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Paul Mayer, Editor

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ABSTRACT

The Lower Silurian (Aeronian) Burnt Bluff Group of Door County, Wisconsin and the Upper Peninsula of Michigan includes the Byron and overlying Hendricks formations, which represent carbonate tidal flat and shallow subtidal environments. *Hercotrema, Alispira* and an indeterminate trimerellid occur in an intertidal Benthic Assemblage 1 fauna, where they are exceeded in abundance by leperditiid ostracods. A subtidal Benthic Assemblage 2 fauna, dominated by stromatoporoids and corals, includes the brachiopods *Hesperorthis, Gnamptorhynchos, Salopina, Dalejina, Megastrophia (Eomegastrophia), Morinorhynchus, Brevilamnulella, Hercotrema, Alispira, Fayettella* n.gen., ?*Howellella,* and an indeterminate trimerellid and rhynchonellide. The Benthic Assemblage 2 fauna of brachiopods appears in discrete beds of the Burnt Bluff Group that represent six major intervals of marine transgression. This fauna is the rough bathymetric equivalent of the *Eocoelia* Community of clastic facies. The brachiopod fauna of the Burnt Bluff Group is very similar to that of the Aeronian Severn River Formation of the Hudson Bay lowlands. New taxa described are *Morinorhynchus korinai* n.sp., *Brevilamnulella doorensis* n.sp., and *Fayettella peninsulensis* n.gen.&sp.

INTRODUCTION

The Burnt Bluff Group of northeastern Wisconsin and northern Michigan consists of Lower Silurian carbonates that were deposited in supratidal to shallow subtidal environments (Harris and Waldhuetter, 1996; Harris et al., 1998). This paper is the first comprehensive study of the brachiopods of the Burnt Bluff Group. Previous work includes names of brachiopods in faunal lists (Shrock, 1940; Ehlers, 1973) and photos of a few species (Ehlers, 1973). Thirteen species are recognized here, including three new species and one new genus. This fauna is significant in documenting early Silurian brachiopod composition in very shallow marine carbonates in which brachiopods were greatly outnumbered by stromatoporoids, corals and ostracods. It also documents a close biogeographic relationship, both taxonomically and ecologically, between the Michigan and Hudson Bay basins.

The Burnt Bluff Group, which consists of the Byron Formation and overlying Hendricks Formation, crops out along the northwestern margin of the Michigan Basin (Fig. 1). The Byron Formation consists mainly of supratidal and intertidal deposits, while the Hendricks Formation includes these facies plus common interbeds of shallow subtidal origin (Fig. 2). Otherwise, the two units are lithologically identical (Harris and Waldhuetter, 1996). Both formations consist of dolostone, except at Hendricks and Fiborn quarries, where the Hendricks Formation consists of limestone.

During deposition of the Burnt Bluff Group, a shoreline was located to the north and northwest, between Fayette and Limestone Mountain, Michigan, and a southward-dipping ramp led to a basinal environment in southern Michigan and southeastern Wisconsin (Watkins and Kuglitsch, 1997). Sections at The Big Quarry (near Sturgeon Bay), Boyer Bluff, Fayette, Hendricks Quarry, and Fiborn Quarry (Fig. 1) contain *Kockelella manitoulinensis* and other conodonts of the upper part of the *Icriodus discreta – Icriodus deflecta* zone (Watkins and Kuglitsch, 1997). This zone indicates an Aeronian age (Aldridge, 1972; Uyeno and Barnes, 1983). Position of the Burnt Bluff Group in the regional stratigraphic column is shown in Fig. 1.

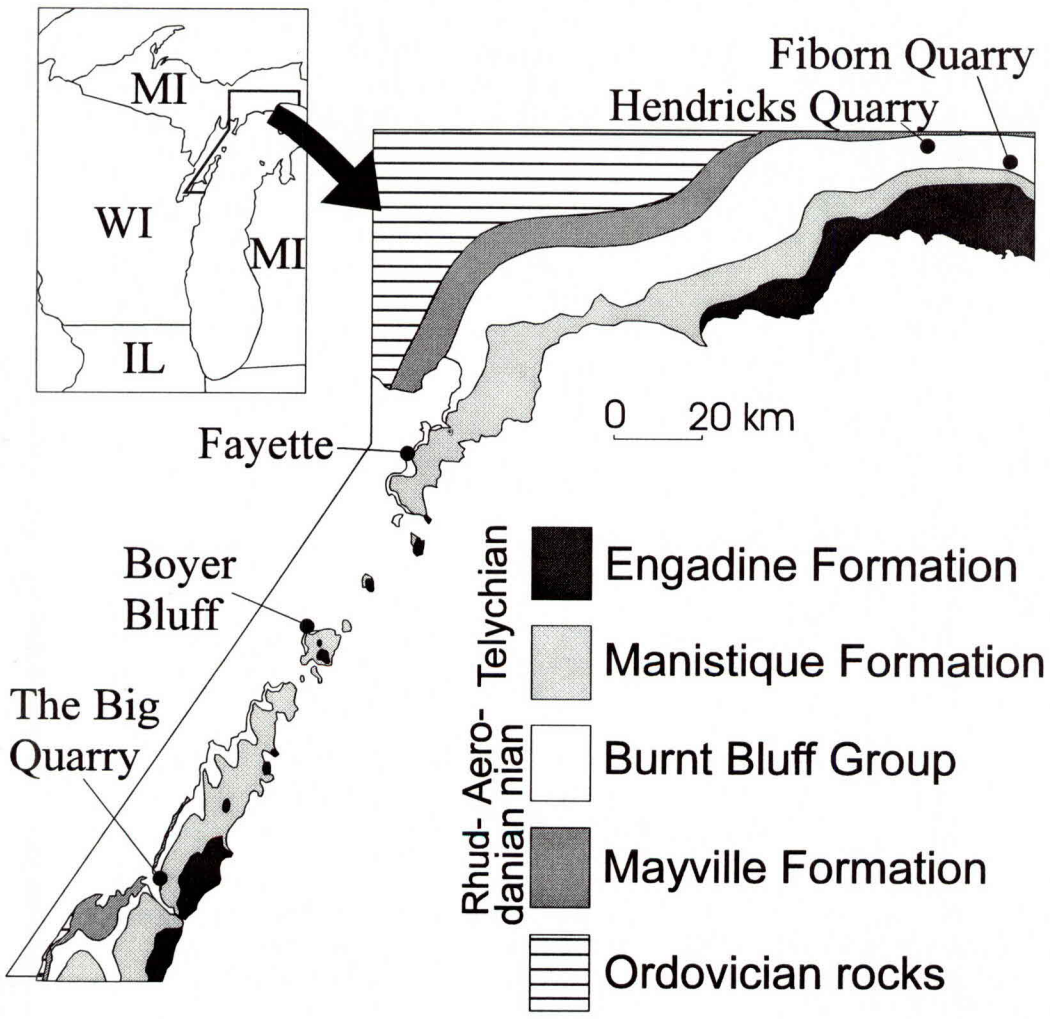

Fig. 1. Geologic sketch map of study area, compiled from Ehlers (1973) and Harris and Waldhuetter (1996). See Appendix 1 for detailed description of the five sampled localities.

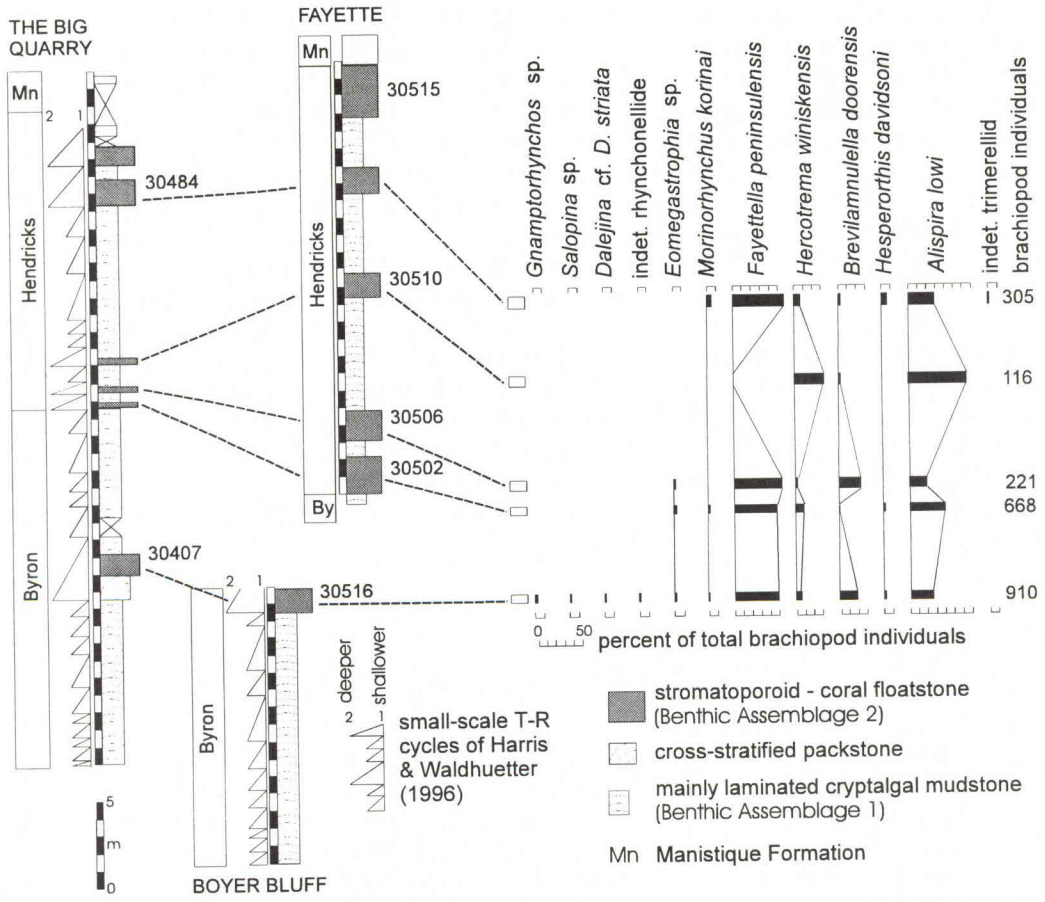

Fig. 2. Stratigraphic succession of BA2 brachiopod taxa in the Burnt Bluff Group, showing six major transgressive horizons represented by stromatoporoid-coral floatstone beds. The stratigraphically highest sample, 30515, yielded one individual of *Hesperorthis davidsoni*, one individual of *Alispira lowi*, and two individuals of *Fayettella peninsulensis*.

MATERIAL AND METHODS

Brachiopods were collected from five sections of the Burnt Bluff Group that were logged in sedimentologic detail by Harris and Waldhuetter (1996) and Watkins and Kuglitsch (1997). Localities are shown in Fig. 1 and described in detail in Appendix 1. All samples were taken as several kg of bulk rock from single beds. The only criterion for taking paleontologic samples was presence of fossils, and no selection was made for particular taxa, abundance, or grade of preservation. In dolostones at The Big Quarry, Boyer Bluff, and Fayette, the fauna is silicified and was prepared by etching in hydrochloric acid. At Hendricks and Fiborn quarries, calcitic specimens in limestone were mechanically prepared with a rock-splitter.

In etched samples of silicified material, all brachiopod specimens, which ranged from 1 mm to over 20 mm in size, were picked, identified and counted according to pedicle valve (PV), brachial valve (BV), and articulated shell (A). Fragments that included cardinalia and could be specifically identified were counted as well as whole valves and shells. Number of brachiopod "individuals" of a species was calculated as A plus maximum number of either PV or BV in a sample. All calcitic brachiopod specimens were similarly retained and counted in mechanically-prepared samples. Very small brachiopods were rare in such samples, probably as a function of an average rock chip size of 2 to 5 cm produced by splitting. In total, 14 samples were processed and 2376 brachiopod individuals were recovered.

In subsequent parts of this report, the Benthic Assemblage (BA) terminology of Boucot (1975) and Brett et al. (1993) is used in paleoecologic discussions. This scheme subdivides the Silurian benthos into a set of ecologic zones that range from BA1 (intertidal) to BA6 (basin).

SEDIMENTARY ENVIRONMENTS AND BIOFACIES

Carbonates of the Burnt Bluff Group consist of meter-scale cycles that shallow-upward from shallow subtidal to supratidal deposits (Harris and Waldhuetter, 1996). In the sections studied here, these deposits include:

Supratidal: Dolostone to limestone consists of cryptalgal-laminated mudstone with little or no bioturbation. Laminae are crinkly, subparallel, and locally truncated and disrupted, with mudcracks and lenses of self-supporting mud chips. Also present are parallel laminae of peloid grainstone. A few beds contain rare, widely-scattered leperditiid ostracods.

Intertidal: Dolostone to limestone includes mudstone with minor bioturbation and wavy parallel lamination, small ripple lamination and scattered fenestrae. Also present are beds of fenestral intraclast-peloid packstone in which clasts show various grades of detachment from the mud matrix. Thin interbeds of mudstone contain self-supporting angular clasts of massive to parallel-laminated mudstone. Leperditiid ostracods, rare brachiopods, and rare gastropods are present.

Low intertidal to restricted subtidal: Dolostone to limestone includes massive, bioturbated, sparsely fenestral mudstone and includes rare packstone laminae of skeletal debris. Leperditiid ostracods are abundant, brachiopods and gastropods are common, and bivalves, stromatoporoids, favositine tabulates, and crinoid ossicles are rare. This fauna and those of intertidal and supratidal deposits, which represent BA1, were designated by Watkins and Kuglitsch (1997) as the "ostracod biofacies" and by Johnson and Campbell (1980) as the "fucoid-ostracod community."

Open marine subtidal: Dolostones consist of 25 to 190-cm-thick beds of highly bioturbated floatstone that include *Thalassinoides*. Laminar to domal stromatoporoids and fa-

vositine tabulates to 15 cm are scattered, variably oriented and supported by a wackestone matrix. The smaller fauna includes common tabulates (favositines, alveolitines, halysitines, auloporines), solitary rugose corals, and brachiopods. Less common to rare taxa include sponge spicules, conulariids, bryozoans, gastropods, cephalopods, siprorbids, cornulitids, leperditiid ostracods, trilobites, and crinoid ossicles.

Watkins and Kuglitsch (1997) designated this fauna as the "stromatoporoid-coral biofacies." It represents BA2, and in terms of rough bathymetry, it is a carbonate equivalent of the *Eocoelia* community. The biofacies was also rather misleadingly called the "coral-algal community" by Johnson and Cambell (1980), who had difficulty distinguishing stromatoporoids from stromatolites in dolostone beds. In beds observed for this study, all laminar to domal skeletons with subparallel microstructure are considered to represent stromatoporoids. Where the floatstone beds occur as limestone, Stock (1997) and Stock and Nestor (1999) reported the stromatoporoid genera *Plectostroma, Pachystroma, Clathrodictyon, Ecclimadictyon, Petridiostroma*, and *Intexodictyon*.

BRACHIOPOD PALEOECOLOGY

BA1. - The Burnt Bluff Group contains two ecologic associations of brachiopods that correspond to Benthic Assemblages 1 and 2. The BA1 fauna, sampled as 113 "individuals" from restricted subtidal to intertidal deposits at Hendricks Quarry, consists of *Alispira lowi* (64.6%), *Hercotrema winiskensis* (34.5%), and an indeterminate trimerellid (0.9%). These brachiopods represent 8.7% of all skeletal material in the BA1 ostracod biofacies (Watkins and Kuglitsch, 1997, fig. 5). Beds dominated by trimerellids occur elsewhere in the Burnt Bluff Group (Ehlers, 1973) and may also represent BA1.

BA2. - The BA2 fauna, sampled as 2263 "individuals" from open marine subtidal beds at all localities, consists of *Fayettella peninsulensis* (46.1%), *Alispira lowi* (32.1%), *Brevilamnulella doorensis* (10.6%), *Hercotrema winiskensis* (6.5%), *Hesperorthis davidsoni* (1.9%), *Morinorhynchus korinai* (1.2%), *Megastrophia* (*Eomegastrophia*) sp. (1.1%), *Dalejina* cf. *D. striata* (<0.1%), ?*Howellella* sp. (<0.1%), indeterminate rhynchonellide (<0.1%), indeterminate trimerellid (<0.1%), and *Gnamptorhynchos* sp. (<0.1%). Brachiopods represent 3.6% of all skeletal material in the BA2 stromatoporoid-coral biofacies (Watkins and Kuglitsch, 1997, fig. 5). The brachiopods are scattered and variably-oriented throughout the matrix of stromatoporoid-coral floatstone beds, and have not undergone major transport or ecologic mixing. Size-frequency distributions of species show a predominance of juvenile shells (Fig. 3).

The BA2 assignment of this fauna is indicated by three lines of evidence. Stratigraphically, the association occurs in the basal, subtidal part of meter-scale shallowing-upwards cycles and is consistently overlain by intertidal to supratidal beds with the BA1 ostracod biofacies. On a larger stratigraphic scale, the Hendricks Formation, which contains the BA2 fauna, is overlain by the Manistique Formation, which represents deeper water conditions (Harris and Waldhuetter, 1996) and contains the BA3 *Pentamerus* Community (Johnson and Campbell, 1980; Watkins, 1994). Laterally, toward the interior of the Michigan Basin to the southeast, Aeronian strata of the Hendricks Formation also contain the BA3 *Pentamerus* Community (Watkins and Kuglitsch, 1997, fig. 1b).

Thus, the subtidal brachiopod fauna of the Burnt Bluff Group is the carbonate equivalent of the Llandovery BA2 *Eocoelia* Community, which was described from clastic facies in the Welsh Borderland by Ziegler (1965), Ziegler et al. (1968), and Cocks and McKerrow (1984). An inner shelf, shallow subtidal setting for the *Eocoelia* Community is indicated by its

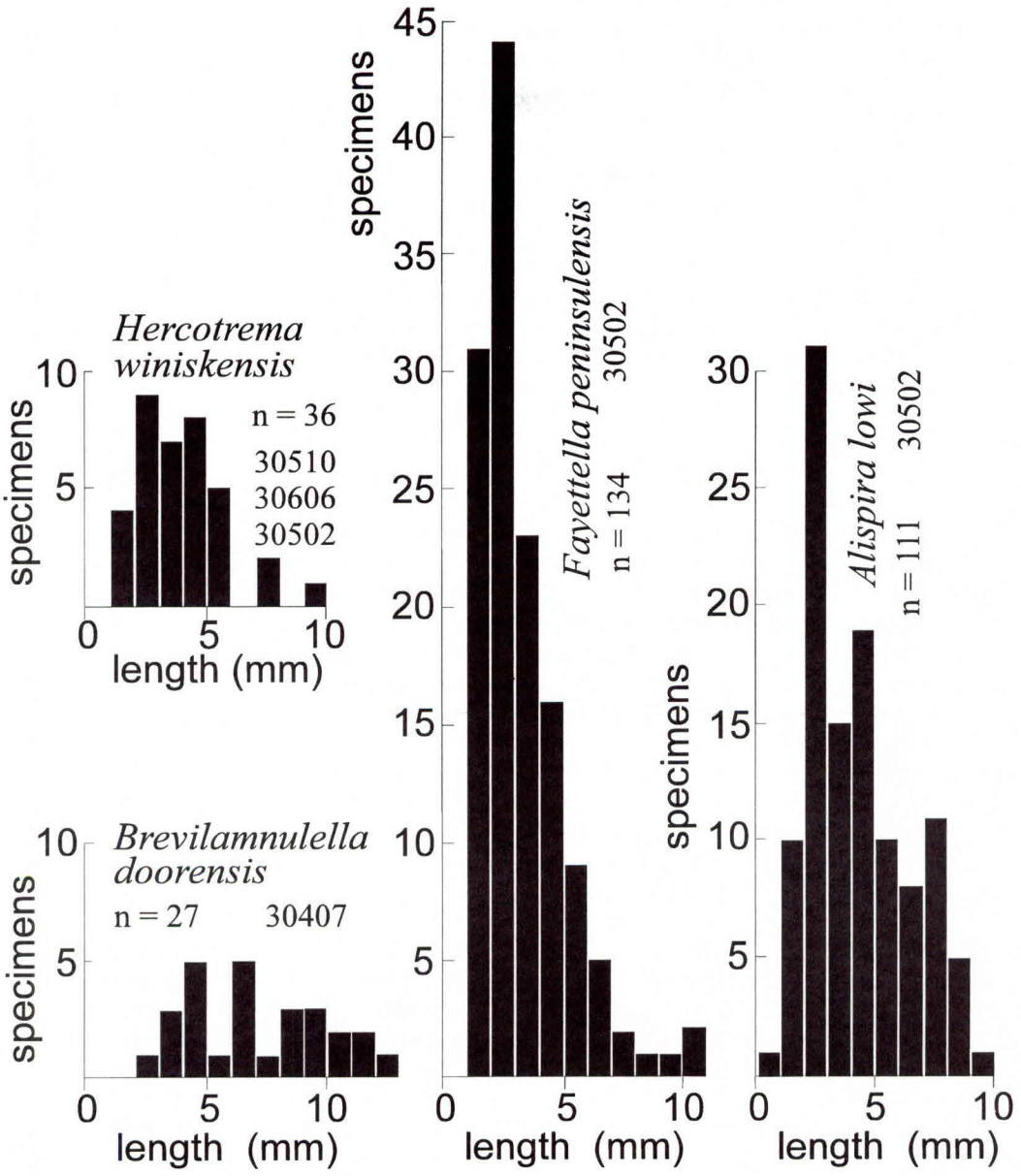

Fig. 3. Size-frequency distributions of selected species, based on measurements of articulated shells and pedicle valves.

paleogeographic position in the Welsh Borderland (Ziegler, 1965), and by the detailed sedimentologic study of the Ross Brook Formation in Nova Scotia (Hurst and Pickerill, 1986), where the community is also present (Watkins and Boucot, 1975). Taxonomically, the Burnt Bluff brachiopod fauna and the *Eocoelia* Community have very little in common, sharing only the genera *Salopina* and *Dalejina*. They also differ in their relation to other benthic groups. Whereas brachiopods of the Burnt Bluff fauna are far outnumbered by stromatoporoids and corals, brachiopods are the dominant taxon in the *Eocoelia* Community. Species diversity, however, is very similar in both the Burnt Bluff fauna and the *Eocoelia* Community, as shown by rarefaction curves in Fig. 4. Both communities show low diversity and high dominance of one or two species, and single samples seldom contain more than seven brachiopod species.

Based on correlation of sections at The Big Quarry, Boyer Bluff, and Fayette, the BA2 brachiopod fauna occurs at one horizon in the Byron Formation and five horizons in the Hendricks Formation (Fig. 2). These horizons of stromatoporoid-coral floatstone represent the six largest Aeronian transgressions in this area of the Michigan Basin (Harris and Waldhuetter, 1996). Each transgression was accompanied by immigration of the BA2 brachiopod fauna into the area and each was followed by intertidal-supratidal conditions in which the fauna disappeared. The Byron transgressive event includes four rare species not found higher in the section, and the Hendricks transgressive events show fluctuations in the abundance of the four dominant taxa, *Fayettella*, *Alispira*, *Brevilamnulella*, and *Hercotrema*. Otherwise, within the limits of sampling performed here, the brachiopod fauna shows a relatively stable level of composition and diversity during its six invasions of the study area.

BIOGEOGRAPHIC RELATIONS OF THE BRACHIOPOD FAUNA

The brachiopod fauna of the Burnt Bluff Group is part of the North Silurian Realm (Boucot, 1990), a vast, warm-water area that included most of present-day North America and Eurasia. Within the North American part of the realm, lineages of Early Silurian virgianids, pentameraceans and stricklandiids indicate at least partial faunal isolation of the Michigan and Anticosti basins from the Hudson Bay and Williston basins (Jin and Caldwell, 1990). In this context, it is significant that Burnt Bluff brachiopods show a close relationship with the Aeronian brachiopod fauna (Jin et al., 1993) of the Severn River Formation of the Hudson Bay Basin. *Alispira lowi, Hercotrema winiskensis*, and *Hesperorthis davidsoni* occur in both the Burnt Bluff and Severn River, and related species of *Dalejina* and *Eomegastrophia* are present. Species diversity and general morphologic composition of the Severn River fauna is also similar to that of the Burnt Bluff. Like the Burnt Bluff Group, the Severn River Formation consists of carbonates deposited in both intertidal and shallow subtidal environments (Jin et al., 1993). In discussing aspects of brachiopod occurrence in the Hudson Bay Basin, Jin et al. (1993, p. 11) stated that "the faunas and lithologies of the Severn River Formation indicate dominantly intertidal and lagoonal deposition...which may have been too shallow for *Pentamerus* and *Stricklandia*. However, this does not explain the concomitant absence of the shallow water brachiopod *Eocoelia*..." It is likely that the BA2 position of the *Eocoelia* Community in carbonates of the Hudson Bay Basin was occupied by a quite different brachiopod association (the fauna of the *Hercotrema winiskensis – Stegerhynchus borealis* Zone of Jin et al., 1993), as is the case with Aeronian brachiopods of the Michigan Basin.

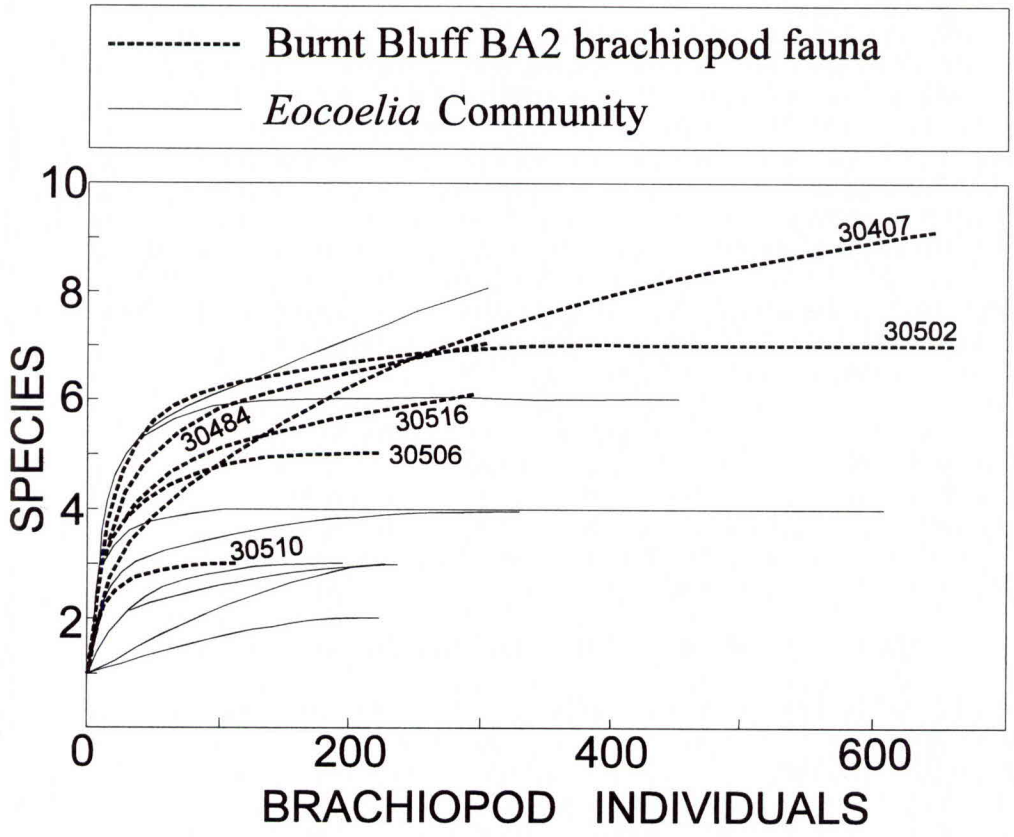

Fig. 4. Rarefaction curves comparing species diversity of the BA2 brachiopod fauna of the Burnt Bluff Group with the *Eocoelia* Community from clastic beds of the Aeronian to Telychian-age Ross Brook Formation, Nova Scotia (Watkins and Boucot, 1975). Curves for the *Eocoelia* Community are for USNM samples 10127, 10128, 10129, 10824, 10832, 10833, 11231, and 11305 in the A.J. Boucot collection.

SYSTEMATIC PALEONTOLOGY

Phylum Brachiopoda Dumeril, 1806
Subphylum Craniiformea Popov, Bassett, Holmer & Laurie, 1993
Order Trimerellida Gorjansky & Popov, 1985
Family Trimerellidae Davidson & King, 1872

indeterminate trimerellid

Discussion. - Two poorly-preserved, subcircular trimerellid valves are not generically determinable. They reach 14 mm in width. Ehlers (1973, pl. 17, figs. 5-6) illustrated *Dinobolus* sp. from Fiborn Quarry and *Trimerella* sp. (pl. 11, figs. 23-24) from Hendricks Quarry, both from the Hendricks Formation.

Occurrence. - Hendricks Formation (BA1): 30492, 1?PV; (BA2): 30484, 1 indeterminate single valve.

Subphylum Rhynchonelliformea Williams, Carlson, Brunton, Holmer & Popov, 1996
Order Orthida Schuchert & Cooper, 1932
Family Dolerorthidae Öpik, 1934
Genus *Hesperorthis* Schuchert and Cooper, 1931

Hesperorthis davidsoni (de Verneuil, 1848)

Pl. 1, figs. 1-5

Orthis Davidsoni de Verneuil, 1848, p. 341, pl. 4, figs. 9a-c.
Hesperorthis davidsoni (de Verneuil), Bassett & Cocks, 1974, p. 6, pl. 1, figs. 1a-c, 2a-b.
Hesperorthis davidsoni (de Verneuil), Jin et al., 1993, p. 111-112, pl. 33, figs. 10-17.

Discussion. - These shells reach 8.9 mm in length and 10.9 mm in width, with the length to width ratio ranging from 1:1.1 to 1:1.5. The hingeline is equal to or slightly less than maximum width, and cardinal extremities are subangular. The ventral valve is moderately convex and apsacline, and the dorsal valve is nearly flat and anacline. Eighteen to 20 strong, rounded costae are present, separated by interspaces of similar size that include a single very fine costella. These shells closely resemble Telychian specimens of *H. davidsoni* from Gotland and the Hudson Bay region figured respectively by Bassett and Cocks (1974) and Jin et al. (1993).

Occurrence. - Byron Formation (BA2): 30407, 2PV; 30516, 18PV, 18BV; Hendricks Formation (BA2): 30484, 15PV, 2BV, 1A; 30502, 2PV, 4BV, 1A; 30515, 1PV, 1BV.

Family Plectorthidae Schuchert, 1929
Genus *Gnamptorhynchos* Jin, 1989

Gnamptorhynchos sp.

Pl. 1, figs. 6-7

Discussion. - One incomplete ventral valve had an original width of about 13 mm. The shell bears 12 costae on the lateral flanks; only the posterior part of the sulcus is preserved, containing two smaller costae. The muscle field and dental plates are typical of the genus. A second, juvenile ventral valve is 4.8 mm in width and 4.0 mm in length, with four costae per lateral flank and two smaller costae in the sulcus. *Gnamptorhynchos* is a short-hinged platystrophiinid that Jin (1989) originally described as a rhynchonellid. It will be transferred to the Orthida in the forthcoming brachiopod *Treatise* (Jin, written communication, 1999). These specimens are comparable to *Gnamptorhynchos selliseptalicium* Jin, 1989 from the Gun River Formation of Anticosti Island.

Occurrence. - Byron Formation (BA2): 30407, 2PV.

Family Enteletidae Waagen, 1884
Genus *Salopina* Boucot, 1960

Salopina sp.

Pl. 1, figs. 11-12

Discussion. - One moderately convex ventral valve has a transverse outline, with a width of 3.4 mm and length of 2.7 mm. The interarea is curved, apsacline, with a height about half that of its width. The dental plates are short, curved, and partly enclose a small muscle field restricted to the umbonal area. A fragmentary dorsal valve is very weakly convex and 4 mm long. These juvenile specimens cannot be meaningfully compared with established species of *Salopina*.

Occurrence. - Byron Formation (BA2): 30407, 1BV; 30516, 1PV.

Family Dalmanellidae Schuchert, 1913
Genus *Dalejina* Havlicek, 1953

Dalejina cf. *D. striata* Jin et al., 1993

Pl. 1, figs. 8-10

Dalejina striata Jin et al., 1993, p. 113-114, pl. 32, figs. 1-18, pl. 33, figs. 1-9.

Discussion. - Four coarsely-silicified specimens reach 6.9 mm in width. The shell outline is subcircular, and the ventral valve, which has a very shallow sulcus developed anteriorly, is slightly more convex than the dorsal valve. Costae increase anteriorly by bifurcation and intercalation, and three costae per 1 mm are present at the anterior margin. These specimens

probably represent juveniles of *D. striata*, described by Jin et al. (1993) from Aeronian/Telychian strata of the Hudson Bay region. However, the single ventral interior from Burnt Bluff collections is poorly preserved, and the characteristic, striated diductor scars of *D. striata* are not apparent.

Occurrence. - Byron Formation (BA2): 30407, 2PV, 3BV.

Order Strophomenida Öpik, 1934
Family Strophеodontidae Caster, 1939
Genus *Megastrophia* Caster, 1939
Subgenus *Megastrophia* (*Eomegastrophia*) Cocks, 1967

Megastrophia (*Eomegastrophia*) sp.

Pl. 1, figs. 20-22

Discussion. - This is a concavo-convex, variably geniculate species represented almost exclusively by fragments; ventral and dorsal interiors are typical of *Eomegastrophia.* The only complete shell recovered is an articulated individual 19.5 mm in width, 18.2 mm in length, and about 7 mm in depth. Maximum width represented by fragmentary valves is about 35 to 40 mm. Parvicostellate ornament varies; at one extreme, strong, rounded first-order costae are separated by 2 to 5 smaller, second-order costae. At the other extreme, intercalated costae rapidly increase in size to produce only a single rank of costae. This variation is sometimes apparent on the same shell. Three to 4 costae are present within a space of 1 mm.

This species is similar to *M.* (*E.*) *acanthoptera* (Whiteaves, 1891) and *M.* (*E.*) *paskoiacensis* (Stearn, 1956), from Aeronian and Telychian strata of the Hudson Bay region (Jin et al., 1993), and *M.* (*E.*) *geniculata* (Waite, 1956), from the Telychian and early Wenlock of Nevada (Sheehan, 1982). The Burnt Bluff material differs from *M.* (*E.*) *acanthoptera* in its more variable and coarser costae and in its apparent lack of cardinal spines. It closely resembles *M.* (*E.*) *geniculata* in ornament, which shows the same variation discussed above, but also differs in apparent lack of cardinal spines. *Megastrophia* (*Eomegastrophia*) sp. differs from *M.* (*E.*) *paskoiacensis* in its larger size and partly differentiated parvicostellate ornament.

Occurrence. - Byron Formation (BA2): 30516, 3PV, 2BV; Hendricks Formation (BA2): 30502, 13PV, 2BV, 5A; 30506, 2PV, 3BV, 1A.

Family Chilidiopsidae Boucot, 1959
Genus *Morinorhynchus* Havlicek, 1965

Morinorhynchus korinai n. sp.

Pl. 1, figs. 13-17

Holotype. – MPM28519, sample 30502, Hendricks Formation, Fayette (Pl. 1, figs. 13-14).

Paratypes. – MPM28520, 28535, 28542.

Derivation of name. - For Korina Butler of West Allis, Wisconsin.

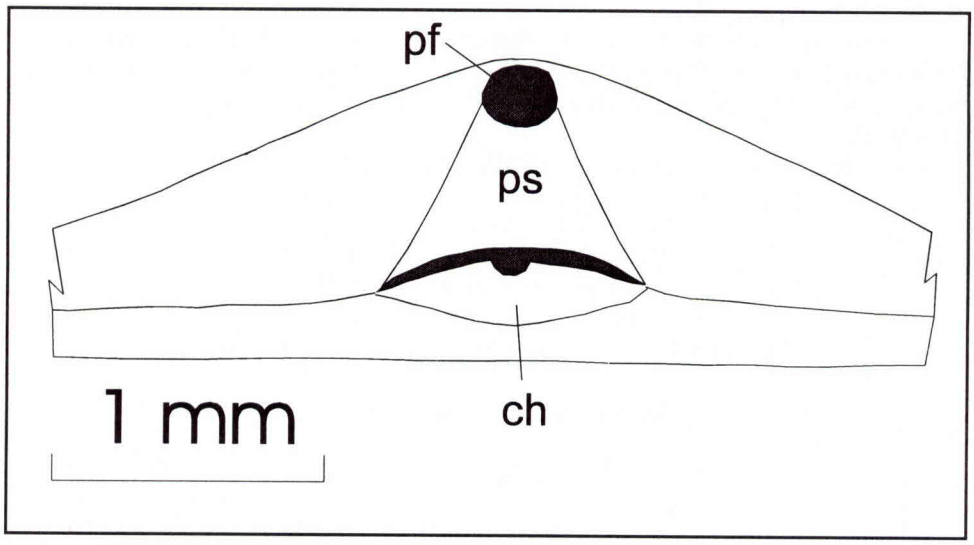

Fig. 5. *Morinorhynchus korinai* n.sp., detail of cardinal area showing chilidium (ch), pedicle foramen (pf) and pseudodeltidium (ps); based on camera lucida drawing of MPM28542.

Description. - Shell small, planoconvex, outline subcircular, cardinal extremities angular, maximum width at or just anterior to hingeline. Length to width ratio ranges from 1:1.3 to 1:1.6. Complete valves 3 to 5 mm in width, but fragmentary specimens suggest maximum width of about 10 mm. Ventral valve slightly to moderately convex, with convexity most prominent in umbonal region. Ventral interarea low, planar, triangular, apsacline, width about 8 to 10 times greater than height. Delthyrium covered by externally convex pseudodeltidium, with pedicle foramen present at apex (Fig. 5). Dorsal valve flat, in some shells with very minor convexity in umbonal region. Dorsal interarea catacline to anacline, very low, almost linear. Chilidial plates small, separate. Costae high, rounded, separated by wider and flatter interspaces, increasing anteriorly by intercalation. Intercalated costae initially smaller, producing a parvicostellate pattern in some shells, but quickly attaining same size as surrounding costae; 3 to 4 costae per 1 mm present at anterior margin. Concentric growth lines closely-spaced, equally developed over both costae and interspaces.

Ventral interior with short, well-developed hinge teeth, triangular in dorsal outline. Dental plates short, laterally-directed, extending anteriorly only about half the length of teeth. Denticular cavities excavated below hinge. Ventral muscle field not impressed. Dorsal interior with posteriorly-directed, bilobed cardinal process. Notothyrial platform very poorly-developed to absent. Socket ridges well-developed, widely-divergent, curved posteriorly at their distal ends; sockets elongate, moderately deep. Dorsal muscle field not impressed.

Discussion. - *Morinorhynchus* has not been previously described below the Wenlock. *Morinorhynchus korinai* n.sp. differs from most other species of *Morinorhynchus* in its combination of small size and planoconvex profile. *Morinorhynchus korinai* is similar to *M. subcarinatus* Johnson et al., 1976, a planoconvex species from the Ludlow of Nevada, but it differs in its lack of a median sulcus in the brachial valve and lack of a subcarinate profile in the pedicle valve.

Occurrence. - Byron Formation (BA2): 30516, 7PV, 5BV, 1A; Hendricks Formation (BA2): 30484, 1PV, 2BV, 10A; 30502, 6PV, 8BV.

Order Pentamerida Schuchert & Cooper, 1931
Family Virgianidae Boucot & Amsden, 1963
Genus *Brevilamnulella* Amsden, 1974

Brevilamnulella doorensis n. sp.

Pl. 1, figs. 18-19; Pl. 2, figs. 1-11

Holotype. – MPM28536, sample 30407, Byron Formation, The Big Quarry (Pl. 2, figs. 1-4).

Paratypes. – MPM28537, 28538, 28539, 28540, 28541.

Derivation of name. – For Door County, Wisconsin.

Description. - Shell small to medium sized, outline slightly transverse, biconvex, with ventral valve more convex than dorsal valve; commissure rectimarginate. Width greater than length, with length to width ratio ranging from 1:1.01 to 1:1.35 (Table 1, Fig. 6); maximum width developed near midpoint of length. Largest specimen is a dorsal valve 23.7 mm in width; most specimens, however, are smaller than 14 mm (Fig. 3). Ventral beak more prominent than dorsal beak; small ventral palintrope variably developed. Shell exterior smooth, with few concentric growth lines.

Ventral interior with spondylium restricted to posterior one fourth of valve, supported in its posterior half by small median septum; each contact of spondylium with hingeline marked by a small tooth. Dorsal interior with thin, anteriorly divergent crus that are overlain by thick inner plates. Inner plates may coalesce to form a small, platform-like area in front of the beak, or they may be separated by a V-shaped trough, with all gradations between. Outer plates fused with secondary shell material as a small raised area at posterior extremity of valve, supporting only the posterior part of crus. In a few specimens, the anterior portions of outer plates are discrete. A low median ridge extends anteriorly from outer plates for about half the length of valve, flanked by shallow adductor scars.

Discussion. - *Brevilamnulella* n. sp. is comparable to *B. thebesensis* (Savage, 1913), as redescribed by Amsden (1974), and *B. undatiformis* Rozman, 1978, but it differs from both in its lack of a fold and sulcus, less conspicuous inner plates, and presence of a low median ridge in the dorsal interior. *Brevilamnulella thebesensis* and *B. undatiformis* occur in strata of early Llandovery age in mid-continent North America and central Siberia, respectively.

Occurrence. - Byron Formation (BA2): 30407, 79PV, 171BV, 1A; Hendricks Formation (BA2): 30484, 6PV; 30502, 5PV, 6BV; 30506, 49PV, 53BV; 30510, 3PV, 1BV.

TABLE 1. Measurements of *Brevilamnulella doorensis* n.sp.

Sample	valve	Width (mm)	Length (mm)
30506	PV	20.5	20.2
30506	BV	23.7	17.5
30407	PV	14	12
30407	PV	8.7	8.5
30407	PV	10.7	10.5
30407	PV	9.4	7.8
30407	PV	9.7	10.2
30407	PV	7.2	6.5
30407	PV	11.8	8.9
30407	BV	13.3	12.6
30407	BV	11.4	10.1
30407	BV	18.1	15.5
30407	BV	12.8	11.6
30407	BV	9.8	8.5
30407	BV	12.9	10.6
30407	BV	9.3	8.7
30407	BV	8.8	7.2
30407	BV	9.4	8.5

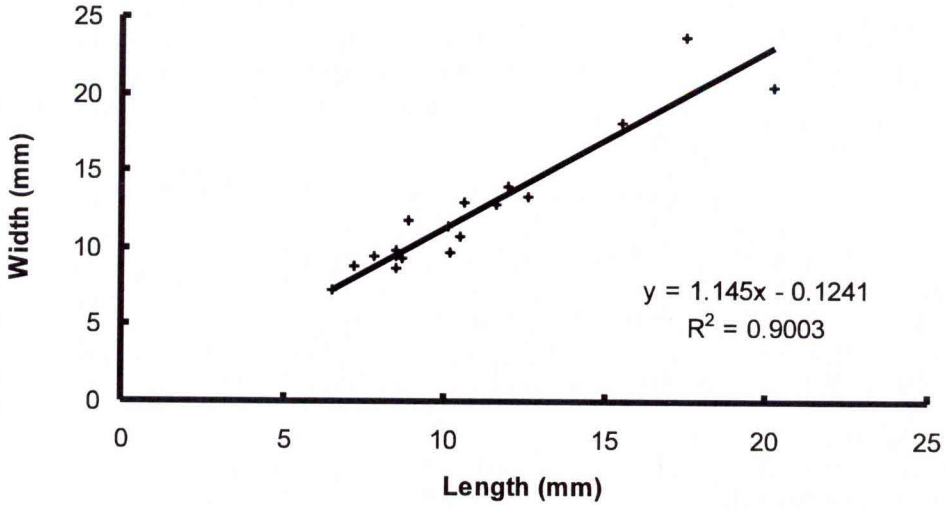

Fig. 6. Scatter diagram plotting width to length of 18 specimens of *Brevilamnulella doorensis* n.sp.

Order Rhynchonellida Kuhn, 1949
Family and Genus uncertain

indeterminate rhynchonellide

Pl. 3, fig. 14

Discussion. – A single elongate ventral valve, 7.6 mm in length, has the general form of *Rhynchotreta* but is generically indeterminate.

Occurrence. – Byron Formation (BA2); 30407, 1PV.

Family Trigonirhynchiidae McLaren, 1965
Genus *Hercotrema* Jin, 1989

Hercotrema winiskensis (Whiteaves, 1906)

Pl. 3, figs. 19-20

Camarotoechia(?) *Winiskensis* Whiteaves, 1906, p. 272, pl. 25, figs. 5-6.
Camarotoechia winiskensis Whiteaves, Stearn, 1956, p. 104, pl. 11, fig. 7.
Camarotoechia winiskensis Whiteaves, Ehlers, 1973, pl. 11, figs. 1-12, pl. 17, figs. 7-8.
Hercotrema winiskensis (Whiteaves), Jin et al., 1989, p. 36, pl. 2.8, figs. 12, 13, 16-23.
Hercotrema winiskensis (Whiteaves), Jin et al., 1993, p. 59-61, pl.15, figs. 1-20.

Discussion. - *Hercotrema winiskensis* (Whiteaves) is known from Aeronian to Telychian strata of the Hudson Bay region (Jin et al., 1993). Shells from the Burnt Bluff Group reach 11 mm in width; see Fig. 3 for size-frequency distribution.

Occurrence. - Byron Formation (BA2): 30407, 2PV, 4BV, 1A; 30516, 8PV, 20BV, 11A; Hendricks Formation (BA1): 30450, 7PV, 6BV, 6A; 30491, 4PV, 6BV, 5A; 30492, 6PV, 1BV, 9A; (BA2): 30455, 5PV, 6BV, 5A; 30484, 1PV, 3BV, 11A; 30502, 9PV, 23BV, 25A; 30506, 1BV, 2A; 30510, 8PV, 19BV, 17A.

Order Atrypida Rzhonsnitskaya, 1960
Family Atrypidae Gill, 1871
Genus *Alispira* Nikiforova, 1961

Alispira lowi (Whiteaves, 1906)

Pl. 3, figs. 15-18

Rhynchospira lowi Whiteaves, 1906, p. 277, pl. 25, figs. 8-9.
Rhynchospira lowi Whiteaves, Ehlers, 1973, pl. 11, figs. 13-19, pl. 21, fig. 12.
Alispira lowi (Whiteaves), Jin & Norford, 1992, p. 790-793, pl. 4, figs. 1-10, 13, 14.
Alispira lowi (Whiteaves), Jin et al., 1993, p. 70-72, pl. 18, figs. 1-22, pl. 31, figs. 11, 16.

Discussion. – Assignment of Burnt Bluff material to *Alispira* is based on presence of a horizontal cardinal plate bridging the crural plates in the dorsal interior. A cardinal cavity is

also present beneath the horizontal plates. *Alispira lowi* (Whiteaves) is known from Aeronian strata of the Hudson Bay region (Jin et al., 1993). Shells from the Burnt Bluff Group reach 10 mm in length and are identical to illustrated Canadian specimens of this species. See Fig. 3 for size-frequency distribution.

Occurrence. - Byron Formation (BA2): 30407, 4PV, 3BV, 14A; 30516, 52PV, 97BV, 122A; Hendricks Formation (BA1); 30450, 19PV, 10BV, 15A; 30451, 1PV, 1BV, 4A; 30457, 1A; 30458, 1BV; 30462, 3PV, 1BV; 30491, 9PV, 8BV, 7A; 30492, 14PV; 13BV, 3A; (BA2): 30455, 14PV, 16BV, 5A; 30484, 16PV, 10BV, 66A; 30502, 52PV, 118BV, 145A; 30506, 18PV, 29BV, 12A; 30510, 19PV, 38BV, 39A; 30515, 1A.

Order Athyridida Boucot, Johnson and Stanton, 1964
Superfamily Meristelloidea Waagen, 1883

Fayettella n.gen.

Derivation of name. – For the former town of Fayette, Michigan.

Type species. – *Fayettella peninsulensis* n.gen.&sp.

Diagnosis. – Shell biconvex, rostrate, smooth; astrophic hinge line. Ventral interior with stout hinge teeth supported by short dental plates. Dorsal interior with prominent, spoon-shaped cardinal plate with medial cleft; cardinal plate bordered on each side by deep, elongate dental socket. Cardinal plate connected to valve floor by two crural plates, between which and beneath the cardinal plate is an open space or "tunnel." A median ridge extends posteriorly from tunnel, flanked by elongate, subparallel muscle scars. No data are available about the spiralium and jugum.

Discussion. – *Fayettella* n.gen. is assigned to the Meristelloidea, as recently diagnosed by Alvarez et al. (1998), on the basis of external form and lack of ornament, open delthyrium and dental plates in the ventral valve, and the peculiar dorsal cardinalia (discussed above). The meristelloid group that *Fayettella* most closely resembles is the subfamily Whitfieldellinae of the family Meristellidae. However, whitfieldellines are characterized by a short, shallow septalium that is partially covered and supported by a high and short median septum. The dorsal cardinalia of *Fayettella* do not have the morphology of a septalium. No family assignment of *Fayettella* is attempted here.

Fayettella peninsulensis n.gen.& sp.

Pl. 3, figs.1-13

Holotype. – MPM28522, sample 30502, Hendricks Formation, Fayette (Pl. 3, figs. 6-10).

Paratypes. – MPM28521, 28523, 28524, 28525, 28534.

Derivation of name. – For the Upper Peninsula of Michigan.

Description. – Shell small, subequally biconvex, with rectimarginate commissure; cardinal margin about 1/3 the dimension of maximum width. Rostrate, with shell outline elongate to less commonly subovate; length to width ratio ranges from 1:0.60 to 1:1.05(Table 2, Fig. 8), with maximum width developed near midpoint of length. Largest specimen is a ventral valve 11 mm in length, but specimens smaller than 5 mm predominate (Fig. 3). Ventral beak prominent, narrow and slightly to moderately curved, with triangular delthyrium. Dorsal beak small, strongly incurved, blocking only dorsal part of delthyrium. Shell exterior smooth, with

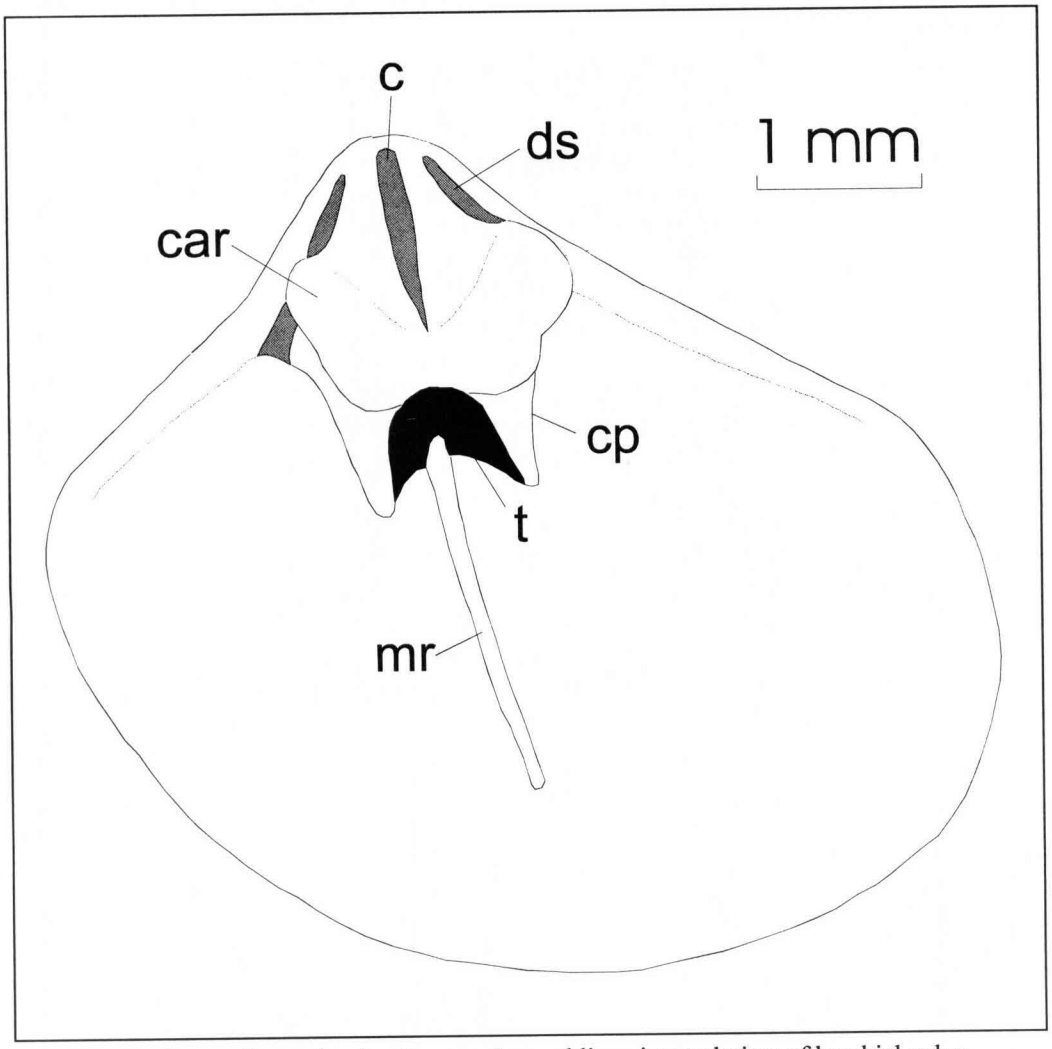

Fig. 7. *Fayettella peninsulensis* n.gen.&sp., oblique internal view of brachial valve, showing dental sockets (ds), cardinal plate (car), cleft in cardinal plate (c), crural plates (cp), "tunnel" beneath cardinal plate and between crural plates (t), and median ridge (mr). Based on tracing from photo of MPM28523 (see pl. 3, fig. 11).

few concentric growth lines. Ventral and dorsal interiors as described in diagnosis of genus. Internal features of the dorsal valve are shown in Fig. 7.

Discussion. – As for genus.

Occurrence. - Byron Formation (BA2): 30407, 69PV, 321BV, 105A; Hendricks Formation (BA2): 30484, 53PV, 92BV, 82A; 30502, 106PV, 178BV, 142A; 30506, 72PV, 70BV, 48A; 30515, 1PV, 1A.

TABLE 2. Measurements of articulated shells of *Fayettella peninsulensis* n.gen.&sp. from sample 30502.

Length (mm)	Width (mm)	Depth (mm)
5.7	5.2	3.3
7.8	7.1	4.7
4.4	3.6	2.6
6.1	6.2	3.7
5.1	3.7	2.8
4.6	3.2	2.1
5.2	4.1	2.9
5.9	4.5	3.5
3.3	2.5	1.9
3.9	2.7	1.9
4.2	3.3	2.1
6.8	5.2	3.7
3.9	2.8	1.8
4	4.2	2.2
2.8	2.1	1.5
3	2	1.5
4.3	3	2.5
4.6	3.1	2.7

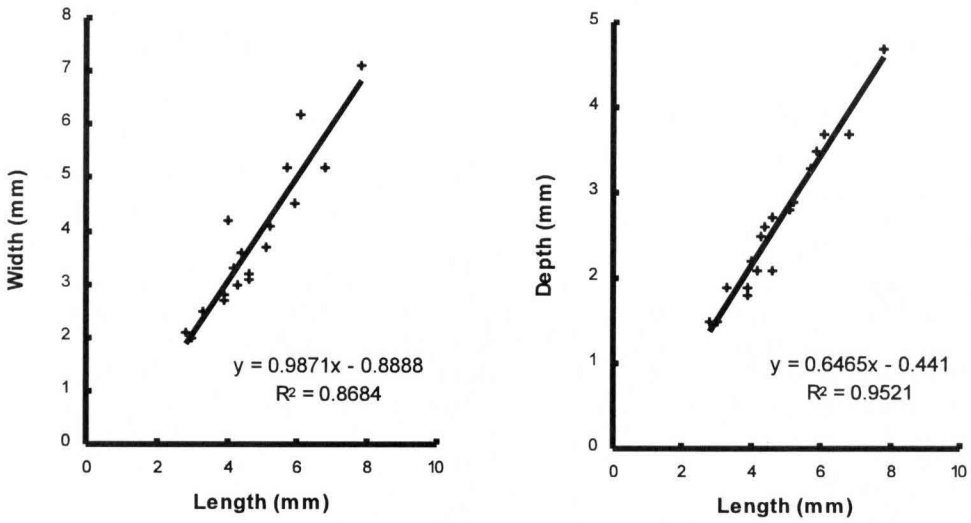

Fig. 8. Scatter diagrams plotting width to length and depth to length of 18 specimens of *Fayettella peninsulensis* n.gen.&sp. from sample 30502.

Order Spiriferida Waagen, 1883
Family Delthyrididae Phillips, 1861
Genus *Howellella* Kozlowski, 1946

?*Howellella* sp.
Spirifer (*Delthyris*) *crispus* Hisinger, Ehlers, 1973, pl. 17, fig. 9

Discussion. – Two small valves reach a width of 10 mm and have three plications on each flank; concentric growth lines are present but not prominent. Interiors have not been observed, and assignment to *Howellella* is uncertain.

Occurrence. - Hendricks Formation (BA2): 30455, 1PV, 1BV.

ACKNOWLEDGMENTS

J.J. Kuglitsch assisted with field work, P.M. Sheehan provided access to his brachiopod library, A.J. Boucot gave advice concerning the new genus *Fayettella*, and Leo Johnson printed photos in Plates 1-3. I am also grateful to F. Alvarez and J. Jin for very helpful reviews of the manuscript.

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APPENDIX 1: DESCRIPTION OF LOCALITIES

The localities described below are shown in Fig. 1.

The Big Quarry: N 1/2 sec. 13, T28N, R25E, Door Co., Wisconsin; located on east side of Highway B about 13 km northwest of Sturgeon Bay. Equivalent to locality TBQ2 of Harris and Waldhuetter (1996), who show its detailed location on their figure 32; also equivalent to locality 6 of Watkins and Kuglitsch (1997). Stratigraphic relations are shown in Fig. 2. Sample 30407 was taken in the Byron Formation at 16.0 to 16.3 m in measured section of Harris and Waldhuetter (1996, p. 84). Sample 30484 was taken in the upper part of the Hendricks Formation at top of highwall at 38.5 to 38.9 m in measured section of Harris and Waldhuetter (1996, p. 89).

Boyer Bluff: NE1/4 sec. 23, T34N, R29E, Door Co., Wisconsin; located at northwest tip of Washington Island. Equivalent to locality BB1 of Harris and Waldhuetter (1996), who show its detailed location on their figure 31; also equivalent to locality 5 of Watkins and Kuglitsch (1997). Sample 30516 was taken in the Byron Formation at the top of the cliff at 14.5 to 16.6 m in measured section of Harris and Waldhuetter (1996, p. 77). This bed is equivalent to unit 12 of Shrock (1940).

Fayette: SW1/4 sec. 33, T39N, R19W, Delta Co., Michigan; located in Middle Bluff, Fayette State Park. Equivalent to locality 37 of Ehlers (1973), who shows its detailed location on his map 5; also equivalent to locality 4 of Watkins and Kuglitsch (1997). Stratigraphic relations of samples 30502, 30506, 30510 and 30515 in the Hendricks Formation are shown in Fig. 2.

Hendricks Quarry: NW1/4 sec. 6, T44N, R8W, and NE1/4 sec. 1, T44N, R9W, Mackinac County, Michigan. Equivalent to locality 78 of Ehlers (1973), who shows its detailed location on his maps 1 and 10; also equivalent to locality 2 of Watkins and Kuglitsch (1997). Section measured in SE wall of quarry and shallow pit on NE side of quarry consists of 7.3 m of Hendricks Formation. Samples taken from beds with BA1 ostracod biofacies (with stratigraphic distance above base of section in parenthesis) include 30491 (0.3 m), 30492 (0.5 m), 30450 (0.6 m), 30451 (2.1 m), 30457 (6.8 m), and 30458 (7.3 m). Sample 30455 from bed with BA2 stromatoporoid-coral biofacies taken 4.7 m above base of section.

Fiborn Quarry: SW1/4 sec. 15, T44N, R7W, Mackinac County, Michigan. Equivalent to locality 80 of Ehlers (1973), who shows its detailed location on his maps 1 and 11; also equivalent to locality 1 of Watkins and Kuglitsch (1997). Section measured in north wall of quarry consists of 4.5 m of Hendricks Formation. Sample 30462 was taken from 1.3-m-thick bed with BA2 stromatoporoid-coral biofacies located 1.15 m above base of section.

Plates

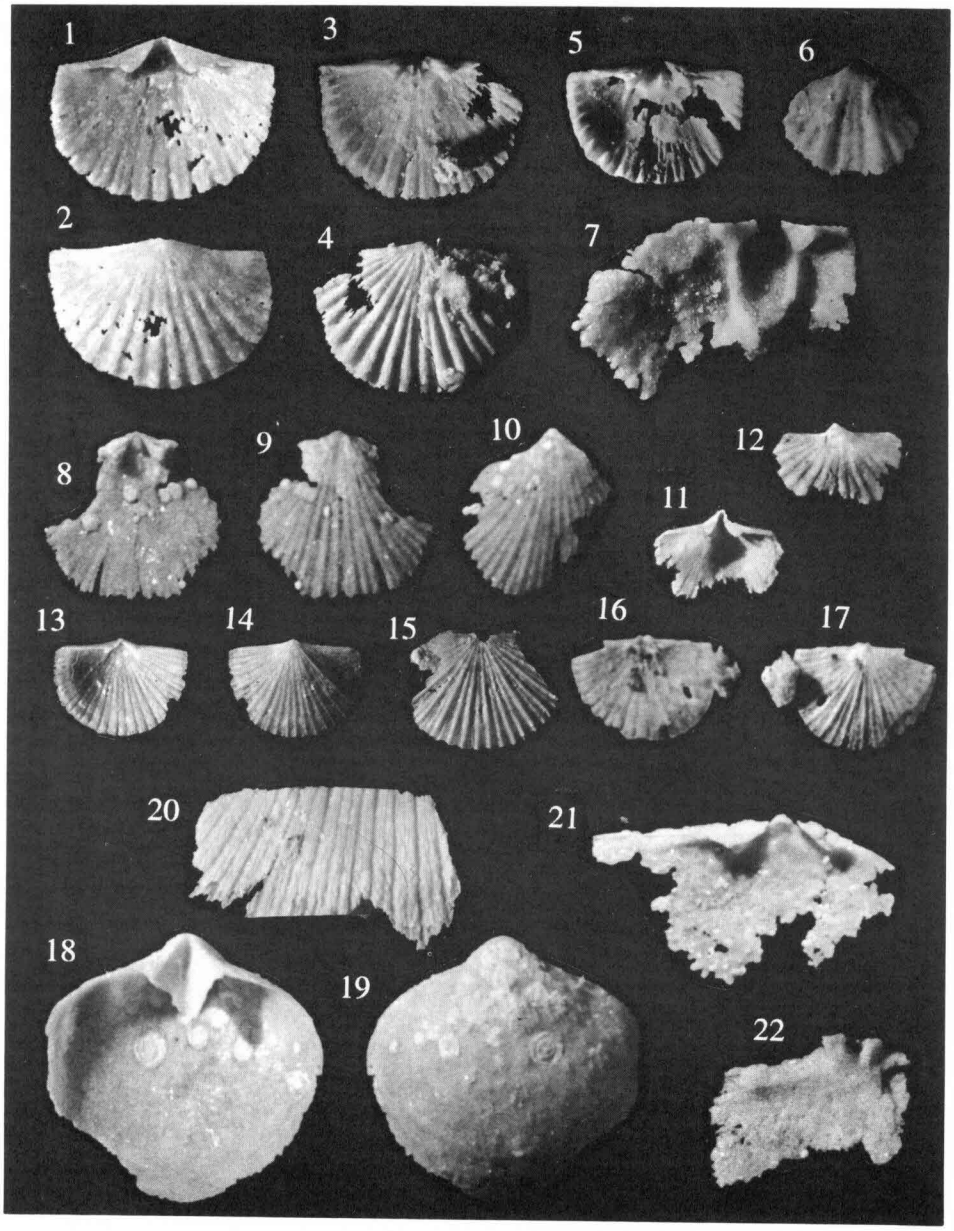
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PLATE 1

Hesperorthis davidsoni (de Verneuil):
1-4 from sample 30516, Byron Formation, Boyer Bluff; 5 from sample 30506, Hendricks Formation, Fayette. □1-2, internal and external views of pedicle valve, x4.5, MPM28509. □3-4, internal and external views of brachial valve, x4, MPM28510. □5, interval view of brachial valve, x4, MPM28511.

Gnamptorhynchos sp.:
Both x4, from sample 30407, Byron Formation, The Big Quarry. □6, external view of pedicle valve, MPM28512. □7, internal view of pedicle valve, MPM28513.

Dalejina cf. *D. striata* Jin et al.:
Both x4, from sample 30407, Byron Formation, The Big Quarry. □8-9, internal and external views of brachial valve, MPM28529. □10, external view of pedicle valve, MPM28530.

Salopina sp.:
□11-12, internal and external views of pedicle valve, x4.5, MPM28514, sample 30516, Byron Formation, Boyer Bluff.

Morinorhynchus korinai n.sp.:
All x4, 13-15 from sample 30502, Hendricks Formation, Fayette, 16-17 from sample 30516, Byron Formation, Boyer Bluff. □13-14, internal and external views of pedicle valve, holotype, MPM28519. □15, external view of brachial valve, MPM28520. □16-17, internal and external views of brachial valve, MPM28535.

Brevilamnulella doorensis n.sp.:
□18-19, internal and external views of pedicle valve, x3.5, MPM28538, sample 30407, Byron Formation, The Big Quarry.

Megastrophia (*Eomegastrophia*) sp.:
All from sample 30506, Hendricks Formation, Fayette. □20, detail of external ornament, x3, MPM28528. □21, internal view of pedicle valve, x3.5, MPM28533. □22, internal view of brachial cardinalia, x4, MPM28532.

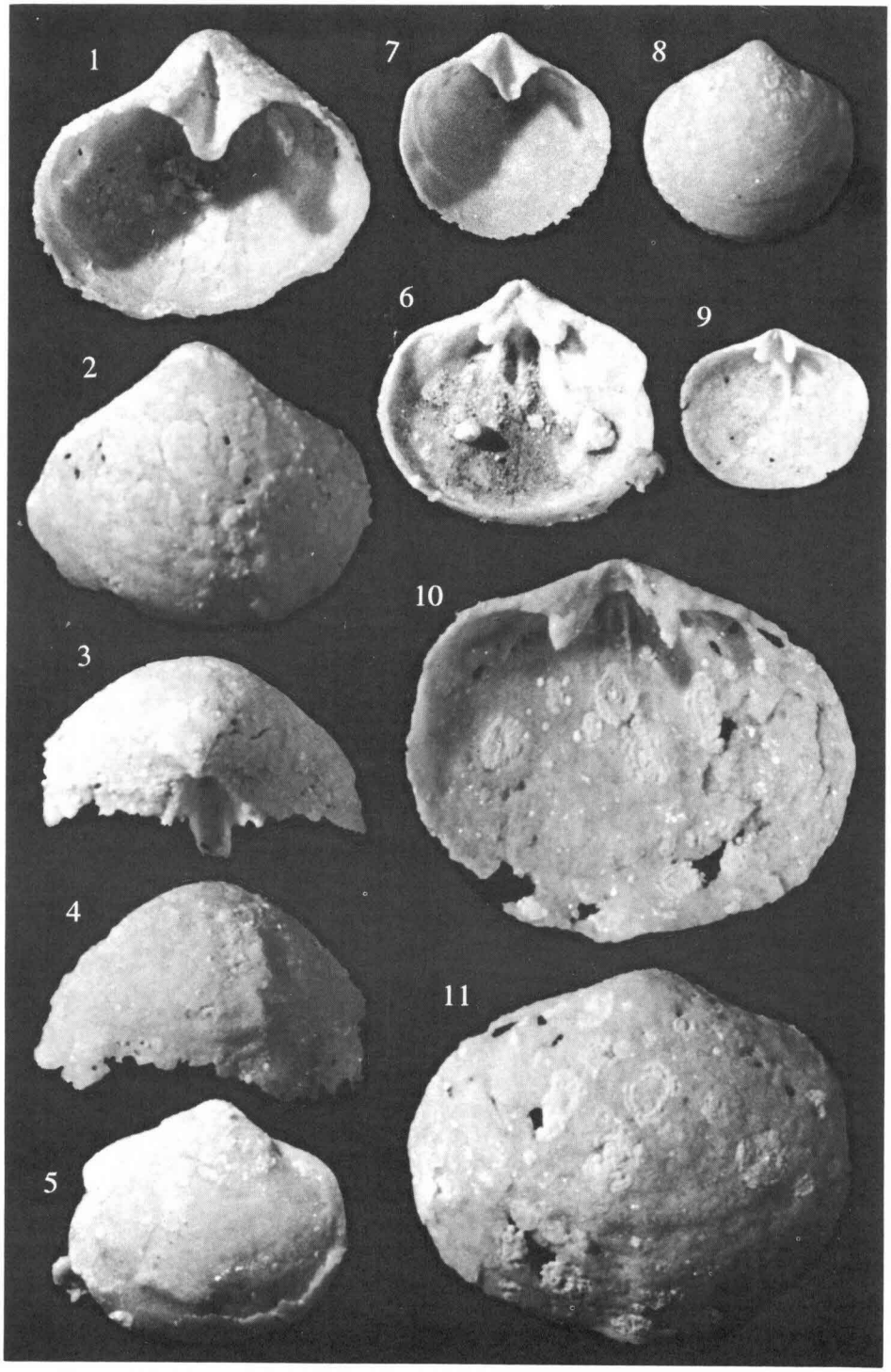
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PLATE 2

Brevilamnulella doorensis n.sp.:
All specimens x3.5, from sample 30407, Byron Formation, The Big Quarry. □1-4, internal, external, posterior and anterior views of pedicle valve, holotype, MPM28536. □5-6, external and internal views of brachial valve, MPM28539. □7-8, internal and external views of pedicle valve, MPM28537. □9, internal view of brachial valve, MPM28540. □10-11, internal and external views of brachial valve, MPM28541.

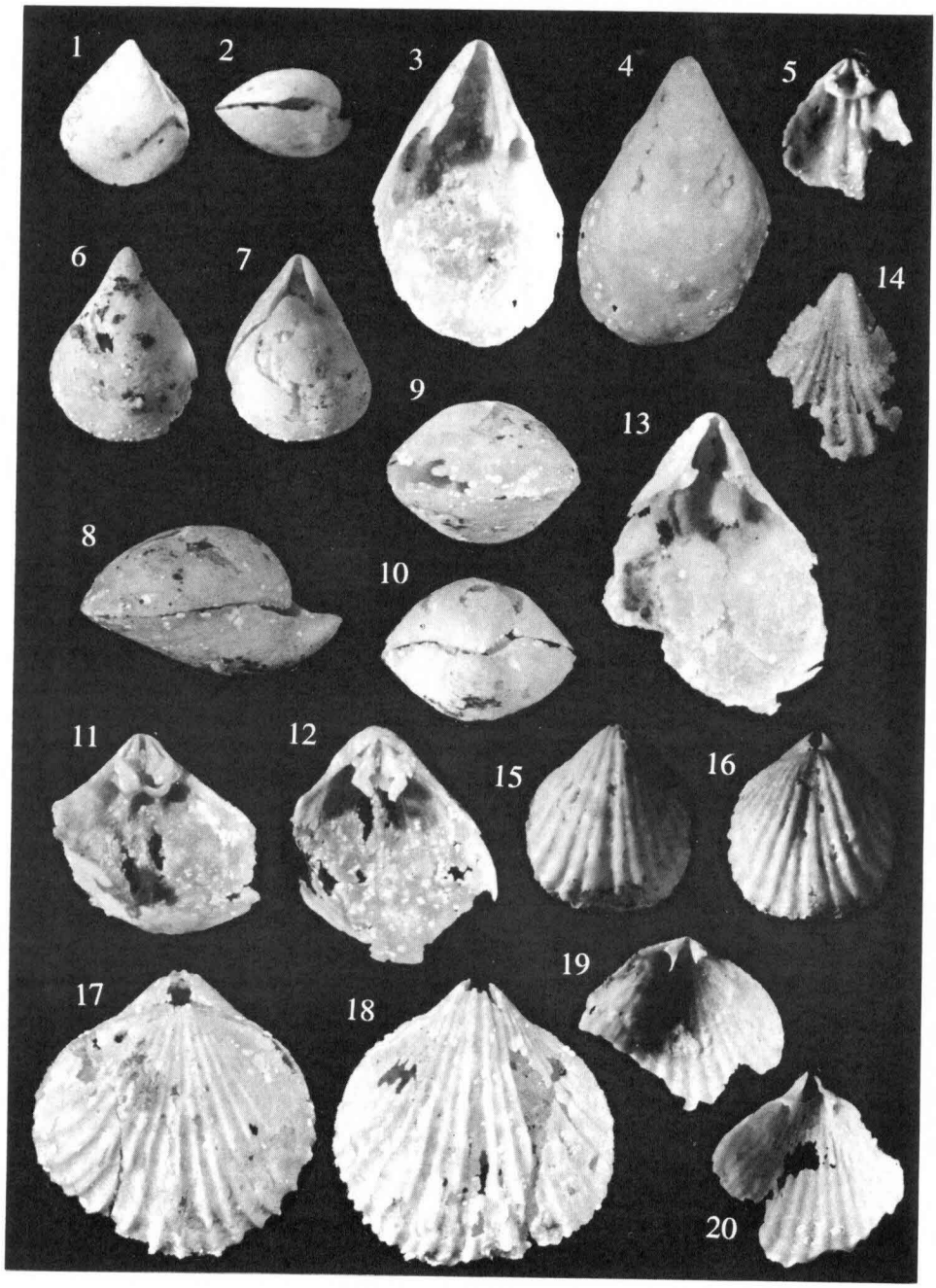
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PLATE 3

Fayettella peninsulensis n.gen.&sp.:
1-2 from sample 30516, Byron Formation, Boyer Bluff; 3-13 from sample 34502, Hendricks Formation, Fayette. □1-2, external and lateral views of shell, x3.5, MPM28534. □3-4, internal and external views of pedicle valve, x4.5, MPM28521. □5, internal view of brachial valve, x4, MPM28524. □6-10, ventral, dorsal, lateral, anterior and posterior views of holotype, 6-7 x4, 8-10 x5, MPM28522. □11-12, oblique internal and internal views of brachial valve, x5, MPM28523. □13, internal view of pedicle valve, x5, MPM28525.

Indeterminate rhynchonellide:
□14, external view of pedicle valve, x3.5, MPM28531, sample 30407, Byron Formation, The Big Quarry.

Alispira lowi: (Whiteaves):
□15-16, ventral and dorsal view of shell, x4, MPM28518, sample 30516, Byron Formation, Boyer Bluff. □17-18, dorsal and ventral view of shell, x5, MPM28515, sample 30502, Hendricks Formation, Fayette.

Hercotrema winiskensis (Whiteaves):
Sample 30510, Hendricks Formation, Fayette. □19, internal view of brachial valve, x4, MPM28526. □20, internal view of pedicle valve, x4, MPM28527.