CHAPTER I.

INTRODUCTION

This report is a companion to the report on the Mississippian series of western Kentucky by E. O. Ulrich and the writer, published by the Kentucky Geological Survey in 1917. In that report the Mississippian series as developed in the western half of Kentucky or west of the meridian of Louisville was described. This report covers the belt of country occupied by the outcrop of the Mississippian rocks extending from the Louisville country to Tennessee and thence northward between the "Coal Measures" and the Bluegrass region to the Ohio River in Lewis and Greenup counties. (See key map on section chart.) It sets forth the classification, order, character, thickness, geographic extent, and regional variations of the various stratigraphic units into which the Mississippian series of that part of Kentucky is divided. As preliminary to the detailed description of the formations a definition and brief general description of the Mississippian series is given.

Name and Definition. The Mississippian series was first defined by Williams[1] in 1891, from the Mississippi Valley, where it is typically developed. The name was a modification of Mississippi group or series of Winchell.[2] It is the lowest of the three divisions of the Carboniferous system, the middle division being the Pennsylvanian series or "Coal Measures," represented by the coal-bearing shales and sandstones of the Kentucky coal fields; and the upper division being the Permian series, which is not represented in Kentucky. Briefly stated, the Mississippian series as usually understood in Mississippi and Ohio valleys is the body of stratified rocks lying between the well-known persistent black shale below and the "Coal Measures" above. In Ohio and northeastern Kentucky the main body of black shale is known as the Ohio shale; in southern and eastern Kentucky, in Tennessee, Alabama, and southern Illinois the black shale is known as the Chattanooga shale; and in the Louisville, Ky., region and in Indiana it is known as the New Albany shale.

[1] Williams, H. S., U. S. Geol. Survey Bull. 80, p. 135, 1891.
[2] Winchell, A., Am. Phil. Soc. Proc., Vol. 11, p. 79, 1869-70.

Some geologists believe that all of the black shale is of Devonian age. Other geologists believe that the greater part of the black shale, and in some regions all of it, is of Mississippian age. The precise location of the lower boundary of the Mississippian series is, therefore, a subject of doubt and discussion among geologists.

General Relations and Stratigraphy. The standard section and time scale of the Mississippian are based on its long-recognized and well-defined subdivisions in the Mississippi Valley, the type region. There at the bottom is the Kinderhook group, consisting of sandstone, shale, and limestone, but varying greatly from place to place in the relative thicknesses and order of succession of those elements, no two sections being alike. Its known thickness nowhere exceeds 100 feet. A section of the Kinderhook as it is at Burlington, Iowa, is given at the bottom of section No. 1 of the section chart.

The Kinderhook group is succeeded above by the Osage group, consisting of the Burlington limestone below and the Keokuk limestone above. Overlying the Osage is the Meramec group, which has been divided into the Warsaw limestone at bottom, the Spergen limestone in the middle, and the St. Louis limestone at top. The St. Louis limestone is followed above by the Ste. Genevieve limestone, by some included in the Meramec group and by others in the next overlying group, the Chester. The Chester group in its fullest development in Johnson County, Ill., as recently worked out by Stuart Weller of the University of Chicago, is composed of an alternating sequence of strata of limestone, limestone and shale, and sandstone, aggregating about 1,300 feet in thickness. The succession in southeastern Illinois is graphically represented in section No. 1 of the chart of sections. Eastward into central Kentucky the Mississippian section undergoes various changes. The Kinderhook either disappears in central Kentucky, or is represented by the black shale of that region. In Ohio and northeastern Kentucky the Kinderhook may be represented by the Bedford shale, Berea sandstone, Sunbury shale, and, in Ulrich's opinion, the Ohio shale above any Genesee shale that may be included in the bottom in places. The Burlington and Keokuk change to shale

and sandstone, as displayed in the knobs of southern Indiana and central and eastern Kentucky. The Meramec group persists to central Kentucky with little change. Between southern Illinois and central Kentucky the Chester group changes by loss of sandstone members in its upper and lower parts, only those of the middle part persisting unchanged into Breckinridge County. The upper limestones, too, change to predominantly shaly beds, represented by the Buffalo Wallow formation of Breckinridge County and the Pennington shale of eastern Kentucky. The character of the Mississippian in Jefferson and Breckinridge counties is shown by section No. 5 of the chart. The changes just outlined are illustrated in the chart of sections accompanying the author's report on the Mississippian formations of western Kentucky.[3] On the northeast the Mississippian of Kentucky passes into Ohio, in which state the series has long been studied, and a classification and names different from those of the Mississippi Valley have long been in use. In Ohio the Mississippian has been divided into the Waverly group below and the Maxville limestone above. According to Ohio usage the Waverly group comprises, from below upwards, the Bedford shale (which succeeds the black Ohio shale), Berea sandstone, Sunbury (black) shale, Cuyahoga formation, Black Hand formation, and Logan formation. The Maxville limestone lies between the Logan formation and the "Coal Measures." The Bedford and Berea seem to fall within the Kinderhook group, although some authors correlate only the Berea with the Kinderhook. The Cuyahoga and Logan formations in the author's opinion correspond to the Fern Glen and early Burlington, while the Maxville limestone represents the Gasper oolite of the Chester group and probably also a part of the Ste. Genevieve limestone, at least in southern Ohio. The Keokuk limestone of the Osage group and the Meramec group are not represented in northeastern Kentucky or in Ohio. The proofs of these general statements of equivalency will be set forth in the succeeding detailed descriptions which form the subject of this report.

[3] Butts, Charles, The Mississippian series in western Kentucky. Kentucky Geological Survey, 1918.

Acknowledgments. In the preparation of this report the author has had the kind assistance of E. O. Ulrich of the U. S. Geological Survey, of R. S. Bassler of the United States National Museum, and of Mr. Frank Springer, and has had free access to the Museum collections and to the type material for comparison in the study of the fossil collections. For all this assistance grateful appreciation is here expressed.

"BLACK SHALE"

Since the "Black shale" is claimed by a number of geologists,* to be mainly of Mississippian age, it is a proper subject for description and discussion here in the introduction, though it is not classified by the U. S. Geological Survey or the Kentucky Geological Survey as Mississippian.

At the outset it should he understood that in Ohio and northern Kentucky there are two black shales, the Ohio shale below, and the Sunbury shale above, the two being separated by the Bedford shale and the Berea sandstone.

OHIO SHALE

Name. The name Ohio was first applied to the lower mass of black shale by Andrews[4] in 1870, under the term Ohio black slate. In 1871 Andrews used the designation Ohio black shale. In 1877 the name was modified by Shaler[5] to Ohio shale.

The name Chattanooga was applied to a thin black shale in the southern Appalachians by Hayes[6] in 1890. The Chattanooga has been found to extend into central Tennessee and Kentucky, where it is, as the writer believes and will show beyond, continuous with the Ohio shale. In 1873 the name New Albany was applied by Borden* to the black shale of Indiana, which is clearly the same as the Ohio. In this report, the name Ohio shale is used in Kentucky throughout all the area in which the outcrop of the formation is continuous with that of the black shale in Ohio, and the name Chattanooga is retained for

* Ulrich and others.

[4] Andrews, E. B., Ohio Geol. Surv. Rept. Prog. for 1869, p. 62, 1870.

[5] Shaler, N. S., Ky. Geol. Survey, New Ser., Vol. 3, pp. 169-175, 1877.

[6] Hayes, C. W., Geol. Soc. of Am. Bull., Vol. 2, p. 143, 1891. Paper read December 29, 1890.

* Borden, W. W., Indiana Geol. Survey, Fifth Ann. Rept. for 1873, pp. 150, et. seq., 1874.

Tennessee and that part of southern Kentucky in which the outcrop of the black shale is continuous with that of Tennessee. The dividing line between these two regions passes through the narrow area in Pulaski and Casey counties in which the black shale is largely covered by higher rocks. That line is ap-

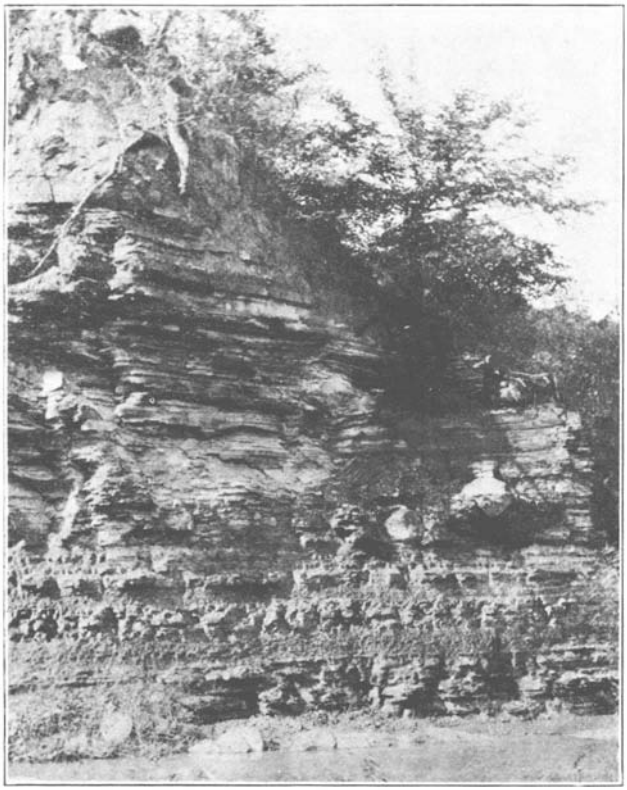

Plate 1. Ohio shale. showing Huron shale representative, with giant nodule, in lower part. Bluff on Salt Lick Creek, one-half mile southwest of Vanceburg, Ky. Looking west. Limestone of Onondaga age just below water level.

proximately the parallel of 37° 15'. At Vanceburg the lower 30 feet of the Ohio shale carries spherical nodules of limestone, of concretionary origin, the largest of which are 2½ to 3 feet in diameter. In Ohio this part has been regarded as a

distinct member of the black shale mass and given formation rank under the name Huron shale. The Huron shale representative at Vanceburg is shown in Plate l.

Distribution. The Ohio shale can be recognized as a distinct unit as far south as Irvine, Estill County, where its thickness is reduced to about 95 feet, and where about 18 inches of indurated fossiliferous gray clay or shale representing the Bedford shale separates it from the overlying Sunbury black shale, about 3 feet thick. The situation at Irvine is exhibited in section No. 37 of the chart of sections. Southward from Irvine the Sunbury as a separate unit has not been recognized, neither have the Bedford and Berea, and it seems fairly certain that they do not extend far south of Irvine. The black shale from Irvine, or a comparatively short distance south thereof, through the counties south and west of the Bluegrass country to Louisville seems to be in the main a thinned southwestward extension of the Ohio shale, although it may include a very thin representative of the Sunbury shale in the top. The alternative to such a conclusion is that the Ohio shale continues to become thinner southwestward, and in the southern counties of Kentucky and in the vicinity of Louisville is locally represented by only a small thickness of the basal part of the black shale, that the Bedford has feathered out entirely, except perhaps locally, hereinafter to be dwelt upon, and that the Sunbury shale has thickened and makes up all, or locally the main body, of the black shale—the Chattanooga of the southern and western counties of Kentucky and of all of Tennessee and the New Albany shale of the Louisville region and Indiana. At present the first alternative, which is in accordance with common acceptance, seems to the writer the more probable. A demonstration of the truth of the matter, however, if possible, can be accomplished only by much more detailed field work.

Character. The Ohio shale is mainly a black fissile rock, but includes layers of green shale and in the bottom in places thin laminae or thin layers of sandstone and in other places thin calcareous layers. In the sections at Vanceburg about 120 feet of the formation, beginning 40 feet below the top, is noted as dark, greenish, or brownish as weathered. While there

are certainly some green shale layers in this part of the section, most of the thickness is dark or black in the fresh condition. Its character at Irvine is shown in the following section:

	Feet.
Sunbury shale	3
Bedford shale:	
6. Clay or lumpy shale, light gray with black shale parting, fossils (dist. No. 1)	1.6
Ohio shale:	
5. Shale, black	78
4. Shale, alternating green and black layers 1 foot thick	7
3. Shale, black; *Schizobolus truncatus*	4
2. Shale, black and hard with dark, probably calcareous and siliceous layers with *Lingulopora williamsana*	6
1. Shale, very soft, brown, with *Dictyonema*, annelid teeth, *Lingula and Orbiculoidea*	1
	100.6
Devonian limestone.	

Generally throughout the state there are no such beds in the black shale as those of the lower 18 feet of the above section, but on Barren River, between Allen and Barren counties, similar beds are present. The section there is as follows:

Fort Payne chert (limestone with chert).	
Chattanooga shale:	
Shale, black fissile, carrying *Lingula melie?*	33
Shale, black, highly fissile with *Schizobolus truncatus*, and thin, calcareous, sandstone laiminae	10
	43
Devonian limestone.	

At Louisville the section is similar.

At New Albany, Ind., the section of the black shale is as follows:

New Providence shale.	
New Albany shale:	Feet.
Shale, black, *Lingula melie* and a few other poorly preserved fossils; 1 foot green shale near bottom	85
Shale with calcareous sandstone layers up to 1 or 2 inches thick, with fish teeth and bones and plant stems, about	5
Shale, black, conchoidal, *Schizobolus truncatus* in bottom	10
	100

The localities of the above 3 sections are the only ones out of many examined in which the lower beds with *Schizobolus* have been found by the author. It seems reasonable to think that they are absent throughout most of the state.

In the vicinity of Lebanon there is intercalated in the black shale of the prevailing black fissile character a bed of gray clay 5 feet thick, shown in Plate No. 2. This is about 15 feet above

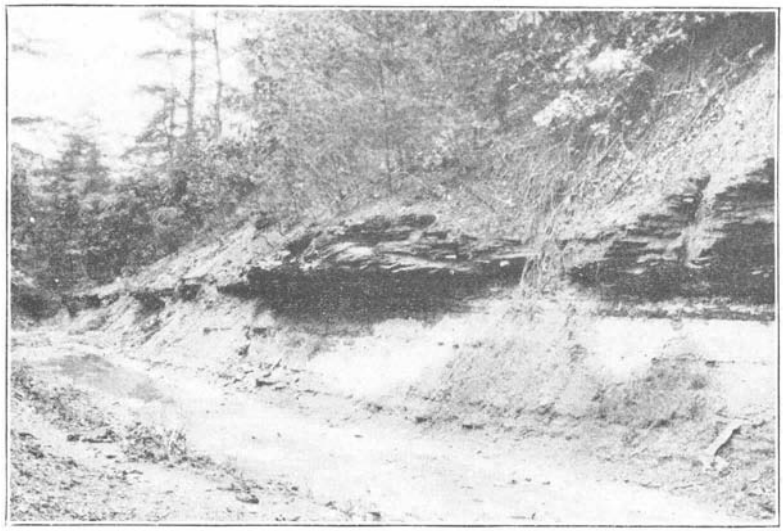

Plate 2. Gray clay 5 feet thick in Ohio black shale, 15 feet above the bottom and 40 to 50 feet below the top. About 3 miles southeast of Lebanon. Looking northwest. This bed of considerable extent in that vicinity. There is a possibility that it represents the Bedford shale of Ohio but that has not been established.

the bottom, the entire thickness being about 60 feet. This gray clay has considerable extent in the vicinity, having been observed at two points 4 or 5 miles apart. It may be in the position of the green clay layers No. 4 of the Irvine section, and the underlying 15 feet of the Lebanon section may correspond to the 10 feet of fossiliferous beds below the green clay layers at Irvine. The clay bed may, however, represent the Bedford shale, and if so the overlying black shale is Sunbury.

Another locality where a deviation from the usual black character of this shale has been seen is at Berea, Ky., where two or three layers of green shale occur 15 or 20 feet below the

top of the black shale. These were exposed in the street leading east from the town. Still another variation is a brown friable sandstone 1 foot thick at the bottom of the Black shale and lying upon the top of the Devonian limestone. This layer of sandstone is most prominent on Barren river in Barren Co., but a thin layer of similar character at the same horizon occurs south of Lebanon and in the vicinity of Berea.

With the exception of the small proportion of sandstone and of green shale, each occurrence of which may be of no great geographical extent, the Ohio shale is a black fissile rock owing its color to the presence of carbonaceous matter.

Thickness. As already stated, the Ohio shale is nearly 300 feet thick at Vanceburg. It thins, probably at a uniform rate to 95 feet at Irvine, 70 feet at least and probably a little thicker at Berea, 45 feet on Fishing Creek west of Somerset, about 65 feet at Lebanon, 106 feet in Hart County in wells, and 120 feet at Meredith in Grayson County, (from well log). In the country south of the Fishing Creek locality the black shale is called Chattanooga. In that region the black shale is 38 feet thick on Cumberland River at Eads Landing north of Monticello; 20 feet on Meshack Creek in Monroe County, about 10 miles west of Tompkinsville; 18 feet on Long Creek, Allen County, near the state line; 20 to 25 feet in Overton County, Tenn.; 43 feet on Barren River, between Barren and Allen counties, Ky.; and 55 to 65 feet in the western part of Barren County as shown by well logs. At Louisville, where the black shale is named New Albany shale, it is 100 feet thick.

Eastward from Irvine the Ohio shale thickens. In Wolfe County it is reported in two wells as 224 and 245 feet thick; in Magoffin County it is reported from 262 to 400 feet thick; in Johnson County its thickness ranges, according to well logs, from 381 to 876 feet; and on the west face of Pine Mountain, in Letcher County, the thickness outcropping has been determined by the writer to be 800 feet and the bottom is nowhere exposed. At Big Stone Gap, Va., the black shale is about 1,100 feet thick, and at Cumberland Gap it appears to be at least 500 feet thick.

Age and Correlation. The age and correlation of the black shale is one of the unsettled questions of American geology.

The question is whether the shale is Upper Devonian or lowest Mississippian. The difficulty in reaching a satisfactory answer to the question arises from two conditions: First, the scarcity and indecisive correlative value of the fossils so far obtained from the shale, and second, the impossibility of tracing the main body of the shale into regions where its relations to rocks of known Upper Devonian or lowest Mississippian age can be seen. In the only region where such relations are decisive as to the age of the Ohio shale, namely, in eastern Ohio, its lateral contacts or its passage into the Upper Devonian is hidden by overlying rocks and cannot be seen.

Fossils. As already given in the sections, page 7, in a few known localities the lower 10 to 15 feet of the Ohio shale carries *Schizobolus truncatus.* At Irvine, in addition to *Schizobolus, Lingulopora williamsana,* a large *Lingula,* a *Orbiculoidea,* a *Dictyonema,* and annelid teeth are present in the lower 10 feet of the Ohio shale. At Irvine, at Rockville, Rowan county, and at Vanceburg, *Lingula melie?* occurs in the upper part of the Ohio. In the vicinity of Irvine a small Lingula, perhaps an immature *L. melie,* and two specimens of a fish scale were found in the middle of the Ohio. In southern Kentucky and northern Tennessee, where the black shale is known as the Chattanooga, *Lingula melie, Orbiculoidea,* and conodonts are common in it. Conodonts are toothed fossils, some species comb-like in form, so small that many of them are scarcely visible to the naked eye. In Ohio the Ohio shale carries fossil fishes which occur commonly in the limestone nodules of its lower part, the Huron shale. These nodules with fish remains occur also in northern Kentucky and one is shown in Plate 1 (one).

Remains of several species of plants occurring in the Ohio shale are also known. There is a fossil tree, *Callixylon newberryi,* in Kentucky and 6 other species have been collected from the nodules at the top of the black shale one-half mile west of Junction City, Ky. In Ohio another form occurs which is variously called *Calamites inornatus* and *Pseudobornia inornatus.* Finally the spore cases of plants belonging to the class of ferns, minute disk-like bodies, many of which are of an amber color, are very abundant and widespread. These are known as *Protosalvinia huronensis* or simply as sporangites.

The carbonized remains of vegetal matter give the shale its black color and it is evident from that fact that vegetation was very abundant while the black shale was being deposited. The vegetation was probably largely acquatic but may also have flourished on the low lands near the water where a large part of the dead plants, the falling leaves, the broken down parts and the pollen and the spore cases were blown or drifted into the Ohio sea and there became finally incorporated into the fine mineral sediment now forming the black shale. From what is known of the nature of such plants, it seems certain that they could live only in fresh, or at most only in very slightly salt water so that they grew only in parts of the sea occupied by fresh or nearly fresh water.

The bearing of the fossils on the determination of the age and correlation of the Ohio shale will now be briefly discussed.

Of the fossils mentioned above, except *Sporangites,* only one, *Schizobolus truncatus,* seems to be certainly known outside of the Ohio shale. *Schizobolus* occurs in the Genesee shale of New York and in its equivalents south into Virginia. The Genesse occurs near the base of the Upper Devonian section of New York. It is apparently conceded by all that the part of the Ohio (or Chattanooga) shale carrying *Schizobolus,* as hereinbefore described, is of Genesee age. It is believed by Ulrich, however, the chief advocate of the Mississippian age of the Ohio shale, that the Genesee representative in Ohio and Kentucky is confined to detached areas and is separated from the overlying part of the black shale, believed by him to be Mississippian, by a stratigraphic gap or hiatus (unconformity) corresponding to the Portage and Chemung formations, which constitute the main part of the Upper Devonian of New York, and which, according to his theory, are absent in central Ohio and in Kentucky. In central Pennsylvania these formations have a combined thickness of 5,000 feet. *Lingula melie, Orbiculoidea newberryi,* and a host of species of conodonts found in the Ohio occur in even greater abundance in the overlying Sunbury shale, of acknowledged Mississippian age, and the weight of their presence is in the direction of the Mississippian age of the Ohio, except the part representing the Genesee shale, sup-

posedly small, at the bottom. The prevalence in the Chattanooga shale of the same species of conodonts as those of the Sunbury shale is one of the main points in the evidence upon which Ulrich bases his correlation of the Chattanooga with the Sunbury.

According to Ulrich (unpublished compilation) there are in the Ohio shale 29 genera of fishes represented by 58 species. Of these 11 or 13 genera are represented by one or more species in the Devonian, but only one species is common to the Ohio shale and the unquestioned Devonian. Six of the Ohio shale genera are known in the Bedford shale, Berea sandstone, or Sunbury shale, overlying the Ohio shale in Ohio, and six genera are common to the Kinderhook group, constituting the basal division of the Mississippian series of Mississippi Valley. There are apparently no species common to these various formations. The testimony of the fossil fishes, therefore, is not decisive. If the Ohio shale is of Devonian age and was laid down in water continuous with the Upper Devonian sea in eastern Ohio and western New York, it would seem that, since fishes are free swimming animals and capable of ranging far and wide, some of the 58 species of the Ohio shale would have wandered eastward into the Devonian sea and have become fossilized there. The same considerations apply to the relations of the Ohio to the Kinderhook sea of the Mississippi Valley. Such facts may reasonably be held to indicate that the Ohio sea was separate from either the Kinderhook sea on the one hand or the Upper Devonian sea on the other, but do not afford a basis for a conclusion as to whether that sea was of Kinderhook or of Upper Devonian age, or whether it may not have persisted through both Upper Devonian and Kinderhook time.

The fossil plants of the Ohio shale have been accepted as evidence of its Devonian age, but the latest investigations throw doubt upon the correctness of the identification of those plants with the Devonian forms of western New York and elsewhere.

Apparently the strongest argument for the Devonian age of the Ohio is its apparent continuity with the Middle and Upper Devonian of western New York and Pennsylvania. The Ohio shale lies between the same upper and lower limits as these De-

vonian formations. The Ohio shale passes beneath the overlying Bedford, Berea and Cuyahoga formations in central Ohio, and where eastward, as along Lake Erie in northeast Ohio and western New York, the rocks occupying the same position are exposed to view, they are unquestionably Devonian. The situation may be made clear by a homely illustration. If, in central Ohio, a tunnel should be started in the middle of the Ohio shale, say 300 feet below the Bedford shale, the formation next above the Ohio, and should be driven eastward to the meridian of Cleveland, keeping the same distance below the Bedford, it would then be in the Chagrin shale, of Upper Devonian age. The same circumstances are revealed by oil-well borings on a line, say between Columbus, Ohio, and Pittsburg, Pa. The facts are susceptible of two explanations: First, the Ohio shale continues eastward, losing its black color, into the Devonian; or, second, the Ohio thins eastward and overlaps the Devonian, which on the contrary thins westward at about the same rate as the Ohio thickens eastward. The two conceptions are illustrated by the accompanying diagrams, Fig. 1.

On the first hypothesis the Ohio is Devonian, on the second it is Mississippian. Which hypothesis is true cannot, for the reason stated on page 10, be definitely established by direct observation. It may in time be determined from deep well drilling across the critical area through the preservation of the drillings. It can then be ascertained whether the black shale overlies the Devonian along a sharply-defined line diagonal to the Devonian stratification, or whether it interfingers with the Devonian, as it must do if it is really a western black facies of the eastern gray and green shale which are the preponderating constituents of the Upper Devonian of eastern Ohio and of western New York and Pennsylvania.

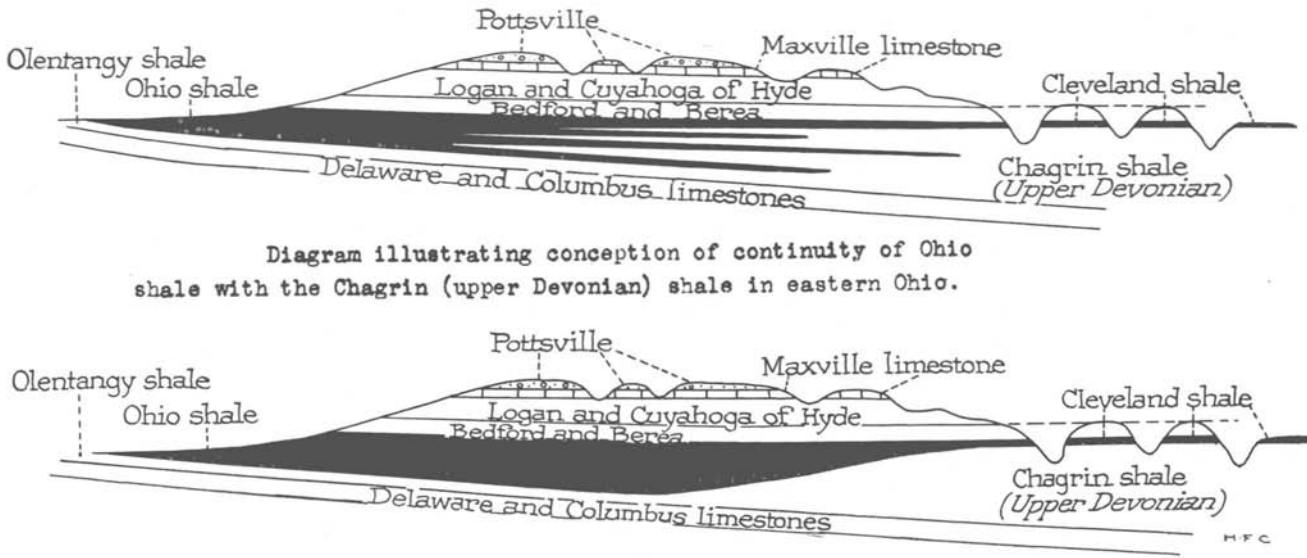

Fig. 1. Ideal sections showing alternative conceptions of the age and equivalence of the Ohio shale.