

NEW LATE EOCENE MOLLUSKS FROM LOCALIZED LIMESTONE DEPOSITS FORMED BY SUBDUCTION-RELATED METHANE SEEPS, SOUTHWESTERN WASHINGTON

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ABSTRACT—The trochid archaeogastropod *Margarites (Pupillaria) columbiana* n. sp., the mytilid bivalve *Modiolus (Modiolus) willapaensis* n. sp., and the vesicomyid bivalve *Calyptogena chinookensis* n. sp. are described from the earliest known fossil communities associated with subduction-related methane seeps. The communities are in very localized limestones of late middle to late Eocene age along the southwestern margin of Washington. These limestones contain large numbers of chemosynthetic bivalves and worm tubes, as well as other macrobenthos, that colonized around cool-temperature methane seeps along the landward slopes of an ancient subduction-zone complex.

Calyptogena chinookensis n. sp. is the earliest known species of this genus, which was previously known from Miocene to Recent.

INTRODUCTION

THREE NEW species of Eocene marine mollusks are described from the earliest known fossil communities associated with subduction-related methane seeps. These communities were recently discovered in southwestern Washington by Goedert and Squires (1990), who reported on the details of the geologic setting, taxonomic composition, and mode of origin. The communities are in three very localized and highly fossiliferous limestone deposits of late middle to late Eocene age enclosed within deep-marine, forearc-basin tuffaceous siltstones or muddy siltstones that are essentially barren of macrofossils.

The limestones always contain specimens of the following: a naticid gastropod and the bivalves *Modiolus (Modiolus) willapaensis* n. sp. and *Calyptogena chinookensis* n. sp. In addition, there can be specimens of the following: vestimentiferan? tube worms, serpulid tube worms, the siliceous sponge *Aphrocallistes polytretos*, a very small fissurellid? limpet, a very small patelliform limpet, the archaeogastropods *Margarites (Pupillaria) columbiana* n. sp. and *Homalopoma?* spp., a buccinid? gastropod, and the bivalves *Acharax* cf. *A. dalli*, *Thyasira (Conchocele) folgeri*, and a large pitarid bivalve. There can also be various decapod parts. Bivalves are always articulated and show growth series (Goedert and Squires, 1990).

Compressive forces related to on-going subduction during the Eocene in southwestern Washington squeezed subsurface methane-rich waters onto the ocean floor. Opportunistic organisms (such as the bivalves *Modiolus* and *Calyptogena*) that were capable of harboring methane-oxidizing chemoautotrophic bacteria colonized around cool-temperature methane seeps where subsurface fluids discharged. Gastropods (such as *Margarites*) were grazers of bacteria that lived on the surfaces of the bivalves and worm tubes. The limestones originated from methane-derived authigenic carbonate deposits (Goedert and Squires, 1990).

Although modern examples of subduction-related communities have been reported, mainly from off the coasts of Oregon (Kulm et al., 1986) and Japan (Hashimoto et al., 1989), ancient examples are rare and so far have been confined to *Calyptogena*-bearing Miocene and Pliocene deposits in Japan (Kanno et al., 1989; Niitsuma et al., 1989) and Miocene-Pliocene deposits in southwestern Washington (Campbell, 1989).

The limestones, which are now mostly covered with slope wash and vegetation, are up to 15 m in thickness, 68 m in length, and 38 m in width. They will be referred to as the Humptulips,

Bear River, and Menlo deposits (Figure 1). Details as to exact location, size of deposit, stratigraphic position, age, and collectors are given in the Appendix of this report.

The abbreviation LACMIP = Natural History Museum of Los Angeles County, Invertebrate Paleontology Section.

SYSTEMATIC PALEONTOLOGY

Class GASTROPODA Cuvier, 1798

Order ARCHAEOGASTROPODA Thiele, 1925

Family TROCHIDAE Rafinesque, 1815

Subfamily MARGARITINAE Stoliczka, 1868

Genus MARGARITES Gray, 1847

Type species.—By monotypy, *Turbo helicinus* Phipps, 1774.

Subgenus PUPILLARIA Dall, 1909

Type species.—By monotypy, *Trochus pupillus* Gould, 1849.

MARGARITES (PUPILLARIA) COLUMBIANA n. sp.

Figure 2.1-2.3

Margarites (Pupillaria) n. sp. GOEDERT AND SQUIRES, 1990, fig. 2q.

Diagnosis.—A *Margarites* with numerous low collabral costae on subtabulation near suture, 6-8 moderately strong and closely spaced spiral ribs between subtabulation, moderately strong angulation on body whorl.

Description.—Shell small, turbiniform, with 3-4 convex whorls increasing rapidly in size, spire moderately low, body whorl large; suture moderately shallow; whorls subtabulate near suture with numerous low but prominent collabral costae; penultimate whorl with 5-6 spiral ribs becoming more closely spaced anteriorly; body whorl with a moderately strong angulation, ornamented by 6-8 moderately strong spiral ribs between subtabulation and angulation and anterior to angulation closely spaced spiral ribs; umbilicus fairly wide and deep; growth lines prosocline; aperture circular. Holotype height 8.2 mm, width 8.9 mm.

Remarks.—Specimens range in height from 4 to 10.5 mm. Some are internal molds. All are incomplete, and the sculpture anterior to the angulation is described from remnants of shell. Details of the umbilical area are obscured by matrix.

The new species resembles *Margarites (Pupillaria) condoni* Dall (1909, p. 98, Pl. 6, figs. 7, 8; Weaver, 1943, p. 290-291, Pl. 62, figs. 17, 19) from the Empire Formation of late Miocene age (Armentrout et al., 1983) in southwestern Oregon. Unlike

the new species, *M. (P.) condoni* is found in shallow-water deposits (Armentrout, 1967). The new species differs from *M. (P.) condoni* in the following features: smaller, lower spire, whorls more convex and less tabulate near suture, numerous low colabral costae on subtabulation near suture, weaker and more closely spaced spiral ribs, six to eight rather than five spiral ribs between suture and angulation, and no nodules on spiral ribs.

The earliest known *Margarites (Pupillaria)* is a single specimen of *M. (P.)?* sp. Hickman (1980, p. 20, Pl. 2, fig. 7) from the Keasey Formation of late Eocene age in southwestern Washington. The new species differs from *M. (P.)?* sp. in the following features: a subtabulation near suture of body whorl, spiral ribs on body whorl much weaker and much more closely spaced, and base of body whorl not as flat.

The earliest known species of *Margarites* s.s. are the same age as the new species. One is *M. (M.) chappelli* Durham (1944, p. 154, Pl. 15, fig. 11) from the Quimper Formation, northwestern Washington. Armentrout et al. (1983) assigned this formation to the late Eocene. The other is *M. (M.) sericeus* Hickman (1980, p. 19–20, Pl. 2, figs. 5, 6, 8) from the Keasey Formation of late Eocene age in southwestern Washington. *Margarites (Pupillaria) columbiana* n. sp. differs from both of these species in having spiral ribs rather than being smooth.

Etymology.—The new species is named for the Columbia River.

Material.—Nine specimens.

Occurrence.—Upper Eocene, southwestern Washington; strata temporally equivalent to lower part of Lincoln Creek Formation, locality LACMIP 5802 (Bear River deposit). (See Appendix.)

Repository.—Holotype, LACMIP 8353; paratypes, LACMIP 8358 and 8359; all from locality LACMIP 5802.

Class BIVALVIA Linné, 1758
Order MYTILOIDA Férussac, 1822
Family MYTILIDAE Rafinesque, 1815
Subfamily MODIOLINAE Keen, 1958
Genus MODIOLUS Lamarck, 1799

Type species.—By subsequent designation (Gray, 1847), *Mytilus modiolus* Linné, 1758. Nomen conservandum pro *Volsella Scopoli, 1777*, ICZN Opinion 325.

Subgenus MODIOLUS s.s.
MODIOLUS (MODIOLUS) WILLAPAENSIS n. sp.
Figure 2.4–2.6

Modiolus (Modiolus) n. sp. GOEDERT AND SQUIRES, 1990, fig. 2m, n.

Diagnosis.—Shell small, smooth, narrowing posteriorly, beaks distinct and projected, hinge line about 50 percent of length of shell, umbonal ridge extending only to middle part of valve.

Description.—Shell small, modioliform, equivalve, inequilateral, maximum height at middle of dorsal margin, narrowing posteriorly; beaks prosogyrate, projecting beyond commissure in anterodorsal region of shell; dorsal margin concave; hinge line about 50 percent of length of shell; posterior dorsal margin deflected ventrally; umbonal ridge on each valve extending obliquely from beak to middle part of valve; lunule small; ventral margin near straight; sculpture of fine commarginal lines of growth, tending to be coarsest on anterior part of valve just ventral of umbonal ridge. Holotype height 10 mm, length 20 mm, thickness 7.5 mm.

Remarks.—Specimens range in length from 6.5 to 27 mm, but most are about 20 mm in length. All are articulated, and no interior features were observable.

The new species resembles *M. (M.) eugenensis* Clark (1925, p. 86, Pl. 9, fig. 4; Weaver, 1943, p. 111–112, Pl. 24, fig. 8;

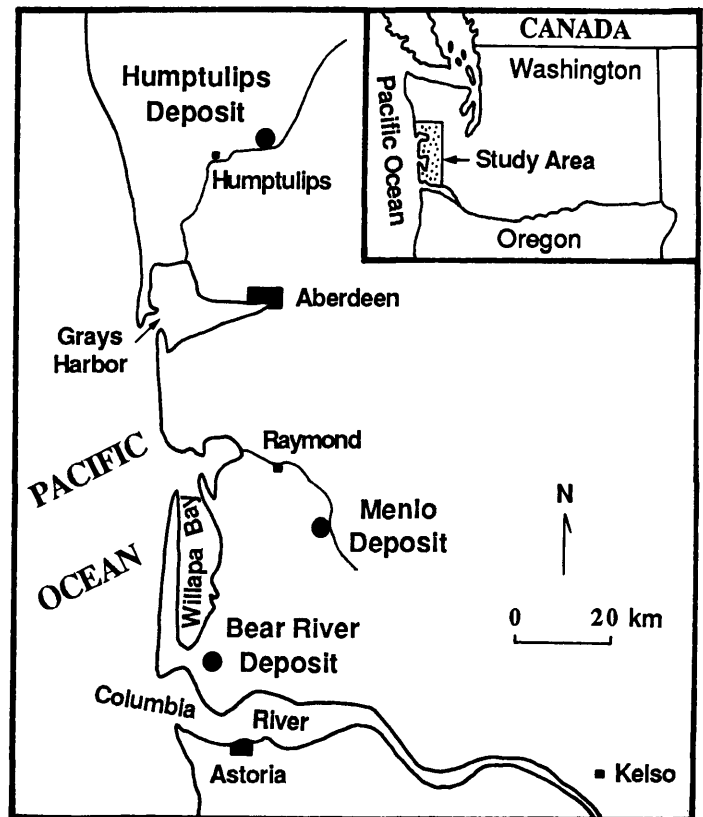


FIGURE 1—Index map to the Bear River, Menlo, and Humptulips limestone deposits, southwestern Washington.

Hickman, 1969, p. 34, Pl. 2, figs. 1–5; Moore, 1983, p. 74, Pl. 19, fig. 12) from the Eugene Formation of late Eocene age (Armentrout et al., 1983) in central-western Oregon and from the upper part of the San Emigdio Formation of late Eocene age in southern California (DeLise, 1967). Unlike the new species, *M. (M.) eugenensis* is found in shallow-water deposits (DeLise, 1967; Hickman, 1969). The new species differs from *M. (M.) eugenensis* in the following features: about three times smaller, smooth shell rather than sculptured by fairly coarse radial ribbing, posterior end of shell narrower, ventral margin straight, beaks more distinct, hinge line only about 50 percent rather than about 65 percent of length of shell, posterior dorsal margin more deflected ventrally, and umbonal ridge does not extend all the way to the posterior end of shell.

Etymology.—The new species is named for the Willapa Hills and the Willapa River Valley of southwestern Washington.

Material.—About 150 specimens.

Occurrence.—Upper middle to upper Eocene, southwestern Washington. Upper middle to upper Eocene: Humptulips Formation, locality LACMIP 12385. Upper Eocene: strata temporally equivalent to lower part of Lincoln Creek Formation, locality LACMIP 5802 (Bear River deposit); lower part of Lincoln Creek Formation, locality LACMIP 12326 (Menlo deposit). (See Appendix.)

Repository.—Holotype, LACMIP 8350; paratypes, LACMIP 8349, 8360 to 8362; all from locality LACMIP 5802.

Order VENEROIDA H. Adams and A. Adams, 1856
Family VESICOMYIDAE Dall and Simpson, 1901
Genus CALYPTOGENA Dall, 1891

Type species.—By monotypy, *Calyptogena pacifica* Dall, 1891.

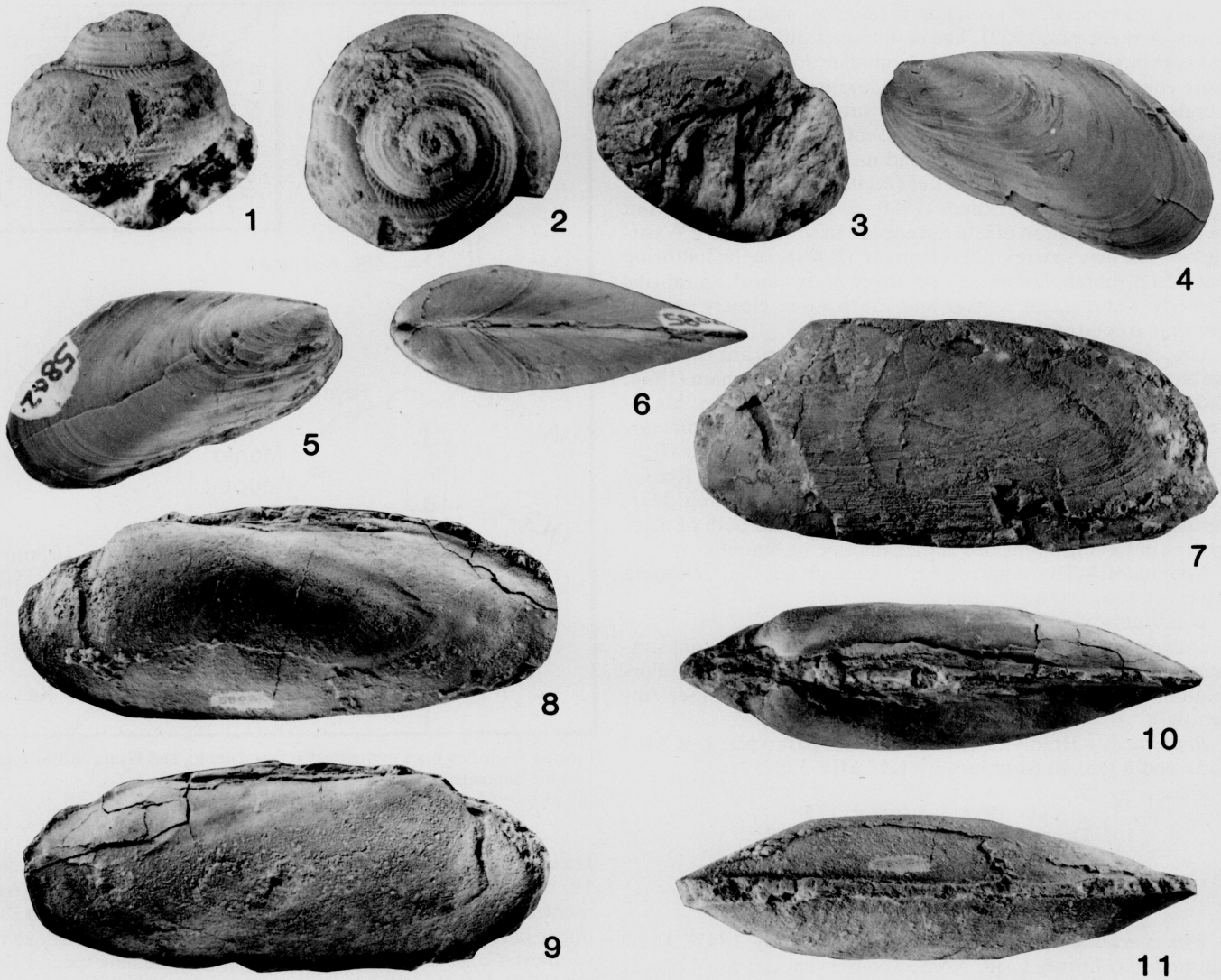


FIGURE 2—1–3, *Margarites (Pupillaria) columbiana* n. sp., holotype, LACMIP 8353, locality LACMIP 5802 (Bear River deposit), $\times 4$. 1, apertural view; 2, dorsal view; 3, oblique apertural view. 4–6, *Modiolus (Modiolus) willapaensis* n. sp., holotype, LACMIP 8350, locality LACMIP 5802 (Bear River deposit), $\times 2.4$. 4, left valve; 5, right valve; 6, dorsal view. 7–11, *Calyptogena chinookensis* n. sp., locality LACMIP 5802 (Bear River deposit). 7, holotype, LACMIP 8351, left valve, $\times 0.8$; 8–11, paratype, LACMIP 8352, internal mold, $\times 0.9$; 8, left valve, low-angle lighting used to bring out the narrow groove extending posteroventrally from umbo; 9, right valve; 10, dorsal view; 11, ventral view.

CALYPTOGENA CHINOOKENSIS n. sp.

Figure 2.7–2.11

Calyptogena n. sp. GOEDERT AND SQUIRES, 1990, fig. 2o, p.

Diagnosis.—Shell medium-sized, moderately elongate, umbones located at anterior fourth of valve, anterior margin somewhat elongate, posterior margin tapered, and interior of both valves with a narrow ridge extending posteroventrally from umbo.

Description.—Shell medium-sized, equivalve, inequilateral, moderately elongate, inflated with both valves of equal convexity; umbones low and located at anterior fourth of valve; anterior margin of valves somewhat elongate, ventral margin long and straight, and posterior margin tapered; ligamental area opisthodontic, occupying about three-fourths of the length of posterior dorsal margin; valves sculptured with very closely spaced growth lines and a few irregular growth ridges; growth lines more prominent ventrally; interior of both valves with a narrow ridge

extending posteroventrally from umbo. Holotype height 38 mm, length 90 mm, thickness 27 mm.

Remarks.—Specimens range in length from 9 to 100 mm, but most are about 80 mm in length. Most are internal molds of articulated specimens. Although no valve interiors were directly observable, an internal narrow ridge extending posteroventrally from the umbo of each valve is indicated by the presence of a groove in this region on many of the internal molds.

Because dentition features are not observable on the new species, assignment to a subgenus of *Calyptogena* is not possible.

The new species resembles the extant *Calyptogena nautilei* Okutani and Métivier (1986, p. 148–151, text fig. 1a, Pl. 1, figs. 1–3) from about 3,800 m depth in the eastern Nankai subduction zone off the Pacific coast of Japan. Horikoshi (1989) showed that *C. laubieri* Okutani and Métivier (1986, p. 151, text fig. 1b, Pl. 2, figs. 4–7) is conspecific with *C. nautilei*. *Calyptogena chinookensis* n. sp. differs from *C. nautilei* in the following features: ventral margin straight rather than sinuous, ventral mar-

gin without a shallow concavity centrally, posterior end more tapered, interior of both valves with a narrow ridge extending posteroventrally from umbo.

Previously, the geologic range of genus *Calyptogena* was thought to be Miocene to Recent, with fossil occurrences confined to Japan and the Pacific coasts of North America and Central America (Keen, 1969; Boss and Turner, 1980). With the discovery of *Calyptogena chinookensis* n. sp., the geologic range of this genus is now extended into the late Eocene.

Etymology.—The new species is named for the town of Chinook, Washington, which is a few kilometers south of the type locality.

Material.—About 50 specimens.

Occurrence.—Upper middle to upper Eocene, southwestern Washington. Upper middle to upper Eocene: Humptulips Formation, locality LACMIP 12385. Upper Eocene: strata temporally equivalent to lower part of Lincoln Creek Formation, locality LACMIP 5802 (Bear River deposit); lower part of Lincoln Creek Formation, locality LACMIP 12326 (Menlo deposit). (See Appendix.)

Repository.—Holotype, LACMIP 8351, paratypes, LACMIP 8352, 8363 and 8364; all from locality LACMIP 5802.

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APPENDIX

LOCALITIES

LACMIP 5802. Bear River deposit. In an abandoned quarry on the south side of Bear River in the SE $\frac{1}{4}$, SE $\frac{1}{4}$, sec. 20, T10N, R10W, Chinook 7.5 minute quadrangle, Pacific County, southwestern Washington. In 1954, during the last active quarrying, the limestone was reported as 15 m thick, 68 m in length, and 38 m wide (Danner, 1966). Informal "siltstone of Cliff Point" (Wells, 1989). Age: late Eocene (calcareous nannofossil CP15b Zone of Okada and Bukry (1980) and benthic foraminiferal Refugian Stage) (Goedert and Squires, 1990); temporal equivalent to lower part of Lincoln Creek Formation. Collectors: J. L. and Gail Goedert, 1978, 1979, 1990.

LACMIP 12326. Menlo deposit. On the north bank of the Willapa River adjacent to the Chehalis-Raymond highway, in the SW $\frac{1}{4}$, NW $\frac{1}{4}$ sec. 24, T13N, R8W, Raymond 15 minute quadrangle, Pacific County, southwestern Washington. Danner (1966) reported the deposit to be 2 m thick, 7.5 m in length, and 3 m in width. Lincoln Creek Formation (Wagner, 1967). Age: late Eocene (benthic foraminiferal Refugian Stage) (Goedert and Squires, 1990). Collectors: J. L. and Gail Goedert, and K. L. Kaler, 1990.

LACMIP 12385. Humptulips deposit. Cut by an abandoned meander on the East Fork of Humptulips River in the northwest part of sec. 4, T20N, R9W, Quinault Lake 15 minute quadrangle, Grays Harbor County, southwestern Washington. Danner (1966) reported the deposit to be 15 m thick, 30 m in length, and 15 m in width. Humptulips Formation (Rau, 1986). Age: late middle to late Eocene (benthic foraminiferal Narizian Stage) (Rau, 1986). Collectors: J. L. and Gail Goedert, 1990.