A GENERAL DISCUSSION OF THE MIDDLE SILURIAN ROCKS OF THE CINCINNATI ANTICLINAL REGION, WITH THEIR SYNONYMY.

BY AUG. F. FOERSTE.

Along the Ohio River, in Indiana and Kentucky, between Madison and Westport, the top of the Lower Silurian consists of 30 to 50 feet of arenaceous limestones, forming massive layers, and weathering into steep cliffs over which plunge numerous falls. The hard stratum at the top of the cliffs consist of the Clinton or the immediately overlying Niagara rocks. The massive rock is often banded with light and dark brown and, occasionally, with purple tinges. It contains very few fossils, which usually elude discovery. They consist of Lower Silurian forms similar to those which occur in the strata below. This rock has been called by the writer the Madison bed, and was called the Cumberland sandstone by Prof. N. S. Shaler, in Kentucky. Following the Madison bed northward, it is found to change into a complex of limestone, calcareous shales, and clays, in Ripley County, Indiana; and, into shaly clays, with some clayey limestone, in Franklin County. In the northern counties of the Lower Silurian area in Indiana and Ohio, shaly clay predominates. A few layers of solid limestone are found at various horizons, and these are at times quite fossiliferous. Along the eastern counties of the Lower Silurian area in Ohio, a large part of the shales are replaced by soft clays, whose prevailing color is light blue, but which are often mottled with light purple.

Tracing the Madison bed southward into Kentucky it soon loses its color banding, and presents a more even brown color. Its layers are no longer as massive; the separate courses being often only a few inches thick. It is still the seat of waterfalls, but it disintegrates less rapidly, and forms less vertical banks, so that the falls are not so high; on the contrary they are often rather low. It remains, however, a sandy limestone, varying locally towards shaly limestone. Even in the most southern exposures in Lincoln and Casey counties, Ken-

tucky, it does not resemble a sandstone. Northeast of these counties it becomes a more shaly, clayey limestone, and in Madison County parts of the formation weather into a brownish gritty clay.

Overlying the Madison beds, especially in various parts of Kentucky and southern Indiana, is a variable thickness of very fossiliferous Lower Silurian limestones. The considerable variation in thickness of these limestones, often within only a few miles, and, so far, best noticed in Marion County, Kentucky, suggests that the Clinton lies unconformably upon the Lower Silurian, and that this unconformity could be well established if a careful study of this problem were made. The writer was, however, not able to find anything suggesting that this unconformity was in any way related to the formation of the Cincinnati axis. If the elevation of the Cincinnati axis began in Middle Silurian times, this still remains to be proved. There is ample proof of local elevation in various parts of Indiana, Kentucky, and Ohio, but not of any connection between these elevations and the formation of the Cincinnati axis.

The Clinton in the northern counties bordering the Lower Silurian areas in Ohio and Indiana, is a crinoidal limestone, of white, pink, or reddish color. It thins out rapidly southwestward, and at the same time changes in color. In northern Franklin County it is often tinged with salmon brown, and in the southern part of the county, and in Decatur, the salmon brown color prevails. The salmon brown color is characteristic of the Clinton from Decatur County, Indiana, to western Oldham County, Kentucky, excepting along the most eastern exposures of this belt, where the Clinton is more siliceous and has a pinkish tinge.

In the short distance between Jefferson and Nelson counties, Kentucky, the Clinton changes to a series of whitish, light blue, or light brown limestones, with more or less chert in thin layers or nodules, resembling lithologically some phases of the Laurel Niagara, rather than the Clinton of more northern localities. It retains this form as far as western Marion County.

In Lincoln County, south of Stanford, the Clinton has a bluish color, and is a somewhat more siliceous limestone Where weathered, it assumes a light brown, rather rusty brown color.

In Ohio, the crinoidal Clinton merges into a light blue limestone, with chert, in southern Clinton and in Highland counties. Farther eastward, in southern Highland County, the Clinton changes into a sandy limestone, having the appearance of a calcareous sandstone, and its color is in places a deep reddish brown.

The Osgood beds, in southern Indiana, consist of a thick layer of

shaly clay, followed by a much thinner layer of limestone, and then by more clay, the second clay bed being thin, as compared with the lower. This series may be traced southward into Kentucky, and may be recognized at Bardstown, in Nelson County, Kentucky. In the more southern exposures of Kentucky, the upper shale is often replaced by a poor quality of limestone, which can not be distinguished readily either from the Osgood limestone below, or the Laurel limestone above. The difficulty is increased by the fact that the Osgood limestone becomes more argillaceous. The lower shaly clay, which forms the main body of the Osgood, remains, however, a characteristic feature. In southern Nelson, and in Marion County, the shaly clay turns into a very soft clay in places, its color becomes a light blue, and it increases considerably in thickness. In Lincoln County the Osgood clay is very thick, and has a light blue color; this feature it preserves in Garrard County and northward.

The lower six or twelve inches of the Osgood clay series are often replaced by thin limestones, in southern Indiana and northern Kentucky. In the most eastern exposures along the railroad, east of Bardstown, in Nelson County, Kentucky, the amount of limestone at the base of the Osgood clays increases, so that it is difficult to draw the line between the Osgood beds and the underlying Clinton. This is even more true of the exposures in Garrard and Madison counties, the limestone element at the base of the Osgood shale having increased considerably. The rather abundant presence of *Whitfieldella cylindrica*, at the base of the Osgood beds, is of considerable assistance in drawing the line between these formations. Thin limestone beds occur also above the base at various levels in the Osgood clays. This may be seen in Garrard and Madison counties.

Following the Osgood shales from the Ohio River counties, in Indiana, northwards, the upper part of the main, lower, Osgood shale becomes a poor, rotten, clayey limestone, in Ripley County, in Indiana. I have referred to it as the Madison-like bed of the Osgood series. The upper shale either disappears or becomes calcareous, so that it becomes very difficult to draw the line between the Osgood limestone and the Laurel limestone, immediately above. Going farther northward, into Fayette County, Indiana, even the lower part of the main, lower shale becomes calcareous, and turns into an inferior limestone. The whole Osgood formation is represented by various qualities of limestone, near Longwood, in Fayette County. It maintains this character, northeastward in Ohio. In Montgomery, Clark, and Greene counties, a part of this limestone, corresponding roughly to the lower, main clays of the typical Osgood sections, becomes shaly, locally. The

lowest part of the Osgood section develops into a white, hard limestone, valuable for building purposes. It is known as the Dayton limestone. It corresponds roughly to the basal Niagara, of the Indiana sections. The shaly element increases south of Greene County, and, in Highland and Adams counties, often exceeds 100 feet, and has become a genuine shale, with only an occasional limestone layer. The limestone at the top of the Osgood sections in Indiana, seems to be replaced in the more southeastern counties of Ohio by the West Union cliff rock.

It seems therefore as though the Osgood series could be readily recognized both in Indiana and Ohio, in the counties near the Ohio River. The shaly clays begin to merge into various grades of limestone in the northern half of Ripley County, Indiana, and in the northern half of Highland County, Kentucky. It is impossible to recognize the Osgood limestone as distinct from the remainder of the Osgood series north of Fayette County, Indiana, or to distinguish the West Union cliff rock north or west of Greene County, Ohio. This suggests that the Osgood series, once formed a continuous series across the present northern half of the Cincinnati anticline, and that from certain characteristics which it possessed near the Ohio River, and southward for some distance, it varied to a limestone formation on going northward. It is difficult to evade the conclusion from this that the Cincinnati anticlinal could not have been in existence at this time.

The overlying Laurel limestone, Waldron shale, and Louisville limestone of Indiana may be recognized in their most southern exposures in Kentucky, in Nelson County. In Indiana they have been traced as far north as Shelby and Rush counties. Here they change lithologically, although it is believed that it would be possible to trace the equivalent beds considerably farther north. In Ohio, the beds are represented by the Springfield and Cedarville limestones.

Before the deposition of the Devonian beds, extensive erosion removed various thicknesses of Upper Silurian and even of Lower Silurian rocks from various parts of Kentucky, Ohio, and Indiana, due to the partial elevation of the Cincinnati axis. The investigations leading up to this conclusion have been occupying the writer for several years.

During the progress of these studies it was learned that the literature of the Middle Silurian formations in the Cincinnati anticlinal regions of Indiana, Kentucky, and Ohio was often misleading. The unraveling of this literature has consumed much time, and it seems very undesirable that every student entering this field should be

obliged to take up this process of deciphering anew. Without a guide, students who depend upon the literature for many of their conclusions, are likely to be more misled than benefited by their researches. For this reason it has seemed desirable to the writer to put on record his conclusions. Whatever value they possess is chiefly due to the fact that he has seen nearly every portion of the entire field, and has been able to follow the exposures from outcrop to outcrop, rather than examining them only at widely remote localities.

SYNONOMY OF MIDDLE SILURIAN BEDS OF CINCINNATI ANTICLINAL REGION.

A.—TABLE.

A.—MADISON BEDS.

I. INDIANA.

(a) Ohio River counties.

I. Lower Silurian.

1874, 1876, Dr. W. S. T. Cornett, Jefferson County.
1879, E. T. Cox, Jefferson County.
1889, G. C. Hubbard, Jefferson County.
1897, A. F. Foerste, Ohio River counties.
(Name "Madison beds" suggested by A. F. Foerste, 1897.)

II. Upper Silurian.

1859, Richard Owen, and D. D. Owen, Jefferson County.

III. Medina.

1872, Prof. E. Orton, Jefferson County.
1872, Prof. R. B. Warder, Dearborn, Ohio, and Switzerland counties.

IV. Clinton.

1841, Trip of 1841, Prof. James Hall, Jefferson County.
1874, 1875, 1876, Prof. W. W. Borden, Ohio River counties.
1886, Maurice Thompson, quoting Borden.
1889. Prof. A. H. Young, Jefferson County, quoted by A. F. Foerste.

V. Niagara.

1876, Prof. W. W. Borden, Reuben Daily section, Jefferson County.
(Misled by changed lithological conditions.)

(b) Counties north of Ohio River counties.

I. Lower Silurian.

1869, Dr. Rufus Haymond, Franklin County.
1897, 1898, A. F. Foerste, various counties.

II. Clinton, accidentally including some Lower Silurian.

1884, Dr. M. N. Elrod, Fayette County.
1886, Maurice Thompson, quoting Elrod.

III. Niagara.
1876, Prof. W. W. Borden, Ripley County, branch of Cedar Creek.
(Misled by white color of limestone.)

II. KENTUCKY, CUMBERLAND SANDSTONE.
I. Upper Silurian.
1857, D. D. Owen, Cumberland County.
1891, Prof. Edw. Orton, Cumberland County.
II. Medina.
1877, Prof. N. S. Shaler (Oneida and Medina).
1882-1887, W. M. Linney, Washington, Lincoln, Garrard, Nelson, Clarke, Montgomery, Mason, Bath, Fleming, Henry, Shelby, Oldham counties.
1885, Dr. W. T. Knott, Marion County.
1890, Dr. R. H. Loughridge, Clinton County.
III. Niagara.
1873, Prof. J. S. Newberry, Cumberland County.
1882, W. M. Linney, by mistake separated from his sandy Medina beds.

III. OHIO, UPPER CLAYS, CINCINNATI GROUP.
I. Lower Silurian.
1873, Prof. J. S. Newberry, southwestern Ohio.
1873, Prof. E. Orton, Clarke County.
II. Between Lower and Upper Silurian.
1878, Prof. E. Orton, Miami County.
III. Upper Silurian.
1878, Prof. E. Orton, Warren County.
IV. Medina.
1869-1893, Prof. E. Orton, Montgomery, Highland, Adams, Greene, and other southwestern counties.
1873, 1878, Prof. J. S. Newberry, southwestern Ohio.

B.—CLINTON.

I. INDIANA.
I. Clinton.
1883-1884, Dr. M. N. Elrod, Decatur, Fayette counties.
1896-1898, Aug. F. Foerste, southeastern Indiana.
II. Niagara.
The Clinton was not recognized as a distinct formation in the early reports of the Indiana survey. Hence it was placed in the basal part of the Niagara by all who considered the Madison bed as equivalent to the Medina or Clinton. The only exceptions are those mentioned above.

II. KENTUCKY.
I. Lower Silurian.
1898, Marius R. Campbell, by implication, at the railroad cut, half a mile south of Whites, Madison County.

II. Medina.
1882-1884, M. Linney, Washington, Lincoln, Garrard, Nelson counties.
1885, Dr. W. T. Knott, near Marion-Nelson county line.
III. Clinton.
1857, D. D. Owen, eastern counties.
1877, Prof. N. S. Shaler, eastern counties.
1884-1886, M. Linney, Clarke, Montgomery, Mason, Bath, Fleming counties.
1887, M. Linney, Oldham County; even Middle Niagara layers are included.
IV. Panola formation.
1898, Marius R. Campbell, Madison County, and neighboring counties. Forms base of Panola.

III. OHIO.
I. Clinton.
1869-1893, Prof. E. Orton, Prof. J. S. Newberry, and others.

C.—OSGOOD BEDS.

INDIANA.
I. Niagara.
The Osgood beds are not distinguished from the main mass of Niagara in any of the early reports.
II. Lower Niagara shales.
1883, Dr. M. N. Elrod, Decatur County.
1897, 1898, Aug. F. Foerste, under the name Osgood beds.

KENTUCKY—Crab Orchard shales.
I. Clinton.
1882-1886, M. Linney, all county reports.
1887, Linney, included with several other horizons in the Clinton.
II. Great Marl bed=Lower Niagara shale.
1857, D. D. Owen.
III. Niagara or above.
1877, Prof. N. S. Shaler.
IV. Panola formation.
1898, Marius R. Campbell, forms middle part of Panola section.

B. DISCUSSION OF THE LITERATURE.

A.—MADISON BEDS.

I.—INTRODUCTORY.

At the top of the Lower Silurian in many parts of Kentucky, Indiana and Ohio, are a series of sandy limestones and shales of variable thickness, nearly devoid of fossils, to which the name *Madison beds* has been given by the writer. In some localities limestones with abundant Lower Silurian fossils overlie the Madison beds, but this fact does not seem to have been recognized until 1889, when Mr.

George C. Hubbard discovered a layer of dense bluish limestone, with Lower Silurian fossils, above the Madison beds at Madison, Indiana. Indeed, fossils are found in the Madison beds, but they are sufficiently rare to have escaped attention until 1874, when Dr. W. T. S. Cornett, of Madison, Indiana, found Lower Silurian fossils at several levels near the top of these beds, thus conclusively proving their age, 15 years before the discovery by Mr. Hubbard. Previous to this year (1874), the age of the Madison beds was in doubt.

This, however, did not prevent geologists from expressing opinions as to their age, but these opinions were necessarily based upon lithological characteristics. At that time it was customary to correlate the sections presented by the rocks in the middle states with the section exposed in New York, which had been best studied. Now, in New York the richly fossiliferous Lower Silurian beds are followed first, by the Oneida conglomerate, and then by the Medina sandstone, both scantily fossiliferous; above the Medina occur the richly fossiliferous Clinton shales and Niagara limestones. In Kentucky, Indiana, and Ohio there is an abundant development of richly fossiliferous Lower Silurian limestones. Moreover, on the eastern side of the anticlinal in Kentucky and Ohio it seemed possible to easily identify the Clinton by lithological means. In some parts of New York, the upper part of the Clinton contains layers of oölitic iron ore. Overlying the sandy limestones and shales of the eastern border of the Cincinnati anticlinal in Kentucky and Ohio, which are the equivalent of the Madison beds of Indiana and neighboring Kentucky, is a limestone formation, the upper layers of which in various localities consist of similar oölitic iron ore. It was therefore correlated with the Clinton of New York. Very little was known about the fossils of this Clinton of Kentucky and Ohio until Prof. E. Orton began his labors in Ohio in 1869. To him belongs the credit of having first identified the Clinton of Ohio by means of fossils capable of forming the basis of such an identification.

The highest fossils known to be of Lower Silurian age previously to the investigations of Dr. W. T. S. Cornett were found just beneath the Madison beds. The lowest layer of the limestone associated with the Clinton oölitic iron ore was found just above the Madison bed. The Madison bed itself, which occurs between these horizons, was therefore regarded as being the equivalent of the Medina of New York, and was placed in the Upper Silurian. In Indiana, where the Clinton is often but poorly represented, the Madison bed has at times been even called Clinton.

This has given rise to a rather confused terminology for the Lower

Silurian Madison beds, which it is the purpose of the following pages to unravel.

As long ago as 1857, Dr. D. D. Owen placed the upper limit of the Lower Silurian at the uppermost beds with recognizable Lower Silurian fossils. The nonfossiliferous sandy limestones and shales (Madison) just above, were referred to the Upper Silurian. See, for instance, the old reports of the Geological Survey of Kentucky, Second Volume, 1857, pages 102, 103; and the Third Volume, 1857, pages 93, 100, 142, 147. The same method of determining the upper limit of the Lower Silurian was pursued by Richard Owen in Indiana, when, in 1859, he considered the *Favistella* bed at Madison, Indiana, as the upper limit of the Lower Silurian, and referred the overlying nonfossiliferous sandy limestones (Madison beds) to the Upper Silurian. The name Medina was not used for these beds until later.

A.—MADISON BEDS.

II.—INDIANA.

Both Indiana and Ohio renewed State geological survey operations in 1869.

In the report on Franklin County, in the First Report of the Indiana Survey, 1869, Dr. Rufus Haymond correctly placed the lower limit of the Upper Silurian at the base of the hard limestone layer (Clinton) which forms the waterfalls in various parts of the county. The underlying sandy shales are referred to the Lower Silurian (pages 177, 178, 181, 184). This correct identification of the sandy (Madison) shales was probably due to the fact that after all they are not very different in Franklin County from the shales with interbedded limestones of undoubted Lower Silurian age which occur lower down in the section at Derbyshire falls, and at other localities in the north central parts of the county.

In the river counties of Indiana, the Madison beds are typically developed. Here they consist of massive beds of limestone, of brownish or bluish color, of an evidently sandy texture, and sufficiently distinct lithologically, from the Lower Silurian still farther down, to suggest the idea that they form a distinct horizon.

In the report on Dearborn, Ohio, and Switzerland counties, in the Third and Fourth Reports of the Indiana Survey, 1872, Prof. R. B. Warder referred to the fact that Prof. Richard Owen places the *Favistella stellata* bed at the top of the Lower Silurian, and that Prof. E. Orton provisionally regarded the immediately overlying beds as Medina (pages 399, 400, 415, 418). His reference to the exposures east of Osgood, shows that he recognized the fact that Lower Silurian

fossils occurred there above the *Favistella* bed, but he did not draw the legitimate conclusion that the occurrence of Lower Silurian fossils disproves the Upper Silurian age of these rocks (page 401).

In the report on Clark and Floyd counties in the Fifth Report of the Indiana Survey, 1874, Prof. W. W. Borden referred to the Clinton Group, a gray and yellow stratified sandstone, averaging 20 feet, occurring at the summit of the ridge at Camp Creek and continuing to Marble Hill. The *real* Clinton at the localities mentioned, however, does not exceed 4½ feet. In the section at Marble Hill (page 140), the 20-foot layer of sandstone, called Clinton by Prof. Borden, is placed 66 feet above the *Murchisonia* shell marble, worked in Dean's quarry, and 26 feet above limestones with abundant Cincinnati Group fossils. The sandstone of this report can therefore be nothing but the sandy limestone described in my report on the same area under the name *Madison bed,* and is therefore of Lower Silurian age. In the general section, page 172, the same bed (Clinton of Borden) is referred to as a magnesian limestone, equivalent to the Clinton Group of New York, and overlying the Madison (of Borden) limestone. The Madison limestone of Prof. Borden is, however, not the Madison bed of my reports, but the richly fossiliferous limestone section belonging to the Cincinnati Group, which immediately underlies the Madison beds of my reports. Borden's Clinton is therefore evidently equivalent to the Madison beds of my reports. Their reference by Borden to the Cinton was probably due to Prof. Hall, who in the notes of his journey of 1841, calls the strata above the fossiliferous blue limestones at Madison, Indiana, *Clinton.*

In the report on Jefferson County, in the Sixth Report of the Indiana Survey, 1875, Prof. W. W. Borden again identified 23 feet of rock as Clinton. The section at Dog Falls (page 157) shows that this Clinton of Borden is the sandy (Madison) limestone now known to be at the top of the Lower Silurian, for the water at the falls tumbles over a ledge of real Clinton, about four feet thick. The rock below the falls is the Madison bed of my reports, and its Lower Silurian age is demonstrated by fossils found at its very summit. (See the Twenty-First Report of the Indiana Survey, 1896.) The 35 feet of Clinton rock mentioned by Prof. Borden, as occurring at Lee's Falls (page 158) the 19 to 22 feet of Clinton in Saluda Township (page 160), the 16 to 20 feet of light yellow and brown glistening sandstone (Clinton) at Crow's Falls, the Clinton at Butler's Falls and at the Chain Mill Falls, the 12 to 23 feet of Clinton on the New Pike, College Hill, Hanover, the 23 feet of Clinton along the railroad cut at Madison (pages 158 to 165), and the Clinton as identified by Prof. Borden, on

page 168, must all be considered as equivalent to the Lower Silurian *Madison bed.*

The Lower Silurian age of the rocks referred to the Clinton by Prof. Borden, is shown at Crow's Falls, Butler's Falls, the Chain Mill Falls, along the New Pike (at present the "landing road") at Hanover, and along the hills bordering the railroad cut at Madison, by the presence of undoubted Lower Silurian fossils, which at these localities occur just above the supposed Clinton beds of Prof. Borden. (See the Twenty-first Report, Indiana, 1896.) The section northeast of Mud Lick, on the land of Reuben Daily, does not show the presence of the *real* Clinton because the section was taken from a locality too far down the stream. The supposed Niagara white and gray limestone of this section, however, is the equivalent of the sandstones which Prof. Borden elsewhere calls *Clinton;* in other words, Prof. Borden's Niagara at this locality is the equivalent of the *Madison bed* of my report. (See the Twenty-First Report, Indiana, 1896.) The real Clinton and Niagara are found farther up the stream. The upper parts of the Madison bed cease to be sandy on going from Madison northward (not northeastward), and change to a limestone formation, becoming richly fossiliferous considerably farther north, in the middle parts of Ripley County. At Mud Lick, an intermediate locality, some parts of the Madison bed section are so very similar to the white limestones of Niagara age of this part of Indiana, that the mistake made by Prof. Borden during a hasty survey is readily understood.

The most curious blunder in Prof. Borden's report on Jefferson County occurs, however, on pages 159, 160, 167 and 184, where he discusses the section at Madison. This blunder caused Mr. S. A. Miller to deny the existence of the Clinton in the entire State of Indiana, and made him unwilling to recognize any species published as coming from the Clinton of Indiana, Ohio or Kentucky as being of anything but Niagara age. The blunder was made by Prof. Borden owing to the fact that he had learned from an article by Dr. W. T. S. Cornett (Indianapolis Journal, July 10, 1874), that Lower Silurian fossils extended much farther up the section at Madison than had formerly been supposed, and that on this account it was necessary to place the line of separation between the Lower and Upper Silurian at a considerably higher level. He failed, however, to recognize that the discoveries of Dr. Cornett removed all of his (Dr. Borden's) Clinton to the Lower Silurian and necessitated a revision of the nomenclature of this and immediately overlying rocks. His descriptions, therefore, show a confusion of his and Dr. Cornett's ideas. To unravel this confusion, it is best to state more fully just what were the discoveries of Dr. Cornett.

It will be remembered that Dr. D. D. Owen, in 1857, placed the upper limit of the Lower Silurian rocks of Kentucky with the uppermost fossiliferous rocks of that series. This, in a number of instances, made the *Favistella stellata* layer the top of the Lower Silurian. When, in 1862, he and his brother Richard Owen investigated the hills behind Madison they came to the conclusion that the *Favistella stellata* layer formed the top of the Lower Silurian there also. Later, Professor Orton found *Tetradium fibratum* six feet above the *Favistella* layer, and 12 to 15 feet above the *Favistella* layer were found other well-known Cincinnati Group fossils. (Ohio Survey, Vol. I, 1873, page 388.) From this latter layer, Dr. Cornett enumerates, among others, *Orthis occidentalis, Chætetes frondosa, Chætetes mammulatus* and *Ambonychia radiata.* The line of separation between the Lower and Upper Silurian was therefore removed to a level 12 feet higher. Professor Orton, having come to the conclusion that the shales and clays at the top of the Lower Silurian in Ohio were probably of Medina Age, consistently came to the conclusion that the sandy Madison beds overlying the highest fossil layer discovered by him at Madison were also of Medina age. Dr. Cornett, however, found two layers containing Cincinnati Group fossils at a level 31 to 32 feet above the highest fossil layer found by Professor Orton. Among the fossils enumerated by Dr. Cornett from these upper layers are *Orthis occidentalis* and *Ambonychia radiata.* Dr. Cornett's discoveries raised the line of separation between the Lower and Upper Silurian 34 feet. This removed the sandy limestones identified as Clinton by Professor Borden and as Medina by Professor Orton entirely from the Upper Silurian and established their Lower Silurian age. This fact was recognized by Dr. Cornett, but not by Professor Borden, who continued to call these sandy rocks *Clinton,* and did not see the bearing of Dr. Cornett's discoveries. Thus, on pages 166 and 167, of the Sixth Indiana Report, Professor Borden took from Dr. Cornett's paper in the Indianapolis Journal, July 10, 1874, a section of the rocks along the Michigan road at Madison. He varied it, however, in such a manner as to place the upper limit of the Lower Silurian at the *Tetradium fibratum* layer, and so as to place the overlying Madison bed, consisting of sandy limestones, in the *Clinton,* as he had done heretofore, *notwithstanding the fact that he acknowledges the presence in his Clinton of Cincinnati Group fossils.* Moreover, he omits the fact given in Dr. Cornett's paper that these Cincinnati Group fossils occur at the 351 foot level, in other words, at the top of his so-called Clinton.

Dr. Cornett's discoveries removed all sandy beds so far called

Medina or Clinton to the Lower Silurian. The presence of Medina in Indiana was therefore denied. Dr. Cornett, however, found it more difficult to admit the absence also of the Clinton. Now, it so happens that the lowest layers of the Cliff limestone of Indiana (that part of the Niagara section called the Laurel limestone in my report) which are exposed along Gale's road near the Michigan road section lie 23 feet above the top of the Madison bed, the top of what Dr. Cornett knew to be Lower Silurian. The intermediate layers constitute what I have called the Osgood beds. The Osgood beds consist of shales and shaly limestones interrupted about one-third of their thickness from the top by several thicker and firmer layers of limestone, called by me the Osgood limestone. This limestone is richly fossiliferous in Ripley and Jennings counties, and along Big Creek in the northern part of Jefferson County; even near Madison it contains quite a number of fossils. These fossils are of Lower Niagara age. Many are specifically identical with well-known Niagara fossils, or are, at least, their immediate precursors; they certainly represent later types than those of Clinton age. These 23 feet of Lower Niagara clayey shales and limestones were considered by Dr. Cornett as of Clinton age, and the Niagara fossils found in the limestone near the upper third of the section were enumerated by him as Clinton fossils. These Lower Niagara fossils, with several additional ones, are also quoted by Professor Borden as occurring in the Clinton rocks of Jefferson County (page 184 of the Sixth Annual Report). Moreover, on page 159 of the same report, Professor Borden quotes the following statement, not indicating, however, the fact that it is a quotation, without a change of word, from Dr. Cornett's paper: "The upper and lower strata of the Clinton are non-fossiliferous. The fossils which characterize this formation are to be found at or near its upper third. They are so compactly cemented in the rock that it is in most instances impossible to isolate them, consequently they have to be studied in fragments. I recognize the following: *Zaphrentis bilateralis, Fenestella prisca, Atrypa reticularis, Illaenus insignis, Dalmania, Orthis biforata, Strophomena rugosa, Leptaena sericea, Rhynchonella neglecta, Encrinites* and fragments of encrinite stems, many of which are encased in calc spar."

Professor Borden failed to recognize that the part of the paragraph which he quoted applies only to rocks overlying his supposed Clinton, and that the Lower Niagara fossils there enumerated occur over 12 feet above his supposed Clinton. On page 160, he adds several statements which he had secured from Dr. Cornett's paper to his own account of the Clinton formation, intermingling the two. This is

shown by the fact that the so-called Clinton rocks of Professor Borden, my Madison bed rocks, are never salmon or pink in color and there are no thin layers in it which can be used for flagging. The flagging stones here referred to belong to my Osgood and Lower Laurel beds of the Niagara formation.

Mr. S. A. Miller knew comparatively little of the Middle Silurian rocks of Indiana from personal experience. Most of the fossils from this part of the Indiana geological section he bought. He was richly supplied by collectors with fossils from Madison, the Big Creek region, and Osgood. The fossils identified by Dr. Cornett and quoted by Professor Borden as Clinton were easily recognized by Mr. S. A. Miller as of Niagara age. Hence, Mr. Miller denied absolutely the existence of any Clinton in Indiana.

Curiously enough, there is a little Clinton in the section at Madison. Between the uppermost sandy limestones (Madison bed), belonging to the Lower Silurian (Professor Borden's Clinton), and the main body of beds called Clinton by Dr. Cornett (my Osgood beds), there is a 12 to 18 inch bed of siliceous pink or salmon colored limestone, which is the sole representative here of the much thicker sections of Clinton found northeastward in Indiana and Ohio. At Madison, it is nearly unfossiliferous. Its age was therefore not recognizable in any hurried survey, and while this layer is actually included by Dr. Cornett in his Clinton, forming its base, this is not due to the fact that Dr. Cornett recognized its age, but rather to the fact that Dr. Cornett followed the custom of his predecessors in terminating the Lower Silurian section with the uppermost layer actually containing Lower Silurian fossils. This left the pink and salmon colored rock at the base of his next formation, his Clinton, which included chiefly the Lower Niagara (Osgood) beds.

In the report on Jennings County, in the Seventh Report of the Indiana Survey, 1876 (page 151), Professor Borden continues to refer to the sandy Madison beds of Clark County as Clinton, because in Fourteen Mile Creek the upper part of the blue fossiliferous Lower Silurian limestones and the overlying sandy unfossiliferous Madison beds are the only beds distinctly tilted, with the upper edges of the inclined strata distinctly cut away. Whether there is actually an unconformity here between the Lower and Upper Silurian is a different matter. The real Clinton on Fourteen Mile Creek is not so exposed as to attract attention in connection with the upturning of the strata to which allusion is made, and probably would not have been recognized by Professor Borden, even if found.

On page 183, Professor Borden quotes a letter from Dr. Cornett, in which the latter makes clear the fact that the line between the Upper and Lower Silurian is between the banded limestone of Owen's report (the Clinton of Professor Borden, my Madison beds) and the overlying beds (my Osgood beds). This he does by insisting once again that Lower Silurian fossils were found 49 feet above the *Favistella* bed, overlying 32 feet of the non-fossiliferous banded limestone of Owen.

The white Niagara limestone at the crossing of a branch of Cedar Creek, on the old Versailles and Osgood pike, now an old dirt road, must be some Lower Silurian layer, since no Upper Silurian rock is exposed there.

The fact that Professor Borden, in spite of Dr. Cornett's correction, did not yet understand what Dr. Cornett meant by the Clinton is shown on page 151, where he states that in some localities the Clinton, upon weathering, leaves behind considerable beds of *sand*, and the fact that on page 154 he refers six feet in the section southeast of Butlerville to the Clinton, because these strata (Madison-like beds at the base of the Osgood beds) resemble the sandy limestone beds (Madison beds) of the bluffs along the Ohio River, in the counties with which he was familiar. They belong, however, to a higher horizon.

The first geologist connected with the survey who had a clear understanding of Dr. Cornett's views, and the change of name which this made necessary for the sandy limestones and shales (Madison) at the top of the Lower Silurian, was Mr. E. T. Cox, the State Geologist (Eighth, Ninth and Tenth Reports of Indiana Survey, 1878, pages 18-20). He mentions the fact that Dr. D. D. Owen called them the "Banded Rock," and gives even more convincing lists of fossils from the layers at the top of the Banded Rock: *Orthis biforata, var. acutilirata; Orthis retrorsa, Orthis subquadrata, Orthis insculpta; Strophomena planumbona, Strophomena sulcata, Streptelasma corniculum, Rhynchonella capax, Rhynchonella dentata, Zygospira headi, Ambonychia radiata.* The Banded Rock is clearly referred to the Lower Silurian. The overlying 23 feet, almost entirely composed of Osgood beds, Mr. Cox does not consider as Clinton, seeing no good ground for separating them from the Niagara. In this he differs from Professor Borden, and correctly so, the Osgood beds being only the basal beds of the Niagara. He fails to recognize the 22 inches of pink and salmon colored rock at the base of this Lower Niagara at Madison as Clinton, as was natural, the pink and salmon colored Clinton near Madison being nearly devoid of fossils. And who would expect to find a whole formation represented by 22 inches of rock, as is the case here?

In the report on Wayne County in the same (Eighth, Ninth and Tenth) report, he refers to the Niagara, the 22 to 25 feet of rock at Elkhorn Creek Falls, which had been variously referred to the Clinton and Niagara. As a matter of fact, the lower 14½ feet of this section are formed by real Clinton; overlying this are three or four feet of Dayton limestone, the lowest member of the Niagara; any higher rock which may be exposed must also be Niagara. There is no representative of the Madison bed here.

In the report on Fayette County, in the Fourteenth Report of the Indiana Survey, 1884, page 51, Dr. M. N. Elrod refers to the Clinton Group 20 feet of stone which probably include the seven feet of hard Lower Silurian limestone which terminates the Lower Silurian at Ball's quarry, and the six feet of brownish limestone overlying the Clinton, which replaces the lower Osgood of more southern localities.

In the Fifteenth Report of the Indiana Survey, 1886, pages 11 and 16, Maurice Thompson quotes Professor Borden's incorrect reference of the gray and yellow stratified sandstone (Madison bed) to the Clinton, and also Dr. Elrod's too extended Clinton section just discussed.

In Notes on the Clinton Group Fossils, with special reference to collections from Indiana, Tennessee and Georgia, Proceedings Boston Society of Natural History, Vol. 24, 1889, page 264, is recorded a section of the rocks at Hanover, Indiana. In this section the real Clinton, 12 to 20 inches thick, is called the fossiliferous Clinton. The so-called cherty bed, two to three feet thick, with *stromatoporoids*, is the top of the Lower Silurian, the stromatoporoids being Labechia. The 20 feet of drab, non-fossiliferous limestones, believed to be Clinton, are the Madison beds. The eight to ten inches of blue shale with fossils, thought to belong to the Medina, contain typical Cincinnati Group fossils, but overlie the Favistella bed, which in turn is at the top of the blue fossiliferous calcareous rocks which are commonly found below the Madison beds.

These notes were furnished by Prof. A. H. Young. In these notes the Clinton of Indiana was for the first time identified by means of fossils. The significance of Dr. Cornett's discoveries as a proof of the Lower Silurian age of the Madison beds was not recognized by Dr. Young, and I was ignorant of both the geology and the literature of the Hanover-Madison region.

At about this time, 1889, Mr. George Hubbard discovered a layer of dense bluish limestone with *Pleurotomaria* and other fossils above the fossil layers at the top of the sandy (Madison) limestones (Proc. Indiana Acad. Sci. 1891). He recognized their Lower Silurian origin.

and he, together with other collectors, furnished a number of new species from this formation to Mr. S. A. Miller. This bed I have named the *Murchisonia hammelli* bed in my report, owing to the frequency of this characteristic fossil. It confirms still further the Lower Silurian Age of the Madison beds.

In the Twenty-first Annual Report of the Indiana Survey (1897) the writer for the first time employed the name Madison beds to designate the massive sandy limestones at the top of the Lower Silurian. The writer attempted to distinguish clearly between the Upper and Lower Silurian formations, and to firmly establish Dr. Cornett's views as to the position of the Banded Rock or sandy limestones at the top of the Lower Silurian. All the typical developments of this formation in Indiana are described. They occur in the neighborhood of the Ohio River.

In the Twenty-second Report (1898), some of the equivalent strata in Franklin County and elsewhere are discussed, but their lithological resemblance to the Madison beds of the river counties is only remote.

A.—MADISON BEDS—CUMBERLAND SANDSTONE.

III.—KENTUCKY.

A.—CUMBERLAND SANDSTONE.

In Kentucky the Madison beds are typically developed in the counties along the Ohio River, opposite Indiana. On going southward into Nelson, Marion and Lincoln counties, the Madison beds vary from the type, losing, for instance, the tendency towards brown and purple banding so often shown in the river counties. They remain, however, nearly barren of fossils. The *Murchisonia hammelli* bed is typically developed in Oldham County. Abundant Lower Silurian fossils are not infrequent, in places, above the Madison beds in Marion and Lincoln counties. But in general the Madison beds beneath are devoid of fossils, and the fact that the Lower Silurian fossils may be found overlying the Madison beds seems to have escaped attention. Professor Shaler studied the Madison beds in the southern part of Kentucky, along the Cumberland River, and he gave to them the name Cumberland sandstone. No section is described and no very precise locality is mentioned with the exception of Burksville, on the Cumberland. It is not possible to determine just where he began his Cumberland sandstone section, and at what level he concluded his section. It is therefore impossible to determine just what was included in his section. This is a matter of some importance, since in

some regions the Cumberland sandstone, or rather its equivalent, is overlain by the Clinton, and this Clinton was never recognized west of the Cincinnati anticlinal. The result has been that in the various Linney reports the name Cumberland sandstone has been oftener employed incorrectly than correctly.

Considerable pains have therefore been taken in the following lines to collate every allusion to the Cumberland sandstone which appears in Vol. III, New Series of the Kentucky Survey, the volume in which the Cumberland sandstone is best described, and to arrange them in such a fashion as to make the chief characteristics of these sandstones as clear as possible. The name will be found very useful in the description of rocks from the southern parts of Kentucky, and may, in the estimation of others, deserve a wider application.

The upper limit of the Lower Silurian of Kentucky was placed by Dr. D. D. Owen just above the *Favistella stellata* bed, or whatever other well recognized fossils closed the record of life in the blue Lower Silurian limestones. The unfossiliferous sandy limestones and clays just above (Madison beds) were referred by him to the Upper Silurian (Kentucky Survey, Vol. 2, Old Series, 1857). With this opinion Professor N. S. Shaler agreed, considering, in 1873, 1874, 1875, the sandy limestones equivalent to the Oneida and Medina formations, which form the base of the Upper Silurian in New York.

In 1877, three years after the discoveries of Dr. W. S. T. Cornett, proving that these sandy limestones (Madison beds) were Lower Silurian, Professor Shaler refers to them under the name Cumberland sandstone as the upper member of the Cincinnati Group.

Professor Shaler added little to our knowledge of the Madison formation beyond the name, *Cumberland sandstone,* given owing to the abundant occurrence of these sandy limestones on the upper waters of the Cumberland in southern Kentucky. Dr. Owen's name, "Banded limestone," very pertinent in southern Indiana, was discarded for Kentucky.

The Cumberland sandstone received its name from a part of the upper Cumberland River, in southern Kentucky. The sandstone occurs on both sides of the river, extending in a narrow area, about 50 miles long, from the southwestern border of Pulaski County, to the southern edge of Kentucky. The typical exposures are located above Burksville, in Cumberland County. Southward, the sandstone may be traced beyond the limits of the State, into Tennessee. Northward, for a distance of about 25 miles, the sandstone is hidden by the overlying formations, but comes to light again along the Green River, in Casey County, and at numerous exposures in Marion, Boyle, and

Lincoln counties. Thence, the sandstone extends northwestward and northeastward, around the borders of the famous blue grass area of north central Kentucky, an area characterized by the richly fossiliferous limestones of the Cincinnati Group. The more typical exposures of the Cumberland sandstone are, therefore, limited to the southern crest of the Cincinnati axis, and to its more northern flanks. (Pages 142, 159, 169, foot note, 387, 394.)

The Cumberland sandstone had not been fully studied at the time of writing the third volume of the Kentucky Survey, and estimates of its thickness vary considerably. It is stated to range from five to fifty feet in thickness, and to be sometimes 100 feet thick, although usually it does not exceed 30 feet. The sandstone is said to thicken considerably on going southward from the Ohio River towards the southern exposures. This is considered tolerably clear proof that the fine-grained sand of which the Cumberland sandstone is composed was derived from some source of supply situated south of Kentucky. This source, it is likely, was an extension of the high land which now forms the northeastern corner of Alabama and the northwestern part of Georgia. This southern area which furnished the sand is probably to be considered a southwestern prolongation of Professor Shaler's Unaka Island. (Pages 142, 160, 163, 170, 192, 387, 394, 409.)

The Cumberland sandstone is rather fine-grained. It commonly has a greenish color. This color is especially characteristic of the southern exposures along the Cumberland River, and is possibly due to phosphate of iron. It is stated to be entirely barren of organic remains, the absence of evidence of life being far more conspicuous in the case of the Cumberland sandstone than in the case of the lower sandstones of Lower Silurian Age exposed within the area of the Cincinnati anticlinal. (Pages 142, 159, 160, 387, 394.)

Owing to the failure to find fossils, Professor Shaler was not able to identify the horizon of the Cumberland sandstone. In the Notes on Investigations of the Survey, during the years 1873, 1874 and 1875, he states that the sandstone totally interrupts the Cincinnati series, so that it can not be called a member of that group, but must be considered the equivalent of the Oneida conglomerate and the Medina sandstone of New York; passage of the fossiliferous Cincinnati Group rocks into the Cumberland sandstone very frequently accomplishing the change. In the report for the year 1877, in the same volume, he states that it forms the upper member of the Cincinnati Group. (Pages 141, 144, 153, 155, 159, 160, 163, 387, 394.)

The statement that the Cumberland sandstone forms the upper member of the Cincinnati Group does not necessarily indicate that

Professor Shaler considered them of Lower Silurian Age. An examination of the literature of the Cincinnati Group suggests that the Cincinnati Group was by many geologists considered a geological complex, whose upper limits were formed by the basal members of the Clinton Group. Even those who believed that the clays and sandy limestones at the top of the Lower Silurian are of Medina Age at times referred to them as members of the Cincinnati Group. A striking example of this form of interpretation is given in Volume I of the Ohio Survey, page 414.

b.—KENTUCKY, WEST OF THE CINCINNATI ANTICLINE.

In the report on Washington County (Kentucky Survey, Nov., 1882, page 18), Mr. W. M. Linney gives the name Cumberland sandstone erroneously to the sandy beds below the *Favistella stellata* and *Columnaria* bed, instead of giving it to the sandy layers above the coral beds, to which it more properly belongs. In his section along the road up the hill, east of Wheatley's Branch, the sandy shales and sandstones and the heavy limestone are Lower Silurian, overlying sandy shales, which in their turn overlie the coral bed. The soft sandstone is the real Clinton. The shales at the top are the Osgood clays of Indiana, and Linney's Crab Orchard shales. (See Linney's later reports.) They are more shaly at the base, and their real thickness is at least 16 feet.

Notwithstanding the fact that Dr. W. S. T. Cornett had identified the sandy limestones (Madison beds) as Lower Silurian already in 1874, and that Professor Shaler in 1877 had referred to them, without proof, as the upper member of the Cincinnati Group, W. M. Linney in his report on Washington County, as well as in his report on Lincoln County (Kentucky Survey, Report on Lincoln County, 1882, pages 14-16), continues to consider them as Medina. He fails to distinguish the Clinton from the underlying Lower Silurian (Madison) sandy limestones, and includes them with the latter in his *Medina*. At James's Mill (page 15), only Clinton is exposed. The occurrence of *Atrypa reticularis* (page 16) is doubtful, even in the Clinton, this fossil never having been found by me in the Clinton limestone anywhere near the Cincinnati anticlinal.

In the report on Nelson County (Kentucky Survey, W. M. Linney, January, 1884), Mr. Linney states: "On Scrub Grass Creek, in Boyle County, some years since, I found resting upon the top of the Hudson River beds a conglomerate two inches thick, with the characters as given the Oneida conglomerate in New York. It is the only point at which I have been able to find it * * " (page 37). Considering the

fact that along Scrub Grass Creek the Devonian black slate rests directly upon the Lower Silurian, and that there is no conglomerate at this horizon, it is difficult to determine what Mr. Linney really found. Mr. Linney continues to refer both the sandy limestones at the top of the Lower Silurian and the overlying Clinton limestones to his Medina. (Pages 37, 38.)

In the report on Marion County (Kentucky Survey, January, 1885), Dr. W. T. Knott follows Mr. Linney in referring the sandy limestones (Madison) above the coral beds to the Medina, instead of to the Lower Silurian. This is shown, among other things, by the geological map accompanying the report, where the sandy limestone is mapped with the yellow color used to indicate Upper Silurian and Devonian rocks. This fact is readily established, owing to the entire absence of the Upper Silurian and Devonian over a large part of the area thus mapped.

In trying to identify the strata near the Nelson-Marion county line, Dr. Knott made a curious mistake. In general he followed the lead of D. D. Owen, Linney and other geologists in making the coral bed the top of the Lower Silurian and classing the immediately overlying rocks as Medina, the still higher clays being considered as of Clinton Age.

However, near the Nelson-Marion county line there are two coral beds; the lower one contains *Favistella, Columnaria,* and *Columnopora;* the upper one contains *Tetradium* as the more characteristic fossil. Believing the *Tetradium* layer to be identical with the coral layer which is found lower down, he gives the name Medina to the rocks overlying the *Tetradium* as well as to the layers overlying the coral bed. But the rock overlying the coral bed is the Madison bed, and the rock overlying the *Tetradium* bed at Coon Hollow, New Hope and near the county line is of Clinton Age. By accident, therefore, some of the Clinton has been correctly named.

The Medina to which Mr. Linney refers in his reports on Henry (page 12), Shelby (page 11), and Oldham (pages 10, 11) counties (Kentucky Survey, 1887) is also the Madison bed at the top of the Lower Silurian.

c.—KENTUCKY, EAST OF THE CINCINNATI ANTICLINE.

In the report on Garrard County (Kentucky Survey, Linney, 1882), it is very evident that Linney failed to see that Professor Shaler's Cumberland sandstone and his own typical Medina are the same rocks, both being Lower Silurian. (Pages 18, 19, 20.) The rock at the top

of Linney's supposed Medina, which weathers red on exposure, is in reality part of the Clinton (page 20).

In the report on Clark County (Kentucky Survey, 1884), Linney again attempts to distinguish between a lower set of sandy rocks, to which he erroneously confines the term Cumberland sandstone (page 24), and an upper set of sandy layers, which he calls Medina (page 26). The *Favistella* bed being absent, he evidently was at a loss where to place the dividing line between the Cumberland sandstone and the Medina, but tried to uphold preconceived notions. The same attempt to divide the sandy beds above the blue, fossiliferous Cincinnati Group limestones into a lower Cumberland sandstone (page 56) and an upper Medina series (page 59) is shown in the report on Montgomery County (Kentucky Survey, Linney, 1884).

In the report on Mason County (Kentucky Survey, 1885), Mr. Linney refers the same Lower Silurian sandy beds to the Medina (page 14). This is also done in the report on Bath County (Kentucky Survey, 1886, pages 16, 17) and in Marion County (Kentucky Survey, 1886, page 68).

In the Richmond folio, United States Geological Survey (1898), Marius R. Campbell adopts the name Richmond shale for the Upper Hudson beds of the Linney reports. This name was suggested by Mr. E. O. Ulrich for corresponding beds in Indiana. The Cumberland sandstone is not distinguished from the richly fossiliferous portion of the Richmond shale. I can scarcely agree with the statement that the calcareous sandstone at the top of the Richmond shales, the representative of the Cumberland sandstone, can with difficulty be distinguished from the formation above.

It would be more true to state that it would be often difficult to determine where the dividing line should be drawn between these calcareous shales and the fossiliferous limestones and clays which form the more typical Richmond beds.

d.—SOUTHERN KENTUCKY.

Professor Shaler's views on the age of the Cumberland sandstone (Oneida, Medina, 1873-1875; top of Lower Silurian, 1877) are given earlier in this paper.

In Volume I, Ohio Survey, Professor Newberry refers the Cumberland sandstone (50 feet of limestone and shales) in his Burksville section to the Niagara.

In the report on Clinton County (Kentucky Survey, 1890), Dr. R. H. Loughridge refers the Cumberland sandstone to the Medina. (Pages 9-11.)

Prof. Edward Orton, in his report on Petroleum, Natural Gas and Asphalt Rock (Kentucky Survey, 1891), alludes to Upper Silurian limestone in the neighborhood of Burksville. This can refer only to the Cumberland sandstone.

In the Geological Survey of Minnesota, Volume III, Part II, 1892-1896 (1897), page ciii, Prof. N. H. Winchell and Mr. E. O. Ulrich place the Cumberland sandstone at the top of the Cincinnati Group, more specifically at the top of the Richmond Group. That part of the section exposed in Marion County which contains abundant masses of *Columnaria, Tetradium, Labechia,* and rarer specimens of *Beatricea,* belongs just beneath the Cumberland sandstone or Madison bed, as identified by the present writer. In some localities there is a recurrence of *Tetradium* and *Labechia* in a thin layer at the summit of the Madison bed, but this is not the coral bed of the Kentucky surveys.

On page 103, Mark Linney is quoted as correlating the Cumberland sandstone with the Oswego sandstone, and it is suggested that "Linney was probably correct."

A.—MADISON BEDS—MOTTLED CLAYS.

IV.—OHIO.

In Ohio the Madison beds are replaced by clays and clayey shales which are at times mottled with purple and reddish purple and are usually devoid of recognizable fossils. Near the crest of the anticlinal, from the Miami River westward toward the Indiana State line, the clays are less often mottled, are more calcareous, and contain more fossils. In the more western localities Lower Silurian fossils occur even in the highest layers of the clay series, and their Lower Silurian Age is unquestioned. The exposures on Morris Hill tell a similar story for the mottled clays on the eastern side of the anticlinal, notwithstanding the fact that the more eastern exposures of these clays have so far not yielded identifiable fossils. The following notes will indicate the position assigned to these clays by various members of the Ohio Geological Survey.

In Ohio, after a lapse of many years, geological investigations were resumed under the auspices of the State in 1869. In the first Report of Progress of the Ohio Survey for 1869, published in 1871, page 54, Prof. J. S. Newberry does not include the Medina in his chart of the geological formations of the State. In the report on Montgomery County, however, Prof. E. Orton, in describing the Lower Silurian rock, says:

"The uppermost layers of the series from 6 to 20 feet generally deviate in mineral character from the beds already described, in that they consist, for the most part, of red and yellow clays, though occasionally of a yellowish, arenaceous limestone, which is sometimes turned to account as a firestone or as a building rock. It is probable that this portion of the series will be hereafter identified as the representative of a distinct group of rocks, viz., the Medina sandstone of the New York Survey." (Pages 147, 148 and 164.)

In his reports on Highland County and the Cliff limestones of Highland and Adams counties, in the Report of Progress for 1870, published 1871, Professor Orton speaks of these shales, clays and shaly limestones at the top of the Lower Silurian with much more confidence, again calling them Medina. (Pages 257, 267, 268, 277, 295.)

In Volume I of the Geological Survey of Ohio, 1873, Professor Newberry states that the Medina "has been struck in borings for oil in northern Ohio, but does not show itself by any well marked outcrop within the State." (Page 61.) On page 101, these well borings are stated to have been made at Toledo, Waterville and Vermillion; and on page 127 at Columbus. On page 103 a tendency is shown to refer the red, blue and mottled calcareous shales at the top of the Lower Silurian, so far not known to have fossils, to the Medina. I do not know where, in the vicinity of Dayton (page 126), clay or shales occur at the top of the Lower Silurian which do not contain easily recognizable Lower Silurian fossils. Indeed, my experience has been that while it is extremely difficult to find fossils in these clays and shales at many points along the eastern outcrops of the Cincinnati anticlinal, fossils become rather frequent at this horizon along the crest of the arch and westward. The strata at Madison, Indiana (page 127), which Professor Hall, in the notes on his journey of 1841, referred to the Clinton, belong to the top of the Lower Silurian (Madison beds). On page 414, the red shales of the Ohio end of the Cincinnati anticlinal are considered by Professor Orton to be Medina. On page 462, Professor Orton refers the often red, non-fossiliferous shales or marlites of Clarke County to the Lower Silurian, indicating that he was not always successful in persuading himself that these shales were Medina.

In Volume II of the Ohio Survey, 1874, in the report on Greene County, page 663, the light blue or red colored unfossiliferous shales are again tentatively placed by Prof. Edward Orton in the Medina.

In Volume III of the Ohio Survey, 1878, Professor Newberry refers both the red, mechanical sediments struck in well borings in northern Ohio and the calcareous colored clays outcropping in southwestern

Ohio to the Medina. By this time it had become known that the Banded Rock of Indiana was not Clinton, but Lower Silurian (discovered by Dr. W. S. T. Cornett, in 1874), but it was not recognized that the age of the Banded Rocks of Indiana was identical with that of the colored clays at the top of the Lower Silurian in Ohio (pages 4 and 6).

On page 384, in the report on Warren County, Professor Orton expresses the view, held certainly as early as 1857 (Vol. II, Old Series, Kentucky Survey, D. D. Owen, pages 102, 103), that the coral bed marked the junction between the Upper and Lower Silurian when other well recognizable Lower Silurian fossils (usually brachiopods) were not at hand; under the term "corals" are included true corals and stromatoporoid sponges. The overlying clays completing the series to the Clinton limestone (page 384, line 8) are evidently considered as Upper Silurian. According to my own notes, the Clinton at Morris Hill lies 14 feet above the *Tetradium* and *Stromatopora* bed of Orton. Four feet of clay, mottled with green and purple, lie two feet above this bed; that mottled clays can belong to the Lower Silurian is shown by two feet of limestone, with *Orthis occidentalis* six feet above the coral bed and two feet of thin limestone layers, with bryozoans of Lower Silurian age, eight feet above the coral bed, leaving only four feet of shaly rock not accounted for. Morris Hill is nearly straight south of Dayton, and lies along the line at which the clays at the top of the Lower Silurian, the supposed Medina clays of Orton, become fossiliferous on going westward. This is the reason why no Medina is identified in Preble County (pages 404-419), which lies still farther west.

The five feet of sandy limestone alternating with thin beds of clay, which occur at the base of the Clinton in Clinton County along Todd's Fork (pages 442, 443), I have called the Belfast bed. Their position will be referred to later.

In the report on Miami County, page 481, Professor Orton's section, in order to correspond with his belief that red shales are Medina, should read (not correcting his measurements):

Clinton, 35 feet.
White, fine grained sandy layer, 6 inches; associated with the Clinton.
Medina light blue clay, 5 feet. } Strata dividing rocks known to be Upper Silurian from those known to be Lower Silurian.
Medina red shales, 4 feet. }
Blue shale, known to belong to the Cincinnati Group, 20 feet.

When I visited this locality I found a section very different from the one just quoted beneath the Clinton at this locality; so very different,

in fact, that it is impossible for me to determine what are the elements of Professor Orton's section.

At the railroad cut north of Tippecanoe (page 481), annelid teeth, such as are found in the Lower Silurian, occur within seven feet of the Clinton, but the first easily recognized Lower Silurian fossil, *Orthis occidentalis*, occurs 21 feet beneath the Clinton. At the bridge a short distance below the falls at West Milton (page 481), however, according to my notes, *Orthis occidentalis* occurs nine feet below the Clinton, the upper five feet corresponding to the Belfast bed to be described later.

In Volume VI of the Ohio Survey, 1888, Professor Orton (pages 4, 11) again refers the red and otherwise colored shales at the top of the Lower Silurian to the Medina. Small pebbles are said to occur in some of the sandstone beds, included in the Medina. Where? The Medina is identified in the wells at Findlay (page 115).

In Volume VII of the Ohio Survey, 1893, the statements of Volume VI are repeated (page 11).

In Notes on a Geological Section at Todd's Fork, Ohio (Clinton County), published in the American Geologist, pages 412 to 419, I referred the five feet of sandy rock below the Clinton to the Medina, and described the fossil annelid teeth which this layer contains. The layers were in a later publication referred to the Belfast bed. Two feet of sandy limestone at Fair Haven were erroneously considered Medina, owing to the presence of a large unfamiliar aviculoid shell.

In my paper "On Clinton Conglomerates and Wave Marks in Ohio and Kentucky," Journal of Geology, Vol. III, '95, the sandy limestones at the top of the Lower Silurian in Kentucky are erroneously referred to the Oneida and Medina (page 13), and the Crab Orchard shales of Kentucky are erroneously referred to the Clinton (page 14).

There is no chert in the Clinton of Henry or Marion counties (page 15). There is no Clinton conglomerate near Fredericktown in western Washington County (page 15). In fact, all of the references to Kentucky strata (pages 31-40) must be revised in accordance with my later discoveries. In these earlier statements, I merely followed the Kentucky Survey reports, and the corrections suggested by later personal observations have already been made on the preceding pages of the present paper.

A.—V.—BELFAST BED.

OHIO.

On the eastern side of the Cincinnati anticlinal, as exposed in Ohio from Clarke to Highland counties, there is a series of rather sandy, massive limestones, which occur between unequivocal Lower and Upper Silurian rocks: between the mottled unfossiliferous clays and the crinoidal Clinton limestones. They have been called by me the Belfast bed.

In his report on the geology of Highland County, Second Report of Progress, 1871, pages 268, 277, Prof. E. Orton expresses the belief that the massive sandy limestones used for bridge abutments near Belfast (Belfast bed) supply the place of the red shales (Prof. Orton's Medina), when the latter are wanting.

In the report on Greene County, Ohio Survey, Vol. II, '74, pages 663, 665, Prof. E. Orton evidently includes the sandy limestones (Belfast bed) in his Clinton, near Mr. Goe's residence, and elsewhere.

A similar disposition of these sandy limestone beds (Madison) was made by Prof. Orton in the report on Warren County, Ohio Survey, Vol. III, '78, pages 384, 385, and by Mr. John Hussey, in the case of the corresponding beds in Clinton County, page 442.

The more clayey representatives of the Belfast bed in Miami County (page 481), and at other western exposures, were naturally classed with the clayey Medina of Orton.

In my paper "On Clinton Conglomerates and Wave Marks in Ohio and Kentucky," 1895, the five feet of sandy limestone with annelid teeth at Todd's Fork, later called the Belfast bed, are here still called Medina (page 18). The four feet of similar stone (Belfast bed) near Sharpsville with an unknown Orthis (page 21), and the four feet of similar rocks (Belfast bed) in the various sections near the type locality, Belfast, with annelid teeth and *Halysites* (pages 24-26), are all referred to the Medina.

In my paper giving "An Account of the Middle Silurian Rocks of Ohio and Indiana," Journal Cincinnati Society of Natural History, Vol. XVIII, '96, I give a full discussion of what was, at that time, known of the rocks at the top of the Lower Silurian. The heading at the top of page 163, "The Belfast Bed of Ohio, Formerly Called Medina, With Frequent Observations on the Clinton of Ohio," is misleading. The four to five feet of sandy limestones which I here, for the first time, call the Belfast bed, are not the typical Medina rocks of Prof. Orton and other writers on Ohio geology, and are therefore not the rocks formerly called Medina in Ohio. It should be remembered

that the identification of the Medina in Ohio has not only been solely lithological, but has been practically made upon the sole basis of color. Had the clays near the top of the Lower Silurian not had a single touch of red, or purple color, it is probable that the name Medina would never have been applied to them. Prof. Orton's typical Medina, consists not of the four to five-foot sandy limestone bed I called the Belfast, but of the much thicker underlying clays.

The sandy limestone beds could not be definitely assigned even in Prof. Orton's section. They lie between Prof. Orton's unequivocal Clinton and his reported Medina. I am not certain as to the age of the Belfast bed myself. The presence in it of *Halysites catenulatus* seems to determine its Upper Silurian age, and annelid teeth are hardly good means of identifying horizons in the present state of our knowledge of these forms. I do not see in what way we gain by insisting that the Belfast bed is of Medina age, before we have positive reasons for making this identification. The red, purple, and otherwise colored clays below the Belfast bed and its equivalent, are, however, Lower Silurian, as is shown by the presence in them of Lower Silurian fossils. A good section illustrating this, is seen at Morris Hill (pages 173, 174), already commented upon.

The Belfast bed, whatever its age, is well exposed along the whole eastern outcrop of the Middle Silurian. It is seen in the most western outcrops on the eastern side of the summit of the Cincinnati anticlinal, being exposed near Dodds, Lytle, Centerville, Soldiers' Home, near Dayton, and at Ludlow Falls. It loses its sandy character and becomes a layer of hardened calcareous clay in its more western exposures, from Lytle to Centerville and Ludlow Falls. In Preble County it is entirely absent, and nothing corresponding to it has been discovered in Indiana. The Belfast bed is the only bed which I have seen in Indiana, Ohio or Kentucky whose position at present is doubtful. It is the only bed which may be Lower Silurian and which may be of Medina age. As far as known at present, it is confined to the eastern side of the Ohio end of the Cincinnati anticlinal.

B.—CLINTON.

I.—INDIANA.

The second Geological Survey of Indiana began its labors in 1869. The first Middle Silurian rocks studied occur in the counties along the Ohio River. This is not a favorable location for the recognition of the Clinton formation. The Clinton in the river counties of Indiana

rarely exceeds four feet in thickness, and often thins down to about one foot. In the more southwestern exposures it is often a siliceous limestone, almost devoid of fossils, and lithologically similar to the more immediately adjacent rocks. In the more northeastern exposures, where it has a salmon brown color, and contains fossils, the fossils are so firmly imbedded in the rock that their collection is of no interest to collectors, and their study is likely to be neglected. The Clinton was therefore never identified as a separate formation in this part of Indiana until 1889, when Prof. A. H. Young recognized the Clinton character of the fossils in the salmon colored limestone layer near Hanover, and sent to me a fair collection of these fossils.

In the meantime the thin band of Clinton was classed by different writers either with the Madison bed below, or the Osgood bed above. As far as can be determined, Prof. Borden, in the early reports, included the Clinton, with the overlying beds, in the Lower Niagara, but called the underlying Lower Silurian beds (Madison beds), *Clinton.* Mr. E. T. Cox also includes the real Clinton in the Lower Niagara, but he calls the underlying rocks, *Lower Silurian,* which is correct (Eighth, Ninth, and Tenth Reports, '79).

In his report on Jennings County (Seventh Report, 1876, page 154), Prof. Borden incorrectly refers the Madison-like beds, at the base of the Osgood beds, north of Madison (in Jefferson County), to the Clinton, on account of their lithological resemblance to the sandy limestones which occur at the top of the Lower Silurian (Madison beds), *his Clinton.* Prof. Borden's error is easily explained. The resemblance of the lower Osgood rocks in some parts of Jennings County to the Madison bed exposures at various points along the Ohio River is so great, that, in my account of the strata in Jennings County, I refer to them as the *Madison-like* Osgood beds.

Dr. M. N. Elrod (in the Twelfth Report of the Indiana Survey, Decatur County, 1883) was the first person to recognize clearly that there were two shales in the Niagara; one near the top, *Waldron* shale, and one at the base, which he called the Lower Niagara shale (Osgood shale). While it is evident that Dr. Elrod knew that the Lower Niagara shale was not a homogeneous mass, but consisted of a thin upper shale, a thin intermediate set of flag limestones, and a thick bed of marls at the base, he did not succeed in identifying all three parts of the Lower Niagara shale in all of his sections. He seems to have been of the opinion that the Lower Niagara shale varied considerably in thickness, so that in some places it was represented by only one or two feet of shale.

Dr. Elrod did not succeed in recognizing the Clinton either lithologically or paleontologically. He called anything Clinton which lay between the base of what he considered the Lower Niagara shale and the top of what he considered as Lower Silurian, without reference to the lithological or paleontological characteristics of whatever at any locality he identified as Clinton. The result is that he identified both real Clinton and also rocks belonging below the upper shale of his Lower Niagara shale as *Clinton*. Owing to the fact that some of these identifications are correct, Dr. Elrod is the first geologist who gave the name *Clinton* to rocks which are Clinton, occurring in Indiana, without including in the same section, at the same locality, rocks which are not Clinton.

Clinton and Lower Silurian rocks are the only rocks exposed at Parker's Mill. The identification, therefore, must be correct (page 130).

Clinton occurs in the creek bed, east of Hollensbe's quarry, and west of Rossburg. It occurs about eight feet below the Upper Osgood shale. Dr. Elrod gives a thickness of only two inches to the shaly clay which he identifies as Lower Niagara shale. It is very probable that he meant to give it a thickness of 20 inches, a cipher being omitted. The context shows that he was aware of the fact that this was only the upper part of his Lower Niagara shale section. Dr. Elrod's suggestion that the remainder of the Lower Niagara shale section (including the Osgood limestone and the Lower Osgood shale) is six feet thick is fairly correct. This makes it very probable that when he identifies the underlying rock as Clinton, that he had the Clinton in mind. It is difficult, however, to understand why he should call the salmon brown Clinton *buff*, and why he should refer to the Clinton as being found nearer Rossburg, when the Clinton is exposed very close to the first exposures of the Lower Niagara shale (pages 120, 121).

At Ducrow and Gleason's quarry, Sand Creek Township (page 123), Dr. Elrod again applies the name Lower Niagara shale to the one foot two inches of marly clay at the top of the Osgood section. The three feet of thin ledges of flagging include the Osgood limestone and the upper part of the Lower Osgood clay, which forms a sort of rubble limestone in this section of the State. The Clinton is said to be eight inches thick and to be a hard, buff stone. It must, therefore, be a part of the lower portion of the Lower Osgood clay, at times called by me the Madison-like Osgood rock. There is no real Clinton found at this quarry.

At the foot of the milldam, opposite the Boicourt quarry (page 126), Dr. Elrod once more applies the name Lower Niagara shale to a 12-inch bed of marl, which is the Upper Osgood clay. In this case, however, he makes no allowance for the lower part of the Lower Niagara shale section, but calls the 10-inch persistent layer, just beneath, which is the Osgood limestone, *Clinton*. There is no Clinton here.

Even if the six feet which Dr. Elrod found covered in the section taken on Squaw Creek had been exposed, he would not have been able to find real Clinton, this formation being absent (south of Millhousen, page 122).

At Larkin Walter's quarry (pages 118, 119), Dr. Elrod once more identifies the Upper Osgood shale, one foot eight inches thick, as Lower Niagara shale. Underlying this shaly marl he says there are beds of hard stone; these beds correspond in position to the Osgood section below the Upper Osgood shale. The Clinton is said to be a buff ledge about eight inches thick, occurring a few yards down the creek. The real Clinton is a salmon brown rock, about five or six feet thick, and is well exposed about 200 yards down the creek.

It may be noted in connection with all of the sections here discussed, that the word *buff* applies far better to the rocks at the base of the Osgood section than to the salmon brown Clinton of this county.

Shells identifiable with *Meristina intermedia* are far more common and more characteristic of the Osgood limestone than of the Clinton. The report does not state where the brachiopod was obtained, whether it occurred where Clinton was to be found.

In middle Fayette County, the Osgood beds, Dr. Elrod's Lower Niagara shales, are not very similar, lithologically, to the corresponding beds of Decatur County. The result is that all of the hard limestone beds underlying the undoubted Niagara are placed in the Clinton (Fourteenth Report of Indiana Survey, 1884, pages 47, 51). The result is that Dr. Elrod here includes rocks both above and below the real Clinton in his Clinton section, as already explained. (See above, the discussion on the Fourteenth Report.)

In the Fifteenth Report of the Indiana Survey, 1886, Maurice Thompson quotes Dr. Elrod's incorrect identification of the Clinton, just mentioned, for the second time.

The various references to the Clinton in Prof. E. P. Cubberley's paper on "Indiana's Structural Features, as Revealed by the Drill," in the Eighteenth Report of the Indiana Survey, 1893, pages 222 to 255, can scarcely receive serious attention when it is remembered how little success had up to that time attended the identification of this formation, where actually exposed, often with abundant fossils.

In 1896, I identified the Clinton at various points between Richmond and Osgood (An Account of the Middle Silurian Rocks of Ohio and Indiana, Jour. Cincinnati Soc. Nat. Hist., Feb., 1896), but interpreted the section at Ball's quarry incorrectly. This was the first attempt to trace the Clinton formation in Indiana by means of its fossils.

In the Twenty-first Annual Report of the Indiana Survey, 1897, I gave an account of the Clinton Group, tracing it from Charlestown Landing to the southern end of Decatur County.

In the Twenty-second Report of the Indiana Survey, 1898, I continued these studies of the Clinton, tracing it as far northward as middle Fayette County, correcting the interpretation of the section at Ball's quarry. In the last two reports, the Clinton was again identified at numerous localities, by its fossil contents.

B.—CLINTON.

II.—KENTUCKY. *a*, EASTERN COUNTIES.

The Clinton was identified in Kentucky as long ago as 1857, by Dr. D. D. Owen (Kentucky Survey, Vol. III, Old Series, 1857). A section taken in Lewis County, on the Ohio River below Vanceburg, near the mouth of Salt Lick Creek (page 120), contains strata doubtfully referred to the Clinton of New York. A section taken at Poplar Flats (page 125) includes flinty or cherty magnesian limestones, at base encrinital, referred to the Clinton. In Fleming County, at Mount Carmel, east of Poplar Plains (page 127), the Clinton is credited with the fossils *Glyptocrinus plumosus, Leptæna depressa,* and *Orthis circulus.* In Bath County, near Owingsville (page 130), ten or more feet of encrinital limestone are referred to the Clinton. Clinton is mentioned as occurring on Lulbegrud Creek, in Montgomery County (page 134), and in Estill County (page 137).

Dr. Owen did not identify the Clinton in the eastern counties of Kentucky by means of its fossils, although reference is made to these. *Glyptocrinus plumosus* was described by Hall from scattered fragments of crinoids which he believed to belong to the same species. These fragments consisted of parts of arms, parts of columns, and joints of columns. When Dr. Owen identified the Clinton in Kentucky, five years later, he must have identified the crinoid in question upon material of very questionable specific identity, to say the least. The *Leptæna depressa* is only a small *Leptæna rhomboidalis;* this

species actually occurs in the Clinton, but it ranges from the Cincinnati Group through the Clinton and Niagara, so that it can not be used very well to identify the Clinton. *Orthis circulus*, as far as I know, is not found anywhere in the Cincinnati anticlinal region. It seems to me almost certain that this must have been an incorrect determination. *Orthis flabella*, the form with rather numerous plications, i. e., with more plications than the more typical forms, is fairly common, and, together with *Leptæna rhomboidalis* and various joints of crinoid stems, is almost the only fossil commonly found, when fossils in general are scarce, in the Clinton of southeastern Kentucky. This may also be true in Fleming County.

The identification of the Clinton in Kentucky was chiefly based upon the presence of an iron ore bed at the summit of a series of limestones. A similar oölitic iron ore bed occurs at the top of the Clinton in New York. The identification of the Clinton was therefore lithological. In the eastern counties of Kentucky, where the iron ore bed is found, the Clinton is correctly identified. In southern Kentucky, where the iron ore bed is absent, the Clinton is more commonly referred to the Medina, and, in western Kentucky, to the Niagara, being placed in these formations together with other rocks.

Owing to the presence of the iron ore, Professor Shaler, also, called the oölitic iron ore bed and the limestones just beneath, Clinton. (Kentucky Survey, Volume III, New Series, pages 165, 166, 169.) It is evident, however, that a vague idea prevailed that the oölitic iron ore marked the upper limit of the Upper Silurian. The sentence at the bottom of page 163 (Kentucky Survey, Volume III, 1877) was evidently intended to read: "The most remarkable feature in the formation is the presence at various points of extensive deposits of iron ore at its upper limit."

And, on page 169, it is stated that "this so-called Clinton iron bed may not unusually be found at the top of the Silurian section." The diagrammatic section, on page 166, gives further direct expression to this belief. The name Silurian ore is therefore preferred to the name Clinton ore.

Professor Shaler's hesitancy to accept the term Clinton is the more noteworthy since, in 1877, when the third volume of the Kentucky Survey went to press, Prof. E. Orton had for six years considered the oölitic iron ore and the underlying limestones in the southern counties of Ohio as Clinton. Moreover, in 1873, F. B. Meek had identified certain fossils as belonging to the Clinton in Ohio (Volume I, Ohio Paleontology), and, in 1875, Professors Hall, Whitfield and Nicholson had referred fossils to the Clinton (Volume II, Ohio Paleontology).

There was no doubt that the Clinton of Ohio and Kentucky were identical. Aside from the presence of the oölitic iron ore bed at the summit of the Clinton in each State, the limestones beneath the iron ore bed, which were included in the Clinton, contained considerable chert in both States. These cherts were especially conspicuous, in both States, nearer the Ohio River. Moreover, in both States a great series of clays and clayey shales are found overlying the oölitic iron ore beds. And, finally, all the strata concerned could be easily traced from one State into the other.

In the various county reports of Kentucky, Mr. W. M. Linney follows Owen and Shaler in calling the oölitic iron ore bed and the underlying limestones *Clinton*. But it is difficult to determine without further study just what rocks, in addition to the real Clinton, were included by Linney in his Clinton. Before Mr. Linney took up the study of the more northeastern counties of the Cincinnati anticlinal region, he had become familiar with the great mass of clays and clayey shales in Lincoln and Garrard. The clayey shales are of Lower Niagara Age (Crab Orchard shales, Osgood bed), but were identified by Linney as Clinton. Accordingly, it was necessary for Linney to trace the clays of Lincoln and Garrard counties northward, and to show their stratigraphical identity with the oölitic iron ore and the Clinton limestones of more northern counties. The result is that he includes in his more northern sections of Clinton a number of clays at various horizons where it is not very likely that clays form a part of the Clinton section, excepting at the summit of this formation. It seems that in places he included even Lower Silurian clayey shales in his Clinton.

In the main, however, Linney's identifications of the Clinton, in Clark (1884), Montgomery (1884), Mason (1884), Bath (1886), and Fleming (1886) counties, are correct. Had Mr. Linney worked from the Ohio River counties southward, instead of in the reverse direction, it is very likely that he would have identified the Crab Orchard shales as Lower Niagara, and all the subsequent confusion resulting from this error would have been avoided.

In the Richmond folio, United States Geological Survey (1898), Marius R. Campbell does not distinguish the Clinton. The meagerness of fossil remains to be found in this and in the overlying formations is no doubt accountable for this. The failure to distinguish even the Silurian formations from the Devonian limestones is due to the difficulty of securing enough evidence to enable the geologist in the field to determine where to draw the line between them. The result is that the name Panola formation is suggested for the Upper

Silurian formations and the Devonian limestones. It is recognized that this is a complex. At the base of this complex is a series of coarse, rusty yellow sandy limestones, the greater part of which belongs to the Clinton. Near the top of these limestones large crinoid beads are very common. Immediately above, internal casts of *Whitfieldella cylindrica* are often fairly common. This fossil is characteristic of the Osgood beds in the Cincinnati anticlinal region. It does not occur in the Clinton, but in some localities is fairly common in the Osgood beds. The last two or three feet of the more continuous series of limestones are, therefore, to be classed with the Osgood beds. The immediately overlying clays belong to the Osgood beds, and form the characteristic element of this formation in the southern and eastern portion of the Silurian area in Kentucky. In the lower portion of these clays straggling layers of limestone are intercalated, so that the Osgood beds in this part of Kentucky open up with sandstone beds, followed by clay beds with intercalated sandy limestones, and these in turn are followed by a considerable mass of clays which form the bulk of the Osgood beds.

Near Whites, half a mile south of the station, along the railroad track, about 27 feet of the Panola formation are exposed. The upper three inches consist of a blue, argillaceous, gritty limestone, with fish teeth. It belongs to the Devonian formation. The lower 12 feet consist chiefly of limestone with shaly partings, belonging to the Clinton.

In the half a foot of rock above that assigned to the Clinton, large crinoid beads from the Clinton and specimens of *Whitfieldella cylindrica* are intermingled. This fossil is considered as the characteristic fossil of the Osgood beds. It is difficult to find traces of it in the railroad cut, although fragments are not infrequent in the dump north of the cut, where the stone removed from the cut was thrown. According to this, the 14 feet of limestone and shale overlying the *Whitfieldella* bed are to be assigned to the Osgood beds. The great thickness of clays forming the main element of the Osgood beds elsewhere were removed here before the deposition of the Devonian. The equivalents of the Laurel limestone, of the Waldron shale, and of the Louisville limestone are also gone. The result of all of my investigations for the last five years in Ohio, Kentucky, and Indiana have tended to confirm the conclusion that at the close of the Upper Silurian a considerable part of the folding which now constitutes the Cincinnati axis took place; that a period of denudation took place, removing most strata from the axis of this fold, and proportionally smaller amounts from its flanks; and that the Devonian rests uncon-

formably upon the denuded Upper Silurian rocks upon the flanks of the axis, and that it rests upon the Lower Silurian upon the middle portions of this axis. These observations will be soon ready for publication.

B.—CLINTON.

II.—KENTUCKY. *b*, WESTERN COUNTIES.

Owing to the identification of the Crab Orchard shales as Clinton, Mr. Linney was obliged to refer all real Clinton exposures, wherever found, to the next lower-lying formation, his Medina. This is true in the reports on all the counties lying west of the Cincinnati anticlinal—Lincoln (1882), Garrard (1882), Nelson (1884)—and northward, wherever he thought he could recognize the Crab Orchard shales. The limestone which he identifies as Medina at James's Mill is unquestionably Clinton (Lincoln County, 1882).

A number of other errors occur. In the report on Washington County (1882), Linney refers to possible remains of Clinton iron ore beds (page 20). Since the oölitic iron ore bed of the Clinton seems never to have extended farther west than the summit of the present Cincinnati anticlinal, it is difficult to determine what it was that Linney found, and identified as Clinton. The Clinton in the section east of Wheatley's branch is difficult to recognize; indeed, this is true of the entire upper section. The Clinton is the rock just beneath the heavy bed of clays at the summit of the section.

The real Clinton of Henry County does not contain chert beds (Linney, 1887). Both the Lower Silurian and Upper Silurian contain chert across the Ohio River, near Charlestown Landing, in Indiana. Owing to the fact that Linney includes the Clinton, Osgood shale and Laurel limestone in his Clinton, in Oldham County (1887, pages 11 and 12), it is not impossible that the cherty Clinton of Henry County is the Laurel limestone. The Laurel limestone includes chert, and was identified as Clinton in Oldham County, as already stated.

Dr. W. T. Knott follows Mr. Linney in calling the Crab Orchard shales *Clinton*. Moreover, he places the rocks underlying the Crab Orchard shales in the Medina. The Medina of both Linney and Knott includes all the strata lying below the Crab Orchard shales and above the "coral" bed. The coral bed is a series strata only a few feet thick, characterized by the presence of an unusual number of corals, such as *Favistella stellata, Columnopora sp.?*, and *Columnaria*. It is found at the base of the Madison bed, or Linney's Medina. (Linney's Medina includes both the Madison bed and also the Clinton, in the counties extending from Garrard County northwestward.) It so hap-

pens, however, that along the Louisville & Nashville Railroad in western Marion County and in the adjacent parts of Nelson County, there is a bed with *Tetradium* at the top of the Madison bed, within a short distance of the Clinton base. Dr. Knott did not recognize that the *Tetradium* bed was at a higher level than the bed which he usually took as the base of his Medina section, and he therefore made the *Tetradium* bed the base of the Medina at Coon Hollow, New Hope, and at the Marion-Nelson County line. While this still leaves the real Clinton in the Medina as heretofore, the Medina at these localities does not include the Madison bed. But the Madison bed is Linney's typical Medina rock, the Clinton being placed in the Medina only because it is a much thinner formation in this part of Kentucky, so that it was not suspected that it represented an age quite distinct from the main mass of sandy limestones below, which formed Linney's typical Medina.

B.—CLINTON.

III.—OHIO.

The Clinton was correctly identified by Prof. E. Orton at the very beginning of the operations of the Second Geological Survey, and no error has been made in any of the reports of this survey. The presence of the oölitic iron ore at the top of the Clinton is noted at various points between Adams County and the Todd's Fork locality in Clinton County. The presence of chert is recorded in Adams and Highland counties. The conglomerate in the Clinton at Belfast in Highland County is described. The following are the main references to the Clinton in the reports of the survey: Report of Progress for 1869 (1871), page 148; Report of Progress for 1870 (1871), pages 257, 263, 268, 269, 270, 296, 298, 299; Volume I (1873), pages 62, 103, 127, 452, 453, 463; Volume II (1874), pages 663-667, 674; Volume III (1878), pages 2, 5-7, 384-386, 400, 406-408, 441-443, 478-480; Volume V (1884), pages 371, 372, 611; Volume VI (1888), pages 11-13, 705, 727; Volume VII (1893), pages 10-11, 518.

In the third volume of the survey a list of fossils found in the Clinton is given (pages 415, 416). *Lichenalia concentrica* does not occur in the Clinton. *Atrypa nodostriata* is *Atrypa marginalis*, and *Zygospira modesta* is a small specimen of the same *Atrypa*. *Orthis circulus* must be a fairly large specimen of *Orthis elegantula*, and *Streptorhynchus subplana* does not occur in the Clinton. *Cyclonema bilix* is a Lower Silurian species. For the Clinton species described from the Clinton of Ohio, the name *Cyclonema daytonensis* may be suggested.

C.—OSGOOD BEDS.

I.—INDIANA.

The first geologist in Indiana to distinguish the shaly and clayey beds (Osgood) at the base of the Niagara from the rest of the Niagara formation, and to give them a separate designation, was Dr. M. N. Elrod. (Report on Decatur County, Twelfth Report of Indiana Survey, 1883.) He recognized in it the upper thin strata of shale (upper Osgood shale), the intermediate thin flag (Osgood limestone), and the thicker beds of marl at the base (lower Osgood shale). (Page 108.) But, judging from some of his subsequent determinations, he failed to recognize the degree of constancy of this order of lithological succession. The separation was made on the basis of lithological characters, not paleontological.

In 1896, I recognized, in a confused way, that the Lower Niagara beds north of Osgood contained many fossils distinct from those farther up the series, especially distinct from those in the Waldron bed. I therefore referred to them as forming the Lower Osgood phase of the Laurel formation. (An Account of the Middle Silurian Rocks of Ohio and Indiana, Journal of Cincinnati Society of Natural History, February, 1896, pages 190, 191.)

Having learned in conversation with Mr. E. O. Ulrich, who had made considerable collections in this formation at Osgood, and along Big Creek, that he had become satisfied that this represented a horizon very distinct from the Waldron, I began to investigate this formation more carefully, and gave a much more accurate account of its lithological features, as far as its exposures along Big Creek and northward in the area then being investigated are concerned, in my report on the Geology of the Middle and Upper Silurian Rocks of Clark, Jefferson, Ripley, Jennings and Southern Decatur Counties (Twenty-first Report of the Indiana Survey, 1897). The name Osgood beds was here first applied to this formation.

In the Twenty-second Report of the Indiana Survey (1898), the lithological study of the Osgood beds was continued for the more northern counties of Indiana.

C.—OSGOOD BEDS—CRAB ORCHARD SHALES.

II.—KENTUCKY.

The Osgood beds are represented in central and southeastern Kentucky by a thick series of clays which merge northward into clayey shales. In the neighborhood of Crab Orchard they were called Crab

Orchard shales by M. Linney, and were supposed to be Clinton. Mr. Linney was not very successful in tracing these shales and clays from the type locality northward, nor in identifying them where they merge into the Osgood shales on approaching the Ohio River opposite Indiana.

The shales at Crab Orchard were erroneously referred by Mr. Linney to the Clinton. Hence, the corresponding clayey shales, in Lincoln (1882), Garrard (1884), Nelson (1884), Marion (by W. F. Knott, 1885), and Oldham counties, are also referred to the Clinton.

In the reports on Clark (1884, pages 27, 28), Montgomery (1884, page 59), Mason (1885, page 14), Bath (1886, pages 21, 22), and Fleming (1886, pages 69-71), the corresponding shales are more correctly referred to the Niagara. It was not known, however, that they were the Crab Orchard shale, but it was supposed that the Crab Orchard shales merged into the Clinton on going northward, and that the clayey shales of the counties in question represented the Niagara shale (Fleming County report, 1886, pages 70, 71), at the base of the Niagara, in Ohio, and this is their correct position.

In the report on Oldham County (1887), the real Clinton is made the base of Linney's Clinton. The 15 feet of blue Crab Orchard (Osgood of Foerste) shales, and the 30 feet or more of Niagara rock (Laurel of Foerste) overlying the same, are all classed in the Clinton, the uppermost 20 feet of the limestone being called the cavernous layer (pages 11, 12).

Resting on this cavernous bed (top of Laurel of Foerste) are blue clay shales (Waldron shale of Foerste), and above these is a considerable thickness of limestones (Louisville of Foerste). Linney calls the cavernous bed Clinton. The Waldron bed he places at the base of the Niagara; he must therefore identify it as equivalent to Niagara shale. And the Louisville limestone he identifies as the main mass of the Niagara. He evidently did not know of the presence of two clays in the Niagara—one at the bottom, and one near or above the middle.

Linney's identification of the Waldron shale as the Lower Niagara shale, and the underlying Niagara (Laurel) limestone as Clinton, is exactly matched by a note in the last volume of the Indiana Survey, which erroneously credits Mr. A. F. Foerste with the belief that the limestones below the Waldron shale are Clinton.

The Crab Orchard shales are correctly referred to a position above the Clinton, and are made equivalent to the Great Marl bed of Adams County in Ohio, by Dr. D. D. Owen (in Volume 3, Old Series, Kentucky Survey, 1857), in Lewis County, pages 120, 125, and Bath County, page 130. The uncertainty left by the few references of

Prof. N. S. Shaler, in the third volume of the Kentucky Survey, 187 have already been commented upon in connection with the discussic of the Clinton of Kentucky.

The existence of the Osgood shale as a member of the Panola fo mation on the eastern side of the Cincinnati axis in Kentucky ha been already commented upon in the discussion of the Clinton forma tion of this section of the State.

C.—OSGOOD BEDS—NIAGARA SHALE.

III.—OHIO.

At the base of the Niagara in Ohio are several feet—two to five—of hard, fine-grained, white limestone, which have been called the Dayton stone. The following are the chief references to this stone in the literature of the survey: Report of Progress for 1869 (1871), page 149; Report of Progress for 1870 (1871), pages 272, 297-302; Volume I (1873), pages 104, 465; Volume II (1874), page 668; Volume III (1878), pages 5, 386, 409; Volume V (1884), pages 613-616; Volume VI (1888), page 13; Volume VII (1893), pages 12, 519.

Above the Dayton stone is a series of rocks which vary considerably in different parts of the State, but which evidently correspond stratigraphically to the Osgood beds of Indiana. In the southeastern part of the Silurian area, in Adams and Highland counties, the series consist of clayey shales of considerable thickness, often exceeding 100 feet. North of Hillsboro, thin fragile courses of shaly limestone begin to replace the clayey shales, and in the more northern and northwestern counties the lower courses are replaced chiefly by a poor quality of limestone, readily weathering, while the upper more shaly courses are very calcareous. In Clarke and Montgomery counties the shale series is reduced to 10 to 15 feet. In the Ohio reports the shale series is called the Niagara shale. The West Union cliff may correspond to the limestone courses in the upper part of the Osgood beds in Indiana and western Kentucky, but it has so far not been sufficiently investigated to admit of correlation. The following are the chief references to the Niagara shale in the literature of the survey: Report of Progress for 1870 (1871), pages 272, 297, 302; Volume I (1873), page 465; Volume II (1874), page 669; Volume III (1878), pages 7, 386; Volume V (1884), page 615; Volume VI (1888), page 13; Volume VII (1893), pages 11-12.