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Late Cretaceous Occurrences on the Pacific Slope of North America of the Melanopsid Gastropod Genus *Boggsia* Olsson, 1929

by

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Abstract. The shallow-marine gastropod *Potamides tenuis* Gabb, 1864, from Upper Cretaceous (Campanian Stage) rocks in northern California, western Washington, and southwestern Canada, belongs to the gastropod genus *Boggsia* Olsson, 1929, formerly known only as two species from lower Eocene strata of northwestern Peru. The northern California specimens of *Boggsia tenuis*, are early Campanian in age, plentiful, and were deposited on an inner shelf in storm-lag accumulations composed of nearshore-marine and shelf-dwelling mollusks. The Washington specimens are middle Campanian in age and are rare. The Canadian specimens are middle to late Campanian in age and are also rare.

Boggsia tenuis has an anterior canal that is turned sideways and a very low, smooth protoconch poorly demarcated from the teleoconch. These features were previously unknown for the genus, hence its familial placement was uncertain. It can now be placed in family Melanopsidae, which ranges from Early Cretaceous (Albian) to Recent. New World melanopsids range from Early Cretaceous (Albian) to early Eocene and were shallow-marine dwellers. *Boggsia tenuis* is the first report of a melanopsid from the Pacific slope of North America. Old World melanopsids range from Late Cretaceous to Recent and are restricted to brackish or freshwater deposits.

INTRODUCTION

This paper concerns a shallow-marine gastropod species that is mostly found in Upper Cretaceous (lower Campanian Stage) rocks near Chico and Pentz, northern California (Figure 1). Rare specimens are found about 135 km northwest of Seattle on Sucia Island, San Juan County, Washington, and about 120 km northwest of Vancouver on Hornby Island, eastern British Columbia. The species has long been known as *Potamides tenuis* Gabb, 1864, but it is not a potamidid and is herein assigned to genus *Boggsia* Olsson, 1929. This particular genus was previously known only as two species from lower Eocene shallow-marine rocks of northern Peru, but the familial position of the genus was uncertain due to lack of information regarding the protoconch and the anterior end of the aperture. These features are preserved in *Boggsia tenuis*, and the genus can now be placed in family Melanopsidae.

As will be discussed below, the classification of family Melanopsidae has been inconsistent, with some workers regarding it as a subfamily of Thiaridae and other workers regarding it as a family of its own. The geologic history of family Melanopsidae is poorly known because most members lived in brackish or freshwater habitats, which have a low potential for preservation. The fossil record

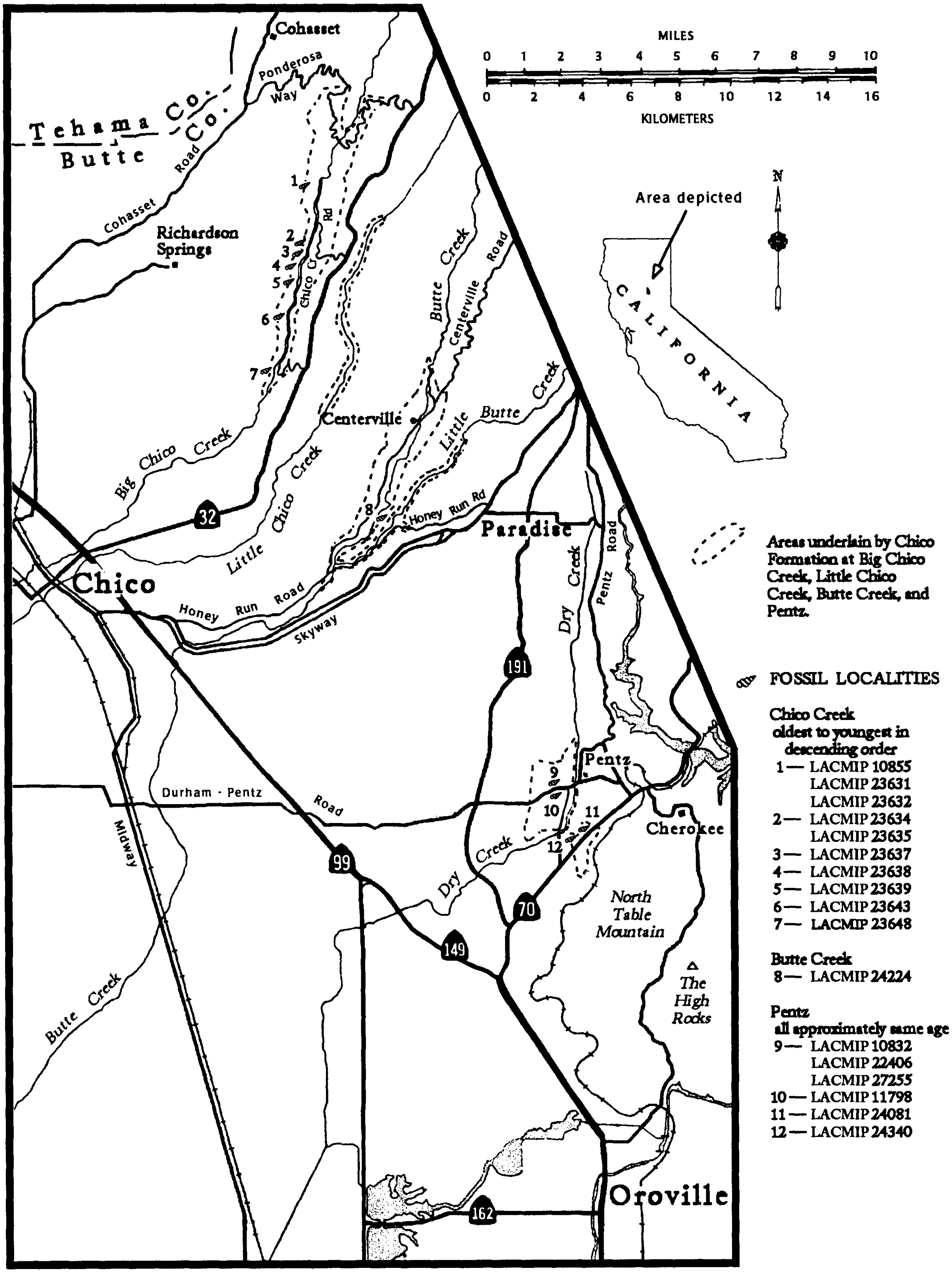


Figure 1

Index map for northern California localities of *Boggsia tenuis* (Gabb, 1864).

of melanopsids in the New World is very sketchy, and the recognition of *Boggsia* as a melanopsid from Upper Cretaceous rocks in California, Washington, and British Columbia, as well as from Eocene rocks in Peru, helps greatly in understanding the evolutionary history of this family. The shallow-marine habitat of *Boggsia* allowed the genus to achieve more widespread distribution than it could have if it lived in brackish or freshwater environments.

Abbreviations used are: CIT, California Institute of Technology (collections now stored at LACMIP); GSC, Geological Survey of Canada, Ottawa; LACMIP, Natural History Museum of Los Angeles County, Section of Invertebrate Paleontology, Los Angeles; UCLA, University of California, Los Angeles (collections now stored at LACMIP).

SYTEMATIC PALEONTOLOGY

Superorder CAENOGASTROPODA Cox, 1959

Order NEOTAENIOGLOSSA Haller, 1882

Superfamily CERITHIOIDEA Ferrussac, 1819

Family MELANOPSIDAE H. & A. Adams, 1854

Discussion: The family Melanopsidae usually has been regarded as a subfamily of Thiaridae Troschel, 1857. In a cladistic analysis, Houbrick (1988) showed melanopsids to be distinct from thiarids and deserving of full familial status. In his analysis, the Melanopsidae is in a separate branch but relatively close to the branch supporting the Thiaridae.

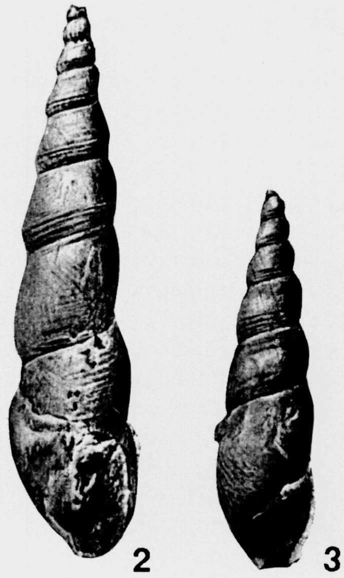
Family Melanopsidae is characterized by members having an operculate oval aperture with an anterior channel, a simple protoconch not clearly demarcated from the teleoconch, and a usually calloused columellar lip bent anteriorly (Davies & Eames, 1971; Bandel & Riedel, 1994).

Genus *Boggsia* Olsson, 1929

Original description: "Shell melanoid to sub-turritelloid, subulate, with numerous convex to subangulated whorls; sutures distinct, strongly oblique or descending; early whorls smooth or finely sculptured with revolving spirals; later whorls smooth; growth lines oblique but not sinuous; aperture subovate, *Littorina*-like in shape and with a thin outer lip" (Olsson, 1929:78).

Type species: *Turritella anceps* Woods, 1922, by original designation; early Eocene of northwestern Peru.

Discussion: Olsson was mistaken in reporting that *Boggsia* has a round aperture because he based his description on incomplete specimens. Although he did not figure *Turritella anceps*, the type species of *Boggsia*, illustrations of this species by Woods (1922:pl. 8, figs. 12, 13; pl. 9, figs. 1, 2) show that the anterior ends of the type specimens are broken, even though Woods mentioned that the aperture is rounded in front. The same is true for *T. annectens* Woods (1922:pl. 9, figs. 3, 4), the only other species assigned by Olsson to genus *Boggsia*.



Figures 2–3

Reprints of Woods (1922:pl. 8, figs. 12, 13) illustrations of *Turritella anceps* Woods, 1922, the type species of *Boggsia*; apertural views, ×1.6. Specimens stored at Sedgwick Museum, Cambridge, England. Figure 2. Same as Woods figure 12. Figure 3. Same as Woods figure 13.

Wenz (1938:fig. 887) reprinted two of the original illustrations of *T. anceps*, but the reprint of Woods' (1922) figure 12 is poor, and it is not obvious that the larger specimen has a broken anterior end of the aperture. Woods' (1922:pl. 8, figs. 12, 13) illustrations of *Turritella anceps* are included herein (Figures 2, 3). The extreme anterior parts of the apertures of these specimens look exactly like those of incomplete specimens of "*Potamides*" *tenuis* Gabb whose extreme anterior parts of the apertures are missing (e.g., Figure 13). These specimens of "*Potamides*" *tenuis*, have all of the diagnostic characters of genus *Boggsia*, especially in terms of the shape of the elongate teleoconch with anteriorly subangulated whorls that show sculpture on the spire. Well-preserved specimens of "*P.*" *tenuis* show the following additional characters not available from the type species: a short anterior canal that is not twisted but is turned sideways; a very low, smooth protoconch that is difficult to distinguish from the teleoconch; and a thin to moderately thick columellar callus. The western North American Cretaceous "*Potamides*" *tenuis*, which is herein unequivocably assigned to genus *Boggsia*, thus adds valuable new morphologic information about the genus and establishes that *Boggsia*'s so-called round aperture is only an apparent feature associated with specimens whose anterior end is broken.

Because Olsson (1929) mistakenly believed that *Boggsia* had a rounded aperture without an anterior channel, he assigned *Boggsia* to the family Pseudomelaniidae Fischer, 1885. Wenz (1938) later questionably used this familial assignment. Family Pseudomelaniidae is characterized by an oval-rounded aperture without an anterior channel, a smooth and slightly elevated protoconch, and a smooth to weakly ornamented teleoconch. Olsson did not have available specimens of *Boggsia* whose extreme anterior end of the aperture was intact, nor did he have any information regarding the protoconch morphology of *Boggsia*. The morphologic features of *B. tenuis*, however, dictate that genus *Boggsia* cannot belong to family Pseudomelaniidae. Instead, the genus belongs in family Melanopsidae, whose characters were listed earlier under "Family Melanopsidae."

Genus *Nudivagus* Wade, 1917, also resembles *Boggsia*, in terms of the turriculate shell with a slightly curved, short anterior canal. *Nudivagus*, which is smoothish, is known primarily from Upper Cretaceous strata of the southeastern United States. Abbass (1973) also reported it from Lower Cretaceous (Aptian Stage) strata of the Isle of Wight, southern England. The familial status of *Nudivagus* has been somewhat problematical, and the most recent workers that addressed this problem were Sohl (1960) and Abbass (1973). Both believed it to be a member of family Procerithiidae.

With future taxonomic revisions, we consider it likely that turriculate gastropods distinguished by a short and slightly curved anterior canal, like that seen on *Boggsia*, on *Nudivagus*, and on certain fossil forms of "*Faunus*" (discussed below) will be grouped together either as a subgroup of melanopsids or as a new family, closely related to the melanopsids.

Boggsia tenuis (Gabb, 1864)

(Figures 4 to 17)

Potamides tenuis Gabb, 1864:130–131, 227, pl. 20, fig. 86; 1869, p. 227. Stanton in Turner, 1894:460. Stewart, 1927:356, pl. 23, figs. 8, 9. Anderson, 1958:164. Russell et al., 1986:191:1–2.

Potamides tenuis Gabb. Whiteaves, 1879:121 (in part), pl. 15, figs. 8a–8c; 1903:363. Not *Potamides tenuis*, variety *nanaimoensis* Whiteaves, 1879:12–122, pl. 15, figs. 9, 9a [= *Anchura nanaimoensis* (Whiteaves) *fide* Elder & Saul, 1996].

Original description: "Shell elongated, slender; spire high; whorls increasing gradually in size, seven to seven and a half. Upper two-thirds sloping almost perpendicularly; lower third sloping rapidly inwards towards the suture, which is narrowly channelled. Angle of whorls marked by pretty distinct, elongated tubercules, which, on the body whorl, sometimes take the form of elongated sinuous ribs; at other times the surface of this whorls is smooth. Aperture elongated, acute behind, widest in the middle, contracted in advance. Outer lip acute, sinuous; inner lip thinly incrusted. Canal gently curved. Length, 0.75 inch [19 mm]; width of body whorl, 0.25 inch [6.3 mm]" (Gabb, 1864:130–131).

Supplementary description: Moderately small in size (up to 25 mm high, estimated), elongate-turrited to fusiform, approximately eight whorls (including protoconch); high-spired, spire approximately one-half of shell height. Sutures oblique, impressed. Protoconch approximately one whorl, very low, smooth, and poorly differentiated from teleoconch. Teleoconch approximately six whorls; sculpture changes from early whorls to later whorls. Upper spire whorls with flattish posterior portion, a strong angulation on anterior one-third of whorl, and 10 to 11 broad opisthocline axial ribs. Strength of axial ribs variable; either broadly swollen from suture to suture or only as knobby swellings on the angulation. Upper spire whorls with minute (usually same strength as the growth lines) spiral threads, producing, on some specimens, a reticulate pattern where intersecting the opisthocline growth lines, especially in the high-sloping area between the angulation and anterior suture. Spiral ribs rarely moderately strong over entire whorl; on some specimens, a single moderately prominent spiral rib present in area between angulation and anterior suture. On middle spire whorls, axial ribs either better developed than on preceding whorls, or none at all; knobby swellings on angulation weak to obsolete; spiral ribs minute to obsolete.

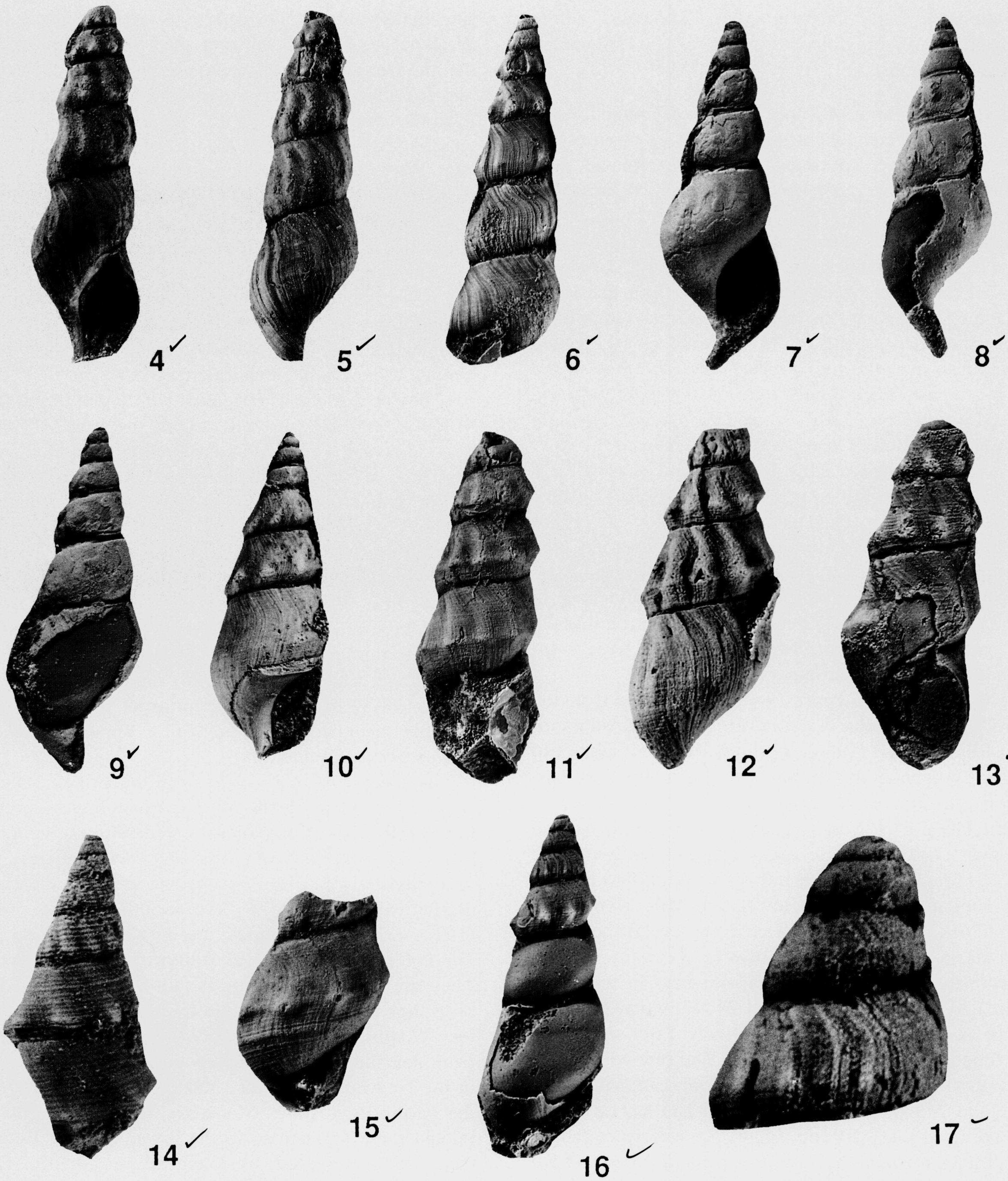
Adult body whorl smooth; opisthocline growth lines usually moderately strong, especially near outer lip. Aperture small, elliptical, tapered anteriorly. Anterior canal spoutlike, very shallow, short, projecting, and bent sideways. Columella smooth, not twisted, with a thin to moderately thick callus; rarely a groove present between columellar callus and base of body whorl. Outer lip thin, not carrying a varix.

Lectotype: ANSP 4288 (designated by Stewart, 1927).

Type locality: Near Pentz, Butte County, northern California.

Hypotypes: ANSP 27858 and LACMIP 7898 to 7907.

Distribution: NORTHERN CALIFORNIA: Chico Creek, Butte County, Chico Formation, lowermost part of Ten Mile Member (LACMIP locs. 10855, 23631, 23632, 23634, 23635, 23637, 23638, 23639, 23643, 23648); Butte Creek, Butte County, Chico Formation, lowermost part of Ten Mile Member (LACMIP loc. 24224); Pentz area, Butte County, Chico Formation, informal Pentz Road member (LACMIP locs. 10832, 11798, 22406, 24081, 24340, 27255). WESTERN WASHINGTON: Sucia Island, San Juan County, Cedar District Formation (LACMIP loc. 10442). BRITISH COLUMBIA: Hornby Island, probably the Spray Formation.



Explanation of Figures 4 to 17

Specimens coated with ammonium chloride.

Figures 4 to 17. *Boggsia tenuis* (Gabb, 1864). Figures 4-5. Hypotype LACMIP 7898, LACMIP loc. 24340, height 22.7 mm, ×2.4. Figure 4. Apertural view. Figure 5. Abapertural view. Figure 6. Hypotype LACMIP 7899, LACMIP loc. 24081, abapertural view, height 19.7 mm, ×2.7. Figures 7-9. Hypotype LACMIP 7900, LACMIP loc. 24340, shell material partially decorticated, height 15.2 mm, ×3.5. Figure 7. Apertural view. Figure 8. Left-lateral view. Figure 9. Abapertural view. Figure 10. Hypotype LACMIP 7901, LACMIP loc. 24081, apertural view, height 13.5 mm, ×3.7. Figure 11. Hypotype LACMIP 7902, LACMIP loc. 24340, apertural view, height 18.7 mm, ×2.9. Figure 12. Hypotype LACMIP 7903, LACMIP loc. 22406, abapertural view, height 13.4 mm, ×3.9. Figure 13. Hypotype LACMIP 7904, LACMIP loc. 23637, apertural view, height 16.6 mm, ×3.2. Figure 14. Hypotype LACMIP 7905, LACMIP loc. 23637, right-lateral view, height 8.3 mm, ×6. Figure 15. Hypotype LACMIP 7906, LACMIP loc. 24081, left-lateral view, height 7.4 mm, ×4.7. Figures 16-17. Hypotype LACMIP 7907, LACMIP loc. 10832. Figure 16. Abapertural view, height 13.5 mm, ×3.9. Figure 17. Abapertural view of protoconch and uppermost spire, height 2.5 mm, ×17.

Geologic age: Early Campanian in California, middle Campanian in Washington, and middle to late Campanian in British Columbia.

Discussion: A total of 683 specimens were studied. Preservation is poor to excellent, and there is no obvious evidence of abrasion. Specimens that have retained their protoconchs, however, are very rare. Nearly all the specimens are juveniles (less than about 15 mm high).

Specimens of *B. tenuis* in northern California are known from 17 localities: 10 from the Chico Creek area, one from the Butte Creek area, and six from the Pentz area (Figure 1). Specimens from Chico Creek range from the lowermost part of the Ten Mile Member of the Chico Formation to near the top, but are more common in the lowermost part. Their range extends throughout Chron 33R and into Chron 33N (= early Campanian). A single specimen from Butte Creek was collected from the lowermost part of the Ten Mile Member and is also early Campanian in age, utilizing the detailed molluscan biostratigraphic work by Saul (1959). Russell et al. (1986) and Baum et al. (1987) inferred that this member at Chico Creek consists of inner shelf sediments deposited by storm-surge events and that the fossils accumulated in lensoidal shell lags. Russell et al. (1986) inferred that the basal part of the Ten Mile Member at Butte Creek represents a shoreface environment.

Specimens from the Pentz area were collected from the lower Chico Formation in the informal Pentz Road member of Russell et al. (1986), who reported the member to be early Campanian in age, based on the ammonites *Submortoniceras chicoense* (Trask) and *Baculites chicoensis* (Trask). The presence of the gastropod *Anchura callosa* Whiteaves, 1903, in these rocks suggests, utilizing the work of Elder & Saul (1996), that the Pentz Road member is similar in age to the lower Ten Mile Member of Chico Creek. The depositional environment of these particular rocks will be discussed below.

Specimens are present in great numbers in the Pentz area at LACMIP locs. 10832 and 24340, where 370 and 118 specimens were found, respectively. Fifty specimens were found at LACMIP loc. 24081. The few adult specimens that have been found are from LACMIP locs. 24081 and 24340. The best preserved and largest specimens are from LACMIP loc. 24340. Specimens of *B. tenuis* that have retained their anterior canal are rare and are also from this locality. One of these specimens (hypotype LACMIP 7900) that best shows the anterior canal is illustrated in Figures 7 to 9. The smooth-looking shell of this specimen is only an apparent feature because much of the shell material has been removed by weathering. The second best locality for preservation is LACMIP loc. 24081.

Whiteaves (1879) reported two specimens of "*Potamides*" *tenuis* from Upper Cretaceous strata on the northwest side of Denman Island, British Columbia, and other specimens from Upper Cretaceous strata on Sucia Island, Washington. In 1903, he corrected himself and reported that the Denman Island specimens were actually from the northwest side of nearby Hornby Island and that the Sucia Island specimens are not "*P.*" *tenuis*. We obtained Whiteaves' (1879:pl. 15, fig. 8a–c) hypotype GSC 5762 of "*P.*" *tenuis* that was collected from the northwest side of Hornby Island (latitude 49°35", longitude 124°43"), which is just offshore of the east-central part of Vancouver Island, British Columbia. The specimen belongs to *B. tenuis*. The exact locality where it was collected is indefinite but is most likely from within the Spray Formation, to which Elder & Saul (1996) assigned a middle to late Campanian age. The Hornby Island occurrence is the youngest, as well as the northernmost, record of *B. tenuis*.

A few specimens of *B. tenuis* from Sucia Island (LACMIP loc. 10442) were detected in the LACMIP collection. They are from the Cedar District Formation, which Muller & Jeletzky (1970) assigned a Campanian age. Elder & Saul (1996) refined the age of this formation as middle Campanian.

Whiteaves (1879) also named and described *Potamides tenuis*, variety *nanaimoensis* Whiteaves (1879:121–122, pl. 15, figs. 9, 9a) from the northwest side of Hornby Island in strata that Elder & Saul (1996) tentatively assigned to the Spray Formation of late middle to late Campanian age. Elder & Saul (1996) reported also that Whiteaves (1879) based his description of this "variety" on juvenile specimens belonging to the apporhaiid *Anchura nanaimoensis* (Whiteaves).

The specimens of *Boggsia* from the United States and Canada extend the geologic range of this genus into the Late Cretaceous (Campanian) and extend the geographic range into western North America. Previously, the genus was only known as two Eocene species from the extreme northernwestern part of Peru, South America. Woods (1922) originally assigned these two species to genus *Turritella*, although he was somewhat reluctant to do so. They are *Turritella anceps* Woods (1922:81, text fig. 8, pl. 8, figs. 12, 13; pl. 9, figs. 1, 2) and *Turritella annectens* Woods (1922:81–82, pl. 9, figs. 3, 4). The former is from nearshore sandy deposits containing beach pebbles in the Negritos Formation, and the latter is mainly from the Parinas Sandstone. Marsaglia & Carozzi (1991) correlated these formations to the lower Eocene. Both species are represented by plentiful specimens. Olsson (1929:12–13, unfigured) assigned these two species to his genus *Boggsia*. He noted that the genus had a marine rather than a freshwater habit.

Russell et al. (1986:191–192, fig. 12) reported that the Upper Cretaceous strata in the Pentz area comprise the estuarine facies of their Pentz Road member (informal). They described this member as containing faunal assemblages that represent shallow-marine to brackish conditions. They referred to the faunal assemblage containing the specimens of *Potamides tenuis* as the "*Potamides ten-*

uis assemblage" and reported it to contain a mixture of soft-bottom bivalves and transported rocky shoreline gastropods that were deposited under estuarine conditions. Our findings dispute this paleoenvironmental interpretation. *Boggsia tenuis* (Gabb) was not a rocky shoreline dweller. Rather, it was a soft-bottom dweller and probably a shallow burrower, as indicated by its short anterior canal. In the Pentz area, specimens of *B. tenuis* are associated with a moderately diverse assemblage of subtidal, shelf-dwelling mollusks, such as ammonites. We see no indication that the specimens of *B. tenuis* were deposited under estuarine conditions.

Most melanopsids have a body whorl with a robust cylindrical shape and an aperture with an anterior notch, but lacking an anterior canal. Some melanopsids, however, have a short but distinct anterior canal. Those that are similar to *Boggsia* in that they have a turriculate shape, as well as a distinct anterior canal, are certain fossil forms of "*Faunus*." The aperture of *Boggsia tenuis* is very similar to "*Faunus*" *cerithiformis* (Watelet, 1851: 121, pl. 1, figs. 1, 2) from uppermost Paleocene (Sparnacian) strata in the Paris Basin, France. A well-preserved LACMIP collection specimen of this species from Pourcy, France, has a curved, spoutlike anterior canal just like *Boggsia*. *Boggsia tenuis* differs from "*F.*" *cerithiformis* by being smaller, narrower, and having axial ribbing.

The spoutlike anterior canal of *Boggsia tenuis* is also very similar to that of "*Faunus*" *dufresnei* (Deshayes, 1825:120, pl. 12, figs. 3, 4; Cossmann & Pissarro, 1910–1913:pl. 19, fig. 117–7; Farchard, 1936:pl. 23, fig. 11) from upper Paleocene (Thanetian Stage) and lower Eocene (Ypresian Stage) strata in Paris Basin, France. *Boggsia tenuis* differs from "*F.*" *dufresnei* in the following features: smaller, narrower, and angulate whorls with axial ribs becoming obsolete on adult whorls rather than more pronounced. Unlike *Boggsia tenuis*, as "*F.*" *dufresnei* becomes more mature, the outer lip thickens considerably, the sculpture on the body whorl becomes very prominent, and the anterior canal becomes much less apparent. "*Faunus*" *dufresnei* is now assigned to genus *Pseudobellardia* Cox, 1931. Wenz (1939:fig. 2003 a–d) figured the growth stages of a species of *Pseudobellardia*, and he placed *Pseudobellardia* in the melanopsids.

In 1991, Houbrick discussed *Faunus sensu stricto* and put the single living species, *Faunus ater* (Linnaeus, 1758) in subfamily Melanopsinae of family Thiaridae. It is important to mention, however, that on *Faunus ater* the anterior canal has been replaced by a wide, deep sinus. *Faunus ater* does not have an anterior canal, and in this respect is unlike "*F.*" *cerithiformis* and "*F.*" *dufresnei*.

Tracey et al. (1993) reported the geologic range of melanopsids to be Late Cretaceous (Turonian) to Recent, but this range can be emended based on a report by Kollman (1984) of a melanopsid species from Baja California, Mexico. Allison (1955) used the name *Microschiza* (*Cloughtonia*) *scalaris* (Conrad, 1852) for this earliest species and assigned it to family Pseudomelaniidae. Kollman (1984) placed the species in the melanopsid genus *Megalonoda* Kollmann, 1984. *Megalonoda scalaris* is the earliest member of the family and is of Early Cretaceous (Albian) age. It is from the Alisitos Formation, Baja California, Mexico (Allison, 1955). Kollman (1984) reported that this genus is also known from Upper Cretaceous strata in Austria, Greece, and North Africa. Although Kollman (1984) reported that *Megalonoda* is restricted to deposits of brackish water, the deposits in the Alisitos Formation, Baja California, are tropical shallow-marine in origin and are associated with reef corals, nerineid gastropods, caprinid rudistid bivalves, and numerous other shallow-marine invertebrates.

The Cretaceous New and Old World genus *Megalonoda* has a distinctive robust cylindrical shape that closely resembles the late Miocene *Melanopsis handmanniana* Fischer, 1996 [= *Melanopsis fossilis* Wenz, 1929, *fide* Fischer, 1996] from Austria and the Recent *Melanopsis* (*Canthidomus*) *costata* Férussac, 1828, from Syria and Jordan. It could be that during the Late Cretaceous, the marine *Megalonoda* migrated from Baja California, Mexico, to Europe, where the genus adapted to brackish and freshwater environments and has endured in those environments ever since.

Melanopsids live today in a variety of freshwater to brackish-water habitats, including saline lakes, freshwater lakes, rivers, streams, and springs in the areas surrounding the Mediterranean Sea, the Black and Caspian seas, and in New Zealand and New Caledonia (Tchernov, 1975; Geary, 1990). Transition of marine forms to freshwater forms might have occurred in Late Cretaceous times, according to Bandel (1993). Bandel & Riedel (1994) reported several smooth-shelled genera of melanopsids from Upper Cretaceous (upper Santonian-?lower Campanian) freshwater deposits in the Ajka region, Bakony Mountains, Hungary. From Paleocene to late Eocene time, many Paris Basin species (Cossmann & Pissarro, 1910–1913) seem to have inhabited brackish and shallow-marine environments (Tracey et al., 1993). At least one late Oligocene subspecies is known from Hungary (Báldi, 1973), and several late Miocene and Recent species are known from central and eastern Europe (Geary, 1990; Fischer, 1996).

None of the ancient or Recent Old World melanopsids resembles the shape of *Boggsia*, possibly because the shell of *Boggsia* was adapted for living in a shallow-marine environment. This habitat also allowed for a much wider paleogeographic distribution than if *Boggsia* had been restricted to brackish or freshwater habitats.

A review of the scant literature revealed that fossil melanopsids are not likely to be part of an admixed molluscan fauna consisting of freshwater species and shallow-marine species. For example, Bandel & Riedel (1994) reported that although the melanopsid-bearing Upper Cretaceous (upper Santonian/?lower Campanian) freshwater deposits in the Bakony Mountains of Hungary were part of a river-mouth coastal swamp near a sea, the molluscan fauna consists only of typical freshwater forms containing fully grown unionid bivalve shells. Similarly, Geary (1990) reported that late Miocene melanopsids in scattered freshwater deposits from the margins of the Pannonian basin of eastern and central Europe never co-occur with marine organisms.

Boggsia tenuis closely resembles *Brotiopsis wakinoensis* (Kobayashi & Suzuki, 1936) from Lower Cretaceous (Barremian) brackish-water deposits of Japan and Lower Cretaceous freshwater deposits of South Korea. Kase (1984:127–128, pl. 20, figs. 1–6) illustrated this species, and the specimen in his figure 4 especially resembles *B. tenuis* in terms of the slender turriculate shell with opisthocline and spinose axial ribs. *Brotiopsis wakinoensis*, which shows considerable variability, is imperfectly known and is represented by incomplete external molds of juvenile to early adult? specimens. The anterior part of the aperture and the protoconch are unknown. It is possible that with better preserved material, *Brotiopsis wakinoensis* might prove to be a melanopsid. If so, it would be the earliest one.

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APPENDIX LOCALITIES CITED NORTHERN CALIFORNIA

The northern California localities are listed in groups corresponding to the following (arranged north to south) geographic areas: Chico Creek, Butte Creek, and Pentz areas:

CHICO CREEK

U. S. Geological Survey, 15-minute, Paradise Quadrangle, 1953, Butte County, northern California. Chico Formation, unless otherwise noted = lowermost part of Ten Mile Member. Age: Late Cretaceous (early Campanian). Unless otherwise noted, collectors = L. R. Saul and R. B. Saul, August, 1952.

LACMIP 10855 [= CIT 1309]. 30.5 m (100 ft.) S and 114 m (375 ft.) E of NW corner of section 12, T. 23 N, R. 2 E. Collectors: W. P. Popenoe & Clark, October 24, 1935.

LACMIP 23631. West side of Chico Creek Canyon about 0.5 km (0.3 mi.) up "deep" ravine and 1.1 km (0.66 mi.) S of Mickey's Place. On line between sections 11 and 12, 533 m (1750 ft.) S of NW corner of section 12, T. 23 N, R. 2 E.

LACMIP 23632. 7.6 m (25 ft.) farther up "deep" ravine than LACMIP loc. 23631.

LACMIP 23634. On E bank of Chico Creek about 104 m (300 ft.) S of twin meadows and W from the H_B House, 518 m (1700 ft.) S and 160 m (525 ft.) E of NW corner of section 13, T. 23 N, R. 2 E.

LACMIP 23635. On E bank of Chico Creek W from H_B House and approximately 122 m (400 ft.) S of twin meadows, 543 m (1800 ft.) S and 122 m (400 ft.) E of NW corner of section 13, T. 23 N, R. 2 E.

LACMIP 23637. On E bank of Chico Creek approximately 0.8 km (0.5 mi.) S of southern H_B gate and W of sharp bends in Chico Creek county road; locality is just barely inside E line of SE corner of section 14 at 381 m (1250 ft.) N of SE corner of section 14, T. 23 N, R. 2 E.

LACMIP 23638. On E bank of Chico Creek in concretions weathering out of 4.5-m (15-ft.) bank about 0.5 km (0.3 mi.) S of LACMIP loc. 23637; there is a large westward bend in the creek to the north of the loc. 23638, and the creek then runs straight in a southerly direction; 168 m (550 ft.) S and 260 m (850 ft.) W of NE corner of section 23, T. 23 N, R. 2 E.

LACMIP 23639. In concretions in massive, greenish-gray sandstone, approximately 213 m (700 ft.) downstream from LACMIP loc. 23638; southern edge of NE 1/4 of the NE 1/4 of section 23, T. 23 N, R. 2 E.

LACMIP 23643. West side of Chico Creek in concretions weathering out of sandstone cropping out at stream edge, 671 m (2200 ft.) S and 762 m (2500 ft.) W of NE corner of section 26, T. 3 N, R. 2 E.

LACMIP 23648. Sandstone bluff on W side of Chico Creek about 0.4 km (0.25 mi.) above Salt Springs and approximately 61 m (200 ft.) above Chico Creek, 533 m (1750 ft.) S and 549 m (1800 ft.) E of NW corner of section 35, T. 23 N, R. 2 E.

BUTTE CREEK

LACMIP 24224. From nodules in mine tunnel on E bank of Butte Creek, about 3 m (10 ft.) above water's edge, 4.5 km (2.8 mi.) by road NW of Honey Run Road covered bridge, approximately 610 m (2000 ft.) S and 76 m (250 ft.) E of NW corner of section 17, T. 22 N, R. 3 E, U.S. Geological Survey, 15-minute, Paradise Quadrangle, 1953, Butte County, northern California. Chico Formation, lowermost part of Ten Mile Member. Age: Early Campanian. Collector: W. P. Popenoe, August 29, 1952.

PENTZ AREA

U. S. Geological Survey, 7.5-minute, Cherokee Quadrangle, 1949, Butte County, northern California. Chico Formation, Pentz Road member (informal) of Russell et al. (1986). Age: Early Campanian.

LACMIP 10832 [= CIT 1012]. Fossiliferous layers cropping out in the beds of small gullies in the field on both sides of the E-W highway connecting Pentz and Chico, about 1.3 km (0.8 mi.) N86°W of Pentz, NW ¼ of the NW ¼ of section 25, T. 21 N, R. 3 E. Collectors: W. P. Popenoe and D. W. Scharf, August 15, 1931.

LACMIP 11798. Across the road and S from LACMIP loc. 10832. Collector: W. P. Popenoe.

LACMIP 22406. Gullies W of Pentz, 260 m (850 ft.) S and 107 m (350 ft.) E of NW corner of section 25, T. 21 N, R. 3 E. Collector: W. P. Popenoe, 1946.

LACMIP 24081. Fossiliferous conglomerate approximately 2.4 km (1.5 mi.) S of Pentz along Wicks-Pentz-Magalia Road and approximately 0.8 km (0.5 mi.) E of road in W-flowing tributary gully to Dry Creek, near middle of section 36, T. 21 N, R. 3 E. Collector: A. Clark, 1935.

LACMIP 24340. Conglomerate beds cropping out just below a drainage canal, SE side of Oroville Highway, about 1.2 km (0.75 mi.) NE of intersection of the highway and Pentz-Magalia-Oroville Road, and 427 m (1400 ft.) S and 183 m (600 ft.) W of the NE corner of section 36, T. 21 N, R. 3 E. Collector: W. P. Popenoe, May 13, 1960.

LACMIP 27255. In concretionary lenses in gray sandstone (stained red when weathered) next to culvert under Durham-Pentz Road, about 0.8 km (0.5 mi.) W of junction with Oro-Pentz Magalia Road and 3.3 km (2 mi.) E of junction of Clark and Durham-Pentz Road; culvert is westernmost of two which are approximately 100 ft. apart; 244 m (800 ft.) S and 46 m (150 ft.) E of NW corner of section 25, T. 21 N, R. 3 E. Collector: L. R. Saul, August 23, 1954.

WASHINGTON SUCIA CREEK

LACMIP 10422. Float on beach, south side of Fossil Bay near its mouth, section 25, T. 38 N, R. 2 W, Sucia Island, San Juan County, Washington. Cedar District Formation. Age: Middle Campanian. Collectors: R. Durbi, H. L. Popenoe, & W. P. Popenoe, July 24, 1935.