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New Species of Early Eocene Small to Minute Mollusks from the Crescent Formation, Black Hills, Southwestern Washington

by

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Abstract. Seven new species of small to minute gastropods and one new species of a minute bivalve are reported from the early Eocene upper part of the Crescent Formation in the Black Hills west of Olympia, Washington. These species lived in a rocky intertidal environment where accumulation of basalt flows caused shoaling of marine waters. Their shells were deposited as the matrix of coquina that infilled cracks between individual eroded boulders of basalt, but the small size of the new species prevented them from being broken during transport. Associated macrofossils indicate a middle early Eocene age ("Capay Stage").

Description of these new species extends the geographic and chronologic range of each of the supraspecific taxa to which the species are assigned. The fissurellid *Emarginula* ***washingtoniana*** is the first reported Cenozoic species of this genus from the Pacific coast of North America. The trochid *Calliovarica* ***pacifica*** is only the second known species of this early Eocene genus and extends its geographic range from California into Washington. The skeneid *Haplocochlias* ***montis*** is the first positively known fossil species of *Haplocochlias* and the earliest known representative of family Skeneidae, whose previous geologic range was early Miocene to Recent. The neritid *Nerita* (*Theliostyla*) ***olympia*** is the first "Capay Stage" species of this subgenus from the Pacific coast of North America. The rissoid *Lapsigyrus* ***crescentensis*** is the earliest record of this genus, whose previous geologic range was Pleistocene to Recent. The columbellid *Mitrella* (*M.*) ***blackhillsensis*** is the earliest record of this genus, whose previous geologic range was early Miocene to Recent. The ellobiid *Ovatella* (*Myosotella*) ***coneyi*** is the first record of a marine pulmonate in the lower Tertiary of the Pacific coast of North America. The tellinid bivalve *Linearia* (*Linearia*) ***louellasaulae*** is the first confirmed species of this genus from the Pacific coast of North America and the youngest record of this genus, whose previous geologic range was Early to Late Cretaceous.

INTRODUCTION

Molluscan assemblages from the Eocene Crescent Formation in Washington have received little study. Nearly all of the previous reports deal with the Crescent Bay area along the north shore of the Olympic Peninsula (Figure 1). One of these reports is by Weaver & Palmer (1922), who described, named, and illustrated five species of gastropods and two species of bivalves. Recently, Squires et al. (1992) did a detailed study of the macrofossils of the upper Crescent Formation at Pulali Point in the eastern Olympic Peninsula just west of Seattle (Figure 1), and this study spawned two additional articles (Squires, 1992a, 1993) on certain bivalves from the Pulali Point area. More recently, Squires & Goedert (in press) have done a detailed study of the macrofossils of the upper Crescent Formation in the Little River area in the southern Olympic Peninsula (Figure 1).

The present study, which is a continuation of our investigation of the macrofossil faunas of the Crescent Formation in western Washington, differs from our previous studies in that many of the fossils are small to minute (i.e., less than 5 mm in longest dimension). Eocene small to minute gastropods and bivalves from the Pacific coast of North America are not well known. They easily become an integral part of the cement that holds a rock together and, in nearly every case, cannot be extracted for study. Previous investigations that included minute mollusks concern a part of the fauna found in the upper Eocene part of the Lincoln Creek Formation in the "Gries Ranch beds" in southwestern Washington (Effinger, 1938), a fauna from middle Eocene rocks in the Vacaville, northern California area (Palmer, 1923), and a part of the fauna found in the middle to upper Eocene Tejon Formation in south-central California (Anderson & Hanna, 1925). The present study area in the Black Hills of southwestern Washington has a more diverse gastropod assemblage than these other locales because, as will be discussed below, the study area contains a rocky intertidal assemblage that has been preserved nearly in place. Lindberg & Squires (1990) noted that rocky intertidal organisms are poorly represented in the pre-Pleistocene fossil record because they are usually swept away and broken up by wave action. The Black Hills assemblages, therefore, contain genera that are very rare in the fossil record due to two factors: their small size and their preference for a rocky intertidal habitat.

The molluscan stages used in this report stem from Clark & Vokes (1936), who proposed five mollusk-based provincial Eocene stages, namely, "Meganos," "Capay," "Domengine," "Transition," and "Tejon." The 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 classification system used for taxonomic categories higher than the family level generally follows that of Haszprunar (1988). Abbreviations used for catalog and/or locality numbers are: CSUN, California State University, Northridge; LACM, Natural History Museum of Los Angeles County, Malacology Section; LACMIP, Natural History Museum of Los Angeles County, Invertebrate Paleontology Section; UCMP, University of California Museum of Paleontology (Berkeley).

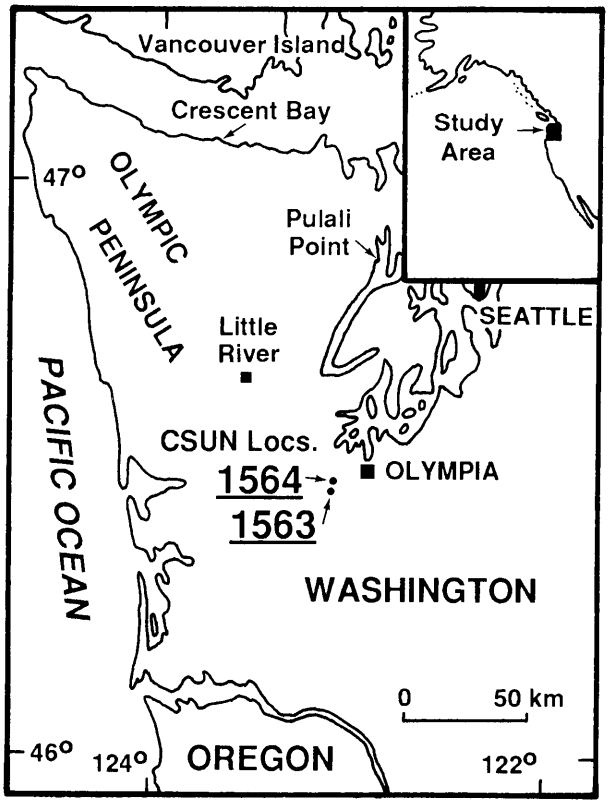


Figure 1

Index map to CSUN collecting localities, Crescent Formation, Black Hills area, west of Olympia, Washington.

GEOLOGIC AND DEPOSITIONAL SETTING

The basement rock in the Olympic Peninsula of southwestern Washington is the upper Paleocene to lower middle Eocene Crescent Formation, which consists predominantly of oceanic tholeiite basalt flows. Several models have been proposed for the origin of these flows. Most of the early models, which are reviewed by Snavely (1987), envisage accretion of seamounts, but in recent years, the models favor a rift-basin environment (Babcock et al., 1992). The upper third of the formation ranges from a deep-to-shallow marine environment to one that is locally terrestrial. Interbedded marine sedimentary rocks locally contain fossils, especially at places like Pulali Point and the Little River area where the extrusion of the basalt flows caused

shoaling of the marine waters (Squires et al., 1992; Squires & Goedert, in press).

About 15 km west of Olympia (Figure 1), in the Black Hills area in the Washington Coast Range, there is a > 600 m-thick sequence of basalt flows and breccias, with minor interbeds of basaltic sandstone and siltstone that are correlated with the Crescent Formation in the Olympic Peninsula (Globerman et al., 1982). The Black Hills is one of several large basement uplifts in the Washington Coast Range and is heavily forested with rock exposures generally limited to roadcuts and quarries. Macrofossils were found at only two localities in the Crescent Formation in the Black Hills. One of these is near Larch Mountain at CSUN loc. 1563, which is the same site that Pease & Hoover (1957) first noted, but their coordinates differ slightly. The other locality is about 3.5 km to the northeast and near Rock Candy Mountain at CSUN loc. 1564 (Figure 1).

At the Larch Mountain locality, there is a roadcut exposure of light-colored sedimentary rock interbedded with basalt. The exposure is 1 m thick and consists of an eroded vesicular basalt with the cracks between individual subangular boulders filled with fossiliferous sedimentary rock. The exposure is capped by pillow basalt. At and near the bottom of the cracks is a black silty mudstone containing pulverized shell hash with many small to minute gastropods that are complete and well preserved. The silty mudstone is poorly indurated, and shells can be removed intact. The new species described in this paper were found in this silty mudstone, and the specimens, which could easily be missed by a cursory examination of the outcrop, are fragile and easily broken if care is not taken in their removal from the rock. Also in the silty mudstone are some scattered, large (up to 2.5 cm) fragments of colonial corals, gastropods, and bivalves. The abundance of shell hash is usually so great that it forms coquinas. Near the tops of the cracks, there are smaller, angular basalt clasts, up to 5 cm across, supported by white-to-gray muddy siltstone and sandstone with pulverized shell hash containing some scattered large (up to 3 cm) disarticulated bivalves and colonial-coral fragments. Locally, there are also patches of well-indurated, white-to-gray muddy siltstone with a great abundance of fragments of coralline algae.

The macrofauna at CSUN loc. 1563 is a mixture of rocky intertidal and shallow-subtidal taxa. There are many shells of the gastropods *Nerita* and *Arene* and the bivalve *Barbatia*. These taxa, plus *Emarginula, Haplocochlias,* and *Mitrella,* as well as the abundant fragments of colonial corals and coralline algae, indicate a warm-water, rocky intertidal environment. Modern *Nerita, Arene, Barbatia,* and *Mitrella* are indicative of rocky shores in tropical waters, and modern *Emarginula* live on rocky bottoms, intertidally to several hundred meters deep, usually in tropical waters (Keen, 1971; Abbott & Dance, 1982). Modern *Haplocochlias* live intertidally to 10 m on hard substrates in tropical waters (Keen, 1971; Hickman & McLean, 1990). The presence of the marine pulmonate *Ovatella* further confirms an intertidal, or even a supratidal environment. Modern species of *Ovatella* are air breathers that can tolerate short submersion at the highest spring tides and are never out of the reach of salt and spray in the following environments: high tidal or supratidal, upper shore of estuaries, or salt marshes and the fringes of salt marshes (Morton, 1955). Also at CSUN loc. 1563, there is a diverse assemblage of other mollusks that elsewhere on the Pacific coast of North America are indicative of shelflike depths where silty deposits accumulated. These mollusks include the gastropods *Turritella, Bittium, Pachycrommium, Colwellia,* and *Conus,* and the bivalves *Venericardia, Glyptoactis,* and *Corbula.*

The extrusion of the basalts in the vicinity of CSUN loc. 1563 caused shoaling and the establishment of a rocky shoreline community where *Nerita, Arene, Barbatia, Emarginula, Haplocochlias,* and *Mitrella* lived alongside colonial corals and coralline algae. The pounding surf broke and pulverized most of the larger macro-invertebrates, but many of the small to minute gastropods escaped destruction. All the shell material, as well as the muddy debris and clasts of basalt, were transported a short distance seaward where they were deposited in cracks between individual boulders of basalt. These boulders were adjacent to where mollusks like *Turritella* and *Venericardia* lived, and some of their shells also were washed into the cracks between the boulders. The minute-shelled *Lapsigyrus* ***crescentensis*** and *Linearia* (*L.*) ***louellasaulae,*** a tellinid, may have also lived among the *Turritella* and *Venericardia* because modern *Lapsigyrus* live in shallow water (approximately 20 m depth) in warm-water bays (Shasky, 1970; Keen, 1971), and modern tellinids are nearshore to offshore burrowers (Abbott & Dance, 1982). Continued extrusion of basalt covered this habitat before encrusting organisms could attach to the cobbles and boulders, and further protected the deposit from erosion.

The sedimentary rocks at CSUN loc. 1563 can be assigned to the "Capay Stage" (middle lower Eocene) on the basis of the presence of *Turritella andersoni* Dickerson, which is restricted to this stage elsewhere on the Pacific coast of North America (Squires & Demetrion, 1992).

At the Rock Candy Mountain locality, a thin exposure of sedimentary rock is in a roadcut and in a small nearby quarry. The lithologies are the same as those at CSUN loc. 1563, except that there is less mudstone matrix, less coralline-algal remains, and more large bivalves. There are also fewer small to minute gastropods, and the only new species of gastropod present in the silty mudstones at CSUN loc. 1564 is *Emarginula* ***washingtoniana.***

The environment of deposition and age of the sedimentary rocks at CSUN loc. 1564 are the same as for CSUN loc. 1563, on the basis of identical lithologies and similar fossil content. Globerman et al. (1982:1153) also reported a shallow-water depth (< 50 m) for the rocks at CSUN loc. 1564, on the basis of benthic foraminifera, and they

also reported an early Eocene age (K/Ar age of 53.1 ± 2 m.y.) for the associated basalts.

SYSTEMATIC PALEONTOLOGY

Class Gastropoda Cuvier, 1797

Subclass Prosobranchia Milne-Edwards, 1848

Order Vetigastropoda Salvini-Plawén, 1980

Family FISSURELLIDAE Fleming, 1822

Genus *Emarginula* Lamarck, 1801

Type species: *Emarginula conica* Lamarck, 1801, by original designation, Miocene through Recent, living in Finland and coasts of Great Britain to the Adriatic Sea (Palmer, 1937).

Emarginula ***washingtoniana***
Squires & Goedert, sp. nov.

(Figures 2–5)

Diagnosis: A tall *Emarginula* with apex not strongly curved posteriorly, moderately deep slit, and 16 primary radial ribs.

Description: Shell small, high conical, up to 4 mm high, with height about two-thirds of length. Apex situated about one-third the distance from posterior end, curved posteriorly, with beaklike appearance. Anterior slope convex and steep; posterior slope concave. Anal slit situated at anterior margin, narrow and moderately deep, measuring 0.5 mm deep (=11 percent of shell length). Area of slit band coincident with raised area extending nearly to apical area. Sculpture of about 16 primary radial ribs originating near apex. Interspaces between primary radial ribs with a single, moderately strong, secondary radial rib; rarely a single tertiary radial rib in interspace between a primary and a secondary radial rib. Radial sculpture crossed by intermittently prominent growth rugae, especially near margin of aperture and on posterior slope. Aperture ovate-circular.

Dimensions of holotype: Length 4.5 mm, width 3 mm, height 3 mm.

Holotype: LACMIP 12279.

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

Paratype: LACMIP 12280.

Discussion: Five specimens of the new species were found. Except for the holotype, they are fragments. Four of the specimens are from CSUN loc. 1563, and one specimen is from CSUN loc. 1564. The holotype has been slightly crushed, and this crushing may have affected the area of the slit band, causing it to appear raised. The holotype also has an encrusting polychaete worm shell attached to it near the apex (Figures 2–4).

The new species is similar to *Emarginula mariae* Cossmann (Cossmann & Pissarro, 1910–1913:pl. 2, fig. 9-4) from the upper Paleocene (Thanetian Stage) of the Paris Basin, France. *Emarginula* ***washingtoniana*** differs in the following features: shell taller, apex not as strongly curved posteriorly, and concentric ribbing not as well developed.

In the position of its apex, *E.* ***washingtoniana*** is more similar to European Cretaceous species than to Caribbean Cretaceous species. The European species usually have an apex that is situated well forward of the posterior margin, whereas the Caribbean species have an apex that distinctly overhangs the posterior margin (Sohl, 1992).

Cox & Keen (1960) reported the geologic range of *Emarginula* to be Jurassic to Recent. Haber (1932) listed 41 species from Jurassic rocks, and all are restricted to Europe. The species occur mainly in shallow-water carbonate-bank, or reef-associated assemblages (Sohl, 1992). Sohl (1992) listed 80 species from Cretaceous rocks, most restricted to Europe. They are most common in environments similar to their Jurassic occurrence. Only three Cretaceous species have been described from the Western Hemisphere (Sohl, 1992). Two are from the Caribbean region, and the third is *E. gabbi* Stewart (1926:313, pl. 23, fig. 10 [= a replacement name for *E. radiata* Gabb, 1864:140, pl. 21, figs. 102, 102a]) from Cretaceous strata in northern California. The new species differs from *E. gabbi* Stewart in the following features: aperture ovate-circular rather than elongate, steeper sides, posterior slope more concave, and fewer ribs (16 rather than 20).

The number of known early Tertiary species of *Emarginula* is far less than that known for the Mesozoic. Cossmann & Pissarro (1910–1913) illustrated only two Paleocene species and seven Eocene species of *Emarginula* from the Paris Basin, France. Similarly, Glibert (1962) listed two Paleocene, six Eocene, and one Oligocene species from rocks of Europe.

Palmer & Brann (1966) listed only one named species and two unnamed species (based on internal molds) of *Emarginula* from middle to upper Eocene rocks of the southeastern United States. The new species differs from these *Emarginula* by being much smaller and with a higher shell.

Since the Oligocene, *Emarginula* has been represented by a relatively low number of species. Today, the geographic range is mostly in warm waters in Europe, the Mediterranean, Georgia (U.S.A.) to Brazil, the Philippines, New Zealand, Chile, Galápagos Islands, Colombia, and the Gulf of California (McLean, 1970; Abbott & Dance, 1982).

Emarginula ***washingtoniana*** is the first Cenozoic species of this genus to be reported from the Pacific coast of North America. Other than the Cretaceous species *E. gabbi* Stewart, the genus was unknown in this area until the description of a Recent species from the Gulf of California (Shasky, 1961). Only three other species of Recent *Emarginula*

are known from the eastern Pacific: two from Chile and one from the Galápagos Islands and Colombia (McLean, 1970).

Etymology: The species is named for the state of Washington.

Occurrence: "Capay Stage" (middle lower Eocene). Crescent Formation, Larch Mountain and Rock Candy Mountain, Washington (CSUN locs. 1563, 1564).

Family TROCHIDAE Rafinesque, 1815

Genus *Calliovarica* Vokes, 1939

Type species: *Calliovarica eocensis* Vokes, 1939, by original designation, early Eocene, central California.

Calliovarica ***pacifica*** Squires & Goedert, sp. nov.

(Figures 6–8)

Diagnosis: Moderately low-spired *Calliovarica* having teeth on inner lip, denticles on outer lip, and narrow umbilicus.

Description: Shell moderately small, up to 12.5 mm in height, turbiniform, thick, with four to five convex whorls showing moderate rate of expansion. Spire moderately high, body whorl large, whorls subtabulate anterior to moderately impressed suture. Basal edge of body whorl angulate. Penultimate whorl with five to six prominent spiral ribs. Body whorl with approximately 14 spiral ribs; three to four at periphery strongest, eight ribs on base of body whorl approximately equal to two ribs nearest suture. All spiral ribs crossed by prosocline axial ornament producing reticulate (beaded to scaly) pattern. Outer shell layer generally missing; inner layer nacreous and showing spiral ribs but lacking axial ornament. Aperture slightly oblique, circular, outer lip reflected and strongly thickened with multiple (about 10) irregular denticles. Inner lip calloused with a prominent tooth and two smaller teeth anteriorly. Heavy rim of parietal callus continuous with inner and outer lips. Narrow umbilicus, nearly filled by columellar callosity.

Dimensions of holotype: Height 13.5 mm, width 12.5 mm.

Holotype: LACMIP 12281.

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

Paratype: LACMIP 12282, CSUN loc. 1563.

Discussion: Eleven specimens were found, and all are from CSUN loc. 1563. Most of the shells are chalky due to weathering and/or diagensis, and fall apart when collected. The holotype of the new species is a resting-stage individual on the basis of the well-developed apertural characteristics and the presence of the thickened outer lip (J. H. McLean, personal communication).

Previously, the genus *Calliovarica* was monotypic, represented by *C. eocensis* Vokes (1939:183, pl. 22, figs. 20, 23, 25, 28) known only from UCMP loc. 1817 in Urruttia Canyon, central California. Squires (1988) reported that this locality is in the "Capay Stage" Cerros Shale Member of the Lodo Formation. The new species differs from *C. eocensis* in the following features: shorter spire, presence of teeth on inner lip and denticles on outer lip, and narrowly umbilicate. The new species extends the geographic range of *Calliovarica* into Washington.

Hickman & McLean (1990) included *Calliovarica* within the chilodontine trochids, whose shell morphology is distinguished by apertural thickening and denticulation, a circular aperture produced by this apertural thickening, and reticulate or cancellate shell sculpture.

Etymology: The species is named for the Pacific Ocean.

Occurrence: "Capay Stage" (middle lower Eocene). Crescent Formation, Larch Mountain, Washington (CSUN loc. 1563).

Family SKENEIDAE Clark, 1851

Genus *Haplocochlias* Carpenter, 1864

Type species: *Haplocochlias cyclophoreus* Carpenter, 1864, by original designation, Recent, western Mexico.

Haplocochlias ***montis*** Squires & Goedert, sp. nov.

(Figures 9–11)

Diagnosis: A *Haplocochlias* with fine spiral ribbing, nearly closed umbilicus, and denticles on outer and inner lips.

Description: Shell minute, up to 2.5 mm in height, turbiniform, with three to four convex whorls, increasing rapidly in size. Spire low, body whorl globose with medial angulation. Suture distinct and impressed. Whorls with many closely spaced, fine spiral ribs, coarsening toward base of body whorl. Aperture ovate, nearly continuous, oblique. Outer lip slightly reflected, prosocline, many small denticles, especially on anterior end. Inner lip flattened anteriorly, with a low ridge near inner margin and paralleling it; ridge terminating posteriorly with a protuberance. Umbilicus nearly closed, slitlike.

Dimensions of holotype: Height 2.5 mm, width 2.5 mm.

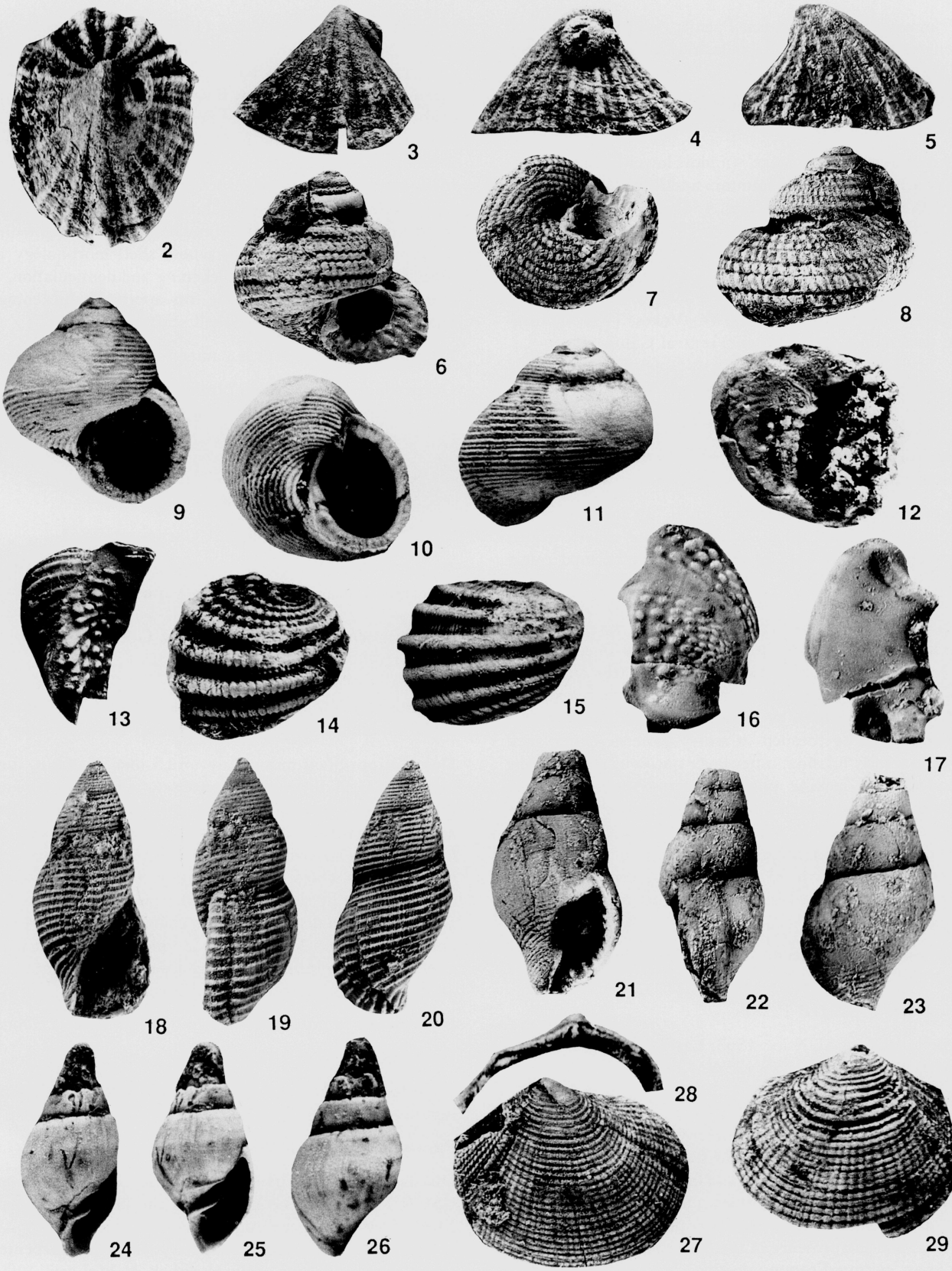
Holotype: LACMIP 12283.

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

Paratype: LACMIP 12284.

Discussion: Six specimens were found, and all are from CSUN loc. 1563. The holotype is the largest specimen. Most of the others are fragments.

The new species resembles *H. cyclophoreus* Carpenter (1864; Keen, 1971:fig. 119; Hickman & McLean, 1990: fig. 95B), the type species of the genus, but differs in the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following features: thinner shell, stronger spiral ribbing, and an aperture with denticles.

Haplocochlias previously was known with certainty only as a Recent genus in the eastern Pacific and western Atlantic (Hickman & McLean, 1990). The fossil record of the family Skeneidae had been reported as early Miocene to Recent, with some of the Eocene species assigned to *Collonia* Gray, 1850 by Cossmann (1918:pl. 1, figs. 42–47; pl. 2, figs. 1–3) possibly included in the family (Hickman & McLean, 1990). The new species has a much higher spire and a much narrower umbilicus than these Eocene species, which are from the Paris Basin, France.

Cossman & Pissarro (1910–1913:pl. 4, figs. 33-1 to 33-4, 33-7 to 33-13; pl. 5, figs. 33-14 to 33-28) illustrated additional Eocene species of *Collonia* from the Paris Basin, France. Of these, the new species is most like *Collonia (Cirsochilus) grignonensis* (Deshayes, 1864–1866:pl. 60, figs. 22–24 [= *Turbo grignonensis*]; Cossmann & Pissarro, 1910–1913:pl. 4, fig. 33-13) from middle Eocene (Lutetian Stage) strata. The new species differs in the following features: finer spiral ribbing on body whorl angulation, an aperture with denticles, and no beaded umbilical cord.

The new species is the first positively known fossil species of *Haplocochlias* and the earliest known representative of family Skeneidae.

Etymology: The species name is from the Latin *montis*, mountain, and refers to the position of the type locality of this species.

Occurrence: "Capay Stage" (middle lower Eocene). Crescent Formation, Larch Mountain, Washington (CSUN loc. 1563).

Order Neritoida Golikov & Starobogatov, 1975

Family NERITIDAE Rafinesque, 1815

Genus *Nerita* Linné, 1758

Type species: *Nerita peloronta* Linné, 1758, by subsequent designation (Montfort, 1810), Recent, Caribbean Sea.

Subgenus *Theliostyla* Mörch, 1852

Type species: *Nerita albicilla* Linné, 1758, by subsequent designation (Kobelt, 1879), Recent, Indo-Pacific.

Nerita (Theliostyla) ***olympia***
Squires & Goedert, sp. nov.

(Figures 12–17)

Diagnosis: A *Theliostyla* with a body whorl having seven to eight noded carinae separated by interspaces as wide as the carinae.

Description: Shell small, up to 7 mm in height, broader than high, with rapidly expanding body whorl. Spire flattened, apex barely elevated above nearly flat dorsal surface. Dorsal surface with three to four noded spiral ribs (excluding carina on shoulder) that become coarser and more elevated toward outer lip. Body whorl with seven to eight, evenly spaced and usually equal-strength nodose carinae becoming, in some specimens, increasingly coarse toward base of body whorl. Interspaces approximately as wide as carinae and with or without a single, beaded spiral rib. Axial riblets fine, crossing spiral carinae and interspaces. Aperture large, quadrate. Outer lip flared, grooved at body-

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Explanation of Figures 2 to 29

All specimens coated with ammonium chloride. Pictures taken by the senior author. All from CSUN loc. 1563.

Figures 2–5. *Emarginula* ***washingtoniana*** Squires & Goedert, sp. nov., holotype LACMIP 12279. Figure 2. Dorsal view, ×9.2. Figure 3. Anterior view, ×10. Figure 4. Left-lateral view, ×8.7. Figure 5. Right-lateral view, ×7.6. Figures 6–8. *Callovarica* ***pacifica*** Squires & Goedert, sp. nov., holotype LACMIP 12281. Figure 6. Apertural view, ×2.4. Figure 7. Umbilical view, ×2.5. Figure 8. Abapertural view, ×2.8. Figures 9–11. *Haplocochlias* ***montis*** Squires & Goedert, sp. nov., holotype LACMIP 12283. Figure 9. Apertural view, ×14.4. Figure 10. Umbilical view, ×13. Figure 11. Abapertural view, ×13. Figures 12–17. *Nerita (Theliostyla)* ***olympia*** Squires & Goedert, sp. nov. Figure 12. Holotype LACMIP 12285, apertural view, ×16. Figure 13. Paratype LACMIP 12286, deck area, ×9.5. Figure 14. Paratype LACMIP 12287, abapertural view, ×4.6. Figure 15. Holotype LACMIP 12285, abapertural view, ×11. Figures 16–17. Paratype LACMIP 12288, operculum, ×11. 16. Exterior view. 17. Interior view. Figures 18–20. *Lapsigyrus* ***crescentensis*** Squires & Goedert, sp. nov., holotype LACMIP 12289, ×8. Figure 18. Apertural view. Figure 19. Lateral view showing outer lip. Figure 20. Abapertural view. Figures 21–23. *Mitrella (Mitrella)* ***blackhillsensis*** Squires & Goedert, sp. nov., holotype LACMIP 12291. Figure 21. Apertural view, ×7.8. Figure 22. Lateral view showing outer lip, ×7.5. Figure 23. Abapertural view, ×7.5. Figures 24–26. *Ovatella (Myosotella)* ***coneyi*** Squires & Goedert, sp. nov., holotype LACMIP 12292, ×14. Figure 24. Apertural view. Figure 25. Apertural view, rotated so as to reveal parietal plica. Figure 26. Abapertural view. Figures 27–29. *Linearia (Linearia)* ***louellasaulae*** Squires & Goedert, sp. nov. Figure 27. Holotype LACMIP 12294, right valve, ×10.3. Figure 28. Paratype LACMIP 12295, right-valve hinge, ×14.6. Figure 29. Paratype LACMIP 12296, left valve, ×12.3.

whorl carinae. Inner lip with seven teeth. Two posteriormost teeth stronger than rest, with tooth next to posteriormost tooth strongest. Five small, subequal teeth medially. Deck with numerous small tubercles, round to elongate, arranged loosely in rows. Operculum calcareous with peglike projection anteriorly and two small protuberances on inner lip side; exteriorly with numerous small tubercles medially and posteriorly arranged loosely in rows; interiorly smooth.

Dimensions of holotype: Height 2 mm, width 3 mm.

Holotype: LACMIP 12285.

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

Paratypes: LACMIP 12286 to 12288, all from CSUN loc. 1563.

Discussion: Thirty specimens of *Nerita* ***olympia*** were found, and all are from CSUN loc. 1563. Most of the shells are chalky due to weathering and/or diagensis and fall apart when removed from the brittle, silty mudstone that encloses them. Ten specimens of the operculum were found, and they are also all from CSUN loc. 1563.

The new species is similar to *Nerita* (*T.*) *héberti* Szöts (1953:30, 141–142, pl. 2, figs. 3–5) from the Eocene of Hungary. The new species differs by having fewer carinae on the dorsal surface and on the body whorl and stronger carinae on the body whorl. Szöts (1953) did not assign his species to the subgenus *Theliostyla,* but *N. héberti* has a dentate outer lip, a granulate deck area, and a finely dentate inner lip. These features are listed by Keen & Cox (1960) as being diagnostic of *Theliostyla,* hence Szöts' species belongs in *Theliostyla.*

There are only two other known species of *Nerita* (*Theliostyla*) from the Pacific coast of North America. One is *N.* (*T.*) *triangulata* Gabb (1869:170, pl. 28, figs. 52, 52a) from middle lower Eocene ("Capay Stage") to upper Eocene ("Tejon Stage") deposits from southern California to southwestern Oregon. Squires (1992b) reviewed the considerable range of morphologic variation of this species. The new species differs by having more carinae on the body whorl, more widely spaced carinae, and fewer or no ribs in the interspaces. The other known species is *N.* (*T.*) n. sp. (?) Woods & Saul (1986:649, figs. 6.13, 6.16, 6.17) from the upper Paleocene? or lower Eocene? ("Capay Stage") Sepultura Formation, Baja California Sur, Mexico. The new species differs by having many fewer carinae on the body whorl and more widely spaced carinae.

There are three known species of *Nerita* s.l. from Eocene rocks along the Pacific coast of North America. Two, *N. washingtoniana* Weaver & Palmer (1922:28–29, pl. 11, fig. 4) from the upper middle Eocene Cowlitz Formation, southwest Washington, and *N. vokesi* Durham (1944:156, pl. 17, figs. 11, 12) from the upper Eocene of northwest Washington (Squires, 1992b), are quite different from the new species because they possess smooth body whorls. The third, *N. cowlitzensis* Dickerson (1915:58–59, pl. 5, fig. 7a, b) from the Cowlitz Formation in southwest Washington also differs significantly from the new species by possessing a body whorl with only minute sculpture.

Theliostyla probably originated in the Old World Tethyan paleobiotic province and immigrated to the Pacific coast of North America during the early Eocene (Squires, 1992b).

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

Occurrence: "Capay Stage" (middle lower Eocene). Crescent Formation, Larch Mountain, Washington (CSUN loc. 1563).

Order Caenogastropoda Cox, 1960

Family RISSOIDAE Gray, 1847

Genus *Lapsigyrus* Berry, 1958

Type species: *Alvania contrerasi* Jordan, 1936 (= *Alaba mutans* Carpenter, 1857), by original designation, Pleistocene to Recent, west Mexico.

Lapsigyrus ***crescentensis*** Squires & Goedert, sp. nov.

(Figures 18–20)

Diagnosis: A *Lapsigyrus* having an elongate shell with 16 to 17 spiral threads on the body whorl.

Description: Shell minute, up to 5.5 mm in height, elongate, ovately conic, having approximately six convex whorls; spire high. Nucleus of 2½ whorls, smooth and conical. Spiral sculpture of thin ribs with 10 to 11 on penultimate whorl and 16 to 17 on body whorl; five terminal ribs on base are about twice as strong as preceding ribs; channels between spiral ribs filled with innumerable minute axial threads producing finely netted appearance within channels only. Suture indistinct. Body whorl strongly descending, exposing anteriormost part of preceding whorl. Aperture large, D-shaped. Outer lip slightly opisthocline, with narrow varix.

Dimensions of holotype: Height 5.5 mm, width 2.3 mm.

Holotype: LACMIP 12289.

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

Paratype: LACMIP 12290, CSUN loc. 1563.

Discussion: Three specimens were found, and they are all from CSUN loc. 1563. The holotype is the largest specimen. The new species is remarkably similar to the living *Lapsigyrus myrioshirissa* Shasky (1970:189, fig. 3) from west Mexico. The new species differs by having a more elongate shell with thicker and more widely spaced spiral ribs.

Previously, the geologic range of genus *Lapsigyrus* was Pleistocene to Recent, with a single Pleistocene species and a few living species (Shasky, 1970; Keen, 1971). The geographic range of the genus was from Magdalena Bay, Baja California Sur, Mexico, to Costa Rica (Keen, 1971; Ponder, 1985). The new species extends the geologic range to the early Eocene and the geographic range to Washington.

Etymology: The species is named for the Crescent Formation.

Occurrence: "Capay Stage" (middle lower Eocene). Crescent Formation, Larch Mountain, Washington (CSUN loc. 1563).

Family COLUMBELLIDAE Swainson, 1840

Genus *Mitrella* Risso, 1826

Type species: *Mitrella flaminea* Risso, 1826, by subsequent designation (Cox, 1927), Recent, Mediterranean Sea.

Subgenus *Mitrella* s.s.

Mitrella (*Mitrella*) ***blackhillsensis***
Squires & Goedert, sp. nov.

(Figures 21–23)

Diagnosis: A small *Mitrella* having a broad body whorl and no teeth on inner lip.

Description: Shell small, up to 5.5 mm in height, ovalfusiform. Suture distinct and impressed. Spire high with flat-sided, smooth whorls. Body whorl somewhat broad, smooth. Neck and siphonal fasciole areas with many fine spiral ribs. Aperture ovate. Outer lip varicose with 13 denticles on interior. Inner lip smooth. Anterior notch narrow.

Dimensions of holotype: Height 5.5 mm (incomplete); width 3 mm.

Holotype: LACMIP 12291.

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

Discussion: Only two specimens were found. The new species is most similar to *Mitrella richthofeni* (Gabb, 1869: 10, pl. 2, fig. 16) from Pliocene beds in northern California (Keen & Bentson, 1944) and tentatively from lower Miocene beds in southern California (Loel & Corey, 1932). The new species differs in the following features: smaller size, broader body whorl, and no teeth on inner lip.

Wenz (1941) reported the geologic range of *Mitrella* s.s. to be Miocene to Recent. Several late Cenozoic species are known from the Pacific coast of North America. *Mitrella tenuilineata* (Clark, 1918:173, pl. 22, figs. 2, 3) has been reported from Oligocene beds in northern California, but does not belong to *Mitrella* s.s. because it has spiral ribbing over the entire teleoconch.

The new species is the earliest record of *Mitrella* s.s.

Etymology: The species is named for the Black Hills, Washington.

Occurrence: "Capay Stage" (middle lower Eocene). Crescent Formation, Larch Mountain, Washington (CSUN loc. 1563).

Subclass Pulmonata Milne-Edwards, 1848

Order Basommataophora Schmidt, 1855

Family ELLOBIIDAE H. & A. Adams, 1855

Genus *Ovatella* Bivona, 1832

Type species: *Ovatella punctata* Bivona, 1832 [= *Auricula firminii* (Payraudeau, 1826)], by original designation, Recent, Mediterranean Sea.

Subgenus *Myosotella* Monterosato, 1906

Type species: *Auricula myosotis* Draparnaud, 1801, by original designation, Recent, Europe and both east and west coasts of the United States.

Ovatella (*Myosotella*) ***coneyi***
Squires & Goedert, sp. nov.

(Figures 24–26)

Diagnosis: A narrow shelled *Ovatella* having subtabulate whorls, inner lip with two plicae, and anterior end of aperture pointed.

Description: Shell minute, up to about 3 mm in height, narrowly ovate-fusiform, with approximately five convex whorls; spire elevated (approximately 36 percent of shell height). Suture distinct and impressed. Whorls smooth and subtabulate near suture; middle of body whorl with very faint shoulder. Aperture ovate, anterior end pointed and flattened. Inner lip with two plicae continuing deep inside of aperture, anteriormost plica formed by turning of lip within the aperture and twice as strong as the posteriormost plica; posteriormost plica in parietal area. Outer lip broken off.

Dimensions of holotype: Height 2.75 mm, width 1.5 mm.

Holotype: LACMIP 12292.

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

Paratype: LACMIP 12293, CSUN loc. 1563.

Discussion: Only two specimens were found and both are from CSUN loc. 1563. The new species resembles some variants of the living species *O.* (*M.*) *myosotis* (Draparnaud, 1801), a Mediterranean and eastern Atlantic species

dispersed by man to the east and west coasts of North America, the West Indies, South Africa, Australasia, and New Zealand (Climo, 1982). *Ovatella* (*M.*) *myosotis* shows considerable variation in the number of teeth on the inner and outer lips. The inner lip can have two to four teeth, and the outer lip can have one tooth or none (Climo, 1982). The new species resembles those specimens of *O.* (*M.*) *myosotis* that have two teeth on the inner lip and are without teeth on the outer lip (e.g., Climo, 1982:fig. 1A; and a few specimens in LACM lot 46780 from Purfleet, Essex, England). When compared to these particular examples, the new species differs in the following features: smaller size, spire whorls less convex, suture more impressed, subtabulate rather than non-tabulate whorls, base of body whorl more constricted, and aperture more elongate anteriorly.

Climo (1982) discussed the nomenclatural history of the family name that *Ovatella* should be assigned to, and Paulson (1957) reviewed the complex history of the genus name *Ovatella*. Zilch (1959–1960) discussed synonyms.

Zilch (1959–1960) reported the geologic range of *Ovatella* to be Paleocene to Recent. The early Tertiary species are from the Paris Basin, France, and the new species somewhat resembles *Ovatella* (*Myosotella*) *depressa* (Deshayes, 1864–1866:pl. 58, figs. 19–21; Cossmann & Pissarro, 1910–1913:pl. 58, fig. 256-8) from lower Eocene (Cuisian Stage) strata of the Paris Basin. The new species differs in the following features: smaller size, body whorl much less inflated near the suture, no spiral band anterior to suture, anterior end of aperture more pointed, no parietal callus, and no tendency to have more than one parietal plica.

Ovatella (*Myosotella*) ***coneyi*** is the first record of a marine pulmonate in the lower Tertiary of the Pacific coast of North America.

Etymology: The new species is named in memory of Charles Clifton Coney, who made valuable contributions to the study of Recent freshwater bivalves and terrestrial pulmonates.

Occurrence: "Capay Stage" (middle lower Eocene). Crescent Formation, Larch Mountain, Washington (CSUN loc. 1563).

Class Bivalvia Linné, 1758

Order Veneroida H. & A. Adams, 1856

Family TELLINIDAE de Blainville, 1814

Genus *Linearia* Conrad, 1860

Type species: *Linearia metastriata* Conrad, 1860, by monotypy, Late Cretaceous, Alabama.

Subgenus *Linearia* s.s.

Linearia (*Linearia*) ***louellasaulae***
Squires & Goedert, sp. nov.

(Figures 27–29)

Diagnosis: A minute, circular-ovate *Linearia* having beaks located posteriorly, radial ribbing weak on center of valves, and posterior slope with different curvature than rest of valve.

Description: Valves minute, up to 3 mm high, thin and fragile, circular-ovate in plan: beaks small, slightly anterior of center; anterior end rounded, posterior end truncate. Sculpture of closely spaced, thin concentric ribs crossed by numerous fine radial ribs, except on umbonal area. Radial ribbing weak on center of valves. Intersections of concentric and radial ribs beaded, strongest anteriorly and posteriorly. Posterodorsal slope with different curvature than rest of valve and with approximately seven serrated ribs; rib on umbonal ridge coarsest. Right-valve hinge with two cardinals separated from each other by deep and narrow socket, anterior cardinal slender and obliquely directed downward; posterior cardinal shorter, thicker, and directed nearly vertically downward. Dorsal margin of right valve beveled to serve as laterals. Left-valve hinge not observable.

Dimensions of holotype: Height 3 mm, length 4 mm.

Holotype: LACMIP 12294.

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

Paratypes: LACMIP 12295, 12296, both from CSUN loc. 1563.

Discussion: Eight specimens were found. Four are right valves, two are left valves, and two are fragments. The very delicate left valves are embedded in well-indurated matrix, and the hinges could not be exposed.

The new species is remarkably similar to *L.* (*L.*) *metastriata* Conrad (1860:279, pl. 46, fig. 7; Stephenson, 1923: 329, pl. 84, figs. 1–5; Afshar, 1969:58, pl. 24, figs. 12–15; Keen, 1969, figs. E109-11a, 11b) from Upper Cretaceous strata of New Jersey, Maryland, North Carolina, Tennessee, and Mississippi. The new species differs in the following features: much smaller size, less elongate shell, beaks posteriorly located, posterior slope with a different curvature than rest of valve, and right-valve posterior cardinal thicker and not oblique.

Keen (1969) reported that the geologic range of *Linearia* s.s. is Early through Late Cretaceous, with species in Europe, North America, and Africa, but Stoliczka (1871:pl. 5, figs. 6, 7) reported *Linearia* from the Cretaceous of southern India. The North American species are primarily from the Upper Cretaceous of the east coast of the United States from New Jersey to Texas (Stephenson, 1923, 1941; Wade, 1926).

Only a few species of *Linearia* are known from the Pacific coast of North America. *Linearia suciensis* Whiteaves (1879:146–147, pl. 17, fig. 12) has the external features of *Linearia*, but the hinge characters are unknown and the only known specimen has been lost. This species

was found in Cretaceous rocks of Sucia Island in the Strait of Georgia, northwest Washington. These rocks are the Cedar District Formation, and the highest fossiliferous beds on the island have ammonites indicative of middle Campanian age (L. R. Saul, personal communication). The new species differs from *L. suciensis* in the following features: beaks more posteriorly located, posterior more truncate, radial ribs on ventral margin, coarser radial ribs on dorsal areas, and a distinct postero-dorsal umbonal ridge.

Whiteaves (1903:377) placed *L. suciensis* in synonymy with *Asapis multicostata* Gabb (1869:181, pl. 29, fig. 70) from Crooked Creek, central Oregon. The type locality of *A. multicostata* is somewhat vague. There are Cenomanian strata along the Crooked River (Jones, 1960:438), however, and Gabb's (1869:181) associated fossils suggest Gabb's material is from the same horizon as *A. multicostata.* Stewart (1930:284–285, pl. 4, figs. 8,9) also considered *L. suciensis* and *A. multicostata* to be the same and called them *Linearia multicostata* (Gabb). These two taxa are morphologically quite different, and it seems likely that they are not the same species. *Asaphis multicostata* lacks the fine, crowded concentric striae of *L. suciensis,* and *A. multicostata* is geologically older than *L. suciensis.*

Whiteaves (1879:147) assigned *Tellina meekiana* Whiteaves (1874:268, unnumbered plate, fig. 6) to *Linearia* (*Leiothyris*) *meekana* (Whiteaves). This species was found in Cretaceous rocks of Gabriola Island, just west of Vancouver, British Columbia, Canada. Examination of the LACMIP-collection plaster cast of the holotype of *Tellina meekiana* revealed that this species is quite unlike a *Linearia.* Saul (1993) studied Cretaceous venerids from the Pacific coast of North America, and she put *T. meekiana* in synonymy with *Paraesa* (?) *lens* (Gabb, 1864:23, fig. 143). She also reported that *P.* (?) *lens* [= *Flaventia lens* (Gabb, 1864)] is a common species in deposits of Campanian age from southern British Columbia to southern California.

Dailey & Popenoe (1966) described the tellinid *Palaeomoera dyskritos* Dailey & Popenoe (1966:18–19, pl. 5, figs. 1, 2, 5) from the Upper Cretaceous Jalama Formation, Santa Barbara County, southern California. They mentioned that they thought that this species belonged to *Linearia* until they found a specimen that showed the hinge of the left valve. It contained only one oblique cardinal; hence, it could not be assigned to *Linearia.*

The new species is the youngest record of genus *Linearia* anywhere in the world.

Etymology: The species is named for LouElla Saul, in recognition of her many valuable contributions to the study of Cretaceous mollusks from the Pacific coast of North America.

Occurrence: "Capay Stage" (middle lower Eocene). Crescent Formation, Larch Mountain, Washington (CSUN loc. 1563).

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CSUN 1563. At elevation of 2230 feet (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, T17N, R4W, and 500 m S32°E of Larch Mountain, Capitol Peak U.S. Geological Survey quadrangle, 7.5-minute, provisional edition 1986, Thurston County, Washington. Crescent Formation. Age: Middle early Eocene ("Capay Stage"). Collectors: J. L. & G. H. Goedert, July, 1992.

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, T18N, R3W, and 950 m N25°W of Rock Candy Mountain, Summit Lake U.S. Geological Survey quadrangle, 7.5-minute, 1981, Thurston County, Washington. Crescent Formation. Age: Middle early Eocene ("Capay Stage"). Collectors: J. L. & G. H. Goedert, August, 1992.

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