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A New Species of the Volutid Gastropod *Fulgoraria* (*Musashia*) from the Oligocene of Washington

by

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Abstract. A new species of volutid gastropod, *Fulgoraria* (*Musashia*) ***ellenmooreae***, is present throughout Oligocene deep-water strata in western Washington. Previous workers reported but did not formally name the new species from the Blakeley Formation near Seattle and from the Lincoln Creek Formation in southwestern Washington. It is herein reported for the first time from the Makah and Pysht Formations along the north side of the Olympic Peninsula. This new species represents one of the earliest known records of subgenus *Musashia* in the world and is unusual among fulgorariine volutids because of its large protoconch, well-developed siphonal fasciole, and almost smooth sculpture. Its closest relatives are *F.* (*M.*) *nagaoi* Shikama from the upper Oligocene to lower Miocene of northern Japan and *F.* (*M.*) *olutorskiensis* (Krishtofovich) from the Oligocene of northeastern Kamchatka Peninsula, Russia.

INTRODUCTION

The volutid gastropod genus *Fulgoraria* Schumacher, 1817, and its subgenus *Musashia* Hayashi, 1960, are restricted today to warm to temperate waters in Japan and its adjacent seas (Shikama, 1967) at bathyal depths most commonly between 200 and 750 m (Oleinik, 1993:fig. 20). During the Cenozoic, *Fulgoraria* was more widespread than today, and species were especially common in bathyal environments during the Oligocene on both the eastern and western margins of the north Pacific Ocean (Oleinik, 1993). The earliest known *Fulgoraria* in the world is *F.* (*Psephaea*) *zinsmeisteri* Mount, 1976 from the upper Paleocene of Simi Valley, Ventura County, southern California (Mount, 1967).

Moore (1984a) reported that the earliest known species of *Musashia* is probably *Musashia* (*Nipponomelon?*) *caucasica* (Korobkov, 1949:694–695, text figs. 1, 2; 1955:205–206, pl. 4, figs. 6, 6a) from the middle Eocene in the Caucasus of Russia. Illustrations of the holotype show that it is poorly preserved with unclear morphology, and the holotype is missing from the paleontological collections at the University of St. Petersburg, Russia (A. E. Oleinik, personal communication). The earliest undoubted records of *Musashia* in the eastern Pacific and in the world are *F.* (*Musashia*) *weaveri* (Tegland, 1933) and *F.* (*Musashia*) ***ellenmooreae*** sp. nov. Both are from rocks as old as early Oligocene in Washington. It is the purpose of the present paper to describe this new species, which has been recognized before but not formally named. In addition, we report it, for the first time, from the north side of the Olympic Peninsula, Washington (Figure 1).

The molluscan zones used in this report stem from Durham (1944) who proposed the *Echinophoria rex* (Tegland, 1931) and *Echinophoria apta* (Tegland, 1931) Zones, and from Armentrout (1975) who proposed the *Echinophoria fax* (Tegland, 1931) Zone. Moore (1963) subsequently assigned *E. fax, E. rex,* and *E. apta* to *Liracassis*; however, Moore (1984b) later referred to *E. fax* as "*Echinophoria*" *fax*.

The molluscan stages used in this report stem from Armentrout (1975) and Addicott (1976). The former worker proposed the Galvinian and Matlockian Stages, and the latter worker proposed the Juanian and Pillarian

Stages. The chronostratigraphic relationships between the molluscan zones and molluscan stages used in this report are shown in Figure 2.

Abbreviations used for catalog and/or locality numbers are: JLG, James L. Goedert field locality; LACMIP, Natural History Museum of Los Angeles County, Invertebrate Paleontology Section; UCMP, University of California Museum of Paleontology (Berkeley); USGS, United State Geological Survey, Menlo Park, California; UWBM, University of Washington (Seattle), Thomas Burke Memorial Washington State Museum (= UW in older literature).

STRATIGRAPHIC DISTRIBUTION AND GEOLOGIC AGES

Durham (1944) reported, under the name of *Miopleiona* sp. A, several poorly preserved specimens of the new species from UCMP locs. A1803, A1804, A1807, and A1812 from the *Echinophoria rex* (now *Liracassis rex*) Molluscan Zone in the Blakeley Formation on and near Bainbridge Island and at Seattle, Washington (Figure 1). The *L. rex* Zone is correlative to most of the lower Oligocene (Figure 2).

Armentrout (1973:339) reported specimens of the new species from 12 localities in the Lincoln Creek Formation, Satsop River area, approximately 50 km northwest of Olympia, Washington (Figure 1). The stratigraphically lowest locality is UWBM loc. B0356, and the stratigraphically highest locality is UWBM loc. B0406 (Figure 2). Armentrout (1973) reported that the stratigraphic range of the new species in the Satsop River area corresponds to the "*Echinophoria*" *fax, L. rex,* and *L. apta* Zones. Prothero & Armentrout (1985), who refined the age of the Eocene/Oligocene boundary by means of magnetostratigraphic studies of the Lincoln Creek Formation in the Satsop River area, correlated the "*E.*" *fax* Zone with the lowermost Oligocene, the *L. rex* Zone with the rest of the lower Oligocene, and the *L. apta* Zone with the upper Oligocene (Figure 2). It is important to mention that Armentrout (1973:pl. 6, figs. 10, 13) found, within the stratigraphic range of the new volutid in the Lincoln Creek Formation in the Satsop River area, forms of *L. rex* transitional to *L. apta*. The presence of these transitional forms indicates an age of latest early Oligocene to earliest late Oligocene. The siltstones that contain the new species in the Lincoln Creek Formation in the Satsop River area also contain benthic foraminifera that are indicative of open-sea conditions in cool- to cold-water temperature at upper bathyal depths (Rau, 1966).

Moore (1984a, b) reported several specimens of the new species from the upper Lincoln Creek Formation near Knappton, in the proximity of the mouth of the Columbia River, southwestern Washington (Figure 1). In this area, the formation consists of poorly bedded, dark gray siltstone with scattered fossiliferous concretions that are argillaceous and resistant. The outcrops are in landslide scarps on hillsides and on a tidal flat accessible only during extreme low tides. The resistant fossiliferous concretions erode out of the toes of landslides and beach-terrace exposures and accumulate along the shoreline. Beginning in the late 1970s, J. L. and G. H. Goedert extensively collected these concretions and grouped them in relation to where they were collected along the shoreline. They established four informal groupings (units 1 through 4) of the float concretions, with each successively higher number roughly corresponding to a stratigraphically higher part of the formation. We herein use quote marks with these field "units" because they are not true stratigraphic units. The Goedert collection was sent to LACMIP where it was subsequently studied by Zullo (1982), Rigby & Jenkins (1983), and Moore (1984a, 1988).

A diverse assemblage of fossils is associated with the upper part of the Lincoln Creek Formation in the Knappton area. There are benthic foraminifera, solitary corals, siliceous sponges brachiopods, scaphopods, many gastropods (including *Bathybembix*) and bivalves, nautiloids (in-

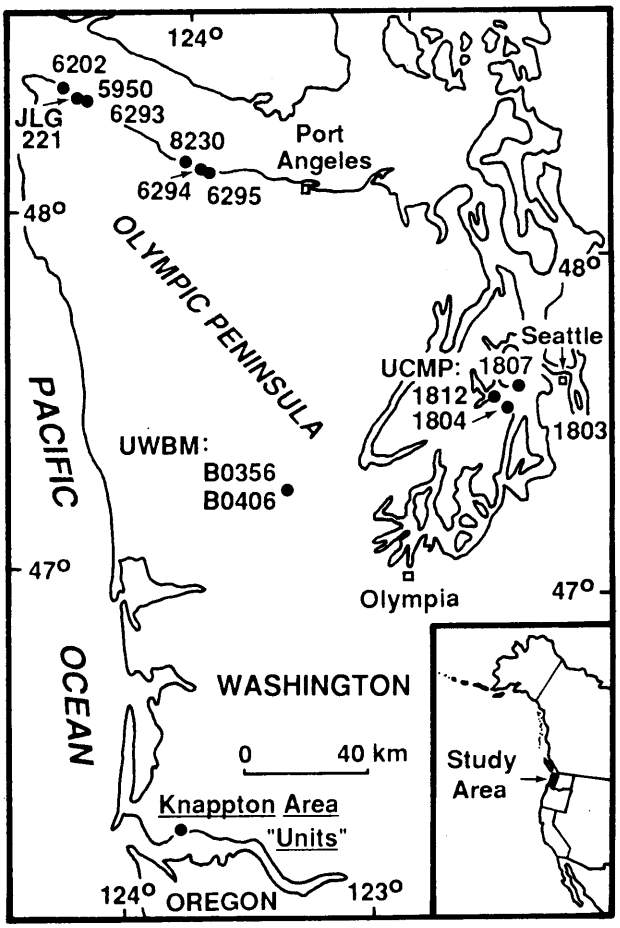

Figure 1

Index map to localities of *Fulgoraria* (*Musashia*) ***ellenmooreae*** Squires & Goedert, sp. nov. Unless otherwise indicated, localities are LACMIP localities.

cluding many *Aturia* specimens), sepiids?, decapods, spatangoids, barnacles (including many arcoscalpellids), shark teeth, mammal bones, and *Tisoa* burrows (Zullo, 1982; Rigby & Jenkins, 1983; Moore, 1984a), as well as pteropods (Squires, 1989), the large isopod *Palaega goedertorum* Wieder & Feldmann, 1989, crinoid stems, starfish, and bored wood. The siliceous sponges indicate a paleoenvironment at depths of between 300 and 350 m (Rigby & Jenkins, 1983), and the other fossils indicate a similar depth range (Moore, 1984a).

Zullo (1982), Rigby & Jenkins (1983), and Moore (1984a) utilized the same four field "units" established by the Goederts. Zullo (1982:fig. 2) and Rigby & Jenkins (1983:fig. 2) gave a chronostratigraphic significance to the "units" and assigned "unit 1" to the late Eocene, "unit 2" to the early Oligocene, and "units 3 and 4" to the late Oligocene on the basis of barnacles. Moore (1984a:fig. 3) plotted a stratigraphic position for each "unit" and assigned all the "units" to the early Miocene on the basis of mollusks. Her focus of study was on "unit 4" (= LACMIP loc. 5842), and she reported that Juanian Stage fossils in this "unit" represent a rarely preserved *Liracassis apta* Zone fauna that is transitional between the well-known part (upper Oligocene) of the Juanian Stage and the Pillarian Stage (lower Miocene).

Based on our examination of these float concretions in the LACMIP collection, we found that the fauna of each "unit" is similar and that the new volutid is present in "units 1, 2, and 4." Specimens of the new volutid and of the age-diagnostic *Liracassis* are most common in "unit 4," where there are forms of *L. rex* transitional to *L. atpa*. The presence of these transitional forms indicates an age of latest early Oligocene to earliest late Oligocene. It is important to mention that the fauna (including the transitional forms of the *Liracassis,* as well as the new volutid) found in the upper part of the Lincoln Creek Formation is very similar to that found at LACMIP locs. 6294 and 6295 in the lower Pysht Formation and LACMIP loc. 6293 from the upper Makah Formation. These three localities, which are discussed below, have yielded fossils indicative of an age of latest early Oligocene to earliest late Oligocene. Based on these faunal similarities, and pending a detailed biostratigraphic study of the *in situ* fossils in the Knappton area, we tentatively conclude that the age of the new species in the upper part of the Lincoln Creek Formation in the Knappton area is also latest early Oligocene to earliest late Oligocene (Figure 2).

Seven new stratigraphic localities are reported herein for the new species. All are on the north side of the Olympic Peninsula (Figure 1). Four of the localities are from the Makah Formation, and three are from the Pysht Formation (Figure 2). Assignment of each locality to its respective formation was based on a study of geologic maps by Tabor & Cady (1978) and by utilizing the stratigraphic refinements of Snavely et al. (1977).

Three of the Makah Formation localities (JLG 221, LACMIP 5950 & 6202) are from the Jansen Creek Member, a transported olistostromal rock unit containing mostly shallow-water marine conglomerate and fossiliferous sandstone enclosed in deep-water (1000 to 2000 m) marine siltstone and sandstone (Snavely et al., 1980; Kaler, 1988: 17). Specimens of the new species from the Jansen Creek Member are uncommon, poorly to moderately well preserved, and associated with the gastropod *Bathybembix*. This genus is one of the most abundant elements in bathyal faunas around the Pacific margin today (Hickman, 1984). The nautiloid *Aturia* is also present at localities LACMIP locs. 5950 and 6202. According to Armentrout et al. (1983), the Jansen Creek Member is earliest Oligocene in age. Carole S. Hickman (personal communication) also assigned the rocks from the Jansen Creek Member localities to the earliest Oligocene and determined that the associated fossils definitely belong to a bathyal assemblage.

The other locality (LACMIP 6293) from the Makah Formation is in the middle of the formation and is in nearly barren mudstone and siltstone. This part of the formation corresponds to the bathyal environment that is pervasive throughout the formation (Snavely et al., 1980). Only a few specimens of the new species were found at this locality, and they are well preserved. Associated fossils are rare specimens of a scaphopod, gastropods (including *Bathybembix*), bivalves, the nautiloid *Aturia,* and the large isopod *Palaega goedertorum. Palaega* lives today at depths ranging from about 310 to 1280 m (Holthuis & Mikulka, 1972). The rocks at this locality contain *L. rex* and specimens that look like *L. apta* (E. J. Moore, personal communication). The presence of these transitional forms indicates an age of latest early Oligocene to earliest late Oligocene.

The three localities (LACMIP 6294, 6295, 8230) in the lower part of the Pysht Formation are just west of the mouth of Murdock Creek and are in close proximity to each other. The type locality for the new species (LACMIP 6294) contains numerous and well-preserved invertebrates in small, discontinuous concretionary lenses of sandstone containing masses of shells surrounded by nearly barren mudstone. Sixteen specimens of the new species were found at LACMIP loc. 6294. They are well preserved, complete, and make up a partial growth series, ranging from 28 to 112 mm in height. Associated fossils are brachiopods, scaphopods, numerous gastropods and bivalves, the nautiloid *Aturia,* and the teeth of the shark *Heptranchias howelli* (Reed, 1946). The isopod *Palaega goedertorum* is rare in surrounding mudstone. Most of the fossils are complete, and those that are fragmentary show no evidence of rounding. Although the fossils have undergone some degree of post-mortem concentration into lens-shaped masses, the distance of transport was short. The mudstones surrounding LACMIP loc. 6294 contain mid-bathyal foraminifera (Hal Heitman, personal communication). The *Liracassis* specimens at this locality are forms of *L. rex* transitional to *L. apta,* and the presence of these transitional forms

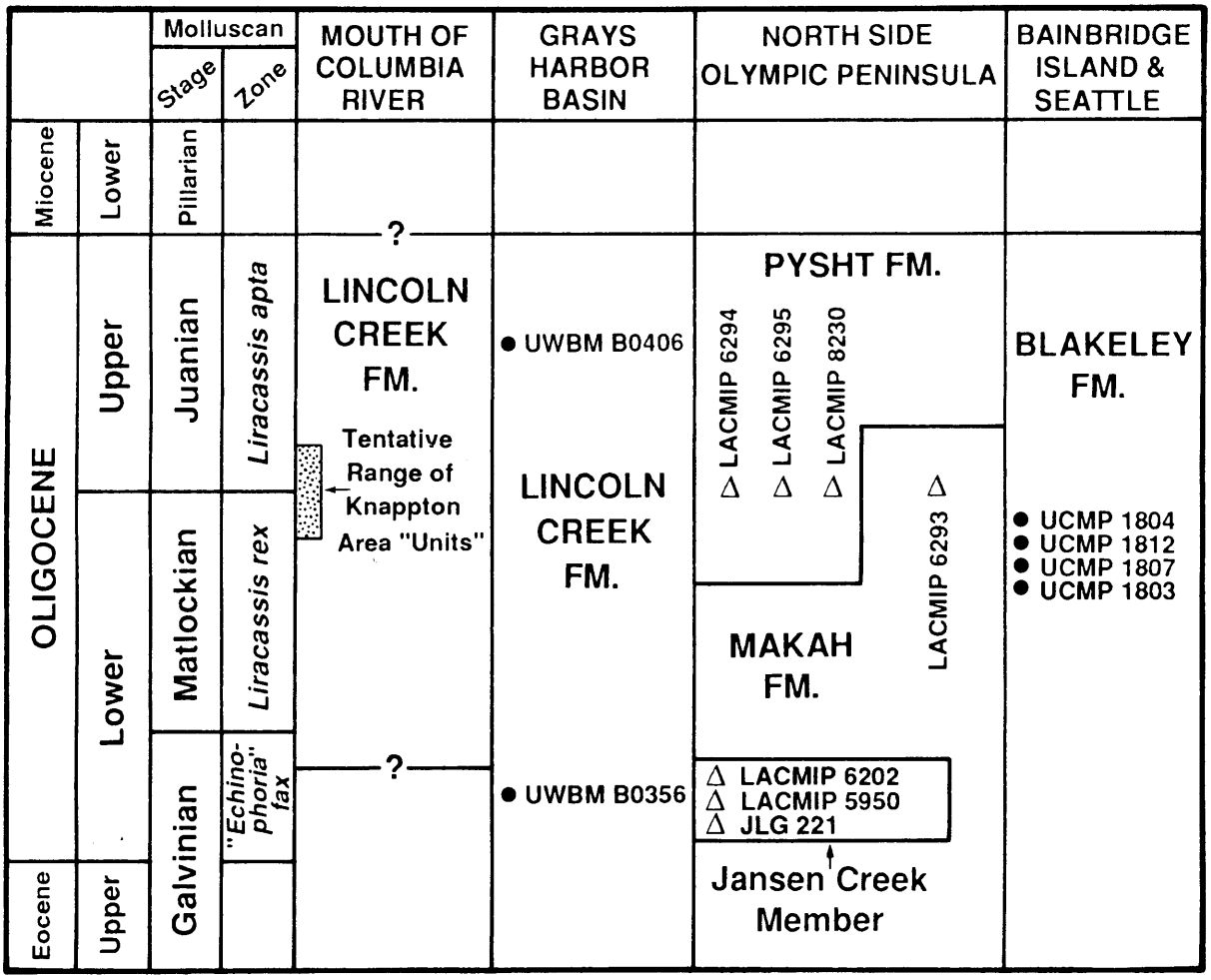

Figure 2

Chronostratigraphic chart showing position of previously known localities (black dots) and new localities (open triangles) for *Fulgoraria* (*Musashia*) ***ellenmooreae*** Squires & Goedert, sp. nov. For the Lincoln Creek Formation in the Grays Harbor area, only the stratigraphically lowest and highest localities are shown. Correlation of molluscan stages and zones versus geologic time is derived from Moore (1984b, fig. 6) and Prothero & Armentrout (1985: figs. 2, 3).

indicates an age of latest early Oligocene to earliest late Oligocene.

At LACMIP loc. 6295, fossils are rare in concretions found as float derived from mudstone and siltstone in beach cliffs and the beach terrace in the vicinity of LACMIP loc. 6294. A few specimens of the new species were found, and they are moderately well preserved. Associated fossils are a scaphopod, gastropods and bivalves, pteropods (Squires, 1989), the nautiloid *Aturia*, the isopod *Palaega goedertorum*, and rare leaves and wood. Rocks in this vicinity have also yielded a bird (Olson, 1980) and a diverse assemblage of primitive cetaceans (Goedert, 1988:100). Squires (1989) reported that the fossils at LACMIP loc. 6295 consist of a mixed assemblage with most of the remains apparently derived from deep-water, low-diversity benthic communities. Foraminifera from rocks in the vicinity of LACMIP loc. 6295 indicate that deposition probably took place at a depth of between 300 and 2000 m (Rau, 1964). Olson (1980) and Squires (1989) assigned this part of the Pysht Formation a late Oligocene age, whereas Goedert & Squires (1993) tentatively assigned it an early Oligocene age. The age of the locality is herein refined to the same age as the rocks at locality 6294; namely, an age of latest early Oligocene to earliest late Oligocene.

At LACMIP loc. 8230, only a single specimen of the new species was found, in float. The only associated fossil was an articulated specimen of the solemyid bivalve *Acha-*

rax. These float specimens are undoubtedly the same age as the specimens collected from nearby LACMIP locs. 6294 and 6295.

The age of the Pysht Formation just west of the mouth of Murdock Creek at LACMIP locs. 6294, 6295, and 8230 is older than generally reported for this formation. Armentrout et al. (1983) reported the age of the entire Pysht Formation as late Oligocene and earliest Miocene. The age of the lower part of the Pysht Formation was discussed by Domning et al. (1986) who tentatively assigned slightly higher strata an age of "middle" of late, but not latest, Oligocene. All three localities are near the base of Durham's (1944) reference section of the *L. rex* Zone (early Oligocene). Because forms of *L. rex* transitional to *L. apta* are present in the lower part of the Pysht Formation west of Murdock Creek, the age of this part of the formation is latest early Oligocene to earliest late Oligocene.

Mixed with the concretions at LACMIP loc. 6295 and near loc. 8230 are rare blocks of micritic limestone, up to 1 m across, with articulated specimens of the bivalves *Calyptogena* (*C.*) *chinookensis* Squires & Goedert, 1991, *Thyasira* sp., and *Modiolus* (*M.*) *willapaensis*(?) Squires & Goedert, 1991. Goedert & Squires (1993) interpreted these bivalve associations as cold-methane-seep communities.

SYSTEMATIC PALEONTOLOGY

Class Gastropoda Cuvier, 1797

Family VOLUTIDAE Rafinesque, 1815

Subfamily FULGORARIINAE Pilsbry & Olsson, 1954

Discussion: The higher systematics of this subfamily are not fully resolved. The most recent revisions (Shikama, 1967; Weaver & du Pont, 1970) differ primarily in the ranking of supraspecific taxa, and the reader is referred to Oleinik (1993) for a complete listing of these taxa. Shikama (1967), using only shell characters, recognized three genera: *Fulgoraria* Schumacher, 1817, *Musashia* Hayashi, 1960, and *Saotomea* Habe, 1943. He also recognized four subgenera of *Musashia*: *Musashia* s.s., *Nipponomelon* Shikama, 1967, *Miopleiona* Dall, 1907, and *Neopsephaea* Takeda, 1953. Weaver & du Pont (1970), using both shell and radular characters, recognized only the genus *Fulgoraria,* with several subgenera, including *Musashia*. They considered *Nipponomelon* to be a synonym of *Musashia*. The present paper follows the more modern classification of Weaver & du Pont (1970).

Genus *Fulgoraria* Schumacher, 1817

Type species: *Fulgoraria chinensis* Schumacher, 1817 = *Voluta rupestris* Gmelin, 1791, by original designation, Recent, Taiwan.

Subgenus *Musashia* Hayashi, 1960

Type species: *Voluta hirasei* Sowerby III, 1912, by original designation, Recent, south coast of Japan.

Fulgoraria (*Musashia*) ***ellenmooreae*** Squires & Goedert, sp. nov. (Figures 3–8)

Miopleiona sp. A Durham, 1944:178.
Musashia (*Musashia*) *evelyni* [MS Name] Armentrout, 173: 338–339, pl. 5, figs. 25, 27, 28.
Musashia (*Musashia*) n. sp. Moore, 1984a: 18, figs. 62, 65, 76, 80, 87; 1984b:table 1.

Diagnosis: A *Musashia* with a large low protoconch, a moderately short spire, an inner lip with two subequal folds, almost smooth sculpture, and a well-developed siphonal fasciole.

Description: Shell of medium to moderately large size, up to 112 mm in height, fusiform, moderately high spired, apical angle about 27 degrees. Body whorl composing about 82% of shell height. Protoconch of about 1.5 whorls, large, rounded, low, and smooth. Teleoconch of about five whorls. Suture moderately inclined and slightly impressed. Penultimate and body whorl almost smooth except for faint spiral lines. Teleoconch surface with microscopic growth striae that bend abaperturally near suture. Subsutural band obsolete. Inner lip covered by a thin callus and with two subequal folds. Outer lip thickened. Siphonal fasciole well developed. Aperture narrow, with a siphonal notch.

Holotype: LACMIP 12274.

Type locality: LACMIP loc. 6294, near mouth of Murdock Creek, latitude 48°09′37″N, longitude 123°52′28″W.

Paratype: LACMIP 12275, also from LACMIP loc. 6294.

Dimensions: Of holotype, height 70.3 mm, width 25.2 mm; of paratype, height 84.4 mm, width 30 mm.

Discussion: Certain specimens of the new species have less elongate upper spire whorls relative to other specimens from the same locality. An example is the holotype (Figures

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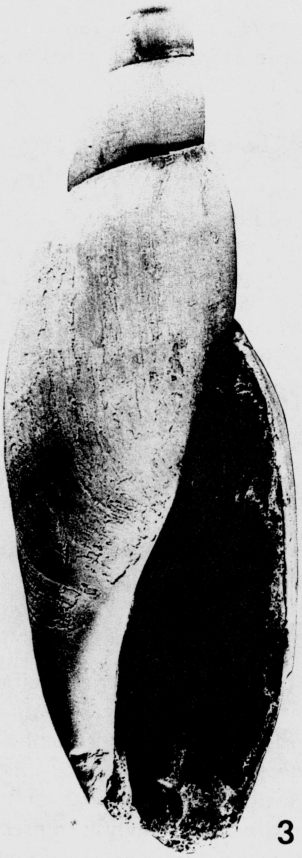
Explanation of Figures 3 to 8

Figures 3–8. *Fulgoraria* (*Musashia*) ***ellenmooreae*** Squires & Goedert, sp. nov., LACMIP loc. 6294, Pysht Formation, north side of Olympic Peninsula, Washington. Figures 3–6: holotype LACMIP 12274. Figure 3: apertural view, ×1.6. Figure 4: abapertural view, ×1.6. Figure 5: oblique apertural view showing the two plaits on the inner lip, ×1.6. Figure 6: magnified oblique apertural view showing the two plaits on the inner lip, ×3.5. Figures 7–8: paratype, LACMIP 12275, ×1.1. Figure 7: apertural view. Figure 8: abapertural view.



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3–5), whose antepenultimate whorl is less elongate than that of the paratype (Figures 7, 8).

Specimens of the new species from the Jansen Creek Member (LACMIP locs. 5950, 6202 and JLG loc. 221) have a shorter spire and are smaller in size than most of the other studied specimens of the new species. These specimens are indistinguishable, however, from a few specimens found in the Makah Formation at LACMIP loc. 6293.

The large, low protoconch of the new species is very unusual for genus *Fulgoraria* and more closely resembles protoconchs found on some, but not all, species of the fulgorariine genera *Ericusa* H. & A. Adams, 1858, and *Livonia* Gray, 1855. In particular, the protoconchs of modern *Livonia mammilla* (Sowerby I, 1844) and *Ericusa* (*E.*) *sericata* Thornley, 1951 are very similar to the protoconch of the new species. Illustrations of these modern species, both of which are from Australia, are in Weaver & du Pont (1970:pl. 17, figs. A–C; pl. 20, figs. C–D), respectively. The new species is not assigned to either one of these genera because, according to Weaver & du Pont (1970), *Livonia* is characterized by spiral ribbing and *Ericusa* is characterized by three or more folds on the columella. In addition, the siphonal fasciole in these two genera is either indistinct or absent.

As noted by Moore (1984a), the only other described species at all similar to the new species is *Fulgoraria* (*Musashia*) *nagaoi* Shikama (1967:111–112, pl. 13, figs. 9–12) from the upper Oligocene to lower Miocene Poronai Formation, Hokkaido, northern Japan. The new species and *F.* (*M.*) *nagaoi* are unique among the fulgorarines because they have smooth shells and a well-developed siphonal fasciole. The new species differs from *F.* (*M.*) *nagaoi* in the following features: smaller size teleoconch, larger and more rounded protoconch, narrower spire, suture more inclined, and body whorl less inflated.

The new species resembles *Fulgoraria* (*Musashia*) *olutorskiensis* (Krishtofovich 1973:77, pl. 22, figs. 8, 9) from the Oligocene formations of northeastern Kamchatka Peninsula, Russia. The synonymy of *Fulgoraria* (*Musashia*) *olutorskiensis* was recently updated by Oleinik (1993). The new species differs from *F.* (*Musashia*) *olutorskiensis* in the following features: two columellar folds rather than one, well-developed siphonal fasciole, and an obsolete subsutural band.

The new species, along with another Washington species, *Fulgoraria* (*Musashia*) *weaveri* (Tegland, 1933:127–128, pl. 11, figs. 1–5), are the earliest undoubted records of *Musashia* in the eastern Pacific and in the world. The new species ranges from early to late Oligocene, and *F.* (*M.*) *weaveri* was reported by Addicott (1976:98) as ranging from the early through late Oligocene in the vicinity of Seattle, Washington. The new species differs from *F.* (*M.*) *weaveri* by having an almost smooth shell. We concur with Moore (1984a) that *Miopleiona scowensis* Durham (1944:177–178, pl. 17, fig. 5) from the Oligocene of Marrowstone Island, Jefferson County, Washington is the same as *F.* (*M.*) *weaveri*.

There are three other reported species of *Musashia* in the eastern Pacific. One is *F.* (*M.*) *shikamai* Moore (1984a: 18, 20, figs. 49, 63, 72, 74, 75, 77, 78, 82, 83, 88, 89) from the upper part of the Lincoln Creek Formation at Knappton, Washington. This species is found in association with specimens of the new species. The age of *F.* (*M.*) *shikamai*, like that of the new species in the Knappton area, is herein tentatively assigned to the latest early Oligocene to earliest late Oligocene. The other two species of eastern Pacific *Musashia* are *F.* (*M.*) sp. of Allison & Marincovich (1981[1982]:pl. 3, figs. 12, 13) from the upper Oligocene or lowermost Miocene on Sitkinak Island, Gulf of Alaska; and *F.* (*M.*) n. sp. of Addicott (1976:pl. 4, fig. 18) from the upper Miocene of the Grays Harbor area, southwestern Washington. The new species differs from all of these other species by having an almost smooth shell.

Etymology: The new species is named in honor of Ellen James Moore for her many valuable contributions to the study of Tertiary mollusks in the eastern Pacific.

Occurrence: Early and late Oligocene (upper part of Galvinian, Matlockian, and Juanian Stages), Washington. EARLY EARLY OLIGOCENE ("*Echinophoria*" *fax* Zone): Jansen Creek Member of the Makah Formation, north side of Olympic Peninsula, Washington (herein); lower Lincoln Creek Formation, Satsop River area, Grays Harbor basin, Washington (Armentrout, 1973); EARLY OLIGOCENE (*Liracassis rex* Zone): Blakeley Formation, Bainbridge Island and Seattle, Washington Durham (1944). LATEST EARLY OLIGOCENE to EARLIEST LATE OLIGOCENE (approximately equivalent to the *Liracassis rex-Liracassis apta* Zonal boundary): Upper Makah Formation, north side of Olympic Peninsula, Washington (herein); lower part of the Pysht Formation, north side of Olympic Peninsula, Washington (herein); middle Lincoln Creek Formation, Satsop River area, Grays Harbor basin, Washington; upper Lincoln Creek Formation, Knappton area, near mouth of Columbia River (tentatively, herein). LATE OLIGOCENE (*Liracassis apta* Zone): Upper Lincoln Creek Formation, Satsop River area, Grays Harbor basin, Washington (Armentrout, 1973).

ACKNOWLEDGMENTS

Gail H. Goedert helped in collecting many of the specimens. Ellen J. Moore loaned specimens of the new species, provided locality information, and identified some associated fossils. Edward C. Wilson (LACMIP) allowed access to collections, provided catalog numbers, and shared his knowledge of the Knappton area. Lindsey T. Groves (Malacology Section, Natural History Museum of Los Angeles County) obtained some important references. Ross E. Berglund (Bainbridge Island) loaned a key reference. Bruce Welton (Mobil Oil Company, Dallas, Texas) iden-

tified the shark. Carole S. Hickman provided an age assignment of the strata at LACMIP loc. 6202. Hal Heitman (Unocal Corporation, Houston, Texas) processed and identified foraminifera from rocks in the Murdock Creek area. Anton E. Oleinik (Purdue University, Indiana) commented on an early version of the manuscript and kindly shared his knowledge of volutids. The manuscript benefited from reviews by Anton E. Oleinik and an anonymous referee.

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LOCALITIES CITED

All quadrangle maps are those of the U. S. Geological Survey.

JLG 221. Mollusks collected from sandstone exposed in beach terrace, approximately 300 m SE of mouth of Jansen Creek and approximately 140 m N of SW corner of sec. 25, T. 33 N, R. 14 W, Sekiu River quadrangle, 7.5-minute, 1984 provisional edition, Clallam County, Washington. Jansen Creek Member of the Makah Formation. Age: Earliest Oligocene (Hickman, personal communication). Collectors: J. L. Goedert, 1987.

LACMIP 5842. Specimens collected at low tide from fossiliferous concretions weathering out of a landslide block in upper part of the Lincoln Creek Formation between Knappton and Grays Point, in the center of the N ½, N ½ of sec. 9, T. 9 N, R. 9 W, Knappton quadrangle, 7.5-minute, 1949 (photo-revised 1973), on the Columbia River, Pacific County, Washington. Upper part of the Lincoln Creek Formation. Tentative Age: Latest early Oligocene to earliest late Oligocene. Collectors: J. L. & G. H. Goedert, 1979 to date. [Locality is equivalent to USGS loc. M8995.]

LACMIP 5950. From concretions on beach and shales on beach, approximately 0.8 km (0.5 mi.) W of Shipwreck Point, and 1.1 km (0.7 mi.) E of mouth of Jansen Creek, NW ¼ of sec. 36, T. 33 N, R. 14 W, Clallam Bay quadrangle, 15-minute, 1957 edition, Clallam County, Washington. Jansen Creek Member of the Makah Formation. Age: Earliest Oligocene. Collectors: J. L. & G. H. Goedert, 1980 to 1984, and W. Buchanan, 1984.

LACMIP 6202. Invertebrate specimens collected from float and concretions weathering out of concretionary sandstone exposed on S shore of Strait of Juan de Fuca, 0.2 km W of mouth of Rasmussen Creek, NE ¼ of sec. 27, T. 33 N, R. 14 W, Clallam Bay quadrangle, 15-minute, 1957 edition, Clallam County, Washington. Jansen Creek Member of the Makah Formation. Age: Earliest Oligocene. Collectors: J. L. & G. H. Goedert, July, 1982.

LACMIP 6293. Float and *in situ* fossils from shales and siltstones at first small point approximately 500 m W of mouth of Sekiu River, NE ¼ of sec. 8, T. 32 N, R. 13 W, Clallam Bay quadrangle, 15-minute, 1957 edition, Clallam County, Washington. Makah Formation. Age: Latest early Oligocene to earliest late Oligocene. Collectors: J. L. & G. H. Goedert, May, 1983.

LACMIP 6294. Numerous and well-preserved invertebrates exposed as small, discontinuous, concretionary lenses and masses of shells in bedrock at base of low cliff and beach terrace on S shore of Strait of Juan de Fuca, approximately 770 m W of mouth of Murdock Creek, latitude 48°09'37"N, longitude 123°52'28°W, NW ¼, NW ¼ of sec. 29, T. 31 N, R. 9 W, Disque quadrangle, 7.5-minute, 1950 (photo-revised 1978), Clallam County, Washington. Pysht Formation. Age: Latest early Oligocene to earliest late Oligocene. Collectors: J. L. & G. H. Goedert, June, 1983 to date. [Locality is equivalent to USGS loc. M8986; and float from LACMIP loc. 6294 is equivalent to USGS loc. M9002.]

LACMIP 6295. Fossils found as float (derived from rocks in the vicinity of LACMIP loc. 6294) on beach in concretions which cover the beach between 850 m and 300 m W of the mouth of Murdock Creek, NW ¼ of sec. 29, T. 31 N, R. 9 W, S shore of Strait of Juan de Fuca, Disque quadrangle, 7.5-minute, 1950 (photo-revised 1978), Clallam County, Washington. Pysht Formation. Age: Latest early Oligocene to earliest late Oligocene. Collectors: J. L. & G. H. Goedert, June, 1983 to date, April, 1984.

LACMIP 8230. Specimens collected as float on beach approximately 275 m W of point which is approximately 950 m NW of mouth of Murdock Creek, S shore of Strait of Juan de Fuca, SE ¼ of sec. 19, T. 31 N, R. 9 W, Disque quadrangle, 7.5-minute, 1950 (photo-revised 1978), Clallam County, Washington. Pysht Formation. Age: Latest early Oligocene to earliest late Oligocene. Collectors: J. L. Goedert & G. H. Goedert, 1984.

UCMP A1803. Behind Olympic Foundry, along E side of Duwamish River in southern part of Georgetown, Seattle, King County, Washington. Blakeley Formation. Age: Early Oligocene. Collector: J. W. Durham, circa early 1940s.

UCMP A1804. Conglomerate on S side of Bremerton Inlet, Middle Point, sec. 15, T. 24 N, R. 2 E, Bremerton East quadrangle, 7.5-minute, 1953 (photo-revised 1981), Kitsap County, Washington. Blakeley Formation. Age: Early Oligocene. Collector: J. W. Durham, circa early 1940s.

UCMP A1807. Conglomerate at Beans Point, SW ¼ of NW ¼ of sec. 14, T. 24 N, R. 2 E, Bremerton East quadrangle, 7.5-minute, 1953 (photo-revised 1981), Kitsap County, Washington. Blakeley Formation. Age: Early Oligocene. J. W. Durham, circa early 1940s.

UCMP A1812. Conglomerate and shale on small peninsula of S side of Bremerton Inlet, NW ¼ of SW ¼ of

sec. 8, T. 24 N, R. 2 E, Bremerton East quadrangle, 7.5-minute, 1953 (photo-revised 1981), Kitsap County, Washington. Blakeley Formation. Age: Early Oligocene. Collector: J. W. Durham, circa early 1940s.

UWBW B0356. Siltstone bed on S side of Middle Fork Satsop River along well exposed face, 46 m (150 ft.) along strike, 3 m (10 ft.) stratigraphic interval, 960 m (3150 ft.) W, 847 m (2780 ft.) N of SE corner of sec. 20, T. 21 N, R. 6 W, Mt. Tebo quadrangle, 15-minute, 1953 edition, Mason County, Washington. Lincoln Creek Formation. Age: Earliest Oligocene. Collectors: J. M. Armentrout & Bill Fletcher, 1971. [Locality equivalent to MF-5 of Armentrout, 1973:226].

UWBW B0406. Siltstone, SE side of Middle Fork Satsop River, base of strata exposed along cliff face to W, 12 m (40 ft.) stratigraphically below base of sandstone exposed in cliff above, 618 m (2030 ft.) W and 1555 m (5100 ft.) N of SE corner of sec. 6, T. 20 N, R. 6 W, Mt. Tebo quadrangle, 15-minute, 1953 edition, Mason County, Washington. Lincoln Creek Formation. Age: Late Oligocene. Collectors: J. M. Armentrout and Bill Fletcher, 1971. [Locality equivalent to MF-32 of Armentrout, 1973:23].

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