J. Paleont., 71(5), 1997, pp. 847–861

0022-3360/97/0071-0847$03.00

TAXONOMY AND DISTRIBUTION OF THE BUCCINID GASTROPOD *BRACHYSPHINGUS* FROM UPPERMOST CRETACEOUS AND LOWER CENOZOIC MARINE STRATA OF THE PACIFIC SLOPE OF NORTH AMERICA

RICHARD L. SQUIRES
Department of Geological Sciences, California State University, Northridge 91330-8266
⟨richard.squires@csun.edu⟩

ABSTRACT—*Brachysphingus* is a low-spired bucciniform neogastropod known only from the fossil record of California and northern Baja California. The earliest species, *Brachysphingus gibbosus* Nelson, 1925, ranges in age from latest Cretaceous or possibly earliest Paleocene to the late Paleocene. During the early Paleocene, the smoothish *B. gibbosus* evolved into the axially ribbed *B. sinuatus* Gabb, 1869, which is the senior primary synonym of *B. gabbi* Stewart, 1927. During the late Paleocene, *B. sinuatus* evolved into *B. mammilatus* Clark and Woodford, 1927, which is the youngest species of *Brachysphingus* and which lasted into the early Eocene.

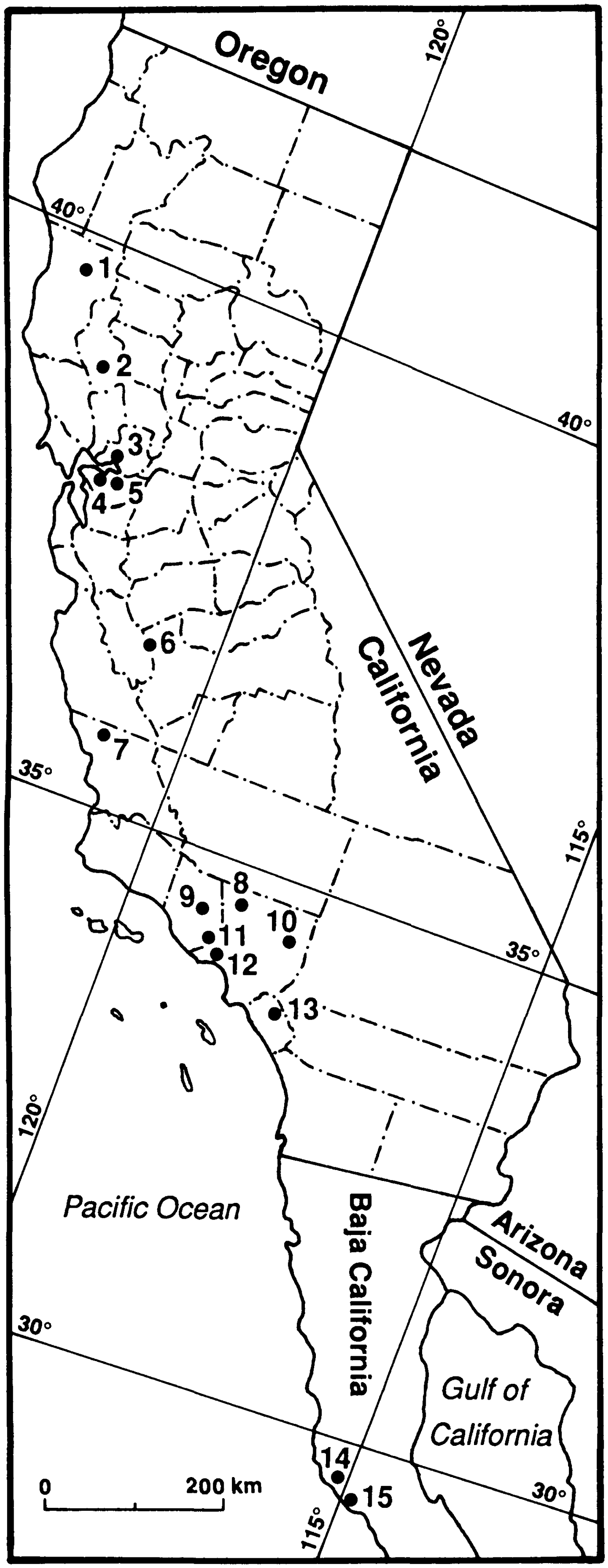
All three species of *Brachysphingus* were shallow-marine dwellers subject to transport into deeper waters via turbidity currents.

INTRODUCTION

THE GASTROPOD genus *Brachysphingus* has long been used as an indicator of Paleocene marine rocks on the Pacific slope of North America. Although rocks of this age are not that common in this region, *Brachysphingus* is present in nearly every area of outcrops (Figure 1). At nearly every *Brachysphingus* locality there is at least one species of associated *Turritella.* This is a fortunate circumstance because *Turritella* species are crucial in determining geologic age, and the zonation used in this report follows that of Saul (1983a).

Four species of *Brachysphingus* were previously described: *B. liratum* Gabb, 1864, *B. gibbosus* Nelson, 1925; *B. sinuatus* Gabb, 1869, and *B. mammilatus* Clark and Woodford, 1927. *Brachysphingus liratum* is a homonym, and in 1927, Stewart substituted the name *B. gabbi* Stewart, 1927. All the species were originally regarded as restricted to the Paleocene, except for *B. mammilatus,* which was reported by Clark and Woodford (1927) and Givens (1974) as restricted to the Eocene. The stratigraphic and geographic distributions of these taxa have never been tabulated, and the phylogenetic relationships among them have never been determined. These are the primary objectives of this report.

Previous workers had few problems in recognizing *B. gabbi* because its robust axial ribs make it very distinctive. Recogni-



tion of the other species of *Brachysphingus,* however, proved troublesome because they are smoothish and, generally, similar in shape. It is not uncommon while observing museum collections to come across labels with two or three different identifications for the same specimen. This confusion has greatly hindered any potential biostratigraphic utility that might be associated with the evolution of *Brachysphingus.* Initially, in my own work, I had the same kind of difficulty when I tried to identify just a few lots of specimens of smoothish *Brachysphingus.* It was only after I had observed a large number of specimens that I finally understood how one smoothish species is morphologically distinguishable from another. Using museum collections at several institutions, I found a total of 562 specimens. While doing so, I also came across 14 new stratigraphic occurrences of *Brachysphingus.* These are indicated in the "Occurrence" sections later in this paper.

By careful comparative studies of all the known specimens of *Brachysphingus,* I was able to determine that only three of the previously named species are valid; namely, *B. gibbosus, B. sinuatus,* and *B. mammilatus. Brachysphingus sinuatus* and *B. gabbi* are synonyms, and the name *Brachysphingus sinuatus* has priority. Figure 2 illustrates the stratigraphic ranges of the valid species of *Brachysphingus.* All the species of *Brachysphingus* are found in California, and all except *B. mammilatus* are found in northern Baja California. This investigation is important because it establishes the evolutionary sequence of species in the genus and when these evolutionary steps took place. Even rare transitional specimens between species are recognizable. Information like this is uncommon for the early Tertiary fossil record of the Pacific slope.

Detailed paleoenvironmental analyses are wanting for most formations where *Brachysphingus* is present. For those formations that have been studied (Table 1), the associated mollusks are always shallow-marine forms. Specimens of *Brachysphingus gibbosus,* however, are commonly found as transported material in lenses of sandy siltstone contained within deep-water turbidites. The distance of transport from their shallower water habitats into deeper waters was not great because the amount of shell abrasion is low. The other two species, although also subject to displacement via turbidity currents, are usually found in shallow-marine rocks. *Brachysphingus sinuatus* is usually in medium-grained sandstone, whereas *B. mammilatus* is usually in fine-grained sandstone. Evidently, the axial ribs of *B. sinuatus* strengthened the shell and allowed for living in agitated waters where coarser grained sediment accumulated.

Brachysphingus is unusual in that it is one of the few latest Cretaceous to early Tertiary, shallow-marine gastropod genera seemingly indigenous to the Pacific slope of North America. As far as I am aware, there are no confirmed ancestors or successors to *Brachysphingus* in the fossil record. It is present only in California and northern Baja California, Mexico. As will be dis-

←

FIGURE 1—Index map showing geographic locations of species of *Brachysphingus.* Localities are grouped into 15 areas that are numbered from north to south: 1—Middle Fork Eel River. 2—Lower Lake. 3—Potrero Hills. 4—Martinez-Pacheco area. 5—Deer Valley. 6—Junction of Silver and Panoche Creeks. 7—Dip Creek (Lake Nacimiento area). 8—East Fork Fish Creek and Warm Springs Mountain. 9—Sespe Hot Springs. 10—Big Rock Creek (Valymero area). 11—East side of Browns Canyon, north side Simi Valley, south side Simi Valley (Bus and Meier Canyons), and Simi Hills (Las Virgenes Canyon and summit area). 12—Stokes Canyon, Encino Reservoir, Stone Canyon Reservoir, Garapito Creek, Temescal Canyon, and Pulga Canyon. 13—North of Lake Irvine. 14—Mesa San Carlos. 15—Santa Catarina Landing.

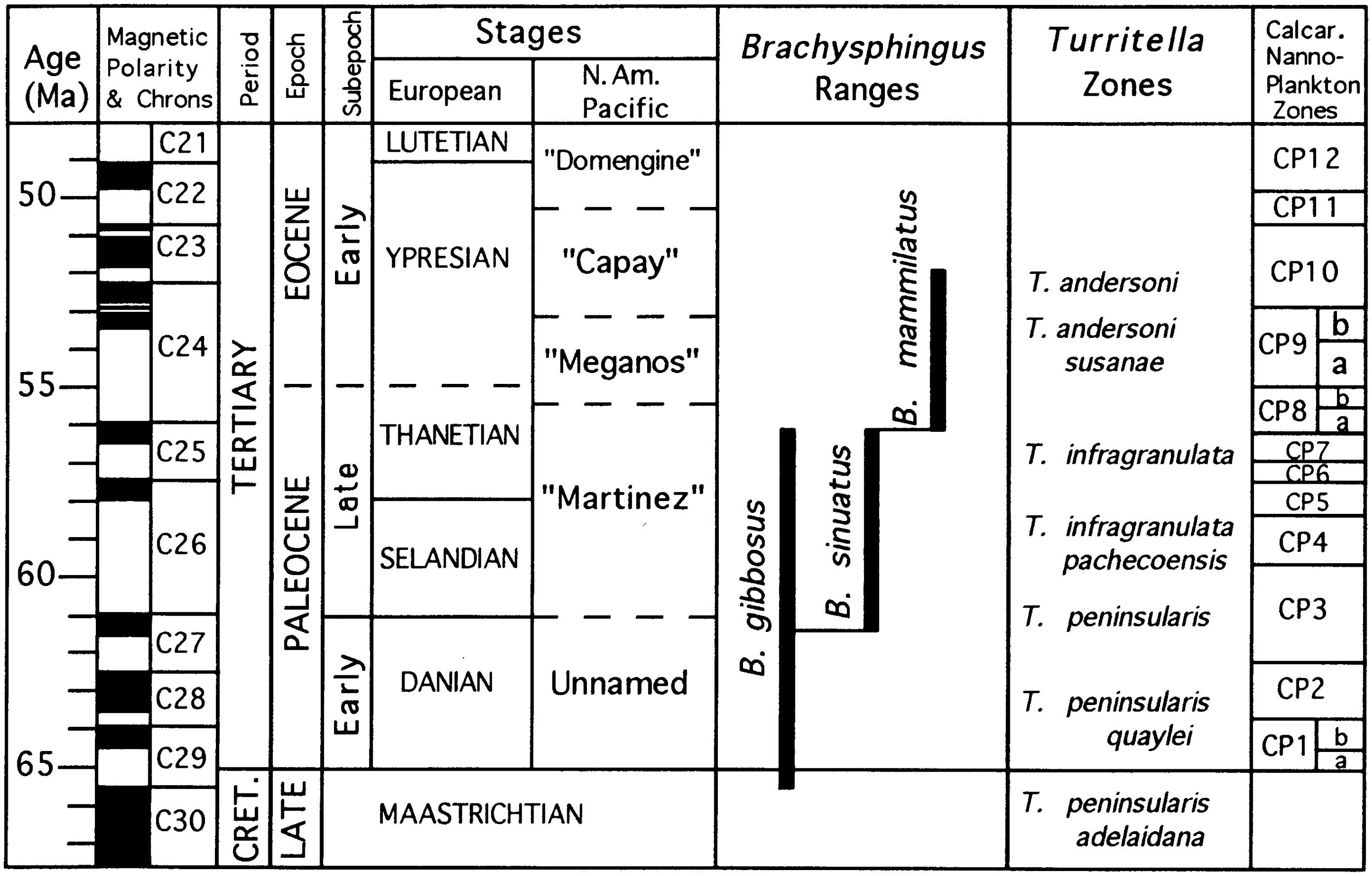


FIGURE 2—Geologic ranges of species of *Brachysphingus* plotted against geochronologic time scale, magnetic polarity and chrons, European stages, and calcareous nannofossil zones (from Berggren et al., 1995), North American Pacific stages (from Saul, 1983a, 1983b; Squires, 1988), and selected *Turritella* zones (from Saul, 1983a).

cussed more thoroughly later in this paper, Cossmann's (1901) report of *Brachysphingus* from the Eocene of Paris Basin, France, proves to be false. Stewart (1927) noted that possibly "*Fusus*" *luciani* Briart and Cornet (1871, page 24, plate 2, figures 3a–c), from the Calcaire Grossier de Mons in Belgium, is related to *Brachysphingus*. The Calcaire Grossier de Mons is of Danian age (Schuler et al., 1992). "*Fusus*" *luciani*, however, has a long anterior canal, very strong spiral ribs, and no siphonal fasciole. The species does not belong in genus *Brachysphingus*.

Abbreviations used are: ANSP = Academy of Natural Sciences of Philadelphia; CASG = California Academy of Sciences, Geology; CSUN = California State University, Northridge; IGM = México Museo del Paleontologia del Instituto de Geología; LACMIP = Natural History Museum of Los Angeles County, Invertebrate Paleontology; UCMP = University of California Museum of Paleontology, Berkeley; UCR = University of California, Riverside; UWBM = Thomas Burke Memorial Washington State Museum (=UW in older literature).

SYSTEMATIC PALEONTOLOGY

Superfamily MURICOIDEA Rafinesque, 1815
Family BUCCINIDAE Rafinesque, 1815

Remarks.—Bucciniform neogastropods started to diversify during the late Mesozoic and early Tertiary, but little is known about their branching order relative to each other. In the study of these gastropods, there has been a tendency to place them in the living families Buccinidae or Nassariidae. The choice of which family has been controversial because they are closely related with no known characters to unambiguously define either group (Allmon, 1990). Ponder (1973) and Cernohorsky (1984) suggested that the differences between the two groups could be treated as subfamilial, and Ponder and Warén (1988) combined both groups in the family Buccinidae. Their classification scheme is used in this paper. I agree with Allmon (1990) that the placing of all late Mesozoic and early Tertiary bucciniform neogastropods into a few traditionally recognized living families has led to obscuring of family-level phylogeny and an underestimating of family-level diversity during this time interval. It is likely that with further study, new families will be erected in order to accommodate early bucciniform neogastropods, like *Brachysphingus*.

Most early workers in the first half of this century followed the usage of Cossmann (1901) and assigned *Brachysphingus* to the nassariids. He based his determination, in large part, on the similarity of *Brachysphingus* to *Buccinum patulum* Deshayes (1835, page 646, plate 88, figures 5, 6), a species known from Eocene rocks in the Anglo-Paris Basin, western Europe. Cossmann (1901) referred to Deshayes' species as *Buccinanops* (*Brachysphingus*) *patulum* and considered it to be a nassariid and the only known Eocene species of *Brachysphingus*. This species was illustrated by Cossmann and Pissarro (1904–1913, pl. 36, fig. 175-1). Allmon (1990, p. 86, pl. 9, figure 12) referred to the same species as "*Ancillopsis*" *patula* (Deshayes) and reported it to be of late Eocene (Auversian-Bartonian) age. He excluded it from his nassariid *Bullia* group and considered that it had independently achieved a shell form somewhat similar to that of some living species of *Bullia*.

TABLE 1—Reported depositional environments of formations containing *Brachysphingus*.

Formation; location	Literature source	Depositional environment
	Brachysphingus gibbosus	
Unnamed; Dip Creek, San Luis Obispo Co.	Grove, 1986	Deep-water turbidities with displaced shallow-marine mollusks
San Francisquito; Warm Springs Mtn., Los Angeles Co.	Kirby, 1991	Transition zone between shoreface and offshore with accumulations of shallow-marine mollusks
San Francisquito; Big Rock Creek, Los Angeles Co.	Kooser, 1980	Deep muddy water with displaced shallow-marine mollusks
Lower and middle Santa Susana; South side Simi Valley, Ventura Co.	Parker, 1983	Middle bathyal turbidities with displaced shallow-marine mollusks
Sepultura; Mesa San Carlos, Baja Calif., Mexico	Zinsmeister and Paredes, 1988	Shallow-shelf with storm accumulations of mollusks
Basal Lodo; Silver Creek and Panoche Creek junction, Fresno Co.	Smith, 1975	Submarine canyon? with localized displaced shallow neritic to sublittoral mollusks
	Brachysphingus sinuatus	
Uppermost Las Virgenes; South side Simi Hills, Ventura Co.	Parker, 1983	Nearshore marine along a low-energy coast; fossils in storm lags
Lower and middle Santa Susana; South side Simi Valley, Ventura Co.	Parker, 1983	Transition zone between nearshore and offshore
Sepultura; Mesa San Carlos, Baja Calif., Mexico	Zinsmeister and Paredes, 1988	Shallow-shelf with storm accumulations of mollusks
San Francisquito; Warm Springs Mtn., Los Angeles Co.	Kooser, 1982	Deep-sea fan turbidites with displaced shallow-marine mollusks
Basal Lodo; Silver Creek and Panoche Creek junction, Fresno Co.	Smith, 1975	Submarine canyon? with localized displaced shallow neritic to sublittoral mollusks
	Brachysphingus mammilatus	
Margaret Hamilton Sand; Deer Valley, Contra Costa Co.	Almgren, 1978	Probable mid-neritic
Basal Lodo; Silver Creek and Panoche Creek junction, Fresno Co.	Smith, 1975	Submarine canyon? with localized displaced shallow neritic to sublittoral mollusks
Uppermost Santa Susana; North side Simi Valley, Ventura Co.	Heitman, 1983	Outer shelf
Lower Juncal; Sespe Hot Springs, Ventura Co.	Givens, 1974	Nearshore shallow-marine

In my private collection, I have specimens of "*Ancillopsis*" *patula* from the middle Eocene Bracklesham Group, Bracklesham Bay, Sussex, England. Although "*A.*" *patula* does bear close resemblance to *Brachysphingus sinuatus,* there are important differences. "*Ancillopsis*" *patula* is characterized by a dorsoventrally flattened shape, minute spire, and expanded callus in the parietal area, and a non-projecting siphonal fasciole that extends a considerable distance posteriorly. None of these features is present in *B. sinuatus*; therefore, "*A.*" *patula* should not be considered as a member of genus *Brachysphingus.* Thus, the basis for Cossmann (1901) placing *Brachysphingus* in the nassariids is removed.

Modern workers have been reluctant to classify *Brachysphingus* as a nassariid. Nuttall and Cooper (1973) doubted that it is nassariid as it lacks the terminal plait found in all definite nassariids. They also stated that the siphonal-fasciole ridge and growth lines suggest that *Brachysphingus* might belong in the very broadly construed Buccinidae. Cernohorsky (1984) considered *Brachysphingus* to be a buccinid genus. To Allmon (1990) it did not appear to belong to the nassariids, and he considered its placement uncertain.

Cossmann (1901, page 221, plate 9, figure 14) reported that *Ancilla subglobosa* (Conrad, 1832, page 25, plate 10, figure 13), a species from Eocene strata of the southeastern United States and northeastern Mexico (Allmon, 1990), belongs in *Buccinanops* (*Brachysphingus*). According to Allmon (1990), this species is a junior synonym of "*Bullia*" *altilis* (Conrad, 1832), which is a problematic taxon allied to genus *Bullia.* "*Bullia*" *altilis* is characterized by a dorsoventrally flattened shape, very expanded parietal callus that can cover the entire ventral surface of the shell, a siphonal fasciole that is weak or absent, and no external sculpture. None of these features is present in *Brachysphingus*; therefore, "*Bullia*" *altilis* is not a member of *Brachysphingus.*

Genus BRACHYSPHINGUS Gabb, 1869

Remarks.—Nuttall and Cooper (1973) suggested that the lectotype of *Molopophorus striatus* (Gabb, 1869, pages 157, 219, plate 26, figure 36), which is the type species of genus *Molopophorus* Gabb, 1869, is actually a juvenile specimen of *Brachysphingus* sp. If their suggestion is correct, which has not been proven, then genus *Molopophorus* becomes a junior synonym of *Brachysphingus. Molopophorus striatus,* however, differs significantly from any *Brachysphingus* by being much smaller (only up to 6 mm high) and by having the suture bordered by a rib on the top of the succeeding whorl. I do not consider *M. striatus* as belonging to genus *Brachysphingus. Molopophorus striatus* is known from upper Eocene rocks of California (Allmon, 1990).

Allmon (1990) reported that *Molopophorus* is probably a nassariid but that the genus has an uncertain status and should be used in an informal sense (denoted by quote marks).

Brachysphingus gibbosus, and to a lesser degree *B. mammilatus,* bear close resemblance to "*Molopophorus*" *clarki* (Weaver, 1912, page 48, plate 4, figure 38; plate 6, figure 57) from the Cowlitz Formation (Weaver, 1942) of late middle Eocene age (Nesbitt, 1995) in southwestern Washington. Although "*Molopophorus*" *clarki* resembles the smooth forms of *Brachysphingus,* "*M.*" *clarki* has a slight terminal fold, which is usually a nassariid character (Allmon, 1990).

The upper spire of nearly every specimen of *Brachysphingus* is preferentially decorticated, whereas the body whorl has all or most of its shell material intact. The upper spire, therefore, is almost always preserved as an internal mold. On a few specimens, remnants of shell give the upper spire the appearance of having a sutural cord or cords. Rare specimens that have shell material present, on at least the penultimate whorl, do not have any sutural cords.

The suture on every specimen of *Brachysphingus* has been adversely affected by weathering. It seems to be very shallowly grooved, but that might just be an artifact of weathering. Nuttall and Cooper (1973) reported that the suture appeared to be canaliculate (grooved) on at least one specimen of *B. gibbosus* that they had available for study.

The illustrations (Figures 3, 4) of representative specimens of each of the species of *Brachysphingus* are arranged in a growth-series pattern, from juvenile to adult. Where appropriate, unusual specimens are included after the growth-series of the normal specimens. Measurements of these specimens, as well as non-illustrated paratypes, are given in Table 2.

Type species.—*Brachysphingus sinuatus* Gabb, 1869, by subsequent designation (Cossmann, 1901).

BRACHYSPHINGUS GIBBOSUS Nelson, 1925
Figure 3.1–3.16

Brachysphingus gibbosus NELSON, 1925, table opposite p. 402, p. 426, pl. 57, figs. 5a, 5b, 6; CLARK AND WOODFORD, 1927, p. 117; KEEN AND BENTSON, 1944, p. 133–134; NUTTALL AND COOPER, 1973, pl. 8, figs. 3, 4; ALLMON, 1990, table on p. 23.

Brachysphingus sinuatus Gabb. ZINSMEISTER AND PAREDES-MEJIA, 1988, pl. 1, figs. 12, 13.

Brachysphingus gabbi Stewart. ZINSMEISTER, 1983, pl. 4, figs. 13, 14

Brachysphingus cf. *B. gibbosus* Nelson. KIRBY, 1991, p. 67–68, pl. 1, fig. 8.

Brachysphingus n. sp. SAUL, 1986, figs. 52–53.

Original description.—"Shell short, thick, subovate; spire low; whorls 5; suture linear, slightly appressed; body whorl swollen, in most specimens roughly con-shaped in upper portion, curving rather abruptly inward below. Main portion of body whorl smooth except for more or less prominent sinuous growth lines; portion of body whorl just above canal marked by 6 or 7 fine revolving ribs. Aperture roughly oval-shaped with maximum width just anterior to center, pointed behind, notched anteriorly. Outer lip simple; inner lip moderately calloused; canal short" (Nelson, 1925, p. 426).

Supplemental description.—Shell medium size (up to 35.1 mm high), consisting of approximately six convex whorls. Suture shallowly grooved?; protoconch unknown. Spire low to moderately elevated; very rarely projected, never concave-looking. Juveniles globose, uncommonly with projected anterior area; adults (greater than approximately 27 mm high) cylindrical-ovoid. Penultimate whorl with approximately seven to eight closely spaced, fine spiral ribs, usually without a finer spiral rib in the interspaces. Body whorl usually smooth, rare specimens (never more than 22 mm high) with fine spiral ribbing on posterior half of ventral surface of body whorl; rarer specimens (never more than 21 mm high) with fine spirals on entire ventral surface of body whorl. A few coarse growth rugae near outer lip moderately common. Neck area with 8 to 12, fine spiral ribs, becoming fainter posteriorly; spiral ribs on neck stronger than elsewhere on the shell; necl-area spiral sculpture usually obsolete on large adults. Siphonal fasciole distinct but usually not strongly developed. Anterior notch short. Inner lip callus light to moderate. Growth line sigmoidal with strongest deflection between the rounded shoulder and the suture.

Type specimens.—Holotype UCMP 30526 and paratype UCMP 30527.

Type locality.—UCMP 3776, upper lower Santa Susana Formation, Runkle Canyon, south side of Simi Valley, Ventura County, southern California.

Remarks.—A total of 237 specimens were found in museum collections. Early juvenile specimens are scarce and poorly preserved. None was less than 13 mm high. Late-stage adults are not that common; only 15 were detected in the museum collections. Specimens of *B. gibbosus* generally show good preservation, but they are usually weathered and missing the uppermost spire, the anterior end of the shell, and the outer lip. The aperture on most specimens is plugged with hard matrix.

The area with the most specimens and localities of *B. gibbosus* is on the south side of Simi Valley in the Meier Canyon area, Ventura County, southern California, where there are numerous float boulders from the almost completely covered, so-called "Martinez marine member" of the lower Santa Susana Formation. This is area where Nelson (1925) collected his type specimens of *B. gibbosus.* Every museum collection studied has an appreciable number of specimens from this area. Inspection of the specimens revealed that nearly all are globose juveniles. Only a few are adults.

The change in shape of the body whorl of *B. gibbosus* from globose juveniles to ovoid adults is new information, as is the observation that juveniles can have spiral ribs on the ventral surface of the body whorl. On the globose juveniles, the maximum diameter is on the medial part of the body whorl and perpendicular to the axis of coiling. On the ovoid adults, the maximum diameter is very oblique to this axis and extends from near the shoulder to the anterior third of the body whorl.

Nelson's (1925, plate 57, figures 5a, 5b, 6) illustrations of the two primary type specimens of *B. gibbosus* have drawbacks in that they do not show complete specimens and both are late juveniles. The spire is missing on the holotype, and the base is missing on the paratype. These specimens are illustrated (Figure 3.3, 3.7, 3.8), and a comparable size, but more complete specimen, is also illustrated (Figure 3.5, 3.6).

Nuttall and Cooper (1973, plate 8, figures 3, 4) illustrated two specimens of *B. gibbosus* from Ventura County. One illustration is of a sectioned specimen, and it shows that there is no columellar plait. The other illustration is an oblique view of the spire, and it shows how the growth lines are reversed at the suture.

The earliest known specimens of *B. gibbosus* are from unnamed strata at LACMIP locs. 26525 and 26526 in the Dip Creek area, along the south shore of Lake Nacimiento, San Luis Obispo County, central California. Saul (1983a, 1986) and Squires and Saul (1993) assigned these strata to an age of latest Cretaceous (or possibly earliest Paleocene). Four specimens of *B. gibossus* were found in the Dip Creek area. They range in morphology from globose to narrow with a projecting spire (Figure 3.13, 3.14). The narrow form is unusual and may give a clue as to the progenitor of the *Brachysphingus* lineage.

A few of the late-stage juveniles (approximately 19 to 20 mm high) of *B. gibbosus* are unusual in that, in addition to the globose body whorl, they have a narrow and elongate neck area. This anterior elongation is present only on the geologically older specimens. It is present on one of the geologically oldest specimens of *B. gibbosus* from the Dip Creek area. It is also present on a specimen (Figure 3.11, 3.12) from LACMIP loc. 1581 in upper Danian strata in East Fork Canyon near Warm Springs Mountain, Los Angeles County, southern California.

Specimens of *B. gibbosus* are uncommon in Thanetian-age rocks. Only six specimens were detected in the museum collections.

The most obvious way of distinguishing *Brachysphingus gibbosus* from *B. sinuatus* is that *B. gibbosus* has no axial ribs. There are, however, certain specimens that are intermediate between *B. gibbosus* and *B. sinuatus.* These specimens, which are known

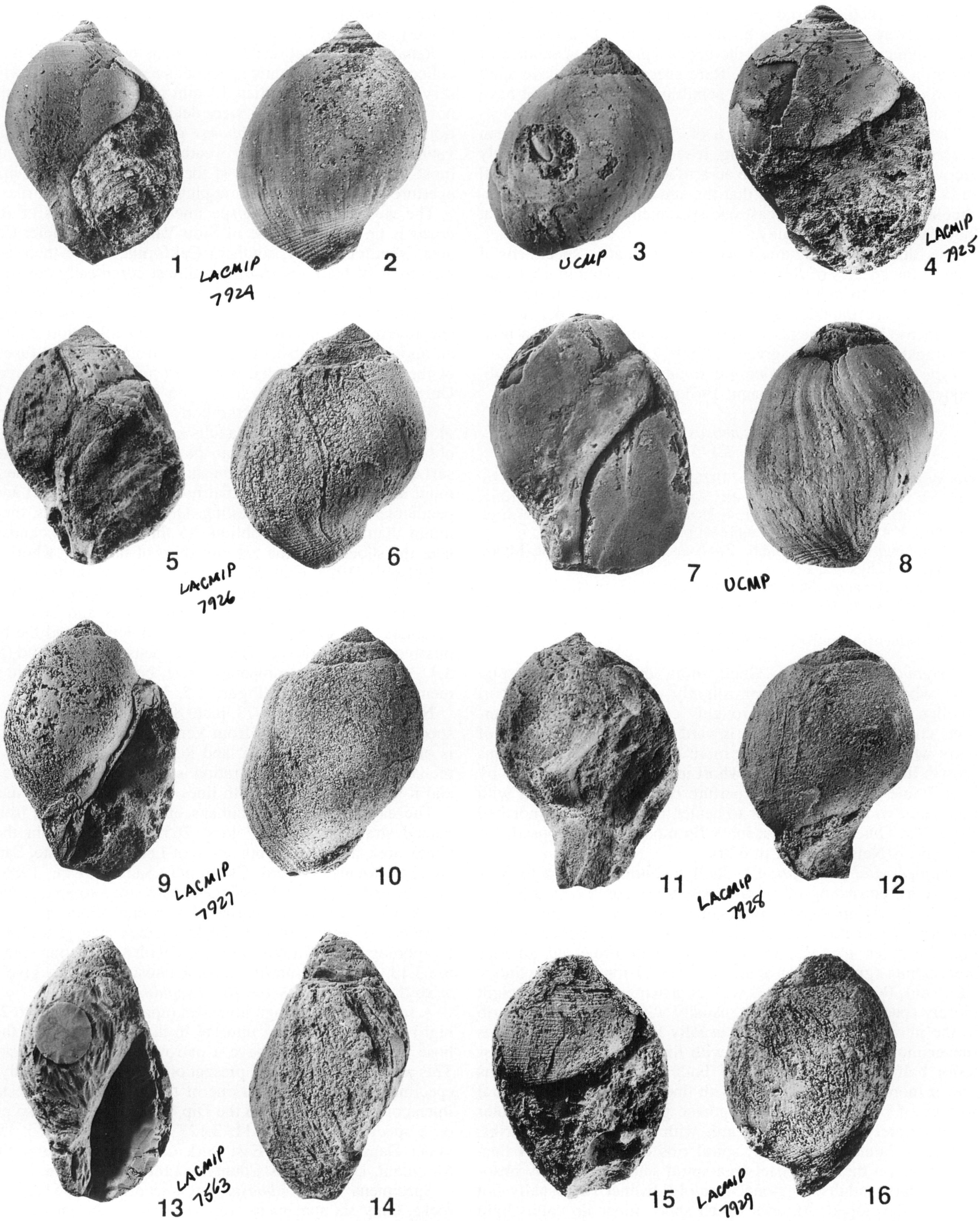


FIGURE 3—*1–16, Brachysphingus gibbosus* Nelson, 1925. *1, 2,* hypotype, LACMIP 7924, LACMIP loc. 22330, apertural and abapertural views, ×2.7. *3,* paratype, UCMP 30527, UCMP loc. 3776, abapertural view, ×2. *4,* hypotype, LACMIP 7925, LACMIP loc. 22330, apertural view, ×2.3. *5, 6,* hypotype, LACMIP 7926, CSUN loc. 123c, apertural and abapertural views, ×2. *7, 8,* holotype, UCMP 30526, UCMP loc. 3776, apertural and abapertural views, ×2.1. *9, 10,* hypotype, LACMIP 7927, LACMIP loc. 22702, apertural and abapertural views, ×1.4. *11, 12,* hypotype, LACMIP 7928, LACMIP loc. 21581, apertural and abapertural views, ×2.4 *13, 14,* hypotype, LACMIP 7563, LACMIP loc. 26526, apertural and abapertural views, ×1.7. *15, 16,* hypotype, LACMIP 7929, LACMIP loc. 23110, apertural and abapertural views, ×2.2.

CSUN 123c = LACMIP 17086

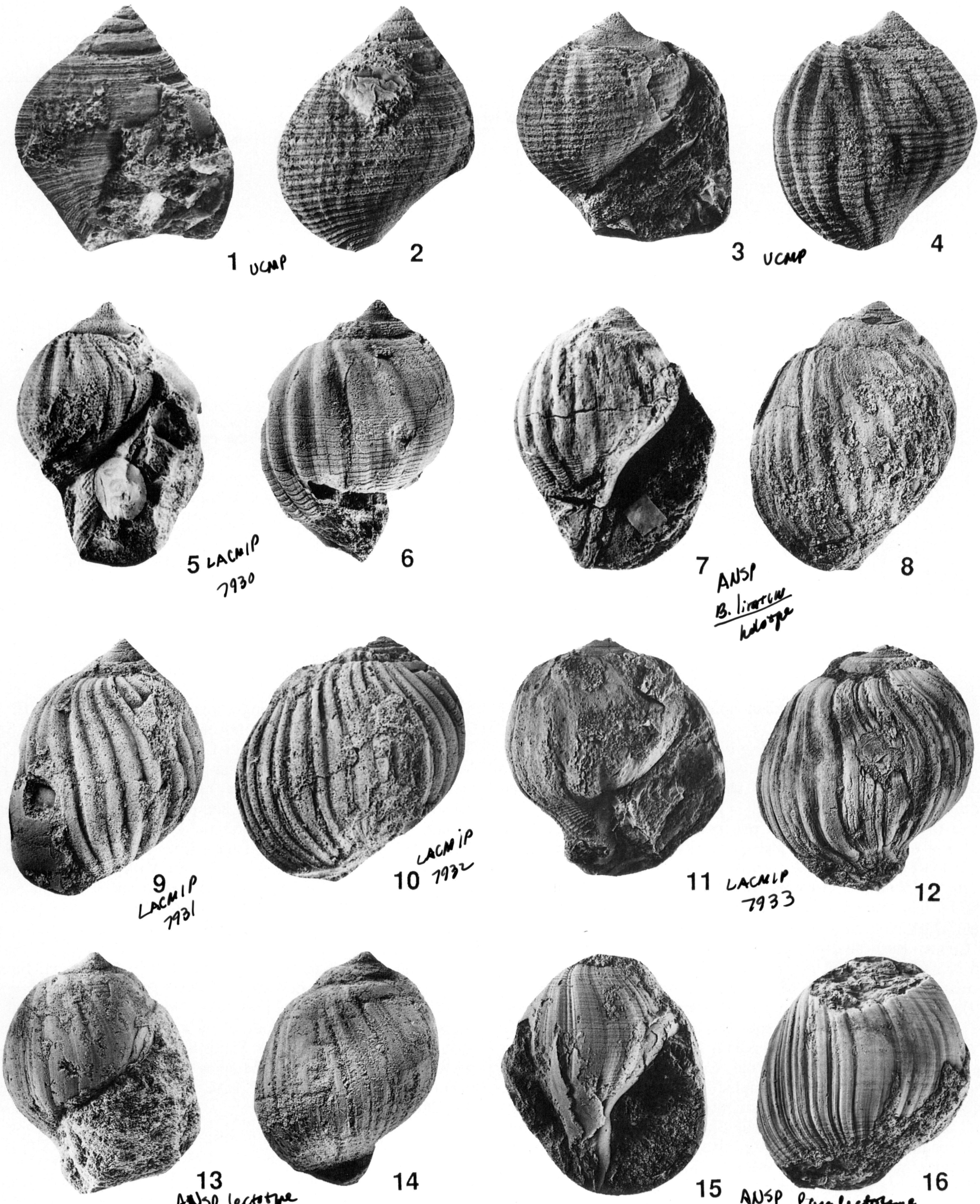


FIGURE 4—*1–16, Brachysphingus sinuatus* Gabb, 1869. *1, 2,* hypotype, UCMP 154001, UCMP. A-1523, apertural and abapertural views, ×3.4. *3, 4,* hypotype, UCMP 154002, UCMP. A-1523, apertural and abapertural views, ×2.9. *5, 6,* hypotype, LACMIP 7930, LACMIP loc. 7047, apertural and abapertural views, ×1.9. *7, 8,* holotype, ANSP 4196 of *Buccinum liratum* Gabb, 1864, exact locality unknown, apertural and abapertural views, ×1.5. *9,* hypotype, LACMIP 7931, LACMIP loc. 7051, left-lateral view, ×1.3. *10,* hypotype, LACMIP 7932, LACMIP loc. 7051, abapertural view, ×1.2. *11, 12,* hypotype, LACMIP 7933, LACMIP loc. 22701, apertural and abapertural views, ×2. *13, 14,* lectotype, ANSP 4258 of *Brachysphingus sinuatus* Gabb, 1869, exact locality unknown, apertural and abapertural views, ×1.7. *15, 16,* paralectotype, ANSP 79503 of *Brachyshingus sinuatus* Gabb, 1869, exact locality unknown, apertural and abapertural views, ×1.7.

TABLE 2—Tabulation of measurements (in mm) of specimens of *B. gibbosus* Nelson, *B. sinuatus* Gabb, and *B. mammilatus* Clark and Woodford illustrated in this paper. Also included are additional paratypes of *B. mammilatus*. All measurements taken from abapertural side. WN = number of whorls (this is a minimum number because the protoconch is missing on all specimens); * = maximum width measured oblique to axis of coiling rather than perpendicular to it.

Specimen	Height	Width	WN	Remarks
		Brachysphingus gibbosus		
UCMP 30526 (holotype)	21.8	18.2	4?	Upper spire missing
UCMP 30527 (paratype)	20.3	18.0	4	
LACMIP 7563	27.4	17.2	4+	Upper spire missing
LACMIP 7924	18.2	12.5	3?	Tip of spire missing
LACMIP 7925	21.2	17.0	4	Tip of spire missing
LACMIP 7926	21.7	17.8	4	
LACMIP 7927	32.7	27.8*	5?	Tip of spire missing
LACMIP 7928	19.6	14.5	4	
LACMIP 7929	20.3	13.8	4?	Upper spire missing
		Brachysphingus sinuatus		
ANSP 4196 (holotype)	32.2	24.9	5	
ANSP 4258 (lectotype)	26.4	22.7	4+	
ANSP 79503 (paralectotype)	25.3	22.3	?	Entire spire missing
LACMIP 7930	25.3	18.9	4+	
LACMIP 7931	35.0	30.0	5+	
LACMIP 7932	37.0	35.0	6	
LACMIP 7933	22.1	20.3	4+	Tip of spire missing
UCMP 154001	12.7	11.0	5+	Base missing
UCMP 154002	14.8	14.4	4+	Base missing
		Brachysphingus mammilatus		
UCMP 31234 (holotype)	33.3	22.0	5	Tip of spire missing
UCMP 31235 (paratype)	43.9	30.5	6?	Extreme tip of spire missing
UCMP 31236 (paratype)	30.3	25.0	5	Tip of spire missing
UCMP 31237 (paratype)	33.4	28.0	5+	Tip of spire missing
UCMP 31238 (paratype)	33.1	26.1	5+	Tip of spire missing
LACMIP 7934	17.3	15.6	4?	Upper spire and base missing
LACMIP 7935	19.5	16.7	4+	Base missing
LACMIP 7936	27.9	19.1	4+	
LACMIP 7937	29.2	22.3	5	
LACMIP 7938	35.9	26.7	5+	
LACMIP 7939	27.1	24.0	5	Tip of spire abraded

from near the Danian/Selandian boundary, are discussed under "Remarks" for *B. sinuatus.*

The ovoid shape of adult *B. gibbosus* resembles the elongate morphology of adult *B. mammilatus.* The differences between these two species are discussed under "Remarks" for *B. mammilatus.*

Occurrence.—Uppermost Cretaceous (uppermost Maastrichtian) or possibly lowermost Paleocene (lowermost Danian) to upper Paleocene = *Turritella peninsularis adelaidana* to *T. infragranulata* Zones. Uppermost Maastrichtian or Possibly Lowermost Danian (*Turritella peninsularis adelaidana* Zone): Unnamed strata, Dip Creek, south shore of Lake Nacimiento. San Luis Obispo County (new stratigraphic occurrence, LACMIP locs. 26525 and 26526). Danian (*T. p. qualeyi* Zone): Lower San Francisquito Formation, Warm Springs Mountain, Los Angeles County (Kirby, 1991); lower San Francisquito Formation, East Fork Fish Creek, Los Angeles County (new stratigraphic occurrence, LACMIP locs. 21579A and 21581). Selandian (*T. peninsularis* Zone): San Francisquito Formation, Big Rock Creek (Valymero area), Los Angeles County (new stratigraphic occurrence, LACMIP loc. 20894); lower Santa Susana Formation, "Martinez marine member," Bus Canyon, south side of Simi Valley, Ventura County (new locality, UCMP loc. 3810); lower Santa Susana Formation, "Martinez marine member," Meier Canyon, south side of Simi Valley, Ventura County (Waring and McLaughlin, 1914; Waring, 1917; Nelson, 1925; Zinsmeister, 1983); Sepultura Formation, Santa Catarina Landing, Baja California, Mexico (new locality, LACMIP loc. 26364). Selandian (*T. i. pachecoensis* Zone): Middle Vine Hill Sandstone near Pacheco, Contra Costa County (new stratigraphic occurrence, CASG loc. 2296); Middle Santa Susana Formation, north of Meier Canyon, south side of Simi Valley, Ventura County (new stratigraphic occurrence, LACMIP loc. 22374); Middle Santa Susana Formation, Encino Reservoir, Santa Monica Mountains, Los Angeles County (new locality, LACMIP loc. 26583); Middle Santa Susana Formation, Stone Canyon Reservoir, Santa Monica Mountains (new locality, LACMIP 20343); Silverado Formation, north of Lake Irvine, Santa Ana Mountains, Orange County (new stratigraphic occurrence, LACMIP loc. 7079). Selandian (undifferentiated): Reworked specimen in Santa Susana Formation, north side of Simi Valley, Ventura County (new locality, LACMIP 7142); Reworked specimens in Stokes Canyon Breccia Member of the middle Miocene Calabasas Formation, Stokes Canyon, Santa Monica Mountains, Ventura County (new stratigraphic occurrence, LACMIP loc. 25281); Sepultura Formation, Mesa San Carlos, northern Baja California, Mexico (Zinsmeister and Paredes-Mejia, 1988). Thanetian (*T. infragranulata* Zone): Basal Lodo Formation, junction of Silver and Panoche Creeks, Fresno County (new stratigraphic occurrence, LACMIP loc. 7044); Upper Santa Susana Formation, west side of Temescal Canyon, Santa Monica Mountains (new stratigraphic occurrence, CASG loc. 2692, LACMIP loc. 7062, and LACMIP loc. 26897).

BRACHYSPHINGUS SINUATUS Gabb, 1869
Figure 4.1–4.16

Buccinum liratum GABB, 1864:96, 223, pl. 28, fig. 11; STOLICZKA, 1868:143 (suggested species belongs possibly to *Bullia*); COSSMANN, 1901:222 (placed under *Buccinanops* (*Brachysphingus*)); KEEN AND BENTSON, 1944, p. 134.

Not *Buccinum liratum* MARTYN, 1784:fig. 43.

Brachysphingus liratus Gabb. GABB, 1869:156, 219; TRYON, 1881, p. 106, pl. 31, fig. 81 ("*Brachysphingus* allied probably to *Cominella* or *Volutharpa*"; 1883, p. 150, pl. 51, fig. 70); STANTON, 1896, p.

1048, pl. 66, figs. 5, 6; MERRIAM, 1897, table on p. 770, 771, table on p. 773; DICKERSON, 1914a, table on p. 109 (in part), pl. 15, fig. 4; 1914b, p. 295; WARING, 1917, p. 82; CLARK AND WOODFORD, 1927, p. 117; CLARK, 1929, p. 12, pl. 2, fig. 6; BAILEY, 1930, p. 323; MERRIAM AND TURNER, 1937, p. 96; CLARK, 1940, p. 128; WEAVER, 1953, p. 26; SMITH, 1975, table on p. 469.

Brachysphingus sinuatus GABB, 1869, p. 156, 219, pl. 26, fig. 35; COSSMANN, 1901, p. 221–222 (placed under *Buccinanops* (*Brachysphingus*)); DICKERSON, 1914a, table on p. 109; WARING AND MCLAUGHLIN, 1914, pl. 1, fig. 16; WARING, 1917, table on p. 72, 82, pl. 13, figs. 7, 8; KEW, 1924; NELSON, 1925, table on p. 403, 426; STEWART, 1927, p. 392, pl. 25, fig. 2; CLARK AND WOODFORD, 1927, p. 117; WENZ, 1943, p. 1228, fig. 3493; KEEN AND BENTSON, 1944, p. 134; WEAVER, 1953, table on p. 29; ZINSMEISTER, 1983, pl. 4, figs. 11, 12; SMITH, 1975, table on p. 469, table on p. 471; CERNOHORSKY, 1984, p. 26; ALLMON, 1990, table on p. 23.

Brachysphingus gabbi STEWART, 1927, p. 392–393, pl. 25, fig. 9 (new name for *Buccinum liratum,* preoccupied); SCHENCK AND KEEN, 1940, pl. 20; HANNA AND HERTLEIN, 1941, p. 168, figs. 62-1, 62-2; KEEN AND BENTSON, 1944, p. 133; WEAVER, 1953, p. 29; EVANS AND MILLER, 1978, faunal list on geologic map sheet; KOOSER, 1980, table on p. 21; ZINSMEISTER, 1983, table on p. 64; ZINSMEISTER AND PAREDES-MEJIA, 1988, table 1 on p. 12; PAREDES-MEJIA, 1989, p. 282–283, pl. 10, figs. 7, 8; ALLMON, 1990, table on p. 23.

Brachysphingus species. ALLMON, 1990, pl. 10, fig. 14.

Not *Brachysphingus sinuatus* Gabb. ZINSMEISTER AND PAREDES-MEJIA, 1988, pl. 1, figs. 12, 13 [=*B. gibbosus*].

Not *Brachysphingus gabbi* Stewart. ZINSMEISTER, 1983, pl. 4, figs. 13, 14 [=*B. gibbosus*].

Original description of B. liratum.—"Shell ovoid, robust, test thick; spire low, whorls four and a half to five, convex. Aperture elongate, deeply notched in advance; outer lip simple; inner lip lightly incrusted, more heavily below than above; umbilicus distinct, but imperforate. Surface marked by numerous rounded, longitudinal ribs, with intermediate spaces somewhat smaller than the ribs themselves; these run somewhat obliquely, especially at the top, where they curve slightly from behind forwards. The lower third to half of the shell is marked by numerous small, revolving, impressed lines" (Gabb, 1864, p. 96).

Original description of B. sinuatus.—"Shell short, thick, subovate; spire low, whorls four to four and a half, almost entirely hidden, except on their upper margin; suture variable, sometimes deep and bordered by a thickening of the succeeding whorl, sometimes almost linear, body whorl swollen in the middle, and marked by sinuous longitudinal lines of growth, and in some specimens by undulations of the same form, on the anterior part of the shell are a few minute revolving lines. Aperture broad in the middle, acute behind, narrowed in front, and deeply and narrowly notched; a rib revolves backwards from this notch around the anterior portion of the shell, occupying the former position of the notch at the successive stages of growth; outer lip simple, slightly sinuous in outline; inner lip heavily incrusted. A very variable shell, both in the height of the spire and in the intensity of the surface markings. Some specimens are perfectly smooth except for the revolving lines, while others are strongly costate by well marked but irregular sinuous longitudinal ribs produced by irregular growth" (Gabb, 1869, p. 156).

Supplemental description.—Shell medium size (up to 36.6 mm high), consisting of approximately five convex whorls. Suture shallowly grooved?; protoconch unknown. Spire moderately elevated and concave-appearing, uncommon specimens with very low spire. Body whorl globose and rapidly increasing in size relative to spire, some adult specimens somewhat globose-elongate. Juvenile specimens (about 12 to 15 mm high) covered by closely spaced, fine spiral ribs and finer rib(s) in the interspaces; dorsal side of body whorl with axial ribs. Axial ribs becoming stronger and over entire body whorl on larger specimens, and spiral ribbing on specimens larger than about 26 mm high restricted to fine ribs on spire whorls and coarser ribs on anterior third of shell (neck area). Axial ribs sigmoidal with strongest deflections between rounded shoulder and suture, and, on some specimens, on medial dorsal part of body whorl; axial ribs wide with interspaces about one-half as wide, about 20 axial ribs on body whorl extending from suture to siphonal fasciole; on rare specimens axial ribs take form of variable-width growth rugae separated by very narrow interspaces or the axial ribs become obsolete toward outer lip and are replaced by growth rugae. Body whorl base with a well-developed and raised siphonal fasciole bearing a short but distinct anterior notch. Aperture oval shaped, inner lip with moderate callus, smooth; outer lip simple.

Type specimens.—Of *liratum:* holotype ANSP 4196. Of *sinuatus:* lectotype ANSP 4285.

Type locality.—Of both *liratum* and *sinuatus:* Unknown, probably in the lower Vine Hill Sandstone, Pacheco area, Contra Costa County, northern California.

Remarks.—A total of 151 specimens were found in museum collections. Early juvenile specimens are scarce. No specimens were less than about 12 mm high. Large shells are moderately common. Preservation of *B. sinuatus* specimens is generally good, although those from the basal Lodo Formation in the Silver Creek-Panoche Creek intersection, Fresno County, are usually quite weathered.

Although Gabb (1864) did not mention it, the axial ribs on the holotype (ANSP 4196) of his *Buccinum liratum* become very faint near the outer lip (Figure 4.8). This same feature was also observed on some of the type specimens of *Brachysphingus sinuatus* Gabb, 1869, discussed below.

Gabb (1869) noted that *B. sinuatus* showed a wide range in morphology, with some specimens smoothish and others strongly ribbed. Stewart (1927, p. 392) echoed this comment and reported that two of eight type specimens of this species have weak axial ribs and are "probably smooth forms of *B. gabbi.*" Initially these descriptions seem almost paradoxical, but an inspection of the type specimens reveals that the morphology of *B. sinuatus* is intermediate between *B. gibbosus* and *B. gabbi.* Of the eight type specimens, five are fragments that show smoothish parts of body whorls like those found on *B. gibbosus.* Three of the eight specimens are complete, but only two of these three specimens are preserved well enough to observe the entire body whorl. These two specimens (lectotype ANSP 4258 and the best preserved and most complete paralectotype ANSP 79503), which are illustrated in Figure 4.13 to 4.14 and 4.15 to 4.16, respectively, are very rare specimens that show the intermediate stage between the smooth *B. gibbosus* and the sculptured species that Stewart (1927) referred to as *B. gabbi.* Although the lectotype of *B. sinuatus* is figured in Stewart (1927, plate 25, figure 2), only the abapertural view is shown. The apertural view of this specimen is shown, for the first time, in this present paper in Figure 4.13. On both specimens, there are axial ribs on the apertural part of the body whorl but only growth rugae on the abapertural part. *Brachysphingus sinuatus* and *B. gabbi,* in fact, are the same species, and Stewart (1927) should have used *B. sinuatus* Gabb, 1869, as the replacement name for the homonym *B. liratum* Gabb, 1864, rather than proposing the new name *B. gabbi.*

Other than the Martinez Formation of the Martinez area, Contra Costa County, northern California, no more information is known about the geographic and stratigraphic positions of the type specimens of both *B. sinuatus* and Stewart's *B. gabbi.* The earliest known record of Stewart's *B. gabbi* is of latest Danian or earliest Selandian age (*Turritella peninsularis qualeyi-T. peninsularis* Zone boundary) (Figure 2) in the Martinez Formation at LACMIP loc. 7051 in the Lower Lake area, Lake County, northern California. The lower part of the Vine Hill Sandstone in the Martinez-Pacheco area is also of this age (Saul, 1983a), and these rocks are probably the ones that yielded the type specimens of *B. sinuatus* because, as discussed above, the type specimens represent the earliest specimens of this species and are transitional with *B. gibbosus*.

The most complete growth series of *B. sinuatus* is also present at LACMIP loc. 7051 in the Lower Lake area. As at other localities where this species is found, juvenile and early adult specimens show moderately strong spiral ribs over the entire body whorl, as well as axial ribs. In fact, they show cancellate ornamentation (Figure 4.1–4.3), and this is new information about the species. On more mature specimens, the axial ribs dominate the sculpture, whereas the spiral ribs are restricted to the anterior part of the body whorl. Most adult specimens have a moderately elevated upper spire that has a concave profile (Figure 4.3) and is similar to *B. mammilatus* in that respect. A few adult specimens, however, have a lowly elevated upper spire (Figure 4.10–4.12).

Four specimens of *B. sinuatus* are unusual in that the upper spire is very low and the axial ribs look like closely crowded, irregular growth rugae. One of these specimens is illustrated in Figure 4.11, 4.12. Three of these specimens are from LACMIP loc. 22701 near the summit of the Simi Hills, Ventura County, southern California. Fantozzi (1955), who collected these specimens, plotted the locality on his geologic map as near the top of the late Danian? (*T. peninsularis qualeyi* Zone) Las Virgenes Sandstone, but the fine-grained matrix surrounding the specimen looks like the rock type of the overlying early Selandian, lower Santa Susana Formation (*T. peninsularis* Zone). The Simi Hills specimens are about 20 mm high, cylindrical, and intergrade with smoothish specimens that strongly resemble *B. gibbosus*. An additional specimen (Paredes-Mejia, 1989, plate 10, figures 7, 8) is from Sepultura Formation float at Mesa San Carlos, northern Baja California. The similarity between the Sepultura Formation specimen and those from the lower Santa Susana Formation in the Simi Hills suggests that the Sepultura Formation specimen is also of early Selandian age. This age is in close agreement with the *Turritella*-based age of the Sepultura Formation reported by Saul (1983a).

At LACMIP loc. 7044 in the basal Lodo Formation where Silver Creek intersects with Panoche Creek, Fresno County, there are specimens of *B. sinuatus* that are intermediate with *B. mammilatus*. They will be discussed under "Remarks" of *B. mammilatus*.

Occurrence.—Paleocene (Danian through Thanetian) =*Turritella peninsularis quaylei* through *T. infragranulata* Zones. Near the Danian-Selandian boundary (near the *Turritella peninsularis quaylei* Zone–*T. peninsularis* Zone boundary): Martinez Formation, Lower Lake, Lake County (Stanton, 1896); Lower Vine Hill Sandstone, Martinez-Pacheco area, Contra Costa County (Weaver, 1953); Las Virgenes Sandstone, upper Las Virgenes Canyon, Simi Hills, Ventura County (Fantozzi, 1955). Selandian (*Turritella peninsularis* Zone): Lower Santa Susana Formation, east of Browns Canyon, Santa Susana Mountains, Los Angeles County (Evans and Miller, 1978); lower Santa Susana Formation, upper Las Virgenes Canyon and summit area of Simi Hills, Ventura County (Fantozzi, 1955); Sepultura Formation, Mesa San Carlos, Baja California, Mexico (Paredes-Mejia, 1989). Selandian (*T. infragranulata pachecoensis* Zone): Middle Santa Susana Formation, north of Meier Canyon, south side of Simi Valley, Ventura County (new stratigraphic occurrence, UCMP loc. 3768); San Francisquito Formation, Big Rock Creek (Dickerson, 1914b) and Warm Springs Mountain area (Kooser, 1980), Los Angeles County; Silverado Formation, north of Lake Irvine, Santa Ana Mountains, Orange County (Schoellhamer et al. 1981). Thanetian (*T. infragranulata* Zone): "Martinez" Formation, south of Round Valley, Middle Fork of Eel River, Mendocino County (Merriam and Turner, 1937; Clark, 1940); Martinez Formation, west side of Potrero Hills, Solano County (Bailey, 1930); upper Vine Hill Sandstone near Pacheco, Contra Costa County (Stewart, 1927; Weaver, 1953); Basal Lodo Formation, junction of Silver and Panoche Creeks, Fresno County (new stratigraphic occurrence, LACMIP loc. 7044); upper Santa Susana Formation, Garapito Creek, Quarry Canyon, and near head of Pulga Canyon, Santa Monica Mountains, Los Angeles County (new stratigraphic occurrence, CSUN loc. 354, CASG loc. 2693, and LACMIP loc. 11980, respectively).

BRACHYSPHINGUS MAMMILATUS Clark and Woodford, 1927
Figure 5.1–5.14

Brachysphingus mammilatus CLARK AND WOODFORD, 1927, p. 116–117, pl. 20, figs. 8–15; CLARK, B. L., 1929, p. 13, pl. 4, figs. 3, 10; MERRIAM AND TURNER, 1937, p. 96–97; SCHENCK AND KEEN, 1940, pl. 22; CLARK, S. G., 1940, p. 129; KEEN AND BENTSON, 1944, p. 134; GIVENS, 1974, p. 84, pl. 10, fig. 3, table 1 (in pocket); ALLMON, 1990, table on p. 23.

Pseudoliva sp. SMITH, 1975, pl. 1, figs. 14, 15; SQUIRES, 1989, p. 39 (tentatively assigned to *Brachysphingus*).

Original description.—"Shell heavy, compact, medium in size; 5 or 6 whorls; the spire low, acute, each whorl convex but the rapidity with which successive whorls increase in size gives the spire as a whole a concave profile. Sutures slightly depressed or appressed. Body whorl large, with a smoothly rounded, oval outline; length four or five times the length of the spire. Aperture elongate, ovate; acute anteriorly to the short, deeply notched, recurved canal; outer lip thin; inner lip covered by a narrow heavy callus which only partially conceals a prominent revolving rib and transverse ridges formed by the successive stages of growth of the notched canal. Surface of the shell unornamented except for minute lines of growth over the whole shell; 12 or 15 rather fine revolving ribs on the anterior part of the body whorl with the heavier revolving rib (above mentioned) on the canal. On some specimens there are a few revolving ribs at the tip of the body whorl; on the others, on the final quarter-turn of the body whorl adjacent to the outer lip, the growth lines are so heavy as to suggest longitudinal ribbing very similar to that seen on *B. liratus* (Gabb)" (Clark and Woodford, 1927, p. ref. 116).

Supplemental description.—Shell medium size (up to 43.9 mm high), consisting of approximately 6 convex whorls. Suture shallowly grooved?; protoconch poorly preserved, smooth? Spire moderately elevated and concave appearing; spire low only on late adults. Body whorl very globose, with widest part posteriorly. Late juvenile to early adult specimens (about 20 mm high) with closely spaced, fine spiral ribs (and a finer rib in interspaces) covering ventral side and entire shoulder of body whorl; spire sculpture unknown. Larger specimens with about three moderately coarse spiral ribs on penultimate whorl, 10 to 12 moderately coarse, closely spaced spiral ribs (becoming obsolete posteriorly) on neck, and fine incised lines separating wide, low spiral bands on body whorl shoulder. On grontic adults, spiral ribbing obsolete. Siphonal fasciole usually well developed, bearing a short but distinct anterior notch; some specimens with channel along inner side of siphonal fasciole. Aperture oval shaped, inner lip with moderate callus, smooth; outer lip simple, thickest at shoulder; intersection of outer lip and inner lip delineated by low groove. Growth line sigmoidal with strongest deflection between rounded shoulder and suture. Growth rugae rare, near outer lip.

Type specimens.—Holotype UCMP 31234 from UCMP loc. 3157, paratype UCMP 31235 from UCMP loc. 3577, paratype UCMP 31236 from UCMP loc. 3159, paratype UCMP 31237

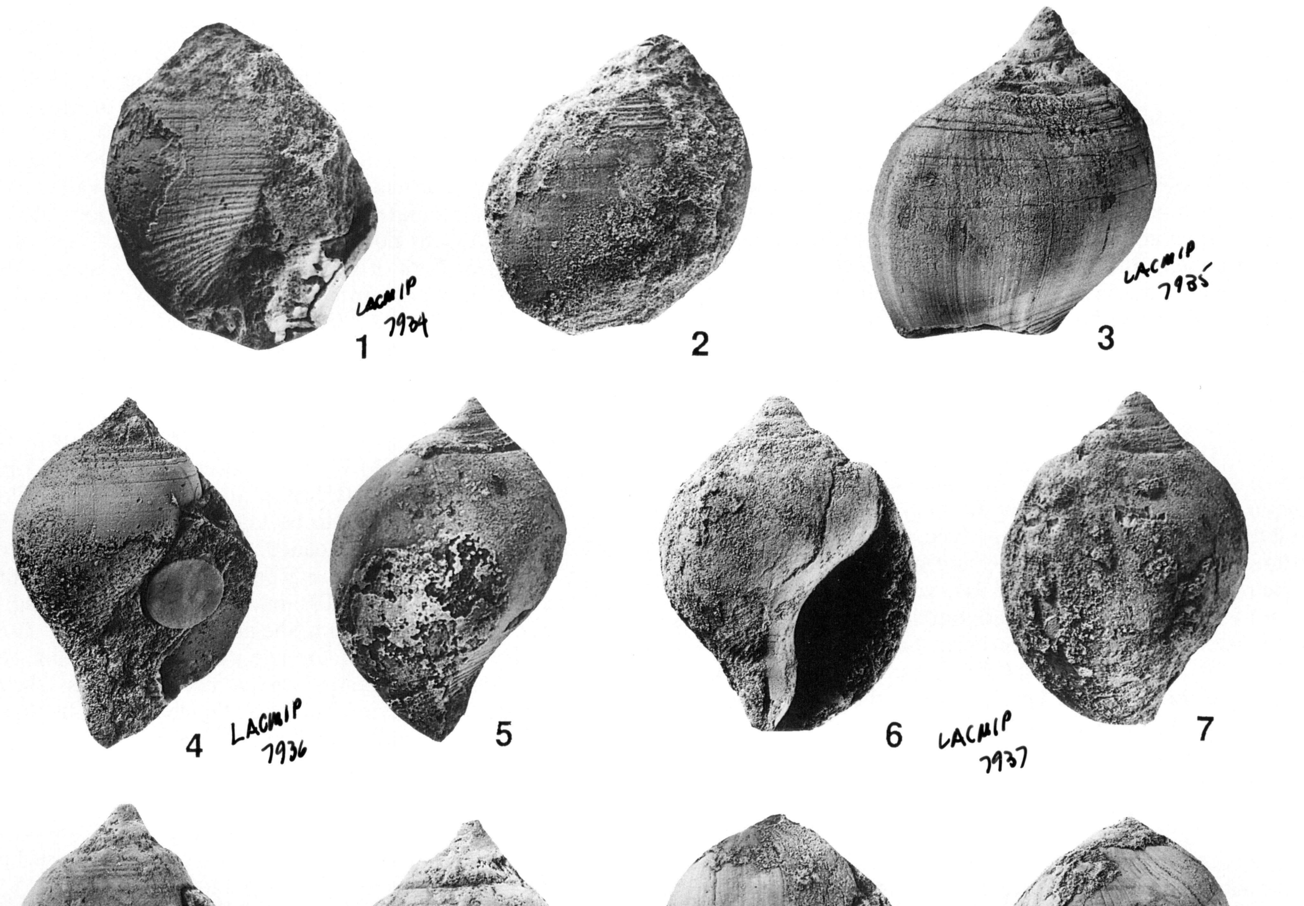


FIGURE 5—*1–14, Brachysphingus mammilatus* Clark and Woodford, 1927. *1, 2,* hypotype, LACMIP 7934, LACMIP loc. 7173, apertural and abapertural views, ×2.5. *3,* hypotype, LACMIP 7935, LACMIP loc. 7173, abapertural view, ×2.4. *4, 5,* hypotype, LACMIP 7936, LACMIP loc. 22387, apertural and abapertural views, ×1.7. *6, 7,* hypotype, LACMIP 7937, LACMIP loc. 26456, apertural and abapertural views, ×1.5. *8, 9,* holotype, UCMP 31234, UCMP loc. 3157, apertural and abapertural views, ×1.5. *10, 11,* paratype, UCMP 31235, UCMP loc. 3159, apertural and abapertural views, ×1.1. *12,* hypotype, LACMIP 7938, LACMIP loc. 7044, abapertural view, ×1.3. *13, 14,* hypotype, LACMIP 7939, LACMIP loc. 7044, abapertural and outer lip views, ×1.6.

from UCMP loc. 3159, paratype UCMP 31238 from UCMP loc. 3577.

Type locality.—UCMP loc. 3157, Margaret Hamilton Sand [=division D of Meganos Formation as used by Clark and Woodford (1927)], Deer Valley, Contra Costa County, northern California.

Remarks.—A total of 174 specimens were found in museum collections. Juvenile specimens are very rare, and no specimens were less than about 15 mm high. Adults are common, but gerontic specimens, like paratype UCMP 31325 (Figure 5.10, 5.11) are extremely rare. Preservation is generally good to very good. Specimens from the basal Lodo Formation in the Silver Creek–Panoche Creek intersection, Fresno County, are the most numerous of any locality, but they are badly weathered.

The primary type specimens are not fully representative of the species because they consist of only adults. One of these, paratype UCMP 31235, is 43.9 mm high and is the largest known specimen of any *Brachysphingus.* Other than its large size, it is unusual because of its very low spire and lack of sculpture. Although the primary type specimens are from three different localities, the localities are near each other and along strike of the same stratigraphic interval in the Deer Valley area, Contra Costa County. This stratigraphic interval was referred to as "division D of the Meganos Formation" by Clark and Woodford (1927). Almgren et al. (1988, Figure 4) assigned "division D strata of the Meganos Formation" to the CP9 Zone (lowest Eocene) of the standard calcareous nannoplankton zonation. These strata are now referred to as the Margaret Hamilton Sand (Edmondson, 1984).

The presence of spiral ribbing on much of the body whorl on juveniles (Figures 5.1, 5.2) and the presence of fine incised spiral ribs separating wide and low bands on the shoulder whorl of many adult specimens (Figure 5.3, 5.4) represent new and very useful information about this species.

At LACMIP loc. 7044 in the basal Lodo Formation (Thanetian age) at the junction of Silver and Panoche Creeks, Fresno County, north–central California, there are specimens that are intermediate in morphology between *B. sinuatus* and *B. mammilatus.* Like most adult specimens of *B. sinuatus,* these specimens of *B. mammilatus* have a somewhat elongate shape with a moderately elevated and somewhat concave-profiled spire. These intermediate specimens also have weak axial ribs on the dorsal part of the body whorl. Two representative specimens are illustrated in Figure 5.12–5.14. These intermediate specimens are very important because they establish that *B. mammilatus* evolved from *B. sinuatus.*

Some of the specimens of *B. mammilatus* at LACMIP loc. 7044 are smooth forms. The presence of this species in late Paleocene-age rocks (Thanetian) is new information. Prior to this present report, the species was only known from Eocene-age rocks (e.g., Clark and Woodford; 1927; Givens, 1974).

Some specimens of *B. mammilatus* resemble *B. gibbosus. Brachysphingus mammilatus* differs from *B. gibbosus* by having a concave-appearing upper spire; fine, incised spiral ribs on the body whorl shoulder of adults (except late-stage ones or weathered specimens); and a globose adult body whorl whose maximum diameter is located posteriorly and measured perpendicularly (rather than obliquely for *B. gibbosus*) to the axis of coiling. This latter feature is very useful in identifying poorly preserved specimens of *B. mammilatus* whose spire might be mostly missing or whose surface sculpture has been obliterated.

Occurrence.—Late Paleocene (Thanetian) to early Eocene (Ypresian = "Meganos" and "Capay" "Stages" =*Turritella infragranulata* to T. *andersoni* Zones. Thanetian (*T. infragranulata* Zone): Basal Lodo Formation, junction of Silver and Panoche Creeks, Fresno County (new stratigraphic occurrence, LACMIP loc. 7044). "Meganos" (*T. meganosensis* Zone): "Meganos" Formation, south of Round Valley, Middle Fork of Eel River, Mendocino County (Merriam and Turner, 1937; Clark, 1940); Margaret Hamilton Sand [=division D of Meganos Formation as used by Clark and Woodford (1927)], Deer Valley, Contra Costa County (Clark and Woodford, 1927); uppermost Santa Susana Formation, north side of Simi Valley, Ventura County (new stratigraphic occurrence, CSUN loc. 958). "Capay" (*T. andersoni* Zone): "Capay" Formation, south of Round Valley, Middle Fork of Eel River, Mendocino County (Merriam and Turner, 1937, as *Brachysphingus* very similar to *B. mammilatus*; Clark, 1940, as *Bracysphingus* very similar to *B. mammilatus*); lower Juncal Formation, Sespe Hot Springs, Ventura County (Givens, 1974).

ACKNOWLEDGMENTS

L. T. Groves (LACMIP), M. Kooser (UCR), D. R. Lindberg (UCMP), and P. Rodda (CASG), allowed access to collections and arranged for material to be loaned. E. Benamy (ANSP) allowed for material to be loaned. M. C. Perriallit (IGM) made high-quality resin replicas of specimens from Baja California, Mexico. L. R. Saul (LACMIP) informed me about the Dip Creek specimens and cleaned them. She also identified many *Turritella* species that were crucial for age control. A. Oleinik (Purdue University) shared his knowledge of neogastropods. The manuscript benefited by reviews of C. R. Givens (Nicholls State University, Lousiana) and L. R. Saul.

REFERENCES

Allmon, W. D. 1990. Review of the *Bullia* Group (Gastropoda: Nassariidae) with comments on its evolution, biogeography, and phylogeny. Bulletins of American Paleontology, 99, 179 p.

Almgen, A. A. 1978. Timing of Tertiary submarine canyons and marine cycles of deposition in the southern Sacramento Valley, California, p. 276–291. *In* D. J. Stanley and G. Kelling (eds.), Sedimentation in Submarine Canyons, Fans and Trenches. Dowden, Hutchinson and Ross, Stroudsberg, Pennsylvania.

——, M. V. Filewicz, and H. L. Heitman. 1988. Lower Tertiary foraminiferal and calcareous nannofossil zonation of California: an overview and recommendations, pp. 83–105. *In* M. V. Filewicz and R. L. Squires (eds.), Paleogene Stratigraphy, West Coast of North America. Pacific Section, Society of Economic Paleontologists and Mineralogists, West Coast Paleogene Symposium, Volume 58. Los Angeles, California.

Bailey, T. L. 1930. The geology of the Potrero Hills and Vacaville region, Solano County, California. University of California Publications Bulletin of the Department of Geological Sciences, 19:321–333.

Berggren, W. A., D. V. Kent, C. C. Swisher, and M.-P. Aubry. 1995. A revised Cenozoic geochronology and chronostratigraphy, p. 129–212. *In* W. A. Berggren, D. V. Kent, M.-P. Aubry, and J. Hardenbol (eds.), Geochronology, Time Scales, and Global Stratigraphic Correlation. SEPM (Society for Sedimentary Geology) Special Publication, 54.

Briart, A., and F.-L. Cornet. 1871. Description des fossiles du Calcaire Grossier de Mons. Part 1. Gastéropodes. Ordre 1. Prosobranches. Section A. Siphonostomes. Mémoires Couronnés et Mémoires des Savants Étrangers l'Académie Royale des Sciences des Lettres et des Beaux-Arts de Belgique, 36, 76 p.

Cernohorsky, W. O. 1984. Systematics of the family Nassariidae (Mollusca: Gastropoda). Bulletin of the Auckland Institute and Museum, 14, 343 p.

Clark, B. L. 1929. Stratigraphy and Faunal Horizons of the Coast Ranges of California with Illustrations of Index fossils of Tertiary Horizons. Privated published, 30 p.

——, and A. O. Woodford. 1927. The geology and paleontology of the type section of the Meganos Formation (lower middle Eocene) of California. University of California Publications Bulletin of the Department of Geological Sciences, 17:63–142.

Clark, S. G. 1940. Geology of the Covelo district Mendocino County, California. University of California Publications Bulletin of the Department of Geological Sciences, 25:119–142.

CONRAD, T. A. 1832. Fossil shells of the Tertiary Formations of North America, Illustrated by Figures Drawn on Stone by T. A. Conrad. 1(2):21–28. [Reprinted by G. D. Harris (1893) and by the Paleontological Research Institution, Ithaca, New York (1963)].

COSSMANN, A. E. M. 1901. Essais de Paléoconchologie Comparée. Volume 4. Published by the author: Paris. 293 p.

——, AND G. PISSARRO. 1904–1913. Iconographie complète des coquilles de l'Éocène des environs de Paris. 2 Volumes Socíété Geologique de la France, Paris.

DESHAYES, G.–P. 1835. *In* J. B. Lamarck, Histoire Naturelle des Animaux sans Vertèbres. 2nd ed., Paris, Volume 1.

DICKERSON, R. E. 1914a. Fauna of the Martinez Eocene of California. University of California Publications Bulletin of the Department of Geology, 8:61–180.

——. 1914b. The Martinez Eocene and associated formations at Rock Creek on the western border of the Mohave Desert area. University of California Publications Bulletin of the Department of Geology, 8: 289–298.

EDMONDSON, W. F. 1984. The Meganos gorge and the geologic effects produced by compaction of the gorge fill, p. 37–51. *In* A. A. Almgren and P. D. Hacker (eds.), Paleogene Submarine Canyons of the Sacramento Valley, California. Pacific Section, American Association of Petroleum Geologists, Symposium Volume 1.

EVANS, J. R., AND R. V. MILLER. 1978. Geology of the southwestern part of the Oat Mountain Quadrangle, Los Angeles County. California Division of Mines and Geology, Map Sheet 33.

FANTOZZI, J. H. 1955. The stratigraphy and biostratigraphy of a portion of the Simi Hills on the south side of the Simi Valley, Ventura County, California. Unpublished M. A. thesis, University of California at Los Angeles, Los Angeles, 68 p.

GABB, W. M. 1864. Description of the Cretaceous fossils, California Geological Survey, Palaeontology, 1:57–243.

——. 1869. Cretaceous and Tertiary fossils. California Geological Survey, Palaeontology, 2:1–299.

GIVENS, C. R. 1974. Eocene molluscan biostratigraphy of the Pine Mountain area, Ventura County, California. University of California Publications in Geological Sciences, 109:1–107.

GROVE, K. 1986. Field trip boat log: depositional environments of Upper Cretaceous and lower Tertiary strata around Lake Nacimiento, central California Coast Ranges, p. 43–59. *In* K. Grove and S. Graham (eds.), Geology of Upper Cretaceous and Lower Tertiary Rocks Near Lake Nacimiento, California. Pacific Section, Society of Economic Paleontologists and Mineralogists, Book Number 49.

HANNA, G. D., AND L. G. HERTLEIN. 1941. Characteristic fossils of California, p. 165–182. *In* O. P. Jenkins (ed.), Geologic Formations and Economic Development of the Oil and Gas Fields of California. Part 2. Geology of California and the Occurrence of Oil and Gas. California Division of Mines Bulletin, 118.

HEITMAN, H. L. 1983. Paleoecological analysis and biostratigraphy of the lower Paleogene Santa Susana Formation, northern Simi Valley, Ventura County, California, p. 33–44. *In* R. L. Squires and M. V. Filewicz (eds.), Cenozoic Geology of the Simi Valley Area, Southern California. Pacific Section, Society of Economic Paleontologists and Mineralogists, Fall Field Trip Volume and Guidebook, Book Number 35.

KEEN, A. M., AND H. BENTSON. 1944. Check list of California Tertiary marine Mollusca. Geological Society of America Special Papers, 56: 1–280.

KEW, W. S. W. 1924. Geology and oil resources of a part of Los Angeles and Ventura Counties, California. U.S. Geological Survey Bulletin, 753:1–202.

KIRBY, M. X. 1991. Macropaleontology and biostratigraphy across the Cretaceous/Tertiary boundary, San Francisquito Formation, Warm Springs Mountain, Los Angeles County, southern California. Unpublished M.S. thesis, California State University, Northridge, 134 p.

KOOSER, M. A. 1980. Stratigraphy and sedimentology of the San Francisquito Formation, Transverse Ranges, California. Unpublished Ph.D. dissertation, University of California, Riverside, 201 p.

——. 1982. Stratigraphy and sedimentology of the type San Francisquito Formation, southern California, p. 53–61. *In* J. C. Crowell and M. H. Link (eds.), Geologic History of Ridge Basin, Southern California. Pacific Section, Society of Economic Paleontologists and Mineralogists, Los Angeles.

MARTYN, T. 1784–1786. The Universal Conchologist. 4 Volumes London.

MERRIAM, C. W., AND F. E. TURNER. 1937. The Capay middle Eocene of northern California. University of California Publications Bulletin of the Department of Geological Sciences, 24:91–114.

MERRIAM, J. C. 1897. The geologic relations of the Martinez group. Journal of Geology, 5:767–775.

NELSON, R. N. 1925. A contribution to the paleontology of the Martinez Eocene of California. University of California Publications Bulletin of the Department of Geological Sciences, 15:397–466.

NESBITT, E. A. 1995. Paleoecological analysis of molluscan assemblages from the middle Eocene Cowlitz Formation, southwestern Washington. Journal of Paleontology, 69:1060–1073.

NUTTALL, C. P., AND J. COOPER. 1973. A review of some English Palaeogene Nassariidae, formerly referred to *Cominella*. Bulletin of the British Museum (Natural History) Geology 23:179–219.

PAREDES-MEJIA, L. M. 1989. Late Cretaceous–Early Cenozoic stratigraphy and paleontology (Mollusca: Gastropoda) of the Sepultura Formation, Mesa San Carlos, Baja California Norte, Mexico. Unpublished M.S. thesis, Purdue University, 527 p.

PARKER, J. D. 1983. Lower Paleocene to lower Eocene, nonmarine to deep-marine strata of the Simi Hills, Ventura County, California, p. 3–22. *In* R. L. Squires and M. V. Filewicz (eds.), Cenozoic Geology of the Simi Valley Area, Southern California. Pacific Section, Society of Economic Paleontologists and Mineralogists, Fall Field Trip Volume and Guidebook, Book Number 35.

PONDER, W. F. 1973. The origin and evolution of the Neogastropoda. Malacologia, 12:295–338.

——, AND A. WARÉN. 1988. Classification of the Caenogastropoda and Heterostropha—a list of the family-group names and higher taxa. Malacological Review, 1988, supplement 4:288–326.

RAFINESQUE, C. S. 1815. Analyse de la nature, ou tableau de l'univers et des corps organisées. Palermo, 224 p.

SAUL, L. R. 1983a. *Turritella* zonation across the Cretaceous–Tertiary boundary, California. University of California Publications Geological Sciences, 125:1–165.

——. 1983b. Notes on Paleogene turritellas, venericardias, and molluscan stages of the Simi Valley area, California, p. 71-80. *In* R. L. Squires and M. V. Filewicz (eds.), Cenozoic Geology of the Simi Valley Area, Southern California. Pacific Section, Society of Economic Paleontologists and Mineralogists, Fall Field Trip Volume and Guidebook, Book Number 35.

——. 1986. Mollusks of latest Cretaceous and Paleocene age, Lake Nacimiento, California, p. 25–31. *In* K. Grove and S. Graham (eds.), Geology of Upper Cretaceous and Lower Tertiary Rocks Near Lake Nacimiento, California. Pacific Section, Society of Economic Paleontologists and Mineralogists. Los Angeles.

SCHENCK, H. G., AND A. M. KEEN. 1940. California Fossils for the Field Geologist. Preliminary edition. Stanford University: Stanford, California. 86 p.

SCHOELLHAMER, J. E., J. G. VEDDER, R. F. YERKES, AND D. M. KINNEY. 1981. Geology of the northern Santa Ana Mountains, California. U.S. Geological Survey Professional Paper, 420-D:1–109.

SCHULER, M., AND SEVEN OTHERS. 1992. The Paleogene of the Paris and Belgian Basins. Standard-stages and regional stratotypes. Cahiers de Micropaléontologie, Nouvelle Série, 7:29–92.

SMITH, J. T. 1975. Age, correlation, and possible Tethyan affinities of mollusks from the Lodo Formation of Fresno County, California, p. 464–483. *In* D. W. Weaver, G. R. Hornaday and A. Tipton (eds.), Future Energy Horizons of the Pacific Coast. Paleogene Symposium and Selected Technical Papers. Pacific Sections, American Assocation of Petroleum Geologists, Society of Economic Paleontologists and Mineralogists, and Society of Exporation Geologists. Annual Meeting.

SQUIRES, R. L. 1988. Geologic age refinement of west coast Eocene marine mollusks, p. 107–112. *In* M. V. Filewicz and R. L. Squires (eds.), Paleogene Stratigraphy, West Coast of North America. Pacific Section, Society of Economic Paleontologists and Mineralogists, West Coast Paleogene Symposium, Volume 58.

——. 1989. A new pseudolivine gastropod genus from the lower Tertiary of North America. Journal of Paleontology, 63:38–47.

——, AND L. R. SAUL. 1993. A new species of *Otostoma* (Gastropoda:

Neritidae) from near the Cretaceous/Tertiary boundary at Dip Creek, Lake Nacimiento, California. The Veliger, 36:259–264.

STANTON, T. W. 1896. The faunal relations of the Eocene and Upper Cretaceous on the Pacific coast. U.S. Geological Survey Annual Report, 17:1005–1060.

STEWART, R. B. 1927. Gabb's California fossil type gastropods. Proceedings of the Academy of Natural Sciences of Philadelphia, 57: 287–447.

STOLCZKA, F. 1868. The Gastropoda of the Cretaceous rocks of southern India. Memoirs of the Geological Survey of India, Palaeontologis Indica, Series 5, 2:1–498.

TRYON, G. W., JR. 1881. Manual of Conchology, Structural and Systematic, with Illustrations of the Species. Series 1., Volume 3. Philadelphia.

——. 1883. Structural and Systematic Conchology: an Introduction to the Study of the Mollusca. Volume 2. Published by the author: Philadelphia. 430 p.

WARING, C. A. 1917. Stratigraphic and faunal relations of the Martinez to the Chico and Tejon of southern California. Proceedings of the California Academy of Sciences, 4th series, 7:41–124.

——, AND R. P. MCLAUGHLIN. 1914. Fossils characteristic of California formations. Pl. 1 in map folio (oversized) accompanying Petroleum Industry of California. California State Mining Bureau Bulletin, 69.

WEAVER, C. E. 1912. A preliminary report on the Tertiary paleontology of western Washington. Washington Geological Survey Bulletin, 15:1–80.

——. 1942. Paleontology of the marine Tertiary formations of Oregon and Washington. University of Washington Publications in Geology, 5(1–3):1–789.

——. 1953. Eocene and Paleocene deposits at Martinez, California. University of Washington Publications in Geology, 7:1–102.

WENZ, W. 1943. Familia Nassariidae, Pp. 1224–1240. *In* O. H. Schindewolf (ed.), Handbuch der Paläozoologie, Band 6, Prosobanchia, Teil 5. Gebruuder Borntraeger: Berlin [reprinted 1960–1961].

ZINSMEISTER, W. J. 1983. Late Paleocene ("Martinez Provincial Stage") molluscan fauna from the Simi Hills, Ventura County, California, p. 61–70. *In* R. L. Squires and M. V. Filewicz (eds.), Cenozoic Geology of the Simi Valley Area, Southern California. Pacific Section, Society of Economic Paleontologists and Mineralogists, Fall Field Trip Volume and Guidebook, Book Number 35.

——, AND L. M. PAREDES-MEJIA. 1988. Paleocene biogeography of the west coast of North America: a look at the molluscan fauna from Sepultura Formation, Mesa San Carlos, Baja California Norte, p. 9–22. *In* M. V. Filewicz and R. L. Squires (eds.), Paleogene Stratigraphy, West Coast of North America. Pacific Section, Society of Economic Paleontologists and Mineralogists, West Coast Paleogene Symposium, Book Number 58.

ACCEPTED 20 DECEMBER 1996

LOCALITIES CITED

All quadrangles are U.S. Geological Survey quadrangles, and unless otherwise noted, are 7.5-minute.

CASG

2296. From cut along "Santa Fe" Railway where it cuts the north part of Vine Hill, 5.6 km (3.5 mi.) S76°E of the mouth of Arroyo del Hombre, Vine Hill Quadrangle, 1959 (photorevised 1980), Contra Costa County, northern California. Collected by H. G. Schenck, October 19, 1929. Middle Vine Hill Sandstone; Selandian (*Turritella infragranulata pachecoensis* Zone).

2692. In siltstone on west side of Temescal Canyon, 4,862 m (15,950 ft.) south and 3,962 m (13,000 ft.) west of northeast corner of Topanga Quadrangle, 1952 (photorevised 1967), east-central Santa Monica Mountains, Los Angeles County, southern California. Collected by R. R. Compton, Dec., 1941. Santa Susana Formation; Thanetian.

2693. In siltstone overyling coralline-algal limestone in Quarry Canyon, 4,145 m (13,600 ft.) south and 5,456 m (17,900 ft.) west of northeast corner of Topanga Quadrangle, 1952 (photorevised 1967), east-central Santa Monica Mountains, Los Angeles County, southern California. Collected by R. R. Compton, Dec., 1941. Santa Susana Formation; Thanetian.

CSUN

123c. At elevation of 381 m (1,250 ft.) on west side of Meier Canyon, 358 m (1175 ft.) south and 3,103 m (10,180 ft.) east of the northwest corner of Calabasas Quadrangle, 1952 (photorevised 1967), south side of Simi Valley, Ventura County, southern California. Collected by R. L. Squires, May 25, 1996. Float derived from lower Santa Susana Formation, "Martinez marine member," Selandian (*Turritella peninsularis* Zone).

354. On the east bank of the south fork of Garapito Creek, 518 m (1,700 ft.) S20°E from the intersection of the San Bernardino base line and Los Angeles City boundary, Topanga Quadrangle, 1952 (photorevised 1967), east of Sylvia Park, Santa Monica Mountains, Los Angeles County, southern California. Collected by R. L. Squires, 1978. Upper Santa Susana Formation; Thanetian.

958. On edge of valley floor [now filled], 381 m (1250 ft.) S and 107 m (350 ft.) east of section 5, T2N, R17, Santa Susana Quadrangle, 1951 (photorevised 1969), north side of Simi Valley, Ventura County, southern California. Collected by R. L. Squires, 1989. Uppermost part of Santa Susana Formation; "Meganos."

LACMIP

7044. Road cut on east bank of Silver Creek 0.4 km (0.25 mi.) south of its junction with Panoche Creek, SE ¼ of section 20, T15S, R12E, Tumey Hills Quadrangle, 1956 (photorevised 1971), west side of San Joaquin Valley, Fresno County, north-central California. Collected by C. E. Weaver, 1949. Basal Lodo Formation; Thanetian. [Same as Stanford University (LSJU) loc. 2073 (collections now housed at CASG) and same as UCMP locs. A-1284, A-8394, A-4657, A-9717].

7047. A thin but richly fossiliferous layer of limonite-stained white sandstone, 0.9 km (0.75 mi.) east of Lower Lake, 366 m (1,200 ft.) south from bridge over Copsey Creek, in gully on W side of creek, SE ¼ of NE ¼ of section 11, T12N, R7W, Lower Lake Quadrangle, 1975, Lake County, northern California. Collected by D. W. Scharf and W. P. Popenoe, August 26, 1930. Martinez Formation; latest Danian or earliest Selandian.

7051. Same as LACMIP loc. 7047. Collected by W. P. Popenoe, May, 12, 1944.

7062. On top of ridge on west side of Temescal Canyon at edge of fire road, 2,743 m (9,000 ft.) N30°W of Pacific Palisades/Assembly Park, Topanga Canyon Quadrangle, 1952 (photorevised 1967), east-central Santa Monica Mountains, Los Angeles County, southern California. Collected by H. D. B. Wilson, June, 1941. Upper Santa Susana Formation; Thanetian.

7079. Concretionary sandstone outcop on hilltop N50°E and 4.4 km (2.75 mi.) from Bench Mark 610, Black Star Canyon Quadrangle, 1949, north of Irvine Lake, Santa Ana Mountains, Orange County, southern California. Collected by B. N. Moore, September, 1929. Silverado Formation; Selandian (*Turritella infragranulta pachecoensis* Zone).

7142. Fossiliferous boulder in conglomerate bed along ridge, 785 m (2575 ft.) south and 305 m (1,000 ft.) west of northeast corner of section 5, T2N, R17W, Santa Susana Quadrangle, 1951 (photorevised 1969), north side of Simi Valley, Ventura County, southern California. Collected by A. Clark and L. Hookway, June 17, 1929. Reworked [Selandian (undifferentiated)] fossils in Santa Susana Formation.

7173. From crest of first ridge north of Deer Valley at a point about 0.3 km (0.2 mi.) west of the main Deer Valley-Horse Valley road, NW ¼ of section 20, T1N, R2E, Antioch South Quadrangle, 1980, Contra Costa County, northern California. Collected by D. W. Scharf and W. P. Popenoe, August, 1930. Meganos Formation; "Meganos."

11980. Spheroidally weathering siltstone and fine sandstone in canyon botton (now filled) about 250 m (820 ft.) N88°W of hill 1672, near head of Pulga Canyon, northwest side of Pulga Canyon about at northeast tip of second "E" in "FIREBREAK," Topanga Quadrangle, 1952 (photorevised 1067), east-central Santa Monica Mountains, Los Angeles County, southern California. Collected by J. Alderson, October, 1988. Upper Santa Susana Formation; Thanetian.

20343. On a ridge just W of Stone Canyon Reservoir, Beverly Hills Quadrangle, 1966 (photorevised 1981, minor revision 1994), eastern Santa Monica Mountains, Los Angeles County, southern California. Collected by Bryson and Curry, 1933. Santa Susana Formation; Selandian (*Turritella infragranulata pachecoensis* Zone).

20894. In tributary canyon of Big Rock Creek, approximately 244 m

(800 ft.) SW of center of SW ¼ of section 16, T4N, R9W, Valyermo Quadrangle, 1958, north side of San Gabriel Mountains, Los Angeles County, southern California. San Francisquito Formation; Selandian (*Turritella peninsularis* Zone).

21579A. South of East Fork Fish Canyon, Warm Springs Mountain Quadrangle, 1958 (photorevised 1974), Los Angeles County, southern California. Collected by R. W. Webb and E. H. Quayle, 1941. San Francisquito Formation; late Danian.

21581. Black nodular shale and conglomerate on road 1.78 km (1.1 mi) E from Cienaga Camp on northwest side of ravine, north side of East Fork Fish Canyon, approximately 625 m (2050 ft.) north and 229 m (750 ft.) east of BM 2205, T6N, R16W, Warm Springs Mountain Quadrangle, 7.5-minute, 1958 (photorevised 1974), Los Angeles County, southern California. Collected by R. W. Webb and E. H. Quayle, June 23–24, 1941. San Francisquito Formation; late Danian.

22330. Beds cropping out on nose of spur on west side of Meier Canyon, approximately 183 m (600 ft.) north of second "n" in Meier Canyon, Calabasas Quadrangle, 1952 (photorevised 1967), south side of Simi Valley, Simi Hills, Ventura County, southern California. Collected by W. P. Popenoe, April 3, 1946. Lower Santa Susana Formation, "Martinez marine member," Selandian (*Turritella peninsularis* Zone).

22374. On west side of low ridge 290 m (950 ft.) S and 2,423 m (7950 ft.) east of northwest corner of Calabasas Quadrangle, 1952 (photorevised 1967), south side of Simi Valley, Simi Hills, Ventura County, southern California. Collected by W. P. Popenoe, April 3, 1946. Middle Santa Susana Formation, in strata stratigraphically above "Martinez marine member," Selandian (*Turritella peninsularis* Zone).

22387. On low ridge 579 m (1,900 ft.) south and 1463 m (4,800 ft.) east of northwest corner of sec. 28, T1N, R2E, Antioch South Quadrangle, 1980, Contra Costa County, northern California. Collected by W. P. Popenoe, April 13, 1947. Meganos Formation; "Meganos."

22701. On long ridge immediately west of summit of Simi Hills (=hill 2160), Calabasas Quadrangle, 1952 (photorevised 1967), Ventura County, southern California. Collected by J. H. Fantozzi, June, 1951. Lower Santa Susana Formation, "Martinez marine member," Selandian (*Turritella peninsularis* Zone).

22702. In saddle at elevation of 602 m (1,975 ft.), 229 m (750 ft.) S13°E of summit of Simi Hills (=hill 2160), Calabasas Quadrangle, 1952 (photorevised 1967), Ventura County, southern California. Collected by J. H Fantozzi, June, 1951. Lower Santa Susana Formation "Martinez marine member," Selandian (*Turritella peninsularis* Zone).

23110. Silty sandstone at elevation 625 m (2,050 ft.), 3406 m (11,175 ft.) south and 914 m (3,000 ft.) east of northwest corner of Calabasas Quadrangle, 1952 (photorevised 1967), Ventura County, southern California. Collected by J. H Fantozzi, July, 1953. Lower Santa Susana Formation "Martinez marine member," Selandian (*Turritella peninsularis* Zone).

25281. Sandstone at elevation of 305 m (1,000 ft.), about 122 m (400 ft.) south and 305 m (1,000 ft.) west of northeast corner of section 5, T1S, R17W, Malibu Beach Quadrangle, 1950 (photorevised 1967), on west side of northern tributary to Stokes Canyon, western Santa Monica Mountains, Ventura County, southern California. Collected by J. Stark and T. Susuki, May 21, 1965. Reworked [Selandian (undifferentiated)] fossils in middle Miocene Calabasas Formation, Stokes Canyon Breccia Member.

26364. At elevation of 186 m (610 ft.), about 5.6 km (4 mi.) south of Santa Catarina Landing near top of pass through mesas; top of basalt mesa is about 46 m (150 ft.) above locality, northern Baja California, Mexico. Collected by G. Weir and H. Stager, January, 1949. Sepultura Formation; Selandian (*Turritella peninsularis* Zone).

26456. Slope on abrupt hill on S side of road, south side of Panoche Creek, about 1.2 km (0.75 mi) E of Silver Creek, 1052 m (3,450 ft.) south and 152 m (500 ft.) east of northwest corner of section 21, T15S, R12E, Tumey Hills Quadrangle, 1956 (photorevised 1971), west side of San Joaquin Valley, Fresno County, north-central California. Collected by L. R. Saul, June 10, 1977. Lodo Formation; Selandian (*Turritella infragranulata pachecoensis* Zone).

26525. About 232 m (760 ft.) elevation, poorly sorted conglomeratic sandstone exposed on east side of Dip Creek, south side of Lake Nacimiento, 427 m (1,400 ft.) S and 61 m (200 ft) west of northeast corner of section 30, T25S, R10E, U.S. Geological Survey Lime Mountain Quadrangle, 7.5-minute, 1948, San Luis Obispo County, central California. Collectors: R. B. Saul and L. R. Saul, December 31, 1977. Unnamed strata. Age: Maastrichtian (*Turritella peninsularis adelaidana* Zone) or possibly earliest Danian (*Turritella peninsularis qualeyi* Zone).

26526. About 226 m (740 ft.) elevation, poorly sorted conglomeratic sandstone exposed on east side of Dip Creek, south side of Lake Nacimiento, 457 m (1,500 ft.) south and 122 m (400 ft.) west of northeast corner of section 30, T25S, R10E, U.S. Geological Survey Lime Mountains Quadrangle, 1948, San Luis Obispo County, central California. Collectors: R. B. Saul and L. R. Saul, December 31, 1977. Unnamed strata. Age: Maastrichtian (*Turritella peninsularis adelaidana* Zone) or possibly earliest Danian (*Turritella peninsularis qualeyi* Zone).

26583. Near the 320 m (1,050 ft.) contour on east side of the southwest arm of the Encino Reservoir, approximately 549 m (1,800 ft.) S60°E of the intake tower, Canoga Park Quadrangle, 1952 (photorevised 1967), Santa Monica Mountains, Los Angeles County, southern California. Collected by T. Susuki, March 6, 1961. Santa Susana Formation; Selandian (*Turritella infragranulata pachecoensis* Zone).

26897. Float in gully on west side of Temescal Canyon opposite second "e" of Temescal at about 450 m (1,475 ft.) elevation, approximately 1082 m (3,550 ft.) S and 533 m (1,750 ft.) east of hill 2036, Topanga Quadrangle, 1952 (photorevised 1967), east-central Santa Monica Mountains, Los Angeles County, southern California. Collected by J. Alderson, March 9, 1980. Santa Susana Formation; Thanetian.

UCMP

3157. On ridge top on north side of Deer Valley, 792 m (2,600 ft.) S and 411 m (1,350 ft.) west of NE corner of section 20, T1N, R2E, Antioch South Quadrangle, 1980, Contra Costa County, northern California. Collected by B. L. Clark and A. O. Woodford, circa 1923. Margaret Hamilton Sand [=division D of Meganos Formation as used by Clark and Woodford (1927)]; "Meganos."

3159. On same ridge top as UCMP loc. 3157, 1036 m (3,400 ft.) south and 46 m (150 ft.) west of northeast corner of section 20, T1N, R2E, Antioch South Quadrangle, 1980, Contra Costa County, northern California. Collected by B. L. Clark and A. O. Woodford, circa 1923. Margaret Hamilton Sand [=division D of Meganos Formation as used by Clark and Woodford (1927)]; "Meganos."

3577. On ridge top 3399 m (11,150 ft.) north and 610 m (2,000 ft.) east of southwest corner of Brentwood Quadrangle, 1978, Contra Costa County, northern California. Collected by B. L. Clark and A. O. Woodford, circa 1923. Margaret Hamilton Sand [=division D of Meganos Formation as used by Clark and Woodford (1927)]; Meganos Formation; "Meganos."

3768. Elevation of 402 m (1,320 ft.), just south of minor saddle on ridge, NW ¼ of the NW ¼ of section 24, T2N, R18W, and 2,987 m (9,800 ft.) N14°E of hill 2150 in Simi Hills, east of Meier Canyon, Calabasas Quadrangle, 1952 (photorevised 1967), south side of Simi Valley, Ventura County, southern California. Middle Santa Susana Formation; Selandian (*Turritella infragranulata pachecoensis* Zone).

3776. At bottom of "e" in "Runkle," east side of Runkle Canyon at mouth of small tributary, south side of Simi Valley, Calabasas Quadrangle, 1952 (photorevised 1967), south side of Simi Valley, Ventura County, southern California. Collected by R. N. Nelson, circa early 1920's. Lower Santa Susana Formation, "Martinez marine member," Selandian (*Turritella peninsularis* Zone).

3810. Elevation at 518 m (1,700 ft.), at western end of ridge at point where it narrows down and starts to slope abruptly into canyon, SE ¼ of the SE ¼ of section 28, T2N, R18W, and 792 m (2,600 ft.) S86°E of hill 1926 in Simi Hills, east side of Bus Canyon, Thousand Oaks Quadrangle, 1950 (photorevised 1967), south side of Simi Valley, Ventura County, southern California. Lower Santa Susana Formation; Selandian (*Turritella peninsularis* Zone).

A-1523. Same as LACMIP loc. 7047. Collected by B. L. Clark, 1935.

UWBM

1394. From cut along Santa Fe Railway, 762 m (2,500 ft.) N63°E from overpass at intersection of Pacheco Road and Santa Fe Railway, Vine Hill Quadrangle, 1959 (photorevised 1980), west side of Pacheco Creek, Contra Costa County, northern California. Collected by C. E. Weaver, circa 1950. Lower Vine Hill Sandstone; Selandian (*Turritella peninsularis* Zone).