THE CUYAHOGA SHALE AND THE PROBLEM OF THE OHIO WAVERLY.

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INTRODUCTION.

It is not my purpose to enter into a discussion of the opinions which have from time to time been advanced with reference to the age and homologies of the so-called Waverly formation of Ohio. This has been done *in extenso* by A. Winchell* and by Newberry and Orton in the various reports of the Ohio Geological Survey.

Neither is it necessary to repeat in detail the reasons for regarding the Waverly as a highly composite (and hence unnatural) rather than a simple element in the series, for it is hoped that the paleontological and stratigraphical evidence presented in the papers published in the Bulletin of Denison University, the American Geologist and elsewhere by the writer and his associates during the last few years may serve to sufficiently demonstrate this. The study has been so prolonged and minute that its results

*Proc. American Philosophical Society, vol. XI, 1870. pp. 385-416.

may be relied upon to justify the statement, once for all, that at least three well-marked divisions must be recognized in the Ohio Waverly. These divisions must always rest chiefly upon paleontological evidence, although, their approximate limits are formed by two bands of conglomerate which apparently represent periods of exceptionally rapid oscillation.

To us the great interest centering in a careful paleontological study of the Waverly lies in the fact that the disturbances referred to were neither violent nor extensive enough to seriously interfere with the peaceful evolution of types. From the end of the Corniferous to the beginning of the Coal Measures in Ohio a quiet, shallow sea was the rule and local fluctuations or perturbations the exception. The result of this long period of quiet is a marvelous record of the slow changes in life which bridges over the interval between mid-Devonian and early Carboniferous times. Although the number of species found in any one horizon is, with perhaps two exceptions, rather small, the aggregate in the Waverly is considerable. Should an attempt be made to collate all species reported from Ohio a considerable allowance would certainly need to be made for duplication, while, on the other hand, it is certain that the resources of our Ohio fauna are by no means exhausted.

The proper way to contribute to the ultimate elimination of the disturbance and ambiguity introduced by the vague descriptions and meager data of some of the earlier writers has seemed to be the systematic description *with figures* of such species as are actually found at the various typical exposures upon well-defined horizons. It certainly is true that in a case like the present one, in which much, nay, all, depends on the ability to recognize beyond doubt each stratigraphical horizon by means of its fossils, and in which lithological peculiarities are so nearly valueless, no pains can be excessive when applied to the correlation of local cotemporaneous faunas.

The necessity of repeating much of the work done previously grows out of the absence of figures of fossils and (worst of all) of minute data as to position, locality, etc. So long as the belief prevailed that the Waverly was essentially homogeneous, it was thought sufficient in the majority of cases to say from "the Waverly group of Ohio," "the Marshall group of Michigan," or "the Kinderhook of Illinois." This is very much as though one should locate a fossil in the "Silurian group of New York."

It is thus only that the writer hopes to apologize for having entered a field which properly belongs to the paleontologist, and very probably failing in many cases to identify the species previously described. Accordingly the effort has been made to locate every species described, both stratigraphically and geographically, so minutely that its exact position may be subsequently determined. Hence, even though changes in the nomenclature employed may be rendered necessary by reidentification of the species previously de-

described, we have ventured to hope that such changes would but slightly impair the usefulness of the attempt to refer our species to definite horizons and thus form the basis for correlation and generalization. In this attempt we have been reasonably successful and feel confident that, with a dozen species of well-preserved fossils from any given stratum, the stratigraphical position can generally be determined within a few feet.

Reference to current discussion as to the limits of the Carboniferous system may seem necessary, but in the light of recent revelations the search for a hard and fast line of demarkation between Devonian and Carboniferous seems futile. For our own part, the convenience of the time-honored nomenclature and the application of the law of priority outweigh all other considerations yet advanced, unless the whole Sub-Carboniferous group be dropped and the Paleozoic be restored to its primitive simplicity—Silurian, Devonian, Carboniferous—with only a single series of coördinate terms included in each; in which case one might let the Berea grit form the base of the Carboniferous.*

THE GENERAL STRATIGRAPHY.

About the Ohio Waverly the sequence has proved quite simple in central Ohio, but curious misapprehensions have been perpetuated up to the present moment. While Professor Andrews was the first to distinguish the great mass of shales, freestones and conglomerates previously confused with the Carboniferous conglomerate, he introduced so many elements of error that his discovery was nearly unfruitful. To Professor Orton belongs the credit of first distinctly differentiating on purely stratigraphical grounds the Cuyahoga shales from the typical Waverly of central and southern Ohio. And we may claim the task of carrying out (though quite independently) the minuter subdivision and correlation of the several horizons in the southern part of the Waverly domain. It was a great misfortune that Dr. Newberry's studies of the Waverly were so largely restricted to and based upon the northern exposures which, as we shall see, contain only a poor one-third of the series. The most recent discussion of the problems here touched upon is that contained in Professor Orton's volume VI of the reports of the Geological Survey of Ohio. It will, therefore, be convenient to summarize the results of our work by reference to that report, and it will, of course, be understood that this reference is not in the nature of criticism, but rather to facilitate comparison with the most conservative and adequate basis for an understanding of the Waverly which up to this time exists.

The Bedford Shale.—This argillaceous bed has been considered the base of the Waverly, and is so constant and, in southern and central Ohio, so dis-

* Cf. the suggestion of Professor Williams in the present volume, p. 19.

inct lithologically that, as Professor Orton says, "there is not a stratum in our geological column that can be followed across the state in more easily demonstrated identity than this."

Another statement of that author requires modification in view of our discovery (published about the same time) of abundant evidences of life in the shale. This statement is the following:

"In the lower beds of the Bedford shale fossils are, in northern Ohio, at a few points, abundant. They are of pronounced Sub-Carboniferous character, comprising *Syringothyris typa*, *Hemipronites crenistria*, *Chonetes logani*, *Orthis michelini*, *Spiriferina solidirostris*, and others of like association. None of these fossils have been reported south of the lake shore." *

In 1888 we found at Central College, near Columbus, in the lower part of the Bedford shale, an abundant fauna of evident Devonian habit, including about twenty species, at least half being closely allied to or identical with Hamilton species and with no admixture of strictly Waverly species. At the same place we traced such species as *Strophomena rhomboidalis* and *Atrypa reticularis* to a point above the Berea grit. Subsequently the same association of fossils was found in the middle Bedford of Chagrin falls, Cuyahoga valley, and elsewhere. Even in the typical locality at Bedford *Macrodon hamiltonæ*, *Microdon bellistriatus*, *Leda diversa*, *Palæoneilo constricta* and *Chonetes scitula* are found 40 feet below the Berea grit. It is true that the forms identified by Newberry, and upon which the Carboniferous age of the Bedford has been maintained, do occur associated with *Macrodon hamiltonæ*; but, so far as observed (and I think I have seen most of the specimens), they are thus associated in the bands of flags intercalated with the shale and not in the shale itself. However that may be, out of the list quoted, *Syringothyris typa* and *Spiriferina solidirostris* are the only species which could carry conviction; the others are either too widely distributed or too closely allied with Devonian types to be positively identified from crushed and imperfect specimens. As to the *Syringothyris*, after careful examination I incline to think it distinct from the species characteristic of the middle Waverly, while it is very rarely found in the shales 100 feet above the Berea. The generic assemblage also counts for nothing, for Professor James Hall has shown that *Syringothyris* is certainly not a Carboniferous genus but arises in the Devonian. Again, such well-known Devonian forms as *Strophomena rhomboidalis* and *Atrypa reticularis* rise to the summit of the Cuyahoga shale.

The lithological character of the Bedford deposits changes as it passes eastward and assimilates with that of the Erie, so that where the Cleveland shale loses its distinctive features the two merge insensibly.

While we may dissent from Professor Orton's classification of the Ohio shales in some respects, enough has been said to prove that if we are to look

* Rep. Geol. Survey of Ohio, vol. VI, 1885, p. 34.

for a definite lower boundary of the Waverly it must be found in the Berea grit, which, as so well shown by Orton, is a sharply limited and easily recognizable horizon throughout Ohio. If, however, it can be proved that the original application of the term Waverly was primarily to the Bedford shale, whatever else was also included, we are placed in an awkward predicament not wholly without parallel in the history of geological progress.

Lithologically and faunally, I repeat, the affinities of the Bedford are certainly with the underlying shales rather than the shales above the grit.

The Berea Grit.—We have nothing to add to Orton's admirable account of this distinctive bed, which forms the next element in the column, except to note the occurrence of the Devonian forms already mentioned in the upper courses and the immediately overlying shales.

The Berea Shale.—This term is conveniently applied to the thin band of bituminous shale above the grit and perhaps should not be extended (as the writer has done in a previous paper) to the gray and blue shales above. In southern Ohio it varies from fifteen to twenty feet in thickness and is little more than two feet thick at Chagrin falls. It is typically exposed in the Cuyahoga valley, but its fossils at that place extend upward to the flags which form the "Big falls of the Cuyahoga," thus justifying from the standpoint of paleontology the attempt to extend the application of the name. The fossils are mostly *Lingula* and *Discina* of several species, but *Chonetes*, *Productus* and other forms also occur.

The Cuyahoga Shale.—Using this term, in the sense in which it was employed by Professor Orton, for the 100–150 feet above the Berea shale, we here encounter one of the surprises of our study. As is well known, Dr. Newberry applied the term Cuyahoga shale to the whole series of strata filling the interval between the Berea grit and the Chester limestone. I have sufficiently shown that this use is impossible, because of the fact that at least three important formations are included and confused. In central Ohio it is easy to recognize these horizons and to determine approximately their limits. In 1888 Professor Orton, on stratigraphical grounds, determined that the entire series as exposed in the Cuyahoga valley lies below the reddish and yellowish freestones and conglomerates constituting our divisions II and III and his Logan group. He makes the natural error, however, of concluding that "as here limited it is, for the most part, very poor in fossils," suggesting that "the fossils with which the Cuyahoga shale has been credited have been largely derived from the division next to be described"—*i. e.*, the Logan group.

Until the summer of 1890 I have had little opportunity to examine carefully the exposures in Cuyahoga county, and have refrained from attempting to complete the correlation. Last summer (1889) Mr. Cooper was commissioned to examine the exposures in Richland, Wayne and Summit

counties, and extended the exact knowledge as far as Lodi and Burbank ;* but there still remained the problem of the Cuyahoga shale proper, and with the solution of this rested the raveling of the strange snarl which has so long puzzled geologists. The very simple solution of the problem suggested by Orton seemed cut off by the results of Mr. Ulrich's study of the bryozoa from Lodi, Bagdad, Richfield and other localities within the area occupied by the Cuyahoga shale. Mr. Ulrich, after describing forty-one species, finds 41 per cent. of the number identical with those identified by him from the Keokuk and Burlington of Illinois. Inasmuch as these species were known in several cases to also occur in shales only fifty feet below the Carboniferous conglomerate at Cuyahoga Falls and the large fauna at that place had not yet been studied, we felt that his conclusions had much weight, especially in view of the fact that undoubted Keokuk and Burlington strata occur in central and southern Ohio within the one hundred feet immediately below the Coal Measures.

The work of the present season has happily set the general question quite at rest, and will doubtless shed a flood of light on the affinities of the crinoids of the Cuyahoga which have caused so much discussion. Their curious resemblances to the Devonian species and the strange commingling of Carboniferous characters can no longer be regarded as abnormal. Regarding the bryozoa, it must be remembered that the Kinderhook has thus far produced few bryozoa, and the bryozoan fauna of the Chemung is yet to be discovered. At what time the Burlington bryozoa appeared and what their range in time may have been remain to be seen. A large supply of bryozoa may be found in the Keokuk and Burlington of southern Ohio, but they must be studied microscopically when the rocks are first broken open, as they are too fragile to bear transportation. The mistakes which have prevented a proper paleontological understanding of the Waverly consisted in the belief that the uppermost part of the Cuyahoga shale, the lower part of the Waverly in central and southern Ohio, and the Bedford shale are unfossiliferous.

We have been so fortunate as to discover a rich fauna within 15 feet of the conglomerate at Cuyahoga Falls and extending 50-60 feet below. This also occurs at Akron (in spite of the assurance of numerous collectors who have stated that the shales are positively barren)†. The most remarkable storehouse of fossils is derived from calcareous and ferruginous concretions containing galenite and blende. These occur 50 feet below the Millstone grit at Cuyahoga Falls and Akron. They occur at Richfield, Bagdad, Lodi, Ashland county, Moot's run, Licking county, and even in Scioto county, on the Ohio river. In short, they indicate a practically constant horizon from

* See his report, Bul. Denison Univ., vol. V, 1890, pp. 24-34.

† Professor Claypole informs me that he had also noticed this fossiliferous horizon at Akron.

the extreme northern to the southern limits of the state, which is not only constant in lithological character and in the main elements of the fauna but also in its stratigraphical relations when referred to the Berea grit as a base line, in spite of slight local modifications, which have value as representing zoological and geological stations simply. Evidence can be given on this point which is absolutely conclusive. In the first place, a careful instrumental survey has correlated the horizons stratigraphically beyond possibility of error. On these grounds alone we can positively assert that the Cuyahoga shale as represented in the northern tier of counties is identical with that part of the Waverly lying below conglomerate I—i. e., below the undoubted actual equivalent of the Kinderhook of central Ohio. The fossiliferous horizons of Granville, Newark, Rushville and Winchell's division 4 on the Ohio river are all above the top of the Cuyahoga. Mr. Cooper and myself have traced the limits of division II by means of the conglomerates and associated fossils along a line emerging from beneath the Coal Measures apparently not far from Seville, passing between Wooster and Burbank, southeast of Ashland, west of Independence, west of Granville and Newark, east of Lancaster and west of Rushville to the Ohio river near Buena Vista. But the evidence which is beyond suspicion is that derived from the fauna. The large assemblage of fossils derived from Moot's run, Licking county, is sharply distinguished from anything found in the remaining Waverly in central Ohio. Very few of these species occur elsewhere in the series. The specimens hitherto derived from the upper part of the Cuyahoga were from the shales and were curious depauperate forms baffling identification; but the recently discovered fauna of the concretions from the same horizon reveals a large series of familiar forms sharply characteristic of the Moot's run and Lodi horizon. These forms include, besides many others, the following species:

1. <i>Pterinopecten shumardianum</i> .	8. <i>Spirifer tenuispinatus</i> .
2. <i>Edmondia sulcifera</i> .	9. <i>Productus newberryi</i> .
3. <i>Phaëthonides spinosus</i> .	10. <i>Pterinopecten cariniferus</i> .
4. <i>Crenipecten cancellatus</i> .	11. <i>Athyris ashlandensis</i> .
5. <i>Proëtus præcursor</i> .	12. <i>Terebratula inconstans</i> .
6. <i>Fenestella herrickana</i> .	13. <i>Crenipecten cooperi</i> .
7. <i>Spirifer marionensis</i> .	

The Waverly Shale.—The stratum so termed by us is lithologically similar to the Cuyahoga shale, and, being confined to central Ohio and occupying a thickness of only 40 feet immediately below conglomerate I, might be ignored in our enumeration were it not for the fact that it contains a large number of species found also in Michigan and Illinois. Its fossils have been found thus far only in Licking and the adjoining counties. The term is perhaps

unfortunate, and for convenience this shale might be merged with our division II, from paleontological resemblance, though continuous with the Cuyahoga shale stratigraphically and resembling it lithologically.

The Kinderhook.—With this section (our division II) we enter the group of olive and yellowish freestones and conglomerates called by Professor Orton the Logan group. The term was originally applied to our division III, to which it should apparently be restricted.

Even Professor Orton fails to distinguish the conglomerates which in typical sections sharply limit the middle Waverly. The local thickenings in these conglomerates have caused more trouble than any other feature of the Waverly. The band of characteristic fossils lying beneath the second conglomerate, *Sanguinolites obliquus*, *Allorisma winchelli*, *Prothyris meeki*, etc., is, fortunately, very persistent and well limited, even when the conglomerate is absent, having been traced from Sciotoville to the northern exposures in Wayne county.

The Burlington and Keokuk.—These formations are in part, at least, represented by the 200 feet or so which lie beneath the Chester and are very fossiliferous in some localities. Unfortunately the beds referred to the Keokuk are usually removed by erosion and if not are seldom well exposed. They are characterized by a deep red color and a great abundance of fossils which, though often well preserved, can rarely be removed from their matrix. *Phillipsia meramecensis*, *P. serraticaudata* and *Spirifer keokuk* are among the characteristic fossils.

Summary.—The general results of our study may be summarized as follows:

1. The Berea grit is the natural floor of the series, the Bedford shale having its faunal relations decidedly with the shales of the Devonian below.
2. The Bedford affords a striking exemplification of the doctrine of colonies,* and that portion lying to the southwest beyond the western limits of the Erie retained a fauna derived from the Hamilton long after this fauna had perished to the eastward.
3. The Cuyahoga shales (including the whole series above the Berea so far as present in the Cuyahoga valley) is divisible into three minor sections, the uppermost of which is characterized by a vast abundance of fossils, which are especially well preserved in calcareous or ferruginous concretions, is a constant and almost unvarying horizon, extending from Lake Erie to the Ohio river. The Cuyahoga proper is never more than 200 feet thick, and forms a transition zone, with a prevailing Devonian habitus.
5. The upper portion of the Waverly is quite distinct from what precedes in fauna, and contains an undoubtedly lower Carboniferous assemblage.

*It is suggested by Williams that this term can only be used in a modified sense.

6. None of the larger divisions of the Carboniferous of the west are entirely unrepresented in Ohio.
7. The transition is nevertheless so gradual that we have an instructive illustration of the evolution of one age from the preceding with neither catastrophe nor annihilation.
8. There is an opportunity to trace the geographical variations in a species as distributed over a great area, and to observe the evolution of new types therefrom.
9. The entire thickness of the Waverly is not far from 700 feet, though the highest consecutive section measures only 670 feet.
10. The Cuyahoga fauna bears an unmistakable resemblance to the so-called Sub-Carboniferous of Belgium, especially that of Etage I, the limestone of Fornai.

In the present state of our knowledge of the stratigraphy of Missouri it is perhaps hazardous to attempt to parallelize Ohio and western horizons, but if, as Professor Calvin states, the Chouteau and therefore also the Lithographic limestone are faunally lower than the Kinderhook at Burlington, we may easily regard the Cuyahoga shale as the eastern equivalent of the series including these limestones, the shales included, and possibly also the shales below extending to the deep-blue shales superposed upon the Black shale which here, as elsewhere, affords a well-marked horizon.* Professor Safford offers a hint which seems to open the way for extending the generalization into Tennessee as well.

REPRESENTATIVE SECTIONS.

The following representative sections derived from the northern and southern exposures in the state, respectively, may be offered in illustration of the stratigraphical correlations suggested. The figures are all actual measurements, there being no composition of different partial sections, and are as nearly accurate as need be.

*A small *Phillipsia*, practically indistinguishable from our *P. serraticaudata*, has been received from the lower Burlington beds of Louisiana, Mo.

Cuyahoga Valley and Bedford.		Portsmouth.	
	Thickness.		Thickness.
Carboniferous conglomerate	70 ft.	Carboniferous conglomerate, fire-clay, or Chester limestone	2-10 ft.
This		Sandy freestone and reddish sandstone, with Keokuk fossils, <i>Phillipsia meramecensis</i> , etc.	35 ft.
entire			
series		Yellow or grey freestone and shales, with Burlington fossils, <i>Crenipecten crenistriatus</i> , <i>Grammysia ovata</i> , <i>Spirifer biplicatus</i> , <i>Spirifer striatiformis</i> , <i>Schizodus newarkensis</i>	200-215 ft.
is		Massive freestone, usually with some bands of conglomerate; <i>Productus arcuatus</i> (conglomerate II)	50 ft.
absent			
in the		Immediately below the conglomerate lie bluish or greenish and very soft shales, with <i>Prothyris meeki</i> , <i>Sanguinolites obliquus</i> , <i>Allorisma winchelli</i>	90 ft.
northern			
tier of		Freestone representing the quarry rock of central Ohio, containing <i>Crenipecten winchelli</i> , etc. Shales of same series.	20 ft.
counties		Freestone, the lower courses of which represent conglomerate I of central Ohio; variable in thickness; entire series	70 ft.
to the			
base			
of			
Conglomerate I.			
The fauna of this horizon is not here represented.		Shales	50 ft.
Cuyahoga shale, with <i>Spirifer marionensis</i> , <i>Phaëthonides spinosus</i> , <i>Proëtus præcursor</i> , etc.	50 ft.	Shales, with <i>Spirifer marionensis</i> , <i>Phaëthonides spinosus</i> , and many other fossils	50 ft.
Concretions with same fauna.		Flags	20 ft.
Shales	40 ft.	Concretionary shales, with <i>Productus newberryi</i> , <i>Spirifer marionensis</i> , etc. Variable in thickness.	
Flags and shales, with <i>Productus newberryi</i> , <i>Allorisma cuyahoga</i> , <i>Discina newberryi</i> , etc.	35 ft.	Flags of Buena Vista	25 ft.
Berea black shale	10-15 ft.	Berea black shale	15 ft.
Berea grit	45 ft.	Flags, Berea grit	30-40 ft.
Blue to green Bedford shale	45 ft.	Blue to green Bedford	} Thickness variable.
Flags	10 ft.	Red Bedford	
Soft fossiliferous shale	25 ft.		
Flags	10 ft.		
Cleveland shale.			

THE FAUNA OF THE CUYAHOGA SHALE.

The following list of common fossils from the Cuyahoga shale is not only very incomplete, but doubtless contains many identifications requiring verification as soon as a revision of the published species from the same horizon in Michigan and Illinois shall make this possible. It will, however, give a fair idea of the assemblage of forms under consideration. The numerals affixed indicate in a general way the known geographical distribution as follows: (1) localities on the Ohio river; (2) localities in central Ohio, chiefly in Licking county at Moot's run; and (3) exposures within the northern tier of counties:

CRUSTACEA.

<i>Phaethonides spinosus</i> , Her. (1, 2, 3).	<i>Proetus minutus</i> , Her. (2).
" <i>immaturus</i> , Her. (3).	" <i>præcursor</i> , Her. (2, 3).
" <i>lodiensis</i> , Meek (3).	<i>Dalmanites cuyahoga</i> , Claypole (3).
" <i>consors</i> , Her. (3).	

LAMELLIBRANCHIATA.

<i>Allorisma cuyahoga</i> , Her. (3).	<i>Mytilarca fibristriatus</i> , W. and W. (1).
<i>Avicula</i> (?) <i>recta</i> , Her. (3).	" <i>occidentalis</i> , W. and W. (2).
<i>Crenipecten cooperi</i> , Her. (2, 3).	<i>Palæaneilo marshallensis</i> , Win. (2).
" <i>subcardiformis</i> , Her. (2).	" (?) <i>ohioensis</i> , Her. (2).
" <i>cancellatus</i> , Her. (2, 3).	" <i>consimilis</i> , Her. (2, 3).
<i>Conocardium alternistriatum</i> , Her. (3).	" <i>ignota</i> , Her. (2, 3).
<i>Ctenodonta iowensis</i> , W. and W. (?) (2, 3).	<i>Palæaneilo sulcatina</i> , Her. (2).
<i>Ctenodonta</i> sp.	<i>Promacra truncata</i> , Her. (2).
<i>Cypricardinia scitula</i> , Her. (2, 3).	<i>Pterinopecten shumardianus</i> (1, 2, 3).
<i>Edmondia sulcifera</i> , Her. (1, 2, 3).	" <i>cariniferus</i> , Her. (2, 3).
<i>Leptodesma ortonii</i> , Her. (2).	" <i>ashlandensis</i> , Her. (2, 3).
" <i>nasutus</i> , Her. (= <i>hector</i> , H. (?) (2, 3).	" <i>lætus</i> , Hall (2).
<i>Lyriopecten nodocostatus</i> , Her. (2, 3).	<i>Schizodus harlamensis</i> , Her. (2).
<i>Macrodon striato-costatus</i> , Her. (cf. <i>parvus</i> , W. and W.) (2, 3).	<i>Sphenotus contractus</i> , Hall (2).
	" <i>fragilis</i> , Her. (2).
	" <i>media</i> , Her. (2).

GASTEROPODA.

<i>Bellerophon</i> sp.	<i>Loxonema</i> sp. (1, 2, 3).
" <i>perelegans</i> , Win. (2 ?).	<i>Naticopsis</i> sp. (1, 2, 3).
<i>Conularia gracilis</i> , Her. (2).	<i>Orthoceras</i> sp. (2, 3).
" <i>miconema</i> , Meek (2).	<i>Platyceras paraliun</i> , Win. (1, 2, 3).
<i>Cyclonema levenworthanum</i> (?) (2).	<i>Platyceras</i> sp.
" <i>strigillatum</i> , Her. (1, 2, 3).	<i>Pleurotomaria textiligera</i> , Meek (3).

BRACHIOPODA.

<i>Athyris lamellosa</i> , Lev. ? (2).	<i>Productus</i> (<i>Productella</i>) <i>speciosus</i> ,
“ <i>ashlandensis</i> , Her. ? (1, 2, 3).	Hall (2).
<i>Atrypa reticularis</i> , Hall (3).	<i>Productus raricostatus</i> , Her. (2).
<i>Chonetes logani</i> , Nor. and Pratt (2).	“ <i>newberryi</i> , Hall (1, 2, 3).
“ <i>scitula</i> , Hall (2, 3).	<i>Rhynchonella contracta</i> , Hall (1, 2, 3).
“ <i>tumida</i> , Her. (2, 3).	“ <i>sappho</i> , Hall (1, 2, 3).
<i>Crania hamiltonæ</i> , Hall ? (2).	<i>Rhynchospira ashlandensis</i> , Her. (1, 2,
<i>Cyrtina acutirostris</i> , ? (2, 3).	3).
<i>Hemipronites crenistria</i> , Phil. (?) (1,	<i>Spirifer marionensis</i> , Shum. (1, 2, 3).
2, 3).	“ “ var. <i>centronotata</i> ,
<i>Lingula atra</i> , Her. (3).	Win. (3).
“ <i>membranacea</i> , Win. (3).	<i>Spirifer tenuispinatus</i> , Her. (2, 3).
“ <i>melie</i> , Hall (3).	<i>Spiriferina</i> sp. (2, 3).
<i>Discina newberryi</i> , Hall (3).	<i>Syringothyris cuspidatus-typa</i> , Win. (2,
<i>Productus shumardianus</i> , Hall (2).	3).
“ <i>concentricus</i> , ? Hall (2).	<i>Syringothyris</i> sp. (2, 3).
“ (<i>Productella</i>) <i>lachrymosus</i> ,	<i>Terebratula inconstans</i> , Her. (1, 2, 3).
Hall (2).	

The crinoids and bryozoa need not be specially catalogued, as nearly all of the species described from the Ohio Waverly are derived from this group.

NOTES ON NEW AND LITTLE-KNOWN WAVERLY FOSSILS.

This opportunity is embraced to add a few notes upon Waverly species hitherto overlooked or imperfectly described.

PHAËTHONIDES SPINOSUS, HERRICK.

(Plate 1, fig. 13.)

A large series of specimens collected by Mr. Cooper and myself indicate that the species was very abundant and widely distributed during the period represented by the shales of Moot's run and Lodi. The species likewise occurs in the very upper Cuyahoga at Cuyahoga Falls and Akron. In the shales we found for a long time only the depauperate form described by us as *Phaëthonides immaturus*. Examination of the recently discovered fauna of the concretions of the same horizon revealed many specimens of the type. Since then intermediate stages have been encountered and typical examples of *P. spinosus* have been found at Lodi, Akron and Cuyahoga in the shales. The fine example figured was derived from the same horizon in Scioto county less than 50 feet above the Berea. The name *Phaëthonides immaturus* may

lapse, but upon what form *Phillipsia lodiensis* may have been founded remains to be seen. Collectors are generally agreed that the species as characterized by Meek does not occur at Lodi or elsewhere on that horizon. The evidence is strongly suggestive that the specimen forming the basis of the species was imperfect and distorted. It will also be very interesting to rediscover the *Dalmanites* described by Professor Claypole from this horizon.

Phaëthonides spinosus is reported from Missouri, though I have not seen specimens.

PHILLIPSIA (?) CONSORS, HERRICK.

(Plate 1, fig. 12.)*

Additional specimens seem to indicate that the numerous pygidia upon which this species chiefly rests do not belong to the same species as that represented by the associated glabellæ, but that the latter pertain to immature or slightly variant forms of *Proëtus præcursor*, the resemblance to which was noted in the original description. Pygidia obtained at Akron and Lodi can be identified certainly with that species, though the glabellæ exhibit minor points of difference which may perhaps be correlated with the small size. The glabella of *P. consors* being, therefore, unknown, it cannot be at present determined whether it represents a *Phaëthonides*, as is quite possible, or a *Proëtus*.

Figure 12 (plate 1) gives a greatly enlarged view of the pygidium of *P. præcursor* as seen in the shales 40 feet below the Carboniferous conglomerate at Cuyahoga Falls.

PHILLIPSIA MERAMECENSIS, SHUMARD.

(Plate 1, fig. 14.)

This, for the purpose of determining the stratigraphical equivalence of the upper part of the Waverly, is one of the most important species. Until recently the only specimen seen was that figured in the Bulletin of Denison University, volume IV, plate I, fig. 6, which was derived from an isolated exposure immediately below the Chester. More recently other specimens have been found in Scioto county which are derived from the uppermost layers of the Waverly. Some slight variation is observable, but the smooth surface, evenly rounded ribs, and almost obscure margin prevent confusion with other forms. It does appear, however, that *Phillipsia serraticaudata* becomes gradually modified, in passing from lower to higher strata, in the direction of this species.

* Bulletin Denison University, vol. IV, 1888, p. 53.

CYTHERELLA UNIONIFORMIS, SP. N.

(Plate 1, figs. 8-10.)

Carapace elongate, subovate, acutely rounded behind, the greatest prolongation above the middle; anterior margin oblique at an angle of 120° with the hinge nearly straight; hinge-line nearly straight; ventral margin a gentle curve; valves similar, gently convex, slightly compressed posteriorly, abruptly deflexed anteriorly. In the cast a ridge appears nearly parallel to the anterior margin, from which the surface descends abruptly to the margin. The ridge terminates in a conical projection (indicating a pit in the interior of the valve which may or may not have a corresponding external elevation), from which a faint ridge passes obliquely backward toward the superior margin. Muscle pit large, nearly central, and surrounded by a nearly circular ridge. Greatest width near the middle. Length ($.04 \pm$ mm.) about 1.7 times the width and about 2.5 times the thickness.

This species is very abundant in the upper layers with *Phillipsia meramecensis*. Another entomostrocon is figured on plate 1 (fig. 11), the description of which is reserved. A considerable number of species of *Cytherella* are in our collections from other horizons of the Waverly series, but the present species is the most characteristic and widely distributed. The same or a very similar species occurs in the upper layers of the Cuyahoga shale.

LEPTODESMA NASUTUS, HERRICK.*

(Plate 1, fig. 6.)

This species, briefly indicated in an earlier publication,† proves to be widely distributed, though nowhere common upon the horizon of the concretionary zone of Moot's run. The right valve figured is from Burbank, Ohio, and differs in no obvious respect from the corresponding valve of the Chemung species quoted. On the other hand, other specimens connect it with *L. ortonii* from a somewhat higher horizon.

LEIOPTERIA CUYAHOGA, SP. N.

(Plate 1, fig. 7.)

Species of small or medium size, subrhomboidal, oblique, subfalcate; body narrow, compressed, produced posteriorly, sharply elevated at the post-umbonal ridge, forming an angle of 30° with the hinge-line; height equal to less than two-thirds the length; basal margin gently curved, posterior margin sinuate; byssal sinus moderate; left valve sharply elevated at the post-umbonal ridge, sloping to the ventral margin by a very flat curve; hinge straight, shorter than posterior prolongation of the body; wing de-

* Cf. *L. hector*, Hall.

† Bul. Denison Univ., vol. IV, 1888, p. 29.

pressed, concave; ear small, obtuse, convex; surface ornamented by about thirty sharp, equidistant striae, which are nearly obsolete on the wing. Length, 23 mm.; height, 10 mm.; length of wing, about 10 mm.

This pretty little species occurs at Cuyahoga Falls, 50 feet below the Carboniferous conglomerate. A few specimens of a similar, if not identical, form were also found at Moot's run, Licking county.

CONOCARDIUM ALTERNISTRIATUM, HERRICK.

(Plate 1, figs. 1-4.)

Several imperfect specimens of this fine species were found by W. F. Cooper at Wooster in shales 60 feet below conglomerate I. The fossiliferous zone is on the same stratigraphical level as that at Moot's run, Licking county, and, like that layer, is characterized by calcareous concretions frequently filled with perfectly preserved fossils.

The characteristics differentiating *C. alternistriatum* from other Waverly species are chiefly the distant flat-topped ribs and distinctly bifaceted surface. The species also attains a larger size than the others reported from Ohio. Unfortunately no perfect specimens have been obtained. Among the fragments of this familiar form at Wooster was found a nearly perfect small individual with surface characters of *C. alternistriatum*. As the specimen is undistorted and retains the shell with even its original brown color in places, it has been carefully figured. The chief difference between this specimen and the specimens of *C. alternistriatum* thus far seen is in the structure of the posterior proloungation. The shell is exfoliated over this region, but the cast exhibits coarse, rounded ribs very unlike the remainder of the surface. In *C. alternistriatum* the posterior facet of the lateral surface is covered with finer and more numerous plicae than the anterior, while here the conditions seem reversed. Length from beaks to posterior extremity, $\frac{3}{4}$ in.; extreme length from antero-ventral to postero-dorsal extremity, $\frac{1}{2}$ in.; greatest breadth, 1.33 in.

The species figured is in some respects like *C. meekanum*, Hall, but seems quite distinct. It is much more oblique, and is more distinctly compressed posteriorly. Without definitely deciding upon its specific relations, the figures are given for subsequent comparison.

Another species of *Conocardium* is present at the same place in the same stratum, which in surface characters resembles *C. pulchellum*.

SPIRIFER PSEUDOLINEATUS, H. ?

(Plate 1, fig. 18.)

The *Martinia* group is very difficult, and although we have at least three nominal species from the Waverly they are by no means well distinguished.

S. tenuispinatus, Her., from the Cuyahoga, nearly resembles *S. setigerus* of the Chester, but is more rhombic in outline. The form we have compared with *S. hirtus* is quite different and is from the Kinderhook. The specimens of the present species so far seen are from the sandstone of the upper 35 feet of the series at Portsmouth and elsewhere, and, though much smaller than the western types, agree with the Keokuk species better than either of the others noted. The enormous curved spines are well shown in the figure. (It may be added that all the Keokuk species found in Ohio are smaller than their western representatives from limestone strata.)

CYPRICARDINIA (CF. SCITULA).

(Plate 1, fig. 15.)

This species is figured because of its close resemblance to the form described from Moot's run, in the lowest one hundred feet of the Waverly—i. e., the Cuyahoga shales. The beautiful little shell occurs sparingly in the concretions of Richland beds also.* The form figured herewith occurs in the upper 35 feet of the Waverly in Scioto county, and would thus seem to be upon the horizon of the Keokuk or upper Burlington, and is associated with fossils of that age. It differs from the types of the species quoted in the less prominent beak, more uniformly arched anterior margin, and less obliquity of the posterior margin. In surface characters and general appearance the two are very similar, and it seems at present unwarrantable to attempt to separate them.

SPIRIFERINA SPINOSA, HALL.

(Plate 1, fig. 19.)

While possibly a distinct variety, the little form occurring rather abundantly on the uppermost horizon of the Waverly appears more closely allied to the Chester species than either of those common beneath that level.

DISCINA MAGNIFICA, SP. N.

(Plate 1, fig. 17.)

The largest of our specimens of the Carboniferous genus *Discina* was found by W. F. Cooper in freestone a few feet above conglomerate II, at Hemlock Falls, Ashland county, and also upon the same horizon at Wooster. It is, therefore, upon the same stratigraphical level as *Orbiculoides* (?) *pleurites*.

Upper valve oval, elliptical, or nearly circular, usually with the sides somewhat straightened; beak exactly one-fifth the length from the dorsal margin;

* Bulletin Denison University, vol. IV, 1888, p. 38.

convexity greatest a little in front of the beak, the region from that point to the front elevated; surface marked by relatively strong concentric ribs; structure of shell unknown; lower valve flat or slightly concave.

Our specimens are all casts, and none of them preserve the structure of the lower valve. There is no species with which it could be confounded. Dimensions of one individual: length, 52 mm.; width, 50 mm.; beak from front, 11 mm.; of a second individual, 50 mm., 46 mm. and 11 mm.; and of a third, 48 mm., 47 mm. and 11 mm.*

* Bulletin Denison University, vol. V, 1889, p. 28.

DESCRIPTION OF PLATE 1.

New or imperfectly known Fossils from the Ohio Waverly.

- Figures 1-4—Four views of a nearly perfect specimen of *Conocardium* for comparison with *C. alternistriatum*, Herrick. From concretionary shales of the Cuyahoga division at Wooster. Greatly enlarged.
- Figure 5—A minute specimen of *Nucula* sp. From the Cuyahoga shales, drawn with the camera lucida and much enlarged.
- Figure 6—*Leptodesma nasuta*, Herrick, from Burbank, Ohio, to illustrate the similarity of the right valve with that of *L. hector*, Hall.
- Figure 7—*Leiopteria cuyahoga*, sp. n. From the concretionary shales of the Cuyahoga valley, 50 feet below the Millstone grit.
- Figures 8-10—Three different specimens of *Cytherella unioniformis*, sp. n., highly magnified. From the upper layers (Keokuk) of Scioto county, Ohio.
- Figure 11—Unidentified Ostracode from same place.
- Figure 12—Fragment of the interior of pygidium of *Proetus præcursor*, Herrick, from Cuyahoga Falls. Complete heads of the same species have been found at this locality since the drawing was prepared, making its presence certain.
- Figure 13—Pygidium of *Phaëthonides spinosus*, Herrick, from horizon of the shaly beds at Moot's run (Cuyahoga shale), in Scioto county, Ohio.
- Figure 14—Pygidium of *Phillipsia meramecensis*, Shumard. From upper layers (Keokuk) of Scioto county, Ohio.
- Figure 15—A close homologue of *Cypricardinia scitula*, from the Keokuk of Scioto county, Ohio, to illustrate the persistence of the type.
- Figure 16—*Chonetes illinoisensis*, from the Keokuk of Scioto county, Ohio.
- Figure 17—*Discina magnifica*, sp. n. From Hemlock Falls, Ashland county, Ohio, a few feet above conglomerate II. Two-thirds natural size.
- Figure 18—*Spirifer pseudolineatus*, Hall. Locality and position the same as fig. 15.
- Figure 19—*Spiriferina spinosa*, Hall. Locality and position same as the last.

NEW OR IMPERFECTLY KNOWN FOSSILS FROM THE OHIO WAVERLY.