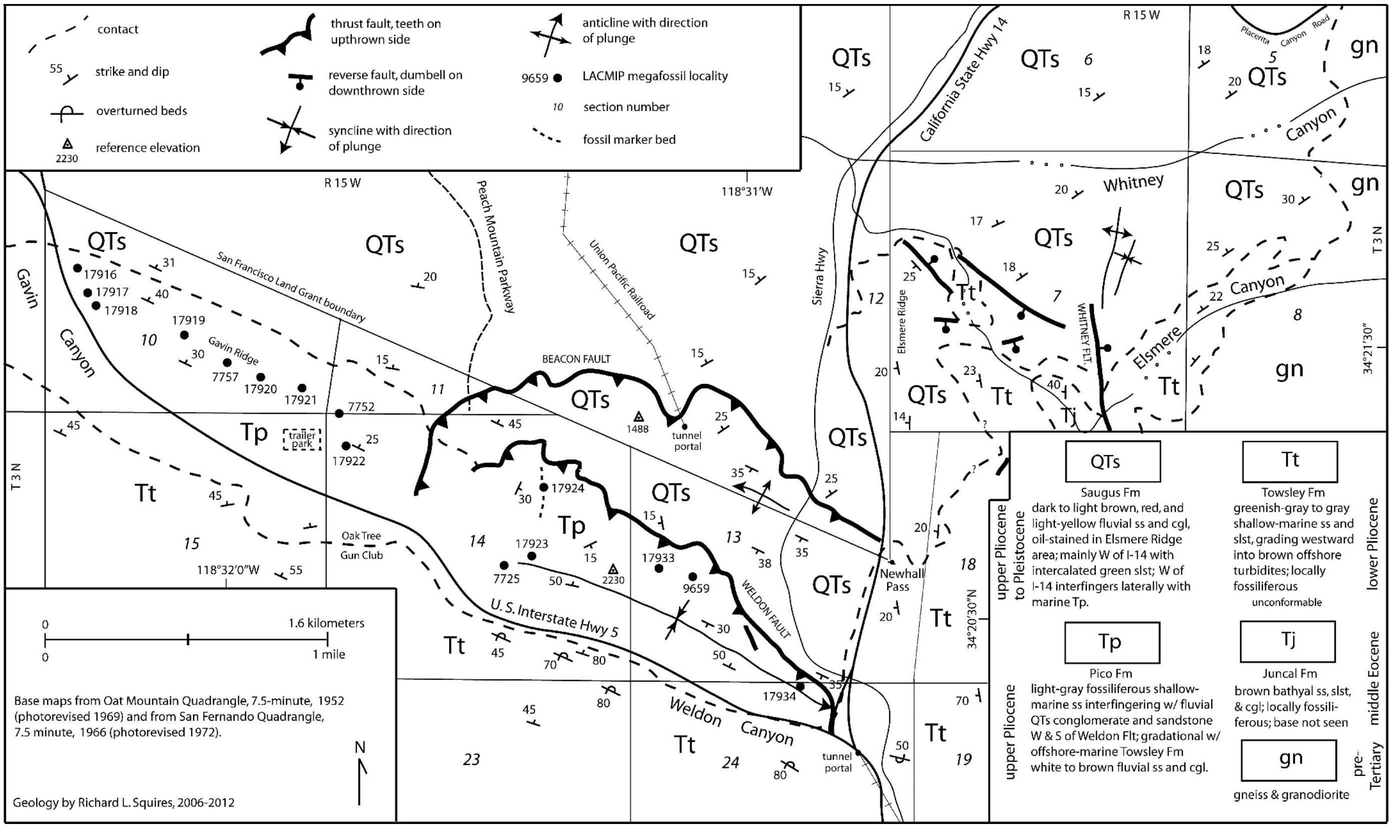


Figure 2 Geologic map of the study area south of Newhall, northern Los Angeles County, California.

A total of 2020 specimens were studied, and approximately half of these specimens were personally collected. The figured specimens, as well as all the other megafossils collected in the course of this study, were deposited in the LACMIP collection.

Matrix was removed from the fossils by the use of hammer and chisel, and, for fine cleaning, a high-speed drill. A systematic treatment for each megafaunal species is not given here because no new information was gleaned for most of the species collected during the present study. Previous synonymies, distinctive morphologic characters, and stratigraphic distributions, etc. are available for most of the species in works such as Arnold (1903), Grant and Gale (1931), Hertlein and Grant (1972), Groves (1991), Davis (1998), and Squires et al. (2006). New information is given here in the "Systematics" section for newly recognized synonyms of the pectinid *Argopecten invalidus* and for two potential new species of gastropods. Figures of the taxa listed in Table 1 are included here in order to verify this list, and the numerical order of these figures corresponds to the systematic organization used for the faunal list.

ABBREVIATIONS: Abbreviations used for locality and/or catalog numbers are CAS (California Academy of Sciences, San Francisco; includes the Stanford University [SU] collection), and LACMIP (Natural History Museum of Los Angeles County, Invertebrate Paleontology Section).

LOCALITIES

All are LACMIP localities in the Pico Formation of upper Pliocene age, and located relative to the United States Geological Survey Oat Mountain Quadrangle (7.5 minute), 1952 (photorevised 1969), Los Angeles County, southern California.

7725. 118°31′40″W, 34°20′35″N. Elevation 549 m (1800 ft.), crest of spur at base of power-line tower, 703 m (2300 ft.) north and 703 m (2300 ft.) west of southeast corner of section 14. Collectors: H.M. Rice (*circa* early 1930s) and R.L. Squires, October 1, 2011. **7752 [= 5547].** 118°31′15″W, 34°21′08″N. Elevation 427 m (1400 ft.), northeast of trailer park in north–south-trending canyon, on south section-line, 91 m (300 ft.) east of northeast corner of section 14. Locality represents float material from a bed located a short distance to the north at the head of a box canyon with inaccessible vertical cliffs. Collectors: H.M. Rice (*circa* early 1930s); L.G. Barnes and G. Campbell, April 1965; and R.L. Squires, October 9, November 13, and December 4, 2011. **7757.** 118°32′33″W, 34°21′15″N. Elevation 525 m (1725 ft.), on ridgeline, 290 m (950 ft.) north and 1036 m (3400 ft.) east of southwest corner of section 10. Collectors: H.M. Rice (*circa* early 1930s) and R.L. Squires, October 21, 2011. **9659.** 118°31′14″W, 34°20′34″N. Elevation 637 m (2090 ft.), on ridgeline, 655 m (2150 ft.) north and 381 m (1250 ft.) east of southwest corner of section 24. Collectors: G.A. Rynearson (1938) and R.L. Squires, September 4, 2011. Equivalent to loc. 212 of Grant and Gale (1931:102). **17916.** 118°32′49″W, 34°21′33″N. Elevation 434 m (1425 ft.), south side of disused road near south end of housing tract south of Calgrove Blvd., 899 m (2950 ft.) north and 168 m (550 ft.) east of southwest corner of section 10, T 3 N, R 16 W. Collector: R.L. Squires, October 21, 2011. **17917 [= 7761 and approximately 7226 and 10339].** 118°32′47.5″W, 34°21′30″N. Elevation 480 m (1575 ft.), east side of power line road east of Gavin Canyon, 747 m (2450 ft.) and 213 m (700 ft.) east of southwest corner of section 10, T 3 N, R 16 W. Collectors: H.M. Rice (*circa* early 1930s); G.M. Dorwat, March 22, 1943; C.R. Stauffer, 1949; and R.L. Squires, October 21, 2011. **17918 [= 7760].** 118°32′48″W, 34°21′28″N. Elevation 450 m (1475 ft.), north side of power line

Table 1 Megafossils of the Newhall area Pico Formation listed systematically and with relative abundance vs. localities (arranged west to east).

Taxa	LACMIP locs.														
	17916	17917	17918	17919	7757	17920	17921	7752	17922	17925	17923	17924	17933	9659	17934
Brachiopoda: Articulata															
Terebratalia occidentalis (Dall, 1871)		A*	A*	R*				C*		A*					
Mollusca: Bivalvia															
Jupiteria taphria (Dall, 1896)		R*	A*				R*	R							
Arcopsis sp.			R												
Anadara trilineata (Conrad, 1856)								R							R*
Limaria sp., cf. *L. orcutti* (Hertlein & Grant, 1972)		F													
Myrakeena veatchii (Gabb, 1866)	R	A*	F	A*	R*	R		C*						A*	F
Argopecten invalidus (Hanna, 1924)		A*	A*	A*	A*	F		A*	F*	C*	C*	F		C*	A*
Lyropecten catalinae (Arnold, 1906)	F	R	F*	R	R			F*		C*		R		F	R*
Swiftopecten parmeleei (Dall, 1898)				R											
Leopecten stearnsii (Dall, 1878)						R				F*					
Patinopecten healeyi (Arnold, 1906)		R*	R	R		R			R	C	R	R*		R*	
Pododesmus macroschisma (Deshayes, 1839)		R													
Epilucina californica (Conrad, 1837)			F					R		R					
Here excavata (Carpenter, 1857)	R	F*	A*		R	R	R	A*			R		F		R
Lucinisca nuttalli (Conrad, 1837)			R							R					
Lucinoma annulatum (Reeve, 1850)			R*								R				
Miltha xantusi (Dall, 1905)	F	F		R		R		R*	F*	R*		F*			R*
Cyclocardia occidentalis Conrad, 1855		C	A		R	A				C					R
Trachycardium (*Dallocardia*) *quadragenarium* (Conrad, 1837)		R	R*	R	R*	R		F*		C	R*		R	R	F*
Chione (*Anomalocardia*) *fernandoensis* English, 1914			A	R*			R	R*		C				R	R
Callithaca tenerrima (Carpenter, in Gould and Carpenter, 1857)	R	R*	R*	R*				F*		R					R
Compsomyax subdiaphana (Carpenter, 1864)		R*	R*		R			F							
Amiantis callosa (Conrad, 1837)	F							F							
Dosinia ponderosa (Gray, 1838)										R*					
Saxidomus nuttalli Conrad, 1837							R*	R*							
Tresus nuttallii (Conrad, 1837)	R*							F*							R*
Macoma (*Rexithaerus*) *secta* (Conrad, 1837)	R*							R*		F*		R*			
Macoma nasuta (Conrad, 1837)	R*							F							
Leporimetis obesa (Deshayes, 1855)		F*		R*	R*		R*	R*							
Tellina (*Tellinella*) *idae* Dall, 1891		R*	R*			F*							R*		R*
Gari sp.		R*		R	F					R*					
Solen (*Ensisolen*) *sicarius* Gould, 1850	R	F	C	F	A*	R	R	C	R	C	R				
Solen sp., cf. *Solen perrini* Clark, 1915			R					C			R*				
Panopea abrupta (Conrad, 1849)	R*	R*	R*		R			A*		R*	R				R*
?*Chaceia ovoidea* (Gould, 1851)					R										
Pandora (*Heteroclidus*) *punctuata* Conrad, 1837			R		R										
?*Cyathodonta pedroana* Dall, 1915				R	R			R							
Mollusca: Gastropoda															
Haliotis sp.							R								
Calliostoma sp., *C.* cf. *splendens* Carpenter, 1864			F					R							
Calliostoma sp.,aff. *C. grantianum* Berry, 1940			R												

Table 1 Continued.

Taxa	LACMIP locs.														
	17916	17917	17918	17919	7757	17920	17921	7752	17922	17925	17923	17924	17933	9659	17934
Chlorostoma gallina form *multifilosa* Stearns, 1892		R						F							
Homoploma paucicostatum? (Dall, 1871)			R												
Pomaulax gradata Grant and Gale, 1931		R	F					C							R
Lirobittium asperum (Gabb, 1861)			A					R							
Turritella cooperi Carpenter, 1864	A	A	A	A	A	A	F	A	F	A	A	A	C	A	A
?*Calyptraea* (*Trochita*) sp.		F	A					R		R					
Crepidula aculeata (Gmelin, 1791)	R		A					R		A					
Grandicrepidula princeps (Conrad, 1857)							R								
Zonaria (*Neobernaya*) *spadicea* (Swainson, 1823)					R			R							
Glossaulax reclusiana (Deshayes, 1839)	R	F	A	F	F	F		A	R	C	R			R	
Cryptonatica clausa (Broderip & Sowerby, 1829)								R							
Sinum scopulosum (Conrad, 1849)			R		R			R							
Asperiscala sp., cf. A. *minuticostata* (De Boury, 1912)	R				R										
Amaea (*Scalina*) sp., cf. *A.* (*S.*) *edwilsoni* DuShane, 1977		R													R
Cymatium sp., cf. *C.* (*Reticutriton*) *elsmerense* (English, 1914)		R													
Ocinebrina atropurpurea (Carpenter, 1865)								R							
Ocinebrina sp., aff. *O. fraseri* (Oldroyd, 1920)			R												
Calicantharus humerosus (Gabb, 1869)		A	C	R	C	R	R	A		C	C	R			C
Calicantharus fortis (Carpenter, 1864)		F	R		R	R									
Alia tuberosa (Carpenter, 1864)			F												R
Amphissa sp.			R												
Barbarofusus barbarensis (Trask, 1855)		R	C	R											R
Nassarius (*Demondia*) *californianus* (Conrad, 1856)		F	A		R		R	C		A					A
Callianax baetica (Carpenter, 1864)			R												
Californiconuscalifornicus? (Reeve, 1843a)			R		R										
Ophiodermella inermis (Reeve, 1843b)			R		R										
Cockerella conradiana (Gabb, 1866)			R												
Elaeocyma sp.			R					R							
Crassispira sp.			R												
Terebra (*Strioterebra*) *martini* English, 1914		R	A		R	R		F		R					R
Cancellaria altispira Gabb, 1869															R
Cancellaria hemphilli Dall, 1909					R										
Cancellaria tritonidea? Gabb, 1866								R							
Cancellaria hamlini Carson, 1926				R											
Turbonilla sp.			R												
Rictaxis painei grandior Grant & Gale, 1931			R					R		R				R	
Acteocina culcitella? (Gould, 1853)			R												
Mollusca: Scaphopoda															
Dentaliumneohexagonum Sharp and Pilsbry, in Pilsbry and Sharp, 1897		R		R											
Arthropoda: Crustacea: Cirripedia(barnacles)															
Balanus? sp.		R						R							

Table 1 Continued.

Taxa	LACMIP locs. 17916	17917	17918	17919	7757	17920	17921	7752	17922	17925	17923	17924	17933	9659	17934
Arthropoda: Decapoda															
Crab leg (partial)			R												
Echinodermata: Echinoidea (sea urchins)															
Eucidaris sp. (spine)		R	R				F	R							
Vertebrata:Chrondrichthyes															
Myliobatis sp. (ray tooth)								R							
Plantae: Pinophyta (conifers)															
Pine cone								R							

Abbreviations: A = abundant (>10 specimens); C = common (5–9 specimens); F = few (3–4 specimens); R = rare (≤2 specimens).
* Some or all valves paired.

road east of Gavin Canyon, 701 m (2300 ft.) north and 267 m (875 ft.) east of southwest corner of section 10, T 3 N, R 16 W. Collectors: G.M. Dorwat, March 22, 1943, and R.L. Squires, October 21, 2011. **17919.** 118°32′38″W, 34°21′16.5″N. Elevation 506 m (1660 ft.), on ridgeline just below "0" in "10," 480 m (1575 ft.) north and 777 m (2550 ft.) east of southwest corner of section 10, T 3 N, R 16 W. Collector: R.L. Squires, November 7, 2010, and October 21, 2011. **17920.** 118°32′30″W, 34°21′12″N. Elevation 518 m (1700 ft.), on ridgeline 259 m (850 ft.) north and 419 m (1375 ft.) west of southeast corner of section 10, T 3 N, R 16 W. Collector: R.L. Squires, December 10, 2011. **17921.** 118°32′22″W, 34°21′,10″N. Elevation 549 m (1800 ft.), on ridgeline 152 m (500 ft.) north and 129 m (425 ft.) west of southeast corner of section 10, T 3 N, R 16 W. Collector: R.L. Squires, December 10, 2011. **17922.** 118°32′14″W, 34°21′00″N. Elevation 479 m (1570 ft.), on east side of power line road just east of trailer park, 198 m (650 ft.) south and 122 m (400 ft.) east of northwest corner of section 14. Collector: R.L. Squires, October 9, 2011. **17923.** 118°31′40″W, 34°20′35.5″N. Elevation 610 m (2000 ft.), 739 m (2425 ft.) north and 533 m (1750 ft.) west of southeast corner of section 14. Collector: R.L. Squires, September 4, 2011. Equivalent to southernmost loc. of Dibblee (1992a). **17924.** 118°31′38″W, 34°20′53″N. Elevation 632 m (2075 ft.), on north–south-trending ridgeline, 1204 m (3950 ft.) north and 488 m (1600 ft.) west of southeast corner of section 14. Collector: R.L. Squires, September 25, 2011. Equivalent to loc. 213 of Grant and Gale (1931:102) and to the northernmost loc. of both Rynearson (1938) and Dibblee (1992a). **17933.** 118°31′16″W, 34°20′35″N. Elevation 582 m (1910 ft.), small outcrop north side of road along ridgeline, 671 m (2200 ft.) north and 183 m (600 ft.) east of southwest corner of section 13. Collector: R.L. Squires, September 4, 2011. **17934 [= approximately 422, 4720, and 7797].** 118°30′22″W, 34°20′15″N. Elevation 552 m (1810 ft.), on east side of power line road just north of small concrete building, 30 m (100 ft.) north and 975 m (3200 ft.) east of southwest corner of section 13. Collectors: G.P. Kanakoff (date unknown), G.A. Rynearson (1938), and R.L. Squires, September 4, 2011. In vicinity of locs. 211 and 214 of Grant and Gale (1931:102) and loc. F76 of Winterer and Durham (1962).

STRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS

In the eastern and central parts of the study area (Figs. 2, 3), the Saugus Formation consists of fluvial (braided-river) deposits that include siltstone, sandstone, conglomeratic sandstone, and interspersed lenses of conglomerate. No mudstone was found, nor were any fossils. The siltstone is green, red, or brown and crops out mainly in the eastern part of the study area. West of California State Highway 14, the green siltstones are intercalated within lighter colored and coarser deposits. The sandstone is medium to coarse grained and white on fresh surfaces. Horizontal laminated bedding and low-angle crossbedding are common. Locally, there can be higher angle, large-scale trough crossbedding. The conglomerate occurs as channel fills with erosive bases and sharp tops. Crude fining-upward sequences are common, and crude imbrication of clasts is less common. Clasts are matrix supported and poorly to moderately well sorted. Most of the pebble- to boulder-size (up to 50 cm length) clasts are commonly rounded to subrounded, but some are flat. They mostly consist of leucogranite and granite, which together make up approximately one-half of all the clasts, with the granite commonly accounting for 30% and leucogranite 20%. Other clasts, listed in decreasing abundance are gneiss, volcanic porphyry, quartzite, anorthosite, hornblende-rich diorite, schist,

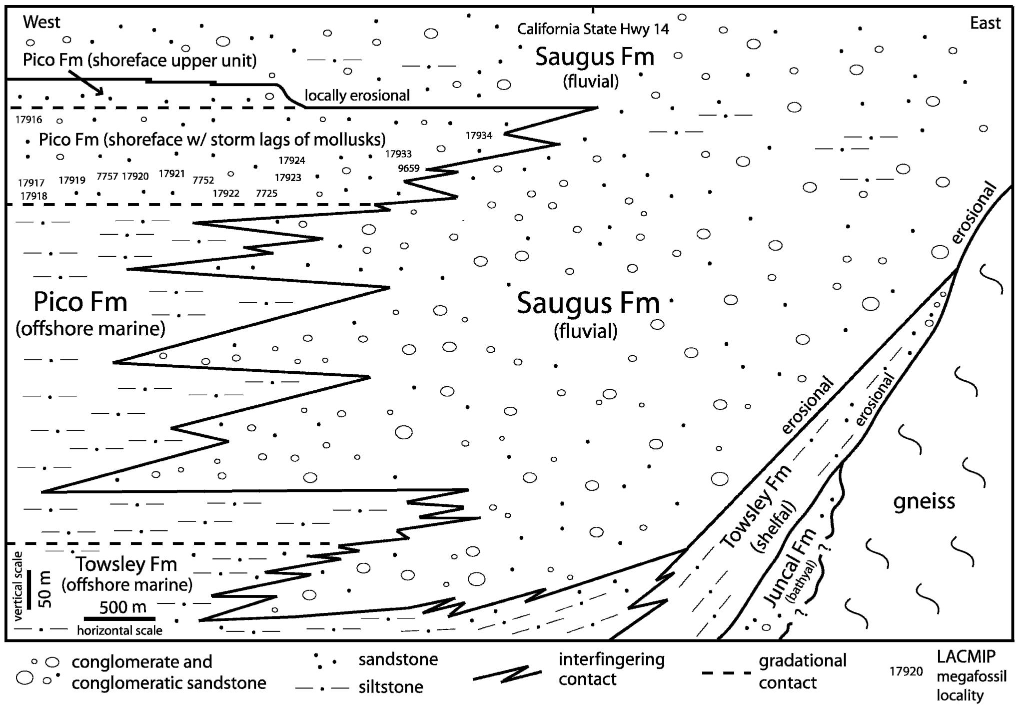


Figure 3 Schematic cross section of the study area braid delta, with folds and faults removed. Vertical exaggeration ×5.5.

and argillite. Up-section, the amount of conglomerate decreases. Beds in the Saugus Formation commonly weather brown or orange-brown, and, locally, are oil stained and weather gray, especially in lower Elsmere Canyon. The sandstone is white on fresh surfaces. Stratigraphic relationships of the Saugus Formation with the underlying and overlying rocks are shown in Figure 3. The lower part of the Saugus Formation in the study area has many dark-colored deposits (e.g., dark brown, yellow brown, green, and red) that eventually might prove to belong to Oakeshott's (1950) Sunshine Ranch stratigraphic unit, whose type section is approximately 5.5 km south of the study area.

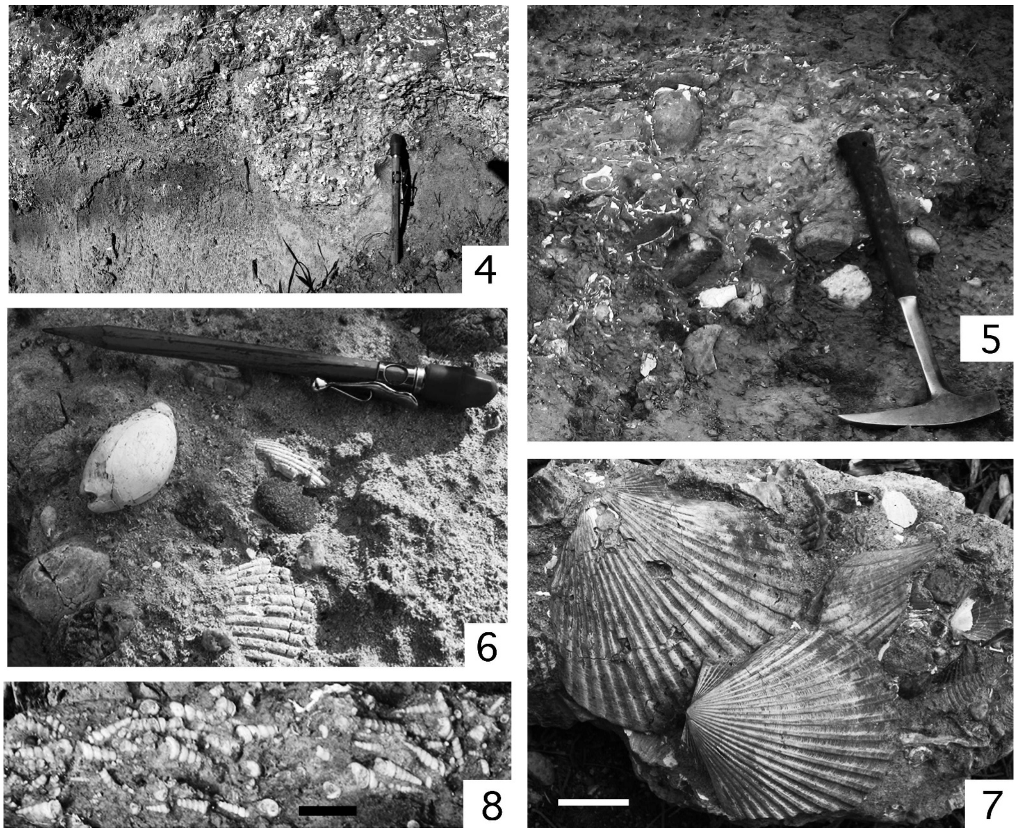
In the western part of the study area, the Saugus Formation laterally interfingers with the marine Pico Formation, and the term "braid delta," which McPherson et al. (1987) coined for a gravel-rich delta that forms where a braided river system progrades into a standing body of water, aptly applies to the study area. Initially, the fluvial deposits interfingered with offshore-marine siltstones (barren of megafossils) in the upper part of the Towsley Formation and in the lower and middle parts of the Pico Formation. The conglomerates that interfinger with these relatively quiet-water offshore siltstones are unfossiliferous. They are also thicker, more wedge-shaped, more laterally continuous; have much more distinct boundaries; and show more incisement (up to 3 m) than do the commonly fossiliferous conglomeratic storm lags that are present higher in the section in the shoreface deposits. This interfingering continues, but to a lesser degree, in the adjacent Valencia area to the west.

The offshore-marine siltstone (approximately 450 m thick) that makes up most of the western part of the Pico Formation in the study area grades up-section into the sandstones of the shoreface facies, which consists of a lower fossiliferous part and an upper unfossiliferous part. The lower part consists of grayish white, very fine to fine sandstones (approximately 130 m thick) with scattered channelized lenses and lentils filled with storm lags of mollusks and associated pebble- and cobble-sized clasts similar in size and composition to those of the fluvial facies (Figs. 4–8). Locally, there can be angular clasts in addition to the more commonly occurring rounded clasts. Locally there are coquinas, but the shells are unabraded. The shells were transported and concentrated by storm waves, and distance of transport was relatively short (see "Taphonomy" for details). These fossiliferous deposits represent a marine transgression that deposited the shoreface facies as far east as LACMIP loc. 17934, in the immediate vicinity of California State Highway 14, just north of the south portal of the Union Pacific Railroad tunnel. The lower part of the shoreface facies also contains some relatively thick intervals of unfossiliferous sandstone that locally have intervals of bidirectional crossbeds (e.g., in the vicinity of LACMIP loc. 7752), probably caused by inflow and outflow of tidal currents. The lower fossiliferous part of the shoreface facies is equivalent to the "basal unit" and "middle unit" described by Squires et al. (2006) for strata immediately west of the Newhall area.

The upper part of the shoreface facies (approximately 35 m thick) is gradational with the underlying megafossiliferous shoreface facies and consists of white, unfossiliferous, fine to medium sandstone that is parallel-laminated and amalgamated. Minor conglomeratic sandstone beds can also be present. The upper part of the shoreface facies crops out west of the Beacon Fault to beyond U.S. Interstate Highway 5 and is the same as the "upper unit" described by Squires et al. (2006) from strata immediately west of the Newhall area. The upper unit interfingers with the overlying Saugus Formation. East of this fault the upper unit has been removed by erosion.

OVERVIEW OF MEGAFOSSILS

The megafossils were collected mostly from localities in the lower part of the shoreface facies, which trends in a northwest–southeast direction between Gavin Canyon and California State Highway 14 (Fig. 2). The locations, whose geographic and



Figures 4–8 Selected outcrops of the megafossiliferous, shoreface storm-lag deposits in the upper part of the Pico Formation in the Newhall area. **4.** Channel, filled with fossils, vicinity of LACMIP locality 17913, pencil 13 cm length. **5.** Channelized lens of fossils, pebbles, and small cobbles, vicinity of LACMIP locality 7757, hammer 32.5 cm length. **6.** Top of channel fill with pectinid fragments, cobbles, and a complete *Zonaria* (*Neobernaya*) *spadicea* (Swainson, 1823) (same specimen shown in Figs. 68, 69), LACMIP loc. 7752, pencil 13 cm length. **7.** Part of a lens of *Turritella cooperi* showing bimodal-preferred orientation, LACMIP loc. 7752, scale bar 15 mm. **8.** Part of a fossiliferous lens with valves of *Argopecten invalidus* and scattered pebbles, LACMIP loc. 7757, scale bar 20 mm.

relative stratigraphic positions are shown on Figure 2, are from an interval approximately 130 m thick in the upper part of the shoreface facies west of the Beacon Fault. This interval contains scattered lenses of megafossils. The species and their relative abundance are listed in Table 1, along with information about the occurrence of paired valves of the bivalves. The listed megafauna consists of 83 species: one brachiopod, 36 bivalves, 40 gastropods, one scaphopod, one crab (partial leg), one barnacle, one sea urchin (spine), one shark (ray tooth), and one land plant (pine cone). All these taxa are illustrated here (Figs. 9–106). The ray tooth and pine cone occur together in the same hand specimen. A few epibionts were also found but are badly weathered: some small patches of an encrusting bryozoan and some minute tubes of an encrusting annelid (spirorbid) were detected on the same brachiopod specimens from LACMIP loc. 17918. These poorly preserved taxa are not illustrated here because of their very limited taxonomic information. Boreholes are scarce. Those made by sponges? or algae? are present on some oyster valves, those made by predatory gastropods occur on a few bivalves. Preservation differs greatly among the mollusks. Calcitic pectinids, oysters, and turritellas are well preserved, whereas aragonitic mollusks are commonly poorly preserved due to weathering. Some of the very weathered, small-sized mollusks are especially prone to disintegration upon touch.

The species found at the greatest number of localities and in the greatest numbers, are the following: *Turritella cooperi* Carpenter, 1864, *Argopecten invalidus*, *Calicantharus humerosus* (Gabb, 1869), *Glossaulax reclusiana* (Deshayes, 1839), *Myrakeena veatchii* (Gabb, 1866), and *Here excavata* (Carpenter, 1857). Paired valves are common, especially for *Argopecten invalidus*, *Myrakeena veatchii*, *Trachycardium* (*Dallocardia*) *quadragenarium* (Conrad, 1837), *Callithaca tenerrima* (Carpenter, in Gould and Carpenter, 1857), *Saxidomus nuttalli* Conrad, 1837, *Tresus nuttallii* (Conrad, 1837), and *Panopea abrupta* (Conrad, 1849).

SYSTEMATICS

Phylum Mollusca Linnaeus, 1758
Class Bivalvia Linnaeus, 1758
Family Pectinidae Rafinesque, 1815
Genus *Argopecten* Monterosato, 1889
Argopecten Monterosato, 1889:20
Plagioctenium Dall, 1898:696

TYPE SPECIES. *Pecten solidulus* Reeve, 1853, by subsequent designation (Monterosato, 1899:193) = *Pecten ventricosus* G.B. Sowerby II, 1842, not *Pecten circularis* G.B. Sowerby I, 1835 (*fide* Waller, 1995); Holocene, southern California and Gulf of California to Peru (Coan et al., 2000:235).

Argopecten invalidus (Hanna, 1924)
Figures 16–19

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*) *subdolus* Hertlein, 1925:20, pl. 5, figs. 2, 4, 7.
Pecten (*Plagioctenium*) *callidus* Hertlein, 1925:22, pl. 5, figs. 1, 3, 5, 6.
Pecten (*Plagioctenium*) *invalidus* Hanna. Jordan and Hertlein, 1926:441; Minch et al., 1976:table 15.
Pecten (*Aequipecten*) *purpuratus* Lamarck variety *subdolus* Hertlein. Grant and Gale, 1931:211, pl. 5, fig. 1 (west of San Fernando Pass).
Pecten (*Aequipecten*) *purpuratus* Lamarck variety *callidus* Hertlein. Grant and Gale, 1931:211, pl. 5, fig. 4.
Pecten (*Aequipecten*) *deserti* Conrad variety *invalidus* Hanna. Grant and Gale, 1931:213–214, pl. 5, figs. 5a–c, 6a–c.
Aequipecten callidus (Hertlein). Wilson, 1955:tables 7, 8.
Aequipecten subdolus (Hertlein). Wilson, 1955:table 8.
Argopecten invalidus (Hanna). Vedder, 1960: table 151.1; Moore, 1984:B37, pl. 10, fig. 5; Squires et al., 2006:11–12, figs. 15, 16.
Pecten (*Argopecten*) *subdolus* Hertlein. Moore, 1968:50, pl. 23, figs. a, b.
Chlamys (*Argopecten*) *callida* Hertlein. Hertlein and Grant, 1972:198–199, pl. 32, figs. 9, 11.
Chlamys (*Argopecten*) *invalida* Hanna. Hertlein and Grant, 1972:200–201, pl. 33, figs. 1, 3, 8.
Chlamys (*Argopecten*) *subdola* Hertlein. Hertlein and Grant, 1972:201–202, pl. 30, figs. 7, 8; pl. 35, figs. 2, 5, 9.
Argopecten subdolus (Hertlein). Moore, 1984:B37–B38, pl. 10, figs. 3, 4.
Argopecten callidus (Hertlein). Moore, 1984:B38–B39, pl. 10, figs. 7, 9.

EMENDED DESCRIPTION. Shell medium size, up to height 117 mm; specimens commonly approximately height 45–55 mm. Valves slightly longer than high on most specimens; smaller specimens tend to be slightly longer than high, larger specimens tend to be slightly higher than long. Left valve more convex than right valve on most specimens; valves nearly equally convex on few specimens. Hinge line approximately half of disk length. Umbonal (apical angle) 100°–105°. Ribs 20–22 in number on both valves, with lamellae in interspaces. Ribs become obsolete on anteriormost and posteriormost parts of valves and tend to flatten out and become more convex in the later stages of growth. Auricles with prominent radial riblets on both valves; riblets stronger on anterior auricles of both valves. **Left valve:** ribs narrower than on right valve; interspaces wider than ribs and wider than those on right valve; anterior auricle with very small notch; posterior auricle slightly truncated; anterior and posterior auricles, both auricles with seven to nine riblets. **Right valve:** ribs wider than on left valve; interspaces narrower than ribs and narrower than those on left valve; anterior auricle with small notch; five to seven flattish riblets, strongest one coincident with notch area and variable in width and elevation; posterior auricle slightly truncate; six to seven (rarely more) radial riblets.

COMPARISON. *Argopecten invalidus*, *A. callidus*, and *A. subdolus* are conspecific based on a comparative study of actual specimens of each "species" that shows they lack consistent, reliable morphologic differences separating them from one another. Their reported differences (see Hertlein, 1925; Hertlein and Grant, 1972) were based on whether or not the ribs are flat-topped, rounded, and on the depth of the interspaces. These differences, however, are attributable to how much weathering the specimens have experienced. In the study area, for example, specimens of *A. invalidus* at any one locality show variation in the shape and depth of the ribs, with the variation clearly attributable to the degree of weathering.

In addition to *A. invalidus*, *A. callidus*, and *A. subdolus*, Grant and Gale (1931:see pages 210, 211, 212, 214) reported three other argopectinid species in the study area beds: *A. percarus* (Hertlein, 1925), *A. mendenhalli* (Arnold, 1906), and *A. imposter* (Hanna, 1924). *Argopecten percarus* differs from *A. invalidus* by having 24–25 ribs on the left valve and an umbonal angle of 118°. *Argopecten mendenhalli* differs from *A. invalidus* by having a much longer hinge line, weak sculpture on the right-valve anterior auricle, obsolete sculpture on the left-valve anterior auricle. *Argopecten imposter* differs from *A. invalidus* by having weak grooves along the sides of the major ribs and a left valve with narrower interspaces.

Argopecten invalidus is similar to *A. deserti* (Conrad, 1855) and the extant *A. ventricosus* (G.B. Sowerby II, 1842). *Argopecten invalidus* differs from *A. deserti* by having larger size, right-valve interspaces narrower than the ribs, left-valve ribs narrower than those on the right valve, left-valve interspaces wider than the ribs, more ribs on the right-valve anterior auricle, and a shorter hinge line. *Argopecten invalidus* differs from *A. ventricosus* by having a larger maximum height (95 mm), less-inflated right valve, as well as narrower and generally more ribs on the right-valve anterior auricle.

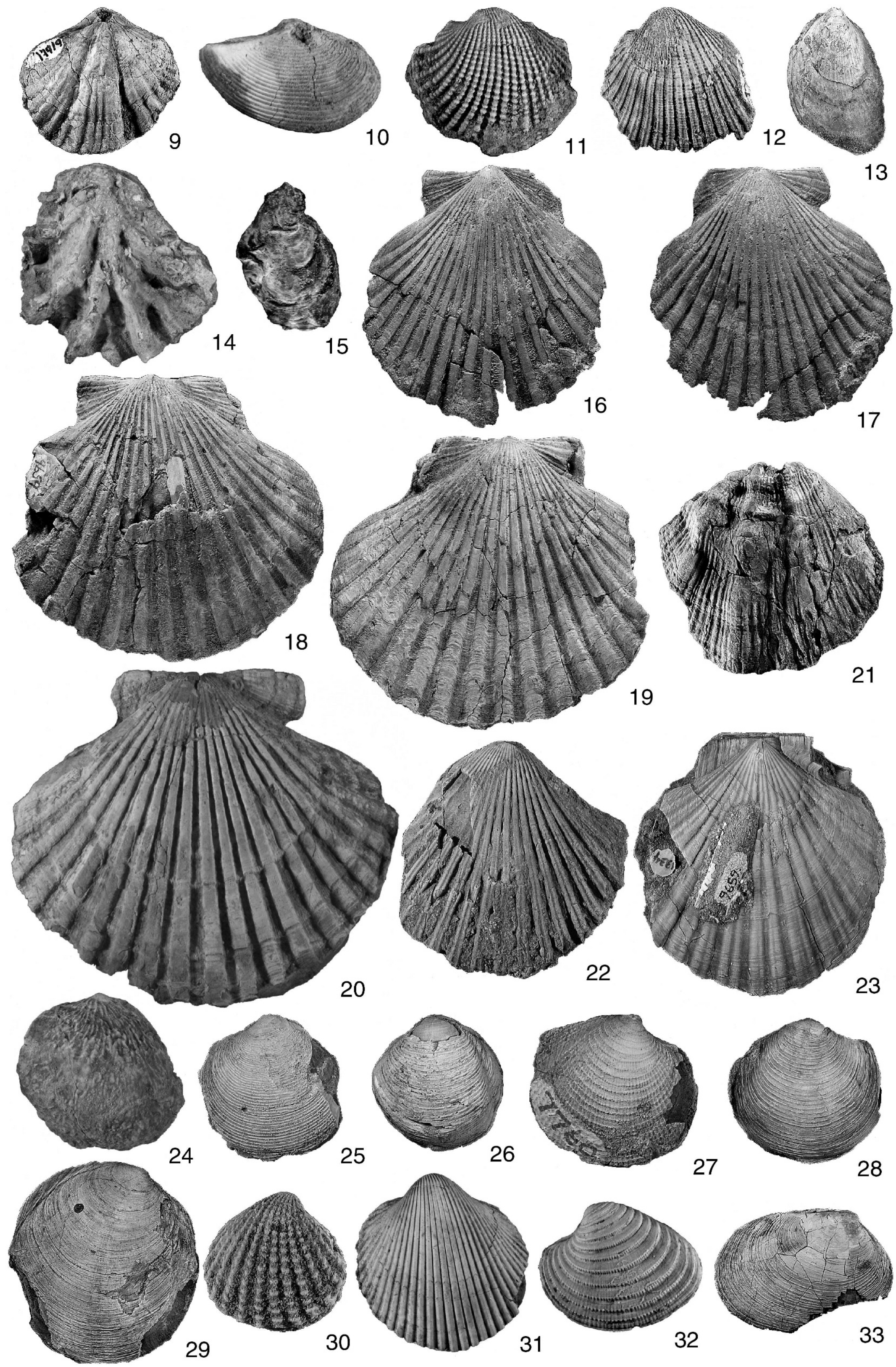
In the comparision of the above-mentioned argopectinids, only the ribs that extend continuously from the beak to the venter were counted. Specimens with one or two weak, noncontinuous ribs that are present on both the anteriormost and posteriormost sides of the specimens were not included. The largest specimen of *A. invalidus* in the study area is 70 mm in height.

TYPE MATERIAL. Holotype of *Pecten* (*Plagioctenium*) *cooperi* Arnold, 1906: CAS 61855.01 [*ex* CAS/SU 8]; holotype of *Pecten* (*Plagioctenium*) *subdolus* Hertlein, 1925: CAS 61881.01 [*ex* CAS/SU 51]; holotype of *Pecten* (*Plagioctenium*) *callidus* Hertlein, 1925: CAS 61882.01 [*ex* CAS/SU 53].

TYPE LOCALITY. Of *Pecten* (*Plagioctenium*) *cooperi*: Pacific Beach, San Diego, San Diego County, California; San Diego Formation, Pliocene. Of *Pecten* (*Plagioctenium*) *subdolus*: CAS loc. 61881 [*ex* SU loc. 115], San Diego County, California; San Diego Formation, Pliocene. Of *Pecten* (*Plagioctenium*) *callidus*, CAS loc. 61882 [*ex* SU loc. 116], Cedros Island, Baja California, Mexico, Almejas Formation, Pliocene.

GEOLOGIC AGE. Early to late Pliocene.

STRATIGRAPHIC DISTRIBUTION. LOWER PLIOCENE: Almejas Formation, eastern Cedros Island and Tortugas Bay, Baja California Sur, Mexico (Hertlein, 1925; Jordan and Hertlein, 1926; Minch et al., 1976); Tirabuzon Formation [formerly Gloria Formation], Baja California Sur, Mexico (Wilson, 1955). UPPER PLIOCENE: Pico Formation, Holser Canyon area, Los Angeles County, (Grant and Gale, 1931); Pico Formation, northern Simi Valley (especially Las Llajas Canyon), Ventura and Los Angeles counties, California (new information); and Valencia and Newhall areas, northern Los Angeles County, California (Grant and Gale, 1931; Squires et al., 2006; present report); Niguel Formation, San Juan Capistrano, Orange County, California (Vedder, 1960); San Diego Formation, lower member, San Diego County, California (Hertlein and Grant, 1972;



Figures 9–33 Brachiopod (first figure) and bivalves from upper Pliocene Pico Formation in the Newhall area. All specimens coated with ammonium chloride. **9.** *Terebratalia occidentalis* (Dall, 1871), hypotype LACMIP 14335, LACMIP loc. 17919, brachial valve, height 32.6 mm, ×0.7. **10.** *Jupiteria taphria* (Dall, 1896), hypotype LACMIP 14336, LACMIP loc. 17917, right valve, height 5.7 mm, ×3. **11.** *Arcopsis* sp., hypotype LACMIP 14337, LACMIP loc. 17917, partial left valve, height 6.8 mm, ×3. **12.** *Anadara trilineata* (Conrad, 1856), hypotype LACMIP 14338, LACMIP loc. 7752, partial

Deméré, 1983); and Infierno Formation (Wilson, 1955), Baja Californa Sur, Mexico.

REMARKS. *Argopecten invalidus* is one of the most common megafossils in the study area, and its preservation is excellent. Specimens range from 3 mm to 67.6 mm in height. Although they can be weathered, they are unabraded, many have their fragile auricles intact, and many specimens are paired valves (i.e., Table 1).

Class Gastropoda Cuvier, 1797
Family Calliostomatidae Thiele, 1924
Genus *Calliostoma* Swainson, 1840

TYPE SPECIES. *Trochus conulus* Linnaeus, 1758, designated by Herrmannsen, 1846; Holocene, Mediterranean Sea.

Calliostoma sp., aff. *C. grantianum* Berry, 1940
Figures 53–54

REMARKS. This gastropod is represented by three specimens from LACMIP loc. 17918. Preservation is very good, but two of the specimens are incomplete. The illustrated specimen, which is the most complete one, consists of approximately 3.25 teleoconch whorls and is 5 mm in height. This gastropod is similar to *Calliostoma grantianum* Berry (1940:12–13, pl. 2, figs. 4, 5) from middle Pleistocene strata in San Pedro, Los Angeles County, California. The Pico Formation specimens differ by having smaller size, fewer whorls, wider pleural angle, more closely spaced spiral ribs on the sides of the teleoconch whorls, beads on the spiral rib adjacent to the suture on the last half turn of the last whorl, obsolete spiral ribs on the medial part of the flattish base, and three rather than five ribs in the umbilical region. The immaturity of the Pico Formation specimens could explain the difference in size and fewer whorls. Mature *C. grantianum* have up to 6.5 whorls and are 15.4 mm in height. There is a possibility that the Pico Formation specimens represent a new species, but specimens that are more mature are needed for confirmation.

The Pico Formation gastropod resembles *C. canaliculatum* (Lightfoot, 1786), whose chronologic range is late Pliocene to Holocene (Grant and Gale, 1931:833). This gastropod's species name stems from Martyn (1784:table 1, pl. 32), but his work was rejected for nomenclatural purposes by the International Commission on Zoological Nomenclature (1957:Opinion 456). As noted by Rehder (1967:19), Lightfoot (1786:101, no. 2220) is regarded by modern workers as the author of this species. See McLean (1978:19, fig. 7.2) for a description and illustration of it. The Pico Formation specimens differ by having a much smaller size, 10° wider pleural angle, lower spire, fewer and more widely spaced spiral ribs on last whorl, some beading, and fewer and less well-developed ribs on the base.

According to McLean (1978:19), *C. dolarium* (Holten, 1802) is a synonym of *C. canaliculatum*. Moore (1968:56, pl. 27, fig. b) illustrated a specimen that she identified as *C. doliarium* [sic] from Pliocene strata in San Diego, and this particular specimen looks very similar to the Pico Formation gastropod in terms of the spacing of the spiral ribs on the last whorl. The Pico Formation gastropod differs by having fewer, more widely spaced, and less well-developed ribs on the base, as well as by having some beading on the spiral rib next to the suture on the last whorl.

Family Muricidae Rafinesque, 1815
Genus *Ocinebrina* Jousseaume, 1880

TYPE SPECIES. *Murex corallinus* Scacchi, 1836, by original designation; Holocene, North Atlantic and Mediterranean.

Ocinebrina sp., aff. *O. fraseri* (Oldroyd, 1920)
Figures 77–79

REMARKS. This gastropod is represented by a single specimen from LACMIP loc. 17918. Preservation is good, but the tip of its spire is missing, as well as some of the shell on the dorsal surface of the last whorl. The specimen, which is 19.3 mm in height, is similar to the extant *Ocinebrina fraseri* (Oldroyd, 1920:135, pl. 4, figs. 1–3), from the Pacific Northwest. Northeastern Pacific species formerly placed in *Ocenebra* Gray, 1847 were transferred to *Ocinebrina* by McLean (1996). The Pico Formation specimen differs from Oldroyd's species by having slightly stronger irregular varices, more and narrower spiral ribs, and reticulate sculpture on the spire whorls and posterior half of the last whorl. The Pico Formation specimen is unusual for an *Ocinebrina* because it has both an immature-stage open siphonal canal and a mature-stage outer lip (i.e., outer lip interior with at least four strong nodes). In *Ocinebrina*, the siphonal canal remains open until final maturity and the lip expands and forms labrial denticles (McLean, 1996:80). Future collecting might show that this species is new.

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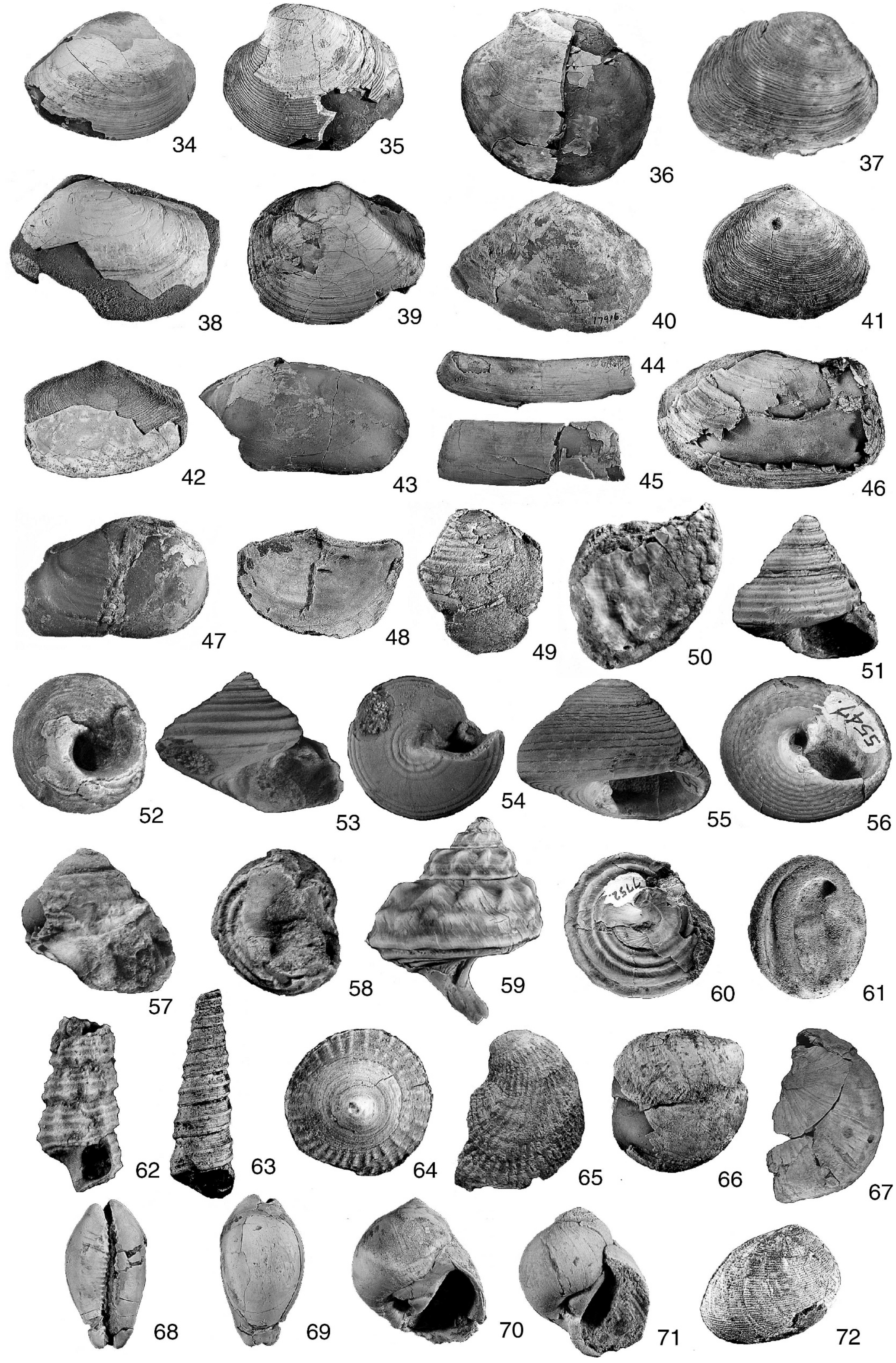
left valve, height 23.2 mm, ×1. **13.** *Limaria* sp., cf. *L. orcutii* (Hertlein and Grant, 1972), hypotype LACMIP 14339, LACMIP loc. 17917, steinkern of left? valve, height 45.7 mm, ×0.5. **14.** *Myrakeena veatchii* (Gabb, 1866), hypotype LACMIP 14340, LACMIP loc. 9659, left valve, height 68.8 mm, ×0.5. **15.** *Myrakeena veatchii* (Gabb, 1866), hypotype LACMIP 14341, LACMIP loc. 9659, right valve (juvenile), height 18.2 mm, ×1.2. **16–19.** *Argopecten invalidus* (Hanna, 1924). **16.** Hypotype LACMIP 14342, LACMIP loc. 9659, left valve (originally paired with following specimen), height 61 mm, ×0.7. **17.** Hypotype LACMIP 14343, LACMIP loc. 9659, right valve, height 60 mm, ×0.7. **18–19.** Hypotype LACMIP 14344, LACMIP loc. 9659, height 66.7 mm, ×0.7. **18.** left valve. **19.** right valve. **20.** *Lyropecten catalinae* (Arnold, 1906), LACMIP 14345, LACMIP loc. 7752, right valve, height 122 mm, ×0.4. **21.** *Swiftopecten parmeleei* (Dall, 1898), hypotype LACMIP 14346, LACMIP loc. 17917, left? valve, height 53 mm, ×0.6. **22.** *Leopecten stearnsii* (Dall, 1878), hypotype LACMIP 14347, LACMIP loc. 7752, right valve, height 57.2 mm, ×0.6. **23.** *Patinopecten healeyi* (Arnold, 1906), hypotype LACMIP 14348, LACMIP loc. 9659, right valve, height 58.6 mm, ×0.7. **24.** *Pododesmus macroschisma* (Deshayes, 1839), hypotype LACMIP 14349, LACMIP loc. 17917, left valve, height 49 mm, ×0.5. **25.** *Epilucina californica* (Conrad, 1837), hypotype LACMIP 14350, LACMIP loc. 7752, left valve, height 26.7 mm, ×0.9. **26.** *Here excavata* (Carpenter, 1857), hypotype LACMIP 14351, LACMIP loc. 17920, left valve, height 17.9 mm, ×1.2. **27.** *Lucinisca nuttalli* (Conrad, 1837), hypotype LACMIP 14352, LACMIP loc. 17918, right valve, height 14 mm, ×1.7. **28.** *Lucinoma annulatum* (Reeve, 1850), hypotype LACMIP 14353, LACMIP loc. 17917, left valve, height 56.4 mm, ×0.4. **29.** *Miltha xantusi* (Dall, 1905), hypotype LACMIP 14354, LACMIP loc. 17934, right valve, height 98.3 mm, ×0.2. **30.** *Cyclocardia occidentalis* Conrad, 1855, hypotype LACMIP 14355, LACMIP loc. 7752, right valve, height 8.2 mm, ×2.6. **31.** *Trachycardium* (*Dallocardia*) *quadragenarium* (Conrad, 1837), hypotype LACMIP 14356, LACMIP loc. 7752, left valve, height 73.3 mm, ×0.4. **32.** *Chione* (*Anomalocardia*) *fernandoensis* English, 1914, hypotype LACMIP 14357, LACMIP loc. 17918, left valve, height 11.2 mm, ×1.8. **33.** *Callithaca tenerrima* (Carpenter, in Gould and Carpenter, 1857), hypotype LACMIP 14358, LACMIP loc. 17918, right valve, height 85 mm, ×0.2.



Figures 34–72 Bivalves and gastropods from upper Pliocene Pico Formation in the Newhall area. All specimens coated with ammonium chloride. **34.** *Compsomyax subdiaphana* (Carpenter, 1864), hypotype LACMIP 14359, LACMIP loc. 7757, right valve, height 30.6 mm, ×07. **35.** *Amiantis callosa* (Conrad, 1837), hypotype LACMIP 14360, LACMIP loc. 7752, left valve, height 47.5 mm, ×0.5. **36.** *Dosinia ponderosa* (Gray, 1838), hypotype LACMIP 14362, LACMIP loc. 7725, left valve, height 101.7 mm, ×0.3. **37.** *Saxidomus nuttalli* Conrad, 1837, hypotype LACMIP 14361, LACMIP loc.

DISCUSSION

AGE

The chronologic ranges of the Newhall-area species that have the shortest ranges are depicted in Figure 107. Based on overlap of these ranges, these species indicate a late Pliocene age, which is in agreement with the age reported by Squires et al. (2006) for the Pico Formation in the Valencia area. Their age was based on mollusks and benthic foraminifera, as well as on paleomagnetic studies of the overlying Saugus Formation. Squires et al. (2006:fig. 23) provided a diagram showing the chronostratigraphic framework for the Pliocene and Pleistocene and included magnetostratigraphy and various biostratigraphic zones/stages. Their figure, however, is out of date in terms of the age of the base of the Pleistocene. In 2009, the International Commission on Stratigraphy (see Gibbard et al., 2009) reported that the Pliocene ranges from 5.33 to 2.58 Ma. The "early Pliocene" (Zanciean Stage) ranges from 5.33 to 3.6 Ma, and the "late Pliocene" (Piacenzian Stage) ranges from 3.6 to 2.58 Ma. The "middle Pliocene" is no longer recognized.

A late Pliocene age for the Pico Formation in the Newhall area contradicts a latest Miocene to earliest Pliocene age (5.5 ± 0.4 Ma) reported by Berry et al. (2009:fig. 4) based on strontium-isotope studies of fragments of oyster and pectinid shells from Gavin Canyon. Weathered shells might account for the contradictory age report.

Presence of the gastropods *Cancellaria hamlini* Carson, 1926 and *Rictaxis painei grandior* Grant and Gale (1931) in the Newhall area Pico Formation refines their poorly known geologic age. Carson (1926:51) reported *C. hamlini* only from strata of early Pliocene age in Elsmere Canyon, but Kern (1973), in his detailed study of the fauna there, did not detect this species. Grant and Gale (1931:444) reported *R. p. grandior* only from undifferentiated Pliocene strata in Holser Canyon near Val Verde, Ventura County, California. These strata are part of an almost continuous section of Pico Formation that extends from Newhall Pass to Holser Canyon (Grant and Gale, 1931:33). In conclusion, the geologic age of both of these gastropods is late Pliocene.

The taxonomic composition of the megafauna of the Pico Formation in the Newhall area and adjacent Valencia area is most similar to the upper Pliocene Niguel Formation at San Juan Capistrano, Orange County, California (see Vedder, 1960; Stadum, 1984) and to the upper Pliocene lower member of the San Diego Formation, San Diego County, California (see Deméré, 1983). There is also similarity to the megafauna of the upper Pliocene Cebada and Craciosa members of the Careaga Sandstone, Santa Maria, Santa Barbara County (see Woodring and Bramlette, 1950).

DEPTH

Table 2 provides the depth-range data for the 41 extant species found in the Newhall area; the average depth range of these species is 8 to 144 m. Using Valentine's (1961:fig. 2) diagram of the classification of marine environments, the Newhall-area megafauna lived predominantly in the inner sublittoral marine environment.

Winterer and Durham (1962) reported that based on benthic foraminifera, the marine facies on the north side of Gavin Canyon shallowed up-section. The extant *Epistominella pacifica* (Cushman, 1927) is especially common in beds referred here to the quiet-water, offshore-marine braid-delta siltstones of the Pico Formation. They reported that this species lives in waters that range in depth from 7 to 70 m. Up-section, in the lower part of the overlying shoreface sandstone, they found sparse benthic foraminifera, with the extant *Nonion scaphum* (Fichtel and Moll, 1798) as the best-represented species. They reported that this species lives in waters that range in depth from intertidal to 16 m. They found no benthic foraminifera in the stratigraphically higher deposits in the Pico Formation.

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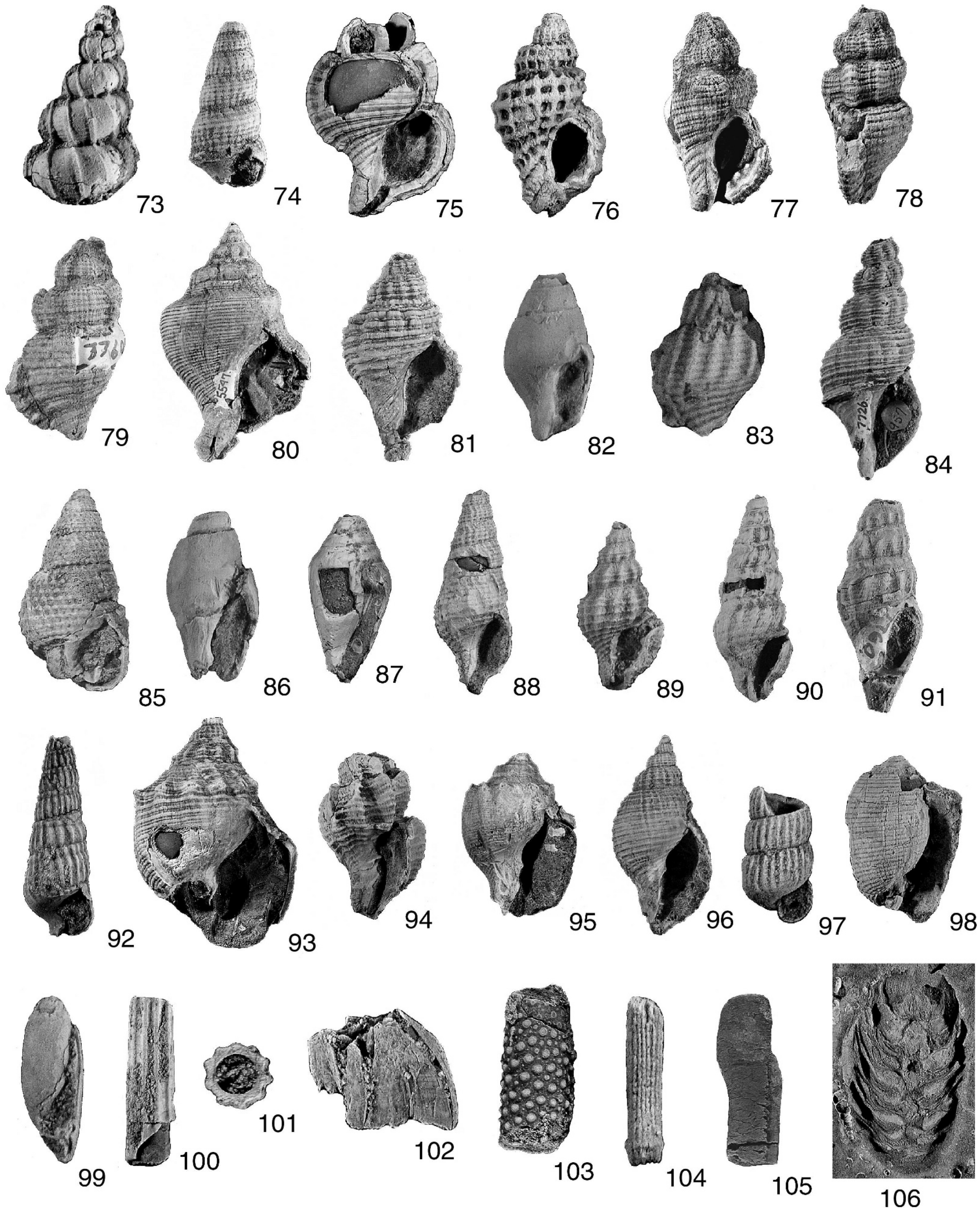
17921, right valve, height 89.7 mm, ×0.3. **38.** *Tresus nuttallii* (Conrad, 1837), hypotype LACMIP 14370, LACMIP loc. 17918, right valve, height 60 mm, ×0.4. **39.** *Macoma* (*Rexithaerus*) *secta* (Conrad, 1837), hypotype LACMIP 14364, LACMIP loc. 7752, left valve, height 54.5 mm, ×0.4. **40.** *Macoma nasuta* (Conrad, 1837), hypotype LACMIP 14365, LACMIP loc.17916, right valve, height 49.4 mm, ×0.4. **41.** *Leporimetis obesa* (Deshayes, 1855), hypotype LACMIP 14366, LACMIP loc. 17921, right valve, height 33.3 mm, ×0.7. **42.** *Tellina* (*Tellinella*) *idae* Dall, 1891, hypotype LACMIP 14363, LACMIP loc. 17920, external mold of right valve, height 24.3 mm, ×0.7. **43.** *Gari* sp., hypotype LACMIP 14367, LACMIP loc. 7757, internal mold of partial left valve, height 62.4 mm, ×0.3. **44.** *Solen* (*Ensisolen*) *sicarius* Gould, 1850, hypotype LACMIP 14368, LACMIP loc. 17917, left? valve, height 10.5 mm, ×0.6. **45.** *Solen* sp., cf. *S. perrini* Clark, 1915, hypotype LACMIP 14369, LACMIP loc. 17917, right? valve, height 32.6 mm, ×0.3. **46.** *Panopea abrupta* (Conrad, 1849), hypotype LACMIP 14371, LACMIP loc. 17917, left valve, height 65.6 mm, ×0.3. **47.** ?*Chaceia ovoidea* (Gould, 1851), hypotype LACMIP 14372, LACMIP loc. 7757, right valve, height 42.9 mm, ×0.4. **48.** *Pandora* (*Heteroclidus*) *punctuata* Conrad, 1837, hypotype LACMIP 14373, LACMIP loc. 7757, right-valve interior, height 10.1 mm, ×1.6. **49.** ?*Cyathodonta pedroana* Dall, 1915, hypotype LACMIP 14374, LACMIP loc. 7757, partial right valve, height 47.7 mm, ×0.5. **50.** *Haliotis* sp., hypotype LACMIP 14375, LACMIP loc. 17921, partial specimen, longest dimension 57 mm, ×0.33. **51–52.** *Calliostoma* sp., cf. *splendens* Carpenter, 1864, hypotype LACMIP 14376, LACMIP loc. 17918, height 6.7 mm, ×3.3. **51.** apertural view. **52.** umbilical view. **53–54.** *Calliostoma* sp., aff. *C. grantianum* Berry, 1940, hypotype LACMIP 14377, LACMIP loc. 17918, height 5 mm, ×4.2. **53.** apertural view. **54.** umbilical view. **55–56.** *Chlorostoma gallina* form *multifilosa* Stearns, 1892, hypotype LACMIP 14378, LACMIP loc. 7753, height 15.8 mm, ×1.4. **55.** apertural view. **56.** umbilical view. **57–58.** *Homoploma paucicostatum*? (Dall, 1871), hypotype LACMIP 14379, LACMIP loc. 17918, height 5.9 mm, ×4. **57.** apertural view. **58.** ventral view. **59–60.** *Pomaulax gradata* Grant and Gale, 1931, hypotype LACMIP 14380, LACMIP loc. 7752, height 36.4 mm, ×0.6. **59.** apertural view. **60.** umbilical view. **61.** Operculum of ?*Pomaulax gradata* Grant and Gale, 1931, hypotype LACMIP 14381, LACMIP loc. 7752, interior view, longest dimension 17.5 mm, ×1.3. **62.** *Lirobittium asperum* (Gabb, 1861), hypotype LACMIP 14382, LACMIP loc. 17918, apertural view of partial specimen, height 5.5 mm, ×4.8. **63.** *Turritella cooperi* Carpenter, 1864, hypotype LACMIP 14383, LACMIP loc. 17917, apertural view, height 31.8, ×1. **64.** ?*Calyptraea* (*Trochita*) sp., hypotype LACMIP 14384, LACMIP loc. 17918, dorsal view, diameter 7.5 mm, ×3. **65–66.** *Crepidula aculeata* (Gmelin, 1791), LACMIP loc. 17918. **65.** Hypotype LACMIP 14385, dorsal view, height 16.7 mm, ×1.4. **66.** hypotype LACMIP 14386, two specimens vertically stacked, total height 26.9 mm, ×0.5. **67.** *Grandicrepidula princeps* (Conrad, 1857), hypotype LACMIP 14387, LACMIP loc. 17921, dorsal view, height 56.4, ×0.5. **68–69.** *Zonaria* (*Neobernaya*) *spadicea* (Swainson, 1823), hypotype LACMIP 14388, LACMIP loc. 7752, height 40.1 mm, ×0.6. **68.** Apertural view. **69.** dorsal view. **70.** *Glossaulax reclusiana* (Deshayes, 1839), hypotype LACMIP 14389, LACMIP loc. 7752, apertural view, height 46.7 mm, ×0.5. **71.** *Cryptonatica clausa* (Broderip and Sowerby, 1829), hypotype LACMIP 14390, LACMIP loc. 7752, apertural view, height 9.6 mm, ×2.4. **72.** *Sinum scopulosum* (Conrad, 1849), hypotype LACMIP 14391, LACMIP loc. 7757, abapertural view, height 19.6 mm, ×0.8.



Figures 73–106 Gastropods and other megafauna from upper Pliocene Pico Formation in the Newhall area. All specimens coated with ammonium chloride. **73.** *Asperiscala* sp., cf. *A. minuticostata* (De Boury, 1912), hypotype LACMIP 14392, LACMIP loc. 7757, apertural? view, base missing, height 8 mm, ×3.3. **74.** *Amaea* (*Scalina*) sp., cf. *A.* (*S.*) *edwilsoni* DuShane, 1977, hypotype LACMIP 14393, LACMIP loc. 17917, apertural? view, base missing, height 20.2, ×1.1. **75.** *Cymatium* sp., cf. *C.* (*Reticutriton*) *elsmerense* (English, 1914), hypotype LACMIP 14394, LACMIP loc. 17917, spire missing, height 27.5 mm, ×1.3. **76.** *Ocinebrina atropurpurea* (Carpenter, 1865), hypotype LACMIP 14395, LACMIP loc. 7752, height 11.4 mm, ×2.4. **77–79.** *Ocinebrina* sp., aff. *O. fraseri* (Oldroyd, 1920), hypotype LACMIP 14396, LACMIP loc. 17918, height 19.3 mm, ×1.3. **77.** apertural view. **78.** Right-lateral view. **79.** Abapertural view. **80.** *Calicantharus humerosus* (Gabb, 1869), hypotype LACMIP 14397, LACMIP loc. 7752, height 43.5, ×0.7. **81.** *Calicantharus fortis* (Carpenter, 1864), hypotype LACMP 14398, LACMIP loc. 17917, height 33.1 mm, ×0.8. **82.** *Alia tuberosa* (Carpenter, 1864), hypotype LACMIP 14399, LACMIP loc. 17918, height 5.2 mm, ×4.2. **83.** *Amphissa* sp., hypotype LACMIP 14400, LACMIP loc. 17918, abapertural view, height 5.2 mm, ×4.2. **84.** *Barbarofusus barbarensis* (Trask, 1855), hypotype LACMIP 14401, LACMIP loc. 17917, height 49.4 mm, ×0.7. **85.** *Nassarius* (*Demondia*) *californianus* (Conrad, 1856), hypotype LACMIP 14402, LACMIP loc. 17918, height 20.7 mm, ×1.3. **86.** *Callianax baetica* (Carpenter, 1864), hypotype LACMIP 14403, LACMIP loc. 7752, height 9 mm, ×2.6. **87.** *Californiconus californicus*? (Reeve, 1843a), hypotype LACMIP 14404, LACMIP loc. 7757, height 16.9 mm, ×1.4. **88.** *Ophiodermella inermis* (Reeve, 1843b), hypotype LACMIP 14405, LACMIP loc. 7757, height 14.3 mm, ×1.9. **89.** *Cockerella conradiana* (Gabb, 1866), hypotype LACMIP 14406, LACMIP loc. 17918, height 6.4 mm, ×3.5. **90.** *Elaeocyma* sp., hypotype LACMIP 14407, LACMIP loc. 7752, height 17.6 mm, ×1.6. **91.** *Crassispira* sp., hypotype LACMIP 14408, LACMIP loc. 17918, height 21.7 mm, ×1.3. **92.** *Terebra* (*Strioterebra*) *martini* English, 1914, hypotype LACMIP 14409, LACMIP loc. 17918, height 15.8 mm, ×1.7. **93.** *Cancellaria altispira* Gabb, 1869, hypotype LACMIP 14410, LACMIP loc. 17934, height 44.3 mm, ×0.7. **94.** *Cancellaria hemphilli* Dall, 1909, hypotype LACMIP 14411, LACMIP loc. 7757, spire missing, height 18.4 mm, ×1.2. **95.** *Cancellaria tritonidea*? Gabb, 1866, hypotype LACMIP 14412,

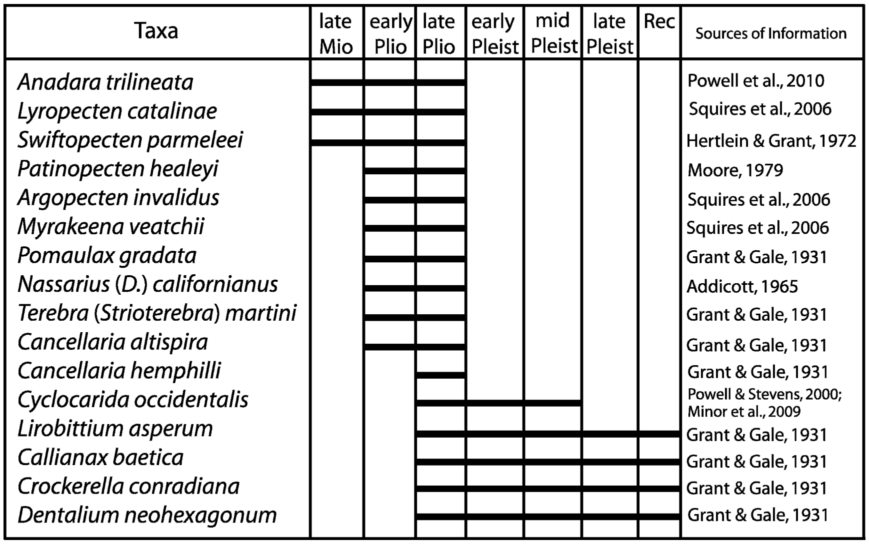


Figure 107 Chronostratigraphic distribution of the study area species with the most constrained geologic ranges indicating a late Pliocene age.

SUBSTRATE

At least three substrate types are recognized for the study area deposits: fine-grained offshore sediments, fine- to medium-grained sandy deltaic sediments, and hard surfaces. The first type was located immediately seaward of the delta and essentially fringed the delta; the second occurred on the delta complex itself; and the third occurred in association with coarse debris on the delta. The presence of fine-grained offshore substrate is indicated by the very abundant gastropod *Turritella cooperi*. Valentine and Mallory (1965) assigned this species to their Group III Pleistocene offshore fossil community, along with the bivalve *Lucinoma annulatum* (Reeve, 1850), another megafaunal element, but a rare one, of the Newhall Pico Formation assemblages. Although details are lacking about how *T. cooperi* lives, it is probably like most species of extant *Turritella*. Bandel (1976) reported that *Turritella variegata* (Linnaeus, 1758) from the Caribbean coast of Colombia lives as a suspension feeder shallowly buried in soft substrates. Large populations migrate only at the time of spawning once a year, and they crawl to more sandy bottoms or bottom covered with gravel where they can attach their spawn more firmly in coarse debris than is possible in muddy environments. Allmon et al. (1992) reported that *Turritella gonostoma* Valenciennes, 1832, from the northern Gulf of California lives in depths less than 5 m and, in the winter, migrates into shallow water to reach nutrient-rich waters and to lay its eggs. It seems very likely that the specimens of *T. cooperi* that dominate the fossil assemblages at most localities in the Newhall area preferred to live in close proximity to a river delta because the river would deliver nutrients on which it feeds. During the winter, individuals could migrate, from silty substrate to shallower water and sandy and gravelly substrates, in order to lay their eggs.

The fine- to medium-grained sandy delta substrate is indicated by paired-valved epifaunal bivalves (e.g., *Argopecten*, *Lyropecten*, *Patinopecten*), epifaunal gastropods (e.g., *Glossaulax*, *Conus*), and paired-valved infaunal bivalves (e.g., *Trachycardium*, *Saxidomus*, *Tresus*, *Panopea*). Hard-surface biotopes were very localized. The *Haliotis* specimen and the *Terebratalia occidentalis* brachiopods most likely attached to shell debris or larger rock clasts. The latter, in a few cases, provided hard substrate for encrusting bryozoan and spirorbid tubes. Some individuals of the plicate oyster *Myrakeena veatchii* lived attached to each other, based on a cluster of specimens found attached to each other at LACMIP loc. 9659, where a growth series of this oyster was also found. The occurrence of the paired-valved single specimen of the pholadid ?*Chaecia ovoidea* (Gould, 1851) is anomalous because this species normally bores into clay or shale (Coan et al., 2000). Kennedy (1974:39) reported that *C. ovoidea* has been known to bore into waterlogged wood, and this could explain its presence in the study area megafauna.

The above-mentioned three types of substrate are compatible with the findings derived from Table 2 showing that the majority of the 41 extant species of the Pico Formation megafauna live in/on sand or mud; only a few live on hard surfaces (Table 2).

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LACMIP loc. 7752, height 23.8 mm, ×0.9. **96.** *Cancellaria hamlini* Carson, 1926, hypotype LACMIP 14413, LACMIP loc. 17919, height 21.5 mm, ×0.9. **97.** *Turbonilla* sp., hypotype LACMIP 14414, LACMIP loc. 17918, upper spire missing, height 6 mm, ×3.1. **98.** *Rictaxis painei grandior* Grant and Gale, 1931, hypotype LACMIP 14415, LACMIP loc. 7752, height 13.3 mm, ×1.7. **99.** *Acteocina culcitella*? (Gould, 1853), hypotype LACMIP 14416, LACMIP loc. 7760, height 3 mm, ×7.5. **100–101.** Scaphopod *Dentalium neohexagonum* Sharp and Pilsbry, in Pilsbry and Sharp, 1897, LACMIP loc. 7752. **100.** Hypotype LACMIP 14417, height 9.8 mm, ×2.4. **101.** Hypotype LACMIP 14418, diameter 2.3 mm, ×3.7. **102.** Barnacle *Balanus*? sp., hypotype LACMIP 14419, LACMIP loc. 17917, side view, height 5.5 mm, ×2. **103.** Crab leg (partial), hypotype LACMIP 14420, LACMIP loc. 17918, height 10.2 mm, ×2.2. **104.** Echinoid spine *Eucidaris* sp., hypotype LACMIP 144421, LACMIP loc. 17917, height 4.2, ×5.4. **105.** Ray tooth *Myliobatis* sp., hypotype LACMIP 14422, LACMIP loc. 7752, maximum dimension 25 mm, ×0.9. **106.** Pine cone, hypotype LACMIP 14423, LACMIP loc. 7752, cross-section, height 50 mm, ×0.6.

Table 2 Depth ranges, substrate preferences, geographic ranges, and faunal provinces of Newhall area Pico Formation extant species.

	Meters	Substrate	Latitudinal range (°N)	Refs.
Terebratalia occidentalis	50–250	On hard surfaces	26–23	1
Jupiteria taphria	10–100	In sand and clay	39.5–28.2	2
Pododesmus macroschisma	0–90	On hard surfaces	70.6–27.9	2
Epilucina californica	0–80	Sand and gravel of exposed shorelines	41.8–25	2
Here excavata	25–125	In sand or mud	34.4–27.9	2
Lucinisca nuttalli	10 to 75	In sand or muddy sand	36.7–27.8 into Gulf of California to 22.4	2
Lucinoma annulatum	0–665	In sand of exposed shorelines	60.8–25.7	2
Miltha xantusi	20–150	In sand	22.1 into Gulf of California to Panama (8.3)	3
Trachycardium (*D.*) *quadragenarium*	0–50	In sand or mud, bays and offshore	36.6–27	2
Callithaca tenerrima	0–30	In gravelly sand	57.1–27.6	2
Compsomyax subdiaphana	2–500	In soft mud	60.8–30.4 + local pop. in Gulf of California (30.3)	2
Amiantis callosa	0–20	In sand, exposed headlands	34.4–24.8	2
Dosinia ponderosa	0–60	Soft bottoms	27.8 into Gulf of California to Peru (3.5°S)	3
Saxidomus nuttalli	0–10	In mud or sand, bays and lagoons	40.7–27.7	2
Tresus nuttallii	0–80	In mud, sheltered bays and foreshores	57–24.6	2
Macoma (*Rexithaerus*) *secta*	0–100	In silt and sand of bays	54–24.6	2
Macoma nasuta	0–50	In sand or silt, exposed or sheltered	60.2–27.7	2
Leporimetis obesa	subtidal–50	In sand	34.5–24.6	2
Tellina (*Tellinella*) *idae*	0–100	In sand	34.4–32.7	2
Solen (*Ensisolen*) *sicarius*	intertidal	In sand or mud, sheltered bays	54–30.4	2
Panopea abrupta	0–100	In sand or mud	57.6–33.6	2
?*Chaecia ovoidea*	0–subtidal	Boring into clay, shale, or wood	37.9–27.7	2, 4
Pandora (*Heteroclidus*) *punctuata*	subtidal–50	In mud	49.9–26.2	2
Cyathodonta pedroana	9–114	In mud	36.7–24.6	2
Calliostoma splendens	?	Rocky areas	35–32.5	5
Chlorostoma gallina form *multifilosa*	mid tidal	Rocky areas	34–25	6
Turritella cooperi	25–100	On sand	37–24 into W side Gulf of California to head of Gulf	7
Crepidula aculeata	intertidal	On hard surfaces	42–Chile (30°S)	8
Zonaria (*Neobernaya*) *spadicea*	sublittoral	Under overhung rock ledges	35–28	9
Glossaulax reclusiana	0–50	On sand or mud, common in bays	41.8 into Gulf of California to 21.5	10
Cryptonatica clausa	9–970	On soft bottoms	60–32.5	10
Sinum scopulosum	15–171	On sand or mud, common in bays	36.5–27.6	10
Asperiscala minuticostata	18–137	On sand and broken shells	28 into Gulf of California to Ecuador (0°)	11
Ocinebrina atropurpurea	0–sublittoral	Rocky bottoms	60–30.5	9
Alia tuberosa	sublittoral	In gravel under kelp	60–25	9
Barbarofusus barbarensis	50–350 m	Soft bottoms	36.5–23	7
Callianax baetica	0–offshore	On sandy bottoms	55–23	9
Californiconus californicus	0–30	On rock and sand	37.5–24.5	9
Ophiodermella inermis	0–70	Soft bottoms	53–24.5	7
Crockerella conradiana	24–240	Soft bottoms	34–32	7
Acteocina culcitella	0–offshore	On sand flats and mudflats in bays	55–27.5	9

References: 1 = Hochberg, 1994; 2 = Coan et al., 2000; 3 = Coan & Scott, 2012; 4 = Kennedy, 1974; 5 = Grant and Gale, 1931; 6 = McLean, personal communication; 7 = McLean, 1996; 8 = Keen, 1971; 9 = McLean, 1978;10 = Marincovich, 1977; 11 = DuShane, 1979.

TAPHONOMY

As mentioned earlier, the shoreface-facies megafauna occurs in channelized, storm-lag deposits. It is striking how the taxonomic composition of one storm-lag deposit differs so much from one that is nearby, in either a lateral or vertical stratigraphic sense. For example, at LACMIP loc. 17918, *Turritella cooperi* shells are so abundant that they constitute a coquina bed (with unworn specimens). In a storm lag a few meters up section, there are relatively few *T. cooperi*. Instead, there are concentrations of both the brachiopod *Terebratalia hemphilli* and the gastropod *Crepidula aculeata* (Gmelin, 1791) (some of which are vertically stacked). In addition, both species are represented by juvenile and adult specimens.

The storm-lag deposits in the upper Pico Formation commonly represent a mixture of species that lived in different life associations on different types of substrate. Occasional large storm waves raked all these shallow waters and thereby mixed the life associations together. Distance of postmortem transport was short based on the presence of paired valves of most of the brachiopods and many of the bivalves (e.g., *Panopea*, *Solena*, *Myrakeena*, *Argopecten*, *Lyropecten*) (see Table 1). None of

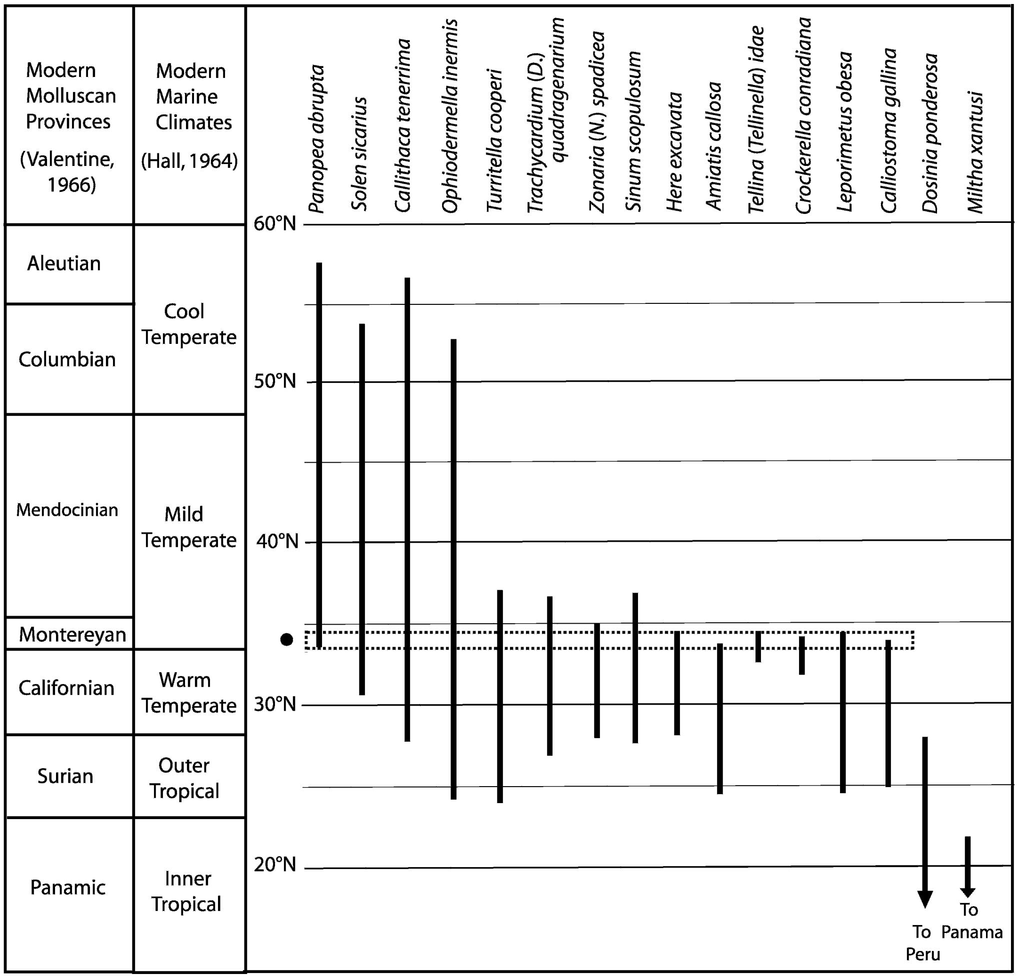

Figure 108 Latitudinal distribution of selected mollusks (see Table 2 for details) from the upper part of the Pico Formation, Newhall area vs. modern molluscan provinces and marine climates. Dashed box shows zone of maximum overlap of mollusk distributions at 31°N to 33.5°N. Solid circle = latitude of the study area (34°21′N).

these infaunal bivalves were found in their burrows. These specimens were displaced from their burrows and transported while alive. Additional evidence of short distance of transport is based a scarcity of any obvious signs of abrasion. Some examples are fragile protoconchs of some specimens of *Calliostoma* sp., aff. *C. grantianum* (Fig. 53), *Nassarius* (*Demondia*) *californianus* (Conrad, 1856) and *Cancellaria hamlini* Carson, 1926 (Fig. 96); delicate apical tips of many *Turritella cooperi*; delicate auricles of the pectinids, including those of juvenile *Argopecten invalidus*; thin varices of *Asperiscala minuticostata*? (De Boury, 1921); and four sets of two vertically stacked specimens of *Crepidula aculeata* at LACMIP loc. 17918. This is the first report of vertical stacking of this species. An additional indicator of short distance of transport is the presence, at LACMIP loc. 9659, of a growth series of the oyster *Myrakeena veatchii*. Specimens range from 18.5 to 85 mm in height. The smallest specimen is illustrated (Fig. 15) because no juvenile specimen of this species has ever been illustrated.

Some of the lentils in the upper Pico Formation storm deposits consist of dense concentrations of unworn, small-sized, mostly disarticulated specimens of bivalves. There are also a few lenses containing abundant *Turritella cooperi* that show preferred bimodal distribution (Fig. 8) in the way their shells were oriented by shallow-marine wave movements. Occasional large storm waves, which would be more common during the winter, would move and concentrate the copious *Turritella* shells, as well as other offshore shells, in storm-lag deposits on the shoaling parts of the braid delta.

ZOOGEOGRAPHIC IMPLICATIONS

Squires et al. (2006) reported that the Pico Formation megafauna in the Valencia area just west of the Newhall area is mostly indicative of warm-temperate conditions, with a few species indicative of warmer conditions. This present study corroborates these findings. Table 2 lists the latitudinal ranges of all the extant species found in the Pico Formation in the Newhall area, and Figure 108 shows that the zone of maximum overlap of representative extant species from this list is between 33.5°N and 31°N. This zone plots within the "Californian" molluscan province of Valentine (1966) and the warm-temperate, marine-climate zone of Hall (1964). There is, however, a warmer water component (tropical) based on the presence of two extant species found today considerably south of maximum overlap zone:

Miltha xantusi (Dall, 1905) and *Dosinia ponderosa* (Gray, 1838) live in the southern (tropical) part of the Gulf of California, as well as much farther south (see Table 2 for references).

Two of the extinct mollusks from the Newhall area are warm-water indicators found only in fossil deposits of Southern California and Baja California, Mexico. They are *Argopecten invalidus* and *Lyropecten catalinae* (Arnold, 1906) [= *Lyropecten gallegosi* (Jordan and Hertlein, 1926)]. Both are known (Minch et al., 1976) from as far south as the Pliocene Almejas Formation just south of Bahia Tortugas on the Vizcaino Peninsula, Baja California Sur, Mexico.

Another pectinid, *Patinopecten healeyi* (Arnold, 1906) which is present at most of the localities in the study area, is also significant in the interpretation of Neogene zoogeography. This species, like *Lyropecten catalinae*, is a giant pectinid (see Addicott, 1974), because of having a size commonly greater than 90 mm. *Patinopecten healeyi* has an early to late Pliocene chronologic range (e.g., Addicott, 1974; Moore, 1979). It reached its northernmost occurrence (Cape Mendocino in northern California), but during the late Pliocene, the species ranged farther south, with its southernmost occurrence in the Almejas Formation in Baja California Sur (Moore, 1979:fig. 1)), along with the warm-water species *Argopecten invalidus* and *L. catalinae*.

The extinct epitoniid gastropod *Amaea* (*Scalina*) *edwilsoni* DuShane, 1977, tentatively identified from the Newhall area, has been reported (DuShane, 1977) only from the Pliocene Tirabuzon Formation [formerly Gloria Formation] (Wilson, 1955) near Santa Rosalia on the Gulf of California, Baja Sur, Mexico.

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