

NEW CRETACEOUS GASTROPODA FROM CALIFORNIA

by L. R. SAUL and R. L. SQUIRES

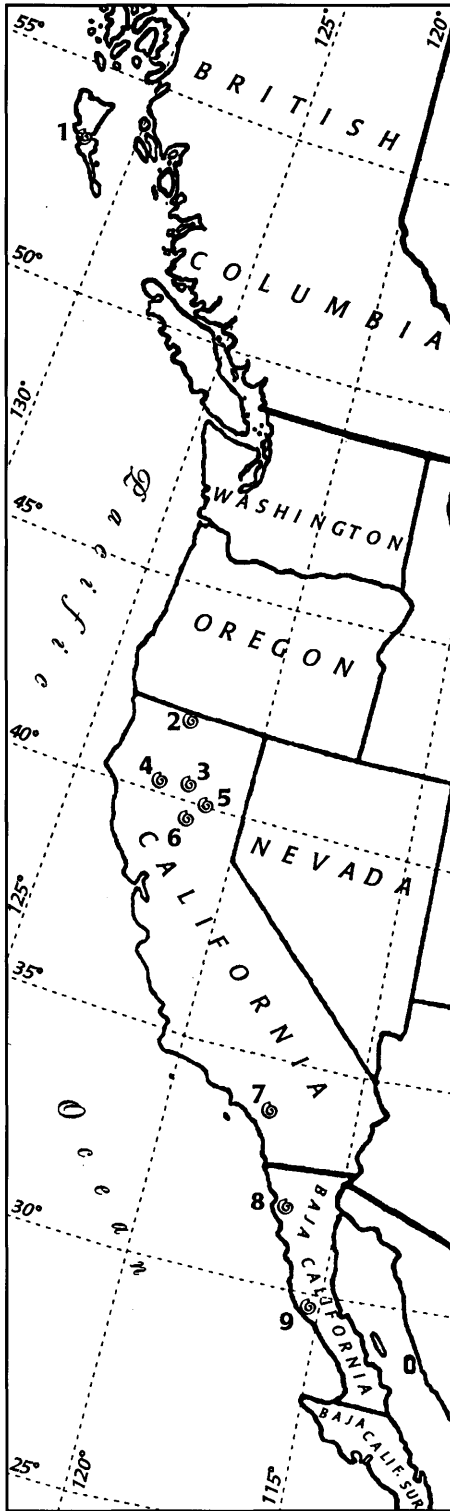
ABSTRACT. Two genera of subtropical to tropical, nearshore-marine nerineid gastropods, *Aphanoptyxis* and *Nerinella*, are recognized for the first time in the Cretaceous of California. A listing of Cretaceous nerineid species from between British Columbia and Baja California, an area presently north of the tropics, records 12 species of nerineids, including two new species, *Aphanoptyxis californica* and *Nerinella santana*. *Aphanoptyxis andersoni* nom. nov., of Early Cretaceous (Hauterivian) age from near Ono, northern California, is the earliest *Aphanoptyxis* recorded in the western hemisphere; *A. californica* sp. nov., of Late Cretaceous (Turonian) age from near the city of Hornbrook, Siskiyou Co. and Little Cow Creek valley near Redding, Shasta Co., northern California, is the youngest *Aphanoptyxis* recorded. *Nerinella santana* sp. nov. is from the Turonian of the Santa Ana Mountains near Los Angeles, southern California. No North American Pacific coast nerineid of younger than Turonian age has been found. Four species originally described as *Nerinea* have been reallocated to neotaenioglossan families.

Two new Cretaceous cerithiform species, which resemble nerineids in having a narrow pleural angle, are: *Potamidopsis? grovesi* sp. nov., a possible potamidid of Early Cretaceous (Hauterivian) age from near Ono, northern California, and *Diozoptyxis ursana* sp. nov., a campanilid of Late Cretaceous (Coniacian-Santonian) age from south-east of Redding, Shasta Co., and Chico Creek, Butte Co., northern California. *Diozoptyxis ursana* is the earliest campanilid recognized from North America.

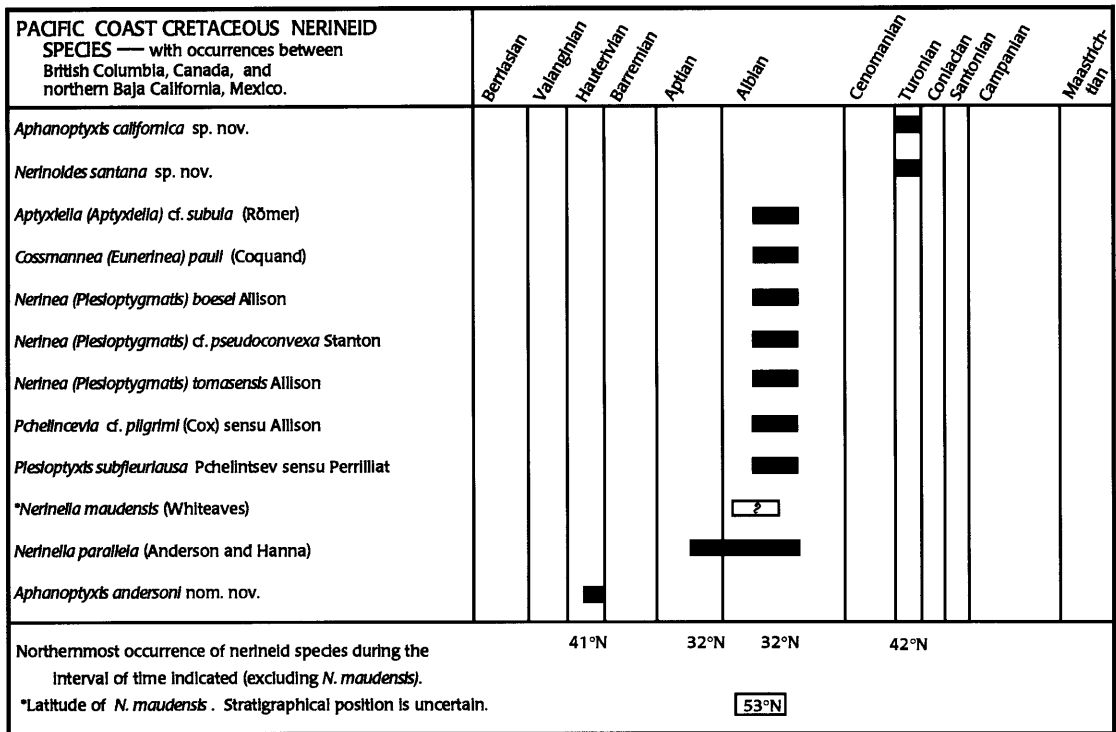
THIS paper concerns the discovery of four new gastropod species: two nerineids, a campanilid, and a possible potamidid from non-carbonate, Cretaceous rocks in California. Both new nerineid species are of Late Cretaceous (Turonian) age. The first new species, *Aphanoptyxis californica*, is present in Turonian strata north-east of Redding, as well as near the town of Hornbrook near the California-Oregon border (Text-fig. 1). Specimens are plentiful. The second new Turonian species, *Nerinella santana*, is from the Santa Ana Mountains near Los Angeles, southern California (Text-fig. 1). Specimens are locally common. In addition, a new name, *Aphanoptyxis andersoni*, is provided for *Nerinea archimedis* Anderson, 1938, of Early Cretaceous (Hauterivian) age, from the Budden Canyon Formation near Ono, Shasta Co., northern California.

Nerineid gastropods form a conspicuous and important element in Mesozoic carbonate faunas and are considered to be indicative of subtropical to tropical conditions (Sohl 1987; Barker 1990). On the Pacific coast of North America, north of the present tropics, nerineid occurrences are sparse and specimens are rare. The only area where nerineid gastropods are moderately common and diverse is Baja California, Mexico, where outcrops of biohermal limestone in the Lower Cretaceous (middle Albian) upper member of the Alisitos Formation contain five genera of nerineids (Allison 1955). Other Cretaceous nerineids have been reported from the Queen Charlotte Islands, British Columbia, Canada (Whiteaves 1884) and from the Lower Cretaceous near the town of Ono, northern California (Anderson 1938). The most distinctive and well-known morphological feature of these gastropods is the development, in most genera, of spiral folds within the body cavity of the shell (Barker 1990). The earliest nerineid reported north of Baja California on the Pacific slope is *Nerinea thompsonensis* Crickmay, 1933 described from the Thompson Limestone (Diller 1892) in the Mt Jura section, Plumas County, northern California. These beds are considered to be early Mid Jurassic age (Crickmay 1933).

The following nerineids have been reported from the Pacific slope Cretaceous strata of North



TEXT-FIG. 1. Index map for Pacific Slope of North America fossil sites mentioned in text. 1 - Maude Island, Queen Charlotte Islands, British Columbia; 2 - north of Hornbrook, Siskiyou Co., California; 3 - Redding area, Shasta Co., California; 4 - Ono area, Shasta Co., California; 5 - Mt Jura, Plumas Co., California; 6 - Chico Creek, Butte Co., California; 7 - Santa Ana Mountains, Orange Co., California; 8 - Punta China and environs, Baja California, Mexico; 9 - South of Rosario (north of Misión San Fernando; south of Arenoso) to Arroyo Santa Catarina, Baja California, Mexico.



TEXT-FIG. 2. Time ranges of Pacific Slope Cretaceous nerineid species. Species plotted occur between Queen Charlotte Islands, British Columbia, Canada (c. 54° N) and Baja California, Mexico (c. 29° N). Palinspastic reconstructions are not addressed in citing latitude, but as all localities are west of the North American craton, they have been moved north relative to it and are probably north of their latitudes of deposition. If *Nerinella maudensis* is indeed of Albian age, the most diverse and most northern Pacific Slope occurrences are contemporaneous.

America between British Columbia and Baja California. Their geological ranges are summarized in Text-figure 2. Two-thirds of the species reported are from the Alisitos Formation in Baja California, Mexico, which is of Aptian–Albian age (Allison 1955, 1974; Gastil *et al.* 1975). Two-thirds of the Alisitos species have been recognized as the same species or very similar to species from the Mediterranean area, Texas, or mainland Mexico. No nerineid species of younger than Turonian age has been reported from between British Columbia and Baja California. These distributions resemble those noted by Sohl (1987) for nerineoideans elsewhere in that nerineids from the Pacific coast are most diverse in the middle Cretaceous, with an abrupt decline before its end, and the species apparently had less restricted geographical ranges during the time of maximum diversity. Nerineoidea constitutes one of the two most characteristic gastropod superfamilies of Tethys (Sohl 1987), and their absence throughout the Upper Cretaceous north of Baja California Sur may be another indication of post-Turonian cooling (Saul 1986).

Aphanoptyxis andersoni nom. nov., herein.

Aphanoptyxis californica sp. nov., herein.

Aptyxiella (*Endiutracheus*) *parallela* (Anderson and Hanna, 1935). Allison 1955, p. 426, pl. 43, figs 8–9. See: *Nerinella parallela*, herein.

Aptyxiella (*Aptyxiella*) cf. *subula* (Römer, 1888). Allison 1955, pp. 425–426, pl. 43, figs 3–4. Middle Albian; upper member of the Alisitos Formation; Punta China, Baja California, Mexico.

Cossmannea (*Eunerinea*) *pauli* (Coquand, 1862, p. 177, pl. 4, fig. 3). Allison 1955, p. 426, text-fig. 3D. Barremian–Aptian, Mediterranean area. Middle Albian; upper member of the Alisitos

- Formation; Punta China, Baja California, Mexico (Allison 1955). Barremian, Agua del Burro Formation, north-east of San Juan Raya, Puebla, Mexico (Buitrón and Barceló-Duarte 1980).
- Cossmannia (Eunerinea) riograndensis* (Stanton, 1947, p. 89, pl. 59, figs 7–10, 12–16). Perrilliat-Montoya 1968, p. 23, pl. 7, figs 1–4. Upper Albian; Devil's River Limestone of Texas (Stanton 1947). Upper Aptian–Albian; San Fernando Formation = Alisitos Formation, east of El Rosario and north of Misión San Fernando, Baja California, Mexico (Perrilliat-Montoya 1968). *Nerinea riograndensis* Stanton has a barely concave to slightly convex whorl profile. Specimens illustrated by Perrilliat-Montoya (1968) appear to have concave whorl sides and may be the same species as *C. (E.) pauli* (Coquand) of Allison (1955).
- Diozoptyxis* cf. *pilgrimi* (Cox, 1936). Allison 1955, pp. 426–427, text fig. 3c. Middle Albian; upper member of the Alisitos Formation; Punta China, Baja California, Mexico. Not *Diozoptyxis* of Delpy (1941) or Kollmann (1987). *Fide* Cox (1954), *Adiozoptyxis* Dietrich, 1914, is the appropriate name for this group, but because of Dietrich's (1914) original hesitant proposal of the genus and subsequent questioning of the species name for the specimens he allocated to it (Dietrich 1925), Kollmann and Peza (1997) considered *Adiozoptyxis* taxonomically invalid. They suggested that *Pchelincevia* Lyssenko and Aliev, 1987 includes forms agreeing with *Adiozoptyxis* Dietrich, 1914. *Nerinea pilgrimi* Cox, 1936 (p. 22, pl. 3, fig. 1a–b) from Khamir, Iran was considered to be of Cenomanian–Turonian age. It is much more widely umbilicate than the specimen figured by Allison which is unlikely to be conspecific with Cox's *N. pilgrimi*. Although Allison's drawing (1955, text-fig. 3c) resembles *Adiozoptyxis coquandiana* (d'Orbigny, 1842) which is of Aptian age (Hernandez-Lascars and Buitrón 1992), on Text-figure 2 this species is listed as *Pchelincevia* cf. *pilgrimi* (Cox) *sensu* Allison.
- Nerinea* sp. Anderson, 1938, p. 132, pl. 9, figs 2–3. See: *Aphanoptyxis andersoni* nom. nov.
- Nerinea archimedis* Anderson, 1938, p. 132, pl. 9, fig. 1. See: *Aphanoptyxis andersoni* nom. nov.
- Nerinea maudensis* Whiteaves, 1884, pp. 214–215, pl. 27, figs 2, 2a–2d. Probably Lower Cretaceous (?Albian); Haida Formation (Bolton 1965); east end of Maude Island, Queen Charlotte Islands, western British Columbia. Whiteaves indicated that it belonged in the subgenus *Nerinella*. See: *Nerinella maudensis* (Whiteaves), herein.
- Nerinea (Plesioptygmatis) boesei* Allison, 1955, pp. 424–425, pl. 43, fig. 11, text-fig 3A. Middle Albian; upper member of the Alisitos Formation; Punta China, Baja California, Mexico.
- Nerinea (Plesioptygmatis) cf. pseudoconvexa* Stanton, 1947. Allison 1955, pp. 423–424, pl. 43, figs 5–6. Middle Albian; Edwards Limestone and Fredricksburg Group, Texas (Stanton 1947). Upper member of the Alisitos Formation; Punta China, Baja California, Mexico (Allison 1955).
- Nerinea (Plesioptygmatis) tomasensis* Allison, 1955, p. 425, pl. 43, figs 10, 12; text fig. 3B, E. Middle Albian; upper member of the Alisitos Formation; Punta China, Baja California, Mexico (Allison 1955). Upper Aptian–lower Albian; Encino Formation, Cerro de Tuxpan, southern Jalisco, Mexico (Buitrón 1986, p. 27, as *Ptygmatis tomasensis* (Allison)).
- Nerinella maudensis* (Whiteaves, 1884), herein.
- Nerinella parallela* (Anderson and Hanna, 1935), herein.
- Nerinella santana* sp. nov., herein.
- Plesioptyxis subfleuriausa* Pchelintsev, 1953, p. 166, pl. 33, figs 3–4. Perrilliat-Montoya, 1968, p. 23, pl. 7, figs 5–6. Cenomanian of Transcaucasus, Russia (Pchelintsev 1953). Upper Aptian–Albian; San Fernando Formation = Alisitos Formation; Mesa Sepultura, south of Arenoso, Baja California, Mexico (Perrilliat-Montoya 1968).
- Turitella parallela* Anderson and Hanna, 1935. p. 26, pl. 9, figs 1–3. See: *Nerinella parallela*, herein.

Although originally described as nerineids, the following species belong elsewhere:

- Nerinea dispar* Gabb, 1864, p. 113, pl. 19, figs 66, 66a. Lower Cretaceous; North Fork of Cottonwood Creek; Ono area, Shasta Co., California. See: *Opalia (Claviscala) dispar* (Gabb) (Durham 1937, p. 503, pl. 56, fig. 20).
- Nerinea dispar?* Gabb. (Var.) Whiteaves, 1896, p. 127, pl. 3, fig. 4. Whiteaves, 1903, p. 363. Upper Cretaceous; Nanaimo Group; Hornby Island, British Columbia. See: *Opalia (Claviscala)* n. sp.

Durham 1937, p. 503. Probably not *Opalia* or *Claviscala*; may be an epitoniid similar to '*Nerinea stewarti* Anderson.

Nerinea robertiana Anderson 1958, p. 155, pl. 66, fig. 3. Lower Maastrichtian; upper part of the Moreno Formation; Pacheco Pass area, Fresno County, central California. See: *Turritella chaneyi* Merriam, 1941 (Saul 1983, p. 81).

Nerinea stewarti Anderson, 1958, p. 155, pl. 30, figs 2-3. ?Middle Turonian; ?Gas Point Formation; Hickman ranch, on the Middle Fork of Cottonwood Creek, Shasta Co., northern California. A deep water, cold-seep epitoniid (W. P. Elder, pers. comm. 1997).

North American Pacific slope Cretaceous campaniloideans and cerithioideans have not been much studied. The two new species described here resemble nerineids in having a narrow pleural angle. *Potamidopsis? grovesi* sp. nov., of Hauterivian age, is rare and occurs with *Aphanoptyxis andersoni* nom. nov. near Ono, Shasta Co., California. *Diozoptyxis ursana* sp. nov., which is similar in overall shape to *Aphanoptyxis californica* sp. nov., is also from the Redding Formation east of Redding, Shasta Co., California, but is younger, of Coniacian and Santonian, rather than Turonian, age.

ECOLOGICAL IMPLICATIONS

Nerineids are noted for their presence in Mesozoic carbonate reefal-facies rocks of the Tethyan Province (Barker 1990), but such rocks are rarely found on the Pacific coast of North America. Only in the Middle Cretaceous Alicitos Formation of Baja California, Mexico, do carbonate-reefal rocks yield nerineids. The nerineids discussed herein, however, are from coarse- to fine-grained arenaceous rocks. Habitat preference and life-style have been suggested for some nerineid Jurassic genera by Barker (1990), amongst which are *Aphanoptyxis* and *Nerinella*. *Aphanoptyxis* is considered to have been epifaunal and inhabited low-energy, subtidal-intertidal (in places supratidal) mud flats (Barker 1990). *Nerinella* was inferred to have been infaunal and lived, in addition to areas similar to those inhabited by *Aphanoptyxis*, in somewhat deeper water, and in higher energy locales (Barker 1990). Modern and fossil campanilids and potamidids are found in warm temperate to tropical, nearshore habitats, including sand and mud flats. Modern potamidids are especially characteristic of muddy estuarine habitats and live in vast numbers in mangroves and salt marshes (Houbrick 1984; Wilson 1993).

Specimens of *Aphanoptyxis californica* sp. nov. occur in abundance in moderately coarse-grained sandstone north-east of Redding in Little Cow Creek valley. Their abundance and range in specimen size suggest deposition proximal to a very nearshore habitat. *Aphanoptyxis andersoni* nom. nov. and *Potamidopsis? grovesi*, both from the Budden Canyon Formation near Ono, are represented by a few, largely immature specimens. All of the *P.? grovesi* specimens are small and may be only the early whorls. These specimens are associated with other shallow-marine molluscs, such as the bivalve *Plicatula variata* Gabb, 1864, that have apparently been transported offshore into deeper water.

Nerinella santana sp. nov. is locally abundant in near-shore, coarse-grained sandstone of the Baker Canyon Member of the Ladd Formation in the Santa Ana Mountains, Orange Co., southern California. *Nerinella parallela* was listed as common from a tuffaceous siltstone of Aptian age in the lower Alicitos Formation at Punta China, and, as less common, from tuffaceous siltstone and sandstone of Albian age in the upper Alicitos Formation (Allison 1955). This latter species apparently occurs at a number of places within the Alicitos Formation, at least as far south as Santa Catarina (near 29° 30' N) (Text-fig. 1, area 9), Baja California, Mexico.

Nerineids are considered indicative of tropical conditions and the Tethyan Province (Sohl 1987), but gastropods of the families Campanilidae and Potamididae, although also present in the tropics, range into warm-temperate waters and may reflect slightly cooler conditions than those required by the nerineids. The disappearance of campanilids from European waters is indicated by Delpy (1941) to have been related to late Miocene emergences. Houbrick (1984) considered seaway

constrictions and trophic niche competition with the strombids to have contributed to disappearance of campanilids from European waters. The sole living representative of the Campanilidae, *Campanile symbolicum* Iredale, 1917, is from the Flindersian warm-temperate province along the coasts of Western Australia and South Australia (Ludbrook 1971). Several strombids recorded from the tropical northern coasts of Australia are lacking along the warm-temperate southern coasts inhabited by *C. symbolicum*. Whether the occurrence of *C. symbolicum* is restricted more by temperature or by strombid competition is unknown, but both may have an effect. Strombids of Cretaceous age are, however, unknown from North American Pacific coast deposits, which renders their probable impact on Cretaceous campanilids to be slight. In the distribution of campanilids as she recognized them, Delpy (1941) saw a migration from European waters to an Australian refuge. However, *Campanile* is present in the Paleocene of California and Brazil, and in the Eocene of California, Baja California, Panama, and Jamaica, and was probably pantropical in the early Tertiary (Wrigley 1940, fig. 14; Squires 1993).

SYSTEMATIC PALAEONTOLOGY

Abbreviations. The following abbreviations are used: CASG, California Academy of Sciences, Geology Section, San Francisco; CIT, California Institute of Technology (collections now stored at LACMIP); LACMIP, Natural History Museum of Los Angeles County, Invertebrate Paleontology Section; UCLA, University of California, Los Angeles (collections now stored at LACMIP). A slightly modified Ponder and Warén (1988) classification is used.

Phylum MOLLUSCA Linnaeus, 1758
 Class GASTROPODA Cuvier, 1797
 Subclass PROSOBRANCHIA Milne-Edwards, 1848
 Superorder CAENOGASTROPODA Cox, 1959
 Order NEOTAENIOGLOSSA Haller, 1888
 Superfamily CAMPANILOIDEA Douvillé, 1904, emend. Houbriek, 1989
 Family CAMPANILIDAE Douvillé, 1904

Remarks. *Campanile* has long been associated with *Cerithium* Bruguière, 1789, as a subgenus (e.g. Cossmann 1906), a genus within Cerithiidae (e.g. Hanna and Hertlein 1939), a genus of the subfamily Campanilinae of the Cerithiidae (e.g. Wenz 1940), or as a genus of the family Campanilidae in the superfamily Cerithioidea (e.g. Douvillé 1904; Houbriek 1981). Houbriek (1981, 1984, 1988, 1989) reviewed earlier classifications and presented evidence, mainly from soft-part anatomy, which resulted in his exclusion of Campanilidae from Cerithioidea and its placement in Campaniloidea (Houbriek 1989). He considered the Campaniloidea to have been an earlier, major radiation from the mainstream of the stem-group giving rise to modern Cerithioidea, the radiation having as its sole surviving member the living *Campanile symbolicum* Iredale, 1917.

Delpy (1941) derived *Campanile* from mid Cretaceous *Nerinea* and stated that *Campanile* was not known before the Cenomanian. However, if Houbriek (1989) is correct in regarding Campaniloidea as an early, major radiation off the stem that gave rise to Cerithioidea and Caenogastropoda, Campaniloidea would presumably have split from that stem as stem forms became classifiable as cerithioideans. The probability of as yet unrecognized Jurassic campanilids is suggested by Ponder and Warén (1988), who listed in Cerithioidea several genera having Jurassic representatives.

Haszprunar (1988) considered that *Campanile* has characteristics which indicate affinities with the Euthyneura (= Heterobranchia in Ponder and Warén 1988) and that *Campanile* probably represents a first step toward the euthyneurous level of organization, but Ponder and Warén (1988) are sceptical because undoubted euthyneurons extend back to the Carboniferous. Ponder and Warén (1988) placed *Campanile* in Cerithioidea, order Neotaeniglossa, but placed nerineoideans in the subclass Heterobranchia (= Euthyneura), order Heterostropha. Houbriek (1981) considered

the derivation of campanilids from nerineids most unlikely because 'nerineids have heterostrophic protoconchs and deep anal sulci and are considered to be in the subclass Euthyneura'. Barker (1990, p. 249) defined all Nerineidae as possessing a juxta-sutural selenizone (slitband), a rudimentary siphonal canal, and heterostrophic protoconchs, but also wrote (Barker, 1990, p. 253) 'apart from a brief mention by Bigot (1896) no nerineid protoconch has yet been adequately described or figured'. Both K. Bandel (pers. comm.) and M. J. Barker (pers. comm.) have indicated that Vaughan (1988, text-fig. 6.1–6.3) has provided photographs of the heterostrophic protoconch of a nerineid, *Polyptyxisella schicki* (Fraas, 1878)?, from the Campanian of the North Alpine Gosau. Unfortunately, protoconchs of both nerineids and campanilids are difficult to recover and the teleoconchs, which may be very similar, are difficult to assign with certainty to either family (K. Bandel, pers. comm.). Houbriek (1984) suggested that a number of fossil species described under other generic names, especially *Telescopium*, are actually *Campanile*.

Although *Diozoptyxis* Cossmann, 1896, (type species *Nerinea monilifera* d'Orbigny, 1842, Cenomanian of France) was described as a nerineid, Delpy (1941) classed it as a subgenus of *Campanile* Bayle, in Fischer, 1884. Both Delpy (1941) and Kollmann (1987) referred to the type species *Nerinea monilifera* d'Orbigny as their basis for classifying *Diozoptyxis* as a campanilid with one columellar fold which develops in the last whorl. *Diozoptyxis* was raised to generic status by Kollmann (1987) who examined d'Orbigny's type specimens. In part because of the single columellar fold in *N. monilifera*, he considered it close to *Campanile* and within Campanilidae. Mustafa and Bandel (1992), referring to the unpublished thesis of Vaughan (1988), used *Diozoptyxis* as did Cossmann (1906), for a genus belonging to Nerineidae, with three folds (two columellar and a palatal) and a narrow umbilicus. According to Kollmann and Peza (1997), Vaughan did not argue with Delpy's placement of *N. monilifera* in Campanilidae but suggested that ICZN Article 70c (Ride *et al.* 1985) should be applied. Article 70c would seem to require a misidentification or misapplication of the specific name, but there is no indication that Cossmann's *N. monilifera* is not that of d'Orbigny, and the type species of *Diozoptyxis* is apparently not a nerineid.

Delpy (1941) considered that most species assigned to *Cimolithium* Cossmann, 1906, should be placed in *Campanile* (*Diozoptyxis*) but that *Cerithium belgicum* d'Archiac, 1847 (Cenomanian of Belgium, the type species of *Cimolithium*) is not a campanilid but is a high-spined *Microschiza* (*Cloughtonia*) and belongs in the family Pseudomelaniidae.

Diversity of shell morphology in Campanilidae is increased by the inclusion in this family of the involute genus *Itruvia* Stoliczka, 1868, whose type species is *Itruvia canaliculata* (d'Orbigny, 1843) (Kollmann and Sohl 1980; Kollmann 1987), but as most species formerly referred to *Itruvia* are *Vernedia* Mazeran, 1912, family Itieriidae Cossmann, 1896, of the Nerineoidea this diversity fails to decrease similarities between Campaniloidea and Nerineoidea.

The type species of *Campanile*, *Campanile giganteum* Lamarck, 1804 (by subsequent designation, Sacco 1895; Eocene, Calcaire Grossière, Paris Basin, France), has two strong folds on its columella and parietal and basal tubercles, but Delpy (1941) followed Iredale (1917) in considering *Campanile symbolicum* Iredale, 1917 to be the type species. *Campanile symbolicum* lacks the two strong folds on the columella of *C. giganteum*, and Delpy suggested the use of *Campanilopa* Iredale, 1917 (type species *C. giganteum*) for the giant campaniles which she considered arose in about the Santonian and ranged through the Oligocene. Species of late Tertiary age have one or no folds, as does the modern Australian species. Houbriek (1981) did not consider the number of folds diagnostic in *Campanile*, and Delpy (1941) and Kollmann (1987) included Cretaceous species having one fold in Campanilidae. Houbriek's (1981, 1988, 1989) delineation of Campanilidae is based on soft-part anatomy, unavailable in Pacific coast Cretaceous specimens. Shell features that pertain to Campanilidae include the overall elongate, turritid-conoidal shape; the short anterior canal; simple outer lip; the thick calcified periostracum that produces a finely pitted and striated shell surface; and a growth line that is opisthocline across the whorl flank and curves forward toward the aperture near the posterior suture. The anal sulcus of campanilids is less deep and less narrow than that of nerineids and is not as tightly juxtaposed to the suture.

As Houbrick (1984) has noted, the whole spectrum of *Campanile*-like fossil forms is in need of a thorough revision, and he suggested that Campanilidae was more diverse in the Tertiary than indicated by Delpy (1941), but he mentioned only *Dirocerithium* Woodring and Stenzel, in Woodring, 1959 by name. Cretaceous genera that resemble campanilids and might belong in this family include *Macrocerithium* Stephenson, 1952 (type species *Cerithium tramitense* Cragin, 1893, Cenomanian, Woodbine Formation of Texas) and *Nudivagus* Wade, 1917 (type species *Nudivagus simplicus* Wade, 1917, Maastrichtian, Ripley Formation, Coon Creek, McNairey Co., Tennessee). *Serratocerithium* Vignal, 1897, based on *Cerithium serratum* Bruguière, 1792 of the Paris Basin Eocene, was included by Wenz (1939) in Campanilinae, but its shell lacks the finely pitted and striated surface of *Campanile*. Another Tertiary genus having a form and growth line similar to that of *Campanile* is *Perucercerithium* Olsson, 1929, based on *Cerithium* (*P.*) *restinense* Olsson, 1929, of the Peruvian Eocene. In general, Mesozoic cerithiform gastropods are poorly known. Reasons for this lack of knowledge include poor preservation, the gastropods' probable preference for very shallow-water habitats that are less commonly preserved than more offshore habitats, and the misperception that such gastropods are poor age indicators and unrewarding to study.

This is the first allocation of a Cretaceous North American species to the Campanilidae.

Genus DIOZOPTYXIS Cossmann, 1896 (emend. Delpy, 1941, and Kollmann, 1987)

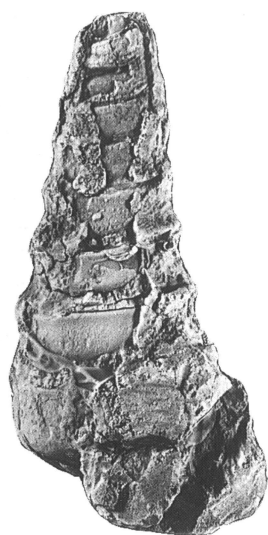
Type species. *Nerinea monilifera* d'Orbigny, 1842, by original designation; from the Cenomanian of France.

Remarks. Although, as previously mentioned, *Diozoptyxis* was originally described by Cossmann (1896, 1906) as a nerineid with three internal folds, it has been recognized as a campanilid by Kollmann (1987) and Kollmann and Peza (1997) based on the characteristics of d'Orbigny's specimens of the type species *Nerinea monilifera*. The California specimens share with species assigned to *Diozoptyxis*, as recognized by Delpy (1941), Kollmann (1987) and Kollmann and Peza (1997), an overall sculpture pattern, single columellar fold, and a sigmoidal growth line. Cossmann (1896) gave *Diozoptyxis* two columellar folds, but Delpy (1941), Kollmann (1987) and Kollmann and Peza (1997) agree that it has but one. Kollmann (1987) characterized *Diozoptyxis* as having a low whorl height to diameter ratio, two noded carinae, and a weak fold on the lower part of the columella. Furthermore, this fold is only developed in the last whorl (Kollmann and Peza 1997).

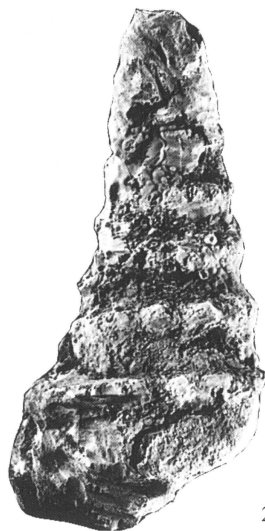
Allison (1955) reported *Diozoptyxis* cf. *pilgrimi* from the middle Albian. His figure is a drawing of a section through his only specimen, a fragment of a large individual having two columellar folds, a labral fold, and a wide umbilicus. It is not a *Diozoptyxis* in the sense of Delpy (1941) and Kollmann (1987). The fold pattern and the umbilicus are similar to those of the ill-proposed *Adiozoptyxis* Dietrich (1914, 1925) and to *Pchelincevia* Lyssenko and Aliev (1987) which has for its type species *Nerinea renauxiana* d'Orbigny, 1842, the species that Pchelintsev (1965) incorrectly tried to substitute for *Nerinea monilifera* d'Orbigny, 1842 as type species of *Diozoptyxis*.

EXPLANATION OF PLATE 1

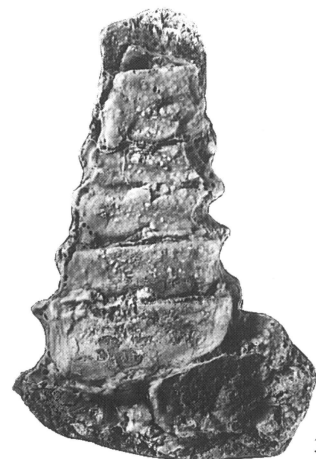
Figs 1–6. *Diozoptyxis ursana* sp. nov. 1–4, LACMIP loc. 10905, Bear Creek, California. 1–2, LACMIP 7908, holotype, $\times 1.7$; 1, apertural view; 2, abapertural view. 3–4, LACMIP 7909, paratype; $\times 2.2$; 3, apertural view; 4, abapertural view. 5, LACMIP 7910, paratype; LACMIP loc. 23621, Chico Creek, California; apertural view; $\times 3$. 6, LACMIP 7911, paratype; LACMIP loc. 15797, Bear Creek, California; latex peel; $\times 1.9$. Figs 7–10. *Potamidopsis? grovesi* sp. nov.; North Fork of Cottonwood Creek, California. 7–8, CASG loc. 62583; latex peels. 7, CASG 67884.01, holotype; $\times 7.3$. 8, CASG 67885.01, paratype; $\times 9.2$. 9, CASG 67885.03, paratype; CASG loc. 62606; $\times 6$. 10, CASG 67885.02, paratype; CASG loc. 62583; $\times 5.5$. All specimens coated with ammonium chloride.



1



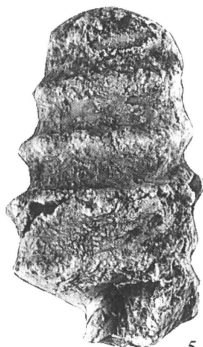
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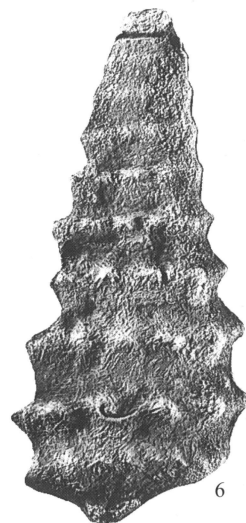
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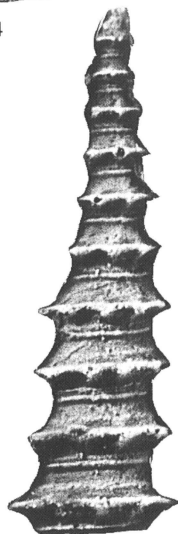


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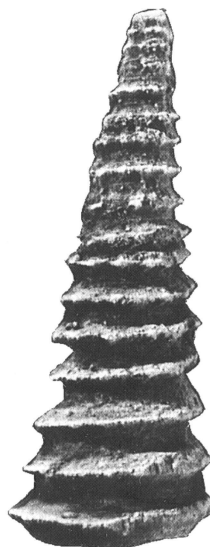
7

Holotype
CAS 67864.01



8

Paratype
CAS 67866.01



9

Paratype
CAS 67865.03
loc. 67606



10

Paratype
CAS 67865.02
loc. 67583

SAUL and SQUIRES, *Diozoptyxis*, *Potamidopsis*?

Diozoptyxis ursana sp. nov.

Plate 1, figures 1–6

- 1959 *Telescopium* n. sp. Saul, p. 116, pl. 10, fig. 8.
 1959 *Tympanotonus* n. sp. Saul, p. 117, pl. 10, fig. 11.
 1959 *Potamides?* sp. Saul, p. 117, pl. 10, fig. 10.

Derivation of name. The specific name is derived from Latin for bear *ursus*, reflecting the occurrence of this species in the Bear Creek drainage.

Holotype. LACMIP 7908.

Type locality. LACMIP loc. 10905, Bear Creek, Shasta Co., California, latitude 40° 33' 54" N, longitude 121° 54' W.

Paratypes. LACMIP 7909 from LACMIP loc. 10905; 7910 from LACMIP loc. 23621; 7911 from LACMIP loc. 15797.

Diagnosis. A *Diozoptyxis* with the posterior carina prominent and having larger nodes, the anterior one weaker with smaller, weaker nodes becoming obsolete.

Description. Shell medium sized, turrated-conical with an elongate and narrow upper spire; pleural angle 20–25°. Protoconch unknown. Teleoconch consisting of more than nine whorls with noded posterior carina at posterior suture and subordinate barely noded anterior carina posterior to rounded basal angulation; whorl flanks concave between posterior and anterior carinae, rounding abruptly into convex base; base with about three weak, equidistant medial spirals. Growth line strongly opisthocline across whorl side and on to base, reversed at posterior carina. Columella thick, bearing one fold near the base. Aperture rhomboidal? with slightly twisted, short anterior canal; outer lip unknown.

Dimensions of holotype. Height 36.6 mm, diameter 16.8 mm.

Remarks. The single fold on the columella of this species is suggestive of *Diozoptyxis*. The whorl diameter/height ratio is 2.3. *Diozoptyxis ursana* resembles *Diozoptyxis monilifera* (d'Orbigny) (Cossmann 1896, pl. 2, fig. 5) but has larger nodes on its posterior carina and weaker anterior nodes. *Diozoptyxis ursana* is similar in overall shape to *Aphanoptyxis californica* from which it differs in having larger, fewer, more persistent nodes on the posterior carina; the posterior carina slightly farther from the suture; the basal angulation more rounded and the base more convex; and a relative narrower and less twisted columella. Although poor preservation makes observation of the anterior canal and columellar fold difficult, some specimens suggest that the anterior canal is longer than in *A. californica*. *Aphanoptyxis californica* has a single parietal fold on the posterior part of the body whorl. Because in most specimens of *D. ursana* the shell is leached and partially peeled away, specimens of *D. ursana* are difficult to separate from those of *A. californica*. *Diozoptyxis ursana* appears to lack the spiral sculpture of *A. californica*.

Diozoptyxis ursana has been found in two areas: near the base of the Bear Creek Sandstone Member of the Redding Formation in the Bear Creek area, Shasta Co.; and in the Musty Buck Member of the Chico Formation on Chico Creek, Butte Co., California. In the Bear Creek area, specimens are common but usually leached, somewhat flattened, and difficult to extract. That so few specimens are at hand for study is a reflection of their preservation rather than their abundance: LACMIP loc. 10905 – three specimens, LACMIP loc. 15758 – three specimens, LACMIP loc. 15761 – one specimen, LACMIP loc. 15797 – one specimen, LACMIP 15944 – three? specimens. At LACMIP loc. 15944 leached and flattened molluscs are associated with carbonized plant remains. The molluscs include, in addition to *D. ursana*, two other kinds of cerithiform gastropods, namely a *Pyrazus?* and a potamidid or batillariid. Ammonites from overlying beds of this member provide a Coniacian age (Haggart 1986) for the marine part of this member, and Haggart (1986) inferred

that the depositional environment of this part of the member was shallow marine (inner shelf). The specimens of *D. ursana* at these localities are in coarse-grained, porous sandstone beds in lenses of coquina associated with abundant plant remains, and they and another undescribed cerithiform gastropod are the largest specimens. These *D. ursana* show a characteristic outline with each whorl projecting more than the previous one and having a stronger projection than that of *A. californica*. Flattening of the specimen causes them to have a much wider pleural angle than *A. californica*. Despite this poor preservation, a sigmoidal growth line, opisthocline across the anterior portion of the flank, is discernible on several specimens.

In the Chico Creek area, specimens of *D. ursana* were collected at LACMIP locs 23621 (two specimens), 23622 (one specimen), and 23625 (one specimen) in the Musty Buck Member of the Chico Formation approximately 100 m below occurrences of *Baculites capensis* Woods, 1906 (Saul 1959). All of these specimens are of early Santonian age (Matsumoto 1960; Haggart and Ward 1984). Russell *et al.* (1986) inferred that the depositional environment of this member in the Chico Creek area was the seaward edge of a delta complex. Specimens of *D. ursana* from these localities are small fragments with poor to moderately good preservation.

Distribution. Northern California, vicinity of Bear Creek, Shasta Co., Redding Formation, Bear Creek Sandstone Member; and Chico Creek, Butte Co., Chico Formation, Musty Buck Member.

Stratigraphical range. Coniacian and lower Santonian.

Family POTAMIDIDAE H. and A. Adams, 1854?

Genus POTAMIDOPSIS Munier-Chalmas, *in* Chédeville, 1904

Type species. *Potamidopsis tricarinata* (Lamarck, 1804) [*Cerithium*], by original designation; from the Eocene, Bartonian, 'Sables Moyén', Paris Basin, France.

Potamidopsis? grovesi sp. nov.

Plate 1, figures 7–10

Derivation of name. The species is named after Lindsey T. Groves in recognition of his assistance.

Holotype. CASG 67884.01.

Type locality. CASG loc. 62583, North Fork Cottonwood Creek, Shasta Co., northern California; latitude 40° 28' 12" N, longitude 122° 36' 40" W.

Diagnosis. A questionable *Potamidopsis* with a very protruding medial carina.

Description. Shell small, high spired, aciculate, multi-whorled, with flaring antemedial carina. Pleural angle about 13°. Whorl profile above and below carina concave, base concave, anterior canal short; edge of carina rippled by elongate nodes; whorl with a cord posterior to carina, a cord anterior to carina, and a weak cord at posterior suture; anterior cord strong, at base of whorl; posterior cord about midway between carina and suture. Suture at basal cord. No axial sculpture. Inner whorl shape round, without folds. Columella thick. Growth line appears prosocline at posterior suture with broad medial sinus, deepest near carina. Aperture unknown.

Measurements. Holotype CASG 6788.01: height 10 mm, diameter 3 mm, height of largest whorl 1.3 mm. Paratype CASG 67885.01 from CASG loc. 62583: height 9.5 mm, diameter 2 mm. Paratype CASG 67885.02 from CASG loc. 62583: height 11 mm, diameter 1.75 mm. CASG 67885.03 from CASG loc. 62606: height 11.6 mm, diameter 4.2 mm.

Remarks. Available specimens (five) are small and may all be juveniles. There are several from the type locality. Some are preserved as exquisite natural moulds; others have the shell preserved. The suture is against the basal cord and a moderate cord of the succeeding whorl is appressed to the

basal cord. The narrow pleural angle and rather thick columella suggest nerineids, but unlike most high-spined nerineids *P.?* *grovesi* has a convex whorl profile, made even more so by the flaring carina, and a suture that is at a narrower part of the whorl. The elongate nodes of the carina are not apparent posterior to the carina, but they have a short abapical expression. Growth lines are difficult to discern on these small specimens, but irregularities of the whorl surface suggest a growth line with a broad medial sinus.

The new species is surprisingly similar to *Potamidopsis tricarinatus crispicentis* Boussac, 1905 (Lutetian and Bartonian stages, Paris Basin, France). *Potamidopsis?* *grovesi* differs from *P. tricarinatus crispicentis* in having fewer more elongate nodes on the carina and stronger and unnoded cords posterior to the carina. *Potamides?* *grovesi* also resembles *Campanile (Diozoptyxis) ataxense* (d'Orbigny) (Delpey 1941, p. 10, fig. 10) from the Santonian of Corbières, France, but the strong carina of *P.?* *grovesi* is more medially placed.

The associated fauna at the type locality of *P.?* *grovesi* includes the bivalves *Nanonavis breweriana* (Gabb, 1864), *Plicatula variata* Gabb, 1864, and a gastropod '*Potamides*' *diadema* Gabb, 1864. *Potamidopsis* has been known previously only from late Paleocene and early mid Eocene brackish-marine strata in France (Gilbert 1962) and early mid Eocene brackish-marine strata in southern California (Squires 1991).

Distribution. Northern California, Budden Canyon Formation, Ogo Member (CASG locs 62583 and 62606).

Stratigraphical range. Lower Cretaceous (Hauterivian).

Subclass HETEROBRANCHIA Gray, 1840

Order HETEROSTROPHA Fischer, 1885

Superfamily NERINEOIDEA Zittel, 1873

Family NERINEIDAE Zittel, 1873

Genus APHANOPTYXIS Cossmann, 1896

Type species. *Cerithium defrancii* Eudes-Deslongchamps, 1843, by original designation; Middle Jurassic (Bathonian), Aubigny, France. M. J. Barker (pers. comm.) has shown us that Fischer (1969) considered *C. defrancii* Eudes-Deslongchamps, 1843 *non* Deshayes, 1833 to be a synonym of *Cerithium langruensis* d'Orbigny, 1850.

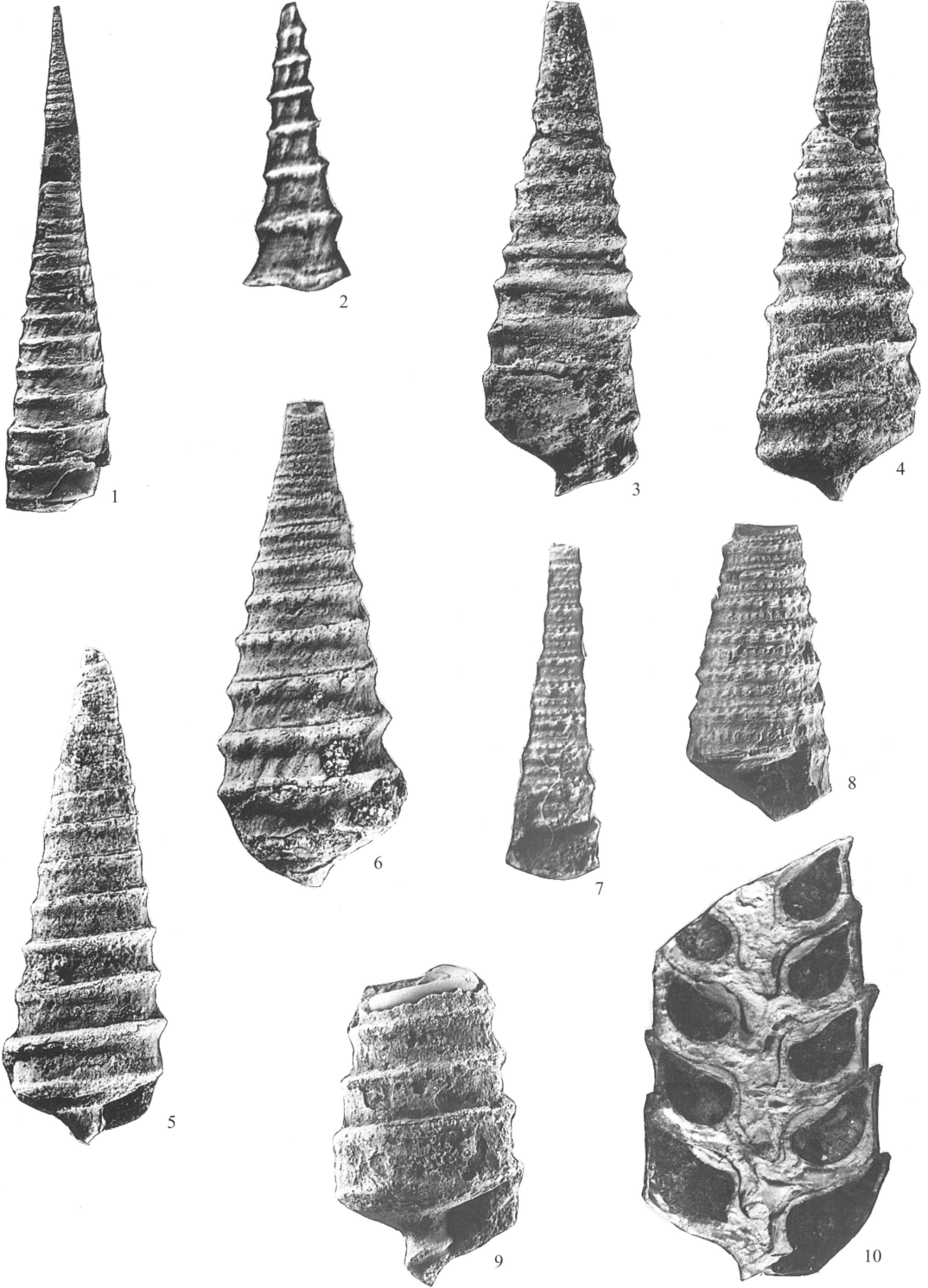
Diagnosis. Turrated-conical, multi-whorled nerineids of moderate size, with concave whorls; carina adjacent to suture, and weaker spiral ribs on the whorl face. Interior with no palatal or columellar plaits. No umbilicus. Columella terminated by a twisted anterior canal.

Remarks. The geological range of genus *Aphanoptyxis* is given as Middle Jurassic (Bathonian) to Lower Cretaceous (Urgonian) in Wenz (1940). The Urgonian, a diachronous, white-limestone facies

EXPLANATION OF PLATE 2

Figs 1–2. *Aphanoptyxis andersoni* nom. nov. = *Nerinea archimedis* Anderson, 1938; North Fork of Cottonwood Creek, California. 1, CASG 66460.02, holotype; CASG loc. 66460 (= CASG loc. 1353, in part); abapertural view; $\times 1.5$. 2, CASG 67886.01, holotype; CASG loc. 62583; latex peel; $\times 9.2$.

Figs 3–10. *Aphanoptyxis californica* sp. nov. 3–4, LACMIP 7912, holotype; LACMIP loc. 10761; $\times 1.9$. 3, apertural view; 4, abapertural view. 5, LACMIP 7913, paratype; LACMIP loc. 10761; $\times 2.6$. 6, LACMIP 7914, paratype; LACMIP loc. 10761; right-side view, low-level lighting shows opisthocline growth lines; $\times 3.3$. 7, LACMIP 7915, paratype; LACMIP loc. 10761; apical area; $\times 6$. 8, LACMIP 7916, paratype; LACMIP loc. 24649; upper spire; $\times 4.1$. 9, LACMIP 7917, paratype; LACMIP loc. 24649; apertural view showing twisted columella; $\times 2$. 10, LACMIP 7918, paratype; LACMIP loc. 24649; interior view; $\times 3.1$. All specimens, except that in figure 10, coated with ammonium chloride.



SAUL and SQUIRES, *Aphanoptyx*

of southern Europe, typically carries a Tethyan fauna rich in corals, rudists, and nerineas. Its age is predominantly Barremian to early Aptian, but, in places, ranges into the early Albian (Gignoux 1955; Ager 1980). Pchelintsev (1965) gave the range of *Aphanoptyxis* as Bathonian through Tithonian, but Kollmann (1976) extended the geological range of the genus into the late Albian. *Aphanoptyxis californica* extends the geological range of the genus into the Upper Cretaceous Turonian Stage.

Aphanoptyxis andersoni nom. nov.

Plate 2, figures 1–2

1938 *Nerinea archimedis* Anderson, p. 132, pl. 9, fig. 1 [*non Nerinea archimedi* d'Orbigny, 1842].

1938 *Nerinea* sp. Anderson, p. 132, pl. 9, figs 2–3.

Holotype. CASG 66460.02.

Anderson's hypotypes of Nerinea sp. CASG 66460.03–66460.04 from CASG loc. 66460.

Type locality. CASG 66460 (= CASG 1353 in part), North Fork Cottonwood Creek, Shasta Co., northern California; latitude 40° 28' 12" N, longitude 122° 36' 40" W.

Remarks. *Nerinea archimedis* Anderson is a junior homonym of *Nerinea archimedi* d'Orbigny, 1842, a species from the Lower Cretaceous of Europe. We herein place Anderson's species in *Aphanoptyxis* and rename it as *Aphanoptyxis andersoni* nom. nov. Specimens of *A. andersoni* are rare and none available shows a better cross section than those of Anderson (1938, pl. 9, figs 2–3). Neither CASG 66460.03 or 66460.04 is cut parallel to the columella; both are broken at low angle to the columella giving Anderson an impression of a wider pleural angle than that in CASG 66460.02. In addition to the specimens figured by Anderson (1938), a specimen (CASG 67886.01) from CASG loc. 62583, consisting of the early whorls of this species is figured. It is associated with *Plicatula variata* Gabb, 1864 and *Potamidopsis? grovesi* sp. nov. Of available specimens, only the holotype CASG 66460.02 is of comparable size to *A. californica*, and the others are smaller and less complete. The two species are very similar: *Aphanoptyxis andersoni* differs from *A. californica* in lacking the median spiral cord on the early adult whorls, in having finer nodes, and in having a pleural angle near 14° rather than 18°.

Distribution. Near Ono, Shasta Co., northern California, Budden Canyon Formation, Ogo Member.

Stratigraphical range. Lower Cretaceous, Hauterivian.

Aphanoptyxis californica sp. nov.

Plate 2, figures 3–10

Derivation of name. The species is named for the state of California.

Holotype. LACMIP 7912.

Type locality. LACMIP loc. 10761, Little Cow Creek valley, Shasta County, northern California; latitude 40° 40' 22" N, longitude 122° 8' W.

Paratypes. LACMIP 7913–7915 from LACMIP loc. 10761; 7916–7918 from LACMIP loc. 24649.

Diagnosis. An *Aphanoptyxis* with a noded carina at posterior suture, a low medial spiral cord, and an anterior cord at the angle between whorl side and base; carina more prominent on adult whorls than on juvenile whorls, medial spiral rib obsolete on adult whorls.

Description. Shell medium sized (up to 38.7 mm high), turritid-conical, multi-whorled (about 14 whorls), with an elongate and narrow upper spire. Pleural angle about 18°. Very early whorls (approximately first 13 mm of

growth) nearly flat-sided, later whorls concave, with deepest part medially. Protoconch unknown. Sculpture at diameter 0.5 mm to 2.3 mm of four noded spiral cords, each with numerous nodes; sutural cord finely noded, at suture; posterior cord strongest, most coarsely noded; medial cord weaker and more finely noded; basal cord barely as strong as posterior cord, nodes stronger than on medial and smaller than on posterior cord; sculpture at diameter 2.3 mm to 4.8 mm of coarsely noded posterior cord; medial cord becomes band of collabral (opisthocline) riblets; basal cord barely visible, nearly overlapped by succeeding whorl; sculpture at greater diameters becoming obsolete, basal cord overlapped by suture; posterior cord protruding on adult whorls. Base of body whorl slightly convex with faint spirals, a slight depression adjacent to anterior carina followed by spiral row of low nodes. Aperture small, wider than high; columella short and rising to form sharp rim bordering posterior side of anterior canal. Anterior canal strongly twisted, almost at right angle to columella, and well defined by strongly raised borders. Outer lip unknown. Whorls without interior plaits, except for a single parietal plait on posterior portion of body whorl. Whorl interiors with posterior constriction, resembling a gutter. Interior of columella complexly layered. Growth lines indistinct, opisthocline? across whorl flank and especially on anterior slope of posterior carina, looping? sharply forward across posterior carina.

Dimensions of holotype. Height 38.7 mm, diameter 12 mm.

Remarks. Specimens are moderately numerous, and preservation is poor to moderately good. Many of them are weathered and abraded. The shell surface tends to peel, and growth lines are obscure except on the base. Nearly all of the specimens are missing the early whorls. The holotype has the greatest height of any specimen found. A fragment from LACMIP loc. 10780 has the greatest diameter (15.5 mm) of any specimen found. An inferred complete specimen of the new species is estimated to be approximately 45 mm high and approximately 16 mm wide. A whorl with diameter of 11.3 mm is 4.6 mm high, giving a ratio of 2.5.

The sculpture changes from early to later whorls. Uppermost whorls have a noded spiral thread next to the posterior suture, a noded spiral cord forming a posterior carina, a less angulate noded spiral cord on the medial part of the whorl, and a noded spiral thread next to the anterior suture. Nodes on the medial cord of these early whorls start out as beads, then change into opisthocline, short, axial ribs at a diameter of about 3–5 mm. Middle spire whorls have a swollen noded spiral carina next to the posterior suture and a fading band of riblets on the medial part of the whorl. The spiral cord next to the anterior suture becomes a low unmoded swelling. Later whorls have an unnoded, much projecting, tabulate carina next to the posterior suture and the rest of the whorl is smooth, concave-sided, with a slight spiral swelling next to the anterior suture.

In the Hornbrook area, Siskiyou Co., ten specimens of the new species were collected at a single locality in Shasta Valley, LACMIP loc. 27228, from the Osburger Gulch Sandstone Member of the Hornbrook Formation. Nilsen (1984) reported the age of this member in Shasta Valley as Turonian, based on abundant molluscan fossils, including ammonites, bivalves, and gastropods, and he considered that this member was deposited under high-energy, shallow-marine conditions. The Osburger Gulch Sandstone Member specimens of *A. californica* are poorly preserved but show the prominent spiral carina next to the posterior suture.

In Little Cow Creek valley, Shasta Co., the new species was found at four localities in the Bellavista Sandstone Member of the Redding Formation: LACMIP 10761, 10780, 10784, and 24649. These localities are also plotted on a generalized geological map in Jones *et al.* (1978, fig. 5). The age of this member is Turonian, based on ammonites (Jones *et al.* 1978; Haggart 1986). Haggart (1986) inferred that the depositional environment of the member was inner to middle shelf. Specimens are most abundant at LACMIP loc. 24649 [= UCLA loc. 4649 of Jones *et al.* 1978], where about 100 were collected, including some upper spire fragments. The specimens were in a coquina, faunally dominated by the new species. About 40 specimens, including some upper spire fragments, were collected at LACMIP loc. 10784 [= CIT loc. 1009 of Jones *et al.* 1978]. Of these specimens, about one-half are small fragments. Nearly all of the larger specimens are abraded. Their sculpture is much reduced, and the whorls are flat sided with only low spiral bands. This locality is stratigraphically the lowest of four localities, and the specimens were subjected to abrasion caused

by agitated-water conditions associated with deposition of the basal part of the member. Sixteen specimens were collected at LACMIP 10761 [= CIT loc. 1439 of Jones *et al.* 1978]. This locality is stratigraphically the highest of four localities and represents the deepest water and least agitated-water conditions of the member. Specimens from this locality were subjected to the least amount of abrasion. They are the best preserved specimens of *A. californica* available. Only four specimens were collected at LACMIP loc. 10780 [= CIT loc. 1193 of Jones *et al.* 1978]. They are badly corroded, but one moderately well preserved specimen shows some abrasion.

The new species is very close to *A. andersoni* from the Lower Cretaceous (Hauterivian Stage) of Cottonwood Creek, Shasta Co., northern California. In addition to differences mentioned under *A. andersoni*, *Aphanoptyxis californica* differs from *A. andersoni* in the following features: carina stronger and more strongly noded, and medial spiral rib stronger on early adult whorls. The two species are so similar that slightly weathered specimens of the two are indistinguishable.

Aphanoptyxis californica closely resembles *Aphanoptyxis excavata* (Brongniart 1822, pl. 9, fig. 10; Kollman 1976, pp. 173–174, pl. 2, figs 13–16; pl. 3, figs 17–19) from the Lower Cretaceous (middle Albian) of Poland and Lower Cretaceous (upper Albian) of France and England (Kollmann 1976). *Aphanoptyxis californica* differs from *A. excavata* in having whorls that are wider than high, a noded posterior carina, and, on the early whorls a medial spiral cord or band of riblets.

The new species also resembles *Aphanoptyxis* aff. *sturi* (Stolickza) Kollmann (1982, p. 351, pl. 2, fig. 35; pl. 4, fig. 56) from the Upper Cretaceous (Cenomanian) of Romania and Greece and Upper Cretaceous (Turonian) of Bulgaria (Kollmann 1982). Although poor preservation makes comparison with *Aphanoptyxis* aff. *sturi* difficult, *Aphanoptyxis californica* differs by having a medial spiral cord or riblets on the early whorls and a less heavily noded carina on the adult whorls.

The new species resembles *Aphanoptyxis bladonensis* Arkell (1931, pp. 618–619, pl. 50, figs 8–13) from the upper Great Oolite in England of Middle Jurassic, Bathonian age (Gignoux 1955; Harland *et al.* 1990), *aspidoidea* zone (M. J. Barker, pers. comm.). The new species differs from *A. bladonensis* by having a medial spiral cord or riblets on the early whorls and a projecting carina on the much more concave adult whorls.

Aphanoptyxis californica also somewhat resembles *Macrocerithium tramitense* Cragin, 1893 (p. 222; Stephenson 1952, p. 160, pl. 37, figs 23–29) from the Upper Cretaceous (Cenomanian) Lewisville Member of the Woodbine Formation in north-eastern Texas. The genus *Macrocerithium* is known solely from this species, which has been reported only from Texas. *Macrocerithium tramitense*, whose growth lines are very similar to those of *A. californica*, might be a nereinid. A study of the interior of *M. tramitense* or recovery of a protoconch, both presently unknown, should greatly assist in its classification. The new species differs from *M. tramitense* in the following features: spiral cords on upper spire more strongly noded, no fine intermediate spiral riblets on upper spire, broader pleural angle, sides of adult whorls concave, spiral carina next to the posterior suture on adult whorls much more heavily noded and more projecting, posterior part of twisted anterior canal much stronger. The adult whorls of *M. tramitense* have subdued sculpture which may result from abrasion. In fact, Stephenson (1952) noted that most of the specimens of *M. tramitense* are corroded. If the abraded adult specimens of the new species from LACMIP loc. 10784 are compared with *M. tramitense*, then the adult whorls of the two species show a greater similarity, in that they both have a low spiral rib next to the positive suture and they both have flattish whorls. Also like *A. californica*, *M. tramitense* is found abundant in shallow-marine coquinas that are faunally dominated by it.

The new species resembles the figures of *Cerithium depressum* (Zekeli 1852, p. 116, pl. 24, figs 6–7) from the Rondobach part of the Gosau Group, north-eastern Alps, west-central Austria. Summesberger (1985) assigned this part of the Gosau Group to the Upper Cretaceous (Santonian). *Aphanoptyxis californica* has a narrower pleural angle, a flatter whorl profile, and a weaker less noded medial spiral rib on the later whorls.

Distribution. Northern California: Hornbrook Formation, Osburger Gulch Sandstone Member, just south of the California–Oregon border, Siskiyou County (LACMIP loc. 27228); and Redding Formation, Bellavista

Sandstone Member, Little Cow Creek valley, Shasta County (LACMIP locs 10761, 10780, 10784, 24649).

Stratigraphical range. Upper Cretaceous (Turonian).

Genus *NERINELLA* Sharpe, 1850

(= *Nerinoidea* Wenz, 1940; *non Nerinella* Nardo, 1847 (ICZN Opinion 316; 1954))

Type species. *Nerinea dupiniana* d'Orbigny, 1842, by original designation; Lower Cretaceous (Hauterivian), France.

Diagnosis. Slender, acicular multiwhorled nerineids of moderately large length but small diameter, with concave whorl profile, protruding sutural ridges (suture between two spiral ribs), and granulate spiral costae. Interior with one palatal plait, one or two columellar plaits, and a weak or absent parietal plait. No umbilicus.

Remarks. Wenz (1940) provided the new name *Nerinoidea* for *Nerinella* Sharpe, 1850 *non* Nardo, 1847, and he considered *Nerinoidea* to be a subgenus of *Aptyxiella* Fischer, 1885. Kase (1984) recognized *Nerinoidea* Wenz as a distinct genus. Cox (1951) applied for an ICZN ruling that would conserve *Nerinella* Sharpe, 1850. *Nerinella* Sharpe, 1850 was subsequently placed on the *Official List of Generic Names in Zoology*, and its type species *Nerinea dupiniana* d'Orbigny, 1843 was placed on the *Official List of Specific Names in Zoology* (ICZN 1954). *Nerinella* is, in general, longer and more slender than *Nerinea*. According to Abbass (1963), on some specimens of *Nerinella*, the columellar and parietal folds virtually disappear. The geological range of *Nerinella* is lowermost Jurassic (Hettangian) to uppermost Cretaceous (Maastrichtian) (Wenz 1940).

Three Pacific Slope species are here included in *Nerinella*.

Nerinella parallela (Anderson and Hanna, 1935)

- 1934 [?]*Nerinella* sp. Nagao, p. 251, pl. 38, figs 8–10.
 1935 *Turritella parallela* Anderson and Hanna, p. 26, pl. 9, figs 1–3.
non 1942 '*Turritella* sp. cf. *T. parallela*' Anderson and Hanna; Popenoe, p. 179 [= *Turritella hearni* Merriam, 1941].
 1955 *Aptyxiella (Endiatricheus) parallela* (Anderson and Hanna); Allison, p. 426, pl. 43, figs 8–9.
 1958 *Nerinea parallela* (Anderson and Hanna); Anderson, p. 155.

Remarks. As indicated by Allison (1955), who collected this species near Punta China from several localities in the Alisitos Formation from both the lower and upper members, the recorded locality information (Burckhardt 1930, p. 259) is misleading, and the species has not subsequently been found in the 'Catarina' = Rosario Formation. Although Anderson and Hanna (1935) gave the age as 'Late Cretaceous', and the locality as '2 miles east of Puerto Catarina' [= Santa Catarina Landing], Baja California, the species has not been recovered from rocks of Late Cretaceous age nor from outcrops within 2 miles of Santa Catarina Landing. Their material was probably from the Alisitos Formation, which crops out more than 3.2 km (2 miles) north, south, and east of Santa Catarina Landing, Baja California, Mexico, and is of Early Cretaceous, Aptian–Albian age.

Allison (1955) considered *Nerinea quadrilineata* Stanton, 1947, of Aptian to late Albian age, from the Edwards Limestone and Glen Rose Limestone, south-west of Forth Worth, Texas, to be a synonym of *A. (E.) parallela*. In overall shape, type of sculpture, and internal structures, *N. quadrilineata* appears to be a *Nerinella*, but judging from Stanton's figures, it differs from *N. parallela* in having a more concave whorl profile, the spiral ribs weaker, more widely spaced, more finely beaded, and of more nearly equal strength, and a well developed sutural ridge.

Nerinella parallela has a straighter whorl profile, coarser sculpture, and a narrower pleural angle than *Nerinella maudensis* (Whiteaves, 1884). If *N. maudensis* is of Albian age, then *N. parallela* is the earliest known *Nerinella* from the Pacific coast of North America.

Beaded ribs and a narrow pleural angle make *Nerinella parallela* more similar to *N. santana* than to *N. maudensis*. *Nerinella parallela* lacks the strong sutural ridge of *N. santana* and has more, less strongly beaded spiral ribs.

Distribution. Baja California, Mexico.

Stratigraphical range. Aptian–Albian.

Nerinella santana sp. nov.

Plate 3, figures 1–6

Derivation of name. The species is named for the Santa Ana Mountains.

Holotype. LACMIP 7919.

Type locality. LACMIP loc. 8170, Santa Ana Mountains, Orange County, southern California; near latitude 33° 30' N, longitude 117° 30' W.

Paratypes. LACMIP 7920–7923, all from the same locality.

Diagnosis. A *Nerinella* with four noded spiral cords bearing ten or eleven nodes; interior with a strong palatal plait and a medial columellar plait.

Description. Shell elongate, length in excess of 80 mm at 5 mm diameter, multiwhorled, whorls wider than high (height of whorls about 60 per cent. of diameter), incremental angle of whorl sides extremely small, pleural angle about 5°. Very early whorls nearly flat sided, later whorls concave, with deepest part medially. Protoconch unknown. Aperture unknown. Sculpture of four noded spiral cords, each with ten or eleven nodes: anterior (first) cord forming basal keel of whorl, slightly weaker than second cord; second cord near anterior quarter line, strongest, bearing largest nodes; third cord near posterior quarter line, weakest with finest nodes; fourth cord at suture, tightly appressed to first (basal) cord, commonly slightly stronger than the first cord. Interior with a strong palatal plait near mid whorl, a medial columellar plait, and possibly an anterior columella plait. Columella moderately thick.

Dimensions of holotype. Height 43.9 mm, diameter 8.7 mm.

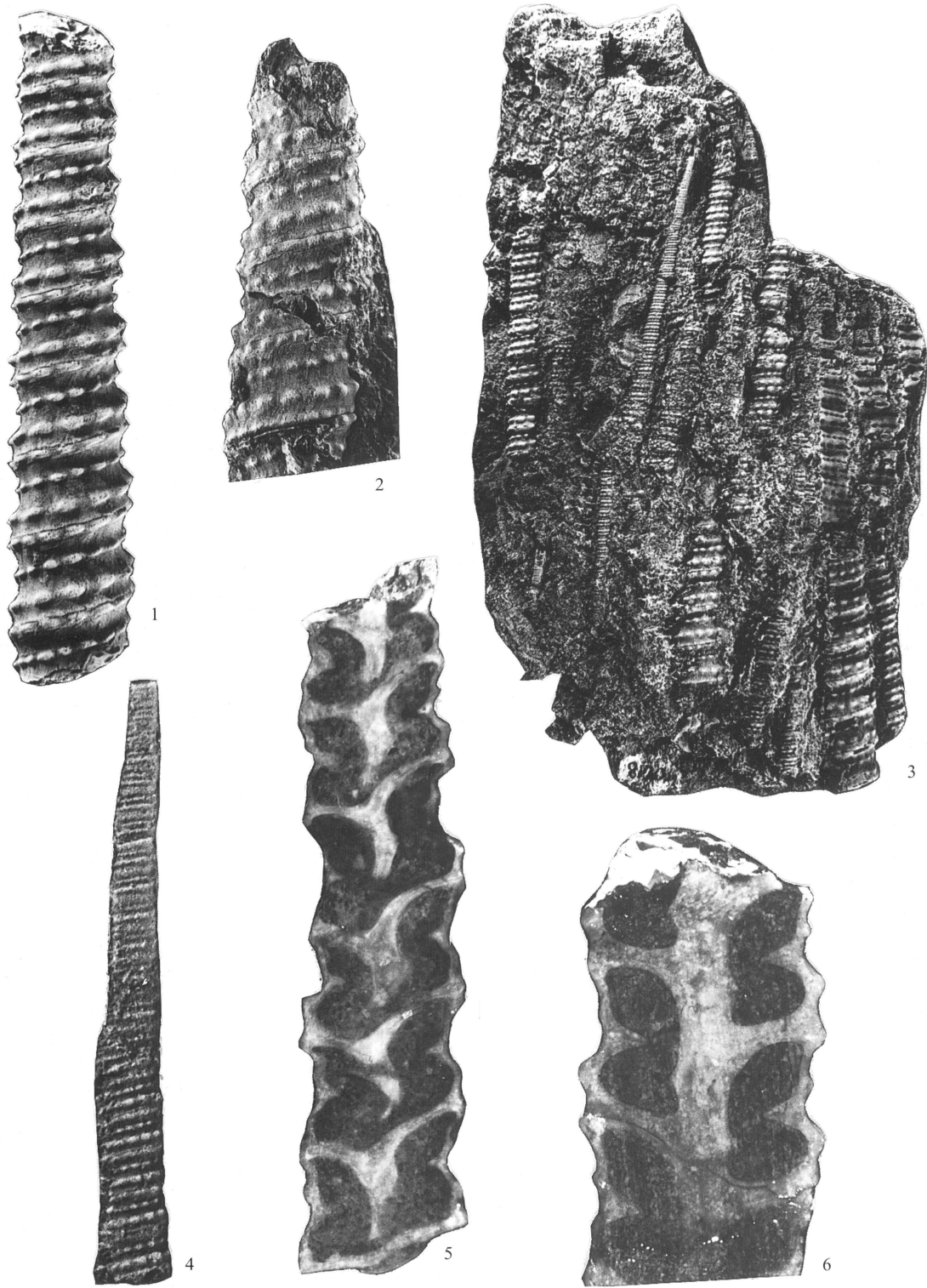
Remarks. Although occurrences are rare, specimens are locally abundant, and preservation is good. The specimens are in a single block of sandstone and show preferred orientation (Pl. 3, fig. 3). The longest specimen, height 76.9 mm, is incomplete both apically and basally and has a maximum diameter of 5.4 mm. The specimen with the greatest diameter, 10.5 mm, is also broken apically and basally, but its diameter indicates that this very slender species would have exceeded 150 mm in height.

The hand specimen containing the new species was collected as float, but the lithology – coarse-grained, very micaceous quartz sandstone – indicates that the stratigraphical horizon is probably a sandstone in the Baker Canyon Member of the Ladd Formation. The sedimentological details of

EXPLANATION OF PLATE 3

Figs 1–6. *Nerinella santana* sp. nov.; LACMIP loc. 8170; Santa Ana Mountains, California. 1, LACMIP 7919, holotype; abapertural view; $\times 2.4$. 2, LACMIP 7920, paratype; $\times 2.2$. 3–4, LACMIP 7921, paratype; 3, hand specimen showing preferred orientation of specimens; $\times 0.93$; 4, apical area of specimen shown in upper middle part of figure 3; $\times 4.8$. 5, LACMIP 7922, paratype; interior view; $\times 4.4$; 6, LACMIP 7923, paratype; interior view; $\times 5.7$.

All specimens, except those in figures 5–6, coated with ammonium chloride.



SAUL and SQUIRES, *Nerinella*

this member indicate a fluctuating, moderate to high-energy, lower to upper shoreface palaeoenvironment associated with a fan-delta setting (Cooper *et al.* 1982). A late Turonian age for the member is indicated by the ammonites *Subprionocyclus normalis* (Anderson, 1958) and *Subprionocyclus cf. neptuni* (Geinitz, 1849) (Saul 1982). Associated fossils at the type locality of the new species are an undescribed cerithioidian? gastropod and bivalves, including specimens of ribless small pectinids, *Crassatella gamma* Popenoe, 1937, and an impression of *Alleinacin sulcata* (Packard, 1922). This last-named bivalve species is an abundant and characteristic faunal element in the Baker Canyon Member (Popenoe 1937; Squires and Ritterbush 1981).

Nerinella santana is much more strongly sculptured than the type species, *N. dupiniana*. *Nerinella santana* is similar to *Nerinella quadralineata* (Stanton, 1947, p. 88, pl. 62, figs 1–2) from north-eastern Texas in the upper part of the Glen Rose Limestone, of early Albian Age (Stephenson *et al.* 1942). *Nerinella santana* differs from *N. quadralineata* in having a wider (5° rather than 3°) pleural angle and fewer spiral cords. Despite its name, *N. quadralineata* has five to six cords rather than the four of *N. santana*. Both species appear to have one fewer cord than is actually present because the first and last cords are tightly appressed, with only the fine line of the suture between them to indicate that what seems to be one cord is actually two cords.

The exterior of the new species is similar to that of *Nerinea flexuosa* Sowerby (1832, pl. 38, fig. 16; Bronn 1836, p. 563, pl. 6, fig. 19; Goldfuss 1844, p. 47, pl. 177, fig. 7; Zekeli 1852, p. 38, pl. 5, fig. 5; Tiedt 1958, p. 504, text-fig. 11 as *Aptyxiella (Acroptyxis) flexuosa*) from the Upper Cretaceous of Austria. Internally, the new species differs from *N. flexuosa* by having much weaker columellar folds.

The interior of the new species resembles both *Nerinella stantoni* Cragin (1905, p. 98, pl. 21, figs 6–9; Shimer and Shrock 1944, p. 495, pl. 203, figs 9–11) from the Upper Jurassic of Texas and *Nerinea (Nerinella?) decipiens* Stanton (1947, p. 82, pl. 60, figs 1–3) from the Lower Cretaceous of Texas. Like the new species, these two Texas species have a palatal fold on the medial part of the outer wall surface, but the new species differs by having a weak columellar fold. Externally, the new species differs from *N. stantoni* by having spiral cords that are much stronger, fewer in number (three rather than four), and noded. Externally the new species differs less from *Nerinea (Nerinella?) decipiens* by having noded spiral cords and stronger spiral cords.

The interior of the new species resembles *Cossmannea imlayi* Sohl, 1965 (pp. D23–D24, pl. 4, figs 1–8) from the Middle Jurassic of central and southern Utah. Internally, *Cossmannea imlayi* has a palatal fold on the medial part of the outer wall surface and a very low, rounded, obscure columellar fold. The palatal fold persists from the earliest whorls, but the columellar fold does not develop until a late growth stage. Externally, the new species differs greatly from *C. imlayi* by having prominent sculpture rather than smooth whorls with a swollen sutural area. Sohl (1965) placed his species in the genus *Cossmannea* with some misgivings because his species lacked the strong columellar fold that is diagnostic of *Cossmannea*. It is possible that Sohl's species belongs in the genus *Nerinella*.

Nerinella santana has fewer and much more prominent spiral ribs, noded ribs, a weaker palatal plait, a medial columellar plait, and a thinner outer wall than does *Nerinella maudensis* (Whiteaves).

Distribution. All specimens are from a single piece of float consisting of coarse-grained sandstone, probably derived from the Baker Canyon Member of the Ladd Formation, Santa Ana Mountains, Orange County, southern California.

Stratigraphical range. Upper Cretaceous (Turonian).

Nerinella maudensis (Whiteaves, 1884)

1884 *Nerinaea maudensis* Whiteaves, p. 214, pl. 27, figs 2, 2a–2d.

Remarks. Whiteaves' description and figures suggest that his placement of this species in *Nerinella* is correct. Whiteaves (1884) reported *Nerinaea maudensis* from brittle and very friable shale at the east end of Maude Island, opposite Leading Island in Skidegate Inlet, Queen Charlotte Islands,

western British Columbia. On the geological map of McLearn (1949), this imprecise locality could plot in either the Yakoun Formation or the Haida Formation. Bolton (1965) listed the type specimens as being of Early Cretaceous age and from the Haida Formation. Haggart (1992) considered the Yakoun Formation to be of Mid Jurassic, Bajocian age, and the Haida Formation to range from the Early Cretaceous to the Late Cretaceous (Albian to mid Turonian). Other than Bolton's (1965) catalogue of the type specimens, we have seen no further report of the occurrence of this species, although Whiteaves (1884) said that it was not uncommon. According to J. W. Haggart (pers. comm.) the 'brittle and very friable shale' is probably the Haida Formation, and the species may be of Albian age.

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APPENDIX

Cited fossil localities

The localities are listed in groups corresponding to the following (arranged north to south) geographical areas in California: Hornbrook, Cottonwood Creek, Little Cow Creek valley, Bear Creek, Chico Creek, and Santa Ana Mountains.

Hornbrook

LACMIP 27228. SW 1/4, SW 1/4 Sec. 33, T47N, R7 [or 6?]N, U.S. Geological Survey, 15-minute, Hornbrook Quadrangle, 1955, Shasta Valley, Siskiyou County, northern California. Collector: M. Gaona, June, 1984. Hornbrook Formation, Osburger Gulch Sandstone Member. Age: Late Cretaceous, Turonian.

Cottonwood Creek

U.S. Geological Survey, 15-minute Ono Quadrangle, 1952, Shasta County, northern California. Budden Canyon Formation, Ogo Member. Age: Early Cretaceous, Hauterivian.
CASG 62606. In stream bottom of the North Fork of Cottonwood Creek, downstream from the Ono Bridge and stratigraphically below the section exposed in first large bluff (north side of creek) downstream from the bridge. Locality is 59.7 m (196 ft) stratigraphically above the mouth of Rector Creek.

CASG 62583. Downstream from the base of section of first bluff described above and 24 m (80 ft) stratigraphically above the base of section exposed in this bluff.

Little Cow Creek Valley

U.S. Geological Survey, 15-minute, Millville Quadrangle, 1953, Shasta County, northern California. Redding Formation, Bellavista Sandstone Member. Age: Late Cretaceous, Turonian.

LACMIP 10761 [= CIT 1439]. Upper part of Bellavista Sandstone Member, north side of Little Cow Creek, near north-east corner SW 1/4 Sec. 31, T33N, R2W, latitude 40° 40' 22" N, longitude 122° 8' W. Collector: W. P. Popenoe, March 19, 1940.

LACMIP 10780 [= CIT 1193]. Thin conglomerate beds interbedded with massive drab sandstone cropping out on east side of Stinking Creek Valley, estimated as 7.5 m stratigraphically above Triassic-Cretaceous contact, 2353 m (7720 ft) N70° 20' W from south-east corner Sec. 6, T32N, R3W. Collectors: W. P. Popenoe and Ahlroth, June, 21, 1936.

LACMIP 10784 [= CIT 1009]. Near base of Bellavista Sandstone member, sandstone cropping out on a small hill on the east bank of Willow Creek about 0.40 km (0.25 mi.) above its confluence with Salt Creek and about 91 m (300 ft) east of the creek channel, NE 1/4, NE 1/4 Sec. 34, T33N, R3W. Collectors: W. P. Popenoe and Scharf, August 11, 1931.

LACMIP 24649 [= UCLA 4649]. Gritty sandstone cropping out on east bank of Stinking Creek, 122 m (400 ft) west and 305 m (1000 ft) south of north-east corner Sec. 1, T32N, R4W. Collector: W. P. Popenoe, May 19, 1961.

Bear Creek

U.S. Geological Survey, 15-minute, Whitmore Quadrangle, 1956, Shasta County, northern California. Redding Formation, Bear Creek Sandstone Member. Age: Late Cretaceous, Coniacian.

LACMIP 10905. Massive sandstone in bed of Bear Creek, approximately 305 m (1000 ft) due west of the south-east cor. Sec. 6, T31N, R1E, U.S. Geological Survey, 15-minute, Whitmore Quadrangle, 1956, Shasta County, northern California. Collectors: W. P. Popenoe and W. M. Tovell, September 10, 1941.

LACMIP 15758. (P 63-36) Along Ponderosa Way east of Di Hill, descending into Snow Creek, 0.32 km (0.2 mi.) south-east of road fork, 450 m east, 480 m south of north-west corner Sec. 18, T31N, R1E, Whitmore 15' Quadrangle, Shasta Co., northern California. Collector: W. P. Popenoe, August 17, 1936.

LACMIP 15761 [= UCMP M7244]. Shell bed in fine-grained sandstone on both banks of Bear Creek, 270 m north, 245 m east of south-west corner Sec. 5, T31N, R1E, Whitmore Quadrangle, Shasta Co., northern California. Collector: Jim Haggart, December 1, 1983.

LACMIP 15797. (Continental Oil HS2) Southeast slope Blue Mtn, North Fork Bear Creek, SE 1/4 Sec. 6, T31N, R1E, Whitmore Quadrangle, Shasta Co., California.

LACMIP 15944. North side of North Fork Bear Creek, spoil pile of Alberta-Bakersfield pipeline, about on section line and almost at south-east corner Sec. 6, T31N, R1E, Whitmore Quadrangle, Shasta Co., California. Collectors: L. R. Saul, R. B. Saul, and Lanny Fisk, June 23, 1993.

Chico Creek

U.S. Geological Survey, 15-minute, Paradise Quadrangle, 1953, Butte County, northern California. Chico Formation, Musty Buck Member. Age: Late Cretaceous, Santonian. Collectors: L. R. Saul and R. B. Saul, August, 1952.

LACMIP 23621. Micaceous grey sandstone cropping out in upper part of meadow east of Chico Creek County Road, 625 m (2050 ft) south and 701 m (2300 ft) west of north-east corner Sec. 12, T23N, R2E. Age: early Santonian.

LACMIP 23622. Coarse-grained grey sandstone containing black pebbles, about 268 m (880 ft) above west side of Chico Creek, 244 m (800 ft) north, 427 m (1400 ft) east of south-west corner Sec. 1, T23N, R2E. Age: early Santonian.

LACMIP 23625. East bank of Chico Creek, 91 m (300 ft) north of right-angle bend in Chico Creek, 610 m (2000 ft) north, 290 m (950 ft) east of south-west corner Sec. 12, T23N, R2E. Age: late Santonian.

Santa Ana Mountains

U.S. Geological Survey, 15-minute, Santiago Peak Quadrangle, 1954, Orange County, southern California, Ladd Formation, Baker Canyon Member. Age: Late Cretaceous, Turonian.

LACMIP 8170 [= CIT loc. 1828]. Creek at road junction, Aliso Creek, Trabuco Oaks, Santa Ana Mountains, Orange County, southern California. Collector: C. R. Stauffer.

NOTE ADDED IN PROOF

Illustrations of heterostrophic protoconchs of two species of nerineids are in KOWALKE, V. T. and BANDEL, K. 1996. Systematik and Paläoökologie der Küstenschnecken der nordalpinen Brandenberg-Gosau (Oberconiac/Untersanton) mit einem Vergleich zur Gastropodenfauna des Maastrichts des Treppebeckens (Südpirenen, Spanien). *Mitteilungen der Bayerischen Staatssammlung für Paläontologie und historische Geologie*, **36**, 15–71, pls 1–10.