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By Rodney Watkins, Paul S. Mayer, and Patricia J. Coorough
Geology Section
Milwaukee Public Museum
800 West Wells Street
Milwaukee, WI 53233, USA

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ABSTRACT

The Waubakee Formation, which occurs in Milwaukee and Ozaukee counties, is the youngest Silurian unit in southeastern Wisconsin. Ranging from about 20 to 30 m thick, the Waubakee consists of dolomite of intertidal to supratidal origin. It conformably overlies the Wenlockian Racine Formation and is unconformably overlain by the Givetian Thiensville Formation. Lithologies in the Waubakee include cryptalgal-laminated mudstone, parallel-laminated mudstone, discontinuously-laminated mudstone, bioturbated mudstone, ripple-laminated mudstone, and rare ooid-intraclast packstone. Mudcracks and autobrecciated horizons are common, and small-scale shallowing-upwards sequences are recognizable throughout the formation. The Waubakee includes a rare fauna of brachiopods, bivalves, cephalopods, leperditiid ostracods, and phyllocarids.

Key words: Silurian, Waubakee Formation, Wisconsin, intertidal, marine communities.

INTRODUCTION

The Waubakee Formation is an Upper Silurian unit of dolostone that occurs in Milwaukee and Ozaukee counties, Wisconsin. This paper is a study of its stratigraphy, sedimentology, and paleontology. Outcrop of the Waubakee is very limited, and most of the data reported here are from cores obtained in conjunction with the Inline Storage project of the Milwaukee Metropolitan Sewerage District (MMSD).

The Waubakee Formation was named by Alden (1906), who noted its presence in northern Milwaukee County and near the town of Waubeka, in Ozaukee County (Figure 1). The type area, near the town of Waubeka, is exposed only in the bed of the Milwaukee River. Alden (1906, 1918) described the Waubakee as a thin-bedded, poorly-fossiliferous unit stratigraphically above the Racine Formation and below Devonian rocks. The Waubakee received little subsequent attention until the work of Mikulic and Kluessendorf (1988), who plotted its subsurface occurrence in Milwaukee County and described sedimentary structures indicating an intertidal origin.

AGE OF THE WAUBAKEE

Klug (1977) summarized previous work of the Waubakee Formation. The Waubakee conformably and gradationally overlies the Racine Formation, which contains Homerian conodonts in its uppermost portion (Kuglitsch 1996). The Waubakee is disconformably overlain by the Thiensville Formation, which contains a megafauna of Middle Devonian

(probable Givetian) age (Schumacher 1971). On this basis, we have concluded that the Waubakee is of Silurian age, as suggested by Berry and Boucot (1970).

Although Klug (1977) reported no conodonts from the Waubakee, he verbally informed Kuglitsch (2004, oral communication) that he found sparse *Panderodus* in beds at Lincoln Creek. *Panderodus* has no refined biostratigraphic significance. For this study, 9988 g of dolostone from all stratigraphic portions of the Waubakee were dissolved in acetic and formic acid. No conodonts were found.

DISTRIBUTION OF STRATA

The Waubakee Formation occurs in two separate areas (Figure 1). The southern area occurs between Hampton Avenue and the course of the Milwaukee River in Glendale, Shorewood and Milwaukee. It crops out only in a small area at Lincoln Creek (Figure 3) and is otherwise wholly subsurface. The Waubakee ranges from 20 to 30 m thick throughout this area and consists of a lower, very poorly bioturbated unit and a thicker upper, partly bioturbated unit (Figure 2).

The northern part of the Waubakee occurs in the area around Waubeka and extends north to Lake Church, where it is about 0.7 m thick (Cleland, 1911; although Klug, 1977 quoted Raasch as stating that this report was erroneous.). Limited outcrop occurs in the Milwaukee River bed at Waubeka, and hand specimens collected previously from this area consist of cryptalgal-laminated dolomite and parallel-laminated dolomite identical to the Waubakee to the south.

ROCK TYPES

Six discrete rocks types in the Waubakee Formation are recognized on the basis of a combination of sedimentary structures, bioturbation and particle composition. These rock types are shown in the measured section and core logs (Figures 5 - 9)

Cryptalgal-laminated mudstone

Plates 7.1; 8.1, 8.3, 8.4; 9.1, 9.2; 11.3, 11.5, 11.6, 11.7; 12.1, 12.4, 12.6, 12.7, 12.9.

This lithology consists of alternating dark dolomitic laminae and lighter dolomitic laminae with wavy to domal shapes. Dark laminae range from 0.1 to 6 mm thick; lighter dolomitic laminae range from 0.1 to 10 mm thick and alternate between clotted, microbial appearance or massive, plane mud. The laminae are wavy in appearance and pinch and swell in thickness. Laminae

often contain chips of thin dark argillaceous material to 1.4 mm length. Fenestrae are present and mudcracks are common, and small areas of autobrecciation occur at some horizons. Autobrecciation refers to small angular areas of rock that have been separated and variously rotated with respect to one another, but which appear to have originally fitted together.

The cryptalgal-laminated mudstone occurs as stratigraphic units from 0.1 m to several m in thickness. The clotted, cryptalgal laminae often cut out underlying laminae.

Parallel-laminated mudstone

Plates 7.2, 7.4; 8.2; 9.3; 12.5, 12.8.

This lithology consists of alternating dark dolomitic laminae and lighter dolomitic laminae with flat parallel shapes. Dark laminae range from 0.5 to 3.0 mm thick and lighter dolomitic laminae range from 0.5 to 9.0 mm thick. Bioturbation is typically absent, although horizontal burrows to 1 mm diameter are rarely present. Fenestrae are typically present.

Massive mudstone

Plates 7.3, 7.4; 8.2.

This lithology consists of massive, bioturbated mudstone. Bases of beds are typically sharp and flat, while tops of beds may be slightly gradational to overlying laminated mudstone.

Ripple-laminated mudstone

Plates 8.2: 12.2, 12.3.

This lithology consists of mudstone with alternating dark dolomitic and lighter dolomitic laminae that define small ripple lamination.

Discontinuously-laminated mudstone

Plate 10.4

This lithology is known only from a single, lens-shaped unit in the lower part of the section at Lincoln Creek, where it occupies the low points of two swales. It consists of dull grey to white dolomite mudstone disrupted by wavy, discontinuous light green laminae 0.2 to 2 mm thick. The laminae occur at vertical spacings of 1 to 5 mm and pinch out over distances of several centimeters. The lithology appears to represent original thin layers of carbonate that have been disrupted and pulled apart and later penetrated by the greenish clayey laminae.

Ooid-intraclast packstone

Plates 11.1, 11.2.

This lithology consists of a single bed of ooid packstone in which a matrix of fine-grained dolomite with common void spaces encloses ooids 0.2 to 0.7 mm in size and intraclasts 0.3 to 10.0 mm in size. Intraclasts are subangular to mainly rounded, variably oriented, and consist of massive light dolomite and identical ooid packstone. Many intraclasts have an ooid coating up to 0.5 mm thick.

STRATIGRAPHY

The Waubakee Formation can be divided into a lower and an upper unit. The lower unit, 6 to ll m thick, is characterized by very low bioturbation. The upper unit, 12 to 23 m thick, is characterized by a much higher proportion of bioturbated sediment (Figures 7 - 9). The lower unit overlies the Racine Formation conformably and gradationally. In its upper portion, the Racine consists of bioturbated dolomite mudstone with a sparse fauna of crinoids, brachiopods, stromatoporoids and bryozoans (Figure 8). At the top of the Racine, the sediment becomes less bioturbated, partial parallel lamination appears, and fossils become markedly less common. This unit is then overlain by cryptalgal-laminated dolomite of the Waubakee Formation, and no bioturbation or fossils were observed.

The succeeding lower unit of the Waubakee consists mainly of cryptalgal laminated dolomite. Apparent shallowing-upwards sequences consist of bioturbated mudstone overlain by parallel-laminated mudstone to cryptalgal-laminated mudstone, in turn overlain by cryptalgal-laminated mudstone with mudcracks and autobrecciation. These sequences are one to several meters in scale and cannot be matched precisely from one core to another. Bioturbated mudstone is a very minor part of each sequence and consists of beds 5 to 60 cm thick. Thin intervals with small ripple lamination and ripple marks are present (Plate 3.2), as are very rare leperditiid ostracods. A thin bed of ooid-intraclast packstone is present at the base of a shallowing-upwards sequence in Downer Woods (Figure 9; Plates 11.1, and 11.2) but has not been identified in other cores. Trace fossils are very rare, but at Lincoln Creek, a horizontal sinuous burrow is 4 mm in width and at least 15 cm long. Core I30-NS-DS-4 includes common cross-cutting gypsum veinlets (Figure 8).

The lower unit also includes dolomite pseudomorphs of calcite crystals in the lower part of the section at Lincoln Creek. The pseudomorphs occur within a small chute structure in parallel-laminated mudstone in the lower part of the section (Plates 3.1; 10.1, 10.2). Larger pseudomorphs of calcite occur in scree at Lincoln Creek (Plate 10.3).

The only outcrop of the Waubakee Formation in Milwaukee County, consisting of the basal part of the lower unit, occurs at Lincoln Creek (Figure 3), an area that has been recently modified by an MMSD flood control project.

Measured sections are shown in Figures 5 and 6. Photos of this area are shown in Plates 1 through 6. The base of the Waubakee is exposed here where small dome structures bring up the uppermost dolomites of the underlying Racine Formation, which consist of bioturbated mudstone with rare silicified *Thalassinoides* and indeterminate horizontal burrows. The Waubakee Formation here is about 7 m thick and is dominated by parallel-laminated mudstone (Figure 5).

The upper unit of the Waubakee contains closely-spaced beds of bioturbated mudstone. Beds are 5 to l50 cm thick, have sharp, flat bases and slightly gradational tops. Small, cylindrical burrows 0.8 to 3.2 mm in diameter are occasionally present (Plate 12.5). Intervening between bioturbated mudstone beds are intervals of cryptalgal-laminated mudstone and parallel-laminated mudstone. These intervals variably include mudcracks and autobrecciation. Rare intervals with small ripple lamination are also present, and the lower part of the unit in I30-NS-DS-4 contains cross-cutting gypsum veinlets. A very rare fauna of leperditiid ostracods is also present,

The top of the Waubakee Formation is an eroded surface with up to 50% sulfides. Interconnecting fractures to 4 cm wide extend to 20 cm below the upper contact, filled with light green clay-rich carbonate and angular dolostone clasts 1 to 20 mm long. Common hairline to 1 mm thick fractures are common for a further 1 m below the contact. The Devonian Thiensville Formation rests unconformably over this contact.

INSOLUBLE RESIDUES

Samples from borehole I30-8-NS and the outcrop section at Lincoln Creek were studied for insoluble residues. A small sample from every one foot interval of core and a continuous interval of outcrop section were digested in hydrochloric acid. Sample weights ranged from 15.7 to 114.5 g. Residues were weighed on filter paper and were not screened. Results are given in Figures 5 and 8.

Grey mud is the main fraction of the residues and ranges from 1 to 31% of samples by weight. It was divided into three categories by visual inspection: light grey, medium grey, and dark grey. Light grey mud comprises the residues in the lowest stratigraphic part of the Waubakee, to a level 2 m above the base. Above this, the bulk of the residues consist of medium grey mud, with very rare occurrences of dark grey and light grey mud. Small grains of sulfides and gypsum are also present.

Clay content in Waubakee mud consists of 100% illite and mica. Pyrite comprises 1.4 to 9.1% of whole rock weight, and gypsum comprises 0 to 1.8%.

SEDIMENTOLOGICAL INTERPRETATION

The Waubakee Formation is interpreted as an intertidal to supratidal mudflat. Diagnostic criteria are cryptal-laminated mudstone, salt crystal pseudomorphs, mudcracks, and autobecciation (Shinn 1983, Demicco and Hardie 1994: table 4). In addition, halite crystal pseudomorphs, like those described by Demicco and Hardie (1994), were found at Lincoln Creek. Cryptalgal-laminated mudstone resembles modern sequences described by Gerdes and Krumbein (1987) from the Gulf of Aqaba, and was probably formed by cyanobacteria. Similar crytalgal-laminated sediments of intertidal origin are illustrated by Demicco and Hardie (1994). Strata of the Waubakee Formation are also similar to intertidal strata of the subsurface Silurian in the Michigan Basin described by Pope et al. (2000). In the Milwaukee area, an initial phase of primarily supratidal deposition is represented by the lower unit of the Waubakee, followed by a somewhat deeper, intertidal environment represented by the upper unit. Apparent shallowing-upwards sequences grading from bioturbated beds to mudcracked and autobrecciated dolostone are present throughout the formation, but could not be correlated between the various cores, probably because of contemporaneous, small-scale erosion. One definite marker bed, the ooid-intraclast packstone of Downer Woods, was not recognized in any other core.

PALEOECOLOGY

The fauna of the Waubakee Formation includes four species of articulate brachiopods, one species of bivalve, one species of cephalopod, one species of ostracod, and two species of phyllocarid. These taxa are discussed below in the Systematic Paleontology. Only the phyllocarid *Cetatiocaris monroei* is included; the other species is represented by only a single specimen, not seen by us, and is described by Whitfield (1896).

The Waubakee benthic fauna represents negligible to very low tiering and inhabited very shallow marginal marine environments (Watkins, 1996). Ostracods are the most abundant members of the fauna, which for the Paleozoic is usually characteristic of intertdal to shallow subtidal environments (Walker and Laporte 1970; Knox and Gordon 1999). The presence of brachiopods and cephalopods in the Waubakee, albeit rarely, suggests at least occasional influx of marine water.

At least two separate local communities are represented, including an association of the brachiopod ?*Meristella* and ostracods at Lincoln Creek, and a more diverse association of ostracods, phyllocarids, three species of brachiopods, and bivalves at Waubeka, which also includes cephalopod fragments probably introduced from the open sea.

SYSTEMATIC PALEONTOLOGY

Phylum Brachiopoda
Order Orthida Schuchert and Cooper, 1932
Family Dalmanellidae Schuchert, 1913

"*Orthis*" *oblata* Hall
Plate 13.1

Orthis oblata Hall, Whitfield, 1882, p.320, pl. 25, fig. 1, 2.

Material and occurrence. - Three pedicle valves, all collected at Waubeka from 16 to 30 mm thick beds of massive grey brown bioturbated dolomite mudstone alternating with dark grey dolomite mudstone layers 1 to 2 mm thick

Description. - External molds of two pedicle valves, width 10.2 mm, length 8.2 mm; and width 9.2 mm, length 7.8 mm. Ribs narrow, moderate relief, separated by rounded interspaces three times as wide; 7 ribs per 3 mm width at anterior margin.

Genus *Resserella* Bancroft, 1928
Resserella subcarinata (Hall)
Plate 13.4

Orthis subcarinata Hall, Whitfield, 1882, p. 320, pl. 25, fig.3, 4.

Material and occurrence. - One brachial valve from Waubeka collected from same lithology as described above.

Description. - External mold, length 8.1 mm, ribbing of *Resserella* type. Ribs of moderate relief, separated by interspaces about 1.5 times as wide; 7 ribs per 3 mm width at anterior margin.

Order Atrypoidea
Family Atrypiidae

atrypacean, indeterminate
Plates 13.5, 13.6

Material. - 1BV, 2 indeterminate single valves.

Description. - The brachial valve is an internal mold 15.9 mm in width and 13.8 mm in length and does not preserve cardinal structures. Maximum width is present at midpoint of length; beak is prominent. A medial fold is present and includes four costae of medium relief and U-shaped cross section. Each flank includes about 5 costae each, and three sharp, imbricate concentric growth lines are present on the anterior half of the valve. The two other

specimens are less than 8 mm in size and have identical ornament.

Occurrence. - All specimens were collected at Waubeka. The brachial valve occurs parallel to bedding on a single lamina of parallel-laminated argillaceous dolostone that has no bioturbation. The other two valves occur parallel to bedding in cryptalgal-laminated dolostone with no bioturbation.

Genus *Meristella* Hall
Meristella? *nucleolata* (Hall)
Plate 14.1, 14.2, 14.3

Atrypa nucleolata Hall, 1852, p.328, pl. 74, fig. 10 a-m.
Meristella nucleolata Hall, Whitfield, 1882, p. 321, pl. 25, fig. 5

Material. - 1PV, 4BV, 4A.

Description. - Shell subequally biconvex, slightly longer than wide, with a very weak median sulcus in ventral valve. Beak narrow, pointed; lacking interarea, no apparent pedicle opening. ventral valve with low median septum; dorsal valve with low median septum flanked by small brachial plates. Ornament consists of sparse, poorly-defined concentric rugae.

Occurrence. - The material occurs in cryptalgal-laminated dolostone at Lincoln Creek.

Valve	length (mm)	width (mm)
BV	14.6	12.3
BV	7.8	6.2
BV	15.1	12.1
BV	11.7	9.9
BV	7.3	7.1
A	11.8	10.5

TABLE 1 Maximum width and length of brachial valve in mm:

Phylum Mollusca
Class Bivalvia
Order Pteriomarpha
Genus *Pterinea*

Pterinea aviculoidea Hall
Plates 14.4, 14.5

Material and occurrence. - From bottom of Milwaukee River near Waubeka. Left valve occurs parallel to bedding in 1 mm thick lamina of dark

grey argillaceous dolomite mudstone, underlain by 6 mm of bioturbated light grey-brown massive dolomite mudstone, underlain by 11 mm of similar light grey-brown dolomite mudstone with wavy, parallel laminae to 1 mm thick of dark grey mud, underlain by 1 mm dark grey argillaceous mudstone. A right valve occurs on another dark grey lamina in a similar specimen .

Description. - External mold of left valve (width 24.6 mm, length 16.8 mm) and right valve (width 17.5 mm, length 15.0 mm); regular, complete concentric ornament, 8 ribs per 3 mm.

Class Cephalopoda
Plate 15.1

Material. - Two body chamber fragments.

Description. - Two body chambers are 38.6 and 48.1 mm in length. The larger one increases from 12.2 to 20.0 mm in breadth over a length of 22 mm. Four to five parallel, slightly sinuous, transverse growth lines occur per 1 mm of length, plus a larger, note always distinct set of larger, rounded transverse ridges set 1 to 2 mm apart along length.

Occurrence. - Present in parallel laminated argillaceous shaly dolostone from Waubeka.

Phylum Arthropoda
Class Ostracoda

Leperditiid ostracod
Plates 15.2, 15.3

Material. - Lincoln Creek, 3A, 2i.

Description. - Both valves moderately and evenly inflated; hingeline about 60% of maximum length, which reaches 10.7 mm. Outline below hinge is ellipsoidal, evenly rounded. No internal structures preserved.

Occurrence. - This species occurs rarely at Lincoln Creek and boreholes where it is present as single valves and butterflied individuals oriented parallel to bedding. Specimens are widely scattered and occur in cryptalgal laminated mudstone.. Single laminae of densely-packed ostracods have also been reported.

Class Phyllocarida Packard, 1879
Order Archaeostraca Claus, 1888
Family Ceratiocarididae Salter, 1860
Genus *Ceratiocaris* M'Coy, 1849

Ceratiocaris monroei Whitfield, 1896
Plates 15.4, 15.5; 16; 17; 18

Ceratiocaris monroei Whitfield, 1896, p. 301-302, pl. 13, figs. 1-5, pl. 14, figs. 3-8.
Entomocaris telleri Whitfield, 1896, p. 300-301, p. 12, fig, 1, pl. 14, fig. 1, 2, 7.
Ceratiocaris monroei Whitfield: Rolfe, 1962, pl. 131, fig. 4.

Material. - 17 individuals or partial individuals; 26 styles; 32 mandibles.

Description. - Carapace with intersecting very finely inscribed grooves. Elevated nodes to 1.5 mm diameter are present, and areas with subcircular pits 0.1 to 0.2 mm in diameter may represent borings. Paired mandibles present with gnathal lobe and six incisors. Gnathal lobe reaches 10.0 mm in length and 3.0 mm in breadth; molars striated, to 1.4 mm in 2.4 m in length and 1.4 mm in breadth. Abdomen of 7 to 8 segments heavily phosphatized, with chevron ornament as finely inscribed grooves. Abdominal fragments reach 110 mm long and 24 mm in breadth.

One individual is 140 mm total length, including style, 7 abdominal segments (ranging in breadth from 16 mm anteriorly to 8 mm distally), and carapace. Carapace is about 60 mm long and about 30 mm wide. Anterior outline of carapace is typical of *Ceratiocaris*, posterior outline is indistinct.

Style very gradually tapering, pointed at end, with 5 - 6 longitudinal ribs bearing spine bases. About 10 - 12 spine bases per 2 mm along crest of rib. Stylets smooth, also gradually tapering, with ratio of style length to stylet length 1:0.48 to 1:0.62.

Occurrence. - All studied material is from Waubeka, where it occurs in laminated cryptalgal mudstone, oriented with flat surfaces parallel to bedding.

	Width	Length
Style	4.0	30.6
Stylet	1.7	16.3
Style	4.1	21.7
Stylet	1.8	10.7
Style	5.1	20.3
Stylet	2.8	11.4
Style	5.8	32.9
Stylet	2.6	20.2
Style	6.3	34.0
Stylet	2.6	20.2
Style	6.9	33.9
Stylet	3.3	16.6
Style	7.1	41.9
Stylet	3.5	23.7
Style	7.3	34.9
Stylet	3.8	21.7
Style	7.3	41.0
Stylet	3.9	19.7
Style	7.6	51.2
Stylet	5.6	24.4
Style	8.5	48.9
Stylet	4.3	26.1
Style	10.2	41.8
Stylet	4.2	21.5

TABLE 2 Maximum proximal width and length of style and stylets in mm:

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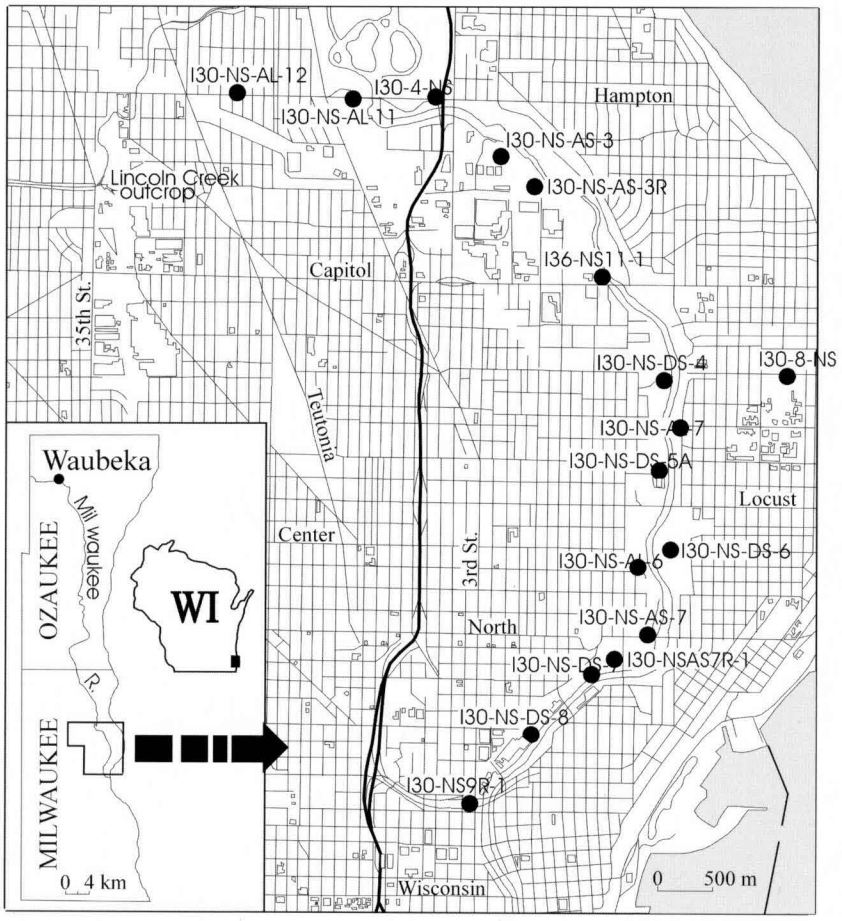


FIGURE 1 Index map for Waubakee Formation in Ozaukee and Milwaukee counties, showing type locality of formation at Waubeka and location of MMSD cores in Milwaukee County.

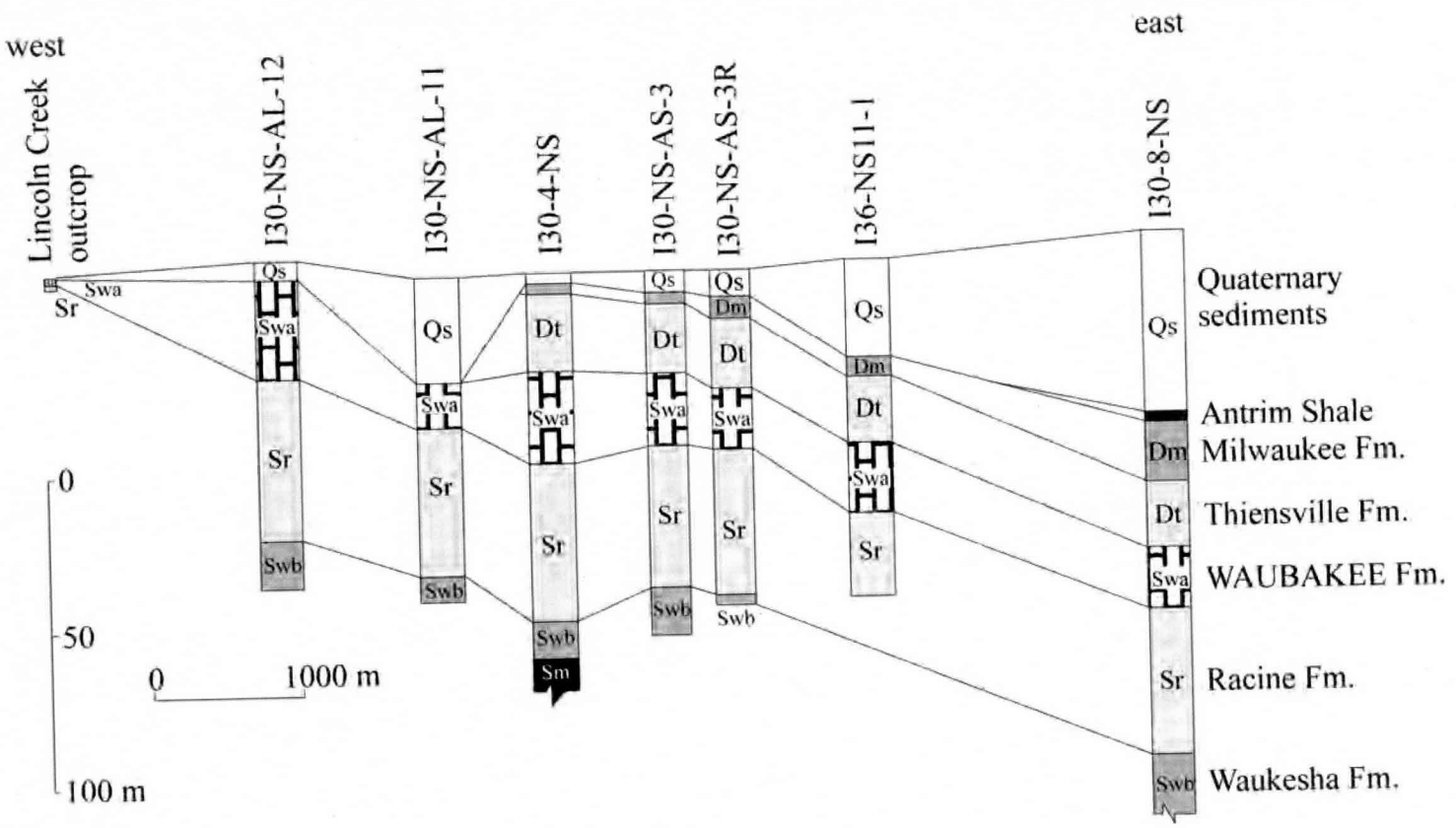


FIGURE 2 Correlation of cores containing Waubakee Formation in Milwaukee County; see Figure 1 for locations.

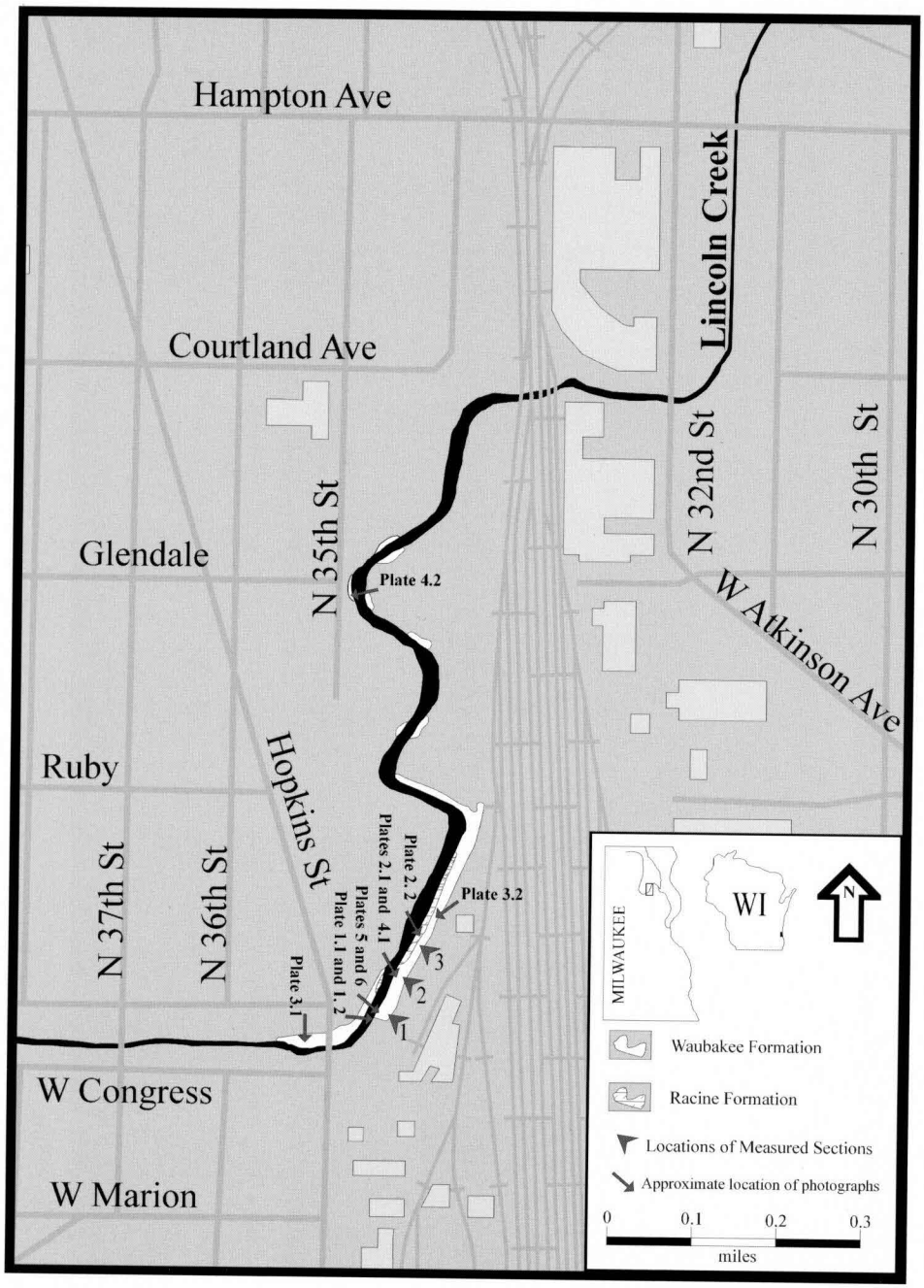


FIGURE 3 Outcrop and locality map for Lincoln Creek.

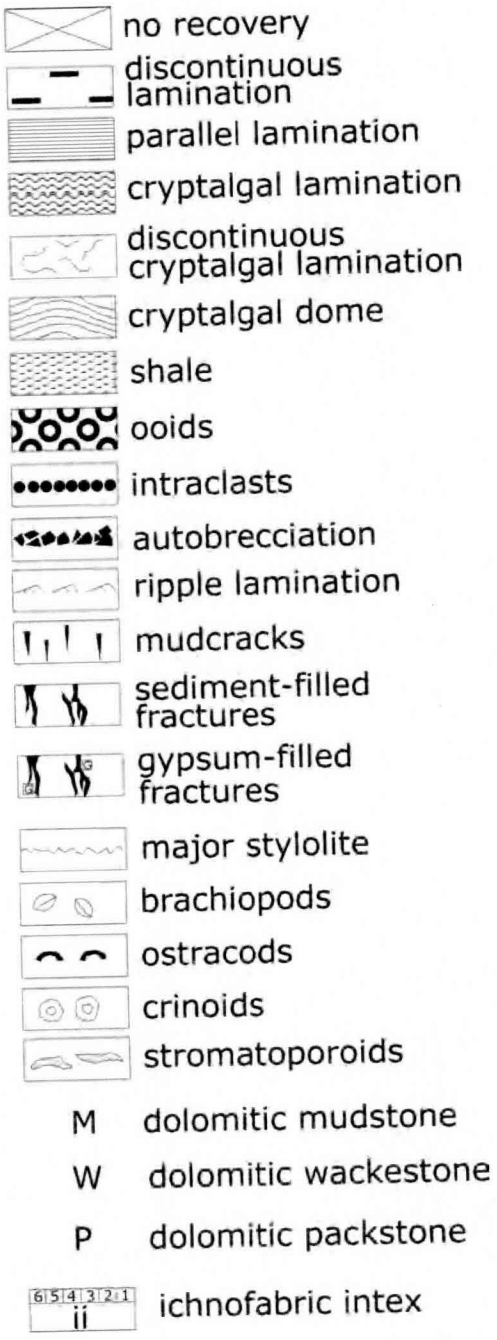


FIGURE 4 Explanation of symbols shown in Figure 5 to 9.

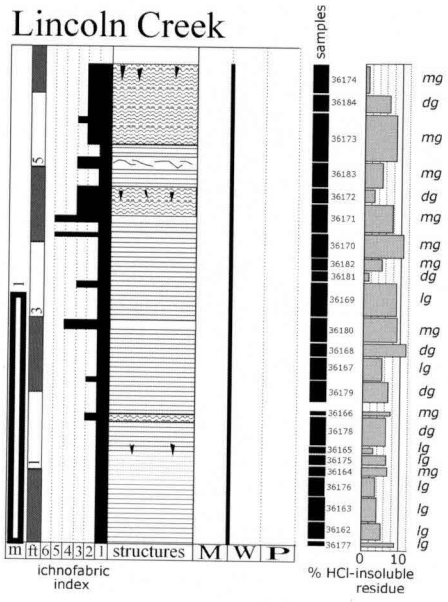


FIGURE 5 Lincoln Creek main outcrop section, showing samples and HCl-insoluble content; see Figure 1 for location and Figure 4 for explanation of symbols.

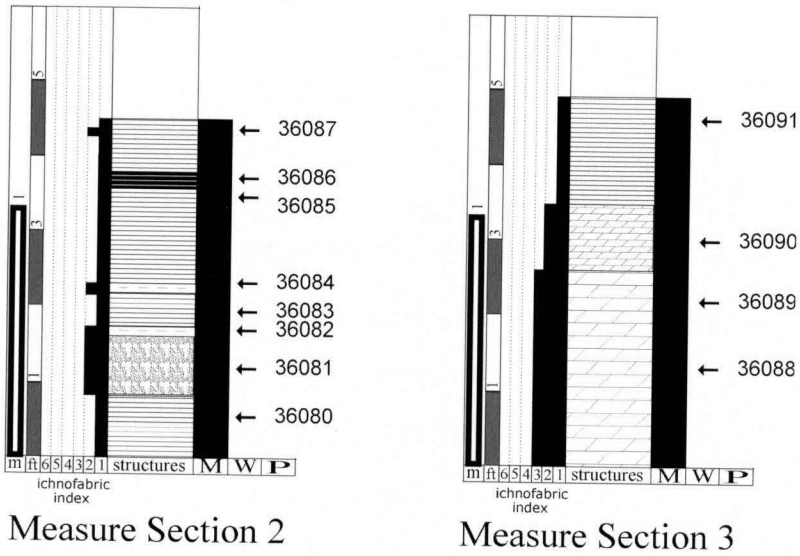


FIGURE 6. - Lincoln Creek, supplementary outcrop sections.

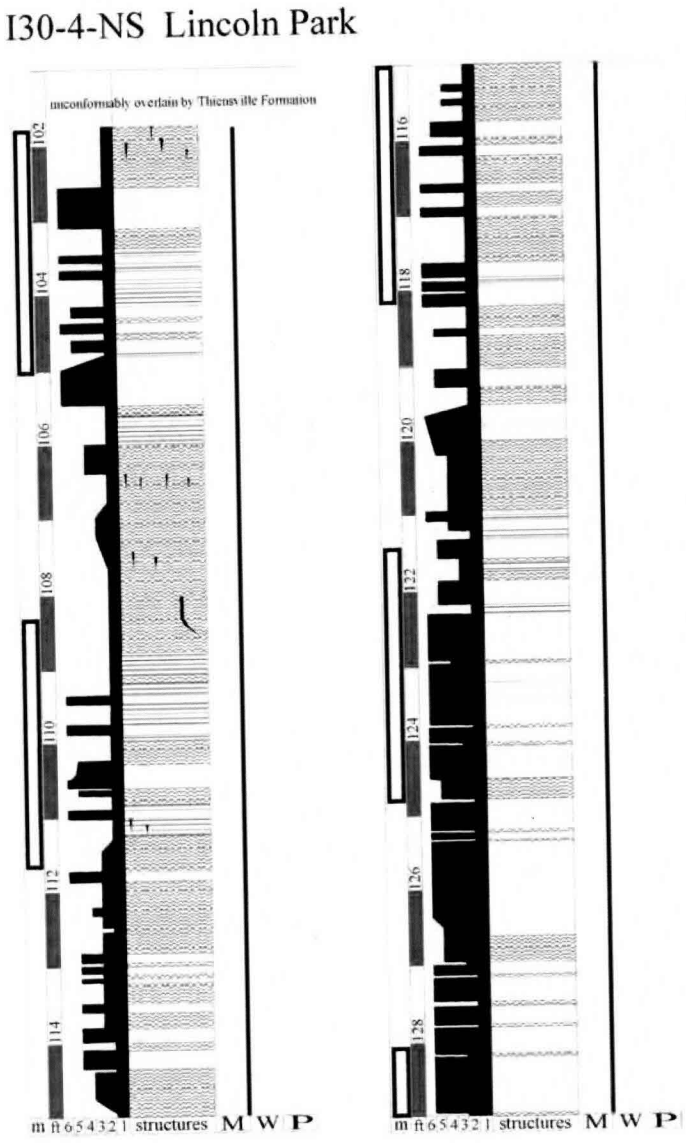


FIGURE 7 Part 1 of 4 - Core I30-4-NS (Lincoln Park); see Figure 1 for location and Figure 4 for explanation of symbols.

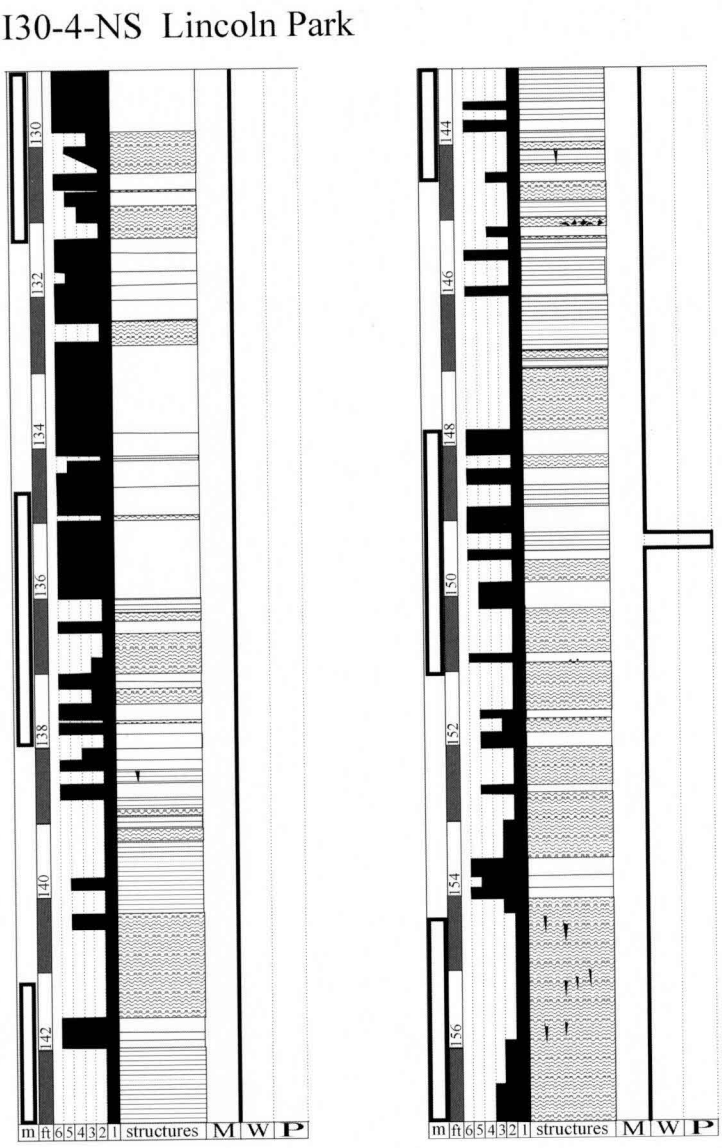


FIGURE 7 Part 2 of 4 - Core I30-4-NS (Lincoln Park); see Figure 1 for location and Figure 4 for explanation of symbols.

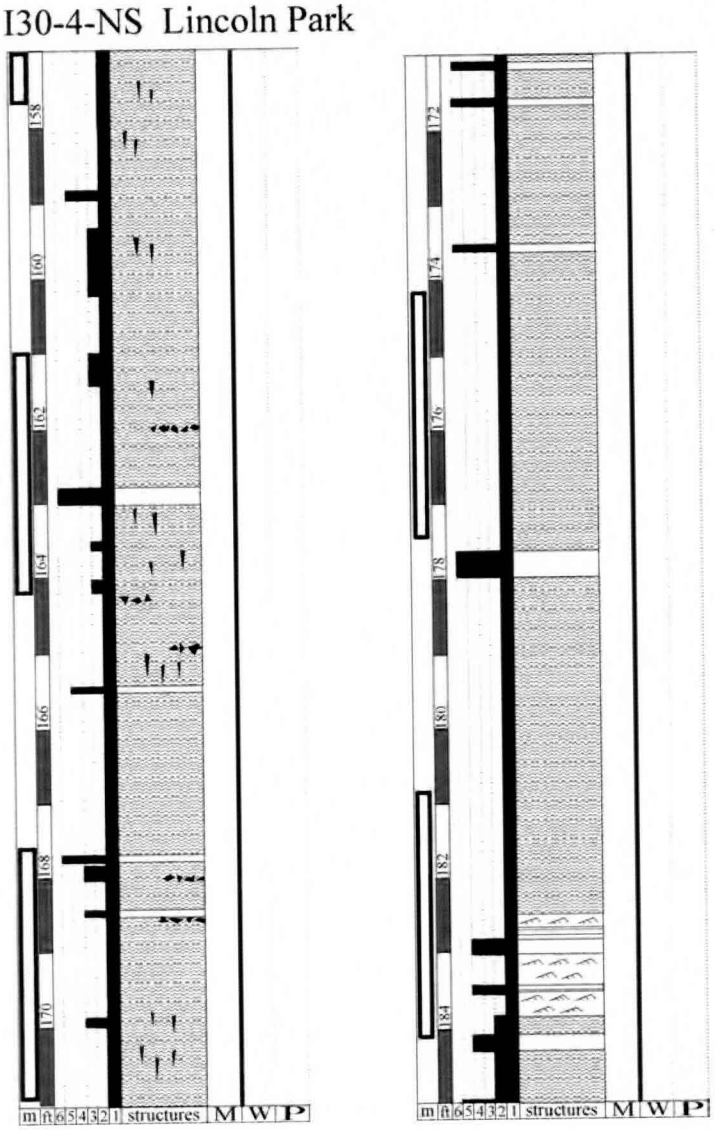


FIGURE 7 Part 3 of 4 - Core I30-4-NS (Lincoln Park); see Figure 1 for location and Figure 4 for explanation of symbols.

FIGURE 7 Part 4 of 4 - Core I30-4-NS (Lincoln Park); see Figure 1 for location and Figure 4 for explanation of symbols.

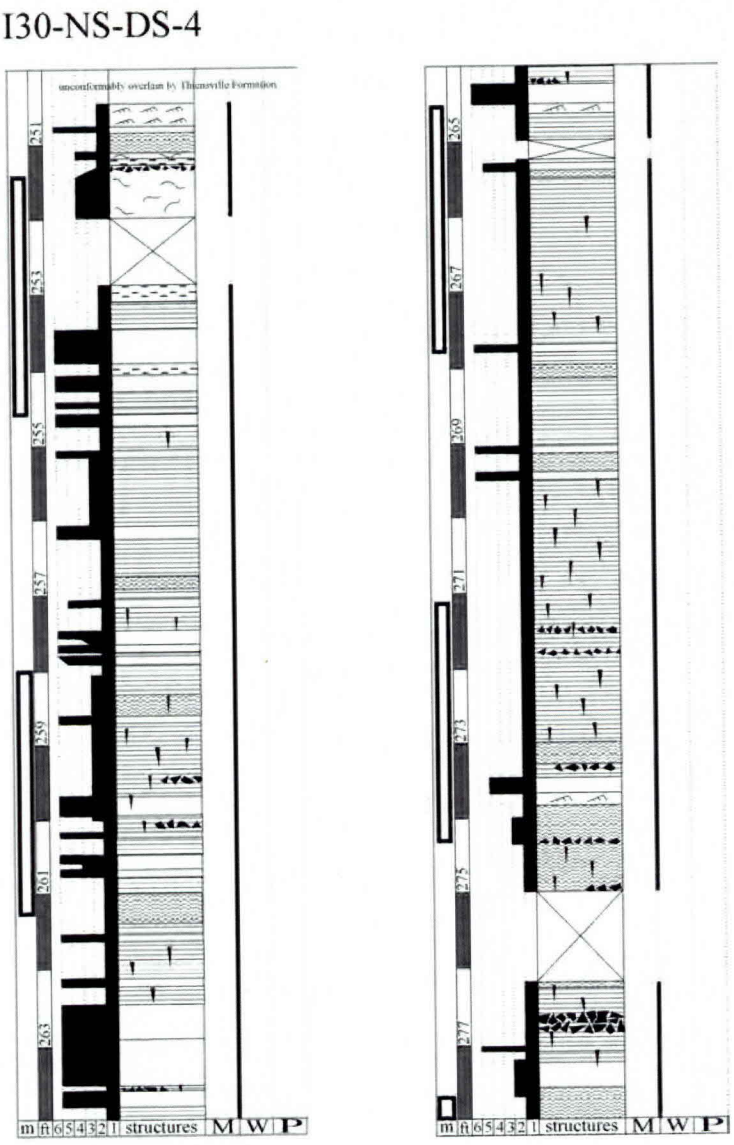


FIGURE 8 Part 1 of 4 - Core I30-NS-DS-4; see Figure 1 for location and Figure 4 for explanation of symbols.

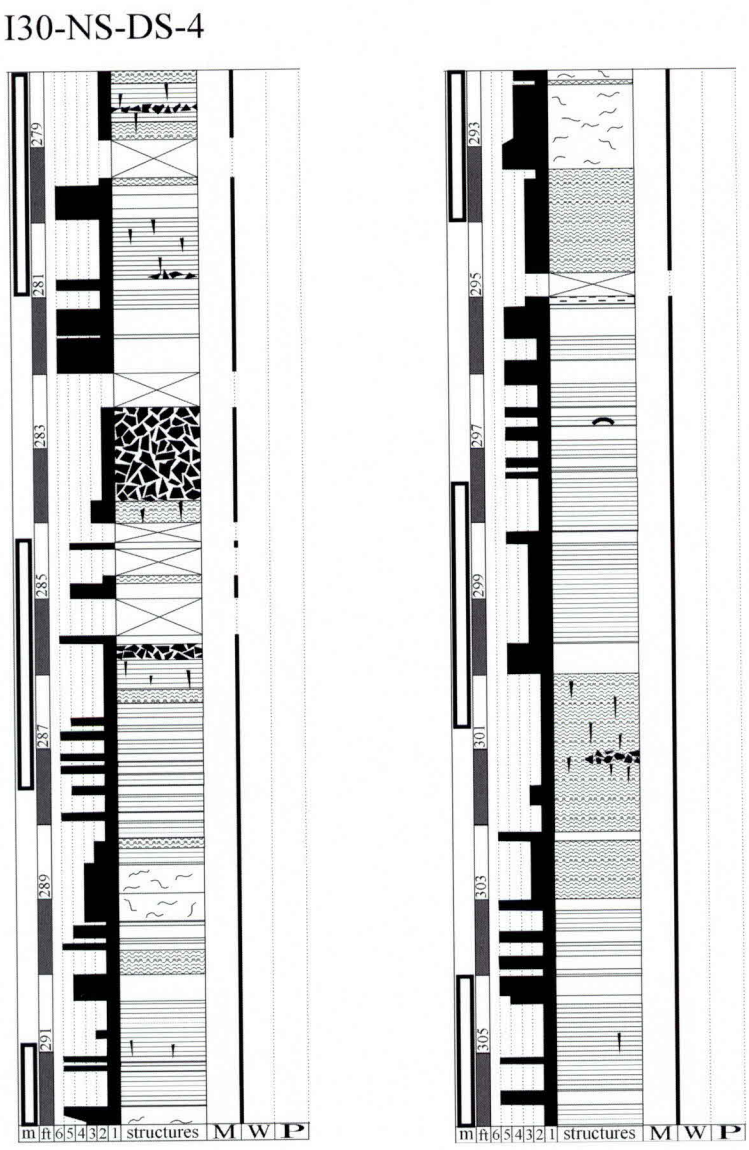


FIGURE 8 Part 2 of 4 - Core I30-NS-DS-4; see Figure 1 for location and Figure 4 for explanation of symbols.

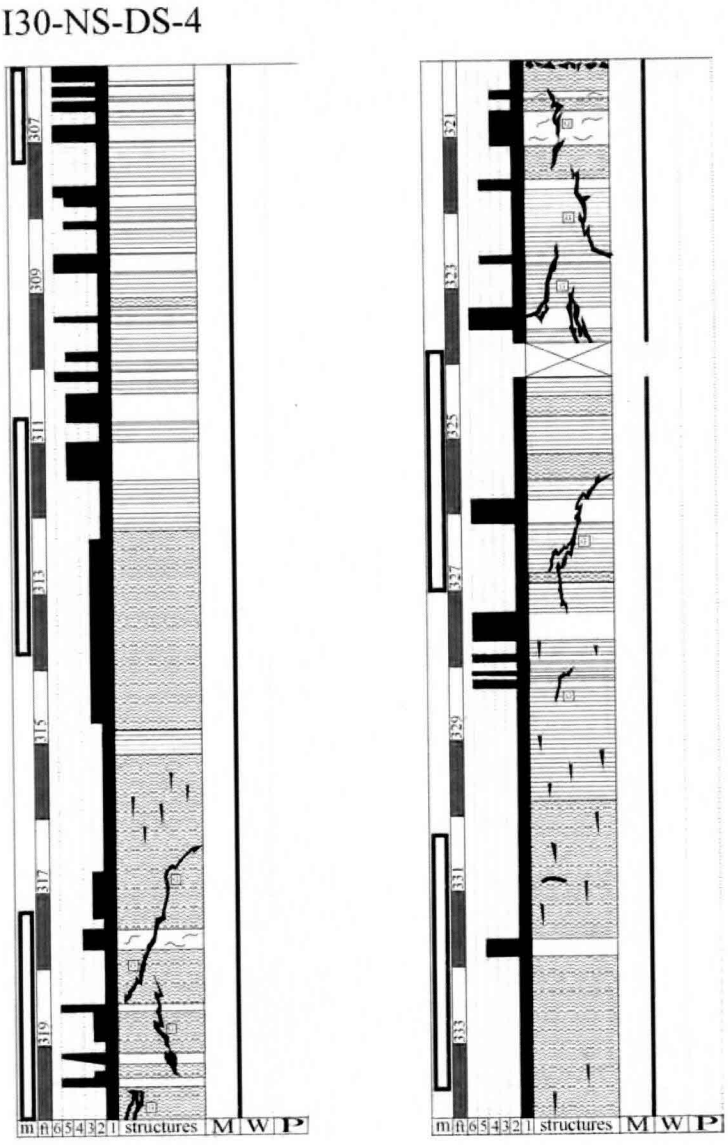


FIGURE 8 Part 3 of 4 - Core I30-NS-DS-4; see Figure 1 for location and Figure 4 for explanation of symbols.

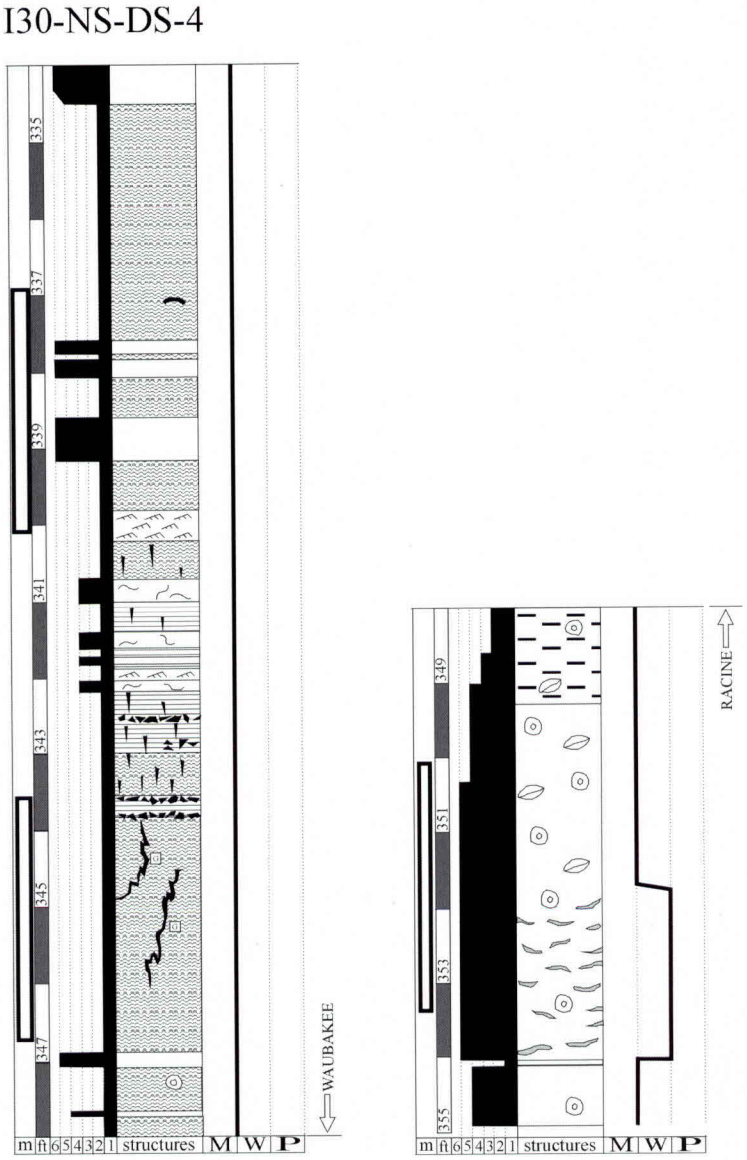


FIGURE 8 Part 4 of 4 - Core I30-NS-DS-4; see Figure 1 for location and Figure 4 for explanation of symbols.

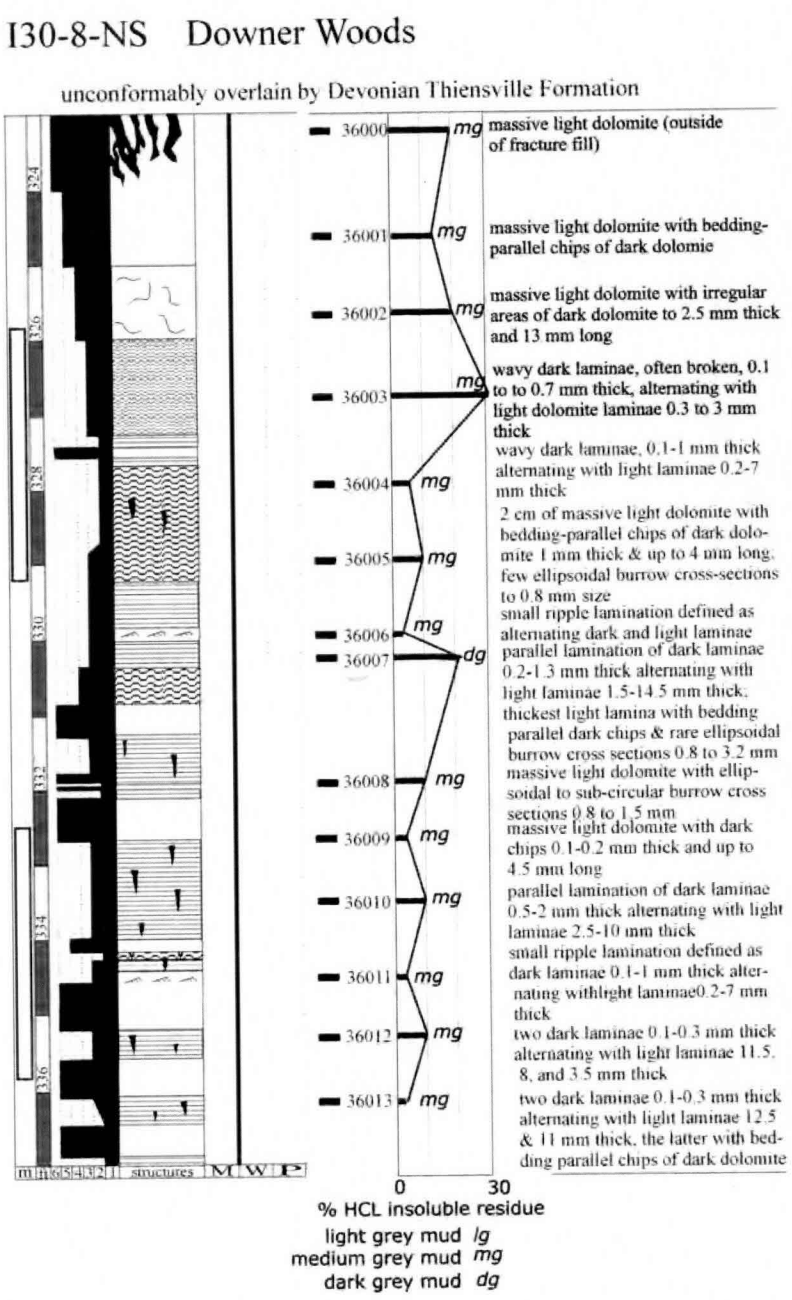


FIGURE 9 Part 1 of 5 - Core I30-8-NS (Downer Woods); see Figure 1 for location and Figure 4 for explanation of symbols.

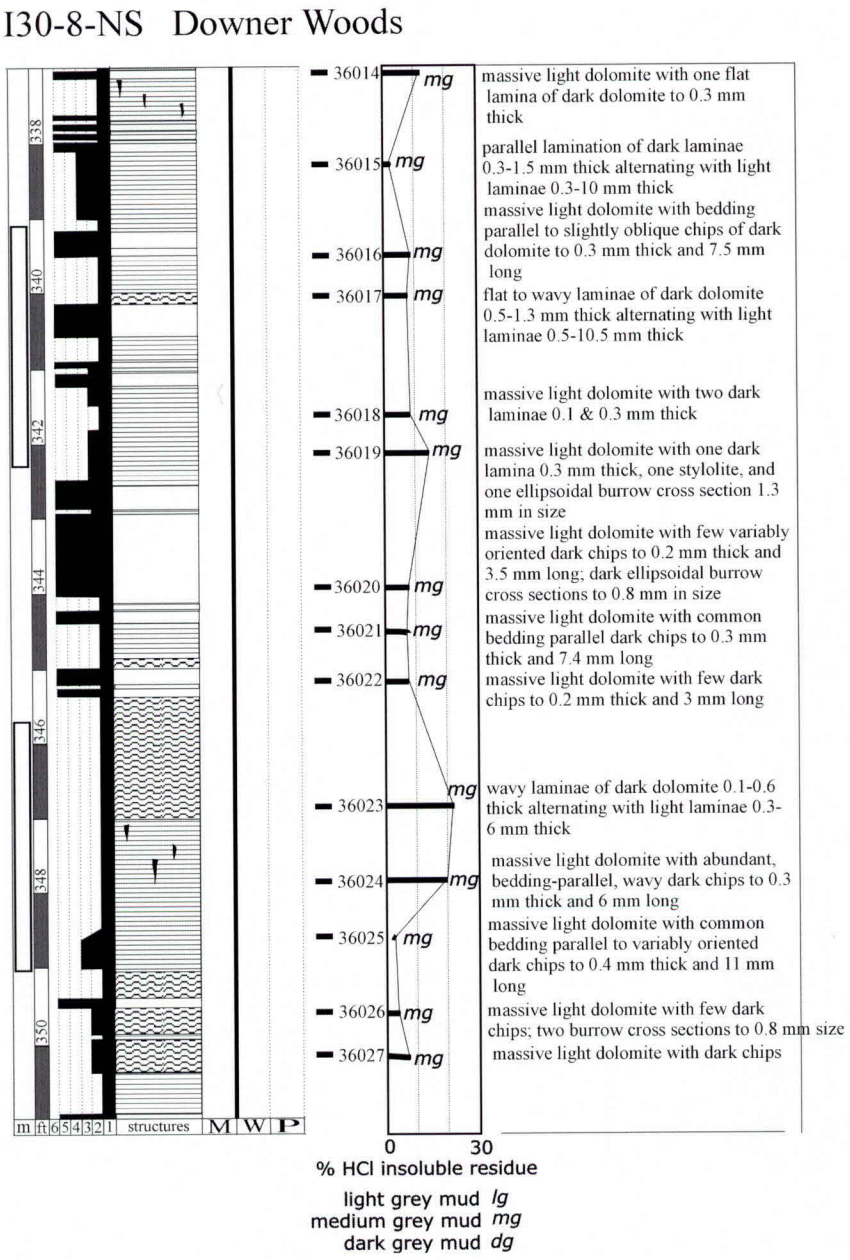


FIGURE 9 Part 2 of 5 - Core I30-8-NS (Downer Woods); see Figure 1 for location and Figure 4 for explanation of symbols.

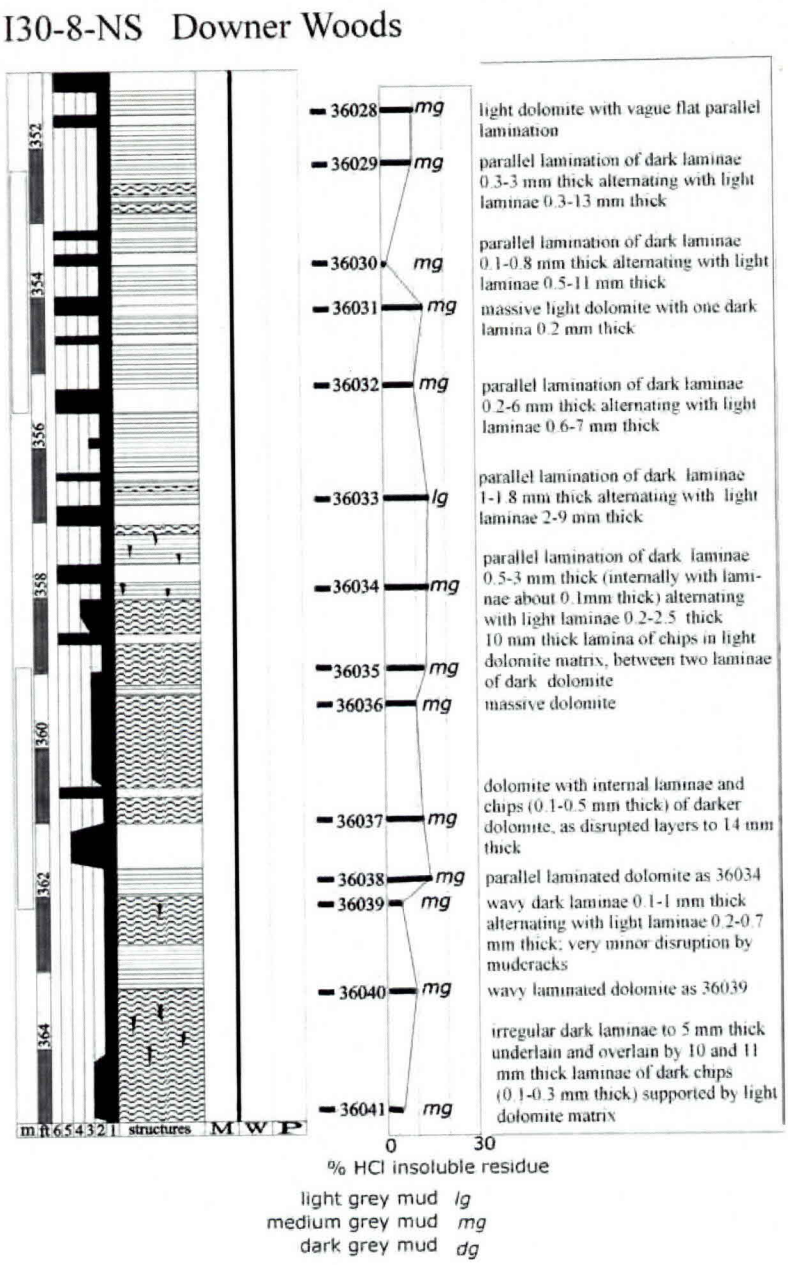


FIGURE 9 Part 3 of 5 - Core I30-8-NS (Downer Woods); see Figure 1 for location and Figure 4 for explanation of symbols.

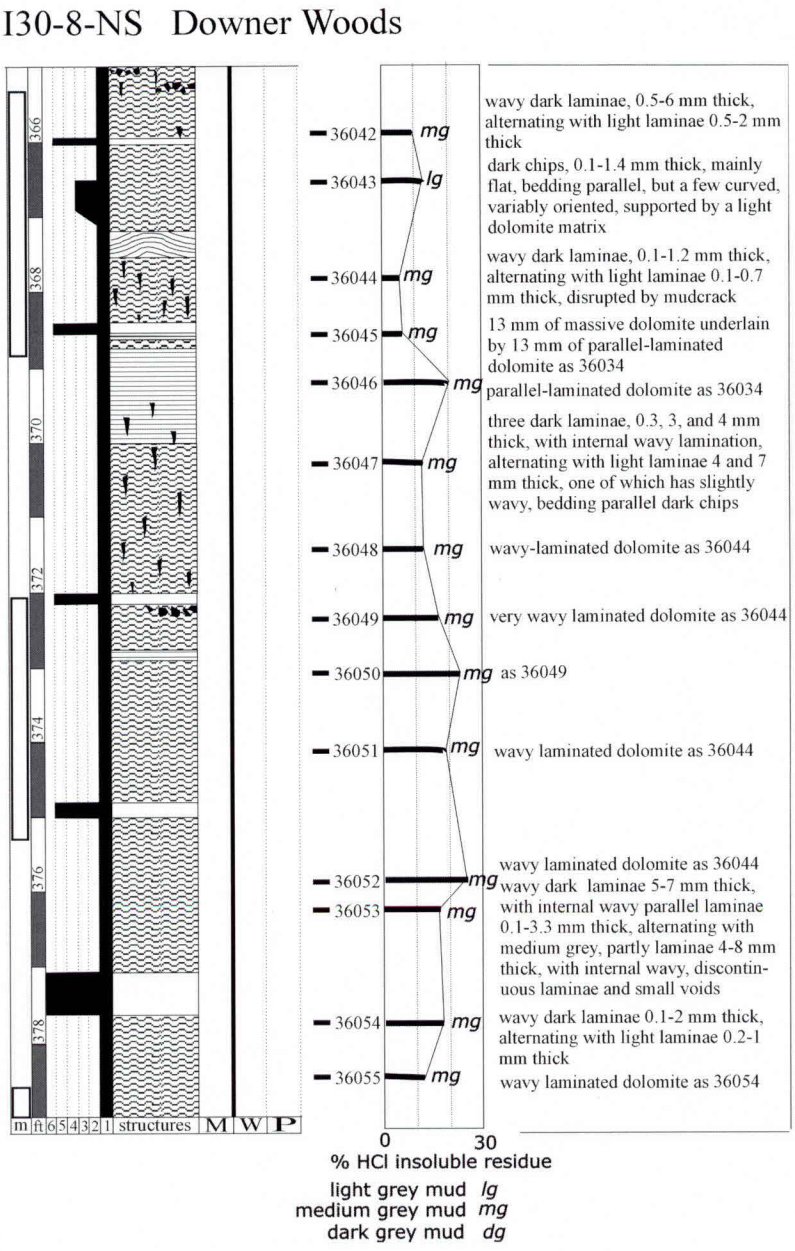


FIGURE 9 Part 4 of 5 - Core I30-8-NS (Downer Woods); see Figure 1 for location and Figure 4 for explanation of symbols.

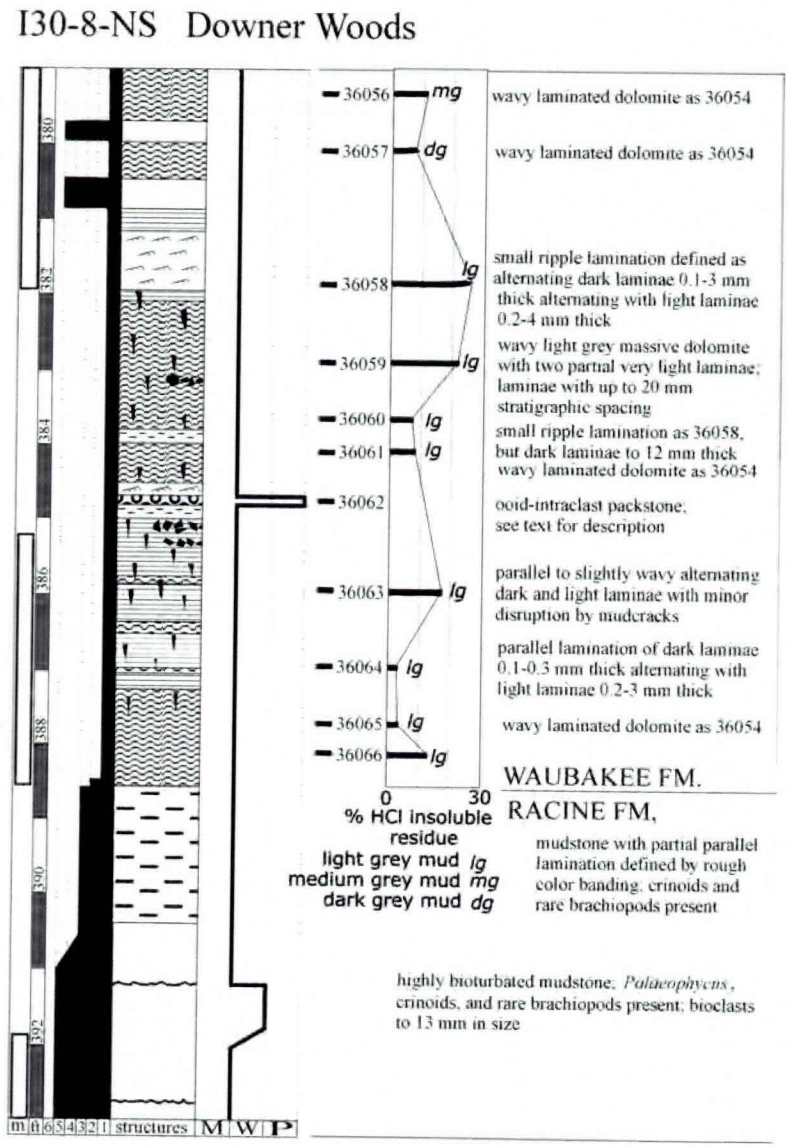


FIGURE 9 Part 5 of 5 - Core I30-8-NS (Downer Woods); see Figure 1 for location and Figure 4 for explanation of symbols.

PLATE 1 1.1 - Outcrop of Waubakee Formation at Lincoln Creek, showing measured section before flood control project (see Figure 1, location 1). 1.2 - Similar location, after flood control project.

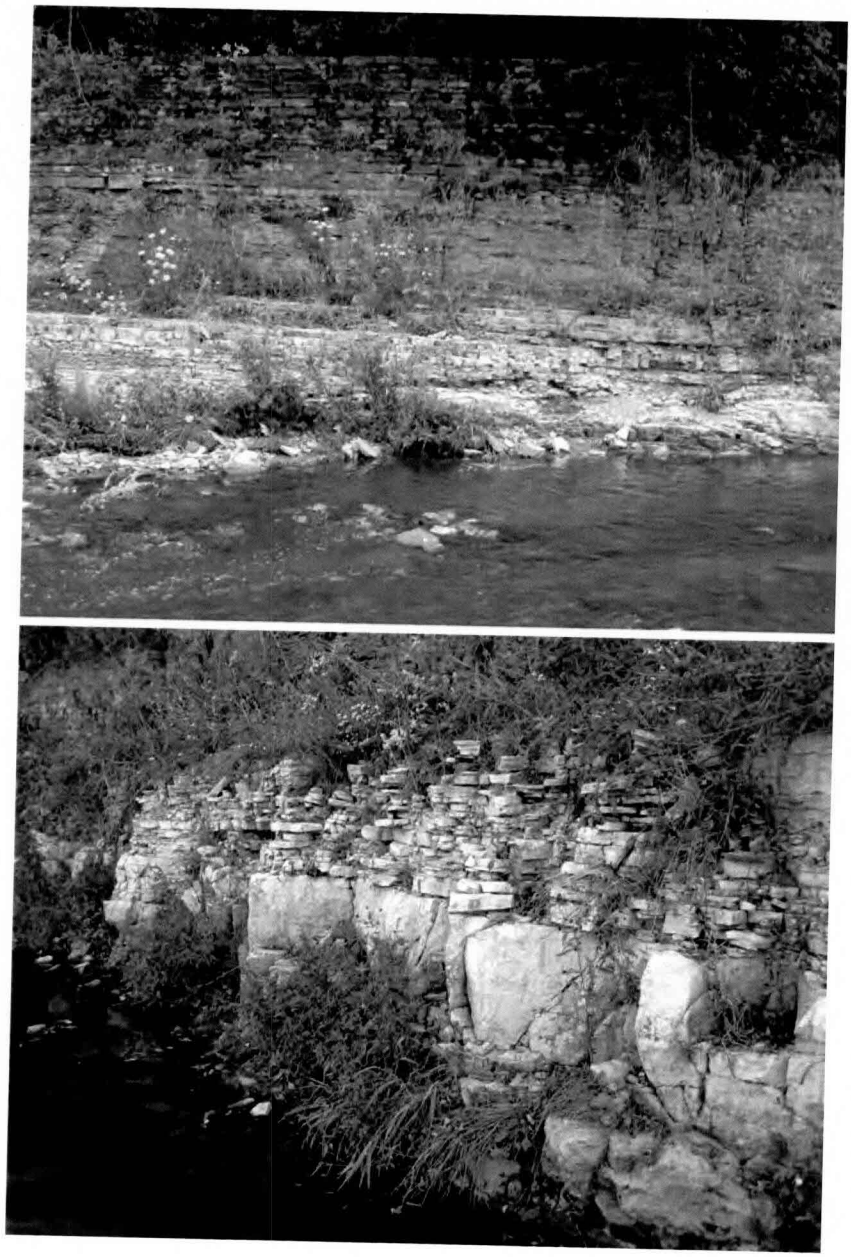


PLATE 2 2.1 - Outcrop of Waubakee Formation at Lincoln Creek, showing location of measured section 2. 2.2 - Outcrop of Racine Formation near measured section 3 of Figure 3.

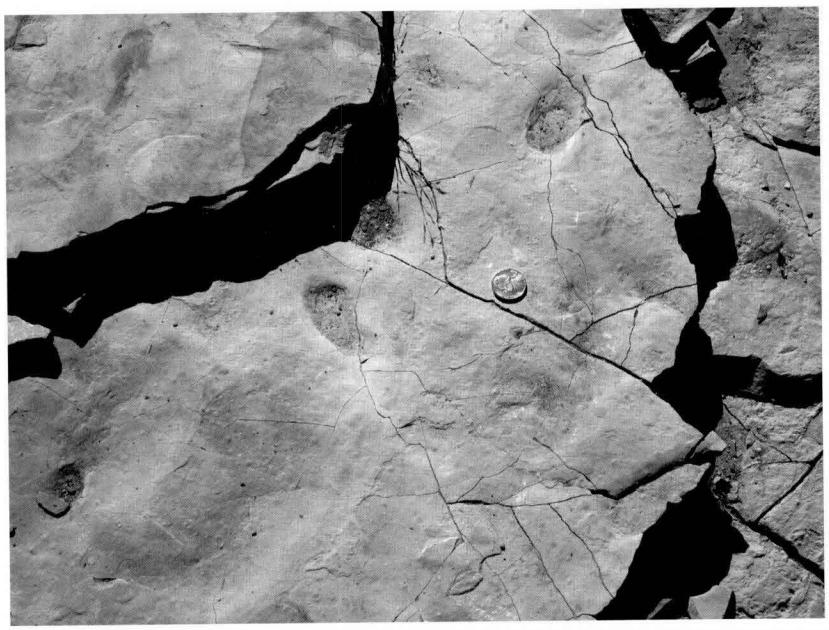


PLATE 3 3.1 - Chute structures; nickel for scale. 3.2 - Ripple marks; rock hammer is 33 cm long.

PLATE 4 4.1 - Small dome structure. 4.2 - Typical outcrop downstream of main outcrop at Lincoln Creek.

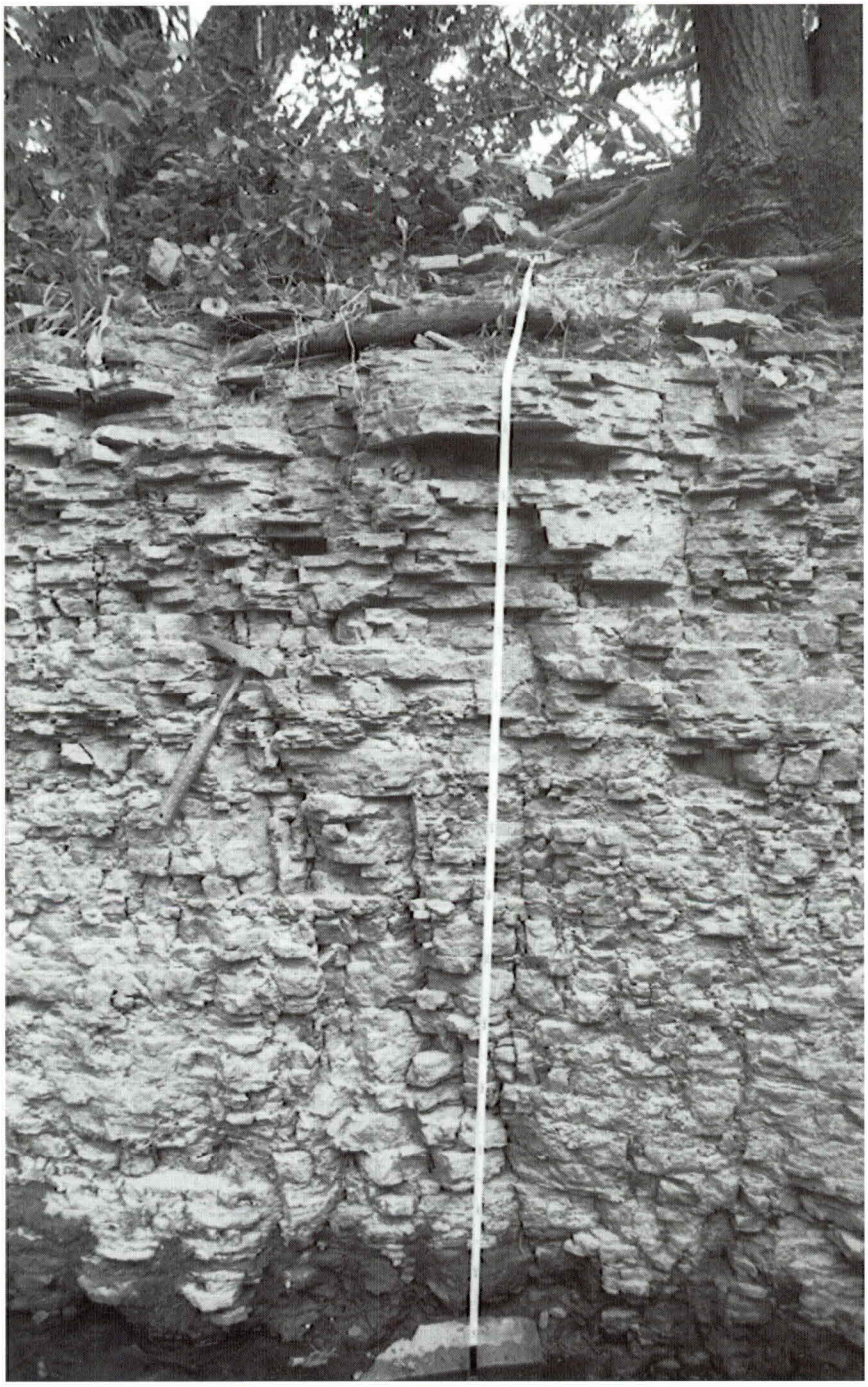


PLATE 5 Measured section shown in Figure 5.

PLATE 6 Same area as Plate 5, after flood control project; newly exposed rocks at bottom of photo are lighter colored.

PLATE 7 All Core samples have a 6 cm diameter and are printed at 0.67X.

7.1 - I30-4-NS, 153 ft, cryptalgal-laminated mudstone, MPM27822.

7.2 - I30-NS-DS-4, 296 ft, parallel-laminated mudstone with ostracod cross section, MPM27821.

7.3 - I30-NS-DS-7, 186 ft, massive mudstone with unidentified skeletal material, MPM28623.

7.4 - I30-8-NS, 336.5 ft, interbedded massive mudstone and parallel-laminated mudstone with mudcracks MPM28624.

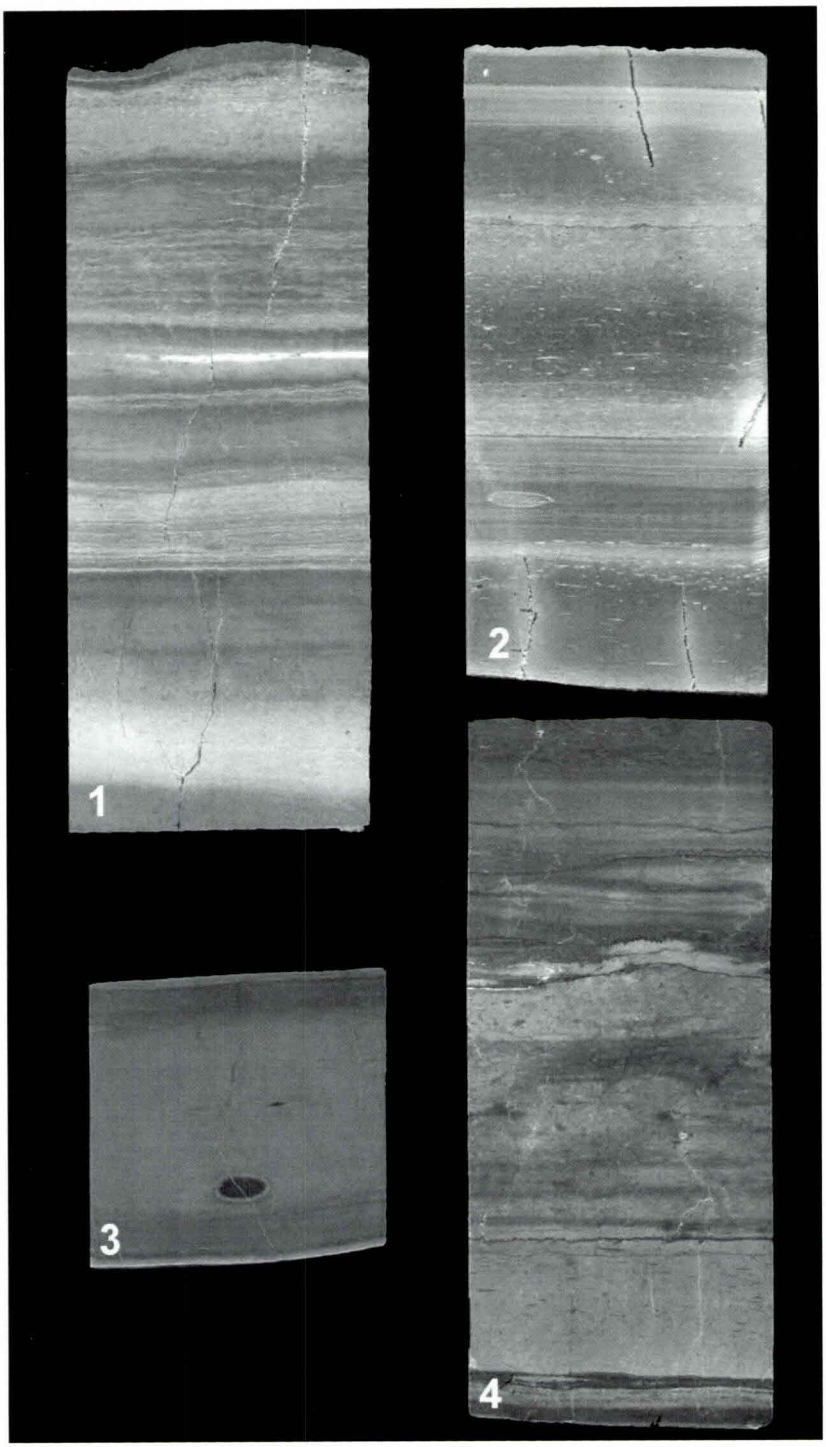

1
2
3
4

PLATE 8 All Core samples have a 6 cm diameter and are printed at 0.67X.

8.1 - I30-4-NS, 158 ft, cryptalgal-laminated mudstone with cut-and-fill structures and fenestrae, MPM28625.

8.2 - I30-8-NS, 335 ft, massive mudstone overlain by ripple-laminated mudstone and parallel-laminated mudstone with mud filled mudcracks MPM28632.

8.3 - I30-4-NS, 175.5 ft, cryptalgal-laminated mudstone with fenestrae, MPM28633.

8.4 - I30-4-NS, 155 ft, cryptalgal-laminated mudstone with fenestrae, mudcracks and soft sediment deformation, MPM28634.

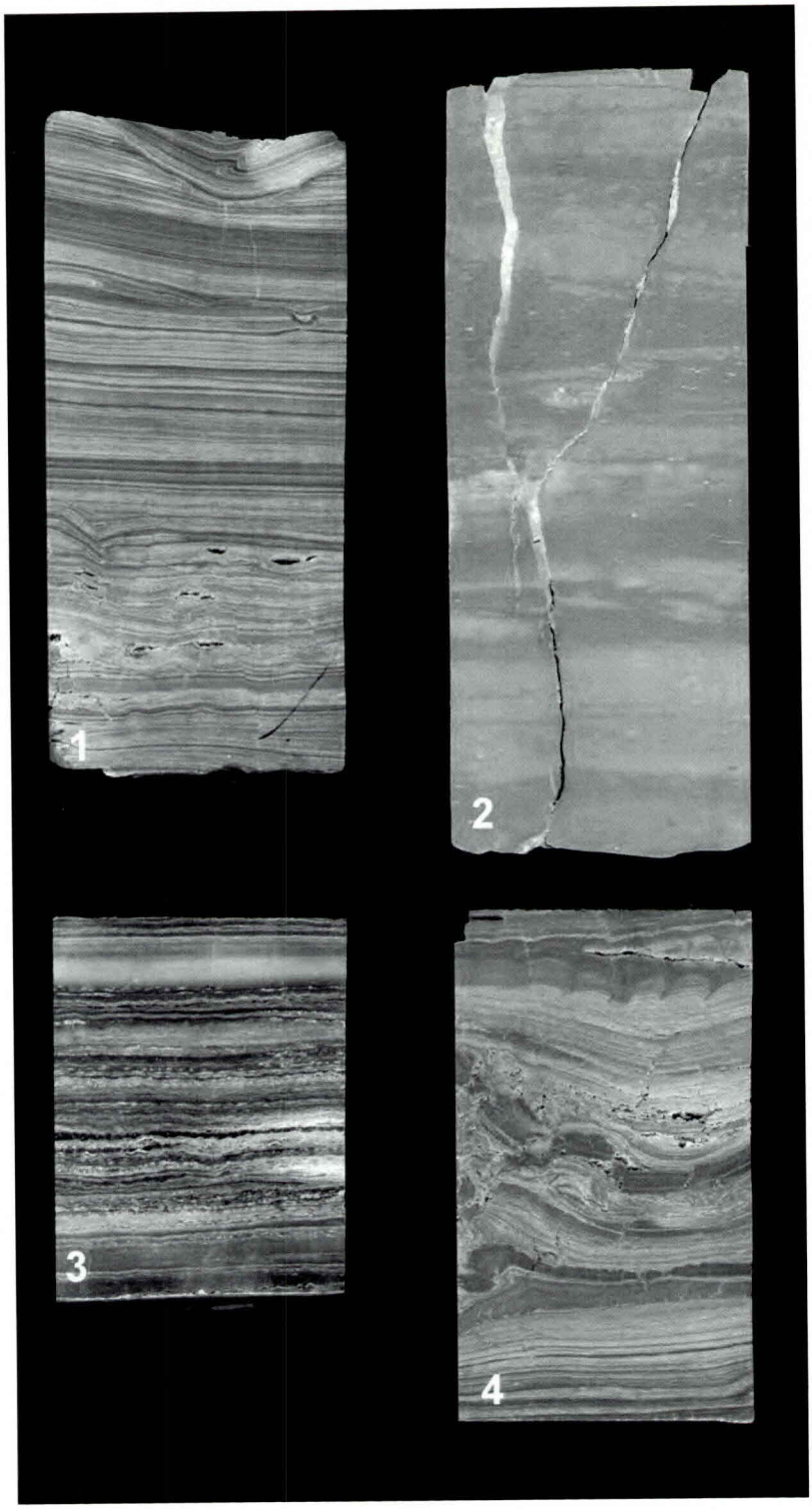

1
2
3
4

PLATE 9 All Core samples have a 6 cm diameter and are printed at 0.67X.

9.1 - I30-NS-DS-4, 320.5 ft, cryptalgal-laminated mudstone with gypsum veinlets, MPM28626.

9.2 - I30-NS-DS-4, 320 ft, cryptalgal-laminated mudstone with gypsum veinlets, MPM28627.

9.3 - I30-NS-DS-4, 277.5 ft, parallel-laminated mudstone with interbedded autobrecciated horizon, MPM28628.

9.4 - I30-NS-DS-4, 278.5 ft, parallel-laminated mudstone and autobrecciated horizon, MPM28629.

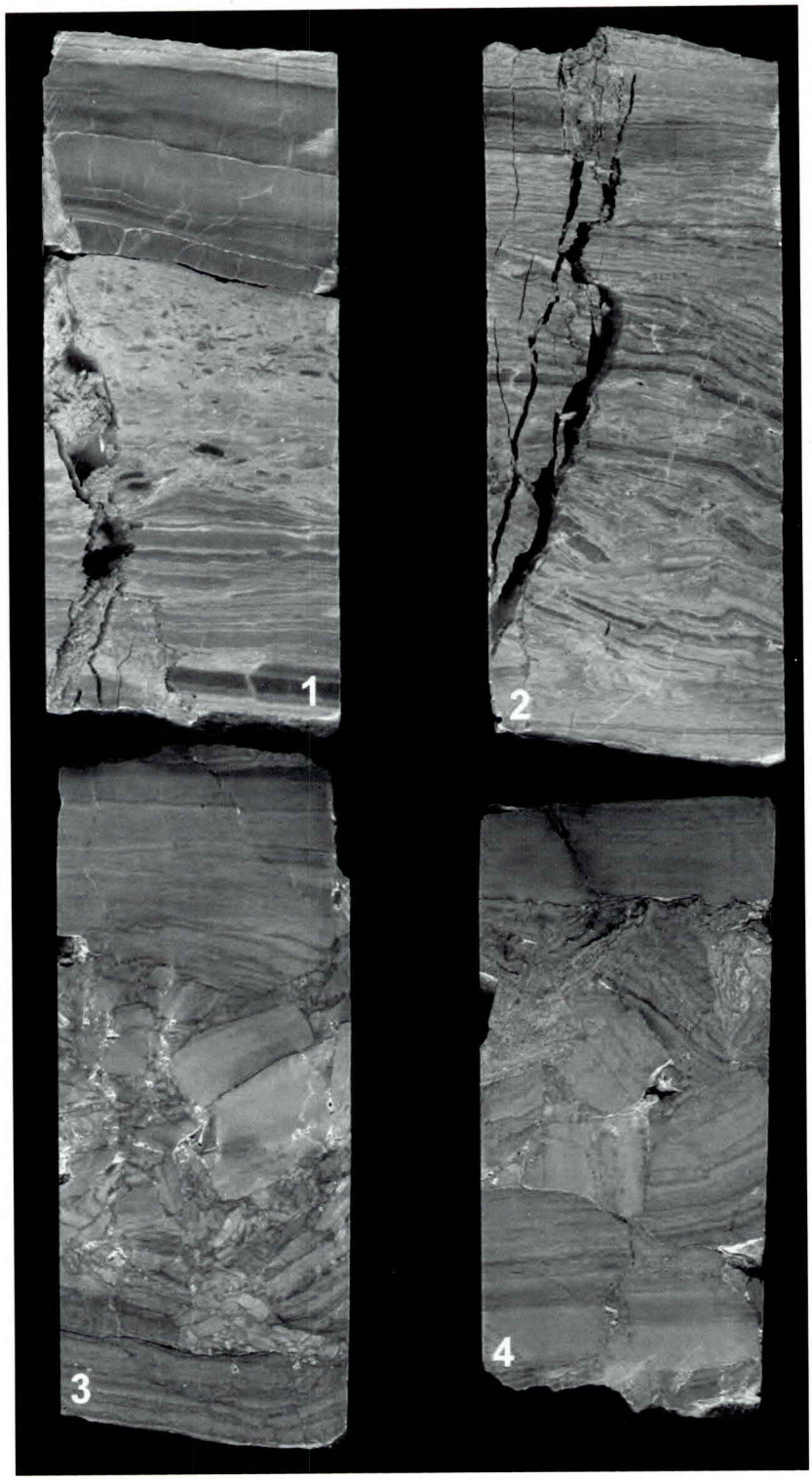

1
2
3
4

PLATE 10 Outcrop samples from Lincoln Creek; all scales are in cm.

10.1 - Small chute structure containing pseudomorphs of salt crystal casts.

10.2 - Cross section of small chute structure.

10.3 - Detail of pseudomorphs of salt crystal casts, MPM28630.

10.4 - Discontinuously-laminated mudstone.

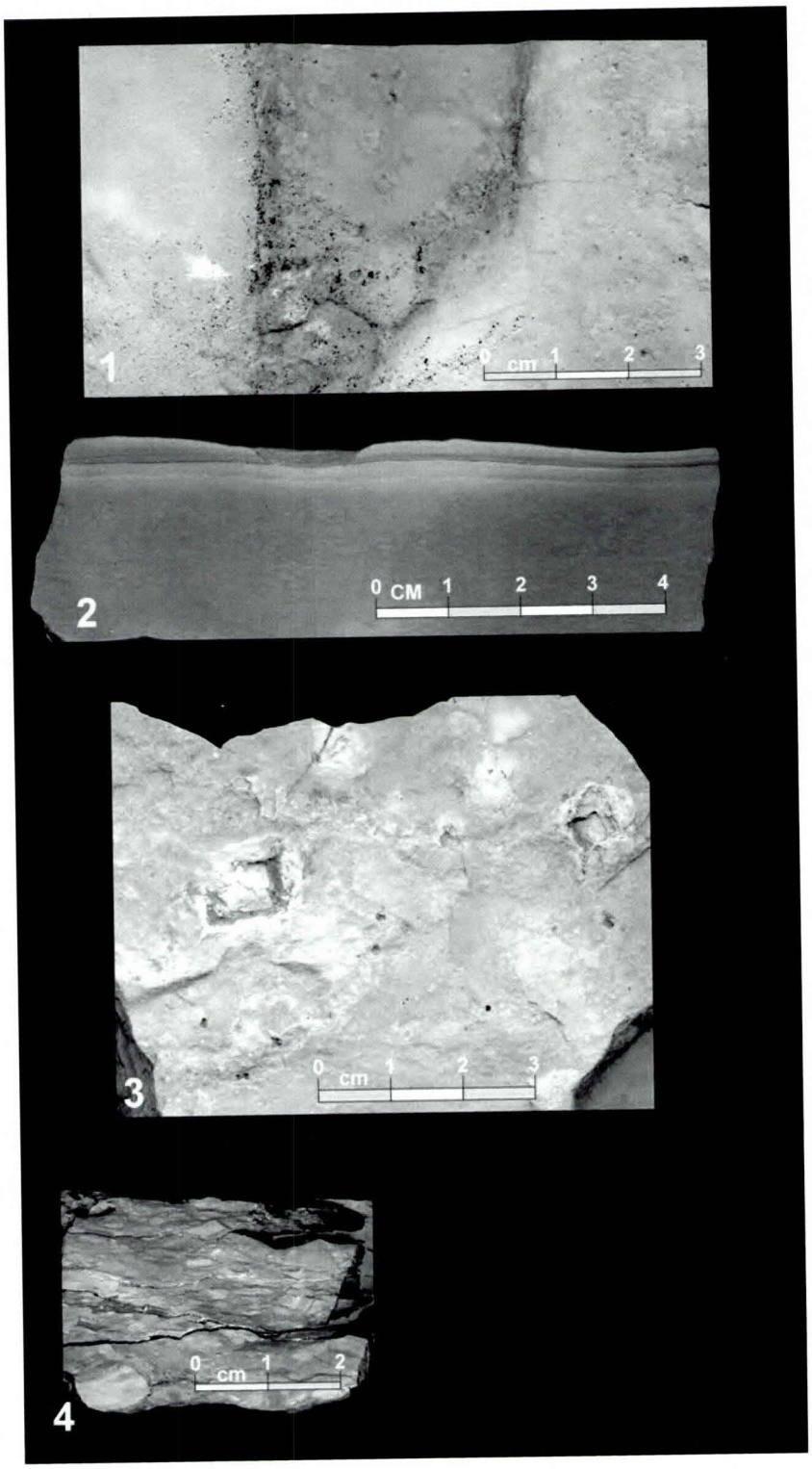

1
0 cm 1 2 3
2
0 CM 1 2 3 4
3
0 cm 1 2 3
4
0 cm 1 2

PLATE 11 All from I30-8-NS.

11.1 - Ooid-intraclast packstone.

11.2 - Ooid intraclast packstone.

11.3 - Cryptalgal-laminated mudstone with fenestrae.

11.4 - Parallel-laminated mudstone with fenestrae.

11.5 - Cryptalgal-laminated mudstone with fenestrae.

11.6 - Cryptalgal-laminated mudstone.

11.7 - Cryptalgal-laminated mudstone with stylolite.

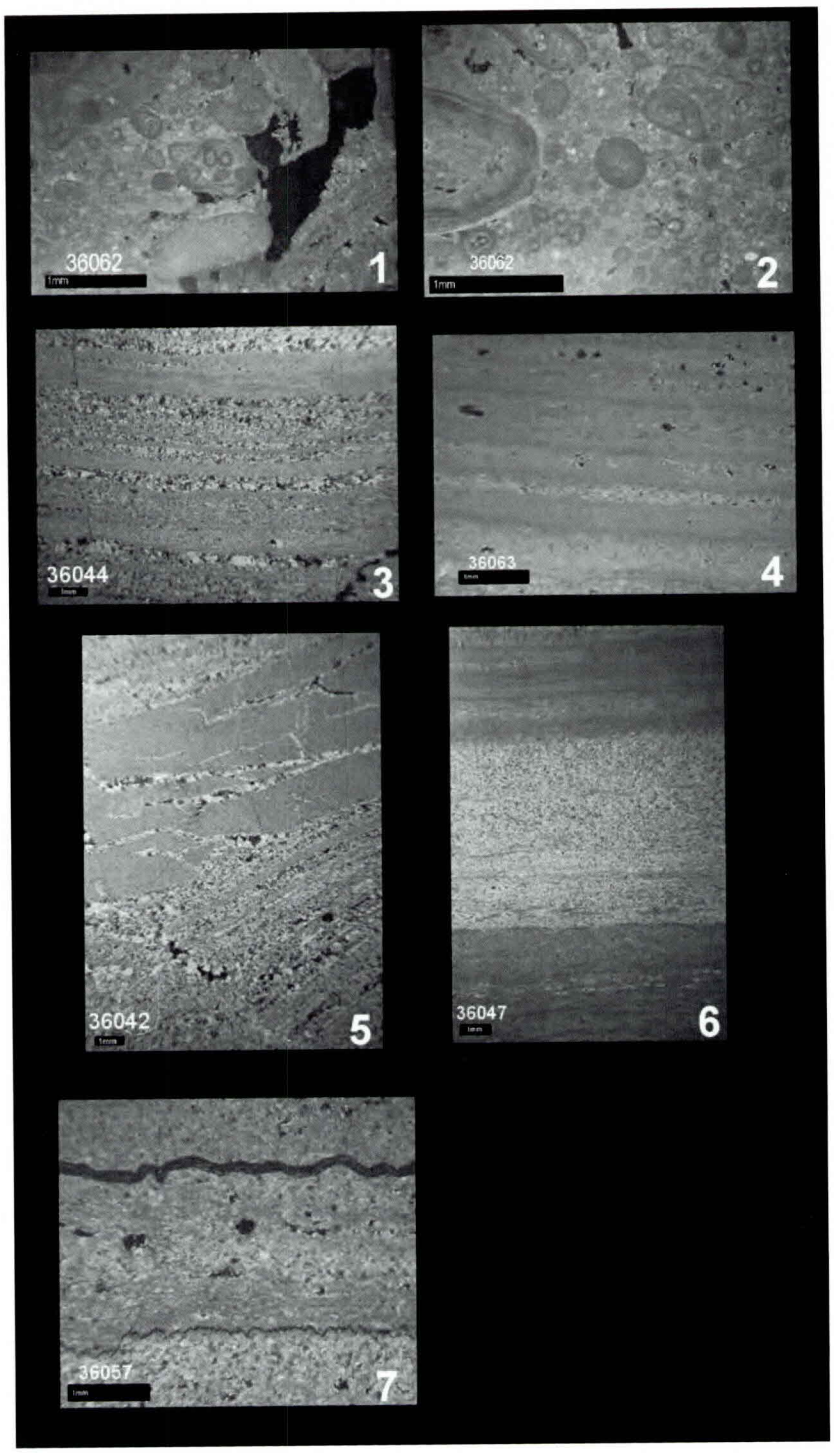

36062
1mm
1
36062
1mm
2
36044
3
36063
4
36042
5
36047
6
36057
7

PLATE 12 -All from I30-8-NS.

12.1 - Cryptalgal-laminated mudstone.

12.2 - Small ripple-laminated mudstone.

12.3 - Small ripple-laminated mudstone.

12.4 - Cryptalgal-laminated mudstone with fenestrae.

12.5 - Parallel-laminated mudstone with burrow cross sections.

12.6 - Cryptalgal-laminated mudstone with fenestrae.

12.7 - Cryptalgal-laminated mudstone with fenestrae.

12.8 - Parallel-laminated mudstone with fenestrae.

12.9 - Cryptalgal-laminated mudstone with fenestrae.

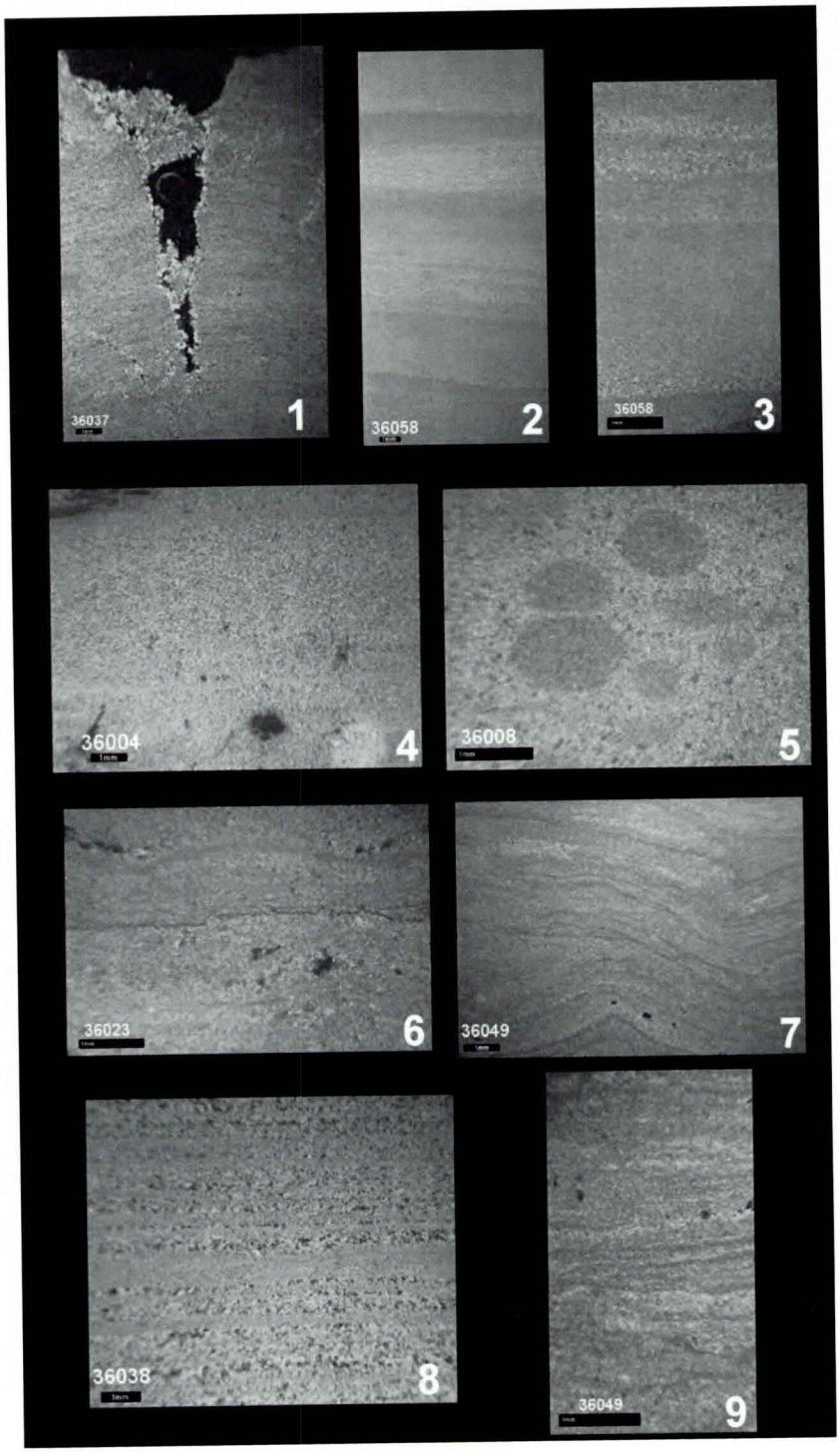

36037
1
36058
2
36058
3
36004
4
36008
5
36023
6
36049
7
36038
8
36049
9

PLATE 13

13.1 - "*Orthis*" *oblata* Hall, USNM136991, exterior of pedicle valve.

13.2 - "*O.*" *oblata* Hall, USNM137045, exterior of brachial valve.

13.3 - ?Orthide, exterior of pedicle valve, 1.4.

13.4 - *Resserella subcarinata* (Hall), USNM137076, exterior of brachial valve.

13.5 - Atrypacean, brachial valve, internal mold, 1.3.

13.6 - Atrypacean, indeterminate single valves, external molds, 2.

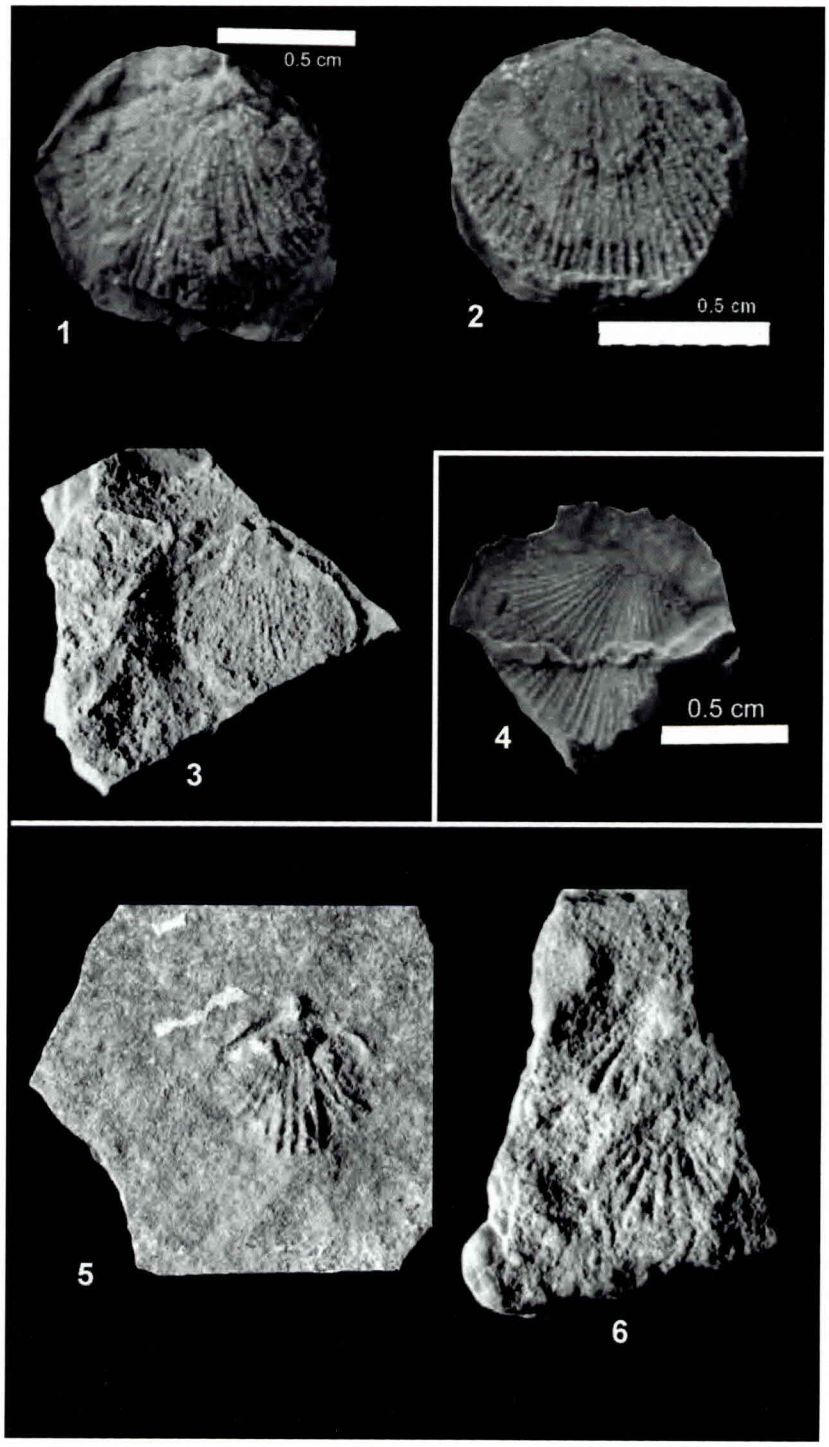

0.5 cm
1
2
0.5 cm
3
4
0.5 cm
5
6

PLATE 14

14.1 - "*Meristella*" *nucleolata* (Hall), internal mold of brachial valve, MPM28618, 3.1.

14.2 - "*M.*" *nucleolata* (Hall), USNM137067, exterior of pedicle valve USNM137067.

14.3 - "*M.*" *nucleolata* (Hall), interior of pedicle valve, MPM26819, 7.7.

14.4 - *Pterinea aviculoidea* (Hall), exterior mold of left valve.

14.5 - *P. aviculoidea* Hall, USNM137064, exterior mold of left valve.

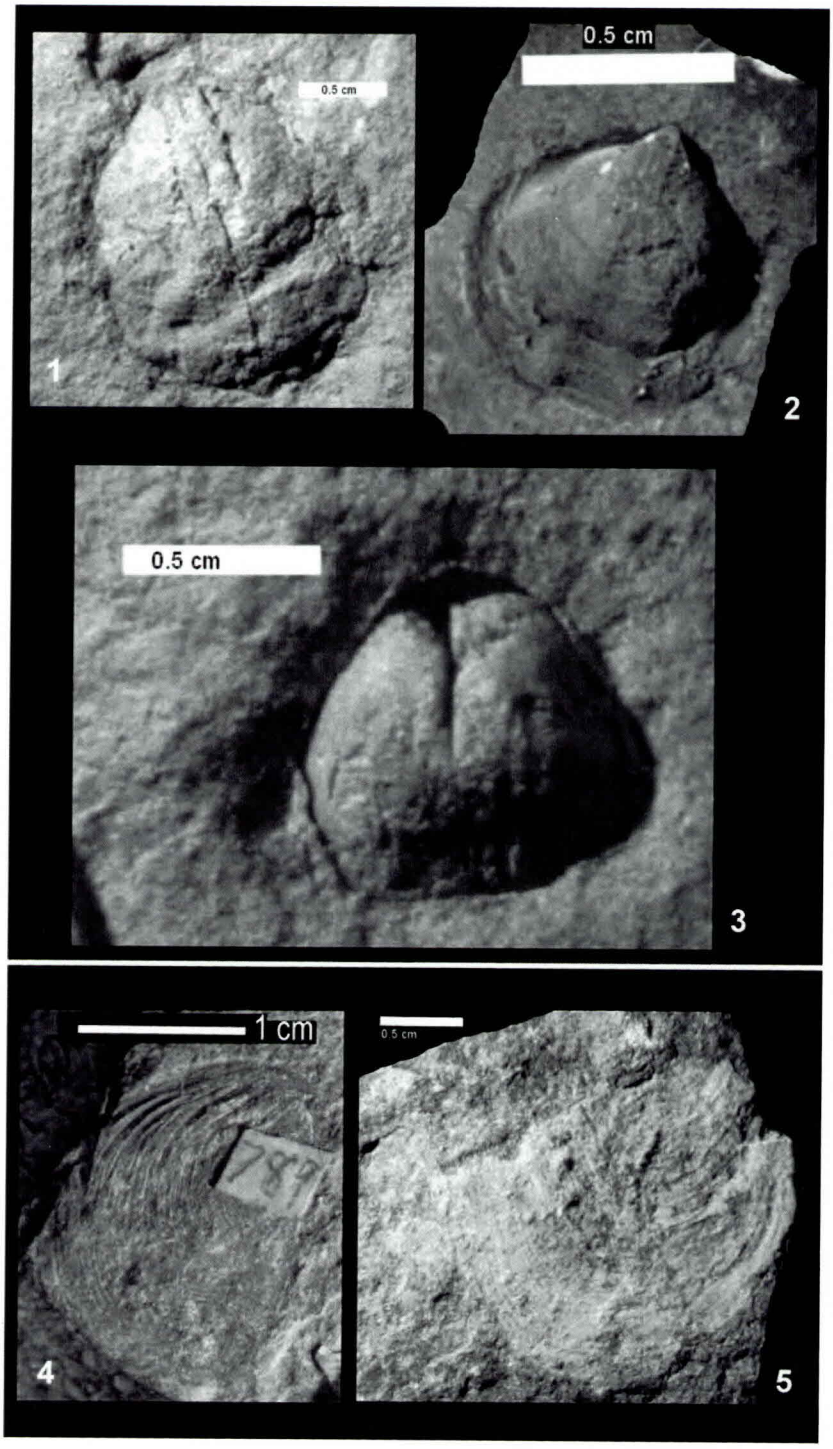

0.5 cm
1
0.5 cm
2
0.5 cm
3
1 cm
4
0.5 cm
5

PLATE 15

15.1 - Cephalopod, external mold of body chamber, 1.2.

15.2 - Leperditiid ostracod, conjoined valves, MPM28620, 3.1.

15.3 - Leperditiid ostracod, cross section, MPM12982, 1.8.

15.4 - *Ceratiocaris monroei* Whitfield, mandible; scale bar is 1 mm.

15.5 - *C. monroei* Whitfield, mandible.

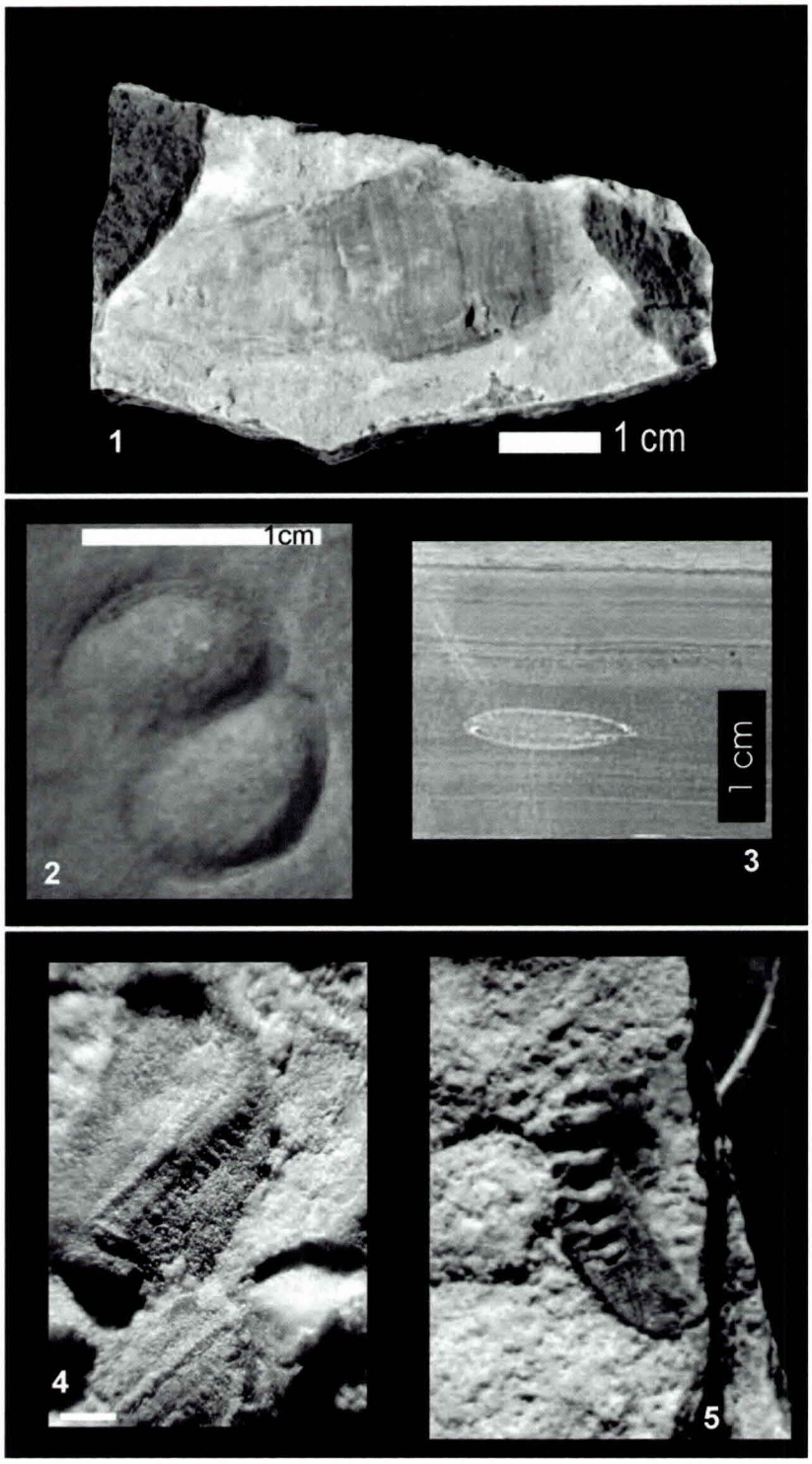

1
1 cm
1cm
2
1 cm
3
4
5

PLATE 16 all *Ceratiocaris monroei* Whitfield.

16.1 - Mandible; scale bar is 1 cm.

16.2 - Mandible; scale bar is 1 cm.

16.3 - Mandible; scale bar is 1 mm.

16.4 - Mandible; scale bar is 1 mm.

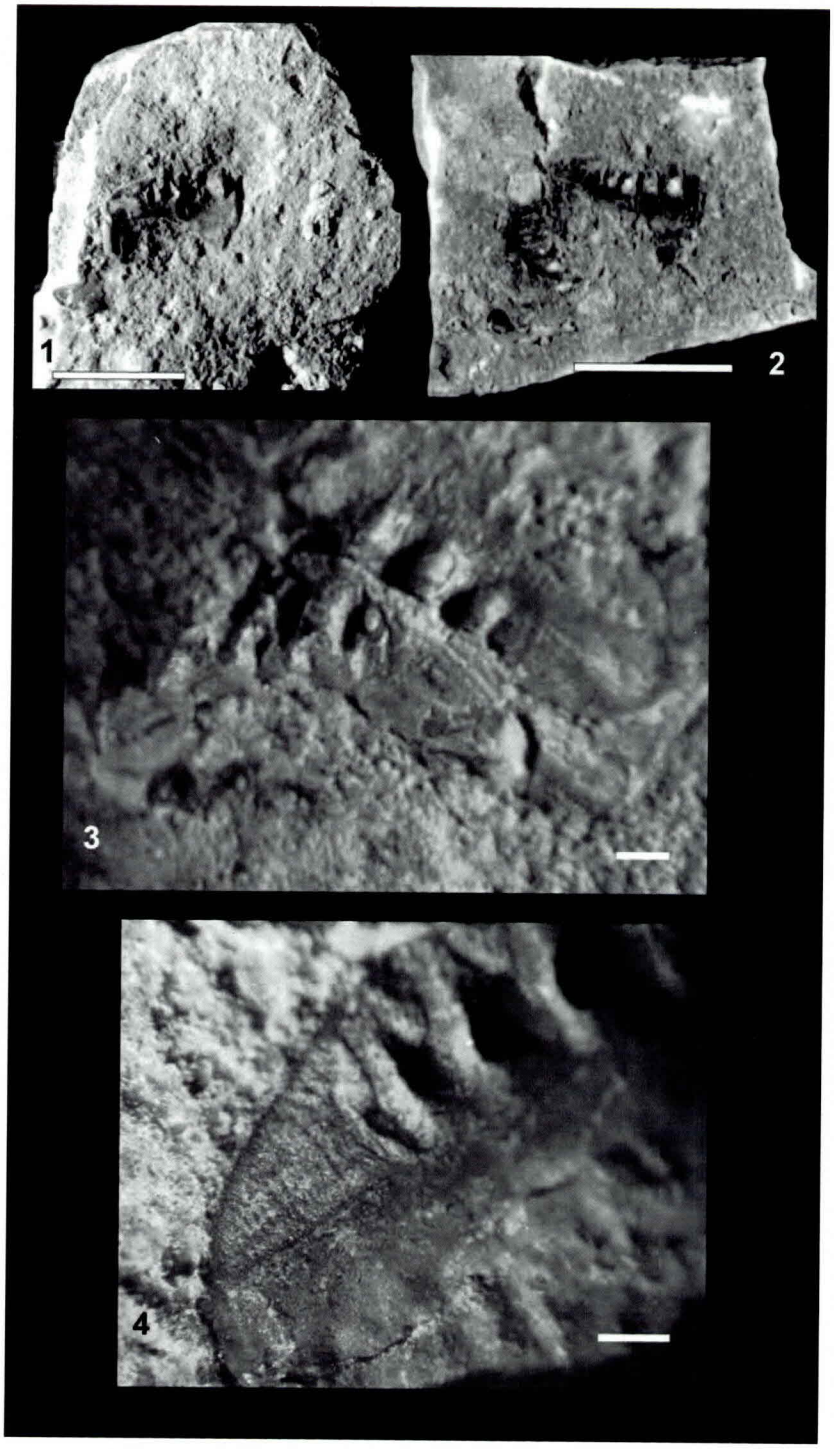

1
2
3
4

PLATE 17 all *Ceratiocaris monroei* Whitfield, scale bars are 1 cm., except for Fig. 6, which is 1 mm.

17.1 - Style and two stylets.

17.2 - Style and two stylets.

17.3 - Style and two stylets.

17.4 - Style and one stylet.

17.5 - Style and one stylet.

17.6 - Detail of style.

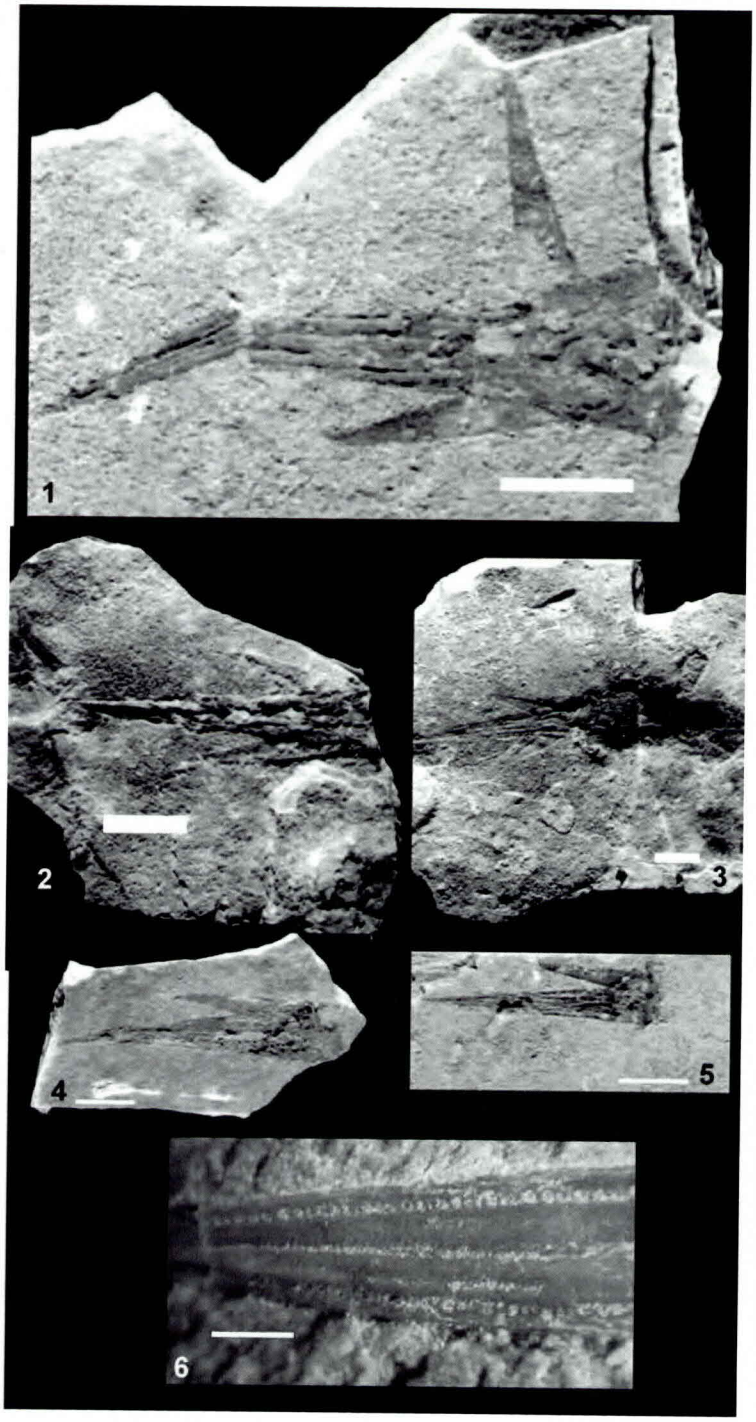

1
2
3
4
5
6

PLATE 18 all *Ceratiocaris monroei* Whitfield; scale bars are 1 cm.

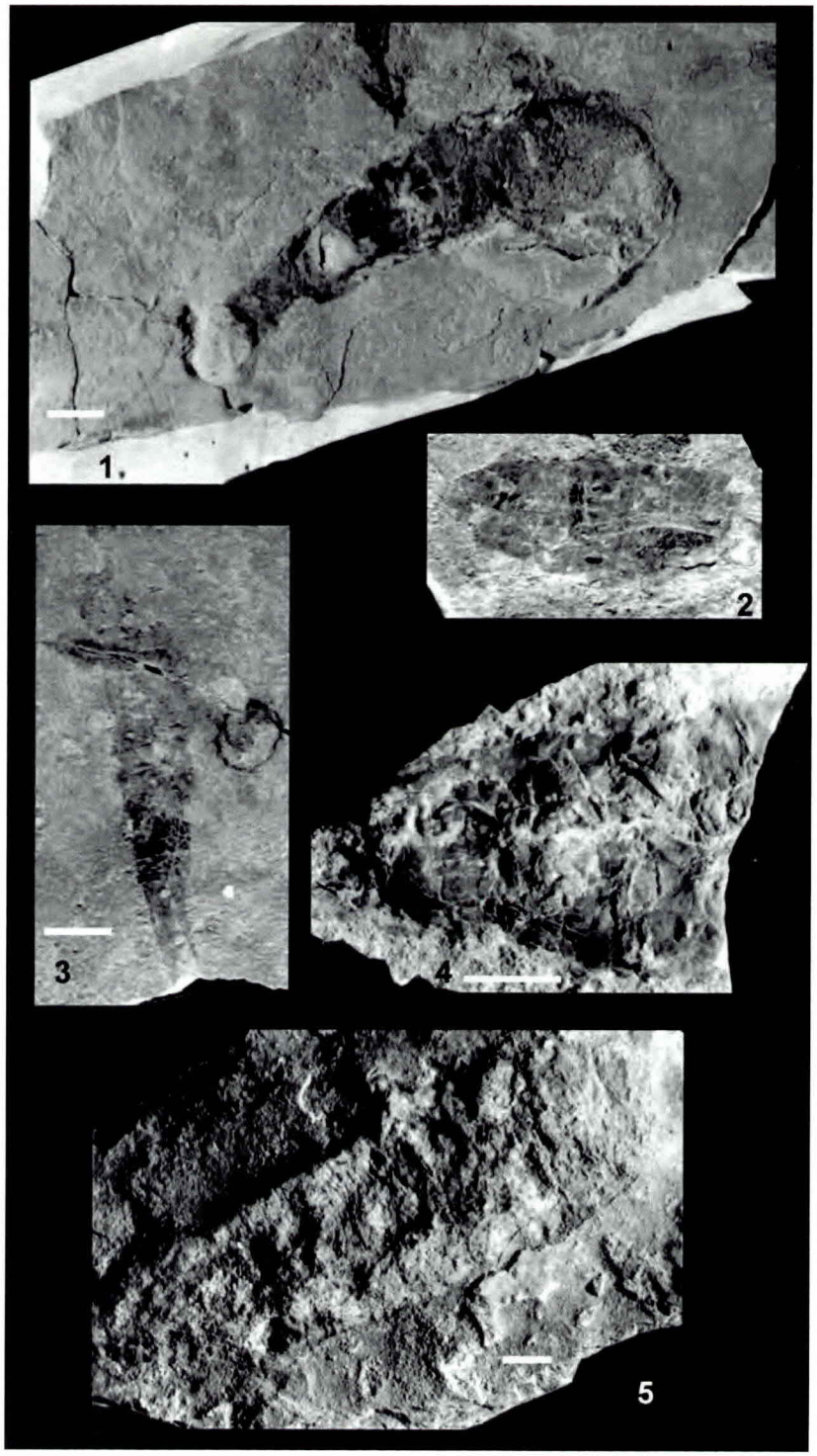
18.1 - Individual.

18.2 - Carapace.

18.3 - Abdomen and style.

18.4 - Abdomen.

18.5 - Abdomen.


1
2
3
4
5

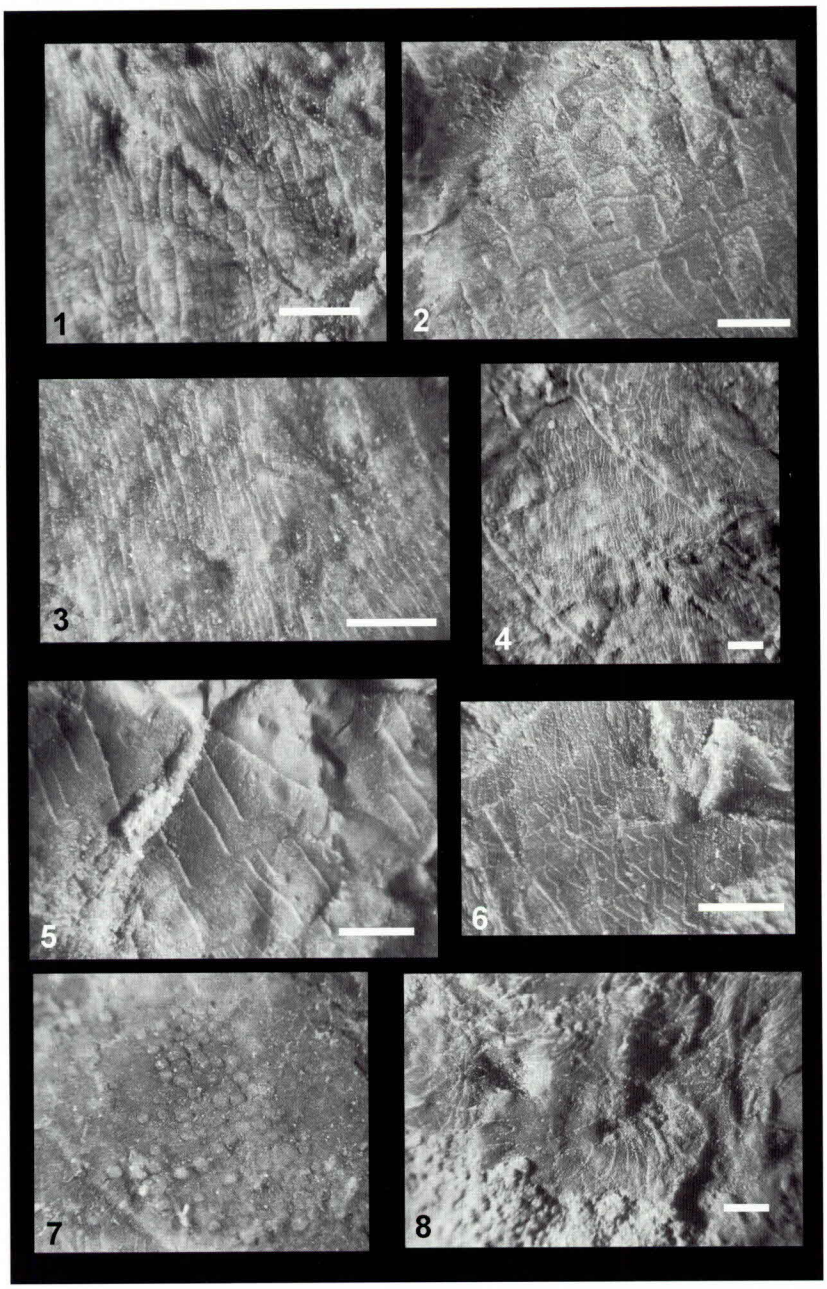


PLATE 19 all *Ceratiocaris monroe*i Whitfield. Details of body ornament; scale bars are 1 mm

Dr. Rodney Watkins was a Geology Curator at the Milwaukee Public Museum since 1988 and took over as editor of this publication in 1991. He retired from the Museum in 2005.

A list of Dr. Watkins' publications follows.

Dr. Rodney Watkins
Curator of Geology, Emeritus
Milwaukee Public Museum
Publications

Watkins, R., Mayer, P.S., and Coorough, P.J. 2007. Silurian of the Great Lakes region; Part 5, Sedimentology and Paleontology of the Silurian Waubakee Formation, Milwaukee and Ozaukee counties, Wisconsin, Contributions in Biology and Geology, vol. 103, pp. 62.

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