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THE RICHMOND FORMATION OF MICHIGAN

BY
R. C. HUSSEY

UNIVERSITY OF MICHIGAN
ANN ARBOR

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CONTRIBUTIONS FROM THE MUSEUM OF GEOLOGY

UNIVERSITY OF MICHIGAN

Editor: EUGENE S. MCCARTNEY

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THE RICHMOND FORMATION OF MICHIGAN

R. C. HUSSEY

CONTENTS

PART I: GENERAL STATEMENT OF THE PROBLEM

ACKNOWLEDGMENTS

SEVERAL persons have been very helpful to me during the course of this study. I am greatly indebted to Professor E. C. Case, who directed the research work, for aid in revising and criticising the paper; to Professor G. M. Ehlers for assisting with his knowledge of the literature and in problems of correlation; to Dr. A. F. Foerste for checking many of the old and new species of fossils; to Professor W. H. Shideler for help with the Bryozoa of the Stonington region of Michigan; to Dr. E. O. Ulrich for many valuable suggestions concerning correlation and problems involved

in the study of the fossils; and to Dr. W. I. Robinson for the use of his field-notes dealing with the region described. Finally, I wish to express appreciation of help received from the state geologist of Michigan, with whose permission this paper is published.

Introduction

This paper is concerned with the paleontology and stratigraphy of the Richmond (Upper Ordovician) formation, found in Bay de Noc, Nahma and Masonville townships, Delta County, Michigan. The peninsula lying between Little and Big Bay de Noc is about eighteen miles long and eleven miles wide at the widest part, and many of the chief outcrops of Richmond rocks occur within this area. The surface of the region is comparatively flat and controlled in a general way by the underlying rock, most of which is concealed by forests and glacial deposits. A high bluff along the western side of the peninsula is formed by outcrops of argillaceous and cherty limestone. From the crest of the bluff the land slopes gently to the southeast, with the dip of the rocks, and disappears beneath the waters of Big Bay de Noc in a low shore.

Michigan has long been regarded as a synclinal basin, with the rocks dipping in towards the center from all sides. This structure may be compared to a pile of plates, with each plate having a larger diameter than the one above, and with the edges of the plates representing the arcs of the rock outcrops. The Richmond forms the arc which swings in a general westerly and southwesterly direction from Drummond Island, at the eastern end of the Northern Peninsula of Michigan, to the Green Bay region of Wisconsin.

The location of places mentioned in the text, the position of outcrops of the various beds and members, and the localities where fossils were collected are indicated on the Map (p. 117).

Glacial Striae

Top of bluff, west of the home of A. Reinholdson (Loc. 17), one mile south of J. B. Stratton's farm (Loc. 7).....Direction, N. 11° W.
Top of bluff, west of Stonington Post Office (Loc. 6). Direction N. 10°–11° W.
In a shallow roadside ditch, in front of the home of Andrew J. Leadman, 3½ miles east of Stratton's farm (Loc. 16).....Direction N. 18°–20° W.
A small hill-side exposure, north of the road, 2 miles south and one quarter of a mile east of Alton (Loc. 15).....Direction N. 18°–20° W.

The approximate elevations above sea-level of the various locations mentioned in this paper were determined by an aneroid barometer as follows:

	FEET
Eastern end of Maywood road	660
Top of Hinkin's Hill	697
Eastern end of road running along south side of Stratton's farm	605
Top of ditch bank, along north side of road, just south of Stratton's farm	600
Road at top of hill, just before it descends to the creek level, on the George Demitt farm	700
At a point where the north and south road crosses the Soo Line Railroad, 1½ miles west of Ensign	715

New names are proposed in this paper for the various divisions of the Richmond of Michigan. If later discoveries of fossils, or other additional information, make more exact correlation with the Richmond of other regions possible, these new names may be abandoned and those already in use adopted.

Historical Review

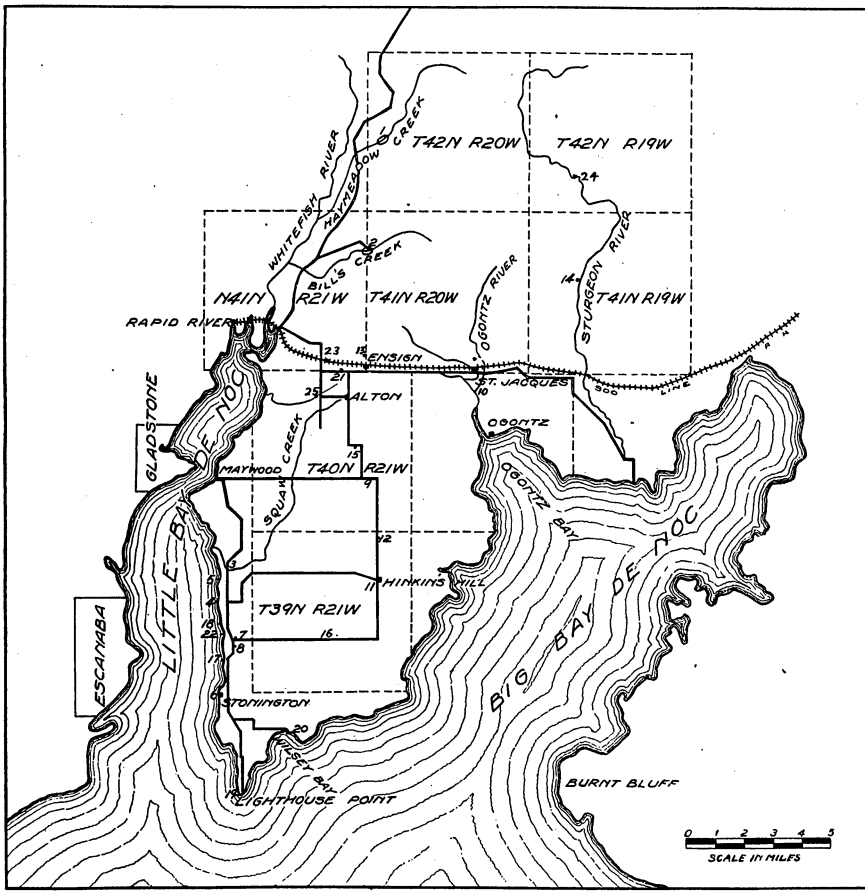
Work of Douglas Houghton

The first recorded observations upon the Richmond rocks of Michigan were made by Douglas Houghton, the first state geologist of Michigan. These notes appear in writing upon pages 187–189 of his Journal and Field Notes, under the date August 20, 1837. During the course of an extensive cruise in a small boat along the shores of Green Bay, Houghton skirted the eastern shore of Little Bay de Noc, and made a brief reconnaissance of the rocks exposed from Lighthouse Point (Loc. 19) to the end of the outcrop, about seven miles farther north. A generalized section is given, in which the rocks are divided into two members; a lower, argillaceous one and an upper, cherty one. No definite names are proposed for the beds. Houghton saw at least one of the two persistent layers of fine grained, argillaceous limestone, so prominent in the Bay de Noc member of the Stonington beds (page 134). Very little is said

KEY TO THE MAP OF THE STONINGTON REGION OF MICHIGAN

The Map shows the location of the outcrops of the Richmond formation. The numbers of the items in this list correspond to the numbers upon the map. The figures after the entries indicate the pages on which the locations are described.

1. Bill's Creek shale on Haymeadow Creek (see p. 122)
2. Bill's Creek shale on Bill's Creek (p. 121)
3. Bill's Creek shale on Squaw Creek (p. 124)
4. Bill's Creek shale, exposed along the eastern shore of Little Bay de Noc, north of Stratton's farm (p. 126)
5. Northern end of the outcrop of Bill's Creek shale, eastern side of Little Bay de Noc, one and one-half miles north of Stratton's farm (p. 127)
6. Stonington Post Office (p. 134)
7. Home and farm of Mr. J. B. Stratton (pp. 114, 118, *etc.*)
8. The Church (p. 139)
9. Exposure of Big Hill beds at eastern end of Maywood Road. Outcropping along north side of road for one quarter of a mile west of corner (p. 144)
10. Outcrop on Ogontz Creek (p. 145)
11. Hinkin's Hill or the Big Hill (p. 146)
12. Outcrop of Big Hill beds, along both sides of road from Hinkin's Hill north to eastern end of Maywood Road (p. 145)
13. Outcrop of Ogontz member of Stonington beds, on the farm of Andrew Barbeau, north of Ensign (p. 139)
14. "Eight-mile" rapids on the Sturgeon River. Big Hill beds (p. 147)
15. Exposure of Big Hill beds
16. Outcrop of Big Hill beds in front of the home of Andrew L. Leadman (p. 147)
17. Outcrop of Bay de Noc and Ogontz members of the Stonington beds, eastern side of Little Bay de Noc, west of the home of A. Reinholdson (p. 142)
18. Southern end of the Bill's Creek beds, outcropping along eastern side of Little Bay de Noc (p. 140)
19. Lighthouse Point. Ogontz member of Stonington beds (p. 132)
20. Wilsey Bay exposure of Big Hill beds (p. 146)
21. Bill's Creek shale exposed along the road, one mile north and one quarter mile west of Alton (p. 127)
22. Northern end of Stonington beds, outcropping along eastern side of Little Bay de Noc (p. 132)
23. Exposure of Bill's Creek shale, one and one-half miles west of Ensign (p. 124)
24. Exposure of Big Hill beds at the "twelve-mile" rapids on the Sturgeon River (p. 147)
25. Exposure on the George Demitt farm (p. 141)



MAP OF THE STONINGTON REGION OF MICHIGAN

of the Bill's Creek shale (page 121), and the relation of this bed to the higher rocks is not clearly defined. Many fossils were observed, and several field identifications made, but no systematic collecting was attempted. The report indicates great care in preparation, and its priority makes it a very valuable contribution to the stratigraphy of Michigan rocks.

WORK OF DR. CARL ROMINGER

In 1873 the Michigan Geological Survey published a paper by Dr. Carl Rominger upon *Paleozoic Rocks*, in which appears a short account (pp. 50–56) of the Hudson River or Cincinnati Group. This work also was of a reconnaisance nature, and no attempt was made to construct a section.

The lowest rock, stratigraphically, that Dr. Rominger observed, was the shale exposed in Bill's Creek (see p. 121); the thickness of the outcrop is estimated at 12 feet. The presence of "*Lingula* shells and *Clidophorus*" in the shale, and of Bryozoa in the interbedded argillaceous limestone at the top of the section, is especially noted. The beds are placed stratigraphically below the exposures along the eastern side of Little Bay de Noc, and are considered similar to the shales in the "lead regions of Illinois and Iowa."

The rocks exposed from Stratton's south to Lighthouse Point (see p. 132) are divided into lower "blue-colored argillaceous limestones, alternating with blue shales, and perfectly crowded with fossils," and upper "light-colored siliceous limestones, full of flint nodules, and enclosing a great number of fractured shells, of the same kinds as those found in the beds below." The total thickness of these beds is estimated at about 60 feet. A faunal list is presented, including fifteen genera and seventeen species.

Dr. Rominger saw the exposures at the "eight-" and "twelve-mile" rapids on the Sturgeon River (Locs. 14, 24), and noted there the presence of "a dark bluish-gray arenaceous limestone," and a "darker, bluish-green rock, more arenaceous, and interstratified with arenaceous marls." The two most important fossils observed were *Halysites* and *Sarcinula obsoleta*, now called *Columnaria* (*Paleophyllum*) *stokesi*.

WORK OF DR. A. F. FOERSTE

Dr. Foerste published a paper upon "The Richmond Faunas of Little Bay de Noquette, in Northern Michigan," in *The Ottawa Naturalist* for December, 1917. This study was confined to the rocks exposed along the eastern shore of Little Bay de Noc, and is a very important contribution to the paleontology and stratigraphy of the Richmond of Michigan.

Two accurately-made sections are given, in which the rocks are divided into three major divisions, the shale beds, exposed along the bay north of Stratton's (see map p. 117), and above these, in order, the argillaceous Richmond, and cherty Richmond, exposed from Stratton's south to Lighthouse Point. The faunal discussion is very full, and includes, besides descriptions and illustrations of several new species and varieties, much material dealing with Michigan representatives of forms already described. Tentative faunal correlations are made, particularly with the Richmond of the Ohio region.

The following classification of the Richmond Formation of Ohio is given for purposes of comparison with the Richmond of Michigan:

SERIES	FORMATION	BEDS
Cincinnatian	Richmond	Elkhorn Whitewater Saluda Liberty Waynesville Blanchester division Clarksville division Fort Ancient division Arnheim Oregonia division Sunset division

GENERALIZED SECTION OF THE RICHMOND ROCKS IN THE STONINGTON REGION OF NORTHERN MICHIGAN

Ordovician	Cincinnatian	Richmond	Stonington	Big Hill	?	20′ ±
						Exposure at Hinkin's Hill, and along road to north. Limestone, varying from light gray, moderately hard, non-crystalline, to dark gray, hard, coarsely crystalline.
						----------Covered interval. 5 feet----------
						2′
						Exposure at eastern end of Maywood road.
						Covered interval. 10 feet
				Ogontz		5′–6″ to 14′–10″
						Exposure along eastern side of Little Bay de Noc, south of Stratton's. Limestone, mostly hard, cherty, with argillaceous lenses. Color light gray through yellowish-brown to dark brown; on fresh surfaces, argillaceous parts bluish after weathering.
				Bay de Noc		22′ – 6″
						Exposure along eastern side of Little Bay de Noc, south of Stratton's. Argillaceous limestone in alternate hard and soft layers. Coarsely crystalline to non-crystalline. Grayish-brown to dark brown on fresh surfaces, general color bluish after weathering. Fossils abundant.
						---------- Covered interval ----------
						5′ +
						Exposure along eastern side of Little Bay de Noc, north of Stratton's. Basal part of Bay de Noc. Argillaceous limestone, dark gray, coarsely crystalline, hard, massive bedded.
						Disconformity
			Bill's Creek			21′
						Shale, thinly bedded to layers 6 inches thick. Exposure along eastern side of Little Bay de Noc, north of Stratton's.
						---------- Covered interval ----------
						?
						67′ – 4″
						Exposure at Bill's Creek. Shale varying from thinly-bedded, fissile, soft, to layers 6 inches thick, moderately hard. Color light gray to dark chocolate-brown on fresh surfaces, general color bluish after weathering. Thin layers of argillaceous limestone interbedded with shale near top of outcrop. Fossils abundant in the limestone, and locally abundant in the shale.
						Exposure along Soo Line Railroad, west of Ensign, correlated with upper part of Bill's Creek outcrop.

PART II: DESCRIPTION OF FORMATIONS

THE BILL'S CREEK BEDS

EXPOSURE ON BILL'S CREEK, THE TYPE LOCALITY (LOC. 2). — Bill's Creek rises in the northern part of Sec. 9, T. 41 N., R. 20 W., and, after pursuing a southwesterly course for about 6 miles, flows into Haymeadow Creek. For most of the way the stream runs through sand plains and cut-over timber land, but in the eastern part of Sec. 12, and the western part of Sec. 7, T. 41 N., R. 20 W., the creek has cut into thinly-bedded shale and limestone, having a total thickness of 67 feet 4 inches, as measured in the exposure along the stream banks (Fig. 1).

FIG. 1. Typical appearance of the Bill's Creek beds, as exposed in the bed and along the north bank of Bill's Creek. View taken about 100 yards east of the road crossing.

Character of the rock. — The rock is for the most part a thinly bedded, soft shale, with occasional layers 6 inches thick and moderately hard, which break with a conchoidal fracture. The color of fresh surfaces varies from light gray to dark chocolate-brown, becoming bluish after weathering. Numerous thin layers of argillaceous limestone are interbedded with the shale toward the

top of the outcrop. The shale and limestone often grade horizontally and vertically into each other. The limestone varies from hard, coarsely crystalline, and very fossiliferous, to soft, argillaceous, and without fossils. About one quarter of a mile up the creek from the point where the road crosses the outcrop, the shale gives place to thicker-bedded, argillaceous limestone.

Laminated lake clay. — A long discussion of this deposit is not pertinent to the subject-matter of this paper, but the following note may be of interest to anyone studying the seasonal changes which occurred during the Pleistocene. The clay, which is

FIG. 2. The little falls on Haymeadow Creek. The Bill's Creek shale is exposed in the bed of the creek and along the banks. *Graptolites* are numerous in the right-hand bank of the stream, just below the falls.

reddish-brown, and with a fine, smooth texture, is found at the down-stream end of the exposure of shale on Bill's Creek. At the outcrop the clay is 12 feet thick, and shows over two hundred so-called annual layers.

EXPOSURE ON HAYMEADOW CREEK (LOC. 1). — Haymeadow Creek rises near the center of Sec. 3, T. 42 N., R. 20 W., and runs in a southwesterly direction for about 8 miles, finally flowing into the Whitefish River. In the northern part of Sec. 19, T. 42 N., R. 20 W., the creek has cut into 14 feet of shale.

Character of the rock. — The shale is for the most part thinly-bedded and fissile. The color of fresh surfaces varies from light gray to dark chocolate-brown, becoming bluish after weathering. The odor of petroleum is noticeable from fresh fractures. The general appearance of the rock is the same as in all other exposures of the Bill's Creek shale described in this paper. A layer rich in *Graptolites* occurs in the right bank, just below the falls (Fig. 2).

Stratigraphic position of the rock. — This is the most northerly exposure of the Bill's Creek beds yet found. The dip of the rock in the region is comparatively slight, and it is hardly possible that the Haymeadow Creek outcrop is lower than that at Bill's Creek. *Graptolites* and *Ostracods* of the same species occur in both places, and it is probable that the rocks at Haymeadow Creek may be correlated with that part of the Bill's Creek section exposed just a short distance east of the road crossing.

Section of the Bill's Creek beds, at the type locality on Bill's Creek:

Top of Section	Feet	Inches
13. Argillaceous limestone, dark brown and earthy-colored on fresh surfaces, light to dark brown after weathering. Hard, coarsely crystalline. Very fossiliferous in places. Down the creek about 200 yards, this limestone gives place to an alternation of shale and thinly-bedded limestone	4	
12. Shale, thinly-bedded, fissile. Light gray to dark chocolate-brown on fresh surfaces, bluish after weathering	3	8
11. Argillaceous limestone, soft to hard, medium to coarsely crystalline, dark gray to dark brown on fresh surfaces, light brown after weathering. Lenses of shale common. Limestone and shale often grade horizontally into each other	3	8
10. Shale, dark gray, fissile, interbedded with indurated, buff-colored shale	3	2
9. Argillaceous limestone, dark gray, like that in layers 5 and 7		1
8. Shale, dark gray, like that in layer 6		$\frac{1}{4}$
7. Argillaceous limestone, dark gray, like that in layer 5		2
6. Shale, dark gray		$\frac{3}{4}$
5. Argillaceous limestone, dark gray, moderately hard to hard. Bryozoa abundant		$1\frac{1}{2}$
4. Shale, light gray to dark gray-chocolate-brown on		

Top of Section	Feet	Inches
fresh surfaces, bluish after weathering. Thicker-bedded than the shale in layer 1. Not fissile. Main *Lingula* horizon. Numerous water-worn specimens of *Clidophorus sp.*, 3 feet 8 inches from bottom of layer	15	
3. Shale, thinly-bedded, fissile, grayish-brown on fresh surfaces, bluish after weathering. Like that in layer 1	10	1
2. Shale, breaking into angular fragments, becoming fissile after weathering; mud lumps numerous. Grayish-brown on fresh surfaces, bluish after weathering	10	2
1. Shale, grayish-brown on fresh surfaces, bluish, much softer and fissile after weathering. *Dalmanellae* abundant	21	9

Exposure West of Ensign. — One and one-half miles west of Ensign the Soo Line Railroad has cut into thinly-bedded shale and interbedded argillaceous limestone, in general appearance like that exposed in the upper part of the section at Bill's Creek. The two horizons contain similar fossils, and may be correlated with each other.

Section of the Bill's Creek beds at the Ensign exposure:

Top of Section	Feet	Inches
4. Argillaceous limestone, dark brown on fresh surfaces, lighter brown after weathering. Moderately hard, medium to coarsely crystalline	8	
3. Shale, thinly-bedded, light gray to dark chocolate-brown on fresh surfaces, bluish after weathering	2	6
2. Argillaceous limestone, thinly-bedded, medium to coarsely crystalline, dark gray on fresh surfaces, light gray after weathering. Lenses of shale numerous; limestone and shale grade horizontally into each other in places. Bryozoa abundant	1	1
1. Shale like that in layer 3	4	6

Exposure at Squaw Creek (Loc. 3). — Squaw Creek rises just south of the village of Alton, and taking a general south-westerly course, flows into Little Bay de Noc about 3½ miles north of Stratton's farm. The creek is crossed by a bridge on the road 3½ miles south of Maywood. Loose slabs of shale are found in the creek bed for a distance of 100 yards below, and about one quarter of a mile above, the bridge.

Character of the rock. — The shale is grayish-brown to dark chocolate-brown on fresh surfaces, sometimes becoming bluish after weathering, but often remaining very dark brown or almost black. The odor of petroleum is noticeable from fresh fractures of the dark-colored slabs. This rock is similar to that exposed in Haymeadow Creek, Bill's Creek, the railroad cut west of Ensign

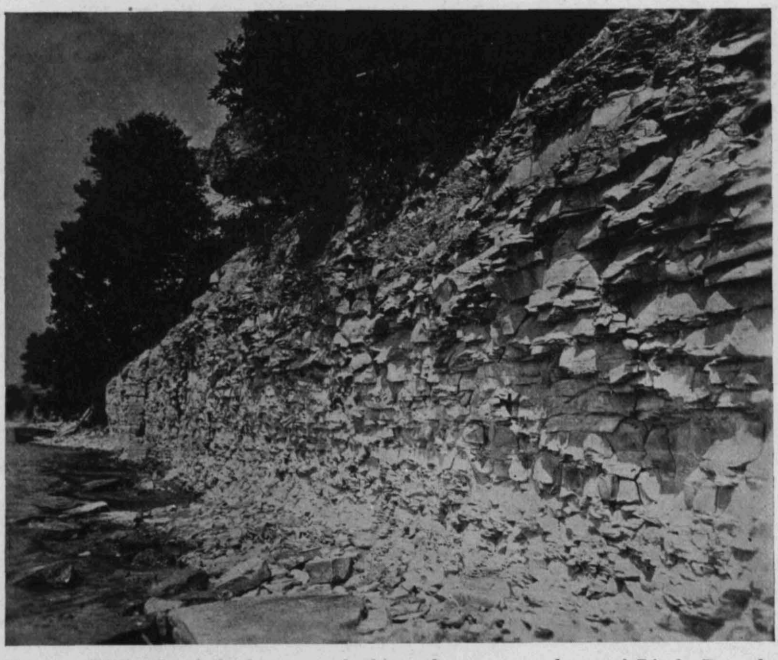


FIG. 3. Bill's Creek beds exposed along the eastern shore of Little Bay de Noc, about three quarters of a mile north of Stratton's farm. In the upper left-hand part of the figure, in the break between the trees, is seen the basal portion of the Stonington beds, Bay de Noc member, lying just above the disconformity separating the Bill's Creek beds from the Stonington.

(Loc. 23) and along the eastern shore of Little Bay de Noc. A few *Graptolites* and large numbers of *Leptobolus insignis* occur on some of the slabs.

Stratigraphic position of the rock. — This exposure lies along the strike of the Bill's Creek beds, and its geographic position,

about one half of a mile northeast of the exposure along the eastern shore of Little Bay de Noc, indicates that its probable position in the section is at, or a little below, the base of the Little Bay de Noc outcrop of the Bill's Creek beds.

Exposure along Little Bay de Noc (Locs. 4, 5, 18). — This exposure extends in an unbroken outcrop for a mile along the

Fig. 4. Close-up view of the Bill's Creek beds, exposed along the eastern shore of Little Bay de Noc, about three quarters of a mile north of Stratton's farm. Thicker layers, like that seen in the upper half of the figure, are often lens-shaped.

eastern shore of Little Bay de Noc, its southern end being one half of a mile north of Stratton's farm. The rocks are very accessible for study, the best exposure being at the extreme northern end. The base of the outcrop is in places covered by talus (Figs. 3 and 5).

Character of the rock. — The rock consists almost entirely of shale, varying from thinly-bedded and often fissile, to layers 6

inches thick. The color varies from light gray to dark chocolate-brown on fresh surfaces, becoming bluish after weathering. The odor of petroleum is noticeable upon fracture of the darker-colored rock. A few very thin layers of calcareous shale occur near the top of the section at the northern end (Fig. 5). Here the outcrop is 21 feet thick, and dips to the southeast at the rate of

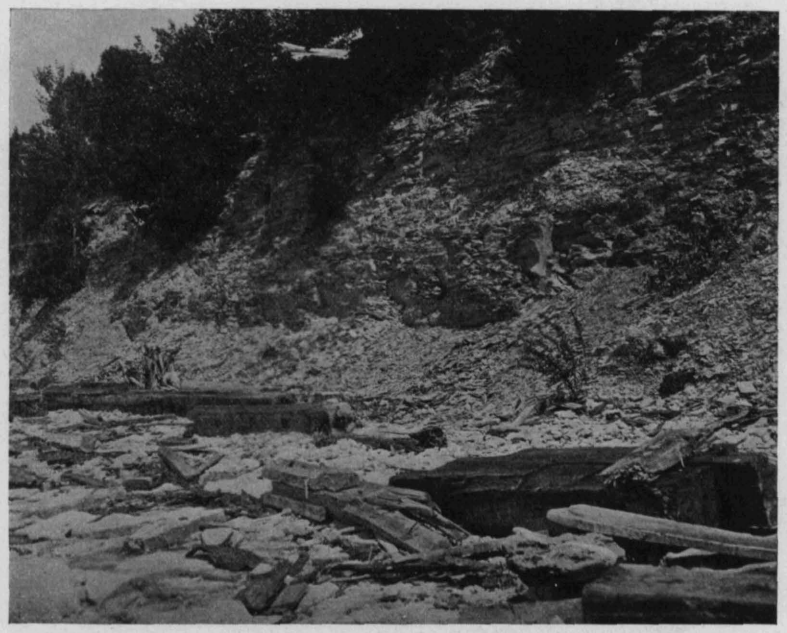


FIG. 5. Bill's Creek beds exposed along the eastern shore of Little Bay de Noc, one and one-half miles north of Stratton's farm. The thinly-bedded, fissile character of the shale is shown in the upper part of the figure; the thicker layers appear at about the middle of the picture.

21 feet to the mile. This dip is much greater than that of the higher beds to the south, and may be the result of local folding; this explanation is supported by the presence, in higher beds 6 miles to the east, of low anticlines and synclines.

ROADSIDE EXPOSURE. — During the course of road-grading operations the ditches along either side of the road may be cleaned

out sufficiently to expose the underlying rock; these exposures may later be covered by surface wash. Such an exposure of Bill's Creek shale, with no measurable thickness, occurs along the south side of the road, one mile north and one quarter of a mile west of Alton (Loc. 21). The shale varies from light gray to dark chocolate-brown on fresh surfaces, becoming bluish after weathering.

Section of the Bill's Creek and higher beds, exposed along the eastern shore of Little Bay de Noc, 1½ miles north of Stratton's farm, measured from the top of the bluff formed by glacial Lake Nipissing, westward across the fields to the level of the Bay:

STONINGTON BEDS

Ogontz member

TOP OF SECTION	FEET
5. Cherty limestone with argillaceous bands and lenses; grayish brown to yellowish brown; moderate to flinty hard. Exposure poor, due to soil covering	6

Bay de Noc member

4. Mostly a covered interval. Some of upper part may belong to Ogontz member. Middle part probably the Bay de Noc member. Lower 5 feet belongs to the basal limestone of the Bay de Noc, exposed in a few places	53
3. Argillaceous limestone, dark gray, medium to coarsely crystalline, hard. Fossils abundant. The basal limestone of the Stonington beds, Bay de Noc member, as interpreted at present	5

Disconformity

BILL'S CREEK BEDS

TOP OF SECTION	FEET
2. Shale, varying from thinly-bedded, fissile, to layers 6 inches thick, which often break with conchoidal fracture. Color light gray to dark chocolate-brown on fresh surfaces, bluish after weathering. Odor of petroleum very noticeable upon fracture of the darker-colored layers. Occasional very small sun-cracks. Fossils very scarce, with exception of *Tetradella regularis*, which is abundant in certain layers	21
1. Covered interval to level of Bay	5

Disconformity between the Bill's Creek and Stonington beds

At the top of the Bill's Creek beds, exposed along the eastern side of Little Bay de Noc, there is a persistent layer of fine-grained, argillaceous limestone, 4 to 5 inches thick, with an irregular upper surface showing a relief of 3 inches in places, probably due to subaërial erosion (Fig. 6). Immediately above the disconformity

FIG. 6. Detail of the Bill's Creek beds, exposed along the eastern shore of Little Bay de Noc, about one-half mile north of Stratton's farm. The hammer rests upon the erosion surface which marks the disconformity between the Bill's Creek and Stonington beds.

lies a bed of coarsely crystalline, massive-bedded, argillaceous limestone, near the bottom of which is a thin layer of basal conglomerate composed of water-worn fragments of the immediately underlying fine-grained, argillaceous limestone. Innumerable water-worn fragments of *Isotelus sp.* occur at the base of the limestone immediately above the disconformity. The disconformable contact is a cemented one, although the rocks can usually be made to separate cleanly. The line marking the break is very sharp,

easily visible to the eye, and the rocks on either side are quite different in appearance and lithologic character. The disconformity is further emphasized by the almost complete faunal break between the Bill's Creek and Stonington beds; only a few forms such as *Rafinesquina alternata*, *Pterinea* (*Caritodens*) *demissa*, and *Tetradella regularis* being common to both beds. A study of the faunal list will make this change apparent.

Conditions of deposition of the Bill's Creek beds

The several hundred layers of shale making up most of the Bill's Creek beds may have been deposited upon a broad, gently sloping, tidal flat, over which the water periodically spread layers of mud varying in thickness from paper-thinness to 6 inches. A gradual subsidence of the flat might be necessary in order to explain the total thickness of the beds — about 88 feet. The thicker layers probably represent periods when the streams were furnishing greater quantities of sediment to the sea, as during times of heavy rain. Sun-cracks are not common, but the presence of a few very small ones indicates actual exposure of the sediment to the rays of the sun, at least occasionally. The thin layers of argillaceous limestone interbedded with the shale near the top of the section at Bill's Creek and in the railroad cut west of Ensign, indicate occasional clearing of the water sufficient to permit the existence of limestone-forming organisms. The last four feet of the Bill's Creek section, consisting entirely of argillaceous limestone may represent a more permanent clearing of the water or an offshore phase of deposition in the clearer water some distance from the land.

Tetradella regularis as a possible horizon-marker

The vertical range and horizontal distribution of the Ostracod *Tetradella regularis* should be noted, as this form may prove of value as a possible horizon-marker in the Richmond of Michigan. The fossil is most abundant in the upper part of the Bill's Creek shale exposed along the eastern side of Little Bay de Noc, $1\frac{1}{2}$ miles north of Stratton's farm. Its known vertical range is from the

basal part of the Stonington beds immediately above the disconformity, where a few specimens have been found, down to about the middle part of the section exposed along Bill's Creek. It has been found in the Bill's Creek shale near the level of the creek on the George Demitt farm, in the railroad cut 1½ miles west of Ensign, and at irregular intervals along the entire exposure on the eastern side of Little Bay de Noc north of Stratton's farm.

Correlation of the Bill's Creek beds

Foerste (1919) notes the lithologic similarity between the Bill's Creek shale and the Sheguindah clay shale on Manitoulin Island. This shale lies beneath horizons containing Eden bryozoa, but there are no fossils in the Bill's Creek beds which would justify their correlation with the Sheguindah.

Tetradella regularis is known from the basal Waynesville and is associated with *Primitia cincinnatiensis* in both Ohio and Michigan.

Bythopora striata from the Bill's Creek beds occurs in the Arnheim and Waynesville of Ohio, Indiana and Kentucky. The abundant *Arthropora shafferi* is like the form from the lower Waynesville, and quite unlike any species from the Eden.

Near the base of the Maquoketa shale at Dubuque, Iowa, there is a zone containing *Clidophorus neglecta.* A thin layer containing numerous water-worn specimens of a pelecypod very closely related to *Clidophorus neglecta* occurs in the shale exposed along Bill's Creek, 27 feet 2 inches from the top of the section.

The dark, Lower Maquoketa shale of Iowa, Missouri and Minnesota is lithologically similar to the Bill's Creek shale.

Ulrich has examined the *Lingulae* from the Bill's Creek exposure and found three of the species to have identical forms in the Maquoketa at Graf, Iowa. The author examined specimens from these two localities and found them exactly alike.

Largely upon the evidence of the *Lingulae,* supported by the evidence of the lithologic similarity and the *Clidophorus neglecta* zones, the upper part of the Bill's Creek beds is correlated with the Maquoketa. The lower part may not belong to the Richmond.

THE STONINGTON BEDS

The Stonington beds, lying disconformably upon those of Bill's Creek, outcrop at Lighthouse Point and extend northward in a series of outcrops for eight miles along the eastern shore of Little Bay de Noc (Loc. 22). The main exposure extends from Stratton's dock two miles south in a continuous outcrop, forming a steep cliff vertical in most places, and varying in height from 30 to 50 feet.

FIG. 7. Bluff along the eastern side of Little Bay de Noc, just south of Stratton's dock, showing Ogontz or upper member, and Bay de Noc or lower member, of Stonington beds. The straight black line shows contact between the two members. The talus slope, from which most of the fossil-collecting at this point was done, appears at the foot of the cliff.

The base of the cliff is concealed by talus, from which fossils are easily collected, but the exact horizon and vertical range of the various forms can seldom be determined (Fig. 7).

The Stonington beds can be divided, upon faunal and lithologic grounds, into two members (Fig. 8); the name Bay de Noc is here proposed for the lower one, composed largely of argillaceous limestone, and the name Ogontz for the upper one, which consists mostly of cherty limestone.

The Bay de Noc member

The basal part. — The basal part outcrops for a mile along the eastern shore of Little Bay de Noc, beginning about one half of a

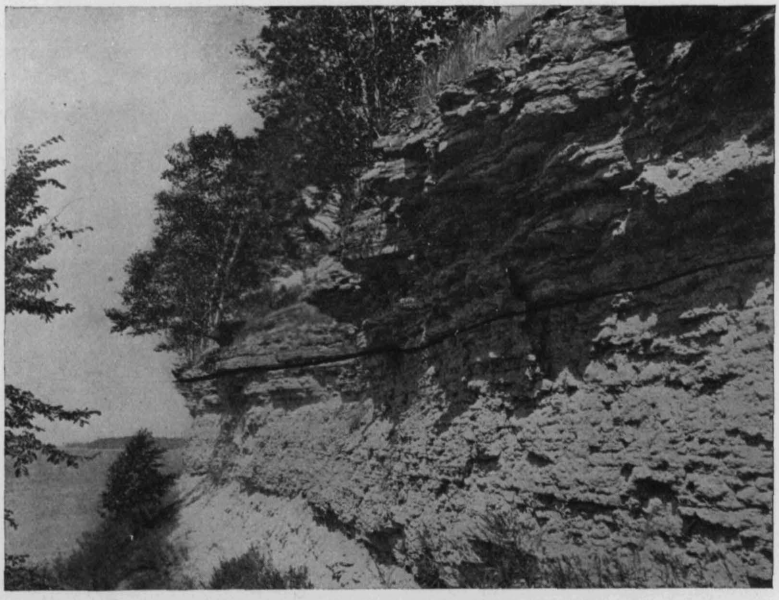


FIG. 8. Both members of the Stonington beds, exposed along the eastern shore of Little Bay de Noc, just west of the home of A. Reinholdson. The continuation of the beds is seen in the distant bluff, in the lower left-hand part of the figure. Black line marks contact between the two members.

mile north of Stratton's farm and extending northward. At the upper end of the outcrop the rock consists of argillaceous limestone, massive-bedded, coarsely crystalline and hard. The color is dark gray on fresh surfaces, weathering to grayish-brown. Fossils

are abundant, although well-preserved specimens are difficult to obtain. At the southern end of the outcrop this basal limestone changes to an alternation of thinly-bedded shale and argillaceous limestone, 15 feet thick. This is further discussed on page 139 under "Conditions of deposition of the Stonington beds."

The upper part. — The upper portion of the Bay de Noc member is the more important of the two, and is exposed from Stratton's farm south to the Stonington Post Office. It consists of argillaceous limestone, relatively hard, coarsely crystalline, dark gray on fresh surfaces, weathering bluish, interbedded with argillaceous limestone, non-crystalline, gray to dark brown on fresh surfaces, weathering bluish and brown. The harder layers are usually very fossiliferous, while the softer ones are almost devoid of organic remains. The bedding planes are in undulating lines, which are not continuous for any considerable distance. The rock weathers rapidly, breaking down into a sticky clay. The general dip of the beds is to the southeast at the rate of about 4 feet to the mile.

A pelecypod horizon. — Two layers of argillaceous limestone, very fine-grained, non-crystalline, and moderately hard, occur near the bottom of the Bay de Noc exposure, along the shore west of the Stonington Post Office. The upper one is 2 feet thick, and the lower one 2 feet 6 inches thick (Fig. 9). The two are separated from each other by 6 feet 2 inches of argillaceous limestone, coarsely crystalline and hard. The upper layer can be traced continuously as far north as Stratton's farm, but the lower one is concealed in most places by talus. This rock has been called indurated clay, but an analysis shows it to contain 73 per cent of calcium carbonate. The material breaks off in irregular masses with conchoidal fracture. These horizons have yielded many specimens of *Whiteavesia* (*Pholadimorpha*) *pholadiformis* and *Modiolopsis valida.*

Block fault. — A small down-thrown block with a displacement of 11 inches occurs in the Bay de Noc member exposed along the shore west of the Stonington Post Office.

The total thickness of the Bay de Noc member can not be exactly determined because the rocks are everywhere partly con-

cealed by talus or soil, but the thickness is approximately 38 feet 6 inches.

About 15 feet of the middle part of the Bay de Noc member is poorly exposed three quarters of a mile north of Stratton's farm, along the east side of the road running south from Maywood.

FIG. 9. Detail of the Bay de Noc member of the Stonington beds, exposed along the eastern shore of Little Bay de Noc, west of the Stonington Post Office. The lower layer of fine-grained argillaceous limestone appears between the chisel and hammer head. This is the chief pelecypod layer of the Bay de Noc.

The Ogontz member

EXPOSURE. — The Ogontz member appears at Lighthouse Point and extends northward along the eastern shore of Little Bay de Noc for 6½ miles. The beds are conformable upon the immediately underlying Bay de Noc in all the observed exposures.

Character of the rock. — The Ogontz consists of from 3 to 20

feet 2 inches of massive and irregularly bedded limestone, varying from soft and argillaceous to hard and cherty, the latter condition predominating (Fig. 10). The color ranges from light gray through yellowish-brown to dark brown. The softer material usually occurs in irregular bands and lenses. Vertical joints are occasionally developed (Fig. 11).

FIG. 10. Ogontz member of the Stonington beds exposed along the eastern shore of Little Bay de Noc, just west of the home of A. Reinholdson. The irregularity of the bedding is well shown.

The contact between the two members is especially well shown just south of Stratton's dock. The change from the lower to the upper member is not always abrupt, and it is sometimes impossible to locate exactly the line of contact. Toward the top of the Bay de Noc limestone the rock often becomes cherty, and the base of the Ogontz is usually argillaceous. The contact is very sharply

defined in some places. The transition is always accomplished within a vertical distance of one foot.

Fossils are abundant in the harder, cherty parts of the rock. They are sometimes preserved in excellent condition, but most commonly the cherty nature of the matrix makes good specimens difficult to obtain.

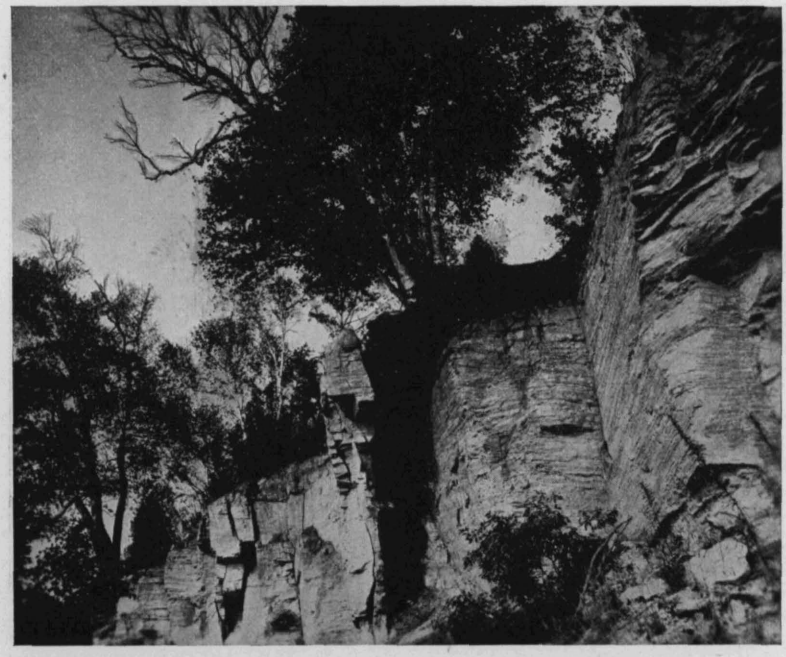


FIG. 11. Vertical jointing in the Ogontz member of the Stonington beds, exposed along the eastern shore of Little Bay de Noc, west of the Stonington Post Office.

Intraformational conglomerate. — A well-defined layer of intraformational conglomerate, about 1 foot 3 inches thick, occurs near the top of the Ogontz member, and can be traced for one quarter of a mile north along the exposure west of the Stonington Post Office. The conglomerate consists of nodules and thin slabs; the nodules are irregular, most of them having rounded edges; the slabs lie as those in typical edgewise conglomerate, with the long

axes parallel to the bedding-planes of the rock. The fragments are composed of the same material as the matrix. Often the nodules and slabs are fossiliferous, and the fossils are frequently cut off sharply, not continuing into the surrounding matrix.

MINOR EXPOSURES. — 1. A large amount of limestone was blasted from the ditch just north of the road which runs along the

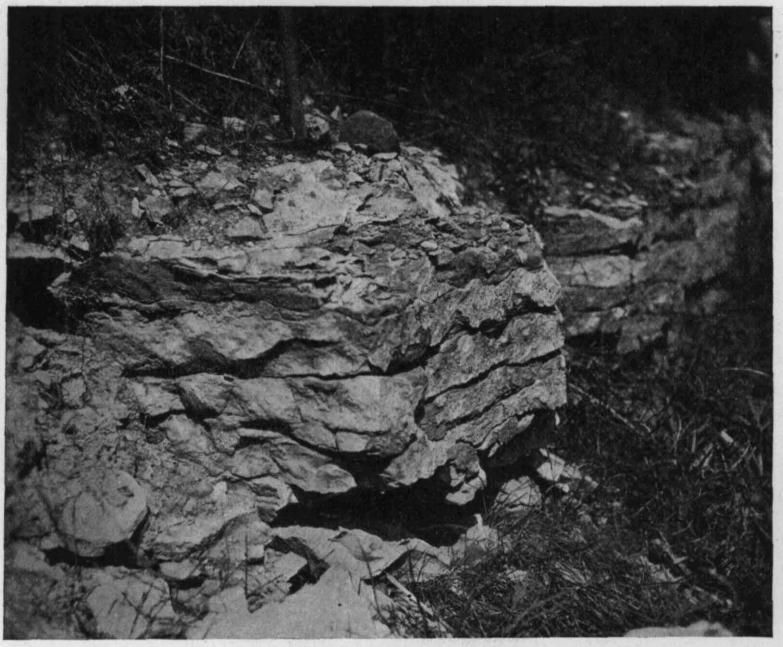


FIG. 12. Ogontz member of the Stonington beds exposed in the ditch along the east and west road, which runs just south of Stratton's farm. The limestone blasted from this ditch is piled along the north side of the road, and is very fossiliferous.

south side of Stratton's farm; this is a good place for collecting fossils (Fig. 12).

2. The basal part of the Ogontz is poorly exposed in a shallow ditch along the east side of the road, 2½ miles north of Stratton's farm.

3. Many large slabs of Ogontz limestone are found in the field just east of the church, one half mile south of Stratton's farm (Loc. 8).

4. A poor exposure occurs about three eighths of a mile west of Wilsey Bay in the road bed, and in the ditch along the north side of the road.

5. The most northerly exposure yet found is on the farm of Andrew Barbeau, about one half mile north of Ensign (Loc. 13).

Conditions of deposition of the Stonington beds

Bay de Noc member: Basal part. — The basal part of the Bay de Noc member, outcropping along the eastern shore of Little Bay de Noc, 1½ miles north of Stratton's farm, consists of argillaceous limestone, massive-bedded, with an exposed thickness of 5 feet and a total thickness of about 10 feet. One mile south near the southern end of the outcrop this bed gives place to at least twenty-four thin layers of interbedded shale and limestone having a total thickness of about 15 feet. The massive part of the bed may represent deposition in water largely beyond the reach of shore material, while the alternate layers of shale and limestone were possibly laid down nearer the shore where periodic fouling of the water by mud from the land drove out or killed the limestone-forming organisms. Such conditions might exist at the mouth of a river. The presence of ripple marks in the massive-bedded limestone supports the idea of its deposition in shallow water although it is not absolute proof.

The upper part. — The more argillaceous, non-fossiliferous layers were probably deposited in water too muddy for most forms of life, while the fossiliferous layers may represent deposition in clearer water where animals could exist. Among the possible explanations for this condition the following are suggested: alternate rainy and dry seasons, causing a variation in the amount of mud being swept into the sea; periodic rejuvenation of the rivers enabling them to transport more sediment than usual; oscillations of the strand-line. Under this last condition while the non-fossiliferous sediment was being deposited near shore, the fossilif-

erous layer was forming in clearer water some distance from the land. A change in position of the strand-line might then bring the fossil-bearing layer nearer the shore, where it would be covered by material containing few organic remains. Many oscillations of this sort would produce the conditions existing in the upper part of the Stonington beds.

The Ogontz member. — The relatively small amount of argillaceous material in the Ogontz limestone indicates deposition in comparatively clear water. The following possibilities are suggested for this condition. The mud which the land was furnishing during the deposition of the Bill's Creek and Bay de Noc beds may have been swept into the sea by Ogontz time, leaving the water clear. A lowering of the land might have reduced the transporting power of the streams to such a point that they were able to carry very little sediment. A change to more arid conditions would greatly reduce the amount of argillaceous material which the sea was receiving. The Ogontz limestone may represent a phase of the Stonington beds deposited in the clear offshore water.

Section of the basal part of the Stonington beds, one-half mile north of Stratton's, on the eastern shore of Little Bay de Noc.

STONINGTON BEDS

Bay de Noc member

TOP OF SECTION	FEET	INCHES
24. Argillaceous limestone, dark gray, hard, coarsely crystalline	2	
23. Fissile shale		4
22. Argillaceous limestone, same as in 24	4	
21. Argillaceous limestone, light to dark brown, moderately hard		1
20. Fissile shale		6
19. Argillaceous limestone, grayish-brown, moderately hard. Bryozoa numerous		2
18. Fissile shale		2
17. Argillaceous limestone, grayish-brown, medium coarsely crystalline, hard		1
16. Fissile shale. Bryozoa abundant		2
15. Argillaceous limestone, similar to that in 17	2	
14. Fissile shale		1
13. Argillaceous limestone, similar to that in 17		2

12.	Thinly-bedded shale		4
11.	Argillaceous limestone, medium to coarsely crystalline. *Clidophorus* abundant	1	10
10.	Fissile shale		8
9.	Argillaceous limestone, gray, fine-grained		1
8.	Shale, very fissile		2
7.	Argillaceous limestone, similar to that in 9		2
6.	Fissile shale		2
5.	Argillaceous limestone, similar to that in 11. *Clidophorus* abundant		2
4.	Shale, very fissile		1
3.	Argillaceous limestone, similar to that in 9		4
2.	Fissile shale		6
1.	Argillaceous limestone, dark gray, moderately hard to hard, medium to coarsely crystalline. Fossils abundant		5

Disconformity

BILL'S CREEK BEDS

Section of the Stonington beds, exposed along the eastern side of Little Bay de Noc, west of the Stonington Post Office:

STONINGTON BEDS

Ogontz member

TOP OF SECTION	FEET	INCHES
2. Limestone, massive and irregularly bedded, moderately soft and argillaceous to hard and cherty. Light gray, through yellowish-brown to dark brown. Intraformational conglomerate, 1 foot 3 inches thick, located 4 feet 9 inches from top of section. Fossils abundant	14	10

Bay de Noc member

1.	Limestone, argillaceous, made up of interbedded hard and soft layers. The hard parts coarsely crystalline, the soft parts non-crystalline. Dark gray on fresh surfaces, weathering bluish. Bedding planes in undulating lines	22	6

Section of the Stonington and upper part of the Bill's Creek beds on the George Demitt farm, as measured along the east side of the road, from the top of the low bluff to the creek level:

STONINGTON BEDS

Ogontz member

TOP OF SECTION	FEET	INCHES
4. Limestone, moderately soft, argillaceous, to flinty hard and cherty. Color light gray through yellowish-brown to darkbrown. Actual base of member concealed....	20	3

Bay de Noc member

3. Covered interval, probably occupied almost entirely by the Bay de Noc member.....	38	6

BILL'S CREEK BEDS

2. Limestone, moderately hard to hard, argillaceous, medium to coarsely crystalline; and interbedded fissile shale, light gray to dark chocolate-brown on fresh surfaces, weathering bluish and brown. Exposure poor. Contact with Bay de Noc member mentioned above not seen. Suggests the interbedded limestone and shale immediately above the disconformity, along the eastern side of Little Bay de Noc, one half mile north of Stratton's farm.....	3	
1. Covered interval to creek level.....	1	

Section of the Stonington beds, exposed along the eastern side of Little Bay de Noc, west of the home of A. Reinholdson:

STONINGTON BEDS

Ogontz member

TOP OF SECTION	FEET	INCHES
6. Limestone, soft and argillaceous, to hard and cherty. Soft material in irregular bands and lenses. Color light gray through yellowish-brown to dark brown. Fossils abundant.....	5	9

Bay de Noc member

5. Limestone, argillaceous, moderately hard to hard, medium to coarsely crystalline; interbedded softer layers, argillaceous, non-crystalline. Bluish after weathering. Fossils abundant in harder layers; few fossils in soft parts.....	9	1
4. Argillaceous limestone, very fine-grained, moderately hard, non-crystalline, dark gray on fresh surfaces, weathering bluish. Breaks off in irregular masses, with conchoidal fracture. Constitutes chief horizon for *Whiteavesia pholadiformis*.....	2	
3. Argillaceous limestone, similar to that in 5.....	6	2
2. Argillaceous limestone, similar to that in 4.....	2	6
1. Argillaceous limestone, similar to that in 5. *Platystrophia* horizon near top.....	3	

Correlation of the Stonington beds

The first attempt to correlate the Stonington beds was made by Dr. A. F. Foerste in *The Ottawa Naturalist*, Vol. 31 (1917), pages 125–126. The Bay de Noc, equivalent to his argillaceous Richmond, he puts in the late Waynesville or early post-Waynesville. The Ogontz, equivalent to his cherty Richmond, he correlates provisionally with the post-Waynesville beds of the typical Ohio Richmond. Foerste notes the lithologic similarity between the Ogontz limestone and the upper part of the cherty Richmond exposed on Manitoulin Island, 1½ miles south of Kagawong, on the Gore Bay road. A slab found at the top of the Ogontz on the George Demitt farm shows this resemblance especially well, according to Foerste.

The following list includes some of the most typical Stonington fossils, with their stratigraphic range in the Richmond section at various localities:

1. *Lichenocrinus tuberculatus*, common in the Ogontz. Found in the Whitewater of Ohio.
2. **Mesotrypa sp.,** sp. nov., both members of the Stonington. The Elkhorn at Hamburg, Indiana.
3. *Dinorthis subquadrata*, both members of the Stonington. The Liberty and Whitewater of Ohio.
4. *Hebertella alveata*, both members of the Stonington. The Liberty and Whitewater of Ohio.
5. *Rafinesquina breviusculus*, both members of the Stonington. The Elkhorn at Hamburg, Indiana, and Oswego, Illinois.
6. *Strophomena parvula*, both members of the Stonington. The Elkhorn at Oswego, Illinois.
7. *Strophomena neglecta*, both members of the Stonington. The Maquoketa at Savannah, Illinois; upper Waynesville of Ohio; a few specimens in the Whitewater at Richmond, Indiana.
8. *Strophomena sulcata*, common in the Bay de Noc. From the Clarksville division of the Waynesville to the Whitewater of Ohio.
9. *Strophomena vetusta*, common in the Bay de Noc. From the Waynesville to the Whitewater, of Ohio, Indiana and Kentucky.

10. *Strophomena huronensis*, common in the Bay de Noc. Top of the Arnheim and Waynesville of Kentucky; Ohio.

11. *Helicotoma brocki*, common in the Ogontz. From the Waynesville, south of Kagawong, on Manitoulin Island.

12. **Conularia noquettensis,** sp. nov., from the Ogontz. The Elkhorn at Morning Sun, Ohio.

Two of the characteristic fossils found in the Stonington beds which may prove especially significant in correlation are *Strophomena parvula* and *Rafinesquina breviusculus*. Shideler has found the first in the Elkhorn at Oswego, Illinois, and the second in the Elkhorn at Hamburg, Indiana, and Oswego, Illinois. The forms from these three localities are identical, and suggest a free migration route connecting the places.

The presence of so many Waynesville and Whitewater fossils in the Stonington beds, together with the Elkhorn forms, makes it unwise to attempt positive correlations at this time. *Rafinesquina breviusculus* and *Strophomena parvula* may occur in rocks stratigraphically lower than the Elkhorn, although they have not yet been found in such. It is possible that the lower part of the Bay de Noc member, including the *Whiteavesia pholadiformis* horizon, may be close to the Waynesville. The upper part of the Bay de Noc and the Ogontz may be equivalent to the Whitewater.

Exposure on Maywood Road (Loc. 9). — Three and one half miles north of Hinkin's Hill the road turns to the west, and rock outcrops in the shallow ditch along the north side of the road for one quarter of a mile.

Character and relationship of the rock. — The exposure consists of 2 feet of argillaceous limestone, medium coarsely crystalline, moderately hard to hard, gray to dark gray on fresh surfaces, somewhat bluish after weathering. Fossils are abundant. The exact relation of this bed to the underlying Ogontz and the overlying Big Hill is in doubt. The base is concealed, and the contact with the upper beds has not been seen. There is a covered interval of possibly 10 feet between the bottom of the outcrop and the top of the Ogontz, to which it may belong. The presence of such forms as *Calapoecia cribriformis, Columnaria alveolata, Beatricea* and

Rhynchotrema perlamellosum, suggests that the rock belongs to the Big Hill beds, and may represent a lower coral horizon.

EXPOSURE IN OGONTZ CREEK. — About 2 miles northwest of Ogontz, at a point where the Ogontz Creek or River crosses the road beneath a little bridge, rock is poorly exposed in the bed of the stream for one quarter of a mile eastward (Loc. 10). The outcrop consists of argillaceous limestone, moderately hard to hard, light gray to dark gray on fresh surfaces, with greenish, somewhat siliceous inclusions of irregular shape and size. Well-preserved fossils are not abundant. The presence in the rock of *Dalmanella jugosa subplicata*, *Platystrophia acutilirata*, *Plectambonites rugosus cf. noquettensis*, *Strophomena parvula*, *Zygospira recurvirostris cf. turgida* and *Whiteavesia pholadiformis*, suggests the fauna of the Bay de Noc member of the Stonington beds, although the geographic position of the Ogontz Creek outcrop is about 4 miles east of the known line of outcrop of the Stonington. The beds may have been brought to the surface by a fold.

THE BIG HILL BEDS

The term 'Big Hill' is here proposed for the rocks of the Michigan Richmond section lying above the Ogontz member of the Stonington beds. The contact between the two beds is concealed, but the separation is easily made because of the appearance in the Big Hill rocks of a characteristic faunal assemblage which includes such forms as *Calapoecia cribriformis*, *Halysites gracilis*, *Columnaria (Paleophyllum) stokesi* and *Columnaria alveolata*. This *Calapoecia* fauna is characteristic of the widespread invasion of the late Richmond sea, mentioned by Ulrich on page 306 of *The Revision of the Paleozoic Systems*, and has been recognized elsewhere, as in Texas, Colorado, Utah, the Big Horn Mountains of Wyoming, in Manitoba, and possibly in the Seward Peninsula of Alaska.

EXPOSURE NORTHWARD FROM HINKIN'S HILL. — From the crest of Hinkin's Hill, north to the eastern end of the Maywood road, a distance of 4 miles, there is an almost continuous outcrop in the shallow ditches on either side of the road (Loc. 12). Only the upper surface of the rock is exposed, and fossils are not abundant. The fossiliferous zone is rather thin, for shallow depressions

in the road often penetrated into the non-fossiliferous parts below. The rocks are folded into a series of at least three low anticlines and synclines, with the limbs dipping to the north and south. These rocks are stratigraphically higher than those at the eastern end of the Maywood road, since a covered interval estimated at about 5 feet separates the two.

Character of the rock. — The rock consists mostly of argillaceous limestone, varying from soft to hard, with a considerable amount of siliceous material irregularly distributed throughout it. Greenish inclusions are common, as in the outcrop at Ogontz Creek. The color varies from light gray to brown.

Exposure at Hinkin's Hill (Loc. 11). — Hinkin's Hill, called also the Big Hill, is the largest of the anticlines mentioned above; and here the highest, as well as some of the lower, of the Big Hill beds are exposed. The chief outcrop is on the southern dip slope of the hill, and is so poor that the thickness of the various divisions could not be determined.

Tentative section of the Big Hill beds, measured along the western side of the road, on the southern slope of Hinkin's Hill:

The Big Hill beds

Top of Section

4. Limestone, light gray, very fine-grained, soft to moderately hard. Surface covered with shallow pits, which may originally have been worm borings. A few poorly preserved casts of Pelecypods.
3. Limestone, argillaceous, light gray to dark gray, soft to moderately hard, weathering brownish. Surface pitted, similar to that in 4.
2. Limestone, argillaceous, gray to dark gray, finely crystalline, hard, breaking with conchoidal fracture.
1. Limestone, argillaceous, dark gray, soft to hard, somewhat siliceous, the hard parts finely crystalline.

Exposure at Wilsey Bay (Loc. 20). — Wilsey Bay is part of Big Bay de Noc, and is situated on the southeastern side of the Peninsula, about 4 miles northeast of Lighthouse Point. The rock outcrops along the northeastern shore of the bay for about three eighths of a mile.

Character and probable stratigraphic position of the outcrop. — The rock is a limestone, argillaceous and siliceous, moderately hard to hard, dark gray, with greenish, irregular bands and lenses.

Fossils are few and poorly preserved. The beds probably belong to the barren zone mentioned above in the description of the outcrop along the road north of Hinkin's Hill.

EXPOSURE AT LOCATION 16. — A poor outcrop occurs along the south side of the road, directly in front of the home of Andrew J. Leadman. The rock consists of argillaceous limestone, moderately hard, with greenish and yellowish-brown siliceous bands and lenses. A few poorly-preserved specimens of *Platystrophia sp.*, *Streptelasma rusticum* and *Columnaria alveolata* were found.

Probable stratigraphic position of the rock. — Between the bottom of this exposure and the top of the Ogontz which outcrops in the ditch along the north side of the road, about one quarter of a mile west of Leadman's, there is a covered interval of 12 feet. This places the Leadman exposure in a stratigraphic position not far above the top of the Ogontz, and probably close to the position of the Big Hill beds along the road north of Hinkin's Hill.

EXPOSURES ALONG THE STURGEON RIVER (LOCS. 14 AND 24). — About 8 miles up the Sturgeon River in a direct line from the mouth, the river runs over ledges and loose blocks of dark gray and greenish-gray, argillaceous and somewhat siliceous limestone, moderately hard to hard. Rocks of the same kind appear in the river banks, interbedded with bluish-green argillaceous limestone, moderately soft to hard, and finely to coarsely crystalline; the same beds outcrop again four miles farther up the river at the "twelve-mile" rapids. The exposures are not continuous, since most of them are covered by glacial drift and forest growth. The total thickness of the beds is not less than 15 feet.

Stratigraphic position of the rock. — The presence in these outcrops of *Columnaria (Paleophyllum) stokesi* and *Halysites gracilis* correlates them with the Big Hill beds; their exact position with relation to the other outcrops of the same beds can not yet be determined, but they belong to the *Columnaria (Paleophyllum) stokesi* horizon, typically developed in the exposure along the side of the road immediately north of Hinkin's Hill.

Correlation of the Big Hill beds. — Some of the most characteristic Big Hill fossils, with their ranges in various localities, are listed in the following table:

1. *Beatricea undulata*, occurs in the Liberty of Kentucky, and at the base of the Saluda, near Madison, Indiana.

2. *Calapoecia cribriformis*, from the Waynesville to the Elkhorn in Kentucky; from the Waynesville of Ohio and Indiana.

3. *Columnaria (Paleophyllum) stokesi*, from the Richmond of Green Bay, Wisconsin; Lake Winnipeg, Lake St. John, and so forth, Canada.

4. *Halysites gracilis;* the Richmond of Green Bay, Wisconsin; Lake Winnipeg, Anticosti, Ontario.

5. *Rhynchotrema perlamellosum*, referred by Foerste to the Waynesville.

6. *Strophomena planumbona*, the Waynesville and Liberty of Ohio, Indiana and Kentucky.

7. *Strophomena planumbona elongata*, the Waynesville of Ohio, Indiana and Kentucky.

According to Ulrich (*Revision of the Paleozoic Systems*, page 306), the bed containing the *Calapoecia* fauna rests on Maquoketa shale in Lincoln County, Missouri; on the eroded surface of the Girardeau at Thebes, Illinois; on the lower Trenton in Lake Huron; locally on earlier Richmond, but commonly on Galena, in Colorado, Utah, Wyoming, Nevada, New Mexico, Texas and in Manitoba.

The Big Hill beds may be of approximately the same age as the Stonington, or they may be younger. The exact correlation must for the present remain in doubt. The presence of *Strophomena planumbona elongata*, a Waynesville form, in the Big Hill beds which are probably higher than the Waynesville, reminds us that our conclusions as to the vertical range of fossils are always subject to revision.

PART III: SUMMARY AND CONCLUSIONS

THE rocks of the Richmond Formation of Michigan outcrop along a comparatively narrow arc, that swings in a general westerly and southwesterly direction, from the eastern side of the Northern Peninsula to the Green Bay region of Wisconsin.

The rocks can be divided, upon faunal and lithologic grounds, into two beds, the upper one having two members.

The Bill's Creek beds. — These beds which are the lowest, stratigraphically, in the Richmond of the Stonington region, consist largely of thinly-bedded shale, with a few thin layers of interbedded argillaceous limestone, highly fossiliferous. The chief exposures are on Bill's Creek, the type-locality, and along the eastern shore of Little Bay de Noc. Total thickness of the section about 88 feet. The upper part of the beds has been definitely correlated with the Maquoketa; the lower part may not belong to the Richmond.

STONINGTON BEDS

Bay de Noc member. — These rocks are separated from the Bill's Creek below by an erosional disconformity. The basal portion of the member is a massive-bedded, argillaceous limestone, and the upper, or main part, consists of argillaceous limestone in alternate, comparatively thin, hard and soft layers. The chief exposure is along the eastern shore of Little Bay de Noc, south of Stratton's. Total thickness about 28 feet. Fossils abundant.

Ogontz member. — This member rests conformably upon the Bay de Noc. The rock consists largely of cherty limestone, with lenses of argillaceous material. Clearer water conditions at this time caused the introduction into the fauna of the Ogontz of many forms not found in the Bay de Noc, particularly gastropods and trilobites. Thickness varies from 3 to about 20 feet.

Correlation of the Stonington beds is difficult, because the fossils characteristic of the rocks range from the Waynesville to the Elkhorn. The lower part of the beds may belong to the Waynesville, and the upper part to the Whitewater-Elkhorn.

Big Hill beds. — These beds occur above the Ogontz, and are separated from it by a covered interval of from 5 to 10 feet in thickness. The rocks vary from light gray limestone, moderately hard, non-crystalline, to dark gray, argillaceous limestone, hard, coarsely crystalline. These beds belong to the late Richmond Arctic submergence, and contain a characteristic group of fossils, among them the corals *Halysites gracilis* and *Columnaria* (*Paleophyllum*) *stokesi*. Along the road north of the Hinkin's Hill exposure, the rocks are folded into at least three low anticlines and

synclines. The correlation of the beds is in doubt; they may be close to the Whitewater-Elkhorn.

The Richmond rocks of Michigan are found to contain faunal elements resembling those of the Richmond of southwestern Ohio and forms found in the Elkhorn of Indiana and Illinois. Some of the Michigan fossils bear a strong resemblance to others found in Wisconsin. The Black River aspect of the fauna is especially strong in the Ogontz, where many recurrent forms are found. The nearest approach to a definite coral horizon comes in the Big Hill beds.

The Michigan basin was not completely isolated at this time; the presence of numerous *Graptolites* in the Bill's Creek beds indicates a possible connection to the eastward.

The evidence for these conclusions is embodied in the descriptions of formations, the descriptions of fossils and the tabular faunal list.

Descriptions of Fossils

General faunal discussion. — To one who has collected in the typical Richmond localities of southwestern Ohio, the fauna of the Michigan Richmond appears less rich in numbers, genera and species, as if a partial barrier prevented the free migration of forms from other regions. The arms of the Cincinnati Anticline did, doubtless, partly enclose the so-called Michigan basin on the south, east and west, but the presence of *Graptolites* in the Bill's Creek beds shows the existence of currents at that time and probably of a free connection with the more open sea, possibly to the eastward.

There is one specimen whose zoölogical classification is uncertain:

PASCEOLUS (?) SP.

(Plate I, Fig. 1)

Description. — A single poorly preserved specimen has been provisionally referred to the genus Pasceolus. Part preserved subcircular. Surface flattened, covered with low, blunt tubercles, varying in diameter from 2 to $2\frac{1}{2}$ mm. and arranged in diagonal rows.

Horizon and locality. — Bill's Creek beds. Bill's Creek.

Phylum COELENTERATA

Corals and stromatoporoids. — The horizontal distribution of some of the most characteristic Big Hill corals and stromatoporoids within the Stonington region is as follows:

Calapoecia cribriformis occurs in the outcrop at the eastern end of the Maywood road, and at intervals along the road south to Hinkin's Hill.

Halysites gracilis was found in place at Hinkin's Hill, and loose specimens, which had probably weathered out of the immediately underlying rock, were found at intervals along the road north of Hinkin's Hill, for a distance of 3 miles.

Columnaria (*Paleophyllum*) *stokesi* is so abundant along the road just north of Hinkin's Hill that broken pieces literally cover the ground in places. Fragments were found at intervals along the road for a distance of 3½ miles. It occurs at the "twelve-mile" rapids on the Sturgeon River.

Catenipora gracilis (*Halysites gracilis*) from the eastern shore of Green Bay, Wisconsin, and *Sarculina* (?) *obsoleta* (*Columnaria* (*Paleophyllum*) *stokesi*) from the same locality and from Big Bay de Noc, are reported by Foster and Whitney in Part II of the *Report on the Geology of the Lake Superior Land District*, pages 212–213. The report states that *Columnaria* (*Paleophyllum*) *stokesi* once formed continuous layers on the eastern shore of Green Bay, where it was associated with *Halysites gracilis*, as it is at Hinkin's Hill.

Beatricea nodulifera occurs at the eastern end of the Maywood road.

Beatricea sinuata and *Beatricea undulata* were found at Hinkin's Hill, and at intervals for 2 miles along the road north of the hill.

Class ANTHOZOA

COLUMNARIA GOLDFUSSI (Billings)

(Plate X, Fig. 7)

Description. — A single specimen of this coral, found in the Big Hill beds, represents an almost complete colony, roughly cir-

cular in outline, 38 mm. wide and 9 mm. high. Corallites nearly all polygonal, crowded together, leaving few interspaces. Walls moderately heavy, considering the size of the specimen. Diameter of corallites varies from one half to about three quarters of a millimeter. In the description of this species given in *Contributions to Canadian Paleontology*, Vol. 4, Part I, pages 88–89, the septa are said to extend about 2 mm. beyond the walls of the corallites, which is probably an error, since the diameter of the whole corallite is not over 2 mm. Septa blunt, extending but slightly out from the wall.

Horizon and locality. — Big Hill beds, Hinkin's Hill, Loc. 11.

Class HYDROZOA

BEATRICEA (?) SP.

(Plate X, Figs. 5, 6)

Description. — Specimens of a *Beatricea*-like form having a more or less central tube, crossed by transverse, concavo-convex and straight septum-like partitions, occur in the Big Hill beds. Any other structures that may originally have been present, are now destroyed. The spaces between the septa are usually empty, although in a few cases they are partly filled with crystalline limestone. Figure 5, Plate X, shows a specimen containing both straight and concavo-convex septa. In Figure 6, Plate X, the septa are all curved.

In the absence of better material the relation of this form to *Cryptophragmus* of Raymond can not be discussed.

Horizon and locality. — Big Hill beds, Road north of Hinkin's Hill, Loc. 12.

BEATRICEA NODULIFERA Foerste

(Plate X, Figs. 2–4)

Description. — This species is represented in the Stonington region by a form in which the nodes are smaller and more numerous than in typical *Beatricea nodulifera*, of which it may be a variety.

Horizon and locality. — Big Hill beds, eastern end of Maywood road, Loc. 9.

BEATRICEA UNDULATA Billings

(Plate X, Fig. 1)

Description. — The direction of the ridges, on the Stonington representatives of this species, is irregular; branching of the ridges is common.

Horizon and locality. — Big Hill beds, along road, about $1\frac{1}{8}$ miles north of Hinkin's Hill.

Phyllum MOLLUSCOIDEA

Class BRACHIOPODA

LINGULA OGONTZENSIS, sp. nov.

(Plate VII, Fig. 16)

Description. — Shell oval in outline, elongate, narrow. Valve flatly convex, greatest convexity toward beak, flattening somewhat toward the front. Beak blunt. Shoulders meet at angle of about 111 degrees. Sides slightly convex, subparallel. Anterior margin moderately convex. Surface covered with numerous rather crowded, moderately coarse, concentric lines. A few radiating lines visible in the region of the beak.

Comparison. — Differs from *Lingula progne* in the greater apical angle, and more convex anterior margin.

Horizon and locality. — Stonington beds, Ogontz member, east side of Little Bay de Noc, west of Stonington Post Office.

LINGULA CHANGI, sp. nov.

(Plate I, Figs. 3, 7)

Description. — Shape round-oval, widest part about the middle. Apex blunt, shoulders meeting at angle of about 130 degrees. Valve very flatly convex, with greatest convexity in region of beak. It is difficult to say how much of the flattening, if any, is due to crushing. Sides strongly, regularly convex. Anterior margin broadly rounded. Surface covered with numerous strong, crowded, concentric lines. Interior of valve covered with numerous pits.

Comparison. — Differs from *Lingula coburgensis* in the less

regular, oval form, the narrowing toward the beak, and greater convexity of the sides.

Horizon and locality. — Bill's Creek beds, Bill's Creek, Loc. 2. *Lingula* zone just west of road crossing.

TREMATIS RUGOSA, sp. nov.

(Plate VII, Fig. 14)

Description. — Shell of medium size, wider than high, greatest width about the middle. Brachial valve (the only one preserved) strongly convex, greatest convexity toward the beak which is not well preserved, but apparently not prominent; somewhat blunt. Front margin broadly convex, lateral margins strongly convex. Valve narrows toward beak. Exfoliation has removed most of outer layer of shell, together with surface ornamentation. Surface strongly punctate, but arrangement of puncta not certain. Chief characteristic of shell the strong growth-lines.

Comparison. — Differs from *Trematis millepunctata* in the stronger growth-lines, the less suborbicular shape, the less prominent beak, and greater convexity of shell.

Horizon and locality. — Stonington beds, Ogontz member, Ditch, north side of road running along south side of Stratton's farm.

GENUS PLATYSTROPHIA KING

General discussion of the Platystrophiae of the Michigan Richmond. — Most of the *Platystrophiae* occur in the Bay de Noc member of the Stonington beds The genus, as usual, exhibits considerable variation in its development, and in attempting to place the various Michigan forms in species already described one often encounters considerable difficulty, which may later make it necessary to describe several new species, or at least to indicate the variations from the types. These differences may be due to environmental conditions which have resulted in the development of a Michigan expression of the genus, or the Michigan forms may be largely intermediate.

PLATYSTROPHIA SP. (No. 1)

(Plate V, Figs. 1–3)

Description. — Shells of large size, greatest width along hinge-line. Slopes of brachial valve moderately convex, becoming slightly concave toward cardinal extremities and hinge-line. Fold prominent, broad, flattened, with four plications, the lateral ones a little the weakest. Slopes of pedicle valve straight, becoming very gently concave toward cardinal extremities. Sinus broad, deep, with three nearly equal plications. Slopes of valves with eight to nine strong, angular plications.

Comparison. — Related to *Platystrophia clarksvillensis*. Differs from it in the somewhat larger size and more prominent fold. Its relation to *Platystrophia moritura* is not certain, because of the variability of that species. Differs from it in the fewer plications and the slightly straighter slopes of the pedicle valve.

Horizon and locality. — Stonington beds, Bay de Noc member, east side of Little Bay de Noc, south of Stratton's dock.

PLATYSTROPHIA SP. (No. 2)

(Plate V, Figs. 4–6)

Description. — Shell very ventricose, hinge-line longer than width across middle of shell. Slopes of brachial valve moderately convex, becoming concave toward cardinal extremities and hinge-line. Fold very high, somewhat compressed, with two strong central plications and two much weaker lateral ones. Slopes of pedicle valve moderately concave, dropping away steeply from edge of sinus. Sinus wide, deep, with three plications, the central one the strongest. The great length of the sinus causes a conspicuous truncation of the fold. Brachial valve with seven, and pedicle valve with eight, strong, angular, rather widely spaced plications.

Comparison. — The specimen illustrated is an old individual, but younger ones show the same general form. In the American Museum at Washington, D.C., a specimen labelled *Platystrophia moritura* agrees very well with the Michigan form in size and shape.

More ventricose than *Platystrophia cypha, Platystrophia cypha tumida* and *Platystrophia laticosta.*

Horizon and locality. — Stonington beds, Bay de Noc member, east side of Little Bay de Noc, south of Stratton's dock.

PLATYSTROPHIA AFF. CYPHA James

(Plate V, Figs. 7–9)

Description. — Shell greatly extended along hinge-line. Slopes of brachial valve straight, slightly concave toward cardinal area. Fold high, compressed, with four plications, the lateral ones much the weakest. Slopes of pedicle valve strongly concave. Sinus wide, deep, with three plications, the central one the strongest. Valve strongly elevated along edges of sinus, especially toward front. Great extension of sinus very strongly truncates fold. Slopes with ten angular plications.

Comparison. — This form agrees quite closely with *Platystrophia cypha,* illustrated by Foerste in *Bulletin of the Scientific Laboratories of Denison University,* June, 1910, Plate IV, figures 10 *a* and 10 *b.*

Horizon and locality. — Stonington beds, Bay de Noc member, east side of Little Bay de Noc, south of Stratton's dock.

PLATYSTROPHIA SP. (No. 3)

(Plate V, Figs. 10–12)

Description. — Hinge-line a little longer than the greatest width across middle of shell. Slopes of brachial valve moderately convex, becoming slightly concave toward the cardinal extremities. Fold high, narrow, much compressed, with two moderately strong median plications and two very weak lateral ones, becoming obsolete a little more than half way toward the front. Slopes of pedicle valve moderately concave, a little inflated along edges of sinus. Sinus deep, narrow, much extended, strongly truncating fold; with one strong median plication, and two very weak lateral ones, obsolete toward front. Eight to nine plications on the slopes of both valves.

Comparison. — Differs from *Platystrophia cypha, Platystrophia cypha tumida* and *Platystrophia laticosta* in the narrower, more

compressed fold, and the narrower sinus; also in the obsolescence of the lateral plications on fold and in sinus.

Horizon and locality. — Stonington beds, Bay de Noc member, east side of Little Bay de Noc, south of Stratton's dock.

PLATYSTROPHIA SP. (No. 4)

(Plate V. Figs. 13–15)

Description. — Form somewhat flattened. Slopes of brachial valve very flatly convex, almost straight, becoming a little concave toward cardinal extremities. Fold moderately high, slightly compressed, with four plications, the lateral ones much the strongest. Slopes of pedicle valve rather strongly concave. Sinus moderately wide, deep, with three plications, the lateral ones the weakest. Most of the specimens are considerably extended along hinge-line. Slopes of both valves with eleven to thirteen plications.

Comparison. — Related to *Platystrophia acutilirata*, but less gibbous than the typical form.

Horizon and locality. — Stonington beds, Bay de Noc member, east side of Little Bay de Noc, south of Stratton's dock.

Genus HEBERTELLA Hall and Clarke

HEBERTELLA ALVEATA Foerste

(Plate II, Fig. 7; Plate VI, Fig. 18)

Description. — In Figure 7, Plate II, the growth-lines are very strong, and the plications bifurcate a great number of times. In Figure 18, Plate VI, the hinge-line is greatly extended, as in the typical forms.

Horizon and locality. — Stonington beds, both members.

HEBERTELLA ALVEATA RICHMONDENSIS Foerste

(Plate IV, Fig. 10)

Description. — In the Michigan representatives of this variety, the hinge-line is shorter than the width of the shell across the middle. Sinus broad, well developed. Beak broad, blunt.

Horizon and locality. — Stonington beds, Ogontz member, field east of Church, Loc. 8.

HEBERTELLA OCCIDENTALIS Hall

(Plate VIII, Figs. 8–9)

Description. — This species is represented in the Richmond of Michigan by specimens in which the median depression near the beak of the brachial valve is very slight, approaching *Hebertella sinuata.* Hinge-line considerably shorter than width of shell across middle.

Horizon and locality. — Stonington beds, Ogontz member, various localities.

Genus DALMANELLA Hall and Clarke

DALMANELLA JUGOSA SUBPLICATA Foerste

(Plate I, Figs. 12, 14, 15, 16, 18, 19, 20)

Description. — This variety is especially abundant just below the upper layer of fine-grained argillaceous limestone, in the Bay de Noc member of the Stonington beds. In the variety *D. subplicata,* the difference between the width and height is one of the most variable factors; the width is always the greater, and the differences vary from $1\frac{1}{2}$ to 6 mm. In some, the greatest width is below the middle of the shell; in some, about the middle; and in others, just above. A young individual is occasionally found with the fold very slightly developed, but in most cases it is fully as strong as in the adult. Some of the variations are shown on Plate I. Figure 12 shows a young, very transverse form; Figures 15 and 19, quadrate forms; Figures 16 and 20, transverse elliptical individuals.

Horizon and locality. — Stonington beds, both members.

DALMANELLA SP. (No. 1)

(Plate I, Fig. 10)

Description. — Most of the forms flattened by pressure. The brachial valve illustrated in Plate I, Figure 10 is very similar to the variety *D. subplicata.* The depression found upon either side of the fold in many specimens of *D. subplicata* is very slightly

developed or absent. Some of the individuals have a somewhat more quadrate form than the one figured.

Comparison. — Fold somewhat less prominent than in the variety *D. subplicata*, and brachial valve a little flatter.

Horizon and locality. — Bill's Creek beds, Bill's Creek, layer 1, 12 feet from bottom of exposure.

DALMANELLA SP. (No. 2)

(Plate I, Fig. 11)

Description. — The young individual illustrated in Plate I, Figure 11, may not be typical of the adult form, but larger specimens are not available for study. Fold sharp, prominent. Striations heavy, considering size of shell, increasing by bifurcation. Beak prominent, somewhat less pointed than appears in the Figure.

Comparison. — Shoulders squarer, plications relatively stronger and fewer than in *Dalmanella sp.* from layer 1 of the Bill's Creek exposure.

Horizon and locality. — Bill's Creek beds, thin argillaceous limestone layers near top of Bill's Creek section.

Genus DINORTHIS Hall and Clarke

DINORTHIS SUBQUADRATA NOQUETTENSIS, var. nov.

(Plate I, Fig. 8; Plate IV, Fig. 15)

Description. — Brachial valve moderately convex, with a broad, rather shallow, but well-defined sinus. Plications coarse, about nine within a width of 10 mm., measured near front margin, increasing by bifurcation. The pedicle valve figured on Plate I, Figure 8, does not belong to the individual described above and illustrated on Plate IV, Figure 15. This valve is convex at the umbo, somewhat concave toward the hinge-line and cardinal extremities, flattening very decidedly toward front and lateral margins. Plications same as on the brachial valve.

Comparison. — Plications heavier than in *Dinorthis subquadrata.*

Horizon and locality. — Stonington beds, Bay de Noc member, exposure along east side of Little Bay de Noc.

Genus PLECTAMBONITES Pander

PLECTAMBONITES RUGOSUS NOQUETTENSIS, var. nov.

(Plate VII, Fig. 6)

Description. — Only the interiors of brachial valves well enough preserved for description. General outline of shell like that of *Plectambonites rugosus clarksvillensis.* Interior of brachial valve slightly thickened along hinge-line by presence of small, transverse ridges and tubercles, which do not encroach upon hinge area; thickening continues to a stronger degree around lateral and anterior borders. Interior covered with small papillae. Median interior part of brachial valve traversed by two diverging ridges, becoming heavier anteriorly. An adductor scar on each side of the median ridges. Each scar divided longitudinally into two nearly equal parts by a moderately heavy ridge, becoming indistinct posteriorly.

Comparison. — General shape of whole muscle scar area more nearly circular than in *Plectambonites rugosus clarksvillensis.*

Horizon and locality. — Stonington beds, Ogontz member, field east of Church.

Genus RAFINESQUINA Hall and Clarke

RAFINESQUINA BREVIUSCULUS Foerste

(Plate II, Figs. 1–5)

Description. — This is a somewhat variable species. Hinge-line varies from shorter to much longer than greatest width across middle of shell. Oblique wrinkles usually developed along hinge-line. Interior of valves covered with numerous large and small papillae.

Comparison. — A geniculation is usually developed on the pedicle valve, especially around the anterior border, as in *Leptaena;* in fact this form belongs more probably to *Leptaena* than to *Rafinesquina.*

Horizon and locality. — Stonington beds, both members, but especially common in the Bay de Noc.

RAFINESQUINA ALTERNATA VARICOSA Foerste

(Plate IV, Fig. 13)

Description. — The coarseness of the radiating striae in this variety varies somewhat, but the form is very characteristic, and can always be recognized.

Horizon and locality. — Stonington beds, base of the Bay de Noc member, east side of Little Bay de Noc, 1½ miles north of Stratton's farm.

RAFINESQUINA ALTERNATA NOQUETTENSIS, var. nov.

(Plate II, Figs. 8–9)

Description. — Only the pedicle valve preserved. General shape subquadrate. Valve a little inflated just anterior to umbo, becoming concave toward cardinal extremities and hinge-line. In cross-section from beak to front, valve slopes strongly up anteriorly for 8 mm., then becomes flatly convex for 20 mm., then slopes strongly to front. Section about like that of *Rafinesquina alternata* var. *loxorhytis* (?), figured in the *32d Annual Report of Indiana, Department of Geology and Natural Resources*, Plate XXXVII, Figure 2 *a*. Hinge-line slightly extended. Surface ornamentation poorly preserved, but apparently as in *Rafinesquina alternata*.

Comparison. — Differs from *Rafinesquina alternata loxorhytis* in the much less extended hinge-line.

Horizon and locality. — Stonington beds, basal part of Bay de Noc member, east side of Little Bay de Noc, 1½ miles north of Stratton's farm.

RAFINESQUINA SP. cf. MINNESOTENSIS (N. H. Winchell)

(Plate XI, Figs. 11–13)

Description. — Shell small. Pedicle valve strongly convex, slightly inflated at umbo, becoming gently concave toward cardinal extremities and hinge area. Hinge-line longer than width across middle of shell. Beak small, pointed. Every third or fourth striation stronger than the intermediate ones. A tendency toward the development of broad wrinkles near the anterior

border, parallel to the striations. Growth-lines strong. Cardinal area moderately high. Brachial valve strongly concave.

Comparison. — Profile view about the same as that of *Rafinesquina minnesotensis*, figured in *The Geological and Natural History Survey of Minnesota*, Vol. III, Part I, Plate XXXI, Figure 26. Pedicle view about the same as that of *Rafinesquina minnesotensis inquassa*, illustrated in the same volume, Plate XXXI, Figure 27. Pedicle valve more convex than in the variety *R. inquassa*.

Horizon and locality. — Big Hill beds, Sturgeon River exposure, Loc. 14.

Genus STROPHOMENA (RAFINESQUE) Blainville

STROPHOMENA HURONENSIS Foerste

(Plate I, Figs. 13, 17, 21–23)

Description. — Shells subtriangular, some having the anterior edge sharply rounded, almost nasute, others with the edge more evenly convex. Brachial valve, in profile from beak to anterior margin, varies from strongly to very strongly convex; flattened in region of beak. Every third, fourth, fifth, or sixth striation stronger than intermediate ones. This character is usually very marked, especially toward anterior margin. Oblique wrinkles on brachial valve along hinge-line, making an angle with the hinge-line of from 30 to 90 degrees, with the average between 50 and 55. Interior of pedicle valve strongly resembles that of *Strophomena nutans*.

Horizon and locality. — Stonington beds, Bay de Noc member, east side of Little Bay de Noc.

Genus ZYGOSPIRA Hall

ZYGOSPIRA RECURVIROSTRIS NOQUETTENSIS, var. nov.

(Plate XI, Figs. 1–3)

Description. — Shell subcircular in outline. Pedicle valve strongly convex, full in region of beak. Fold very slightly developed posteriorly. Beak small, pointed, strongly incurved, overlapping that of opposite valve. Brachial valve much flattened,

somewhat swollen just below beak. Sinus broad, moderately shallow, well marked from beak to anterior margin. Plications strong, rounded.

Comparison. — Brachial valve much flatter than that of *Zygospira recurvirostris turgida.*

Horizon and locality. — Stonington beds, Ogontz member, ditch along east and west road, running just south of Stratton's farm.

Phylum MOLLUSCA

Class PELECYPODA

Genus VANUXEMIA Billings

VANUXEMIA NOQUETTENSIS, sp. nov.

(Plate IX, Figs. 5–7)

Description. — Species represented by very well preserved cast of interior. Shell ventricose, greatest thickness a little above middle. Ventral and anterior margins together circular. Beaks very prominent, large, slightly incurved, concave on inner sides, closer together posteriorly. Pallial line well defined. Anterior scar not shown. Posterior muscular impression large, circular, situated a little over half way down the slope, near edge.

Comparison. — Valves less gibbous, and base of beaks not as heavy as in *Vanuxemia dixonensis.* Differs from *Vanuxemia wortheni* in the wider separation of beaks, position of greatest thickness of shell above middle, and absence of oblique ridge extending posteriorly from a little behind beaks.

Horizon and locality. — Stonington beds, Ogontz member, field east of the Church, Loc. 8.

VANUXEMIA STRATTONI, sp. nov.

(Plate IX, Figs. 3–4)

Description. — Species represented by casts of interior. Shell very moderately ventricose, greatest thickness a little above middle. Ventral margin strongly rounded. Toward end of hinge-line, posterior margin straight for about 14 mm., then curving

abruptly down to posterior edge. Anterior edge straightened. Beaks nearly terminal, close together, rather strongly incurved, concave on inner sides. A fairly well defined ridge extends downward, parallel to anterior edge, from a point a little posterior to beaks, to about middle of valves This indicates a corresponding groove on interior of shell, somewhat like that in *Vanuxemia wortheni*. Posterior muscular scars large, rounded, situated about half-way down posterior side.

Comparison. — Shorter than *Vanuxemia wortheni*, with beaks closer together.

Horizon and locality. — Stonington beds, Ogontz member, field east of the Church, Loc 8.

Genus CYRTODONTA Billings

CYRTODONTA POTTERI, sp. nov.

(Plate IX, Figs. 9–11)

Description. — Specimens preserved as casts of interior. Shell of medium size, oblique, ventricose. Beaks large, blunt, projecting moderately above hinge-line. Slopes of valves falling away steeply to anterior and posterior extremities, where they flatten out a little. Point of greatest convexity of valves about three fourths of the way up toward beaks. Anterior border sloping backward and downward with a broadly convex curve to ventral edge. Ventral and posterior border subcircular. Anterior scar near hinge-line, moderately strong. Posterior scar elongate, subovate, situated a little less than half-way down posterior side. Pallial line well marked. Surface markings not preserved, shell probably smooth.

Comparison. — Posterior edge curves much less strongly upward and forward toward hinge-line than in *Cyrtodonta grandis*.

Horizon and locality. — Stonington beds, Ogontz member, east side of Little Bay de Noc, south of Stratton's dock.

Genus CLIDOPHORUS Hall

CLIDOPHORUS STONINGTONENSIS, sp. nov.

(Plate VII, Fig. 7)

Description. — Shell small, elongate-oval. Valves rather strongly convex. Ends subequally rounded, beaks small, blunt, projecting but slightly above hinge-line, situated well toward anterior end. Clavicular furrow well-developed, extends slightly forward from a point immediately in front of beaks to about middle of valve. No surface markings preserved.

Comparison. — Outline more regularly oval than in *Clidophorus neglectus*, and furrow extends forward rather than backward, from in front of beaks.

Genus OPISTHOLOBA Ulrich

OPISTHOLOBA GOULDI, sp. nov.

(Plate VIII, Fig. 1)

Description. — Shell moderately large. Hinge-line extended, straight. Anterior end broadly, evenly convex. Ventral margin strongly, evenly rounded, circular, curving up posteriorly to the wing-like extension of the valve, which it joins in a sharp curve. A strong, rounded indentation divides the posterior edge of the wing into two lobes, the lower one a little the larger. Valves moderately convex, flattening at point of union with wing. Beaks not well preserved, but apparently blunt, moderately large, projecting a little above hinge-line. A flattened border is preserved in many places around anterior, ventral and posterior edges. Surface covered with strong radiating costae, unevenly spaced as preserved. At marginal ends of costae, along anterior edge, are well-developed nodes.

Horizon and locality. — Stonington beds, Ogontz member, ditch along east and west road, running along south side of Stratton's farm.

Genus ANOMALODONTA Miller

ANOMALODONTA SP. cf. GIGANTEA

(Plate III, Fig. 7)

Description. — Preserved as interior impression of left valve. Shell large, moderately convex, flattening ventrally and posteriorly. Hinge-line straight, rounding strongly into posterior end, which is not well preserved. Ventral border strongly, regularly convex. Anterior edge slightly convex. Beak moderately prominent, pointed, a little incurved. Posterior adductor suboval, located in center of valve. Surface covered with at least twenty-six radiating costae.

Comparison. — General shape similar to that of *Anomalodonta gigantea.* Posterior adductor scar situated more nearly in center of valve.

Horizon and locality. — Stonington beds, Bay de Noc member, the fine-grained, argillaceous limestone.

ANOMALODONTA GRIFFINI, sp. nov.

(Plate VI, Fig. 15)

Description. — Preserved as interior cast of left valve. Shell moderately large and convex; convexity greatest in region below umbo, flattening out into a wing-like extension, which is separated from the umbonal swell by a broad, shallow, sulcus. Hinge-line straight, extending almost at right angles to anterior edge. Posterior margin may be slightly sinuous toward hinge-line, but not well preserved in this region.

Ventral edge strongly, regularly convex, semicircular. Anterior edge straight, or slightly concave below beak, rounding regularly into ventral border. Beak not well preserved, but apparently moderately pointed, and in cast not extending above hinge-line. Posterior adductor scar located in center of valve, strong, with concave inner margin. What is apparently a strong pedal muscle scar located back of beak near hinge-line. Two prominent ridges, separated by a deep groove, extend obliquely backward from about middle of hinge-line. Surface markings poorly preserved, but consist of strong radiating lines, rather closely spaced. Pallial

line preserved near anterior end. Part of wing near hinge extremity destroyed.

Comparison. — Nearest to *Anomalodonta alata*, from which it differs in the more numerous and crowded radiating lines.

Horizon and locality. — Stonington beds, Ogontz member, ditch along east and west road, running just south of Stratton's farm.

Genus BYSSONYCHIA Ulrich

BYSSONYCHIA OBESA Ulrich

(Plate IX, Figs. 1–2)

Description. — Preserved as cast of interior. A little higher in proportion to length than specimen figured by Ulrich in the *Geological Survey of Ohio, Geology*, VII, Plate XLV, Figures 10–12. Agrees well with other examples of the species now at the American Museum, Washington, D.C.

Horizon and locality. — Stonington beds, Ogontz member, field east of Church, Loc. 8.

BYSSONYCHIA ELROYI, sp. nov.

(Plate IX, Fig. 8)

Description. — Only the left valve preserved. Shell rather small. Beak prominent, full, moderately incurved. Valve strongly convex toward umbo, flattening ventrally and posteriorly to the wing-like extension, which is partly destroyed. Anterior edge moderately concave, rounding gradually to the ventral border, which is strongly convex, simicircular, deflected posteriorly at point of junction with wing. Surface markings partly destroyed, but thirty-one radiating costae can be seen, separated by moderately deep grooves.

Comparison. — Differs from *Byssonychia radiata*, *Byssonychia precursa* and *Byssonychia richmondensis* in the wing-like extension of valve.

Horizon and locality. — Stonington beds, Ogontz member, ditch along east and west road, running along south side of Stratton's farm.

Genus CLIONYCHIA Ulrich

CLIONYCHIA ANGUSTA Foerste

(Plate IV, Fig. 3; Plate 7, Fig. 13)

Description. — The best preserved specimen is that figured on Plate IV, Figure 3. The other figure represents a cast of the interior, and is not well preserved. Shell rather small, moderately convex below umbo, flattening toward periphery. Some of the strong forward curvature of beak may be due to distortion. Ventral border strongly convex. Posterior edge and hinge-line, as preserved, semicircular. Anterior edge straight below beak for about 7 mm., then rounding gradually into ventral border. Surface markings consist of moderately strong growth-lines, and fine concentric striae.

Horizon and locality. — Stonington beds, Ogontz member, east side of Little Bay de Noc, south of Stratton's dock.

Genus PSILOCONCHA Ulrich

PSILOCONCHA SP.

(Plate VIII, Figs. 2–3)

Description. — Specimen preserved with valves open. Shell moderately large, valves somewhat flattened. Ventral margin straight posteriorly, passing into anterior edge with a broad, even curvature, and more strongly into posterior end, which is somewhat narrowed. Dorsal margin straight. Beaks prominent, blunt, moderately incurved, the anterior slope much shorter and steeper than posterior. Anterior end obliquely rounded below. Umbonal ridge moderately well defined, narrow, extending from beak posteriorly, almost to ventral border. A broad, shallow sinus extends along nearly entire length of ridge. Surface covered with strong concentric growth-lines.

Comparison. — Not extended as much in front of beaks as *Psiloconcha grandis*. Beaks more prominent than in *Psiloconcha grandis* and *P. subrecta*.

Horizon and locality. — Stonington beds, Bay de Noc member, east side of Little Bay de Noc, south of Stratton's dock.

Genus MODIOLOPSIS Hall

MODIOLOPSIS NOQUETTENSIS, sp. nov.

(Plate VII, Fig. 15)

Description. — Only the left valve preserved. Shell small, ventricose. Posterior end strongly, evenly rounded, semicircular. Ventral border oblique, gently concave. Anterior end greatly constricted, sharply rounded. Beak prominent, blunt, very moderately incurved, posterior edge straight, sloping upward posteriorly. A prominent characteristic is the rapid increase in height of valve toward posterior end. Umbonal ridge well developed, broadening and flattening a little posteriorly. Sinus broad, shallow, extending from umbo to ventral border. Surface markings mostly destroyed, but faint concentric lines visible around posterior end.

Comparison. — Differs from *Modiolopsis nana* in the relatively greater increase in height of valve posteriorly, the somewhat more prominent umbo, with its steeper anterior slope.

Horizon and locality. — Stonington beds, Ogontz member, east side of Little Bay de Noc, south of Stratton's dock.

Genus ORTHODESMA Hall and Whitfield

ORTHODESMA cf. SUBANGULATUM Ulrich

(Plate IX, Figs. 12–13)

Description. — Shell elongate, thin, greatest thickness about the middle. Anterior end partly destroyed, but apparently strongly rounded. Posterior end obliquely rounded above. Ventral margin broadly concave. Dorsal edge straight or very slightly concave. Beaks not prominent, very blunt, about level with dorsal margin. Umbonal ridge moderately strong, narrow, traceable nearly to the postero-ventral edge. Sinus broad, indistinct. A few concentric growth-lines preserved.

Comparison. — Differs from the specimen illustrated by Ulrich in *Geological Survey of Ohio, Geology*, Vol. VII, Plate LV, Figures

21–22, in the less oblique rounding of the posterior end, and thinner posterior end of shell.

Horizon and locality. — Stonington beds, Ogontz member, ditch along east and west road, running just south of Stratton's farm.

Genus COLPOMYA Ulrich

COLPOMYA COLGATEI, sp. nov.

(Plate II, Fig. 13)

Description. — Shells small, subelliptical, ventricose. Beaks prominent, blunt, situated near anterior extremity. In some individuals the posterior end is more expanded than in the type. Umbonal ridge prominent, rounded, expanding a little postero-ventrally. Sinus extending from beak to base. Ventral border always indented broadly where sinus terminates. Anterior end more strongly rounded than posterior, which may be blunted.

Comparison. — Nearest to *Colpomya faba.* Differs chiefly in being less extended posterior to beaks.

Horizon and locality. — Stonington beds, Ogontz member, various localities.

Class GASTROPODA

Genus SCENELLA Billings

SCENELLA (?) SP.

(Plate VII, Figs. 9–10)

Description. — Shell preserved as cast of interior. Conical, compressed latero-posteriorly. Apex blunt in cast, but probably moderately pointed, situated slightly in front of center. Surface markings almost entirely destroyed, but in a few places obscure traces of fine concentric and radiating striae exist.

Comparison. — Slopes not as steep as in *Scenella compressa* and *affinis.*

Horizon and locality. — Stonington beds, Ogontz member, east side of Little Bay de Noc, south of Stratton's dock.

Genus ARCHINACELLA Ulrich and Scofield

ARCHINACELLA SIMMONSI, sp. nov.

(Plate VI, Fig. 1)

Description. — Shell above medium size, aperture subcircular in outline. Apex blunt, situated slightly back of anterior margin. Anterior slope nearly straight. Slope posterior to apex regularly convex for about 10 mm., then deflected rather steeply down to border. Surface markings destroyed.

Comparison. — Differs from *Archinacella kagawongensis* in the straighter anterior slope and in the less regularly convex posterior slope.

Horizon and locality. — Stonington beds, Ogontz member, east side of Little Bay de Noc, three quarters of a mile south of Stratton's dock.

ARCHINACELLA KAGAWONGENSIS Foerste

(Plate VI, Figs. 2, 3, 4, 9, 10)

Description. — This is a variable species. Plate 6, Figure 2, shows a form in which the slope below the apex is nearly straight. Posterior slope steeper than in the species *A. kagawongensis*. In Figure 3 the slope below apex is especially concave. Figure 4 is more like the typical form; Figure 9 is an apical view of Figure 3; and Figure 10 an apical view of Figure 4.

Horizon and locality. — Stonington beds, Ogontz member, various localities.

Genus PHRAGMOLITES Conrad

PHRAGMOLITES SLAWSONI, sp. nov.

(Plate VII, Fig. 8, 12)

Description. — Shell small, consisting of about $2\frac{1}{2}$ volutions, the outer one partly embracing the one next within. Keel prominent, rather sharp, destroyed toward aperture. Slope of volutions on side toward umbilicus short, steep; on opposite side longer, moderately convex. Surface closely covered by prominent diagonally transverse lamellae, consisting of backward and forward

loops, the backward parts being narrower than those extending forward. Lamellae arranged so as to give appearance of revolving ridges.

Comparison. — Differs from *Phragmolites bellulus* in the presence of the revolving ridges. Differs from *Phragmolites dyeri* in the less crowded lamellae, and the smaller difference in size between the backward and forward loops.

Horizon and locality. — Stonington beds, Bay de Noc member, east side of Little Bay de Noc, south of Stratton's dock.

Genus TROCHONEMA Salter

TROCHONEMA WARTHENI, sp. nov.

(Plate VII, Fig. 19)

Description. — Apical angle about 60 degrees. About four angular whorls. Peripheral band 4 mm. wide at widest part, vertical, flat, or very slightly concave, marked off above and below by sharply angular carinae. Above peripheral band a wide, concave slope extends up to the sharp edge of a shoulder-like, flattened space, bordering suture. Below band surface is moderately convex. Peripheral band crossed by moderately coarse, straight lines, inclined slightly forward. On concave slopes above band, and on shoulder-like spaces bordering sutures, the lines are straight, and inclined toward aperture.

Comparison. — Apical angle less than in *Trochonema (Eunema) salteri, Trochonema umbilicatum* and *madisonense.*

Horizon and locality. — Stonington beds, Ogontz member, ditch along east and west road, running along south side of Stratton's farm.

Phylum ARTHROPODA

Class CRUSTACEA

GENUS CALYMENE BRONGNIART

CALYMENE SP.

(Plate I, Fig. 5)

Description. — Glabella strongly defined, elevated a little above cheeks. Third lateral lobes much the largest, broadly convex at posterior end, constricted anteriorly; middle lobes globular, directed anteriorly. First lateral pair very small, vestigial. Lobes separated from one another by deep grooves. Frontal lobe flattened at anterior end, extending as far to sides as first laterals. Anterior border of cephalon strongly reflexed. Occipital groove moderately broad, deep. Surface finely granular.

Comparison. — Differs from *Calymene meeki* and *Calymene meeki-retrorsa* in the more anteriorly directed middle lobes, and the smaller first lateral, and wider frontal lobes. Differs from the former also in the flattened anterior end of frontal lobe.

Horizon and locality. — Bill's Creek beds, Bill's Creek and outcrop along Soo Line Railroad, west of Ensign, chiefly the thin argillaceous limestone layers.

CALYMENE SP.

(Plate VII, Fig. 3)

Description. — Preserved as cast of interior. Chracterized by the considerable lateral extent of frontal lobe and the blunt projections from the fixed cheeks, opposite each end of the frontal lobe.

Comparison. — Anterior border of cephalon not reflexed as much as *Calymene sp.* from the Bill's Creek beds.

Horizon and locality. — Stonington beds, Ogontz member, east side of Little Bay de Noc, south of Stratton's dock.

Genus ONCHOMETOPUS Schmidt

ONCHOMETOPUS SP.

(Plate VI, Figs. 5–7)

Description. — This glabella bears a strong resemblance to the glabella of *Onchometopus susae* in general shape, the position of the lobes, and the abrupt decline to the frontal margin, as shown in Figure 7.

Horizon and locality. — Stonington beds, Ogontz member, ditch along east and west road, running along south side of Stratton's farm.

Genus CERAURUS Green

CERAURUS SIMMONSI, sp. nov.

(Plate VII, Figs. 1–2)

Description. — Glabella 10 mm. long, 6 mm. wide at posterior end, 8 mm. at anterior end. The three pairs of lateral lobes globular, well developed; posterior pair separated from median part of glabella by deep furrows; first and second pairs joined to glabella by depressed, constricted necks. Frontal lobe with extremities, crescent-shaped. Genal angles blunt, rounded. Occipital groove and extension across fixed cheeks well defined. Surface covered with numerous large and small granules, the small ones especially numerous along occipital groove at posterior end of glabella, and the large ones arranged roughly in two rows, one along each side of the median part of glabella.

Comparison. — Differs from *Ceraurus miseneri*, its nearest relative, in the less rapid widening of glabella from posterior to anterior end.

Horizon and locality. — Stonington beds, Ogontz member, east side of Little Bay de Noc, 1½ miles south of Stratton's dock.

Genus CHASMOPS McCoy

CHASMOPS BREVICEPS (Hall)

(Plate VII, Figs. 4–5)

Description. — Frontal lobe greatly developed, anterior margin crescentiform. First and second lateral lobes fused, the fusion being shown by presence of vestigial second lateral furrows, appearing as rounded pits or slightly elongate grooves at base of lobes. Anterior pair present, but very greatly reduced in size, vestigial. All lobes separated by deep furrows. Surface pustulose.

Horizon and locality. — Stonington beds, Ogontz member, various localities.

Class EUCRUSTACEA

Genus PRIMITIELLA Ulrich

PRIMITIELLA STONINGTONENSIS, sp. nov.

(Plate I, Fig. 6)

Description. — Shell elongate, subelliptical. Dorsal margin straight. Ventral margin sloping obliquely up to narrowed anterior end. A blunt spine situated about half-way up valve near posterior end, and directed posteriorly, but not elevated above general surface of valve.

Comparison. — Differs from *Primitiella unicornis* in the more constricted anterior end of shell, and position of spine which is not as close to margin.

Horizon and locality. — Bill's Creek beds, various localities.

FAUNAL LIST

Only the chief localities where fossils were found are included in the faunal list. The tables are arranged so that the vertical range of the various species of fossils can easily be seen. Other species will undoubtedly be added to the Richmond of Michigan as further studies are made.

Faunal List

Species	Bill's Creek					Stonington						Big Hill		
						Bay de Noc		Ogontz			?			
	Haymeadow Creek	Bill's Creek	Squaw Creek	Railroad cut west of Ensign	Eastern side of Little Bay de Noc	Basal part north of Stratton's farm	Upper part south of Stratton's dock	Ditch, south side of Stratton's farm	South from Stratton's dock	Field east of Church	Ogontz Creek	Eastern end of Maywood Road	Hinkin's Hill and road north	Sturgeon River
Algae														
Girvanella richmondensis (Miller)	....	....	....	.....	.....	.....	.....	.....	.....	.....	....	x	.....	....
Porifera														
Hindia subrotunda (James)	....	....	....	.....	.....	.....	.....	.....	.....	.....	....	x	.....	....
Anthozoa														
Calapoecia cribriformis (Nicholson)	....	....	....	.....	.....	.....	.....	.....	.....	.....	....	x	x	....
Columnaria alveolata Goldfuss	....	....	....	.....	.....	.....	.....	.....	.....	.....	....	x	x	....
Columnaria (Paleophyllum) stokesi (Edwards and Haime)	....	....	....	.....	.....	.....	.....	.....	.....	.....	....	.....	x	x
Halysites gracilis (Hall)	....	....	....	.....	.....	.....	.....	.....	.....	.....	....	.....	x	x
Lyopora goldfussi (Billings)	....	....	....	.....	.....	.....	.....	.....	.....	.....	....	.....	x	....
Paleofavosites asper D'Orbigny	....	....	....	.....	.....	.....	.....	.....	.....	.....	....	.....	x	....
Protarea richmondensis Foerste	....	....	....	.....	.....	.....	.....	.....	.....	.....	....	x	.....	....
Streptelasma rusticum (Billings)	....	....	....	.....	.....	.....	x	x	x	x	x	x	x	x
Streptelasma divaricans (Nicholson)	....	....	....	.....	.....	.....	x	.....	.....	.....	....	.....	x	....
Tetradium huronense Billings	....	....	....	.....	.....	.....	x	.....	.....	.....	....	.....	.....	....

HYDROZOA														
Beatricea nodilifera Foerste	....	....	....	.....	.....	.....	.....	.....	.....	.....	....	x	x	....
Beatricea undulata Billings	....	....	....	.....	.....	.....	.....	.....	.....	.....	....	x	.....	....
Beatricea (?) sp.	....	....	....	.....	.....	.....	.....	.....	.....	.....	....	.....	x	....
GRAPTOLITOIDEA														
Glossograptus (Orthograptus) quadrimucronatus (Hall)	x	x	....	.....	.....	.....	.....	.....	.....	.....	..	.....	.....	....
VERMES														
Cornulites corrugatus (Nicholson)	....	....	....	.....	.....	.....	.....	x	x	.....	....	.....	.....	....
Cornulites flexuosus (Hall)	....	x	....	.....	.....	.....	.....	.....	.....	.....	....	.....	.....	....
Cornulites cf. sterlingensis (Meek and Worthen)	....	....	....	.....	.....	.....	.....	x	x	.....	....	.....	.....	....
Oenonites aff. curvidens Hinde	....	x	....	.....	.....	.....	.....	.....	.....	.....	....	.....	.....	....
ECHINODERMATA														
Lichenocrinus tuberculatus Miller	....	x	....	.....	.....	.....	.....	x	x	.....	....	.....	.....	....
BRYOZOA														
Arthropora shafferi (Meek)	....	x	....	.....	.....	.....	.....	.....	.....	.....	....	.....	.....	....
Batostoma sp., sp. nov.	....	....	....	.....	.....	.....	.....	x	.....	.....	....	.....	.....	....
Bythopora striata Ulrich	....	x	....	.....	.....	.....	.....	.....	.....	.....	....	x	.....	....
Hallopora subnodosa Ulrich, var.	....	....	....	.....	.....	.....	x	.....	.....	.....	....	.....	.....	....
Heterotrypa sp.	....	....	....	.....	.....	.....	.....	x	.....	.....	....	.....	.....	....
Homotrypella rustica Ulrich	....	....	....	.....	.....	.....	.....	x	.....	.....	....	.....	.....	....
Mesotrypa sp., sp. nov.	....	....	....	.....	.....	.....	x	.....	.....	.....	....	.....	.....	....
Monticulipora epidermata Ulrich and Bassler	....	....	....	.....	.....	.....	x	x	x	.....	....	.....	.....	....
Pachydictya sp.	....	....	....	.....	.....	.....	.....	.....	.....	.....	....	x	.....	....
Peronopora decipiens (Rominger)	....	....	....	.....	.....	.....	x	.....	.....	.....	....	.....	.....	....
Proboscina auloporoides (Nicholson)	....	....	....	.....	.....	.....	x	x	.....	.....	....	.....	.....	....

FAUNAL LIST—*Continued*

SPECIES	BILL'S CREEK					STONINGTON						BIG HILL		
						BAY DE NOC		OGONTZ			?			
	Haymeadow Creek	Bill's Creek	Squaw Creek	Railroad cut west of Ensign	Eastern side of Little Bay de Noc	Basal part north of Stratton's farm	Upper part south of Stratton's dock	Ditch, south side of Stratton's farm	South from Stratton's dock	Field east of Church	Ogontz Creek	Eastern end of Maywood Road	Hinkin's Hill and road north	Sturgeon River
BRYOZOA—*Continued*														
Rhombotrypa quadrata (Rominger)	....	x	....	.....	.....	.....	x	x	.....	.....	....	.....	.....	....
Rhombotrypa subquadrata (Ulrich)	....	....	....	.....	.....	.....	x	.....	.....	.....	....	.....	.....	....
Stigmatella sp., sp. nov.	....	....	....	.....	.....	.....	x	.....	.....	.....	....	.....	.....	....
BRACHIOPODA														
Crania scabiosa Hall	....	....	....	.....	.....	.....	x	x	.....	.....	....	.....	.....	....
Dalmanella jugosa subplicata Foerste	....	....	....	.....	.....	.....	x	x	x	x	x	.....	.....	....
Dalmanella sp. (No. 1)	....	x	....	.....	.....	.....	.....	.....	.....	.....	....	.....	.....	....
Dalmanella sp. (No. 2)	....	x	....	.....	.....	.....	.....	.....	.....	.....	....	.....	.....	....
Dinorthis (Plaesiomys) subquadrata (Hall)	....	....	....	.....	.....	.....	x	x	.....	.....	....	.....	.....	....
Dinorthis subquadrata noquettensis, var. nov.	....	....	....	.....	.....	.....	x	x	.....	.....	....	.....	.....	....
Hebertella alveata Foerste	....	....	....	.....	.....	.....	x	x	x	x	x	.....	.....	x
Hebertella alveata richmondensis Foerste	....	....	....	.....	.....	.....	.....	.....	.....	x	x	.....	.....	....
Hebertella occidentalis Hall	....	....	....	.....	.....	.....	x	x	x	x	....	x	.....	....
Lingula ogontzensis, sp. nov.	....	....	....	.....	.....	.....	.....	.....	x	.....	....	.....	.....	....
Lingula changi, sp. nov.	....	x	....	.....	.....	.....	.....	.....	.....	.....	....	.....	.....	....
Leptobolus insignis Hall	....	x	x	.....	.....	.....	.....	.....	.....	.....	....	.....	.....	....

Platystrophia annieana Foerste	....	....	....	.....	.....	.....	x	.....	.....	.....	....	.....	.....	....
Platystrophia acutilirata (Conrad)	....	....	....	.....	.....	.....	x	x	x	x	x	.....	.....	....
Platystrophia aff. cypha James	....	....	....	.....	.....	.....	x	.....	.....	.....	....	.....	.....	....
Platystrophia moritura (Cumings)	....	....	....	.....	.....	.....	x	x	x	x	....	.....	.....	....
Platystrophia clarksvillensis Foerste	....	....	....	.....	.....	.....	x	x	x	.....	x	.....	.....	....
Platystrophia sp. (No. 1)	....	....	....	.....	.....	.....	x	.....	.....	.....	....	.....	.....	....
Platystrophia sp. (No. 2)	....	....	....	.....	.....	.....	x	.....	.....	.....	....	.....	.....	....
Platystrophia sp. (No. 4)	....	....	....	.....	.....	.....	x	.....	.....	.....	....	.....	.....	....
Platystrophia sp. (No. 4)	....	....	....	.....	.....	.....	x	.....	.....	.....	..	.....	.....	....
Plectambonites rugosus noquettensis, var. nov.	....	....	....	.....	.....	.....	.....	.....	.....	x	?	.....	.....	....
Rafinesquina alternata (Emmons)	....	x	....	.....	.....	.....	x	x	x	x	x	.....	.....	....
Rafinesquina alternata varicosa Foerste	....	....	....	.....	.....	x	.....	.....	.....	.....	....	.....	.....	....
Rafinesquina alternata noquettensis, var. nov.	....	....	....	.....	.....	x	.....	.....	.....	.....	....	.....	.....	....
Rafinesquina breviusculus Foerste	....	....	....	.....	.....	.....	x	x	x	.....	....	.....	.....	....
Rafinesquina pregibbosa Foerste	....	....	....	.....	.....	.....	x	x	.....	x	....	.....	.....	....
Rafinesquina sp. cf. minnesotensis (N. H. Winchell)	....	....	....	.....	.....	.....	.....	.....	.....	.....	....	.....	.....	x
Rhynchotrema capax (Conrad)	....	....	....	.....	.....	.....	.....	.....	.....	.....	....	x	.....	x
Rhynchotrema perlamellosum (Whitfield)	....	....	....	.....	.....	.....	.....	.....	.....	.....	....	x	x	x
Strophomena huronensis Foerste	....	....	....	.....	.....	.....	x	.....	.....	.....	....	x	.....	....
Strophomena neglecta (James)	....	....	....	.....	.....	.....	x	x	x	.....	x	.....	.....	....
Strophomena cf. nutans Meek	....	....	....	.....	.....	.....	x	.....	.....	.....	....	.....	.....	....
Strophomena planumbona (Hall)	....	....	....	.....	.....	.....	.....	.....	.....	.....	....	x	.....	x
Strophomena planumbona elongata (James)	....	....	....	.....	.....	.....	.....	.....	.....	.....	....	x	.....	x
Strophomena parvula Foerste	....	....	....	.....	.....	.....	x	x	x	x	x	.....	.....	....
Strophomena sulcata (Verneuil)	....	....	....	.....	.....	.....	x	.....	.....	.....	....	x	.....	x
Strophomena vetusta (James)	....	....	....	.....	.....	.....	x	.....	.....	.....	....	x	.....	x
Trematis rugosa, sp. nov.	....	....	....	.....	.....	.....	.....	x	.....	.....	....	.....	.....	....
Zygospira recurvirostris turgida Foerste	....	....	....	.....	.....	.....	x	x	.....	.....	x	.....	.....	....
Zygospira recurvirostris noquettensis, var. nov.	....	....	....	.....	.....	.....	.....	x	.....	.....	....	.....	.....	....
Zygospira cf. modesta Hall	....	....	....	x	.....	.....	.....	.....	.....	.....	....	.....	.....	....

FAUNAL LIST—*Continued*

SPECIES	BILL'S CREEK					STONINGTON							BIG HILL		
						BAY DE NOC		OGONTZ			?				
	Haymeadow Creek	Bill's Creek	Squaw Creek	Railroad cut west of Ensign	Eastern side of Little Bay de Noc	Basal part north of Stratton's farm	Upper part south of Stratton's dock	Ditch, south side of Stratton's farm	South from Stratton's dock	Field east of Church	Ogontz Creek	Eastern end of Maywood Road	Hinkin's Hill and road north	Sturgeon River
PELECYPODA														
Anomalodonta griffini, sp. nov.	....	....	....	.....	.....	.....	.....	x	.....	.....	....	.....	.....	....
Anomalodonta sp. cf. gigantea Miller	....	....	....	.....	.....	.....	x	.....	.....	.....	....	.....	.....	....
Byssonychia obesa Ulrich	....	....	....	.....	.....	.....	.....	.....	.....	x	....	.....	.....	....
Byssonychia elroyi, sp. nov.	....	....	....	.....	.....	.....	.....	x	.....	.....	....	.....	.....	....
Byssonychia richmondensis Ulrich	....	....	....	.....	.....	.....	x	.....	.....	.....	....	.....	.....	....
Byssonychia carinata (Goldfuss)	....	....	....	.....	.....	.....	x	.....	.....	.....	....	.....	.....	....
Clionychia angusta Foerste	....	....	....	.....	.....	.....	.....	x	.....	.....	....	.....	.....	....
Clidophorus noquettensis Foerste	....	x	....	.....	.....	x	.....	.....	.....	.....	....	.....	.....	....
Clidophorus neglectus Hall	....	x	....	.....	.....	x	.....	.....	.....	.....	....	.....	.....	....
Clidophorus ogontzensis, sp. nov.	....	....	....	.....	.....	.....	.....	x	.....	.....	....	.....	.....	....
Colpomya colgatei, sp. nov.	....	....	....	.....	.....	.....	.....	x	.....	.....	....	.....	.....	....
Cyrtodonta potteri, sp. nov.	....	....	....	.....	.....	.....	.....	x	x	.....	....	.....	.....	....
Cyrtodonta grandis (Ulrich)	....	....	....	.....	.....	.....	.....	x	.....	.....	....	.....	.....	....
Cymatonota cf. typicalis Ulrich	....	....	....	.....	.....	.....	.....	x	.....	.....	....	.....	.....	....
Cuneamya miamiensis Hall and Whitfield	....	....	....	.....	.....	.....	.....	x	.....	.....	....	.....	.....	....
Modiolopsis valida Ulrich	....	....	....	.....	.....	.....	x	?	.....	.....	....	.....	.....	....
Modiolopsis noquettensis, sp. nov.	....	....	....	.....	.....	.....	.....	x	?	.....	....	.....	.....	....
Opisthoptera cf. casei (Meek and Worthen)	....	....	....	.....	.....	.....	.....	x	x	.....	....	.....	.....	....

Opistholoba gouldi, sp. nov.	....	....	....	.....	.....	.....	.....	x	x	.....	....	.....	.....	....
Orthodesma cf. subangulatum Ulrich	....	....	....	.....	.....	.....	.....	x	.....	.....	....	.....	.....	....
Orthodesma sp.	....	....	....	.....	.....	.....	.....	x	.....	.....	....	.....	.....	....
Psiloconcha sp.	....	....	....	.....	.....	.....	x	.....	.....	.....	....	.....	.....	....
Pterinea (Caritodens) demissa (Conrad)	....	x	....	.....	.....	.....	x	x	.....	.....	....	x	.....	....
Pterinea aff. insueta (Emmons)	....	x	....	.....	.....	.....	.....	.....	.....	.....	....	.....	.....	....
Pterinea sp.	....	x	....	.....	.....	.....	.....	.....	.....	.....	....	.....	.....	....
Vanuxemia noquettensis, sp. nov.	....	....	....	.....	.....	.....	.....	.....	.....	x	....	.....	.....	....
Vanuxemia strattoni, sp. nov.	....	....	....	.....	.....	.....	.....	.....	.....	x	....	.....	.....	....
Whiteavesia pholadiformis (Hall)	....	....	....	.....	.....	.....	x	.....	.....	.....	x	.....	.....	....
GASTROPODA														
Archinacella simmonsi, sp. nov.	....	....	....	.....	.....	.....	.....	x	.....	.....	....	.....	.....	....
Archinacella kagawongensis Foerste	....	....	....	.....	.....	.....	.....	x	x	.....	....	.....	.....	....
Bellerophon sp.	....	....	....	.....	.....	.....	x	.....	.....	.....	....	.....	.....	....
Conularia formosa Miller and Dyer	....	....	....	.....	.....	.....	x	.....	.....	.....	....	.....	.....	....
Conularia sp.	....	....	....	.....	.....	.....	.....	x	x	.....	....	.....	.....	....
Cyclora minuta Hall	....	x	....	.....	.....	.....	x	x	x	.....	....	.....	.....	....
Cyrtolites ornatus Conrad	....	....	....	.....	.....	.....	.....	x	.....	x	....	.....	.....	....
Hormotoma gracilis (Hall) var.	....	....	....	.....	.....	.....	.....	x	x	x	....	.....	.....	....
Hormotoma gracilis (Hall) aff. var. multivolvis Ulrich and Scofield	....	....	....	.....	.....	.....	.....	x	.....	.....	....	.....	.....	....
Helicotoma brocki Foerste	....	....	....	.....	.....	.....	.....	x	x	.....	....	.....	.....	....
Holopea aff. hubbardi Miller	....	....	....	.....	.....	.....	.....	x	.....	.....	....	.....	.....	....
Liospira micula (Hall)	....	....	....	.....	.....	.....	.....	x	x	.....	....	.....	.....	....
Lophospira bicincta (Hall)	....	....	....	.....	.....	.....	.....	x	.....	.....	....	x	.....	x
Lophospira aff. pulchella Ulrich and Scofield	....	....	....	.....	.....	.....	.....	x	.....	.....	....	.....	.....	....
Lophospira sp.	....	....	....	.....	.....	.....	.....	x	x	.....	....	.....	.....	....
Phragmolites slawsoni, sp. nov.	....	....	....	.....	.....	.....	x	.....	.....	.....	....	.....	.....	....
Scenella (?) sp.	....	....	....	.....	.....	.....	.....	x	.....	.....	....	.....	.....	....
Sinuites sp.	....	....	....	.....	.....	.....	x	.....	.....	.....	....	.....	.....	....
Trochonema wartheni, sp. nov.	....	....	....	.....	.....	.....	.....	x	.....	.....	....	.....	.....	....

FAUNAL LIST—*Continued*

SPECIES	BILL'S CREEK					STONINGTON						BIG HILL		
						BAY DE NOC		OGONTZ			?			
	Haymeadow Creek	Bill's Creek	Squaw Creek	Railroad cut west of Ensign	Eastern side of Little Bay de Noc	Basal part north of Stratton's farm	Upper part south of Stratton's dock	Ditch, south side of Stratton's farm	South from Stratton's dock	Field east of Church	Ogontz Creek	Eastern end of Maywood Road	Hinkin's Hill and road north	Sturgeon River
CEPHALOPODA														
Actinoceras cf. bigsbyi Bronn	....	....	....	.....	.....	.....	.....	.....	.....	.....	....	x	.....	....
Billingsites newberryi noquettensis Foerste	....	....	....	.....	.....	.....	.....	.....	.....	x	....	.....	.....	....
Endoceras sp.	....	....	....	.....	.....	.....	x	.....	.....	.....	....	.....	.....	....
Oncoceras sp.	....	....	....	.....	.....	.....	.....	x	.....	.....	....	.....	.....	....
Orthoceras sp.	....	....	....	.....	.....	.....	.....	x	.....	.....	....	.....	.....	....
Spyroceras sp.	....	....	....	.....	.....	.....	.....	.....	.....	.....	....	x	.....	....
TRILOBITA														
Acidaspis sp.	....	x	....	.....	.....	.....	.....	.....	.....	.....	....	.....	.....	....
Amphilichas cucullus (?) (Meek and Worthen)	....	....	....	.....	.....	.....	.....	x	.....	.....	....	.....	.....	....
Calymene sp.	....	x	....	x	.....	.....	.....	.....	.....	.....	....	.....	.....	....
Ceraurus simmonsi, sp. nov.	....	....	....	.....	.....	.....	?	x	x	.....	....	.....	.....	....
Isotelus gigas deKay	....	x	....	.....	.....	?	.....	.....	.....	.....	....	.....	.....	....
Isotelus sp.	....	....	....	.....	.....	.....	.....	x	.....	.....	....	.....	.....	....
Onchometopus sp.	....	....	....	.....	.....	.....	.....	x	.....	.....	....	.....	.....	....

Ostracoda														
Bythocypris cylindrica (Hall)	x	....	....	......	......	......	......	......	......	......	....	......	......	....
Primitia cincinnatiensis (Miller)	....	x	....	......	......	......	......	......	......	......	....	......	......	....
Primitiella stoningtonensis, sp. nov.	x	x	....	......	......	......	......	......	......	......	....	......	......	....
Tetradella regularis (Emmons)	....	x	....	x	x	x	......	......	......	......	....	......	......	....
Position Uncertain														
Pasceolus (?) sp.	....	x	....	......	......	......	......	......	......	......	....	......	......	....

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Late Ordovician Erosion in the Mississippi Valley, pp. 308–311;
Arctic Ordovician, p. 494;
Significance of Black Shale Deposition, pp. 356–361;
"Edgewise" Intraformational Conglomerate, p. 540;
Stratigraphic Hiatuses, p. 458;
Principles of Stratigraphic Correlation, pp. 501–517;
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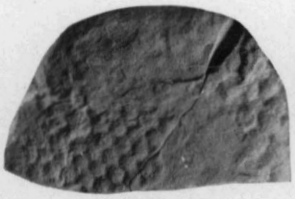
PLATES AND EXPLANATIONS OF PLATES

NOTE. — In these plates a number of fossils which have been described by other writers are figured for convenience of comparison. In a few cases, however, additional statements have been made in the text about forms already described.

EXPLANATION OF PLATE I

PLATE I



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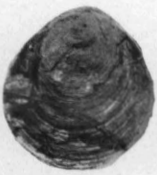

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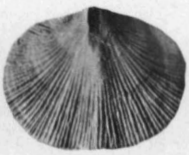

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EXPLANATION OF PLATE II

FIGURES — PAGE

1–5. *Rafinesquina breviusculus* Foerste 160

1. Pedicle valve of individual with short hinge-line
2. Pedicle valve of the ordinary form
3. Pedicle valve of a variety with a greatly extended hinge-line
4. Interior of brachial valve
5. Profile view of pedicle valve
6. *Strophomena vetusta* (James). Brachial valve
7. *Hebertella alveata* Foerste. Pedicle valve

8–9. *Rafinesquina alternata noquettensis*, var. nov..... 161

8. Profile view of pedicle valve
9. Pedicle valve
10. *Strophomena vetusta* (James). Interior of pedicle valve
11. *Strophomena neglecta* (James). Interior of pedicle valve
12. *Rafinesquina alternata* (Emmons). Interior of brachial valve of a large specimen
13. *Colpomya colgatei*, sp. nov. Cast of interior of right valve. × 1.5 170

14–15. *Tetradella regularis* (Emmons). × 13

14. Right vlave
15. Left valve
16. *Clidophorus neglectus* Hall. Cast of interior of left valve. × 9

PLATE II

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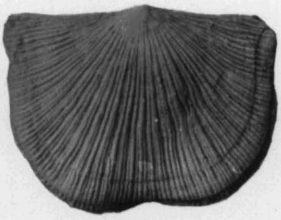

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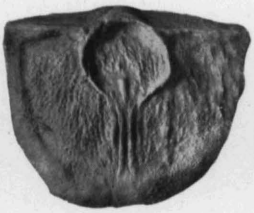

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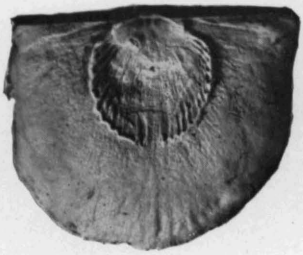

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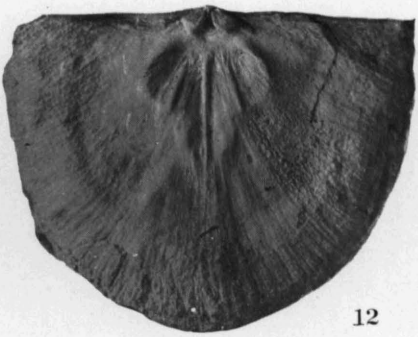

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EXPLANATION OF PLATE III

FIGURES — PAGE

1–3. *Modiolopsis valida* Ulrich

1. Cast of interior, left valve. Undistorted
2. Left valve of a specimen distorted posteriorly by pressure
3. Right valve of a specimen shortened by pressure
4. Right valve of a pelecypod of uncertain generic relations. Possibly an *Anomalodonta*

5–6. *Anomalodonta (?) sp,*

5. Posterior view
6. Cast of interior of right valve
7. *Anomalodonta sp. cf. gigantea* Miller. Cast of interior of left valve 166

PLATE III

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EXPLANATION OF PLATE IV

FIGURES — PAGE

1–2. *Helicotoma brocki* Foerste. × 1.5
1. Lateral view
2. Apical view
3. *Clionychia angusta* Foerste. × 1.5 168
4–5. *Liospira micula* (Hall). × 1.5
4. Lateral view
5. Apical view
6. *Strophomena vetusta* (James). Brachial valve, showing oblique wrinkles along hinge-line
7–9. *Rafinesquina pergibbosa* Foerste
7. Profile view, showing great convexity of pedicle valve, illustrated in Figure 9
8. Interior of brachial valve
9. Pedicle valve
10. *Hebertella alveata richmondensis* Foerste
Brachial valve 157
11. *Strophomena huronensis* Foerste. Interior of pedicle valve, showing unusually large muscle scar, and wrinkles around anterior margin of shell 162
12. *Strophomena vetusta* (James). Brachial valve. An unusually quadrate form
13. *Rafinesquina alternata varicosa* Foerste. Pedicle valve 161
14. *Strophomena vetusta* (James). Interior of brachial valve
15. *Dinorthis* (*Plaesiomys*) *subquadrata noquettensis*, var. nov. Brachial valve showing the coarse plications characteristic of this variety 159
16. *Dinorthis* (*Plaesiomys*) *subquadrata* (Hall). Brachial valve
17. *Rafinesquina alternata* (Emmons). Pedicle valve. Large, quadrate form
18. *Pterinea sp.* A form from the Bill's Creek beds, Bill's Creek locality, showing the strong, radiating ribs

PLATE IV

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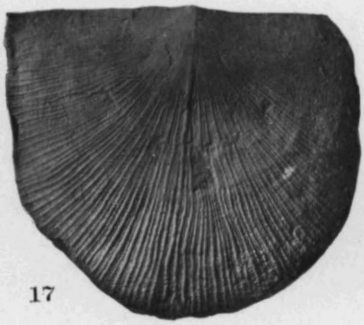

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EXPLANATION OF PLATE V

PLATE V

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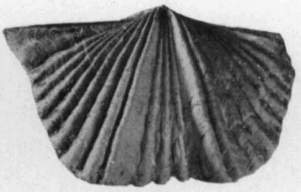

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EXPLANATION OF PLATE VI

FIGURES — PAGE

1. *Archinacella simmonsi*, sp. nov. Lateral view.
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2. Lateral view of a variety with the slope below the beak unusually straight
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9. Apical view of the same specimen shown in Figure 3. × 1½
10. Apical view of the same specimen shown in Figure 4. × 1½

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5. Posterior view of glabella. × 1½
6. In this figure the specimen is orientated to show the entire glabella. × 1½
7. Lateral view of glabella to show the strong downward flexure towards the anterior end

11, 14. A pelecypod of uncertain generic relations. May be a *Byssonychia*. A single specimen was found in the Ogontz member of the Stonington beds, south of Stratton's dock
11. Anterior view of right valve
14. Right valve

12. *Lichenocrinus tuberculatus* Miller. × 1.5
13. *Strophomena sulcata* (Verneuil). Brachial valve
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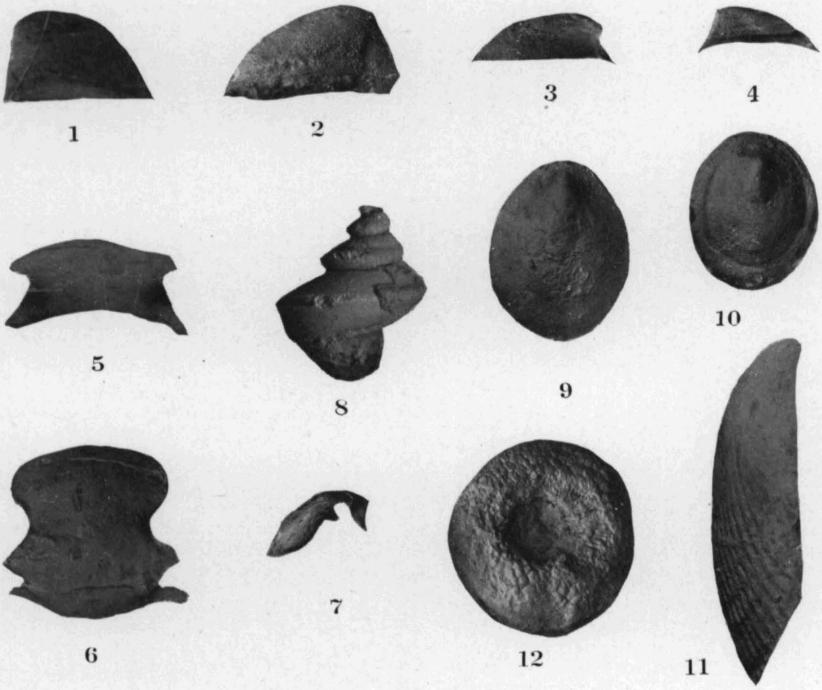
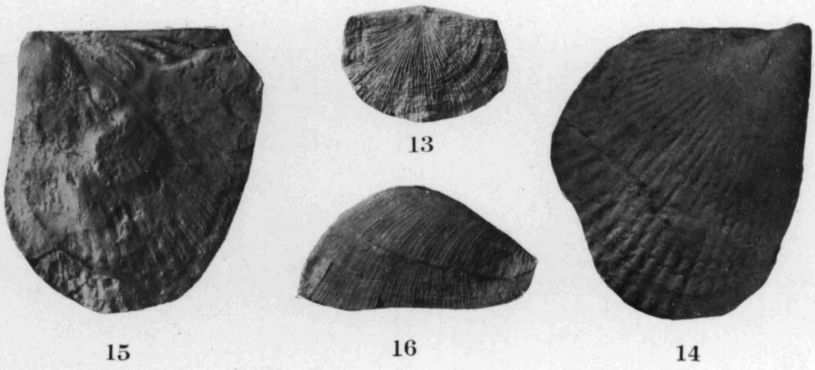
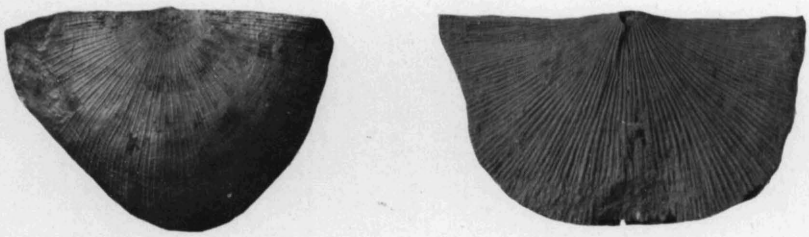
16–17. *Strophomena neglecta* (James)
16. Profile view showing the great convexity of brachial valve
17. Brachial valve

18. *Hebertella alveata*; Foerste. Pedicle valve 157

PLATE VI







EXPLANATION OF PLATE VII

PLATE VII

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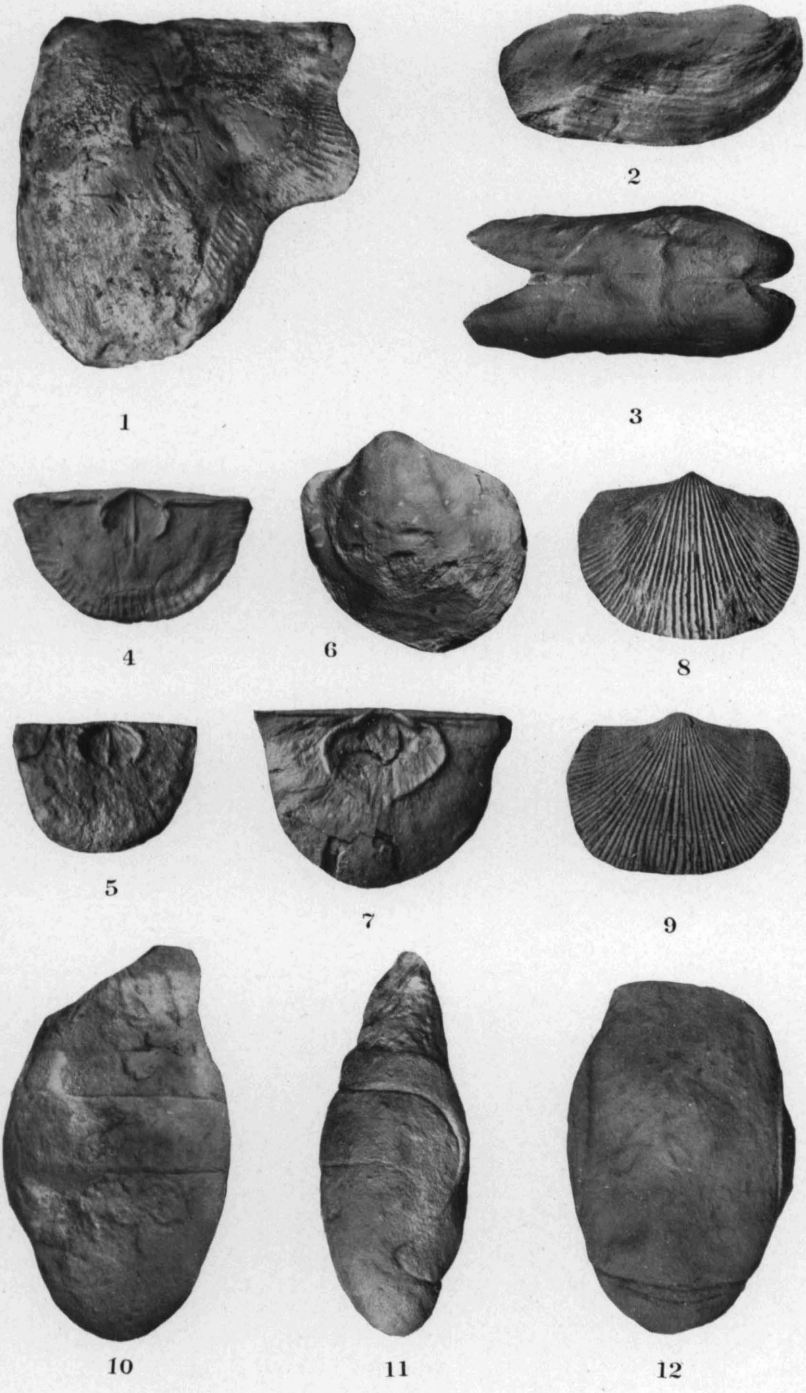
EXPLANATION OF PLATE VIII

PLATE VIII



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EXPLANATION OF PLATE IX

PLATE IX

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EXPLANATION OF PLATE X

PLATE X

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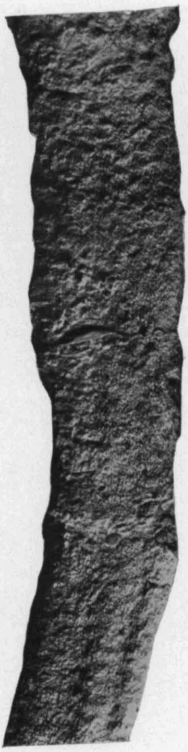

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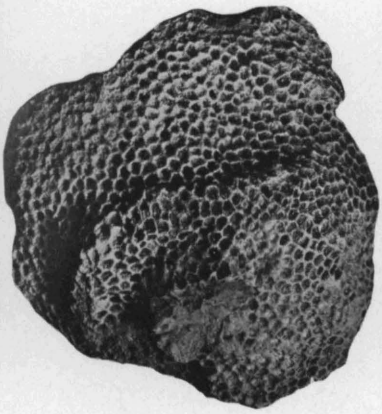

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EXPLANATION OF PLATE XI

FIGURES — PAGE

1–3. *Zygospira recurvirostris noquettensis*, var. nov. 162
1. Brachial valve
2. Pedicle valve
3. Lateral view

4–7. *Zygospira recurvirostris turgida* Foerste
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8–10. *Strophomena parvula* Foerste
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11–13. *Rafinesquina sp. cf. minnesotensis* (N. H. Winchell) 161
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14. *Halysites gracilis* (Hall). Showing quadrangular shape of the corallites. × 1.5
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PLATE XI