THE VELIGER

The Veliger 38(3):254–269 (July 3, 1995)

New Species of Middle Eocene Gastropods from the Northern Doty Hills, Southwestern Washington

by

RICHARD L. SQUIRES

Department of Geological Sciences, California State University,
Northridge, California 91330-8266, USA

AND

JAMES L. GOEDERT

15207 84th Ave. Ct. NW, Gig Harbor, Washington 98329, and Museum Associate,
Section of Vertebrate Paleontology, Natural History Museum of Los Angeles County,
900 Exposition Boulevard, Los Angeles, California 90007, USA

Abstract. Five new species of gastropods were found at three localities in pebbly mudstones in the transition zone of interbedded volcanic and sedimentary rocks between the upper part of the Crescent Formation and the overlying lower part of the McIntosh Formation, Lewis County, southwestern Washington. The depositional environment is interpreted to have been on the flank of an oceanic volcanic island in outer shelf to upper slope (bathyal) muds subject to the influx of shells of nearshore and shallow-marine megainvertebrates and pebbly basalt debris. Associated calcareous nannofossils and megafossils indicate assignment to the middle Eocene.

The fissurellid *Emarginula* ***dotyhillsensis*** is the second Eocene species of this genus to be found on the Pacific coast of North America. The turbinid *Liotia* ***washingtoniana*** is the earliest record of this genus and only the second Eocene species to be found on the Pacific coast of North America. The trochid *Cidarina* ***antiqua*** is the first Paleogene species and the earliest record of this genus, whose previous geologic range was early Pleistocene to Recent. The trochid *Solariella* (*Solariella*) ***garrardensis*** is the third species of this genus to be found in Eocene rocks of Washington. The muricid *Pterynotus* (*Pterynotus*) ***washingtonicus*** is the second Eocene report of *Pterynotus* s.s. from the Pacific coast of North America.

INTRODUCTION

In the northern Doty Hills area, Lewis County, southwestern Washington (Figure 1), the junior author discovered abundant and well-preserved megafossils in Eocene rocks previously considered to be nearly barren of megafossils. Five new species of gastropods were found, and the objectives of this paper are to name and describe them and provide new information as to their stratigraphic position, geologic age, and general depositional environment.

The molluscan stages used in this report stem 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). The subseries equivalencies (shown in parentheses) of these stages are derived from Bartow (1992). The stage names are in quotes because they are informal terms and generally the same as formation names. Givens (1974) modified the use of the "Capay Stage," and it is in this modified sense that the "Capay Stage" is used herein. The calcareous nannofossil biozones follow that used by Okada & Bukry (1980). The classification system used for the turbinid and trochid gastropods follows that of Hickman & McLean (1990). 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.

STRATIGRAPHY AND MEGAFAUNA

On the geologic map of Pease & Hoover (1957), the study area localities plot in the lower member of the McIntosh Formation. Pease & Hoover (1957) were the first to recognize lower and upper members of this formation and reported that the lower member consists of a sequence of interbedded sedimentary and volcanic rocks usually transitional with the underlying Crescent (?) Formation. In a sense, Pease & Hoover (1957) emended the definition of the McIntosh Formation, which originally referred (Snavely et al., 1951) to chiefly dark gray, well-indurated tuffaceous marine siltstone and claystone interbedded with basaltic and arkosic sandstone in the lower part, and massive arkosic sandstone interbedded with andesite flows in the upper part. The type section of the McIntosh Formation is near Tenino, Washington, approximately 40 km northeast of the study area. According to early workers, invertebrate megafossils are rare in the McIntosh Formation and too poorly preserved for detailed study (Snavely et al., 1951; Pease & Hoover, 1957; Snavely et al., 1958). The only reference to a particular type of invertebrate megafossil was the report of unidentified "mud pectens" from the upper part of the McIntosh Formation (Pease & Hoover, 1957). The McIntosh Formation is gradationally overlain by or locally interbedded with the Northcraft and Skookumchuck Formations, and the latter formation is correlative to the upper middle Eocene (Armentrout et al., 1983).

The study area lithologies of thin lenses and pods of greenish pebbly mudstone, thin fossiliferous beds, muddy siltstone, and muddy sandstone, all interbedded with black basalt flows, are very similar to some lithologies in the upper Crescent Formation at the following locales: type section of the Crescent Formation west of Crescent Bay on the northern shore of the Olympic Peninsula (Arnold, 1906); Pulali Point on the east side of the Olympic Peninsula (Squires et al., 1992); and Little River area in the Satsop River drainage (Rau, 1966; Squires & Goedert, 1994a) (Figure 1). Because of these lithologic similarities, we believe that the upper Crescent Formation crops out in the study area and the use of a "question mark" by Pease & Hoover (1957) with the Crescent Formation in the northern Doty Hills is unnecessary. We believe also, pending detailed stratigraphic fieldwork, that the study area localities should be assigned to the transition zone of interbedded volcanic and sedimentary rocks present between the upper Crescent Formation and the overlying lower member of the McIntosh Formation (as used in the emended sense of Pease & Hoover, 1957).

The new species were found at three localities (CSUN locs. 1567, 1569, 1570, listed in ascending stratigraphic order) in a rock quarry where 17 m of section are exposed.

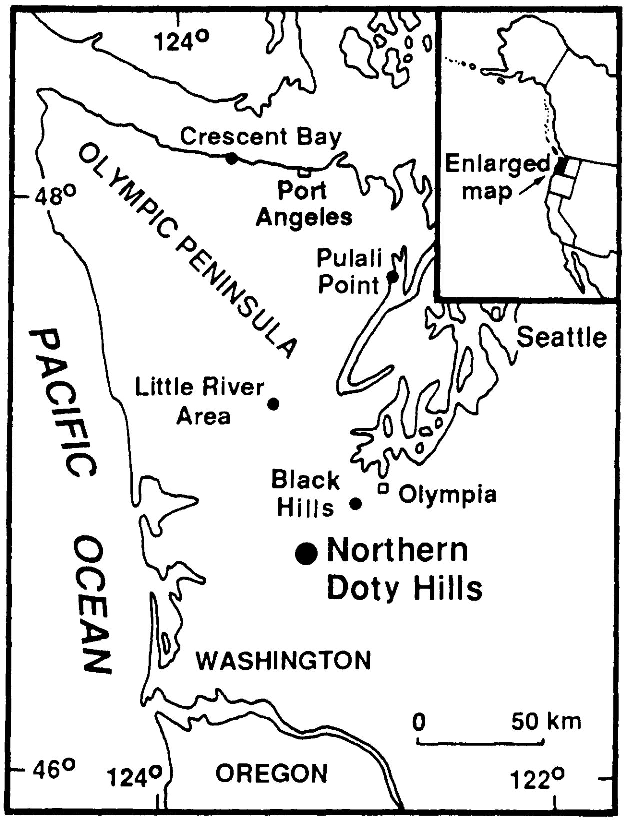


Figure 1

Index map to the northern Doty Hills, southwestern Washington.

The basal part, a 1 m-thick interval of siltstone and sandstone, is overlain by a 10 m-thick basalt unit that is blocky and fractured in the lower 7 m and brecciated in the upper 3 m. The lower contact of the 10-m thick basalt unit is baked, and the upper contact is erosional. There appears to have been paleo-relief in the area because the basalt flow crops out stratigraphically higher, relative to the quarry section, 100 m west of the quarry, and there is no evidence of faulting.

Overlying the basalt unit are 6 m of sedimentary rocks that include the three localities. The sedimentary strata in this 6 m-thick interval consist of fossiliferous siltstone interbedded with thin lenses and pods of pebbly mudstone, coarse sandstone, and minor amounts of coquina. Locality 1567 is near the top of a 20 cm-thick, greenish brown, poorly indurated pebbly mudstone bed that immediately overlies the 10 m-thick basalt unit. The rock clasts in the pebbly mudstone are subrounded and as large as 5 cm in length. The amount of mud increases upward in this bed, and locally there is laminated mudstone. Locality 1569 is 2 m stratigraphically above locality 1567 and consists of hard, platy grayish brown siltstone with scattered fossils. The siltstone locally encloses lenses of coquina, and they show normal graded bedding. Locality 1570, approximately 2 m upsection from locality 1569, is in a 2 m-thick brown sandstone bed with scattered lenses of basalt pebbles. At these three localities, the taxonomic composition of the macrofossils is similar (Table 1) and dominated by gastropods (including some minute specimens less than 5 mm in longest dimension) and bivalves. In addition, there can be megascopic benthic foraminifera (up to 2.8 mm in longest dimension), siliceous sponges, solitary corals, bryozoans, inarticulate and articulate brachiopods, polychaete tubes, scaphopods, a nautiloid, "gooseneck" barnacle opercula, crab chelipeds, isocrinid columnals, and shark teeth.

Fossils are abundant at all of the localities, and preservation of the fossils ranges from poor to good. The fossils are loosely packed and poorly sorted (terms used in the sense of Kidwell, 1991), except in the localized closely packed coquina lenses. Shells are not encrusted and rarely show any signs of boring. At all the localities, specimens of bryozoans and polychaetes are fragments. Specimens of the solitary coral *Flabellum clarki* Bentson are complete and have retained their delicate basal areas. The *Aphrocallistes polytretos* Rigby & Jenkins sponges are small fragments, but the *Eurete goederti* Rigby & Jenkins sponges are much larger fragments (up to 4 cm across). Brachiopods are usually unbroken single valves, but the bivalves are usually broken single valves, except for the unbroken *Parvamussium stanfordense* (Arnold), a small species. Some of the scaphopods are nearly complete. Gastropods are usually complete, especially *Solariella* (*Solariella*) ***garrardensis*** and *Cantrainea hieroglyphica* (Hickman). Many of the gastropods have retained their delicate morphologic features (e.g., protoconch, uppermost spire, sharp nodes, thin ribs, winged varices, long siphonal canal). Some of the "archaeogastropods" (including two of the new species) and some of the bivalves also have the mother-of-pearl luster of their interior shell layers preserved. The nautiloid has been crushed by sediment weight. The opercular plates of the barnacle *Aporolepas* sp. are unbroken. Most of the isocrinid columnals are disarticulated, although one specimen consists of an articulated columnal 1 cm in length.

AGE

The Crescent Formation, which can be as much as 16 km thick and is one of the thickest accumulations of volcanic rock in the world, ranges in age from the late Paleocene to the middle Eocene (Armentrout, 1987).

The McIntosh Formation transgresses time from middle to late Eocene and becomes younger in age toward the west from its type section east of the study area (Pease & Hoover, 1957). Armentrout et al. (1983), however, reported that the time transgressiveness of the McIntosh Formation encompasses only the middle Eocene. Just south of the Doty Hills area, the lower part of the McIntosh Formation was assigned by Rau (1958) to the upper part of Laiming's (1940) benthic foraminiferal Zone A-2, which is equivalent to the lower part of Mallory's (1959) benthic foraminiferal Narizian Stage. Almgren et al. (1988) recently emended Laiming's (1940) zones and correlated most of Zone A-2 to the middle Eocene calcareous nannofossil Zone CP13 Zone of Okada & Bukry (1980). Relative to molluscan stages, Zone CP13 corresponds to the upper part of the "Domengine Stage," the "Transition Stage," and the lower part of the "Tejon Stage" (Bartow, 1992).

A poorly preserved but moderately diverse assemblage of calcareous nannofossils was found at CSUN locality 1567. Though classic zonal markers are absent, this sample can be assigned (M. V. Filewicz, personal communication) to the middle Eocene (Zones CP12 to CP14 of Okada & Bukry, 1980) based on the range overlap of *Chiasmolithus solitus* (Bramlette & Sullivan) and abundant large (>6 microns) *Reticulofenestra* spp., including *R. samudorovi* (Hay, Mohler & Wade). Bukry & Snavely (1988) found a very similar calcareous nannofossil assemblage in a sedimentary and volcanic sequence of middle Eocene age just east of Dolph, northwestern Oregon. A microfossil sample from CSUN loc. 1570 is barren of nannofossils except for very rare *Reticulofenestra* spp. Unfortunately, the range of Zones CP12 to CP14 is quite broad and encompasses the "Domengine Stage," "Transition Stage," and part of the "Tejon Stage."

An analysis of the stage ranges of the identifiable species of megafossils in the study rocks (Table 1) shows that the megafossil data are not that conclusive and encompass the "Domengine," "Transition," and the "Tejon Stages." Although a few species (the solitary coral *Flabellum clarki* Bentson; the inarticulate brachiopod *Craniscus edwilsoni* Squires & Goedert; and the gastropod *Hapolcochlias montis* Squires & Goedert) indicate the "Capay Stage," we do not assign the study area rocks to this stage because the fossil record of these species is incomplete. They are known only from single formations, and the gastropod *H. montis* is not commonly preserved because of its minute size. In addition, the nannofossil data put a constraint on the age of the study area rocks as younger than the "Capay Stage." Of all the other positively identified species listed in Table 1, only the gastropod *Homalopoma umpquaensis domenginensis* Vokes does not have a geologic range that includes the "Transition" and "Tejon" "Stages." Its range is "Capay Stage" to "Domengine Stage," but this species is also relatively rare in the fossil record.

Although two species (the colonial coral *Dendrophyllia tejonensis* Nomland and the gastropod *Conus aegilops* Anderson & Hanna) seem to indicate the "Transition Stage," this is misleading because no molluscan species are known to be restricted to the short "Transition Stage" (Givens & Kennedy, 1979). The fossil record of these two species is incomplete, and both are known only from a single formation. Future work will undoubtedly show them to occur in more than just the "Transition Stage." Species listed in Table 1 that are more widespread and that have a moderately restrictive geologic age range are the gastropods *Patelloida tejonensis* (Gabb), *Pseudoperissolax blakei* (Conrad), and the bivalve *Brachidontes?* (*B.?*) *dichotomus* (Gabb), and they indicate the "Transition" to "Tejon" "Stages." Four other species listed in Table 1 (the articulate bra-

Table 1

Eocene megafossil taxa from the transition zone of interbedded volcanic and sedimentary rocks between the upper Crescent Formation and the overlying lower McIntosh Formation, northern Doty Hills, Washington. M = "Meganos Stage," C = "Capay Stage," D = "Domengine Stage," Tr = "Transition Stage," Te = "Tejon Stage."

Taxa	Localities & number of specimens			Previously reported stage range	Previously reported paleoenvironment; geologic range comments
	1567	1569	1570		
PORIFERA					
Hexactinellida					
Aphrocallistes sp. cf. *A. polytretos* Rigby & Jenkins, 1963	1	—	—	Middle Eocene?, Te-Oligocene (Rigby & Jenkins, 1963; Goedert & Squires, 1990)	300–350 m (Rigby & Jenkins, 1983); chemosynthetic cold seeps (Goedert & Squires, 1990). Presence in Doty Hills is the earliest confirmed occurrence of this species.
Eurete goederti? Rigby & Jenkins, 1963	1	—	18	Oligocene (Rigby & Jenkins, 1963)	100–350 m (Rigby & Jenkins, 1983). Presence in Doty Hills is the earliest occurrence of this species.
CNIDARIA					
Anthozoa					
Dendrophyllia tejonensis Nomland, 1916	4	—	3	Tr (Squires, 1989a; Lindberg & Squires, 1990)	Rocky nearshore, reported only from basal Tejon Formation, southern California (Squires, 1989a; Lindberg & Squires, 1990).
Flabellum clarki Bentson, 1943	3	3	6	C (Bentson, 1943)	Marine, reported only from Capay Fm., northern California (Bentson, 1943).
BRYOZOA					
Unidentified encrusting bryozoan	2	—	—	—	—
Unidentified frond-like bryozoan	2	—	1	—	—
BRACHIOPODA					
Inarticulata					
Craniscus edwilsoni Squires & Goedert, 1994	1	—	—	C (Squires & Goedert, 1994a)	Hard substrate associated with volcanic island or pillow basalt in shallow-marine waters, reported only from upper part of Crescent Fm., Washington (Squires & Goedert, 1994a).
Terebratulina washingtonensis (Weaver, 1912)	—	25	4	Te	Marine, reported only from Cowlitz Fm., Washington (Weaver, 1912). Armentrout et al. (1983) assigned formation to the upper Eocene.
ANNELIDA					
Polychaetia					
Rotularia (*Rotularia*) *tejonense* (Arnold, 1910)	1	—	—	C-Tr (Squires & Goedert, 1994a)	Subtidal in rubble derived from closely adjacent basalt flows extruded into shallow-marine waters, and hard substrate associated with volcanic island or pillow basalt in shallow-marine waters (Squires et al., 1992; Squires & Goedert, 1994a).

Table 1

Continued.

Taxa	Localities & number of specimens 1567	1569	1570	Previously reported stage range	Previously reported paleoenvironment; geologic range comments
Rotularia sp. (smooth)	—	3	6	—	—
MOLLUSCA					
Scaphopoda					
Dentalium sp. (ribbed)	—	6	2	—	—
Dentalium sp. 2 (smooth)	1	3	5	—	—
Gastropoda					
Cantrainea hieroglyphica (Hickman, 1974)	2	54	5	Te	Outer shelf to upper slope (bathyal), reported only from upper Cowlitz Formation, northern Oregon (Hickman, 1974). Armentrout et al. (1983) assigned this formation to the upper middle Eocene.
Cidarina ***antiquua*** sp. nov.	—	1	10	—	Previously, genus only known as Recent.
Conus aegilops Anderson & Hanna, 1925	1	10	2	Tr	Only known from Liveoak Shale Members of the Tejon Formation (unpublished data). Nilsen (1987) and Squires (1989b) assigned this member to the "Transition Stage." Nilsen (1987) assigned this member to the deep marine (bathyal).
Cypraeagemmula warnerae Effinger, 1938	3	—	2	Te	Interbedded nearshore or littoral facies and slightly deeper (not over 60 to 90 m in depth) facies, reported only from Gries Ranch beds, Washington (Effinger, 1938). Lindberg (1988) assigned the Gries Ranch beds to the upper Eocene.
Cyclichnina tantilla (Anderson & Hanna, 1925)	—	—	2	C-Te (Squires & Demetrion, 1992)	Subtidal, in rubble derived from closely adjacent basalt flows extruded into shallow-marine waters (Squires et al., 1992). Shallow marine (Squires & Demetrion, 1992).
Emarginula ***dotyhillsensis*** sp. nov.	—	—	3	—	—
Erginus vaderensis (Lindberg, 1979)	2	—	3	C-Te (Squires & Goedert, 1994a)	Hard substrate associated with volcanic-island or pillow basalt in shallow-marine waters (Squires & Goedert, 1994a).
Gemmula abacta Anderson & Hanna, 1925	—	—	1	Eocene undifferentiated (Anderson & Hanna, 1925)	Tejon Formation (Anderson & Hanna, 1925).
Gemmula barksdalei? Weaver, 1942	—	—	1	Te	Cowlitz Formation, Washington (Weaver, 1912). Armentrout et al. (1983) assigned this formation to the upper middle Eocene. Also found near base of Metralla Sandstone in Liveoak Canyon, Tehachapi Mountains, southern Cal-

Table 1

Continued.

Taxa	Localities & number of specimens 1567	1569	1570	Previously reported stage range	Previously reported paleoenvironment; geologic range comments
					ifornia (unpublished data). Nilsen (1987) assigned this formation to the "Tejon Stage" and assigned this formation in Liveoak Canyon to the shallow-marine environment.
Haplocochlias montis Squires & Goedert, 1994b	5	1	—	C (Squires & Goedert, 1994a)	Rocky intertidal, reported only from upper part of Crescent Formation, Washington (Squires & Goedert, 1994a).
Hipponix arnoldi Dickerson, 1917	—	—	3	Te	Interbedded nearshore or littoral facies and slightly deeper (not over 60 to 90 m in depth) facies, reported only from Gries Ranch beds of the late Eocene age (Effinger, 1938). Lindberg (1988) assigned the Gries Ranch beds to the upper Eocene.
Homalopoma umpquaensis domenginensis Vokes, 1939	1	—	2	C-D (Squires, 1988a)	Transition zone between protected rocky shoreline and offshore (Squires, 1988a).
Liotia ***washingtoniana*** sp. nov.	2	—	—	—	—
Patelloida tejonensis (Gabb, 1869)	—	—	1	Tr-Te (Lindberg & Squires, 1990)	Rocky nearshore (Lindberg & Squires, 1990).
Polinices (*Polinices*) *hornii* (Gabb, 1864)	1	—	3	Upper Paleocene-Te (Marincovich, 1977)	Most abundant in upper Eocene rocks (Marincovich, 1977).
Pseudoperissolax blakei (Conrad, 1855)	—	—	1	Tr-Te (Givens & Kennedy, 1979; Nilsen, 1987)	Inner neritic on rocky substrate and shallow marine (Nilsen, 1987). Presence in Doty Hills is first occurrence in Washington.
Pterynotus (*Pterynotus*) ***washingtonicus*** sp. nov.	—	—	2	—	—
Solariella (*Solariella*) ***garrardensis*** sp. nov.	3	—	53	—	—
Turritella sp. indet.	1	—	—	—	—
Bivalvia					
Acila sp. indet.	—	2	—	—	—
Brachidontes (*Brachidontes*) *cowlitzensis* Weaver and Palmer, 1992	2	—	—	Me-lower Oligocene (Squires & Goedert, 1994a)	Hard substrate associated with volcanic island or pillow basalt in shallow-marine waters (Squires & Goedert, 1994a).
Brachidontes? (*Brachidontes*?) *dichotomus* (Gabb, 1864)	3	—	3	Tr-Te (Weaver, 1912; Lindberg & Squires, 1990)	Rocky nearshore (Lindberg & Squires, 1990).
Chama sp.	1	—	—	—	—
"*Crassatella*" *uvasana* Conrad, 1855	—	—	2	D-Te (Squires, 1987)	Shallow marine (Squires, 1984) and transition zone just seaward of a delta front (Squires, 1987).
Glycymeris sp.	5	—	9	—	—
Isognomon (*Isognomon*) *clarki* (Effinger, 1938)	1	—	—	D-Te (Squires, 1989a)	Rocky nearshore to possibly bathyal (Squires, 1989a).

Table 1

Continued.

Taxa	Localities & number of specimens			Previously reported stage range	Previously reported paleoenvironment; geologic range comments
	1567	1569	1570		
Nemocardium linteum (Conrad, 1855)	—	—	3	Upper Paleocene-Te (Squires & Goedert, 1994a)	Shallow marine (Squires, 1984); subtidal in rubble derived from closely adjacent basalt flow extruded into shallow marine waters (Squires et al., 1992); and offshore (Squires & Demetrion, 1992)
Ostrea sp.	1	—	3	—	—
Parvamussium stanfordense (Arnold, 1906)	—	—	10	C-Te (Moore, 1984)	Presence in Doty Hills is first occurrence in Washington. "Capay Stage" occurrence not given *per se* by Moore (1984) but a specimen (pl. 1, fig. 15) is reported by her from the Cerros Shale Member of the Lodo Formation, central California. See Squires (1988b) for a discussion of the age of this member.
Pteria sp., cf. *P. clarki* Weaver & Palmer, 1922	—	—	1	Te	Cowlitz Formation, Washington (Weaver & Palmer, 1922). Armentrout et al. (1980) assigned this formation to the upper middle Eocene.
Spondylus carlosensis Anderson, 1905	1	—	—	C-Te (Weaver & Kleinpell, 1963; Squires & Goedert, 1994a).	Hard substrate associated with volcanic island or pillow basalt in shallow-marine waters (Squires & Goedert, 1994a).
Cephalopoda					
Unidentifiable nautiloid	—	1	—	—	—
ARTHROPODA					
Cirripedia					
Aporolepas sp. (opercular plates)	15	—	4	—	Known species are from a subtidal/inner shelf agitated environment (R. T. Perreault, personal communication).
Brachyura					
Crab chelipeds	—	4	—	—	—
ECHINODERMATA					
Crinoidea					
Isocrinid (columnals)	1	—	4	—	—
CHORDATA					
Chondrichthyes					
Notorhynchus? sp. (tooth)	—	1	—	—	—

chiopod *Terebratulina washingtoniana* (Weaver), and the gastropods *Cantrainea hieroglyphica* (Hickman), *Cypraeagemmula warnerae* Effinger, and *Hipponix arnoldi* Dickerson, indicate the "Tejon Stage," but the reported stage ranges of these species are suspect because the species are known only from a single formation. The same reasoning holds for the sponge *Eurete goederti* Rigby & Jenkins listed in Table 1.

In summary, the megafossil data are not useful in assigning the study area rocks to any one molluscan stage with certainty. Based on Rau's (1958) work on the age of the formation, as well as on the constraint of the nannofossil data at locality 1567, and considering that megafossils with the best fossil record indicate the "Transition Stage" to "Tejon Stage," the latter of which is mostly of middle Eocene age, we conclude that the study area rocks should be generally assigned to the middle Eocene.

GENERAL DEPOSITIONAL ENVIRONMENT

Taken as a whole, the Crescent Formation accumulated in a subsiding basin that was formed by rifting along the continental margin of Washington and Oregon, and volcanic islands developed where extrusion exceeded the rate of basin subsidence (Babcock et al., 1992, 1994). The upper third of the formation ranges from a deep-to-shallow marine environment to one that is locally terrestrial. Where extrusion of basalt flows caused shoaling of the marine waters, interbedded marine sedimentary rocks locally contain megafossils (Squires et al., 1992; Squires & Goedert, 1994a; Squires & Goedert, 1994b).

The lower part of the McIntosh Formation includes nearshore sequences of basaltic and arkosic sandstone that grade toward the west into offshore deep-water siltstone and claystone that make up the middle part of the formation (Armentrout, 1987).

An analysis of the paleoenvironments that have been previously reported for the identifiable species found in the study area rocks (Table 1) shows that most of the paleoenvironments are nearshore to shallow-subtidal and contain rubble derived from closely adjacent rocky shores usually made up of basalt flows. The paleoenvironments for the siliceous sponges and the gastropods *Cantrainea hieroglyphica* and *Conus aegilops,* however, are outer shelf to upper slope (bathyal). The close association of a nearshore paleoenvironment with an outer shelf paleoenvironment for the study area rocks is compatible with the above-mentioned depositional history of the upper part of the Crescent Formation, as well as with the depositional history of the lower part of the McIntosh Formation.

In terms of lithologies, the Doty Hills study area rocks are most similar to the upper Crescent Formation at Pulali Point on the east side of the Olympic Peninsula, Washington, where muddy pebble conglomerates were deposited in a shallow-subtidal environment next to basalt flows that had caused shoaling of the marine waters (Squires et al., 1992). The similarities are the following: muddy pebbly bed immediately overlies a basalt flow, pebble clasts are subrounded and consist of basalt, muddy pebbly bed grades upward into thicker intervals of siltstone or mudstone, and megafossil groups are dominated by gastropods and bivalves in association with bryozoans, brachiopods, scaphopods, and nautiloids.

In terms of taxonomic composition, the Doty Hills study area rocks are most similar to the upper Crescent Formation in the Little River area on the south side of the Olympic Peninsula, Washington, where a diverse assemblage of megainvertebrates lived on a hard substrate produced by the accumulation of bouldery rubble derived from volcanic-island or pillow basalt in shallow-marine waters (Squires & Goedert, 1994a). Species found in the Doty Hills study area that are conspecific with those in the Little River area are: *Craniscus edwilsoni* Squires & Goedert, *Rotularia* (*R.*) *tejonense* (Arnold), *Erginus vaderensis* (Dickerson), *Brachidontes* (*B.*) *cowlitzensis* Weaver & Palmer, *Spondylus carlosensis* Anderson, and *Nemocardium linetum* (Conrad). In addition, the barnacle *Aporolepas* sp. is present at both sites.

The depositional environment of the sedimentary rocks in the study area is interpreted to have been on the flank of an oceanic volcanic island in outer shelf to upper slope (bathyal) muds and silts subject to the influx, during storms, of shells of nearshore and shallow-marine megainvertebrates and pebbly basalt debris. On the flank of a volcanic island, the distance of downslope transport would not have been necessarily great to reach upper bathyal depths. There was minimum duration of seafloor exposure because the shells do not show evidence of borers, encrusters, or crushers, which are normally associated with delayed burial (Kidwell, 1991). Species indigenous to this outer shelf to upper slope environment were the siliceous sponges and the gastropods *Cantrainea hieroglyphica* and *Conus aegilops.* A detailed paleoecologic/taphonomic study is needed to determine which of the other species are indigenous or exotic to the site of accumulation, but such a study is beyond the scope of the present report.

SYSTEMATIC PALEONTOLOGY

Class Gastropoda Cuvier, 1797

Family FISSURELLIDAE Fleming, 1822

Subfamily EMARGINULINAE Gray, 1834

Genus *Emarginula* Lamarck, 1801

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

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

(Figures 2–4)

Diagnosis: An *Emarginula* with apex near posterior margin, moderately long anal slit, 16 primary radial ribs with two main rows of nodes (diverging and coarsening anteriorly), and double or single row of punctations between ribs.

Description: Shell small, sturdy, with nearly parallel sides. Apex strongly curved posteriorly and directly above posterior margin. Anterior slope convex and steep near anterior margin; posterior slope concave below the apex. Apex smooth, nucleus turned under the succeeding part of shell. Anal slit situated at anterior margin, narrow and moderately deep, measuring 0.75 mm deep. Slit band coincident with raised area extending nearly to apex. Sculpture of 16 strong primary radial ribs originating near apex. Interspaces between primary radial ribs with double rows of punctations on anterior and posterior slopes; single row (less commonly, double rows) of punctations on lateral slopes. Concentric sculpture consists of two raised ridges, noded at intersections with the primary radial ribs on lower part of shell; nodes diverge and coarsen anteriorly; a third row nodes only near the slit band. Aperture ovate.

Dimensions of holotype: Length 3.4 mm, width 2.6 mm, height 3 mm.

Holotype: LACMIP 12338.

Type locality: CSUN loc. 1570, latitude 46°45′52″N, longitude 123°19′00″W.

Discussion: Only a single specimen was found, but it is complete and well-preserved. The new species is similar to *Emarginula fenestrata* Deshayes (1864–1866:350, pl. 3, figs. 37–41; Cossmann & Pissarro, 1910–1913:pl. 2, fig. 10-1;) from the middle Eocene (Lutetian Stage) of the Paris Basin, France. The new species differs in the following features: no secondary radial ribs, concentric ribs only on lower part of shell rather than covering the shell, apex more posteriorly located, deeper anal slit, and presence of nodes on lower part of shell.

Emarginula ***dotyhillsensis*** is only the second Cenozoic species of this genus to be reported from the Pacific coast of North America. The other species is *Emarginula washingtoniana* Squires & Goedert, 1994b from "Capay Stage" rocks in the upper Crescent Formation at Larch Mountain, Black Hills, southwestern Washington (Squires & Goedert, 1994b). *Emarginula* ***dotyhillsensis*** differs from *E. washingtoniana* in the following features: no secondary radial ribs, apex more posteriorly located, presence of nodes on lower part of shell, and presence of rows of punctations between the primary radial ribs.

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

Family TURBINIDAE Rafinesque, 1815

Subfamily LIOTIINAE Adams & Adams, 1854

Genus *Liotia* Gray, 1847

Type species: *Delphinula cancellata* Gray, 1828, by monotypy, Recent, northern Chile.

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

(Figures 5–8)

Diagnosis: A species of *Liotia* with many closely spaced axial ribs on body whorl.

Description: Minute shell, three whorls. Very low spire but not flattened. Moderately strong cancellate sculpture, body whorl tabulate with three equal spiral ribs between shoulder and base of whorl, four additional ribs on base. Approximately 21 closely spaced axial ribs on body whorl; axial ribs extend from suture to narrow umbilicus. Aperture round. Shell interior nacreous.

Dimensions of holotype: Height 1.5 mm, diameter 2.5 mm.

Holotype: LACMIP 12339.

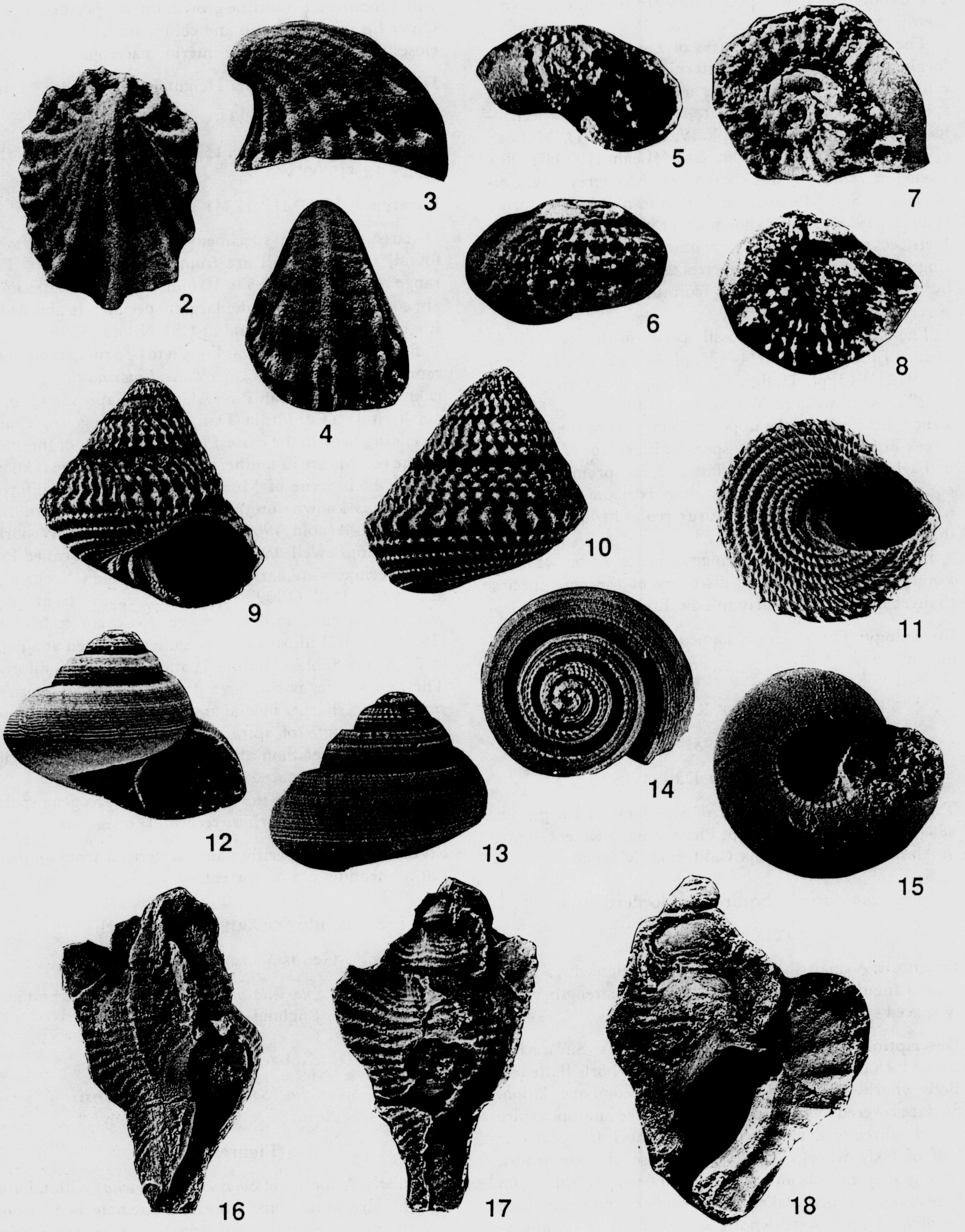
Type locality: CSUN loc. 1567, latitude 46°45′52″N, longitude 123°19′00″W.

→

Explanation of Figures 2 to 18

All specimens coated with ammonium chloride; photographed by the senior author. All specimens from CSUN loc. 1570, unless otherwise noted.

Figures 2–4. *Emarginula* ***dotyhillsensis*** Squires & Goedert, sp. nov., holotype LACMIP 12338. Figure 2: dorsal view, ×12, length 3.4 mm. Figure 3: left-lateral view, ×10, height 3 mm. Figure 4: anterior view, ×11, width 2.6 mm. Figures 5–8. *Liotia* ***washingtoniana*** Squires & Goedert, sp. nov., holotype LACMIP 12339, CSUN loc. 1567. Figure 5: apertural view, ×14, height 5 mm. Figure 6: abapertural view, ×14, height 6 mm. Figure 7: apical view, ×15, diameter 2.5 mm. Figure 8: umbilical view, ×14, diameter 2.5 mm. Figures 9–11. *Cidarina* ***antiqua*** Squires & Goedert, sp. nov., holotype LACMIP 12340. Figure 9: apertural view, ×5.6, height 7.1 mm. Figure 10: abapertual view, ×5.6, height 7.1 mm. Figure 11: umbilical view, ×5.6, width 7 mm. Figures 12–15. *Solariella* (Solariella) ***garrardensis*** Squires & Goedert, sp. nov. Figure 12: holotype LACMIP 12343, ×5.3, height 6.2 mm. Figures 13–14: paratype LACMIP 12344. Figure 13: abapertural view, ×6.9, height 4.4 mm. Figure 14: apical view, ×6.9, width 5.3 mm. Figure 15: holotype LACMIP 12343, umbilical view, ×5, width 7.4 mm. Figures 16–18. *Pterynotus* (*Pterynotus*) ***washingtonicus*** Squires & Goedert, sp. nov., Figures 16–17: holotype LACMIP 12351. Figure 16: apertural view, ×3.2, height 17.5 mm. Figure 17: abapertural view, ×3.3, height 17.5 mm. Figure 18: paratype LACMIP 12352, apertural view, ×6.8, height 18.8 mm.


2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18

Discussion: Only two specimens were found; one is very poorly preserved.

There are two living species of *Liotia,* one from California and northern Baja California, and one from northern Chile. The new species is most similar to the living species *L. fenestrata* Carpenter, 1864, which has been illustrated by Palmer (1958:pl. 19, figs. 10, 11), McLean (1978:fig. 7), and Hickman & McLean (1990:fig. 8c). *Liotia fenestrata,* which is known from Monterey Bay, California, to San Martin Island, northern Baja California (Palmer, 1958), is also known as a rare fossil in the lower Pleistocene Lomita Marl of southern California (Woodring et al., 1946). The new species differs from *L. fenestrata* by having weaker cancellate sculpture and more closely spaced ribs.

The only other known fossil species of this genus is *L. weaveri* Effinger (1938:374–375, pl. 46, figs. 15, 21; Weaver, 1942 [1943]:pl. 63, figs. 13, 18) from the "Gries Ranch beds" of southwestern Washington. Lindberg (1988) assigned these beds to the upper Eocene part of the Lincoln Creek Formation. The new species differs from *L. weaveri* by having a spire that is not flattened, less prominent ribs, equal-strength ribs, 21 rather than 16 axial ribs, much narrower umbilicus, and aperture circular in outline rather than subhexagonal.

Previously, the geologic range of genus *Liotia* was late Eocene to Recent, but the discovery of the new species changes this range to early middle Eocene to Recent.

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

Family TROCHIDAE Rafinesque, 1815

Subfamily EUCYCLINAE Koken, 1897

Genus *Cidarina* Dall, 1909

Type species: *Margarita cidaris* A. Adams *in* Carpenter, 1864, by original designation, Pleistocene to Recent, living in Alaska to northern Baja California, Mexico.

Cidarina ***antiqua*** Squires & Goedert, sp. nov.

(Figures 9–11)

Diagnosis: A small-shelled species of *Cidarina* with a sharp medial angulation on body whorl and equal strength, closely spaced spiral ribs on spire.

Description: Shell small, five to six whorls. Suture impressed, channeled. Spire elevated, spire whorls flattened. Body whorl overall rounded but with a medial angulation. Surface covered by nodose spiral ribs: three on upper spire whorls, three to five on penultimate whorl and posterior half of body whorl, and seven on base of body whorl. Strongest spiral rib on angle on body whorl. Spirals on base of body whorl weaker than the others and nodes more beadlike. Upper spire whorls with cancellate ornamentation. Remaining whorls, especially base of body whorl, with prominent prosocline growth lines. Aperture circular. Outer lip thin. Inner lip and columella with a callus that closes the umbilicus. Shell interior nacreous.

Dimensions of holotype: Height 7.1 mm, width 7.0 mm.

Holotype: LACMIP 12340.

Type locality: CSUN loc. 1570, latitude 46°45′52″N, longitude 123°19′00″W.

Paratypes: LACMIP 12341 and 12342.

Discussion: Eleven specimens of the new species were found, and almost all are from CSUN loc. 1570. They range in height from 2.5 to 10 mm. Seven of the specimens are complete, and only the largest specimen is abraded. A single specimen was found at CSUN loc. 1569.

Previously, *Cidarina* was known to be a monotypic genus represented by the extant *C. cidaris. Cidarina cidaris,* which is known from Kasaän Bay, Alaska to Cape San Quintin, northern Baja California (Dall, 1909), has a geologic range extending back to the early Pleistocene. Most of the Pleistocene records are in southern California, but one is known for the Pleistocene of Monterey Bay, central California, and one is known for the Pleistocene of northern Baja California (Arnold, 1903; Grant & Gale, 1931; Woodring et al., 1946; Powell, 1994). Arnold's (1903) so-called Pliocene specimens are early Pleistocene in age (Woodring et al., 1946). Dall (1909) reported *C. cidaris* from "deep waters" but gave no depth range. Hickman & McLean (1990:fig. 44G) illustrated a specimen collected at a depth of 27 m off Santa Catalina Island, southern California. The new species is similar but differs from *C. cidaris* by smaller size, sharper medial angulation on the body whorl, uniform strength of spiral ribs posterior to the medial angulation rather than alternating weak and strong ribs, and more closely spaced spiral ribs on the spire.

The new species is the first reported Paleogene species of *Cidarina* and the earliest record of this genus.

Etymology: The specific name is derived from *antiquus,* Latin, meaning old or ancient.

Subfamily SOLARIELLINAE Powell, 1951

Genus *Solariella* Wood, 1842

Type species: *Solariella maculata* Wood, 1842, by monotypy, Pliocene, England.

Subgenus *Solariella* s.s.

Solariella (*Solariella*) ***garrardensis***
Squires & Goedert, sp. nov.

(Figures 12–15)

Diagnosis: A species of *Solariella* (*Solariella*) with tabulate whorls, bicarinate spire whorls, tricarinate body whorl, whorls covered by numerous very fine spiral ribs, cancellate upper spire whorls, and smoothish body whorl base.

Description: Small, up to 10 mm high, six to seven convex whorls. Suture distinct. Spire elevated, about one-half of shell. Body whorl moderately expanding. Protoconch smooth. Spire whorls and body whorl bicarinate with tabulate shoulder and medial angulation. On shells larger than about 8 mm height, medial angulation obsolete. Base of body also delineated by an angulation. Upper spire whorls cancellate, with axial ribs continuing across tabulate shoulder to suture. Remaining portion of spire and body whorl covered only with numerous, closely spaced, very fine spiral ribs. Spiral ribs obsolete to nearly obsolete on nearly smooth base of whorl. Growth lines prosocline. Umbilicus moderately wide and deep, umbilical shoulder delineated by a low row of numerous nodes. Interior of umbilicus smooth. Aperture quadrate, discontinuous. Shell interior nacreous.

Dimensions of holotype: Height 6.2 mm, width 7.4 mm.

Holotype: LACMIP 12343.

Type locality: CSUN loc. 1570, latitude 46°45′52″N, longitude 123°19′00″W.

Paratypes: LACMIP 12344 to 12350.

Discussion: Fifty-three specimens were found at CSUN loc. 1570, and three were found at CSUN loc. 1567. They are mostly complete and unabraded. At CSUN loc. 1570 they range in height from 2 to 7 mm and form a partial growth series.

The new species is similar to *Solariella olequahensis* Weaver & Palmer (1922:27–28, pl. 12, figs. 10, 12; Weaver, 1942 [1943]:293, pl. 64, figs. 6, 9) from the upper middle Eocene Cowlitz Formation, southwestern Washington. The new species differs in the following features: larger (up to 7 mm height rather than only 4 mm), whorls more tabulate, spiral ribs finer and not beaded or scalelike, spiral ribs much more numerous on body whorl, body whorl tricarinate rather than bicarinate, body whorl base not as sharply angulate, and spiral ribs on body whorl base tend to be obsolete.

There are only two other known species of Eocene *Solariella* from the Pacific Northwest. One is *S. crescentensis* Weaver & Palmer (1922:28–29, pl. 12, fig. 11; Weaver, 1942 [1943]:293–294, pl. 63, fig. 27) from the upper Crescent Formation on the north side of the Olympic Peninsula, Washington. The new species differs by not having well-defined beaded spiral ribs on the base of the body whorl. The other known species is *S. cicca* Hickman (1980:21–22, pl. 2, figs. 13, 14) from the upper Eocene Keasey Formation, northwestern Oregon, and in coeval strata on the Willapa River at Holcomb, Washington. The new species differs by having a lower spire, a wider umbilicus, a more pronounced and flatter spire, fewer and weaker spiral ribs on the body whorl, and no faintly cancellate pattern on the body whorl.

There are six other known species of *Solariella* from the Paleogene of the west coast of North America, and these species are listed in Keen & Bentson (1944). Two of these species are Paleocene in age, and the others are Eocene. The one that is most similar to the new species is *S. hartleyensis* Clark & Woodford (1927:122–123, pl. 22, fig. 12) from lowermost Eocene ("Meganos Stage") strata near San Francisco, northern California. Although the apex of *S. hartleyensis* is not known, the new species differs by more tabulate body whorls, no sutural collar, more spiral ribs, no alternating strength of spiral ribs, and a more convex base.

Etymology: The new species is named for Garrard Creek, which is just east of the type locality.

Family MURICIDAE Rafinesque, 1815

Subfamily MURICINAE Rafinesque, 1815

Genus *Pterynotus* Swainson, 1833

Type species: *Murex pinnatus* Swainson, 1822, by subsequent designation, Swainson, 1833, Recent, western Pacific and eastern Indian Ocean.

Subgenus *Pterynotus* s.s.

Pterynotus (*Pterynotus*) ***washingtonicus***
Squires & Goedert, sp. nov.

(Figures 16–18)

Diagnosis: A *Pterynotus* s.s. with prominent spiral ribs, one intervarical noded axial rib, and very weak denticles on the outer lip.

Description: Small shell, about six convex whorls. Suture distinct. Fusiform with a moderately high spire. Protoconch and uppermost spire missing. Shell bears three winglike varices, each extending along siphonal canal to upper spire and, presumably, to apex. Each wing broadest in its shoulder portion. Wings continuous but undulating, with each recurved and overlapping in its uppermost portion to the corresponding varical wing of the preceding whorl. Other axial sculpture consists of a low ridge, nodose at shoulder, in each intervarical space. Spiral sculpture consists of about 20 spiral cords, more closely spaced and finer near the suture. Ornament of spiral cords continues onto both sides of the wings, with the spiral cords on the leading sides (apertural sides) of wings, especially at broadest points, weaker or even obsolete. Aperture narrow, outer lip erect and very faintly dentate with at least six denticles. Inner lip callused and smooth. Siphonal canal open. Growth lines well developed near suture and more strongly prosocline than elsewhere.

Dimensions of holotype: Height 17.5 mm, width 10.0 mm.

Holotype: LACMIP 12351.

Type locality: CSUN loc. 1570, latitude 46°45′52″N, longitude 123°19′00″W.

Paratype: LACMIP 12352.

Discussion: Only two specimens were found, and both are from CSUN loc. 1570. They range in height from 17.5 to 18.6 mm. Preservation is moderately good, but the uppermost spire and anteriormost portions of the shell are missing, as well as portions of the delicate varical wings. Only the paratype shows the outer lip, but the anterior part is missing. The portion of the outer lip that is present has very low denticles that do not photograph well.

The new species is assigned to *Pterynotus* s.s. because of the following: three varices that project beyond the varical rib into a flange or winglike blade, ovate aperture, open siphonal canal, spiral ornamentation on the varical wings, and dentate outer lip. Muricine taxa with trivaricate winged shells that, on teleoconch characters, closely resemble *Pterynotus* s.s. are *Purpurellus* Jousseaume, 1880, *Pteropurpura* Jousseaume, 1880, and *Pterochelus* Jousseaume, 1880. *Purpurellus* is distinguished by a round aperture and a sealed siphonal canal with the left margin overlapping the right. *Pteropurpura* is distinguished by a round aperture and a fused siphonal canal (or at least the posterior two-thirds). *Pterochelus* is distinguished by having a varical wing that ends at the shoulder in a spine with a well-developed median channel.

The new species is very similar to *Pterynotus* (*Pterynotus*) *flemingi* Beu (1967:102, pl. 1, fig 9; 1970:138–141, pl. 2, figs. 16–17, 19–26) from the late Pliocene to Recent in New Zealand. This New Zealand species was originally deemed by Beu (1967) to be a subspecies of *P.* (*P.*) *laetifica* and assignable to genus *Pterynotus* s.s. Although Beu (1970) reassigned the subspecies to genus *Pteropurpura*, Beu & Maxwell (1990) put *laetifica* and *fleminigi* back in genus *Pterynotus* s.s. and elevated *flemingi* to the species level. *Pterynotus* (*Pterynotus*) ***washingtonicus*** differs from *Pterynotus* (*Pterynotus*) *flemingi* in the following features: smaller shell, narrower spire, narrower aperture, weaker denticles on outer lip, and no tendency for outer lip to be scaly. That the new species is very similar to the living *P.* (*P.*) *flemingi* is not surprising because *Pterynotus* is a very conservative group, and there has been little morphological change in this line since the Paleocene (Vokes, 1970, 1971a). Harasewych & Jensen (1979) also reported very close similarity between a Paleocene species and a Recent species of *Pterynotus* s.s.

The new species is similar to *Murex trigonus* Roualt (1850:493, pl. 17, figs. 17–17a) from the lower Eocene (Ypresian Stage) near Pau in southern France. Roualt's species is preoccupied by *Murex trigonus* Gmelin, 1791. The new species differs in the following features: presence of an axial ridge in each intervarical space, absence of cancellate sculpture, much weaker denticles on the outer lip, and varices not scaly.

The new species resembles *Pterynotus crenulatus* (Röding, 1798) from the middle and upper Eocene (Lutetian and Bartonian Stages) of the Anglo-Paris Basin, France. Wrigley (1930), Vokes (1971b, 1992), and Le Renard (1992) have given discussions or comments regarding the rather involved nomenclatural history of *P. crenulatus.* Illustrations of *P. crenulatus,* under the name of *Murex tricarinatus* Lamarck, 1803, are given in Palmer (1977:pl. 4, figs. 7a, 7b) and in Cossman & Pissarro (1910–1913:pl. 35, fig. 169-5). The new species differs from *P. crenulatus* in the following features: intervarical spiral sculpture more pronounced, 20 rather than about nine spiral cords, no hint of a channel in the posterior portion of the winged varix on the outer lip, and much weaker denticles on the outer lip.

The new species also resembles *Pterynotus* (*Pterynotus*) *sabinola* (Palmer, 1937:266, pl. 36, figs. 7, 11, 12; Vokes, 1970:9–10, pl. 1, figs. 2a, 2b; Vokes, 1992:9, pl. 1, fig. 5) from the middle Eocene of Texas and Louisiana. The new species differs in the following features: more flared varices, spiral sculpture much stronger, 20 rather than five to seven spiral cords, intervarical axial rib stronger, weaker denticles on the outer lip, and an absence of a projecting inner lip.

Pterynotus has only been reported once before from the Paleogene of the Pacific coast of North America. Givens (1974:82) reported three poorly preserved specimens of *Pterynotus* n. sp. from the *Turritella uvasana applinae* fauna ("Domengine Stage") of the Juncal Formation, Pine Mountain area, Ventura County, southern California. The new species differs in the following features: a single intervarical axial rib rather than three and stronger and more closely spaced spiral ribs.

A poorly preserved specimen of *Pterynotus* sp. indet. was found recently by the senior author while examining the LACMIP collection of mollusks from the "Stewart bed" in the Llajas Formation, north side of Simi Valley, Ventura County, southern California. Squires (1984) assigned the "Stewart bed" to the middle Eocene ("Domengine Stage").

Turner (1938) reported the trivaricate muricid *Murex* (*Alipurpura*) *coosensis* Turner (1938:80, pl. 15, fig. 25; Weaver, 1942 [1943]:454–455, pl. 88, fig. 19) from the so-called lower and upper Umpqua of southwestern Oregon. Squires (1984) considered the "lower Umpqua" to correspond to the middle lower Eocene ("Capay Stage") Roseburg Formation and the "upper Umpqua" to correspond to the middle lower Eocene ("Capay Stage") Lookinglass Formation and the upper lower to lower middle Eocene ("Domengine Stage") Flournoy Formation. The new species differs from *M.* (*A.*) *coosensis* in the following features: three varices on all whorls rather than only on the body whorl and penultimate whorl, winglike varices rather than just thick swellings, and early whorls without seven axial ribs. Although the holotype of *M.* (*A.*) *coosensis* is very poorly preserved, examination revealed that it may be a cymatiid.

Another reported trivaricate muricid from the Eocene of the Pacific coast of North America is *Murex packardi* Dickerson (1915:69, pl. 9, figs. 6a–6b; Weaver, 1942 [1943]: 455, pl. 88, figs. 17–18) from the upper middle Eocene Cowlitz Formation, southwestern Washington. The new species differs in the following features: varices more wing-like (especially on outer lip), varices not ruffled, only one rather than two nodose intervarical axial ribs, and spiral ribs weaker and more closely spaced.

The genus *Pterynotus* is one of the most ancient muricine lineages and dates back to at least the Paleocene in Alabama (Vokes, 1964, 1970). During Eocene time, the *Pterynotus* group dominated the muricine world, especially in the warm, shallow seas of the Anglo-Paris Basin (Vokes, 1970). Although *Pterynotus* was widely distributed during the Eocene (Harasewych & Jensen, 1979; Beu & Maxwell, 1990), modern species are restricted to subtropical and tropical regions, usually in moderately deep waters.

The new species is only the second species of *Pterynotus* s.s., including the fossil and Recent record, known from the Pacific coast of North America. No species of *Pterynotus* s.s. occurs in the Panamic province today (Keen, 1971).

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

ACKNOWLEDGMENTS

Gail H. Goedert helped collect the fossils. James H. McLean (LACM) gave much help in the identification of the genera. Emily H. Vokes (Tulane University, Louisiana) shared her knowledge of muricines, provided key literature, and reviewed the section on the new species of *Pterynotus*. Alvin A. Almgren (Bakersfield) and R. E. Wells (United States Geological Survey, Menlo Park) shared their knowledge of Eocene stratigraphy of southwestern Washington. Charles R. Givens (Nicholls State University, Louisiana) shared his knowledge of the fossil record of *Pterynotus* on the Pacific coast of North America and provided literature. Mark V. Filewicz (Houston, Texas) processed two microfossil samples and identified the calcareous nannofossils. Ray T. Perreault (Jarreau, Louisiana) identified the barnacles. Jean DeMouthe (California Academy of Sciences, San Francisco) and David R. Lindberg (University of California, Berkeley) arranged for the loan of primary type specimens. Lindsey T. Groves (LACM) provided loans of comparative specimens and access to literature. The manuscript benefited from comments by Ellen J. Moore (Oregon State University, Corvallis) and an anonymous reviewer. Expenses were partially paid by a Conchologists of America grant to the senior author.

LOCALITIES CITED

CSUN 1211. At elevation of 2200 ft. (670 m) on power-line road adjacent to power tower number 395 on E side of mouth of Grapevine Canyon, 2484 m (8150 ft.) N38°W of radio relay station on Grapevine Peak, U.S. Geological Survey, 7.5-minute, Grapevine Quadrangle, 1958 (photorevised 1974), Kern County, California. Liveoak Shale Member of the Tejon Formation. Age: Middle early Eocene ("Capay Stage"). Collector: R. L. Squires, 1988.

CSUN 1567, 1569, 1570. Localities are about 2 m apart, in ascending stratigraphic order, in a 17-m-thick section of sedimentary rocks interbedded with a basalt unit in quarry at E end of bluff overlooking W side of Garrard Creek, latitude 46°45′52″N, longitude 123°19′00″W, 46 m (150 ft.) N and 518 m (1700 ft.) W of SE corner of section 21, T. 15 N, R. 5 W, U.S. Geological Survey, 7.5-minute, Cedarville Quadrangle, 1986, extreme NW corner of Lewis County, Washington. Transition zone of interbedded volcanic and sedimentary rocks between the upper Crescent Formation and the overlying lower member of McIntosh Formation (as used in the emended sense of Pease & Hoover, 1957). Age: Middle Eocene. Collectors: J. L. & G. H. Goedert, 1993–1994.

LITERATURE CITED

ALMGREN, A. A., M. V. FILEWICZ & H. L. HEITMAN. 1988. Lower Tertiary foraminiferal and calcareous nannofossil zonation of California: an overview and recommendation. Pp. 83–105 in M. V. Filewicz & R. L. Squires (eds.), Paleogene Stratigraphy, West Coast of North America. Pacific Section, Society of Economic Paleontologists and Mineralogists. Vol. 58: Los Angeles.

ANDERSON, F. M. & G. D. HANNA. 1925. Fauna and stratigraphic relations of the Tejon Eocene at the type locality in Kern County, California. Occasional Papers of the California Academy of Sciences 11:1–249, pls. 1–16.

ARMENTROUT, J. M. 1987. Cenozoic stratigraphy, unconformity-bounded sequences, and tectonic history of southwestern Washington. Pp. 291–320 in J. E. Schuster (ed.), Selected Papers on the Geology of Washington. Washington Division of Geology and Earth Sciences Bulletin 77.

ARMENTROUT, J. M., D. A. HULL, J. D. BEAULIEU & W. W. RAU. 1983. Correlation of Cenozoic stratigraphic units in western Oregon and Washington. Oregon Department of Geology and Mineral Industries Oil & Gas Investigation 7:90.

ARNOLD, R. 1903. The paleontology and stratigraphy of the marine Pliocene and Pleistocene of San Pedro, California. Memoirs of the California Academy of Sciences, Vol. 3:1–420, pls. 1–37.

ARNOLD, R. 1906. Geological reconnaissance of the coast of the Olympic Peninsula, Washington. Bulletin of the Geological Society of America 17:451–468, pls. 55–58.

BABCOCK, R. S., R. F. BURMESTER, D. C. ENGEBRETSON & A. WARNOK. 1992. A rifted margin origin for the Crescent basalts and related rocks in the northern Coast Range volcanic province, Washington and British Columbia. Journal of Geophysical Research 97(B5):6799–6821.

BABCOCK, R. S., C. A. SUCZEK & D. C. ENGEBRETSON. 1994. The Crescent "terrane," Olympic Peninsula and southern Vancouver Island. Pp. 141–157 in R. Lasmanis & E. S. Cheney (convenors), Regional Geology of Washington State. Washington Division of Geology and Earth Resources, Bulletin 80.

BARTOW, J. A. 1992. Paleogene time scale for southern California. Sheet 2 of 2. U.S. Geological Survey Open-File Report 92-212.

BENTSON, H. 1943. Eocene (Capay) corals from California. Journal of Paleontology 17(3):289–297, pls. 50–51.

BEU, A. G. 1967. Deep-water Pliocene Mollusca from Palliser Bay, New Zealand. Transactions of the Royal Society of New Zealand, Geology 5(3):89–122, pls. 1–2.

BEU, A. G. 1970. New Zealand gastropod molluscs of the genus *Pteropurpura* Jousseaume. Transactions of the Royal Society of New Zealand, Biological Sciences 12(12):133-143, pls. 1-2.

BEU, A. G. & P. A. MAXWELL. 1990. Cenozoic Mollusca of New Zealand. New Zealand Geological Survey Paleontological Bulletin 58:1-518, pls. 1-57.

BUKRY, D. & P. D. SNAVELY, JR. 1988. Coccolith zonation for Paleogene strata in the Oregon Coast Range. Pp. 251-263 in M. V. Filewicz & R. L. Squires (eds.), Paleogene Stratigraphy, West Coast of North America. Pacific Section, Society of Economic Paleontologists and Mineralogists: Los Angeles, California.

CLARK, B. L. & H. E. VOKES. 1936. Summary of marine Eocene sequence of western North America. Bulletin of the Geological Society of America 47:851-878, pls. 1-2.

CLARK, B. L. & A. O. WOODFORD. 1927. The geology and paleontology of the type section of the Meganos Formation (lower middle Eocene) of California. University of California Publications Bulletin of the Department of Geological Sciences 17(2):63-142, pls. 14-22.

COSSMANN, M. & G. PISARRO. 1910-1913. Iconographie complète des coquilles fossiles de l'Éocène des environs de Paris. Vol. 2 (Scaphopodes, Gastropodes, Brachiopodes, Céphapodes & supplément). H. Bouillant: Paris. 65 pls.

DALL, W. H. 1909. Contributions to the Tertiary paleontology of the Pacific coast. I. The Miocene of Astoria and Coos Bay, Oregon. U. S. Geological Survey, Professional Paper 59:1-278, pls. 1-23.

DESHAYES, M. 1864-1866. Description des animaux sans vertèbres découverts dans le bassin de Paris. Vol. 3 (Texte):1-667. Atlas (Part 2):pls. 1-107. J.-B. Baillière et Fils: Paris.

DICKERSON, R. E. 1915. Fauna of the type Tejon: its relation to the Cowlitz phase of the Tejon Group of Washington. Proceedings of the California Academy of Sciences, 4th series, 5(3):33-98, pls. 1-11.

EFFINGER, W. L. 1938. The Gries Ranch fauna (Oligocene) of western Washington. Journal of Paleontology 12(4):355-390, pls. 45-47.

GIVENS, C. R. 1974. Eocene molluscan biostratigraphy of the Pine Mountain area, Ventura County, California. University of California Publications in Geological Sciences 109: 1-107, pls. 1-11.

GIVENS, C. R. & M. P. KENNEDY. 1979. Eocene molluscan stages and their correlation, San Diego area, California. Pp. 81-95 in P. L. Abbott (ed.), Eocene Depositional Systems. Pacific Section, Society of Economic Paleontologists and Mineralogists: Los Angeles, California.

GOEDERT, J. L. & R. L. SQUIRES. 1990. Eocene deep-sea communities in localized limestones formed by subduction-related methane seeps, southwestern Washington. Geology 18:1182-1185, figs. 1-2.

GRANT, U. S., IV & H. R. GALE. 1931. Catalogue of the marine Pliocene and Pleistocene Mollusca of California and adjacent regions. Memoirs of the San Diego Society of Natural History, Vol. 1:1-1036, pls. 1-32. [Reprinted, 1958].

GRAY, J. E. 1847. A list of the genera of Recent Mollusca, their synonyma and types. Proceedings of the Zoological Society of London 15:129-219.

HARASEWYCH, M. G. & R. H. JENSEN. 1979. Review of the subgenus *Pterynotus* (Gastropoda: Muricidae) in the western Atlantic. Nemouria (Occasional Papers of the Delaware Museum of Natural History) 22:1-16, figs. 1-17.

HICKMAN, C. S. 1974. *Nehalemia hieroglyphica,* a new genus and species of archaeogastropod (Turbinidae: Homalopomatinae) from the Eocene of Oregon. The Veliger 17(2):89-91, figs. 1-8.

HICKMAN, C. S. 1980. Paleogene marine gastropods of the Keasey Formation in Oregon. Bulletins of American Paleontology 78(310):5-112, pls. 1-10.

HICKMAN, C. S. & J. H. MCLEAN. 1990. Systematic revision and suprageneric classification of trochacean gastropods. Natural History Museum of Los Angeles County Science Series 35:1-169, figs. 1-100.

JOUSSEAUME, F. P. 1880. Division méthodique de la famille des Purpuridés. Le Naturaliste 2(42):335-336.

KEEN, A. M. 1971. Sea Shells of Tropical West America. Marine Mollusks from Baja California to Peru. 2nd ed. Stanford University Press: Stanford, California. 1064 pp.

KEEN, A. M. & H. BENTSON. 1944. Check list of California Tertiary marine Mollusca. Geological Society of America Special Papers 56:1-280.

KIDWELL, S. M. 1991. Taphonomic feedback (live/dead interactions) in the genesis of bioclastic beds: keys to reconstructing sedimentary dynamics. Pp. 268-282 in Einsele et al. (eds.), Cycles and Events in Stratigraphy. Springer-Verlag: Berlin.

LAIMING, B. 1940. Foraminiferal correlations in Eocene of San Joaquin Valley, California. Bulletin of the American Association of Petroleum Geologists 24(11):1923-1939.

LAMARCK, J.-B., P. A. DE M. DE. 1801. Système des animaux san vertèbres, ou tableau général des classes, des ordres et des genres de ces animaux. Paris. 432 pp.

LE RENARD, J. 1992. Notes de nomenclature sur quelques mollusques caractéristiques de l'Éocène de Bassin de Paris. Cossmanniana 1(2-4):1-14.

LINDBERG, D. R. 1988. Recent and fossil species of the genus *Erginus* from the North Pacific Ocean (Patellogastropoda: Mollusca). PaleoBios 12(46):1-8, pl 1.

LINDBERG, D. R. & R. L. SQUIRES. 1990. Patellogastropods (Mollusca) from the Eocene Tejon Formation of southern California. Journal of Paleontology 64(4):578-587, figs. 1-8.

MALLORY, V. S. 1959. Lower Tertiary Biostratigraphy of the California Coast Ranges. The American Association of Petroleum Geologists: Tulsa, Oklahoma. 416 pp.

MARINCOVICH, L., JR. 1977. Cenozoic Naticidae (Mollusca: Gastropoda) of the northeastern Pacific. Bulletins of American Paleontology 70(294):1-494, pls. 1-42.

MCLEAN, H. H. 1978. Marine shells of southern California. Natural History Museum of Los Angeles County, Sciences Series 24 (revised edition):1-104, figs. 1-54.

MOORE, E. J. 1984. Tertiary marine pelecypods of California and Baja California: Propeamussiidae and Pectinidae. U.S. Geological Survey Professional Paper 1228-B:1-112, pls. 1-42.

NILSEN, T. H. 1987. Stratigraphy and sedimentology of the Eocene Tejon Formation, western Tehachapi and San Emigdio Mountains, California. U.S. Geological Survey Professional Paper 1268:1-110.

OKADA, H. & D. BUKRY. 1980. Supplementary modification and introduction of code numbers to the low-latitude coccolith biostratigraphic zonation. Marine Micropaleontology 5(3):321-325.

PALMER, K. V. W. 1937. The Claibornian Scaphopoda, Gastropoda and dibranchiate Cephalopoda of the southern United States. Bulletins of American Paleontology 7(32, pts. 1-2):1-548, pls. 1-90.

PALMER, K. V. W. 1958. Type specimens of marine Mollusca described by P. P. Carpenter from the west coast (San Diego