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REVISION OF THE CHILLICOTHE TEST-CORE SECTION

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This paper presents a correction in the interpretation of the section of the Chillicothe test-core as given by the present writer in an article published in this Journal (Carman, 1947). The core came from a well 3 miles southwest of Chillicothe on the Hirsh fruit farm. The well was drilled by the Engineering Experiment Station, The Ohio State University, to obtain a core for the determination of the petroleum content of the Ohio shale, foot by foot (Kerr, 1948). The entire core was studied by the writer for the determination of the rock units passed through, and discussed in the 1947 paper. The list of rock units penetrated was given in that paper as follows:

Rock Unit	*Thickness*			*Depth to Base*		
	Ft.		*In.*	*Ft.*		*In.*
Mantle rock	6	—	6	6	—	6
Sunbury shale	1	—	0	7	—	6
Berea sandstone	25	—	6	33	—	0
Bedford shale	91	—	0	124	—	0
Ohio shale	376	—	6	500	—	6
Olentangy shale	64	—	0	564	—	6
Niagaran dolomite	12	—	6	577	—	0

The present paper deals only with the basal unit of the above section, 12 ft. 6 in. thick which in the earlier paper was assigned to the Niagaran dolomite and described as follows (Carman, 1947, p. 53). "The dolomite is bluish-gray to brownish-gray and quite variable in texture. In part it is firmly crystalline and compact; in part of very rough texture with open spaces containing petroliferous staining; at places apparently brecciated as if crushed reef material; the basal 4 feet is largely oolitic dolomite. No identifiable fossils were found in the dolomite but in the porous, crushed reef-rock material there are structures that suggest the compound coral *Favosites* and concentrically laminated masses suggesting stromatoporoids, all greatly altered. Although not absolutely conclusive, the evidence indicates that this dolomite is upper Niagaran." This correlation agreed with the fact that in Highland and Adams counties to the southwest, the Ohio shale rests disconformably on a surface of Niagaran and Greenfield dolomites.

In the spring of 1953, in the studies of another geologist on detrital materials at the disconformable contact at the base of the Upper Devonian shale, the piece of the Chillicothe test-core containing the top of the dolomite was sectioned vertically. This section revealed a fossil entirely against the Niagaran age of the dolomite and led to a very thorough restudy of this lower part of the core with sections and polished surfaces at a number of horizons.

The Olentangy shale overlying the calcareous strata is dominantly blue-gray in color, but with many thin layers of brownish-black shale. The lowest 3 ft. is black and brownish-black shale with a few thin layers of blue-gray shale. The restudy of the 12 ft. of calcareous strata next below resulted in the following described section which is also shown graphically in figure 1.

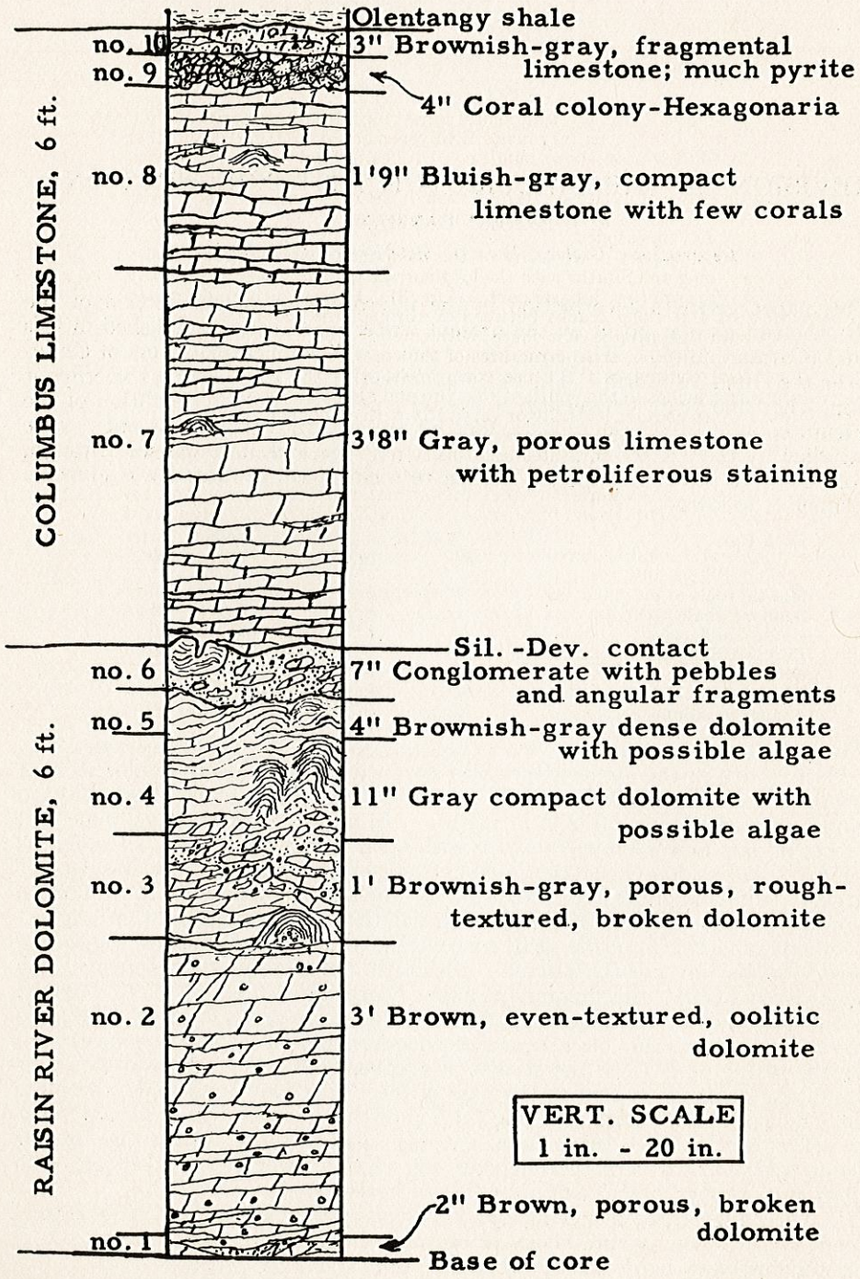


FIGURE 1. Columnar section of calcareous strata below upper Devonian shale

SECTION OF THE CALCAREOUS ROCK STRATA PENETRATED BY THE CHILLICOTHE TEST-CORE BELOW THE UPPER DEVONIAN SHALE

The zones are numbered from the base upward but discussed from above downward.

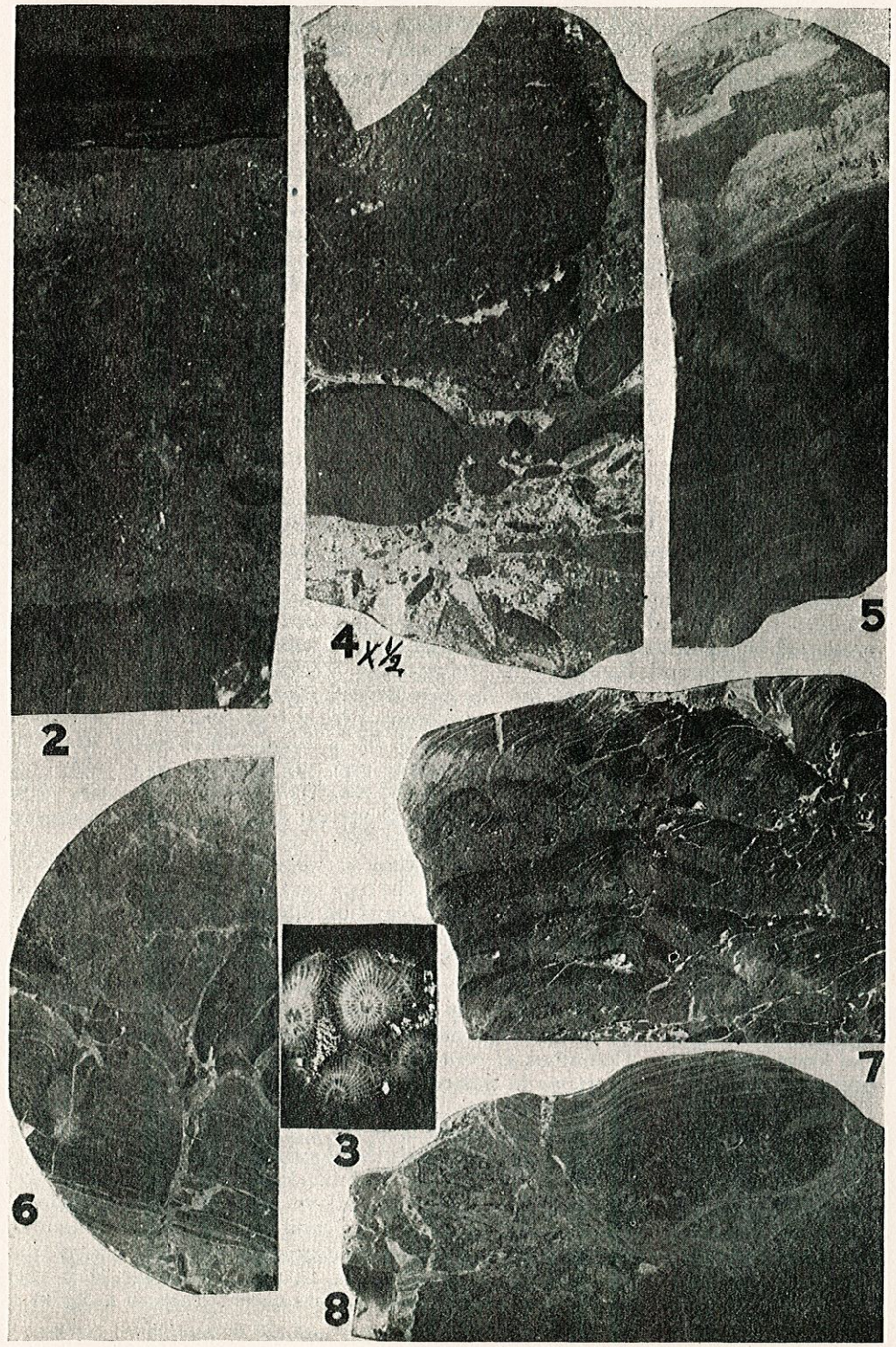
		Thickness Ft.	In.
10.	Gray to brownish-gray, compact, fragmental limestone with much pyrite. Composed of small calcareous fragments firmly cemented in a matrix of finer grain. The polished section shows small coral tubes, a horn coral, and a compound Favosites-like coral, all pyritized, poorly preserved, and unidentifiable. There are small lenses of pyrite scattered through the mass and the upper ½ in. is dark in color and largely pyrite (fig. 2, middle part).	0	3
9.	Blue-gray, compact, limestone. Composed entirely of part of a colony of the compound, compact coral *Hexagonaria prisma* (Lang and Smith) with the long corralities extending horizontally entirely across the core (fig. 2, basal part and fig. 3). Pyrite has been deposited in porous places and along cracks between or through the corallities. The contact with the unit above is sharp, with small jagged irregularities which cut across and into the internal structures of the corallites without any distortion. The basal contact of the dense coral mass, with the grainy limestone below, drops two inches in the width of the core and along this surface the limestone forms a sharp contact laterally or vertically with any part of the corallites. These contacts of the coral mass are interpreted as solution contacts. The horizontal position of the corallites and the nature of the contacts indicate that the coral colony must have been overturned, probably moved, and was lying on the surface when buried by the detrital material above. The coral is thus a part of the detrital zone but certainly originated in the limestone unit below.	0	4
8.	Bluish-gray, fine-grained, compact limestone with some blue streaking and mottling on polished surfaces. Locally, slightly porous with petroliferous staining. In the upper part are poorly preserved, unidentifiable, tubular corals and compound Favosite-like corals.	1	9
7.	Gray to bluish-gray, porous, crystalline limestone with much petroliferous staining. Favosite-like, coral structure can be recognized in several of the porous areas and probably most of the porous spaces have originated by the weathering of corals. The basal 9 in. is firmer and more finely crystalline.	3	8
6.	Dark-gray to brown conglomerate containing a large pebble or cobble, medium-sized pebbles, small slabby fragments, all dolomite and all set in a matrix of medium to small grains (fig. 1, no. 6, and fig. 4). A longitudinal, polished section of the entire 7 in. of this zone shows at the top a cobble of dark-brown, dense dolomite over 4 in. across and several pebbles, ½ in. to 1 in. across. The lower part of the zone is made up of sub-angular, lenticular, and slabby particles of the dark-brown and gray dolomite. Finally all of these are enclosed in a matrix consisting of medium to fine grains of dark-brown and gray dolmite, oolites, quartz sand grains and much pyrite. The polished surface of the large cobble shows undulating, more or less contorted, discontinuous, alternating bands or lenses of dark-brown dolomite and less distinct, grayish-brown dolomite. The dark-brown color dominates but the undulating pattern is brought out by the floculent streaks of graysh brown. It is one of the types of structure commonly referred to algae and is so regarded by the writer although no positive algal structures have been found. Between the bands, singly or as thin partings, or in pockets, are small round or oblong dolomite grains 0.2 to 0.3 mm. in diameter, some of which appear to have concentric or radiating structure or appear hollow, and apparently are oolites. Most interesting are the cases where a number of these oolite-like bodies occupy a pocket which must have been at one time a depression in the surface of the algal mass made by the thinning and downfolding of the laminae locally. Such pockets have been figured by authors under the name conceptacles and the oolite-like bodies interpreted as spore cases or some other type of reproductive body (Wieland, 1914). The matrix consists of small sub rounded grains of compact gray dolomite; quartz sand grains; oolites; and fine calcareous sediment and pyrite which form the cementing material. The oolites are most distinct at the basal contact of the zone where the cement has been partly removed allowing each oolite to show its distinct form, and the absence of any interlocking crystalline texture. The upper contact of this zone in the core is a sloping, solution contact with a parting about 1 mm. thick of greenish, argillaceous material with quartz sand grains and	0	7

		Thickness Ft.	In.
	much pyrite. The stone below the parting across most of the core is the brown algal cobble and on one side of the core a stylolite prong of the gray, fine-grained limestone of the zone above, ¼ in. across and ⅛ in. long, extends down into the dense, brown, algal dolomite of the cobble showing the extent to which interlayer solution has taken place (fig. 1, zone 6).		
5.	Gray to brownish-gray, dense dolomite. This zone (fig. 5) may be largely of algal origin but is of a different type from the algal mass of zone 6. The lowest one inch is made up of thin laminae which have a broad domal structure ½ in. to 1½ in. across. This grades upward into a part in which the units are ½ in. to ¾ in. across and the laminae are more strongly domed, and this grades back quite abruptly to essentially horizontal laminae. The laminae consist of very thin, at places discontinuous, gray partings alternating with thicker brown units about three times as thick as the gray partings, which indeed appear to be inserted in the denser, brown stone. The upper 1 to 2 in. is light-gray and dark-gray, dense dolomite in alternating, undulating layers ⅛ to ½ in. thick with uneven contacts.	0	4
4.	Light-gray to brownish-gray, compact dolomite. The core of this zone was sectioned for its full length. The upper 2 to 3 in. is an algal mass composed of brownish-gray, dense dolomite with some irregularly shaped open spaces (figs. 6 and 7). It consists of thicker brown laminae and thin gray partings similar to those in zone 5 above but the mode of growth is quite different. The domed units are quite distinct columns being about ½ in. across and 3 in. long, lying transverse to the vertical of the core. The doming of the laminae is more pronounced. At the base of this algal mass in the core is a ½ in. to 1 in. layer of breccia in which angular fragments of brown algal stone are enclosed in a gray matrix. Farther down through the zone the texture is somewhat irregular and the color mottled as if crushing had taken place, and at the base of the zone much of the width of the core is breccia.	0	11
3.	Brown and brownish-gray, vesicular and porous, irregular-textured, broken dolomite. This zone consists of angular fragments of dark-brown, dense dolomite in a matrix of smaller fragments of brown dolomite, oolites, and brownish-gray, finer material. It was apparently formed by the crushing of a vesicular rock, possibly an algal mass with openings. At the base of this zone is a smooth rounded, domed surface 2 by 2½ in. and rising ½ in. above the enclosing stone (fig. 8). A vertical section through this domed mass, plus broken laminae on the upper surface, shows fifteen pairs of the characteristic succession of brown, dense layer and brownish-gray parting. The entire ball-like mass is enclosed in oolites.	1	0
2.	Brown, even-textured, oolitic dolomite. The stone is composed almost entirely of small oolites about 0.5 mm. in diameter. They are dominantly round, a few are oblong. On a polished surface of the stone they are shown imbedded in a dense dark-brown matrix.	3	0
1.	Brown, irregularly-textured, porous dolomite. Rough-textured dolomite consisting of masses of brown, dense stone, some oolite grains and gray porous matrix. It is somewhat broken or crushed thus resembling the stone of zone 3. This is the base of the core at well-depth 577 ft.	0	2

EXPLANATION OF FIGURES 2-8

2. Upper part, is base of Olentangy shale. Middle part is zone 10, the detrital material on top of Columbus limestone. Basal part is top of coral colony, Hexagonaria.
3. Cross section of corallites of *Hexagonaria prisma* showing diagnostic characteristics. Zone 9, Columbus limestone.
4. (X½) The detrital material at Siluro-Devonian contact, zone 6 entire. The large cobble above may show algal structure.
5. Structure in Raisin River dolomite, zone 5, that may be of algal origin.
6. Structure in Raisin River dolomite, zone 4, that may be of algal origin.
7. Same specimen as in No. 6, sectioned at right angle.
8. Specimen from Raisin River dolomite, zone 3, showing laminated domal mass enclosed in oolitic and detrital material.

Sections and photographs by Richard Bowman.



GEOLOGIC AGE OF THE CALCAREOUS ROCK STRATA

The following is a geologic column of the rock units present along a north-south belt through central Ohio. To this the reader may refer for the stratigraphic position of the unit-names used in the following discussion.

Upper Devonian	Ohio Shale	
	Olentangy shale	
Erian	Prout limestone	—not known South of Erie Co.
	Plum Brook shale	
	Delaware limestone—not known south of Franklin Co.	
Ulsterian	Columbus limestone—not known south of Pickaway Co.	
	Detroit River dolomite—not known south of Sandusky Co.	
	Hillsboro sandstone—locally at Sil.-Dev. contact.	
Bass Islands	Raisin River dolomite	
	Put-in-Bay dolomite	
	Tymochtee shaly dolomite	
	Greenfield dolomite	
Niagaran	Peebles dolomite	—in Highland and Adams Cos.
	Lilley dolomite	
	Bisher dolomite	

In the foregoing section of the calcareous strata below the Upper Devonian shale there are two detrital units; zone 10 and 9 at the top just below the shale where one might expect a stratigraphic break, and zone 6 near the center of the calcareous section where a stratigraphic break would be much less probable.

Zones 8 and 7 above the lower detrital zone consist of gray to bluish-gray, compact to somewhat porous, finely-crystalline dolomitic limestone. Very poorly preserved, unidentifiable corals, including slender tubular types, a small horn coral and compound Favosites-like forms exist in zones 7, 8, and 10. These corals suggest a Devonian age but the one decisive fossil of the entire calcareous section is the colony of the compound, compact coral *Hexagonaria prisma* (Lang and Smith) which forms zone 9 (fig. 1, no. 9; fig. 2, basal part; and fig. 3). The characteristics of the genus are very definite and our specimen is notably well preserved showing on polished sections all the essential internal structures. The genus *Hexagonaria* is known only from the Devonian and *H. prisma* is a species present in the Columbus limestone of central Ohio.

On the basis of this *Hexagonaria prisma* colony, supported by the unidentifiable corals of zones 7 and 8, we must decide that the rock unit which lies disconformably below the Upper Devonian shale is the Columbus limestone down to the lower detrital zone. This includes zones 7 to 10 with a total thickness of 6 ft.

In the Columbus region of central Ohio *Hexagonaria prisma* is known only in zone H at the top of the Columbus limestone, which formation has there a total thickness of about 100 ft. Further, it is believed, on fossil evidence that this upper part of the Columbus continues northward to the Sandusky region but that the lower part of the Columbus of central Ohio is overlapped northward. The presence of *Hexagonaria prisma* in this core suggests that it is the highest part of the Columbus that is represented here. Since the Columbus is only 6 ft. thick in the core and the specimen of *Hexagonaria* is at the top, this interpretation would require that the Columbus sea did not reach this locality until late in Columbus time. It seems improbable that the marine Columbus limestone overlaps eastward away from the Cincinnati anticline. As noted above (zone 9) there is evidence that the Hexagonaria mass is part of the detrital unit resting on the Columbus and therefore may have originated at a higher stratigraphic level and a later time than the limestone layer on which it finally came to rest. However, it is very improbable that a piece of limestone released from its parent ledge in a region of

denudation could remain on or in the mantle rock during the time required for the lowering of the region some 50 to 75 ft. and then become buried beneath the sediments of a new cycle of deposition without complete disintegration or decomposition.

It is noted in the description of the geologic section that the matrix of the lower detrital zone (no. 6) contains quartz grains. In the basal 3 to 4 in. these quartz grains may constitute 10 to 15 percent of the whole, decreasing rapidly upward. When freed from the dolomite by treatment with acid most of the grains are clear rock-crystal quartz between 0.25 and 0.5 mm. diameter, well rounded and pitted or frosted with minute pits. Some of the grains show secondary enlargement by growth of hexagonal pointed ends and high-luster prism faces. The characteristics of these sand grains are identical with those found at the Siluro-Devonian systemic contact from north to south across Ohio; the Sylvania sandstone of Lucas County, the basal zone A of the Columbus limestone of central Ohio, and the Hillsboro sandstone of Highland County in southern Ohio. At all places, this sand or sandy material rests disconformably on the highest Silurian rock unit present at that locality when the sand was deposited. This is commonly on one of the four members of the Bass Islands group but in Highland County where the erosion had been greater, the Hillsboro sandstone at places rests on a still lower unit, the Niagaran dolomite. The sand unit is overlain by the first rock unit deposited at that place by the encroaching Devonian sea. In northern Ohio this is the Detroit River dolomite, the lowest Devonian rock unit in Ohio; in central Ohio the Detroit River is missing and the sand is found in the basal layers of the next overlying unit, the Columbus; and in southern Ohio where the Columbus and Delaware limestones are also absent the Upper Devonian shale rests on the sandstone or in its absence, on Niagaran dolomite.

On the basis of the characteristics of the quartz sand in this lower detrital zone and its stratigraphical position below the Columbus limestone in this part of Ohio, this zone 6 must mark the Siluro-Devonian contact horizon.

Zones 1 to 5 below the lower detrital unit consist of gray through brownish-gray to brown, compact to dense, and in part crushed or fractured dolomite. Oolites are present, and in zone 2 they constitute most of the rock material. No animal fossils were found in the 6 ft. of this lower division of the calcareous section but structures which are noted in the foregoing pages as probably fossil algae are present in zones 3, 4, 5, and 6. So far as the writer knows fossil algae have not been previously reported from any Silurian rock unit of Ohio and there are very few references to algae in Silurian or Devonian strata anywhere. Therefore these probable algae may have very little value for correlation purposes even when more thoroughly determined. The writer has long suspected that certain spheroidal and domal, laminated forms in the Bass Islands group might have had an algal origin but has found no conclusive evidence for this interpretation. One such rudely spherical, laminated form from the Greenfield dolomite of the Bass Islands was studied by John W. Wells with a negative conclusion as to having an algal origin (Wells, 1942).

The lithology of this lower unit accords well with that of the upper Bass Islands dolomite and especially with that of the Raisin River formation, the highest unit of the Bass Islands, and of the Silurian system in Ohio. The Raisin River is also suggested by the presence of oolitic dolomite so notably developed in zone 2 of the foregoing section and present also in zones 1, 3, and 6. Oolites are very characteristic of the Raisin River dolomite of Monroe County of southeastern Michigan, the type locality for this member (Grabau and Sherzer, 1910), and they have been seen at a few places in the Raisin River member in Lucas County, Ohio. There are many references in the literature noting the association of oolites and fossil algae in the same formation. Probably both require or are favored by a high percentage of calcium carbonate in the sea water whether they have an organic or a physico-chemical origin.

The Raisin River member has not been positively identified in central Ohio by its type fossils as known in southeastern Michigan and northwestern Ohio. However, the strata directly underlying the Columbus limestone in western Delaware and Franklin counties are certainly Upper Bass Islands (Put-in-Bay or Raisin River) and there, as in this Chillicothe test-core, the lithology indicated Raisin River rather than Put-in-Bay. In neither case does the lithology suggest the Greenfield or the Tymochtee, the two lowest members of the Bass Islands group.

On the bases of 1. stratigraphic position directly below the Columbus limestone; 2. the presence in the detrital zone 6 of the distinctive quartz sand that characterizes the Siluro-Devonian contact widely over Ohio; 3. the similarity of lithology; 4. the presence of oolitic dolomite; we assign zones 1 to 6 of the foregoing section to the Raisin River dolomite here penetrated only 6 ft.

The revision here presented does not effect the areal distribution of the rock formations concerned. There is therefore no change on the areal geologic map. It does however make somewhat more exact our knowledge of the actual distribution of certain formations under cover. Along a north to south course thru central Ohio the Upper Devonian shale (Olentangy and Ohio) overlaps the Prout and Plum Creek units south of Erie County so that in central Ohio the Olentangy rests on the Delaware limestone. Continuing southward it overlaps successively the Delaware and the Columbus and south of Pickaway County, rests on the Bass Islands or the Niagaran. The presence of 6 ft. of Columbus limestone in the test-core indicated that the north-south course of the west edge of the Devonian limestone under cover probably passes just west of Chillicothe.

South of Fayette County the Upper Bass Islands unit is not represented on the outcrop and the Lower Bass Islands unit has only a patchy distribution thence southward to beyond the Ohio River. On this basis it has been natural to assume that probably the Upper Bass Islands unit was never deposited in southern Ohio. The presence of strata here interpreted as Raisin River dolomite, the highest unit of the Bass Islands group, in the base of the test-core section, 18 mi. east of where the Greenfield passes beneath the upper Devonian shale, suggests that the complete section of the Bass Islands is present under cover to the east and southeast under southeastern Ohio.

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SMALL FORAMINIFERA OF THE POTTSVILLE FORMATION IN OHIO

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The Pottsville is the oldest formation of the Pennsylvanian system in Ohio. It contains four marine limestone members which may logically be expected to contain foraminifera. In ascending order these are; the Lowellville or Poverty Run, the Boggs, the Lower Mercer and the Upper Mercer limestones. Although these are spoken of as limestones, their lithologies vary from place to place. Flint, limestone, shale and iron ore may be present, either singly, or in any combination,—or the marine member of the cyclothem may be wanting altogether, due to local erosion or to nondeposition.

Each of the four limestone members was sampled at a number of points along the outcrop belt across the state. Foraminifera were found in 32 samples, in the Poverty Run, Lower Mercer and Upper Mercer limestones. As yet, I have found no microfossils in the Boggs member, which may be because they have not been preserved, or may only be the result of unlucky sampling. Foraminifera occur in all of the lithologies which may be encountered in these marine zones, but seem to be most abundant in the calcareous shales. This greater abundance may be more apparent than real;—the small fossils are more easily recovered from shales than from the harder rocks. There are localities in Scioto and Jackson counties where the Lower Mercer could be described as a "foraminiferal limestone", the hard limestone being composed very largely of the tests of the genus *Ozawainella*.

A fauna of 17 species, grouped under six families of the smaller foraminifera, has been identified. All of these forms are assigned to previously described species. The Poverty Run contained nine species, one of which, *Glomospira* cf. *G. simplex* Harlton, was found only in this member. The Lower Mercer contained 16 species, seven of which were limited to it, so far as this study is concerned. Of the five species in the Upper Mercer, no form was found that was not also present in the Lower Mercer.

A number of workers have studied the Pennsylvanian foraminifera of Texas and the Mid-Continent areas. Like the larger fossils of the Pennsylvanian, the foraminifera seem to have changed slowly and had wide geographic distribution. All of the species found in Ohio have been found, also, in the Southwest. Ten are common to both the Ohio Pottsville and to the Pennsylvanian strata of several epochs in Texas. Ten species reported from a lower Des Moinesian limestone in Indiana are found in the Pottsville in Ohio. Fourteen species found in Ohio have also been reported from Pennyslvanian rocks in Oklahoma.

The present study, then, gives further evidence that Pennsylvanian small foraminifera are long-ranging in both time and space, and in the present state of our knowledge cannot be used for close correlation of strata.

COLLECTING LOCALITIES

1. Mahoning County, Grindstone Run.
2. Mahoning County, Berlin Township, Little Mill Creek at Route 224.
3. Holmes County, Richland Township, Section 13, N.E. Quarter, at junction of road and lane which comes in from east.
4. Holmes-Coshocton County Line Road between Section 23, Richland Twp. Holmes County and Section 3, Tiverton Twp. Coshocton County.
5. Muskingum County, Falls Township, gully two miles northwest of Dillon.
6. Muskingum County, Hopewell Township, Poverty Run.

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7. Muskingum County, Hopewell Township, Section 18, N.W. Quarter, at turn in the road.
8. Perry-Muskingum County Line, Limestone Hollow.
9. Perry County, Somerset Railroad cut.
10. Perry County, Reading Township, Section 22, two miles south of Somerset.
11. Hocking County, Falls Gore Township, Hocking Valley Brick Company clay pit.
12. Vinton County, Elk Township, Section 32, N.E. Quarter.
13. Jackson County, Coal Township, Section 10, Old Grace Mine.
14. Scioto County, Vernon Township, Section 24, S.W. Quarter, along the abandoned road south of Lyra.

TABLE 1

Distribution of Species

	Localities													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Hyperammina bulbosa Cushman and Waters												×	....	×
Spirillina concavaconvexa Galloway and Rynicker	×	....	×	×	....	×	×	×	.....					
Ammovertella inversa (Shellwien)			×	.....		×	.....		×	.....		×	.....	
Ammovertella cf. *A. latimerensis* Galloway and Harlton			×	.....		×	.....		×	.....		×	×	....
Ammodiscus semiconstrictus var. *regularis* Waters					×	×	....	×	.....			×	×	....
Clomospira cf. *G. simplex* Harlton						×	.....							
Tolypammina confusa (Galloway and Harlton)												×	.....	
Endothyra excentralis Cooper	×	.....				×	.....		×	×	.....			
Endothyra ovata Waters	×	.....						×	.....			×	.....	
Endothyra rothrocki Harlton								×	×	.....				
Endothyranella minuta Waters	×	.....					×	×	×	....	×	×	.....	
Endothyranella sobrina (Plummer)	×	×	.....			×	×	×	.....			×	.....	
Tetrataxis concava Galloway and Rynicker						×	.....		×	....	×	....	×	....
Tetratasis lata Spandel	×	.....				×	.....		×	....	×	.....		
Reophax asper Cushman and Waters												×	.....	
Ozawainella ciscoensis (Harlton)			×	....	×	×	.....					×	×	....
Ozawainella radiata (Brady)						×	.....					×	×	....

SYSTEMATIC PALEONTOLOGY

Order FORAMINIFERA d'Orbigny, 1826
Family ASTRORHIZIDAE Brady, 1881
Subfamily HYPERAMMININAE Cushman, 1910
Genus HYPERAMMINA Brady, 1878

Hyperammina bulbosa Cushman and Waters
Figures 1–3

Hyperammina bulbosa Cushman and Waters, 1927, Cont. Cushman Lab. Foram. Res., vol. 3, pt. 2, No. 4, p. 109, pl. 22, Fig. 7.

Test free, elongate, consisting of a swollen proloculum and a long, straight second chamber with a number of slight, but noticeable, constrictions at regular intervals. The tube, however, is not divided into chambers. Aperture the open end of the tube. Shell wall very finely arenaceous with a large proportion of cement.

Average diameter of the tube approximately 0.10 mm. The length is difficult to determine because all of the specimens are broken, the pieces averaging between 0.50 mm. and 1.0 mm.

Lower Mercer limestone, Localities 12 and 14. Very abundant.

Family SPIRILLINIDAE Reuss, 1861
Subfamily SPIRILLININAE Brady, 1884
Genus SPIRILLINA Ehrenberg, 1843

Spirillina concavaconvexa Galloway and Rynicker
Figures 4–6

Spirillina concavaconvexa Galloway and Rynicker, 1930, Oklahoma Geol. Survey Circ. 21, p. 7, pl. 1, Figs. 2 a–c.

Test apparently free, minute, a single tube coiled planispirally; one side of the coil convex, the other slightly concave; coil covered with a white calcite deposit which is ornamented on the convex side by fine, radial grooves; coils slightly embracing; aperture crescentic.

Diameter of coil, 0.13 mm.; thickness of last whorl, 0.04 mm.

Poverty Run limestone, Locality 6. Rare. Lower Mercer limestone, Localities 1, 4, 6, 7 and 8. Very abundant. Upper Mercer limestone, Locality 3. Common.

Genus AMMOVERTELLA Cushman, 1928

Ammovertella inversa (Schellwien)
Figures 7–8

Test attached by the whole of one side; a long tube, closely coiling at first, then wandering off irregularly, enlarging very gradually. Schellwien describes the wall as siliceous. Galloway and Rynicker consider it to be calcareous. Some of our specimens show the characteristic noted by the latter authors of the shell substance appearing to spread out on the substratum beyond the wall proper. Surface smooth. Aperture terminal, semicircular.

Diameter of tube approximately 0.1 mm.

Poverty Run limestone, Locality 6. Very abundant. Lower Mercer limestone, Localities 6, 9 and 12. Very abundant. Upper Mercer limestone, Locality 3. Very abundant.

Remarks. There is some disagreement as to the nature and relationship of this form. Cushman, (Cont. Cushman Lab. Foram. Res. vol. 4, pt. 2, pp. 45–49) recognized several species having the same general characteristics but differing chiefly in the pattern of coiling. Galloway (Oklahoma Geol. Surv. Circular 21, p. 10) on the other hand, states that "*Ammovertella* is probably not a foraminifer at all, but a worm. The pattern made by the coiling . . . is probably a distinction not valid for species and surely not for genera."

The opinion of Helen Jean Plummer (University of Texas Bull. 3019, pt. 2, p. 44) was, "That these are true Foraminifera is shown, not only by the structure of the test in thin sections, but also by the occurrence of both microspheric and megalospheric forms .....To place all of these forms together is to overlook much of the data that should be used in the study of these primitive, but very useful foraminifera."

Warthin (Oklahoma Geol. Survey Bull. 53, p. 13) would lump all of the following under the name *Ammoverteila inversa* (Schellwien); *Psammophis inversus* Schellwien, *P. inclusus* Cushman and Waters, *Ammovertella inversus* Cushman, *Calcitornella elongata* Cushman and Waters. *C. heathi* Cushman and Waters, *Calcivertella adherens* Cushman and Waters, *Ammovertella undulata* Galloway and Harlton, *A. latimerensis* Galloway and Harlton, and *A. adherens* Galloway and Rynicker. Warthin says, "this species is here interpreted to include all the irregularly coiled, embracing, attached forms with probably hyaline walls, found in this part of the column. The shape of each individual is determined chiefly by the proportions of the object to which it adheres. There is so much variation that, if so inclined, one could make a new species for almost every specimen."

The present writer concurs with this opinion.

Ammovertella sp. cf. **A. Latimerensis** Galloway and Harlton
Figure 9

Ammovertella latimerensis Galloway and Harlton, 1928, Journ. Paleontology vol. 2, p. 342, pl. 45, figs. 3, 4.

If members of this genus are to be assigned specific names on the basis of the manner of their coiling, then certain of our specimens resemble **A. latimerensis** since, after forming a planispiral coil, the tube is bent back and forth sharply upon itself.

Lower Mercer limestone, Localities 6, 9, 12 and 13. Upper Mercer limestone, Locality 3. Very abundant.

Family AMMODISCIDAE Rhumbler, 1895
Genus AMMODISCUS Reuss, 1861
Ammodiscus semiconstrictus var. **regularis** Waters
Figures 10–11

Ammodiscus semiconstrictus var. *regularis* Waters, 1928, Journ. Paleontology vol. 1, p. 132, pl. 22, fig. 2.

Test consisting of a proloculum and a long, undivided second chamber coiled in a nearly planispiral disc; aperture the open end of the tube; wall arenaceous.

Diameter of the test of the figured specimen, 0.27 mm.

Poverty Run limestone, Localities 5 and 6. Very abundant. Lower Mercer limestone, Localities 8, 12 and 13. Very abundant.

EXPLANATION OF FIGURES IN PLATE I

FIGURES 1–3. *Hyperammina bulbosa* Cushman and Waters
1, 2. Initial end, showing typically enlarged proloculum.
3. Fragment of tube, broken at both ends.
O. S. U. M. 19907, Lower Mercer Limestone, Loc. 12.

FIGURES 4–6. *Spirillina concavaconvexa* Galloway and Rynicker
4. Lateral view, showing radial markings.
5. Opposite, or concave side.
6. Apertural view.
O. S. U. M. 19908, Shale over Lower Mercer Limestone, Loc. 9.

FIGURES 7–8. *Ammovertella inversa* (Schellwien)
7. Partially exfoliated specimen in matrix.
8. Another specimen, showing initial coil and variation in later coiling.
O. S. U. M. 19909, Upper Mercer limestone, Loc. 3.

FIGURE 9. *Ammovertella* cf. *A. latimerensis* Galloway and Harlton. Showing tube coiled back sharply upon itself.
O. S. U. M. 19911, Shale under Lower Mercer Limestone, Loc. 8.

FIGURES 10–11. *Ammodiscus semiconstrictus* var. *regularis* Waters. Lateral and apertural views.
O. S. U. M. 19912, Shale under Lower Mercer Limestone, Loc. 12.

FIGURE 12. *Glomospira* cf. *G. simplex* Harlton.
O. S. U. M. 19913, Poverty Run limestone, Loc. 6.

FIGURES 13–14. *Tolypammina confusa* (Galloway and Harlton)
Opposite views of the same individual adhering to a brachiopod spine.
O. S. U. M. 19914, Lower Mercer limestone, Loc. 4.

FIGURES 15–18. *Endothyra excentralis* Cooper
15, 16. Lateral and apertural views of an individual in which the right side is involute and the left, umbilicate.
O. S. U. M. 19915, Shale under Lower Mercer limestone, Loc. 8. 17, 18. Apertural and lateral views of an individual in which the left side is involute and the right, umbilicate.
O. S. U. M. 19916, Lower Mercer limestone, Loc. 1.

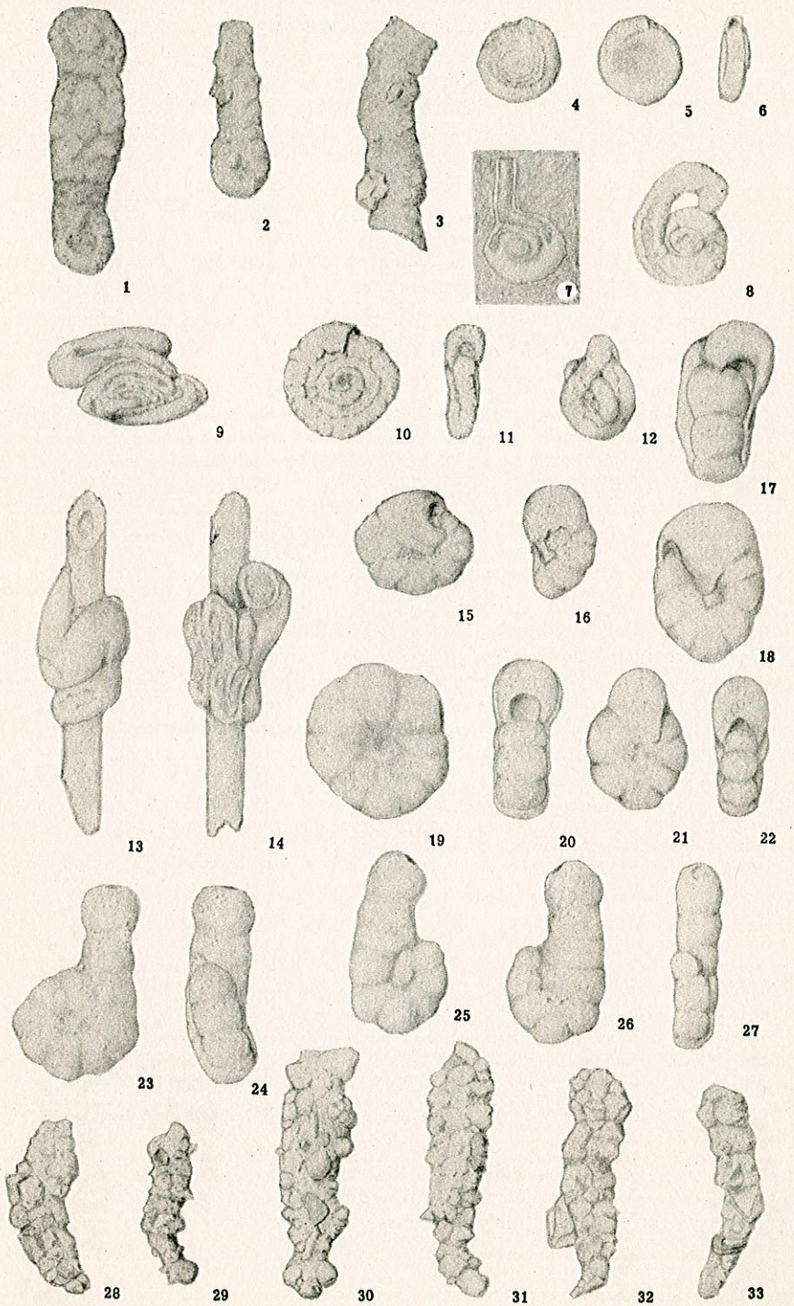
FIGURES 21–22. *Endothyra ovata* Waters
Lateral and apertural views showing rapid increase in size of chambers, and symmetry of coil.
O. S. U. M. 19917, Lower Mercer limestone, Loc. 12.

FIGURES 19–20. *Endothyra rothrocki* Harlton
Lateral and apertural views showing gradual increase in size of chambers, and symmetry of coil.
O. S. U. M. 19918, Shale under Lower Mercer limestone, Loc. 9.

FIGURES 23–24. *Endothyranella sobrina* (Plummer)
Lateral and peripheral views of a typical individual.
O. S. U. M. 19919, Shale over Lower Mercer limestone, Loc. 12.

FIGURES 25–27. *Endothyranella minuta* (Waters)
25. Lateral view showing about two whorls.
26. Opposite side, showing one whorl.
27. Peripheral view.
O. S. U. M. 19920, Shale over Lower Mercer limestone, Loc. 12.

FIGURES 28–33. *Reophax asper* Cushman and Waters
Showing variation in size and materials of test.
O. S. U. M. 19921, Lower Mercer limestone, Loc. 12.



Genus GLOMOSPIRA Rzehak, 1888

Glomospira cf. **G. simplex** Harlton
Figure 12

Glomospira simplex, Harlton, 1928, Journ. Paleontology vol. 1, p. 305, pl. 52, figs. 2 a–c.

Test free, nearly spherical, consisting of a proloculum and a long, tubular second chamber, irregularly coiled and wound around itself; wall arenaceous, nearly smooth, with much cement.

Diameter of test 0.18 mm.; diameter of tube, 0.05 mm.

Poverty Run limestone, Locality 6. Rare.

Genus TOLYPAMMINA Rhumbler, 1895

Tolypammina confusa (Galloway and Harlton)
Figures 13–14

Ammovertella? confusa Galloway and Harlton, 1928, Journ. Paleontology vol. 2, p. 344, pl. 44, fig. 5.
Tolypammina confusa Galloway and Rynicker, 1930, Oklahoma Geol. Survey Circ. 21, p. 11, pl. 1, fig. 14.

A long tube, coiled in an irregular, confused mass, attached usually to brachiopod spines; wall very finely arenaceous; surface nearly smooth. All of our specimens are broken and neither the proloculum nor the aperture is shown.

Diameter of tube, 0.1 mm. or slightly less.

Lower Mercer limestone, Locality 12. Rare to common.

Family ENDOTHYRIDAE Rhumbler, 1895
Subfamily ENDOTHYRINAE Brady, 1884
Genus ENDOTHYRA Phillips, 1846
Endothyra excentralis Cooper
Figures 15–18

Endothyra excentralis Cooper, 1947, Jour. Paleontology vol. 21, p. 88, pl. 20, figs. 19–23.

Test small, free, an asymmetrical, nautiloid coil, about eight chambers in the last volution; chambers inflated, especially the last; one side involute, the other umbilicate; aperture crescentic extending from the center of the margin down the umbilicate side.

Diameter, average, 0.32 mm.

Remarks.—Our specimens average smaller than the type, whose diameter is given as 0.48 mm. In describing the species, Cooper speaks only of forms having the right side involute and the left side umbilicate. Among our specimens there are also individuals which are the mirror image of these, the left side being involute and the right side umbilicate.

Poverty Run limestone, Locality 6. Rare. Lower Mercer limestone, Localities 1, 9 and 10. Rare.

Endothyra ovata Waters
Figures 21–22

Endothyra ovata Waters, 1928, Journ. Paleontology vol. 1, p. 274, pl.42, fig. 6.

Test free, almost planispiral, partially involute, chambers rounded, increasing rapidly in size, about seven or eight in final whorl; aperture arched, at the base of the septal face.

Diameter of figured specimen, 0.33 mm.

Lower Mercer limestone, Localities 1, 8 and 12. Very abundant.

Endothyra rothrocki Harlton
Figures 19–20

Endothyra rothrocki Harlton, 1928, Journ. Paleontology vol. 1, p. 306, pl. 52, fig. 3.

Test free, planispiral, nearly bilaterally symmetrical, umbilicate; margin rounded, lobate; nine chambers in final whorl, increasing very gradually in size; aperture a low crescent at the base of the septal face.

Diameter, 0.35 mm.

Lower Mercer limestone, Localities 8 and 9. Rare.

Genus ENDOTHYRANELLA Galloway and Harlton, 1930

Endothyranella sobrina (Plummer)
Figures 23–24

Endothyranella armstrongi subsp. *sobrina* Plummer, 1944, Texas Univ. Bull. 4401, p. 242, pl. 16, figs. 12–17.

Early portion of test coiled like *Endothyra*, later portion a series of chambers set in a row, tangent to the coil; chambers inflated, increasing in size very gradually; about nine chambers in the last whorl of the coil, three to seven rectilinear chambers; early portion of the coil somewhat obscured by secondary calcite deposits.

Average diameter of coil, 0.27 mm., average length, 0.49 mm.

Poverty Run limestone, Locality 6; Lower Mercer limestone, Localities 1, 2, 6, 7, 8 and 12; Upper Mercer limestone, Locality 3. Very abundant.

Endothyranella minuta (Waters)
Figures 25–27

Endothyranella minuta Galloway and Rynicker, 1930, Oklahoma Geol. Survey Circ. 21, p. 14, pl. 2, figs. 5 a–c, 6 a–c.

Test small, early portion coiled, later portion a series of three or four rectilinear chambers. The plane of coiling diverges from the plane of the rectilinear portion so that two whorls are visible on one side but only one on the other Aperture round, terminal

Diameter of coil, 0.25 mm ; total length, 0.46 mm

Lower Mercer limestone, Localities 1, 7, 8, 9, 11 and 12 Very abundant.

Subfamily TETRATAXINAE Galloway, 1933
Genus TETRATAXIS Ehrenberg, 1843
Tetrataxis concava Galloway and Rynicker
Figures 34–36

Tetrataxis concava Galloway and Rynicker, 1930, Oklahoma Geol. Survey Circ. 21, p. 18, pl. 3, figs. 6 a–c.

Test apparently free, trochoid, conical; many long, narrow, arcuate chambers, four chambers in final whorl; whorls about eight in number; curve of dorsal side concave from apex to margin; ventral side concave with wide vestibule into which the aperture opens under a protecting flap.

Diameter, 0.7 mm. This is slightly smaller than the type.

Poverty Run limestone, Locality 6. Very abundant. Lower Mercer limestone, Localities 9, 11 and 13. Abundant.

Tetrataxis lata Spandel
Figures 37–39

Tetrataxis conica var. *lata* Spandel, 1901, Festschrift Naturhist. Gesell. Nuremberg, p. 186, figs. 6 a, b.
Tetrataxis lata Galloway and Rynicker, 1930, Oklahoma Geol. Survey Circ. 21, p. 17, pl. 3, figs. 3 a–c.

Test free, round, conical; ventral surface very slightly concave, slope of dorsal surface nearly straight from apex to margin; four to six whorls; five chambers in the last whorl each with a small, valvular projection extending into the vestibule.

Diameter, 0.59 mm.

Poverty Run limestone, Locality 6. Rare. Lower Mercer limestone, Localities 1, 9, and 11. Very abundant.

Family REOPHACIDAE Cushman 1917
Genus REOPHAX Montfort, 1808
Reophax asper Cushman and Waters
Figures 28–33

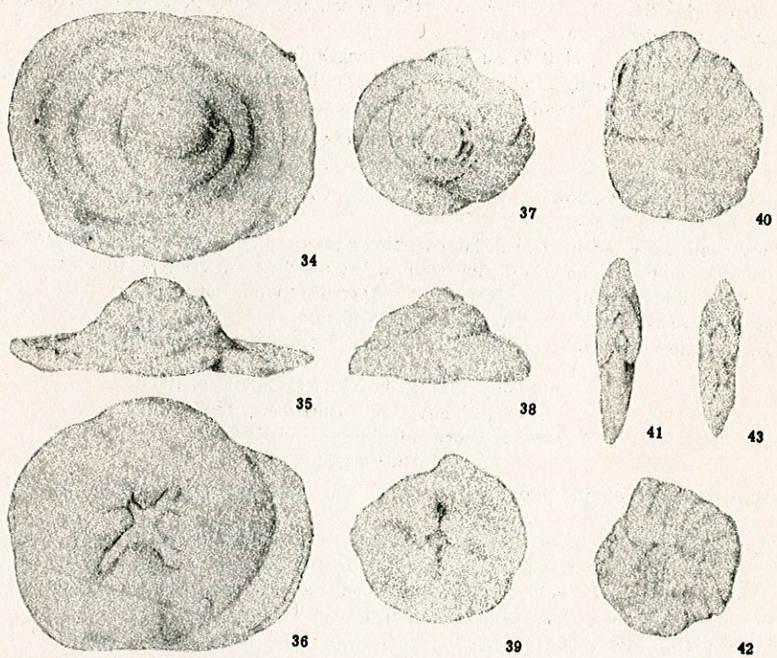
Reophax asperus Cushman and Waters, 1928, Cont. Cushman Lab. Foram. Res. vol. 4, p. 37, pl. 4, fig. 7.

Reophax asper Cushman and Waters, 1930, Univ. Texas Bull. 3019, p. 37, pl. 2, fig. 10.
Reophax asper, Plummer, 1945, Univ. Texas Bull. 4401, p. 226, pl. 17, fig. 23.

Test elongate, very gradually expanding, round in cross section; chambers set in a slightly curved row, sutures obscure; wall arenaceous, very rough, with coarse, angular sand grains and mica flakes; aperture small, terminal.

Average length, 0.51 mm.

Lower Mercer limestone, Locality 12. Common.



FIGURES 34–36. *Tetrataxis concava* Galloway and Rynicker
Dorsal, lateral and ventral views.
O. S. U. M. 19922, Poverty Run limestone, Loc. 6.

FIGURES 37–39. *Tetrataxis lata* Spandel
Dorsal, lateral and ventral views.
O. S. U. M. 19923, Lower Mercer limestone, Loc. 11.

FIGURES 40–41. *Ozawainella radiata* (Brady)
Lateral and apertural views.
O. S. U. M. 19925, Shale under Poverty Run limestone, Loc. 6.

FIGURES 42–43. *Ozawainella ciscoensis* (Harlton)
Lateral and apertural views.
O. S. U. M. 19924, Lower Mercer limestone, Loc. 12.

All figures X60 except Figs. 4, 5 and 6 which are X120.
All figured specimens are deposited in the Geological Museum of the Ohio State University.

Family FUSULINIDAE Möller, 1878
Subfamily OZAWAINELLINAE Thompson and Foster, 1937
Genus OZAWAINELLA Thompson, 1935

Ozawainella ciscoensis (Harlton)
Figures 42–43

Staffella ciscoensis Harlton, 1928, Journ. Paleontology vol. 1, p. 307, pl. 52, figs. 9 a–c.
Orobias ciscoensis Galloway and Harlton, 1928, Journ. Paleontology vol. 2, p. 350, pl. 45, figs. 11 a–c.

Orobias ciscoensis Galloway and Rynicker, 1930, Oklahoma Geol. Survey Circ. 21, p. 15, pl. 2, figs. 9 a, b.
Oribias ciscoensis Warthin, 1930, Oklahoma Geol. Survey Bull. 53, p. 22, pl. 2, fig. 1.

Test free, planispiral, involute, peripheral margin acute; chambers short, 20 to 25 in the last whorl; aperture a high narrow arch on the septal face.

Diameter, 0.34 mm., thickness 0.08 mm.

Poverty Run limestone, Localities 5 and 6. Very abundant. Lower Mercer limestone, Localities 12 and 13. Very abundant. Upper Mercer limestone, Locality 3. Very abundant.

Ozawainella radiata (Brady)
Figures 40–41

Involutina radiata Brady, 1869, Rep. Brit. Assoc. (Exeter) p. 379.
Endothyra radiata Brady, 1876, Pal. Soc. Mono. p. 97, pl. 5, figs. 10–12.
Orobias radiata Galloway and Harlton, 1928, Journ. Paleontology, vol. 2, p. 350, pl. 45, figs. 12 a–c.
Orobias radiata Galloway and Rynicker, 1930, Oklahoma Geol. Survey, Circ. 21, p. 14, pl. 2, figs. 8 a, b.

Similar to *O. ciscoensis* (Harlton) but with fewer chambers in the final whorl,—about 16. The test is also thinner in proportion to its diameter.

Diameter, 0.46 mm., thickness, 0.1 mm.

Poverty Run limestone, Locality 6, Very abundant. Lower Mercer limestone, Localities 12 and 13. Very abundant.

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AGE RELATIONS OF THE MIDDLE DEVONIAN LIMESTONES IN OHIO

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The long continued practice of correlating the Middle Devonian limestones on the east and west flanks of the Cincinnati arch in Ohio has been questioned by more recent workers. This doubt has arisen partly because of a better understanding of stratigraphic relationships with rocks of similar age in adjoining states, partly on a more detailed knowledge of the lithologic conditions, but mainly because of a better understanding of the fossils within the formations.

The "Columbus" limestone of northwestern Ohio west of the anticline is recognized now as a continuation southward of the Dundee limestone of the southern peninsula of Michigan, and the approximate age of the Delaware limestone east of the anticline in Ohio and southwestern Ontario. It is therefore younger than the Columbus limestone which lies below the Delaware limestone in these latter regions.

The purpose of this paper is to bring together data already known on these Devonian limestones in this State, and to add further information, particularly on the faunas, which might help to underwrite existing opinions on the subject.

OUTCROP AREAS

The Middle Devonian limestones of central and northcentral Ohio consist of two formations: the Columbus limestone below, and the Delaware limestone above. They crop out east of the Cincinnati anticline in a narrow, north-south belt, about 20 miles across at the greatest width which is in Wyandot and Crawford counties (fig. 1). The beds dip gently east to southeast, and are thickest in central Ohio, notably in Franklin and Delaware conuties, where the Columbus attains a thickness of 105 ft., and the Delaware about 40 ft. Southward from the city of Columbus in Franklin County, the outcrop extends for 25 mi. to the southern part of Pickaway County, where the beds become concealed by the overlapping upper Devonian Olentangy and Ohio shales.

Northward from central Ohio there is a continuous band of outcrop to the southern shore of Lake Erie, and detached exposures occur in the adjoining Johnson and Kellys Islands. North of the international boundary the furthest known northern outcrop up to 1951 was on Pelee Island, where Stauffer (1915, p. 206–213), reported about 28 ft. of Onondaga limestone in Captain Jack McCormick's quarry, at the northwest corner of the island. However, Ehlers and Stumm (1951) reported an exposure of the Columbus limestone in the Chemical Lime Company's quarry near Ingersoll, Ontario (fig. 1). This exposure consists of 15 ft. of gray to buff-gray dolomitic limestone with many fossils, and 1 ft., 2 in. of calcareous sandstone below with few fossils. The sandstone rests with disconformable contact on the Lucas formation of the Detroit River group. The contact of the limestone above with the overlying Delaware limestone is not seen in the quarry, but is believed to be a short distance southwest of the present quarry wall. On the basis of lithology and fossils Ehlers and Stumm interpret these rocks as the upper part of the Columbus formation (zone H), and that they rest disconformably on the underlying Lucas formation as a result of stratigraphic overlap from the south. The presence of the sandstone suggests a nearby shore since the outcrop is very close to the northern limit of the limestone.

A second area of outcrop in Ohio, of much smaller extent, occurs just a little east of the crest of the Cincinnati arch. This is the Bellefontaine outlier, about 40

mi. northwest of Columbus (fig. 1). The outlier is an elliptical elevated area, of about 160 sq. mi., which extends from the northern part of Logan County south to the village of Cable in Champaign County, a distance of about 23 mi. It is rimmed by the Columbus limestone, which is overlain unconformably by the black Ohio shale. The uneven character of the unconformity is well shown in the quarry of the East Liberty Stone Company, one mile west of the town of East Liberty,

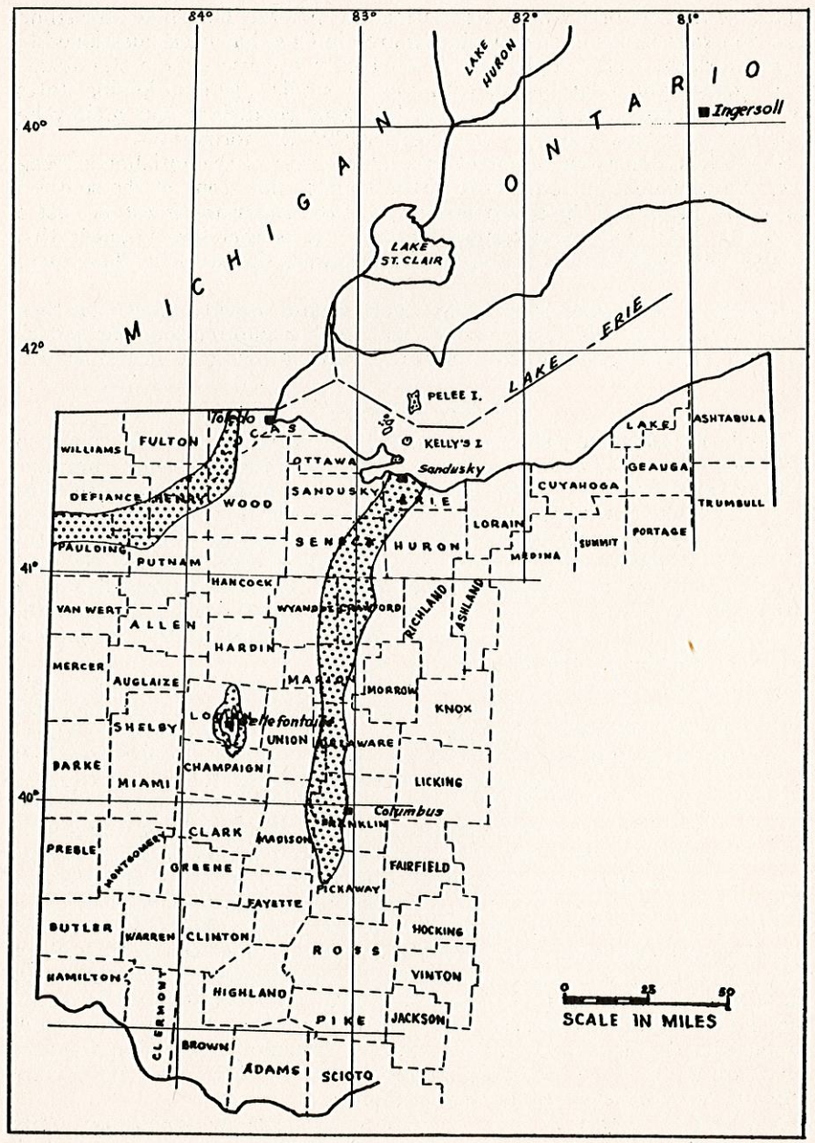

FIGURE 1. Index map showing outcropping areas of Devonian limestone in Ohio.

where about 39 ft. of Columbus limestone is exposed. A thin, well-developed bone bed accumulation fills in much of the irregular surface of the limestone. The total thickness of the limestone is approximately 80 ft. The Delaware limestone and Olentangy shale are apparently missing from the section.

A third region of Devonian limestone is in the northwestern part of the state, west of the Cincinnati arch. A crescent-shaped belt of outcrop extends southward from Michigan into Lucas and Henry counties, and thence swings westward in the vicinity of Antwerp, Paulding County, into Indiana (fig. 1). Because of the flat character of this interior lowland area, and the general covering of glacial drift, the outcrops are very scarce, and the geology has to be interpreted largely from quarry sections. These are best known from Lucas County (fig. 2).

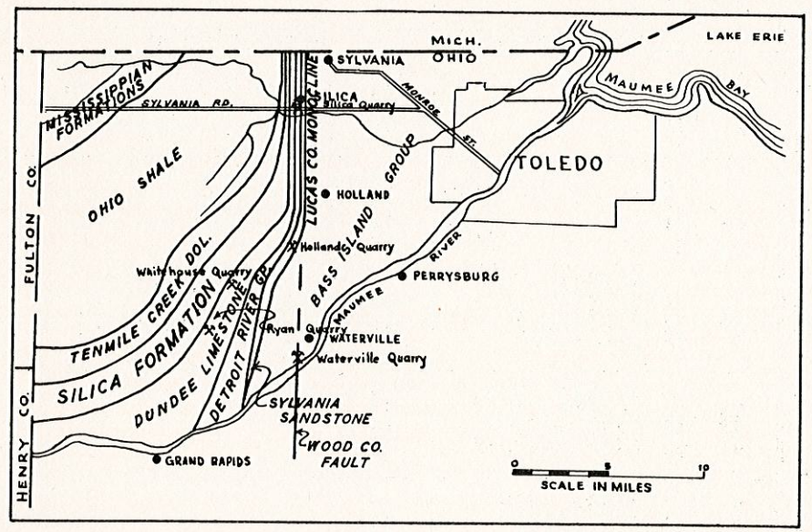

FIGURE 2. Map of Lucas County showing areal extent of several rock units.

Three Middle Devonian formations are recognized in this northwestern area: The Dundee ("Columbus")limestone below, overlain by the Silica formation and Tenmile Creek dolomite above. Originally Stauffer (1909, p. 149) introduced the Michigan term Traverse into the Ohio section for the rocks of northwestern Ohio lying between the top of his "Columbus" limestone and the Ohio shale. The "Columbus"—Traverse contact of Stauffer was at the base of zone 8 of the Whitehouse quarry section of figure 3. But the top of the Dundee, as now used, is at the top of zone 10 of the Whitehouse quarry section. That is zones 8, 9, and 10 at Whitehouse, totaling 4½ ft. are moved from the base of the Traverse of Stauffer to the top of the Dundee ("Columbus"). Figure 3 shows that the equivalent units at Silica, zones 4, 5, and 6, total 11 ft.

REVIEW OF TERMINOLOGY

First mention of the Ohio limestones goes back to the reports of the earliest Geological Survey in Ohio (table 1). In these early surveys the Devonian limestones were not differentiated from the older Silurian formations below, and the Cliff formation of Locke (1838), included the Silurian beds also. It was Hall (1842) who recognized the upper part of the Cliff limestone as a continuation of

TABLE 1

Historical Review: Classification of Middle Devonian Limestones of Central and Northcentral Ohio

Locke 1838	Hall 1843	Mather 1859	Newberry 1873	Winchell 1874	Orton 1878	Whitfield 1880	Prosser 1905	Swartz 1907	Stauffer 1909	Westgate 1926 Delaware Co.		Cooper, et al. 1942	Wells 1947	Zones of Stauffer (1909) Modified by Wells (1947)
Cliff limestone (included Silurian limestone.)	*Corniferous limestone* (first named and identified with the New York Corniferous by Hall. Included present Columbus and Delaware limestones.)	*Columbus limestone* (used Columbus to replace Corniferous in "Report on State House Artesian Well at Columbus.")	*Sandusky limestone* (Included upper part of Columbus limestone of Mather.)	*"Delaware limestone"* (Did not suggest formational value —recognized Hamilton age of fossils.)	*Delaware limestone* (Suggested name to replace Sandusky Ls. of Newberry in Central Ohio.)	*Delaware limestone* (Confirmed Hamilton age as suggested by Winchell by discovery of Marcellus fossils in lowerpart.)	*Delaware limestone* (Further consolidates position of Delaware, and shows that most of Newberry's Sandusky Ls. in N. Ohio is Columbus Ls.)	*Delaware limestone* (Was first to prove term Sandusky Ls. invalid in personal communication with Prosser.)	*Delaware limestone* Zones I - M (Recognized 5 zones in central Ohio.)	*Delaware limestone*	L.Erian (Cazenovia)	*Delaware limestone* "*Hadrophyllum Zone*"	*Delaware formation* Zones I—M of Stauffer.	*Delaware formation* M—Includes 2 minor Bone beds L—Zone of *Hadrophyllum d'Orbigni* (3rd Bone bed) K—Zone of *Grammysia bisulcata* J—Zone of *Tentaculites scalariformis* I—Zone of *Martiniopsis maia*
			Columbus limestone (First to separate the limestones, and the lower greater part was retained as Columbus.)	**Corniferous limestone*	*Bone Bed* *Columbus limestone* (Thought limestones probably covered same age as Corniferous and Hamilton of New York but didn't definitely correlate them. Recognized and described for first time Bone Bed top of Columbus.)	*Columbus limestone*	*Columbus limestone*	*Columbus limestone* Venice member Marblehead member Bellepoint member (Correlated north central and central Ohio sections; recognized 3 members of Columbus Ls.	*Columbus limestone* Zones A–H (Recognized 8 zones in central Ohio.)	*Columbus limestone* Klondike member Heavy Ls. Coral layer Bellepoint member (Term Klondike used to replace Delhi of Winchell = U. Zone E through H of Stauffer. Zone C = Coral Zone A–B = Bellepoint)	U. Ulsterian (Onesquethaw)	*Columbus limestone?*	*Columbus formation* Delhi member (Klondike) = Zones E—H of Stauffer Eversole member (Zone D) Bellepoint member (Zones A - C) Zone D (Chert Zone) named Eversole and given member rank.	*Columbus formation* H—Zone of *Nucleocrinus verneuili* (Includes 1st and 2nd Bone beds) G—Zone of *Coldringia cyclops* (cephalopod zone) F—Zone of *Brevispirifer gregarius* E—Zone of "*Spirifer*" *macrothyris* D—Zone of *Laevidentalium martini* (gastropod and chert zone) C—Coral zone B—Few fossils A—Conglomerate zone

*In 1903 the name Onondaga was adopted to replace *Corniferous* in New York State. Clarke, N. Y. State Museum, Handbook No. 19, pp. 8, 21, 22.

the Helderberg group of New York State, and in the following year named it the Corniferous limestone from exposures in the vicinity of Columbus.

The name Columbus limestone was used first by Mather (1859) in a communication to the State. The term was used to replace Corniferous limestone without any explanation.

Further study on the limestones was continued during the work of the second Geological Survey of Ohio under the direction of Dr. J. S. Newberry, Chief Geologist. The distribution of the limestones was shown on the "Preliminary Geological map of Ohio" by Newberry in 1869 and a short discussion of their occurrence, lithology, and fossils was given (p. 17, 18). Newberry used the term "Corniferous," thereby accepting Hall's identification. However, a more detailed report is given in the first volume of the Geological Survey of Ohio (Newberry, 1873, p. 142–149), where Newberry recognized two divisions: an upper one, which he named the Sandusky limestone, and mentioned as being quarried at Sandusky and Delaware, and which he described as a thin-bedded, blue limestone, from 15 to 20 ft. in thickness; and a lower one, the Columbus limestone, which he said supplied the stone from which the State Capitol in Columbus is built. Newberry noted the occurrence of characteristic Hamilton fossils in the Sandusky limestone such as *Mucrospirifer mucronatus* (Conrad), and *Cyrtina hamiltonensis* (Hall), but concluded that since the larger number were Corniferous in age both limestones should be correlated with the Corniferous of New York.

He listed and illustrated some characteristic species from the Corniferous limestone in the following order: *Platyceras* (*Platyceras*) *dumosum* Conrad, *Pentamerus aratus* Conrad, *Spirifer raricosta* Conrad, *Lucina? proavia* Goldfuss, *Paraspirifer acuminatus* (Conrad), *Nucleocrinus verneuili* Troost, *Megastrophia hemispherica* (Hall), *Brevispirifer gregarius* (Hall), and *Conocardium trigonale* Conrad.

The foregoing are all Columbus limestone species, apart from *Spirifer raricosta* which is found in the Delaware limestone. Newberry pointed out that the most striking fossils of the Corniferous group are fishes, and he discussed, but did not illustrate them.

The Corniferous age of the Devonian limestone in northwestern Ohio was also recognized by Newberry, and likewise the limestones in the Bellefontaine outlier where he speaks of them as forming "part of the Devonian island in Logan County." (p. 143).

The term Delaware was first used for the upper part of the Corniferous in Ohio by Winchell (1874, p. 293, 294) in which he refers to the "Delaware stone", in one place, and the "Delaware limestone" in another, apparently not thinking of the rocks in the light of a formation. He described the geology of several counties in central and northwestern Ohio and stressed the Hamilton aspect of the fossils in this upper limestone in both these places. He used the name "Hamilton group" in the legend of the geologic maps of Delaware, Paulding, and Henry counties (facing p. 272, 336, and 416).

Winchell (1875, p. 59) correlated the Devonian outcrops in Sandusky, Delaware, Marion, and Sec. 17, Defiance, Defiance County, Ohio, with the Hamilton blue limestone in the region about Thunder Bay, Lake Huron, and near Clarlevoix, in the northern part of the Lower Peninsula of Michigan. Newberry still objected to Hamilton age for the Sandusky limestone beds.

Orton (1878, p. 606), first used the term Delaware as a formational term for the upper 32 ft. of blue limestone exposed near the town of Delaware, to replace Newberry's older name of Sandusky limestone in central Ohio. He retained the name Columbus limestone for the lower part, and was the first to recognize and describe the 6-inch layer of bone bed material at the top of the Columbus. This, incidentally, is one of the best developed bone beds in the Columbus limestone in central Ohio, and is designated Bone Bed No. 2 in more recent literature. Where

well developed, this unit is most helpful in determining the boundary between the two formations. Orton thought the two limestones probably covered at least part of the time in which the Corniferous limestone and Hamilton group were forming.

The next significant development toward a closer correlation with the New York section was in 1878 when Professor R. P. Whitfield visited Franklin County, and recognized a thin bed of dark brown shale at the base of the Delaware limestone at Slate Run and further north along the Scioto River just across from the town of Dublin. At the first locality he found two small species of inarticulate brachiopods, *Discina minuta* Hall and *Lingula manni* Hall, and *Leiorhynchus limitare* (Vanuxem). At the second locality, *L. limitare* and *Orbiculoidea lodiense* (Vanuxem). These are typical Marcellus species, *D. minuta* and *L. limitaris* being restricted to it. Recently the writer has found *Leiorhynchus limitare* and a large species of *Lingula* about 20 ft. above the base of the formation at the now abandoned quarry of the Miami Stone Company about 3 mi. north of Bartholomew Run along the Olentangy River in Delaware County.

Whitfield's discovery seemed to confirm Winchell's earlier opinion of Hamilton age of the Delaware limestone, and he pronounced it the equivalent of the Marcellus shale of New York (Whitfield, 1880, p. 297, 298). Later Whitfield (1883) published a list of the fossils found in the shales, and described two new species. Descriptions of all the species (16) were published in the seventh report of the Geological Survey of Ohio (p. 441–452). Only one of these species, *Leptaena rhomboidalis* (Wilckens), occurs in the Columbus limestone below. The extremely abundant *Tentaculites scalariformis* Hall was not included in the list. Whitfield listed 6 species restricted to the limestone above the bone bed which included 4 Hamilton species: *Spirifer ziczac* Hall, *Cornellites flabella* (Conrad), *Nyassa arguata* H. and W., and *Grammysia bisulcata* (Conrad).

Prosser (1905, p. 413–422) outlined in chronological order the contributions made by various geologists on the Devonian limestone problem up to that time, and in some detail discussed the Delaware limestone. His main contribution was to establish the fact that most of Newberry's Sandusky limestone in northern Ohio, belonged in the lower instead of the upper division of what he called the "Corniferous limestone." Prosser gave due credit to Dr. Charles K. Swartz of Johns Hopkins University, whom he says in 1903 "correctly determined the stratigraphic position of the limestones in the city of Sandusky, and correlated them with the Columbus limestone of central Ohio." (Communication made to him by letter, p. 441). This was primarily on faunal grounds. Swartz reported about 87 percent of the species from the Columbus limestone in the Columbus vicinity as represented in the part of the Sandusky formation which he referred to as the Columbus in the Lake Erie region. Prosser concluded that the term Sandusky should be dropped since it involved two formations. In place of it he proposed the name Delaware to conform with the nomenclature of rocks of similar age further south in the state.

Two years later Swartz (1907) published a paper in which his views as already transmitted to Prosser were included. He presented evidence, mostly faunal, that the Sandusky and Delaware limestones were not equivalent, that the Sandusky limestone was partly Columbus and partly Delaware in age, and therefore could not be considered as an independent unit. He divided the Columbus limestone into 3 members on lithologic and faunal grounds, naming them from the regions where they were best exposed. The members from the oldest to the youngest are: Bellepoint, Marblehead, and Venice.

Probably the most comprehensive and detailed study of the Ohio Middle Devonian limestone was made by Stauffer (1909). Although this work deals primarily with the limestones, the Olentangy and Ohio shales are also included if they were present in the regions where his sections were made. Numerous

sections are included in the volume, some well known ones from earlier workers, and many new ones of his own. Descriptions of the lithology, stratigraphy, and paleontology are given in much more detail than in any previous publication. The formations are divided into zones on a paleontological and lithologic basis.

In the central area of outcrop, more particularly in Franklin County, alphabetical letters were used by Stauffer for the various zones where they could be correlated with a fair degree of accuracy. Eight zones, A-H, were established for the Columbus limestone, and 5 zones, I-M, for the Delaware limestone. Northward from the village of Stratford which is 3 mi. south of Delaware, the faunal zones could not be correlated so readily from section to section, so the zones were numbered, the numbers not being correlative necessarily from section to section. A similar system was used for the northwestern part of the State, and for the Bellefontaine outlier which is assumed to be a detached portion of the central area cut off by preglacial erosion. This work brings together for the first time names of all the known fossil species up to that time from the Columbus, Delaware, and Olentangy formations, and in addition a few new ones were added and described. Stauffer's work has been the principal source of information for all subsequent workers on the Devonian limestone formations in Ohio.

Westgate (1926, p. 22, 23), adopted a four-fold subdivision for the Columbus limestone based largely on physical characters, because he believed that unless one knew the fossils thoroughly Stauffer's zones could not be used. He named the upper division the Klondike member, replacing the term Delhi originally used by Winchell (1874, p. 296) for these beds. The Klondike member according to Westgate includes zones E (upper part), F, G, and H of Stauffer in Franklin County, and most of the Venice and Marblehead members of Swartz (1907). The lowest division was named the Bellepoint member after Swartz (p. 63) from the village of that name. It comprises zones A and B of Stauffer.

The two intermediate divisions were not named. The first division below the Klondike (6-foot zone), was designated the "heavy limestone layer," and correlated with the lower part of Stauffer's zone E. Below this was the "coral layer," which is zone C, or the coral zone, of both Franklin and Delaware counties. Westgate did not recognize the chert zone (D) in Delaware County north of White Sulphur. No zonal divisions for the Delaware formation were made.

Cooper (1942) questioned the stratigraphic position of upper Onesquethaw for the Columbus limestone, but accepted lower Cazenovian for the Delaware.

In a paper title "Provisional Palaoecological Analysis of the Devonian Rocks of the Columbus Region," Wells (1947) introduced the name Eversole member for Zone D (chert zone) of the Columbus limestone, and designated it "zone of *Laevidentalium martini*," in reference to this characteristic species of the zone. He reinstated the old name Delhi of Winchell for the upper division of the Columbus limestone, designated Klondike by Westgate, including in it zones E-H of Stauffer. His lower division, the Bellepoint member, was extended to include zones A-C. Wells' paper is the most detailed and critical biostratigraphic analysis of the Devonian rocks in the Columbus region that has been published.

As previously mentioned Newberry recognized the "Corniferous" age of the Devonian limestones in northwestern Ohio, and stressed the Hamilton aspect of the fossils in the upper part, and Winchell correlated them with the central and northcentral outcrops, and with those of southeastern Michigan. Later when a division into two formations, Columbus limestone and Delaware limestone, was made on the east side of the anticline, the names were automatically carried over to the northwest although the correct position of the boundary between the two formations was doubtful.

An examination of table 2 shows that Stauffer recognized two Middle Devonian formations in northwestern Ohio, the Columbus limestone and the Traverse formation. On the basis of lithology and fossils he correlated the lower formation

with the Columbus limestone east of the anticline in Ohio as earlier geologists had done. For the upper formation, however, he introduced the Michigan term Traverse into the State, recognizing the rocks as an extension of the upper part of that group from southeastern Michigan. On the basis of the many Hamilton fossils he considered the formation to be the equivalent of the Delaware and Olentangy formations east of the Cincinnati arch in Ohio.

Stewart (1927) accepted the correlation of the two limestones on either side of the anticline, and named the Silica shale for a unit in the lower part of Stauffer's Traverse not recognized by him.

TABLE 2

Historical Review: Classification of Middle Devonian Formations of Northwestern Ohio

Stauffer 1909	Stewart 1927	Bassett 1935	Cooper, et al. 1942		Ehlers Stumm Kesling 1951
Traverse formation (Stauffer introduced Michigan term; regarded rocks as upper Traverse and equivalent in time to Delaware and Olentangy formations of central Ohio; and the fauna as Hamilton in age.)	(Named by Stewart for 10 ± ft. of shale with Hamilton fauna in lower part of Stauffer's Traverse.) *Silica shale*		L. Tioughniog.	*Tenmile Creek dolomite*	*Tenmile Creek dolomite*
			Cazenovia	*Upper Silica shale*	*Silica formation*
				Lower Silica shale with Paraspirifer	
				"Blue bed"	
Columbus limestone (Was correlated with Columbus limestone of central and north central districts on basis of lithology and fossils.)	*Columbus limestone*	*Columbus limestone* (Bassett correlated the Columbus limestone of northwestern Ohio with the Dundee of Michigan and with the "Upper Columbus" of Carman's unpublished manuscript.)		*Dundee limestone* (= *Delaware limestone*)	*Dundee limestone* (= *Delaware limestone*)
Detroit River Group	*Detroit River Group*			*Detroit River Group*	*Detroit River Group*

*Named by Carman (unpublished manuscript).

For the first time Bassett (1935) correlated the Dundee as exposed in the Sibley quarry in southeastern Michigan, with the "upper Columbus" of the Silica and Whitehouse quarries in Lucas County, northwestern Ohio, on the basis of lithology and similarity of fossils. Bassett's published sections from the "upper Columbus" were from Carman's unpublished manuscript. The younger age of the northwestern Columbus limestone as compared with the central Ohio Columbus was apparently firmly established.

In the chart of Cooper et al. (1942), the Dundee position of the northwestern Ohio "Columbus limestone" is recognized, and its equivalence to the Delaware limestone. The name Dundee appears for the first time in print for the Ohio exposures. These in turn approximate the stratigraphic position of the Marcellus shale of the Appalachian Mountain region. In regard to the chart as a whole,

however, the authors caution the reader not to accept the correlations as final and fixed, but that "it is a statement of existing knowledge only."

Finally, Ehlers et al. (1951) in their publication, prepared as a guide book for the Geological Society of America, give in detail the zones of the Ohio Dundee limestone, give the Silica shale formational rank, and extend it downward to include the "Blue limestone" of Carman (unpublished manuscript).

DESCRIPTION AND CORRELATION OF THE LIMESTONES

The provisional classification of the Middle Devonian rocks in Ohio as presently recognized is shown in table 3 and is the result of the collective efforts of past and contemporary workers. Some of it may be only of a temporary nature, particularly in the smaller units. The three formations with which we are especially concerned in this study are the Columbus, Delaware, and Dundee limestones.

TABLE 3

Provisional Classification of the Bedrock Divisions of the Middle Devonian Rocks of Ohio As Presently Recognized

Series	Stages	Bellefontaine Outlier	Central Ohio	Northcentral Ohio	Northwestern Ohio
Erian	Taghanic	Upper 10 ft. of Columbus may represent Delaware time or younger.	[1]*"Olentangy shale"*	*Prout limestone*	*Tenmile Creek dolomite*
	Tioughnioga			*Plumb Brook shale*	*Silica formation* (includes "Blue ls.")
	Cazenovia		*Delaware limestone* Zones I - M	*Delaware limestone*	*Dundee limestone*
Ulsterian	Onesquethaw	*Columbus limestone* Delhi member?	*Columbus limestone* Delhi member Zones E - H Eversole member? Zone D Bellepoint member Zones A - C	*Columbus limestone* Venice number Marblehead member Bellepoint member	
		Detroit River Group		Detroit River Group	Detroit River Group

[1]Position and relationship of Olentangy blue shale to upper Devonian Ohio black shale not certainly known. It is probably upper Devonian in age.

Columbus Limestone

In the central belt of outcrop are exposed the Columbus and the Delaware limestones. The older of the two formations, the Columbus limestone, is the thicker of the two, and in Franklin County reaches a thickness of 105 ft. At the base it rests disconformably upon the upper Bass Island series (Silurian), and the contact may be observed 7 mi. north-northwest of Columbus on Mill Creek near Bellepoint. Evidence of this erosional break may be seen in the one-foot layer of conglomerate at the base of the Columbus which contains large and small water-worn pebbles of the Bass Island rocks in a Columbus limestone matrix. The upper contact is marked by a bone bed layer, from 3 to 15 in. thick, which locally may be absent. Where absent, changing lithology and fossils may be used fairly satisfactorily to determine the boundary.

Two major distinct lithogic (lithotope) facies are commonly developed in the Columbus limestone. The lower part, which comprises less than half of the formation (zones A-C of Stauffer) is a massive, brown limestone, with two systems of well-developed oblique joints. This is a dolomitic limestone with a high percentage of magnesium carbonate. Fossils are scarce and poorly preserved, except in the upper 4 ft. (zone C), which constitutes a coral and stromatoporoid biostrome. Simple horn-shaped corals of the family Zaphrentidae, and large branching masses of the colonial family Favositidae, make up most of the layer. Large, cylindrical specimens of *Siphonophrentis gigantea* are among the most striking fossils in this coral community (biocoenose).

The upper half or more of the Columbus limestone (zones D-H of Stauffer), is typically light gray in color, apart from the top layers (zone H) which is usually bluish. Rock layers are thinner as a rule than in the lower division, although portions, such as zone G, may be very massive. Chert is present in considerable abundance, either in lenses, or in more or less continuous layers such as developed in zone D, known locally as the chert or gastropod zone. In this zone the chert is very fossiliferous, and the external markings of the original shells are beautifully preserved in the chalky shell replacement. The limestone is surprisingly pure, in places nearly 94 percent pure calcium carbonate. Much of the rock is crystalline or subcrystalline in structure. Fossils are distributed all through the limestone, certain layers packed together in a thanacoenose assemblage of various origins.

The same dual lithologic facies is recognized in the northern portion of the central belt. The limestone is thinner there though, and attains a thickness of approximately 60 ft. Only the upper part of the Columbus limestone is present, much of the lower part (zones A-D) apparently disappears as a result of overlapping of the higher beds northward. The bone bed at the top is very sketchily developed as compared with central Ohio. The best exposures are quarry sections, notably at Sandusky, Marblehead, and Kelly's Island.

The subdivsions of the limestone in this northern area involved the problem of the Sandusky formation already discussed. Three divisions, established by Swartz (1907), and the lithologic and faunal features are:

1. *Venice member* (zone H of central area).—The rock is a massive blue limestone with little chert, and an intermittent bone bed at the top. Two fossil horizons below the bone bed were designated the "*Spirifer*" *duodenarius* horizon, and the upper *Paraspirifer acuminatus* horizon because of the abundance of these brachiopod species. Additional characteristic fossils of the latter horizon are: *Nucleocrinus verneuili* (Troost), *Eridophyllum verneuilanum* (Edward and Haime), and *Platyceras* (*Platyceras*) *dumosum* Conrad. The equivalence of this fauna to that of the upper Delhi (zone H) in central Ohio was established by Swartz (1907, p. 64) when he estimated that 87 percent of the species were represented in the corresponding horizon there. Likewise wave markings occur at the base of these rocks in both regions.

2. *Marblehead member* (zones E-G of central area). —The rock is a gray, fossiliferous limestone. Three spiriferid horizons, not all in one section, were distinguished by Swartz: lower *Paraspirifer acuminatus* faunule (in north), *Brevispirifer gregarius* faunule, and "*Spirifer*" *macrothyris* faunule (in south).

In central Ohio *P. acuminatus* (Conrad) is especially characteristic of zone H, but also occurs in zone G, but not to the extent of constituting a faunule. *B. gregarius* (Clapp) is the common species of zone F, but has a range from E through G. "*S.*" *macrothyris* (Hall) is the common spiriferid of zone E, but extends down into D. In other words an equivalence with the lower two-thirds of the Delhi is evident. The chert zone D (Eversole member) is not recognized in the northern area.

3. *Bellepoint member* (upper zone B and C of central area).—Only 6 ft. of a brown, dolomitic limestone are included in this division. It is typified by many corals, and has a one-inch sandy layer at the base. The dolomitic phase of the Columbus limestone is much thicker in central Ohio.

In the Bellefontaine outlier the Columbus limestone is known from various exposures along runs and in quarries. As mentioned previously the total thickness is approximately 85 ft. In general the limestone is more dolomitic than in the Franklin County region, and that is one reason why Stauffer regarded it as probably equivalent to the lower Columbus of that area. However, this is probably not the case because typical fossils of upper Columbus zones are found in the formation here. Moses (1922, p. 20) recognized three distinctive divisions based on lithology and fossils as follows:

1. *Upper Division.* Forty to 45 ft. of gray-brown, subcrystalline to crystalline limestone, interbedded with chert in the upper three-fourths. The upper 10 ft. at the East Liberty quarry is a hard blue limestone, with many fish teeth and plates. This is a local arenaceous layer, overlain by the East Liberty bone bed of Wells (1944, p. 280), which may represent Delaware time of the central area. Corals are common throughout a large part of the formation, of which *Zaphrentis phrygia* (Rafinesque and Clifford) and *Favosites turbinatus* (Billings) are the most common. The presence of *Paraspirifer acuminatus* (Conrad) suggests a position probably not below zone G of the central district.

2. *Middle Division.* Thirty feet or less of massive, hard, gray, dolomitic limestone, with some chert nodules; in general highly fossiliferous. The occurrence of *Brevispirifer gregarius* (Clapp) suggests a stratigraphic position relative to zones E and F of the central area. The thickest section is on the north branch of a run one mile north of the north edge of East Liberty where 22 feet are exposed. This is near the base of the formation here because contact with the underlying Detroit River series is visible a few hundred yards to the north in a small quarry and ravine at approximately the same elevation, i.e., 1,165 ft.

3. *Lower Division.* About 20 ft. of dark gray, thick-bedded fossiliferous limestone, exposed only at Cable and Middleburg in the southern part of the outlier. At Cable Stauffer (1909, p. 98) recognized 23 ft. of Columbus limestone, divisible into 6 zones. The upper zone 6, a massive, 3-foot layer of very fossiliferous, gray limestone, probably belongs in the middle division because of lithologic and faunal features. Fossils in this zone which suggests this higher stratigraphic position are: *Stropheodonta demissa* (Conrad), *Megastrophia hemispherica* (Hall), *Pholidostrophia iowaensis* (Gwen), *Brevispirifer gregarius* (Clapp), and *Paracyclas proavia* (Goldfuss).

The 3-foot layer which comprises zone 4, contains much white, extremely fossiliferous chert. The most distinctive and abundant species are: *Pleurodictyum* (*Procteria*) *michelinoides* (Davis), and *Odontocephalus aegeria* (Hall). These are not known in central Ohio.

Delaware Limestone

The Delaware limestone is the upper of the two Middle Devonian limestones, and reaches an average thickness of about 36 ft.. in central Ohio; the maximum thickness in the type area at Delaware is estimated at about 45 ft. Where the bone bed (No. 2) at the top of the Columbus below is well developed the lower contact of the Delaware limestone is easily determined. But where the bone bed is lacking, the thin shaly layers which are always developed above the bone bed, help to determine the lower limit of the formation. The presence of the brachiopods *Leiorhynchus limitare*, *Orbiculoidea lodiense*, and *Discina minuta* was the reason why Winchell determined the Delaware as Marcellus in age as mentioned previously. The contact with the Olentangy shale above is usually definite and easily recognized.

The Delaware limestone is variable in its lithology and appearance, but is typically a blue limestone which weathers to a brown color, and is interbedded with thin brown shale and chert layers. The chert is black, gray, or white in color, and commonly is not very fossiliferous. It gives the rock a mottled appearance in many of the outcrops. In general it is a thinner-bedded formation than the Columbus, but it is likely to be massive where the shale and chert are missing. Fossils are abundant, although unevenly so. The formation is well exposed along the Scioto River valley, and in the various runs tributary to it and to the Olentangy River valley.

Stauffer divided the Delaware limestone into 5 zones (I-M) partly on lithologic differences, but mostly on changes in the fossil content (table 1).

The Delaware limestone of northcentral Ohio constitutes the upper part of the Sandusky formation of Newberry (1873). It is the "upper blue limestone" of Swartz, and he describes it as a blue limestone with chert from 6 to 15 ft. above the base, and having a thickness from 31 to 47 ft. More detailed information by Stauffer (1909) shows interbedded layers of impure limestone, having a brown or bluish-brown color, and occasional bands of chert; crinoidal layers occur at intervals, and occasional crinoidal shale partings. The contact with the Plum Brook shale above is usually sharp and definite. Zones are not distinguished as in central Ohio, and the basal shaly layer is missing. However, the two areas share many fossil species in common. Some of the more significant ones are: *Hadrophyllum d'Orbigni* Edwards and Haime, *Leiorhychus limitare* (Vanuxen), *Martiniopsis maia* (Billings), *Ambocoelia umbonata* (Conrad), and *Tentaculites scalariformis* Hall.

Rocks of Delaware age are not recognized in the Bellefontaine outlier.

Dundee Limestone

As previously mentioned the Dundee limestone of northwestern Ohio is the southward extension of the same formation in southeastern Michigan. Because of faunal similarities the Dundee is correlated with the Delaware limestone on the east side of the Cincinnati anticline in Ohio and southwestern Ontario. In Ohio the Dundee has a stratigraphic position between the Detroit River group below, and the Silica formation above (Table 3). The lower contact is disconformable, but the upper is transitional and not so easy recognizable. Establishment of the boundary is made on the basis of fossils. It is now placed at the base of the "Blue" limestone layer (Ehlers et al., 1951, p. 18), an 8-foot bluish-gray limestone tentatively named by Carman (unpublished manuscript), and included in Bassett (1935, p. 437). The "Blue" layer has in its lower part a great abundance of *Chonetes coronatus* Conrad, and in fewer members *Tropidoleptus carinatus* (Conrad).

The crescent-shaped pattern of outcrop of the Dundee and younger formations is indicated in figure 2. The width of outcrop narrows abruptly northward in the vicinity of the Lucas County monocline where the beds have a steep westward dip. Further south the rocks dip gently northwestward into the Michigan basin.

As already mentioned, practically all exposures of the Dundee are limited to quarry excavations in Lucas County. Three quarries in the Silica region expose an almost complete section: the west quarry of the France Stone Company, and the south and north quarries of the Medusa Portland Cement Company. Other sections are exposed in abandoned quarries: a small quarry on the southeast edge of the village of Whitehouse, and a small quarry about 3 mi. southeast of Whitehouse, known locally as the Ryan quarry. (figure 2.)

In the Silica quarries a total thickness of 61 ft., 5 in. of Dundee limestone is recognized (Ehlers et al., 1951, p. 18). Of this 20 ft. constitutes the "upper" Columbus of Carman, and Bassett (1935). The rocks exhibit various blue, gray, and brown hues, and occur in beds of variable thickness. They are exceedingly fossiliferous, and the fossils together with the lithology are the bases used for

the subdivision of these upper beds into 5 zones (units 7–11 of Ehlers, etc.). A few of the several species in common with the Dundee in Michigan are: *Productella spinulicosta* Hall, *Brevispirifer lucasensis* (Stauffer), *Atrypa costata* Bassett, and *Paracyclas proavia* (Goldfuss).

The lower Columbus (Ehlers, 1951, p. 18,) (units 1–6) comprise approximately 41½ ft., the lower 8 ft. in large part a covered interval. Lithologically this division differs from the upper in that it is much more dolomitic, contains more chert, and is much less fossiliferous. Colors tend to be buff-gray rather than bluish-gray. The most fossiliferous layer is unit 4, exposed in a cut in the east wall of the west quarry of the France Stone Company. The nodular chert layers are especially rich in fossils. The ostracods described by Kesling (1954) came from this unit. Common Dundee species present are *Brevispirifer lucasensis* (Stauffer), *Glyptodesma erectum* (Conrad), *Atrypa elegans* Grabau, and *Tentaculites scalariformis* Hall.

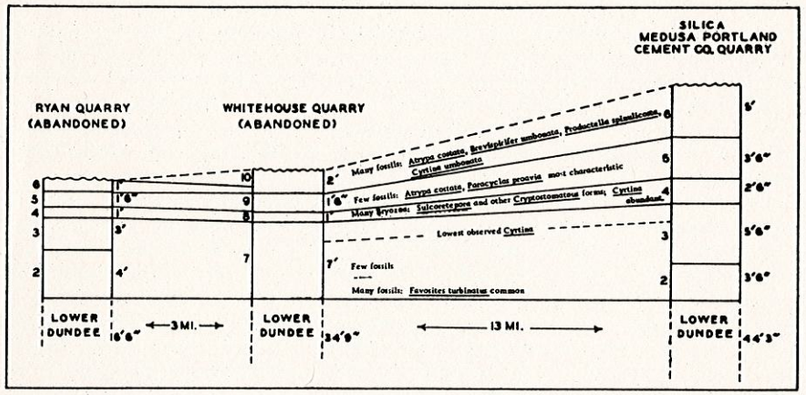

FIGURE 3. Zones of the upper Dundee limestone at Ryan, Whitehouse and Silica quarries. (After Carman, unpublished manuscript)

The three sections shown in figure 3 are sections of the upper Dundee ("Upper" Columbus) after Carman (unpublished manuscript). The zones at Silica, in the quarry of the Medusa Portland Cement Company are identical with those published in the field guide of Ehlers et al. The Whitehouse quarry section is thinner, 11½ ft., and the four zones recognized there may be correlated with the zones at Silica on the basis of fossils, zone 7 being the equivalent of zones 2 and 3 (7 and 8 of Ehlers). About 35 ft. of the lower Dundee are exposed, which are similar lithologically to the lower Dundee at Silica.

In the Ryan quarry, 10½ ft. of upper Dundee are exposed, which may be correlated with the 5 zones in the Medusa Portland Cement Company quarry. Only 6½ ft. of the lower Dundee are exposed here.

Since the concentration of fossils seems to be biocoenose in the various assemblages, highly fossiliferous layers alternate with layers having few or practically no fossils. Therefore in table 4 it will be noted the zones recorded for the different quarries are those which contain most of the fossils. An exception to this is zone 2 at Silica which is quite fossiliferous, but no species were collected from it that were not recognized in the other zones. One of the most striking features of brachiopod distribution is exemplified by the genus *Cyrtina* which is abundantly represented in all zones from its first appearance in the upper half of zone 3 to zone 6 at the top of the formation where it appears to have its greatest development.

FAUNAL CONTENT AND RELATIONSHIPS

Since the type region for the Middle Devonian limestones in Ohio is in the central part of the state, an understanding of their fossil content is a matter of first consideration, because correlation with Middle Devonian rocks elsewhere, particularly in the New York and Applachian regions was made here first primarily on fossils. Where the diastemic contact between the Columbus and Delaware limestones is not recognizable, and where the bone bed layer at the top of the Columbus is poorly developed or missing, fossils are the only reliable means of separating the two formations.

Fauna of the Columbus Limestone

The Columbus limestone is an abundantly fossiliferous formation particularly in the upper half. The fossils are very commonly preserved as casts, external molds, and steinkerns. In many of the chert layers, however, particularly in zone D, the delicate external markins of the shells are beautifully preserved. The invertebrate fauna is typically marine but the vertebrate fauna has remains of fresh water fishes. Remains of these fishes, in the form of teeth, dermal plates, and spines, are particularly abundant in the bone bed layer at the top of the formation. Likewise the remains of fresh water plants, ancient trochiliscids, are represented by spores which are present in abundance in certain layers. These are identified as *Eutrochiliscus devonicus* (Willard) by Raymond E. Peck (personal communication).

The fossils are not distributed uniformly throughout the formation. Some beds, particularly zone A (conglomerate) and a large portion of zone B, are sparingly fossiliferous, while in others, such as zones C and F, fossils are so abundant as to constitute distinct biozonal faunules. Certain species are long ranging forms such as *Favosites turbinatus* Billings, *Sulcoretepora gilberti* (Meek), *Atrypa "reticularis"* (Linnaeus), *Productella spinulicosta* Hall, and *Tentaculites scalariformis* Hall. Others are restricted stratigraphically and are excellent guide fossils for this age rocks: *Paraspirifer acuminatus* (Conrad), *Brevispirifer gregarius* (Clapp), and *Nucleocrinus verneuili* (Troost). Numerous gastropod species are found only in the chert zone (D).

In the progress of time, evolutionary changes must have taken place in the indigenous faunas, but migratory elements too probably played a very important part in producing the highly diversified elements of the Columbus limestone fauna. Many believe these faunal migrations came from two sources: a southern source where related forms are found in older Devonian beds in South America, and a northern source having elements related to north and north-central Europe. However, in view of the fact that the Columbus limestone thins northward with only the upper beds extending to the northern-most limit near Ingersoll, Ontario, it is questionable whether a sea ever did extend into Ohio from the north at this time.

The nearest correlative of the Columbus limestone fauna eastward in the Appalachian region of New York is not certainly known. Although long considered a typical Onondaga fauna, it probably approximates in age only the upper part of it. In the Beachville-Ingersoll area in Ontario about 40 mi. north of Lake Erie, the Columbus limestone overlies the Detroit River group, whereas a few miles to the northeast the Onondaga occurs below the Detroit River group. (Caley 1947, p. 1, 170). The Columbus limestone, therefore, is stratigraphically younger than the Onondaga limestone in that region.

As already stated the Columbus fauna is dominantly one of marine invertebrates. By far the greatest percentage of species is made up of brachiopods, gastropods, corals, pelecypods, cephalopods, and bryozoa, in that order of importance, with trilobites, echinoderms, and stromatoporoids comprising a much smaller element.

In more recent years, a number of species of foraminifera (Stewart and Lampe, 1947), and of ostracodes (Stewart, 1950) have been added to the list. Conodonts have been recovered in considerable abundance from the bone bed layers, and a study of them is now underway by the writer.

Corals.—The Columbus limestone is amazingly rich in corals, in dolomitic as well as in the purer calcium carbonate phases of the formation. The best known and probably greatest concentration is in the coral biostrome (zone C), but locally smaller assemblages of the reef type occur at several different horizons. The smaller individual cup corals, i.e., *Zaphrentis phrygia* and *Cystiphylloides vesiculosum* are found scattered from zone C up through zone H. In the upper 3 or 4 ft. of zone H these two species may be found in abundance along exposed and weathered joint surfaces where the exposed part is always silicified.

The coral biostrome (zone C) is made up of many different species of the family Favositidae, sprawling, branching types, such as *Favosites limitaris*, *Emmonsai carmani*, and many species of *Cladopora*. Larger, headlike masses are also represented, particularly such species as *Favosites goldfussi*, *F. turbinatus*, and *Emmonsi emmonsi*. Long cylindrical specimens of the tetracoral *Heliophyllum halli* are particularly striking in the quarry exposure on the south edge of the town of Dublin in Franklin County. Stromatoporoids make up a large portion of the biostrome here of which *Clathrodictyum ponderosa* appears to be the most common, if not the only species. The largest of all the solitary tetracorals *Siphonophrentis gigantea* (Lesueur) is found in all zones above A.

Of the smaller biostrome assemblages, one occurs locally in zone H, about 4 ft. below the top of the Delhi member, made up almost entirely of *Eridophyllum seriale*. This species is recognized in many exposures along the Scioto valley and north to Ingersoll, Ontario, but not in the Bellefontaine outlier. Stratigraphically it appears to be restricted to the upper few feet of the Columbus formation.

The genus *Hexagonaria prisma* likewise forms a secondary biostromal layer in the upper part of zone H in central Ohio. The species is also recognized in the Bellefontaine outlier, in a 2-foot exposure of the Columbus limestone in the General Pratt quarry, near West Liberty. This suggests a stratigraphic position high up in the Columbus for the rock at this place.

And yet another small biostrome is developed by the coral *Emmonsia emmonsi* in the lower part of the Delhi (zone E), at the base of the falls in Hayden Run, which is tributary to the Scioto River. However this coral must have had its optimum development in lower Columbus time, since it forms such a large part of the coral zone (C), and later occurrences such as this are doubtless due to stragglers that were able to survive a changing environment without significant change in fundamental specific features.

About a mile southwest of Cable in a small abandoned quarry, and along a small run which passes through it, 22 ft. of Columbus limestone are exposed (Stauffer 1909, p. 98). In chert layers in Bed 4 of this section occurs the species *Pleurodictyum (Procteria) michelinoidea* (Davis) [1] in sufficient abundance to form a secondary biostrome. This is the lower Columbus of Moses (1922, p. 57). The species identified by Stewart (1938, p. 65), as *Favosites pleurodictyoides* Nicholson from Erie and Sandusky counties is probably consepecific with it. Stumm (1950, p. 212) recognized the species in Erie County. So far as the writer knows these are the only reported occurrences of this coral in Ohio. On Kelly's Island in Erie County, the species occurs high up in the Columbus in association with *Paraspirifer acuminatus*.

Blastoids. Although only two species of blastoids have been recognized in the Columbus limestone, they are of distinct value because of their limited stratigraphic range in the formation. They are known only in zone H. in central Ohio,

[1] This is the *Pleurodictyum problematicum* Goldfuss of Stauffer, Stewart, and others.

and in the stratigraphic equivalent northward. The two species are: *Codaster pyramidatus* Shumard, and *Nucleocrinus verneuili* (Troost). *C. pyramidatus* is one of the more common species in the zone, and is frequently found in a silicified condition along weathered joint surfaces in the rock. To my knowledge the geographic distribution of this blastoid is limited to Franklin and Delaware counties. On the other hand *N. verneuili* is found distributed throughout the central belt to Lake Erie, and is such a distinctive and abundant fossil that Wells (1947, p. 121) designated zone H, the zone of *Nucleocrinus verneuili*. It is an excellent guide fossil for this stratigraphic unit in Franklin and southern Delaware counties. Outside of Ohio both species are known only in rocks of Onondaga age.

Crinoids. Although several species of crinoids belonging to the genera *Dolatocrinus* and *Megistocrinus* have been reported from the Columbus limestone by earlier workers in the State very little additional material has been found apart from crinoid stems and plates. The latter form crinoidal layers in many places and, it is probable that the break down of the crown was brought about by shifting currents and sediments. Crinoids cannot be considered as an important element in the Columbus fauna, and have not been helpful for stratigraphic and correlation purposes. In all 13 species have been reported, but careful collecting and study are necessary to establish their validity. Only fragmental plates and stems have been recognized in the Bellefontaine outlier.

Bryozoa. The presence of many bryozoa throughout the upper half of the Columbus formation indicates they must have formed populous communities in the middle Devonian seas. However, they are never assembled in large biozonal masses which suggests they never did assume too great importance as reef-building organisms. The cryptostomatous forms are by far the most prevalent, and are mostly represented by the lace-like fronds of the family Fenestrellinidae. These are especially noticeable in zone D, where they are commonly found enclosed in the chert layers. Other delicate branching forms, such as *Sulcoretopora gilberti* (Meek) are more common in zone C, although they are recognized in all the upper zones of the Columbus and into the Delaware limestone above. In general, the importance of the bryozoa diminished considerably with the oncoming of the more muddy seas of the Delaware.

Since the days of James Hall very little active research has been done on this important rock forming group of invertebrates in the middle Devonian limestones here. At least 25 species have been recorded from these rocks, but much detailed work is necessary in order to evaluate the validity of these species. Their use in the stratigraphy of the rocks and for correlation elsewhere has yet to be determined. It may be said, however, that the Columbus limestone species, at least, tie in fairly closely with the Onondaga forms of New York State.

Brachiopods. Hosts of brachiopods must have lived in the Columbus seas since their shells are preserved in such abundance and variety in the limestone. Their concentration in great numbers in certain layers has proved to be most helpful in the zonation of the formation. They are usually excellently preserved either by replacement, or by infiltration of mineral matter. Some specimens appear to have had very little change in shell substance. Brachiopods are present in all zones above A, and reach their maximum development in the more highly calcareous phase of the formation in zones E through H. More than 80 species have been reported, some of which occur in extreme abundance, while others are represented by only occasional specimens. The brachiopod fauna, probably more than any other group of invertebrates in the limestone has an undeniably Onondaga cast, but in addition certain Hamilton species suggest a possible later age than the New York and Ontario Onondaga. There is a remarkable similiarity in species throughout the whole of the central belt and the Bellefontaine outlier.

Probably the most important group is to be found in the *Spiriferacea*. Certain species have a limited stratigraphic range in the formation, and hence have proved

to be extremely useful as guide fossils for the zones. Swartz (1907, p. 64, 65) used them first in helping establish the upper boundary of the Columbus limestone in northcentral Ohio, and in correlating the rocks with the central area. Later Stauffer (1909), Ireland (1922), and Wells (1947) demonstrated additional stratigraphic values, and paleoecological factors relative to the ancient environment of these organisms.

Outstanding species of the spiriferids are *Paraspirifer acuminatus* (Conrad) and *"Spirifer" duodenarius* (Hall) of the upper Columbus, notably zone H; *Brevispirifer gregarius* (Clapp), especially common in zone F and not found above zone G; *"Spirifer" macrothyris* Hall of zone E; and *"Spirifer" varicosa* Hall, most abundant in zone D. These various species constitute the Spiriferid hemerae of Wells (1947, p. 121). Outside of Ohio they are especially characteristic of upper Onondaga (Onesquethaw) rocks, and are not recognized in younger formations.

Members of the superfamily Strophomenacea take second place in importance to the Spiriferacea in abundance of individuals and variety of species. Two of the most striking species because of their large size are common middle Devonian forms: *Megastrophia hemispherica* (Hall) and *Strophonella ampla* (Hall). The former occurs in all zones but A of the Columbus limestone and ranges up into the Delaware with no apparent change. The latter is confined to the Columbus, but is not so abundant northward as in the central region where it is especially characteristic of zone E, but occurs in the upper zones too. *S. ampla* is a widely distributed species in lower Onondaga rocks in other regions. The Ohio form may be different because it has a longer hinge than is typical elsewhere.

The identification in the Columbus limestone of two other species of the family, *Protoleptostrophia perplana* (Conrad) and *Stropheodonta demissa* (Conrad) is questionable, because outside of Ohio they have been recognized in rocks of Hamilton age only. In Ohio both species are known in rocks of comparable age: Delaware limestone, Olentangy and Silica formations. The Columbus limestone specimens are usually smaller and less robust, particularly *S. demissa*, than in the younger rocks.

The Middle Devonian aspect of the brachiopods is emphasized in the character and abundance of the atrypids. Most of them are identified, probably incorrectly, with two species: *"Atrypa reticularis"* (Wilckens) a catch-all species name for many unnamed Devonian species of *Atrypa*, and *A. "spinosa"* Hall, an upper Hamilton (Moscow) age form in New York State and associated areas. Mature specimens of the former species are large and robust, with finely plicate surface, and with an exceptionally convex brachial valve. The latter species is much smaller, both valves are somewhat flattish, and the plications are strong. It is extremely abundant in zone F, much more so in certain layers than the typical *Brevispirifer gregarius* of the zone. Some specimens with still heavier plications, and sometimes with shelly, spinose extensions may belong to yet another species.

The occurrence of the long-ranging *Leptaena "rhomboidalis"* Wilckens in the upper two zones of the limestone in relative abundance, particularly in zone H, as compared with its extreme profusion in the lower zones J and K of the Delaware above is noteworthy. The same stratigraphic positions are maintained in the northcentral area, but interestingly enough the species has not been found in the Bellefontaine outlier. The typical Columbus example is a large, robust individual, and should be restudied, and probably renamed.

At least nine species of the genus *Chonetes* have been reported from the Columbus limestone, but many of these identifications are questionable. One Middle Devonian species, *Chonetes mucronatus* Hall, is the species most commonly recognized in both limestones, ranging through several zones of each. It has been reported as a common brachiopod in zones C through H, but this abundance is not evident in casual collecting as it is with many other brachiopods. The whole group here needs restudy and revision.

Other distinctive brachiopods rather widely distributed but never abundant are: *Pholidostrophia nacrea* (Hall), *Productella spinulicosta* Hall, *Rhipidomella vanuxemi* Hall, and *Schizophoria propinque* Hall. These will be discussed in connection with the northwest section since they are of much more consequence in the faunas there than in the central area.

Pelecypods. Although 60 or more species of pelecypods have been reported from both Columbus and Delaware limestones, only 8 or 10 occur in abundance, and these more commonly in the shaly phases of the Delaware. However, more species are known from the Columbus, but generally they are scattered, and seldom constitute biozones of appreciable development. As a rule the shell features are not well preserved. The three most common species in the Columbus limestone are: *Conocardium cuneus* (Conrad), *Paracyclas proavia* (Goldfuss), and *Cornellites flabella* (Conrad).

Of the foregoing *C. cuneus*, suggested designation by Branson (1942, card 7) *C. cuneus cuneus* to separate it from associated varieties, is certainly the most distinctive if not the most abundant of the three. It was first recognized by Hall (1885, p. 410) in the limestones in Franklin County, and since then has been reported from almost every outcrop of the Columbus limestone throughout the whole of the central belt, and from the Delaware limestone in the northcentral area. The species is especially abundant in zone C of the former formation, and in zone D associated species are: *Conocardium cuneus attenuatum* (Conrad), *C. cuneus subtrigonale* d'Orbigny, and *C. ohioense* Meek. *C. cuneus* is the most commonly recognized species of the genus in eastern Devonian faunas, ranging from Oriskany through Hamilton.

Paracyclas proavia (Goldfuss)[2] (the *P. elliptica* of most writers) likewise has been reported from nearly all exposures of the formation, and is one of the more common fossils in zones C-G. It extends into the Delaware above but is much more restricted within the formation. In contrast to *Conocardium cuneus*, which usually has the shell features preserved, *P. proavia* seldom has any shell retained, and internal molds or steinkerns are the usual mode of occurrence. The stratigraphic range of the species is Onondaga and Hamilton.

Two other species of *Paracyclas* of more local and less abundant occurrence in central Ohio are: *Paracyclas ohioense* Meek, in zones C and D of the Columbus limestone, and *P. lirata* (Conrad) in the Delaware limestone.

Cornellites flabella (Conrad), a rather widely distributed Middle Devonian pelecypod in New York and adjoining states, is most common in the shaly phases of the Hamilton, but in Ohio it is most common in the more highly calcareous phase of the Columbus, notably in zones E and G, and in the lower part of the Delaware, especially zone K. The species in the two formations may not be conspecific, since the specimens in the Columbus limestone are larger, and have coarser surface sculpture than in the Delaware. A Hamilton species of doubtful identification is *Modimorpha concentrica* (Conrad), which is found in considerable abundance from zones D through G, but is most common in zones E and F. It might be noted from the few foregoing species cited, that the Columbus limestone pelecypods show a close affinity to those in younger age rocks, more specifically, Hamilton.

Gastropods. Although gastropods form a rich and varied element in the Columbus limestone fauna they do not usually occur in such profusion as some other groups of fossils, such as corals and brachiopods. Their greatest concentration is to be found in the cherty layers of zone D (Eversole member) in the central area, near the base of the formation. This zone is commonly referred to as the gastropod zone. At least 60 species have been reported from this zone by various paleontologists, which is an amazingly large number, when all told only about 75 species have been recorded from the entire formation. Perhaps the more conservative figure of 30 of Wells (1947, p. 122) is nearer the truth, and from my own observations even less than this. However, gastropods are found in more or less abundance in all zones in the limestone above the chert layer.

[2]See LaRocque, 1950.

Gastropods in zone D are characteristically the smaller-shelled forms such as several species of bellerophontids, pleurotomarids, and high-spired turritellid forms, represented especially by the genera *Murchisonia* and *Loxonema*. The external shell features are generally remarkably well-preserved in the more chalky phases of the chert.

In the higher more calcareous rocks of the limestone the usual mode of preservation is in the form of internal molds or steinkerns, and in general the larger, thicker-shelled species are best represented.

Since earlier paleontologists and stratigraphers considered the Columbus limestone to be more or less the equivalent in age of the Onondaga of New York State and adjoining areas a large proportion of the fossils are identified with species of this age. Many of these species are based on Ohio material, the major contributions having been made by Whitfield, Newberry, James Hall, and Stauffer. A critical study of this whole important group is necessary in order to determine the validity of the many lower Onondaga species that have been identified in the Ohio rocks.

Although numerous gastropod species have been reported from the Columbus limestone, only a relatively few occur in any great abundance. In the local collecting areas in the quarries in Franklin and Delaware counties along the Scioto River the common and more abundant species in the chert zone D are: several species of the bellerophontids, *Bellerephon pelops* Hall being one of the more abundant ones, *Elasmonema bellatulum* (Hall) and *Elasmonema lichas* (Hall) which are probably synonymous species, *Isonema humile* Meek, *Mourlonia lucina* (Hall), *Pleuronotus decewi* Billings, one of the largest gastropods in the zone, and usually preserved as a steinkern; and *Loxonema pexatum* Hall, *Loxonema robustum* Hall, and *Murchisonia desiderata* Hall among the high-spired turritellid forms.

Higher up in the limestone, notably in zones E, F, and G, *Mourlonia lucina*, *Pleuronotus decewi*, *Loxonema pexatum*, and *Murchisonia desiderata* are the most abundant and conspicuous forms. In zone H, the spiny platycerids are the dominant type, *Platyceras* (*Platyceras*) *dumosum* Conrad, and *P.* (*Platyceras*) *carinatum* Hall being the more common forms. In the upper part of the zone, *Tentaculites scalariformis* Hall, which is widespread and extremely abundant in zone J of the Delaware limestone, occurs in relative abundance in certain layers in zone H, and is sparingly distributed down to zone D. This questionable pteropod has a stratigraphic distribution from Onondaga through Hamilton in the Appalachian states and west to Michigan.

All of the aforementioned species have been recognized in the Columbus limestone in Ohio northward to Lake Erie, and in the Bellefontaine outlier exposure, but nowhere approaching the abundance in the central area. The total gastropod species likewise falls far below that of the central region. The paucity of species can be readily understood with the realization that the lower Columbus of the central area (zones A to D) is missing from these regions, hence ruling out the rich concentration of species of the chert zone D.

Cephalopods. Although 40 or more species of cephalopods have been reported from the Columbus limestone by various workers, probably not more than half that number are commonly recognized. Of the 36 species listed by Stauffer (1909), 16 were not collected by him, but some of these are represented in the Geological Museum collections at The Ohio State University. Most of the collection in the museum was studied by Flower (1945), with the result that several described species were assigned to new genera, and some new ones recognized.

The cephalopod fauna is almost exclusively nautiloid. The shells and shell features are rarely preserved. Steinkern fillings are the common mode of preserva-

tion, and since the siphunclar features have either been destroyed or made indistinct in the process of fossilization, identification in many cases is difficult and uncertain.

Although cephalopods form an important element in the Columbus fauna they are not generally abundant as to individuals. The peak of development is in zones E and G, particularly in the latter zone which is commonly referred to as the "cephalopod zone." Specimens are rare in zone C, but in zones D and E straight orthoceracones and gently curved cyrtoceracones appear in fair abundance in species and individuals. *Michelinoceras ohioensis* (Hall) is the most commonly recognized of the straight forms. Several associated species originally referred to the genus *Orthoceras* are now known to belong in other genera, such as *Spyroceras*, but at the moment their correct specific category is not known.

The notable development of gyroceracones and exogastric brevicones is the outstanding feature of zones E and G. Occasional specimens of these groups are found at lower stratigraphic levels in the formation down to zone D, but the climax of their development is in the upper part of the formation. Because of the large size attained by many individual specimens they are unquestionably the most striking fossils in this part of the limestone. The large, loosely coiled, gyroconic types are best represented. Of these *Goldringia cyclops* (Hall) and *Wellsoceras columbiense* (Whitfield) are by far the most common species. An amazingly large size, up to a foot in length, is reached by some specimens of the exogastric brevicone *Acleistoceras eximium* (Hall).

North of Delaware County there is a striking decline in the cephalopod fauna, and specimens are few and identification very uncertain. Apart from one or two questionable specimens none at all have been collected from the Bellefontaine exposure.

The cephalopod fauna of the Columbus and adjoining areas is recognized as having its closest affiliations with that of the Schoharie grit and Onondaga limestone of New York, and the Jeffersonville limestone of Indiana. Most conspicuous genera common to these formations are *Goldringia*, *Wellsoceras*, and *Needyceras*, which seem to be best represented in the lower middle Devonian of these areas.

Trilobites. Trilobites form an interesting if not a prolific portion of the Columbus limestone fauna. They are distributed throughout the formation from zones C through H in the exposures around Columbus and adjoining areas where they are most common in the upper, more calcareous phase of the limestone, particularly in zones E and F. As is usual with this class of Crustacea the remains are fragmentary so that seldom is a specimen found in a complete state of preservation.

From all areas of exposure throughout the whole of the central outcropping belt and the Bellefontaine region 15 species have been reported. However 3 of these have a generally recognized stratigraphic position higher in the middle Devonian, typically Hamilton, and should be withdrawn from the list, restudied, and redefined. These are *Phacops rana* (Green), *Dechenella* (*Basidechenella*) *rowi* (Green), and *D.* (*Dechenella*) *planimarginata* (Meek). Specimens of *D.* (*Basidechenella*) *rowi?* are found more frequently than any other trilobite in the Columbus area, particularly in zone F of the limestone. The species does not fit into any of the Proetidae of Stumm (1953). Because of the smaller and less convex pygidium, and certain cephalic differences, the specimens can be readily distinguished from the associated *Proetus* (*Crassiproetus*) *crassimarginatus* (Hall).

The trilobite fauna is dominated by the families Phacopidae and Proetidae, and is unquestionably lower Middle Devonian (Ulsterian) in its content. The most outstanding species in the central area is the large-tailed *Coronura aspectens* (Conrad) of the latter family, but parts other than the pygidium are seldom found. The genus *Odontocephalus* is represented by 2 species, one of which, *O. aegeria* Hall has not been recognized outside of the Bellefontaine outlier. *Phacops cristata* Hall of the Phacopidae is probably the most abundant of the trilobites in the Columbus district.

Ostracods. Only a few fragments of ostracods have been recovered from the limestone. The study by Stewart (1950) on Ostracoda of the Middle Devonian Bone Beds in Central Ohio showed their occurrence to be mainly in Bone Bed 3 of the Delaware limestone. Additional study is necessary to determine their almost certain presence in other parts of the formation.

Vertebrate Remains. Vertebrate remains are represented mostly by fish remains and conodonts. The outstanding contribution on fishes was made in the several reports of John S. Newberry, and in the more recent report of Wells (1944) on the microscopic fish remains from the bone beds of the Cincinnati arch region. Fish remains in both Columbus and Delaware formations are important and varified, and represent both fresh and marine water types.

Conodonts appear to be concentrated in the bone bed layers, and are almost exclusively represented by the families Icriodidae and Polygnathidae. Publication on this interesting, but debatable group of microfossils is still to be made.

Fauna of the Delaware Limestone

The wealth of fossils in the upper two-thirds of the Columbus limestone gives way to a much more restricted and conservative assemblage in the Delaware limestone. The change in lithology from a highly calcareous limestone to scattered beds of shale, particularly in the lower part, and to dark unfossiliferous chert and rather massive, blue to brown limestone further up evidently represents an environment not nearly so favorable for living organisms as the clear seas of earlier times. There were probably many factors which contributed to the reduction of the highly populous community of late Columbus time.

However, the fauna of the Delaware limestone is by no means meagre, although large parts of it have few or no fossils. Over a hundred species have been reported from it, which is less than a third of the number in the Columbus limestone below. As a rule the fossils are not scattered through the formation to the same extent, and are more likely to be found concentrated to form highly fossiliferous layers. Few species but abundant individuals seem to have been the rule in these ancient colonies. A good example of prolifity in individuals is demonstrated in zone J where innumerable individuals of the pteropod *Tentaculties scalariformis* are interspersed with relatively few specimens of other species. Likewise zone K offers another notable instance where some rock layers are literally paved with finely preserved specimens of *Leptaena rhomboidalis* to the exclusion of all but a few other fossils, mainly brachipods, and the distinctive pelecypod *Grammysia bisculata.* These striking accumulations of so many individuals in restricted stratigraphic zones are valuable aids in the zonation of the formations.

The Delaware formation begins with a 6-foot layer of shale interbedded with black chert and thin limestone layers which is characterized faunally by the inarticulate brachiopods *Lingula manni* Hall and *Orbiculoidea lodiensis* (Vanuxem), and the articulate form *Leiorchynchus limitare* (Vanuxem). *Lingula manni* is not so common as the other two species in the Columbus district, but further north in southern Delaware County it appears in greater abundance and higher up in the formation. It was the recognition of these typically Marcellus species of New York State that lead Whitfield to confirm Winchell's earlier opinion of the Hamilton age of the Delaware limestone.

In general the mode of preservation of the fossils is much the same as in the Columbus limestone, although it does seem that more specimens have the shell and shell features better preserved. This is particularly true of many brachiopods, such as *Leptaena.*

The general content of the fauna is in striking contrast to the lower formation. Gone are the the hosts of reef-forming corals although a few of the more hardy, adaptible species survive. Lingering colonies of the long ranging Favositidae occur here and there, such as *Emmonsia emmonsi* (Rominger), and *Favosites*

"*turbinatus*" Billings. Dominant tetracorals of the earlier sea are represented by only scattered specimens of former ubiquitous species, as *Cystiphylloides vesiculosum* (Goldfuss), and *Heliophyllum halli* Edwards and Haime. The spot light of the coral population rests in the little button-shaped *Hadrophyllum d'orbigni* Edwards and Haime, which by all odds is the most abundant and distinctive coral in the formation. The species is not restricted to the Delaware limestone, but is also represented in zone H of the Columbus limestone. Its peak of development, however, is in zone L of the Delaware which is commonly spoken of as the *Hadrophyllum d'orbigni* zone because of the great profusion of this coral species here. This zone is also Bone Bed 3 of the Middle Devonian limestone series, a thanatocoenose assembly of mostly microscopic organisms such as small teeth, plates, and spines of fresh water fishes, marine ostracodes and conodonts, and plant spores. It is believed this little coral flourished in the sandy bottom close to shore rather than in the calcareous oozes of the deeper water.

Gone too is most of the rich stromatoporoid fauna of Columbus times. This is to be expected because stromatoporoids occur most commonly in association with coral reefs, and next to corals are probably the most important reef-forming organisms in the clear seas of the Silurian and Devonian periods. Their association with corals is best exemplified in the Columbus area in zone C of the Columbus limestone where large masses of rock are almost completely made up of them.

Of other clear-water sedentary invertebrates, such as blastoids and crinoids, apparently few had the fortitude to survive the turbid, stale environment of the Delaware seas. There is no evidence of the blastoid *Nucleocrinus verneuili* which survived to the very end of Columbus time, and which serves as an excellent index marker for zone H of the uppermost Columbus. Although a couple of species of the crinoid *Dolatocrinus* have been reported from the Delaware, crinoidal remains are commonly found only as frgamental plates and stems, concentrated in thin layers, particularly in the bone bed assemblages.

Of the Mollusca, gastropods and cephalopods are notably diminished from the Columbus. The gastropod population is decreased in species to possibly only one-sixth of the rich representation in the lower, calcareous limestone. Of those remaining the most common are the spiny Platycerids, which evidently accustomed themselves best to the changed environment. Some of the upper Columbus species still persisting into this higher horizon are *Platyceras* (*Platyceras*) *carinatum* Hall, *P.* (*Platyceras*) *dumosum* Conrad, and *P.* (*Platyceras*) *erectum* (Hall). The association of the Platycerids with crinoidal remains is found in restricted instances (Wells, 1947, 1. 120), but not to the extent of their development in the upper part of the Columbus.

The almost complete disappearance of the great exogastric brevicones of the lower limestone, and of most of the gyroceracones marks another significant change in the fauna. Of the latter, *Neadyceras contractum* Flower, and *Nassausoceras? ohioensis* Flower, are almost the sole representatives of this fast dwindling race. The Orthoceracones likewise have been reduced to a mere remnant of their former importance, and occasional specimens of *Michelinoceras? eriense* (Hall), and *M. ? ohioense* (Hall) are the most likely ones to be found.

Trilobites too have made a rapid exit from the scene, and careful collecting is rewarded usually by only an occasional example. In the general Sandusky area the two most common trilobites have commonly been identified with *Phacops rana* (Green), and *Proetus rowi* (Green). More recently Stumm (1953, p. 13) has recognized two species of the family Proetidae in northcentral Ohio: *Dechenella* (*Basidechenella*) *eriensis* Stumm, and *D.* (*Basidechenella*) *rowi sanduskiensis* Stumm. This latter subspecies name doubtless should replace the earlier, more casual identification with *Proetus rowi* of the Marcellus shale of New York. Whether this holds true in central Ohio, where only occasional poorly preserved and mostly unidentifiable fragmentary proetic material has been seen, is not definitely known at present. *Phacops rana* is a common Hamilton species in the eastern and central states.

A glance at a list of Delaware limestone species shows the fauna to be dominantly one of brachiopods, with pelecypods following next in point of species. The two groups together comprise more than half of the macrofossil invertebrates reported from the formation. Between 50 and 60 species of brachiopods have been recognized, and about 20 species of pelecypods. The brachiopod fauna then is of first consequence in the fossil picture of the formation.

One of the outstanding aspects of the brachiopods is their concentration in layers, usually a great abundance of individuals for any given species. In all zones of the formation they are the most abundant fossils in point of species. Much of the fauna is reminiscent of the Columbus below, and many species have persisted into this higher horizon with little or no change. Some examples of these long-ranging forms are: *Atrypa "reticularis"* (Linnaeus), *Chonetes mucronatus* Hall, *Leptaena rhomboidalis* (Wilckens), *Pholidostrophia iowaensis* (Owen), *Productella spinulicosta* Hall, and certain of the *Stropheodonidae* such as *Stropheodonta demissa* (Conrad), *Protoleptostrophia perplana* (Conrad), and *Megastrophia hemispherica* (Hall).

However the decline in the spiriferids is notable, particularly those of recognized Onondaga age. Few of the Columbus types persist and the absence of striking species such as *Paraspirifer acuminatus* (Conrad), and *Brevispirifer gregarius* (Clapp) is one of the significant changes. Many new forms appear having a Hamilton cast. Some of these are *Mucrospirifer consobrinus* (d'Orbigny), *M. mucronatus* (Conrad), *Brachyspirifer audaculus* (Conrad), *Brevispirifer lucasensis* (Stauffer), and *Cyrtina hamiltonensis* (Hall). *M. consobrinus* is probably the most abundant of these species in the exposures around Columbus. *Brevispirifer lucasensis* has been recognized only in the northern part of the central belt.

Other brachiopod species of Hamilton age are: *Ambocoelia umbonata* (Conrad), *Chonetes coronatus* (Conrad), and *C. scitulus* Hall.

Pelecypods, like brachiopods, seem to have flourished in the advancing Delaware seas. A few of the species indigenous to the Columbus limestone still persist, but the appearance of new migrant types heralds the arrival and development of a new generation of species common to rocks of Hamilton age almost everywhere in the eastern and east-central states. Among the more common and characteristic Columbus forms that still remain but with sparse representation are: *Concardium cuneus* (Conrad) and *Paracyclas proavia* (Goldfuss). Hamilton age forms are recognized in such species as: *Pterinopecten* (*Pseudaviculopecten*) *princeps* (Conrad), *Glyptodesma erectum* (Conrad), *Grammysia bisulcata* (Conrad), *Paracyclas lirata* (Conrad), *Sphenotus cuneatus* (Conrad), and *Cypricardella tenuistriata* (Hall). The concentration of many individuals of *Grammysia bisculata* in zone K was remarked upon by Stauffer (1909, p. 30) and prompted Wells (1947, p. 121) to define it as the "zone of *Grammysia bisulcata.*"

Throughout the whole of the central belt of the Delaware formation in Ohio there seems to be a similarity in the distribution of pelecypod species. The species best represented appear to be *Glyptodesma erectum* and *Grammysia bisulcata*, particularly in the central region. They have never been found in the Bellefontaine outlier where the Delaware is believed to be absent.

In addition to the foregoing fossils, as previously mentioned, zone L (Bone Bed 3) has a wealth of microscopic fossils throughout the central region where it is exposed. A large fish fauna of 25 species was described by Wells (1944). Before this at least 15 species of fish had been described from the entire formation by Newberry and others. More recent studies by Stewart (1950) has revealed the presence of approximately 20 species of ostracodes in this bone bed which seem to have their closest affiliation with faunas of the Jeffersonville limestone of Kentucky, and with formations of Hamilton age at other localities. A considerable

conodont fauna has also been recovered which is represented almost exclusively by the Icriodids and Polygnathids, and which bears a surprising resemblance to the conodont fauna in the Olentangy shale above.

Fauna of the Dundee ("Columbus") Limestone

At first glance a list of fossil species from the Dundee ("Columbus") limestone of northwestern Ohio suggests a close resemblance to those of the Columbus limestone of the central area (table 4). Stauffer (1909, p. 182) remarked "The fauna of the Columbus limestone is essentially the same as in central Ohio. Only one, and possibly two species were obtained in the northwestern region which were not found to the east of the anticline." The writer, however, has not found such striking similarity in the faunas in the two areas. It is true that there are a considerable number of species in common, but many of these are forms that range through rocks of Onondaga and Hamilton age in New York State and other eastern areas.

Most of the fossils in the Dundee are to be found in the upper, more calcareous half of the formation. Certain layers are very fossiliferous, and these together with the changing lithology are very useful in zonation of the rocks. The lower half of the limestone, about 30 ft., is much more dolomitic in character, and fossil zones are much more infrequent. The only one of much consequence is a 1′ 3″ cherty, dolomitic limestone layer. The chert nodules in the limestone are quite fossiliferous, and contain a brachiopod fauna, some species of which have not been recognized in the formation before. The pteropod, *Tentaculities scalariformis* is especially abundant, and there are many ostracods described recently by Kesling (1954).

The accompanying list of fossils from the Dundee limestone (table 4) shows 103 species reported by various workers. However, only 60 which can be identified with reasonable accuracy, have been recognized in the collections which have formed the basis for this study. This includes the ostracods of Kesling which the writer has not examined personally, but has recognized as being present in the chert layers.

It will be noted immediately that this list falls far below the number of species reported from the Columbus limestone throughout the whole of the central belt. This may be explained partly by the fact that there are few natural outcrops in the northwestern area, and rock exposures of any extent are restricted to quarry excavations which are fewer than east of the anticline. But more important still the rich coral fauna of zone C and the highly diversified gastropod fauna of zone D, have no counterpart in the Dundee faunas. In addition the formation is at least 25 ft. thinner than the Columbus limestone.

As is true of the Columbus limestone the predominance of brachiopods species is the most notable feature of the Dundee. This is by no means true in abundance of individuals though, and in many instances a few meagre specimens seem to be the rule rather than the exception, whereas the same species in the central belt may be represented in most occurrences by a wealth of individuals. Forty-six species are included in the list presented here, 20 of which were reported by Stauffer and others, but were not collected or seen during the course of this study. Part of this discrepancy lies in the fact that the boundary between the Traverse and the Dundee as established by Stauffer is not generally accepted now, and the lower 4½ ft. of his Traverse at Whitehouse is included now in the upper Dundee as well as the equivalent 12 ft. now exposed in the Silica quarries. Therefore certain species such as *Cyrtina alpenensis* Hall and *Cyrtina hamiltonensis* (Hall) reported by him from these layers as Traverse, are recognized now as Dundee. The former species is common in the Traverse formation of Michigan, but only a few specimens of evidently identical specific features have been recognized in zones 7 and 10 of the Whitehouse quarries. A great abundance of *Cyrtinas* are

concentrated in zone 8 at the Whitehouse quarries, but these are believed to be more nearly related to *Cyrtina umbonata* (Hall) and are so regarded in this report. This species is believed to have a middle Devonian distribution.

There is no comparable development of *Cyrtinas* in the Columbus limestone east of the anticline. *Crytina hamiltonenesis* has been reported from both the Columbus and the Delaware limestones, but it is questionable whether the species in the two formations are identical. It is of frequent occurrence in zones G and H of the Columbus limestone, but never abundant.

On the other hand *Chonetes coronatus* Conrad, a typical widespread Hamilton species was reported by Stauffer from the Traverse only, but is recognized in this paper as extending down into the upper Dundee, but sparingly so. The great development of this species is in the Blue limestone of the Silica formation, the lower part of which is usually spoken of as the *Chonetes* zone. It is recognized also in the Delaware and Olentangy formations of central Ohio, but only by occasional specimens.

The atrypids are represented by species typical of the Dundee further north. *Atrypa costata* Bassett, which is more or less common throughout all the Upper Dundee, has been recognized in all the quarry outcrops of the present report, and *Atrypa elegans* Grabau in the upper part of the lower Dundee (zone 3 of Ehlers et al., 1951). It is probable that most of the specimens referred to *A. spinosa* Hall by Stauffer and others are more correctly identified with the first named species. *Atrypa elegans* has also been reported from the Delaware of Central Ohio although the writer has not collected any specimens of this species, nor has she seen any that might be referred to it. *Atrypa "reticularis"* (Linnaeus) previously reported from both Dundee and lower Traverse may include more than one unnamed species. Some specimens from zone 10 of the Whitehouse quarry probably represent still another undescribed form. They are closest to *A. spinosa* but have finer plications and more pronounced shoulders.

The Spiriferid population of the Dundee limestone is a mere shadow of the wealth of species and individuals in the Columbus limestone. The typical upper Onondaga *Paraspirifer acuminatus* so common in zone H, has not been recognized in the present study although Stauffer (1909, p. 148, 1551) reported it from the Dundee limestone along Tenmile Creek, and at Silica. Another typical Columbus species of zone H that is missing is *Spirifer duodenarius* (Hall). *Brevispirifer gregarius* (Clapp) is questionably present. It has been succeeded by a closely related species *Brevispirifer lucasensis* (Stauffer), found also in the Dundee of Michigan, and the Delaware limestone of central and northcentral Ohio. This is undoubtedly the most characteristic of the Dundee spirifers. *Brachyspirifer audaculus* (Conrad) a Hamilton species, is questionably identified by two or three incomplete specimens. It is recognized in the Delaware limestone of the central district.

The prevalence of *Pholidstrophia nacrea* (Hall) is notable, particularly in the Silica and Whitehouse outcrops, but specimens are not too numerous. Specimens from both Columbus and Delaware limestones in central Ohio are certainly similar, and there seems to be no valid reason not to identify them with this Hamilton species.

Productella spinulicosta Hall, has a similar stratigraphic and areal distribution, as *Pholidstrophia nacrea*, but is present in much greater abundance in the Dundee limestone. It is especially common in zones 4 and 6 at the Silica quarry, where the former zone is commonly referred to as the *Productella* zone. In the correlative zones 8 and 10 at Whitehouse, abundance of individuals is not so pronounced. Ehlers et al (1951, p. 17) notes that this species is the most characteristic fossil of the uppermost unit in the Silica quarries. It is likewise well represented in the Dundee of Michigan. *Productella spinulicosta* is regarded as a Hamilton species, although certainly I can find no appreciable difference between the Dundee form

TABLE 4

Dundee ("Columbus Limestone") fossils of northwestern Ohio and their distribution elsewhere in the state

Total list of species reported from Northwestern Ohio	Species from northwestern Ohio recognized in this report								Species reported by Stauffer (1909)	Species in Dundee of Michigan	N. Central and Central Ohio		Bellefontaine Outlier Columbus limestone
	Silica		Whitehouse			Ryan							
	4	6	7	8	10	3	4, 6	Total			Columbus limestone	Delaware limestone	
PLANTS													
Eutrochiliscus devonicus (Wieland)		X					X	X	X		X		X
STROMATOPOROIDEA													
Clathrodictyon ponderosum (Nicholson)	X				X			X	X		X		X
Clathrodictyon undulatum Parks		X						X					
Syringostroma densa Nicholson						X		X	X		X		
ANTHOZOA													
Bethanyphyllum sp.						X	X	X					
Coenites roemeri (Billings)					X			X			X		
Coenites tela (Davis)									X		X		
Cystiphylloides "americanus" (Edwards and Haime)	X					X		X			X		
Emmonsia emmonsi (Rominger)									X		X	?	X
Favosites polymorphus Goldfuss									X				
Favosites "turbinatus" Billings	X		X		X	X	X	X	X	X	X	X	X
Heliophyllum halli Edwards and Haime			X				X	X			X	X	
Heterophrentis prolifica (Billings)					X			X		X	X		
Hexagonaria anna (Whitfield)			X					X		X			X
Hexagonaria prisma (Lang and Smith)									X		X		
Hexagonaria tabulata Stumm					X		X	X		X			
Siphonophrentis gigantea (Rafinesque)			X[6]					X	?				
Zaphrentis phyrgia Rafinesque and Clifford	X	X	X[6]		X	X		X	X		X		X
Zaphrentis spp.									X				
CRINOIDEA													
Dolatocrinus sp.		X						X	X		X	X	
Crinoid fragments	X	X		X	X			X	X		X	X	X
BLASTOIDEA													
Nucleocrinus verneuili (Troost)									X		X		
BRYOZOA													
Fenestrellina spp.			X	X			X	X	X		X	X	
Monotrypa tenuis (Hall)									X		X		
Monotrypa sp.	X	X		X		X		X	X		X	X	
Paleochara sp.	X	X	X	X				X					
Sulcoretepora gilberti (Meek)	X	X	X	X				X	X	X	X	X	X
BRACHIOPODA													
Amphigenia elongata (Vanuxem)									X		X		X
Athyris vittata Hall				X				X					
Athyris vittata indianensis Stauffer									X		X		
Atrypa costata Bassett	X	X	X	X	X	X	X	X	X	X		X	
*Atrypa elegans grabau										X			
Atrypa "reticularis" (Linnaeus)									X		X	X	X
Atrypa sp. (undet.)					X	X	X	X					
Brachyspirifer audaculus (Conrad)		X						X				X	
Brachyspirifer manni (Hall)	X		X	X				X	X	X	X		
Brevispirifer gregarius (Clapp)				X				X	X		X		X
Brevispirifer lucasensis (Stauffer)	X		X	X				X		X		X	
Camarotoechia billingsi Hall									X		X	X	
Camarotoechia sp.							X	X					
Chonetes arcuatus Hall									X		X		X
Chonetes coronatus Conrad			X		?			X				X	X
Chonetes hemisphericus Hall									X		X		
Chonetes mucronatus (Hall)				?		?		?	X		X	X	X
Chonetes scitulus Hall									X			X	
Chonetes sp.									X				
Cryptonella lens Hall									X		X		
Cyrtina alpenensis Hall									X				
Cyrtina hamiltonensis (Hall)									X		X	X	X
Cyrtina umbonata (Hall)	X	X		X	X	X	X	X					
Cyrtospirifer ? grieri (Hall)		X						X	?	aff.	X		
Douvillina inaequistriata (Conrad)	X							X					
Eunella lincklaeni Hall									X		X	X	X
Megastrophia hemispherica (Hall)	X	X	X	X	X			X	X	aff.	X		X
Megastrophia inequiradiata (Hall)			X	X	X			X	X		X		X
Mucrospirifer varicosus (Hall)	X								X		X		
Mucrospirifer n. sp.					X	X		X					
Nucleospira concinna Hall						X		X	X		X		
Orthothetis pandora (Billings)									X		X	X	X
Paraspirifer acuminatus (Conrad)									X		X		
Pentamerella arata (Conrad)									X		X		X

TABLE 4—(Continued)

Total list of species reported from Northwestern Ohio	Species from northwestern Ohio recognized in this report								Species reported by Stauffer (1909)	Species in Dundee of Michigan	N. Central and Central Ohio		Bellefontaine Outlier Columbus limestone
	Silica		Whitehouse			Ryan							
	4	6	7	8	10	3	4, 6	Total			Columbus limestone	Delaware limestone	
BRACHIOPODA (continued)													
Pholidops patina Hall and Clark									X		X		
Pholidostrophia nacrea (Hall)	X	X	X	X		X		X	X	X	X	X	X
Productella spinulicosta Hall	X	X	X	X		X	X	X	X	X	X	X	
Protoleptostrophia perplana (Conrad)		X	X					X	X	X	X	X	X
Rhipidomella cyclas Hall									X				
Rhipidomella vanuxemi Hall		X						X	X		X	X	X
Rhipidomella variabilis Grabau	X							X		X			
Schizophoria foleyi Bassett	X							X		X			
Schizophoria propinque Hall									X		X		
Schuchertella n. sp.					X			X					
Spinocyrtia granulosa (Conrad)							?	?					
"Spirifer" segmentum Hall									X		X		
"Spirifer sp."							X	X	X				X
Strophеodonta demissa (Conrad)	?							?	X	aff.	X	X	X
Strophеodonta sp. (probably n. sp.)	X	X						X	X				
Strophonella ampla Hall							?	?	X		X		X
PELECYPODA													
Actinodesna occidentale (Hall)	X		X					X	X	X	X		X
Actinopteria boydi (Conrad)									X		X		X
Aviculopecten sp.									X				
Conocardium cuneus (Conrad)	X	X	X	X	X			X	X		X		X
Conocardium subtrigonale d'Orbigny	X	X						X		X	X		
Cornellites flabella (Conrad)					X			X	X	X	X		
Limoptera macroptera (Conrad)		X						X			X		
Limoptera pauperata Hall									X				
Modiomorpha concentrica (Conrad)									X		X		X
Panenka alternata Hall									X		X		
Paracydas proavia (Goldfuss)	X	X	X	X	X	X		X	X	X	X	X	
Schizodus sp.									X				
GASTROPODA													
Bellerephon pelops Hall	?							?			X	?	X
Elasmonema bellatulum (Hall)		X						X			X		X
Elasmonema lichas (Hall)					X			X	X		X		X
Isonema humile Meek	?							?	X		X		
Loxonema robustum Hall									?		X		
Mourlonia arata (Hall)									X				
Mourlonia lucina (Hall)			X	X				X	X		X		X
Murchisonia desiderate Hall									X		X		X
Murchisonia sp.									X				
Platyceras (Platyceras) carinatum Hall									X	X	X	X	
Platyceras (Platyceras) dumosum Hall	X							X	X	X	X	X	X
Platyceras (Platyceras) keoughi Bassett		X						X		X			
Platyceras sp.									X				
Pleuronotus decewi (Billings)	X			X	X			X	X	X	X		X
Trochonema meekanum Miller									X		X		X
PTEROPODA													
Coleolus tenuicinctus (Hall)	?							?	X	cf.			X
Tentaculites scalariformis Hall	X							X	X	X	X	X	X
CEPHALOPODA													
Acleistoceras eximium (Hall)	?	X						X			X		
Michelinoceras eriense (Hall)					X			X				X	
Michelinoceras ohioensis (Hall)		X						X	X	X	X		
OSTRACODA*													
Barychilina periptyches Kesling	X							X					
Dizygopleura compsa Kesling	X							X					
Endolophia chariessa Kesling	X							X					
Hollinella variopapillata Kesling	X							X					
Octonaria sp.	X							X					
Trypetera barathrota Kesling	X							X					
TRILOBITA													
Coronura sp.						X		X					
Dechenella (Dechenella) planimarginata (Meek)	X	X	X					X	X	X			
Dechenella (Basidechenella) rowi (Green)									X		X	X	X
Phacops cristata Hall			X					X	X		X		X
Proetus (Crassiproetus) crassimarginatus Hall								X	X		X		X
PISCES													
Dipterus eastmani Stauffer			-			X		X	X				

*In lower Dundee (Zone 3 of Ehlers) at Silica. †Zone 4 of Kesling (1954).

and those that we commonly identify with the species in the Columbus limestone. Biozonal development however is not apparent in the latter formation, and specimens are found scattered through it and in the Delaware above.

Of the Strophomenacea there is a notable decrease of several species which are remarkably well developed in the central belt. Of particular note are the large and distinctive forms of *Megastrophia hemispherica* (Hall), and *Strophonella ampla* Hall. Specimens from the Dundee limestone studied by the writer are only questionably referred to these species, and for more accurate determination more and better preserved material is necessary. The genus *Megastrophia* appears in much greater abundance in the basal blue limestone of the Silica formation above, as well as associated species of *Protoleptostrophia* which are very common.

As compared with Central Ohio one of the most striking omissions from this northwestern fauna is *Leptaena rhomboidales* (Wilckens). Because of its wide range through Silurian and Devonian rocks the species is considered to have little stratigraphic value. But certainly its absence from rocks believed to be comparable in age to the Delaware of the central section where it is such an abundant species is surprising. Not even a straggler has been reported from the Dundee further north in Michigan.

Mollusca are represented by gastropods (including pteropods), pelecypods, and cephalopods, in that order of abundance as to species, and next to brachiopods probably make up the largest bulk of the fauna. Again, however, there is nothing even approaching the notable development of this phylum in the central area, and identifications are based for the most part on fragmentary and imperfect material. Identification of the few spiny platycerids that have been observed with *Platyceras* (*Platyceras*) *carinatum* Hall, *P.* (*Platyceras*) *dumosum* Hall, and *P.* (*Platyceras*) *keoughi* Bassett, are believed to be reasonably correct. The first two species are common Columbus limestone forms, and all three are recognized in the Dundee of Michigan. *Mourlonia lucina* (Hall), and *Pleuronotus decewi* (Billings) have been identified, not too confidently, from a few steinkern fillings which show nothing of the external features. Several specimens of *Elasmonema lichas* (Hall) from zone 10 of the Whitehouse quarry appear to be typical of the species. These gastropods apparently represent lingering elements of the flourishing hosts of the earlier Columbus seas.

The persistence of the pteropod *Tentaculites scalariformis* Hall and its relative abundance in the nodular chert layers of unit 4 (Ehlers, 1951) suggests the middle Devonian age of the Dundee. The specimens are a little more delicate in character than those of the Columbus and Delaware limestones, and have the surface features excellently preserved in the chalky matrix of the chert. Associated are some small specimens of what I believe to be *Coleolus tenuicinctus* (Hall), generally recognized as of Hamilton and upper Devonian age.

Only 6 Pelecypod species have been identified by me with a reasonable degree of assurance. Of these, two species which are most conspicuous in the Columbus limestone are also the most commonly occurring ones in the Dundee, but are not nearly so abundant: *Conocardium cuneus* is present in both the Silica and Whitehouse exposures, being most abundant in zone 7 at Whitehouse. Bassett (1935, p. 441) identified the species in these places as *C. subtrigonale* d'Obrigny, but it certainly appears identical with *C. cuneus* of the central Ohio area. Two or three small specimens from zone 4, Silica, are being referred doubtfully to *C. subtrigonale.* The presence of this species in the Dundee of Michigan is questioned by LaRocque (1950, p. 320) since it has been identified there only in drift material. *C. cuenus* is a long-ranging Devonian species from Oriskany through Hamilton. In central Ohio it is found in all zones of the Columbus limestone except A, and continues much less sparingly into the Delaware limestone above.

There seems to be little doubt but that specimens of *Paracyclas* in the Dundee of northwestern Ohio are conspecific with those in Michigan, and therefore I am

referring them to *Paracyclas proavia* (Goldfuss). They appear to be identical with those in central Ohio identified as *P. elliptica* Hall. Since uncertainties exist concerning the validity of Hall's type, and the similarity if not identity of the two species is probable, LaRocque (1950, p. 310) concluded that most of the specimens in the middle Devonian rocks in North America probably should be referred to *P. proavia.* One large specimen collected from zone 7, Whitehouse quarry, may belong in a different species.

The remaining species of pelecypods are represented by very few specimens. *Actinodesma occidentale* (Hall) has been identified from zone 4 at Silica, and zone 7 at Whitehouse. It is also represented in the Dundee limestone in southeastern Michigan.

The large and striking cephalopod fauna of the Columbus limestone is reduced to a few insignificant fragmentary specimens in the Dundee. The identifications of the three species included in the general list has been made with reservation, and therefore has little or no stratigraphic significance.

The corals likewise have dropped to a minor position compared with the remarkably rich assemblage of the Columbus limestone. Only 8 species are here reported from the Dundee as of reasonably accurate identification. Interestingly enough however the "Blue limestone" member of the Silica formation above carries a relatively rich coral fauna, and corals are by no means unimportant in the shale phase of the formation. The common reef building *Favositidae* of the Onondaga seas have declined almost to the vanishing point in the Dundee. The only species which seems to be common is the long-ranging *Favosites turbinatus* Billings, which likewise is recognized in Michigan rocks of similar age, and in the middle Devonian limestones of the central belt in Ohio. It is present in the basal zone of the Upper Dundee at Whitehouse and at Silica and is better represented in the basal blue limestone unit of the Silica formation above. The identification of this low, basin-shaped type of coral, with this common middle Devonian species in all these occurrences may be open to question.

No species of the genus *Emmonsia*, so common in the Columbus limestone, have been observed during the progress of this study. *E. emmonsi*, however, is being included since Stauffer (1909, p. 150) reported it from the upper part of his "Columbus" limestone in the Whitehouse quarries.

Perhaps the most distinctive feature of the Dundee corals is the tetracoral *Hexagonaria*, which is represented by at least two species, *H. anna* and *H. tabulata.* These extend upward into the "Blue limestone," where the genus appears to reach its maximum development with 4 species and one subspecies (Stumm, 1948). *Hexagonaria anna*, and *H. tabulata* are found in the Dundee of Michigan, but have not been reported from a lower stratigraphic horizon any place.

As previously mentioned, apart from the striking development of *Hexagonaria prisma* (Lang and Smith) in zone H of the Columbus limestone in the Franklin County region, little evidence of this coral east of the anticline has been observed by the writer. However, Stumm (1948, p. 15, 26) reported two additional species from the Columbus limestone in both central and northcentral Ohio, i.e., *H. ovoidea* (Davis), and *H. curta* Stumm, and one, *Hexagonaria* sp. cf. *H. prisma*, from the Delaware limestone of the northcentral area. If these additional species are valid, a restudy of the Franklin County forms should be made to conform with these more recent interpretations. It is a matter of consequence that *H. prisma* has not been recognized stratigraphically above rocks of Onesquethaw age, i.e., Columbus limestone, Onondaga limestone, and Jeffersonville limestone.

Most of the remaining corals are the more common long-ranging tetracorals, and in all cases very few specimens have been found. The family *Cystiphylloidea* is represented by a single species, *Cystiphylloides "americanus"* (Edwards and Haime), of which only about half a dozen specimens have come under observation from the Silica and Ryan quarry exposures. This species which ranges throughout

rocks of Onondaga to Hamilton age in all the eastern United States is a very common fossil in the Columbus limestone of the Columbus area, particularly in zone H where small individuals occur in a silicified condition along joint surfaces.

Likewise *Heliophyllum "halli"* Edwards and Haime occurs very meagerly in the Dundee limestone, and only three or four typical specimens have been observed. The long, cylindrical type of individual, so common in the Columbus limestone biostrome, has not been recognized. *Heterophrentus prolifica* (Billings) is a more common form, and a few good specimens have been collected from the Whitehouse quarry. The genus has a much greater development in the Silica formation above. The species is likewise recognized in the Dundee of Michigan.

The almost total absence of *Siphonophrentis gigantea* (Rafinesque) is another striking difference from the Columbus limestone, where this largest of all the solitary tetracorals is abundant and widespread throughout all of the central area.

A few specimens are referred with some question to *Zaphrentis phrygia* Rafinesque and Clifford, one of the most common of the Columbus limestone corals, and especially characteristic of zone H. Likewise the prolific *Cystiphylloides "americanus"* of the Columbus has a scant record in the Dundee, and none at all in the Dundee of Michigan or the Delaware limestone.

Judging from the sparce echinoderm remains, there were no flourishing colonies of them in the Dundee seas. During the progress of this study no specimens of blastoids have been observed by me. The species *Nucleocrinus verneuili* (Troost) is included in table 4 because Stauffer (1909) listed it from the "Columbus limestone," although he himself did not collect it. However it is reasonable to expect this common Devonian genus to be represented, especially since it is in the Silica formation above. Kier (1952) recognized one specimen from unit 13 of the Silica shale which he provisionally identified as *Nucleocrinus* sp. cf. *N. elegans* Conrad. In addition he described a new species of the family Pentremitidae, i.e., *Pentremitidea reimanni* from the same beds. To my knowledge this is the first time the genus *Pentremitidea* has been reported from Devonian rocks in the State.

Crinoidal fragments have been collected but are confined almost exclusively to columnal plates. One fragmentary calyx was obtained from the highest unit of the Dundee limestone in the Silica quarries which has been tentatively identified as *Dolatocrinus* sp. In contrast unit 13 of the Silica shale above carries a remarkably well preserved crinoid fauna, some species of which were originally described by me (Stewart 1927), but additional ones including 4 genera, 3 of which are new, and 5 new species were described by Kier (1952).

At times bryozoa flourished in the Dundee sea, and living conditions probably simulated pretty much the same as those for the Delaware in the central area. Their remains occur in diminished distribution and abundance over the Columbus limestone fauna. The order Cryptostomata still prevails but the broad, fan-like fronds of the Fenestrellinidae are much less in evidence, and much more conspicuous are the ramose, branching forms as exemplified in the genus *Sulcoretepora*. Species of this genus are commonly referred to the widely recognized Onondaga form *S. gilberti* (Meek), which is likewise reported from the Dundee of Michigan, and from both the Columbus and Delaware limestones in the central belt. Because of the rather notable concentration of bryozoa in zone 4 of the Dundee at the Silica quarries, and the correlative zone 8 at the Whitehouse quarry, this zone is commonly referred to as the "bryozoa zone." Trepostomatous bryozoa are likewise well represented in this zone by headlike masses of the genus *Monotrypa* or an allied form. The majority of the bryozoa though, are in the Silica formation, where they occupy a much more important role in the total fauna than in the Dundee below.

Recent studies of Kesling (1954) have revealed an interesting ostracode assemblage in unit 4 of the Dundee limestone (Ehlers et al. 1951, p. 18) exposed by the quarrying operations of the France Stone Company, just west of Sylvania Avenue

near Silica. No ostracodes have been described from the Dundee limestone in Ohio before although they were known to be present. The specimens are all from the weathered chert nodules and layers, and Kesling describes them as being incompletely silicified, with complete carapaces, in many cases exhibiting fine details of surface structure. Details of this structure are beautifully shown in the three plates of illustrations in his publication.

The fauna is not large, 6 genera and 5 species, but is distinctive because 2 of the genera and all of the species are new. The new genera are *Endolophia* and *Trypetera*, and the previously described ones are *Garychilina*, *Dizygopleura*, *Hollinella*, and *Octonaria*, all long-ranging Paleozoic forms.

This fauna does not seem to have a counterpart in rocks of similar age in any other part of Ohio, but the closest approach is in the ostracodes that have been found in Bone Bed No. 3 of the Delaware limestone in Franklin County. (Stewart 1950). This fauna is larger in point of genera and species, but not in individuals. Twenty-one genera and 18 species have been recognized, some of questionable identification. The specimens are ferruginous and the preservation far inferior to the Dundee material. The writer pointed out the apparent similarity between the Delaware fauna and that of the Jeffersonville limestone of Kentucky both in generic and specific content.

On the other hand the resemblance between the Delaware and Dundee faunas is not so evident. There are two genera in common, i.e., *Dizygopleura* and *Hollinella*, but no species. Each genus is represented by one named species in each formation, i.e., *D. compsa* Kesling and *H. variopapillata* Kesling from the Dundee, and *D. trisinuata* Van Pelt, and *H. kolmodini* (Jones) from the Delaware. The latter species is middle Devonian in range, and *D. trisinuata* was reported previously from the Plum Brook shale of Ohio (Stewart and Hendrix, 1945). The genus *Dizygopleura* is especially well represented in Onondaga and Hamilton age rocks in the eastern part of the United States.

Trilobite remains are few and fragmentary. Only pygidia have been observed in the course of this study, none of which is entirely complete. Four genera and 4 species of the families Proetidae and Phacopidae are listed in table 4, but the writer was able to identify only two of these in material studied.

So far as present knowledge goes the proetid types are best represented but by extremely meager remains. Three species belonging in 2 genera have been reported, but the writer is reasonably sure of the identification of only one species: *Dechenella* (*Dechenella*) *planimarginata* (Meek). The material on which the identification is based consists of pygidia: about one half dozen exfoliated specimens from zone 4 of the Silica quarry, (see table 4) incomplete external molds of two pygidia from zone 6 of the same quarry, and one exfoliated pygidium from zone 7 of the Whitehouse quarry. The species was named and described by Meek (1871, p. 89, and 1873, p. 223) from an exfoliated pygidium from the "upper part of the Corniferous group, near Sylvania, Lucas County, Ohio." Bassett (1935, p. 441) and Stumm (1953, p. 20) reported the species from the Dundee of Michigan. No other occurrence of it is known. As previously mentioned the trilobites formerly identified with *D.* (*Dechenella*) *planimarginata* from the Columbus limestone in central Ohio should be restudied and probably renamed. Stumm does not recognize the species in the northcentral region.

Stauffer (1909, p. 102) listed *Dechenella* (*Basidechenella*) *rowi* (Green) from the Dundee ("Columbus") limestone but did not collect it. Stumm in his study of the proetids did not recognize the species outside of the Marcellus formation of western New York, but described a subspecies *sanduskiensis* from the Delaware limestone of the northcentral region. *D.* (*Basidechenella*) *rowi* appears to be restricted to rocks of Hamilton age. As already mentioned many specimens in the Columbus limestone in both the central area and in the Bellefontaine outlier have in the past been identified with this species, and probably should be restudied.

On the other hand those from the Delaware limestone seem to be indistinguishable from the Marcellus forms, and it seems best to continue to identify them with *D.* (*Basidechenella*) *rowi* until such time as a more critical study of them can be made.

It is noteworthy that no specimens of the distinctive and commonly occurring *Proetus* (*Crassiproetus*) *crassimarginatus* Hall of the Columbus limestone of the central area have been recognized in any of the material which has come under survey, although Stauffer (1909, p. 151) reported it from the highest horizon of his "Columbus limestone," in the Whitehouse quarries. Bassett (1935, p. 441), listed the species from several intervals of the Dundee limestone in the Sibley quarry in southeastern Michigan, but Stumm (1953) does not recognize it there. The species is widely distributed in rocks of Oriskany and lower Middle Devonian age throughout the eastern half of the continent.

Evidence of Phacopid trilobites is scarce but identification of two genera seems reasonably certain: *Coronura* and *Phacops*. The only record of *Coronura* is in zone 3 of the Ryan quarry, where a rock specimen containing the impression of a portion of the pygidium of a large-tailed trilobite has been collected. This sparse record is in striking contrast to the splendid development of the genus in the Columbus limestone in the Franklin County region where *Coronura aspectens* (Conrad) is such a common fossil. The genus is known only from Middle Devonian rocks in eastern North America, and the species is restricted to the lower half (Onesquethaw).

Zone 7 at Whitehouse has yielded a few fragmentary pygidia of *Phacops* which are assigned tentatively to *P. cristata* Hall. It is questionable whether the species extends above rocks of Onondaga age.

The poor showing of *Phacops* in the Dundee is rather surprising, since it appears in such abundance in the Silica formation above and in the Traverse of Michigan. Likewise it is well represented in the Middle Devonian limestones of the central area, where *Phacops cristata* is found distributed throughout the Columbus limestone. *Phacops rana* (Green), a Hamilton species, is recognized in the Delaware limestone and Olentangy shale. *P. cristata* has a stratigraphic range through Oriskany, Schoharie, and Onondaga rocks in New York and other eastern states.

Meager remains of fish seem to be the only evidence of vertebrate remains in the Dundee limestone. Only one described species appears in the literature: *Dipterus eastmani* Stauffer, based on one upper, dental plate, from the upper part of the Dundee ("Columbus") limestone in the Whitehouse quarry. One fragmentary specimen in our collections, undoubtedly a fish plate, was obtained from the upper Dundee in the Ryan quarry.

The paucity of fish remains is surprising when one considers that the Devonian rocks on the eastern flank of the Cincinnati anticline in Ohio are classic for their fossil fish. Newberry's famous material seems to have come exclusively from this latter region.

Bone bed accumulations such as are developed in the Columbus and Delaware limestones have no counterpart in the Dundee. Their absence is perhaps not unusual since the special conditions which produced these accumulations of organic materials probably never did exist in this region when the sediments were deposited. According to Wells (1944), the bone beds represent a thanatocoenose assemblage of fresh water fish mostly, accumulated in a shallow sea, bordering the land area of Cincinnati. Their origin is diastemic, in that they developed largely as lag concentrates where the sea bottom fluctuated above and below wave base. Since northwestern Ohio was further removed from the land area, the water would probably be deeper, and the concentration of such material would be extremely unlikely.

So far no conodonts have come to light in the Dundee limestone. They may be present but have not been recognized. The fact that in the Columbus and Delaware limestones conodonts have been recovered from the bone beds only, does not mean necessarily that they are not likely to be found in other lithologic surroundings, which after all possibly approximate more closely the natural biocoenose of the living organism.

Apart from some carbon imprints of probable plant origin, the only record of plants is in the spores of the ancient marine algal trochilisk, *Eutrochiliscus devonicus* (Wieland). Specimens have been observed and collected in two places: zone 6 of the Silica quarry, and zone 4 of the Ryan quarry where they occur in clusters associated with the brachiopod *Cyrtina*. The specimens from the Silica quarry are larger than normal for the species, and are characterized by 10 sharp, curving ridges, similar to *Eutrochiliscus bellatus*. Dr. Raymond Peck kindly inspected the specimens, and was of the opinion they should all be referred to *E. devonicus* because of the difficulty in making fine specific distinctions on the basis of the present state of knowledge on the trochilisks.

Plant spore exines of a similar nature have been reported from numerous places in the Columbus limestone, and erroneously identified as a protozoan, *Calcisphaera robusta* Williamson. Meek, however, (1873, p. 219) was the first to suggest these minute bodies might be the fruit of *Chara*.

Modern trocholisks are fresh water forms.

SUMMARY AND CONCLUSIONS

From the foregoing considerations on the stratigraphic and faunal relationships of the Middle Devonian limestone formations in Ohio it is believed the following pertinent facts have been established and are acceptable:

1. The Dundee ("Columbus") limestone of northwestern Ohio should be correlated with the Dundee of Michigan on a stratigraphic, lithologic, and paleontologic basis.
2. Stratigraphically the Ohio Dundee is a thinning southward extension of the Dundee formation of Michigan, having a maximum thickness of 61½ ft. at the Silica quarries. The thickest exposure in Michigan is about 70 ft. in the Solway Process Company's quarry, near Trenton, Wayne County.
3. Lithologically the Dundee is similar in the various exposures observed, although in Michigan the rock is generally more coarsely crystalline, while in Ohio the lower two-thirds of the formation is more dolomitic in character and contains more chert.
4. Faunas are essentially similar geographically throughout the Dundee, although by no means identical. Species limited to the Dundee or similar-age formations are: *Atrypa elegans*, Grabau, *Brevispirifer lucasensis* (Stauffer), *Rhipidomella variabilis* Grabau, and *Dechenella* (*Dechenella*) *planimarginata* (Meek).
5. The Dundee rests with disconformable contact on the Anderdon limestone of the Detroit River group, and is the approximate age of the Marcellus formation (Lower Cazenovia) of New York State, and the Delaware limestone in Ohio and southwestern Ontario. This correlation has been recognized by Cooper et al. (1942, p. 1754), and Ehlers et al. (1951, p. 26). This author is in agreement with the above interpretation.
6. Faunal similarities between the Dundee and the Delaware limestones are to be found in species common to both such as: *Brevispirifer lucasensis* (Stauffer), *Atrypa costata* Bassett, *Actinodesma occidentale* (Hall), *Paracyclas proavia* (Goldfuss), and *Tentaculties scalariformis* Hall.
7. The Columbus limestone of central Ohio rests with disconformable contact on the upper Bass Island group, and is the approximate age of the upper Onondaga limestone (upper Onesquethaw) of New York State, and the Jeffersonville limestone of southeastern Indiana and northern Kentucky.
8. The formations listed in item 7 above have many species in common. Characteristic forms are: *Hexagonaria prisma* (Lang and Smith), *Zaphrentis phrygia* Rafinesque and Clifford, *Siphonophrentis gigantea* (Lesueur), *Brevispirifer*

gregarious (Clapp), *Paraspirifer acuminatus* (Conrad), *Nucleocrinus verneuili* (Troost), *Phacops cristata* Hall, and *Coronura aspectens* (Conrad). These species are either missing or questionably present in the Dundee of northwestern Ohio.

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