J. Paleont., 75(1), 2001, pp. 46–65

0022-3360/01/0075-46$03.00

NEW LATE CRETACEOUS GASTROPODS FROM THE PACIFIC SLOPE OF NORTH AMERICA

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ABSTRACT—Two new genera and ten new species of shallow-marine, warm-water gastropods are reported from several Upper Cretaceous formations found between British Columbia and southern California. The buccinid *Zaglenum* new genus is represented by two new species and the turbinellid *Fimbrivasum* new genus is represented by three new species. The nododelphinulid *Trochacanthus pacificus* new species is the first record of this genus in the Western Hemisphere, and the procerthiid *Nudivagus*? *califus* new species could be the first record of this genus on the Pacific slope of North America. The xenophorid *Xenophora* (*Endoptygma*) *hermax* new species is only the second known Cretaceous species of this genus on the Pacific slope of North America, and this species establishes that *Endoptygma* Gabb, 1877, is a valid taxon. The neritid *Otostoma sharonae* new species is only the fourth known Cretaceous species of this genus on the Pacific slope of North America. The ringiculid *Ringicula*? (*Ringiculopsis*?) *hesperiae* new species is the first Campanian record of this genus on the Pacific slope of North America and the first recognition of this subgenus in this area.

INTRODUCTION

THIS PAPER concerns new taxa of shallow-marine gastropods found in Upper Cretaceous rocks in northern Baja California, Mexico; southern and northern California; Sucia Island, Washington; and Vancouver Island and the associated Gulf Islands, British Columbia (Fig. 1). Many of the taxa are found in the Point Loma Formation just southeast of Carlsbad, northern San Diego County, southern California. Mollusks from these beds are arguably the best preserved fossils of Late Cretaceous age found on the Pacific slope of North America. Most of the Carlsbad area specimens used in this report were collected in "salvage operations" during grading activities associated with development projects.

The classification system used here generally follows that of Ponder and Warén (1988), Ponder and Lindberg (1997), and Mikkelsen (1996). Abbreviations used for catalog and locality numbers are: CIT, California Institute of Technology (collections now stored at LACMIP); GSC, Geological Survey of Canada, Ottawa; IGM, Instituto de Geología, Universidad Nacional Autónoma de México, Mexico City; LACMIP, Natural History Museum of Los Angeles County, Invertebrate Paleontology Section, Los Angeles; NRM, Swedish Museum of Natural History, Stockholm; SDSNH, San Diego Society of Natural History, San Diego; SDSU, San Diego State University, San Diego; UCLA, University of California, Los Angeles (collections now stored at LACMIP); UCMP, University of California, Museum of Paleontology, Berkeley.

STRATIGRAPHY

The following stratigraphic units are listed from oldest to youngest in geologic age.

Haslam Formation.—The Haslam Formation was named by Clapp (1912) for outcrops on southeastern Vancouver Island, British Columbia. Muller and Jeletzky (1970) reviewed the stratigraphy and depositional environment of this formation and reported it to consist of megafossil-rich nearshore marine shale, siltstone, and minor sandstone. Using ammonites, they reported the age of the formation to range from late Santonian to early Campanian. On the basis of further ammonite studies, which resulted in the placement of the lower *Sphenoceramus schmidti* Zone within the Santonian Stage, Haggart (1989) reported the age of the Haslam Formation to be Santonian. Magnetostratigraphic work could place the stage boundary more precisely because the base of the Campanian Stage is known to be associated with a polarity reversal (Fig. 2). The portion of the Haslam Formation that is normal in polarity is of Santonian age.

Holz Shale of the Ladd Formation.—Popenoe (1942) designated the Holz Shale as the upper member of the Ladd Formation of the Santa Ana Mountains, Orange County, southern California. The fossils included in this present report are from the upper part of the Holz Shale. Saul (1982) reported that localities yielding megafossils in the upper part of the Holz Shale are predominantly thin sandstone beds deposited in a relatively deep-shelfal environment and of early Campanian age.

Pentz Road Member of Chico Formation.—The informal Pentz Road member of the Chico Formation was named by Russell et al. (1986) for outcrops in the vicinity of the hamlet of Pentz, Butte County, northern California. Squires and Saul (1997) reviewed the stratigraphy of the Pentz Road member and reported it to consist of deposits of early Campanian age and that most of these are of shallow-marine origin.

Cedar District Formation.—The Cedar District Formation was named by Clapp and Cooke (1917) for outcrops on southeastern Vancouver Island and on some neighboring much smaller islands near Vancouver, British Columbia. The exposures on two of these smaller islands that concern this present report are on Sucia Island, Washington, and Texada Island, British Columbia (Fig. 1). Muller and Jeletzky (1970) reviewed the stratigraphy and depositional environment of this formation and reported it to consist of megafossil-poor turbidites consisting of marine muds subject to the influx of material from the nearshore area. Jeletzky (*in* Muller and Jeletzky, 1970) reported the age of the Cedar District Formation to range from the *Hoplitoplacenticeras vancouverense* Zone on Sucia Island (uppermost fossiliferous beds) to the *Metaplacenticeras* cf. *M. pacificium* Zone in the upper part of the formation on both Denman Island and north of Trent River on Vancouver Island. Texada Island is east of Denman Island and north of Trent River, and Jeletzky identified *Baculites occidentalis* Meek, 1862, from there in outcrops assigned to the Cedar District Formation. *Baculites occidentalis* has a long range (Fig. 2) but occurs commonly in the *Metaplacenticeras* cf. *M. pacificum* Zone, and the Cedar District Formation on Texada Island might be somewhat younger than that on Sucia Island. Elder and Saul (1996, fig. 1) considered this ammonite zone to be of middle middle through late middle Campanian age.

Pleasants Sandstone Member of the Williams Formation.—Both the Williams Formation and the Pleasants Sandstone Member were named by Popenoe (1942) for outcrops along the

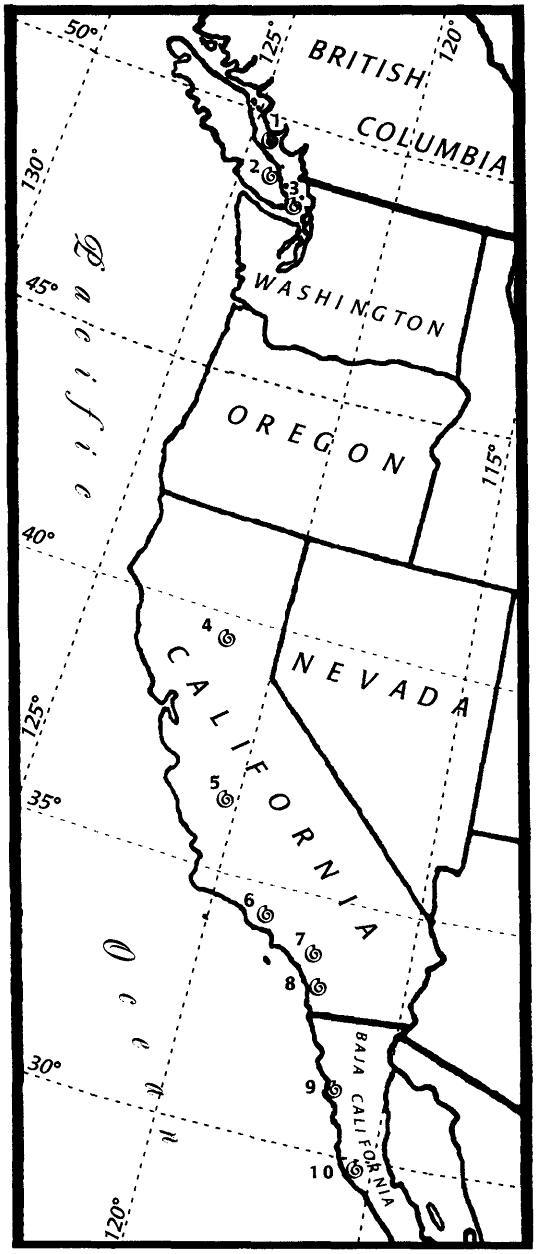

FIGURE *1*—Index map showing geographic areas mentioned in the text. 1 = Texada Island; 2 = Vancouver Island; 3 = Sucia Island; 4 = Pentz; 5 = Anticline Ridge, north of Coalinga; 6 = Simi Hills; 7 = Santa Ana Mountains; 8 = Carlsbad; 9 = San Antonio del Mar; 10 = Arroyo Santa Catarina.

west side of the Santa Ana Mountains, Orange County, southern California. Saul (1982) reported that the Pleasants Sandstone Member is of Late Campanian age and that the mollusks contained therein lived in a shallow-shelf to moderate-depth-shelf environment.

Point Loma Formation.—The Point Loma Formation was named by Kennedy and Moore (1971, p. 711–713), who referred the Rosario Formation in San Diego County to group status, subdivided it into a middle unit (Point Loma Formation) and an upper unit (Cabrillo Formation), and added the nonmarine Lusardi Formation as the basal unit of the group. The Point Loma Formation crops out in San Diego County, southern California along the west side of Point Loma, as well as at La Jolla and in the city of Carlsbad. The Point Loma Formation is underlain by the Lusardi Formation and, in the area of the Carlsbad airport, is overlain by Eocene strata. The Carlsbad area in northern San Diego County concerns this present report. In this area, the Point Loma Formation has yielded several ammonites including the zonal indicators *Baculites lomaensis* Anderson, 1958; *Pachydiscus* (*Neodesmoceras*) *catarinae* (Anderson and Hanna, 1935); and *Didymoceras hornbyense* (Whiteaves, 1896) (Fig. 2). Of these, the pachydiscid is rarest. A specimen of *Baculites lomaensis* was extracted from within the aperture of a specimen of *Xenophora* (*Endoptygma*) *hermax* n. sp. from SDSNH locality 3402. A magnetic reversal, 32R, has been correlated (Elder and Saul, 1996, fig. 1) with the zone of *Didymoceras hornbyense*. On Point Loma this reversal encompasses 30 to 50 m of section (Bannon et al., 1989), and most of the Carlsbad collections might be from within the *D. hornbyense* Zone and thus of middle late Campanian age. This age is in agreement with that of other recent workers who have studied mollusks from this formation (Loch, 1989; Groves, 1990), and of Coombs and Deméré (1996) who used coccolith correlations of D. Bukry to date a dinosaur. However, as the ranges of both *P.* (*N.*) *catarinae* and *B. lomaensis* are considered to include the Campanian–Maastrichtian boundary, and both are identified from the Point Loma Formation in Carlsbad, the possibility remains that some strata near Carlsbad are of early Maastrichtian age.

The section of the Point Loma Formation in Carlsbad consists mostly of mudstone interbedded with sandstone. Paleobathymetric interpretations based upon foraminifers indicate inner shelf (less than 140 m deep) deposition for most of the Point Loma beds in the Carlsbad region. Locally, there are diverse, shallow-marine molluscan fossils (Bartling and Abbott, 1984; Loch, 1989). Most of these fossils are scattered through the mudstones, which are of shallow-marine origin but deposited below storm-wave base. Sundberg and Riney (1984) reported that megafossils have also been found in conglomerates and conglomeratic sandstones of the underlying Lusardi Formation, but these gravelly deposits represent the basal part of the Point Loma Formation (Kennedy et al., in press).

Along Palmer Way near the Madonna Hill Guest Home area in Carlsbad, recent grading uncovered new exposures of the Point Loma Formation (Kennedy et al., in press) that yielded several of the new taxa. They are in the coarse-grained matrix material of a basal conglomerate containing well-rounded metavolcanic pebbles and boulders derived from the nearby Santiago Peak Volcanics of Jurassic age. In addition, there are some granitic clasts, apparently derived from local exposures of the Green Valley Tonalite. The specimens of the new species of *Xenophora* utilized the metavolcanic pebbles as camouflage on their shells. The presence of such coarse-grained sedimentary material, along with shoreline-dwelling gastropods, including the new species of *Otostoma,* oyster valves, rudistids, and rarer pieces of driftwood, algal-encrusted pebbles, and echinoid spines indicate that this particular conglomerate was deposited at or near the shoreline. Some of these same invertebrates, especially the oysters, are also found in poorly sorted sandstone immediately overlying the conglomerate.

At SDSNH locality 3392, where specimens of the new species of *Ringicula*? (*Ringiculopsis*?) were collected, the various invertebrate fossils were found in association with a partial dinosaur skeleton of the nodosaurid ankylosaur *Nodosaurus.* Some oysters and also the bivalve *Spondylus* were found attached to the dinosaur bones (Coombs and Deméré, 1996).

Rosario Formation.—Upper Cretaceous marine deposits in Baja California are assigned to the Rosario Formation (Beal, 1948). The Rosario Formation in northwest Baja California, including the San Antonio del Mar section and Arroyo Santa Catarina, about 100 km and 300 km south of Ensenada, respectively,

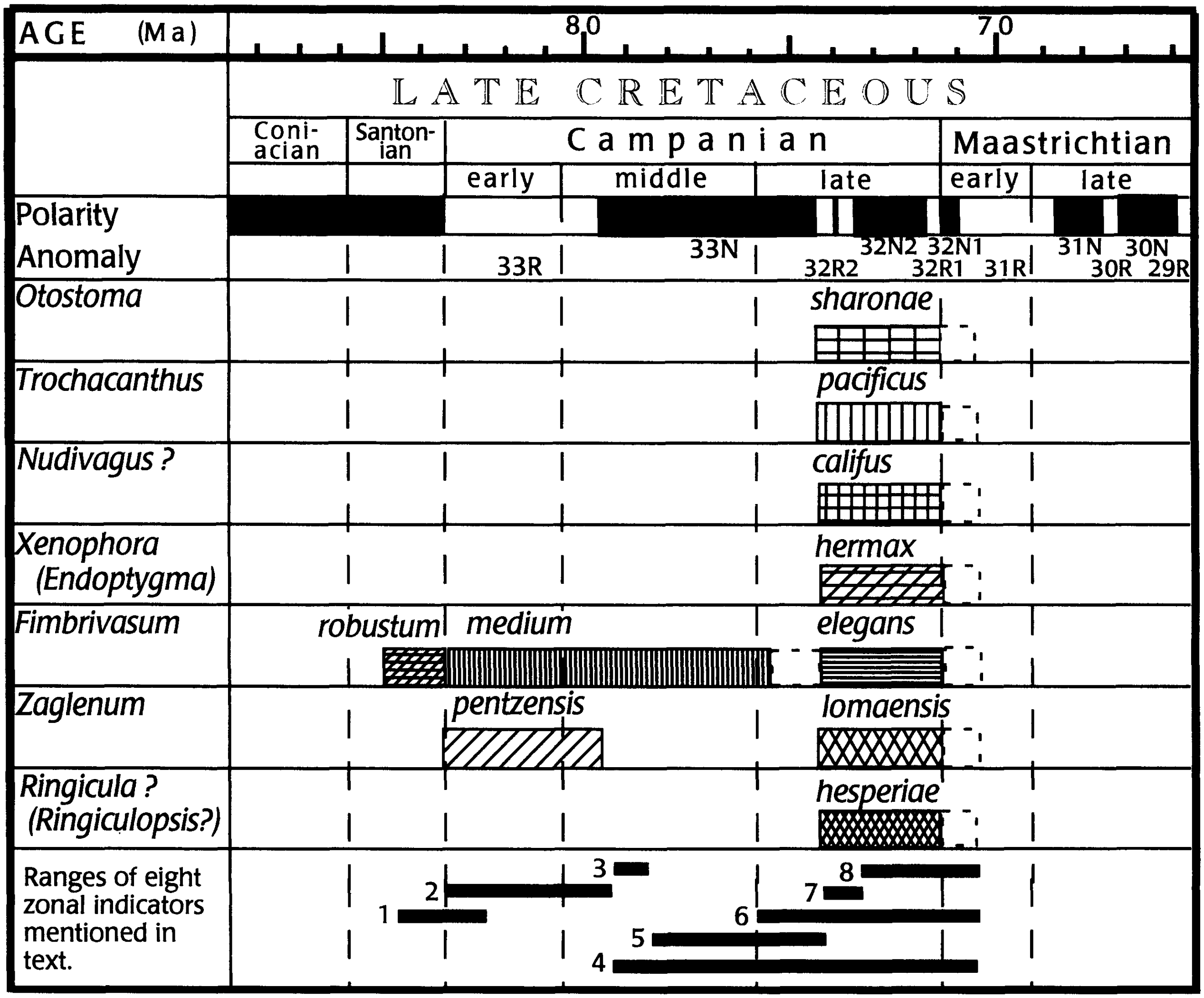

FIGURE 2—Chronostratigraphic positions of the new Cretaceous gastropods from the Pacific slope of North America. Geologic ages, polarity, and ammonite zones after Elder and Saul (1996, fig. 1); Coniacian/Santonian boundary modified to agree with Palmer and Geissman (1999). Zonal indicators referred to in text are 1) the inoceramid *Sphenoceramus schmidti*; and seven ammonites 2) *Submortoniceras chicoense,* 3) *Hoplitoplacenticeras vancouverense,* 4) *Baculites occidentalis,* 5) *Metaplacenticeras* cf. *M. pacificum,* 6) *Baculites lomaensis,* 7) *Didymoceras hornbyense,* 8) *Pachydiscus* (*Neodesmoceras*) *catarinae.*

is stratigraphically equivalent to the Point Loma and Cabrillo formations of the San Diego area (Yeo, 1984). In their reviews of the stratigraphy of the Rosario Formation in Baja California, Yeo (1984) and Cunningham and Abbott (1986) reported it to be of late Campanian to early Maastrichtian age, and that the deposits grade from shallow-marine facies to deep-basin turbidite facies. Webster (1983) tentatively assigned the age of the Rosario Formation in the Arroyo Santa Catarina area to be late Campanian to early Maastrichtian age.

Chatsworth Formation.—The Chatsworth Formation was named by Colburn et al. (1981) for exposures in the Simi Hills, Simi Valley, Los Angeles and Ventura counties, California. The formation consists of slope and deep-sea fan deposits, and the age of the formation is late middle Campanian to early Maastrichtian. Outcrops of the formation in the Lang Ranch area at the west end of the Simi Hills are relevant to this present paper. There, the formation is of early Maastrichtian age, based on the presence of the zonal ammonites *Baculites lomaensis* Anderson, 1958, and *Pachydiscus* (*Neodesmoceras*) *catarinae* (Anderson and Hanna, 1935).

Panoche Formation.—The Panoche Formation was named by Anderson and Pack (1915) for exposures in the Panoche Hills, Fresno County, California. The formation accumulated as deep-sea turbidites in a forearc basin and has an enormous thickness (up to 6,100 m) and variable lithology (Dibblee, 1981). In the Panoche Hills, the formation was divided into several formations by Payne (1962), in order to accommodate the lithologic variability. Dibblee (1981), who mapped the Panoche Formation in the Diablo Range north of the Panoche Hills, reported that few, if any, of Payne's units are recognizable in exposures outside of the Panoche Hills. Dibblee retained the name Panoche Formation as did Anderson (1972), who mapped the Panoche Formation near Coalinga, Fresno County, south of the Panoche Hills. Anderson designated informal members, and it is his "Ragged Valley Shale member" in the upper part of the Panoche Formation that is relevant to this present report. This member is approximately 366 m thick, consists of silty dark mudstone intercalated with numerous thin lenses of sandstone, and Trumbly (1983) suggested that the depositional environment of the member was the outer fan or the basin-plain of a submarine fan. Ammonite assemblages from the "Ragged Valley Shale member" were dated by Matsumoto (1960) as late Campanian or early Maastrichtian, and *Baculites lomaensis* is abundant.

SYSTEMATIC PALEONTOLOGY

Class GASTROPODA Cuvier, 1797
"Order" NERITOMORPHA Golikov and Starobogatov, 1975
Family NERITIDAE Rafinesque, 1815
Genus OTOSTOMA d'Archiac, 1859

Type species.—*Nerita rugosa* Hoeninghaus, 1830, by indication (Douvillé, 1904); Late Cretaceous (Maastrichtian), Netherlands. The type species designation for *Otostoma* has a complicated nomenclatural history, which was discussed fully by Squires and Saul (1993).

OTOSTOMA SHARONAE new species
Figure 3.1–3.5

Diagnosis.—Medium-small shell, flat spire, smooth shell, seven moderately strong squarish teeth on inner lip, and internally dentate outer lip.

Description.—Shell medium small (up to 19 mm in height), subquadrate to globose, broader than high, moderately thick shelled, consisting of about two whorls; spire flat; body whorl smooth and rapidly expanding with rounded shoulder; aperture moderately large; deck wide, smooth and callused, with callus thickest on more mature specimens; inner lip with seven moderately strong squarish teeth; teeth equidistant, except for more closely spaced anteriormost one; teeth approximately same strength, except for anteriormost small one; outer lip thick and broad, and internally with about six roundish teeeth.

Etymology.—The new species is named for Sharon A. Rhodes, of Encinitas, California, who first discovered specimens of *Otostoma* at the type locality.

Types.—Holotype LACMIP 12810. Paratypes LACMIP 12811. CAS 68403 and 68404; IGM 4123 and 4124; NRM Mo 160493 and Mo 160494; UCMP 39940 and 39941. All types are of late Campanian age to possibly early Maastrichtian age and from the basal Point Loma Formation, Carlsbad, San Diego County, California, SDSU loc. 3871.

Measurements.—LACMIP 12810, height 15 mm, width 19 mm. LACMIP 12811, height 19 mm, width 23.5 mm; the other types are within these height and width ranges.

Other material examined.—Thirty-two specimens: one from SDSNH loc. 3162, three from SDSNH loc. 3672, one from SDSNH loc. 3869; 23 (in 2 lots?) 20 from SDSU loc. 3871, three from SDSU loc. 3871, and one each from SDSU locs. 346, 3870, 3877, and 3879.

Occurrence.—Upper Campanian to possibly lower Maastrichtian, Point Loma Formation, Carlsbad, San Diego County, California; and Rosario Formation, San Antonio del Mar, Baja California, Mexico.

Discussion.—A total of 42 specimens were found. Nearly all are well preserved although their apertures are usually plugged with hard matrix.

Otostoma is a Tethyan genus and most species are from the Old World. The geologic range of this genus is Early Cretaceous (Albian) to middle Eocene, with the youngest occurrences being from southern California (Squires, 1995; Saul and Squires, 1997).

Three other Cretaceous species of *Otostoma* have been described from the Pacific slope of California. *Otostoma*? *atopos* Saul and Squires (1997, p. 138–139, figs. 19–21) is found in reworked clasts of late Albian to early Cenomanian age in the Turonian Venado Formation, Colusa County, California. *Otostoma lucanus* Saul and Squires (1997, p. 138, figs. 15–18) is from the Turonian Baker Canyon Member of the Ladd Formation, Orange County, California. *Otostoma aethes* Squires and Saul (1993, p. 261–263, figs. 2–4) is from uppermost Cretaceous or possibly lowermost Paleocene strata on the south side of Lake Nacimiento, San Luis Obispo County, California.

The new species is most similar to *O.*? *atopos* in terms of the smooth shell, size, and thickened outer lip. The new species differs from *O.*? *atopos* by having a flat spire, teeth on the outer lip, and seven rather than six teeth on the inner lip. The new species differs from both *O. aethes* and *O. lucanus* by being smaller in size and having no sculpture on the shell.

The new species also resembles *Nerita* (*Odontostoma*) *bruni* Roman and Mazeran (1920, p. 38–39, pl. 4, fig. 20, 20a) from Turonian strata in southeastern France. The new species differs from *N.* (*O.*) *bruni* by having a flat spire, equal-sized teeth on the inner lip, and teeth on the outer lip.

"Order" VETIGASTROPODA Salvini-Plawén, 1980
Family NODODELPHINULIDAE Cox, 1960
Genus TROCHACANTHUS Dacqué, 1936

Type species.—*Trochus tuberculatocinctus* Münster *in* Goldfuss, 1844, by subsequent designation (Wenz, 1938); Late Cretaceous, Europe (Poland and Germany).

Discussion.—*Trochacanthus* was proposed by Dacqué (1936) for three species of German Late Cretaceous turbiniform gastropods that had, in the past, been assigned to *Turbo, Trochus,* or *Delphinula.* All are phaneromphalus and have an orbicular aperture and two strong, nodose cords exposed on later spire whorls. The last whorl develops a deviant coiling that brings the aperture in under the penultimate whorl. Shell structure for the family Nododelphinulidae has been unknown (Cox, 1960), but the inner shell layer of one Carlsbad specimen (SDSNH 67156) appears to have been nacerous.

TROCHACANTHUS PACIFICUS new species
Figure 3.6–3.11

Diagnosis.—Cancellate spire, single keel on body whorl periphery, diameter of body whorl increased disproportionately to that of earlier whorls, and umbilicus bearing thin radiating ribs separated by wide sunken areas.

Description.—Shell turbinate, of five and one-half whorls, spire narrow adapically, body whorl wide, deviantly coiled at angle of 16 to 18 degrees relative to spire whorls; earlier spire whorls with two strong and noded carinae; medially situated (posterior) carina becoming obsolete on body whorl; anterior carina (adapical to impressed suture on spire whorls) becoming prominent keel on body whorl; spire whorls with numerous collabral ribs, noded across carinae; nodes obsolete on body whorl; spire whorls with row of protruding nodes abapical to suture; on body whorl nodes grade into curved lamellae separated by deep pits, with lamellae becoming wider toward outer lip. Two to three rather weak spiral ribs in concave area between two carinae on spire whorls; three, weakly noded spiral ribs in ramp area; spiral ribbing persists, but weaker and without nodes, onto body whorl region posterior to prominent keel; body whorl anterior to keel smooth, entire body whorl crossed by prosocline growth lines, forming a minute cancellate pattern posterior to keel; umbilicus deep, rimmed by a low spiral rib; interior of umbilicus with numerous radiating bladelike ribs (=reflections of outer lip) separated by deep slots, narrowing toward axis; aperture circular; inner lip smooth, callused; outer lip smooth, somewhat projecting.

Etymology.—The new species is named for the Pacific coast of North America.

Types.—Holotype SDSNH 67155, SDSNH loc. 4071. Paratypes LACMIP 12812, SDSU loc. 3872; LACMIP 11281, SDSU loc. 3879. All types are of late Campanian age to possibly early Maastrichtian age and from the Point Loma Formation, Carlsbad, San Diego County, California.