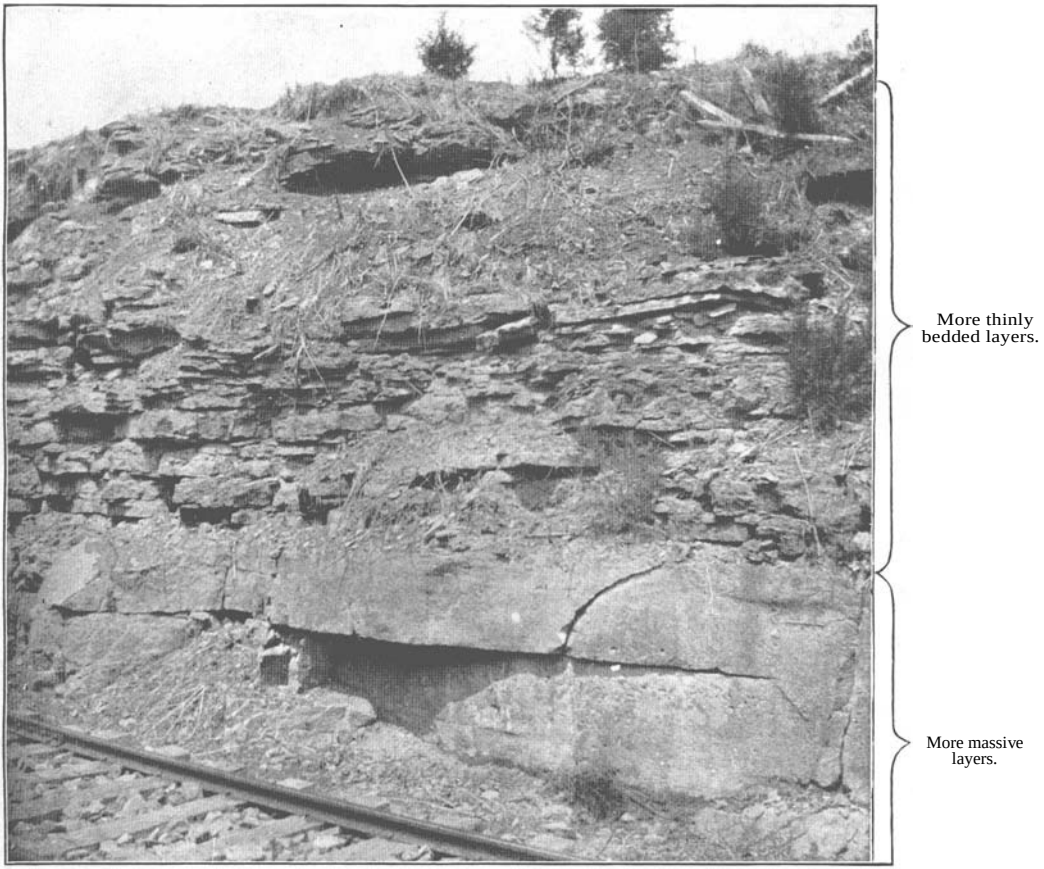


Fig. 1. Brassfield or Clinton Bed, between Brassfield and Panola, on the Louisville and Atlantic R. R. Near the eastern end of the type section.

The Classification of Silurian Rocks of East-Central Kentucky.

TABLE OF FORMATIONS.

Crab Orchard division of Silurian.....	Alger formation.....	Estill clay. Waco limestone. Lulbegrud clay.
	Indian Fields formation.....	Oldham limestone. Plum creek clay.
	Brassfield formation.....	Brassfield limestone.

BRASSFIELD LIMESTONE.

The typical exposure of the Brassfield limestone occurs along the Louisville and Atlantic Railroad, between Brassfield and Panola, in Madison county. Here the lower part of the limestone is exposed best near Panola, while the upper part is seen nearer Brassfield. An equally good exposure is found about a mile and a half northwest of Indian Fields, west of Howard creek, along the Lexington and Eastern Railroad, in Clark county.

The lower part of the Brassfield limestone usually consists of one or several rather thick and massive appearing layers, while the middle and upper part consist of more numerous, thinner-bedded layers; toward the top of the section these limestones often are interbedded with thin layers of clay. (See Fig. 1.)

The massive layers, at the base, usually are unfossiliferous, even on close examination. They do not weather to as deep a rusty-yellowish-brown as the thinner layers of the Brassfield limestone. Frequently they have a more argillaceous appearance than the thinner layers, and their color, when freshly exposed, is more bluish. On this account there was at first a disposition to separate these more massive layers at the base of the Brassfield section from the more thinly bedded limestones above, but further observations have not proven that they form a distinct series. It has been noticed that in some areas the total thickness of these massive layers seems to vary consider-

ably, while the thickness of the entire Brassfield section, in the same area, is fairly constant. In most cases only the lower part of the Brassfield limestone has a massive appearance, while in others almost the entire section has this massive character. From this the conclusion has been drawn that the conditions favoring the formation of massive beds were quite general at the beginning of the period of deposition of the Brassfield limestone, but that the changes favoring the formation of thinner beds entered different parts of the field at different times, so that massive beds continued to be formed at some localities, while thinner layers already were being formed at others.

Between Brassfield and Panola, the total thickness of the massive layers is six feet. Northwest of Indian Fields, it is seven feet. Southeast of Bobtown, it is eight feet. Near Hammack, the massive layer varies between eight and nine feet, and forms practically the entire Brassfield section. East of College Hill, on the contrary, the massive layer is only sixteen inches thick, and the overlying part is well bedded. West of Crab Orchard, on the eastern side of Cedar creek, along the pike to Stanford, the massive layers have a thickness of four feet four inches; the overlying part, three feet four inches thick, is separable into a greater number of layers, but evidently corresponds to the upper part of the massive section as exposed at Hammack, or at the Anderson locality, three and a half miles southeast of Lancaster. In the same manner, at Crab Orchard, a mile and a half west of the railroad station, along the county road, the massive limestone has a thickness of only two and one-half feet; a mile and a half farther west, along the same road, its thickness is two feet; while between these localities, on the western side of the eastern fork of Cedar creek, the Brassfield rock has a fairly massive appearance for a total thickness of eight and one-half feet above the base. About four miles north of Berea, half a mile south of Whites Station, the massive layer at the base of the Brassfield limestone has a thickness of two feet, but the lower part of the immediately overlying thinner-bedded layers evidently corresponds stratigraphically to the upper part of the more massive layers, as exposed southeast of Bobtown.

As far as may be judged from the massive appearance of these layers where they project from the sides of ravines, these

massive layers withstand the action of weathering well, and could be employed locally for building rock. However, owing to the moderate thickness of even the thickest exposures, it would not pay to open extended quarries in this rock.

The overlying parts of the Brassfield limestone are too thin-bedded and irregular to be of value for any purpose except crushed rock. In the lower part of this thin-bedded section, the limestone layers are likely to be separated by very thin layers of clay. In the upper part of the Brassfield section, these layers of clay are likely to be thicker, but not sufficiently to predominate over the limestones. Farther northward, from Montgomery county, in Kentucky, to Highland county, in Ohio, the relative quantity of clay in the upper part of the Brassfield section increases. Northwest of Highland county, however, clay occurs only at the very top of the Brassfield section, and at many localities is absent. It is the upper, thinner-bedded part of the Brassfield limestone which is fossiliferous. Most of the fossils occur near the top of the section.

The greatest thickness of the Brassfield limestone, in the area under investigation, was recorded from the type locality, between Brassfield and Panola (from eighteen to nineteen and one-half feet), and from the railroad cut a mile and a half northwest of Indian Fields (about nineteen feet). About four and a half miles northeast of Berea and a mile southeast of Bobtown, at the northern end of the Jackson hollow, its thickness is seventeen feet. About three and a half miles south of west from Clay City, north of Snow Creek church, the Brassfield limestone measures nearly sixteen feet. However, in by far the greater part of the area between Owingsville and Stanford, the thickness of the Brassfield limestone does not exceed thirteen feet, and often is less than this amount.

The data so far accumulated do not warrant any definite statements as to the relation between the variation in thickness of the Brassfield limestone and the distance of the various exposures from the crest of the Cincinnati geanticline. However, the following variation in thickness was noticed. Southeast of Bobtown the Brassfield limestone is seventeen feet thick. Southeast of Brassfield, it is nineteen feet thick. West of the first mentioned locality, the sections examined so far measure thirteen feet or less, and north of the second locality the record-

ed thicknesses do not exceed thirteen or fourteen feet. These facts suggest that in this area the Brassfield limestone possibly becomes thinner toward the northwest. Several other, isolated, observations favor this view. One of these is the small thickness of the Brassfield section (nine feet) at a locality three and a half miles southeast of Lancaster, on the road to Hammack. Another, is the small thickness (ten feet) seven miles southwest of Indian Fields, and a mile north of Merritt, at the Simpson Brock locality. However, the considerable thickness (sixteen to nineteen feet) of the Brassfield limestone along the long line between Plum creek, southwest of Clay City, and the exposures along the railroad northwest of Indian Fields, suggest that possibly any attempt to generalize regarding the relations between the variations in thickness of the Brassfield limestone and the relative distance of the various exposures from the crest of the Cincinnati geanticline is premature. A great part of these variations may be quite irregular and local.

FAUNA OF THE BRASSFIELD LIMESTONE.

The Brassfield limestone of east-central Kentucky contains the southern extension of the fauna characteristic of the limestone section which in Ohio and Indiana has been identified as Clinton.

Along the railroad between Brassfield and Panola the following species were found in the upper part of the Brassfield limestone, between two and five feet below the *Whitfieldella* horizon, which forms the upper boundary of the Brassfield section:

Calymmene vogdesi,
Cyclonema daytonensis,
Rhynchotrema scobina,
Leptaena rhomboidalis,
Plectambonites transversalis,
Platystrophia reversata,
Dalmanella elegantula,
Rhinopora frondosa,
Aspidopora parmula,
Cyathophyllum calyculum.

Almost directly east of the home of James F. Harris, north of Irvine, where the road crosses White Oak creek, almost at the level of the creek, the following species occur, just beneath the *Whitfieldella* horizon:

Calymmene niagarensis,
Cyclonema daytonensis,
Rhynchotrema scobina,
Leptaena rhomboidalis,
Plectambonites transversalis,
Dalmanella elegantula,
Orthis flabellites,
Rhinopora frondosa,
Phylloporina angulata,
Cyathophyllum calyculum.

Nearly a mile and a half northwest of Indian Fields, along the railroad, in a railroad cut, the following species were found between one and five feet below the Plum creek clay. The layer immediately beneath this clay contains large crinoid beads and a few specimens of the *Whitfieldella* characteristic of this horizon.

Calymmene vogdesi,
Cyclonema daytonensis,
Rhynchotrema scobina,
Triplecia ortoni,
Orthothetes fissiplicata,
Leptaena rhomboidalis,
Dalmanella elegantula,
Phylloporina angulata,
Rhinopora frondosa,
Phaenopora expansa,
Zaphrentis daytonensis,
Cyathophyllum calyculum.

Along the country road south of the railroad, two miles west of Crab Orchard, the following species were seen in the upper part of the Brassfield bed, below the *Whitfieldella* horizon:

Orthis flabellites,
Platystrophia daytonensis,
Leptaena rhomboidalis,
Zaphrentis daytonensis,
Cyathophyllum calyculum.

At the Neal Creek church, three miles south of Stanford, the following species occur in the upper part of the Brassfield limestone:

Orthis flabellites,
Dalmanella elegantula,
Strophonella daytonensis,
Pachydictya bifurcata,
Halysites catenulatus,
Favosites niagarensis,
Cyathophyllum calyculum.

In the railroad cut almost three miles north of Berea, immediately below the layer with large crinoid beads and occasional specimens of *Whitfieldella,* the following species occur:

Orthothetes cf. tenuis,
Platystrophia daytonensis,
Heliolites subtubulata,
Cyathophyllum calyculum.

Heliolites subtubulata occurs in the Brassfield limestone also along the creek, southwest of the railroad station at Panola.

East of Moberly, at Elliston, the top of the Brassfield limestone section contains:

Orthis flabellites,
Leptaena rhomboidalis,
Cyathophyllum calyculum.

South of Indian Fields, at Abbott's Mill, the upper part of the Brassfield section contains:

Rhinopora frondosa,
Zaphrentis daytonensis,
Cyathophyllum calyculum.

In the lower part of this section, the following species are found:

Cyclonema daytonensis,
Leptaena rhomboidalis,
Clathropora frondosa.

About seven miles southwest of Indian Fields, and a mile north of the old Simpson Brock place, the following species

occur in the upper part of the Brassfield limestone, just below the *Whitfieldella* layer:

Dalmanella elegantula,
Rhinopora frondosa,
Ptychophyllum ipomea,
Cyathophyllum calyculum.

A much greater fauna has been discovered in the northern extension of the Brassfield limestone, in Ohio and Indiana. Among the trilobites this fauna includes:

Illaenus daytonensis,
Illaenus ambiguus,
Illaenus madisonianus-elongatus,
Illaenus madisonianus-depressus,
Proetus determinatus,
Cyphaspis clintonensis,
Lichas (Platynotus) clintonensis,
Acidaspis (Odontopleura) ortoni,
Encrinurus ornatus,
Calymmene vogdesi,
Calymmene niagarensis,
Ceraurus (Pseudosphaerexochus) clintonensis.
Deiphon pisum,
Phacops pulchellus,
Dalmanites (Odontochile) werthneri.

Among the brachiopoda, this fauna includes:

Craniella clintonensis,
Plectambonites transversalis-elegantulus,
Plectambonites prolongatus,
Leptaena rhomboidalis,
Strophonella daytonensis,
Strophonella hanoverensis,
Orthothetes daytonensis (=0. tenuis, Foerste),
Orthis fabellites,
Hebertella fausta,
Hebertella daytonensis,
Platystrophia reversata,
Platystrophia daytonensis,
Dalmanella elegantula,

Rhipidomella hybrida,
Triplecia ortoni,
Whitfieldella sp.,
Atrypa marginalis,
Camarotoechia scobina,
Camarotoechia convexa,
Parastrophia sparsiplicata,
Stricklandinia triplesiana.

Among the bryozoans, the following are seen:

Homotrypa confluens,
Aspidopora parmula,
Lioclemella ohioensis,
Callopora magnopora,
Phylloporina angulata,
Hemitrypa ulrichi,
Ptilodictya whitfieldi (= *Pt. expansa,* Hall; 12th Rep. Indiana Geol. Survey, plate 12, Figs. 2, 3; published in 1883; also *Pt. expansa,* Foerste, Bulletin, Lab. Denison Univ., Vol. II, plate 15, Fig. 5, published in 1888. Not *Paenopora expansa,* Hall and Whitfield, Ohio Pal., Vol. II, plate 5, Fig. 1, published in 1875.)
Ptilodictya americana, (= *Pt. expansa.* Foerste, in part; Bulletin, Lab. Denison Univ., Vol. II, page 156).
Clathropora frondosa,
Clathropora clintonensis,
Phaenopora expansa (= *Ptilodictya platyphylla,* James; *Pt. bipunctata,* Hall),
Phaenopora fimbriata,
Plaenopora magna,
Phaenopora welshi (= *Ph. multifida,* Hall),
Pachydicta bifurcata,
Pachydictya instabilis,
Pachydictya crassa,
Pachydictya emaciata,
Trigonodictya catonensis,
Rhinopora frondosa.

These lists are sufficient to indicate the Silurian character of the fauna found in the Brassfield limestone of east-central Kentucky and in the northern extension of this limestone in

Ohio and Indiana. Compared with the Clinton of New York, the absence of the following brachiopoda is noteworthy:

Stropheodonta profunda,
Strophonella (?) patenta,
Orthotetes subplanus,
Pentamerus oblongus,
Barrandella fornicata,
Rhynchonella robusta,
Atrypa reticularis,
Spirifer radiatus,
Spirifer niagarensis,
Spirifer crispus-corallinensis,
Hyatella congesta,
Anoplotheca hemispherica,
Anoplotheca plicatula.

Among these species, *Pentamerus oblongus* makes its first appearance in the Dayton limestone, which immediately overlies the northern extension of the Brassfield limestone in Ohio; *Atrypa reticularis*, *Spirifer radiatus*, and *Spirifer niagarensis* are seen, in Indiana, in the limestones which overlie the clay shales, there known as the Osgood clay. Although these limestone layers have been included in the Osgood formation, on account of an overlying, but much thinner, layer of clay occurring in some parts of that State, they might with equal propriety be considered as forming the base of the Laurel limestone section.

The identification of the Brassfield limestone of Kentucky, and of its northern extension in Ohio and Indiana, in former years, with the Clinton limestone of New York, rests rather upon a somewhat similar facies of the two faunas, and upon the general absence of the more typical species of the Rochester shale fauna of New York in these limestones at the base of the Silurian in Ohio, Indiana, and Kentucky, than upon the presence of any considerable number of species common to both areas. On closer inspection, the fauna of the Brassfield limestone of Ohio, Indiana, and Kentucky appears to differ sufficiently from the fauna of the Clinton limestone of New York to warrant the assumption of the presence of some sort of barrier between these two areas.

Whitfieldella Horizon.

The fossils listed in the preceding section occur chiefly in the upper part of the Brassfield section, consisting of rather thin layers of limestone interbedded with a little clay. Immediately above this section, there is a thicker and more sandy appearing layer, usually about one foot thick, but occasionally equalling two feet. In this layer large crinoid beads, often half an inch in diameter, are common. Wh*itfieldella subquadrata* (Plate 1, Fig. 3) also occurs in considerable abundance at some localities, and has a wide geographical distribution at this horizon in eastern Kentucky. When these species are not intermingled, the *Whitfieldella* usually occurs in the upper part of the sandy appearing layer, and the large crinoid beads are found either in the lower part of this layer or at the top of the immediately underlying rock.

Owing to the porous nature of the sandy appearing layer, the specimens of *Whitfieldella* occur chiefly as casts, the shells having been dissolved and carried away in solution by percolating waters, leaving the impressions of the exterior form of the shell upon the surrounding rock, and often preserving the casts of the interiors of the shells in a remarkable manner. The part usually noticed is that near the hinge line, because here the shell was thickest, and the removal of the shell material left the greatest cavities, exposing beautifully the casts of the interior of the shell, especially of the deep muscular scar in the pedicle valve, and of the strong transverse ovarian ridges on each side. This portion of the cast of the interior of *Whitfieldella subquadrata* frequently appears to have been identified as *Atrypa reticularis,* a fact which it is necessary to keep in mind in reading the literature of this part of the Silurian geology of Kentucky. While such an identification would be inexcusable at the present day, it should be remembered that some valuable work was done in former years by men who did not have the advantages in scientific training which now can be secured by all. As a matter of fact, *Atrypa reticularis* does not occur in the *Whitfieldella* layer.

Associated with the large crinoid beads and the *Whitfieldella subquadrata,* is a small species of cyathophylloid coral, usu-

ally less than an inch in length, which has not been carefully studied, but which passes in these notes under the name *Cyathophyllum calyculum.* A species of *Orthothetes* occurs occasionally.

The most northern locality at which *Whitfieldella subquadrata* has been found in abundance is west of Slate creek, east of Spencer, in Montgomery county. The most northern locality at which it has been identified with certainty is along the railroad, about a mile west of Preston, in the southern part of Bath county. Southward it may be recognized, still at the same horizon, on Fishing creek, directly west of Somerset, and along the Cumberland river, in Pulaski and Wayne counties. Stratigraphically, therefore, the *Whitfieldella subquadrata* layer is remarkably persistent. This makes it valuable as an horizon marker, especially in exposures of limited vertical extent. For instance, at the point a mile north of Irvine, where the road passing Estill Springs crosses White Oak creek, there is a small exposure, only four or five feet high, along the water's edge, on the west side of the creek. One of the layers shows the sandy appearance and contains the large crinoid beads and the *Whitfieldella*. This at once indicates that the immediately underlying rock belongs to the Brassfield limestone section, a fact corroborated by the discovery of fossils characteristic of that horizon in this rock at the same locality.

The most interesting feature of the *Whitfieldella subquadrata* horizon, however, is not its extended distribution or its value as an horizon marker, but the evidence which it presents of some geographical change preceding its deposition. The coarser, sandy, more porous structure of the rock suggest that its materials were swept together by stronger currents than those which brought in the sediments forming the underlying limestones. This evidence is corroborated by the presence of coarse bedding, and occasionally even of cross bedding, at this horizon. The large crinoid beads have the appearance of having been swept together by currents which caused the disintegration of the less compact structure of other remains of animal life. The coarse *Whitfieldella* is one of the few fossils at all common at this horizon. Other remains frequently show considerable rounding at the edges, suggesting that they were rolled by currents of water before reaching their final resting place.

The absence of a considerable part of the fauna characteristic of the Brassfield limestone in this *Whitfieldella* layer, and the sudden introduction of the *Whitfieldella subquadrata* suggests the lapse of a sufficient interval of time to have permitted a shifting of faunas. The *Whitfieldella* horizon probably heralds the introduction of a new fauna, and for this reason it is used in discriminating the overlying beds from the Brassfield limestone. At present, however, comparatively little is known of the faunas of these immediately overlying limestones or of the Oldham bed.

Rose Run Iron Ore.

About a mile west of Preston, along the railroad, a short distance east of the home of William Johnson, the *Whitfieldella* layer is exposed. The top of the Silurian formations is seen farther east, in a railroad cut. The following section is seen, in descending order:

Devonian Black shale.		
Devonian limestone	11 ft.	8 in.
Alger clay	60 ft.	
Oldham limestone and clay	5 ft.	
Plum creek clay	7 ft.	6 in.
Light brown limestone		4 in.
Clay		8 in.
Ferruginous limestone, with large crinoid beads in lower part	1 ft.	
Limestone, containing large crinoid beads and one good *Whitfieldella subquadrata*		5 in.
Clay, top of Brassfield section		7 in.
Limestone		4 in.
Clay		7 in.
Ferruginous limestone	1 ft.	
Remainder of Brassfield section not measured.		

About two miles southwest of Preston, along the road leading to Howard Mills, east of a crossing of a small branch emptying into Slate creek, the following exposure is seen, in descending order:

Cherty Devonian limestone.		
Alger clay	60 ft.	
Oldham limestone and clay, limestones at the top thinner and separated by more clay	9 ft.	6 in.
Plum creek clay	5 ft.	6 in.
Wave-marked limestone		4 in.
Clay		4 in.
Limestone, strongly ferruginous, containing one *Whitfieldella subquadrata*	1 ft.	
Limestone, with large crinoid beads		2 in.
Clay chiefly, top of Brassfield section	2 ft.	
Limestone, strongly wave-marked, with large crinoid beads		9 in.
Chiefly clay	2 ft.	3 in.
Limestone, layers of irregular thickness	1 ft.	2 in.
Limestone, hard layer		10 in.
Clay		6 in.
Massive limestone forming the remainder of the Brassfield section	10 ft.	

About four miles east of Owingsville, on the northern side of Rose Run, there are wide areas in which a hematitic iron ore is quarried. At this locality the following exposures are seen, in descending order:

Oldham limestone and clay, lower part of section	5 ft.	
Plum creek clay	8 ft.	
Limestone, wave-marked		4 in.
Blue hydrated iron ore		5 in.
Red hematitic iron ore	3 ft.	
Brown limestone, top of Brassfield section		5 in.
Clay		4 in.
Limestone with large crinoid beads		6 in.
Remainder of Brassfield section not measured.		

From these sections it may be seen that the horizon of the valuable iron ore deposits of this part of Kentucky is below that of the Plum creek clay, and occupies about the same level as the *Whitfieldella subquadrata* layer. This does not mean that none of the layers of limestone immediately underlying or overlying the *Whitfieldella* layer may be ferruginous, but that the *Whitfieldella* layer is the horizon of the richest ores, and is the only layer of commercial value.

All of the valuable deposits of this hematitic iron ore occur in the immediate vicinity of Owingsville, chiefly along Rose Run. The horizon, however, may be traced farther northward.

At the mill on Fox creek, two miles below Farmville, the following section is exposed, in descending order:

Clay with a little thin-bedded limestone, base of Plum creek clay section	2 ft.	
Light brown limestone		4 in.
Red ferruginous limestone	1 ft.	4 in.
Limestone full of large crinoid beads	1 ft.	
Blue clay, top of Brassfield section	1 ft.	6 in.
Limestone, strongly wave-marked		10 in.
Limestone, thin bedded		8 in.
Clay	1 ft.	4 in.
Limestone, hard layer		6 in.
Clay	1 ft.	6 in.
Clayey rock		6 in.

Remainder of Brassfield section not exposed.

Along the railroad, one mile north of Hillsboro, the following section is exposed, in descending order:

Oldham limestone and clay, 5 ft. 4 in. thick, consisting of the following members:		
Limestone		8 in.
Clay		4 in.
Limestone, slightly ferruginous	1 ft.	7 in.
Clay		4 in.
Limestone		4 in.
Clay	1 ft.	6 in.
Several limestone layers		6 in.
Plum creek section, chiefly clay, 6 ft. 6 in. thick, consisting of the following members:		
Clay		10 in.
Limestone lenses		1 in.
Clay	3 ft.	
Limestone, thin layers		2 in.
Clay		9 in.
Limestone, light brown, thin		4 in.
Clay		4 in.
Limestone, brown tinged with red		2 in.
Limestone, red purple		2 in.
Limestone, strongly ferruginous, dark layer	1 ft.	3 in.
Limestone, not ferruginous, somewhat cross-bedded in places		6 in.
Clay, top of Brassfield section	1 ft.	7 in.
Limestone, wave-marked, often absent along the troughs, but remaining along the ridges as lenses, when seen in cross section, with large crinoid beads		4 in.

Clay	1 ft.	
Limestone, wave-marked, with large crinoid beads		6 in.
Chiefly clay, with a little thin limestone at several levels	4 ft.	2 in.
Limestone, hard		6 in.
Clay		4 in.
Chiefly light brown or blue limestone	2 ft.	2 in.
Blue clay and limestone, poorly exposed	3 ft.	
Limestone		6 in.
Clay		10 in.
Solid massive limestone with chert, base of Brassfield section	5 ft.	6 in.
Belfast layer	3 ft.	

A number of instructive sections occur in Adams county, Ohio, in the neighborhood of West Union, and between West Union and Dunbarton. One of these sections is located along the ravine of the first stream crossing the road east of Sprow's bridge, northeast of Duncansville, not far east of the pike from West Union to Peebles. The section is north of the road, back in the woods, up the gully toward the northeast. Here the following rocks are shown, in descending order:

Limestone, massive, possibly the equivalent of the Dayton limestone	3 ft.	
Limestone and clay, corresponding approximately to the Plum creek horizon; *Atrypa reticularis* occurs 1 ft. above the base	7 ft.	
Purple ferruginous limestone with large crinoid beads.		5 in.
Limestone with large crinoid beads		4 in.
Clay		6 in.
Limestone, massive, crinoidal		6 in.
Clay with a little thin limestone near middle		10 in.
Whitfieldella quadrangularis layer		6 in.
Chiefly clay, top of Brassfield section	1 ft.	3 in.
Limestone, wave-marked		4 in.
Interval not recorded	19 ft.	
Limestone, massive, lower part cherty	2 ft.	8 in.
Limestone, white, forming small fall	1 ft.	
Limestone, very cherty	6 ft.	
Limestone, thin bedded, base of Brassfield section	6 ft.	
Clay rock with calcite	2 ft.	
Belfast bed	4 ft.	

Another section occurs north of the Whipporwill church, along the pike from West Union to Peebles, about three miles

northeast of West Union. Here the following rocks are seen, in descending order:

Limestone, massive, possibly equivalent to the Dayton limestone.		
From the top of this massive limestone to the ferruginous layer the interval, possible equivalent to the Plum creek horizon, is	7 ft.	
Oolitic ferruginous layer, containing *Pleurotomaria inexpectans*, and other fossils.		
From the top of the ferruginous layer to the top of that next mentioned the interval is	3 ft.	8 in.
Limestone, massive, crinoidal, with *Atrypa reticularis* and other fossils	1 ft.	6 in.
Limestone, wave-marked, with many large crinoid beads.		
From the top of the wave-marked layer to the base of the cherty layer the interval is	28 ft.	
Limestone, thin bedded, forming base of Brassfield section, including *Hebertella fausta*	7 ft.	
Belfast bed.		

The third section of importance in this connection is exposed southeast of West Union, along the road to Beasley Fork. The section begins at West Union and is described in descending order:

Alger clay	148 ft.	
Limestone, massive, in 6-inch layers, probably equivalent to Dayton limestone, exposed near home of John Morrison	4 ft.	6 in.
Limestone, poor, thin bedded	1 ft.	6 in.
Clay, with thin limestone layers	1 ft.	2 in.
Limestone, wave-marked		3 in.
Clay		8 in.
Limestone		3 in.
Clay		3 in.
Limestone, with large wave marks		6 in.
Limestone		6 in.
Clay, with a little thin limestone	1 ft.	6 in.
Limestone with large wave marks and containing large crinoid beads		6 in.
From base of last layer to base of cherty limestone, including almost all of the Brassfield section, the interval is	26 ft.	
Limestone	2 ft.	
Limestone, massive, called iron ledge by natives	1 ft.	2 in.

Belfast bed, near home of Matilda F. Blake.....	4 ft.	
Saluda bed	24 ft.	
Interval	26 ft.	
Strongly wave-marked limestone, near home of Simon Nixon		6 in.
Interval	147 ft.	
Leptaena rhomboidalis horizon in Arnheim bed.		

A comparison of these three sections with those in Kentucky suggests that possibly the Oldllam limestone section of east-central Kentucky is represented in Ohio by the Dayton limestone. North of Hillsboro, Kentucky, the Plum creek clay section appears to contain more and more limestone. In this form it may be traced into the central part of Adams county. Farther north this Plum creek section either disappears or becomes a part of the Dayton limestone section. The ferruginous horizon appears to occur at a distinctly higher level in Adams county, Ohio, than east of Owingsville, Kentucky. In Adams county it is separated from the *Whitfieldella quadrangularis* horizon by an interval of at least two feet. Farther northward the Dayton lime usually rests directly upon the Brassfield layer or is separated only by the ferruginous layer.

In Ohio, there evidently is an unconformity between the top of the Brassfield limestone section and the base of the Dayton limestone. This is indicated by the large pebbles found in the ferruginous and wave-marked rock immediately overlying the Brassfield section south of the Elk Run bridge, two miles east of Belfast, in the southeastern part of Highland county, in Ohio. Here many of the pebbles are four to eight inches long, and some are even twelve inches in length. Pebbles, three inches long, occur at the same horizon along the creek immediately northwest of Belfast. Pebbles occur also near the middle, and at several points above the middle of the Brassfield bed at Belfast, and near Sharpsville, also in Highland county. The interpretation of these features has not yet been carefully worked out, but the evidence is in favor of the presence of a number of strata between the Dayton limestone and the Brassfield limestone section, in southern Ohio, and northern Kentucky, which do not appear to be represented farther north, in Ohio and Indiana.

Moreover, in both States, Kentucky and Ohio, the ferruginous oolitic rock appears to be associated with evidences of

stronger current action, such as a sandy appearing texture, cross bedding, wave marks, and, locally, with pebbles, features which characterize the shallower seas. This arouses the inquiry, whether the segregation of the iron in these oolitic beds may not have taken place largely at the time of their deposition, at least in the form of iron carbonate, although subsequent chemical action has undoubtedly changed these carbonates to hematite, and has probably continued the replacement of the lime of the fragments of shells and bryozoans forming the centers of the oolitic grains by these compounds of iron.

Plum Creek Clay.

The relations of the Plum creek clay to the underlying and overlying rocks are well shown along the lower part of Plum creek, about three miles southwest of Clay City, in Powell county. Here, along the western bank of Plum creek, directly east of the home of George McIntosh, an excellent exposure of almost the entire thickness is presented. (Fig. 3.) Farther down the creek, the base of the clay is exposed. The total thickness of the Plum creek clay is about five and a half feet, but opposite the home of George McIntosh the thickness of the exposure is five feet three inches, the base not being seen. The clay rests upon a strongly wave-marked layer of limestone. Beneath the wave-marked layer occurs the layer with large crinoid beads and with *Whitfieldella subquadrata.* The contact with the base of the Oldham limestone, at the top of the clay section, is clearly exposed.

One of the best exposures of the Plum creek clay occurs about a mile and a half northwest of Indian Fields, west of Howard creek, along the Lexington & Eastern Railroad. Here the thickness of the Plum creek clay is five feet. (Fig. 2.) The underlying layer of limestone is strongly wave-marked, as along Plum creek. Beneath the wave-marked layer is limestone containing the large crinoid beads and a few specimens of *Whitfieldella subquadrata.* Above the Plum creek clay, there is an excellent exposure of the lower part of the Oldham limestones, eight feet thick. The Plum creek clay section includes a little interbedded limestone at the top. Thin streaks of limestone occur also in the lower part of the section at irregular intervals.

Fig. 2. Brassfield Limestone, Plum Creek Clay, Oldham Limestone. A mile and a quarter west of Indian Fields, along the Lexington and Eastern Railroad, Clark County.

yond Brassfield, the quantity of interbedded limestone appears to increase, so that, although the clay preponderates, there is enough thin limestone to make the Plum creek horizon far less conspicuous. Still farther west, beyond Crab Orchard, the proportion of limestone in the Plum creek section is at least equally great, if not greater.

To an investigator entering the field from the southwest, the Plum creek horizon does not form a readily distinguishable feature until the southern part of Madison county is reached. Even in Madison county, southwest of Panola and Brassfield, the idea of separating the Plum creek clay from the Oldham limestone does not suggest itself. Farther north, between Indian Fields and Clay City, however, this clay forms a readily recognizable horizon.

There is no question of the increase of the amount of limestone in the Plum creek section on going from Indian Fields southwestward toward Stanford. Near Indian Fields, the thickness of the Plum creek bed is five feet. Southwestward, the thickness varies considerably, and, in general, appears to become somewhat thinner. Locally, however, sections five feet thick appear to occur even as far west as Crab Orchard, but this requires further observation.

Further investigations are necessary also in the territory between Hillsboro, in Fleming county, Kentucky, and West Union, in Ohio. The stratigraphy of this territory has by no means been worked out with the exactness which is desirable.

There is no prospect of the Plum creek clay having any commercial value. Even if it had any special value, it would not pay to work it, since the clay is overlaid by the Oldham limestone which must be removed in order to get at the clay. The Alger clay, overlying the Oldham limestone, agrees so closely, chemically, with the Plum creek clay where the latter is most free from limestone, that it is certain that the Alger clay will be exploited in preference to the Plum creek clay. The chief interest in the Plum creek clay is its stratigraphical position. In a study of the clay resources of the State it becomes necessary not only to determine where the largest clay layers are, but also to determine the location and thickness of the subsidiary layers. Much money is wasted at times in operation where it is hoped that clays, limestones, or other layers

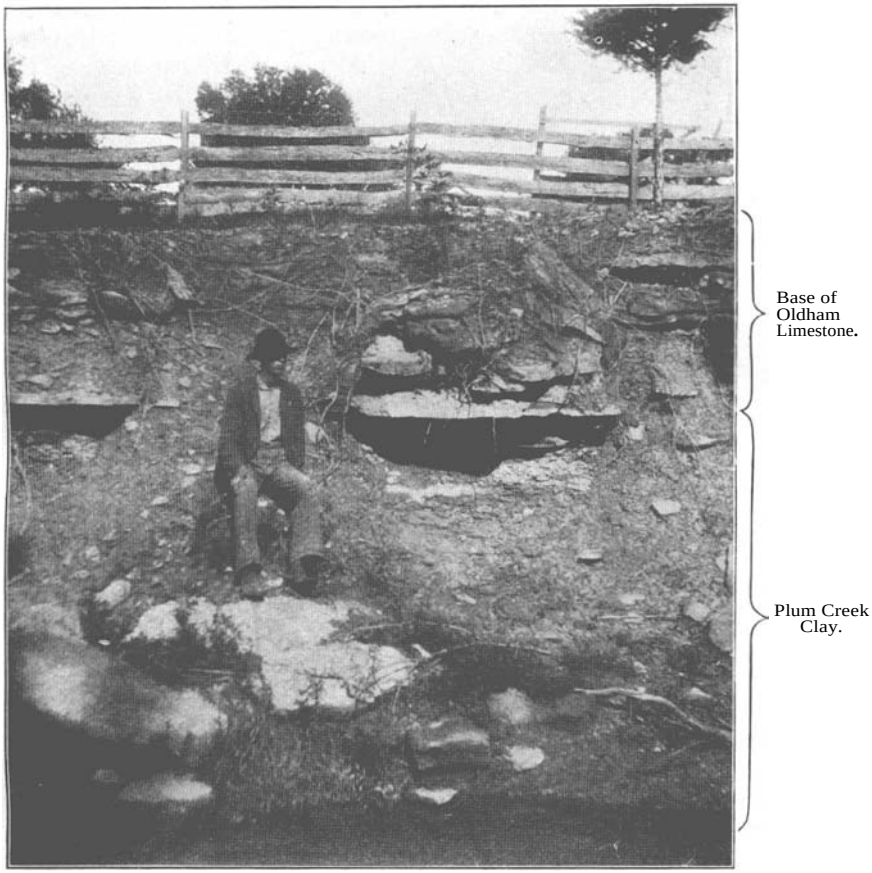


Fig. 3. Plum Creek Clay Shale overlaid by Oldham Limestone. West side of Plum Creek directly east of house of George McIntosh. South end of type section.

of interest will thicken as they are followed beneath the ground. It is one of the objects of the Survey to warn against such false hopes.

Oldham Limestone.

The best exposure of the Oldham limestone section, in the entire territory under investigation, unquestionably is along the almost continuous line of cuts along the railroad between Panola and Brassfield. Here the railroad follows the northern slope of the valley cut by Oldham branch. A layer with large crinoid beads occurs at the top of the Brassfield bed, and is overlaid by a layer of limestone, two and a half feet thick, ferruginous and oolitic at the top, containing *Whitfieldella subquadrata.* Overlying the *Whitfieldella* layer, the following rocks occur in ascending order: thin argillaceous limestone layers interbedded with clay, one foot ten inches thick; clay, three feet three inches thick, unquestionably belonging to the Plum creek horizon; thin limestone interbedded with clay, three feet four inches thick, forming the base of the Oldham limestone section; and, finally, limestone with much less clay, eleven feet thick, forming the most characteristic part of the Oldham limestone section.

In the territory between Brassfield and Indian Fields, a large brachiopod shell, *Stricklandinia norwoodi,* is very abundant at the top of the Oldham limestone section. It is very probable that this shell eventually will be traced beyond the limits of the territory designated, and thus will assist in increasing the area within which the Oldham limestone may be identified with certainty. Indeed, half a mile south of Whites Station, at the railroad cut four miles north of Berea, poor remains have been discovered already at this horizon, and it is hoped that further search may extend still farther its known area of distribution. It is the most characteristic fossil of the Oldham section. The presence of *Stricklandinia norwoodi,* in any limestone section in this part of Kentucky, is a safe indication of the top of the Oldham limestone, in the same manner as the presence of *Whitfieldella subquadrata,* in this same area, is an indication of the presence of the top of the Brassfield limestone immediately beneath.

The most northern exposure, at which the Oldham limestone is known to contain *Stricklandinia norwoodi,* is along the railroad northwest of Indian Fields, west of Howard creek. Here the first cut west of the creek presents a good exposure of the upper part of the Oldham section. *Stricklandinia norwoodi* occurs at the top, and slightly ferruginous layers are found within two feet of the top of the section. At the larger cut, farther west, the lower part of the section, almost eight feet thick, is well exposed, resting upon the Plum creek clay.

Stricklandinia norwoodi is rather abundant at the exposure southeast of the home of J. T. Elkins, about five miles west of south of Indian Fields, along the road to Vienna, a collection of houses on the Red river. Here the *Stricklandinia* is found at the top of the Oldham section, nineteen and a half feet above the layer containing the large crinoid beads, which forms the top of the Brassfield bed. If the thickness of the Plum creek layer, estimated at five feet and a half, be subtracted from this amount, a thickness of fourteen feet would be left for the Oldham limestone. The exposure, however, is not clear enough to determine the amount of dip, if any, so that the estimate of fourteen feet is to be regarded merely as approximate.

Several excellent exposures of the top of the Oldham 1imestone, with its *Stricklandinia norwoodi,* occur on the eastern side of Long branch, about two and a half miles south of Indian Fields, on the Morgan Eubanks farm.

Stricklandinia nonwoodi occurs at the top of the Oldham limestone also three miles southwest of Clay City, along the road crossing Plum creek. The entire thickness of the Oldham section appears to be about eleven feet. A ferruginous layer occurs about six feet below the top. *Stricklandinia* occurs at the top of the Oldham limestone also north of Irvine. Here the thickness of the Oldham limestone section is estimated at twelve feet. An exposure of the Oldham limestone occurs just east of the railroad station at Panola, between the road and the creek. Here the thickness of the measured section appears to be fifteen feet, possibly too large an estimate, but it is not known just what allowance must be made for the dip. *Stricklandinia* has been found also four miles north of College Hill, on the abandoned part of the road to Bloomingdale, about a mile south of the Kentucky river, on the southern side of a

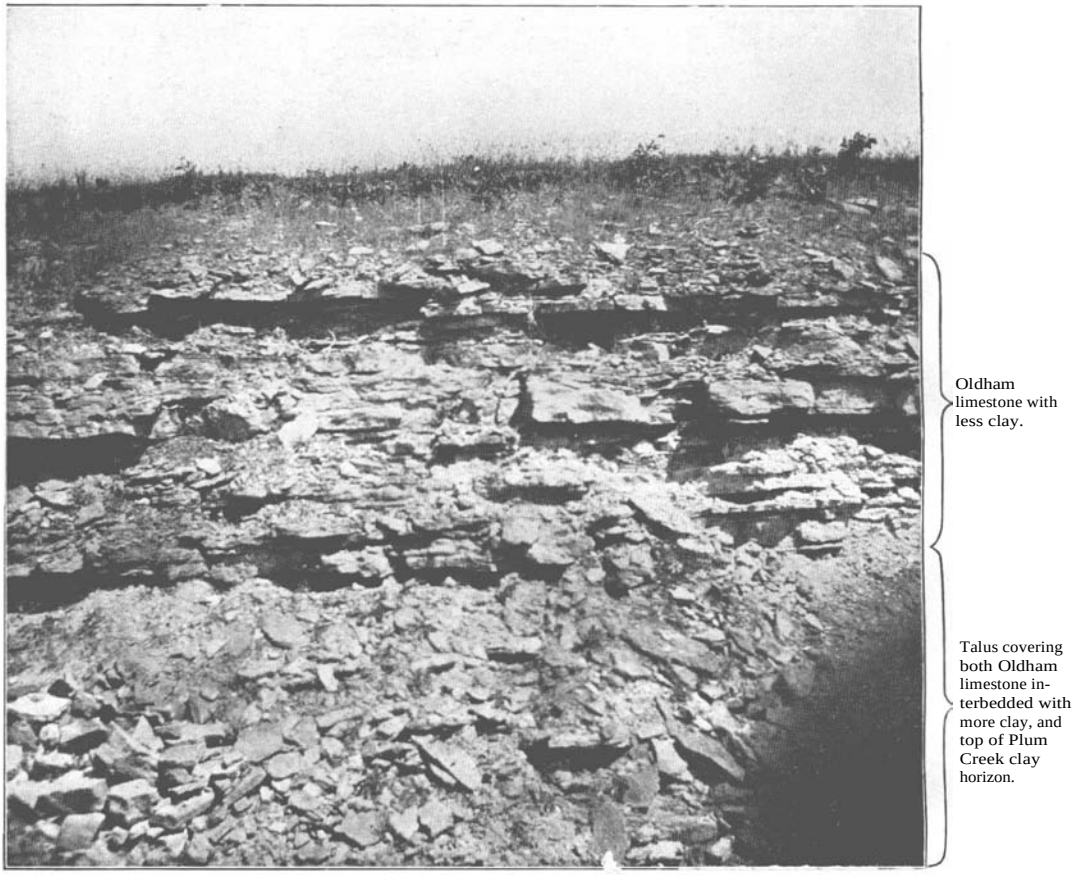


Fig. 4. Oldham Limestone. east of Brassfield, along the Louisville and Atlantic R. R. View of farther end of cut shown in Fig. 5.

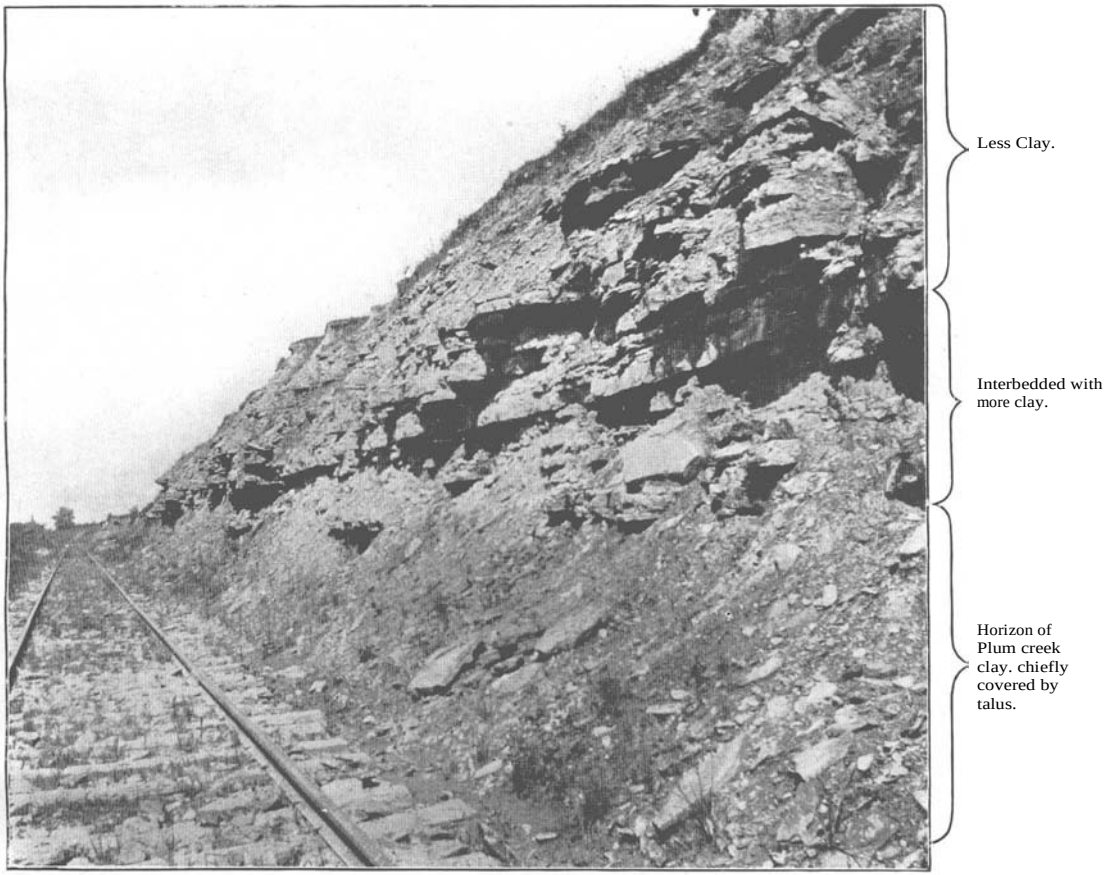


Fig. 5. Oldham Limestone, east of Brassfield, along the Louisville and Atlantic R. R.

deep valley. In fact, between Brassfield, Indian Fields, Clay City, and Irvine, it occurs wherever the proper horizon is exposed.

Four miles north of Berea, in the railroad cut south of Whites, the limestone containing large crinoid beads and *Whitfieldella subquadrata* is overlaid by the equivalent of the Plum creek clay, five feet thick. It consists here of clay interbedded with clay rock. The Oldham limestone section is represented by limestone interbedded with clay, eight feet three inches thick. *Stricklandinia norwoodi* occurs at the top of this section. The overlying limestone one foot three inches thick may belong to the Devonian. The layer with fish remains occurs immediately above, and unquestionably is of Devonian age. Although this layer with fish remains usually forms the base of the Devonian section, it is underlaid by one or two feet of Devonian limestone at Elliston, near Kiddville, and at several other localities.

The identification of the Oldham limestone southwest of Berea is attended with difficulties owing to the absence of the *Stricklandinia* and to the gradual change of the lithological conditions. Eventually, as the result of careful stratigraphical work, the exact equivalency of all the more southwestern strata no doubt will be determined. At present, it is possible only to indicate what conclusions are favored by the evidence at hand.

A mile southeast of Hammack, the thickness of the Plum creek section is estimated at four feet four inches, and that of the Oldham limestone at approximately twelve feet. Half a mile north of Hammack, the thickness of the Plum creek section is estimated at five feet, and that of the Oldham limestone at ten feet three inches. Three miles north of Crab Orchard, on the road to Hammack and Richmond, the layer with large crinoid beads is overlaid by solid limestone, a foot and a half thick. Over this is found considerable clay, five feet thick, interbedded with limestone, forming the Plum creek section. This is followed by limestone interbedded with clay, eleven feet eight inches thick, belonging to the Oldham limestone horizon. About three miles west of Crab Orchard station, along the county road, near the home of Abel Bryant, the layer with large crinoid beads is overlaid by a section poorly exposed, five feet thick, assumed to belong to the Plum creek section. Above this occurs limestone interbedded with clay, twelve feet thick, regarded as belonging to the Oldham limestone horizon.

If these sections west and southwest of Berea, have been interpreted correctly, there is no very evident thinning of the Oldham limestone between Indian Fields and Crab Orchard, although local variations in thickness are apparent.

The Oldham limestone may be readily identified by stratigraphic means as far as Owingsville. At the Rose Run iron ore quarries, the Oldham limestone forms the top of the exposures, and is separated by a very characteristic bed of Plum creek clay from the ferruginous, oolitic layer overlying the top of the Brassfield limestone. Farther north, however, considerable thin limestone occurs in some sections of the Plum creek clay, and the difficulty of discriminating between the Plum creek clay section and the Oldham limestone is considerably increased. In general, the Plum creek clay is to be regarded as a comparatively local formation, best developed between Owingsville, Clay City, Irvine, Brassfield, and Indian Fields. Where this clay can not be readily identified the Oldham limestone can not be readily discriminated. In such territories, the general designation, Indian Fields formation, may be used to include both the Plum creek clay and the Oldham limestone.

It has already been stated that farther northward, in Ohio, the Oldham limestone appears to find its equivalent in the Dayton limestone. In east central Kentucky the fossils of the Oldham horizon are neither numerous nor well preserved, but enough have been seen to indicate a fauna distinctly different from that in the Waco limestone layers.

Lulbegrud Clay.

The Lulbegrud clay directly overlies the Oldham limestone. In the territory between Irvine, Clay City, Indian Fields, and Brassfield, the thickness of the Lulbegrud clay is about thirteen feet. It is well exposed at various points along the tributaries of Lulbegrud creek, in Clark and Powell counties. About a mile southwest of Indian Fields, south of the railroad, there is a road leading from the creek road to Clay City northward across the railroad toward Clay City. Here the top of the Oldham limestone is well exposed a short distance above the level of Lulbegrud creek. Above this Oldham limestone, along the road, the full thickness of the Lulbegrud clay is exposed. The

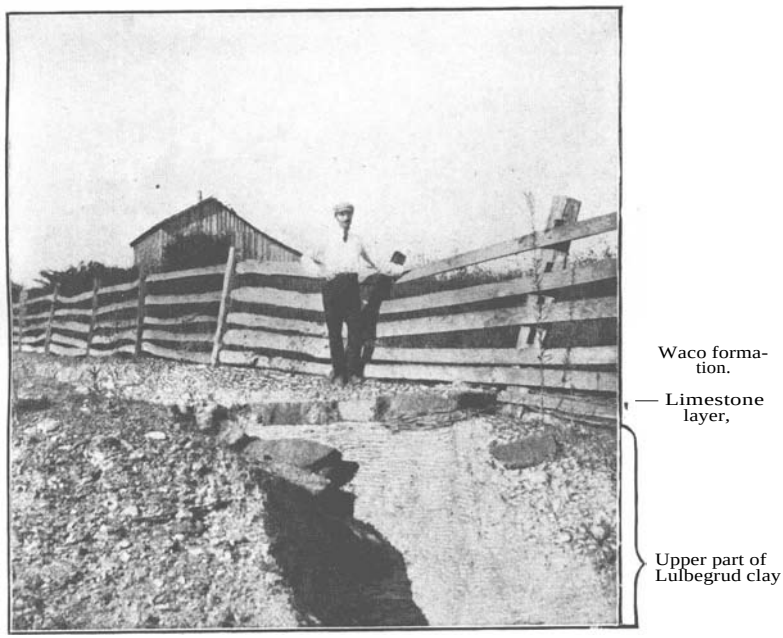


Fig. 6. Top of Lulbegrud clay. Road side gully, one mile south-east of Indian Fields, north of Lulbegrud creek, along the road passing northward across the railroad track toward Kiddville.

clay is covered by a very persistent layer of limestone, above which the very thin layers of limestone characteristic of the Waco horizon are seen. (Fig. 6.) The home of Brownlow Bruner is scarcely a quarter of a mile directly west of this line of exposures, and this locality therefore has been called the Brownlow Bruner locality.

The Lulbegrud clay is exposed also at Abbott's mill, five miles south of Indian Fields, near the home of J. T. Elkins, along the road to Vienna; at several localities near Vienna, on the Red river; a mile east of College Hill, along the road leading to the dam; immediately south of Waco, along the road leading up hill; east of Panola, between the road and the railroad; within three hundred yards of the station; and southeast of Brassfield, along the railroad.

One of the best exposures of the Lulbegrud clay is seen north of Irvine, along the road passing Estill Springs, before reaching White Oak creek, and, again, up the hill, northeast of the point where the road leaves the creek. Here the thickness of the Lulbegrud clay varies between thirteen feet and fourteen feet and a half. On weathering, it softens into a bluish-white clay. The percolating waters often are impregnated with Epsom salts, and springs issuing from these clays belong to the class known as Licks. Gypsum is deposited from these waters. Good crystals are abundant at some localities.

Between Brassfield and Berea the sections become thinner. Three miles slightly north of east of Bobtown a thickness of ten feet is exposed, but the base is not seen. A mile and a half south of east from Bobtown, the thickness of the Lulbegrud clay is twelve feet. Two and a half miles southeast, of Bobtown, the interval between the top of the Brassfield bed and the solid limestone regarded as marking the base of the Waco horizon is sufficient to suggest at least ten feet of Lulbegrud clay as forming a part of this interval. About two miles northeast of Berea, the thickness of the Lulbegrud clay appears to be nearly thirteen feet; three miles north of Berea, along the railroad, the thickness is estimated at eleven feet. Three miles southwest of Berea, the total Silurian section beneath the solid limestone layer, regarded as marking the base of the Waco horizon, is sufficient to warrant an estimate of ten to thirteen feet for the Lulbegrud clay division of this section.

The solid layer of limestone, varying between nine and twenty-four inches in thickness, which overlies the Lulbegrud clay section, has not been traced with certainty beyond Berea. Until a more detailed examination of the territory between Brassfield and Crab Orchard has been made, it is useless to hazard any opinion as to whether the solid layer of limestone found in more southwestern sections is of the same age or not. This layer of limestone also varies between nine and twenty-four inches in thickness, occurs at some distance above the base of a more continuous clay section, and has a rather wide geographical distribution, near Crab Orchard, and as far eastward as Berea. If this limestone layer at Berea and westward could be proved to be of the same age as the limestone overlying the Lulbegrud clay north of Irvine, Panola, and Brassfield, this fact would be of interest, since in that event a distinct thinning of the Lulbegrud clay toward the crest of the Cincinnati geanticline could be shown. Near Crab Orchard, the thickness of the clay between the solid limestone layer can not exceed six feet, and this is the thickness also at Hammack.

Waco Limestone Horizon.

Immediately above the Lulbegrud clay, about thirteen feet above the base of the great clay section here known as the Alger formation, there occurs a layer of solid limestone, varying from less than one foot to fully two feet in thickness. This is followed by numerous layers of fossiliferous thin limestones interbedded with a considerable quantity of clay. Although the clay predominates, this part of the section has been called the Waco limestone horizon, since the presence of the limestone is its characteristic feature. The layer of limestone at the base of the Waco section has been traced over the entire area included between Brassfield, Irvine, Clay City, and Indian Fields, a territory twenty-five miles long and twelve miles broad. No limestone, with which this limestone at the base of the Waco section could be confused, is known at any other elevation in the Alger formation. Hence it has been found a valuable horizon marker in the area designated. Possibly it may prove to extend both farther north and farther south. In that case it may serve to indicate the base of the Waco horizon even where

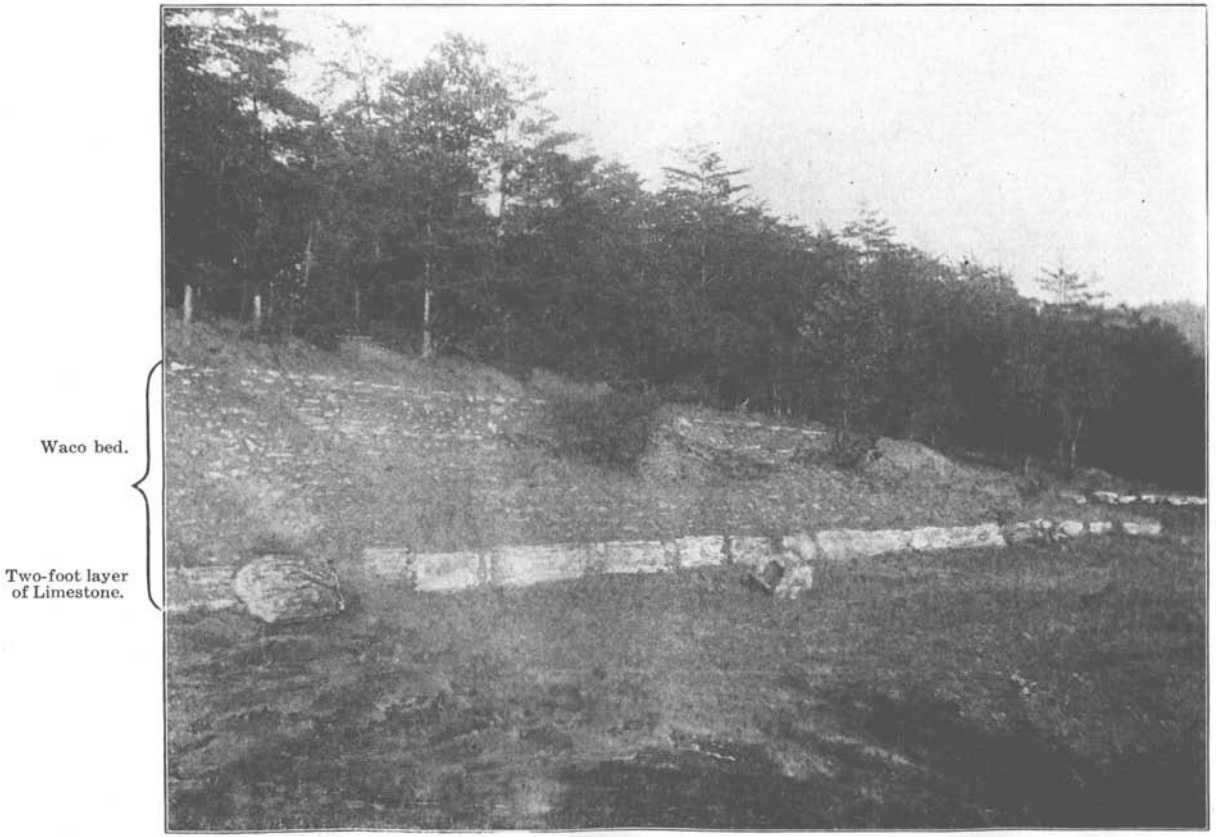


Fig. 7. Waco bed; a part of the Alger formation. A quarter of a mile north of the Estill Springs Hotel; north of Irvine, Estill county, on the eastern side of the pike.

the fossiliferous beds characteristic of this horizon are unknown. An attempt has been made to identify with this solid limestone at the base of the Waco section, the various exposures of limestone having about the same thickness occurring in the Alger clay section between Brassfield and Berea, but the interval between the top of the Oldham limestone and the heavy layer of limestone thus identified differs so much at various localities, that only detailed stratigraphical work can establish their identity, in the absence of the fossiliferous part of the Waco section. West of Berea, at Hammack, and at Crab Orchard, the solid layer of limestone occurs only six or seven feet above the base of the more continuous clay section. If this limestone represents the limestone at the base of the Lulbegrud clay, there is no question of the thinning of the Estill clay toward the west of Panola and Brassfield. Further investigations, however, are necessary to determine this question.

The fossiliferous layers, here called the Waco bed, are found at every locality between Indian Fields, Clay City, Irvine, and Brassfield so far investigated, where this horizon is exposed. The name has been taken from Waco, a small village east of Moberly station, in Madison county. The exposure occurs, about half a mile east of Waco, along the road turning off from the Portland or Bybeetown pike toward Cobb ferry. Here the layer of solid limestone is overlaid by the fossiliferous Waco section, about ten feet thick, consisting of clay with interbedded layers of very thin limestone. The Waco horizon is overlaid by clay, three or four feet thick, followed by Devonian limestone.

The most instructive sections occur north of Irvine (Fig. 7), along the road passing Estill Springs, just before reaching White Oak creek. The layer of solid limestone here has a thickness of two feet. Immediately above, there is a section, ten feet thick, consisting chiefly of clay, but containing so many layers of thin limestone that the rubble from these layers forms the most conspicuous part of the exposure. Fossils occur both in the layers of limestone and in the clay. Corals predominate. Bryozoans are numerous. Other fossils are comparatively scarce.

Another exposure occurs farther north, along the road turning off from the pike as it reaches White Oak creek. This road passes the home of James F. Harris. Here the section con-

tains few fossils. Following the road along White Oak creek, to a point less than a quarter of a mile northeast of the home of Mr. Harris, another road leads toward the east, up the hill. Here the top of the Oldham limestone, containing *Stricklandinia norwoodi*, is overlaid by Lulbegrud clay, fourteen feet six inches thick; followed by the solid limestone layer, two feet thick; the fossiliferous Waco section, ten feet thick; clay with fragments of thin, argillaceous, and comparatively hard, shale, seven feet six inches thick; and soft clay, fifty-six feet thick. The same fossils occur as at the locality nearer Irvine. The lower part of the fossiliferous Waco section contains comparatively little limestone. In the upper part of the Waco section, limestone is more abundant.

The exact reverse of this is found at the Brownlow Bruner locality, a mile southeast of Indian Fields. Here a connecting road leaves the creek road to Clay City, and passes north toward Kiddville. Within a short distance of the creek, the top of the Oldham limestone is exposed. This is overlaid by Lulbegrud clay, thirteen feet thick; the solid limestone layer, nine inches thick; the fossiliferous Waco limestone layers interbedded in a clay section, eight feet three inches thick; and soft clay, twelve feet thick. Most of the fossiliferous layers of thin limestone are found in the lower half of the Waco section, and in the upper part of the Waco section the limestone layers are very thin and far apart.

Between Virden and Clay City, the upper part of the Waco bed, containing characteristic fossils, occurs at numerous localities along the railroad, a short distance below the Devonian limestone, or almost in contact with the latter.

About two miles southwest of Clay City, on the northern side of Tipton ferry, the solid limestone layer, one foot four inches thick, is overlaid by the fossiliferous Waco bed. This part of the section is exposed also along the road crossing Plum creek, about a mile southwest of Tipton ferry.

At the great clay pit, half a mile northwest of Indian Fields, the top of the Waco horizon is exposed. A quarter of a mile south of Indian Fields, along the pike, the top of the Oldham limestone, containing *Stricklandinia norwoodi*, occurs in the bed of the creek beneath the first culvert. This is overlaid by Lulbegrud clay, thirteen feet thick; the solid limestone layer,

nine inches thick; and clay, twenty feet thick, of which the lower half is fossiliferous and belongs to the Waco horizon. The exposure of the Waco bed is poor, but careful search showed the presence of a considerable number of characteristic fossils along the various branches of the creek in the fields toward the west.

The fossiliferous Waco bed is exposed also half a mile east of College Hill, along the road; and four miles north of College Hill, along the abandoned part of the road to Bloomingdale. At these localities the layer of solid limestone is only six to eight inches thick. On the Bloomingdale road this limestone is overlaid by clay, five feet six inches thick, in which no fossils were noticed. Overlying this, however, was a section, also five feet six inches thick, in which numerous characteristic fossils occurred. Here the clay contained thin layers of limestone chiefly in the upper part of the Waco section.

From these statements it may be seen that the fossiliferous Waco section has a comparatively wide distribution. No attempt has been made as yet to trace it farther northward or southward than the localities here listed, but the presence of some species of *Arachnophyllum* in the Alger formation of Bath county, identified by Linney as *Strombodes pentagonus,* suggests the presence of the Waco bed as far north at least as Bath county.

It is hoped that further investigations may result in tracing the Waco horizon farther south and southwest than Brassfield. A few traces of fossils were found several miles west of Crab Orchard, at the proper horizon. It is very evident, however, even from the few observations made so far, that the Waco horizon is not very fossiliferous north of Indian Fields, or south of Brassfield, so that, even if the Waco horizon may be traced further, its typical development will remain within the borders indicated.

FAUNA OF THE WACO LIMESTONE HORIZON.

The following fossils have been found in the Waco limestones of east-central Kentucky:

Isochilina panolensis, not rare,
Calymmene niagarensis,
Encrinurus ornatus, common,

Illaenus cf. imperator,
Diaphorostoma niagarense, small, common,
Cyclonema cf. cancellatum, not rare,
Atrypa reticularis, small, abundant,
Parastrophia sp.,
Brachyprion cf. profunda,
Strophonella cf. tenuistriata,
Dalmanella elegantula, common,
Platystrophia reversata, common,
Hebertella sp.,
Orthis flabellites, Osgood variety, common,
Pholidops ovalis, common,
Stomatopora dissimilis,
Meekopora bassleri, very common,
Crepipora ? *squamata,* common,
Favosites gothlandica, common,
Favosites hisingeri-aplata, common,
Favosites declinata, common,
Syringolites huronensis, not rare,
Halysites catenulatus,
Heliolites spongiosa,
Heliolites subtubulata, varieties *distans* and *nucella,*
Lyellia eminula,
Zaphrentis intertexta, and varieties *irvinensis* and *juvenis,*
Zaphrentis charaxata, not rare,
Lindstroemia lingulifera, not rare,
Polyorophe radicula, not rare,
Cyathophyllum densiseptatum, common,
Cyathophyllum sedentarium, rare,
Chonophyllum solitarium,
Arachnophyllum granulosum,
Arachnophyllum mamillare-distans,
Cystiphyllum spinulosum, common,
Calostylis spongiosa, very common.

The Waco fauna characterizes an horizon between thirteen and twenty-five feet above the base of the Alger clay, and the Alger clay forms the Niagara shale horizon of the Ohio Geological Survey. It has been customary to correlate the Niagara shale of Ohio with the Rochester shale of New York. In that

case it should carry an approximately similar fauna. A comparison of the Waco fauna of Kentucky with the Rochester fauna of New York does not show as close an agreement as is desirable. The following species of the Rochester shale, for instance, are absent from the Waco horizon, as far as known at present:

Dalmanites limulurus,
Homalonotus delphinocephalus,
Lichas boltoni,
* *Whitfieldella nitida,*
* *Whitfieldella nitida-oblata,*
* *Spirifer (Delthyris) sulcatus,*
* *Spirifer crispus,*
** *Spirifer niagarensis,*
** *Spirifer radiatus,*
* *Rhynchotrema cuneata-americana,*
** *Orthothetes subplanus,*
Ichthyocrinus laevis,
* *Eucalyptocrinus decorus,*
Stephanocrinus angulatus,
Caryocrinus ornatus.

The species preceded by one star (*) are found, in New York, already in the limestone lenses at the top of the Clinton; those preceded by two stars are found even in the upper part of the true Clinton, beneath the lenses. The absence of any species of *Spirifer* in the Waco limestone is especially noteworthy.

In the west, in Indiana, this Rochester shale fauna makes its first appearance in the upper part of the Osgood formation, in the so-called Osgood limestone, which overlies the thick clay section which forms by far the greater part of the Osgood formation. This so-called Osgood limestone could be placed stratigraphically just as conveniently at the bottom of the Laurel limestone as at the top of the Osgood formation.

As far as may be determined from the evidence at hand, the Alger clay corresponds to the thick clay forming by far the greater part of the Osgood formation as originally described in Indiana. The fauna of the Waco horizon in the Alger clay is found stratigraphically beneath the fauna in the so-called Osgood limestone of Indiana. The fossils listed from the Os-

good formation of Indiana were obtained from the so-called Osgood limestone, and not from the thick clay section, corresponding to the Alger clay. The first appearance of the Rochester shale fauna in the Cincinnati geanticline region is in the Osgood limestone, above the Osgood clay, or Alger clay, or Niagara shale horizon of these States. The Waco limestone fauna is a different fauna from that of the Rochester shale, and precedes the arrival of the latter in the west.

The thick Osgood clay of Indiana, the so-called Niagara shale of Ohio, and the Alger clay of east-central Kentucky may be the stratigraphical equivalents of the Rochester shale of New York, but they are not the paleontological equivalents. If they are the stratigraphical equivalents, then a part of the Rochester shale fauna must have reached the western part of New York already during the time of formation of the limestone lenses at the top of the Clinton, while in Ohio, Indiana, and Kentucky it did not reach any typical development before the close of the deposition of the great clays formerly identified as Niagara shale. The fauna of the Waco limestones is quite distinct from that of any Silurian formation in New York. It shows distinct affinities with the Silurian of Sweden, and appears to have entered the field across northern Lake Huron.

One of the most interesting results of these preliminary investigations of the fauna of the Waco limestones is the accumulating evidence of a fauna closely allied to that found in the Silurian of Gotland and in the Wenlock division of the Silurian in England. This fauna appears to be absent in New York and along the Appalachian areas of this country, and therefore may have been introduced into this country from the north, across the northern end of Lake Huron, rather than from the northeast. This is suggested by the presence of *Syringolites huronensis* in the Silurian of Manitoulin Island in the northern part of the lake, and by the presence of species in the Niagaran strata of Indiana, Illinois, and Wisconsin, suggesting affinities with those of northwestern Europe.

Among the species in the Waco limestone fauna may be mentioned *Syringolites huronensis,* which finds a near relative, structurally, in *Roemeria kunthiana,* of Gotland; *Lindstroemia lingulifera,* belonging to a genus represented both in Gotland and England; *Polyorophe radicula,* which may not be closely related to *Polyorophe glabra* of Gotland, but which shows sev-

era1 very strikingly similar features; *Calostylis spongiosa,* which can scarcely be distinguished from *Calostylis denticulata,* of Gotland, and which had relatives also in England; and *Crepipora? squamata,* apparently identical specifically with the form bearing this name in the Silurian of Gotland, and in the Wenlock of England. It is likely that a fuller study of this fauna will result in the further accumulation of similar facts. These problems of the directions and times of migrations of ancient faunas are among the most interesting opening up to the naturalists of to-day. They may be of very little economic importance, but they give us an insight into the wonderful complexity of the processes which have resulted in the present life of the world, which can not fail to give an added interest to the study of the works of the Creator.

Estill Clay.

That part of the Alger formation which overlies the Waco horizon is called here the Estill clay. The typical exposure occurs north of Irvine, about a quarter of a mile east of the home of James F. Harris. The exposure is reached by following the road passing Estill Springs to where it follows the bed of White Oak creek, and then taking the first road leading eastward up a steep hill. Here an exposure of clay, fifty-six feet thick, overlies the Waco limestone horizon. Immediately north of Crab Orchard, along the pike to Lancaster, a continuous section of clay, sixty-five feet thick, is exposed on the western side of the road, ending at a salt well which evidently penetrates still lower parts of the clay, so that the total thickness is not known. Farther north, in Fleming and Lewis counties, much thicker sections of soft bluish-white clay are seen. In Lewis county, this thickness exceeds 100 feet. In one instance, a limestone containing *Halysites catenulatus* was found immediately above the clay. From this it is estimated that the thickness of the Alger clay in eastern Kentucky originally was at least 100 feet, and that, where the Waco horizon can be identified, at least seventy-five feet are to be assigned to the Estill clay.

As a matter of fact, little can be known of the original thickness of the Estill clay in eastern Kentucky, owing to the removal by erosion or weathering of more or less of this clay before the deposition of the Devonian limestone. Farther north,

in Ohio, where Silurian limestones conformably overlie the equivalents of the Alger clay, more exact knowledge of its original thickness is obtainable.

At West Union, the thickness of the Alger clay apparently is 148 feet; but part of this apparent thickness may be due to dip. At Peebles, northeast of West Union, the Niagara shale section of the Ohio survey is eighty-five feet thick. At Hillsboro, it is seventy-five feet thick. Farther north it rapidly diminishes in thickness and changes gradually into strongly calcareous clay interbedded with a considerable quantity of thin limestone. At Dayton, in Ohio, the equivalents of the Niagara shale, of southern Ohio, are about thirty feet thick.

From this it is evident that the strata known as Niagara shale, in Ohio, become rapidly thicker southward, at least as far as Lewis county. Whether, before the erosion preceding the deposition of the Devonian limestone, this increase in thickness of the equivalent Alger clay continued as far as east-central Kentucky, can not be determined at present.

Where the Waco limestone can not be identified, it is impossible to determine how much of the Alger clay is to be assigned to the Estill clay section. In these cases, provided the thick layer of limestone, belonging at the base of the Waco section, can be recognized, the name *Flades clay*, from Flades creek, east of Crab Orchard, may be used for that part of the Alger formation which includes both the Waco and Estill horizons.

Only two species of fossils have been identified so far from the Estill clay, both from the thin argillaceous shales interbedded with the clays at the top of the exposures west of Valley, in Lewis county. These are *Beyrichia lata-triplicata* and *Chonetes vetusta.*

Indian Fields Formation.

It has been found convenient to group some of the minor subdivisions of the Silurian, in eastern Kentucky, into larger divisions, here called formations. The lower one of these is the Indian Fields formation. This includes not only the Plum creek clay and the Oldham limestone, but also those layers of limestone beneath the Plum creek clay which are regarded as

belonging above the line of unconformity marked, in east-central Kentucky, by the *Whitfieldella subquadrata* and oolitic iron ore bed. The total thickness of these layers of limestone usually does not exceed one or two feet. This method of classification, evidently, is an attempt to give a paleontological basis to the divisions proposed, and, as long as such a classification is not used for purposes of mapping, it may have a certain degree of usefulness.

Farther north, in Adams county, Ohio, where the *Whitfieldella quadrangularis* layer is distinctly below the oolitic iron ore bed, it appears to be the iron ore bed, rather than the *Whitfieldella* layer, which marks the position of the unconformity.

The typical exposure of Indian Fields formation occurs about a mile and a half northwest of Indian Fields, along the railroad, and extends from the second good cut west of Howard creek, eastward as far as the great fill crossing the valley occupied by that creek. Equally instructive exposures occur along the railroad between Panola and Brassfield.

Alger Formation.

The Lulbegrud clay, Waco limestone horizon, and Estill clay have been united so as to form the Alger formation. This is essentially a clay formation, the total quantity of limestone in the Waco limestone section forming but an insignificant part of the Alger formation, taken as a whole. By far the best sections known occur north of Irvine, along the road passing Estill Springs. The most instructive section is that along a road leading from White Oak creek eastward up a steep hill, about a quarter of a mile east of the home of James F. Harris, since in this section all the members of the Alger formation may be distinguished readily. The section along the road passing the home of Mr. Harris, however, is a continuous section, and, although the Waco horizon here carries few fossils, this very fact is of interest, illustrating the rapid local variation of this horizon. Excellent exposures occur also east of Panola, along the railroad.

The formation takes its name from Alger, a station along the railroad between Panola and Irvine. Here a branch of Drowning creek exposes the formation, and since the name Irvine is preoccupied for another formation, the name Alger will serve

as at least a fairly good index of the region in which typical exposures of this formation may be found.

The various members of the Alger formation have already been described with sufficient detail to make any further description of the Alger formation, as a whole, unnecessary.

Crab Orchard Division.

The Indian Fields formation and the Alger formation have been united to form the Crab Orchard division of Niagaran rocks. This grouping is based upon a combination of stratigraphical and paleontological data, and is merely an effort to construct for the Silurian strata of Kentucky a system of groupings which will serve to indicate the stratigraphical equivalency of the Silurian strata of this State with corresponding strata in Ohio. In other words, the Brassfield limestone is believed to correspond to those strata which in Ohio have been identified as Clinton. The Crab Orchard division of Kentucky is correlated with the strata identified as the Niagara shale in Ohio. In Ohio, the Dayton limestone has been included in the Niagara shale section, forming the basal part of this section. In Kentucky, the Oldham limestone, believed to be the stratigraphical equivalent of the Dayton limestone, also is included in the lower part of the same division as the great mass of clays. But in Kentucky the great mass of clays is called the Alger formation, and the limestone regarded as equivalent to the Dayton limestone has been called the Oldham limestone.

From a lithological standpoint, this grouping of strata is perhaps not as natural as one in which the entire Silurian section of east-central Kentucky would be divided into two great divisions, consisting of a great lower division including chiefly limestone, hut also one considerable clay deposit, and of a great upper division, consisting almost entirely of clay. In this case, the lower division would include the Brassfield, Plum creek, and Oldham beds, while the upper division would include all of the Alger formation. The arrangement adopted in the present bulletin is that best adapted to show the parallelism between the corresponding strata of Ohio and Kentucky.

The name Crab Orchard was introduced by Linney, in his report on Lincoln county. He did not define this term with the

exactness which is necessary for determining its exact equivalency with the various subdivisions here established. There is no doubt of the application of the name Crab Orchard to all of the Alger formation, but apparently Linney included also the Plum creek clay and its equivalents southwest of Brassfield. Under these conditions it has been considered desirable to give this name the widest significance which it possibly could have had, and therefore it has been employed for all Silurian strata of east-central Kentucky which lie above the Brassfield bed. This would include both the Indian Fields and Alger formations.

On account of their historical interest, the observations by Linney are republished on the following pages, with such comments as will serve to make clear the meaning in those cases where at present the language may appear obscure, and such further notes as will show the relationship of the divisions then in use to those now established.

Linney's Reports on the Silurian Rocks East of the Cincinnati Geanticline.

A. LINCOLN COUNTY.

In the Report on the Geology of Lincoln County, by W. M. Linney, published in 1882, the following account is given of the Silurian rocks of the county:

"Medina Sandstone.—In the northeastern portion of Lincoln county there is to be seen, in a number of places, a series of buff sandstones, which sometimes show as hard concretionary shales, which are disposed to break into squares hardly more than an inch in diameter.

"These beds at their thickest points are about thirty-five feet in thickness; and erosion over them is comparatively rapid, and they leave a soil which is sandy and easy to wash. These tracts have a local name of 'Bald Hill Soils,' from a locality in Garrard county where the rocks are exposed, and so called because they have become, in places, sterile from the amount of sand which covers them.

"Internally they show yellow and green spots. Some of

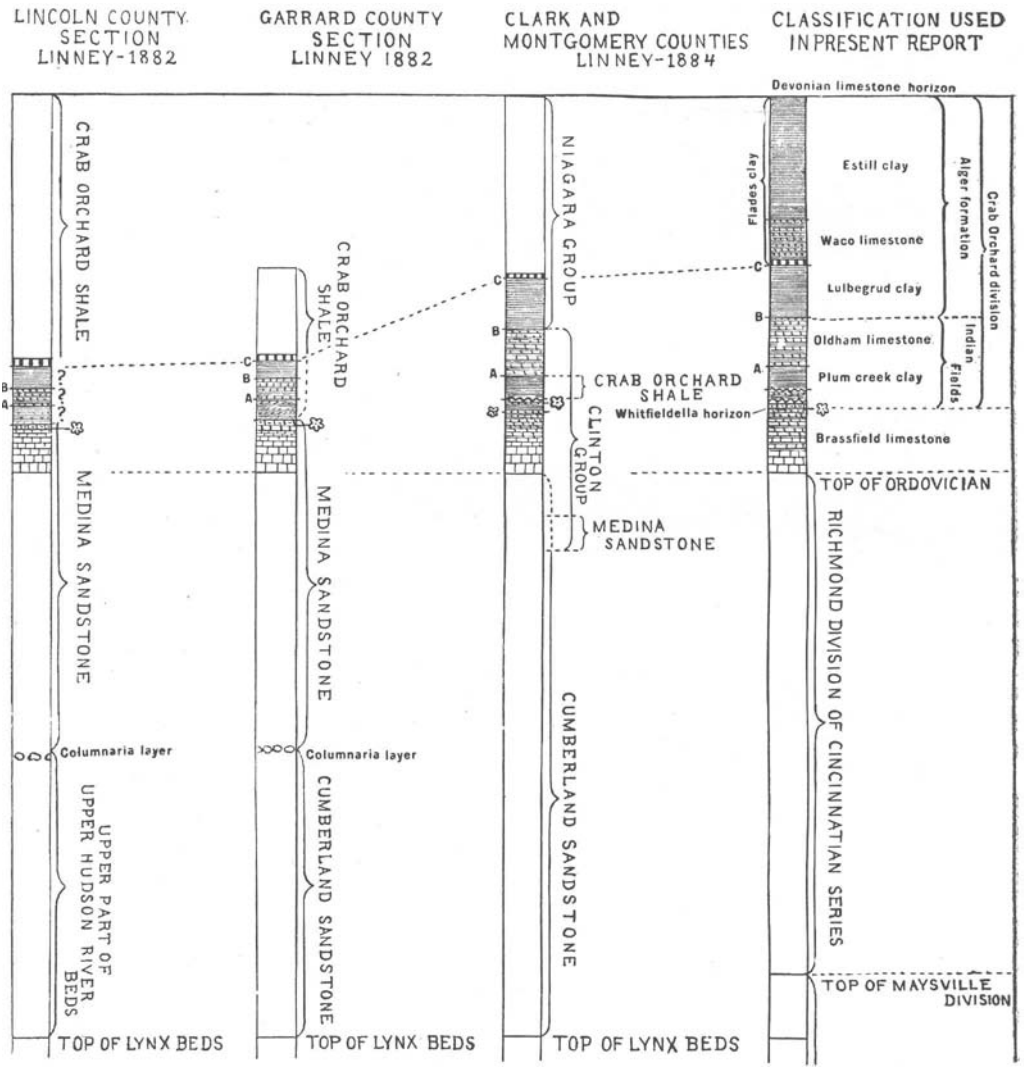


Plate A. Illustrating classification used by W. M. Linney.

the layers have a small portion of lime in them. This series is well exposed on a road leading from Richmond Junction (now called Rowland) to Dudderar's Mill, on Dix river (three miles northeast of Rowland, on the road to Gilbert Creek Station). Here, at many places in the hill-sides, can the *Columnaria* bed be seen covered up in the sand which was brought by the currents and swept over them.

"A little north and east of Hall's Gap Station, and on the road thence toward Crab Orchard, they may be seen as they are presented in Garrard and Madison counties. While at nearly every point exposed the layers seem worthless for building purposes, yet locally there are some fine durable stones among them. At Mr. J. T. Lynn's, about a mile (east) from Hall's Gap Station, stones were quarried for foundations, steps, etc.; a very desirable stone was obtained, which has every appearance of being durable. They are easily taken from the quarry, come out in good shape, and can be dressed with an axe, so soft is their character. They harden on exposure, and become of a deep buff color. At James' Mill, on Dix river (two miles north of Crab Orchard), the stack was made of stones taken from these beds, and nothing could have suited the purpose better.

"In every direction from Crab Orchard these rocks may be seen when looked for, presenting often small sterile spots; in some cases they have been built into stone fences. Some of the soils over these beds are fairly good where they have been taken care of; but too often they present the features which are mentioned in the report on Washington county.

"In some of the heavier layers, at particular points, are included a few geodes filled with calcite crystals of a pinkish color. In some instances I found small masses of celestite or *strontium sulphate* in a heavy hard layer near the top, and occasionally small nodules of zinc blende were seen.

"Many of the layers are remarkably full of sea-weeds; their branching and matted stems covering layers everywhere as far as they can he traced. One bed, a few inches thick, seems to have held branching forms of *Chaetetes* corals (now known as branching bryozoans); the cavities filled with petroleum. Fossils are very few, and exist only as very poor sandy casts. They probably include small forms of *Atrypa reticularis* (probably

the interior casts of *Whitfieldella cylindrica-subquadrata* showing little else than the muscular scars) and *Zaphrentis bilateralis* (probably the common cup-coral, here called *Cyathophyllum caliculum,* which is found in the upper part of the Brassfield or Clinton bed, just beneath the *Whitfieldella* layer); but such was their condition that they could not be determined satisfactorily.

"In the western portion of the county these rocks are seen between Moreland and Carpenter's station; but here they are thinner than in the eastern part, and present no new phases. The whole series has the appearance of being a reef-like accumulation, deposited largely or entirely by currents, and sometimes probably in the face of waves, as at several points one or two layers have a wave-like structure. The life which existed in the waters before seems to have all been destroyed here at this time, and during the invasions of the Medina sand (the rocks so identified in Lincoln county belong in part to the top of the Ordovician and in part to the base of the Silurian) seem not to have been fitted for anything but plant-life, except in rare instances, and for short duration.

"Crab Orchard Shale.—Overlying the Medina sandstone (see comment above) in the eastern part of the county is a group of clay shales, which reach in several instances a thickness of forty feet, but thin down in others to a mere trace. These shales, as seen in exposed places, are gray or white, sometimes green; but when freshly excavated are black, green, olive, blue, and red. They are soft and crumbling, and are soon reduced to clay, and when tramped in wet roads become stiff and tenacious.

"Within this deposit are a few hard smooth plates of thin limestones, with sometimes obscure markings of plants; these plates are hard, and are often seen where all the shales have decomposed. These plates, and sometimes the shales, have a curved structure, and at times some of the laminae overlap the thinned-out edges of others.

"Included in this bed are crystals of selenite (gypsum), and crystals and nodules of iron pyrites; sometimes a plate of iron shale is also seen. The whole bed seems to be impregnated with carbonate of magnesia. To the presence of those three minerals, in the form they assume, is due the peculiar character of the

magnesium compound, which, under the name of Crab Orchard salts, is manufactured from these shales. These shales are placed provisionally in the Clinton (they now are known to overlie the Clinton) until more is learned in regard to their relation. As these shales contain gypsum, soda, and potash, it would be advisable for farmers and others to make some experimental tests with them as fertilizers."

From the preceding paragraphs, quoted from the report on Lincoln county, it is evident that Mr. Linney divided the Silurian, as identified by him, into two divisions. The lower of these he correlated with the Medina of New York. Not being certain of the advisability of correlating the clay shales, forming the upper part of the Silurian section in this part of Kentucky, with the Clinton of New York, he called them the Crab Orchard shales. (Plate A, page 64.)

The "Bald Hill Soils" are of Ordovician age. They form that part of the Richmond group which overlies the *Columnaria* layer. The *Columnaria* layer was regarded as marking the base of the Silurian, whereas as present it is known to be at least seventy-five feet below the top of the Richmond, and to be underlaid by about the same thickness of almost unfossiliferous strata, also of Richmond age. Linney's estimate of thirty-five feet for that part of the Richmond section which overlies the *Columnaria* layer is manifestly incorrect, but this is true of most of his so-called measurements, which in reality were estimates made without the use of instruments. The fine durable stones, found locally between Hall’s Gap Station and Crab Orchard, are of Brassfield or Clinton age. At James' Mill, on Dix river, two miles north of Crab Orchard, on the road to Preachersville, both the Oldham limestone and the top of the Brassfield limestone are exposed, but only the latter is hard and offers layers of suitable thickness for building purposes. The Brassfield limestone is the only one around Crab Orchard which has been built into fences. The heavier layers of limestone are also of this age. The fossiliferous beds undoubtedly belong at the top of the Brassfield section, since the upper part of the Richmond in this section is practically unfossiliferous. The remains identified as *Atrypa reticularis* must have been that part of the internal casts of *Whitfieldella subquadrata* which includes the impressions of the muscular scars of the

pedicle valve (Plate 1, figs. 3-A, B, C), since this is the form commonly associated with the small cup coral identified by Linney as *Zaphrentis bilateralis.* These fossils of the *Whitfieldella* layer form altogether too conspicuous features of the Silurian section to have escaped attention, and are the fossils with which these names were identified by local geologists ten or fifteen years ago.

The pockets of petroleum occur almost exclusively in the Brassfield and Devonian limestones, in this area. The strata between Moreland and Carpenter's station are of Ordovician age.

The Crab Orchard shale of this report includes the Alger clay. The thickness of forty feet is exceeded at all localities in the immediate vicinity of Crab Orchard. North of Crab Orchard, this thickness equals at least seventy-five feet, and its exact thickness is unknown, on account of the unknown dip and the great distance between the top and bottom of the section.

The hard smooth plates of thin limestone with obscure markings of plants are the thin plates of argillaceous shale scattered throughout various parts of the Alger formation. This is also the formation including the Crab Orchard salts.

From these notes it would seem most reasonable to assume that Linney practically included only the Alger clay in his original discussion of the Crab Orchard shale. There is no doubt that he included the *Whitfieldella subquadrata* layer in his Medina. Nothing is said any where which would determine his disposition of the Oldham limestone, but it seems most reasonable to assume that in this report it was included in the Medina.

B. GARRARD COUNTY.

Linney's description of the rocks in Garrard county identified by him as Upper Silurian (now known as Silurian) is as follows:

"The rocks of the Upper Silurian in Garrard amount only to a thickness of some sixty feet, and have at the base thirty-five feet of sandstones, which are the probable equivalents of the Medina sandstone of New York. The greater part of this is a soft, easily pulverized sandstone, sometimes concretionary, containing in places some layers which have been used for building purposes. They quarry very easily, and in good well-shaped

blocks. They are of a dull yellow, but are much lighter in color than the rocks from the middle beds of the Hudson river (the Garrard bed) in other parts of the county. They harden, when placed above drainage, and become very durable.

"The soils derived from these rocks are sandy and easily eroded, consequently one sees many sterile spots in the parts of the county where they exist. They are better exposed in what are called the Bald Hills, than at any other locality. They range across the county from Madison to Lincoln, never forming very wide exposures, and are heavier on the Lincoln side. A single layer of this stone contains a small amount of petroleum; and sometimes through some of the heavier beds are seen crystals of celestine, and, in a few instances, small lumps of zinc blende. Casts of a small form of *Atrypa reticularis*, and some other, but indeterminable, forms are found in the sandstone. At the top of this sandstone are often a few inches of limestone, vesicular in structure. This structure is due to the former inclusion of fossils, which have been removed. While interiorly blue, this stratum turns red on exposure, owing to the oxidation of the iron that it contains.

"Lying on this limestone are from sixteen to twenty-five feet of mud shales or marls, with a few thin plates of limestone intercalated. The shales are blue, black, olive, and brownish-red; are soft and fragile, and decompose directly into stiff, tenacious clay. Crystals of selenite and iron pyrites are common, and the whole series is impregnated with magnesia. These shales are usually seen in the hillsides as white clays and sterile spots, but in one place they cover several miles of surface, except where cut through by hollows. These are the shales from which the celebrated Crab Orchard salts are manufactured, and which are more particularly noticed in my report on Lincoln county. The shales may belong to the Clinton group, but until they are connected with rocks which are undoubtedly Clinton, we may retain the name of Crab Orchard Shales.'" (Plate A.)

It will be noticed that the description of the so-called Medina rocks of Garrard county agrees closey, with that of the rocks identified as Medina in Lincoln county. The single layer of stone containing a small amount of petroleum is the *Whitfieldella* layer, which often contains a little petroleum in the cavities left by the dissolution of the thick parts of the shell of this

species of *Whitfieldella*, near the hinge. This must be the horizon from which the so-called *Atrypa reticularis* was identified. It is undoubtedly the horizon described in the following terms:

"At the top of this (Medina) sandstone are often a few inches of limestone, vesicular in structure. This structure is due to the former inclusion of fossils, which have been removed. While interiorly blue, this stratum turns red on exposure, owing to the oxidation of the iron that it contains." There is only one layer which shows these cavities and which has this ferruginous character, and that is the *Whitfieldella subquadrata* layer.

In this description Linney definitely limits the top of his Medina at the *Whitfieldella* layer, and appears to assign all of the overlying strata to the Crab Orchard shales. As a matter of fact he probably gave no thought whatever to the few layers of limestone belonging to the Oldham horizon. In Lincoln and Garrard counties, the equivalents of the Oldham limestone are too inconspicuous to receive attention in a general survey. Following, however, a literal interpretation of this first definite assignment of limits between the Medina and Crab Orchard shales, this limit must be drawn at the top of the *Whitfieldella* layer and not at the base of the Alger formation.

The estimates of the various thicknesses of the rocks described is again at fault. In his description of the Upper Hudson River beds of Garrard county, Linney definitely states that:

"The top of these (Upper Hudson River) beds and of the Lower Silurian (Ordovician) is marked in places by an irregular mass of limestone, which is filled with large corals of the genus *Columnaria*, and associated with those are many other forms, such as *Tetradium*, *Streptelasma*, etc.; but often the Cumberland Sandstone is at the top, making it difficult to determine the dividing line between it and the next." As a matter of fact, the *Columnaria* layer of Garrard county does not contain many other fossils, *Columnaria* being almost the only fossil found. This part of Linney's statement is due, no doubt, to the presence of numerous fossils immediately above the *Columnaria* layers in Marion, Washington, and Nelson counties, with which he was familiar. The *Columnaria* layer was regarded as marking the line of division between the Cumberland sandstone and the Medina sandstone. The Cumberland sandstone of this description includes that part of the unfossiliferous Ordovician section

which lies beneath the *Columnaria* layer. It consists chiefly of strata of Richmond age, since the top of the fossiliferous beds beneath belongs to about the middle of the Arnheim layer, to the horizon containing *Leptaena rhomboidalis* and *Rhynchotrema dentatum.* Since, owing to the absence of other fossils, the *Columnaria* layer was about the only means, in Garrard county, of distinguishing the Cumberland sandstone from the Medina sandstone of Linney, it is evident that, where the *Columnaria* layer was absent, in other words, where the Cumberland sandstone formed the top of Linney's Lower Silurian, without the intervention of the *Columnaria* layer, it was difficult to determine the dividing line between it and the next.

The thickness of the section between the *Columnaria* layer and the *Whitfieldella* layer, the strata identified by Linney as Medina, is about eighty-five feet, instead of thirty-five feet. The thickness of the Silurian section overlying the *Whitfieldella* layer in Garrard county varies between twenty and sixty-five feet. That part of the section overlying the solid layer of limestone, believed to mark the base of the Waco horizon, varies in thickness from 0 to almost forty feet. From this it seems not impossible that some of the measurements of the Crab Orchard section were made from the solid limestone at the base of the Waco horizon rather than from the *Whitfieldella* layer.

C. CLARK COUNTY.

The reports on Lincoln and Garrard counties were published simultaneously, in December, 1882. They are both, therefore, given equal value in determining what significance should be assigned to the name Crab Orchard Shales.

Two years later, in 1884, in his report on Clark county, Linney changed both the classification and the nomenclature of the rocks which he had formerly included in the Silurian. He divided the rocks identified by him as Silurian into two divisions. The lower of these he considered equivalent to the Clinton of New York. The upper division he correlated with the Niagara group of that State, probably having in mind the Niagara shales, now known as the Rochester shale. The Medina was identified doubtfully, and a much smaller section was included under this

name than heretofore, in his description of the geology of Lincoln and Garrard counties.

Linney's description of the Clark county rocks identified as Clinton is as follows:

"The rocks of the Clinton are for the most part magnesian limestones and shales. At the base are some heavy sandy layers which may represent the Medina sandstone. These are more or less earthy and friable, crumbling into small pieces from the exposed layers, and when thoroughly reduced and washed of the clay there is left often, in places, only pure sand. These rocks contain some casts of shells in very poor condition, though the *Orthis lynx* is often one of them. Perhaps a small form of *Atrypa reticularis* is among them. These are succeeded by thinner layers of coarse-grained limestones and shales, then several layers of heavy, rough-bedded blue limestones, after which there are shales and thin limestones (in the following table these are given in the order—thin limestones and shales) overlaid with heavy strata of limestones.

"These present about the following section, though they are not by any means uniform in every place:

Heavy limestones	8 ft.
Shales	7 ft.
Thin limestones	9 ft.
Heavy limestones	6 ft.
Limestones and shales	11 ft.
Sandstones and shales	9 ft.
Total	50 ft.

"The larger part of the limestones are rough and unevenly bedded, breaking unevenly, and contain some silica and clay. These make a tough material for pikes and have been used for that purpose. While they are a dirty blue, when freshly broken, they all become, on exposure, a dirty yellow, which is, so peculiar to magnesian limestones. There is rather more than 20 per cent. of magnesia in all these limestones. The thin layers are more even in character, and some of them would make flagstones.

"The seven feet of shales seem to be the equivalent of the Crab Orchard shale of Lincoln and Garrard counties. They contain the association of thin plates, balls of iron pyrite and

crystals of sulphate of lime. At Kiddville, at the residence of Mr. J. E. Groves, a well dug in these layers gave a strong epsom water similar to the Crab Orchard variety. These shales are blue and red, but on exposure they became ash-colored or white.

"At Kiddville and several other places one of the layers of limestone was red in color, due to the infiltration of iron. On further examination it was seen that there are two layers, which must be the representatives of the beds of hematite ore in the Clinton group in East Tennessee. The same lenticular structure is prevalent. Sometimes this is a true ore, with all the characters of the Clinton. There is some little strontian contained in these rocks, a very usual thing in Kentucky. *Pentamerus ovalis* and *Zaphrentis bilateralis* are very common fossils. Small forms of *Atrypa reticularis* and other fossils are found, but they are not good specimens."

Regarding the rocks identified as belonging to the Niagara group Linney states:

"Over the Clinton is spread sixteen to twenty feet of blue and red shales, which have intercalated about three inches of thin limestone plates. These make four layers and are filled with small fossils, usually round-stemmed corals (now known as bryozoans). They also contain *Strombodes pentagonus* and *Favosites niagarensis.* They seem to determine the position of this shale, which is the only representative of the (Niagara) group. This shale, when on the surface, gives a very stiff, tenacious clay, and when roads run over it and are not macadamized they become almost impassable. It can be best seen at Eastin's mill (a mile and a half east of Indian Fields), where there is a perpendicular section entirely through it."

The interpretation of these statements by Linney offers certain difficulties. The following interpretation appears most reasonable (Plate A):

Linney's work in Clark and Montgomery counties bridged the connection between Garrard and Bath counties. In Bath county were important deposits of the oolitic iron ore evidently similar in character and stratigraphical position to the oolitic iron ores in Adams, Highland, and Clinton counties, in southern Ohio. It was quite generally agreed that these oolitic iron ores of Kentucky and southern Ohio corresponded stratigraphically to those in the Clinton of New York, and that the overlying

clay shales corresponded to the Rochester shales of New York, then known as Niagara shales. It then became necessary to revise the classification of the rocks of eastern Kentucky so as to meet these views. The results are expressed in these reports on Clark and Montgomery counties, published under the same cover, in 1884.

In the report on Clark county, the Cumberland sandstone is stated to include a series of strata, about 125 feet thick, overlying the *Platystrophia lynx* beds. They include that part of the Arnheim layer overlying the *Leptaena rhomboidalis* and *Rhynchotrema dentatum* horizon, and also all of the Richmond section, excepting possibly some of the strata very near the top. As a matter of fact, the interval between the *Rhynchotrema dentatum* layer and the top of the Richmond in this area is estimated at approximately 145 feet.

The section of rocks, published in connection with Linney's description of the Clinton group, probably was obtained along the Lexington & Eastern Railroad, which, at the time of Linney's investigations, was in the process of grading. Railroad cuts were exposing all the strata northwest of Indian Fields, and Mr. Linney was a frequent visitor at the home of John Goff, a mile south of Indian Fields. The rocks identified as possibly representing the Medina sandstone must be a part of the upper Richmond, since these are the only strata which are earthy, and friable, and which weather to a sandy mass. These rocks also are the only ones in which poor remains of a small species of *Platystrophia,* incorrectly identified as *Platystrophia lynx,* are at all frequent. The form identified by Linney as *Atrypa reticularis* may have been poor specimens of *Strophomena sulcata,* or poor specimens of *Hebertella.* The shales, seven feet thick, undoubtedly belong to the Plum creek horizon. The overlying mass of heavy limestones belong to the Oldham section. The limestones below the Plum creek section belong to the Brassfield bed. The thin limestones forming the upper part of this bed are the fossiliferous part of the section. The heavy limestones beneath form the base of the Brassfield bed. The underlying limestones and shales, said to be eleven feet thick, and overlying the sandstones and shales identified doubtfully as Medina, probably form the very top of the Richmond section, overlying the fossiliferous layers of this part of the Richmond.

The seven feet of shales of this section, called the Plum Creek clay in the present bulletin, were identified by Linney with his Crab Orchard shales on the basis of the thin limestone plates, the balls of iron pyrites, but more especially upon the epsom salts which they contain, a peculiar form of stratigraphic identification not unknown in more recent times. The ferruginous layers at Kiddville, identified with the beds of hematite ore in the Clinton group in East Tennessee, belong to the *Whitfieldella* horizon, and to a second layer about two feet higher up, just beneath the Plum creek clay. The *Pentamerus ovalis* of Linney probably consisted of good specimens of *Whitfieldella subquadrata,* broken out of the rock and almost entire. The *Atrypa reticularis* could hardly have been anything except the interior casts of the upper part of the shell of the same *Whitfieldella,* close to the hinge line, especially parts showing the impressions of the muscular areas in the pedicel valve. *Zaphrentis bilateralis* is the very common simple coral to which the name *Cyathophyllum calyculum* has been applied in the present bulletin.

The Niagara group of Linney's report on Clark county includes the Alger formation. In the neighborhood of Indian Fields only the Lulbegrud clay, the Waco horizon, and the base of the Estill clay are exposed. At most localities in the northern part of the county the thickness of the Estill clay does not exceed ten feet, and occasionally it is 1ess than five feet. The thickness of the Lulbegrud clay is about thirteen feet. That of the Waco limestone is about nine feet. So that here, as elsewhere, the measurements of Linney are not strictly accurate.

The fossils in the thin limestones came from the Waco horizon. The small, round-stemmed corals are now known as bryozoans. *Strombodes pentagonus* is some species of *Arachnophyllum. Arachnophyllum mamillare-distans* is the most common species in the vicinity of Indian Fields. *Favosites niagarensis* occurs, although other species are more common. The section of clay at Eastin's mill belongs to the Lulbegrud horizon. The well dug on the J. E. Grove property, northeast of Kiddville, on the Levee road, penetrated the same clay, the Lulbegrud horizon.

D. MONTGOMERY COUNTY.

In the report on the geology of Montgomery county, Linney uses about the same divisions of the strata, considered by him

as Silurian, as in the case of the report on Clark county. The Clinton group is described as being sixty feet thick, an increase of ten feet in thickness; if compared with the Clinton group of Clark county. This is ascribed to an increase in thickness of the sandy (Ordovician) layers at the base, which, in the more western counties, Marion and Nelson, were identified as Medina sandstone. Above this sandy rock resembling the Medina, according to Linney, occur the rough-bedded, heavy limestones (the Brassfield bed), the shales identified by Linney as the Crab Orchard shales (the Plum creek clay), and somewhat heavier massive layers, of which one, in one or two places, shows well a wave-like structure with large ridges (the Oldham limestone). The Niagara shale (the Alger clay horizon) has about the same thickness as in Clark county, about, eighteen feet. (Plate A.)

E. BATH COUNTY.

In the report on the geology of Bath county, published in 1886, Linney divides the rocks which he identifies as Silurian into three divisions: the Medina, Clinton, and Niagara. To the Medina he assigns only ten feet of rock, sandy, more or less interbedded with shale, at present known to belong to the top of the Richmond division of the Cincinnatian series of rocks. To the Clinton he assigned limestones and shales having a total thickness of thirty-four feet, and presenting the following average section, described in descending order:

Thin limestones and shales	2 ft.	
Limestone		10 in.
Shale	1 ft.	9 in.
Limestones		11 in.
Shales and thin limestones	4 ft.	
Iron ore	2 ft.	
Thin limestone	3 ft.	
Limestone layer	1 ft.	
Wave-marked layer	1 ft.	3 in.
Thin limestones	3 ft.	
Shales	6 ft.	
Heavy limestone with chert	9 ft.	
Total	34 ft.	9 in.

The upper four members of this section, having a total thickness of five and a half feet, belong to the Oldham horizon.

The shales and thin limestones, four feet thick, represent the Plum creek section. Where the exposures are perfectly fresh, so that none of the limestone layers have slumped down over the soft clays, the Plum creek section in the neighborhood of Owingsville is seen to vary between seven and eight feet in thickness. The layer of iron ore, two feet thick, includes at its base the *Whitfieldella subquadrata* section. wave-marked layers of limestone come in at several levels in the upper part of the Brassfield bed, usually within four feet of the iron ore bed, but sometimes immediately below the latter, and occasionally one of the layers immediately over the iron ore bed is wave-marked. This merely corroborates the testimony furnished by the pebbles just below the iron ore bed in some parts of southern Ohio, that there was shallow water during the deposition of the last parts of the Brassfield bed and during the formation of the *Whitfieldella* and oolitic iron ore beds. The heavy limestone with chert at the base of Linney's section forms the base of the Brassfield bed.

The following fossils were identified as occurring in the rocks associated with the iron ore, prabably occurring chiefly at and immediately below this horizon: *Zaphrentis bilateralis (Cyathophyllum calyculum),* small short forms of *Atrypa reticularis* (casts of muscular areas of *Whitfieldella), Favosites niagarensis,* a short oval form of *Pentamerus (Whitfieldella subquadrata),* a *Chaetetes* (some round-stemmed bryozoan), and large numbers of crinoid fragments.

The clay shales identified as Niagara in Bath county belong above the Oldham limestone horizon. They are said to vary in thickness from twenty feet in the western part of the county to 100 feet in the eastern part. Linney states that the peculiar features of these shales in Bath county are to be seen also around Crab Orchard, showing that he recognized that these clay shales, here identified as Niagara, found their equivalents in the clays above the Oldham horizon at Crab Orchard, in spite of the fact that in Clark county and in Montgomery he identified the Plum creek clay as Crab Orchard and used the term Niagara for the Alger clays occurring higher in the series. The presence of the Waco horizon is suggested by the identification of *Strombodes pentagonus* among the few fossils occurring in these so-called Niagara clays.

F. FLEMING COUNTY.

In the geology of Fleming county, published in 1886, the strata identified as Medina (belonging to the top of the Ordovician) are said to be twenty feet thick. The heavy, cherty beds at the base of the strata identified as Clinton, are said to be eight to ten feet thick. The wave-marked layer, farher up in the series, is stated to be very persistent. The iron ore also is found at several localities, although usually absent. The strata identified as belonging to the Niagara group consist almost entirely of clay shales, belonging to the Alger horizon.

G. MASON COUNTY.

In the report on Mason county, written in 1885, sandy rocks and clay shales, twenty feet thick, and belonging near the top of the Ordovician, are identified as Medina. The rocks identified as Clinton are stated to have a thickness of thirty-five feet. These are said to consist of twelve feet of blue shales at the base (forming the top of the Ordovician), eleven feet of limestone, the larger part containing chert, and thirteen feet of shales alternating with layers of limestone. The strata identified as Niagara consists of fifteen or more feet of blue clay shales, weathering to a white clay soil; this part of the section probably belongs above the Oldham horizon, but represents only the base of the Alger formation, much greater thicknesses of the Alger clay being found farther east, in the exposures in Lewis county.

MARION COUNTY.

Linney correlated with the Crab Orchard shales also certain clay shales west of the Cincinnati geanticline, to the Indiana equivalent of which the name Osgood shales has been given. In the report on the geology of Nelson county, published in 1884, Linney refers to the Crab Orchard shale horizon the Osgood clay shales seen so well exposed near the Church of the Holy Cross in Marion county, not more than a mile and a half east of the Nelson county line. Knott, in his geology of Marion county, published in 1885, repeated this reference of the Osgood clays near Holy Cross Church to the Crab Orchard horizon. In the report on Oldham county, published in 1887, Linney does not refer to the Crab Orchard shales.

Beginning with his reports on Clark and Montgomery counties, written in 1884, Linney appears to have become so thoroughly satisfied as to the Niagara age of the great mass of clays forming the upper part of the Silurian section on the eastern side of the Cincinnati geanticline, in Kentucky, and as to the Clinton age of the underlying limestones and clays, that he had no further use for the term Crab Orchard shales, and therefore abandoned it. The most difficult thing to understand is why, in the reports on Clark and Montgomery counties, he should have identified the Plum creek clay as Crab Orchard shale, and have made no reference to the Crab Orchard shale in his description of the far greater mass of clay shales which he identified as Niagara.

It also is difficult to understand how he secured some of his measurements. In some cases it is absolutely impossible to verify these. He must merely have estimated these without any attempt at measurement. Nevertheless, aside from the restrictions here made, Linney did a great deal of faithful work on the geology of the limestone counties of the middle portions of Kentucky. He was obliged to cover large areas in a short period of time and without the advantages offered by later observations in other parts of the field. His reports, in spite of all their defects, have furnished an excellent basis for further work, were a great advance on anything done before in the State, and always will stand as a monument to his industry.

The Classification of Devonian Rocks.

DEVONIAN LIMESTONE.

Lithologically the Devonian deposits of Kentucky may be divided into two divisions, in descending order:

The Devonian Black Shale, and
The Devonian Limestone.

The Devonian limestone of Ohio is divided into the following formations, named in descending order:

Delaware limestone,
Columbus limestone,
Unnamed division, nearly unfossiliferous.

The Devonian limestone of western Kentucky and southern Indiana is divided into the following formations, also named in descending order:

Sellersburg limestone,
Jeffersonville limestone,
Geneva limestone, nearly unfossiliferous.

FAUNA OF DEVONIAN LIMESTONE.

A list of the fossils found in the Columbus limestone within twenty-four miles of Columbus, Ohio, was prepared by E. and H. Hyatt and published by Prof. R. P. Whitfield in the Geology of Ohio, Vol. VII, page 434, in 1893. The fossils of the Jeffersonville and Sellersburg formations were described by E. M. Kindle in the Twenty-fifth Annual Report of the Indiana Survey, page 579, in 1901. A study of the brachiopoda of these faunas has suggested the following methods of comparison:

Among the species listed by R. P. Whitfield as occurring in the Columbus limestone within twenty-four miles of Columbus, Ohio, the following are not cited from the Devonian of Louisville, Kentucky, or from Indiana. The range of these species outside of Ohio is indicated in each case.

Rhynchonella (?) *raricosta,*
Camarotoechia. billingsi; New York, Ontario.
Camarotoechia dotis; New York.
Charionella scitula; New York, Ontario.
Spirifer macrothyris; New York, Ontario.
Spirifer marcyi; New York.
Stropheodonta inaequiradiata; New York, Canada, Nevada.
Stropheodonta patersoni; New York, Illinois.
Strophonella ampla; New York, Ontario.
Orthothetes flabellum.
Orthothetes pandora; New York, Ontario, Nevada.
Schizophoria propinqua; New York.

Among the species listed by R. P. Whitfield as occurring in the Columbus limestone within twenty-four miles of Columbus, Ohio, the following are cited also from the Jeffersonville limestone of Louisville, Kentucky, or from Indiana. The distribution of these species outside of Ohio, Kentucky, and Indiana is indicated in each case.

Camarotoechia carolina.
Eunella sullivanti; Ontario, Canada.
Spirifer acuminatus; New York.
Spirifer grieri; New York.
Spirifer manni; New York.
Meristella nasuta; New York, Ontario, Nevada.
Crania crenistriata; New York, Michigan.
Craniella hamiltoniae; New York, Canada.
Chonetes acutiradiatus; New York.
Chonetes arcuatus; New York.
Chonetes vicinus; New York, Wisconsin, Nevada.
Pentamerella arata; New York, Ontario.

Among this list the following are cited from the Columbus limestone of Ohio, and from both the Jeffersonville and Sellersburg limestones at Louisville, Kentucky, or in Indiana.

Camarotoechia tethys; New York, Ontario, Nevada.
Cyrtina hamiltonensis; New York, Pennsylvania, Maryland, Ontario, Canada, Iowa, Nevada.
Spirifer fornacula; Illinois, Wisconsin.
Spirifer segmentum.
Spirifer varicosus; New York, Canada, Nevada,
Delthyris raricosta; New York, Maine, Ontario, Gaspe, Canada, Nevada.
Reticularia fimbriata; New York, Maryland, Virginia, Ontario, Canada, Illinois, Iowa, Nevada.
Nucleospira concinna; New York, Pennsylvania, Virginia, Ontario, Nevada.
Stropheodonta demissa; New York, Pennsylvania, Ontario, Canada, Illinois, Iowa, Tennessee, Wisconsin, Nevada.
Stropheodonta hemispherica; New York, Ontario.
Stropheodonta perplana; New York, Pennsylvania, Maryland, Maine, Illinois, Iowa, Wisconsin, Nevada, Ontario, Tennessee.
Pholidostrophia iowaensis; New York, Ontario, Illinois, Iowa, Michigan.
Chonetes mucronatus; New York, Ontario, Gaspe, Nevada.
Productella spinulicosta; New York, Canada, Michigan, Wisconsin, Iowa, Illinois, Nevada.

Rhipidomella vanuxemi; New York, Ontario, Michigan, Iowa, Illinois, Tennessee.

Among this list the following species are cited from the Columbus limestone of Ohio, and also from the Sellersburg limestone at Louisville, or in Indiana:

Tropidoleptus carinatus; New York, Pennsylvania, Illinois.
Spirifer duodenarius; New York, Ontario.
Spirifer macrus; New York.
Spirifer granulosus; New York, Pennsylvania, Maryland, Virginia, Michigan.
Roemerella grandis; New York.
Chonetes yandellanus.
Rhipidomella livia; New York, Ontario, Gaspe.

Among the species listed by E. M. Kindle as occurring in the Jeffersonville limestone of Louisville, Kentucky, and of Indiana, the following are not recorded from the Columbus limestone at Columbus, Ohio. The distribution outside of these States is added.

Rhynchonella gainesi-cassensis.
Rhynchonella depressa.
Camarotoechia congregata; New York.
Camarotoechia nitida.
Cyclorhina nobilis; New York, Ontario.
Cryptonella lens; New York.
Cryptonella ovalis.
Eunella harmonia; Ontario.
Eunella lincklaeni; New York, Michigan.
Cranaena romingeri; New York, Michigan, Iowa.
Terebratula jucunda; Iowa.
Atrypa ellipsoidea.
Cyrtina crassa; New York.
Spirifer davisi.
Spirifer gregarius-greeni.
Reticularia knappianum.
Reticularia wabashensis.
Meristella barrisi; New York.
Crania greeni.
Crania granosa; New York.

Stropheodonta plicata; Ontario, Iowa.
Orthothetes arctistriatus; New York, Pennsylvania, Canada, Nevada.
Chonetes subquadratus.
Productella semiglobosa.
Pentamerella thusnelda.
Camarospira eucharis; Ontario.
Gypidula romingeri-indianensis.

The following species are listed both from the Jeffersonville limestone and from the Sellersburg limestone, but are not recorded from the Columbus limestone at Columbus, Ohio:

Rhynchonella gainesi.
Rhynchonella tenuistriata.
Camarotoechia sappho; New York.
Cyrtina hamiltonensis-recta; New York.
Spirifer divaricatus; Canada, New York.
Spirifer gregarius; New York, Ontario.
Spirifer byrnesi.
Ambocoelia umbonata; New York, Pennsylvania.
Parazyga hirsuta; New York, Canada.
Athyris fultonensi; Missouri, Iowa, Michigan, Manitoba.
Pentagonia unisulcata; New York, Ontario.
Stropheodonta concava; New York.
Stropheodonta inaequistriata; New York, Ontario, Wisconsin.
Chonetes coronatus; New York, Pennsylvania, Ontario, Illinois, Wisconsin.
Schizophoria striatula; New York, Wisconsin, Iowa, Illinois, Missouri, Nevada, Canada.
Pentamerella pavilionensis; New York.

The following species, listed by E. M. Kindle from the Sellersburg limestone of Louisville, Kentucky, and of Indiana, are not recorded from the Columbus limestone, at Columbus, Ohio:

Glossina triangulata.
Rhynchonella louisvillensis.
Centronella glansfagea; New York, Ontario, Michigan.
Atrypa spiinosa; New York, Pennsylvania, Maryland, Virginia, Ontario, Canada, Illinois, Iowa, Wisconsin.
Spirifer varicosus-hobbsi.

Spirifer arctisegmentum; New York.
Spirifer audaculus; New York, Wisconsin.
Spirifer iowaensis; Illinois, Iowa, Wisconsin.
Spirifer macconathei.
Spirifer pennatus; New York, Pennsylvania, Maryland, Virginia, Ontario, Wisconsin.
Delthyris sculptilis; New York, Pennsylvania, Ontario.
Martinia subumbona; New York.
Vitulina pustulosa; New York, Pennsylvania.
Athyris spiriferoides; New York, Pennsylvania, Maryland, Virginia, Canada.
Orbiculodea doria; New York, Ontario.
Crania sheldoni; Iowa.
Chonetes manitobensis; Canada.
Rhipidomella leucosia; New York, Maryland.
Rhipidomella goodwini.

A study of these lists suggests, in the first place, that there is a considerable similarity between the fauna of the Columbus limestone and that of the Jeffersonville and Sellersburg limestone. There is no strong evidence of the fauna in western Kentucky and southern Indiana having developed in a different basin from that occupied by the fauna of the Columbus limestone. Although the Cincinnati geanticline during the deposition of these limestones probably rose above the sea in north-central Kentucky and southern Ohio, there appears to have been free connection across the more northern part of the geanticline in central and northern Ohio and Indiana. This is indicated not only by the similarity of the two faunas on opposite sides of the Cincinnati geanticline, but also by the great outlier of Columbus limestone in Logan county, Ohio.

The Columbus limestone includes the faunas of both the Jeffersonville and of the Sellersburg limestone. Twelve species listed from the Columbus limestone are recorded only from the Jeffersonville limestone, seven are recorded only from the Sellersburg limestone, while fifteen are recorded as common to both formations. The fossils common to the Columbus limestone and both to the Jeffersonville and Sellersburg formations in general have a wider geographical distribution than those common only to the Columbus and Jeffersonville limestones, or to the Columbus and Sellersburg limestones. By far the greater

part of the species described from the Devonian limestones of Ohio, Indiana, and western Kentucky have a geographical distribution extending northeastward into New York, and Ontario. Parts of the fauna reach Virginia and Gaspe. Parts reach western Tennessee, Illinois, Michigan, Wisconsin, and extend northwestward into Canada. In general there appears no strong evidence of a western fauna entering this field from beyond the Mississippi. *Spirifer fornacula, Spirifer iowaensis, Terebratula jucunda, Athyris fultonensis, Crania sheldoni,* and *Chonetes manitobensis* are among the few fossils suggesting the presence of a northwestern fauna.

Even in Indiana, the faunas of the Jeffersonville and Sellersburg limestones are distinct only in the more southern parts of the State. About thirty-five miles north of Louisville, Kentucky, the two formations show a mingling of faunas, which becomes greater farther north. Under these conditions it is not strange that the Columbus limestone should show the elements of both the Jeffersonville and Sellersburg faunas.

Of the two formations recognized in Indiana, it is the Jeffersonville limestone which appears to extend in greatest development southward from Louisville to Lebanon, Kentucky, and thence eastward toward the eastern side of the Cincinnati geanticline. This is indicated by the great abundance of corals in the Devonian limestones of Lebanon, Kentucky, many of which are known from the lower part of the Jeffersonville limestone at Louisville. The brachiopoda from the vicinity of Lebanon include *Spirifer divaricatus, Spirifer fornacula, Spirifer varicosus,* and *Reticularia fimbriata,* listed both from Jeffersonville and from the Sellersburg limestone; and *Spirifer grieri, Spirifer manni, Pentamerella arata,* and *Eunella harmonia,* listed from the Jeffersonville limestone, corroborating the Jeffersonville affinities of the Lebanon fauna.

From Lebanon, Kentucky, the Devonian limestone may be traced readily to Junction City and eastward. In the Paleontology of New York, Vol. VIII, Hall and Clarke figure *Pentamerella arata. Spirifer fornacula* and *Reticularia fimbriata* occur in the lower part of the Devonian limestone at Duffin's cut, along the railroad, north of Junction City.

No attempt has been made as yet to study the fauna of the Devonian limestone, east of the Cincinnati geanticline, in Ken-

tucky. In the Paleontology of New York, Vol. VIII, Hall and Clarke describe *Crania favincola* from the Devonian limestone of Crab Orchard. *Pentagonia unisulcata, Athyris fultonensis, Spirifer varicosus* and *Spirifer byrnesi* are abundant at various localities near Crab Orchard. Corals are abundant and include many species. In his Kentucky Fossil Corals, published in 1885, W. J. Davis figures *Michelinia plana* and *Blothrophyllum zaphrentiforme* from Crab Orchard. In his contributions to Indiana Paleontology, published in 1898 and 1904, G. K. Greene records *Blothrophyllum houghtoni* and *Heliophyllum osculatum* from Crab Orchard. *Blothrophyllum cinctutum; Michelinia insignis; Favosites placenta,* and *Trachypora ornata* occur in this vicinity. The great abundance of corals suggests the presence of the Jeffersonville fauna here. There is a sufficient number of fossils here to determine the horizon definitely as soon as time can be found for careful collecting.

In the vicinity of Moberly, *Spirifer fornacula* occurs. Near Indian Fields, *Stropheodonta concava* and *Phacops rana* are found. Along the railroad, half a mile west of Clay City, *Reticularia fimbriata* is seen. The Devonian limestone may be traced from Crab Orchard northeastward as far as Olympia Springs, in Bath county. Both the Jeffersonville and Sellersburg faunas may be present in this area, but, at present, not enough is known to determine the horizon, although the numerous corals at some localities suggest the presence of the Jeffersonville horizon at least. In the absence of diagnostic fossils it is a waste of time to theorize, but these fossils can be obtained and eventually the relationship of these Devonian limestones of east-central Kentucky will be known.

The long gap between the exposures of Devonian limestone in Bath county, Kentucky, and Pickaway county, Ohio, a distance of almost 100 miles, prevents the use of any stratigraphic methods of determining the relationship of the Devonian strata of east-central Kentucky with those of Ohio. It is not unlikely that the Devonian areas of eastern Kentucky and of Ohio are connected, but the overlap of the Devonian Black shale probably has covered up the connecting belt of strata.

E. M. Kindle has correlated the Jeffersonville limestone with the Corniferous or Onondaga formation, and the Sellersburg limestone with the Hamilton formation of New York. The

Sellersburg limestone, however, contains a considerable admixture of Onondaga forms, although traces, at least, of the Hamilton fauna are discovered.

Fossils Cited by Linney from Devonian Limestones of Eastern Kentucky.

Linney correlated the Devonian limestones east of the Cincinnati geanticline with the Corniferous of New York. In his report on Lincoln county he cites from the waste of this limestone the following species:

Zaphrentis corniculum, Lesueur *(=Cyathophyllum corniculum).*
Zaphrentis gigas (=gigantea, Lesueur).
Zaphrentis rafinesquii, Edwards and Haime.
Cyathophyllum halli (=Heliophyllum halli, Edwards and Haime).
Phillipsastrea gigas, Owen.
Cystiphyllum americanum, Edwards and Haime.
Spirifer oweni (=*granulosus,* Conrad).
Spirifer umbonata, (=Ambocoelia umbonata, Conrad).

From the Corniferous of Garrard county Linney cites:

Zaphrentis gigantea, Lesueur.
Zaphrentis proliferum (=*prolifica,* Billings?).
Heliophyllum halli, Edwards and Haime.
Blothrophyllum decorticatum, Billings.
Cystiphyllum americanum, Edwards and Haime.
Phillipsastrea gigas, Owen.
Orthis vanuxemi (=Rhipidomella vanuxemi, Hall).
Spirifer oweni (=*granulosus,* Conrad).
Atrypa reticularis, Linnaeus.
Platyceras ventricosum, Conrad.

In the report on Clark county are cited:

Zaphrentis corniculum, Lesueur *(=Cyathophyllum corniculum).*
Heliophyllum halli, Edwards and Haime.
Phillipsastrea gigas, Owen.

From the Corniferous of Montgomery county Linney cites:

Zaphrentis gigas (=gigantea, Lesueur).
Zaphrentis proliferum (=*prolifica,* Billings?).
Cyathophyllum halli (=Heliophyllum halli, Edwards and Haime).
Amplexus yandelli, Edwards and Haime.
Phillipsastrea gigas, Owen.
Strombodes knotti, Davis.
Cystiphyllum americanum, Edwards and Haime.
Favosites epidermatus, Rominger.
Favosites limitaris, Rominger.

From the Corniferous of Bath county Linney cites:
Zaphrentis proliferum (=*prolifica,* Billings?).
Zaphrentis rafinesquii, Edwards and Haime.
Cyathophyllum gigas (=*Zaphrentis gigantea,* Lesueur).
Cyathophyllum juvene, Rominger.
Cyathophyllum halli (=Heliophyllum halli, Edwards and Haime).
Amplexus yandelli, Edwards and Haime.
Blothrophyllum americanum (=Cystiphyllum americanum?).
Chonophyllum gigas (=*Zaphrentis gigantea*?).
Phillipsastrea gigas, Owen.
Favosites limitaris, Rominger.
Favosites troosti, Edwards and Haime.

From the ore banks north of Preston in Bath county, where the Devonian limestone, the Corniferous of Linney, has been replaced in part by iron ore, Linney cites the following species:

Orthis vanuxemi (Rhipidomella vanuxemi, Hall).
Spirifer oweni (=granulosus, Conrad).
Spirifer raricostatus (=*Delthyris raricostata,* Conrad).
Spirifer umbonata (=Ambocoelia umbonata, Conrad).
Atrypa reticularis, Linnaeus.
Athyris spiriferoides, Eaton.

Spirifer granulosus and *Athyris spiriferoides* occur in the Sellersburg limestone in Indiana. *Delthyris raricostata, Am-*

bocoelia umbonata, and *Rhipidomella vanuxemi* are found both in the Jeffersonville and Sellersburg beds. The preponderance of corals is noteworthy.

Variations in Thickness of Devonian Limestone in East Central Kentucky.

The Devonian limestone varies considerably in thickness. One of the thickest sections is exposed at the western end of Crab Orchard, north of the railroad, where it is nineteen feet thick. Two miles west of Crab Orchard, along the railroad, it is sixteen and a half feet thick. Two miles southwest of Crab Orchard, on the Chapel Gap road, it is eleven feet. Three and a half miles west of Crab Orchard, on the county road, it is eight and a half feet thick. Four miles west of Crab Orchard, on the Cox Gap road, the thickness is eleven and a half feet. About half a mile northwest of the last locality, it is six and a half feet. About a quarter of a mile farther west, the thickness may be five feet, but only two feet four inches are exposed. The same may be said of an exposure a quarter of a mile farther west. A short distance farther west, five miles from Crab Orchard, the clay resulting from the decay of the Devonian limestone suggests a thickness of only one foot. Farther west, as far as the Neal Creek church exposure, the Devonian appears absent. These observations indicate an irregular thinning of the Devonian limestone section from Crab Orchard westward as far as Neals Creek church.

Northwestward, toward Junction City, there is an irregular thickening of the Devonian limestone. At the Duffin cut, north of Junction City, the thickness is eighteen feet. Thick sections of Devonian limestone occur also southwest of Stanford. About five miles southwest of Hustonville, at the store owned by E. H. Kidd, the total Devonian limestone section has the remarkable thickness of forty-seven feet. Further study should be given this section, since here some of the layers poorly represented in the thinner sections are likely to be represented by thicker beds or by a series of layers.

East of Crab Orchard the Devonian limestone section appears to be thinner, the recorded measurements varying from

fourteen to fifteen and a half feet. But farther east, if the Devonian limestone were exposed, it might be found that thicker sections occurred again. The well record near Mullins Station, in Rockcastle county, suggests a thickness of twenty feet.

Another thick section of Devonian limestone occurs three miles southwest of Cartersville, where the road to Crab Orchard crosses the headwaters of Harmon creek. Here the Devonian limestone is seventeen feet thick. Half way between this locality and Crab Orchard the thickness of the Devonian limestone is only six feet, so that the Devonian limestone appears to become thinner from both areas toward this middle region. With the exception of the exposure near the headwaters of Harmon creek, the various recorded sections of the Devonian limestone between Lancaster and Berea vary from eleven to thirteen feet. Possibly the Devonian limestone thins out northward in this area, but if this is the case no evidence of such thinning has been discovered as yet, except along the railroad north of Berea. Here, directly north of Berea, the thickness of the Devonian section is thirteen and a half feet. Four miles north of Berea it is reduced to three inches.

Evidences of thinning are seen also in going from Berea northeast, toward Bobtown. In the vicinity of Bobtown, and from this region for at least three miles toward the east and northeast, the thickness of the Devonian limestone is reduced to about one foot or less, except at the Mat Moody store, a mile and a quarter toward the southeast of Bobtown. Here the thickness of the Devonian limestone is at least four feet four inches, again suggesting an irregular thinning of the Devonian limestone toward the north.

Farther northeast the Devonian limestone section thickens again. Between Berea and Brassfield it varies between five and seven feet. Near Rice Station it shows the remarkable thickness of twenty-one and twenty-three feet, in large part due to the introduction of great quantities of chert. Near Irvine the Devonian limestone sections do not appear to exceed eleven feet, but thicker sections are suggested by some of the well records east of Irvine.

Northwest of Rice Station several thick sections of Devonian limestone are known. West of Cobb ferry it is twenty-one and a half feet thick. A mile and a half farther west, at the head

of Falling branch, the thickness is at least eighteen feet. Southwest of Elliston it is nearly sixteen feet. These observations indicate a thinning of the Devonian limestone southwestward from Rice Station and Moberly toward Bobtown and Whites. Great variations in thickness are noted between Elliston and Cobb ferry. Near Waco the Devonian limestone does not exceed five feet.

Thick sections are exposed also near College Hill, and farther northward, on the road to Jackson ferry. At the more northern localities some of the measurements indicate thicknesses of seventeen feet and more.

Northeast of a line connecting Rice Station, Cobb ferry, and Jackson ferry, the thickness of the Devonian diminishes again. Near Vienna, measurements of eight and eleven feet are recorded. At Log Lick and northward the thicknesses vary between five and seven feet. Half a mile south of Indian Fields it is six feet. Locally it is less. A quarter of a mile south of Indian Fields, for instance, it is two feet and a half. Between Indian Fields and Clay City most of the sections of Devonian limestone vary between four and a half and seven feet, but about three and a half miles west of Clay City, between Hudson mill and Snow Creek church, there is a section in which the Duffin layer alone has a thickness of nine feet, and the underlying cherty Devonian limestone also is known to have considerable thickness.

A mile northeast of Indian Fields the thickness of the Devonian limestone varies between eight and ten feet. Between these localities and Spencer no sections thicker than three feet have been found so far, and between Levee and Jeffersonville are several localities where the thickness is less than two feet. At Spencer, sections nine and twelve feet thick are known. A mile south of Preston there is a section eight feet thick. Two miles east and west of this locality the thickness does not exceed three feet,

From the preceding observations it may be seen that the Devonian limestone varies considerably in thickness when traced along the line of outcrop in east-central Kentucky. In certain areas it appears to become thinner on approaching the Cincinnati geanticline, but if this thinning be general it is too irregular readily to be detected along the greater part of

the comparatively narrow belt of exposures. Possibly the alternate thickening and thinning of the Devonian limestones when traced along the belt of exposures is due to the former presence of a series of minor folds, subsidiary to the great Cincinnati geanticline, and more or less transverse to the eastern slope of the latter. A greater number of observations are needed to decide this matter. Possibly the records of wells bored for the purpose of securing oil may in the course of time yield valuable evidence. At present these records often are very misleading.

Minor Subdivisions of Devonian Limestone in East-Central Kentucky.

No careful study of the fauna of the Devonian limestone of eastern Kentucky has been attempted so far, nor has any attempt been made to determine how far the stratigraphic units present in different sections may be traced. Two layers, however, have attracted attention on the part of all observers, and will receive special consideration in the following discussion. One of these occurs at the base of the series of Devonian limestones, and the other is found at the top. The first is characterized by the presence of fish remains, the latter often has a brecciated appearance, and here is called the Duffin layer. The relative position of these layers may be indicated as follows:

Devonian or Boyle limestone.....	Duffin layer, usually several feet thick, often appearing brecciated. Limestone, sometimes richly fossiliferous and often cherty, usually forming by far the greater part of the Devonian limestone section. Kiddville layer, thin layer with fish remains.

The middle part of the Devonian section often contains great quantities of chert. This is true especially in the neighborhood of faults. In some localities, for instance near Rice Station, the quantity of chert exceeds the quantity of original Devonian limestone. At some localities, where the Devonian limestone is very thick, for this part of Kentucky, very little chert or none at all is found in the limestone, so that the distribution

of the chert appears to be quite irregular. All of this chert appears to be the result of segregation, most of the silica probably being derived from the decay of overlying strata, and being carried in by percolating waters. Where rocks were more or less brecciated, the opportunity for the accumulation of chert seems to have been much increased.

KIDDVILLE LAYER WITH FISH REMAINS.

At the Duffin cut, three quarters of a mile north of the railroad crossing at Junction City, the entire thickness of the Devonian limestone is fully eighteen feet. The lowest layer, two feet six inches thick, consists of dense, light grey limestone. One specimen of *Reticularia fimbriata,* and several large markings known as *Taonurus caudagalli,* occur near the base. Fish teeth are found within an inch of the base. Specimens of *Taonrurus caudagalli,* occur also at higher horizons in the Devonian limestones of Kentucky. For instance, a little over two miles southeast of Crab Orchard, where the Devonian limestone is about fourteen feet thick, the lower part of the exposure, four feet thick, contains small *Spirifers* and other brachiopoda, while the immediately overlying layers contain the *Taonurus caudagalli* markings.

Four miles north of Berea, and half a mile south of White station, the Devonian limestone is reduced to only three inches in thickness, consists of blue, argillaceous, gritty limestone, and contains fish remains. A mile and a half farther south, the layer with fish remains is only one inch thick; but it is overlaid by Devonian limestone, two feet four inches thick, and by the cherty Duffin layer, which was not measured. Nearer Berea the total thickness of the Devonian limestone is thirteen feet six inches. At the localities between Berea and Whites, there are found both fish teeth and the tuberculated plates, which have been referred by Linney and Knott to *Macropetalichthys,* but which have not been carefully studied as yet by those conversant with fossil fish faunas. In the area extending from the locality half a mile south of Whites station to the localities about three miles almost directly east of Bobtown, the thickness of the Devonian limestone frequently is less than one foot. At the most eastern locality in this area, at the headwaters of

Drowning creek, it varies between two and six inches or may be entirely absent; traces of fish remains are found.

A mile and a half east of Moberly, on the western side of Muddy creek, southwest of Elliston, the thickness of the Devonian limestone appears to be fifteen feet eight inches. The lowest layer consists of gray, well-bedded, sandy limestone, two feet thick, overlaid by an equal thickness of similar rock; between these layers of limestone there is a thin film of rock containing fish teeth and small black nodular particles. Wherever these nodular particles occur, careful search will usually result in the discovery of fish remains, and in this connection, therefore, it is of interest to note that in the area between Whites and the localities three miles east of Bobtown, where the thickness of the Devonian limestone is so much reduced, the black nodular particles are rather common, and the rock is decidedly sandy.

Along the exposures extending from a quarter of a mile south of Indian Fields up a small stream to the rear of the home of John Goff, the layer with fish remains, both teeth and tuberculated plates, occurs. Directly south of Indian Fields, the layer containing fish remains is about a foot thick, and quite sandy. The total thickness of the Devonian limestone is about two and a half feet. North of the home of John Goff the Devonian limestone section is fully six feet thick. The lowest layer, five inches thick, contains fish remains and the tiny black nodular particles. The overlying layer of ferruginous brown limestone, eleven inches thick, contains fish plates. This is followed by sandy rotten stone, one foot six inches thick. About a mile east of Indian Fields, at the Hollywood or Stuart mill, where the Devonian limestone is ten feet thick, the lowest layer consists of reddish brown limestone, four feet four inches thick, with *Phacops rana.* This layer is believed to correspond to the reddish brown limestone with tuberculated fish plates found north of the home of John Goff. Above this horizon at the Hollywood locality is found a sandy rock, one foot nine inches thick, containing the tiny black nodules and the fish remains. Half a mile southeast of the Hollywood mill, at the spring north of the home of Will Lawrence, north of the oil spring, fish remains occur at the base of the Devonian section, in a crumbling layer four inches thick. The overlying massive limestone, three-

feet four inches thick, is believed to correspond to the layer with tuberculated plates occurring north of the home of John Goff. The overlying layer is one foot three inches thick, and is shaly rock. The total thickness of the Devonian limestone here is nearly nine feet. A mile and a half southeast of Indian Fields, at the Eastin mill, and several miles down stream at the Abbott mill, the fish layer occurs again, at the base of the Devonian limestone. It is found at the base of the Devonian limestone also half a mile west of the bridge at the western end of Clay City, along the railroad; two miles southwest of Clay City, at Tipton Ferry; at both localities in sandy limestone about half a foot thick.

About a mile south of Preston, east of a small branch entering Mill creek from the west, the thickness of the Devonian limestone is fully eight feet. The layer with fish remains occurs at the base of the Devonian section and is only three inches thick. A magnificent exposure of the layer with fish remains occurs about a mile west of Preston, along the railroad.

Eight miles east of Owingsville, in the extreme western part of Rowan county, northwest of Moore's ferry, a layer of limestone, thirteen inches thick, containing *Taonurus caudagalli,* occurs at or near the base of the Devonian black shale. The rock has a grayish color and apparently belongs to the base of the Black shale series rather than to the Devonian limestone series of more southwestern exposures in Kentucky.

In the Linney reports on the geology of the various counties bordering central Kentucky, the layer with fish remains is referred to the Oriskany. In his report on Lincoln county the following section is published from a locality above the junction of Flax or Flades creek with Dix river, described in descending order:

Heavy corniferous limestone layer	33 in.
Covered space	12 in.
Drab sandstone	12 in.
Rock weathering to olive shale	16 in.
Sandstone with *cauda-galli* fucoids	3 in.
Sandstone with *cauda-galli* fucoids	20 in.
Magnesian limestone	2 in.
Magnesian limestone	27 in.
Crab Orchard shale.	

The magnesian limestone at the base of the section is said to contain a *Spirifer* two and a half inches in length. This *Spirifer* must be one of the Devonian species, no *Spirifer* of this description being known in the Silurian of Kentucky or neighboring States. The large *Spirifer* mentioned by Linney may be the same as a species three and a half inches in length along the hingeline which occurs at the western end of Crab Orchard, north of the railroad, about three feet above the base of the Devonian limestone. Unfortunately, no attempt was made to cut the specimens out of the rock and therefore the species can not be identified at present. The layers with *Taonurus caudagalli* occur two and a half feet above the base of the Devonian according to the published section. There can hardly be any question of the Devonian age of the magnesian limestone layers in the Linney section in view of the fact that near the home of Mr. Howard, north of the railroad, two miles east of Crab Orchard and only a mile and a quarter southeast of the locality described, there is an exposure at which layers containing *Taonurus caudagalli* are underlaid by limestone four feet thick, containing undoubted Devonian brachiopods. The so-called sandstones of Linney's section are gray limestones. These he correlates with similar rocks at the base of the Devonian section in Boyle and Marion counties containing spines, teeth, and plates of large fishes. The tuberculated plates he identifies with the genus *Macropetalichthys,* and states that the rocks here described might represent both the Oriskany sandstone and the *Cauda-galli* grit of New York.

In the report on Clark county, Linney refers to the Oriskany a layer of stone about one foot thick, nearly white where exposed in the bed of creeks, but of a rather dull, dirty blue when broken, containing in the lower part bones, spines, plates, and teeth of fishes, most of which had been ground into pebbles before they were left to be consolidated into rock. Some of the small teeth, however, are whole, and the tubercles on some of the plates are well preserved. At some localities the layer with fish remains is chiefly a limestone; at others it contains enough si1icious matter to rank as a sandstone. The presence of the single layer of rock containing fish remains and *Taonurus cauda-galli* is noted also in the report on Montgomery county, under the name Oriskany sandstone. In the report on Bath

county the layer with fish remains is stated to be present in Marion, Boyle, Lincoln, Garrard, Madison, Clark, Montgomery, and Bath counties. It is described as consisting usually of a single layer of dirty, bluish grey, tough stone, containing sand, lime, and alumina, and marked by *Taonurus cauda-galli.* In the lower part, at nearly every exposure, it contains quantities of the remains of bones, fins, and teeth of fish, with phosphatic nodular masses which may have been the excrement of the same form of life. Rarely a few casts of shells are seen, among others, a well preserved cast of *Conularia.* This layer usually has a thickness of twelve to eighteen inches, but at some points in Bath county, according to Linney, rises to a thickness of about three feet.

DUFFIN LAYER.

In the report on Lincoln county, Linney describes the Duffin layer as follows. In Lincoln, and to some extent in Boyle county, there is to be seen a very peculiar rock, varying from two inches to twelve feet in thickness, at times having very much the appearance of a breccia. This rock has a massive gray base, and at some localities apparently fragments of a brown rock are distributed through it irregularly. At other localities, the brownish particles do not appear to have resulted from brecciation, but from the alteration of fossils. It is doubtful whether any part of this rock is brecciated. The layer is well exposed in the railroad cut near McKinney's station and in the cut near Junction City, on the edge of Boyle county. A fragment sent to Dr. Robert Peter was described by him as a dark gray, fine-grained rock, mottled with whitish and light-yellowish gray spots of various sizes and shapes; containing small cavities, some lined with small quartz crystals, some filled with calcite and containing semi-opal. The rock contains bituminous matter, the irregular infiltration of which has caused some of the mottling. In the report on Garrard county, the Duffin layer is described as appearing as though it had been made of the broken, angular pieces of some rocks, cemented in a base having another shade of color, but Linney states that he found it impossible to determine whether the rock was a true breccia, or whether the brecciated appearance resulted

from the alteration and removal of fossils. In the report on Clark county, the Duffin layer is called the brecciated layer. In the report on Montgomery county it is stated that the layer resembling a breccia is rarely seen. No mention is made of the Duffin layer at any of the localities farther north.

The typical exposure occurs at the Duffin cut (See Fig. 2, Plate 8), three quarters of a mile north of Junction City. Here the Duffin layer forms the top of the Devonian limestone section. The rock weathers to a brownish color, and the weathered surface shows some small quartz concretions. The layer contains a few crinoid stems and corals, and also some fucoidal markings. It is six feet thick, the thickness of the entire section of Devonian limestone being about eighteen feet.

About six miles east of Junction City and three and a half miles northwest of Stanford, the Duffin layer is nearly six feet thick. About a mile west of Stanford, at the Buffalo spring, the Duffin layer is at least five feet thick, and the Devonian section is at least eleven feet thick. Thirteen miles southeast of Stanford, on the Cox Gap road, the top of the Devonian limestone has a brecciated appearance. A little over two miles west of Crab Orchard, along the railroad, the thickness of the Duffin layer is two and a half feet. At the western end of Crab Orchard, north of the railroad, the brownish rock, considered equivalent to the Duffin layer, is eight inches thick. Similar rock is poorly exposed at the home of Bill Monk, a little over a mile southeast of the railroad station at Crab Orchard, north of the railroad. A mile and a quarter north of the center of Crab Orchard, on the Lancaster road, the Duffin layer is four inches thick.

About three miles northeast of Crab Orchard, and a quarter of a mile south of Fall Lick creek, the Duffin layer is four inches thick. About two and a half miles south of Hammack, south of Harmon creek, the thickness of the brownish rock, which may represent the Duffin layer, is one foot. Beneath this rock is a thin streak of black shale, overlying, in descending order, limestone, six feet thick; soft rock, weathering back, five and a half feet thick; and bluish argillaceous rock, four and a half feet thick; a total of seventeen feet of rock belonging to the Devonian limestone section. Two miles southeast of Hammack the Duffin layer is eight feet thick; two miles north-

west of Hammack, on the road to Point Leavell, it is five and a half feet thick; three and a half miles southeast of Lancaster, on the road to Hammack, it is five and a half feet thick. Three quarters of a mile east of Cartersville, where the rock is much disturbed, the thickness appears to be eleven feet, and seems to include all of the Devonian limestone at this point. Two miles northeast of the last locality, near the home of Charles Baker, the Duffin layer is four feet thick, and the entire thickness of the Devonian limestone appears to be about eleven feet. About a mile east of the last locality, three miles southwest of Berea station, the Duffin layer is five and a half feet thick; it contains fragments of crinoid stems and cyathophylloid corals. The total thickness of the Devonian limestone is twelve and a half feet.

Half a mile north of Berea station the Duffin layer is five feet thick. It is exposed again about a mile farther north. Brecciated appearing rock occurs near the bridge over the railroad at Brassfield; it is a foot and a half thick, the total thickness of the Devonian limestone being seven feet. Three quarters of a mile southwest of Rice Station the Devonian limestone section appears to be twenty-three feet thick; at the top is a brownish layer, four feet thick, which appears to be equivalent stratigraphically to the Duffin layer. Nearer Rice Station this brownish limestone is only one foot four inches thick.

East of Moberly, immediately southwest of Elliston, the Duffin layer is two and a half feet thick. West of Cobb ferry the Duffin layer has the brecciated appearance, is five feet thick, and contains fragments of crinoid stems and *Favosites*, with some chert at the base. Three miles north of College Hill, where the Devonian limestone section is fully twenty feet thick, a brownish layer of rock, which may be the equivalent of the Duffin layer, appears at the top of the section. It is one foot thick, and separated by black shale, nine inches thick, from brownish rock, three feet thick, containing abundant specimens of *Taonurus caudagalli*. The top of the cherty layers is one foot three inches lower down. The layer with *Taonurus caudagalli* found in the extreme western part of Rowan county probably is to be correlated with this upper *Taonurus* horizon rather than with the lower horizon, near the base of the series of Devonian limestones, near Crab Orchard.

Three quarters of a mile southeast of Vienna, near the home of James Stone, the Duffin layer is five feet thick. Southwest of Vienna, near the home of Old Jones Finnell, the top of the Devonian limestone section consists of hard brown limestone, five feet three inches thick, underlaid by brecciated appearing rock, one foot thick; soft rock, one foot thick, and cherty limestone, six feet thick. This position of the brecciated appearing layer is unusual. Near Log Lick church the Duffin layer is two feet thick. A mile northward, at the J. T. Elkins locality, it is replaced by argillaceous rock, three feet thick. Between Arlen and Rightangle the Devonian exposures are five feet thick; the greater part of the rock has a brecciated appearance, but the lower part, eighteen inches thick, contains considerable chert. Three and a half miles west of Clay City, on the road from Hudson's mill to Snow creek church, the argillaceous rock at the top of the Devonian limestone section is nine feet thick, contains Devonian brachiopods, and appears brecciated only at the base, in this respect resembling the exposure southwest of Vienna.

The Duffin layer is exposed northwest of Indian Fields, along the railroad. At the oil spring, southeast of the hotel, about a mile northeast of Indian Fields, the brecciated appearing layer is one foot thick and is separated from the underlying solid, light brown limestone by black shale, two inches thick. The overlying rock, ten inches thick, is similar in general appearance, but does not show the brecciated feature; farther up, the rock is more shaly and graduated into the black shale series. At the Hollywood or Stuart mill, the Duffin layer is one foot eight inches thick. At the spring near the home of Will Lawrence, it appears to be nearly four feet thick. East of Spencer, west of Slate creek bridge, the Duffin layer is one foot six inches thick and is overlaid by brownish limestone, four feet three inches thick, which does not have the brecciated appearance. About a mile south of Preston, east of a small branch entering Mill creek from the west, the top of the Devonian limestone section consists of brownish rock, two feet six inches thick, with traces of the brecciated appearance.

The list of localities here given is sufficient to show the very general distribution of the Duffin layer. During the progress of the field work it was noted that the Duffin layer sometimes

presented the brecciated appearance and sometimes not. Unfortunately, the recorded notes do not indicate with sufficient exactness the degree of brecciation suggested by different exposures, nor attempt a very exact correlation of the brecciated appearing layer with those not showing this feature, but which probably belong to the same horizon. Hence one of the series of observations necessary for a solution of the problem as to the brecciated appearance of the Duffin layer is not at hand. Careful study does not warrant the opinion that the small angular appearing particles, seen in the otherwise homogeneous appearing rock, are fragments of some earlier rock, broken up and washed in from some outside source. As far as present observations go, the brecciated appearance is seen best near lines of faulting, though present in rocks at some distance from faults.

Possibly, in the processes of folding and faulting, long after the deposition of the overlying rocks, there was a slight shifting of layers over one another. Such a shifting of layers may have caused the contorted appearance of certain layers in the Cynthiana or Point Pleasant formation, in the Garrard bed, and in the so-called mudstones (Tate) of Mason county, belonging to the Fairmount bed. In the case of the Duffin layer this motion of layers over one another may have resulted in an irregular distribution of pressures within the rock, which at first did not reveal itself in any manner, neither by a system of cracks nor by differences of color. But in the course of time certain particles were affected slightly differently chemically than others, this difference finally leading to the differences in color now observable between the apparent fragments and the enclosing general body of the rock. It must be acknowledged, however, that it is difficult to determine how such an interpretation can be made to explain the differences in chemical composition shown by the analyses furnished by Professor Peter, since, according to these analyses, the proportion of silica and alumina is twice as great, and the proportion of ferrous iron is less, in the gray component of the Duffin layer than in the white component, while the proportion of other ingredients is about the same.

THE DEVONIAN BLACK SHALES.

Near Columbus, Ohio, and northward, the Ohio black shale is underlaid by the greenish Olentangy shale. In the northern part of that State the Ohio shale is divided into the following subdivisions, named in descending order:

Cleveland shale,
Chagrin formation,
Huron shale.

Until more is known of the paleontology of these divisions in northern Ohio, it is idle to attempt to determine whether the Devonian black shale of Kentucky includes elements of all three of these subdivisions or whether it is to be correllated with only one of them. There is no doubt of the rapid decrease in thickness of the Black shale formation on going southward into Kentucky. It is stated by Prof. Charles S. Prosser that the top of the Ohio shale in southern Ohio corresponds with the top of the Cleveland shale, and that Andrew's Ohio shale is equivalent to the Huron, Erie (Chagrin formation), and Cleveland shales of Dr. Newberry in northern Ohio. This statement suggests a similar view of the Devonian black shale, at least in northern Kentucky. Farther southward, where the shale becomes more attenuated, it is probable that one or more of these divisions, or, at least, considerable portions of them, may be found absent.

VARIATIONS IN THICKNESS OF BLACK SHALE.

South of Lebanon, the thickness of the Devonian Black shales is forty-one feet. At Junction City, southwest of the Duffin cut, the aneroid barometer indicated a thickness of about sixty feet, but this instrument is known not to be strictly reliable. Two and a half miles west of Berea the recorded measurements indicate a thickness of eighty-five feet, but there is no means, at present, of determining the amount of dip. South of Indian Fields the thickness is 127 feet. Northeast of Indian Fields, about a mile, the thickness is 125 or 130 feet.

The well records in Powell county suggest thicknesses of 125 to 135 feet. The well records in Menefee county indicate thicknesses varying from 135 to 160 feet. In the extreme eastern

edge of Bath county, in the Hagland field, even greater thicknesses are indicated. From the records of about fifty wells, J. B. Hoeing estimates the average thickness of the Devonian black shale at 205 feet.*

Mr. Hoeing gives the following estimated thicknesses of the Devonian black shale on going from Bath county westward, these estimates being derived from the outcrops:*

Bath county	135 ft.
Montgomery county	110 ft.
Clark county	100 ft.
Powell county	100 ft.
Estill county	100 ft.
Garrard county	50 ft. Estimate too small.
Marion county	60 ft.
Nelson county	50 ft.
Larue county	65 ft.
Bullltt county	70 ft.
Jefferson county	100 ft.

These estimates indicate a general thinning of the Devonian Black shale southward. From Marion county this southward thinning continues as follows:

Marion county	60 ft.
Casey county	45 ft.
Russell county	40 ft.
Clinton county	30 ft.
Cumberland county	25 ft.
Monroe county	20 ft.

This thinning of the Black shale continues southwestward through Tennessee. Along the Harpeth river, southwest of Nashville, the thickness is about twenty feet. Farther south the measurements usually vary between five and eight feet, and in some of the more southern areas the Devonian black shale is entirely absent.

The Devonian black shale thins also westward. Mr. J. B. Hoeing, however, publishes certain measurements secured from well records, which, if corroborated by the diamond drill, indicate a thickening of a very unexpected kind west of the Cincinnati geanticline, in Kentucky at least. These records are as follows:*

*The Oil and Gas Sands of Kentucky, Kentucky Geological Survey. Bulletin No. 1, 1904.

Breckenridge county ..... 95 ft.
Hart county ..... 105 ft.
Warren county ..... 90 ft.

When it is considered that in the neighborhood of Cumberland City, in northwestern Tennessee, the Devonian black shale is only about ten feet thick, and that in western Illinois, in Jersey county, north of St. Louis, only traces are left, the importance of these statements by Mr. Hoeing will be evident. In some parts of Union county, in southern Illinois, Black shale, fifty to seventy feet thick, is recorded by Worthen.

In the "Fluor Spar Deposits of Southern Illinois," published in 1905, H. Foster Bain states that the Black shale near Hicks, in Hardin county, Illinois, the third county east of Union county, is at least fifty feet thick, and that probably one hundred feet or more are present.

Nothing is known at present of the thickness of the Devonian black shale in the area between southern Illinois and Breckenridge, Hart, and Warren counties, in Kentucky.

The Black shale is the great knob formation of Kentucky. All around the Ordovician and Silurian area of central Kentucky it produces the numerous steep rounded hills here known as the knobs. The abrupt change from the fertility of the Ordovician and Silurian areas to the comparative barrenness of the knobs is noticed even by the most careless observer. In Ohio, drain pipes have been burned from the clays resulting from the decay of the Black shale. At some localities a deep red brick has been obtained.

BASE OF BLACK SHALE SECTION.

Sandy rock, six inches thick, appears at the base of the Black shale section, five and a half miles southwest of Berea station. At Abbott's mill, two and a half miles south of Indian Fields, the top of the Devonian limestone shows worm borings. North of the home of John Goff, half a mile south of Indian Fields, a sandy rock with worm borings appears at the base of the Black shale section.

At some localities a thin streak of Black shale is seen between a layer of brownish rock, believed to belong to the Duffin horizon, at the top of the Devonian limestone section, and the

immediately underlying main body of Devonian limestones. Such a section May be seen five and a half miles northeast of Crab Orchard, along the headwaters of Harmon creek. Another exposure occurs three miles north of College Hill, where the road to Union City turns off toward the southwest. At the Oil spring, southeast of the hotel, a mile northwest of Indian Fields, a layer of black shale, two inches thick, occurs beneath the strongly brecciated appearing layer; the underlying part of the Devonian limestone at this locality is only fourteen inches thick. The section a hundred yards northeast of the hotel is quite different in appearance.

At quite a large number of localities, the base of the Black shale series, instead of being very black, and fissile, is dark gray in color, at least when weathered; it is more indurated, less fissile, less carbonaceous, less fine-grained, and breaks in more irregular lumps. This more argillaceous phase at the base of the Devonian Black shale is only four inches thick four miles southwest of Berea. Similar rock occurs at the base of the Black shale series one mile south of Bobtown. A mile and a quarter southeast of Bobtown, at Mat Moody's store, it is one foot four inches thick. Half a mile north of Mat Moody's store it is four feet thick. Two and a half miles north of the store it is two and a half feet thick. Three miles east of Bobtown the argillaceous rock is four feet thick, and is separated from the underlying Devonian limestone by a thin streak of Black shale. West of the railroad station at Irvine, argillaceous rock occurs in the lower six feet of the section. The lower part of the Black shale series is more indurated, and has a grayish color immediately west of Rice Station and, again, three quarters of a mile farther west.

South of Waco, the Devonian limestone is overlaid by grayish, more indurated rock, one foot three inches thick; black shale, six feet three inches thick, with a grayish indurated layer in the middle; and another indurated argillaceous rock layer, six inches thick, followed by the great mass of fissile black shales. A mile and a quarter northeast of Waco, at the Moore Spring, the Devonian limestone is overlaid by argillaceous indurated grayish shale, eleven feet six inches thick; more solid argillaceous shale, three feet thick; softer argillaceous shale, three feet thick; more solid argillaceous, grayish rock, nine

inches thick; graduating into the fissile black shale above. This is the thickest section of indurated clay rock and irregular more massive grayish shale known at the base of the Black Shale section. A part of this indurated shale resembles considerably some of the so-called Waverly shales in southern Kentucky, where this part of the section is not represented by soft clays, but by more indurated clay shales or shaly rocks. Somewhat similar shaly clay rocks occur three miles north of College Hill.

Three and a half miles west of Clay City, between the Hudson mill and Snow creek church, argillaceous clay rock, nine feet thick, occurs at the base of the Black shale series; the lower part is brecciated, the argillaceous rock gradually merging into the brecciated base. Northeast of Indian Fields, at the spring near the home of Will Lawrence, lenticular layers of the clay rock appear in the lower part of the Black shale series, and are overlaid by the main body of fissile black shales. At the Eastin mill, farther north, the lower part of the Black shale series consists of black shale interbedded with more or less clay rock.

A mile southwest of Jeffersonville, a hard argillaceous rock layer appears five and a half feet above the base of the Black shale; the underlying part of the Black shale series has the usual black color. Similar rock is found in the lower part of the Black shale series northwest of Jeffersonville.

From the preceding notes it may be seen that in many parts of east-central Kentucky the Devonian Black Shale series begins with a lighter colored and more massive rock, varying from a few inches to a few feet in thickness. It is less impregnated with carbonaceous matter and not so fine grained as the black fissile shales forming almost all of the remainder of the Black shale section.

West of Rice Station, the top of the Devonian limestone is overlaid by shale, some of it black, and some more gray in color and more indurated. The thickness of this basal part of the Black shale section varies between thirteen and eighteen and a half feet. Overlying this is a solid argillaceous limestone, two feet thick, containing Devonian cyathophylloid corals, *Atrypa reticularis*, and other shells not collected or identified. Clayey layers occur interbedded in the overlying part of the Black shale series for a distance of about seven to ten feet. In some cases these clayey layers are indurated into clay rock.

According to the well records, in the eastern part of Bath county, the hard Devonian limestone is overlaid by about twelve feet of rock described as a brown shale, and this, in turn, by clayey material, six to eight feet thick, described as white fireclay. The interpretation of this part of the section requires further study. In the meantime it may be of interest to note that greenish clay shale, five and a half feet thick, occurs at various localities along Fox creek, in the eastern part of Fleming county. It is well exposed between Fox Spring and Muse's Mills. In this case it is underlaid by massive rock, crinoidal in part, decreasing in thickness from nine feet at the Fox Spring to three feet at the Muse's Mills. Underlying this limestone, the age of which has not been determined, is the top of the Crab Orchard clay section.

NOTES BY LINNEY ON THE DEVONIAN BLACK SHALES.

Linney states in his report on Lincoln county, that in instances limestones are formed locally in the Black shale. The surfaces of some of the plates are wave-marked. The base of the section, in some places, contains quartz grains. Iron pyrites is common throughout the entire series. Sea-plant impressions are common features at some horizons. That the Black shale is bituminous, and that efforts have been made at various times to secure oil and coal from it is well known. In the report on Garrard county Linney states that two inches of worthless asphaltum coal were noticed not far from Dripping Springs. At the base of the Black shale here there occur some rounded grains of transparent quartz sand. Higher up, patches of yellow sand are seen, and marks of plants are not uncommon. Small species of *Lingula* and *Discina* are often found. The Black shale finds very extensive use as a road ballast, and forms good roads, especially during the summer time. In the report on Clark county Linney alludes to the presence of oil in springs issuing from the Black shale, due to the bituminous material in the shale; also, to the frequency with which copperas occurs, due to the destruction of the iron sulphide, or iron pyrites, so abundant in some sections.

Along Copperas creek, near the junction of Clark and Powell counties, very exceptional conditions were noted. Only a few

feet above the base of the Black shale series, interbedded with the Black shale, occurs locally a layer of stone, distinctly wave-marked. Five feet farther up occurs a layer of phosphatic sandstone, two inches thick. This layer is composed of small rounded grains of hyaline quartz, and contains fragments of spines, teeth, and bones of small fishes. A few feet farther up occurred a layer of clay, ten or twelve inches thick. The immediately overlying layers of slate for several inches were covered with the impressions of several species of plants. Some of these were land plants of the genus *Lepidodendron.* Several feet farther up there was seen at several places a layer of crystallized dolomite, two inches thick. At another locality, sandy concretions, over a foot thick, were found. At still another locality there was a thin layer of asphaltum coal. At one locality on Copperas creek, only a few hundred yards from Eastin's mill, there is a larger amount of iron pyrites in the Black shale than at any other known locality in the field. Its decay gives rise to copperas in such quantities that no fish, crayfish, worm, or bug is seen in its waters.

In the report on Bath county, Linney emphasizes the barren character of the soils produced by the decay of the Black shales. The shale breaks up into thin, fissile, ash-colored fragments when exposed for a long time. These crumble into small thin plates, that creep down steep slopes, and leave the hillsides almost bare of earth. These particles weather into cold, stiff clays, forming poor soils. Attention is called to the mineral springs caused by the decomposition of the materials in the Black shale. Near Young's Springs, and at several other places, were seen two layers of blue clay, sixteen to twenty-four inches in thickness, which are regarded as possibly the thin southern equivalent of the Erie shale of Ohio. In the earlier part of this bulletin, the Erie shale is called by the name introduced by Professor Prosser, of the Ohio Geological Survey, the Chagrin formation. If this identification by Linney can be established, the measured sections near Indian Fields suggest a thickness of seventy-five to eighty-two feet for the Huron shale; five and a half to fifteen feet, a very indefinite amount, for the Chagrin formation; and thirty-five to forty feet for the Cleveland shale. According to this interpretation, the huge fish remains on Copperas creek should fall within the Huron shale, but these local-

ities have not been visited, and therefore the position of the fish remains with reference to the clay layers here discussed can not be certified.

In the report on Fleming county, Linney states that the blue clay shales identified with the Erie shales (Chagrin formation) appear to have increased in having come northeast from Bath county.

GREENISH CLAYS ABOVE MIDDLE OF BLACK SHALE SECTION.

The Black shale section usually consists of an almost uniform series of thin, black, fissile shales. At some localities, however, a few thin soft greenish clay layers are intercalated at various intervals. North of the home of John Goff, half a mile southwest of Indian Fields, several of these layers, eight inches thick, are interbedded with the Black shales, between eighty-two and eighty-eight feet above the base of the section. Similar greenish clay layers occur between ninety and one hundred and five feet above the base of the Black shale section, west of the Oil Springs Hotel, northeast of Indian Fields. Along the road between Indian Fields and Clay City, these greenish, soft clay layers intercalated with the Black shales are exposed by the creek along which the road passes.

West of Rice Station, along the railroad between Richmond and Irvine, copperas oozes out of the Black shale, sixty feet above the base of the section. The greenish clays noted between Indian Fields and Clay City should occur farther up.

Greenish clays are exposed at quite a large number of localities in the Black shale section, but it has not been determined, as yet, even whether these clays are found at approximately the same horizon or not. The chief interest in these clays lies in the possibility of their being southern representatives of the Chagrin horizon of northern Ohio. At present there is no evidence in favor of such an interpretation. Several notes on these clays are recorded in the preceding section of this bulletin.

PHOSPHATIC NODULES AT BASE OF WAVERLY SECTION.

At the top of the Black shale section, forming the base of the Waverly series, phosphatic nodules, light gray or purplish in color, are widely distributed. Near Junction City these

nodules often are two and three inches in length, are very abundant, and, although most abundant at the very base of the Waverly series, occur also one or two feet above the same. Farther northeast, these nodules usually are smaller, less abundant, and occur only at the very base of the Waverly. Five and a half miles southwest of Berea station these nodules are one to two inches in length. Small phosphatic nodules occur at the top of the Black shale series also northwest of Indian Fields, on the top of the hill crossed by the road to the Oil Springs. Two and a half miles southeast of Levee, there appears to be a continuous layer of this purplish phosphatic rock, varying between a foot and a foot and a half in thickness. Nothing similar has been found anywhere else in the field. Along the Cumberland river, in southern Kentucky, these phosphatic nodules often are four inches in length, and sometimes attain diameters of six, and even eight, inches.

The phosphatic nodules often are fossiliferous. A considerable fauna could be collected by cracking open great numbers of them, and at some localities these nodules are very abundant.

Phosphatic deposits usually suggest segregation during a period of weathering and erosion. The base of the Devonian limestone section often contains considerable phosphatic material, more than is accounted for by the presence of the fish teeth and scales. In that case a period of erosion preceding the deposition of the Devonian limestone is easily credible, considering the distinct unconformity between the base of the Devonian limestone and the top of the underlying Silurian clays and limestones. But in the case of the phosphatic nodules at the base of the Waverly, such an unconformity has not been made out as yet.

From the phosphatic nodules at Junction City the following crustaceans have been described: *Ceratiocaris (Colpocaris) bradleyi*, *C. e1ytroides*, *Ceratiocaris (Solenocaris) strigata*, and *Archaeocaris vermiformis*; all by Meek.

FOSSILS OF THE DEVONIAN BLACK SHALES.

In the Report on the Geology of Lincoln County, published in 1882, Linney states that *Dadoxylon newberryi*, Dawson, part of the trunk of a large species of tree, is represented by many remains in a silicified condition, in Lincoln and neighboring

counties. In addition to this are mentioned *Discina, Lingula,* and other shells; fish remains, including spines of *Ctenacanthus.* The presence of *Lingula,* and *Discina* in the Black shales is mentioned again in his report on Garrard county. Linney notes the presence of *Dadoxylon newberryi,* Dawson, also in Clark county.

In the report on Clark county, published in 1884, Linney refers to a layer containing *Lepidodendron* in the Black shale series, along Copperas creek, near the junction of Clark and Powell counties. His statements on the stratigraphical position of this plant bed have been quoted in the immediately preceding part of this bulletin. In addition to *Lepidodendron,* as identified by Linney, this layer, several inches thick, contains also leaves eight to ten inches long, said by Linney to resemble our common flags. These plant remains occur in immense numbers. Above these layers, and in one instance also below, were scattered nodules in a very promiscuous manner. These consisted of accretions of fossils replaced by iron pyrites. Among these fossils the genera *Bellerophon* and *Orthoceras* were identified. Two feet farther up were found the remains of two individuals of a very large fish, imbedded in the Black shale. These remains were identified by Linney with *Dinichthys hertzeri,* Newberry, on the basis of two dorsomedian plates, nearly two feet in diameter, one of these more perfect than the plate figured by Newberry in the Ohio report. Another, much more massive bone, could not be identified. These fish remains are now the property of the Kentucky Geological Survey, and are exhibited in the Museum.

Dinichthys hertzeri occurs in the Huron shale, the lower part of the Black shale series of Ohio. *Dinichthvs terrelli,* the large plates of which were at first included under the name *Dinichthys hertzcri,* occurs in the upper part of the Cleveland shale, the upper part of the Black shale series of Ohio. In addition to *Dinichthys terrelli,* the Cleveland shale contains the smaller species, *Dinichthys intermedius, D. curtus,* and *D. goulai;* and still smaller species, *Dinichthys corrugatus* and *D. minor,* have been published. It is not known at present whether the large plates of fishes discovered by Linney on Copperas creek occur above or below the horizon containing interbedded layers of greenish clay, seventy-five to ninety feet above the

base of the Black shale series. These greenish clay layers were believed by Linney to be the southern representatives of the Erie shale or Chagrin formation. As far as known, nothing has been done since Linney's day either to corroborate or disprove Linney's views. Nor is it known whether, in the light of recent observations, the large plates identified by Linney as *Dinichthys hertzeri* would be identified as this species at present.

In the Paleozoic Fishes of North America, published in 1889, Professor Newberry states that he suspects that the large fish plates, from Copperas creek, judging from drawings sent by Morris Fischer, represent gigantic *Placoderms* as yet undescribed.

In the Paleontology of New York, volume VIII, published in 1892, Hall and Clarke figure *Schizobolus truncatus,* Hall, from the Black shale of Madison county, and an unnamed species of *Lingula* from the Black shale near Vanceburg, Kentucky. The Black shale is identified as of Genesee age.

In the American Journal of Science, Volume 3, Fourth series, published in 1897, Professor H. S. Williams states that at Irvine the deposition of the Black shale probably continued beyond the period at which Carboniferous faunas appear in other regions. An equivalent statement is made in Contributons to Devonian Paleontology for 1903, by Williams and Kindle, published in 1905. However, Professor Williams fails to state what these Carboniferous species at Irvine are, and precisely where in the section they occur. They are said to come from somewhere near the top of the Black shale series.

In Volume 6 of the American Journal of Science, published in 1898, George H. Girty refers the Black shale to the Genesee. The species which usually has been identified as *Lingula spatulata,* Vanuxem, in Kentucky, he describes as *Lingula (Lingulipora) williamsana,* Girty, but it is noticed that Williams and Kindle do not use this name in their reports. The following species are identified by Girty at the Oil Springs, a mile northeast of Indian Fields, on Lulbegrud neek:

Lingula (Lingulipora) uilliamsana, Girty.
Leiorhynchus quadricostatum, Vanuxem.
Prioniodus arenatus, Hinde.
Sporangites huronensis, Dawson?

From a locality two miles south west of Jeffersonville, in Montgomery county, he lists:

Lingula (Lingulipora) williamsana, Girty.
Orbiculoidea ?
Leiorhynchus quadricostatum, Vanuxem.
Meristella, resembling *M. haskinsi,* Hall.
? *Plethospira socialis,* Girty.
Sporangites huronensis, Dawson?

From the vicinity of Berea and Vanceburg *Lingula, (Lingulipora) williamsana* is identified.

In the Twenty-fifth Annual Report of the Indiana Geological Survey, published in 1901, E. M. Kindle refers the southern part of the Black shale to the Genesee. The following species are identified from southern Indiana and the adjacent part of Kentucky:

Leiorhynchus quadricostatum, Vanuxem.
Leiorhynchus limitare, Vanuxem.
Chonetes lepidus, Hall.
Lingula spatulata, Vanuxem.
Barroisella subspatulata, Meek and Worthen.
Schizobolus concentricus, Vanuxem.
Orbiculoidea lodiensis, Vanuxem.
Styliola fissurella, Hall.

In the northern part of the State a Portage fauna is recognized in the Black shale.

In the Contributions to Devonian Paleontology for 1903, Williams and Kindle list the following species from the Black shale of Brooks, fifteen miles south of Louisville:

Chonetes scitulus, Hall.
Lingula spatulata. Vanuxem.
Leiorhynchus cf. quadricostatum. Vanuxem.
Pleurotomaria sp.

The writer has not attempted to collect fossils from the Black shale. Incidentally, several specimens of *Orbiculoidea* and *Lingula spatulata* were noticed along the road following the railroad at Alum Springs. Here these species occurred

about fifteen feet above the level of the railroad. *Lingula spa'ulata* occurs also at the the works, at Searcy, near Moberly.

A study of the lists of fossils on the preceding pages indicates that the Devonian Black Shale of Kentucky unquestionably includes strata belonging to the Genesee formation. This is indicated especially by the presence of *Leiorhynchus quadricostatum, Schizobolus concentricus,* and *Lingula spatulata.* E. M. Kindle has shown that at Delphi, in northern Indiana, this Black shale includes also Portage or Nunda forms, especially *Spathiocaris emersoni.* Professor H. S. Williams has shown that in Virginia, at Hot Springs, the black shale sedimentation began as low as the Onondaga formation. Near Covington, in Virginia, he cites *Leiorhynchus limitare,* a Marcellus species, from the Black shale. In Ohio, Black shale sedimentation began with the base of the Delaware formation, where a series of thin fissile brownish shales, about six feet thick, makes its appearance. These brownish shales contain *Leiorhynchus limitare, Orbiculoidea lodiensis, Orbiculoidea minuta., Martinia maia, Tentaculites scalariforrnis,* and *Lingula manni.* They evidently belong to the Marcellus horizon. However, before conditions were favorable to the deposition of typical Devonian Black shales, changes in sedimentation occurred, and the limestones of the Delaware formation, of Hamilton age, and the greenish Olentangy shales, of unknown age, were deposited, so that in Ohio the first typical Black shale deposits appear to be of later than Hamilton age, corresponding thus to the Black shales of Indiana and Kentucky.

THE SILURIAN AND DEVONIAN OF SOUTHERN KENTUCKY, EAST OF THE CINCINNATI GEANTICLINE.

The Silurian is exposed also in southern Kentucky, along the Cumberland river, in Wayne county, at the mouths of Little Cub and Forbush creeks. At the mouth of Little Cub creek, the limestone at the base of the Silurian section is nineteen feet thick. The layer with *Whitfieldella subquadrata* and large crinoid beads occurs three and a half feet below the top of this limestone, and the underlying part is a typical development of the Brassfield bed. Overlying the limestone is greenish clayey shale, two and a half feet thick; clayey limestone, two feet thick; and an interval of nine feet, probably occupied entirely by green-

ish clayey shale. This part of the section corresponds to the attenuated lower part of the Crab Orchard division of the Silurian, as exposed west of Crab Orchard, toward Stanford.

A quarter of a mile above the mouth of Forbush creek, along a small stream entering from the north, the thickness of the limestone at the base of the Silurian section is fifteen and a half feet. The layer with large crinoid beads occurs twenty-one inches below the top. The underlying part corresponds to the Brassfield limestone. Nearer the mouth of the creek, back of the home of William Richardson, the layer with large crinoid beads contains also *Whitfieldella subquadrata.*

Silurian strata are exposed also in Pulaski county, about five miles directly west of Somerset, on both sides of Fishing creek. The exposures may be followed west of the creek, along a branch north of the home of V. L. Gossett. North of the bridge, the massive limestone at the base of the Silurian section is seven feet thick. Overlying this are distinctly bedded layers of limestone, forming a series ten feet thick. The top of this series of limestones is formed by a layer, one foot thick, containing *Whitfieldella subquadrata* and the large crinoid beads, in addition to *Calymmene vogdesi, Dalmanella elegantula*, and *Cyathophyllum caliculum.* The underlying limestone, sixteen feet thick, unquestionably belongs to the Brassfield horizon. The thickness of the overlying clayey beds belonging to the lower part of the Crab Orchard division of the Silurian, could not be determined, although clayey beds of Silurian age are exposed for a distance of fully a mile up the creek. Farther north, the Silurian is overlaid by Devonian limestone.

The most southern outcrops of Devonian limestone occur along the branch separating the farms of Mrs. Al Loval and Sol Jones. Here the limestone is three and a half inches thick and is overlaid by coarse sandy material, half an inch thick. About a quarter of a mile northward, along the Sulphur Spring branch, the Devonian is two feet nine inches thick; it consists, in descending order, of coarse sandstone, six inches; fine-grained bluish limestone, one foot nine inches thick; and brecciated rock, four to six inches thick. A mile and a half northward, just above the home of John Freeman, the Devonian limestone is four feet thick; most of it is white and crinoidal, containing Cyathophylloid corals and large *Spirifers.* A short distance

northward, just above the home of Taylor Brock, the Devonian limestone is twelve feet thick; at the top the rock is cherty; just beneath, it contains Cyathophylloid corals; near the base the rock, five and a half feet thick, is massive and fine-grained. A short distance northward, just below the mouth of Coldwater branch, the Devonian limestone is seventeen feet thick, consisting, in descending order, of brecciated brownish rock, nine inches thick; white limestone, one foot; thin limestone layers, two and a half feet; massive limestone, seven feet eight inches; cherty limestone, two feet six inches; and fine-grained limestone, three feet. The Devonian limestone was traced three miles above the mouth of Coldwater branch; it is said, by people in the neighborhood, to occur in the vicinity of Adam's mill, two miles farther north.

A small number of fossils collected from this limestone was lost during transportation. These included several species of *Spirifer, Stropheodonta, Atrypa reticularis,* cyathophylloid corals and other fossils. Of these, only one specimen, closely related to *Amphigenia elongata,* is at hand. This was found in the neighborhood of the Sulphur Spring locality. The cast of the spondylium is shown distinctly. *Spirifer acuminatus* also occurs. These fossils indicate the presence here of strata equivalent to the Onondaga limestone of New York. The large number of corals and abundance of chert, at several localities, suggest the possibility of a southward extension of the Devonian limestone fauna seen in central Kentucky, and, farther north, in the Jeffersonville limestone, at Louisville, Kentucky.

THE SILURIAN-DEVONIAN UNCONFORMITY.

In east-central Kentucky, the Silurian formations thin out westward toward the Cincinnati geanticline and are overlaid unconformably by the Devonian formations, Along the crest of the geanticline, in Casey and Boyle counties, the Richmond division of the Cincinnatian series also is absent, and here the Devonian rests upon the upper part of the Maysville (Lorraine) division of the Cincinnatian.

North of Crab Orchard the Devonian rests upon at least seventy-five feet of clay belonging to that part of the Alger clay which overlies the massive limestone layer (marked C on

Plate A, page 64) a short distance above its base. If our interpretation of this part of the section be correct, the clay above this massive limestone layer corresponds to the Estill clay, and to the Waco formation, which here is nearly unfossiliferous and is represented only by clay. About two and a half miles west of Crab Orchard, along the pike to Stanford, the thickness of the clay above the massive limestone layer is sixty-six feet. About two and a half miles southwest of Crab Orchard, south of the county road, the thickness is at least fifty feet, but no accurate measurements are at hand. Three miles southwest of Crab Orchard, the thickness of this clay is thirty-five feet. About three quarters of a mile farther west, the thickness is twenty feet. A short distance farther west, at the home of Williall Pleasants, the thickness is eleven feet. Four and a quarter miles west of Crab Orchard station, the thickness of the clay is seven and a half feet. Half a mile farther west the Devonian limestone rests directly upon the massive limestone layer in the lower part of the Alger division of the Silurian. In this distance the Devonian limestone has been thinning irregularly from nineteen feet, west of Crab Orchard station, to about three or four feet at the exposure last mentioned. A short distance farther west, at the home of James Thomas Bailey, the red clay resulting from the decay of the Devonian limestone is only one foot thick, and it rests upon strata nearly ten feet below the level of the massive limestone layer, within two and a half feet of the Whitfieldella layer at the base of the Crab Orchard division of the Silurian, of which the Alger clays and limestones form the upper part.

Farther west, the Devonian limestone is absent, and here the Devonian Black shale rests directly upon the Brassfield limestone, the lowest Silurian formation in this part of the State. Of this Brassfield formation only the lower and middle part, eight feet five inches thick, remain. The upper part, including the layer with large crinoid beads, is absent. Farther west the Devonian limestone is present again, but rests upon Ordovician strata. It is possible that the absence of Devonian limestone south of Stanford, near Neal creek church, is due to the fact that, during the deposition of the Devonian limestone, the Brassfield limestone in this area projected so far above the level of the surrounding Silurian and Ordovician strata as to

be more strongly exposed to wave action or to tidal currents, and hence remained clear of Devonian deposits. Owing to its hardness, and the comparatively small quantity of interbedded clay, the Brassfield limestone would resist weathering and erosion better than the underlying part of the Ordovician and the overlying Silurian strata. Observations favoring this view are noted also at other localities in Kentucky.

As already stated, north of Crab Orchard the Devonian limestone rests on at least seventy-five feet of that part of the Alger clay which overlies the massive layer of limestone. Nine miles north of Crab Orchard, near the home of James M. Anderson, the thickness of this clay is only twenty-two feet. The Devonian limestone lies directly above. The Silurian strata, probably once extended beneath the Devonian cover as far as Lancaster, but at present no exposures in that direction remain.

Along the pike between Crab Orchard and Stanford, exposures of the Devonian limestone are rather poor, but three miles east of Stanford, Devonian limestone waste occurs in considerable abundance within a short distance of the top of the Brassfield bed, suggesting the continuation of the features already described, from the area south of the Louisville & Nashville Railroad, as far north as Stanford, and probably as far north as Lancaster.

Northeast of Crab Orchard, toward Hammack, the Silurian-Devonian unconformity is also in evidence. The clay above the massive limestone layer in the Alger formation is at least seventy-five feet thick north of Crab Orchard. Along the headwaters of Harmon creek, it is thirty-seven feet, thick. Near Hammack it varies between fifteen and twenty feet. The Devonian limestone lies directly above. It is probable that if more were known of the thickness of the Silurian formations where they now are under cover, in the northwestern part of Rockcastle county, it would be evident that the thinning of the Silurian formations here is toward the northwest rather than toward the northeast. Along Fall Lick creek, for instance, northeast of Crab Orchard, the thickness of the clay above the massive limestone layer is known to be much greater than at the head of Harmon creek.

Along the line between Garrard and Madison county, the evidence is less striking. Along Rocky branch, the base of the

Devonian limestone is thirty-four feet above the top of the Brassfield limestone, with its layer of large crinoid beads; the Devonian here rests upon a massive layer of limestone. About a mile northwestward the interval is only 22 feet, and a mile and a half northward it is thirty-five feet, no allowance being made for the dip of the rock.

Along the railroad, north of Berea, the Silurian-Devonian unconformity is well shown. Less than three miles north of Berea, the Devonian limestone appears to rest directly upon the massive limestone at the base of the Waco division of the Alger formation. The layer with large crinoid beads at the top of the Brassfield bed is found thirty-one feet below the Devonian. Half a mile south of Whites, the Devonian rests directly upon some of the layers of the Oldham limestone, containing *Stricklandinia norwoodi,* and the layer with large crinoid beads is found only twelve feet below the Devonian. At the same time, the Devonian limestone, which is thirteen and a half feet thick north of Berea, is reduced to three inches near Whites, being represented by the fish layer. Here again the Brassfield bed may have risen above the level of the upper Ordovician and the overlying Silurian strata during the deposition of the Devonian limestones in the neighboring parts of this section of Kentucky, producing features resembling those described from the vicinity of Neal's creek church, south of Stanford.

Evidences of the presence of the Silurian-Devonian unconformity appear also southeast of Bobtown. At Mat Moody's store, two miles and a quarter southeast of Bobtown, the Devonian limestone occurs about forty-eight feet above the base of the Brassfield bed. A mile farther northward, this interval is about thirty-six feet. Near the Mat Moody store the thickness of the Devonian limestone is at least three feet. A mile northward it is nine inches, and here the Devonian limestone is represented by the fish layer and rests upon clay.

In the greater part of the area between Whites and the exposures three miles east of Bobtown, the Devonian limestone does not exceed twelve inches in thickness and does not rest on the Brassfield limestone. In this area some of the minor limestone layers, such as the layer at the base of the Waco horizon, may have resisted erosion sufficiently to keep this part of

the field at a higher level during the deposition of the Devonian limestone.

Evidences of the Silurian-Devonian unconformity are seen along the railroad between Irvine and Brassfield. North of Irvine the Devonian limestone rests upon the Estill clay, sixty feet thick. East of Panola, about a quarter of a mile, the Estill clay is well exposed for a thickness of about forty-five feet, but the Devonian limestone is not seen at the point where this measurement was made. At Brassfield (Fig. 8) along the railroad cut, the Devonian limestone rests upon clay, fifteen feet thick. The horizon of the top of the Lulbegrud clay at Brassfield is fully seventy-two feet below the level of the top of the Estill clay at Irvine, and at least fifty-six feet below the top of the Estill clay at Panola. It is evident that the greatest unconformity is shown between Brassfield and Panola, and much less between Panola and Irvine. No explanation for this fact has been discovered.

Between Elliston, Waco, Cobb Ferry, College Hill, and the exposures three miles north of College Hill, the degree of unconformity is relatively very small, although considerable differences in the thicknesses of the Devonian limestone exposures are noticed.

Apparently there is a strong Silurian-Devonian unconformity in the area between Vienna and Merritts and Rightangle. South of Vienna the Devonian limestone rests upon some part of the Estill clay, and the massive limestone at the base of the Waco horizon is poorly exposed along the road north of Vienna. A mile north of Merritt, near the Old Simpson Brock place, the Devonian rests apparently, in case there is no fault, on the Oldham limestone. Northeast of Arlen, the Devonian, if not brought near the Brassfield bed by a fault, must be within a short distance of the top of the latter.

North of Vienna, along the road from Vienna to Indian Fields, the massive limestone layer at the base of the Waco horizon, and also at least the base of the Estill clay are exposed. Between Log Lick church and the home of J. T. Elkins, the base of the Devonian limestone practically rests on the massive limestone at the base of the Waco horizon. A quarter of a mile south of Indian Fields, the lower part of the Estill clay, about twelve feet thick, is exposed beneath the Devonian lime-

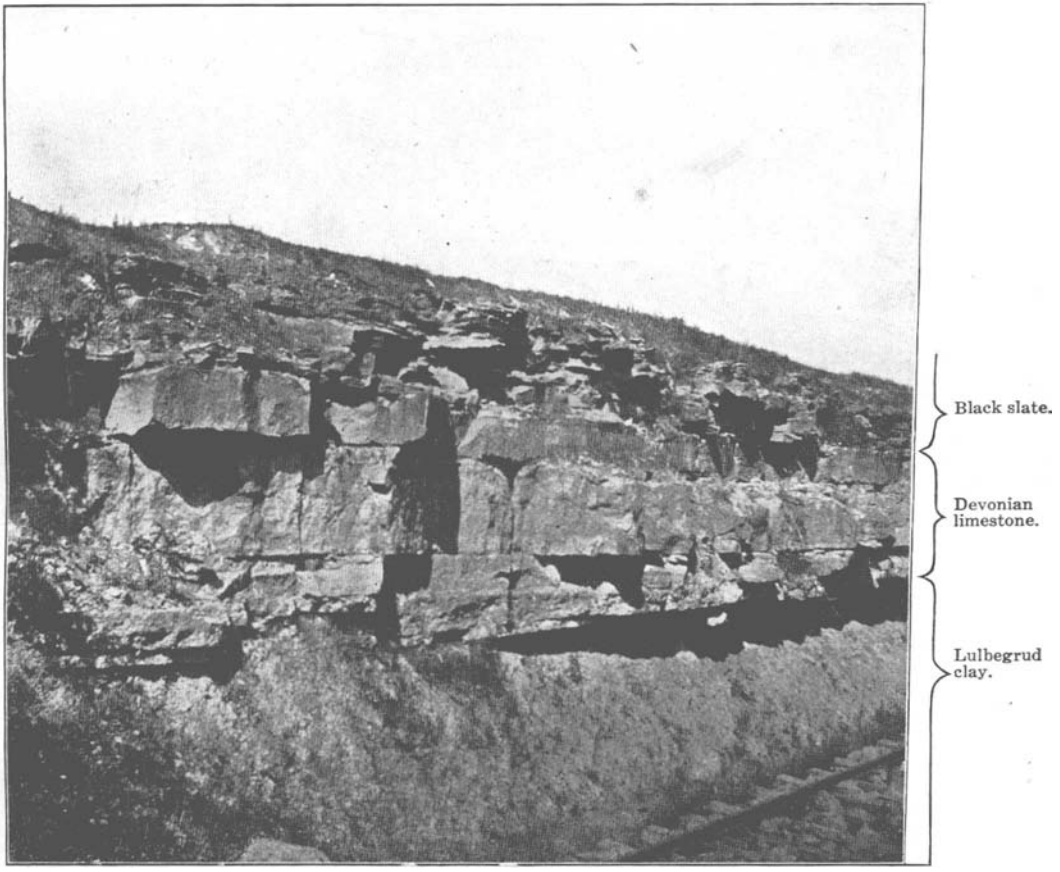


Fig. 8. Contact between Estill Clay and Devonian limestone at Brassfield, along the Louisville and Atlantic R. R.

stone. At the great clay pit along the railroad northwest of Indian Fields, this interval is seven feet. Along the railroad between Virden and Clay City (Fig. 9), the Devonian rests on the Waco bed or upon only a very small part of the Estill clay section. Between Tipton ferry and the Plum creek exposures, the Devonian rests upon the lower part of the Estill clay, only eight or nine feet thick. Comparing these sections with those found farther south, the degree of unconformity between the Silurian and Devonian is relatively slight.

There is evidently a remarkable thinning of the Estill clay between Irvine and Clay City. At Irvine, the Devonian limestone rests upon Estill clay at least sixty feet thick. Along the railroad west of Clay City this interval is reduced to less than ten feet, and at some localities can not exceed two or three feet.

There can be no doubt of a Silurian-Devonian unconformity between Indian Fields and Jeffersonville. At Indian Fields, the base of the Devonian is about fifty feet above the layer containing large crinoid beads, at the top of the Brassfield limestone. A mile southwest of Jeffersonville, this interval is seventeen feet. Half a mile northwest of Jeffersonville, the same interval is shown. At Indian Fields the Devonian limestone rests upon the lower part of the Estill clay, seven to twelve feet thick. Near Jeffersonville the Devonian rests upon strata probably equivalent to the Oldham limestone.

A greater degree of unconformity is shown between Spencer and Jeffersonville. East of Spencer, west of Slate creek bridge, the interval between the Devonian limestone and the layer with large crinoid beads at the top of the Brassfield limestone is sixty-two feet. East of the creek this interval is thirty-six feet. No account is taken in either case of the dip. Near Jeffersonville, this interval is seventeen feet. Two miles southwest of Preston the interval is seventy-five feet, and it is known to exceed sixty feet considerably directly south of Preston, about a mile. The records from the oil wells in the Ragland field indicate intervals of at least 160 feet between the Devonian limestone and the top of the Brassfield bed. At Owingsville the base of the Brassfield limestone is 100 feet below the center of the town; the waste of the Devonian limestone occurs practically in place in the northern part of the town, along the road

to Wyoming. The dip is eastward. The total thickness of the Silurian section is believed not to exceed 100 feet. There is evidence of a thinning of the Silurian section from the Ragland field toward Owingsville.

The well record from the Jack Barnett farm, in Menefee county, suggests the presence of at least 153 feet of Silurian clay. No exposures comparable with this are known in Montgomery county.

The thinning of the Silurian section, in east-central Kentucky, toward the west and northwest is evident, notwithstanding great irregularities in the rate and direction of this thinning. All the evidence so far collected in the field indicates that by far the greater part of the thinning of the Silurian section can not be due to the thinning of the individual members of the various Silurian formations, but must be due to the successive disappearance of the uppermost members of the various formations as these are traced westward or northwestward.

Two theories may be suggested to account for this: One of these assumes that the Silurian sections as seen at present are essentially the Silurian sections as originally deposited. The other assumes that formerly much greater thicknesses of Silurian rocks were present, especially toward, and possibly across, the crest of a great part, or of all of the Cincinnati geanticline, but that extensive erosion removed the upper part of these various Silurian sections, especially toward and along the crest of the geanticline, during the period preceding the deposition of the Devonian limestones of this area, which were deposited in Middle Devonian or Onondaga times.

Both theories assume the gradual elevation of Ordovician and Silurian strata in times preceding the deposition of the Middle Devonian. The first theory assumes that the elevation of the Cincinnati geanticline began in early Silurian, and possibly even in Ordovician times. The second assumes that the elevation resulting in the thinning of the Silurian sections began late in Silurian times, possibly even after the deposition of the latest Silurian strata still preserved in this part of the field.

According to the first theory, illustrated by Fig. 2, on Plate B, the elevation of the Cincinnati geanticline continued throughout the deposition of the Silurian. The Brassfield limestone,

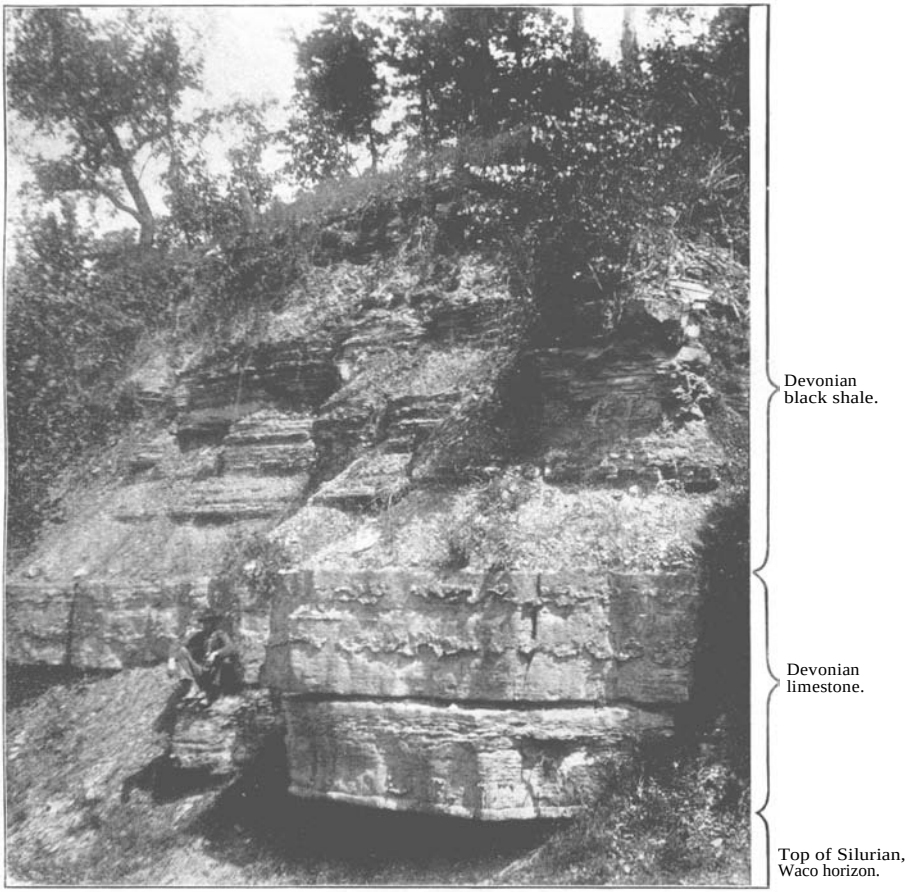


Fig. 9. Devonian limestone, opposite the home of Green McDowell, west of Clay City, on the Lexington and Eastern Railroad, Powell County.

being deposited before the elevation of the geanticline had progressed far, extended farthest up the flanks of the geanticline. The Indian Fields formation, being deposited later, after the geanticline had attained a greater elevation, did not extend as

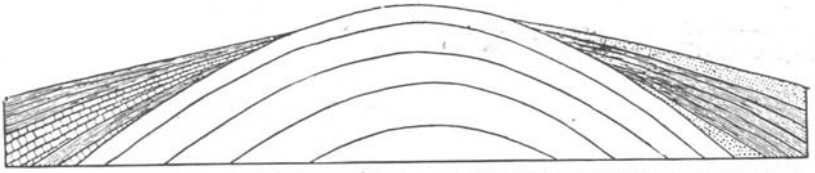


FIG 1. OVERLAPPING EDGES OF STRATA ON FLANKS OF SINKING ANTICLINE.

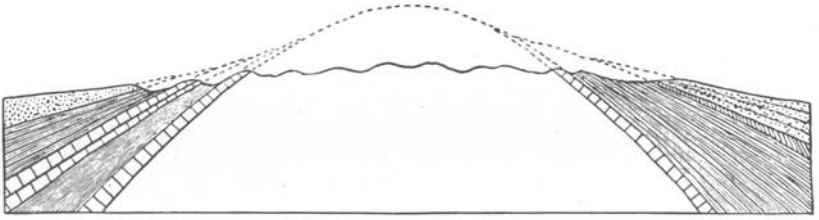


FIG 2. ATTENUATED EDGES OF STRATA ON FLANKS OF RISING ANTICLINE

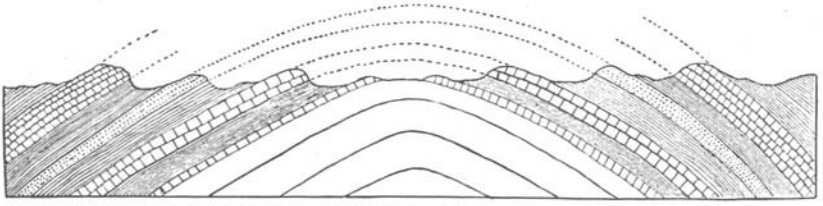


FIG 3. RISE OF ANTICLINE SUBSEQUENT TO DEPOSITION OF STRATA.

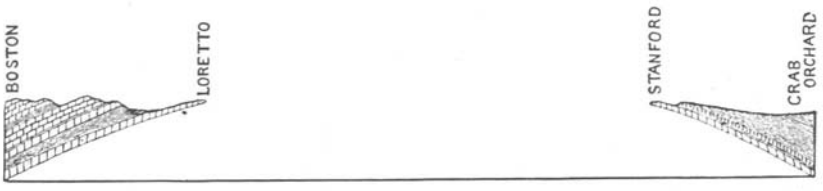


FIG 4. DIAGRAMMATIC SECTION OF SILURIAN STRATA IN CENTRAL KENTUCKY

Plate B. Illustrating various conditions resulting from the formation of geanticlines.

far toward the crest of the geanticline as the Brassfield limestone. By the time that the deposition of the Lulbegrud clay began, the elevation of the geanticline had increased so much that the Lulbegrud clay did not cover that part of the Indian Fields formation which lay nearest the crest. The elevation continued, so that the Waco deposits, where they can be recognized, do not extend as far up the flank of the geanticline as the Lulbegrud clay. Further elevation excluded the Estill clay from any but the more remote parts of the flanks of the geanticline. The thickest deposits of Estill clay are found farthest from the crest. This period of elevation was followed by a lowering of the area affected by the Cincinnati geanticline in east-central Kentucky. During this period of depression, the Devonian limestones extended across the edges of all the Silurian deposits as far as the Richmond and Maysville (Lorraine) areas along the crest of the geanticline. In support of this view of the continual elevation of the geanticline during Silurian times may be adduced the fact that no Silurian formation is known to extend farther up the flank of the geanticline than any of the preceding formations. There is no evidence of overlap preceding Devonian times, although there is some evidence of the thinning of certain Silurian formations toward the crest of the geanticline.

According to the second theory, illustrated by Fig. 3 on Plate B, the reason why there is no overlap of Silurian formation on approaching the crest of the Cincinnati geanticline is because there was no elevation of the Cincinnati geanticline of any considerable proportions either in existence or in progress during Silurian times. Hence, Silurian strata were deposited in succession over a wide area covering the region now affected by the Cincinnati geanticline. The absence, at present, of Silurian strata over the more elevated parts of the Cincinnati geanticline is to be accounted for not by assuming that these strata never had been deposited where now they are absent, but by assuming that Silurian strata once were present, but were removed in later times, after the elevation of the Cincinnati geanticline, by weathering and erosion. The elevation of the geanticline in late Silurian and early Devonian times is assumed to have raised these former Silurian deposits which were along the crest of the geanticline into regions where waves

and currents were most effective, and possibly even where atmospheric agencies would assist in their removal. The result of €erosion and weathering is assumed to have reduced a great part of the more elevated regions of the Cincinnati geanticline to the condition of comparatively flat country, but little elevated above the sea. Such a condition usually is spoken of as a base-level, and the topography produced by the same as a peneplain. The result of this removal of strata from the crest of the Cincinnati geanticline in late Silurian and early Devonian times was the exposure of only the older layers along the crest of the geanticline, and the outcropping of successively younger layers on passing from the crest of the geanticline outward toward its flanks. Subsequent erosion, not failure of deposition, is assumed to account for the absence of Silurian strata along the crest of the Cincinnati geanticline. Reduction of the upper part of the geanticline to a peneplain, and not progressive elevation of the geanticline during the period of deposition of Silurian strata, is assumed to account for the apparently more restricted areas of deposition in the case of each of the successively later Silurian formations. The depression of this peneplain during Middle Devonian times permitted the deposition of the Devonian limestones (Onondaga) of Kentucky.

According to the first theory, those parts of the Silurian formations of east-central Kentucky which lie farthest west, nearest the crest of the Cincinnati geanticline, are, therefore, nearest the shoreline, as it existed during the deposition of this particular formation. According to the second theory, there was no shore line along the flanks of the Cincinnati geanticline, since this geanticline is assumed not to have been sufficiently developed as yet to give rise to dry land and a shore line. According to the first theory, evidences of proximity to the shore should be sought along lines of outcrops nearest the crest, and these evidences should become less pronounced, and should finally disappear on going from the crest toward the flanks of the geanticline. According to the second theory such evidence should not be at hand. According to the first theory, the Silurian faunas on the two sides of the Cincinnati geanticline might have developed distinct features, notwithstanding the connection of these areas farther north, in Ohio and Indiana. According to the second theory, the faunas on the two sides of

the Cincinnati geanticline should not differ more than faunas equally distant in areas more directly connected.

Both theories assume conditions of weathering and erosion in times preceding the deposition of the Devonian limestones. According to the first theory, this erosion began in early Silurian times, or even during the Ordovician. The second theory assumes that the erosion began in late Silurian times.

According to the first theory, the lithological character of the deposits on the opposite sides of the geanticline might be expected to show greater differences (See figures 1 and 2, all plate B), perhaps, than if the conditions predicated by the second theory prevailed.

Very little evidence in favor of either theory has been discovered so far.

Pebbles and wave-marks have been discovered in some Silurian strata, especially in the Brassfield limestone and in immediately overlying strata, but it has not been shown that these occur in the beds nearest the crest of the geanticline and are absent at greater distances. Cross-bedded layers are known, especially in the Brassfield limestone, but it has not been shown that these are best developed nearest the crest of the geanticline. No distribution of species of fossils has been discovered suggesting the presence of shore conditions in those parts of the Silurian deposits of east-central Kentucky which are exposed farthest west. At no point is any Silurian formation known to be resting upon the eroded surface of earlier strata, filling up an earlier water channel, butting up against the side of a cliff, or presenting any other evidence of distinct unconformity. In general, it may be said that evidences favoring shore condition, so far collected, do not serve to determine the location or direction these shares, nor are these evidences of such a character as to demand the presence of any elevation of land following the same general direction as that now taken by the geanticline.

The lithological characteristics of the strata east and west of the geanticline present not only certain differences, but also certain strikingly similar features. If the Alger formation of east-central Kentucky corresponds to the main body of Osgood clay in the west-central part of the State, and if the Brassfield bed corresponds to the so-called Clinton limestone of that part

of the State, it is evident that the Plum creek clay and the Oldham limestone of east-central Kentucky can be represented on the western side of the geanticline only by the layers of limestone at the base of the Osgood clays. The latter rarely present a thickness of more than two feet. At the most eastern exposure known, about six miles east of Bardstown, along the railroad, a mile and a half east of Woodlawn station, formerly known as Gasburg, thin limestones interbedded with clay, forming a section four feet thick, occur at the base of the Osgood clay section, overlying the so-called Clinton. This may represent the western extension of the Indian Fields formation, this being the formation which includes the Plum creek clay and Oldham limestone, as already mentioned.

Both the Alger clay and the Crab Orchard clay present their thickest sections farther south, in east-central and west-central Kentucky. Northward, in Ohio and Indiana, these clays are represented by thinner sections, and, before reaching Dayton, Ohio, and Richmond, Indiana, become not only much thinner, but also are largely replaced by argillaceous limestones. These facts favor the view that the Silurian areas east and west of the geanticline were connected at least during the deposition of these clays, although this connection may have been only across central Kentucky, through Boyle and Marion counties. The evidence is very inconc1usive.

The fossils found in the Brassfield limestone, east of the geanticline, and those found in the so-called Clinton limestone, west of the geanticline, are merely a meagre representation of the so-called Clinton fauna of Ohio and Indiana, and show no differences suggesting their development in different basins.

The abundant Whitfieldellas in the sandy limestone layer, immediately above the top of the Brassfield limestone of eastern Kentucky are unknown west of the Cincinnati geanticline, in Kentucky, although related forms are found in the Osgood bed in Ripley county, Indiana.

The Stricklandinia found near the top of the Oldham limestone is not known west of the geanticline, but specimens of Stricklandinia of a somewhat smaller species are found at the top of the limestones beneath the Osgood clay about six and a half miles southwest of Bardstown, and occur also at several localities in western Tennessee. Of the other fossils found

in the Oldham limestone comparatively little is known, at present, but it may prove that this fauna will show closer relationship with the Brassfield fauna than with the Waco fauna, and that the Oldham fauna will find representatives in the upper part of the so-called Clinton in western Kentucky, which is represented by the white limestones in Nelson and Marion counties, especially in the neighborhood of Bardstown. This white limestone differs considerably in appearance from the salmon brown limestone characteristic of the Clinton in northern Kentucky, and the adjacent parts of Indiana, and may represent a somewhat higher horizon.

The Waco fauna is different from anything known in the Osgood formation, either in western Kentucky or Indiana. It may have formed in a different basin from the latter. The Cincinnati geanticline may already have developed sufficiently during the deposition of the Waco bed to make it possible for a fauna to develop in eastern Kentucky quite distinct from the faunas of western Kentucky, but the evidence does not point to this conclusion necessarily. The Brassfield deposits of eastern Kentucky and Ohio are represented only in part farther west, in southeastern Indiana and the adjacent parts of western Kentucky. It may be that the Osgood formation, west of the Cincinnati geanticline, in a similar manner represents only a part of the Crab Orchard division of the Silurian farther east. It may be attenuation of formations toward the west, in times preceding the formation of the geanticline, attended with omission of part of the series farther westward, rather than the development of distinct faunas in separate basins, on opposite sides of the geanticline, which will prove the explanation of the few facts known so far.

In general, it may be stated that the study of faunas along the Cincinnati geanticline has not progressed sufficiently as yet to determine the things we most would like to know. Of course, speculation on this subject is to be expected, but it is worth while to remember that the number of facts upon which these speculations must be based is still very small.

While there is no doubt of the existence of the Cincinnati geanticline in pre-Onondaga times, preceding the deposition of the Devonian limestones of this area, the Silurian, Cincinnatian, or even earlier origin of this geanticline requires further investi-

gation. Such an early origin may be probable, but probability must not be confounded with proof and fact.

THE DEVONIAN LIMESONE-BLACK SHALE UNCONFORMITY.

In the Report of Progress of the Ohio Geoliogical Survey for 1870, Professor Orton publishes the following very interesting facts:

At Delaware and northward, the Ohio Black shale rests upon a thin belt of shale, at that time identified as the Hamilton, but now known as the Olentangy shale. In Franklin county, of which Columbus is the county seat, the Black shale rests upon the Corniferous limestone, now known as the Delaware and Columbus limestones. In Ross county, in which Greenfield is located, the Black shale rests upon the Greenfield limestone, referred at present to the Monroe formation. In Highland county, the Black shale rests upon the Niagara formation, the highest member of which in this county is called the Hillsboro sandstone. There is a very evident unconformity between the base of the Devonian Black shale and the underlying Devonian and Silurian formations. The absence of the Monroe formation west of the Cincinnati geanticline requires explanation.

In a paper on the Devonian and Lower Carboniferous faunas of southern Indiana and central Kentucky, E. M. Kindle shows a striking unconformity between the base of the Black shale and the Devonian (Jeffersonville) limestone at Brooks run, in Bullitt county, Kentucky, fifteen miles south of Louisville. Erosion preceding the deposition of the Black shale had produced gullies, in the top of the limestone, fully ten to twelve feet deep. Another very marked unconformity was discovered a quarter of a mile south of Huber, in the same county. Here the Black shale rests on the Sellersburg division of the Devonian limestone. It is probable that further observations will result in the discovery of similar evidences of unconformity elsewhere in the field.

In this connection attention should be called to the fact that, in several areas in Kentucky, the Devonian limestone is entirely absent. This is the case, for instance, in part of the area between Bardstown and New Haven, between New Haven and Raywick, between Raywick and Loretto, south of Stanford east of Neals creek church, for at least five miles north and

northeast of Liberty, everywhere along the Cumberland river west of Fishing creek. These localities are all along the more elevated parts of the Cincinnati geanticline in that part of its extent where the Black shale is still preserved, and the absence of the Devonian limestone here is undoubtedly connected with the elevation of the geanticline.

A similar absence of Devonian limestones is noted in the area between the southeastern corner of Fleming county, in Kentucky, and Pickaway county, in Ohio. This has led to the belief that, in times preceding the deposition of the Black shale, a subsidiary anticline passed northeastward across this part of the country, the crest crossing the Ohio river some where in the neighborhood of Vanceburg.

Where the Devonian limestone is reduced to a very thin layer, often less than one foot in thickness, between Whites and the exposures three miles east of Bobtown, it is noticed that the layer containing fish teeth and plates still remains. Similar features are noticed elsewhere, for instance a quarter of a mile south of Indian Fields, where only a thin exposure of Devonian limestone occurs. This fact has suggested that in some areas it may be the upper, rather than the lower part of the Devonian limestone section which may be absent, again suggesting an unconformity. The fact that rocks equivalent to the Delaware limestone and to the Olentangy shale appear to be absent would lead to similar conclusions.

The presence of a thin strip of Black shale below the brown rock regarded as equivalent to the Duffin layer, which has been noted at several localities, suggests that in some areas the deposition of the Black shale may have begun earlier than in others.

THE LEXINGTON PENEPLAIN.

In discussing the topography of that part of Kentucky which lies within twenty miles of Richmond, Marius R. Campbell makes the following statements:

The most striking topographic feature of this area is the great plain of central Kentucky, which shows to excellent advantage at Winchester, Richmond, and Berea, and which is named the Lexington peneplain from the city of Lexington. When viewed from a single locality the apparent parallelism between the surface of this plain and the bedding of the rocks

suggests that it was formed by the erosion of soft beds down to the surface of a more resistant stratum, but when a large area is examined it is found that this plain truncates the Cincinnati geanticline, causing different beds of rock to form the surface in different portions of the plain. In view of this fact it is not possible to ascribe the formation of this topographic feature to the influence of hard beds of rock, or to the geologic structure. There are two methods by which this plain may have been produced: either by the shore action of the waves of a large body of water, or by subaerial erosion of the land to base-level. If this feature was produced by waves, central Kentucky must have been beneath the water of the ocean at some time since the Paleozoic era, later than the time of deposition of Carboniferous or Pennsylvanian strata. If the sea covered this territory, there must have been sediments deposited on its surface; but no such material has ever been discovered: therefore this cause seems not to have operated to produce the plain in question. Subaerial erosion on the land surface which is free from movement will produce such a feature if time enough is allowed for the approximate reduction of the surface to base level. The surface resulting from such conditions will be almost a plain—a peneplain. This hypothesis is in accord with the facts in central Kentucky, so far as known, and consequently this feature will be regarded as of subaerial origin, and it will be referred to as the Lexington peneplain.

The hills which rise above the Lexington peneplain have a fairly constant altitude of about 1,500 feet above sea level. They have generally round or sharp tops, which give no suggestion of a, higher plain; but the regularity of altitude, despite the variation of the underlying rocks, is strong evidence of the former existence of a peneplain at this level, which has been so completely dissected by later erosion that no trace of its surface remains to mark its exact position.

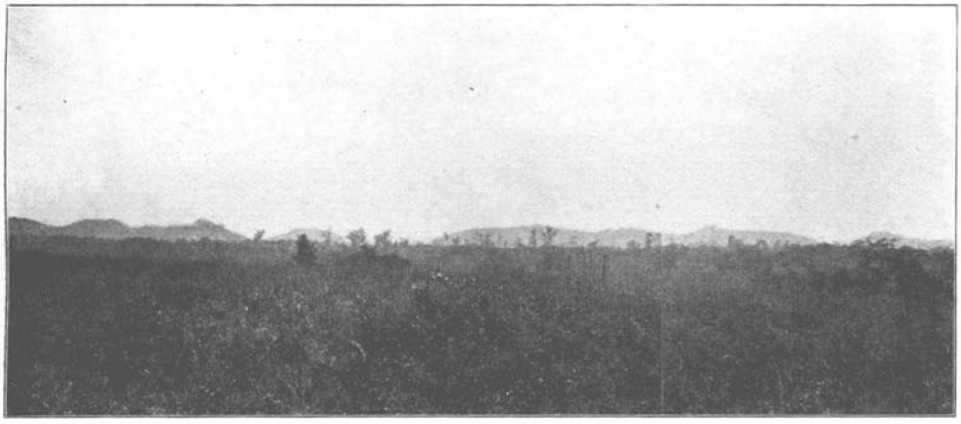
The valleys which are cut below the surface of the Lexington peneplain are complex in character and show that they are the result of two episodes of erosion. When viewed upon the ground it is apparent that there is a long, gentle slope from the surface of the Lexington peneplain leading down to the brink of steep walls which bound the inner valley of the river. The gentle slopes constitute the sides of an older valley, which

was broad. The narrow modern gorge of the Kentucky river has been cut within it.

Upon the floor of the older valley occur deposits of sand and clay which were laid down by the river when it occupied this valley, before the inner gorge was cut out. In order that such widespread deposition should have taken place, the streams must have had moderate fall and have been unable to carry farther the load of sand and mud which they carried with ease in the narrow, upper valley in the Coal Measure plateau. The sediments were laid down in a sort of delta deposit across the entire width of the old valley; they are now found only on the tops of the river hills which mark the surface of the intermediate valley.

No direct evidence has been found in the area under investigation, within twenty miles of Richmond, of the dates of the peneplains or of their allied surface features. The Lexington peneplain and the one 500 feet above it are continuous with similar features throughout the southern portion of the Ohio Basin and the Gulf slope, and it is to these distant portions of the province that we must look for evidence regarding their dates. The higher peneplain can be traced continuously southward to the margin of the Cretaceous sediments of the Gulf coast; it is also a part of the great peneplain which shows over most of the Appalachian province, and which is generally referred to the Cretaceous period. It is obviously very old, and since all of the evidence available agrees with the foregoing statement, it will be accepted as provisionally correct.

The Lexington peneplain is commonly regarded as of post-Cretaceous age, but the period has not yet been satisfactorily determined. The only definite theory yet advanced regarding its age makes its age contemporaneous with the Eocene limestone of the Gulf slope. This has been advocated only as a working hypothesis, but so far as known it is in harmony with the facts found in this region, and will be accepted provisionally. On the assumption that the Lexington plain is of Eocene age, the intermediate valley and the deposits connected with it would presumably be referred to the next succeeding period, the Neocene, and the inner gorge to the remaining portion of the Neocene and the Pleistocene. This determination must be accepted as merely provisional, and subject to change when more direct evidence becomes available.



-Lexington **peneplain.**

Fig. 10. Knobs and hills rising above the Lexington peneplain. View looking from the road east of Brassfield southward across the peneplain. Estill and Madison Counties.

The preceding observations by M. R. Campbell, quoted with few alterations, are so interesting that they have been given in full. The Lexington peneplain covers the great central limestone area of Kentucky. The Black shale and Waverly knobs surround the Lexington peneplain, and form the advance guard of the remnants of the earlier, Cretaceous peneplain. The difference in elevation often is striking. The sharp contrast between level of the strata forming the surface of the Lexington peneplain and the tops of the knobs beyond is well shown by a view from the road northeast of Kiddville, southeastward; also, from the great clay pit half a mile west of Indian Fields, northeastward, and toward the southeast; from the road several miles north of College hill, eastward; from the road a short distance east of Brassfield, southward (Fig. 10).

THE IRVINE FORMATION.

Marius R. Campbell gives the following description of the Irvine formation:*

"The Irvine formation consists of unconsolidated sand, gravel, and clay, which originally covered the intermediate valley of the Kentucky river near the eastern edge of the Richmond quadrangle, the area within twenty miles of Richmond, but which are now found capping the river hills—the few remnants of what was once an extensive and continuous surface. It is named from the town of Irvine, which is located on the Kentucky river, twenty miles southeast of Richmond. No fossils have been found in these sands by which to ascertain their position in the geologic time scale, so that we are forced to fix their age by their relation to the topography of the region. Unfortunately, the dates of the principal topographic features have not been accurately determined, and that of the Irvine formation can be stated only provisionally, but its close connection with the Lexington peneplain certainly indicates that it is much older than the Pleistocene period. Since the sand occurs on the floor of the intermediate valley of the Kentucky river, and is dissected by the erosion which produced the gorge of that stream, it must have been deposited in the period that intervened between the cutting of the intermediate valley and the cutting of the gorge. The geologic period in which the intermediate valley was eroded has not been determined with

*Richmond, Ky., Folio, U. S. Geological Survey. 1898.

certainty, but since it is cut only a slight distance below the surface of the Lexington peneplain, and to only a moderate breadth, it must have been formed soon after the peneplain was raised above sea-level. The age of this peneplain has been provisionally accepted as Eocene, and that of the intermediate valley as Neocene; hence the deposits lying upon the floor of the intermediate valley must have been laid down after the valley was cut, or presumably in the dosing stages of the Neocene period."

On the geological map which accompanies the Richmond folio, published in 1898, Mr. Campbell indicates certain areas between Brassfield, Irvine, and the Kentucky river as containing strata of Irvine age. A study of the areas delineated as underlaid by the Irvine formation between Portwood, or Bybeetown, and Cobb ferry, northeast of Waco, and near College Hill, indicates that the Irvine formation here is the source of the clays from which the pottery-ware, which is manufactured at Waco and Bybeetown, is constructed. Extensive private surveys by the Searcy Roof-tiling Manufacturing Company have demonstrated the presence of these clays over wide areas in the territory indicated. Extensive sandy beds, as well as more limited pure, plastic clays, occur. These deposits rest on the eroded surface of the Devonian Black shale. The deposits at Irvine also rest upon these shales.

Exposures of the Irvine formation are much more extensive than indicated on this map. They occur at numerous points above the 800-foot contour line in the area between Waco, Irvine, Clay City, and Indian Fields, always resting on the Devonian Black shale. An excellent exposure forms the top of the ridge east of Long branch, six miles south of Indian Fields. At the great clay pit along the railroad west of Indian Fields, the thickness of Irvine clay varies from two to five feet. It is very sandy and contains pebbles. Along the road from Indian Fields to the Oil Spring, and, again, south of the home of John Goff, Irvine deposits rest upon the phosphatic nodule layer at the base of the Waverly series. Along the road southwest of Clay City, from Tipton ferry to Plum creek, the Irvine formation rests on Black shale, is sandy, and contains pebbles fully three quarters of an inch in length.

East of Clay City the Irvine formation may be traced up the valley of the Red river to Rosslyn, at the mouth of Cat creek.

Here it rests upon Waverly clay, of which a thickness of ten feet is exposed; the Waverly clay contains thin interbedded layers of ferruginous indurated rock. Above this level is a gravel bed containing both angular and rounded pebbles, consisting of free-stone, quartz, and chert derived from the upper limestones of the Mississippian deposits of this part of Kentucky. The thickness of this gravel layer is two feet nine inches. This is overlaid by sandy clay, six feet thick, followed by a considerable deposit of whitish clay, about thirty feet thick.

From Irvine and Brassfield the Irvine formation may be traced southwestward, everywhere resting on the eroded Black shale. White Irvine clay, with ferruginous sandy material in it, occurs at the Bear Wallow, three miles east of Bobtown; also, southwest of Bobtown, northeast of the New Liberty church. Similar exposures occur at numerous exposures between Cartersville and Wallaceton, and also westward, toward Crab Orchard. Southwest of Crab Orchard, the Irvine formation is exposed along the county road west of the main branch of Cedar creek, resting upon Silurian deposits.

The only deposits which have proved to be of economic interest, so fair at least, are those near Waco. Elsewhere the sandy element in these clays has proved an injurious feature. This does not mean, however, that it is useless to look for other deposits of Irvine clay which might be useful for pottery. Owing to the small amount of overlying material to be removed, even comparatively thin layers of plastic white c1ays would have considerable value provided they were of the desired chemical composition.

DERIVATION OF SEDIMENTS FROM THE WASTE OF THE CINCINNATI GEANTICLINE.

In the American Journal of Science for 1897, Professor H. Williams states his belief that a large share of the Black shale material was derived from the waste of the Cincinnati geanticline, that the Black shale mud was distributed over the area where Black shale deposits now are known by a large current similar to the Florida current, which is a branch of the Gulf Stream. In the area between the Cincinnati geanticline and the most eastern exposures of the Black shale in Virginia the Black shale muds of the Black shale series are believed to

have come from the Cincinnatian arch, while the arenaceous sediments belonging to this series are believed to have resulted from the disintegration of Archaean rocks farther eastward, in the territory to which Professor Williams applies the term Appalachia. These arenaceous sediments increase in quantity and are found lower in the Black shale section on approaching the land edge of the Appalachian territory. Toward the Cincinnati geanticline, however, the deposition of black shale muds continued for a much longer period.

In a paper on the Silurian and Devonian limestones of Tennessee and Kentucky, published in 1901, the writer advocated the idea that the plastic material of this clay might have had an origin similar to those deposits of loess which appear to have resulted from the dissemination of wind-blown dust which found its final lodgment in moist areas, swampy lands, or shallow seas devoid of currents strong enough to sweep these light sediments away. As matters stand at present, this theory is founded rather upon imagination than observation.

It is evident that not only the source of the clastic material of the Devonian Black shales, but also the source of the extensive and thick deposits of the fine-grained Linietta clay at the base of the Waverly series requires explanation. Why do the Black shales contain so much carbonaceous material and the Linietta or Bedford shales, of east-central Kentucky, so little? What caused the abrupt change from carbonaceous to non-carbonaceous deposits? If the Black shale deposits were formed by muds derived from the disintegration of rocks along the Cincinnati geanticline, was the source of the Linietta clays not the same?

In the Richmond folia, published in 1898, Marius R. Campbell refers to the Irvine clays used in the manufacture of pottery at Waco as residual clay of the shale member of the Panola formation. The Panola formation includes the Silurian deposits of east-central Kentucky, and also the Devonian limestones of this area. The shale member of this formation includes the Alger formation, the upper part of the Crab Orchard division of the Silurian. These clays were once exposed much farther east up the flanks of the geanticline than at present, so that the statements by Mr. Campbell may be interpreted as equivalent to saying that the Irvine clays at Waca were derived from the direction of the Cincinnati geanticline.