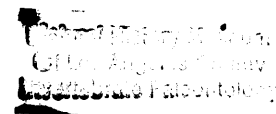


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NEW UPPER PALEOCENE SPECIES OF THE BIVALVE *Plicatula* FROM SOUTHERN CALIFORNIA

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ABSTRACT—Three new species of the shallow-marine, warm-water bivalve *Plicatula* are reported from the upper Paleocene Santa Susana Formation of southern California. *Plicatula simiensis* new species is from the middle part of the formation on the south side of Simi Valley and occurs as a displaced specimen in deep-marine turbidites. *Plicatula lapidicina* new species and *P. trailerensis* new species are both from coralline-algal-rich muddy siltstone just beneath a nearshore, coralline-algal limestone interval in the upper part of the formation in the Santa Ynez Canyon area, east-central Santa Monica Mountains. These three new species represent the first late Paleocene records of genus *Plicatula* on the west coast of North America and the first Paleocene records of this genus in southern California.

INTRODUCTION

THE FOSSIL record of the bivalve genus *Plicatula* from Cretaceous and lower Cenozoic strata of California and Baja California was recently reviewed by Squires and Saul (1997). Since that report, we discovered specimens of three additional new species of *Plicatula* in museum collections. All three new species are rare and are from the Santa Susana Formation of late Paleocene age. One of them, *Plicatula simiensis*, is from the middle part of the formation in moderately deep-marine strata on the south side of Simi Valley (Fig. 1.1). The other two new species are from the upper part of the formation in very shallow-marine strata in the Santa Ynez Canyon area, in the east-central part of the Santa Monica Mountains, about 16 km to the southeast of Simi Valley (Fig. 1.2). Prior to this article, the only Paleocene species of *Plicatula* from the west coast of North America was *P. ostreiformis* Stanton, 1896, from lower Paleocene (upper? Danian Stage) strata of Lake County in northern California (see Squires and Saul, 1997). The relative chronostratigraphic position of *P. ostreiformis* compared to that of the three new species is shown in Figure 2.

Today, *Plicatula* comprises just a small number of living species, which are confined to tropical waters (Watson, 1930). The only extant species of *Plicatula* along the west coast of North America are found in the southern Gulf of California (Keen, 1971). The fossil record of *Plicatula* is quite discontinuous on the west coast of North America, but each occurrence coincided with the presence of warm-water conditions that allowed the influx of migrant shallow-marine mollusks (Squires and Saul, 1997). Although warm-water conditions are known to have been present when the Santa Susana Formation was being deposited during the late Paleocene (Zinsmeister, 1983a; Squires and Kennedy, 1998), no *Plicatula* had ever been reported before from

this formation. The discovery of three species of *Plicatula* in the Santa Susana Formation supports a paleoclimate as tropical as the modern southern Gulf of California.

Abbreviations used for catalog and locality numbers are: LACMIP, Natural History Museum of Los Angeles County, Invertebrate Paleontology Section; UCMP, University of California, Museum of Paleontology, Berkeley.

NEW LOCALITIES OF *Plicatula*

The type locality of *P. simiensis* is east of Meier Canyon on the south side of Simi Valley at UCMP loc. 3754 (Fig. 1.1). The holotype of *P. simiensis* was collected from a silty to very fine sandstone, based on a small amount of rock material adhering to the specimen. Squires (1983) mapped the rocks in the area of locality 3754 as the upper Paleocene Santa Susana Formation, and Parker (1983) included these rocks as part of the "eastern facies" of this formation. Most of this facies consists of mudstone, but at a few places, including east of Meier Canyon, conglomerate and sandstone are interbedded (Parker, 1983). Parker (1983) interpreted the interbedded conglomerate and sandstone east of Meier Canyon as the coarse portion of deep-marine, inner submarine-fan deposits and, perhaps, slope deposits. He also reported that megafossils in the "eastern facies" are possibly displaced. The specimen of *P. simiensis* is articulated, mostly complete, and unabraded. The distance of transport, presumably by turbidity currents, therefore, must not have been far.

There have been no detailed microfaunal or megafaunal studies of the Santa Susana Formation east of Meier Canyon. Elsewhere in the Simi Valley area, however, all of the Santa Susana Formation, except the uppermost 100 m, contains megafossils, as well as microfossils, indicative of late Paleocene age (Zinsmeister, 1983a, 1983b; Saul, 1983a, 1983b; Heitman, 1983; Frederickson, 1983; Filewicz and Hill, 1983; Squires, 1991).

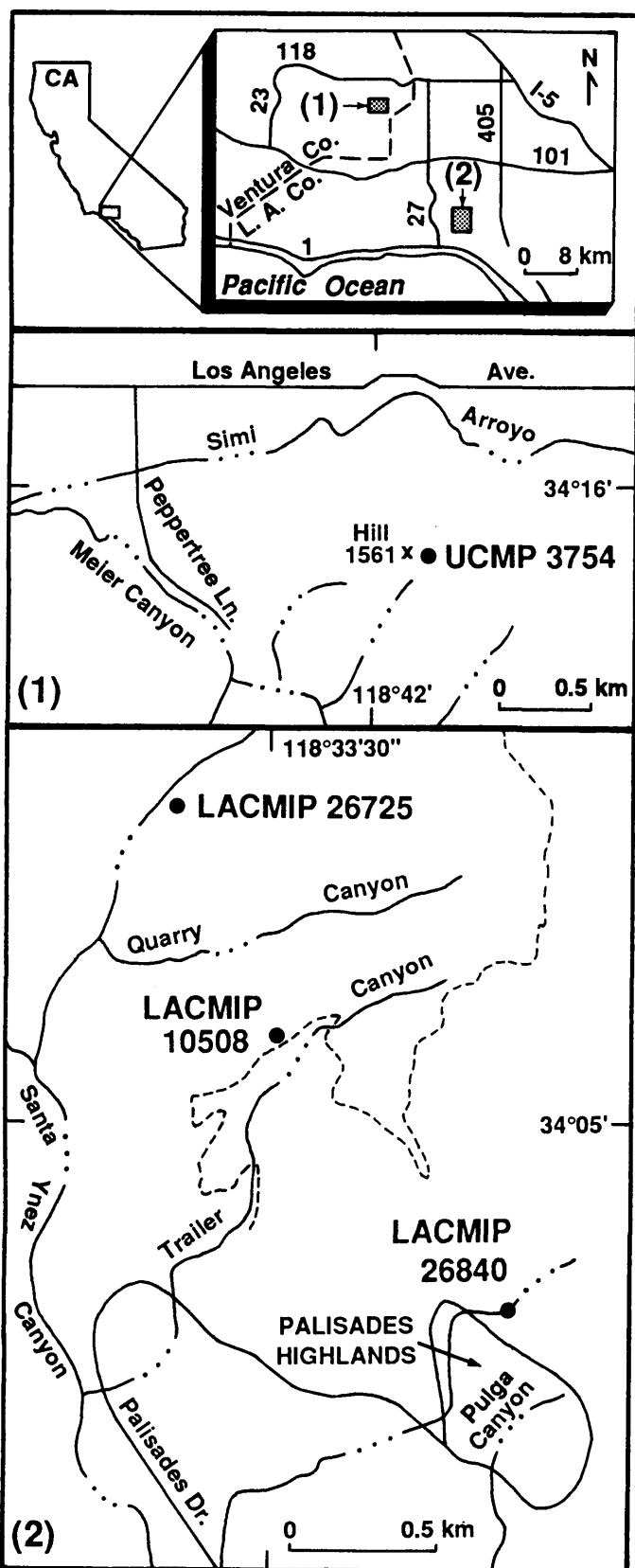


FIGURE 1—Index map showing geographic occurrences of new species of *Plicatula*. 1, South side of Simi Valley; 2, Santa Ynez Canyon area, east-central Santa Monica Mountains.

AGE (Ma)	EPOCH	STAGE	PLICATULA RANGES
60	Early Eoc.	"Meganos"	*
	Late Paleocene	"Martinez"	<i>P. lapidicina</i> and <i>P. trailerensis</i> <i>P. simiensis</i>
	Early Paleocene	Danian	<i>P. ostreiformis</i>
70	Late Cretaceous	Maastrichtian	*

FIGURE 2—Chronostratigraphic positions of the three new species of *Plicatula* from the Santa Susana Formation, southern California. Geochronologic time scale from Berggren et al., 1995. [* = No known west-coast species].

The type locality of *P. simiensis* is in the middle part of the Santa Susana Formation, and based on stratigraphic position this part of the formation is herein assigned to the "Martinez Stage" of late Paleocene age. The locality, however, is stratigraphically higher than the so-called "Martinez marine member" in the lower part of the Santa Susana Formation. This "member" designation stems from usage by Nelson (1925), and Squires (1997) assigned the "Martinez marine member" to the Selandian Stage (equivalent to the *Turritella peninsularis* Zone of Saul, 1983b) of early late Paleocene age.

The type locality of *P. lapidicina* is in Quarry Canyon, at LACMIP loc. 26725. This species was also found at LACMIP loc. 10508, as well as in the Pulga Canyon area at LACMIP loc. 26840 (Fig. 1.2). The type locality of *Plicatula trailerensis* is LACMIP loc. 10508, on the divide between Trailer and Quarry canyons. Dibblee (1992) mapped the rocks in the vicinity of each of these three localities as the Santa Susana Formation. Colburn et al. (1988), Colburn (1996), and Squires and Kennedy (1998) also assigned these rocks to the Santa Susana Formation. At all three localities, specimens of *Plicatula* were found in close association with outcrops of coralline-algal limestone. As discussed by Squires and Kennedy (1998), it is not known whether there is just a single stratigraphic interval of coralline-algal limestone in the Santa Susana Formation in the Santa Ynez Canyon area or whether there might be multiple units of similar lithology. Pending future information, it is best to refer to the coralline-algal limestone(s) as the "coralline-algal limestone interval." Although the exact stratigraphic position of this interval is not known because of structural complications, the interval is apparently about 120 m below the stratigraphically highest outcrops of the formation in this area (Mack, 1993).

At LACMIP loc. 10508, *Plicatula lapidicina* and *P. trailerensis* were found in a coralline-algal-rich, micaceous muddy siltstone about 1 m stratigraphically below the blocky, coralline-algal-limestone interval, which is 24 m thick in this area. Only a single specimen of each new species was found at this locality, even after repeated attempts by the senior author to locate more. The specimens are articulated and complete. The specimen of *P. lapidicina* has small tubercle-like encrustations of coralline algae along the radial ribs, and the specimen of *P. trailerensis* has broad patches of encrusting coralline algae. Both specimens were found alongside numerous specimens of the gastropod *Mesalia clarki* (Dickerson, 1914), and the specimen of *P. lapidicina* was found near a single, large specimen of the neritid gastropod *Corsania (Januncia) rhoga* Saul and Squires, 1997. This latter genus indicates warm-water conditions (Saul and Squires, 1997). Squires (1993) and Squires and Kennedy (1998)

reported the presence of mollusks at several localities just below the coralline-algal limestone interval in the vicinity of and just east of LACMIP loc. 10508. These mollusks, which include the gastropods *Diodora*, *Terebralia*, and *Campanile*, also indicate a very nearshore, tropical to subtropical paleoenvironment.

At LACMIP locs. 26725 and 26840, articulated, single specimens of *Plicatula lapidicina* were also found near the coralline-algal-limestone interval and in association with specimens of *Mesalia clarki*.

Colburn et al. (1988) and Colburn (1996) concluded that the upper part of the Santa Susana Formation in the Santa Ynez Canyon area was deposited in a low-energy protected bay, no deeper than 40 m, with the bay situated behind a barrier bar. They also concluded that the branching coralline algae developed shoals on the bay floor. Strathearn et al. (1988), furthermore, concluded that the coralline-algal limestones represent in situ buildups in subtropical to tropical waters of only about 20 m depth.

Saul (1983b) assigned the coralline-algal limestone interval in the Santa Ynez Canyon area to the upper Paleocene Thanetian Stage, with the lowermost part of the limestone interval equivalent to the *Turritella infragranulata pachecoensis* Zone and the remaining part of the limestone interval equivalent to the *Turritella infragranulata* sensu stricto Zone. She also assigned the entire coralline-algal limestone interval to the Standard Planktonic Foraminiferal Zone P4 and to the upper part of the provincial "Martinez Stage." Molluscan studies by Squires (1993, 1997) and Squires and Kennedy (1998) confirmed this age assignment. Although microfossil studies in the Santa Ynez Canyon area have suggested either a late Paleocene or an early Eocene age (Squires and Kennedy, 1998), the mollusks indicate a consistent age of late Paleocene.

SYSTEMATIC PALEONTOLOGY

Class BIVALVIA Linnaeus, 1758

Family PLICATULIDAE Watson, 1930

Genus PLICATULA Lamarck, 1801

Type species.—*Spondylus plicatus* Linnaeus, 1758, by subsequent designation (Schmidt, 1818); Recent, Java.

PLICATULA SIMIENSIS new species

Figure 3.1–3.3

Diagnosis.—A small-sized *Plicatula* with convex right valve and concave left valve; both with numerous, closely spaced, fine radial ribs, narrower and wider spaced on left valve.

Description.—Valves of small size (17.3 mm high) curved, ostreiform, strongly inequivalved, strongly inequilateral; right valve convex, showing very small area of attachment in dorsal-posterior beak region, and with numerous (approximately 70), very closely spaced, fine radial ribs with some intercalated in early growth stage; left valve concave, sculptured by numerous, closely spaced very fine radial ribs; radial ribs on left valve narrower with slightly wider interspaces than those on right valve; valve interiors not seen except for a minute row of tubercles on portion of dorsal-posterior region of left valve; hinge inaccessible.

Etymology.—The new species is named for the Simi Valley.

Types.—Holotype UCMP 154004, late Paleocene, middle part of the Santa Susana Formation, UCMP loc. 3754, near top of hill east of Meier Canyon, south side of Simi Valley.

Measurements.—UCMP 154004, height 17.3 mm, length 16.7 mm, thickness of articulated valves 4.4 mm.

Occurrence.—Upper Paleocene ("Martinez Stage"), middle part of the Santa Susana Formation, south side of Simi Valley, Ventura County, southern California.

Discussion.—The only known specimen is the moderately

well-preserved holotype. The left valve might be somewhat crushed, and is also badly weathered and missing some of the shell. Weathering has exhumed a minute row of tubercles on the dorsal-anterior part of the valve. Normally, this row of tubercles would only be visible on an interior view of the valve. Similar tubercles are not uncommon in other species of *Plicatula*. For example, the interior of the left valve of *P. variata* Gabb, 1864, a species known from Lower Cretaceous rocks in northern California, has a row of tubercles that encircles the left-valve margin (Squires and Saul, 1997, fig. 3.7). The tubercles, as well as the uniform rib size, help to establish that *P. simiensis* belongs to *Plicatula* rather than to *Spondylus* Linnaeus, 1758.

Plicatula simiensis is most similar to *P. hirsuta* Coquand (1880, p. 165, pl. 4) from Upper Cretaceous strata of northern Africa. Peron (1890–1891) reported *P. hirsuta* from Senonian strata of Tunisia and Algeria. Pervinquière (1912, p. 164–166, pl. 10, figs. 12–15, not figs. 16–19) reported it from Maastrichtian strata of Tunisia. The new species differs from *P. hirsuta* by having a concave left valve rather than a flattened to convex one, a shorter hinge line, and a more oblique shape to the valves.

In terms of the concavo-convex shell, *P. simiensis* somewhat resembles *Plicatula* n. sp.? Squires and Saul (1997, p. 295, fig. 4.1–4.3) from the Upper Cretaceous (Turonian Stage) Baker Canyon Member of the Ladd Formation, Santa Ana Mountains, Orange County, southern California. This Turonian plicatulid, however, is nearly smooth, but the smoothness might be the result of abrasion.

Plicatula simiensis differs from the other two new species described in this article by having an inequivalved shell, a concave left valve, non-plicate valve margins, and much more numerous, unnodded radial ribs.

PLICATULA LAPIDICINA new species

Figure 3.4–3.6

Diagnosis.—A small-sized *Plicatula* with nearly equal and slightly convex valves sculptured by 13 to 15 broad, intercalated, and spinose radial ribs separated by moderately deep interspaces

Description.—Valves of small size (up to 18 mm high), curved, ostreiform, inequilateral, equivalved to slightly inequivalved, dorsal-posterior area auricle-like; both valves nearly flat, with beak area of left valve slightly swollen; both valves with 13 to 15 primary radial ribs (includes intercalated ribs), becoming spinose and broader near ventral margins, especially on posterior-ventral region; interspaces between ribs moderately deep, valve margin plicate, interspaces on right valve correspond to ribs on left valve; valve interiors and hinge inaccessible.

Etymology.—The species is named *lapidicina*, Latin, stone quarry, for its occurrence in Quarry Canyon.

Types.—Holotype LACMIP 11278, late Paleocene, upper part of the Santa Susana Formation, LACMIP loc. 26725, in Quarry Canyon, east-central Santa Monica Mountains. Paratype LACMIP 11279, late Paleocene, upper part of the Santa Susana Formation, LACMIP loc. 10508 in Trailer Canyon, east-central Santa Monica Mountains.

Measurements.—LACMIP 11278, height 17.6 mm, length 15 mm, thickness of articulated valves 6 mm; LACMIP 1279, height 21.4 mm, length 16.8 mm, thickness of articulated valves 6 mm.

Occurrence.—Upper Paleocene ("Martinez Stage"), upper part of the Santa Susana Formation, Santa Ynez Canyon area, east-central Santa Monica Mountains, Los Angeles County, southern California.

Discussion.—Three specimens were found: one from LACMIP loc. 26725, one from LACMIP loc. 10508, and one from LACMIP loc. 26840. All are closed valved. The holotype is well

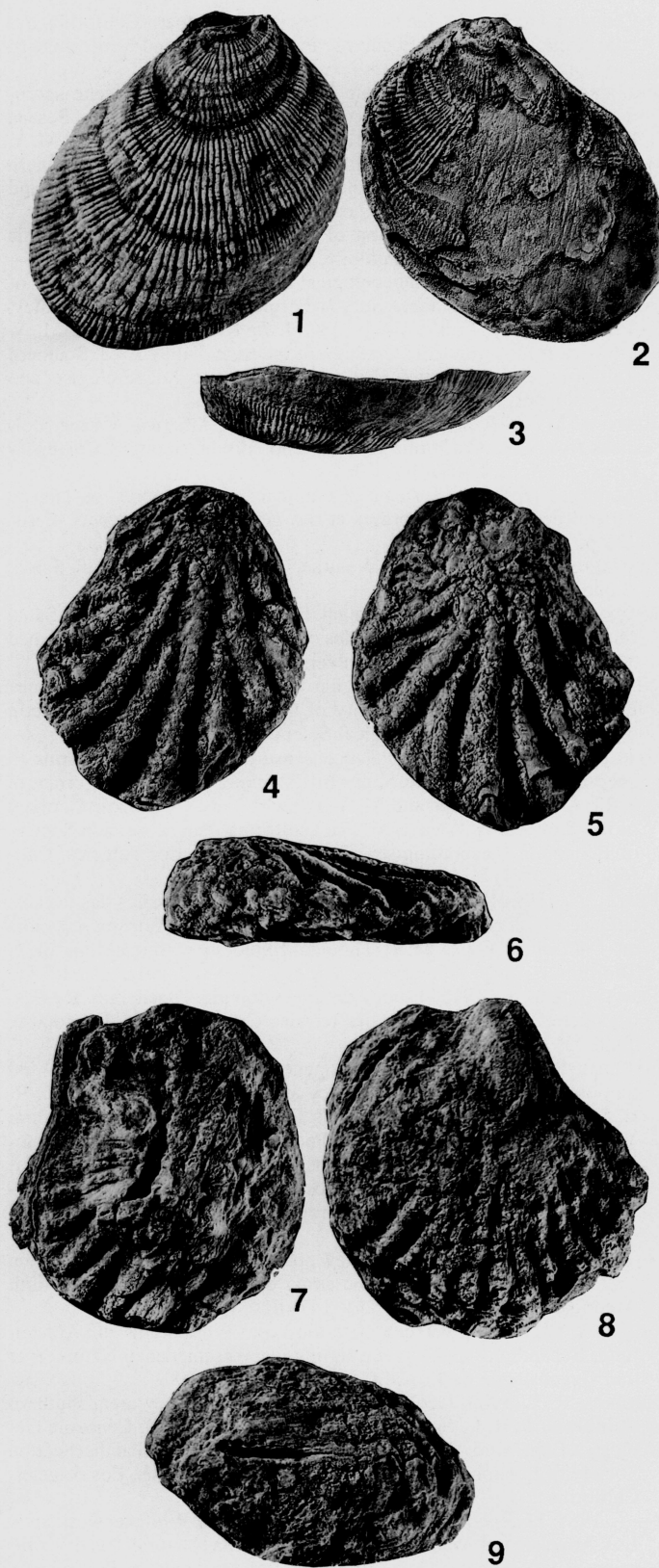


FIGURE 3—New species of late Paleocene *Plicatula* from southern California. All specimens coated with ammonium chloride. 1–3, *Plicatula simiensis* n. sp., holotype UCMP 154004, UCMP loc. 3754; 1, right valve, height 17.3 mm, $\times 2.5$; 2, left valve, height 17.3 mm, $\times 2.5$; 3, anterior view, thickness of articulated valves 4.4 mm, $\times 2.5$. 4–6, *Plicatula lapidicina* n. sp., holotype LACMIP 11278, LACMIP loc.

preserved, and the specimen from locality 10508 has some coralline-algal encrustations. The specimen from locality 26840 is somewhat worn, and its right valve is missing the shell. The equivalveness, the nearly identical sculpture on both valves, the auricle-like dorsal-posterior area, and the swollen beak area on the left valve help to establish that this species is a plicatulid rather than an oyster.

Plicatula lapidicina is most similar to *P. juncalensis* Squires (1987, p. 57–58, figs. 95–96; Squires and Saul, 1997, p. 295, fig. 4.11–4.13) from the middle lower Eocene (“Capay Stage”) part of the Juncal Formation in the Whitaker Peak area, Los Angeles County, southern California. The new species differs by having an equal number of radial ribs on both valves, fewer ribs (14 rather than 24 on right valve and 14 rather than 17 on left valve), no secondary ribs, and broader and more obviously intercalated ribs.

Plicatula lapidicina is somewhat similar to *P. modjeskaensis* Squires and Saul (1997, p. 292–293, figs. 3.12–3.18) from the lower Upper Cretaceous (upper Turonian Stage) Baker Canyon Member of the Ladd Formation, Santa Ana Mountains, Orange County, southern California. The new species differs by having plicate valve margins, somewhat weaker spines on the ribs, more ribs on the right valve (14 rather than nine to 13, rarely 19), and broader and more obviously intercalated ribs with deeper interspaces.

Plicatula lapidicina differs from *P. trailerensis* n. sp. by having an ostreiform rather than a subquadrate shape, much flatter valves, intercalated radial ribs, wider interspaces between radial ribs near the venter, and in lacking the swollen and protruding beak area on the left valve.

PLICATULA TRAILERENSIS new species

Figure 3.7–3.9

Diagnosis.—A medium-sized *Plicatula* with approximately equal and moderately convex valves, posterior dorsal area steeply sloping; left valve with a protruding swollen beak, both valves with narrow and closely spaced, noded radial ribs.

Description.—Valves of medium size (23 mm high), slightly curved, subquadrate, inequilateral, subequivalved to equivalved (estimated), with approximately same degree of moderate convexity; posterior dorsal area steeply sloping, beak area swollen and protruding on left valve; right valve with at least 15 primary radial ribs (slight tendency for bifurcation near venter); left valve with at least 15 primary radial ribs; primary ribs closely spaced, narrow (widest toward venter on right valve), weakly spinose to very slightly lamellose; valve margins gently plicate, with plicae strongest along posterior-ventral area; valve interiors and hinge not accessible.

Etymology.—The new species is named for Trailer Canyon.

Types.—Holotype LACMIP 11280, late Paleocene, upper part of the Santa Susana Formation, LACMIP loc. 10508, on divide between Trailer and Quarry canyons, east-central Santa Monica Mountains.

Measurements.—LACMIP 11280, height 23 mm, length 23 mm, thickness of articulated valves 13.3 mm.

Occurrence.—Upper Paleocene (“Martinez Stage”), upper part of the Santa Susana Formation, Santa Ynez Canyon area,

26725; 4, right valve, height 17.6 mm, $\times 2.5$; 5, left valve, height 17.6 mm, $\times 2.5$; 6, anterior view, thickness of articulated valves 6 mm, $\times 2.5$. 7–9, *Plicatula trailerensis* n. sp., holotype LACMIP 11280, LACMIP loc. 10508; 7, right valve, height 23 mm, $\times 1.9$; 8, left valve, height 23 mm, $\times 1.9$; 9, anterior view, thickness of articulated valves 13.3 mm, $\times 1.9$.

east-central Santa Monica Mountains, Los Angeles County, southern California.

Discussion.—The only known specimen is the articulated holotype. Although the left valve overall is moderately well-preserved, the anterior part is not well-preserved, and the number of radial ribs there cannot be determined. The right valve is encrusted by coralline algae, and its removal would destroy the specimen. This encrustation obscures the radial ribs on the anterior half of the right valve, but the number of ribs there can be roughly estimated by examining the moderately well exposed plicate valve margin. The coralline-algal encrustation on the right valve also obscures the degree of convexity of this valve, but it is estimated to be moderate and approximately the same as the convexity of the left valve. The equivalveness, the nearly identical sculpture on both valves, and the swollen protruding beak area on the left valve help to establish that this species is a plicatulid rather than an oyster.

Plicatula trailerensis is most similar to *P. ferryi* Coquand (1862, p. 221, pl. 16, figs. 7–10) from Upper Cretaceous (Coniacian and Santonian stages) strata of northern Africa. Pervinquier (1912, p. 160–162, pl. 9, figs. 22a–b, pl. 12, figs. 6–14) reported it as a common species. The new species differs from *P. ferryi* by having more inflated valves, less numerous radial ribs, only rarely bifurcated ribs, and a protruding swollen beak area on the left valve.

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APPENDIX

Localities Cited

LACMIP 10508.—At approximately 404 m elevation, just below the coralline-algal limestone interval in limey, muddy siltstone and west

of small fault, in roadcut on north side of dirt road, on north slope of Trailer Canyon near top of ridge between Quarry and Trailer canyons, at approximately 50 m east of steel gate at boundary of Topanga State Park, and 4,435 m south and 5,334 m west of northeast corner of U.S. Geological Survey, 7.5-minute, Topanga Quadrangle, 1952 (photorevised 1981), east-central Santa Monica Mountains, Los Angeles County, California. Upper part of Santa Susana Formation. Age: Late Paleocene (“Martinez Stage”). Collectors: L. R. Saul and students from her Fall, 1982, advanced paleontology class at University of California, Los Angeles; R. L. Squires, June, 1997, and students from his Fall, 1997, advanced paleontology class at California State University, Northridge.

LACMIP 26725.—At 366 m elevation on north side of northern tributary to Quarry Canyon, approximately 160 m north of “Y” of San Vicente y Santa Monica, 3,665 m south and 5,715 m west of northeast corner of U.S. Geological Survey, 7.5-minute, Topanga Quadrangle, 1952 (photorevised 1981), east-central Santa Monica Mountains, Los Angeles County, California. Upper part of Santa Susana Formation. Age: Late Paleocene (“Martinez Stage”). Collector: J. Alderson, November, 1980.

LACMIP 26840.—At about 411 m elevation in coralline-algal-limestone beds exposed by road development in west-flowing tributary to Santa Ynez Canyon, approximately 1,273 m north of southern San Vicente y Santa Monica Grant boundary (shown as red dashed line) and 488 m N73°W of water tanks on ridge between Temescal and Santa Ynez Canyon, U. S. Geological Survey, 7.5-minute, Topanga Quadrangle, 1952 (photorevised 1981), east-central Santa Monica Mountains, Los Angeles California. Upper part of Santa Susana Formation. Age: Late Paleocene (“Martinez Stage”). Collector: J. Alderson, January, 1981.

UCMP 3754.—At approximately 450 m elevation, near high point of hill, 1,341 m northeast of Meier Canyon, NW/4 of NE/4 of sec. 18, T2N, R17W, U.S. Geological Survey, 7.5-minute, Santa Susana Quadrangle, 1951, photorevised 1969, south side of Simi Valley, Ventura County, southern California. Middle part of Santa Susana Formation. Age: Late Paleocene (“Martinez Stage”). Collector: R. N. Nelson?, 1920s.