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Wenlock *Rhipidium* Community and Conodont Fauna
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Rodney Watkins

Department of Geology
Milwaukee Public Museum
800 West Wells Street
Milwaukee, Wisconsin 53233

Jeffrey J. Kuglitsch

Department of Geology and Geophysics
1215 West Dayton Street
University of Wisconsin
Madison, Wisconsin 53706

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ABSTRACT

A small outlier of Silurian carbonates at Limestone Mountain, Houghton County, Michigan, includes a 1.9-m-thick section of Wenlock dolostone. Brachiopod packstone, bioturbated nodular mudstone and crystalgal-laminated mudstone in this section represent barrier, back-barrier and tidal-flat sediments deposited as a single transgressive cycle. The *Rhipidium* community occurs within packstone beds mainly as broken skeletal material that accumulated above wave base. Pentamerid brachiopods, represented by *Rhipidium (Pararhipidium) baragensis* n. sp., dominate the community, and favositids, solitary rugosans, other brachiopods, gastropods, and small crinoids are also present. The associated conodont fauna, which also shows evidence of depositional breakage and sorting, consists of six species and is dominated by *Panderodus unicostatus*.

INTRODUCTION

Limestone Mountain, Michigan, includes a small outlier of Silurian carbonates located 190 km northwest of the Silurian outcrop belt along Lake Michigan (Fig. 1). Regional setting of the outlier and previous geologic studies were summarized by Milstein (1987). The Silurian section at Limestone Mountain is only a few meters thick, and it is significant as a record of several marine transgressions that extended beyond the margins of the Michigan Basin (Colville, 1983; Colville and Sheehan, 1983; Johnson, 1987). This paper is a study of the sedimentary occurrence and paleoecology of the pentamerid brachiopod community and conodont fauna that occur in a single transgressive cycle in the Wenlock part of the Limestone Mountain section. The pentamerid community, dominated by *Rhipidium (Pararhipidium) baragensis* n. sp., and the conodont fauna, dominated by *Panderodus unicostatus*, are both low diversity assemblages characteristic of shallow-marine, rough-water environments. Macrofossil collections discussed here are deposited in the Milwaukee Public Museum (MPM), and figured conodonts are deposited in the Geology Museum of the University of Wisconsin (UW).

STRATIGRAPHY

Case and Robinson (1914) published the first authoritative list of Silurian taxa from Limestone Mountain. These data were reevaluated by Milstein (1987: fig. 3), who recognized a Lower Silurian unit, assigned to the Lime Island Dolomite, and a disconformably overlying Upper Silurian unit, assigned to the Engadine Dolomite. In a more detailed study of the Silurian section, Colville (1983) recognized three stratigraphic units, a Middle Llandovery unit 1.3 m thick (with *Virgiana*), an Upper Llandovery unit 0.3 m thick (with *Pentameroides*), and a Wenlock or Ludlow unit 2.3 m thick (with *Rhipidium* in its lower part and *Harpidium* in its upper part). Colville (1983) also described disconformities and paleosols between each of these three units, which were not given formal names. Silurian outcrop at Limestone Mountain is very limited, and trenching is required to expose the complete section (Case and Robinson, 1914; Colville, 1983). This study is confined to Upper Silurian strata that represent the highest of Colville's three units, as exposed in a small road cut during the Fall of 1992 (Fig. 2). The section in this cut consists of 1.9 m of moderately to poorly indurated, buff-colored, fine-grained dolostone (Fig. 3) in which macrofossils occur as poorly-preserved molds. The lithology of this section does not resemble the Engadine Dolomite of the Lake Michigan area, as described by Ehlers (1973), and Silurian rocks at Limestone Mountain should probably be designated with one or more local lithostratigraphic names.

Age of section studied here

Most conodonts recovered from this section (Table 1) are long-ranging Silurian to Early Devonian taxa. However, *Walliserodus sancticlairi* ranges from Upper Llandovery (Upper Telychian) to Wenlock (Middle Homerian) in the Silurian composite standard section of Kleffner (1989). The brachiopod subgenus *Rhipidium* (*Pararhipidium*) is known from strata of Middle Wenlock to Ludlow age (Boucot and Johnson, 1979). The co-occurrence of *W. sancticlairi* and *R. (Pararhipidium)* is considered to indicate a Wenlock age for the section described in this report.

SEDIMENTOLOGY

The measured section contains three lithologic divisions (Fig. 3). The lower 1.3 m of the section consists of packstone beds 20 to 85 cm thick. Beds are mainly massive and uniform in texture, but lenses of wackestone to 8 cm thick are locally present. The matrix consists of fine-grained dolomite and disseminated sand-grade skeletal fragments. Larger bioclasts, consisting mainly of pentamerids and corals, form 30 to 39 percent of sediment volume. These bioclasts reach 75 mm in size and are loosely packed and self-supporting. Also present are rounded, lath-shaped intraclasts of dolomite mudstone that reach 80 mm in size. The highest packstone bed is overlain by 0.5 m of mudstone that consists of nodular areas of dull white, fine-grained dolomite in a matrix of brown, very fine-grained dolomite. Scattered chert nodules to 12 cm in size are also present. The nodular mudstone includes discontinuous, irregular parting surfaces at 5 to 10 cm stratigraphic intervals. Small crinzoan ossicles comprise less than 1 percent of sediment volume. The section appears to be capped by a 6-cm-thick bed of parallel-laminated dolomite mudstone, as indicated by a limited area of distinctive float within soil immediately overlying the nodular mudstone unit. Laminae within this 6 cm bed are of cryptalgal origin, ranging from flat to wavy and having an average thickness of 0.4 mm. No bioturbation or skeletal material were observed in this bed.

Interpretation

Lithologies and stratigraphic relations in this section suggest an environmental progression from barrier (packstone beds) to back-barrier (nodular mudstone) to tidal-flat (laminated mudstone). The section represents a single transgressive-regressive cycle. Transgressive conditions are represented by the lower part of the packstone interval, which, as discussed above, probably overlies a disconformable surface on Lower Silurian strata. The upper part of the packstone interval and overlying mudstones represent a regression from subtidal to tidal-flat conditions.

THE RHIPIDIUM COMMUNITY

Taphonomy

Rhipidium (*Pararhipidium*) *baragensis* n. sp., the dominant species within packstone beds, occurs mainly as broken pedicle valves. Specimens from five samples include 1039 pedicle valves, 23 brachial valves, and no articulated shells. Broken valves represent over 90 percent of specimens. Tabulate corals have been recorded as one complete colony and 42 colony fragments. The solitary rugosan within the fauna occurs as both complete and broken corallites. Crinzoan remains consist exclusively of disarticulated ossicles. Skeletal material in the packstone beds shows very poor size-sorting and very little preferred orientation. Skeletal material ranges from sand-sized bioclasts to 75-mm tabulates, and no grading or other internal patterns of size distribution are apparent in the packstone beds. Pentamerid valves range from about 5 mm to 44 mm in length. Long axes of bioclasts are oriented subparallel to bedding

in some areas, but orientations are variable in most parts of beds, and pentamerid valves are about equally oriented in convex-up and convex-down positions.

The skeletal fauna preserved in the packstone beds lived in a setting above wave base where skeletal material was broken and moved as bedload. However, no significant mixing of taxa from different life associations is apparent, as the association of pentamerids, corals and crinozoan ossicles in the packstone beds is identical to the composition of pentamerid communities from many other Silurian shelf deposits (Ziegler et al., 1968; Amsden, 1969; Boucot, 1975; Johnson, 1980; Sheehan, 1980; Watkins and Aithie, 1980).

Faunal composition

Using the guild concept employed by Watkins (1991), seven guilds can be recognized in the community, including tabulates (two species), solitary rugosans (one species), inflated free-lying pentamerids (one species), biconvex pedunculate brachiopods (one species), weakly biconvex pedunculate brachiopods (one species), gastropods (one species), and crinozoans (at least one species). In packstone samples prepared with a rock splitter, *Rhipidium* (*Pararhipidium*) *baragensis* n. sp. comprises 87 percent of specimens (Fig. 3), but it is less abundant when point count data are considered. In polished slabs, a count of 224 skeletal points from three samples yielded 61.2% pentamerids, 21.4% rugosans, 15.6% crinozoans and 1.8% tabulates. These figures represent the bulk skeletal composition of the community. Tabulates are represented by two species. Favositid sp. 1 (Pl. 2, fig. 3) is characterized by corallites to 1 mm in diameter; colonies range from domical to irregular, branching shapes and reach breadths of 75 mm and heights of about 40 mm. Favositid sp. 2 (Pl. 2, fig. 4) is characterized by corallites to 3 mm in diameter and occurs as fragments of domical colonies to 52 mm in breadth and 12 mm in height. One colony of favositid sp. 2 encrusts a pentamerid valve, but most colonies were probably free-living. Rugosans are represented by a single species of streptelasmatic (Pl. 2, fig. 5). This rugosan is the second most common species in the community (Fig. 3) and reaches a maximum size of 45 mm.

Brachiopods include the community dominant, *Rhipidium* (*Pararhipidium*) *baragensis* n. sp. (Pl. 1; Pl. 2, figs. 1, 2), as well as an enteletacean (Pl. 2, fig. 7) and a rhynchonellide (Pl. 2, fig. 6). The later two species are rare and 11 mm or less in size. One species of pleurotomariacean gastropod is represented by a single specimen 15 mm in size. Crinozoan ossicles reach a maximum size of 1 mm and may represent a single small species.

Tiering

Relatively little tiering was present among skeletal epifauna. *Rhipidium* (*Pararhipidium*) *baragensis* n. sp. could have lived with its commissure no more than 30 to 40 mm above the bottom, and other brachiopods probably fed within a few millimeters of the bottom. The largest rugosans probably fed at a maximum height of about 25 mm, and favositids reached maximum heights of about 40 mm. The crinoid ossicles suggest small individuals that stood no more than 50 to 60 mm high.

CONODONT FAUNA

Dissolution of 40.9 kg of dolostone from three packstone samples and one nodular mudstone sample yielded 210 condont elements and 151 fragments. Mean yield of samples is low, with an average of 8.8 elements and fragments per kg. Five genera and six species are represented (Table 1). The fauna is dominated by *Panderodus unicostatus*, which represents 58 percent of recovered elements, and two species of *Ozarkodina*, which represent 30 percent of recovered elements. Other genera include *Oulodus*, *Pseudooneotodus*, and *Walliserodus*.

Barrick (1983) distinguished three Wenlock conodont biofacies in the Wayne Formation of Tennessee. These biofacies include a shallow-water, high-energy *Panderodus unicostatus* Biofacies, a quiet-water Mixed Biofacies, and an offshore *Dapsilodus obliquicostatus* Biofacies. The Limestone Mountain conodont fauna resembles the *Panderodus unicostatus* Biofacies in dominance by the nominal species, low species diversity, and low conodont abundance. Dominance of *Ozarkodina* is also characteristic of shallow-water conodont faunas. Barrick (1983) considered the *P. unicostatus* biofacies as characteristic of shallow, persistently agitated water, and he also inferred postmortem disturbance of the conodont assemblage.

Depositional sorting and breakage is also present in the Limestone Mountain conodont fauna. Pa elements are dominant among *Ozarkodina* sp. (68.6%) and rare among *Ozarkodina confluens* (3.3%), in contrast to predicted frequencies in biological species of the genus (18%). Jeppsson (1969, 1976) noted the susceptibility of *O. confluens* to sorting because of the variable shape of elements in its apparatus and the often robust nature of the Pa element. Postmortem disturbance is also indicated by the large number of conodont fragments and broken elements in the fauna. Many of the broken surfaces are rounded. This breakage does not appear to be due to the recovery process.

Taxonomic notes

Panderodus unicostatus (Branson and Mehl, 1933) (Pl. 3, figs 1-3), *Walliserodus sancti-clairi* Cooper, 1976 (Pl. 3, figs. 4-7), and *Ozarkodina confluens* (Branson and Mehl, 1933) (Pl. 4, figs. 1-5) are well-known, frequently described, multielement species. The multielement reconstruction of Cooper (1976) is followed for *W. sancti-clairi*. The lack of a costa on the inner lateral face of the Sc element of *W. sancti-clairi* (Pl. 3, fig. 4) is the sole feature distinguishing it from the older *W. curvatus*.

Only a single fragmentary Pa element of *Ozarkodina confluens* was recovered (Pl. 4, fig. 1). Jeppsson (1969) was able to assign many elements from collections from Scania and Gotland to *O. confluens* based solely upon the distribution of white matter within elements, a trait he considered the most significant characteristic common to elements assigned to the species. In his collections, the white matter of *O. confluens* elements "extends down into the process, leaving only a . . . narrow strip along the lower margin of the processes free from white matter" (Jeppsson, 1969: p. 17). The white matter of *O. confluens* elements recovered in this study is distributed in exactly this fashion (Pl. 4, figs. 1-5). In many of the elements, the denticles and white matter are partially overgrown by hyaline matter, another feature noted by Jeppsson (1969) as typical of *O. confluens*.

Ozarkodina sp. (Pl. 4, figs. 6-7) and *Oulodus* sp. (Pl. 3, figs. 9-12) are left in open nomenclature because the low number and poor preservation of recovered elements make specific assignment inappropriate. The Pa element of *Ozarkodina* sp. closely resembles the Pa element of *Ozarkodina excavata excavata* (Branson and Mehl, 1933), particularly in the extension of the basal cavity as a narrow groove beneath the anterior and posterior processes (Pl. 4, fig. 7). The Pb element assigned to *Ozarkodina* sp. has shorter anterior and posterior processes than those of *Ozarkodina excavata excavata* (Pl. 4, fig. 6).

Bischoff (1986) considered members of *Pseudooneotodus* to be unimembrate, and he distinguished several species among the forms previously assigned to *Pseudooneotodus beckmanni* (Bischoff and Sannemann, 1958). These distinctions are based on variations in the length to width ratio of the subtriangular outline of the basal margin and basal banding. A third of the base of the single recovered element of *Pseudooneotodus* is missing, making specific assignment uncertain. The recovered element (Pl. 3, fig 8.) appears closest to *P. beckmanni*.

CONCLUSIONS

The section described here is a single thin, transgressive-regressive cycle of Wenlock age. The base of this section, not observed during this study, represents flooding of a subaerial surface developed on Lower Silurian carbonates (Colville, 1983). This transgression may represent the late Sheinwoodian eustatic event recognized by Johnson et al. (1991, fig. 5).

Initial deposits of this transgression at Limestone Mountain are skeletal packstones indicative of moderate to high-energy conditions. The macrofauna within these packstones, dominated by *Rhipidium*, corals, and small crinozoans, is typical of Silurian pentamerid communities that lived in shelf areas above wave base. The associated conodont fauna represents a low diversity *Panderodus* biofacies that is also known from other rough-water, shallow-marine environments. Subsequent regression is represented by nodular mudstone of probable back-barrier origin that contains scattered crinozoan ossicles and a sparse, *Panderodus*-dominated conodont fauna.

SYSTEMATIC PALEONTOLOGY

Family Pentameridae McCoy 1844

Subfamily Pentamerinae McCoy 1844

Genus *Rhipidium* Schuchert and Cooper 1931

Subgenus *Pararhipidium* Boucot and Johnson 1979

Rhipidium (Pararhipidium) baragensis n. sp.

Plate 1, Figs. 1-5; Plate 2, Figs. 1-2.

Type material

Holotype: MPM 28390, internal and external mold of pedicle valve; Paratypes: MPM 28391, external mold of pedicle valve; MPM 28392, internal mold of pedicle valve; MPM 28393, external mold of pedicle valve; MPM 28394, external mold of brachial valve; MPM 28395, internal mold of brachial valve.

Name

For the Bishop Baraga Shrine, located east of Limestone Mountain.

Description

Biconvex, with pedicle valve about twice as convex as brachial valve; weakly trilobate, with low medial fold on pedicle valve and very low medial fold on anterior part of brachial valve. Maximum length of pedicle valve 44 mm, maximum width 36 mm; length:width of 7 pedicle valves ranges from 1:0.81 to 1:0.86. Beak of pedicle valve moderately incurved; delthyrium triangular, deltidium not observed. Costellae low, rounded, separated by U-shaped interspaces and increasing in number by bifurcation; seven to ten costellae occupy space of 10 mm, as measured about 30 mm anterior of beak. Concentric growth lines variably present.

Interior of pedicle valve with deep spondylium supported by median septum that occupies posterior third to quarter of valve length. Interior of brachial valves poorly preserved; subparallel outer plates merge smoothly with inner plates, but details of cardinal and hinge areas not observed.

Comparisons

Rhipidium (Pararhipidium) baragensis n. sp. differs from *R. (P.) tenuistriatum* (Lindström, in Angelin and Lindström, 1880) in its smaller size, less elongate shape, and better-developed medial fold on the pedicle valve. *Rhipidium (Pararhipidium) baragensis* n. sp. closely resembles *R. (P.) filicostatatum* Boucot, Johnson and Zhang (1988), but possesses a more incurved beak of the pedicle valve and a somewhat more elongate shape.

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TABLE 1.

Upper Silurian conodont fauna from measured section (Fig. 3) at Limestone Mountain.

| Conodonts | Interval above base of section (cm) | | | |
|---|-------------------------------------|-------|---------|---------|
| | 0-24 | 43-63 | 100-132 | 150-178 |
| <i>Panderodus unicostatus</i> (M) | 9 | 2 | 12 | 1 |
| <i>Panderodus unicostatus</i> (S) | 25 | 5 | 54 | 14 |
| <i>Panderodus unicostatus</i> fragments | 12 | 25 | 26 | 2 |
| <i>Walliserodus sancticlairi</i> (M) | 1 | — | 1 | — |
| <i>Walliserodus sancticlairi</i> (Sa) | — | 1 | 1 | — |
| <i>Walliserodus sancticlairi</i> (Sb) | — | 1 | — | — |
| <i>Walliserodus sancticlairi</i> (Sc) | — | 1 | — | — |
| <i>Pseudooneotodus</i> cf. <i>beckmanni</i> | — | — | 1 | — |
| <i>Ozarkodina confluens</i> (Pa) | — | — | 1 | — |
| <i>Ozarkodina confluens</i> (Pb) | 4 | 1 | 3 | 1 |
| <i>Ozarkodina confluens</i> (M) | 4 | 1 | 2 | 3 |
| <i>Ozarkodina confluens</i> (Sa) | 2 | — | — | — |
| <i>Ozarkodina confluens</i> (Sb) | 1 | — | — | — |
| <i>Ozarkodina confluens</i> (Sc) | 2 | — | — | 4 |
| <i>Ozarkodina</i> sp. (Pa) | 8 | 4 | 11 | 1 |
| <i>Ozarkodina</i> sp. (Pb) | 5 | 3 | 2 | — |
| <i>Ozarkodina</i> sp. (Sa/b) | — | — | 1 | — |
| <i>Oulodus</i> sp. (Pb) | — | — | 2 | — |
| <i>Oulodus</i> sp. (Sa) | 2 | — | 2 | — |
| <i>Oulodus</i> sp. (Sb) | 2 | — | 1 | — |
| <i>Oulodus</i> sp. (Sc) | 2 | — | 3 | 1 |
| indeterminate Sa element | — | — | — | 2 |
| indeterminate non-cone fragments | 24 | 17 | 38 | 7 |
| digested rock (kg) | 9.094 | 9.294 | 13.997 | 8.494 |
| elements per kg | 7.4 | 2.0 | 7.0 | 3.2 |
| elements + fragments per kg | 11.3 | 6.6 | 11.5 | 4.2 |

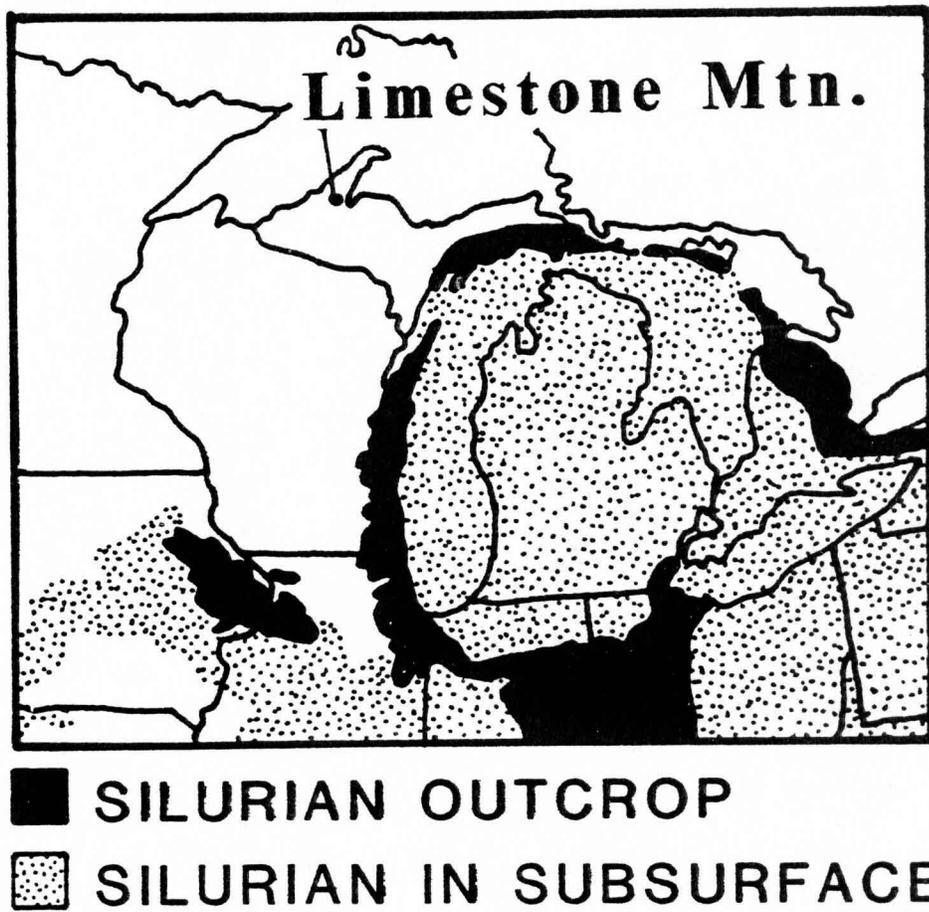


Fig. 1. Sketch map of Great Lakes region showing distribution of Silurian rocks and location of Limestone Mountain.

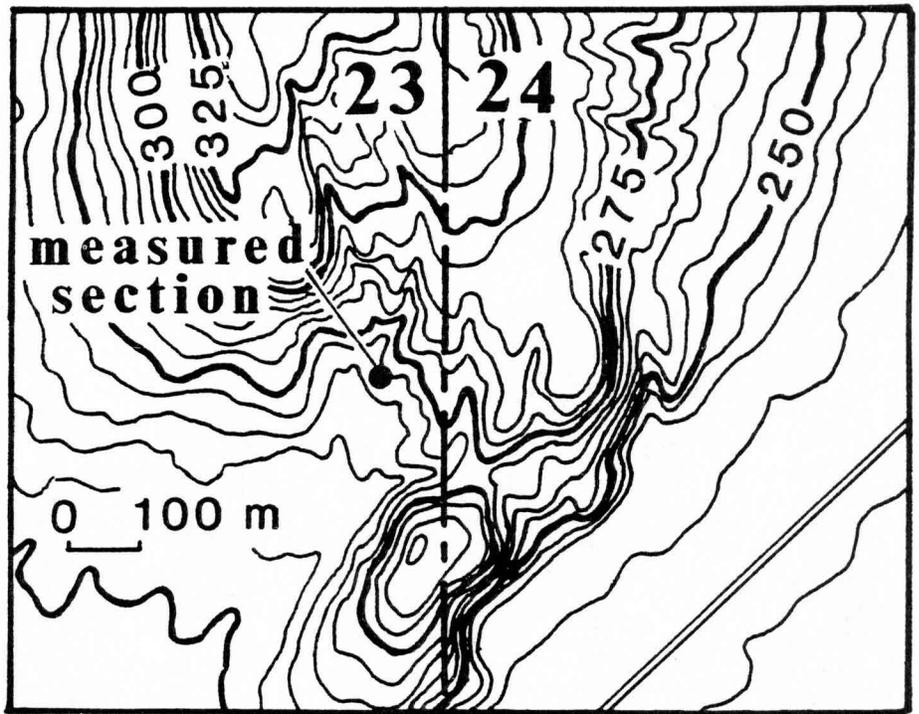


Fig. 2. Map of southern part of Limestone Mountain, Houghton County, Michigan, sections 23 and 24, T51N R35W, USGS Pelkie 7.5' quadrangle, showing location of measured section; contours in meters.

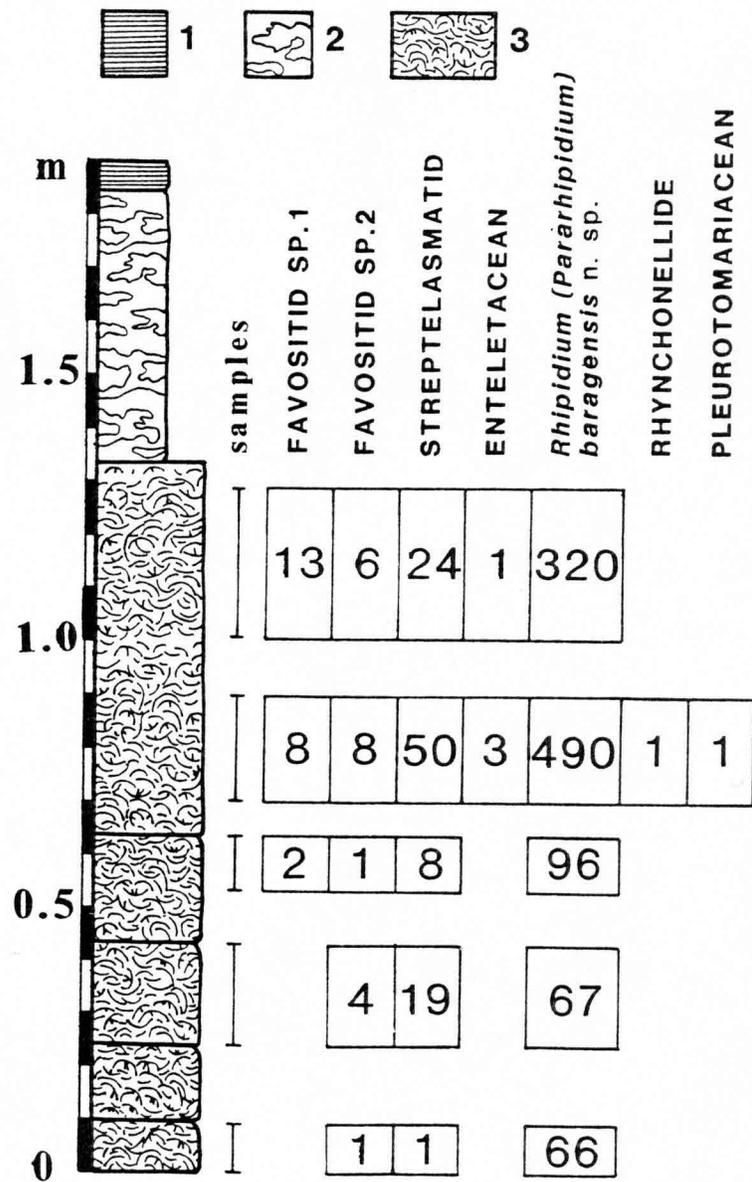


Fig. 3. Measured section of Upper Silurian dolostone showing macrofaunal data from samples prepared with a rock splitter. Numbers for favositids are colonies plus colony fragments; numbers for brachiopods are maximum number of either brachial or pedicle valves; numbers for streptelasmatic and pleurotomariacean are direct counts of individuals; crinozoan ossicles are also present in every sample.

1 - laminated mudstone. 2 - nodular mudstone. 3 - packstone.

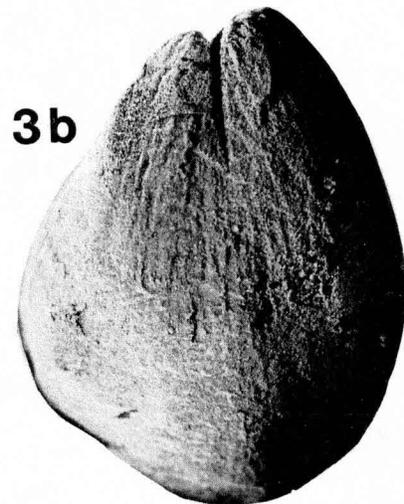
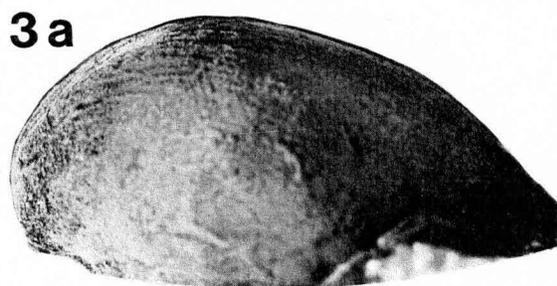
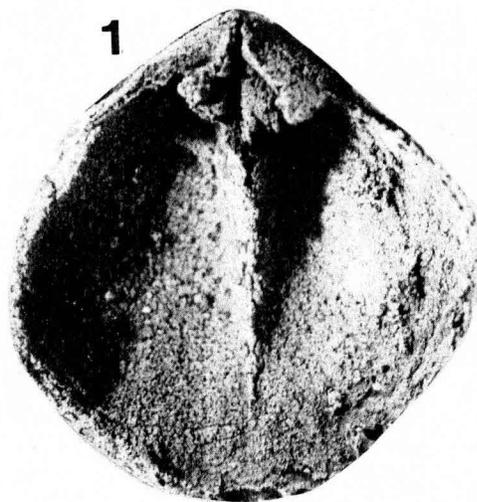


PLATE 1

Rhipidium (Pararhipidium) baragensis n. sp.

Fig. 1. MPM 28392, pedicle valve interior, latex cast, X 5.

Fig. 2. MPM 28391, pedicle valve exterior, latex cast, X 2.

Fig. 3. MPM 28390, internal mold of pedicle valve; a - lateral view X 1.6; b - ventral view, X 1.5.

Fig. 4. MPM 28395, interior of fragmentary brachial valve, latex cast, X 5.

Fig. 5. MPM 28393, beak area of pedicle valve, latex cast, X 3.

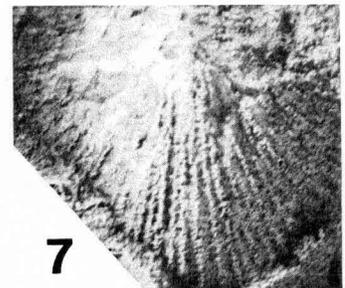
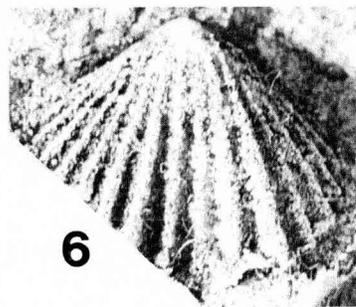
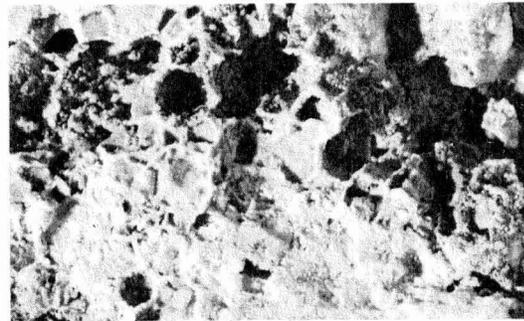
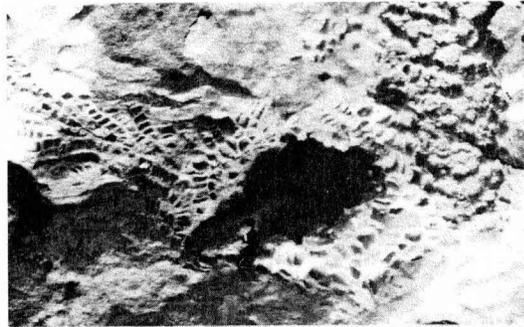
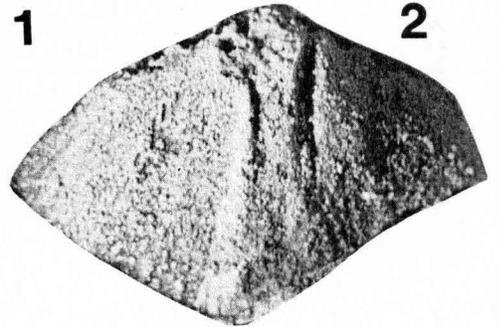
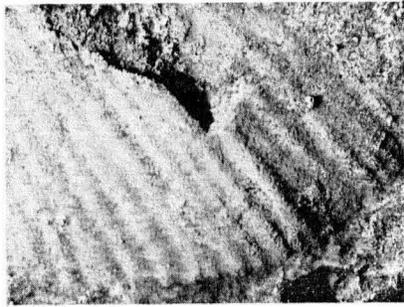


PLATE 2

- Fig. 1. *Rhipidium (Pararhipidium) baragensis* n. sp., MPM 28394, detail of brachial valve exterior, latex cast, X 3.
- Fig. 2. *Rhipidium (Pararhipidium) baragensis* n. sp., MPM 28401, internal mold of brachial valve, X 5.
- Fig. 3. favositid sp. 1, MPM 28399, X 2.
- Fig. 4. favositid sp. 2, MPM 28400, X 2.
- Fig. 5. streptelasmatid, MPM 28398, latex cast, X 3.
- Fig. 6. rhynchonellide, MPM 28397, pedicle valve exterior, latex cast, X 5.
- Fig. 7. enteletacean, MPM 28396, pedicle valve exterior, latex cast, X 4.

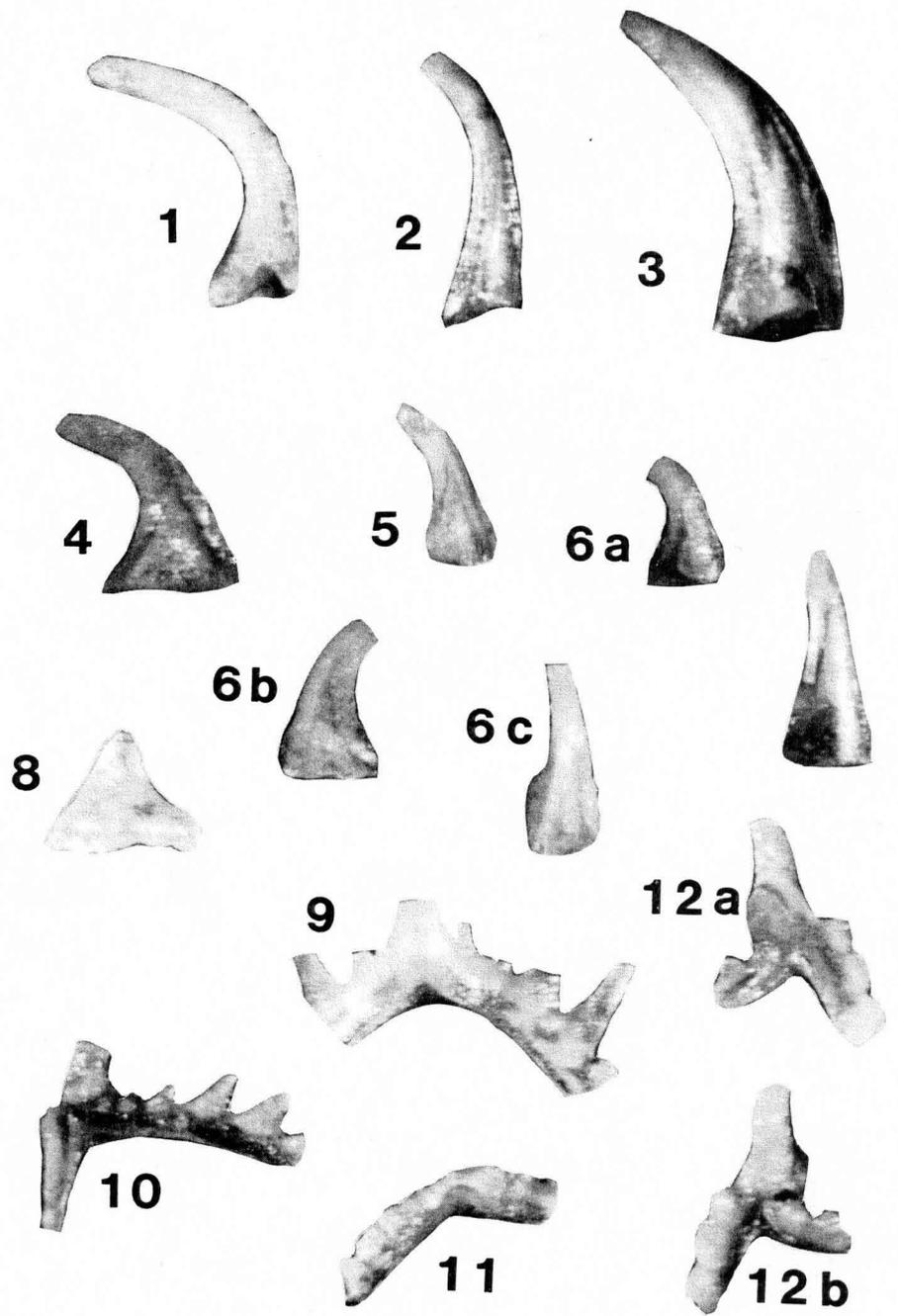


PLATE 3

- Fig. 1. *Panderodus unicastatus*, UW 4201-28, S element, obverse view, X 57.
- Fig. 2. *Panderodus unicastatus*, UW 4201-29, S element, obverse view, X 58.
- Fig. 3. *Panderodus unicastatus*, UW 4201-27, M element, obverse view, X 69.
- Fig. 4. *Walliserodus sancticlairi*, UW 4201-26, Sc element, inner lateral view, X 53.
- Fig. 5. *Walliserodus sancticlairi*, UW 4201-25, Sb element, outer lateral view, X 49.
- Fig. 6. *Walliserodus sancticlairi*, UW 4201-24, Sa element; a - lateral view, X 43; b - lateral view, X 55; c - slightly oblique view of anterior face, X 55.
- Fig. 7. *Walliserodus sancticlairi*, UW 4201-18, M element, outer lateral view, X 58.
- Fig. 8. *Pseudooneotodus cf. beckmanni*, UW 4201-36, X 58.
- Fig. 9. *Oulodus* sp., UW 4201-21, Sa element, posterior view, X 61.
- Fig. 10. *Oulodus* sp., UW 4201-22, Sc element, inner lateral view, X 60.
- Fig. 11. *Oulodus* sp., UW 4201-33, Pb element, posterior view, X 47.
- Fig. 12. *Oulodus* sp., UW 4201-34, Sb element; a - posterior view, X 80; b - anterior view, X 80.

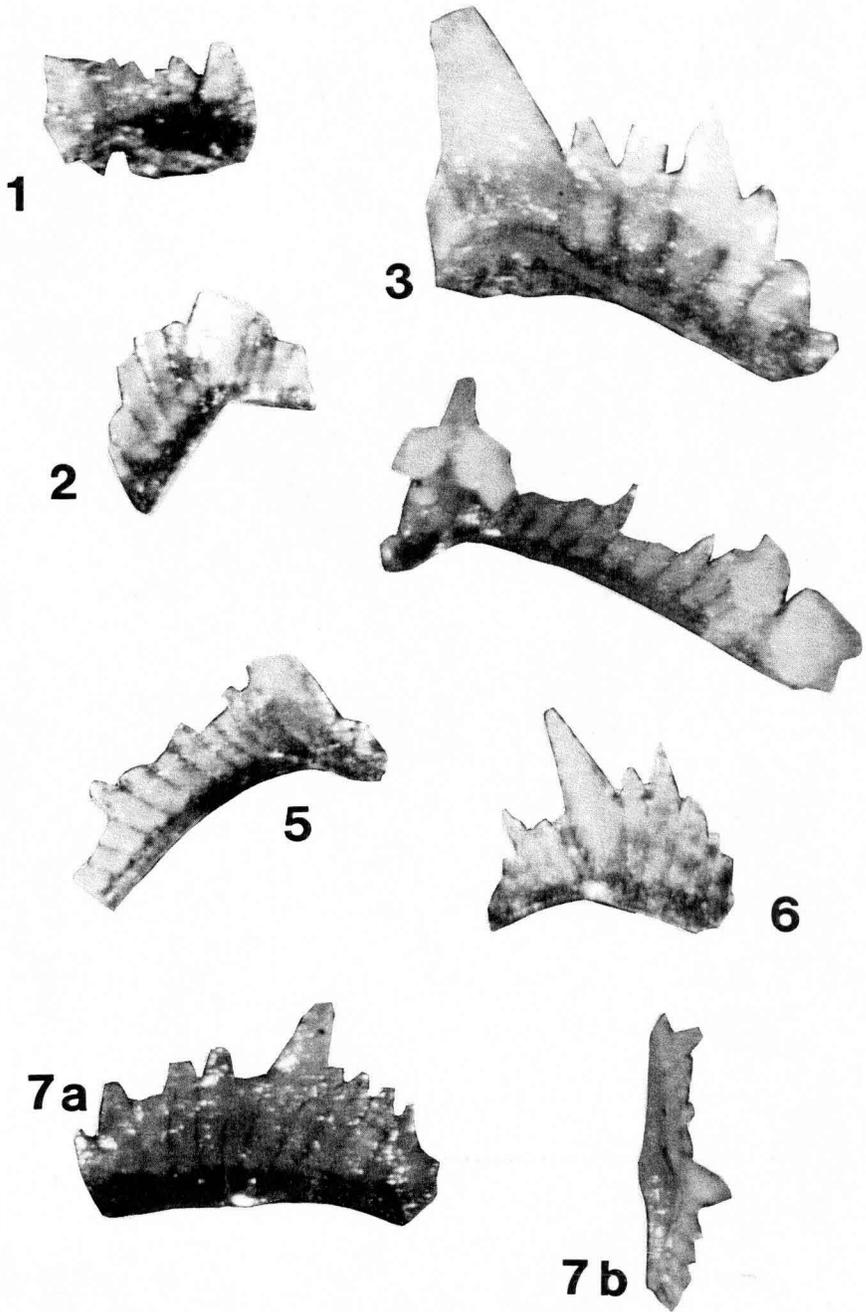


PLATE 4

- Fig. 1. *Ozarkodina confluens*, UW 4201-30, Pa element, X 62.
- Fig. 2. *Ozarkodina confluens*, UW 4201-20, Sc element, inner lateral view, X 50.
- Fig. 3. *Ozarkodina confluens*, UW 4201-19, Pb element, inner lateral view, X 68.
- Fig. 4. *Ozarkodina confluens*, UW 4201-32, M element, inner lateral view, X 72.
- Fig. 5. *Ozarkodina confluens*, UW 4201-31, M element, inner lateral view, X 69.
- Fig. 6. *Ozarkodina* sp., UW 4201-35, Pb element, X 66.
- Fig. 7. *Ozarkodina* sp., UW 4201-23, Pa element, a—lateral view, X 64; b—aboral view, X 52.