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New Species of Small to Minute Gastropods of Early Eocene Age from the Crescent Formation, Black Hills, Southwest Washington

by

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Abstract. Six new species of small to minute gastropods are part of a diverse shallow-water marine assemblage in the upper part of the Crescent Formation at Larch Mountain in the Black Hills west of Olympia, Washington.

The scissurellid *Scissurella* (*Scissurella*) ***malloryi*** is the earliest record of *Scissurella sensu stricto* and its first record from the Pacific coast of North America. The orbitestellid *Orbitestella* ***palaiopacifica*** and the omalogyrid *Ammonicera* ***benhami*** are the earliest records of these genera. In regards to the Pacific coast of North America, *O.* ***palaiopacifica*** is the first fossil record of this genus, and *A.* ***benhami*** is the first record of this genus. The fissurellid *Puncturella* (*Altrix*) ***pacifica*** is the first record of this subgenus from the Pacific coast of North America. The liotiid *Arene* ***olympiata*** is the second Paleogene record of this genus from the Pacific coast of North America. The volutomitrid *Conomitra* ***capitolina*** is the second record for this genus from the Pacific coast of North America.

New information on associated benthic foraminifera confirms a middle early Eocene age that was previously based only on molluscan data.

INTRODUCTION

This study is an outgrowth of our continuing investigation of little-studied molluscan faunas of the upper part of the Crescent Formation in southwestern Washington. The Crescent Formation ranges in age from late Paleocene to early middle Eocene (Snavely, 1987) and is the basement rock in this area. It consists predominantly of oceanic tholeiitic basalt flows, but the original tectonic setting of the Crescent Formation remains uncertain (Suczek et al., 1994). One hypothesis is that the basalts formed seamounts that later accreted to North America (Duncan, 1982), but an alternative hypothesis proposes that the basalts formed in a rift-basin environment along the continental margin (Wells et al., 1984; Babcock et al., 1992, 1994).

The upper third of the Crescent Formation contains mollusk-bearing, shallow-marine deposits and, locally, terrestrial deposits. Prior to 1992, studies of the mollusks (Weaver & Palmer, 1922) dealt with only a few new species from exposures along the north shore of the Olympic Peninsula. Although Weaver (1942) monographed Tertiary marine megafossils from Washington and Oregon, his coverage of species from the Crescent Formation was essentially a review of the species described by Weaver & Palmer (1922). The first detailed analysis of a megafossil assemblage in the Crescent Formation was made by Squires

et al. (1992) and dealt with the shallow-marine upper part of the formation at Pulali Point (Figure 1), west of Seattle. That study spawned two additional articles (Squires, 1992, 1993) on certain bivalves from the Pulali Point area. Squires & Goedert (1994a) made a detailed study of another megafossil assemblage in the upper part of the Crescent Formation in the Little River area in the southern Olympic Peninsula (Figure 1). Squires & Goedert (1994b) reported new species (some minute in size) of mollusks in the upper part of the Crescent Formation in the Black Hills, west of Olympia, at the same localities (CSUN locs. 1563 and 1564) that are the focus of this paper (Figure 1). Squires & Goedert (1995) also reported additional new species of gastropods in the transition zone between the upper part of the Crescent Formation and the overlying lower member of the McIntosh Formation in the northern Doty Hills, approximately 30 km to the southwest of the Black Hills.

Additional work by us in the Black Hills has revealed six more new species of gastropods. The purpose of this paper is to describe and name the new species, all of which were found in the upper part of the Crescent Formation in richly fossiliferous and conglomeratic silty mudstone interbedded with basalt. The extrusion of the basalt caused shoaling and the establishment of a rocky shoreline/shallow-water community where gastropods and bivalves lived alongside colonial corals and coralline algae. The mollusk shells were transported a short distance and deposited in muddy matrix coquina that filled cracks between boulders of basalt. Most of the shells in the coquina are small to minute, and their size prevented them from being pulverized during transport (Squires & Goedert, 1994b; Nesbitt et al., 1994). Extraction of the fossils is possible because the muddy matrix is only poorly indurated and, upon soaking in water, the rock can be broken apart with a strong needle. If care is exercised, intact small to minute fossils can be obtained. Our studies of the minute mollusks would have been impossible without the scanning electron microscopy work by Steven R. Benham (Pacific Lutheran University, Tacoma, Washington). Benham's work also enhanced our knowledge of protoconch morphology and shell microstructure on the small mollusks.

The molluscan stages used in this report stem mainly from Clark & Vokes (1936), who proposed five mollusk-based provincial Eocene stages, namely, "Meganos" (lowermost Eocene), "Capay" (middle lower Eocene), "Domengine" (upper lower to lower middle Eocene), "Transition" (lower middle Eocene), and "Tejon" (middle middle Eocene to upper Eocene). These stage names are in quotes because they are informal terms. Givens (1974) modified the use of the "Capay Stage," and it is in this modified sense that the "Capay Stage" is used herein. The upper Eocene to lower Oligocene Galvinian Stage of Armentrout (1975) is also used in this report. This stage is used in the Pacific Northwest and is correlative to the upper part of the "Tejon Stage" in California.

The classification systems used for taxonomic categories higher than the family level generally follow that of Haszprunar (1988) for the vetigastropods and that of Ponder & Warén (1988) for the caenogastropods and heterobranch gastropods.

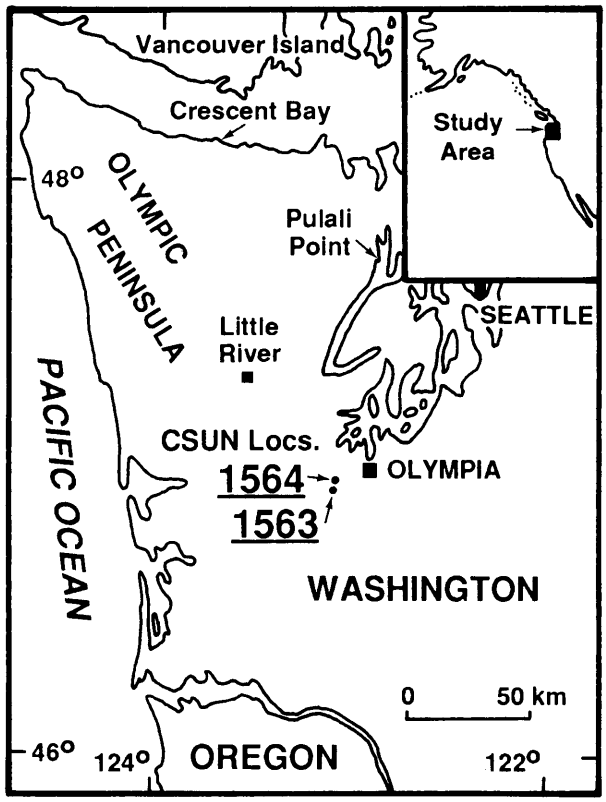

Figure 1

Index map to CSUN locs. 1563 and 1564, upper part of Crescent Formation, Larch Mountain, Black Hills, west of Olympia, Washington.

Abbreviations used for catalog and/or locality numbers are: CSUN, California State University, Northridge; LACMIP, Natural History Museum of Los Angeles County, Invertebrate Paleontology Section.

AGE

Squires & Goedert (1994b) assigned the upper part of the Crescent Formation at CSUN locs. 1563 and 1564 to the middle lower Eocene ("Capay Stage") based on molluscan fossil evidence. Benthic foraminiferal analyses done during the course of the present investigation confirm this age. Two microfossil samples from CSUN loc. 1563 contained a littoral to inner sublittoral fauna and the following key species diagnostic of Mallory's (1959) Penutian Stage: *Anomalina dorri aragonensis, Quinqueloculina yeguaensis, Alabamina wilcoxensis, Cibicides martinezensis, Cibicides whitei,* and *Nonion wilcoxensis* (S. Downs, personal communication). The Penutian Stage, as used in emended sense of Almgren et al. (1988) for shallow-marine strata, is indicative of the middle lower Eocene and correlative to

the molluscan "Capay Stage" (Squires et al., 1992). This corresponds well with the average age of 53.1 (± 2.0) Ma reported by Globerman et al. (1982) for basalts in the Black Hills.

The same two microfossil samples studied for benthic foraminifera were also processed for planktonic foraminifera and calcareous nannofossils, but none were found (M. V. Filewicz & S. Downs, personal communication).

SYSTEMATIC PALEONTOLOGY

Class Gastropoda Cuvier, 1797

Subclass Prosobranchia Milne-Edwards, 1848

Order Vetigastropoda Salvini-Plawén, 1980

Family SCISSURELLIDAE Gray, 1847

Subfamily SCISSURELLINAE Gray, 1847

Genus *Scissurella* d'Orbigny, 1824

Type species: *Scissurella laevigata* d'Orbigny, 1824, by subsequent designation (Gray, 1847), Recent, Mediterranean Sea.

Subgenus *Scissurella sensu stricto*

Scissurella (*Scissurella*) ***malloryi*** Squires & Goedert, sp. nov.

(Figures 2–7)

Diagnosis: A *Scissurella sensu stricto* with a nearly flat spire, sculpture beyond the first teleoconch whorl and posterior to the selenizone comprised of about 28 axial ribs and three to five spiral ribs, and sculpture on body whorl anterior to the selenizone comprised of about 28 axial ribs and 15 weaker spiral ribs.

Description: Shell minute, diameter up to 1 mm, thin and fragile, consisting of slightly more than two post-protoconch whorls. Spire small, very slightly elevated (nearly flat), rapidly expanding. Suture incised. Protoconch just less than one whorl (about 70 microns in diameter), convex, with about 10 weak axial riblets; set off from post-protoconch whorls by a prominent varix. Selenizone on upper half of body whorl, starting after the first one-half whorl of teleoconch. Selenizone on shoulder of body whorl, keel-like and bordered by produced edges; slit long. Selenizone regularly lined with prominent, widely spaced axial ribs. First whorl of teleoconch with 17 axial ribs. Beyond first teleoconch whorl and posterior to the selenizone, about 28 arcuately prosocline axial ribs and three to five, less prominent spiral ribs. Body whorl anterior to selenizone with about 28 axial ribs and 15 less prominent spiral riblets, becoming closer spaced toward the umbilicus. Prominent and deep, smooth spiral sulcus present just anterior to selenizone. Base of body whorl rounded. Umbilicus open, deep, funnel-shaped, semilunar, set off from base by spiral cord; lined within by axial growth lines. Aperture circular. Outer lip incised with slit. Columella smooth.

Dimensions of holotype: Height 1 mm, width 1 mm.

Holotype: LACMIP 11354.

Type locality: CSUN loc. 1563, Larch Mountain, Washington, 47°59′03″N, 123°8′2″W.

Paratypes: LACMIP 11355–11357, CSUN loc. 1563.

Discussion: Fifteen specimens were found, all about 1 mm in height. Thirteen of the specimens were found at CSUN loc. 1563; two were found at locality 1564.

The new species is most similar to the living species *Scissurella* (*S.*) *rota* Yaron (1983:268–270, pl. 3; Herbert, 1986:622–623, figs. 25–27) from the Red Sea and Persian Gulf to eastern Cape Province, southern Africa (Herbert, 1986). The new species differs by having stronger and more (three to five rather than one to two) spiral ribs posterior to the selenizone, more axial ribs (28 rather than 20) on the body whorl anterior to the selenizone, sculpture that is not nodulose on the body whorl at the junction of the axial and spiral ribs, and spiral ribs that do not become coarser near the umbilicus.

The new species is also similar to *S.* (*S.*) *costata* d'Orbigny, 1824, from the Canary Islands, Bermuda, and the Mediterranean Sea (Yaron, 1983). Wenz (1938:173, fig. 269) and Batten (1975:figs. 4, 11, 12) also illustrated this species. The new species differs by having spiral ribbing, much weaker axial ribbing, and a deep spiral sulcus anterior to the selenizone.

The new species resembles *Scissurella parisiensis* Deshayes (1866:5, pl. 65, figs. 8–10; Cossmann & Pissarro, 1910–1913:pl. 2, fig. 12-2) from middle Eocene (Lutetian Stage) rocks of the Paris Basin, France, but the new species has a lower spire and a deep spiral sulcus just anterior to the selenizone.

As discussed by Sohl (1992), current workers believe that family Scissurellidae may have originated during the

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Explanation of Figures 2 to 7

All specimens from CSUN loc. 1563, and all figures = SEM micrographs. Figures 2–7. *Scissurella* (*Scissurella*) ***malloryi*** Squires & Goedert, sp. nov. Figures 2–3. Holotype LACMIP 11354. Figure 2. Apertural view, ×60, height 1.1 mm. Figure 3. Apical view, ×60, maximum diameter 1.45 mm. Figure 4. Paratype LACMIP 11355, abapertural view, ×60, height 1 mm. Figure 5. Paratype LACMIP 11356, umbilical view; ×60, maximum diameter 1.46 mm. Figures 6–7. Paratype LACMIP 11357. Figure 6. Oblique apical view, ×60, maximum diameter 1.2 mm. Figure 7. Apical view of protoconch shown in Figure 6, ×200, maximum length 0.475 mm.

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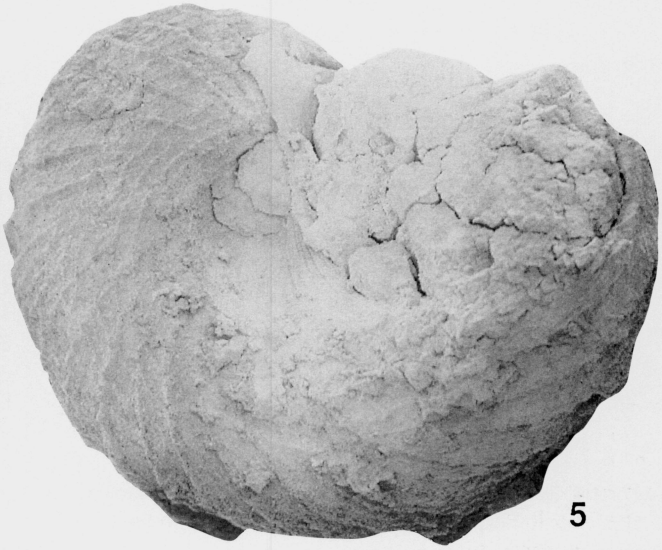

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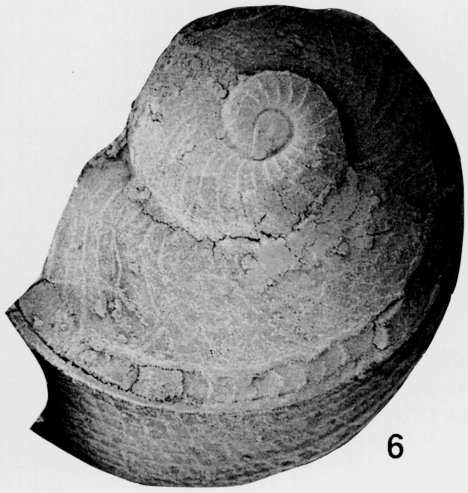

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Triassic. Only a single Cretaceous species is known, *Scissurella marchmontensis* Sohl, 1992 from deposits of Late Cretaceous age (Maastrichtian Stage) in Puerto Rico and Jamaica (Sohl, 1992). Sohl's species is similar to *Scissurella sensu stricto,* a taxon that is characterized (McLean, 1967) by a flattened spire, with the selenizone on the upper half of the whorl. The genus is placed in subfamily Scissurellinae because it has a protoconch with distinct axial ribs (Marshall, 1993). The new species has the characteristics of *Scissurella sensu stricto* and, to our knowledge, is the earliest representative of *Scissurella sensu stricto* anywhere. The new species is the first record of *Scissurella sensu stricto* from the Pacific coast of North America. Today, only four cool- to cold-water species of *Scissurella (Anatoma)* are found in northeastern Pacific (McLean, 1967).

Etymology: The new species is named for V. Standish Mallory for his important contributions to the study of Pacific coast of North America benthic foraminiferal biostratigraphy.

Family FISSURELLIDAE Fleming, 1822

Genus *Puncturella* Lowe, 1827

Type species: *Patella noachina* Linnaeus, 1758, by original designation.

Subgenus *Altrix* Palmer, 1942

Type species: *Fissurella altior* Meyer & Aldrich, 1886, by original designation, Eocene, Alabama.

Puncturella (*Altrix*) ***pacifica*** Squires & Goedert sp. nov.

(Figures 8–9)

Diagnosis: A conical *Puncturella* (*Altrix*) with a nearly circular apical perforation and 28 radial ribs crossed by equally strong concentric ribs.

Description: Shell small, up to 2.8 mm height, conical, slightly longer than high. Apex punctate, at summit and slightly forward of center of shell. Apical perforation nearly circular, with four, very minute constrictions. Posterior slope broadly convex, anterior slope very slightly concave and almost straight in profile. Sculpture of 28 strong, raised radial ribs approximately same width as interspaces. Concentric sculpture of equally strong raised ribs. Intersection of two sculpture components producing a rectangularly cancellate pattern. Aperture broadly circular.

Dimensions of holotype: Length 3 mm, width 3 mm, height 2.8.

Holotype: LACMIP 11358.

Type locality: CSUN loc. 1563, Larch Mountain, Washington, 47°59′03″N, 123°8′12″W.

Discussion: Only two specimens were found, both from CSUN loc. 1563. The holotype is moderately well preserved, but the other specimen is poorly preserved. The nomenclatural history of the name *Altrix* is discussed by Sohl (1992).

The new species is most similar to *Puncturella* (*Altrix*) *leesi* Sohl (1992:420, figs. 6.1–6.7), the earliest known species of this genus and known from Upper Cretaceous (Maastrichtian Stage) rocks of Puerto Rico. The new species differs in the following features: smaller shell, more conical shape, 28 rather than 16–17 radial ribs, and finer radial ribs.

The new species is similar to the type species of *Altrix, Puncturella* (*Altrix*) *altior* (Meyer & Aldrich, 1886:41, pl. 1, figs. 16a–16c; Palmer, 1937:30–31, pl. 3, figs. 1, 3, 6, 8) from middle Eocene rocks in Alabama. The new species differs in the following features: smaller, a more centrally located apex, perforation at summit, sculpture not as strong and there is no tendency for it to become nodular or scaly, and the radial ribs show much less tendency to alternate with any secondary radial ribs.

The geologic range of *Altrix* is Late Cretaceous to Recent, and only a few species are known (Sohl, 1992). The new species is the first record of the subgenus *Altrix* from the Pacific coast of North America.

Etymology: The new species is named for the Pacific Ocean.

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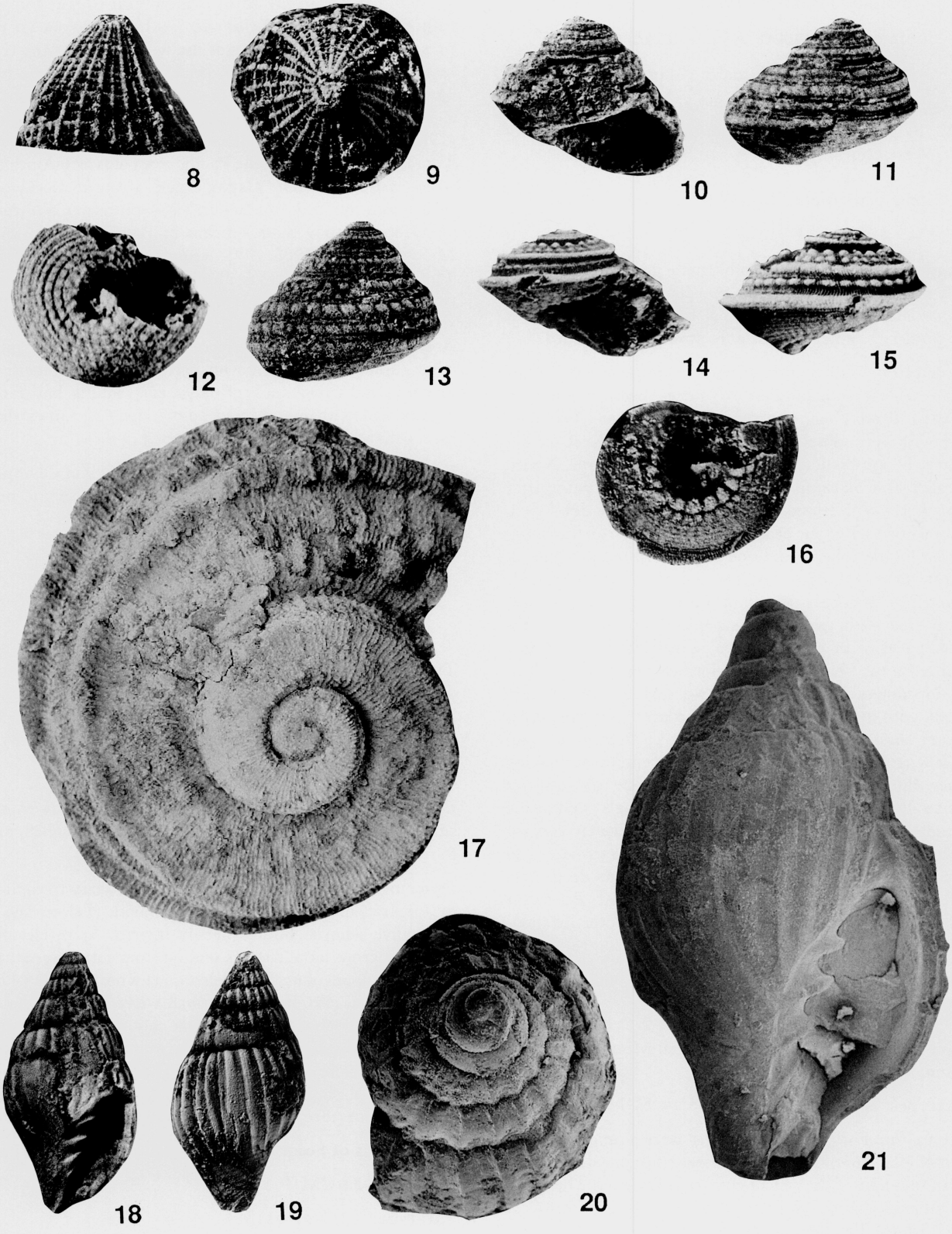
Explanation of Figures 8–21

All specimens from CSUN loc. 1563, and SEM micrographs = Figures 17, 20, 21. Other figures done by the senior author. All non-SEM specimens coated with ammonium chloride. Figures 8–9. *Puncturella* (*Altrix*) ***pacifica*** Squires & Goedert, sp. nov., holotype LACMIP 11358. Figure 8. Left-lateral view, ×8.6, height 2.8 mm. Figure 9. Apical view, ×11, length 3 mm. Figures 10–17. *Arene* ***olympiata*** Squires & Goedert, sp. nov. Figures 10–12. Holotype LACMIP 11359, ×4.9. Figure 10. Apertural view, some shell missing, ×4.9, height 5.7 mm. Figure 11. Abapertural view, ×4.5, height 5.7 mm. Figure 12. Umbilical view, ×4.5, maximum diameter 7.5 mm. Figure 13. Paratype LACMIP 11360, abapertural view, ×2.9, height 8.5 mm. Figures 14–16. Paratype LACMIP 11361, ×11. Figure 14. Apertural view, height 2 mm. Figure 15. Abapertural view, height 2 mm. Figure 16. Umbilical view, maximum diameter 3.1 mm. Figure 17. Paratype LACMIP 11362, apical view, ×60, maximum diameter 1.5 mm. Figures 18–21. *Conomitra* ***capitolina*** Squires & Goedert, sp. nov. Figures 18–19. Holotype LACMIP 11363, ×6.5, height 6.8 mm. Figure 18. Apertural view. Figure 19. Abapertural view. Figures 20–21. Paratype LACMIP 11364, ×40. Figure 20. Apical view, maximum diameter 1.4 mm. Figure 21. Apertural view, height 2.6 mm.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Family TURBINIDAE Rafinesque, 1815

Subfamily LIOTIINAE Adams & Adams, 1854

Genus *Arene* Adams & Adams, 1854

Type species: *Turbo cruentatus* Megerle von Mühlfeld, 1829, by subsequent designation (Woodring, 1928), Recent, West Indies.

Arene ***olympiata*** Squires & Goedert, sp. nov.

(Figures 10–17)

Diagnosis: An *Arene* having a bicostate juvenile body whorl with the anteriormost carina keel-like, and a noded, tricostate adult body whorl; base of body whorl with about 10 spiral ribs, anteriormost ones stronger and noded.

Description: Shell small, conical-turbiniform, of five angulate whorls with tabulate shoulders. Spire moderately elevated. Protoconch, of about two whorls, very low, covered with very closely spaced growth lines. Keel on periphery of spire whorls beginning after 1½ whorls. Noded spiral ribbing on ramp area of spire whorls beginning after two whorls, with rib nearest the suture the first developed. Spire whorls with four beaded spiral ribs (two on the ramp, one on the periphery, and one anterior to the periphery). Spiral rib on tabulate shoulder the strongest, forming a carina. On specimens less than 5 mm height, body-whorl ramp area with two, equal-sized and noded spiral ribs (interspaces with or without a spiral riblet) and three carinae on the periphery. Anteriormost carina on periphery forming a keel; the other two carinae weaker and noded, with the posteriormost one strongest. On specimens greater than 5 mm height, the three carinae on the periphery approaching each other in strength, all having nodes. Interspaces between carinae with one to two spiral riblets. Anteriormost keeled carina strongly delimiting boundary of base of body whorl. Base moderately convex, covered with about 10 spiral ribs that become stronger and more noded toward the umbilicus. Umbilicus deep, bordered by strongly noded spiral funicular cord. Peristome circular. Inner lip narrow and crenulate. Outer lip moderately thick. Growth lines prosocline.

Dimensions of holotype: Height 5.7 mm, width 7.3 mm.

Holotype: LACMIP 11359.

Type locality: CSUN loc. 1563, Larch Mountain, Washington, 47°59′03″N, 123°8′12″W.

Paratypes: LACMIP 11360–11362, CSUN loc. 1563.

Discussion: Forty-four specimens were found, all from CSUN loc. 1563. Preservation is generally good, although about one-half of the specimens are fragments. There is a growth series, with specimens ranging in height from 0.25 to 12.5 mm. The largest specimen is abraded.

The progressive change on the periphery from three unequal-strength carinae in the juvenile to three equal-strength carinae in the adult is important to note for any future identifications of this species. If it were not for the presence of a growth series of the new species at the type locality, it is likely that two species would have been recognized.

The new species is similar to *Arene mcleani* Squires (1988:9–10, figs. 9–11), the only other species of *Arene* from Paleogene rocks of the Pacific coast of North America. *Arene mcleani* is from "Capay Stage" strata in Lockwood Valley and the Orocopia Mountains, southern California, and from "Capay Stage" strata in Baja California Sur, Mexico (Squires, 1988, 1991; Squires & Demetrion, 1992). The new species differs in the following features: always two spiral ribs on ramp area, three spiral carinae on periphery of the body whorl, carinae thinner and not as strongly noded, carinae interspaces can have a single spiral riblet, anteriormost carina on periphery keel-strength in juveniles and somewhat keel-like in early adults, base more convex and with many more spiral ribs (10 rather than three) that are weaker and less noded.

Etymology: The species is named for the city of Olympia, Washington, which is near the type locality of the new species.

Order Caenogastropoda Cox, 1960

Family VOLUTOMITRIDAE Gray, 1854

Genus *Conomitra* Conrad, 1865

Type species: *Mitra fusoides* Lea, 1833, by subsequent designation (Fischer, 1884), middle Eocene, Alabama.

Conomitra ***capitolina*** Squires & Goedert, sp. nov.

(Figures 18–21)

Diagnosis: A *Conomitra* with 23 axial ribs on body whorl, subangulate shoulder, weak spiral ribs on teleoconch, and four teeth on inner lip.

Description: Shell small, fusiform. Protoconch conical, multispiral, of about three whorls, smooth. Teleoconch of about five whorls. Suture deeply incised. Spire elevated with numerous axial ribs, extending from suture to suture. Shoulder subangulate on all teleoconch whorls. Body whorl with 23 axial ribs, becoming much weaker to obsolete on neck. Teleoconch with spiral striae, not noded where they cross axial ribs. Spiral striae most prominent on neck and siphonal fasciole. Aperture elongate, narrow. Anterior siphonal canal short. Inner lip with four teeth, extending deep into aperture; anteriormost tooth weakest.

Dimensions of holotype: Height 6.8 mm, width 3.5 mm.

Holotype: LACMIP 11363.

Paratype: LACMIP 11364.

Type locality: CSUN loc. 1563, Larch Mountain, Washington, 47°59′03″N, 123°8′12″W.

Discussion: Eight specimens were found; they range in height from 4 to 6.8 mm. Seven of the specimens are from CSUN loc. 1563; one is from CSUN loc. 1564.

The new species resembles certain specimens of *Conomitra fusoides* (Lea, 1833:169, pl. 6, fig. 176) from the middle Eocene Gosport Sand in Alabama. *Conomitra fusoides* has considerable variation, and the specimens that resemble the new species are illustrated in Palmer (1937: pl. 66, figs. 24, 26). The new species differs in the following features: shell less tumid, neck more constricted, and axial ribs less prominent on neck of body whorl.

The new species also resembles LACMIP collection specimens of *Conomitra graniformis* (Lamarck, 1803:59–60; Cossmann & Pissarro, 1910–1913:pl. 42, fig. 202 bis 3) from middle Eocene (Lutetian Stage) rocks of the Paris Basin, France. The new species differs in the following features: axial ribs stronger except on the neck and siphonal fasicole and axial ribs not noded anteriorly near the suture.

The only other species of *Conomitra* from the Pacific coast of North America is *Conomitra washingtoniana* (Weaver, 1912:52–53, pl. 2, fig. 16; 1942:497–498, pl. 95, figs. 8, 9, 16; Dickerson, 1915:pl. 11, figs. 11a, 11b) from the upper middle Eocene Cowlitz Formation, southwestern Washington. Turner (1938) reported that Weaver's species may also be in the upper "Umpqua Formation" of southwestern Oregon. Cernohorsky (1970) assigned Weaver's species to genus *Conomitra*. The new species differs from *C. washingtoniana* in the following features: a slightly narrower shell, well-developed axial ribbing rather than a nearly smooth shell with microscopic spiral lines and faint axial ribs on the shoulder, and a subangulate shoulder.

Conomitra ranges from the Paleocene to the Pliocene (Wenz, 1943). Although the genus has been found in the Old World, it was most common in Paleocene to upper Eocene rocks of the Gulf Coast (Palmer, 1937; Palmer & Brann, 1965–1966).

Etymology: The species is named in reference to the proximity of the type locality to both Capitol Peak, in the Capitol Forest, and to the capitol of Washington State.

Subclass Heterobranchia Gray, 1840

Order Heterostropha Fischer, 1885

Family ORBITESTELLIDAE Iredale, 1917

Genus *Orbitestella* Iredale, 1917

Type species: *Cyclostrema bastowi* Gatliff, 1906, by monotypy, Recent, Victoria, southeast Australia.

Orbitestella ***palaiopacifica*** Squires & Goedert, sp. nov.

(Figures 22–26)

Diagnosis: An *Orbitestella* with an upper whorl surface crossed by narrow axial ribs, a keel-like carina on the shoulder, axial ribs in the interspace between the carina on the basal margin and the carina on the edge of the umbilicus, and a wide but deep umbilicus showing overlapping whorls in its interior.

Description: Shell minute, discoidal, with a flat spire and a sunken apex. Protoconch about 1½ whorls, apparently smooth. Teleoconch 2 to 2½ whorls with a hump (ridgelike swollen area) in middle of whorl on first teleoconch whorl but near the deep suture on subsequent whorls. Teleoconch whorls crossed with about 70 axial ribs, tending to become obsolete near outer lip. A well-developed keel-like carina on the shoulder just anterior of the hump; keel-like carina beginning at about 2¾ whorl, very wide for one-half of whorl, then narrower. Another carina on the basal margin. Area between these two carinae smooth and sloping inward. A third carina on the prominent edge of the umbilicus. Interspace between carina on the basal margin and carina on the edge of the umbilicus concave with numerous axial ribs. Umbilicus wide and deep. Interior of umbilicus showing overlapping whorls. Area between carina on edge of umbilicus and the suture smooth and steep. Aperture quadratelike with sinuations corresponding to the hump, to the keeplike carina, and to the carina on the basal margin.

Dimensions of holotype: Height 0.30 mm, diameter 0.53 mm.

Holotype: LACMIP 11365.

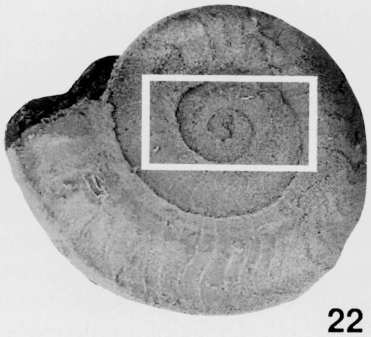
Type locality: CSUN loc. 1563, Larch Mountain, Washington, 47°59′03″N, 123°8′12″W.

Paratypes: LACMIP 11366–11367.

Discussion: Fourteen specimens were found, all about 0.3 mm in height. Ten of the specimens were found at CSUN loc. 1563; two were found at locality 1564.

The new species is most similar to *Orbitestella plicatella* (Cossmann, 1888:225, pl. 11, figs. 43–45; Cossmann & Pissarro, 1910–1913:pl. 6, fig. 105-2; Gougerot & Le Renard, 1977:14–15, fig. 16; Dolin et al., 1980:pl. 3, figs. 34a, 34b) from middle Eocene through lower Oligocene (middle Lutetian through lower Stampien) strata in the Paris Basin, France (Gougerot & Le Renard, 1977). Lozouet & Maestrati (1982) gave a synonymy of this species. Although the new species and *O. plicatella* have essentially identical basal faces, the new species differs in the following features: many more and stronger axial ribs, axial ribbing on dorsal side stronger, suture deeper, and hump on dorsal surface of whorl located closer to the suture.

The new species is also similar to the only other described Eocene species of *Orbitestella,* which is *O. planibasis* (Gougerot & Le Renard, 1977:14–15, figs. 15a–15c) from middle Eocene through upper middle Eocene (middle Lutetian through lower Bartonian) strata in the Paris Basin, France. The new species differs in the following features: axial ribs narrower and not knoblike, a more



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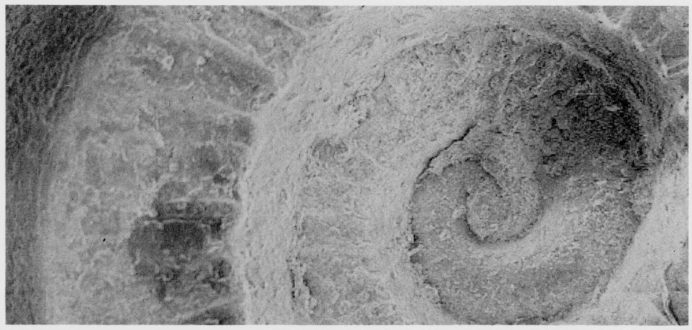

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Explanation of Figures 22–26

All specimens from CSUN loc. 1563, and all figures = SEM micrographs. Figures 22–26. *Orbitestella* ***palaiopacifica*** Squires & Goedert, sp. nov. Figures 22–23. Holotype LACMIP 11365. Figure 22. Apical view, ×60, maximum diameter 0.82 mm. Figure 23. Close-up of apex, box on Figure 22 shows area of coverage ×240, maximum length 0.38 mm. Figures 24–25. Paratype LACMIP 11366. Figure 24. Umbilical view, ×60, maximum diameter 0.65 mm. Figure 25. Close-up of umbilicus, box on Figure 24 shows area of coverage, ×240, maximum length 3.8 mm. Figure 26. Paratype LACMIP 11367, apertural view, ×90, diameter 1.2mm.

prominent keel, and a sloping smooth area in the umbilicus just anterior to suture rather than a vertical area.

The new species is also similar to *Orbitestella diegensis* (Bartsch, 1907:172–173, figs. 7a–c), which is the only species of *Orbitestella* living along the Pacific coast of North America. It is found from Monterey Bay, central California, to northern Baja California, and is common in coarse sand near kelp (McLean, 1978). The new species differs in the following features: the hump on the dorsal surface is lower, the keel is weaker and not noded, there are no spiral ribs between the keel and the basal margin, the border along the umbilicus is stronger, and fewer and coarser spiral ribs are present on the base.

The new species superficially resembles certain Cretaceous species of genus *Neamphitomaria* Bandel, 1988, that Bandel (1988) assigned to family Omalogyridae. Although *Neamphitomaria stantoni* (Sohl, 1960:67, pl. 6, figs. 29, 39, 43, 44; Dockery, 1993:92, pl. 35, figs. 1–3) and *N. planospira* Dockery (1993:93, pl. 35, figs. 4–8), both from Upper Cretaceous (Campanian Stage) strata in Missis-

sippi, superficially resemble the new species, the new species differs by having a smooth protoconch, overlapping whorls within the umbilicus, a carina bordering the umbilicus, and fewer, much more widely spaced axial ribs.

The geologic range of genus *Neamphitomaria* is Late Cretaceous (Campanian Stage) to Eocene (Dockery, 1993). Bandel (1988) placed only one Eocene species, *Neamphitomaria rotella* (Lea, 1833:123, pl. 4, fig. 112; Palmer, 1937: 176, pl. 21, figs. 8, 13; Bandel, 1988:pl. 3, fig. 5; pl. 4, figs. 7, 8, text fig. 3) from the middle Eocene Gosport Sand, Alabama, in his genus. The new species differs from *Neamphitomaria rotella* in the following features: there is a hump on the dorsal surface, there are axial ribs, and the umbilicus is deeper.

The Orbitestellidae are minute, mainly southern hemisphere gastropods. Most species live beneath rocks and among coralline algae in the low intertidal zone (Ponder, 1990). The familial taxonomic position of the orbitestellids was unclear until anatomical work by Ponder (1990) showed them to be primitive heterobranchs, even though their protoconchs are not heterotrophic. Orbitestellids may have originated during the Middle Jurassic in New Zealand, and undescribed species are known from Eocene and Miocene rocks in southern Australia (Ponder, 1990; Beu & Maxwell, 1990).

The genus *Orbitestella* ranges with certainty from the middle early Eocene to Recent. The only described Eocene and Oligocene species are reported from the Paris Basin, France (Cossmann, 1888; Gougerot & Le Renard, 1977; Lozouet & Maestrati, 1982) and from Washington (herein). The Washington occurrence is the earliest record of *Orbitestella* anywhere and is the first fossil record of this genus from the Pacific coast of North America.

Etymology: The new species is named for the ancient Pacific Ocean, and the name is derived from *palaios,* Greek, meaning ancient.

Family OMALOGYRIDAE Sars, 1878

Genus *Ammonicera* Vayssière, 1893

Type species: *Homalogyra fischeriana* Monterosato, 1869, by monotypy, Recent, Atlantic Ocean.

Ammonicera ***benhami*** Squires & Goedert, sp. nov.

(Figures 27–32)

Diagnosis: An *Ammonicera* whose protoconch has a spiral cord and whose teleoconch has broad axial tubercules.

Description: Shell minute, planispiral. Protoconch ¾ whorl, with a low hump. Sutural area of protoconch bearing a spiral cord, bordered by a narrow groove on its inside. Suture deeply incised. Teleoconch almost two whorls with identical sculpture on both sides of whorls. Sculpture of about 27 axial ribs, nodelike and medially located for the first one-half whorl, flattened and extending as broad tubercles across the whorl for remaining whorls. Nine tubercles on first whorl of teleoconch. Upper and lower periphery of body whorl showing a spiral cord, interspace smooth and vertical on early part of teleoconch but bulging on latter part. Aperture quadrate, continuous.

Dimensions of holotype: Height 0.20 mm, diameter 0.59 mm.

Holotype: LACMIP 11368.

Type locality: CSUN loc. 1563, Larch Mountain, Washington, 47°59′03″N, 123°8′12°W.

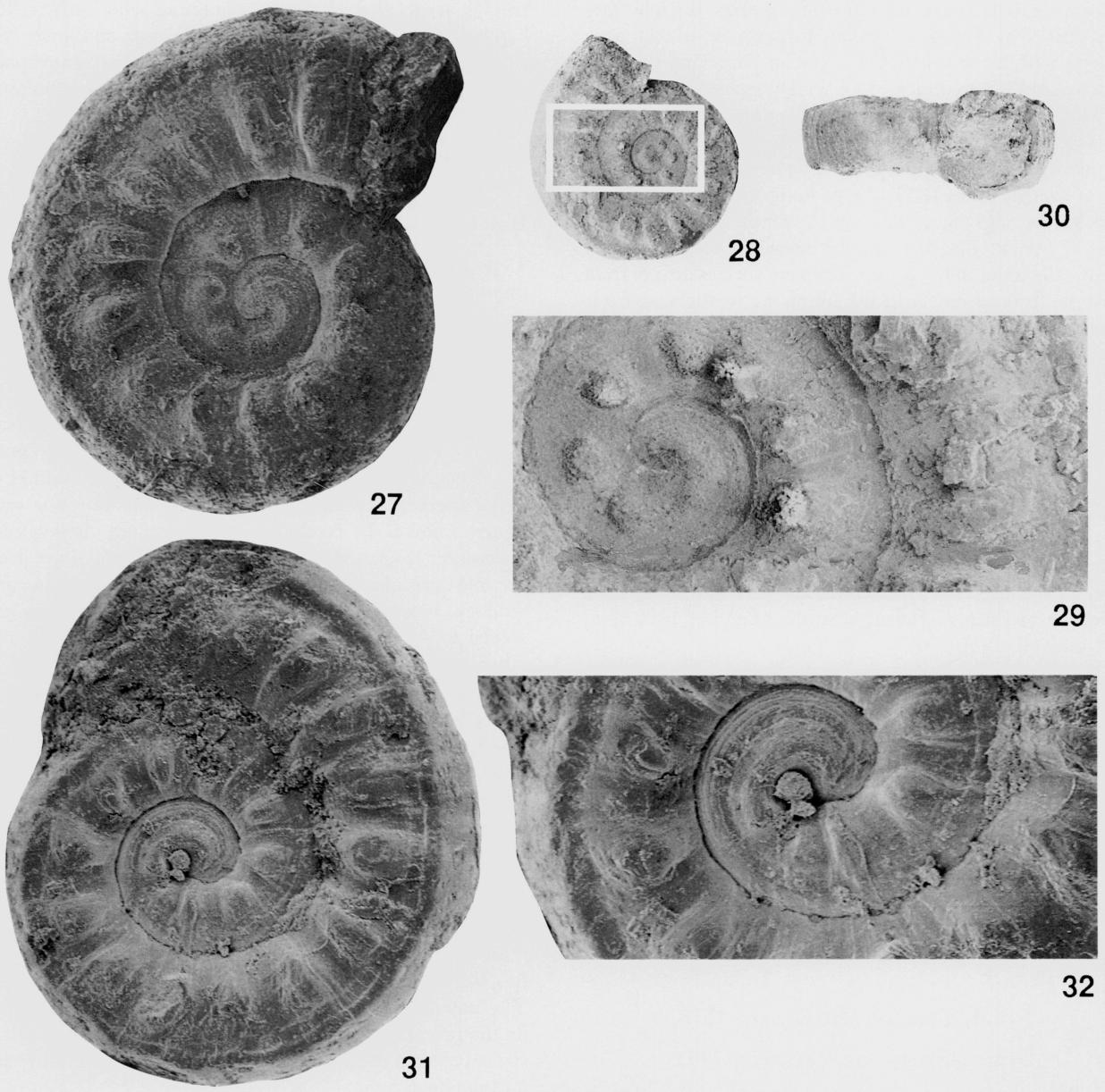
Paratypes: LACMIP 11369–11371.

Discussion: Seven specimens were found, all are from CSUN loc. 1563. They range from 0.4 to 0.59 mm in diameter.

Due to the small size of the species of the family Omalogyridae, there have not been many systematic studies of living species, and the fossil record of this family is very poorly known. In recent years, the genera *Ammonicera* Vayssière, 1893, and *Omalogyra* Jeffreys, 1860, have been the most recognized by workers. There has not been consistency, however, in their usage, with some species assigned to one genus for awhile and then assigned to the other one. The work of Sleurs (1984) and Rolán (1992) has helped to refine the current thinking on diagnostic characters of each genus. Ammonicera has a groove on the protoconch, and the teleoconch has strong axial ribs (Sleurs, 1984). *Omalogyra* has a smooth protoconch or one covered with small tubercles, and the teleoconch is smooth but with a few undulated axial ribs more evident near the suture (Rolán, 1992). The new species is placed in genus *Ammonicera* because the protoconch has a shallow groove and the teleoconch has well-developed axial ribs.

The sculpture of the teleoconch of the new species is most similar to *Ammonicera sculpturata* Rolán (1992:40, figs. 9, 12, 14), which lives in the waters surrounding Cuba. The new species differs by not having three spiral cords on the protoconch and by not having any undulated spiral striae between the periphery and the row of axial tubercles on the teleoconch.

The new species is one of the two earliest known, named species of *Ammonicera.* The other species is *Ammonicera rota* (Forbes & Hanley, 1850:160, pl. 73, fig. 10; pl. 88, figs. 1, 2; Fretter & Graham, 1978:223–224, fig. 187) that ranges in age from the middle Eocene (Lutetian Stage) in the Paris Basin, France, to the Recent in Norway and the Mediterranean (Fretter & Graham, 1978; Lozouet & Maestrati, 1982; Sleurs, 1984). It lives among seaweeds, in rock pools, and also on sandy bottoms in depths of up to 25 m (Fretter & Graham, 1978). Fretter & Graham (1978) included only Recent taxa in their synonymy of *A. rota.* The new species differs from *A. rota* in the following features: fewer axial ribs and more widely spaced, axial ribs on the first one-half of the teleoconch nodelike rather than narrow and long, and axial ribs on the remaining



Explanation of Figures 27 to 32

All specimens from CSUN loc. 1563, and all figures = SEM micrographs. Figures 27–32. *Ammonicera* ***benhami*** Squires & Goedert, sp. nov. Figure 27. Holotype LACMIP 11368, apical view, ×150, maximum diameter 0.55 mm. Figures 28–29. Paratype LACMIP 11369. Figure 28. Apical view, ×60, maximum diameter 0.59 mm. Figure 29. Close-up of apex, box on Figure 28 shows area of coverage, ×240, maximum length 0.36 mm. Figure 30. Paratype LACMIP 11370, apertural view, ×100, diameter 0.4 mm. Figures 31–32. Paratype LACMIP 11371. Figure 31. Umbilical view, ×150, maximum diameter 0.55 mm. Figure 32. Close-up of umbilicus shown in Figure 31, ×240, maximum length 0.38 mm.

part of the teleoconch broad and flattened rather than narrow.

Lozouet & Maestrati (1982) included a fossil species in their synonymy of *A. rota*. They reported that *Homalogyra eocaenica* Allix (1923:19–20, pl. 1, figs. 4, 4a–c) from middle Eocene (Lutetian Stage) rocks of the Paris Basin, France is conspecific with *A. rota*. Gougerot & Le Renard (1977), furthermore, reported that *H. eocaenica* Allix is also conspecific with *Homalogyra praecursor* Gougerot (1965:296–297, pl. 5, fig. 1) from middle Eocene (Lutetian Stage) rocks of the Paris Basin, France. Another species, *Homalogyra cavelieri* Gougerot (1968:222–223, pl. 1, fig. 7) from

upper middle Eocene (lower Bartonian Stage) rocks of the Paris Basin, France, was regarded by Dolin et al. (1980) to be a subspecies of *H. eocaenica* Allix. The new species differs from *H. eocaenica cavelieri* by having wider and more elongate ribs and by not having a smooth body whorl.

Bandel (1988:pl. 1, fig. 7; pl. 3, fig. 6) illustrated an *Ammonicera* sp. from middle Eocene (Lutetian Stage) rocks of the Paris, France area. The new species differs in the following features: shoulder area nearly vertical rather than broadly rounded, axial ribs noded to broadly elliptical rather than narrow, and fewer axial ribs.

The shells of *Ammonicera,* as well as of *Omalogyra,* resemble minute ammonites in that each side is a mirror image of the other. The ammonite shape reflects how the shell is carried; namely, with the aperture directed forward, rather than being carried (as in most gastropods) with the under surface resting on the foot. Thus, the entire animal appears to be bilaterally symmetrical when crawling (Moore, 1971).

Few fossil or modern-day species of *Ammonicera* are known. They have been inadequately studied because of their small size. Only five modern-day species of *Ammonicera* are known from the Indo-Pacific region where they are found associated with coral rubble, covered by *Halimeda* algae, in depths of 1 to 7 m (Sleurs, 1985a, b). About the same number of modern-day species of *Ammonicera* are known from Cuba where they are usually found in depths of 2 to 5 m and no deeper than 20 m (Rolán, 1992). Rios (1985) reported a single species of *Ammonicera* living from Labrador to Florida and in Brazil. As mentioned above, *Ammonicera rota* is found along the North Atlantic coast off of Europe and also in the Mediterranean.

The geologic range of genus *Ammonicera* is middle early Eocene to Recent, and *A. benhami* is the earliest record of this genus. The new species is the first record of genus *Ammonicera* from the Pacific coast of North America.

Etymology: The new species is named for geologist Steven R. Benham (Pacific Lutheran University, Tacoma, Washington).

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CSUN 1563. At elevation of 2230 ft. (680 m), exposed in roadcut on NE side of logging road, latitude 47°59'03"N, longitude 123°8'12"W, 300 m N and 50 m E of SW corner of section 1, T. 17 N, R. 4 W, and 500 m S32 E of Larch Mountain, U.S. Geological Survey, 7.5-minute, Capitol Peak Quadrangle, provisional edition 1986, Black Hills, Thurston County, Washington. Upper part of the Crescent Formation. Age: Middle early Eocene ("Capay Stage"). Collectors: J. L. & G. H. Goedert, July, 1992. = LACMIP loc. 16655

CSUN 1564. At elevation of 1738 feet (530 m), on N side of logging road, 800 m N and 50 m W of SE corner of section 25, T. 18 N, R. 3 W, and 950 m N25 W of Rock Candy Mountain, U.S. Geological Survey, 7.5-minute Summit Lake Quadrangle, 1981, Black Hills, Thurston County, Washington. Upper part of the Crescent Formation. Age: Middle early Eocene ("Capay Stage"). Collectors: J. L. & G. H. Goedert, August, 1992. = LACMIP loc. 16548

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