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William K. HALLIGAN (2023). Washington State (USA) trigoniids (Bivalvia) from the conglomerate of Patterson Lake (Early Cretaceous).

Cover: Silicone cast from an external mold of *Yaadia whiteavesi* (Packard, 1921), the dominant trigoniid from the conglomerate of Patterson Lake

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Washington State (USA) trigoniids (Bivalvia) from the conglomerate of Patterson Lake (Early Cretaceous)

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Despite more than 150 years of research on the Jurassic and Cretaceous trigoniid bivalves of the Pacific Coast of North America, little mention is made of Washington State trigoniids. In this study, five trigoniid species from the Methow Basin are documented from three sites in the Lower Cretaceous conglomerate of Patterson Lake (cPL). Three of the species, *Yaadia whiteavesi*, *Columbitrigonia condoni*, and *Notoscabrotrigonia oregana*, are well-known in the literature. The other two, *Parvitrigonia* n. gen. *cooperi* n. sp. and *Earlpackardia methowensis* n. sp. are undescribed rutitrigoniids. These identifications revise the faunal lists from previous geological studies of the Methow Basin and allow a middle Albian age assignment to the upper portion of the cPL.

Keywords: Trigoniidae, Washington State, conglomerate of Patterson Lake, Methow Basin, Early Cretaceous

INTRODUCTION

Trigoniid bivalves from the Pacific Coast of North America have been studied for over 150 years. The first 100 years focused on describing new species (e.g., Meek 1858, Gabb 1864, 1869, Whiteaves 1876-1903, Packard 1921, Anderson 1958). These included three of the five trigoniids that are found in the conglomerate of Patterson Lake (cPL), north-central Washington State, and described in this study: *Yaadia whiteavesi* (Packard, 1921), *Notoscabrotrigonia oregana* (Packard, 1921), and *Columbitrigonia condoni* (Packard, 1921). Since 1960 much effort has been directed toward creating order out of the increasing number of new species (e.g., Jones 1960a, 1960b, Poulton 1977, Saul 1978) and establishing a reliable classification system (e.g., Cooper 1991, 2015a, 2015b, Cooper and Leanza 2017, 2019).

The only mentions of trigoniids from Washington State in the studies cited above were two brief comments by Whiteaves (1876-1903, pp. 161, 387) in his discussion of *Trigonia evansana* Meek, 1858, a Late Cretaceous trigoniid that, among other localities along the west coast of the United States and British Columbia, can be found in the San Juan Islands (McLellan 1927). But not mentioned at all in those studies are the Washington State Early Cretaceous trigoniids from the Methow Valley, Okanogan County. These trigoniids have appeared in faunal lists (Barksdale 1975, McGroder et al. 1990), but no formal systematic descriptions have ever been published. It should come as no surprise, then, that the identification accuracy of the trigoniids in those faunal lists is problematic. This study revises those lists by formally documenting five Methow Basin trigoniid taxa, two of which represent two new species and one new genus.

ABBREVIATIONS

CASG: California Academy of Sciences Geology collection, San Francisco, CA.
cPL: conglomerate of Patterson Lake.
GSC: Geological Survey of Canada.
LACMIP: Los Angeles County Museum of Invertebrate Paleontology, Los Angeles, CA.
MNCH: Museum of Natural and Cultural History (University of Oregon), Eugene, OR.
USGS: United States Geological Survey.
UWBM: University of Washington Burke Museum, Seattle, WA.

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GEOLOGIC SETTING

The Methow block is in north-central Washington State. In the USA it is approximately 110 km long (max length) and 40 km wide (max width) and extends northward into Canada (Trexler 1985). It is bounded on the east by the Pasayten fault and to the west by the Ross Lake fault zone (Trexler 1985). The Methow Basin contains over 10,000 meters of terrestrial and marine deposits, volcaniclastic rocks, and lavas (Trexler 1985), ranging in age from the Middle Jurassic to possibly the early Paleocene (Haugerud and Tabor 2009). The sediments range from boulder conglomerates to shale.

Conglomerate of Patterson Lake (cPL)

The cPL has been variously called the Patterson Lake Member of the Virginian Ridge Formation (Trexler 1985), the Patterson Lake conglomerate (Maurer 1958, McGroder et al. 1990) and the Patterson Lake unit (Haugerud and Tabor 2009). Since its relationship with the other rock groups in the Methow Basin has not been precisely determined, it has no formally accepted name. For this study, the name that will be used is the conglomerate of Patterson Lake (cPL).

The cPL is exposed in two narrow strips in the southern Methow Basin (Bunning 1990, McGroder et al. 1990) (Fig. 1). The stratotype consists of approximately 450 meters of sediments located on the west flank of Patterson Mountain, just east of Patterson Lake (Trexler 1985). The lowest 100 meters suggest a source-proximal braided stream environment with subaerial debris-flow deposits containing large wood fragments and poorly sorted fluviatile conglomerates. Higher up, the sediments become progressively better sorted, and in the final 100 stratigraphic meters assume a shallow-marine facies with more sandstone and mudstone (Trexler 1985). Near the top of the unit at 400 meters above the base (Trexler 1985), shallow-marine fossils are found (Maurer 1958, Barksdale 1975, McGroder et al. 1990)

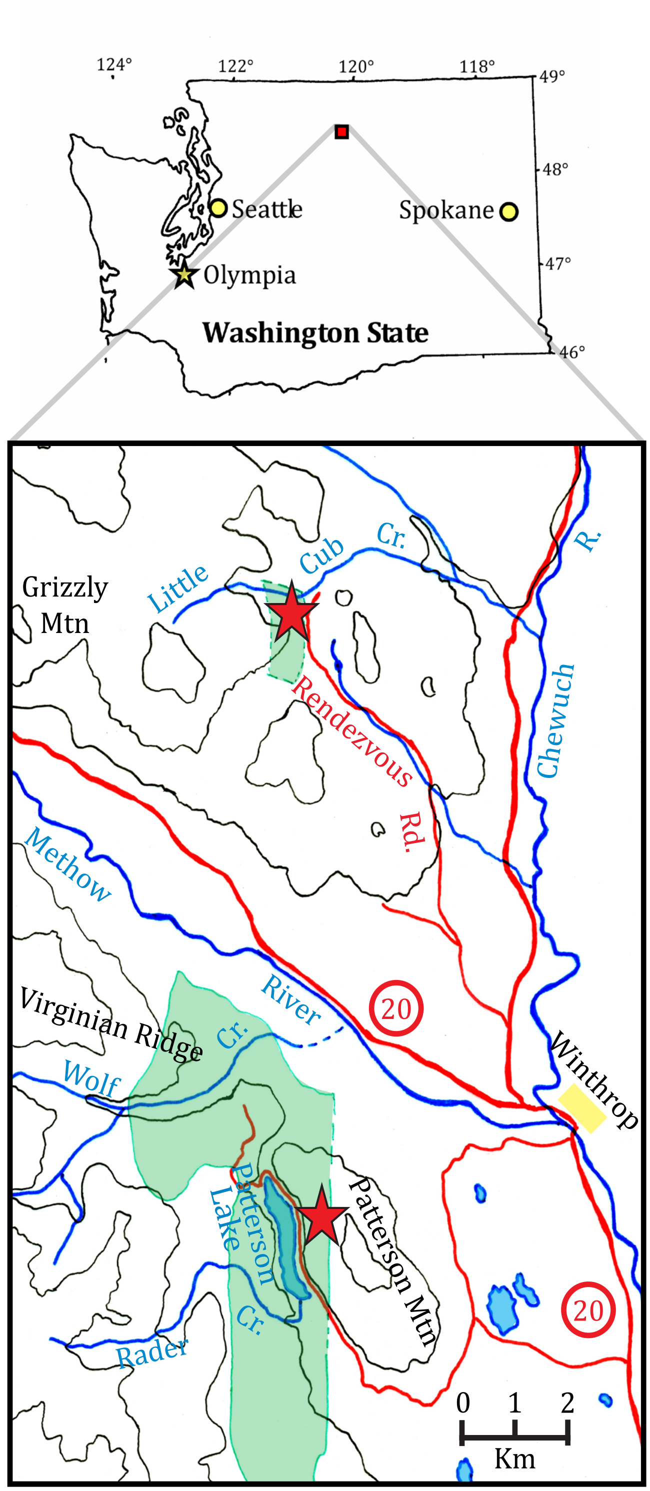


Figure 1. Locality Map for Burke Museum sites B-9486 and B-9487 on Patterson Mountain, and B-9541 on Rendezvous Road. Sites indicated by red stars. Conglomerate of Patterson Lake (cPL) highlighted in green. Specific locality details can be obtained from the UWBM or the author.

MATERIALS AND METHODS

All but one of the trigoniid specimens in this study were collected by the author between 1996-2000 from two sites in a single outcrop on Patterson Mountain. The one specimen (UWBM 115724) that was collected by the author in 2013 came from another cPL site just west of Rendezvous Road, 10.6 kilometers north of Patterson Mountain (Fig. 1). All these sites are from the marine sediments near the top of the cPL. More specific site information can be obtained from the University of

Washington Burke Museum (UWBM) or the author.

In the process of collecting these trigoniids, it is common for shell material to peel, leaving the ornamental shell details attached to the external mold. The internal mold is coated with a thin layer of shell that lacks the ornamental detail necessary to differentiate it from closely related species (Saul 1978). Occasionally a natural cast will show some external shell detail, but generally the best way to demonstrate the ornamental detail and make a positive identification is by creating a silicone cast made from a cleaned external mold. Unfortunately, a common practice among collectors is to discard the external mold and save the internal mold that has insufficient shell detail to make an accurate identification.

Trigoniid specimens collected from the cPL by previous researchers and housed in the UWBM were examined by the author. Except for *Columbitrigonia condoni*, these specimens are mostly internal molds that lack the shell detail needed to make a definite identification. Since most of these specimens came from the same sites as the trigoniids in this study, these older faunal lists (Barksdale 1975, McGroder et al. 1990) can be revised by the species identified in this study (Fig. 2).

Trigoniid fossils from the conglomerate of Patterson Lake (cPL)

This Study	Previous Studies*
Yaadia whiteavesi	*Trigonia* sp. cf. *T. leana*
Notoscabrotrigonia oregana	*Trigonia* sp. cf. *T. evansana*
	Pterotrigonia oregona (sic)
Columbitrigonia condoni	*Megatrigonia* cf. *M. condoni*
Parvitrigonia n. gen. *cooperi* n. sp.	*Trigonia* sp. cf. *T. maudensis*
Earlpackardia methowensis n. sp.	*Trigonia* sp. cf. *T. diversicostata*

Figure 2. Trigoniid list from the conglomerate of Patterson Lake (cPL). This study vs. previous studies *(Barksdale 1975, McGroder et al. 1990).

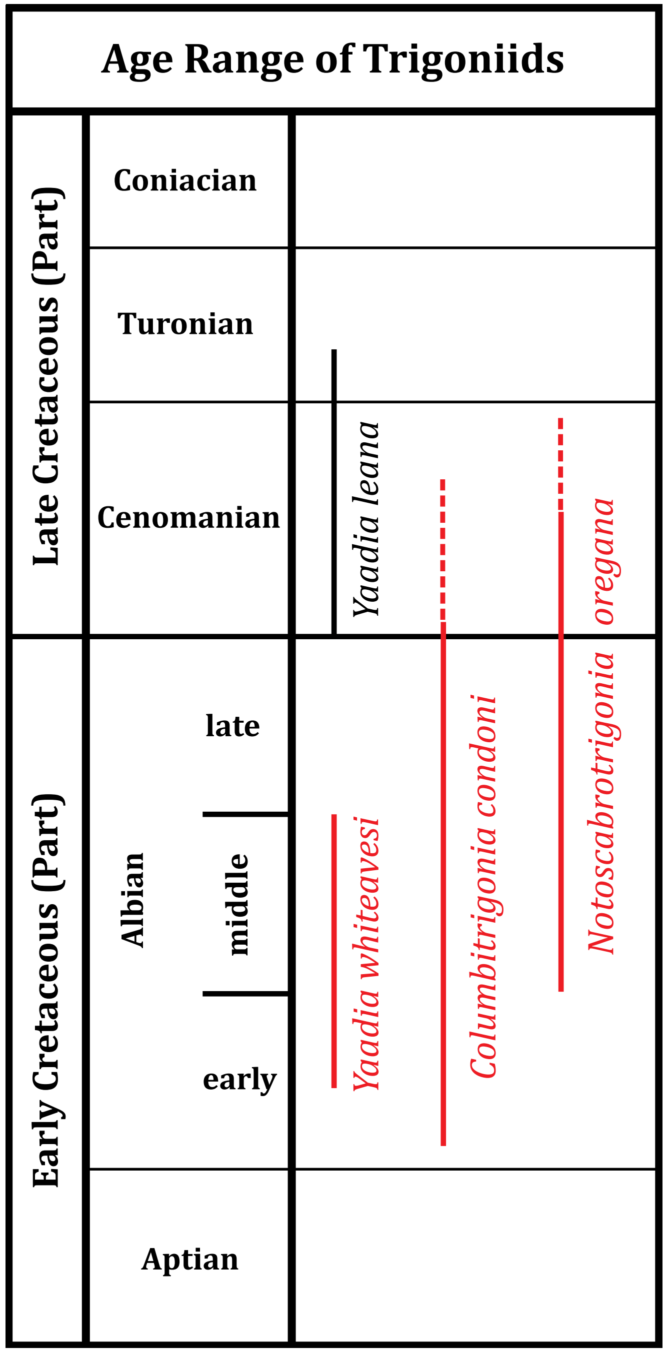


Figure 3. Age ranges of trigoniids in this study. Fossils from the cPL in red. See text for details

RESULTS

Five trigoniid species were collected from the cPL. The dominant species, *Yaadia whiteavesi*, is abundant and commonly preserved as internal and external mudstone molds of entire valves; occasionally both valves are found together. Silicone casts made from cleaned external molds demonstrate fine shell detail, making identification straightforward. *Columbitrigonia condoni*

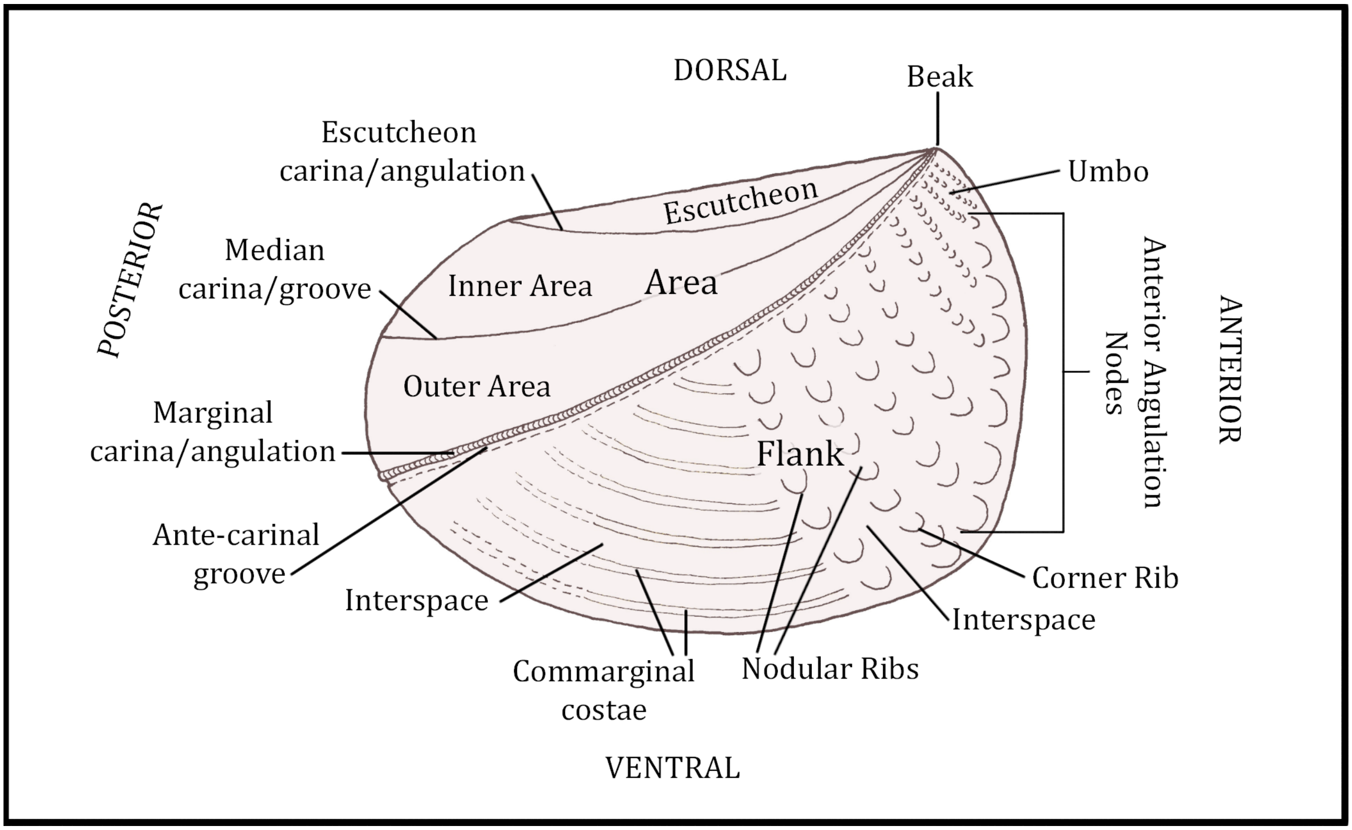


Figure 4. Generalized sketch indicating the terminology used in this study to describe trigoniid shell morphology. For a more detailed discussion see Saul (1978), Poulton (1979), and Leanza (1993).

is the second most common trigoniid in the cPL and is preserved both as external mudstone molds and natural casts. Although some of these mudstone casts preserve sufficient external ornamental detail for accurate identification, silicone casts made from the external molds reveal more shell detail. Internal and external molds of *Notoscabrotrigonia oregana* are found infrequently. A fourth trigoniid preserved as natural mudstone/sandstone casts was collected from both the Patterson Mountain and Rendezvous Road sites. It is a very small rutitrigoniid and is not recognizable as any known genus or species; it has been named *Parvitrigonia* n. gen. *cooperi*. n. sp. The fifth trigoniid found in the cPL is also a new rutitrigoniid; *Earlpackardia methowensis* n. sp. consists of a nearly complete left valve.

Based on the age ranges of the fossils from this study (Fig. 3), an age estimate for the upper part of the cPL can be made. *Yaadia whiteavesi*: late early Albian-middle Albian (Saul 1978); *Notoscabrotrigonia oregana*: middle Albian-late Cenomanian? (Jones 1960b); and *Columbitrigonia condoni*: early Albian-Cenomanian? (Jones 1960a). Therefore, the age of the upper marine part of the cPL is middle Albian.

SYSTEMATIC PALEONTOLOGY

Abbreviations used: RV = right valve, LV = left valve, W = width (or inflation) of single valve, H = valve height, L = valve length. Qualitative terms such as size, inflation, and umbo placement are used as defined by Cooper (2015a). Other morphologic terms are depicted in Fig. 4.

TRIGONIIDA Dall, 1889
MYOPHORELLOIDEA Kobayashi, 1954
STEINMANELLIDAE Cooper, 1991
YAADIINAE Cooper, 2017
YAADIA Crickmay, 1930
YAADIA WHITEAVESI (Packard, 1921)
Fig. 5A-C

Trigonia, sp. indt. Whiteaves, 1876, p. 70, pl. 10, fig. 2, 2a.
Trigonia leana var. *whiteavesi* Packard, 1921, p. 21, pl. 6, fig. 2 only.
Trigonia perrinsmithi Anderson, 1958, p. 110, pl. 2, fig. 7.
Trigonia whiteavesi (Packard). Anderson, 1958, p. 111.
Yaadia whiteavesi (Packard). Saul, 1978, p. 31, pl. 2, figs. 3-5, pl. 3, figs. 1-6, text-fig. 12.

Holotype—GSC Type Collection, Cat. no. 4997.

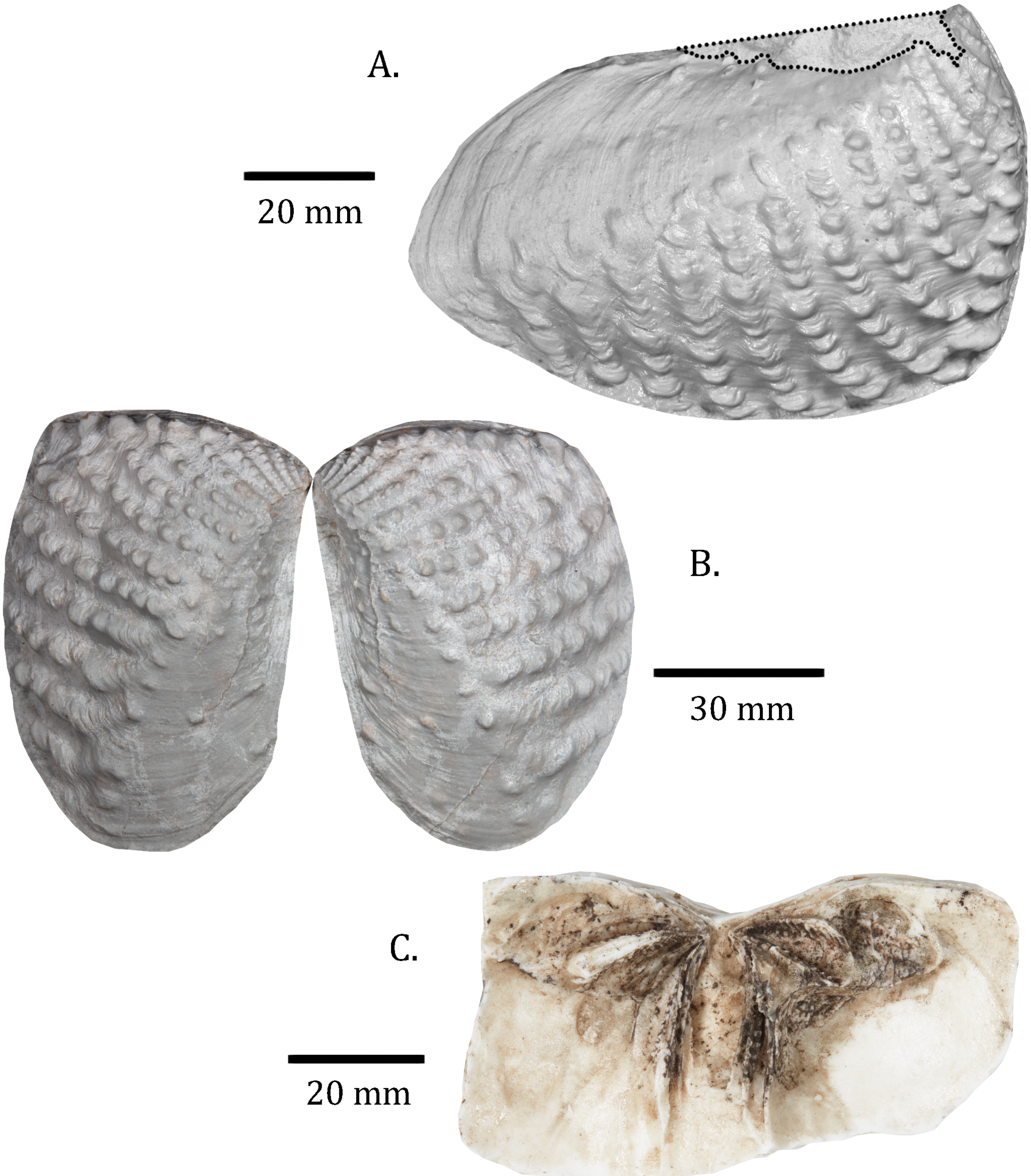


Figure 5. *Yaadia whiteavesi* (Packard, 1921) All are silicone casts of external molds from UWBM loc. 9486. **A**. UWBM 112550: RV. Dotted line indicates missing escutcheon and part of umbo. **B.** UWBM 112551: Both valves, complete, butterfly opened. **C.** UWBM 112556: Schizodont dentition, both valves.

Specimen from the Haida Formation, Queen Charlotte Islands, British Columbia, Canada.

Material—UWBM 112550: Silicone cast from an external mold, RV. Specimen missing the escutcheon and part of the umbo. UWBM 112551: Silicone cast from an external mold of both valves, complete, butterfly opened. UWBM 112556: Silicone cast from an internal mold of the schizodont dentition, both valves. The original internal mold was destroyed in the process of freeing the cast. All specimens from UWBM loc. B-9486.

Occurrence—Endemic to the Cordilleran Province (Cooper and Leanza 2017). Late early Albian (*Brewericeras hulenense* zone) to middle Albian (Saul 1978). California, Oregon, Washington State (USA), and British Columbia (Canada) (Saul 1978).

Description—Moderately large (L = 81 mm, 98 mm), thick-shelled, subrectangular, equivalve, strongly inequilateral. Longer than high (Average H/L = 0.70), moderately inflated (Average W/H = 0.25). Maximum inflation line follows a line along the first node of each flank rib. Umbo anterior, nearly terminal, opisthogyrate. Dorsal margin nearly straight. Posterior end narrower and more convexly curved than anterior end. Anterior end truncated, forming a gentle convexity from the beak to the corner rib at the junction with the ventral margin. Anterior angulation ornamented with row of prominent nodes that increase in size ventrally. Umbo and flank ornamented with rows of nodes forming ribs that arch slightly anteriorly as they approach the anterior/ventral margins; rib nodes enlarge ventrally and elongate along the growth lines. There is a narrow but definite space between the anterior angulation nodes and the flank ribs. Corner rib has 9-11 nodes. Width of nodes equal to interspaces. Outer and inner areas nearly smooth except for fine growth lines. Marginal angulation nodes smaller than the rib nodes and tend to fade as they approach the posterior margin. Median groove nodes weak and fade 3-4 cm from the beak. Escutcheon angulation lined with a row of small nodes similar to the marginal angulation nodes.

Discussion—This trigoniid is the dominant species of the cPL. Without ornamental detail, it is difficult to distinguish it from its Hauterivian ancestor, *Y. jonesi* Saul, 1978, or its Cenomanian descendant, *Y. leana* (Gabb, 1876). Material previously collected from this site was misidentified as *Trigonia* (*Yaadia*) *leana* (Barksdale 1975, McGroder et al. 1990). Compared to *Y. leana*, *Y. whiteavesi* is more elongate, more truncated anteriorly, has more pronounced anterior angulation nodes, and more nodes in the corner rib (9+ vs. 6-7) (Saul 1978). It differs from *Y. jonesi* by having a narrower space between the anterior angulation nodes and the flank ribs, a less ornamented area, and rib interspaces that are similar in width to the rib nodes. (*Yaadia jonesi* has rib interspaces that are wider than the rib nodes [Saul 1978].)

MEGATRIGONIIDAE van Hoepen, 1929
MEGATRIGONIINAE van Hoepen, 1929
COLUMBITRIGONIA Poulton, 1977
COLUMBITRIGONIA CONDONI (Packard, 1921)
Fig. 6A-D

Trigonia condoni Packard, 1921, p. 28, pl.8, fig. 2.
Trigonia packardi Anderson, 1958, p. 109, pl.1, fig. 5.
Megatrigonia condoni (Packard). Jones, 1960a, p. 158, pl. 29, figs. 8-10, 17, 18.
Columbitrigonia? sp. cf. *C. condoni* (Packard). Poulton, 1977, p. 14, pl.2, fig. 44.
Columbitrigonia condoni (Packard). Cooper and Leanza, 2019, p. 27, fig. 3A.

Holotype—Type number 3, Condon Museum, University of Oregon (Packard 1921). Despite multiple searches, the specimen could not be found. Holotype assumed missing.

Plastoholotype—CASG 567. Cast of the external mold holotype, RV.

Material—UWBM 112552: Silicone cast from an external mold, LV, from UWBM loc. B-9486. Missing posterior terminus. UWBM 112554: Silicone cast from an external mold, RV, from UWBM loc. B-9487. UWBM 112555: Silicone cast from an external mold, LV, from UWBM loc. B-9487. This specimen demonstrates commarginal lirae not commonly seen on the posterior terminus.

Occurrence—Endemic to the Cordilleran Province (Cooper and Leanza 2019). Early Albian to Cenomanian(?) (Jones 1960a). California(?), Oregon, Washington State (USA), and British Columbia (?) (Canada) (Poulton 1977).

Description—Elongate-pyriform shape, small to medium size, moderately inequilateral (umbo anterior), moderately inflated (W/H = 0.22), and longer than high (H/L = 0.67). Umbo moderately prominent with pointed, opisthogyrate beak. Anterodorsal margin almost straight, becoming more convex as it merges with the anteroventral margin. Ventral margin becomes straighter posteriorly. Posterior end narrow and roundly truncated. Posterodorsal margin mildly concave. Area/escutcheon sunken, unornamented except for growth lines, and concave near the umbo, becoming flatter posteriorly; it angles sharply upward to form the posterodorsal commissure. Marginal carina sharp and prominent near the

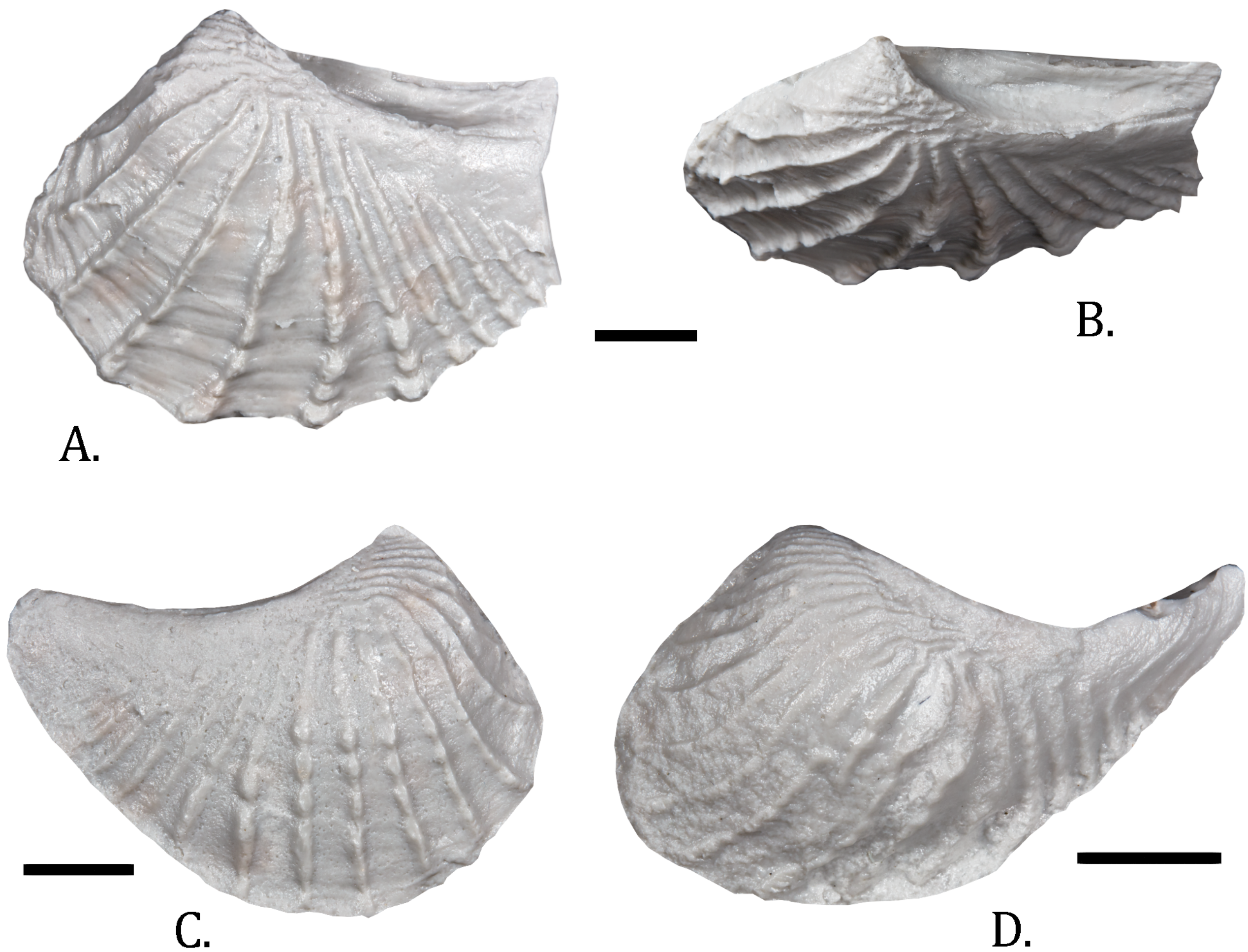


Figure 6. *Columbitrigonia condoni* (Packard, 1921). All are silicone casts of external molds. **A, B.** UWBM 112552 from UWBM loc. 9486. Posterior end missing. **A.** Flank view of LV. **B.** Oblique view showing area and marginal carina. **C.** UWBM 112554 from UWBM loc. 9487. Flank view of RV. **D.** UWBM 112555 from UWBM loc. 9487. Flank view of LV showing commarginal lirae on the posterior terminus. Scale bars = 10 mm.

umbo, but posteriorly becomes flatter and less conspicuous.

Ornamentation is variable but generally presents 3 series of ribs. The initial 5-7 umbo riblets are moderately fine, rounded, and concentric with interspaces equal in width to the riblets. The second series consists of 5-7 ribs that begin at the marginal carina, parallel and similar to the initial juvenile series; but soon they flex ventrally, become larger and slightly nodose, forming a gentle anterior curve as they approach the anterior margin at nearly a right angle. The third series consists of 9-11 flank ribs. They all begin subradially, but the first 4-6 anterior ribs in this series soon assume a gentle anterior curve; as these ribs approach the anteroventral margin they enlarge and become more nodose, especially where they intersect with prominent growth lines. Up to the mid-flank point, the flank interspaces are about 2 to 3 times the width of the ribs. The posterior 5-6 subradial flank ribs become straighter, narrower, shorter, and less nodose; they fade as the posterior terminus is approached. The posterior interspaces are about equal in width to the ribs. There is an unornamented space between the marginal carina and the posterior flank ribs. The posterior terminus is generally smooth except for growth lines. However, as seen in UWBM 112555, commarginal riblets may arise from the final two or three posterior-most flank ribs.

Discussion—*Columbitrigonia condoni* is the second most common trigoniid at this site. The irregular flank ornamentation of these specimens is typical of the species (Jones 1960a). The only other megatrigoniid from the Cordilleran Province that resembles it is *C. jackassensis* Poulton, 1977 which is of Hauterivian/Barremian age.

Figure 7. *Notoscabrotrigonia oregana* (Packard, 1921) UWBM 112553 from UWBM loc. 9486. Silicone cast of an external mold. Flank view of RV. Scale bar = 10 mm.

They differ in that "the juvenile concentric costae of *C. condoni* appear to extend to the marginal carina and succeeding subradial costae develop ventrally from them" (Poulton 1977); the subradial costae of *C. jackassensis* replace the juvenile concentric costae at an early stage.

PTEROTRIGONIIDAE van Hoepen, 1929
SCABROTRIGONIINAE Cooper, 1989
NOTOSCABROTRIGONIA Dietrich, 1933
NOTOSCABROTRIGONIA OREGANA (Packard, 1921)
Fig. 7

Trigonia evansi Meek, 1876, p. 359, pl. 2, figs. 7, 7a, 7b
Trigonia evansana Meek. Packard, 1921, p. 25
Trigonia evansana var. *oregana* Packard, 1921, p. 26, pl. 9, fig. 7.
Trigonia. evansana var. *oregona* Stewart, 1930, p. 93.
Trigonia deschutesensis Packard, 1921, p. 24, pl. 10, fig. 3.
Trigonia oregona Packard. Anderson, 1958, p. 116.
Pterotrigonia oregana (Packard). Jones, 1960b, p. 437, pl. 59, figs. 2, 5, 9, 11-13.
Notoscabrotrigonia oregana (Packard). Cooper 2015a, pp. 25, 27.

Holotype—Type number 4, Condon Collection, Department of Geology, University of Oregon (Jones 1960b). Despite multiple searches, the specimen could not be found. Holotype assumed missing.

Plastoholotype—CASG 573. Cast of the external mold holotype, LV.

Material—UWBM 112553: Silicone cast from an external mold of a nearly complete RV. Missing the beak and some of the escutcheon, anterior and ventral margins. From UWBM loc. B-9486.

Occurrence—Endemic to the Cordilleran Province. Middle Albian to late? Cenomanian (Jones 1960b). Washington State and Oregon (USA).

Description—Shell medium-sized (L = 54mm), crescentic with anterior end much wider than posterior. Strongly inequilateral (umbo anterior and nearly terminal). Shell inflated anteriorly (W/H ≈ 0.34). Prominent umbo with pointed, incurved, opisthogyrate beaks (seen in other specimens from the cPL). Dorsal margin concave, becoming straighter posteriorly. Specimen missing some of the anterior and ventral margins. Posterior terminus bluntly rounded. Inner and outer areas separated by a median groove which is more distinct posteriorly. Both areas unornamented except for transverse growth lines. Escutcheon not well-exposed, but transverse ribs are evident.

Umbo and flank ornamented with about 15 raised, narrow, prominent, sharp ribs that originate at the marginal angulation. They traverse the disk obliquely from the marginal angulation to the anterior and ventral margins, assuming a straight to slightly curved course. The tops of the anterior ribs have small, inconspicuous tubercles. Interspaces are concavely rounded to flat, unornamented except for fine growth lines, and are about twice as wide as the ribs.

Discussion—Meek's original description (1858) of *Trigonia evansana* was based on fossils from Vancouver Island, British Columbia (Canada). In 1876 Meek published another description of the species but (mistakenly?) used the name *Trigonia evansi*. Although he again cited Vancouver Island as the locality of that species, the gutta-percha cast specimen figured in the study (plate 2, figs. 7a, b) was collected from Crooked River, Oregon (USA) (Stewart 1930). Meek's two species names were considered synonyms (Packard 1921, Jones 1960b), and pterotrigoniids from the Crooked River were labelled and curated as *T. evansana* (Jones 1960b). Packard (1921) documented differences between the pterotrigoniids from Vancouver Island and Crooked River; he recognized the Crooked River pterotrigoniid as a new variety and assigned it the name, *Trigonia evansana* var. *oregana* Packard, 1921. In his discussion on the topic, Stewart (1930) misspelled the name as "*oregona*" and this mistake was repeated by Anderson (1958). Finally, Jones (1960b) clarified these issues, elevated the Crooked River pterotrigoniid to species level (*oregana*), and assigned it to the genus, *Pterotrigonia* van Hoepen, 1929. Cooper (2015a) has since assigned it to another genus: *Notoscabrotrigonia* Dietrich, 1933.

According to Jones (1960b), *N. oregana* is part of an evolutionary series: *N. oregana* (Middle Albian-Cenomanian[?]) → *N. klamathonia* (Anderson, 1958) (Early Turonian-Early Coniacian[?]) → *N. evansana* (Early Coniacian-Campanian). *Notoscabrotrigonia oregana* differs from *N. klamathonia* in that the latter has more numerous (20-25), finely tuberculate ribs with narrower interspaces. *Notoscabrotrigonia oregana* differs from *N. evansana* in that the latter has large, blunt tubercles on the anterior ribs and a narrower area (Jones 1960b). Although the specimen from Patterson Mountain is not complete, there is enough ornamental detail present to distinguish it from both *N. klamathonia* and *N. evansana*.

RUTITRIGONIIDAE van Hoepen, 1929
RUTITRIGONIINAE van Hoepen, 1929
RUTITRIGONIINI van Hoepen, 1929

Diagnosis—Small to large, pyriform to ovate and subtrapezoidal, strongly inequilateral to subequilateral, moderately inflated to inflated, with weakly- to strongly-convex anterior margin, obliquely truncate to subrounded respiratory margin, anteriorly-positioned umbones and moderately-incurved opisthogyrous beaks; shallow sunken escutcheon unornamented, or with costellae continuous from area in early growth; escutcheon and areal rims sometimes nodate in early growth; weakly-bipartite area with oblique costellae in early to middle growth continuous from flank, mostly evanescing later; flank costellae mostly non-tuberculate, commarginal in early growth, subcommarginal to subhorizontal and oblique later, cutting across growth striae both anteriorly and posteriorly; flank costellae may become deflexed, wavy and discontinuous anteriorly, sometimes nodate, and effaced at varying distances from the posterior.

Late Kimmeridgian – Late Maastrichtian. (Cooper 2015b)

PARVITRIGONIA n. gen.

Zoobank LSID—urn:lsid:zoobank.org:act:5CF78024-4AE3-478D-9F13-C9F55C98403A

Diagnosis—Very small, moderately inequilateral (umbo in anterior third), elongate-pyriform, and inflated with a narrow, nearly pointed posterior terminus. Marginal angulation conspicuous, rounded, gently concave, coursing from beak to posterior terminus creating an angle of almost 90° between the surfaces of the flank and area. Sunken area/escutcheon forms a platform that mimics the concave curve of the marginal angulation; platform unornamented except for fine growth lines. Area rises up smoothly to form a nearly straight posterodorsal margin. Flank ribs subcommarginal, flat-topped, wavy ventrally, and attenuate as they approach the posterior terminus.

Type species—*Parvitrigonia cooperi* n. sp. Original description below.

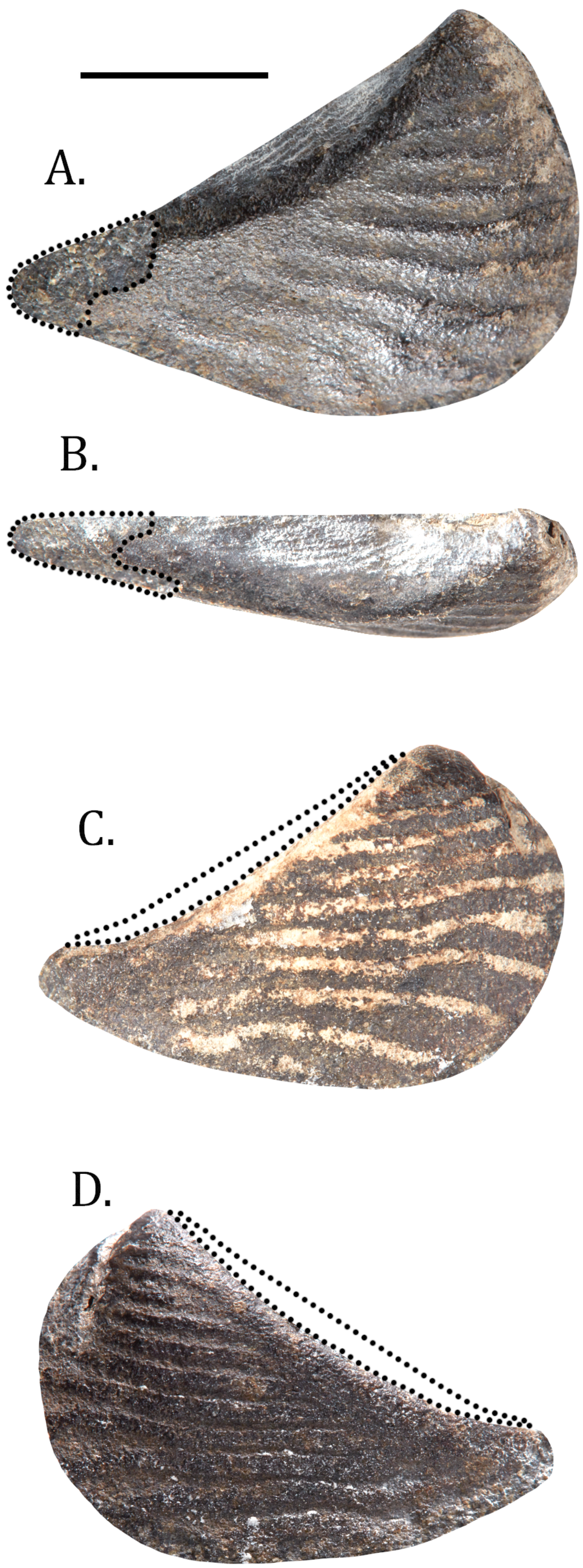
Etymology—A rutitrigoniid named after its small size: *Parvus* (Latin for “small”).

Discussion—There are no clear criteria for the creation of a new genus; for an in-depth presentation of the issues involving trigoniid genera in general and rutitrigoniids in particular, see Leanza (1993) and Cooper (2015b). Given the provincial nature of rutitrigoniids (Cooper 2015b), the first place to look for an appropriate genus assignment for this fossil is a rutitrigoniid genus that is from the Cordilleran province, the province that includes Washington State. The only rutitrigoniid genus found in the Cordilleran province is *Earlpackardia* Cooper, 2015b. Cooper (2015b) describes the genus as: “Moderately large, robust,…with…subparallel ventral and posterodorsal margins and broadly-rounded respiratory margin.” In contrast, *Parvitrigonia* is very small, inflated, pyriform with a narrow, nearly pointed respiratory margin.

Considering rutitrigoniid genera from other provinces that span the middle Albian, there are three possibilities: *Rutitrigonia* van Hoepen, 1929, *Lycettitrigonia* Cooper, 2015b, and *Balaklavella* Cooper, 2015b. While there are some similarities between these genera and the fossil from this study, the following excerpts from Cooper (2015b) demonstrate significant differences that argue against its inclusion in any of those genera.

Rutitrigonia is “pandemic to the Ethiopian (South Africa) and Andean (Argentina) provinces” and described as: “Small…;…respiratory margin subrounded to obliquely subtruncate, posterodorsal margin shallowly concave;…area with commarginal costellae in early growth continuous from flank, occasionally persisting; flank costellae fine, dense, subcommarginal in early growth, later cutting obliquely across growth striae anteriorly and curving downwards posteriorly where they may become crowded.” In contrast, *Parvitrigonia* is very small, with a narrow, nearly pointed respiratory margin; area is unornamented except for fine growth lines; flank costellae are wider (not fine), flat topped, less crowded, and do not curve downward posteriorly.

Lycettitrigonia is “pandemic to the European (England, France, Switzerland), Middle East (Libya, Sinai, ?Jordan) and northern Ethiopian (India) provinces, perhaps extending into the American (?Texas) Province.” The genus is described as: “Small to moderately large;



trigonally ovate to subpyriform…; escutcheon barely sunken, poorly discriminated with indistinct rim;…; fine subcommarginal flank costellae." Posterior margin is smoothly rounded. In contrast, *Parvitrigonia* is very small, elongate-pyriform, with narrow, nearly pointed posterior, sunken area/escutcheon, and conspicuous marginal angulation creating a nearly 90° angle between the surfaces of the flank and area. Flank costellae are more coarse, flat-topped, and wavy ventrally.

Balaklavella is "endemic to the Central Asian (Turkistan) Province" and described as: "Small to medium-sized…with concave posterodorsal margin… conspicuously bipartite area…and fine subcommarginal flank costellae which curve strongly upwards posteriorly so as to meet the area almost at right angles." In contrast, *Parvitrigonia* is very small with nearly straight posterodorsal margin. Area not bipartite; flank costellae more coarse, wavy, flat-topped, and do not curve upwards posteriorly.

There being no existing rutitrogoniid genus that satisfactorily describes the morphology of the fossil in this study, a new genus, *Parvitrigonia*, is proposed.

PARVITRIGONIA COOPERI n. sp.
Figs. 8A-D, 9A, B

Zoobank LSID—urn:lsid:zoobank.org:act:F7F98567-F4C0-4A13-BB52-83B7B83B51ED

Diagnosis—Very small, moderately inequilateral, elongate-pyriform, and inflated. Anteroventral margin smoothly convex becoming nearly straight posteriorly. Posterodorsal margin nearly straight. Posterior terminus narrow, nearly pointed. Beaks small, pointed, opisthogyrate, and located in the anterior third of shell. Marginal angulation conspicuous, rounded, sharper near the umbo, and gently concave as it courses from beak to posterior terminus creating an angle of almost 90° between the surfaces of the flank and area. Sunken

Figure 8 (left). *Parvitrigonia cooperi* n. gen. et sp. **A, B.** UWBM 112557 from UWBM loc. B-9487. Paratype. Natural mudstone cast, RV, complete except for posterior terminus (dotted area). **A.** Flank view showing general outline. Costae mildly eroded. **B.** Dorsal view showing fine growth lines on area/escutcheon. **C, D.** UWBM 112558 from UWBM loc. B-9486. Holotype. Slightly crushed natural mudstone cast of articulated valves. Missing area and escutcheon (dotted area). **C.** RV with some shell remaining, flank view, showing wavy costae anteriorly. **D.** LV, flank view, showing flat-topped costae. Scale bar = 5 mm

Figure 9. *Parvitrigonia cooperi* n. gen. et sp. UWBM 115724 from UWBM loc. B-9541. Paratype. Complete natural sandstone cast of undistorted RV. Because of coarse matrix, fine detail is not well-shown. **A.** Flank view showing general outline of entire shell. **B.** Dorsal view showing overall shape of area/escutcheon and degree of shell inflation. Scale bar = 5 mm.

area/escutcheon forms a platform that mimics the concave curve of the marginal angulation; platform unornamented except for fine growth lines. Umbo and flank ornamented with 11-12 subcommarginal, flat-topped, non-tuberculate ribs. Ventral 5 ribs wavy and attenuate as they approach the posterior terminus.

Holotype—UWBM 112558

Paratypes—UWBM 112557, UWBM 115724.

Age and Occurrence—Type locality: UWBM loc. B-9486. Specimens were found in the upper part of the cPL at both the Patterson Mountain and Rendezvous Road sites (See below), Okanogan County, Washington State (USA). Age: middle Albian.

Material—UWBM 112557: Paratype. A slightly compressed natural mudstone cast of a RV from UMBM loc. B-9487. It is nearly complete and shows some detail of the area/escutcheon but is missing the posterior terminus. UWBM 112558: Holotype. A slightly crushed, mildly deformed, articulated specimen from UWBM loc. B-9486. The LV shows the flank ornamentation and the posterior terminus well, but is missing the anterodorsal margin, area, and escutcheon. The RV retains some shell material and is missing the posterior terminus, area, and escutcheon. The schizodont dentition is partially visible under magnification. UWBM 115724: Paratype. An undistorted natural sandstone cast, RV, complete, from UWBM loc. B-9541. This cast demonstrates the external outline and general shape of the shell, but because of its sandstone matrix, lacks the ornamental detail seen in the other specimens.

Etymology—Named after Michael R. Cooper of South Africa who has worked for over 40 years to bring order to the chaotic world of global trigoniid systematics, and whose encouragement and guidance made this study possible.

Description—Very small (L = 16mm, H = 10mm), elongate-pyriform, longer than high (H/L = 0.625), inflated (W/H = 0.43) and moderately inequilateral (umbo in the anterior third). Umbo weakly prominent, opisthogyrate. Beaks small, pointed, and mildly incurved. Anterior margin convex, merging smoothly with the ventral margin. Ventral margin convex anteriorly becoming nearly straight posteriorly. Posterior end narrow and nearly pointed. Posterodorsal margin nearly straight. Marginal angulation conspicuous, rounded and gently concave as it courses from beak to posterior terminus creating an almost 90° transition between the flank and area surfaces.

Sunken area/escutcheon forms a platform that mimics the course of the concave marginal angulation and narrows posteriorly; platform rises up smoothly to form the nearly straight posterodorsal margin. Area/escutcheon unornamented except for fine, closely spaced, oblique growth lines.

Umbo and flank ornamented by 11-12 subcommarginal, flat-topped, non-tuberculate ribs. Ventral five ribs wavy and fade as they approach the posterior terminus. Interspaces and ribs equal in width in the umbo region; ribs wider than the interspaces in the mid-flank area; interspaces wider than the ribs anteriorly.

EARLPACKARDIA Cooper, 2015b

Diagnosis—Small to moderately large, posteriorly produced and oblong, with prominent umbones, subparallel ventral and posterodorsal margins and broadly-rounded respiratory margin; prominent/conspicuous marginal carina/angulation persisting into middle growth; flank costae fine to coarse, wavy, subnodate, irregular anteriorly and sometimes discontinuous, becoming subcommarginal to nearly horizontal by midflank where they fade and are replaced by fine growth lines posteriorly. Area and escutcheon in some species

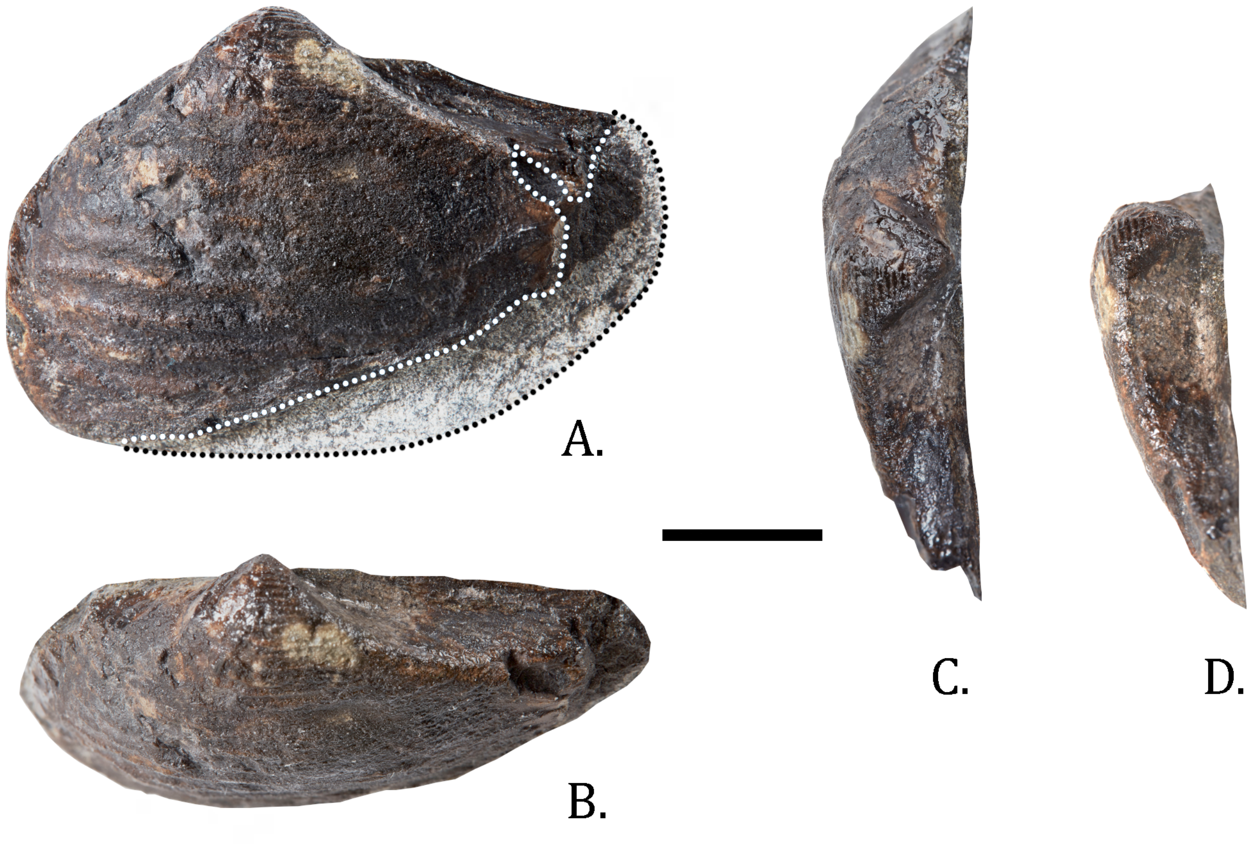


Figure 10. *Earlpackardia methowensis* n. sp., holotype UWBM 112559 from UWBM loc. 9486. **A.** Flank view. Dotted line indicates proposed reconstruction of missing shell based on growth lines. **B.** Oblique view demonstrating the umbo, marginal carina, unornamented area, and escutcheon. **C.** Dorsal view demonstrating the pointed beak and degree of inflation. **D.** Oblique dorsal view showing the incurved umbo, unornamented area, and escutcheon. Scale bar = 1 cm.

may be costellate in early growth but are otherwise flat and unornamented except for fine growth lines. *Neocomian – Turonian* (Emended from Cooper 2015b)

Referred Species—*E. jacksonensis* (Packard, 1921), p. 18, Plate 4, fig. 1. *E. yeharai* (Kobayashi, 1954), p. 77; Tashiro 1990, p. 12, plate 1, fig. 3-6, text-fig. 7. *E. amagensis* (Kobayashi, 1957a) p. 360, plate 3, fig. 2; Hayami 1968, p. 178, plate 21, fig. 6.

Occurrence—Cordilleran, Oriental, and Sinian provinces (Cooper 2015b).

EARLPACKARDIA METHOWENSIS n. sp.
Fig. 10A-D

Zoobank LSID—urn:lsid:zoobank.org:pub:BF86936D-74C7-4D43-A078-08588EA93614

Diagnosis—Small, subequilateral (umbo anterior), oblong; prominent, incurved umbo elevated above dorsal margin, sharply pointed beak, prominent marginal carina extending from the beak toward the posterior margin. Area/escutcheon sunken and unornamented except for fine, oblique growth lines. Posterodorsal margin nearly straight. Umbo and beak ornamented with 16-18 fine, commarginal costellae which are abruptly replaced by 9 coarse, slightly nodular, slightly wavy, subcommarginal, nearly horizontal costae on the anterior flank; costae fade at mid-flank and are replaced by fine growth lines posteriorly.

Holotype—UWBM 112559 from UWBM loc. 9486. A nearly complete LV that is missing the posterior terminus and some of the ventral margin, especially posteriorly. The posterior and ventral shell margins are extrapolated using growth lines as a guide.

Occurrence—Type locality: UWBM loc. B-9486. Upper part of the cPL, Okanogan County, Washington State (USA). Age: middle Albian.

Etymology—Named after the Methow Valley and the sedimentary basin from which it was collected.

Description—Small (L ≈ 41 mm, H ≈ 28 mm), subequilateral (umbo anterior), oblong, inflated (W/H = 0.3), longer than high (H/L = 0.68); prominent, incurved umbo and pointed beak elevated above dorsal margin. Anterodorsal margin nearly straight and slopes toward truncated anterior end. Posterodorsal margin nearly straight as it courses posteriorly. Posterior terminus unknown. Ventral margin (as extrapolated from growth lines) almost straight anteriorly becoming progressively convex posteriorly.

Sunken area/escutcheon unornamented except for fine, oblique growth lines; no median carina or groove. Area gradually narrows posteriorly. Area rises abruptly at almost 90° to form the posterodorsal margin. Prominent, rounded marginal carina gently concave as it courses from the beak toward the posterior terminus.

Umbo and beak ornamented with 16-18 fine, closely spaced, commarginal costellae that are replaced abruptly by 9 coarse, rounded, slightly nodular, slightly wavy, nearly horizontal, subcommarginal flank costae that extend from the anterior margin to mid-flank where they fade and are replaced by fine growth lines posteriorly. Width of the flank costae about equal to their interspaces. Internal features unknown.

Discussion— There are three other species in the genus, *Earlpackardia* Cooper 2015b. From the late Barremian-early Aptian of Japan, *E. yeharai* (Kobayashi, 1954) is morphologically the most similar to *E. methowensis*. (Description of *E. yeharai* from Kobayashi 1957b.) They are both oblong with straight posterodorsal margins and prominent, elevated umbos with pointed beaks ornamented with fine, commarginal costellae. The flank costellae fade at mid-flank in both species and are replaced by fine growth lines posteriorly. Unlike *E. yeharai*, however, the area and escutcheon in *E. methowensis* are sunken and lack the costellae seen in the early growth of *E. yeharai*; the marginal carina is more prominent in *E. methowensis* and takes a less steep course posteriorly; the subcommarginal flank costellae are more horizontal, coarse, and nodular than the fine costae in *E. yeharai*.

Earlpackardia jacksonensis (Packard, 1921) was found in the Osburger Gulch Sandstone of the Hornbrook Formation near Jacksonville, Oregon (USA) and is geographically the closest species of the genus to *E. methowensis*. Although Packard originally gave it the imprecise age of Upper Cretaceous, Sliter et al (1984) dated the Osburger Gulch Sandstone in the Jacksonville, OR area as late Albian(?) to middle Cenomanian. This also makes it chronologically the closest species of the genus to *E. methowensis*. There are some morphological similarities between the two species. (Description of *E. jacksonensis* from Packard 1921.) Both are elongate with a prominent, elevated umbo, straight and sloping posterodorsal margin, unornamented area/escutcheon, and coarse, slightly nodose flank costae that fade at mid-flank, being replaced by fine growth lines posteriorly. Unlike *E. methowensis*, however, *E. jacksonensis* is moderately large, more posteriorly produced, and has a tumid umbo, blunt beak, and flank costae that are more wavy, oblique, and discontinuous. The marginal carina is less prominent than in *E. methowensis*.

Earlpackardia amagensis (Kobayashi 1957a) is from the late Oxfordian (Andal et al. 1968) Amaga River of Mindoro (Philippines). In contrast to *E. amagensis*, *E. methowensis* is less posteriorly produced, more elongate with a more prominent umbo, and a sunken area/escutcheon; its marginal carina is more pronounced. The flank costae are coarser and fewer in number, but like *E. amagensis*, they fade near mid-flank and are replaced by fine growth lines posteriorly.

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