



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

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
<i>Brachysphingus gibbosus</i>				
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
<i>Brachysphingus sinuatus</i>				
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
<i>Brachysphingus mammilatus</i>				
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 incrustated, 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 incrustated. 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 qualeyi* through *T. infragranulata* Zones. Near the Danian-Selandian boundary (near the *Turritella peninsularis qualeyi* 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 (Schoell-

hamer 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 gerontic 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