CHAPTER 2.

MISSISSIPPIAN FORMATIONS OLDER THAN THE NEW PROVIDENCE GROUP

BEDFORD SHALE

Name. The Bedford shale was named by Newberry[7] from Bedford, in Cuyahoga County, Ohio, where the shale is 75 feet thick, is well exposed, and occupies the space between the Berea sandstone above and the top of the Cleveland shale, the upper formation of the Ohio shale group, below. The U. S. Geological Survey classifies the Bedford as Devonian or Carboniferous (Columbus Folio 1915), while the Ohio Geological Survey classifies it as Mississippian and includes it in the Waverly group as the basal formation (Geological map of Ohio 1920).

Limits. The boundary between the Bedford and the Ohio is of course very definite, but the location of the boundary between the Bedford and the overlying Berea sandstone, in Kentucky, where that formation is present, is not always certainly determinable. This is exemplified by the following two Bedford-Berea sections:

Section of the Bedford and Berea formations at Alum Rock, just south of Vanceburg, Ky.

		Feet
Sunbury shale:		
9.	Shale, black	16
Berea sandstone:		
8.	Sandstone, thick-beddd, ripple marked, aluminiferous at bottom, Plate No. 4	22
7.	Not exposed but indications of green shale mainly, with thinly laminated layers of fine-grained, ripple-marked, fucoidal, green sandstone	37
6.	Sandstone	1
5.	Sandstone and shale	5
4.	Sandstone, thick-bedded in middle	26
Bedford shale:		
3.	Not well exposed, indications of clay, thinly laminated sandstone layers, ripple-marked, and fucoidal as in No. 7	23
2.	Shale, green about	5
		119

[7] Newberry, J. S., Ohio Geol. Survey Report for 1869, p. 22, 1872.

Ohio shale:

1. Shale black.

For comparison, the following section of the Bedford and Berea at Alum Rock as made out by Morse and Foerste is quoted:

SECTION AT ALUM ROCK BY MORSE AND FOERSTE.[8]

		Ft.	In.	Ft.
5.	**Cuyahoga formation**			39
	Interval covered except a thick layer of argillaceous sandstone at the top. The sandstone contains *Taonurus*. Small phosphatic nodules are found in the basal part of the interval.			
4.	**Sunbury shale, total thickness**			15½
	Black, fissile, carbonaceous shales, which cannot be distinguished, lithologically, from the Ohio shale.			
3.	**Berea grit, total thickness**			22¼
	Thick layer of gray sandstone	2	6	
	Heavy layer of rather coarse-grained gray sandstone, the upper surface excellently ripple-marked	3		
	Medium to thick-bedded rather coarse-grained gray sandstone, beautifully ripple marked	15		
	Arenaceous shales	1		
	Layer of fairly coarse-grained gray sandstone..		9	
2.	**Bedford formation, total thickness**			95⅝
	Blue arenaceous shales and shaly sandstones. Lower part slightly covered	35		
	Arenaceous shales with thin sandstone partings	7		
	Layer of thick-bedded gray sandstone	1	8	
	Arenaceous shales with two layers of sandstone	6	9	
	Heavy layer of gray sandstone, with lower surface contorted	2	4	
	Arenaceous shales with two layers of gray sandstone	6	6	
	Layer of thick-bedded buff sandstone	1	9	
	Medium-bedded gray sandstone with shaly partings	2	10	
	Arenaceous pink shales with sandstone partings	2	6	
	Covered interval	5		
	Layer of thick-bedded, buff sandstone	2		
	Practically covered interval with some argillaceous shales	22	6	

[8] Morse. W. C. and Foerste, A. F., The Waverly formations of east-central Kentucky. Jour. of Geology, Vol. 17, pp. 165-166, 1909.

		Feet
1.	**Ohio shale** ..... Black fissile, carbonaceous shales. About ten feet from the top, one or two linguloid shells occur. Near the central part the shales become softer and lighter in color and resemble a similar zone in the Ohio at Columbus (Ohio). The interval (242′) is mostly exposed and extends to the level of the Chesapeake and Ohio Railroad.	242

Section along road on the crest of a long narrow spur known as Slate Point, beginning immediately east of Vanceburg, Ky.

			Feet
Cuyahoga formation:			
14.	Sandstone, even bedded (Vanceburg facies of Hyde)		80
13.	Shale, red, about	Henly shale, member of Hyde ...	8
12.	Sandstone, thin, greenish shaly	Henly shale, member of Hyde	2
11.	Shale, soft, green, about	Henly shale, member of Hyde	8
	Not exposed, includes Sunbury shale if present		22
Berea sandstone:			
10.	Sandstone, flaggy		15
9.	Not exposed		5
8.	Sandstone, thick-bedded		8
7.	Shale, green with thin layers of fine-grained, ripple-marked, fucoidal sandstone		12
6.	Not exposed. Debris of No. 7		10
5.	Sandstone, flaggy above, lower 10 feet thick-bedded, layers up to 2½ feet thick, some with uneven lower surface, lower layer makes overhanging ledge; top layers with characteristic even parallel ripple marks 2½ to 3 inches across		22
4.	Not exposed		10
3.	Sandstone, thick-bedded at bottom, has been quarried		10
Bedford shale:			
2.	Not exposed shale debris, much of it fine-grained siliceous, ripple-marked or dimpled		36
1.	Shale, soft-green, about		5
			122
Ohio shale:			

Section just back of town at Buena Vista, Ohio, about 4 miles northeast of Vanceburg, Ky., Barometric measurement.

		Feet
Cuyahoga formation:		
	Sandstone (Buena Vista sandstone member of Cuyahoga formation), old quarry, sandstone, not now exposed.	
	Not exposed, includes Sunbury shale, if present	45

Berea sandstone:

Sandstone, thick and thin-bedded, characteristically ripple marked	15
Sandstone thick-bedded, shale partings	80
Not exposed, includes Bedford-Berea-Ohio contact, about	35
Shale, black (Ohio shale)	80
Not exposed to river's level	110

At Garrison, a few miles east of Buena Vista, the entire interval between the Sunbury and Ohio shale, estimated at about 100 feet, is, judging from all exposures, occupied by thick-bedded sandstone without shale partings even. (See Plates 5 and 6.)

Thirteen miles south of Vanceburg the following section is exposed and was examined by Morse and Foerste,[9] from whom the following section is quoted:

Section at Elk Lick Creek, 13 Miles South of Vanceburg, Ky.

	Feet
Sunbury shale:	
4. Pieces of black, fissile carbonaceous shale directly above the sandstone layers.	
Berea grit and Bedford formation:	75
3. Medium bedded sandstones ripple-marked on the upper surfaces. Unquestionably Berea	7′ 6″
2. Covered interval, which probably contains the contact of the Bedford and Berea	67′ 6″
Ohio shale:	30
1. Black, fissile, carbonaceous shales, which extend down to the level of the highway at the spring.	

The difficulty of establishing the boundary between the Bedford and Berea in this region is apparent from the foregoing sections. In the Alum Rock section Morse and Foerste placed the boundary at the bottom of the conspicuous cliff-making upper 22 feet of sandstone, and included in the Bedford the 26 to 28 feet predominantly sandstone, some of it as thick-bedded as the upper 22 feet. The inconsistency of this procedure is evident from a study of the Slate Ridge section, barely more than a mile farther east, where the upper 82 feet of the section is predominantly ripple-marked sandstone of Berea type. East-

[9] Loc. cit., p. 168.

ward the heavy sandstone becomes still more predominant and finally occupies the entire section. The only logical procedure seems to the writer to be to place the boundary at the bottom of the heavy sandstone, and include in the Bedford only the lower 28 to 40 feet of shale or predominantly shale of the Alum Rock and Slate Ridge sections, and that is the procedure followed in this report. Just where the boundary between the Bedford and Berea is in the Elk Lick Creek section is not determinable. According to Morse and Foerste, 5 miles south of Elk Lick Creek and 18 miles south of Vanceburg the entire Bedford and Berea interval is reduced to 46 1-2 feet, and no representative of the Berea sandstone is certainly present.

Distribution. In Kentucky the Bedford shale extends from Ohio River at Vanceburg to Irvine on Kentucky River in Estill County, where it is reduced in thickness to 18 or 20 inches. It is not known south of Irvine, unless a clay bed 5 feet thick in the black shale in the vicinity of Lebanon should be the Bedford. (See p. 8, and Pl. 2.) Northeastward from Vanceburg the Bedford disappears, either thinning out or changing to a sandstone for at Garrison and along Kinniconick Creek, south of Garrison, in Lewis County, the entire interval between the Sunbury shale and Ohio shale is filled with sandstone that can only be regarded as Berea. Southeastward gray shale, or slate and "shells," in the position of the Bedford shale is reported in many oil well logs in Menifee, Morgan, Johnson, and Lawrence counties. A typical sequence is given below:

Partial Log of Well of Kentucky Block Cannel Coal Company No. 1, Morgan County, Ky.

		Feet
Shale, green	New providence shale	122
Shale, blue		84
Shale, gray		329
Shale, black (Sunbury)		24
Sandstone? (Berea?)		18
Shale, blue (Bedford?)		36
Shale, black (Ohio)		268
Shale, gray		34
Limestone to bottom of well		1
Total depth of well		1609

The succession recorded here is, with variations either actual or due to differences in the drillers' interpretation, duplicated in many well logs.

The credit for the determination of the extent and limits of the Bedford along its outcrop in Kentucky is due to Foerste and Morse[10], who in 1908 traced the Bedford southward from Vanceburg to Irvine, with the resultant discovery of its continuity and gradual thinning southward. To them is due also the important discovery of the typical Bedford fauna, well represented by a number of species at Irvine and Indian Fields.

The best exposures of the Bedford visited by the writer are at and near Rockville, 5 miles southwest of Morehead, Rowan County. (See Pl. 3.) It is partly exposed below the Alum Rock at Vanceburg and in the road ascending the crest of the long spur just east of Vanceburg. At Irvine it is too thin to be conspicuously exposed, but it can be easily uncovered on the denuded spurs at the south base of Minerva Mountain.

Character. At Vanceburg, owing to poor exposure, the details of the Bedford section could not be ascertained. It surely includes thin laminae, apparently ripple-marked, of very fine-grained, greenish sandstone, many fragments of which bearing small fucoidal markings were scattered on the surface of its outcrop. Such material occurs higher in the section, however, in shale interbedded in the Berea sandstone. The main constituent of the formation at Vanceburg appears to be a blue, indurated non-fissile clay. Five feet of soft green shale weathering to a soft green clay lies at the bottom in contact with the top of the Ohio shale. (See sec. 42 of the section chart.) At Rockville and at Bluestone Junction, less than a half of a mile east of Rockville, the Bedford is fully exposed and can be examined in detail. It is almost wholly composed of a bluish-gray, semi-indurated clay with a few rather harder thin layers, only of one of which, an inch or two thick, near the bottom, could be regarded as a very fine-grained sandstone. The exposure and character of the Bedford at this place are excellently exhibited in the photograph plate 3. At Irvine it is nearly all a hard clay, as above described. According to a report by W. S.

[10] Morse, W. C., and Foerste, A. F. Bedford fauna at Indian Fields and Irvine, Kentucky, Ohio Naturalist, Vol. 9, No.7, pp. 515-523, May, 1909.

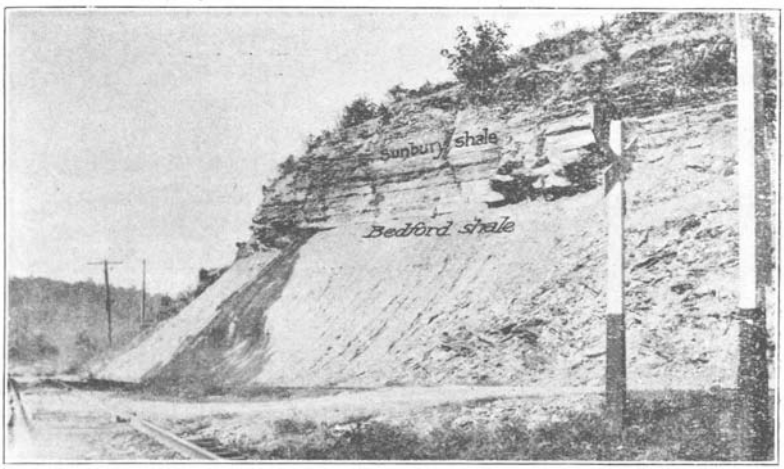

Plate 3. Sunbury shale, 16 feet thick, underlain by Bedford shale, 20 feet thick. Cut on Chesapeake & Ohio Railroad at Bluestone siding near Rockville, five miles southwest of Morehead. Looking west.

Peck, of Frenchburg, the Bedford in Menifee County, as revealed by the drill, is 10 feet thick and is called by the drillers the "10 foot bluish mud bench." This descriptive designation clearly indicates a rock of the character just described.

Age and Correlation. The following list of fossils is made up from material from Irvine collected and indentified by myself supplemented from Foerste's list of material collected and described by him from Irvine and Indian Fields.

List No.1.

(b) Ambocoelia norwoodi, Foerste. Very abundant.
Camarotoechia sp.
Chonetes sp.?
(b)? Cryptonella-like brachiopod.
Lingula irvinensis, Foerste.
Orbiculoidea 2 sp.
(b) Orthotetes (Schuchertella) herricki, Foerste.
Orthotetes (Schuchertella) morsei, Foerste.
(b)? Rhipidomella sp.
(b) Cypricardella cf. C. reservatus, Hall. Figured by Herrick as Microdon bellistriatus.
(b) Macrodon irvinensis, Foerste. Same as Bedford shale form identified as M. hamiltoniae.

(b) Nuculana 2 sp. One, small, figured by Herrick as N. diversa.
Bellerophon 2 sp.
(b) Loxonema, same as figured by Herrick as L. delphicola.?
(b)? Pleurotomaria.
(b) Tropidodiscus aff. cyrtolites (Hall).

Of the forms in this list, those prefixed by a (b) are surely and those marked by (b)? are somewhat doubtfully identified with Bedford shale species of Bedford, Ohio, as listed by Girty,[11] or with Bedford species from other localities illustrated and described by Herrick.[12]

The peculiar character of most of these forms as slightly modified descendents of Middle Devonian (Hamilton) forms, together with their occurrence in the same stratigraphic sequence in both Kentucky and Ohio, leaves no doubt of the fact that the shale of Kentucky carrying this fauna is, on the ground of that circumstance alone, correctly identified with the typical Bedford shale. Besides this, however, it is probable that the Kentucky formation can be traced directly northward into Ohio into or near to the type locality. By most geologists, past and present, the Bedford shale has been accepted as the basal formation of the Mississippian in Ohio, and they have correlated it with part of the Kinderhook group, the basal division of the Mississippian of the Mississippi Valley. Girty,[13] however, influenced by the Devonian affinities of some of the Bedford fossils, has been inclined to class the Bedford as Devonian, as have Kindle, Prosser, Burroughs, Branson, and others, who have been impelled to regard the overlying Berea sandstone as the basal formation of the Mississippian because of the Devonian affinities of the Bedford fauna and also because of irregularities at the contact of the Berea upon the Bedford, which have been interpreted as evidence of extensive unconformity. A widespread unconformity at this horizon would automatically throw the Bedford into the Devonian. On the other hand, Cushing and Hyde of Cleveland have, as reported to the author by Ulrich, been adding considerably to the fossils of the Bedford, which now tend to associate it with

[11] Girty, G. R., Geologic age of the Bedford shale of Ohio. Annals of the New York Academy of Science, Vol. 22, pp. 295, 319, Nov., 1912.
[12] Herrick, C. L., Bull. Sci. Lab., Denison Univ., Vol. 4, P1. 9.
[13] Loc. cit.

the Cuyahoga formation, of universally accepted Mississippian age. It is not likely that the Bedford will be removed from the Mississippian, in the judgment of probably the majority of geologists.

BEREA SANDSTONE

Name. The name Berea, from Berea, Ohio, was first applied by Newberry[14] to this sandstone. He used the form Berea grit, from the fact that the sandstone in northern Ohio is an excellent abrasive and largely utilized for grindstones and whetstones.

In Ohio the Berea is the second formation of the Waverly group above the bottom, according to the Ohio classifications.

Distribution. The Berea extends south across Ohio into northern Kentucky. It is well represented at Vanceburg, Ky., at Buena Vista, in Ohio, just north of the river, and in Lewis County, Ky. It was recognized by Foerste and Morse for several miles south of Vanceburg, but on the outcrop does not extend as far south as the Chesapeake and Ohio Railroad. It seems to extend beneath several of the northeastern counties of the state, including Morgan, ‚Johnson and Lawrence, as shown in drilling for oil. The partial log quoted on p. 19, is representative of the findings and reports of the well drillers generally in that part of the state. Farther south in eastern Kentucky, as in Floyd County, the well logs are less clear in regard to the Berea but generally do not seem to indicate its presence. A line drawn south from Vanceburg to Morgan County and thence eastward to the state line would apparently indicate the approximate limits of the Berea in the state.

The Berea is well exposed along and adjacent to Ohio River, at Vanceburg on the knob known as Alum Rock, along the river bluff in Ohio at and for a mile southwest of Buena Vista, and along the Kinniconick Creek from a mile south of Garrison on the Ohio to a mile southwest of Tannery station, where the Berea passes below creek level.

Character. The Berea is a thick-bedded, fine-grained, rather loosely cemented and soft, gray, or, on exposure, somewhat

[14] Newberry, J. S., Ohio Geol. Survey Report of Progress for 1869, pp. 21, 22, 29, 1870.

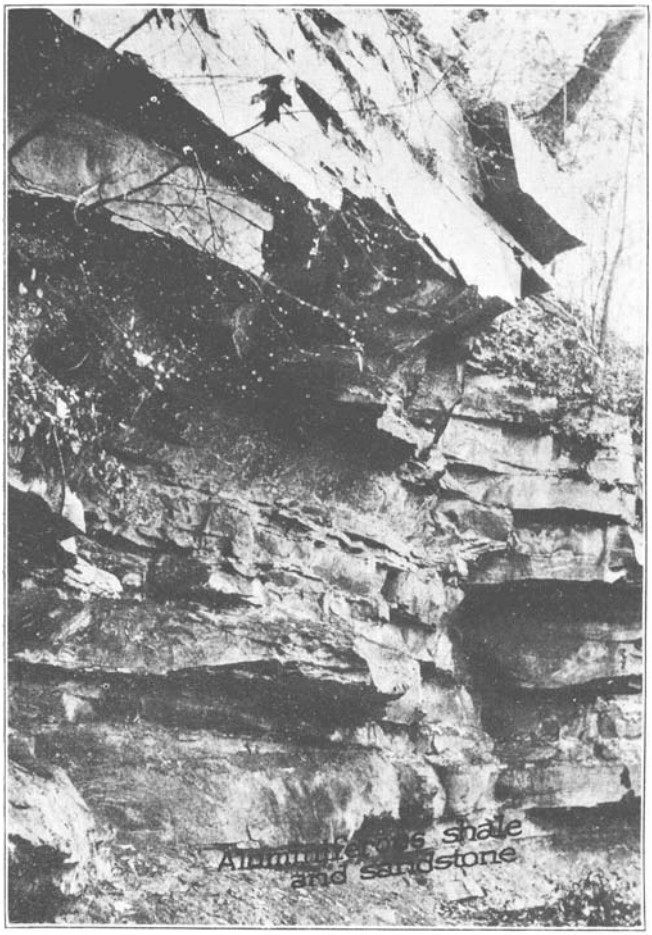

Plate 4. Berea sandstone 22 feet thick. Alum Rock, Vanceburg, Ky.

iron-stained sandstone. Its bedding and general appearance are well displayed in the photographs, plates 4, 5 and 6. A character which seems to extend through the full thickness of the formation is the remarkably even ripple marking, an example of which is exhibited in Plate 7. As there are no such ripple marks in the overlying sandstone facies of the Cuyahoga formation, they are a sure means of identifying the Berea. The Berea is without fossils.

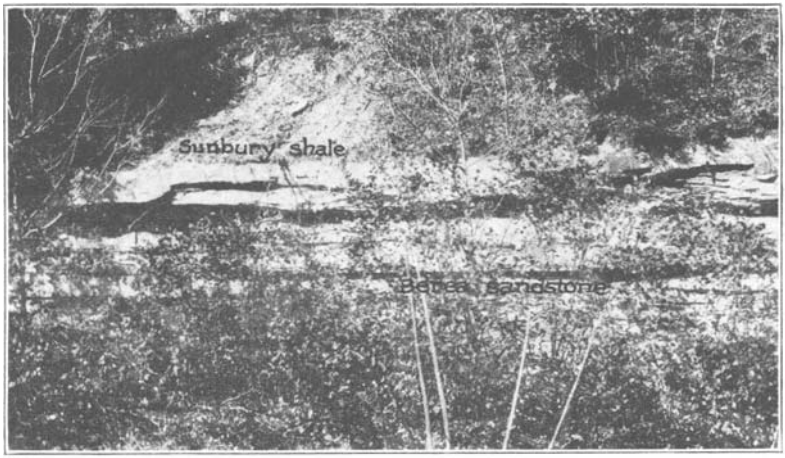

Plate 5. Berea sandstone overlain by Sunbury shale. Bank of stream near Kinniconick Branch of Chesapeake & Ohio R. R. eleven miles west of Carter and about one mile east or Tannery Station. Sunbury shale eleven feet thick, partly exposed in scar to left. Looking south.

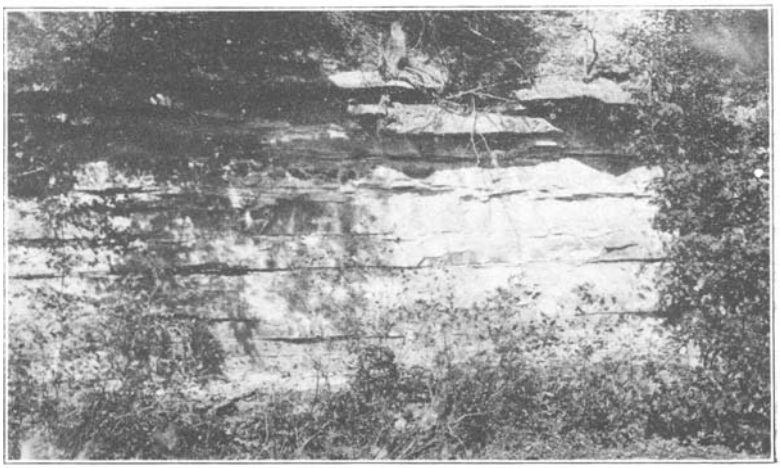

Plate 6. View of the upper fifteen feet of the Berea sandstone near Chesapeake & Ohio Railroad, Kinniconick Branch, about one mile southeast of Tannery Station, Lewis County. Looking south.

Plate 7. Surface of layer of Berea sandstone showing characteristic ripple marking prevalent in the Berea in Kentucky and southern Ohio. Ripples about four inches wide. Alum rock, Vanceburg, Ky. Looking west.

The Berea is of economic importance as a source of oil in some of the wells in eastern Kentucky. It could be used for rough masonry, although it has not been utilized to any extent for that purpose.

Age and Correlation. The Berea is accepted by all geologists as Mississippian (Kinderhook) in age. By some geologists, especially by those who are inclined to regard the Bedford and Ohio shales as Devonian, the Berea is taken as the base of the Mississippian.

SUNBURY SHALE.

Name . The Sunbury shale was so named by Hicks[15] in 1878.

Distribution. In Kentucky the Sunbury shale has been recognized as far south as Irvine, Estill County, where it has thinned to only 3 feet and can be separated from the Ohio shale only through the presence underneath of the thinned Bedford shale. Whether it extends south of Irvine is unknown, and unless the underlying Bedford also extends south, the Sunbury

[15] Hicks, L. E., The Waverly group in central Ohio. Am. Jour. Sci., 3d Ser., Vol. 16. pp. 216-224.

could not be satisfactorily distinguished from the Ohio shale even if it is present south of Irvine. Eastward a shale 5 to 30 feet thick in the stratigraphic position of the Sunbury, and described as black or brown, is recorded in the logs of many wells in Menifee, Morgan, Johnson and Lawrence counties, but apparently has not been noted in many wells south of these counties. This shale is probably the Sunbury, which has about the same southern boundary in the trough of the eastern Kentucky coal field as the Bedford and Berea.

Character. The Sunbury, like the Ohio, is a black, highly fissile shale, its color being due to the presence of considerable carbonaceous matter most or all of which is of plant origin.

Thickness. At Vanceburg the thickness of the Sunbury is about 16 feet; it is the same at Rockville, 5 miles southwest of Morehead, Rowan County; but at Irvine it is only 3 feet thick. About a mile southeast of Tannery, on the Kinniconick Branch of the Chesapeake and Ohio Railroad, it is about 11 feet thick. (See Plate 5.) As recorded in well logs in the counties mentioned above, it ranges from 5 to 30 feet thick.

Age and Correlation. The shale is continuously traceable to the type locality in Ohio, and there is no question of its being the Sunbury. It also carries in Kentucky the same fossils as in Ohio, the principal forms being *Lingula melie* Hall and an *Orbiculoidea* which has been usually indentified with *O. newberryi* of the Bedford shale, but which was regarded by Hall and Clarke[16] as a distinct species, named by them *O. herzeri.* The Sunbury in Ohio carries also a rich variety of the minute fossils called conodonts, and a number of species of fishes have been obtained from it. An occasional fish scale may be found in it in Kentucky. According to Ulrich the conodonts of the Sunbury seem to be characteristic of that formation, and the presence of the same species in the Chattanooga shale is one of the important items of evidence upon which his identification of the Chattanooga with the Sunbury is based.

[16] Hall, James and Clarke, J. M., Geo1. Survey of the State of New York, Paleontology of New York brachiopoda, Part I, p. 126.