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Eocene Megapaleontology, Stratigraphy, and Depositional Environments, Elsmere Canyon, Los Angeles County, Southern California

Richard L. Squires[1]

ABSTRACT. Fieldwork completed as part of this study resulted in the first measured stratigraphic section of the Eocene rocks and the first detailed geologic map of a portion of Elsmere Canyon, east of Newhall, northern Los Angeles County, Southern California. The first Eocene megafossils known from this area are documented. They are in a thin interval in the lower part of a 520-m-thick section that is incomplete because the base is concealed and the top is eroded. The tropical to subtropical assemblage consists of 44 species of marine invertebrates (22 gastropods, 21 bivalves, and 1 crab) and is of late early Eocene age. One of the gastropods is a new species of the solariellid genus *Solariella* Wood that is described herein. The synonymy for the gastropod *Homalopoma wattsi* (Dickerson) is updated.

The megafossils are scarce and underwent postmortem transport via turbidity currents from shallow-marine waters into deeper water associated with the middle-fan part of a submarine-fan environment. These middle-fan turbidites are overlain by inner (upper) fan turbidites, which are overlain by younger middle-fan deposits.

The study area Eocene rocks are assigned to the upper portion of the upper lower Eocene Juncal Formation based on their similarity to submarine-fan facies in this formation in the "narrows" of lower Piru Creek in the Whitaker Peak area, eastern Ventura County. It is highly likely that the San Gabriel Fault offset the Juncal Formation that was once contiguous in these two areas.

INTRODUCTION

Elsmere Canyon is just east of Newhall and in the southwestern-most part of the San Gabriel Mountains, western Transverse Ranges, northern Los Angeles County, Southern California (Fig. 1). Ever since the Elsmere Canyon oil field was discovered in 1889, workers have mentioned that Eocene strata occur in the area. Until this investigation, there has been no documentation of that age determination. Previous claims of Eocene megafossils found there represent erroneous records. On December 13, 2003, Stan Walker of Canyon Country, California, discovered a locality that yielded the first Eocene megafossils from Elsmere Canyon. A total of 44 species of marine invertebrates, including one new species of gastropod, were collected from six localities. The fossils are very scarce, with most found at a single locality. All are gastropods or bivalves, except for one crab.

The Eocene strata are generally well exposed, although contacts are usually covered by slope wash (colluvium). Some of the outcrops were largely inaccessible until a fire in 2004 temporarily removed very dense brush, including dense stands of poison oak, thereby facilitating the first detailed geologic map and the first measured stratigraphic section of these rocks. Detailed depositional-environmental interpretations are given here for the first time.

The base of the Eocene section is concealed. It is very likely that the section rests on pre-Tertiary gneissic and granitic basement rocks because a short distance to the east of the eastern edge of the Eocene outcrops (Fig. 2) this type of basement rock is present. The Eocene section is overlain unconformably by shallow-marine deposits of the lower Pliocene Towsley Formation (see Kern, 1973), but the southeastern edge of the Eocene outcrops is adjacent to the high-angle Whitney Canyon Fault, whose east side is downthrown (Figs. 2, 3).

PREVIOUS WORK

The first person to suggest that there might be Eocene rocks in Elsmere Canyon was Hamlin in Watts (1900), who reported that the rocks resemble Eocene sandstones of the Sespe district, which is approximately 50 km northwest of Elsmere Canyon. For the next 30 years, reports about the Elsmere Canyon area dealt primarily with oil-production records (e.g., Walling, 1934). The first geologic maps of the region (Eldridge and Arnold, 1907; Kew, 1924) did not show any Eocene rocks.

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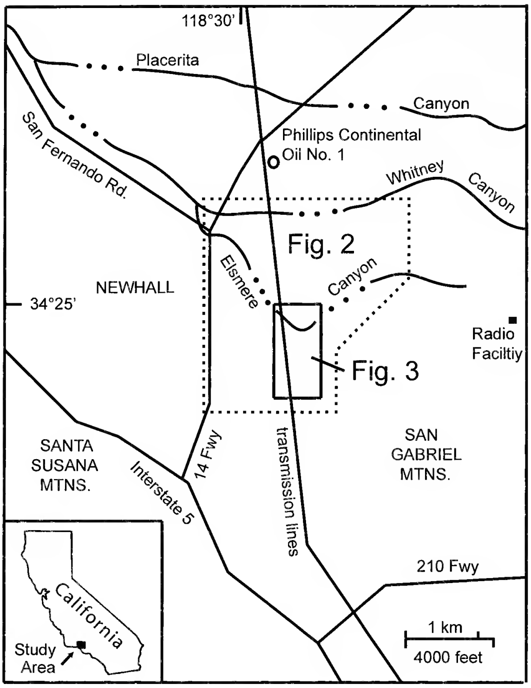


Figure 1 Index map showing location of the Elsmere Canyon area

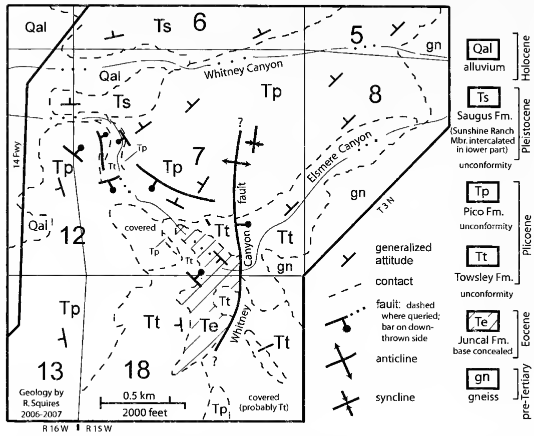


Figure 2 Generalized geologic map of the Elsmere Canyon region. Base map from United States Geological Survey, 7.5 minute, San Fernando and Oat Mountain quadrangles. Formation ages generalized from Dibblee (1991)

It was not until 1931, when Kew read a "paper" before the Geology and Paleontology Club at the California Institute of Technology, that the name "Domengine Formation" was used for Eocene strata in the study area (Brown and Kew, 1932). Attempts to find this "paper" have proved fruitless, and as far as anyone knows, the "paper" was never archived. It is not known how Kew concluded that this name be used, but it was common practice then to use the name "Domengine" for any middle Eocene rocks in California (Clark, 1926).

Kew's "paper" and his subsequent personnel communications strongly influenced graduate students Holloway (1940) and Ford (1941), who reported outcrops of Domengine? or Domengine Eocene, respectively, in Elsmere Canyon. Kew (1943) suggested a middle Eocene age for these rocks, but he did not give any details.

Oakeshott (1950) also reported middle Eocene Domengine rocks in the area and suggested that a probable subsurface fault, which he named the Whitney Canyon Fault, might extend southward from the Placerita Canyon area to the eastern edge of the Eocene exposures in the Elsmere Canyon area. This fault had been postulated by Walling (1934) as a result of his subsurface studies in the Whitney Canyon area. Holloway (1940) and Ford (1941) also mapped this fault, although they used their own informal names for it and extended it from the Elsmere Canyon area northward to Whitney Canyon.

After the Phillips Continental Oil Company's well No. 1 was drilled in early 1950s in the Whitney Canyon area, 2.3 km north of Elsmere Canyon (Fig. 1), Oakeshott (1958) mentioned that (Domengine) foraminifera were found in this well, although he did not list any species. On his geologic map, he assigned the Elsmere Canyon strata to the molluscan "Domengine Stage." He also gave a general description of the lithology of the Eocene outcrops in Elsmere Canyon and their relationship with overlying stratigraphic units. In addition, he was the first to postulate correlation of the outcrops to the lower part of the Llajas Formation in Simi Valley. His findings greatly influenced all subsequent geologic investigations of the Elsmere Canyon Eocene strata (i.e., Oakeshott, 1954a, 1954b, 1958, 1975; Winterer and Durham, 1954). All subsequent workers, including those who have done compilation-style studies of Eocene stratigraphy in California (e.g., Howell, 1975; Nilsen and Clarke, 1975), have essentially reiterated Oakshott's (1958) findings, although there has not been agreement as to which side of the Whitney Canyon fault is downthrown.

Paschall and Off (1961), Winterer and Durham (1962), Kern (1973), and Dibblee (1991) dropped the "Domengine Formation" designation for the Elsmere Canyon Eocene rocks and substituted an "unnamed" designation. Winterer and Durham (1962) made some brief stratigraphic observations and listed Eocene megafossils from the area but not from Elsmere Canyon. Nelligan (1978), Seedorf (1983), and Yeats et al. (1994) applied the name "Llajas Formation" to these rocks, but there are problems with this assignment (see "Correlation" section).

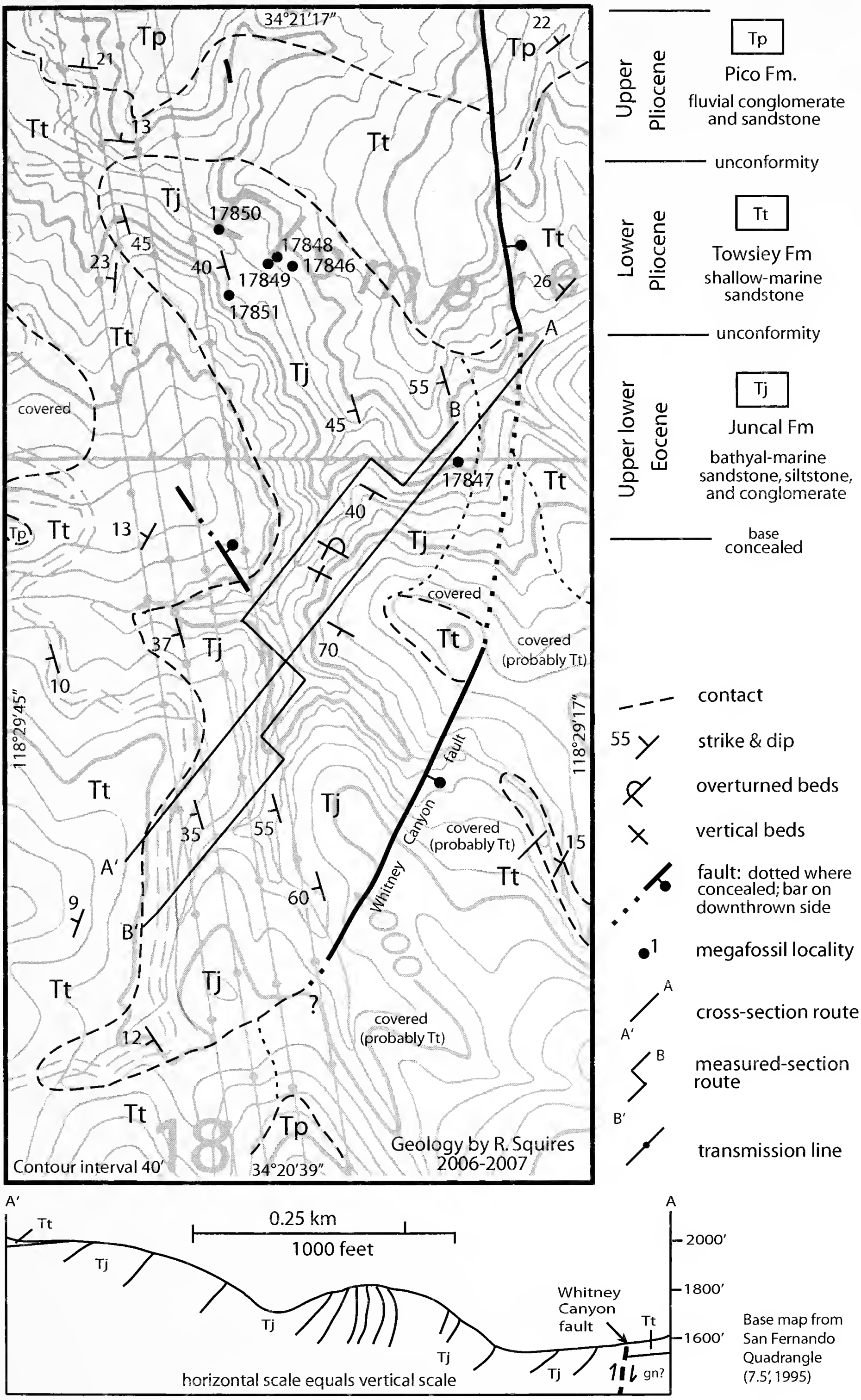


Figure 3 Geologic map and geologic cross section of the Elsmere Canyon area. Base map from United States Geological Survey, 7.5 minute, San Fernando Quadrangle (1995). Formation ages, other than for Juncal Formation, taken from Dibblee (1991)

METHODS AND SYSTEMATIC MATERIALS

The author spent 25 days, between February 2006 and August 2007, doing fieldwork that included detailed geologic mapping, collecting megafossils, and measuring a stratigraphic section by means of the Brunton-and-Jacob staff technique. Additional fossil collecting was done by Stan Walker and John Alderson. The fossils were cleaned from their matrix by the use of hammer and chisel. Fine cleaning was done by the use of a high-speed power tool. Macrophotography was done by means of a digital SLR camera.

Submarine-fan facies terminology is from Walker and Mutti (1973), and the systematic arrangement of higher taxa of the gastropods follows that of Bouchet et al. (2005). Only the systematics for a new species of the gastropod *Solariella* Wood and the gastropod *Homalopoma wattsi* (Dickerson, 1916) are provided here. The latter gastropod has been found in various additional formations since its last synonymy by Weaver (1943), thus requiring an updated synonymy. Recent synonymies, geologic age ranges, and biogeographic ranges are available for all the other species, with one exception (see next paragraph), and the reference for each synonymy is provided in Table 1 as "Range Reference." A refinement to Squires's (1987) synonymy of *Turritella andersoni* Dickerson, 1916, is that Squires (1999) reported that *T. andersoni* differs from *T. andersoni susanae* Merriam, 1941.

A synonymy for *Pitar* (*Lamelliconcha*) *avenalensis*? Vokes, 1939, has not been given in recent years, but because this species has been reported previously only from the "Domengine Stage" Domengine Formation near Coalinga, the comments provided by Vokes (1939:86, pl. 13, figs. 4, 5, 8) are adequate.

Abbreviations for locality and/or catalog numbers are LACMIP (Natural History Museum of Los Angeles County, Invertebrate Paleontology Section) and UCMP (University of California, Museum of Paleontology, Berkeley). The figured specimens, as well as all the other megafossils collected in the course of this study, were deposited in the LACMIP collection.

LOCALITIES

All the LACMIP localities are found on the United States Geological Survey, San Fernando, California Quadrangle (7.5 minute), 1995 edition.

17846—Elevation 1600 ft., sandstone lens in siltstone in stream bed on north side of Elsmere Canyon, 2150 ft. W and 4850 ft. S of NE corner of section 7, T 3 N, R 15 W, collected by S. Walker, spring, 2005.

17847—Elevation 1600 ft., sandstone in stream bed on south side of Elsmere Canyon, 1750 ft. W and 5600 ft. S of NE corner of section 7, T 3 N, R 15 W, collected by R. L. Squires, April 21, 2006.

17848—Elevation 1560 ft., pebbly sandstone lens surrounded by siltstone in cut bank of streambed on north side of Elsmere Canyon, 2375 ft. W and 4825 ft. S of NE corner of section 7, collected by S. Walker, J. Alderson, and R. L. Squires, December 2003 to October 2006.

17849—Conglomeratic sandstone lens (surrounded by siltstone), 1 m stratigraphically above locality 17848 and 70 cm south, collected by S. Walker and R. L. Squires, spring 2005 to October 2006.

17850—Elevation 1540 ft., thin lens of sandstone in siltstone, just above streambed on north side of Elsmere Canyon, 2625 ft. W and 4850 ft. S of NE corner of section 7, T 3 N, R 15 W, collected by R. L. Squires and S. Walker, October 14, 2006.

17851—Elevation 1560 ft., siltstone in cut bank of streambed, south side of Elsmere Canyon, 2600 ft. W and 5000 ft. S of NE corner of section 7, T 3 N, R 15 W, collected by S. Walker, April 2006.

MEGAFOSSIL OVERVIEW

Winterer and Durham (1962:table 1) presented a megafaunal species list of 22 gastropods, 23 bivalves, 1 scaphopod, and 3 echinoids of probable middle Eocene or early late Eocene age from cores of two wells, both approximately 3 km west of Elsmere Canyon and supposedly from an "outcrop" that corresponds to "Kew loc. 4" in Elsmere Canyon. In a footnote, they stated that this latter locality was not shown on their geologic map because its location was uncertain. Their mention of "Kew loc. 4" was evidently in reference to Kew (1924), but, as mentioned earlier, he did not map these outcrops as Eocene nor is there a "loc. 4" on his map. Stan Walker, a collector, and myself independently contacted both Winterer and Durham in an attempt to obtain better information about this locality, but they were not able to provide any specifics. Stan Walker, on the advice of Winterer, obtained Kew's field notes from the United States Geological Society and found that Kew had made no mention of this locality. It is readily apparent that "Kew loc. 4" is an oil-well core sample that was mistakenly attributed to Kew.

In the course of this investigation, a total of 44 species of marine invertebrates (Table 1) was collected from six localities. Their locations are shown on Figure 3, and their stratigraphic positions are shown on Figure 4. All the species are illustrated here (Figs. 9–56). Fossils are very scarce, and most of the specimens were found at LACMIP locality 17848. At three of the other five collecting localities, only a single specimen was found. Except for a few fragments of crab chelipeds, all the collected specimens are mol-

Table 1 Megafossils of the Juncal Formation in Elsmere Canyon

Taxa	Localities						Stages							Range Reference
	17846	17847	17848	17849	17850	17851	Mr	Me	C	D	Tr	Te	Ma	
Gastropoda														
Diodora sp.			r											
Solariella walkeri n. sp.			r											
Homalopoma wattsi (Dickerson, 1916)			c						x					See "Systematics"
Turritella andersoni Dickerson, 1916			r	r					x					Squires, 1987
Turritella buwaldana? Dickerson, 1916								x	x	x	x	x		Squires, 1999
Calyptraea diegoana (Conrad, 1855)			c				x	x	x	x	x	x	x	Squires, 1999
Ectinochilus (Macilentos) macilentus (White, 1889)			f						x	x				Squires, 1987
Eocypraea (E.) sp., cf. *E. (E.) castacensis* Stewart, 1927			r											
Eocernia hannibali (Dickerson, 1914)			c						x	x	x			Squires, 1987
Pachycrommium clarki (Stewart, 1927)			c					x	x	x	x	x		Squires, 1999
Natica? sp. *indet.*			c											
Galeodea (Mambrina) susanae Schenck, 1926			r			r				x	?			Squires, 1984
Ficopsis remondii cresentensis Weaver & Palmer, 1922			f						x	x	x			Squires, 1987
Molopophorus? sp., cf. *M.? aequicostatus* Vokes, 1939			r											
Olivella mathewsonii Gabb, 1864			f				x	x	x	x	x	x		Squires, 1987
Lyria andersoni Waring, 1917			c	f					x	x				Squires, 1987
Turricula sp.					r									
Pleurofusia fresnoensis (Arnold, 1910)			r						x	x	x			Squires, 1987
Cryptoconus cooperi (Dickerson, 1916)			r					x	x	x				Squires, 1987
Conus sp. indet.			r											
Cylichnina tantilla (Anderson & Hanna, 1925)			c		f				x	x				Squires, 1999
Acteon? sp.					c									
Bivalvia														
Barbatia (Cucullaearca) cliffensis Hanna, 1927			r						x	x				Squires, 1987
Glycymeris (G.) rosecanyonensis Hanna, 1927			c							x	x			Squires, 1987
Glycymeris (Glycymerita) sagittata (Gabb, 1864)			a						x	x	x	?		Squires, 1984
Brachidontes (B.) cowlitzensis (Weaver & Palmer, 1922)					r			x	x	x	x	x	x	Squires, 1984
Ostrea sp.	r	r	f		r									
Parvamussium sp.					f									
?Anomia mcgoniglensis Hanna, 1927			r							x				Squires, 1984
Spondylus carlosensis Anderson, 1905			r						x	x	x	x		Squires & Goedert, 1995
Miltha packi (Dickerson, 1916)			r						x	x	x	x		Squires, 1987
Claibornites diegoensis (Dickerson, 1916)			r						x	x				Squires, 1987
Glyptoactis (Claibornicardia) sandiegoensis (Hanna, 1927)			r						x	x				Squires, 1987
Crassatella uvasana (Conrad, 1855)			f							x	x	x		Squires, 1984
Acanthocardia (Schedocardia) breweri (Gabb, 1864)			c						x	x	x	x		Squires, 1984
Nemocardium linteum (Conrad, 1855)			r				x	x	x	x	x	x		Squires, 1999
Tellina? sp.					r									
Callista (Macrocallista) domenginica Vokes, 1939			f							x				Squires, 1987
Pitar (Lamelliconcha) joaquinensis Vokes, 1939			c						x	x				Squires, 1987
Pitar (Lamelliconcha) avenalensis? Vokes, 1939			r							x				Vokes, 1939
Pitar (Calipatria) uvasanus (Conrad, 1855)			r							x	x	x		Squires, 1984
Corbula (Caryocorbula) dickersoni Weaver & Palmer, 1922			f		r				x	x	x	x		Squires, 1999
Teredinid			f		f									
Brachyura														
Raninid (chelipeds)			f											

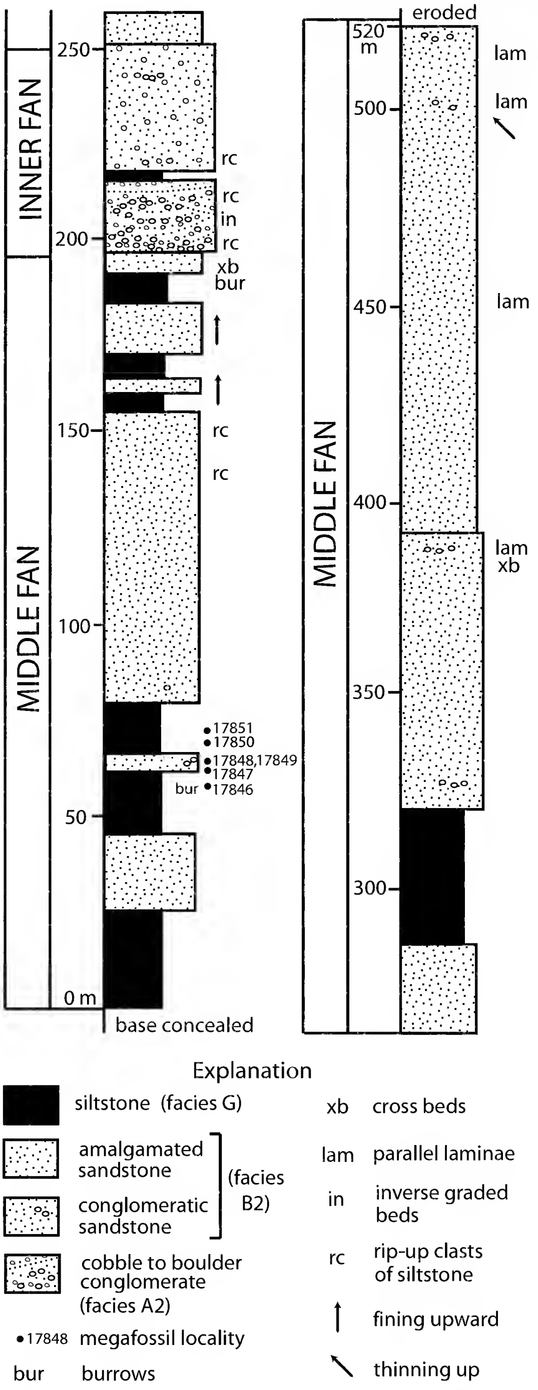


Figure 4 Columnar section showing stratigraphy, positions of the megafossil localities, and depositional environments. Facies terminology from Walker and Mutti (1973)

lusks. Most have moderately poor preservation, except at locality 17848, where preservation can be good, with solid shell material bearing sculpture and, in some cases, growth lines. Of the 215 specimens that were collected, only 155 could be identified to family level or below. The other 60 specimens are internal molds (mostly of bivalves). Most specimens are small fragments, and no articulated bivalves were found.

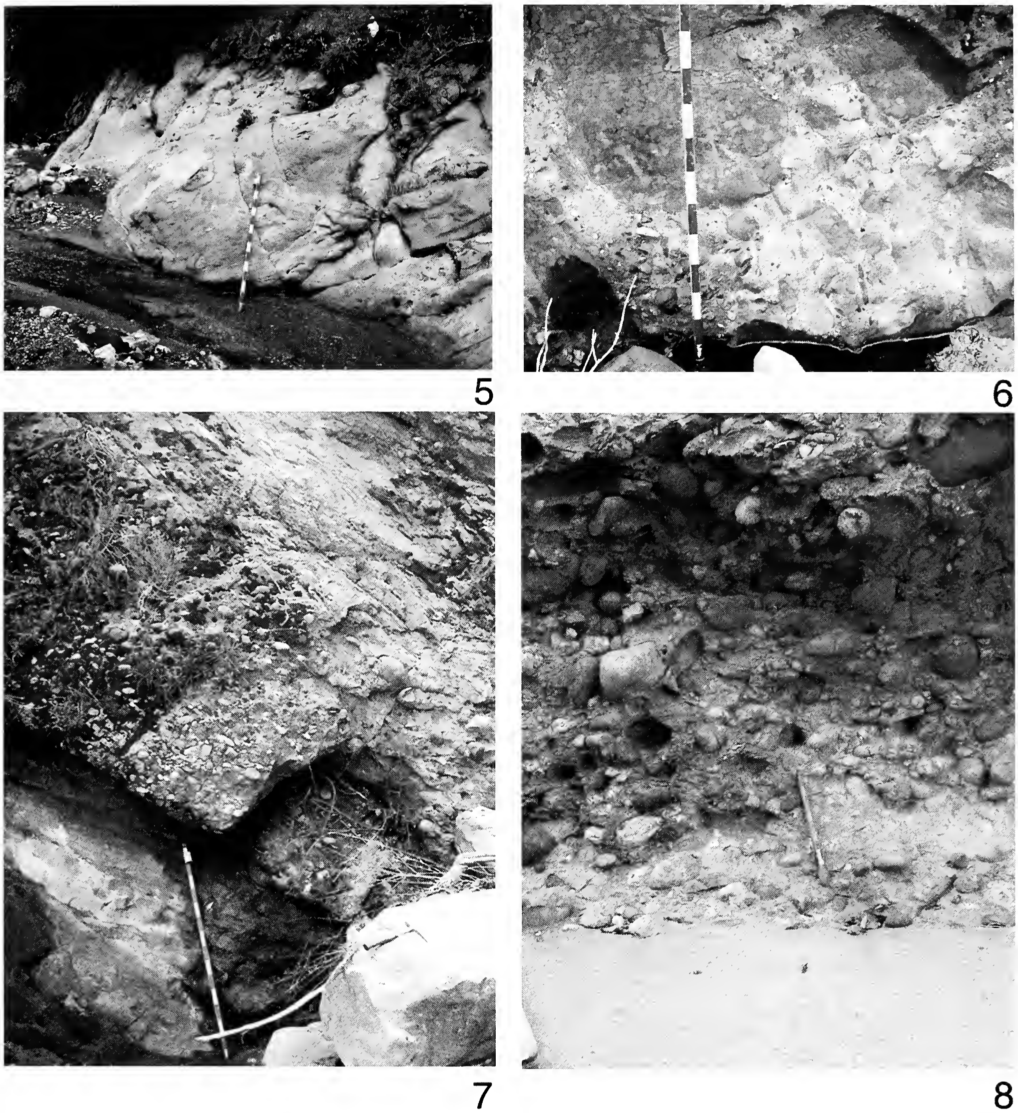
STRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS

A forearc basin setting existed along the continental margin in Southern California from late Cretaceous until early Miocene time, and a sedimentary wedge was deposited along a west-facing coastal plain (Yeats et al., 1994). This sedimentary wedge included, in part, Eocene rocks like those found in the study area.

The lithologies, thicknesses of stratigraphic units, sedimentary structures, and other pertinent data of the 520-m-thick Eocene section in the Elsmere Canyon area are summarized in Figure 4. These data are consistent with a submarine-fan turbidite facies. The studied section consists of sandstone, conglomerate, and siltstone. The sandstone contains features consistent with Walker and Mutti's (1973) middle-fan facies B2: thick-bedded, amalgamated (massive), medium- to coarse-grained sandstone (Fig. 5), with locally a few scattered pebbles, scarce burrows, and very scarce megafossils. The conglomerate contains features consistent with the inner (upper) fan facies A2: some very large siltstone rip-up clasts (up to 90 cm long) (Fig. 6), channels (Fig. 7), inverse grading (Fig. 8), normal grading, organized and clast-supported fabric, some imbricated clasts, and rare cross beds in the associated medium- to coarse-grained sandy matrix. The siltstone contains features consistent with facies G: local gradation into mudstone or very fine-grained sandstone and intercalation between the previously mentioned turbidite facies. According to Walker and Mutti (1973), deposition of facies G can take place before, after, or during turbidite sedimentation of coarser facies.

All the megafossils were found within a 15-m-thick interval in facies B2 deposits in the lower part of the exposed Eocene section. Three of the six localities are within the same sandstone unit. Locality LACMIP 17847 is at the base of this sandstone, whereas LACMIP 17848 and LACMIP 17849 are near where the sandstone pinches out and is intercalated with siltstone beds. Megafossils at the two latter localities occur in two closely situated, vertically stacked, 1-m-thick, 5-m-wide channels containing pebbly sandstone. The channels are surrounded by siltstone. The other three localities occur slightly downsection or upsection (Fig. 4), either in siltstone or in sand lentils surrounded by siltstone.

Facies B2 beds in the upper half of the section occur in two very thick "sandstone packages." The upper one (between 390 and 520 m in the measured section; see Fig. 4) differs from the

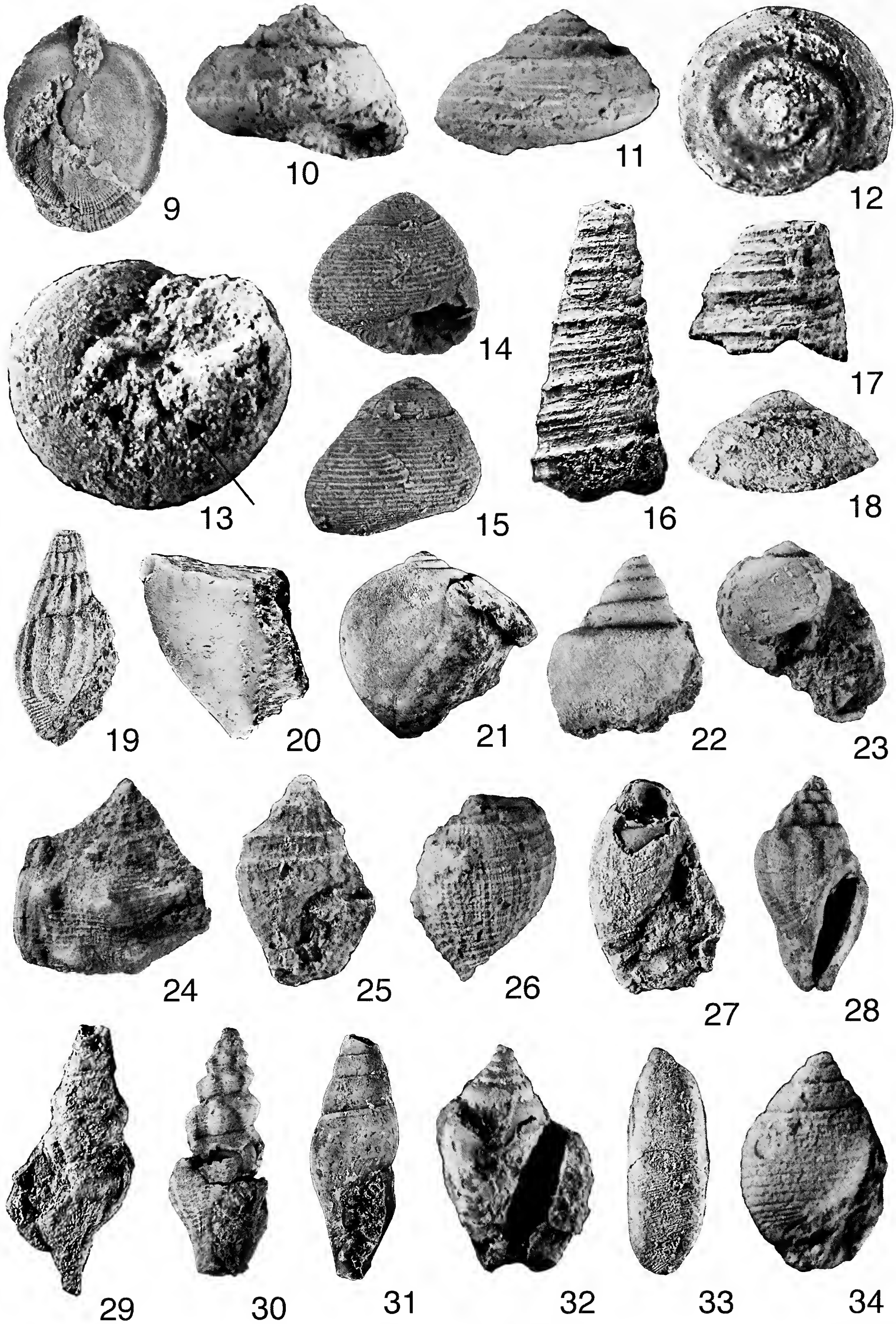


Figures 5–8 Photographs of selected outcrops of the Eocene strata in the Elsmere Canyon area. **5.** Amalgamated middle-fan sandstone (facies B2) at approximately 60 m in measured section (in streambed of Elsmere Canyon), scale 1.5 m; **6.** Siltstone rip-up clasts in inner fan conglomerate (facies A2) at approximately 200 m in measured section, scale 1.2 m; **7.** Channelized inner fan conglomerate (facies A2) at approximately 200 m in measured section, scale 1.5 m; **8.** Inverse-graded bedding in inner fan conglomerate bed (facies A2) showing sharp erosional contact with underlying amalgamated sandstone at approximately 210 m in measured section, pencil 14 cm in length

lower one by having crude subparallel horizontal laminae and alternating cycles of (1) approximately 7-m-thick medium- to coarse-grained sandstone with scattered pebbles and (2) approximately 6-m-thick very fine- to fine-grained sandstone.

The larger clasts in the conglomerates are usually cobble in size, with some boulders. They are always rounded to well rounded, except for the siltstone rip-up clasts in the inner fan deposits (facies A2). These rip-up clasts are usually somewhat angular, indicating a local source and minimal transport distance. The larger clasts are mostly granite (≈54%), gneiss (≈20%), gray to white quartzite (≈12%), siltstone (7%), purplish to reddish and even black porphyritic volcanics (6%), and black aphanitics (1%).

The inner fan conglomerates in the middle of the Eocene section are difficult to access because they are well cemented and their beds form a gorge with precipitous walls and a streambed marked by numerous and sizable waterfalls. This gorge is coincident with overturned beds and a high-angle reverse fault (Fig. 3).



Figures 9–34 Eocene gastropods from Elsmere Canyon, LACMIP locality 17848, unless otherwise specified. All specimens coated with ammonium chloride. **9.** *Diodora* sp., LACMIP hypotype 13413, dorsal view of partial specimen (mostly internal mold), length 32 mm, width 23 mm, ×1.1; **10–13.** *Solariella walkeri* n. sp., LACMIP holotype 13414, apertural view, height 2.6 mm, diameter 3.5 mm: **10.** Apertural view, ×9.7, **11.** Abapertural view, ×9.7, **12.** Apical view, ×9.7, **13.** Basal view, arrow points to crenulations around umbilicus, ×12.4; **14–15.** *Homalopoma wattsi* (Dickerson, 1916), LACMIP hypotype 13416, height 6.5 mm, diameter 6.5 mm, ×4: **14.** Apertural view,

SYSTEMATICS

Phylum Mollusca Linnaeus, 1758
Class Gastropoda Cuvier, 1797
Superfamily Trochoidea Rafinesque, 1815
Family Solariellidae Powell, 1951
Genus *Solariella* Wood, 1842

TYPE SPECIES. *Solariella maculata* Wood, 1842, by monotypy, Pliocene, England.

Solariella walkeri n. sp.
Figures 10–13

DIAGNOSIS. *Solariella* with low-turbinate shell, tricarinate last whorl, smooth and wide subsutural canal, small nodes on shoulder of whorls, and microscopic spiral threads on base.

DESCRIPTION. Shell small (up to height 2.6 mm), low turbinate, approximately 3.5 tabulate whorls, enlarging rapidly. Spire whorls unicarinate. Depressed area between suture and tabulate shoulder flat, normal to axis of shell, and containing at least one spiral riblet. Tabulate shoulder minutely noded; nodes becoming obsolete toward outer lip. Last whorl tricarinate with four very weak spiral ribs between shoulder and submedial angulation and two very weak spiral ribs between submedial and anterior angulations. Submedial angulation bearing very minute nodes. Base rounded and covered with numerous and very closely spaced spiral threads of uniform strength. Umbilicus open, bordered by crenulations.

COMPARISON. Nine other species of *Solariella* are known from the Paleogene record of the west coast, and their key morphologic characters compared to those of the new species are provided in Table 2. The new species is most similar to *Solariella dibitata* Hanna (1927:301, pl. 47, figs. 2, 5, 10, 11) but differs in having a nearly smooth base, no oblique collabral ribs (noded) in the area between the suture and the posterior angulation, and no collabral ribs across the face of the last whorl. *Solariella dibitata* is known from Rose Creek, San Diego County, Southern California. According to Givens and Kennedy (1979:fig. 3), Eocene outcrops in the Rose Creek area are the "Domengine Stage" Ardath Shale and the "Domengine" to "Transition" "stages" Scripps Formation.

HOLOTYPE DIMENSIONS. Height 2.6 mm, diameter 3.5 mm.

PRIMARY TYPE MATERIAL. LACMIP holotype 13414 and LACMIP paratype 13415; both from LACMIP locality 17848.

GEOLOGIC AGE. Late early Eocene (at boundary between "Capay" and "Domengine" "stages."

GEOGRAPHIC DISTRIBUTION. Elsmere Canyon, near Newhall, northern Los Angeles County, Southern California.

REMARKS. Two small specimens were found. The holotype is well preserved (e.g., original shell material, very fine sculpture), and the slightly smaller paratype has poorer preservation.

ETYMOLOGY. The new species is named for Stan Walker, discoverer of the Eocene Elsmere Canyon megafauna.

Superfamily Turbinoidea Rafinesque, 1815
Family Turbinidae Rafinesque, 1815
Genus *Homalopoma* Carpenter, 1864

TYPE SPECIES. *Turbo sanguineus* Linnaeus, 1758; Recent, Mediterranean and Adriatic seas.

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15. Abapertural view; **16.** *Turritella andersoni* Dickerson, 1916, LACMIP hypotype 13417, abapertural view, height 17 mm, diameter 8 mm, ×2.7; **17.** *Turritella buwaldana*? Dickerson, 1916, LACMIP hypotype 13418, abapertural view, height 5 mm, diameter 4 mm, ×4.3; **18.** *Calyptraea diegoana* (Conrad, 1855), LACMP hypotype 13419, lateral view, height 4.5 mm, diameter 8 mm, ×3.8; **19.** *Ectinochilus (Macilentos) macilentus* (White, 1889), LACMIP hypotype 13420, apertural view, height 22 mm, diameter 10 mm, ×1.5; **20.** *Eocypraea (E.)* sp., cf. *E. (E.) castacensis*, LACMP hypotype 13421, apertural view of partial specimen, height 17 mm, diameter 12 mm, height 1.6; **21.** *Eocernina hannibali* (Dickerson, 1914), LACMP hypotype 13422, apertural view, height 33 mm, diameter 31 mm, ×0.9; **22.** *Pachycrommium clarki* (Stewart, 1927), LACMP hypotype 13423, abapertural view, height 17 mm, diameter 15 mm, ×1.5; **23.** *Natica*? sp. indet., LACMP hypotype 13424, apertural view, height 11 mm, diameter 10 mm, ×2.3; **24.** *Galeodea (Mamabrina) susanae* Schenck, 1926, LACMP hypotype 13425, right-lateral view of partial specimen, height 17 mm, diameter 18 mm, ×1.8; **25.** *Ficopsis remondii crescentensis* Weaver and Palmer, 1922, LACMP hypotype 13426, apertural view, height 14 mm, diameter 9 mm, ×2.3; **26.** *Molopophorus*? sp,. cf. *M.*? *aequicostatus* Vokes, 1939, LACMP hypotype 13427, abapertural view of partial specimen, height 6 mm, diameter 5 mm, ×4.5; **27.** *Olivella mathewsonii* Gabb, 1864, LACMP hypotype 13428, apertural view, height 8 mm, diameter 5 mm, ×4; **28.** *Lyria andersoni* Waring, 1917, LACMP hypotype 13429, apertural view, height 29 mm, diameter 15 mm, ×1.1; **29.** *Turricula* sp., LACMP hypotype 13430, LACMIP loc. 17850, abapertural view, height 10 mm, diameter 5 mm, ×4.2; **30.** *Pleurofusia fresnoensis* (Arnold, 1910), LACMP hypotype 13431, apertural view, height 21.5 mm, diameter 11.5 mm, ×1.8; **31.** *Cryptoconus cooperi* (Dickerson, 1916), LACMP hypotype 13432, apertural view, height 20 mm, diameter 7 mm, ×1.9; **32.** *Conus* sp. indet., LACMP hypotype 13433, apertural view, height 6 mm, diameter 4 mm, ×5.8; **33.** *Cylichnina tantilla* (Anderson and Hanna, 1925), LACMP hypotype 13434, abapertural view, height 14 mm, diameter 5 mm, ×2; **34.** *Acteon*? sp., LACMP hypotype 13435, LACMIP loc. 17850, apertural view, height 3 mm, diameter 2 mm, ×11.3

Table 2 Morphology and occurrence checklist of west coast Paleogene *Solariella* species. Abbreviations: CA = California; WA = Washington; Paleoc./Eoc. = near Paleocene and Eocene boundary

Species	Shape	Last whorl	Shoulder	Base	Height (mm)	Area	Age	Other
crenulata (Gabb, 1864)	Discoidal	Bicarinate	Noded	Smooth	3.6	CA	Eoc.	
crescentensis Weaver & Palmer, 1922	High turbinate	Not carinate	Noded	Strong spiral ribs	4	WA	Eoc.	Last whorl with several subequal, strong and beaded spiral ribs
dibitata Hanna, 1927	Low turbinate	Tricarinate	Noded	Weak spiral ribs	3	CA	Eoc.	Wide subsutural canal with many oblique collabral ribs
enamellata Anderson & Hanna 1925	High turbinate	Bicarinate	Noded	Spiral ribs	3	CA	Eoc.	
garrardensis Squires & Goedert, 1995	High turbinate	Tricarinate	Unnoded	Nearly smooth	10	WA	Eoc.	Wide subsutural canal with spiral ribs
hartleyensis Clark & Woodford 1927	High turbinate	Bicarinate	Unnoded	Smooth	5	CA	Paleoc./Eoc.	
minorstriata Nelson, 1925	Turbinate	Tricarinate	Unnoded	Smooth?	4.8	CA	Paleoc.	
olequahensis Weaver & Palmer, 1922	High turbinate	Not carinate	Noded	Weak spiral ribs	2.3	WA	Eoc.	Last whorl with several strong spiral ribs
transennata Nelson, 1925	Low turbinate	Tricarinate	Unnoded	Weak spiral ribs	3.3	CA	Paleoc.	
walkeri n. sp.	Low turbinate	Tricarinate	Noded	Microscopic spiral ribs	2.6	CA	Eoc.	Wide, smooth subsutural canal

Homalopoma wattsi (Dickerson, 1916)
Figures 14, 15

Monodonta wattsi Dickerson, 1916:494, pl. 40, figs. 3a, 3b.
Homalopoma wattsi (Dickerson). Vokes, 1939:179, pl. 21, figs. 21, 21; Turner, 1938:96, pl. 15, fig. 16; Weaver, 1943:298, pl. 64, figs. 11, 14.
Homalopoma aff. *H. wattsi* (Dickerson). Squires, 1991:pl. 1, fig. 9.

TYPE MATERIAL. Holotype UCMP 11828.
TYPE LOCALITY. UCMP loc. 1853 (Marysville Buttes, Sutter County, northern California).
GEOLOGIC AGE. Late early Eocene ("Capay Stage.")
STRATIGRAPHIC DISTRIBUTION. Southwest Oregon (Turner, 1938), in strata now referred to as the White Tail Ridge Formation (see Ryu et al., 1996); Marysville Formation, northern California (Dickerson, 1916); Capay Formation, northern California (Vokes, 1939); Salt Creek, north of Coalinga, central California (Vokes, 1939), in strata now referred to as the Cerros Shale Member of the Lodo Formation (see Squires, 1988); Juncal Formation, Elsmere Canyon, Southern California (new information); Maniobra Formation, Southern California (Squires, 1991).
REMARKS. Seven specimens were found, and all are from LACMIP locality 17848. Most have good preservation (e.g., original shell material, fine sculpture). Most have ribs of medium width on the last whorl, but a few have narrower ribs.

DISCUSSION

AGE

The stage range of each species is given in Table 1. Squires (2003:15–16, fig. 2.1) discussed how these stages were derived and provided their ages. Based on taxon ranges and concurrent-range zones (Table 1), most of the Elsmere Canyon mollusks were previously found in the "Domengine Stage" of late early to early middle Eocene age. *Homalopoma wattsi* and *Turritella andersoni* Dickerson, 1916, however, represent the older "Capay Stage" of middle early to late early Eocene age. In order to explain these conflicting data, it seems plausible that the total megafauna represents an age that corresponds to the boundary between the "Capay Stage" and the "Domengine Stage" and hence of late early Eocene age. Squires (2003) correlated this boundary to the paleomagnetic record mid C22r chron. Using the Paleogene time scale of Gradstein et al. (2004), this boundary corresponds to approximately 50.5 million years ago.

PALEOCLIMATE

During the early Paleogene, warm climates were globally extensive, and the Earth was clearly in a "greenhouse" mode, a condition that appears to have been much exaggerated during the terminal Paleocene, when abrupt warming occurred (Aubry et al., 1998). During the Paleocene and most of the Eocene, West Coast Eocene marine-molluscan megafaunas have long been assigned to tropical or subtropical conditions (see Squires, 1987). As summarized by Squires (1998), during the early Eocene, tropical and hot-humid conditions prevailed in coastal-lowland areas in the Southern California area. Marine gastropod diversity reached its highest level for the West Coast during the early Eocene (Squires, 2003). Representative thermophilic gastropod genera include *Ectinochilus*, *Eocypraea*, *Eocernina*, *Ficopsis*, and *Lyria*, all of which are found in the Elsmere Canyon Eocene megafauna. Among the Eocene bivalve genera that Durham (1950) listed as characteristic of tropical to subtropical conditions, the following also occur in the Elsmere Canyon megafauna: *Crassatella*, *Spondlyus*, and *Pitar*.

STRATIGRAPHIC CORRELATION

The Elsmere Canyon Eocene rocks are most similar lithostratigraphically to the Juncal Formation that crops out at the "narrows" of lower Piru Creek, in the vicinity of the mouth of Michael Creek, approximately 32 km to the northwest of Elsmere Canyon (Fig. 57). Both sections are in close proximity to crystalline basement rocks, and both consist of two conglomerate units alternating with siltstone units (Bachman and Abbott, 1988; Dibblee, 1996). The thicknesses of the different units are remarkably similar in their proportion to the total thickness of their respective section (e.g., the lower conglomerate makes up approximately 20% of the total thickness, and the upper conglomerate makes up approximately 7%).

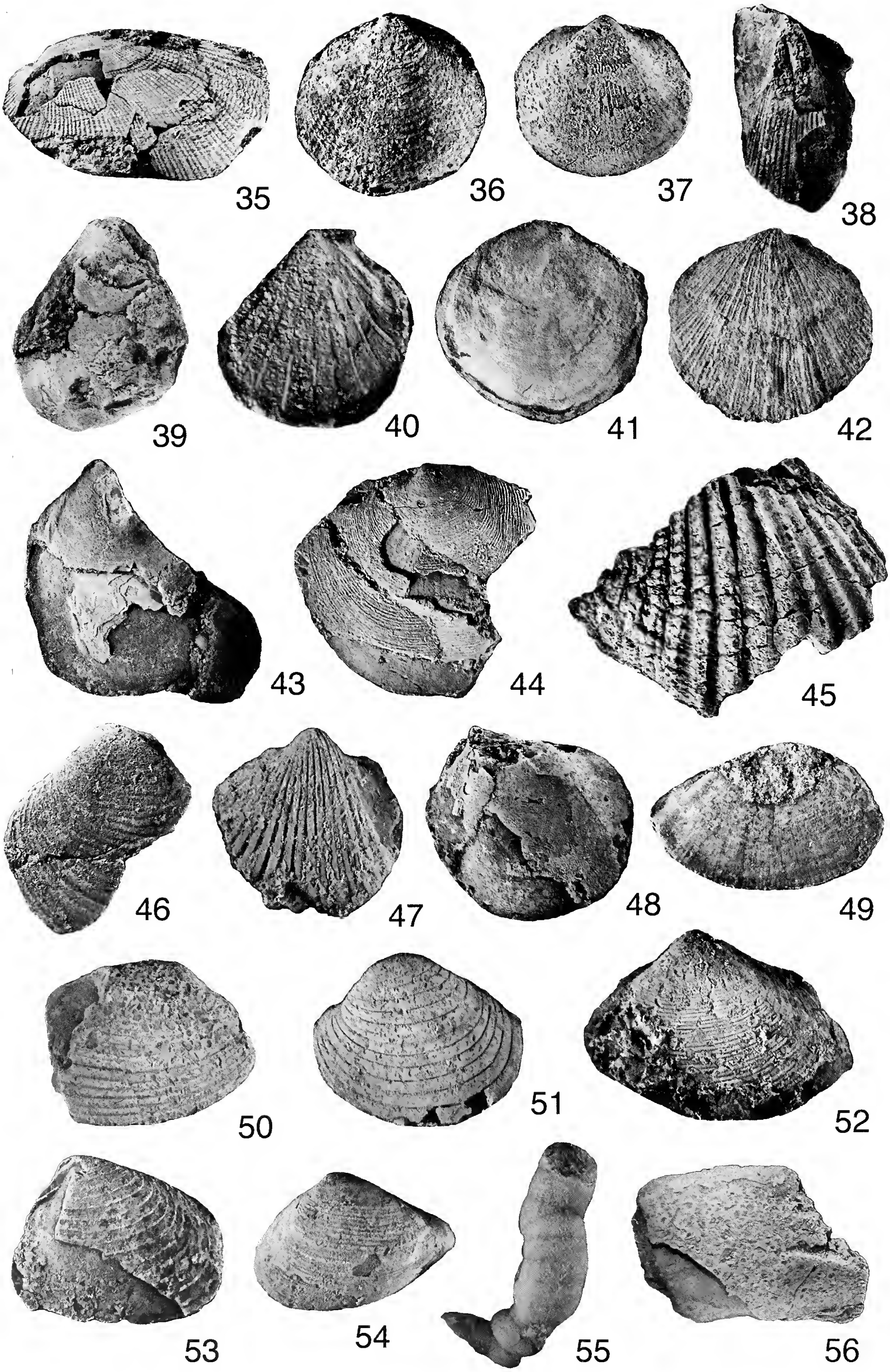
The upper conglomerate interbedded with coarse sandstone in the upper part of the Juncal Formation in the "narrows" area has the greatest similarity to the Elsmere Canyon Eocene rocks. Squires (1987:9) briefly described the sedimentary features of this upper conglomerate. Like the conglomerate in the Elsmere Canyon section, it is made up of submarine-fan (inner channel) conglomeratic turbidites consisting of channelized and amalgamated medium to coarse sandstones locally containing large siltstone rip-up clasts, well-stratified conglomerate beds, exotic volcanic porphyry clasts (although the varieties seem to be less porphyritic in the Elsmere Canyon section), and very scarce megafossils. Squires (1987) reported finding only a few transported fragments of the gastropod ?*Eocernina hannibali* (Dickerson, 1914) in the upper conglomerate in the "narrows" area. Transported remains of this gastropod are also found in the Elsmere Canyon area. Squires (1987:fig. 6) assigned this upper conglomerate to the upper Juncal Formation and temporally correlative to the "Domengine Stage."

Bachman and Abbott (1988:138) made brief reference to the upper conglomerate at the Piru "narrows." They also reported that it represents submarine, inner fan channel (bathyal) deposits containing Ulatisian Stage benthic foraminifera. According to Almgren et al. (1998), this stage corresponds to the late early to early middle Eocene, which is the same age as the Eocene section in Elsmere Canyon. Bachman and Abbott (1988) also reported that, like the lower conglomerate near the basement contact in the "narrows" area, some of the same types of exotic volcanic porphyry clasts are present in the upper conglomerate, but the amount of these clasts is lower than found in the lower conglomerate. Although provenances have not yet been established for the clasts, palinspastic reconstructions by Bachman and Abbott (1988) suggest depositional system contiguity between lower Piru Creek, Garcia Mountain (San Luis Obispo County), and Cuyama Valley (Santa Barbara County): a total of distance of approximately 180 km within the Salinian block. Their study was similar to that of Kies and Abbott (1982), who determined that exotic purplish and reddish rhyolitic clasts (e.g., Poway type), found in Eocene conglomerates in the Peninsular Ranges block in Southern California and northern Baja California, were transported by lengthy, westward-flowing rivers that transported coarse sediments shed from newly upraised mountains to the east in Sonora, Mexico.

Correlation of the Elsmere Canyon Eocene section with the upper Juncal Formation in lower Piru Creek is in keeping with the work that stems from Crowell (1952), who showed that there has been post–late Miocene right-lateral displacement of 24 to 40 km along the San Gabriel Fault zone. This fault zone extends for nearly 145 km through the Transverse Ranges of Southern California, and it passes through the Placerita Canyon area, approximately 5 km north of Elsmere Canyon. The northernmost part of the fault zone is adjacent to the lower Piru Creek area (Fig. 57).

Yeats et al. (1994:fig. 3) hypothesized that Eocene rocks in the vicinity of lower Piru Creek and those in Elsmere Canyon were once continuous and could have been displaced by 25 to 30 km of right-lateral slip along the Devil Canyon fault (Fig. 57), an early formed strand of the San Gabriel Fault. More work is needed to establish whether the Devil Canyon fault is integral in this displacement. It could be that the displacement took place along the San Gabriel fault itself.

Correlation of the Elsmere Canyon Eocene section to the Juncal Formation in lower Piru Creek disagrees with the work of Seedorf (1983:fig. 6b), who relied heavily on the Phillips Continental Oil No. 1 well-log section. He



Figures 35–56 Eocene bivalves and raninid crab (last figure) from Elsmere Canyon, LACMIP locality 17848, unless otherwise specified. All specimens coated with ammonium chloride. **35.** *Barbatia (Cucullaearca) cliffensis* Hanna, 1927, LACMP hypotype 13436, left valve, height 26 mm, length 46 mm, ×0.8; **36.** *Glycymeris (G.) rosecanyonensis* Hanna, 1927, LACMP hypotype 13437, right? valve, height 5 mm, length 6 mm, ×5; **37.** *Glycymeris (Glycymerita) sagittata* (Gabb, 1864), LACMP hypotype 13438, right? valve, height 12 mm, length 11 mm, ×2.2; **38.** *Brachidontes (B.) cowlitzensis* (Weaver and Palmer, 1922), LACMP hypotype 13439, LACMIP loc. 17850, partial left? valve,

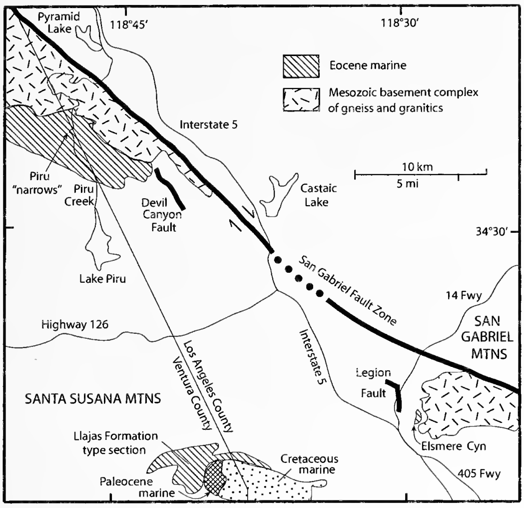


Figure 57 Possible offset of Juncal Formation along the San Gabriel fault zone. Base map from Jennings and Strand (1969)

reported that the lower and upper parts of the Elsmere Canyon section correlate with the Santa Susana Formation and the Llajas Formation, respectively. He based his conclusions on (1) benthic foraminifera (an inappropriate technique to establish lithologic correlation between formations) and (2) an undiscussed subsurface "overlapping relationship" of the Santa Susana Formation. This formation, as well as the Llajas Formation, crops out primarily in the Simi Valley area, Ventura County, approximately 21 km to the west of Elsmere Canyon (Fig. 57). He stated that the so-called Llajas Formation in this well consists of siltstone with minor sandstone. The bulk of the Llajas Formation in Simi Valley, above a basal nonmarine conglomerate, however, consists of shallow-marine sandstone, rich in megafossils and megascopic discocyclinid benthic foraminfera (Squires, 1981, 1983, 1984). It is relevant to mention that in their analysis of the clasts in the basal conglomerate of the Llajas Formation, Squires (1981) and Bachman and Abbott (1988) found no rhyolitic porphyry clasts. Bachman and Abbott (1988) also found no rhyolitic porphyry clasts in the underlying Santa Susana Formation.

Seedorf (1983:fig 6b) also showed a very generalized comparative Elsmere Canyon outcrop section, which shows none of the conglomerate beds that are present. He reported that based on megafossils reported by Oakeshott (1958) and Winterer and Durham (1962), the outcrop section in Elsmere Canyon is correlated to the type Llajas Formation in Simi Valley. As mentioned earlier, however, these reports of megafossils found by early workers are erroneous. Yeats et al. (1994:fig. 4) graphically showed the Phillips Continental Oil No. 1 well log and, like Seedorf (1983:fig. 6b), correlated the 1844 m of Paleogene rocks (i.e., two conglomerate units alternating with two siltstone units) in it to the Santa Susana and Llajas formations. These correlations, however, are untenable based on the results of this present study.

WHITNEY CANYON FAULT

The Whitney Canyon Fault has been recognized by most workers as coincident with the eastern edge of the Eocene section in the Elsmere Canyon area (Fig. 3), but there has been no agreement as to which side of the fault is down and how far north the fault extends. During the course of this study, it was determined that the east side is

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height 8 mm, length 13.5 mm, ×2.3; **39.** *Ostrea* sp., LACMP hypotype 13440, right? valve, height 40 mm, length 32 mm, ×0.8; **40.** *Parvamussium* sp., LACMP hypotype 13441, LACMIP loc. 17850, internal mold of right? valve, height 4 mm, length 3.5 mm, ×8; 41. ?*Anomia mcgoniglensis* Hanna, 1927, LACMP hypotype 13442, LACMIP loc. 17849, right valve, height 39 mm, length 41.5 mm, ×0.8; **42.** *Spondylus carlosensis* Anderson, 1905, LACMP hypotype 13443, left valve, height 14 mm, length 15 mm, ×2.1; 43. *Miltha packi* (Dickerson, 1916), LACMP hypotype 13444, partial right? valve, height 55 mm, length 55 mm, ×0.7; 44. *Clabornites diegoensis* (Dickerson, 1916), LACMP hypotype 13445, left valve, height 40 mm, length 40 mm, ×0.9; 45. *Glyptoactis (Claibornicaradia) sandiegoensis* (Hanna, 1927), LACMP hypotype 13446, left valve, height 38 mm, length 50 mm, ×1; 46. *Crassatella uvasana* (Conrad, 1855), LACMP hypotype 13447, partial left valve, height 28 mm, length 32 mm, ×0.9; 47. *Acanthocardia (Schedocardia) breweri* (Gabb, 1864, LACMP hypotype 13448, left? valve, height 8 mm, length 8 mm, ×3.6; 48. *Nemocardium linteum* (Conrad, 1855), LACMP hypotype 13449, left? valve, height 20 mm, length 24 mm, ×1.3; 49. *Tellina*? sp., LACMP hypotype 13450, LACMIP loc. 17850, right valve, height 12 mm, length 21 mm, ×1.7; 50. *Callista (Macrocallista) domenginica* Vokes, 1939, LACMP hypotype 13451, right valve, height 15 mm, length 18 mm, ×1.8; **51.** *Pitar (Lamelliconcha) joaquinensis* Vokes, 1939, LACMP hypotype 13452, left valve, height 12 mm, length 15 mm, ×2.2; **52.** *Pitar (Lamelliconcha) avenalensis*? Vokes, 1939, LACMP hypotype 13453, left valve, height 10 mm, length 13 mm, ×3.2; **53.** *Pitar (Calipatria) uvasanus* (Conrad, 1855), LACMP hypotype 13454, left valve, height 12 mm, length 14 mm, ×2.3; 54. *Corbula (Caryocorbula) dickersoni* Weaver and Palmer, 1922, LACMP hypotype 13455, left valve, height 5 mm, length 9 mm, ×3.4; 55. Teredinid, LACMP hypotype 13456, LACMIP loc. 17850, height 14 mm, width 3 mm, ×3.3; 56. Raninid crab, partial cheliped, LACMP hypotype 13457, height 13 mm, length 15 mm, ×2.3

definitely downthrown on the basis of field evidence that revealed the juxtaposition of the Eocene section with the Towsley Formation. There is approximately 15 m of stratigraphic displacement. The fault can be mapped northward as far as Whitney Canyon (Fig. 2). In that area, the fault passes into a gentle anticline. The author made several unsuccessful attempts to find evidence of the fault on the north side of Whitney Canyon, where the Saugus Formation crops out. It would appear that Oakeshott (1950) was correct in suggesting that this fault is pre-Saugus in age.

CONCLUSIONS

An Eocene marine section is confirmed to be present in the Elsmere Canyon area. The 525-m-thick section consists of turbidites deposited in the inner (upper) conglomeratic (facies A2) and middle-fan sandy (facies B2) and silty (facies G) parts of a deep-water submarine fan. Some of the conglomerate clasts are purplish to reddish (i.e., Poway type) porphyritic volcanics. Megafossils are very scarce and are confined to a thin interval in the lower part of the section. Forty-four species of warm-water invertebrates have been found, including one new species of the gastropod *Solariella*. The assemblage underwent postmortem transport via turbidity currents from shallow-marine waters into the deeper waters associated with the submarine fan. The megafauna is of late early Eocene age, at the boundary between the "Capay Stage" and the "Domengine Stage." Presence of the gastropod *Homalopoma wattsi* (Dickerson, 1916) in the Elsmere Canyon section extends the molluscan stage range of this species from the "Capay Stage" proper to this boundary.

The Eocene section in Elsmere Canyon has been assigned by others to the Santa Susana and Llajas formations, but here it is assigned to the upper part of the Juncal Formation. It is highly likely that the San Gabriel Fault offset the Juncal Formation that was once contiguous between the study area and the "narrows" of lower Piru Creek in the Whitaker Peak area, eastern Ventura County. The base of the Juncal Formation in Elsmere Canyon is concealed, and the formation is unconformably overlain by the lower Pliocene Towsley Formation. The eastern edge of the Juncal Formation outcrops coincide with the Whitney Canyon Fault, which is downthrown to the east.

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