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Additions and Refinements to Aptian to Santonian (Cretaceous) *Turritella* (Mollusca: Gastropoda) from the Pacific Slope of North America

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Abstract. This paper presents the first detailed paleontologic study of pre-Campanian (pre-late Late Cretaceous) *Turritella* sensu lato from the Pacific slope of North America, mainly from outcrops in California. Seven species, two of which are new, have a cumulative chronologic range of late Aptian to Santonian, an interval of 30 million years that coincides with much of Chron C34, the long-normal interval. One of the new species, *Turritella* ***xylina***, is only the second known Cenomanian *Turritella* from the study area, and the other new species, *Turritella* ***encina***, is the first Santonian *Turritella* reported from the study area. The previously named species are redescribed and are refined in their stratigraphic distributions. They are: *Turritella seriatimgranulata* Roemer, 1849, of late Aptian age; *Turritella infralineata* Gabb, 1864, of late early Albian age; *Turritella petersoni* Merriam, 1941, Cenomanian to early Turonian age; *Turritella hearni* Merriam, 1941, of Turonian and probably Coniacian age; and *Turritella iota* Popenoe, 1937, of late Turonian age. *Turritella seriatimgranulata* is also known from Albian strata in Sonora, Mexico, New Mexico, and Texas.

INTRODUCTION

The shallow-marine gastropod *Turritella* Lamarck, 1799, is common in the uppermost Cretaceous (Campanian and Maastrichtian) through Pleistocene rock record of the Pacific slope of North America. Stemming from the work by Marwick (1957b), many workers have subdivided *Turritella* into other genera and subgenera, and these subdivisions relied on morphologic characters such as the outer lip trace, ontogeny of the primary spirals, and protoconch. Kaim (2004), however, reported that until a thorough review of this genus is done, shell characters cannot be of use for taxonomic purposes above the species level. Lacking this review of turritellas, we refer these species described in this present paper to *Turritella sensu lato*.

Turritellas have been well studied and used with much success for biostratigraphic zonation of the Campanian through Pleistocene rock record of the study area (e.g., Grant & Gale, 1931; Loel & Corey, 1932; Merriam, 1941; Weaver, 1943; Givens, 1974; Saul, 1983a, b; Squires, 1987), but the pre-Campanian record of *Turritella* has received far less study. Reports of pre-Campanian *Turritella* from this region are based mainly on the works of Gabb (1864), Merriam (1941), and Allison (1955). In the last 50 years, however, knowledge of the Pacific slope of North America Cretaceous stratigraphy has increased significantly, and much more collecting has been done. This present study, which expands on the foundation provided by early workers, is based on collections borrowed from all the major museums having extensive collections of Cretaceous fossils from the Pacific slope of North America. We detected 56 lots: 29 at California Academy of Sciences (CAS), 23 at Los Angeles County Natural History Museum, Invertebrate Paleontology (LACMIP), and 4 at University of California Museum of Paleontology, Berkeley (UCMP). These lots were collected mostly from California, and a few were collected from northern Baja California (Figure 1). We found specimens that yielded new morphologic information, and we more fully establish the geologic ranges and geographic/stratigraphic distributions of the five previously named species. In addition, we detected two new species. This study establishes the late Aptian to Santonian record of *Turritella* from California and the northern part of Baja California, Mexico. This interval of geologic time coincides with Chron C34, the long-normal interval (Figure 2). Hereafter, these *Turritella* will be referred to as the ''long normal'' turritellas. The significance of this study is that *Turritella* can be used for biostratigraphic purposes in working with pre-Campanian rocks.

The shallow-marine, warm-water aspect of the studied species of *Turritella* is generally analogous to the ecology of Recent *Turritella.* A sampling of the literature shows that most species of Recent *Turritella* prefer shallow-ma-

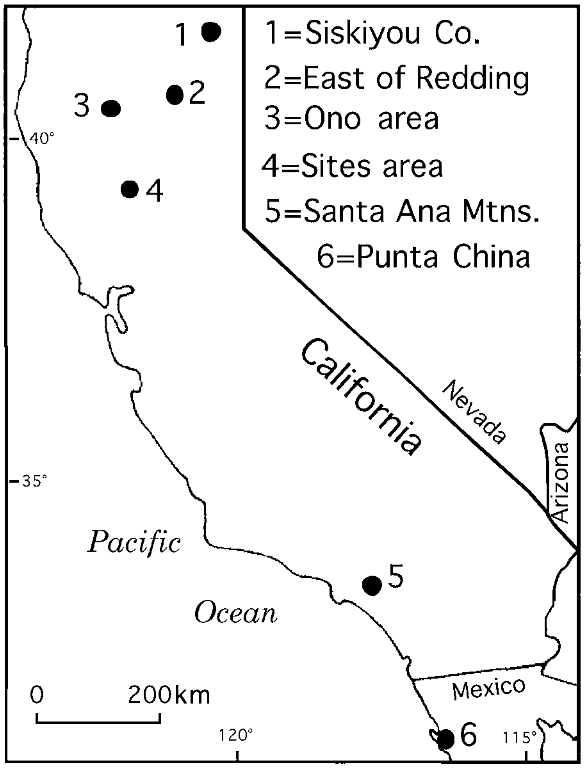


Figure 1. Index map showing locales mentioned in the text.

rine depths between low intertidal and approximately 100 m, even though they have been found in waters as deep as 1500 m (Thorson, 1957; Yonge & Thompson, 1976; Squires, 1984; Saul, 1983a; Allmon, 1988). Recent *Turritella* prefer relatively warm temperatures between 15 and 20°C, although they can live in temperatures between 2 and 24°C (Allmon, 1988). They are, however, specifically more diverse and individually of larger size in the tropics than those found in temperate seas (Merriam, 1941). Most modern-day species are largely sedentary and infaunal/semi-infaunal in relatively soft substrate, but many are also mobile and epifaunal on coarser or harder substrates (Yonge & Thompson, 1976). Some species usually remain immobile for long periods of time, shallowly buried in soft, level-bottom substrates, then voluntarily crawl to more sandy bottoms or bottoms covered with gravel in order to spawn (Bandel, 1976; Yonge & Thompson, 1976; Allmon et al., 1992). Most modern-day species of *Turritella* appear to be ciliary suspension feeders, but some or all might be deposit feeders or grazers at least part of the time (Allmon, 1988; Allmon et al., 1992). They can also be extremely gregarious, with up to approximately 500 individuals per square meter (Merriam, 1941; Petuch, 1976). Information on the mode of development is known (see Marwick, 1957b, Richter & Thorson, 1975, and Bandel et al., 1997) for only a few living species of *Turritella.* Pelagic larval phases are relatively short for these species and range from two days to three weeks (Allmon, 1988).

Figure 3 shows the notational system used here to designate the spiral sculpture. This system, which is based on the work of Marwick (1957a), is explained in the caption for Figure 3.

Abbreviations, other than those cited above, that are used for catalog and locality numbers are: CIT, California Institute of Technology, Pasadena; UCLA, University of California, Los Angeles (collections now housed at LACMIP); USNM, United States National Museum, Washington, D.C.

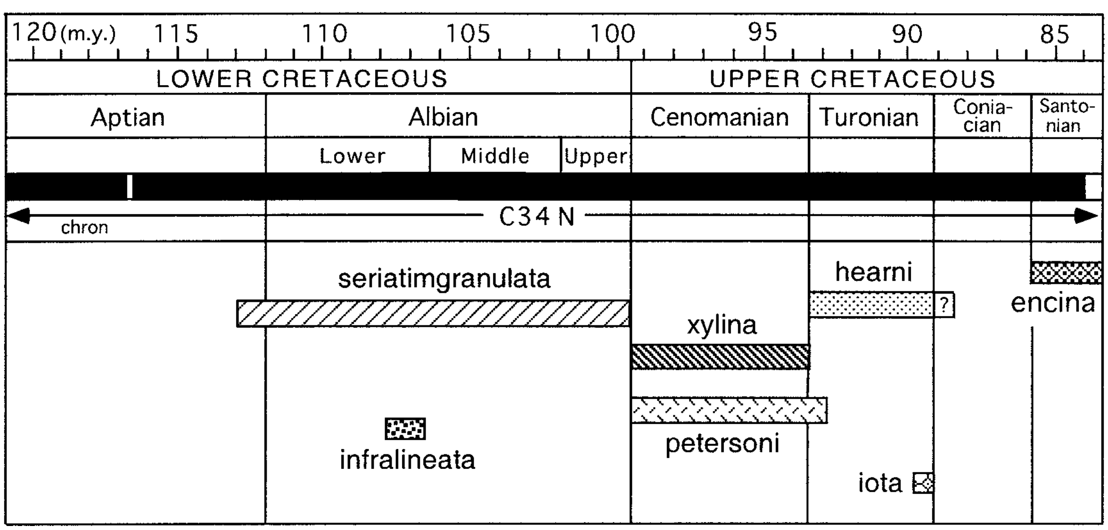


Figure 2. Chronostratigraphic positions of the new and restudied Cretaceous turritellas. Ages of stage boundaries and magnetostratigraphy data from Gradstein et al. (2004:fig. 19.1).

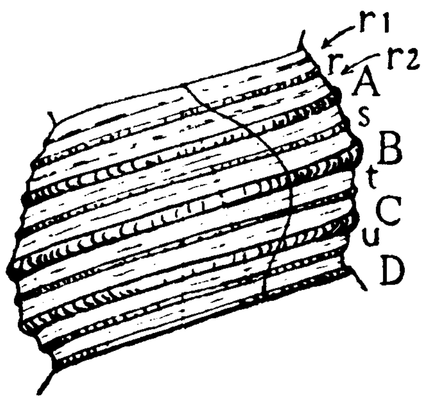


Figure 3. Diagram showing notation of spiral ribs of *Turritella.* Primary ribs are denoted A, B, C, and D; secondary ribs are denoted by r, s, t, and u; and tertiary threads are denoted by r_1, r_2, etc. Change in relative rib strength shown by exchanging upper for lower case letters (i.e., capital letters for strong ribs and lower case for weaker ribs). (Diagram modified from Marwick, 1957a:fig. 1).

STRATIGRAPHY

The geologic ages and depositional environments of most of the Pacific slope of North America formations and members cited in this paper have been summarized in papers by Saul (1982) and Squires & Saul (2003a, b, 2004a, b). These ages range from late Aptian through Santonian, and the depositional environments are usually shallow marine, with post-mortem displacement of some of the shallow-marine faunas into deeper waters via turbidity currents. Stratigraphic information mentioned below concerns those rock units not discussed in recent literature.

Cretaceous Rocks Near Yreka

The holotype of *Turritella hearni* Merriam, 1941, was reported by Merriam (1941:64) as having been collected ''. . . from the Turonian at the type locality near Montague and Yreka . . .,'' both of which are in Siskiyou County, northern California. Montague is approximately 8 km slightly southeast of Yreka. Although Merriam never specifically mentioned whether the type locality is at Montague or Yreka, Anderson (1958:153) reported the locality to be in middle Turonian beds on the Hagerdorn Ranch, 6.4 km north of Montague. Museum labels in the box that contains the holotype have two locations cited: one at 6.4 km north of Montagu and one 13 km northeast of Yreka. The label that has the official CAS locality number (61938) is the former location. Matsumoto (1960: 97) indicated the beds 6.4 km north of Montague to be Coniacian in age, based on a few ammonites. Utilizing the outcrop map of Sliter et al. (1984:figs. 1, 2), beds in the area just north of Montague (i.e., the Black Mountain area) plot in the lower Coniacian part of the Hornbrook Formation and are probably part of the Ditch Creek Siltstone Member. Sliter et al. (1984) based their geologic age on the ammonite *Prionocycloceras* sp. These same workers, however, reported that just southwest of the Black Mountain area, there are extensive covered intervals and small discontinuous outcrops of sandstone and siltstone which cannot be correlated to the exact member of the Hornbrook Formation. The age of the beds at the type locality of *T. hearni*, therefore, cannot be positively determined, but the age is probably early Coniacian.

Turritella hearni is also present in the extension of the Hornbrook Formation in Turonian strata (LACMIP loc. 25272) near Phoenix, Jackson County, southwestern Oregon. For a discussion of the age of the strata in this area, see Squires & Saul (2004b).

Lower Part of Tuna Canyon Formation

Turritella iota Popenoe, 1937, is reported here for the first time from the lower part of the Tuna Canyon Formation west of Rustic Canyon in the east-central Santa Monica Mountains, Los Angeles County, southern California. The specimens are from coarse-grained sandstone at LACMIP loc. 26967 in the basal part of the formation. Overlying the basal part is a black-shale unit containing scaphitoid-ammonites (Popenoe, 1973; Almgren, 1973; Colburn, 1973). Alderson (1988), based on ammonites, reported that the black-shale unit is late Turonian to Coniacian age and that the underlying coarse-grained sandstone beds (i.e., those containing *T. iota*) are late Turonian in age and are coeval to the upper Baker Canyon and the lower Holz Shale members of the Ladd Formation in the Santa Ana Mountains, Orange County, southern California. Prior to this present paper, *Turritella iota* had only been found in the lower Holz Shale Member of the Ladd Formation; thus, the presence of *T. iota* in the Santa Monica Mountains strengthens the age equivalency of these parts of these two formations.

BIOGEOGRAPHIC IMPLICATIONS

The earliest known records of *Turritella* are from the Early Cretaceous (early Valanginian) of Poland (Schröder, 1995; Kaim, 2004) and the Valanginian of France (d'Orbigny, 1842). The earliest known record of *Turritella* on the Pacific slope of North America is *Turritella seriatimgranulata* Roemer, 1849. It occurs in the Tethyan gastropod- and bivalve-rich fauna (Allison, 1955, 1974) of the upper Aptian Alisitos Formation, northern Baja California, Mexico, and this species is described and illustrated in this present report. The arrival of *Turritella* onto the Pacific slope of North America during the late Aptian coincided with both a global trend of rising sea level (Haq et al., 1987) and with warm and equable surface waters (Frakes, 1999).

During the Albian through Turonian, warm-water conditions existed on the Pacific slope of North America

(Saul, 1986). Shallow-water Albian strata are not plentiful in the study area, and most of the shallow-water Albian mollusks contained in these strata are from redeposited blocks. During the Albian, *T. seriatimgranulata* migrated into New Mexico, Texas, and Sonora, Mexico. Although surface currents were predominantly westward-flowing during the Aptian and Albian in the southern part of North America, there were substantial eastward-flowing surface currents (see Johnson, 1999:figs. 2, 3) that could have transported the larvae of *T. seriatimgranulata* eastward from the westward part of Mexico.

The Turonian coincided with widespread warm seas that were at their highest sea-level stand of the Cretaceous (Haq et al., 1987; Frakes, 1999), and the Turonian coincided with the peak in diversity for *Turritella* species in the study area, with collectively three species present (Figure 2). Two of these species, *T. petersoni* and *T. hearni*, had the widest geographic distribution of all the studied species.

Relative to the Turonian, the Coniacian to early Campanian had a slightly cooler climate (Frakes, 1999), and only a moderately high sea-level stand (Haq et al., 1987). The boundaries of the Tethyan Realm were generally broadest during the Aptian to Turonian and the narrowest during the Coniacian to Maastrichtian (Sohl, 1987). These more restrictive conditions might help explain why there is only a single known species, *Turritella* ***encina*** sp. nov., of limited geographic distribution, known from the study area during the interval represented by the Coniacian and Santonian. The paucity of exposures of shallow-water Coniacian strata in California accounts for the scarcity of Coniacian turritellas.

Superorder CAENOGASTROPODA Cox, 1959
Order NEOTAENIOGLOSSA Haller, 1882
Family TURRITELLIDAE Lovén, 1847
Genus *Turritella* sensu lato Lamarck, 1799

Type species: *Turbo terebra* Linneaus, 1758, by monotypy; Recent, western Pacific.

Diagnosis: Shell small to large, turreted-conical, many whorled, elongate, slender, sculptured with spiral ribs and/or threads, growth lines curved, aperture round and entire, outer lip thin, sinuous and prosocline at suture, columella smooth and concave, operculum horny and multispiral (after Davies, 1971:309).

Discussion: The growth lines, noded ribs, and early whorl sculpture of six of the seven turritellas treated in this paper (i.e., *T. seriatimgranulata, T. infralineata, T. petersoni, T. hearni, T. iota,* and *T.* ***encina***) are similar. On the basis of shell characteristics, none of these ''long normal'' turritellas resembles the most common Campanian-Maastrichtian turritella stock of *Turritella chicoensis* Gabb, 1864. Very early whorls of *T. chicoensis* stock appear bicostate (ribs B and C) although the peribasal spiral D is present, and the whorls become quadricostate (A, B, C, D) by the eight whorl. Early whorls of seventh turritella treated in this paper (i.e., *T.* ***xylina***) are unavailable, but adult whorls resemble those of *Turritella chaneyi* Merriam, 1941, stock.

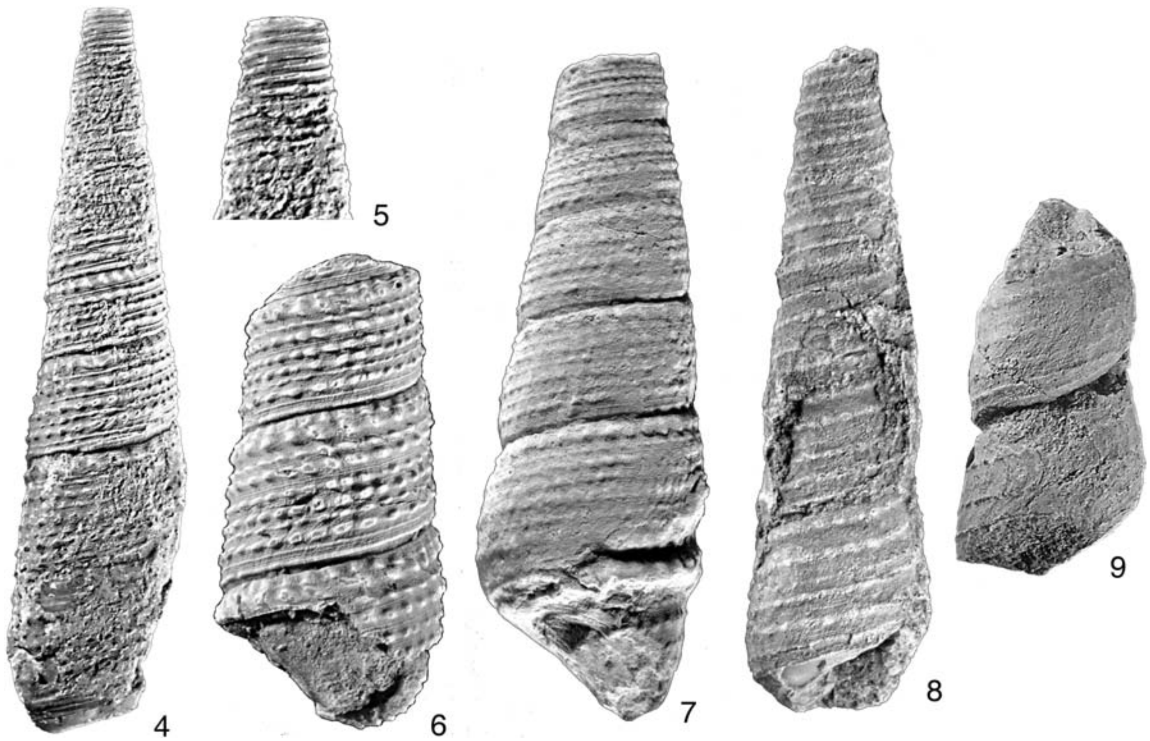
Turritella seriatimgranulata Roemer, 1849
(Figures 4–7)

Turritella seriatim-granulata Roemer, 1849:413; 1852:39, pl. 4, figs. 12a, 12b; Gabb, 1869:263; Stanton, 1947: 75–76, pl. 56, figs. 7, 11, 17–24; Almazan-Vazquez, 1990:159, pl. 1, fig. 8; Akers & Akers, 1997:93, fig. 78.
Not *Turritella seriatim-granulata* Roemer. Gabb, 1864:132, pl. 20, fig. 88 (two views: natural size and magnified) = tentatively, *Turritella packardi* Merriam *fide* Saul (1983a:102–104).
Not *Turritella seriatimgranulata* Roemer. Stewart, 1927: 348–349, pl. 21, fig. 2 = tentatively, *Turritella packardi* Merriam *fide* Saul (1983a:102–104).
Not *Mesalia seriatim-granulata* (Roemer). Shimer & Shrock, 1944:495, pl. 203, figs. 3, 4.
Turritella marnochi White, 1879:314, pl. 7, fig. 5b (not 5a).
Turritella vibrayeana d'Orbigny. Böse, 1910:145, pl. 30, fig. 10; pl. 31, fig. 6.
Turritella macropleura Stainbrook, 1940:712, pl. 33, figs. 17, 20–21.
Mesalia (*Mesalia*) *mauryae* Allison, 1955:414–415, pl. 41, fig. 3.
Turritella (*Haustator*) aff. *T.* (*H.*) *seriatimgranulata* Roemer. Allison, 1955:415, pl. 41, fig. 5.

Diagnosis: Adult whorls generally flat sided, with five nearly equal-strength spiral ribs, closely spaced, noded, and alternating with finer noded ribs; R strongest and carina-like. Interspaces with unnoded threads.

Description: Shell medium-large (up to 90 mm, estimated, in height), slender. Pleural angle narrow (15°). Protoconch and earliest juvenile whorls unknown. Teleoconch whorls approximately 15 to 17, flat-sided; posteriormost part of whorls with slightly rounded profile. Late-juvenile whorls (approximately 1.75 mm diameter) with four (R, A, B, and C) nearly equal and squarish ribs, interspaces deep and smooth and about same width as ribs. Adult whorls (approximately 5 mm diameter and greater) with five (R, A, B, C, and D) spiral ribs, nearly equal in strength (R strongest, projecting and somewhat carina-like), equidistant, noded, and alternating with weaker ribs (also noded); resulting in sculpture pattern R, r_2, A, s, B, t, C, u, and D. Rib r_1 occasionally present, approaching R in strength, with nodes on both ribs nearly merging. Nodes variable in strength, weakest on D. Threads on all interspaces, very thin, variable in number (three to six), and unnoded; threads most numerous on interspace between B and C, and C and D. Suture deep. Aperture round, inner lip can have thin callus pad. Base of last whorl with unnoded spiral ribs.

Holotype: USNM 103148.



Explanation of Figures 4 to 9

Figures 4–9. Specimens coated with ammonium chloride. Figures 4–7. *Turritella seriatimgranulata* Roemer, 1849. Figures 4–5. Hypotype UCMP 156008, UCMP loc. A-9521. Figure 4. Abapertural view, ×3.5. Figure 5. Tip of specimen shown in Figure 4, ×8.7. Figure 6. Hypotype UCMP 156009, UCMP loc. A-9521, right-lateral view, ×4. Figure 7. Hypotype UCMP 156010, from near Arivechi, northern Sonora, Mexico, apertural view, ×2.5. Figures 8–9. *Turritella infralineata* Gabb, 1864, CAS loc. 69104. Figure 8. Neotype CAS 69286, apertural view, ×3.4. Figure 9. Hypotype CAS 69287, abapertural view, ×3.1.

Type locality: Either the Walnut Creek or Comanche Peak formation near Fredericksburg, Gillespie County, south-central Texas (Stanton, 1947:76).

Geologic age: Late Aptian to late Albian.

Distribution: UPPER APTIAN: Alisitos Formation, marine part of upper member, Punta China region, northern Baja California, Mexico. APTIAN-ALBIAN UNDIFFERENTIATED: Morita Formation, Cerro las Conchas, near Ariveachi, Sonora, Mexico. UPPER LOWER ALBIAN: Washita and Fredericksburg Groups, Texas. UPPER ALBIAN: Pawpaw Formation, Texas; Purgatorie Formation, Mesa Tucumcari, New Mexico.

Discussion: This study of *T. seriatimgranulata* is based on approximately 1000 specimens from the Alisitos Formation near Punta China (UCMP loc. A-9521) and two specimens from the Morita Formation near Arivechi. The Alisitos material consists entirely of the tips of specimens, and the preservation is very good.

Poorly preserved small fragments of *Turritella* identified as *T. seriatimgranulata* Roemer in Gabb (1864) and Stewart (1927) from Tuscan Springs, Tehama County, northern California were tentatively regarded by Saul (1983a:102–104) to be *Turritella packardi* Merriam, 1941, which is of early to possibly middle Campanian age.

Shrimer & Shrock (1944) refigured both the natural-size view and the magnified view of Gabb's (1864:pl. 20, fig. 88) specimen and identified it as *Mesalia seriatimgranulata.*

Mesalia (*Mesalia*) *mauryae* Allison, 1955, is known only from one locality in the Alisitos Formation. This locality is where *T. seriatimgranulata* is also found. *Mesalia* (*M.*) *mauryae* is known only from tips of specimens, and their sculpture is identical to that of the tips of some specimens (see Figure 5) of *T. seriatimgranulata.* For this reason, we believe *M.* (*M.*) *mauryae* to be a synonym of *T. seriatimgranulata.*

Gabb (1869:263) reported specimens of *T. seriatimgranulata* from the Morita Formation near Arivechi, Sonora, Mexico. Stanton (1947:76, pl. 56, figs. 17, 18, 23, 24) stated that these Mexican specimens appear to be within the form range of *T. seriatimgranulata,* and he provided illustrations of two specimens of Gabb's original lot.

Comparison of specimens (see Figure 7) of *T. seriatimgranulata* from the Morita Formation near Arivechi with those from Punta China confirmed that this species occurs at these two locales. All the Punta China specimens, however, are just the tips of this species. At Arivechi, specimens are up to 60 mm in height and are missing their tips. We estimate that complete specimens of *T. seriatimgranulata* would be approximately 90 mm in height. Akers & Akers (1997) reported that Texas specimens of this species are up to at least 62 mm in height, and Stanton (1947:75) reported that an average specimen, with the apex restored, would be approximately 70 mm in height.

The age range of the formations in Texas containing *T. seriatimgranulata* is late early Albian to late Albian, according to Akers & Akers (1997); the age of the Purgatorie Formation in New Mexico is late early Albian, according to Cobban & Reeside (1952); and the age of the Morita Formation in northern Mexico is undifferentiated Aptian-Albian, according to Almazan-Vazquez (1990).

Turritella infralineata Gabb, 1864
(Figures 8–9)

Turritella infralineata Gabb, 1864:131–132, pl. 20, fig. 87; Stewart, 1927:291; Merriam, 1941:65, pl. 1, fig. 13 (refigure of Gabb, 1864).
Turritella cf. *T. hearni* Merriam. Rodda, 1959:123–124 (unfig.).

Diagnosis: Adult whorls generally flat-sided, with four to five, nearly equal-strength spiral ribs (C strongest and can be slightly carina-like), widely spaced and weakly noded; interspaces bearing numerous threads.

Description: Shell medium, slender. Pleural angle narrow (11°). Protoconch and juvenile whorls unknown. Teleoconch with flat-sided to weakly concave whorls. Early adult whorls (approximately 5 mm diameter) with four (R, A, B, and C) nearly equal ribs, weakly noded, and separated by wide interspaces bearing numerous unnoded threads; C strongest and somewhat carina-like. Adult whorls with five (R, A, B, C, and D) nearly equal ribs, R and C strongest, with C usually somewhat carina-like. Ribs s and u occasionally somewhat prominent on later whorls. Suture impressed. Aperture round. Base of last whorl unknown. Growth line deeply sinused, sigmoidal with antispiral sinus between A and B ribs.

Neotype: CAS 69286 (designated herein).

Neotype locality: CAS loc. 69104.

Geologic age: Late early Albian, *Brewericeras hulenense* ammonite zone.

Distribution: Budden Canyon Formation, Chickabally Mudstone Member, Texas Springs area, Shasta County, northern California.

Discussion: This study of Gabb's species is based on 49 specimens, all from the Texas Springs area. Preservation is mostly very poor, but at CAS loc. 69104 some of the specimens show moderately good preservation.

According to Stewart (1927:291) and Merriam (1941:65), the holotype of *Turritella infralineata* is lost. A neotype (Figure 8) is chosen here.

Gabb (1864:131–132) reported *Turritella infralineata* from the North Fork of Cottonwood Creek area, Shasta County, northern California and from Orestimba Canyon, Stanislaus County, northern California. His locality description for the Cottonwood Creek locality is stratigraphically imprecise because this fork of the creek cuts through the entire Budden Canyon Formation, which ranges in age from Hauterivian to Turonian (see Murphy et al., 1969:pl. 1). The probable stratigraphic position of Gabb's locality, however, was determined during this present investigation, based on specimens matching the original description of *T. infralineata* from the general vicinity of the North Fork of Cottonwood Creek in the Chickabally Mudstone Member of the Budden Canyon Formation at Texas Springs in the Ono area (Figure 1, locale 3). This member is of late early Albian age and correlative to the ammonite *Brewericeras hulenense* zone (see Squires & Saul, 2004b). Texas Springs is approximately 12 km northeast of the North Fork of Cottonwood Creek area. *Turritella infralineata* occurs at several localities in the Texas Springs area, and a total of 16 specimens were detected. The largest specimen is 35 mm in height, but it is incomplete. Preservation is generally poor, but a few good specimens, including the neotype, are from CAS loc. 69104.

We were not able to confirm Gabb's (1864) report of the occurrence of *T. infralineata* from Orestimba Canyon, Stanislaus County, and we were not able to make definite identifications of many of the fossils from this area. The canyon cuts across rocks ranging from Jurassic? and Early Cretaceous to early Tertiary age, and detailed field studies are needed in this area before any definitive biostratigraphic work can be done.

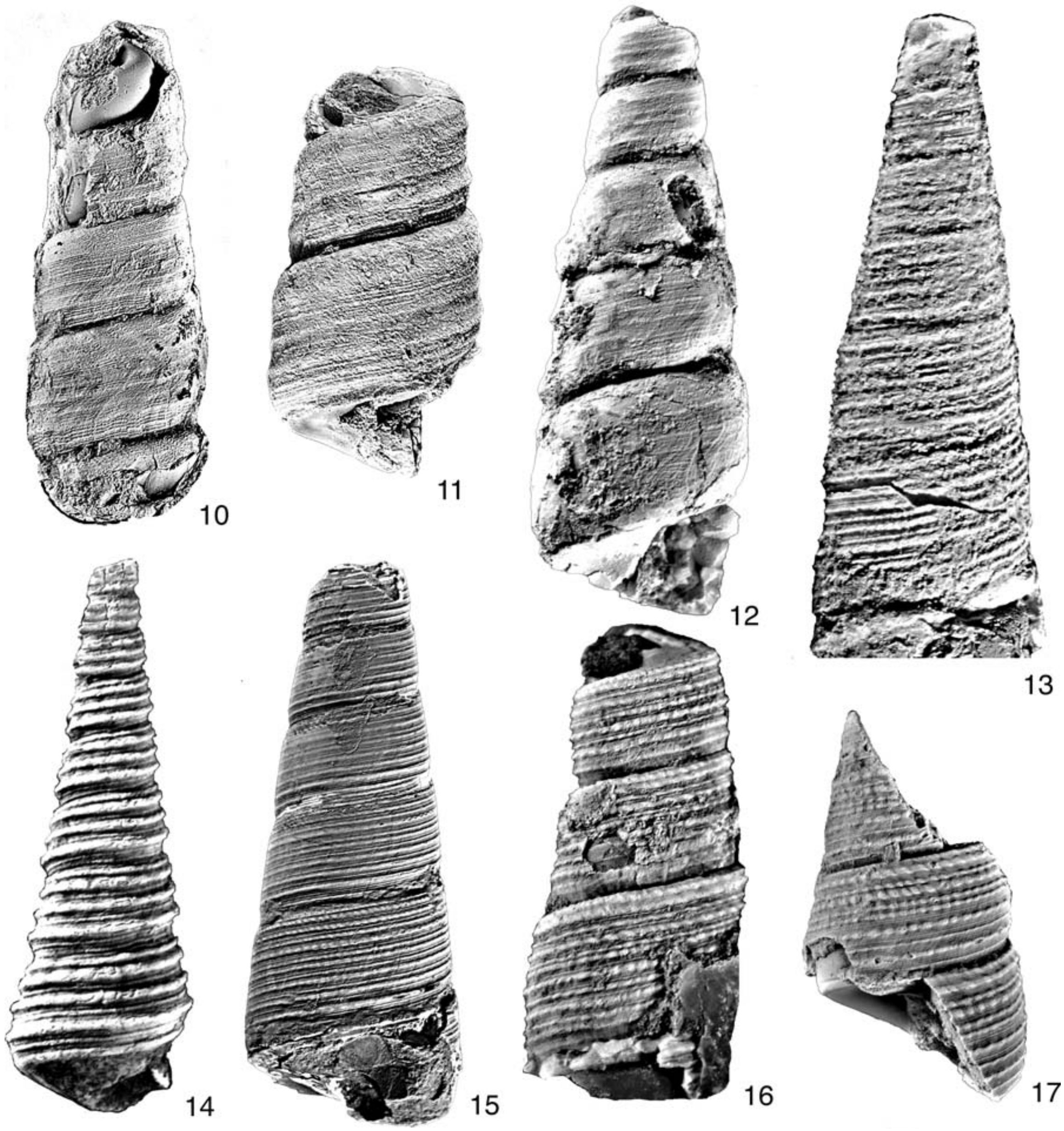
Turritella infralineata resembles *T. hearni*, but *T. infralineata* differs by having much weaker nodes and much wider interspaces.

Turritella ***xylina*** Squires & Saul, sp. nov.
(Figures 10–12)

Turritella cf. *T. robertiana* (Anderson). Rodda, 1959:124; Murphy & Rodda, 1960:text-fig. 2.

Diagnosis: Adult whorls with concave middle part flanked by shoulder and abapical angulations. Sculpture generally subdued, consisting only of numerous spiral threads.

Description: Shell medium (estimated 40 mm total height). Protoconch and early juvenile whorls unknown. Pleural angle 18°. Early adult whorls (approximately 4.5



Explanation of Figures 10 to 17

Specimens coated with ammonium chloride. Figures 10–12. *Turritella* ***xylina*** Squires & Saul, sp. nov. Figure 10. Holotype CAS 69111.02, CAS loc. 69111, right-lateral view, ×2.9. Figure 11. Paratype LACMIP 13315, LACMIP loc. 27242, abapertural view, ×2.5. Figure 12. Paratype LACMIP 13316, LACMIP loc. 23470, apertural view, ×4. Figures 13–17. *Turritella petersoni* Merriam, 1941. Figure 13. Holotype CAS 1291.06, CAS loc. 1291, left-lateral view, ×6.1 Figure 14. Hypotype CAS 69106.02, CAS loc. 69106, apertural view of tip, ×8.8. Figure 15. Hypotype CAS 69107.05, CAS loc. 69107, apertural view, ×2.2. Figure 16. Hypotype CAS 69284, CAS loc. 2335, abapertural view, ×3.9. Figure 17. Hypotype CAS 69285, CAS loc. 69098, right-lateral view, ×2.5.

to 5 mm diameter) slightly convex, covered by spiral threads of generally uniform strength. Adult whorls (approximately 5 mm diameter and greater) concave between very broad and flattened shoulder area and broad to moderately sharp abapical angulation (rib C?); medial part of concave part of whorl commonly bears moderately prominent rib B? and several threads. Suture impressed. Growth line sigmoidal, antispiral on concave part of whorl.

Dimensions of holotype: 24 mm in height, 9 mm greatest diameter (specimen incomplete).

Holotype: CAS 69111.02.

Type locality: CAS 69111, 122°33′30″W longitude, 40°27′15″N latitude.

Paratypes: LACMIP 13315 and 13316.

Geologic age: Cenomanian.

Distribution: Budden Canyon Formation, Bald Hills Member, North Fork Cottonwood Creek, Shasta County, northern California.

Discussion: This new species is based on 38 specimens, and preservation is only moderately good. The largest specimen is 34 mm in height and 13.5 mm in greatest diameter, but the specimen is incomplete.

Turritella ***xylina*** is unlike the other species described in this present paper. It most closely resembles *Turritella chaneyi orienda* Saul (1983a:84–86, pl. 5, figs. 4–11, 16–17) from upper Maastrichtian strata in central and southern California. *Turritella* ***xylina*** differs by having a wider pleural angle, overall weaker ribbing (especially on the concave middle part of the whorls), shoulder closer to suture with narrow interwhorl valley, and whorls sides more vertical with stronger shoulder offset, producing a slightly stepped-whorl appearance.

Rodda (1959) identified the new species as *Turritella* cf. *T. robertiana* (Anderson, 1958). Anderson (1958) had originally referred his species to *Nerinea robertiana*, but, as mentioned in Saul & Squires (1998:465), Anderson's specimens are not nerineids. Saul (1983a) mentioned that *T. robertiana* is similar to *T. chaneyi orienda*. She also mentioned that *T. robertiana* is similar to *T. chaneyi* Merriam, 1941, and tentatively included Anderson's supposed nerineid in synonymy with *T. chaneyi*.

Etymology: The species is named for its occurrence in the North Fork Cottonwood Creek area; Greek, *xylinos* meaning of wood.

Turritella petersoni Merriam, 1941
(Figures 13–17)

Turritella petersoni Merriam, 1941:64–65, pl. 1, figs. 10, 11.

Diagnosis: Adult whorls slightly convex to flattish with ribs thin, numerous, weakly noded, closely spaced, and alternating in strength.

Description: Medium shell. Pleural angle approximately 18°. Protoconch unknown. Early juvenile whorls (approximately 1 mm diameter) convex and bearing ribs r, A, B, and C; interspaces as wide as ribs. Juvenile whorls (1 to 4 mm diameter) convex and bearing ribs r, A, s, B, t, C, u, and d; r approaching strength of A, B, and C on whorls approximately 3 mm diameter); A, B, and C weakly noded. Adult whorls (approximately greater than 5 mm diameter) slightly convex to flattish (occasionally with slightly tabulate shoulder) and with numerous, thin, very closely spaced, weakly noded ribs, and alternating in strength with weaker ribs. Occasional specimens (see Figure 17) with R, s, A, B c, u, and d distinguishable, but notation of spiral ribs usually difficult. Threads most common on anterior part of whorls. Some specimens with numerous cycles of single strong rib alternating with bands containing one to four weaker ribs; stronger ribs usually with nodes, weaker ribs unnoded. Suture at but not overlapping d. Area baseward of d with 2 to 3 fine, faintly beaded riblets; bordered by a stronger rib; followed by weak to stronger alternations of diminishing strength to whorl center. Growth line sigmoidal, maximum of antisinus near midpoint of whorl. Aperture round.

Holotype: CAS 1291.06.

Type locality: ''1 mile east of Peterson's ranch house, 4 miles north of Sites, Colusa County, California'' (Merriam, 1941:64).

Geologic age: Cenomanian to early Turonian.

Distribution: CENOMANIAN: Great Valley Group, Sites area, Colusa County, northern California; Budden Canyon Formation, Bald Hills Member, Ono area, Shasta County, northern California. CENOMANIAN OR TURONIAN: Valle Group, Cedros Island, Baja California, Mexico. LOWER TURONIAN: Budden Canyon Formation, Gas Point Member, lower part, Ono area, Shasta County, northern California.

Discussion: This study of Merriam's species is based on 149 specimens. Preservation is generally good. Many of the specimens are from the Gas Point Member of the Budden Canyon Formation.

Turritella petersoni has been a poorly known species prior to this study. Its geologic age was tentatively reported as Cenomanian by Saul (1978:38–39) because of inexact knowledge regarding the location of its type locality.

Three moderately well preserved specimens of *T. petersoni* were detected from LACMIP loc. 15741 in the Valle Group, Cedros Island, Baja California, Mexico. The specimens are float derived from this group, and utilizing the geologic map provided by Kilmer (1984), the specimens are from either the upper part of the lower member (i.e., the Cenomanian Vargas Formation) or the lower part of the upper member (i.e., the Turonian Pinos Formation).

Turritella petersoni is similar to *Turritella iota* but *T. petersoni* differs by having whorls sides that can be weakly convex (never concave) and in not having a moderate carina at C. *Turritella petersoni* also has more numerous and more closely spaced ribs with the nodes usually stronger, and the sculpture can also vary from ribs having nodes to ribs without almost any nodes. The latter variation might be due to ecologic factors. The basal sculpture differs from *T. iota* in having ribs of alternating strength.

Turritella hearni Merriam, 1941
(Figures 18–21)

Turritella hearni Merriam, 1941:64, pl. 1, figs. 1–9; Saul: 1982:72 (chart).
Turritella tolenasensis Merriam, 1941:62, pl. 1, figs. 14, 15; Saul, 1983a:103.

Diagnosis: Whorls slightly convex with three prominent and equal-strength spiral ribs (nodes not strong) on juvenile whorls, increasing to four prominent spiral ribs (nodes strong and elongate) on later whorls (ribs A and B strongest) and numerous unnoded threads on all interspaces.

Description: Shell medium. Pleural angle 13°. Protoconch and earliest juvenile whorls unknown. Whorls slightly convex to flattish. Juvenile whorls (less than 4 mm diameter) with ribs A, B, and C equally prominent and unnoded; ribs r and d weak (see Figure 21). Later whorls (greater than 4 mm diameter) show ribs R, A, B, C, t, and d; ribs A and B most prominent and noded; rib C slightly less prominent and with or without nodes. Interspaces between ribs on later whorls with 3 to 8 threads; later whorls on some specimens (see Figure 20) only with R, A, B, and C, and their interspaces bearing only threads. Rib d just adapical to suture followed by very fine riblets. At suture, riblet with low elongate nodes; remainder of base with very fine, somewhat wavy riblets. Growth lines sigmoidal, maximum of antisinus somewhat posterior of midpoint of whorl. Suture impressed. Aperture round.

Holotype: CAS 61938.01.

Holotype dimensions: 27.5 mm height, 7 mm greatest diameter, specimen incomplete.

Type locality: CAS 61938.

Geologic age: Turonian, and probably early Coniacian.

Distribution: LOWER TURONIAN: Redding Formation, Bellavista Sandstone Member and Frazier Siltstone Member, Shasta County, northern California; Budden Canyon Formation, Gas Point Member, lower part, Shasta County, northern California. UPPER TURONIAN: Ladd Formation, Baker Canyon Member, Holz-Baker transition, and lower part Holz Shale Member, Santa Ana Mountains, Orange County, southern California. TURONIAN UNDIFFERENTIATED: Hornbrook Formation, Jackson County, southern Oregon. PROBABLY LOWER CONIACIAN: Hornbrook Formation, probably the Ditch Creek Siltstone Member, Siskiyou County, northern California.

Discussion: This study of Merriam's species is based on 239 specimens. Many of these are from the Hornbrook Formation, where the preservation is generally very good. A considerable number of specimens, however, are from the Redding Formation, east of Redding. Preservation of the Redding material is also generally very good.

Saul (1982:fig. 2 on p. 72) plotted the stratigraphic occurrence of this species in the Ladd Formation.

Merriam (1941) reported *Turritella tolenasensis* Merriam (1941:62, pl. 1, figs. 14, 15) from Cenomanian or Turonian strata in northern California. Saul (1983a:103), however, reported that Merriam's species is probably conspecific with *Turritella hearni* and that Merriam's type material of *T. tolenasensis* is definitely of Turonian and not Cenomanian age. In this present report, we put *T. tolenasensis* into synonymy with *T. hearni.*

Merriam (1941) reported *Turritella tolenasensis* subsp. Merriam (1941:62–63, pl. 1, fig. 12) from Tuscan Springs, Tehama County, northern California. Saul (1983a:102–104), however, tentatively put this subspecies into synonymy with *Turritella packardi* Merriam, 1941, an early to possibly middle Campanian gastropod.

Turritella iota Popenoe, 1937
(Figures 22–23)

Turritella iota Popenoe, 1937:401, pl. 49, fig. 8; Saul, 1982: 72 (chart).

Diagnosis: Adult whorls slightly concave to flattish with C rib strongest, forming narrow and projecting, weakly noded carina; posterior to carina sculpture consisting of three to four, weak spiral ribs alternating with weaker ones.

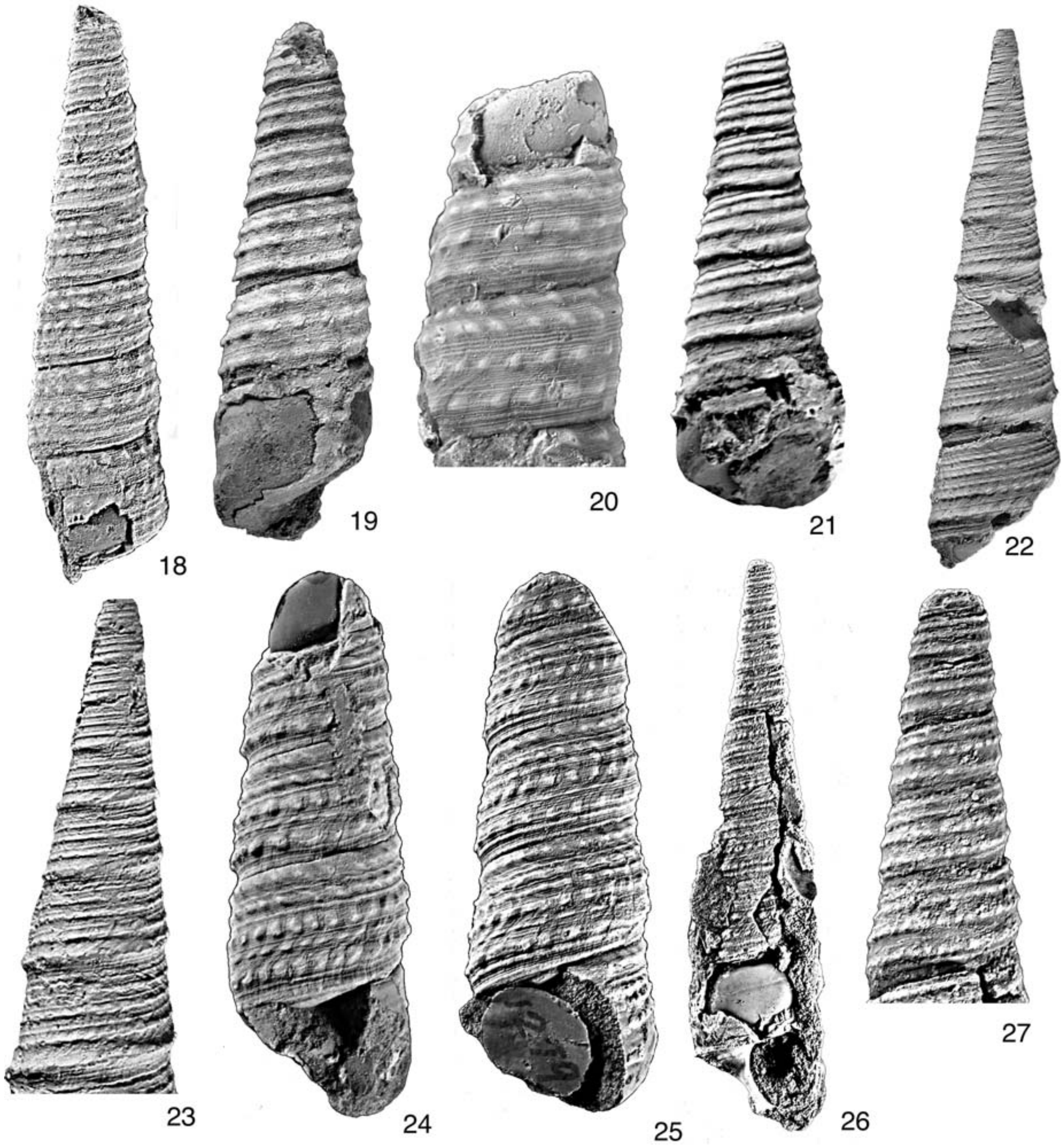
Description: Medium shell, slender. Pleural angle approximately 16°. Protoconch and earliest juvenile whorls unknown. Teleoconch whorls very shallowly concave to flattish. Suture impressed. Juvenile and early adult whorls (2 to 4.5 mm in diameter) with R, A, s, B, T, and C, with d appearing at approximately 2 mm diameter; R, A, B, and d weak and thin, C forming narrow and projecting carina. Adult whorls (greater than 5 mm diameter) similar to earlier whorls but with nodes on R, A, B, and C. Interspaces with threads, especially immediately posterior to carina. Carina of adult individuals rounded on slightly convex base. Base with noded rib adjacent to and paralleling d, another riblet toward mid base, and otherwise with fine striations. Basal ribs weakening toward aperture. Growth line sigmoidal, antisinus at midpoint of whorl and deepest at s.

Holotype: LACMIP 4186.

Holotype dimensions: 35.5 mm height, 9.6 mm greatest diameter, specimen incomplete.

Type locality: LACMIP 8178.

Geologic age: Late Turonian.



Explanation of Figures 18 to 27

Specimens coated with ammonium chloride. Figures 18–21. *Turritella hearni* Merrriam, 1941. Figure 18. Holotype CAS 61938.01, CAS loc. 61938, right-lateral view, ×3. Figure 19. Hypotype LACMIP 13317, LACMIP loc. 24251, abapertural view, ×4. Figure 20. Hypotype LACMIP 13318, LACMIP loc. 24251, right-lateral view, ×4.9. Figure 21. Hypotype CAS 69099.03, CAS loc. 69099, apertural view, ×7.4. Figures 22–23. *Turritella iota* Popenoe, 1937, LACMIP holotype 40673, LACMIP loc. 8178, left-lateral view. Figure 22. ×2.2. Figure 23. Tip of specimen shown in Figure 22, ×4.4. Figures 24–27. *Turritella* ***encina*** Squires & Saul, sp. nov. Figure 24. Holotype LACMIP 13319, LACMIP loc. 10798, apertural view, ×2.9. Figure 25. Paratype LACMIP 13320, LACMIP loc. 10900, apertural view, ×2.9. Figures 26–27. Paratype LACMIP 13321, LACMIP loc. 24336, apertural view. Figure 26. ×1.9. Figure 27. Tip of specimen shown in Figure 26, apertural view, ×5.6.

Distribution: LATE TURONIAN: Tuna Canyon Formation, lower part, west of Rustic Canyon, east-central Santa Monica Mountains, Los Angeles County, southern California; Ladd Formation, transition zone between Baker Canyon and Holz Shale members, and also lower Holz Shale, Santa Ana Mountains, Orange County, southern California.

Discussion: This study of Popenoe's species is based on 13 specimens. Most of them are from the lower part of the Tuna Canyon Formation at LACMIP loc. 26967 and show moderately good preservation.

This species is uncommon. It differs primarily from *T. petersoni* in having whorls that are concave, less numerous ribs, and a moderate carina at C. In addition, *T. iota* has weaker ribs of more uniform strength on the base.

Turritella iota differs from *T. hearni* in having stronger riblets on the base, crossed by strong growth lines that create a pitted surface. Popenoe (1937) indicated that it resembles somewhat a so-called ''*Turritella whiteavesi* Anderson & Hanna,'' but Anderson (1958:152) noted that he and Hanna had never named a *T. whiteavesi*.

Saul (1982:fig. 2 on p. 72) reported on the occurrence of this species in the Ladd Formation, and she also reported that at its type locality, it is found with *Turritella hearni*.

*Turritella **encina*** Squires & Saul, sp. nov. (Figures 24–27)

Diagnosis: Adult whorls weakly convex, with four nearly equal-strength spiral ribs (B and C strongest), noded, and alternating with weaker ribs.

Description: Shell medium, slender. Pleural angle approximately 14°. Whorls weakly convex. Suture impressed. Protoconch and earliest juvenile unknown. Juvenile whorls (approximately less than 4.5 mm diameter) with three, nearly equal-strength equal spiral ribs (A, B, and C), all with weak nodes. Adult whorls (approximately greater than 5 mm in diameter) with four ribs (R, A, B, and C), each strongly noded and alternating with weaker, usually unnoded ribs, resulting in sculpture pattern of R, r_2, A, s, B, t, C, u, and d (d very weak). Ribs B and C strongest. Rib t with several threads posteriorly and anteriorly. Interspace between C and u with threads. Growth line sigmoidal, maxiumum of antisinus coincident with position of rib B. Aperture round.

Dimensions of holotype: 28.1 mm height, 9.7 greatest diameter 9.7 mm, specimen incomplete.

Holotype: LACMIP 13319.

Type locality: LACMIP loc. 10798, 122°04′45″W longitude, 40°38′N latitude.

Paratypes: LACMIP 13320 and 13321.

Geologic age: Santonian.

Distribution: SANTONIAN: Redding Formation, Member V, Old Cow and upper Clover creeks, Shasta County, northern California.

Discussion: This new species is based on 134 specimens, and most show good presevation.

*Turritella **encina*** is most similar to *Turritella hearni*, but *T. **encina*** differs by having ribs (s, t, and u) present, all of which are noded. *Turritella hearni* usually has only threads in its interspaces. In addition, on *T. **encina***, ribs B and C are approximately the same strength, rather than having rib B approximately the same strength as rib A.

Etymology: The new species is named for its occurrence in Oak Run, east of Redding; Spanish, ***encina*** meaning ''oak.''

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APPENDIX

LOCALITIES

CAS 1291. On old Peterson Ranch, 6.4 km NE of Sites, Lodoga Quadrangle (15 minute, 1943), west side of Sacramento Valley, Colusa County, northern California. Great Valley Group, informal Antelope Shale, just below the Venado Formation. Age: Cenomanian. Collector: Unknown.

CAS 2335. Outcrop just beneath rim rock of Logan Ridge, approximately 1.6 km NE of old Peterson Ranch House, 4.8 km NE of Sites, Lodoga Quadrangle (15 minute, 1943), west side of Sacramento Valley, Colusa County, northern California.

CAS 61938. Approximately 6.4 km N of Montague and approximately, 304 m NE of old Hagerdorn Ranch House, Yreka Quadrangle (30 minute, 1939), Siskiyou County, northern California. Hornbrook Formation, probably Ditch Creek Member. Age: Probably early Coniacian. Collector: Unknown.

CAS 69098. [= LACMIP 23903]. Large gray limestone nodules in gray mudstone on S bank of creek, 582 m and 73 m N of SW corner of section 29, T. 30 N, R. 6 W, Ono Quadrangle (15 minute, 1952), Shasta County, northern California. Budden Canyon Formation, Gas Point Member, lower part. Age: Turonian. Collectors: P. U. Rodda, August, 1955.

CAS 69099. [= LACMIP 23817]. Sandstone bed in mudstone section, third major W-heading tributary of North Fork Cottonwood Creek, S of mouth of Huling Creek, 762 m E and 549 m S of SE corner of section 29, T. 30 N, R. 6 W, Ono Quadrangle (15 minute, 1952), Shasta County, northern California. Budden Canyon Formation, Gas

Point Member, lower part. Age: Early Turonian. Collector: P. U. Rodda, August, 1956.

CAS 69104. [= LACMIP 23893]. Texas Springs, Redding Quadrangle (15 minute, 1946) Shasta County, northern California. Budden Canyon Formation, Chickabally Member. Age: Late early Albian. Collector: Unknown.

CAS 69106. [= LACMIP 23808]. Shale bank, left side of Roaring River, about 1.2 km above the dam at the basal conglomerates, 914 m N and 1066 m E of SW corner of section 1, T. 29 N, R. 7 W, Ono Quadrangle (15 minute, 1952), Shasta County, northern California. Budden Canyon Formation, Gas Point Member. Age: Early Turonian. Collectors: W. P. Popenoe and W. Findlay, 1933; P. U. Rodda, 1956.

CAS 69107. [= LACMIP 23937]. On side of small creek, SE 1/4 of section 20, T. 30 N, R. 6 W, Ono Quadrangle (15 minute, 1952), Shasta County, northern California. Budden Canyon Formation, Gas Point Member, lower part. Age: Early Turonian. Collector: P. U. Rodda, August, 1956.

CAS 69111. North Fork of Cottonwood Creek, Ono Quadrangle (15 minute, 1943), Shasta County, northern California. Budden Canyon Formation, Bald Hills Member. Age: Cenomanian. Collector: P. U. Rodda.

LACMIP 8178. [= CIT 984]. On W side of Rose Canyon, 205 m S and 329 m W of NE corner of section 2, T. 6 S, R. 7 W, Santiago Peak Quadrangle (7.5 minute, 1954), Santa Ana Mountains, Orange County, southern California. Ladd Formation, middle part of Holz-Baker transition zone. Age: Late Turonian. Collector: W. P. Popenoe, October 15, 1933.

LACMIP 10798. Massive sandstones interbedded with conglomerates on S side of high E-W trending ridge, S side of Oak Run Valley, 998 m S54°50′W from SE corner of section 10, T. 32 N, R. 2 W, Millville Quadrangle (15 minute, 1953), Shasta County, northern California. Redding Formation, Member V. Age: Early Santonian. Collectors: W. P. Popenoe and C. Ahlroth, July 1, 1936.

LACMIP 10900. South side of Old Cow Creek, NE ¼, SW ¼ of section 20, T. 32 N, R. 1 W, Millville Quadrangle (15 minute, 1953), Shasta County, northern California. Redding Formation, Member V. Age: Santonian. Collector: V. C. Church, April 12, 1937.

LACMIP 15741. Float material from about the middle of the island in a downfaulted synclinal block, Cedros Island, Baja California, Mexico. Valle Group (member unknown). Age: Cenomanian or Turonian. Collector: F. H. Kilmer.

LACMIP 23470. On E side of North Fork of Cottonwood Creek, section 16, T. 30 N, R. 6 W, Ono Quadrangle (15 minute, 1953), Shasta County, northern California. Budden Canyon Formation, Bald Hills Member. Age: Cenomanian? Collector: P. U. Rodda, September, 1955.

LACMIP 24251. Sandstone cropping out along ridge by ranch road, 914 m W and 259 m S of NE corner of section 26, T. 46 N, R. 6 W, 14.5 km NE of Yreka, Yreka Quadrangle (30 minute, 1939), Siskiyou County, northern California. Hornbrook Formation, Osburger Gulch Sandstone Member. Age: Turonian. Collectors: M. A. Murphy, W. P. Popenoe, and T. Susuki, August 30, 1951.

LACMIP 24336. Fossiliferous float concretion in siltstone on N side of Clover Creek Valley, 365 m N and 244 m E of SW corner of section 13, T. 32 N, R. 2 W, Millville Quadrangle (15 minute, 1953), Shasta County, northern California. Redding Formation, Member V. Age: Early Santonian. Collector: W. P. Popenoe, August 15, 1954.

LACMIP 25272. South side of Cherry Hill about 100m W of first big turn on Cherry Hills Road and approximately 1 km N of Pioneer Road, west boundary of NW ¼ of section 12, R. 1 W, T. 38 S, Medford Quadrangle (15 minute, 1938), near Phoenix, Jackson County, southwestern Oregon. Hornbrook Formation. Age: Turonian. Collector: Takeo Susuki, 1962.

LACMIP 26967. Small exposure of coarse-grained, poorly sorted sandstone at bottom of NW-flowing tributary to main fork of Garapito Creek, 450 m S and 2835 m E of NW corner of section 5, T. 1 S, R. 16 W, Topanga Quadrangle (7.5

minute, 1952, photorevised, 1981), Santa Monica Mountains, Los Angeles County, southern California. Tuna Canyon Formation, lower part. Age: Late Turonian. Collector: J. M. Alderson, December 31, 1981.

LACMIP 27242. East bank of Cottonwood Creek about 0.4 km downstream from mouth of Huling Creek, fossiliferous concretions weathering out from near top of conglomerate of Bald Hills Member and just below beginning of slabby sandstones and mudstones of Gas Point Member, approximately 533 m N and 274 m E of SW corner of section 16, T. 32 N, R. 6 W, Ono Quadrangle (15 minute, 1953), Shasta County, northern California. Budden Canyon Formation, Bald Hills Member. Age: Cenomanian. Collector: W. P. Popenoe, April, 1954.

UCMP A-9521. Punta China, 25 km SE of Ensenada, northern Baja California, Mexico. Alisitos Formation. Age: Late Aptian. Collector: Probably E. C. Allison, 1960s.