

A SHORT DESCRIPTION OF THE TOPOGRAPHY OF INDIANA,

And of the Rocks of the Different Geological Periods; to Accompany the Geological Map of the State.

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TOPOGRAPHY OF INDIANA. †

The topography of Indiana is somewhat diversified. The northern part of the State is covered by the ice plains, which are characterized by many lakes and swamp areas, with sluggish streams and no deep valleys or high hills, the broad plain being diversified only by the inequalities of the glacial deposits. These features characterize, in the main, the northern third of the State.

The middle third is somewhat more diversified. The eastern half of it is a broad rolling plain area, with no prominent hills nor any very deep valleys. The streams in places run over the surface of the plain, and in places are slightly intrenched in it. In the western half of the middle third the streams are more deeply intrenched; the Wabash and some of its tributaries, as Sugar Creek, Pine Creek and others, have cut gorges 300 to 400 feet deep along parts of their courses. Some portions of White River and its tributaries are similarly intrenched.

The southern third or more of the State is much more diversified. The area is more deeply trenched by the streams; so much so in places that lower secondary plains have been formed, and the underlying rocks have stamped their character on the surface. As the strata have a low west and southwest dip, the more durable rocks form cuestas or sloping plateaus, with steep escarpments to the east on their outcropping edges, and long plains gently sloping towards the west on the bedded surface. Between these escarpments are irregular plain areas on the softer strata. New-

*The part on the Ordovician and the Silurian was written by A. F. Foerste, as indicated.

†The topography of southern Indiana is discussed by J. F. Newsom in the 26th Annual Report, p. 238, and in the Journal of Geology, Vol. VI, pp. 250-257; by F. Leverett in the 18th Annual Report U. S. Geol. Surv., Pt. IV, pp. 429-431, and by G. H. Ashley in the 27th Annual Report, p. 53.

som cites three of these *cuestas* and three lowland areas, the broadest one of which is on the west on the outcrop of the Coal Measures strata.

The upland sloping plateaus are in many places very much dissected and diversified by the numerous deep valleys cut in them, so that they form a mass of irregular hills. The area in most places along the outcrop of the Mansfield sandstone is very much broken, and along the eastern margin of the outcrop, where the sandstone caps the hills, the latter are high, steep and marked by many perpendicular cliffs and steep talus slopes. This belt of cliffs and gorges is markedly different from the Knobstone area further east which extends through Brown, Monroe, Scott, Lawrence, Jackson, Washington, Clark and Floyd counties. As the name indicates, the hills here are knobs or rounded hills, frequently high and steep but generally free from the perpendicular and overhanging cliffs which characterize the Mansfield sandstone plateau and the limestone plateaus. The highest part of the State is in the vicinity of the "Summit," in Randolph County, about 1,285 feet above sea level. The next highest portion is thought to be the Knob district in Brown County, on the divide between the White and the Ohio rivers. The lowest part of the State is in the southwest part, at the junction of the Wabash and the Ohio rivers. There is very little flood-plain area along the Ohio River in Indiana. It is flanked by the deeply dissected border of the upland plain through which it has cut its deep valley.

The broad outcrop of the Mitchell limestone shown on the map, extending from the northwest central portion of the State, east of south to the Ohio River, is characterized best as possessing a sink-hole topography. It is a very cavernous region, and the openings from the surface into the caverns are basin-like or funnel-shaped depressions known as sink-holes. The many scores of these sink-holes give the area quite a pockmarked appearance.*

THE GEOLOGICAL HISTORY OF INDIANA.

Geological time is divided primarily into four eras—Azoic, Paleozoic, Mesozoic and Cenozoic, to which some writers add a fifth, Psychozoic, and some insert another (Proterozoic) between the first two. These primary divisions are divided and subdivided

*The details of the topography of the area are given in the papers of Newsom and Ashley, already referred to.

into different periods, epochs, and stages, the terms, groups, systems, series and formation are the corresponding terms applied to the rock formations. This terminology, however, is not closely adhered to by many writers.

The record that has been preserved of the events of geological time is that found in the rocky strata which are literally the leaves of the geological history. At no one point are all these leaves preserved, so that the history recorded in the strata at any one point is only a portion of the whole, and to get a complete geological history it is necessary to combine the fragments obtained from the different localities in the world.

In Indiana there is no accessible record of Azoic rocks, none of the Mesozoic, and only a very short part of Cenozoic, which limits the strata practically to the Paleozoic, and not all of that is represented. The relation of the time represented in the rock strata in Indiana to all geological time is shown in the accompanying table:

GEOLOGICAL TABLE.

| <i>Eras.</i> | <i>Periods.</i> | INDIANA. | PENNSYLVANIA AND NEW YORK. | MISSISSIPPI VALLEY. |
|-------------------------------------|---|-------------------------------|------------------------------------|---------------------------------------|
| Cenozoic. | Quaternary-Pleistocene..... | Recent. Glacial. | | |
| | Tertiary. | | | |
| Mesozoic. | Cretaceous. | | | |
| | Jurassic. | | | |
| | Triassic. | | | |
| Paleozoic | Permo-Carboniferous..... | Merom Sandstone..... | Upper Barren. | |
| | | Productive coal measures..... | Upper Productive. Lower Barren. | |
| | | Mansfield Sandstone..... | Lower Productive. | |
| | | | Pottsville Conglomerate..... | Millstone Grit. Chester-Kaskaskia. |
| | Mississippian or Lower Carboniferous..... | Huron..... | | St. Louis. |
| | | Mitchell..... | | Warsaw. |
| | | Bedford fossiliferous..... | Mauch Chunk..... | Burlington. |
| | | Harrodsburg..... | | Keokuk. |
| | | Knobstone..... | | Chouteau. |
| | | Goniatite..... | | |
| | | New Albany..... | Genessee. | |
| | Devonian..... | Sellersburg..... | | Hamilton. |
| | | Silver Creek..... | | Corniferous. |
| | | Jeffersonville..... | | Schoharie. |
| | | Pendleton..... | | Lower Helderberg(?) Salina. |
| Silurian..... (Upper Silurian) | Louisville..... | | | |
| | Waldron..... | | Niagara. | |
| | Laurel..... | | | |
| | Osgood..... | | | |
| | Clinton..... | | | |
| Ordovician..... (Lower Silurian) | Richmond..... | | Hudson River. (Cincinnati.) | |
| | Lorraine..... | | | |
| | Utica..... | | | |
| | Trenton..... | | | |
| | St. Peter's(?)..... | Chazy. | | |
| | Lower Magnesian(?)..... | Calceiferous. | | |
| | Potsdam(?)..... | | | |
| Azoic..... | Cambrian..... | | Huronian. | |
| | Algonkian(?)..... | | Laurentian. | |
| | Archean..... | | | |

GENERAL FEATURES.—The area covered by the State of Indiana has a varied and interesting geological history. During that long Azoic era, that beginning period of which the record is so indefinite, we have little knowledge of what was taking place in Indiana. At some time during that period there was an elevation of the land in the north through Canada, the Adirondack mountains were elevated, and extensive land areas were formed along the eastern United States, extending in places farther out into the Atlantic ocean than the present shore line. There was a land area to the northwest in Wisconsin, one in Missouri, and different land areas along the Rocky mountains and the Pacific coast area.

Sometime previous to the Paleozoic era the central portion of this interior sea became a low land area. A land area, because there are no Lower Cambrian sediments, and probably a low land area near sea level, because there is no evidence of great erosion during the interval. Towards the close of the Middle Cambrian period, this interior land area began to subside and the sea covered all the Mississippi valley area except the few small Azoic areas mentioned above.

During the Ordovician period the Indiana area probably remained beneath the sea. A portion of the time, it was a clear, open sea, in which shell fish, crinoids and corals flourished. Part of the time the seas were muddy with the sediments carried in by the streams and stirred up by the waves. About the close of the Ordovician period there appears to have been an island covering an indefinite area around Cincinnati formed in this great sea, but probably it was not lifted far above the sea. During the Silurian and Devonian periods the area now included in Indiana was probably under the sea the greater part of the time, except possibly a small area in the southeast part of the State. In the Lower Carboniferous period the southwest part of Indiana was covered much of the time by an open sea, in which lived great numbers of lime-secreting organisms that built up the great limestone strata of that age. During the Lower Carboniferous period there was an elevation of the northern part of the State above the sea level. This land area gradually extended southward by the recession of the sea so that each succeeding stratum was shortened at the northern end.

At the close of the Lower Carboniferous period there was a depression of the land, and the incoming beach formed a heavy bed

of sandstone and conglomerate over the southwest part of the State. On this bed of sand (the Mansfield sandstone) the coal beds were deposited during the long Carboniferous period. During part of the time the area, or the greater part of it, would be above sea level and covered with swamps and bogs in which the vegetation accumulated to form the coal beds, and part of the time the area would be depressed below sea level, when the limestones and sandstones would be formed. This fluctuation continued throughout the Carboniferous period, while the coals, clays, sandstones and limestones of that period were being deposited.

At the close of the Carboniferous period the land was elevated above sea level, an uplift which included almost the entire Mississippi Valley, except a small area in southwestern Indiana and Illinois, and part of Kansas, where the sea possibly remained during at least a portion of the Permian. The recession of the sea from Indiana territory during the Permian, left it a land area above tide level, and in this condition it has ever since remained.

But little record is left in Indiana of the long Mesozoic and Cenozoic eras until the Pleistocene period near the close of the Cenozoic, when the land was submerged beneath a great sea of glacial ice.

The different deposits that were formed on the Indiana area during these long geological ages are shown on the accompanying table and described briefly in the pages following.

DESCRIPTION OF THE ROCKS FORMED IN THE DIFFERENT GEOLOGICAL PERIODS IN INDIANA.

The different limestone, sandstone, shale, clay and coal strata have been described in great detail in the preceding 27 volumes of the publications of the Indiana Geological Survey. It has been, however, thought advisable to give a brief connected description or synopsis of the different periods here, as many persons interested in the geology of the State may not have opportunity to consult all the different reports. This description must necessarily be brief, and persons interested in the details of any particular group or area will note the references to the more extended papers in the different volumes.

There is no outcrop of any strata in Indiana older than the Cambrian, but at many other points in the world such strata occur.

The oldest stratified rocks have been called *Azoic* because they contain no life remains. They have also been named *Archean*, meaning ancient. Some writers have divided and subdivided them into the Archean below and Algonkian above, the latter group subdivided into Lower and Upper Huronian and Keweenawan. Presumably, sediments of this very long and ancient period underlie all or part of Indiana, but their presence is not known. We can not be certain whether Indiana was a land or sea area during this period.

The record of Cambrian time in Indiana is not much clearer than the Azoic. It is thought from indications in neighboring States that the central and north-central portions of the United States was a land area during early Cambrian and possibly part of Azoic time. This land was elevated but little above sea level, so that very little erosion took place, and no geographic change of any kind is recorded until towards the end of the Cambrian, when there was a depression of the area, an inflow of the sea and the formation of sediments of Middle and Upper Cambrian age.

The upper division of the Cambrian in New York is a hard quartzitic sandstone, known as the Potsdam sandstone, and this is thought to extend westward across Ohio, Indiana, Illinois, Michigan, Wisconsin and Minnesota. It is one of the widespread sandstone formations of the United States. It does not outcrop in Indiana, but it is supposed to have been penetrated by the deep borings in northern Indiana at Hammond, Crown Point and LaPorte, and possibly underlies at great depths all the State.

The Ordovician or Lower Silurian period is divided in New York into the (1) *Calciferous* (Beekmantown), a grayish limestone, often arenaceous, frequently cherty, usually magnesian and rarely fossiliferous. It is probably the equivalent of the *Lower Magnesian limestone* of Missouri and Wisconsin. It does not outcrop in Indiana, but is thought to have been penetrated by the drill in several deep borings. In the deep boring at Bloomington, the last 50 feet is thought to be Lower Magnesian limestone.

(2) The *Chazy* limestone in eastern New York is gray to black in color, furnishing black marble in places. It is thought to be the equivalent of the *St. Peter's sandstone* of Wisconsin and adjoining States. It does not outcrop in Indiana, but has been penetrated by the drill in a number of deep borings. It is an excellent

water-bearing stratum and is the source of the water in a number of artesian wells. The water is generally salt and frequently called "Blue Lick" water. It contains some magnesia and hydrogen sulphide, which, with the sodium salts renders it undesirable for household purposes. In places it is used quite extensively for its curative properties. The thickness of this rock in Indiana is not definitely known owing to the uncertainty of the drill records at such great depths. The following depths below the surface are recorded: Portland, 1,600 feet; Union City, 1,680 feet, and 600 feet below sea level; Muncie, 1,382 feet, 450 feet below sea level; Rockville, 2,600 feet; Goshen, 2,350 feet.

While it is commonly classed as sandstone by the drillers in Indiana, it is quite calcareous in many places, and is more properly a siliceous limestone. At Connersville, Bloomington and Edinburg there is a bed of black shale, respectively 25, 40 and 83 feet thick, lying on top of the calcareous St. Peters' sandstone and underneath the Trenton. It is uncertain to which of the groups it belongs.

ORDOVICIAN.

(By A. F. FOERSTE.)

The Ordovician or Blue limestone strata occupy the greater part of the area east of a line connecting Richmond, Cambridge City, Connersville, Laurel, New Point, Osgood, Versailles, Cross Plains, Canaan, and Madison, in the southern corner of Indiana. It is exposed along various streams in southern Decatur, western Ripley, and eastern Jennings counties, in areas otherwise occupied by the Silurian. Along the Ohio River it may be traced as far south as Charlestown Landing in Clark County.

The Ordovician consists chiefly of blue clay; with this is interbedded a variable quantity of limestone. The clay is usually soft and plastic. Owing to the presence of calcareous and siliceous constituents it may be indurated into a clay rock or a thin bedded sandy shale. The limestone occurs in the form of thin layers, usually not exceeding 6 inches, and often less than 3 inches in thickness. The layers are often hard. Many show their organic origin by the presence of fossils. Some are distinctly crinoidal. Others consist chiefly of brachiopoda or bryozoa cemented together by a mass of calcareous sediment.

Fossils frequently are abundant and very well preserved. The Ordovician exposures of southeastern Indiana form some of the best collecting grounds in the Central States.

The Ordovician of Indiana includes the top of the Trenton and all of the Cincinnati formations.

THE TRENTON.

The Trenton forms a narrow strip along the Ohio River between the southeastern corner of Ohio County and Markland, near the middle of the southern boundary of Switzerland County. Lithologically it resembles very much the remainder of the Ordovician section in Indiana. The lower part of the Trenton exposures consists of a peculiar bluish argillaceous limestone, which can be easily distinguished from most limestones in the Cincinnati formations when once it becomes familiar. Otherwise it can be recognized only by means of its fossil contents. By drillers for oil and gas in southern Indiana it is classed with the Cincinnati formations. The Trenton of these drillers occupies a considerably lower horizon.

THE CINCINNATIAN SERIES.

The rocks of this series are often called the Hudson River rocks. However, recent studies of the rocks of the Hudson River Valley have shown that the so-called Hudson River rocks do not form a distinct formation in the sense in which this name was applied at first, so that the term Cincinnati is preferable for the mass of Ordovician rocks overlying the Trenton.

The Cincinnati series of rocks of Indiana are divided into three main subdivisions or stages, called in ascending order, the Utica, Lorraine, and Richmond stages.

THE UTICA FORMATION.

The thickness of the Utica formations is about 260 feet. The lower half consists chiefly of clay, with relatively few layers of limestone. In the upper half, limestone forms about one fifth of the section. In Indiana, the Utica may appropriately be called the *Dalmanella multisepta* zone. While the range of this fossil extends into the lower part of the Lorraine it is nowhere so com-

mon at these upper horizons as in the Utica. In fact, in Indiana *Dalmanella* is usually very rare or absent in the lower parts of the Lorraine. In Ohio, the Utica is divided into three beds—the Lower Utica, 80 feet thick; the Middle Utica, 120 feet thick; and the Upper Utica, 60 feet thick.

THE LORRAINE FORMATION.

The thickness of the Lorraine formations in Indiana is about 260 feet.

The lower third of the Lorraine, about 90 feet thick, equivalent to the Mount Hope-Fairmount beds, includes a considerable amount of yellowish, sandy, clayey rock which weathers to a sandy shale or clay. The limestones are usually thin, one or two inches in thickness, occasionally 3 or 4 inches, and are rarely suitable even for cellar stone. Clay forms by far the greater part of the section. This may be called the *Plectorthis* zone. *Plectorthis plicatella* and the varieties varying towards *Plectorthis triplicatella* are common and range from the base to the top of this part of the Lorraine section, although not found in equal abundance at all localities nor at all horizons. *Plectorthis dichotoma* is most common at this horizon, but occasional specimens are found even as far as the top of the Bellevue bed. Near the Ohio line, *Dalmanella meeki* is a common species, *Strophomena planoconvexa* is a form characteristic of this part of the section. It occurs between 3 and 8 feet above the base, and also again between 33 and 38 feet below the top.

The following division of the Lorraine, the Bellevue bed, has a thickness of at least 20 feet. At some localities it may reach 25 feet. It is usually a coarse rubble limestone, but at some localities the lower part of the bed consists of coarse-grained massive limestone, the middle of rubble limestone, and the upper part chiefly of clay. The most characteristic fossils are *Monticulipora molesta* and *Nicholsonella vaupeli*, but in southern Indiana it may be called the *Platystrophia lynx* zone. While *Pl. lynx* occurs also in the Corryville and Mount Auburn beds, in southern Indiana it is abundant only in the Bellevue bed. *Rafinesquina alternatnasuta* occurs in the upper half of the Bellevue bed and extends into the Corryville.

The upper half of the Lorraine is formed by the Corryville, Mount Auburn, and Warren beds, having a total thickness of about 130 or 135 feet. Clays predominate greatly. The limestones are usually thin, rarely coarse-grained, with the fossils confined chiefly to the upper and lower surfaces of the layers. The limestones often weather to a yellowish sandy rock. The upper half of the Lorraine might be called the *Rafinesquina alternata* zone; not because this fossil is confined to this zone, for it ranges throughout the Ordovician; nor because it is more abundant at this horizon than at others, for this is not the case; but because it is the most conspicuous of the few species of brachiopods commonly found at this horizon. It is flat and large, often adheres to the surfaces of the slabs of limestone which cover the slopes of the hills at this horizon, and thus becomes conspicuous. *Platystrophia laticostata* and its varieties are more commonly found in the clays. *Zygospira modesta* is not a conspicuous fossil. Other species of brachiopods do not occur in abundance.

The Corryville bed has a thickness of 45 to 50 feet, the Mount Auburn of about 20 feet, and the Warren of 60 to 70 feet. In many parts of Ohio the Mount Auburn bed is the zone in which *Platystrophia lynx* is prééminent. In Indiana, however, it is never very abundant at this horizon, although at some localities it occurs in sufficient numbers to form a distinct upper *Pl. lynx* zone. *Coelociema oweni* extends from the Mount Auburn into the lower part of the Warren bed.

In the Warren bed the limestones often are distinctly more clayey than in the Mount Auburn and Corryville beds. At the top of the Warren bed there is a mass of indurated, irregular, nodular clay rock which is very characteristic of this horizon. The most characteristic brachiopod of this horizon is *Dinorthis retrorsa*. While this fossil occurs also in the Lower Richmond, it is common only at a very restricted horizon, varying from 33 to 40 feet below the top of the Warren bed in the eastern part of the State, to 47 feet below at Madison.

THE RICHMOND FORMATIONS.

The thickness of the Richmond varies from 280 feet in the southern part of Franklin County, to 177 feet at Madison, 112 feet at Marble Hill, and 75 feet east of Louisville.

The lower part of the Richmond stage is formed by the Waynesville bed. In Franklin and Dearborn counties it has a thickness of about 80 feet. Seven miles north of Madison its thickness is 70 feet. South of Madison its thickness diminishes rapidly, and before passing out of southern Indiana it is reduced to about 25 feet. In the greater part of the State the most characteristic brachiopod in the lower part of the Waynesville bed is *Dalmanella jugosa*, so that this part of the Waynesville bed may be called the *Dalmanella jugosa* zone. In Franklin County *D. jugosa* is found in the Warren bed, and even lower. It ranges into the lower part of the Liberty bed. But it is very abundant only in the Waynesville bed, and usually only in the lower part. Between Moore's Hill and Holman it is common up to 65 feet above the base of the Waynesville bed; south of Friendship, up to 40 feet; seven miles north of Madison, up to 30 feet; on Saluda creek the *D. jugosa* zone is reduced to only a few feet; and at Marble Hill, to a few inches. Farther southward it appears to be absent.

The Middle Richmond is formed by the Liberty and the White-water beds. In the southern part of Franklin County its thickness is at least 150 feet. Seven miles north of Madison this is reduced to 44 feet, and at the mouth of Bull Creek only 10 feet of fossiliferous rock can be assigned with confidence to the Middle Richmond.

At the type locality the thickness of the Liberty bed was estimated at about 35 feet. Its most characteristic fossil is *Hebertella insculpta*, which forms a distinct zone at its base. At the more northern localities the thickness of the *H. insculpta* zone is 7 feet; southward this diminishes slowly to 5 feet in the middle of Dearborn and Ripley counties, and then more rapidly to a foot and a half or less in the northern part of Switzerland and Jefferson counties. At Madison, specimens are very rare and appear to come from the base of the *Dinorthis subquadrata* zone.

In the northern part of the Ordovician area of Indiana the middle and upper part of the Liberty bed and almost all of the White-water bed may be called the *Dinorthis subquadrata* zone. Northward the base of the *Dinorthis subquadrata* zone is separated from the top of the *Hebertella insculpta* zone by an interval of 10 feet. In most of Dearborn and Ripley counties, and in the northern part of Switzerland this interval does not exceed 5 feet.

Farther southward the interval diminishes until near Madison the zones are separated by an interval not exceeding 2 feet. The thickness of the *Dinorthis subquadrata* zone is 140 feet at the more northern exposures. At the most southern exposures of the Richmond the known vertical range of this species is reduced to a few feet, or even inches.

The upper part of the Waynesville bed, and all of the Middle Richmond, is characterized by the presence of numerous specimens of various species of *Strophomena*. In the upper part of the Waynesville bed and in the Liberty bed, *Strophomena planumbona* preponderates. In the Whitewater bed *Strophomena vetusta* preponderates. *Strophomena neglecta* is confined to the upper third of the Waynesville bed. *Strophomena nutans* is found at various levels in this bed. In the *Dalmanella jugosa* zone, *Strophomena* is usually not common or is even rare. *Rhynchotrema capax* is common in the upper part of the Waynesville bed and in the Middle Richmond.

In the lower part of the Waynesville bed clay forms most of the section, but well-bedded limestones, 2 to 4 inches in thickness are rather common, especially near the base of the *Dalmanella jugosa* zone. Near the upper part of the Waynesville bed the relative quantity of clay increases and the limestone layers are thinner. The lower part of the Liberty bed, the *Hebertella insculpta* zone is often a limestone rubble. The remainder of the Liberty bed consists of clay and even bedded limestones averaging 3 inches in thickness. In the Whitewater bed the strata often present a roughish, concretionary, nodular appearance. The limestone layers are seldom over 2 inches thick.

The Madison bed in the northern part of the Ordovician area of Indiana consists of clay and clay-rock. In Jefferson County all except the base of the section is usually indurated into a massive, homogeneous, argillaceous, brownish limestone, which disintegrates readily under the influences of weathering. In all the more southern exposures the greater part of the section is practically unfossiliferous. At the base of the Madison bed in parts of Ripley and Jefferson counties, there is a bed containing *Columnaria alveolata*, *C. halli*, and *Calopoecia cribriformis*; *Tetradium minus* occurs at this horizon or immediately above. It may be known as the coral zone.

The Ordovician rocks of Indiana are of little value commercially. The limestones are of little use except for cellar stones. Recently they have been employed to a great extent for road metal in the southeastern corner of the State, within the area underlaid by Ordovician rocks.

THE SILURIAN OF SOUTHEASTERN INDIANA.

(BY A. F. FORRSTE.)

The western boundary of the Silurian or White limestones of southeastern Indiana may be indicated approximately by a line connecting Newcastle, Rushville, Greensburg, Westport, and Madison. From Madison the Silurian extends down the river as far as Louisville. West of this boundary the Silurian is exposed along the valleys of a number of streams traversing the Devonian areas of Rush, Shelby, Decatur, Bartholomew, Jennings, Jefferson, and Clark counties.

In the former reports of this survey, the writer suggested the following classification for the Silurian rocks of southeastern Indiana, the divisions being named in descending order:

Louisville limestone.

Waldron clay.

Laurel limestone.

Osgood clay and limestone.

Clinton limestone.

THE CLINTON LIMESTONE.

The Clinton of southeastern Indiana is a detrital limestone. At the more northern areas it is distinctly crinoidal and contains numerous small rolled fragments of bryozoa and of various shells. Fossils are quite abundant in this detrital phase of the Clinton. However, they are usually enclosed within the rock and are secured chiefly by breaking it open. In Ohio the top of the Clinton is clayey, and here fossils are often better preserved.

Southward, in the northwestern part of Switzerland County, and in many parts of Jefferson and Clark counties, the Clinton limestone is often very dense, hard, and siliceous, and contains comparatively few fossils, although detrital, fossiliferous phases also are known.

In Wayne County, the Clinton usually is a coarse detrital limestone, having a white, gray, or light red color. In the western part of Fayette County the Clinton is of medium grain, and the color more often is blue, becoming rusty brown on weathering. In Franklin and Ripley counties the limestone is distinctly detrital, often rather coarse-grained, usually fossiliferous, and has a characteristic salmon brown color. These salmon brown phases of the Clinton are seen at various localities in Jefferson and Clark counties, continuing into northern Kentucky.

In the southwestern part of Preble County, Ohio, about six miles east of College Corner, Indiana, the Clinton has a thickness of at least 9 feet. Southeast of Richmond, on Elkhorn Creek, its thickness is 11.5 feet. Southward, in Decatur County, the thickness usually varies between 4 and 6 or 7 feet. In the more southern counties it rarely exceeds 4 or 5 feet, and often is reduced to 1 or 2 feet.

In the western part of Ripley County and in the adjacent parts of Decatur and Jennings counties, the Clinton is absent. Here one or two islands appear to have existed during the deposition of the Clinton. In the lower part of the Clinton limestone bordering upon these islands, angular and rounded fragments of Ordovician rocks are enclosed within the Clinton. At some localities these fragments are common. Southward, in southern Ripley and in Jefferson counties, lenses of clay rock, varying from a few inches to a foot or two in width, are present in the Clinton; these also suggest shallow water conditions. For the hypothetical islands, the name Ripley Island or Islands is suggested. Only the eastern boundary is known.

The genera *Iliaenus*, *Cyphaspis*, and *Encrinurus* are not represented in the Cincinnati strata of Indiana but reappear in the Clinton. Here the genera *Phacops* and *Deiphon* make their first appearance. *Glyptoceras* is known only from the Clinton. *Subulites* is absent in the Cincinnati but reappears in the Clinton. *Platystoma* makes its first appearance in the Clinton. The species described as *Paleopupa abrupta* is probably closely related to the genus *Onychochilus*; at any rate it is not related to *Pupa* or any other land shell. Among the brachiopoda, *Strophonella*, *Rhipidomella*, *Whitfieldella*, *Atrypa* and *Stricklandinia* here make their first appearance. While *Triplecia* is absent in the Cincin-

natian, it reappears in the Clinton. This is true apparently also of *Orthis*. The form identified as *Strophomena patenta* in the Clinton of Ohio is not even closely related to the type from New York; the name *Strophonella filistriata* is here suggested for the Ohio specimens. The absence of *Pentamerus* is of special interest, since *Pentamerus oblongus* is considered one of the most characteristic fossils of the Clinton in New York. Nor has *Atrypa reticularis* or any species of *Cyrtia* or *Spirifer* been found so far.

THE OSGOOD BED.

The base of the Osgood section is formed by several thin layers of limestone having a total thickness of 8 to 15 inches. Above this lies the lower Osgood clay, the most important part of the section, from 11 to 16 feet thick. In Kentucky this clay is usually soft. In Indiana it is often more or less indurated or converted into a clay rock. This is true especially of the upper layers in the more northern parts of Jefferson County and in the adjacent parts of Ripley. In the central parts of Ripley and Jennings counties the upper part of the lower Osgood clay is changed gradually to a rubble limestone, and the entire bed is quarried as an inferior grade of limestone at New Point.

At the Derbyshire falls, southwest of Laurel, less than two feet of rock can be identified as the lower Osgood clay. The section is instructive. The greater part of the Clinton, for a distance of 7 feet above the base, consists of a bluish, irregular, bedded rock, near the upper part of the falls. The remainder of the Clinton section, 1 foot 9 inches thick, has a salmon brown color at the base but is white and fine grained at the top. The greater part of the Osgood section is represented by white well-bedded limestone, the upper layers of which are quarried. In Ohio these layers are known as the Dayton limestone. They evidently represent the lower part of the lower Osgood clay in addition to the limestone usually found at the base of this clay. They maintain their character as limestones also in Fayette and Wayne counties, sometimes closely resembling the Dayton limestone. At the Derbyshire falls, immediately above this limestone, there is a layer of clay, 1 foot 9 inches thick, also referred to the Osgood section. Overlying this are well-bedded white limestones, 6 feet thick,

without chert, forming the valuable quarry rock, and also cherty layers.

In the more southern parts of the State, the lower Osgood clay is overlaid by coarse-grained, often crinoidal limestone. In Clark County this rock is often siliceous and has weathered to a brownish color. Its thickness in this county often equals 5 feet. In the central and northern parts of Jefferson County it is usually a whitish crinoidal limestone, varying between 3 and 4 feet in thickness. In Ripley and Jennings counties it is still a white detrital limestone, not exceeding 3 feet in thickness and sometimes equaling only 15 inches. Farther north it can not be identified with certainty, owing to the alteration of the clayey part of the Osgood section to an inferior quality of limestone.

Overlying the limestone, and forming the top of the Osgood section in Clark, Jefferson and Ripley counties, is the upper Osgood clay, varying from 3 to 5 feet in thickness at the more southern localities, but usually about 1 foot in thickness in the northern part of Ripley County. In Franklin County, the white limestones at the base of the Laurel section are underlaid by a layer of indurated clay rock, usually varying between 1 and 2 feet in thickness. It is not known whether this clay rock is equivalent to the top of the lower Osgood clay or represents the upper Osgood clay of more southern exposures.

In Indiana, *Pisocrinus*, *Stephanocrinus*, *Holocystites*, *Rhynchotreta*, *Spirifer*, *Cyrtia*, and *Nucleospira* make their first appearance in the Osgood bed, especially in the limestones and clay partings between the lower and upper Osgood clays. *Holocystites* is represented by numerous species although the published list may include many duplicates. In fact, in Jefferson and Ripley counties *Holocystites* may be said to characterize the Osgood, although the number of individual specimens found at any one locality usually is very small, even after long continued search. A variety of *Pentamerus oblongus*, but not the typical form, has been found in the Dayton limestone, an equivalent of the lower part of the Osgood bed, in Ohio. In Indiana, however, *Pentamerus* is unknown in the Osgood bed. Moreover, *Stropheodonta profunda*, *Iliaenus ioxus*, *Ceraurus insignis*, and *Homolantus delphinocephalus* have not been found as yet in the Osgood bed. In many respects the Osgood fauna is a forerunner of that

found in the Waldron. It corresponds to the reef fauna at the top of the Clinton of New York, where it occurs in the limestones exposed in the lens-like cross-sections just beneath the Rochester shale.

THE LAUREL LIMESTONE.

Above the Osgood bed is a series of limestones, usually well bedded, called the Laurel bed or Laurel limestone. Its thickness varies usually between 40 and 45 feet. At St. Paul in the north-western part of Decatur county, its thickness is about 48 feet. Farther north its thickness has not been determined with accuracy.

Usually, it is a very white, hard limestone, occurring in even, well-bedded layers. These vary from 4 to 16 inches in thickness, and may be cut into slabs of almost any desirable dimension. In Indiana, it is quarried in Wayne, Fayette, Franklin, Rush, Decatur, Jennings, and Ripley counties. Southward, in Jefferson County, the limestone deteriorates rapidly in quality. The rock is less pure, becomes softer, more argillaceous, and does not form slabs of equally large dimensions. In Clark County, the rock becomes still softer and more argillaceous. Its color changes to brown and usually the rock does not withstand weathering. At some localities, a few of the layers furnish a good building rock while the greater part of the section is of inferior quality. Chert frequently is present, especially in the middle part of the section, 5 or more feet above the base of the Laurel. However, at many localities the layers which are free from chert are readily accessible and are quarried with profit.

Comparatively little is known as yet about the fauna of the Laurel limestone. That the fauna is quite large is shown by the great number of crinoids found at a single locality, St. Paul. The rock is usually very dense, and fossils are exposed only where the rock has been subjected for centuries to weathering. The weathered surfaces show great numbers of fragments of crinoid stems, and occasional crinoid bodies, but other fossils are found also. So far, however, they have received very little attention. As far as may be determined from a hasty examination of specimens in the field, the Laurel fauna shows close affinities with that seen in the Louisville bed, while the Waldron fauna is a

recurrence and farther development of that occurring in the Osgood bed.

THE WALDRON CLAY.

The Waldron clay forms a distinct bed overlying the Laurel limestone. In some parts of southern Indiana, and thence southward as far as central Kentucky, a clayey section often occurs in the lower part of the Laurel limestone, but it is usually less than two feet thick and does not contain the typical Waldron fauna. At the more southern localities the thickness of the Waldron clay varies usually between 4 and 10 feet, although locally it may equal 14 or even 20 feet. Northward, the thickness does not exceed 6 feet, and occasionally is reduced to 1 foot. So far it has not been traced north of Milroy, in the southern part of Rush county. Farther northward the clay gives way to limestone, but it is likely that when the Silurian faunas of the more northern areas become better known, it will be possible to follow the horizon of the Waldron fauna much farther north than it is known at present.

THE LOUISVILLE LIMESTONE.

The Louisville limestone at Louisville has a thickness of more than 55 feet. The total thickness is unknown, since the base of the Louisville bed is not exposed at this point. At Charlestown Landing, its thickness is 57 feet. At Hanover its thickness does not exceed 30 or 35 feet. At Paris Crossing it does not exceed 25 feet. At Vernon it does not exceed 10 feet. East of Greensburg, on Sand Creek, it appears to be absent.

West of Greensburg, in the eastern part of Shelby and Bartholomew counties and in the adjacent parts of Rush and Decatur counties, a series of limestones, at some places eight feet thick, overlying the Waldron clay, is correlated with the Louisville bed.

The Louisville limestone thins out from Louisville in a northward and eastward direction. Judging from exposures in Kentucky this thinning increases from the flanks toward the crest of the Cincinnati anticline, in other words in an easterly direction.

The Louisville limestone is overlaid unconformably by the Devonian limestone. This is true also south of Louisville, at least as far as the central part of Kentucky.

At Louisville, in Kentucky, and at Utica and Charlestown Landing, in Indiana, the Louisville limestone is quarried to a considerable extent for lime. At Louisville it is used also as a building rock.

THE SILURIAN OF NORTHERN INDIANA.

(By A. F. FOERSTE.)

Clarke and Schuchert have recently, 1899, proposed to divide the Silurian rocks of New York into three groups, in descending order:

Silurian { Cayugan.
Niagaran.
Oswegan.

The Oswegan includes the Oneida and Medina. It is not exposed at any point in Indiana, Ohio, or Kentucky.

The Niagaran of New York includes various horizons; in ascending order; the Clinton, Rochester, Lockport, and Guelph. In southern Indiana, it includes the Clinton, Osgood, Laurel, Waldron, and Louisville. In northern Indiana only the uppermost horizon, the Louisville, is exposed.

The Cayugan of New York corresponds in a general way with the rocks formerly known as the Lower Helderberg. In Indiana it has been identified only in the northern part of the State. It is represented by the Waterlime at Kokomo.

THE KOKOMO (WATERLIME) LIMESTONE.

In Indiana, the Waterlime division of the Cayugan, has been definitely identified at only one locality. While it may be present also elsewhere along the flanks of the Indiana extension of the Cincinnati geanticline, it has been identified by means of its fossils only at Kokomo. Only a few species are known: *Eurypterus lacustris*, *E. kokomoensis*, *Carcinosoma newlini*, *C. ingens*, *Wilsonia kokomoensis*, and *Conchidium*. These fossils suggest the equivalence of the Kokomo limestone to the Bertie or Lower Waterlime bed, in the lower part of the Cayugan.

THE NIAGARAN LIMESTONES OF NORTHERN INDIANA.

The Niagaran area of northern Indiana contains comparatively few exposures of rock. Glacial deposits cover most of this terri-

tory, forming a mantle varying usually between 50 and 200 feet in thickness. Exposures of Niagaran rock are confined chiefly to the beds of the larger streams, and even here they are usually too widely separated and display too short a vertical section to make easy the determination of the stratigraphical relationship between the different exposures.

Moreover, the evidence of the relative stratigraphic position of the different exposures which might be furnished by the fossils is at present in too chaotic a condition to admit of many satisfactory conclusions.

None of the lists of fossils so far published from any part of northern Indiana give any evidence of the presence of the Clinton, Osgood, Laurel, or Waldron beds. *Pisocrinus benedicti*, *P. campana*, and *P. gorbyi* are known in Tennessee only from horizons above the Waldron, and *P. gemmiformis* either has a considerable vertical range or the name as used at present includes several species restricted to different horizons. Considering the difficulty of determining accurately the various species of bryozoa without the assistance of microscopical sections and well preserved exteriors, the Waldron bed species listed from the Niagaran of Wabash County scarcely offer a reliable basis for the determination of horizons. *Bilobites biloba* is more common in strata above the Waldron bed than at the Waldron horizon, in Tennessee, and *Meristina maria* is represented in the upper beds by a closely related species. It is not safe to conclude from this that the Waldron and the upper part of the Laurel are absent in the northern half of Indiana. All that can be stated at present is that their presence can not be safely asserted on the basis of the evidence so far at hand. They may be present along some parts of the axis of that part of the Cincinnati geanticline which extends from Richmond across Logansport toward the northwestern corner of the State.

The evidence of the presence of the Louisville and overlying beds, however, is conclusive. The presence of these beds may be asserted in the case of each county from which an extended list of fossils is at hand.

The total thickness of the Niagaran beds in northern Indiana is considerable. Well sections made in connection with the explorations for oil and gas indicate a thickness of several hundred

feet. It seems safe to assume that the thickness of that part of the section which overlies the Waldron horizon equals at least 200 feet.

From this it is evident that the different exposures of Niagaran rock in northern Indiana, even if of more recent age than the Waldron bed, probably include widely different horizons.

In the absence of better data for determining the relative stratigraphic position of the different exposures, the following suggestions may be of service:

The Niagaran exposures nearest Kokomo, and those nearest any other exposures believed to be stratigraphically equivalent to the Kokomo or Lower Waterlime limestone, probably represent the highest horizons of the Niagaran exposed in the northern part of the State. Here, probably, should be placed the exposures of Niagaran rock seen in Carroll, Cass, Miami, and Hamilton counties. These exposures are characterized by the presence of various species of *Conchidium*, in addition to numerous other species frequently found in the upper part of the Louisville bed at Louisville, or at still higher horizons in Tennessee.

Those Niagaran exposures along the crest of the Cincinnati geanticline which are nearest to the northern border of the Ordovician area probably represent the lowest horizons of the Niagaran exposed in northern Indiana. Here probably should be placed the exposures in Randolph, Jay and Delaware counties. These exposures are characterized by the presence of *Pentamerus oblongus*, usually in considerable numbers, and the absence of *Conchidium*.

In other words, it appears possible to distinguish an upper horizon in which *Conchidium* is common from a lower horizon, in which *Pentamerus oblongus* is common. The exposures in Jasper County are referred to the upper or *Conchidium* horizon.

Between the exposures referred to, the upper horizons of the Niagaran and those believed to belong to the lowest Niagaran horizons exposed in northern Indiana must be others which occupy an intermediate position, or whose position can not be determined more definitely. Here are placed the exposures in Madison, Grant, and Wabash counties. The exposures in Huntington County may represent a slightly higher horizon lying along the northern flank of the Cincinnati geanticline.

Along sections transverse to the direction of the Cincinnati geanticline, the lowest horizons should be represented by exposures along the crest, and the highest by points most distant from this crest. All attempts to correlate the data upon this basis have proved of little value so far. Along the Wabash valley, at least, quaquaversal dips complicate the problem.

The records of drillers for oil and gas indicate a depression across the axis of the Cincinnati geanticline in Carroll and Cass counties. The Silurian rocks within these counties have all been referred to the Niagaran by recent investigators, while the Kokomo limestone appears to occur at a higher altitude toward the southwest of this depression. The precise relation of the Kokomo limestone to this depression and to the crest of the Cincinnati geanticline should be determined if possible.

ECONOMIC USES OF SILURIAN ROCKS OF NORTHERN INDIANA.

The Niagaran limestones of northern Indiana are used for the manufacture of lime in almost every county in which they are exposed. The rock usually is a magnesian limestone and the lime produced is a slow setting lime. The rock is used also for building purposes. In the northwestern counties, in White and Jasper, the limestone often is cherty and its usefulness in consequence is diminished very much, but layers and exposures more or less free from chert are known also.

Siliceous and cherty phases are seen also in the central and eastern counties, as far as Jay. It is not uncommon to find the upper and weathered beds of a quarry presenting a siliceous and more or less porous or cavernous phase while the lower beds are more compact and more serviceable both for lime and for building rock. In some parts of Grant, Miami, and Jay counties some of the limestone courses are clayey and will not withstand direct exposure to weathering. However, the more valuable layers occur also. At some localities in Wabash County, the limestone is well bedded, the layers are thin and very serviceable for flagging. In Huntington County, layers 4 to 6 inches thick are frequent. In Wabash and other counties, layers from 1 to 2 feet thick are known.

At Macksville in Randolph County the limestone is soft, friable, coarse-grained, and is suitable only for lime. Near Ridgeville, the rock occurs in layers 2 to 4 inches thick, hardens on exposure, and is used for cellar walls.

No connected study of the economic value of the rocks of the Niagaran area of Northern Indiana has been attempted so far. The exposures usually are few and distant, but this scarcity of exposures increases the importance of the few in existence, since almost of necessity they become the most convenient source of lime and building rock over comparatively wide areas.

THE SILURIAN-DEVONIAN UNCONFORMITY OF NORTHERN INDIANA.

Mr. E. M. Kindle has shown the presence, in the Niagaran area of Northern Indiana, of numerous quaquaversal dips associated with the upbuilding of small domes. He has also shown that the tilting of the Niagaran rocks resulting in these dips must in many cases have preceded the deposition of the Devonian rocks, since the latter in a number of cases are distinctly unconformable to Niagaran limestones. Near Delphi, for instance, at one locality horizontal beds of Hamilton age lie unconformably over Niagaran limestones dipping at an angle of 45 degrees. Near by, the Hamilton beds are absent, but the New Albany shale rests almost directly on the Niagaran strata. Again, on the east side of the river below Georgetown, in Cass County, the Jeffersonville division of the Devonian limestone consists of horizontal beds resting on Niagaran limestones dipping at an angle of 6 to 18 degrees.

Near Bunker Hill, Pipe Creek Falls, Waverly, Keysport, Georgetown, and the mouth of Little Rock Creek, the Devonian limestone resting upon the Niagaran is identified as equivalent to the Jeffersonville or lower division of the Devonian limestone. Near the mouth of Keeps Creek, and near Delphi, the beds resting on the Niagaran are identified as the upper or Sellersburg division of the Devonian. The Devonian beds exposed in White County are also recognized as belonging to the Sellersburg division.

In the southern part of Madison County, near Pendleton, the Devonian rock resting on the Niagaran is the Pendleton sandstone, the equivalent of the Schoharie grit of New York.

The absence of any mention of distinct unconformity at most localities so far examined suggests that the Silurian-Devonian contact is not marked everywhere by strong unconformity, but that at many points in northern Indiana the unconformity is slight. In the southern part of the State the Silurian-Devonian contact is also accompanied by a slight unconformity. A distinct unconformity may be noticed at the William Avery quarry on Conn Creek, south of Waldron, and at the Mary Wurtz locality on the road to Geneva. (Twenty-second annual report, Indiana survey, pages 234 and 235.

The relationship of the Kokomo or lower waterlime limestone to this unconformity has not been determined. Judging from investigations in western Tennessee, the deformation of Silurian rocks preceding the deposition of the Devonian affected also the Kokomo or lower waterlime division.

In central Kentucky and in Tennessee the Devonian rests upon successively lower beds of the Silurian, on approaching the crest of the Cincinnati geanticline from the west. The unconformity at any single locality appears slight, but when localities distant from the crest of the geanticline are compared with those much nearer, it is observed that, notwithstanding the moderate inclination of the Silurian rocks, the Devonian at the more western exposures rests upon the Louisville bed, but that farther east it rests in succession upon the Waldron, Laurel, Osgood, Clinton, Richmond, and finally upon Lorraine beds. Similar conditions are noticed on the eastern side of the Cincinnati geanticline, in central and southern Kentucky.

It is likely that similar conditions obtained in southern and central Indiana. The Devonian formerly may have extended a considerable distance east of its present line of outcrops, and it is probable that it rested eastward upon successively lower beds of the Silurian. The thinning of the Louisville bed from Louisville toward Decatur County, and from Waldron toward St. Paul and Greensburg, is favorable to this suggestion. A study of the Silurian outcrops nearest to contact with the Devonian strata in Howard, Hamilton, and Madison counties may in the future shed much light upon this subject. The Kokomo limestone includes the highest Silurian strata so far identified in Indiana. In Hamilton County, the uppermost Niagaran strata contain the

Conchidium fauna belonging to the upper part of the Louisville section. At Pendleton, in Madison County, *Sphaerexochus romingeri* usually indicates the Louisville horizon, but it does not appear to be confined to any particular horizon. Future studies may suggest that the Madison County exposures occupy a lower horizon than those farther west.

The conditions in northern Indiana and in the adjacent parts of Illinois require much further investigation. At Elmhurst, west of Chicago, Silurian strata remained long enough above water level during early Devonian times to permit the widening of the cracks formed during their elevation. Some of these cracks were filled during the latter part of the Devonian by clayey material containing fish teeth and a few brachiopods.

THE DEVONIAN PERIOD.

| Subdivisions in Indiana. | Corresponding subdivisions in New York. | Synonyms. |
|-----------------------------------|---|-------------------------|
| New Albany Black Shale. | Genessee, Marcellus. | |
| Sellersburg Limestone. | Hamilton. | Crinoidal limestone. |
| Silver Creek hydraulic limestone. | | North Vernon bluestone. |
| Jeffersonville limestone. | | |
| Geneva limestone. | Corniferous. | |
| Shelby beds. | (Onondaga.) | |
| Hartsville beds. | | |
| Pendleton sandstone. | Schoharie. (?) | |

Counties in which the Devonian strata outcrop in Indiana: Clark, Scott, Jefferson, Jennings, Jackson, Bartholomew, Decatur, Rush, Shelby, Johnson, Marion, Hancock, Hamilton, Boone, Clinton, Tipton, Madison, Howard, Carroll, Cass, Tippecanoe, White and Jasper.

A considerable portion of the north half of the outcrop of Devonian strata in Indiana is covered with glacial drift, in places several hundred feet deep. Hence the tracing of the partings and the correlation of the strata have been attended with great difficulty and consequently lack the degree of accuracy found in the groups which have continuous outcrops for study and com-

parison. Dr. Kindle* divides the exposed portions of the Devonian outcrop into three areas, designated the Wabash, Pendleton and Southern Indiana areas. These areas are separated by a wide expanse of drift-covered region in which no bed-rock outcrops have been found.

The southern Indiana area extends from near Indianapolis, southward across the Ohio River and outcrops in many places through Shelby, Bartholomew, Jennings, Jackson, Jefferson, Scott and Clark counties. The best exposures are in the southern portion, where the glacial drift is thin or absent and where the area is more deeply dissected by the streams flowing into the Ohio River. As one goes northward from the Ohio River the valleys become shallower and the glacial drift deposit heavier, and hence the underlying rocks show in fewer exposures. North from Shelby County the only exposures of the Devonian rocks through the drift are, the small area in the vicinity of Pendleton and several small areas in the vicinity of the Wabash River.

Pendleton is 28 miles northeast of Indianapolis, and 42 miles north of the northernmost outcrop of the Devonian rocks in the southern Indiana area. North and east of Pendleton the Niagara limestone outcrops. South there is no outcrop for more than 40 miles. West of Pendleton, in Hamilton County, there is an outcrop of limestone in several places; a limestone which was classed with the Devonian by Dr. R. T. Brown, but which Dr. Kindle places in the Niagara. The only Devonian rocks which Kindle finds in this area is a heavy-bedded, soft, white sandstone, which was named the Pendleton sandstone by E. T. Cox in 1876, and which Hall correlated with the Schoharie of New York. The correlation of the Pendleton sandstone with the Jeffersonville-Sellersburg beds in southern Indiana and with the Schoharie in New York is on a purely paleontologic basis. Well sections at Alert, Decatur County, show several feet of sandstone which is thought to be the equivalent of the Pendleton.

Kindle reports a local development of conglomerate in the top of the Pendleton sandstone, a conglomerate which consists of

*Devonian Fossils and Stratigraphy, in 25th Ann. Rep., 1900, and Bull. Am. Pal., No. 12 1899, pp. 1-111. The following paragraphs on the Devonian are based largely on Kindle's papers and Siebenthal's paper on the Silver Creek hydraulic limestone in the 25th Ann. Rep., 1900, and Newsom's paper in the 26th Ann. Rep. Kindle's papers are devoted largely to the paleontology of the Devonian.

well-rounded chert pebbles, frequently 3 or 4 inches in diameter, in a matrix of coarse sand.

In the Wabash Valley between Peru and Delphi, and in the Tippecanoe Valley near Monticello, are a number of exposures of a fissile black shale which is correlated with the New Albany black shale of southern Indiana. The two divisions of the underlying limestone have been correlated with the Sellersburg and Jeffersonville limestones of the southern area. The distribution of these is shown on the map.

In southern Indiana the *New Albany black shale* is exposed over considerable areas. It is a black to blue-gray fissile shale containing much iron sulphide and a great deal of bituminous matter. The bituminous matter is so plentiful in places that it will burn freely and the volatile gases have been distilled from it. The shale is 104 feet thick at New Albany, and elsewhere it has been reported as much as 140 feet in thickness. The outcrop covers an area from 8 to 15 miles wide, as shown on the map.

The *Sellersburg limestone* of Kindle includes both the crinoidal and the hydraulic limestones, but Siebenthal limits the term Sellersburg limestone to the upper or crinoidal division and the lower hydraulic limestone he calls the Silver Creek hydraulic limestone. The Sellersburg limestone is a white to gray crystalline limestone that lies between the overlying black shale and the underlying hydraulic limestone. Frequently the basal portions are sandy and sometimes there is a layer of pebbly sandstone separating it from the underlying hydraulic limestone. The shining black pebbles are said to be rich in phosphates.

The *Silver Creek hydraulic limestone* lies between the overlying Sellersburg limestone and the underlying Jeffersonville limestone. It is a fine-grained, massively-bedded, argillaceous, magnesian limestone, light to dark drab in color, becoming buff on exposure. It is 15 to 16 feet thick at Silver Creek, 8 to 10 feet at Charlestown and 5 to 6 feet in the vicinity of Lexington.

The *Jeffersonville limestone* is a white to bluish gray crystalline, fossiliferous, flaggy limestone, lying between the Silver Creek hydraulic limestone and the underlying Niagara limestone. It has been correlated with the Corniferous of New York. It is exposed at the Falls of the Ohio River, and from it are obtained

many fine coral fossils. In this part of the area there was a great coral reef, not greatly unlike many forming at the present time, except the corals are a different class from the living ones.

ECONOMIC GEOLOGY.—The New Albany shale contains a great deal of bitumen and may sometime be used as a source of supply of gases and oils which could be distilled from it. It would not be profitable to do so at present, but it is a possible source of supply in the future when gas and oil are scarcer than at present.

The Sellersburg limestone is used locally for building stone, for lime, and for road metal. The Silver Creek limestone is used extensively and mainly for the manufacture of hydraulic cement. It makes an excellent cement and is widely used for that purpose.

The Pendleton sandstone has been used as a glass sand and also as a building stone. Prof. Cox (Ann. Rep. 1878, p. 61), says it has a good reputation as a building stone, both for beauty and durability.

LOWER CARBONIFEROUS OR MISSISSIPPIAN PERIOD.

SUBDIVISIONS.

| <i>In Indiana.</i> | <i>In Mississippi Valley.</i> | <i>In Pennsylvania.</i> |
|--------------------------------|--|-------------------------|
| Huron limestone and sandstone. | Chester, Archimedes, Kaskaskia, Pentremital. | Mauch Chunk red shale. |
| Mitchell limestone. | St. Louis. | |
| Bedford oolitic limestone. | Warsaw. | |
| Harrodsburg limestone. | Burlington. | |
| Knobstone shale. | Keokuk. | Pocono sandstone. |
| Goniatite limestone. | Chouteau. | |

That long and interesting time between the close of the Devonian and the beginning of the Coal Measures has been designated the Lower Carboniferous, the Subcarboniferous, and more recently the Mississippian period. The strata formed during this period in Indiana are prevailingly calcareous. The limestones contain much clay, sand and chert in places, but the greater part of the strata aggregating more than 1,000 feet in thickness are limestones of different textures and different degrees of purity. Attempts have been made at different times to correlate these differ-

ent subdivisions with strata elsewhere, but there is more or less question about the accuracy of any such correlations with the present data. It seems better at present to adopt the local terms and await more thorough study before correlating them with widely different strata.

The subdivisions that have been made are based largely on lithologic characters and for the most part there will be no confusion in identification. Later, when the faunas of the different groups have been thoroughly studied, correlations may be made with distant localities.

There appears to be no unconformity between the Lower Carboniferous strata and the underlying Devonian, and for that reason there has been some difference of opinion as to the proper place to draw the parting between them. Between the Lower Carboniferous and the Coal Measures there is a decided unconformity, marked by erosion. During the latter part of the Lower Carboniferous there was an uplift of the land area beginning at the north and progressing southward. During this elevation there was considerable disintegration and many channels were eroded on the land area. After the depression of the land, the Coal Measure strata were deposited unconformably on this eroded surface.

The Indiana area was only a small part of the great interior sea that extended over the great part of the Mississippi Valley area in which the calcareous layers were accumulated. In Illinois, Iowa, Mississippi, Arkansas, Kentucky and Tennessee similar great thicknesses of limestone occur. On the eastern side of the Cincinnati Island the limestones contain more shale and sand, and in following them east one finds the sand and shale increasing until in eastern Pennsylvania, along the border of the interior sea, the limestones have disappeared entirely and the sediments of Lower Carboniferous age consist of a heavy bed of gray sandstone (the Pocono), overlain by a thick bed of red shale—the Mauch Chunk red shale. Thus, while the sands and mud were accumulating along the eastern shore, the limestones were being formed out in the clearer waters of this interior sea by the remains of the lime-secreting organisms.

THE ROCKFORD GONIAITITE LIMESTONE.

(Synonyms: Marcellus, Hall; Chemung, Hall; Chouteau, Worthen; Lithographic, Kindle.)

Counties in which the Rockford Goniaticite Limestone outcrops: Clark, Scott, Jackson, and Bartholomew (?).

The Rockford Goniaticite limestone is considered by some to be the first stratum formed in the Lower Carboniferous in Indiana, but some geologists think it ought to be classed with the Devonian. James Hall correlated it first (1861) with the Marcellus and later (1862) with the Chemung. Other correlations have been made with the Chouteau and with the Lithographic limestone of Missouri.

The different fossil forms that have been found in this limestone are listed in the Twenty-sixth Annual Report of this Department, pp. 258-260.

The Goniaticite limestone is only a few feet in thickness, frequently not more than 2 feet thick, but it occurs widespread over southern Indiana. It is a close-grained fossiliferous limestone, having a conchoidal fracture and a greenish color when fresh, turning brown on exposure.

THE KNOBSTONE.

Counties in which the Knobstone strata outcrop: Harrison, Floyd, Clark, Washington, Scott, Jackson, Lawrence, Monroe, Brown, Bartholomew, Johnson, Morgan, Owen, Putnam, Hendricks, Marion, Boone, Montgomery, Clinton, Tippecanoe, Fountain, Warren, White, Benton and Jasper.

NAME.—The Knobstone group was so named as early as 1859 by D. D. Owen because of the peculiar conical hills or *knobs* which occur over its weathered outcrop.* The name has been accepted and used by geologists since that time, although it is unfortunate that a definite geographical term was not used. The few lithologic terms that have been used for designating a certain epoch or series in geology are gradually being replaced by geographic terms and Knobstone will probably be added to the list in the near future.

*For particulars and detailed discussion of the group see 26th Annual Report, 1901, p. 260, by J. F. Newsom; and Report of a Geological Reconnaissance of the State of Indiana, made in 1837, by D. D. Owen, p. 21. Indianapolis, 1859.

Other local terms that have been applied to portions of this group are *New Providence shale* and *Riverside sandstone*. The first name was used in 1873 in the Fifth Annual Report, p. 61, by Borden, for the soft greenish or bluish shales in the vicinity of New Albany and New Providence. The sandstone quarried at Riverside above Attica on the Wabash River was named Riverside sandstone by the writer* in 1896, because at that time there was not sufficient data available to definitely correlate it with the Knobstone of southern and central Indiana. Since the correlation has been made the name Riverside should be dropped as a geological term. It may still be used as a commercial term.

KIND OF ROCK.—The rocks of the Knobstone consist of blue gray shales, shaly sandstone, sandstone and rarely a little limestone. In central and southern Indiana where they are best developed the group is divided by Newsom into (1) the New Providence shale at the base, overlain by (2) the Upper Knobstone shale and (3) the Knobstone sandstone. There is considerable variation locally in the relative percentage of sandstone and shale, with the shales prevailing at the base of the group and sandstone at the top. The color is prevailingly bluish gray to greenish gray, changing to buff on the much weathered exposure.

Toward the northern limit of the Knobstone area there is considerable limestone that is thought by some to belong to the Knobstone group, but which the writer thinks is properly correlated with the overlying Harrodsburg limestone, and he so designates it on the map.

CHEMICAL COMPOSITION.—The Knobstone varies considerably in composition in different parts of the area. The most marked variation is in the sand and clay constituents, in some places grading into sandstone and elsewhere into sandy shale. The sand becomes very fine in some places but generally forms an appreciable part of the rock. The following analyses indicate the general chemical character. The first one is a sandstone, the next two are shales.

PARTIAL ANALYSIS OF KNOBSTONE FROM RIVERSIDE, IND.

Insoluble residue, 93.16 per cent. Alumina, 1.6 per cent. Iron oxide, 2.69 per cent. Lime, 0.13 per cent.

*20th Ann. Rep., p. 317, 1896.

ANALYSES OF KNOBSTONE SHALES FROM JACKSON COUNTY, IND.

| | | |
|---|-------|-------|
| Silicia (SiO ₂)..... | 59.64 | 64.59 |
| Titanium oxide (TiO ₂)..... | 1.05 | .30 |
| Alumina (Al ₂ O ₃)..... | 19.14 | 16.37 |
| Combined water (H ₂ O)..... | 4.36 | 3.71 |
| <hr/> | | |
| Clay base and sand..... | 84.19 | 84.97 |
| Ferric oxide (Fe ₂ O ₃)..... | 3.39 | 5.37 |
| Ferrous Oxide (FeO)..... | 4.20 | 1.59 |
| Lime (CaO)..... | .26 | .16 |
| Magnesia (MgO)..... | 2.31 | 1.56 |
| Potash (K ₂ O)..... | 3.53 | 4.24 |
| Soda (Na ₂ O)..... | .80 | .97 |
| <hr/> | | |
| Fluxes..... | 14.49 | 13.89 |
| Carbon dioxide (CO ₂)..... | .35 | .43 |
| <hr/> | | |
| Total..... | 99.03 | 99.29 |

THICKNESS.—The Knobstone group reaches a maximum thickness of 650 feet at Bloomington, near the center of the State. At St. Joseph, in Floyd County, it is 550 feet; at Rockville, Parke County, it is 530 feet. Near New Albany in the southern part of the State it is 471 feet. It apparently thins out and probably disappears in the northern portion of the State but the northern limit is concealed by a heavy mantle of drift.

DISTRIBUTION.—As shown on the map, the Knobstone group outcrops over a belt of quite variable width, extending in a west of north direction from the Ohio River to north of the Wabash River, and possibly further to the northwest, as the area there is so covered with drift as to conceal the underlying rock. The extreme northwest limits as shown on the map are only approximate, based on the very limited data at hand. The widest portion of the area is in the south-central portion of the outcrop in Jackson, Monroe, Brown and Bartholomew counties, where it is from 25 to 38 miles wide. It narrows very perceptibly to the south to scarcely six miles in width at New Albany.

TOPOGRAPHY.—“The generally narrow, V-shaped valleys cutting the country in all directions, apparently without any systematic arrangement, form the most noticeable and important topographic characteristic of the Knobstone area. In the central area, particularly, the valleys are well developed. Here they

have the tangled, dendritic arrangement common to flat, plateau countries, where folds and faults are absent." (*Newsom.*)

A noticeable feature throughout the whole Knobstone area, where the valleys are well developed, is that the south-sloping hillsides have much steeper slopes than the north-sloping areas. This difference is thought to be caused by the different temperature changes. Thus the hillside sloping south faces the winter's sun, which thaws it during the day, and it freezes again at night. It is this constant freezing and thawing which weathers the shale much more rapidly than on the north-facing hillside, which lies in the shadow, and is often covered with snow for many days and weeks when the sun and frost are disintegrating the south-facing hill.

There is some difference also between the east and west sides of the north-south valleys, but it is not so marked as in the preceding. The slope on the east side receives the afternoon sun, which is warmer than the morning sun, and hence the tendency is to weather more rapidly, but the difference is not so marked as in the east-west valleys.

The Harrodsburg limestone and Bedford oölitic limestone overlying these shales are so much more durable, that along the western border of the Knobstone area they form a protecting cap over the Knobstone, which weathers away more rapidly, until the cap rock breaks down from its own weight. Where there is no active stream these boulders accumulate in talus slopes, often concealing the Knobstone outcrop. Where there is an active stream to remove the talus, the Knobstone forms scaling-vertical walls underneath the harder limestone which frequently overhangs. In the northern part of the area, where the overlying limestones do not occur and the Knobstone is overlain by the Mansfield sandstone, which is still more durable, the top-heavy cliffs are even more conspicuous than in the limestone area.

A characteristic feature of the weathering of the Knobstone on all the cliff exposures is the exfoliation or the flaking off of thin slabs parallel with the surface and independent of the bedding. These foliation planes are sometimes so pronounced as to be mistaken for the bedding planes.

There is not the alternation of hard and soft layers so common in many limestone beds, and hence the absence of rock terraces

caused by such alternation. While there is a uniformity in the relative hardness and weathering qualities of the different layers, there are irregular patches and pockets of softer and harder materials, so that the weathered surface is sometimes pitted by the weathering out of the softer spots and sometimes studded with siliceous concretionary masses.

SPRINGS.—Like most shale formations, the Knobstone shales absorb moisture freely but do not transmit it freely, so that it is not a water-producing stratum, and is relatively impervious when compared with the overlying limestones in the central and southern areas or the sandstone of the northern portion. Hence, where it forms the base of the hills which are capped with limestones or sandstones, the top of the shales is a marked horizon for springs, as the waters which find ready passage down through the pores of the sandstone or the caves, joints and fissures of the limestone are led to the surface on the hillsides along the top of the less pervious Knobstone shales.

ECONOMIC.—In a few places the more sandy portions of the Knobstone have been quarried and used as a building stone. Such quarries occur at Riverside on the south bluff of the Wabash River, opposite Independence, and on the north bluff opposite Attica, and at several places along the C. I. & W. Railway, near Raccoon Station. It does not appear to be used so much toward the southern end of the area, possibly because of its proximity to the oölitic limestones which form a better building stone.

It is not a very durable building stone, especially in the presence of moisture, and hence is not adapted to foundations and bridges, where it has been used too frequently. In the walls of buildings above the foundations or as trimmings for brick or stone buildings it is quite serviceable if quarried and selected with some care. It has a fine grain and generally uniform color, either yellowish buff, as generally found in the top layers, or a blue gray in the deeper unoxidized layers. The fineness and evenness of grain, the uniformity in color, the ease with which the stone can be cut and carved are all strong points in its favor as a building stone. If the stone is selected with care and quarried and dressed with proper precautions and laid in proper position in the wall, it can be used safely and with good architectural effects.

The Knobstone shale at Blue Lick, Jackson County, is now being used in the manufacture of *Portland cement*, and there is no apparent reason why larger quantities of it should not be used for this purpose. Points that would apparently indicate an increased use of the Knobstone shale in cement making are (1) its proximity to the excellent limestone beds overlying it and its short distance from the coal fields; (2) uniformity in composition, and (3) ease of quarrying and preparation. In many places the shale and the limestone may be obtained from the same hillside, but generally it may be found more desirable to quarry them at different points because the limestone immediately overlying the Knobstone is generally not a good limestone for cement purposes. The shales may be a little harder to pulverize and mix with the lime ingredients than the softer clays that are sometimes used, but this may be more than counterbalanced by greater uniformity of composition and great thickness of the beds. Care, of course, is necessary in selecting a suitable locality where the shale is not too sandy and has the proper composition.

In many places the Knobstone shale will furnish excellent material for brick making, for either vitrified brick or common brick. It has been used for this purpose at New Albany and probably will be used for similar purposes in many other localities. It is true that Indiana has an abundant supply of brick-making shales in the Coal Measures close to the fuel supply, but for the bricks used along the Knobstone belt it would be cheaper to ship in the coal than the bricks, to say nothing of the increased commercial advantage in having the factory at home and the increased use of the bricks to the improvement of the streets and the buildings.

THE HARRODSBURG LIMESTONE.

(Synonyms: Burlington, Keokuk, Encrinital.)

Counties in which the Harrodsburg limestone outcrops: Floyd, Clark, Washington, Jackson, Lawrence, Monroe, Owen, Putnam, Parke, Montgomery and Fountain.

Overlying the Knobstone group and underlying the oölitic limestone is a series of rocks that has been variously designated in the older geological reports of Indiana. It was early known

as the Enerinital limestone, from the abundant crinoidal remains. It has also been correlated with both the Burlington and Keokuk groups of Iowa. Owing to the uncertainty of the correlation, especially the delimitations of the group, the present State Geologist and his assistants thought it best to use a local name and clearly state its delimitations, and await more thorough paleontological knowledge before correlating with formations so widely separated as are these rocks from Burlington and Keokuk. The name Harrodsburg limestone, from a village of that name in the southern part of Monroe County, was first used in 1896 by Hopkins and Siebenthal in the geology of the oölitic limestone district of Bedford and Monroe County, and this name has been used in all of the reports since 1896. It includes all the beds between the Knobstone shales below and the Bedford oölitic limestone above, and is generally quite sharply separated lithologically from the oölitic limestone above, but grades into the Knobstone shales below in many places.

The Harrodsburg group consists chiefly of limestones which frequently contain a great many crinoidal remains and many well preserved crinoid heads at Crawfordsville and vicinity, a locality which is known in all the large museums of the world for its fine crinoid specimens. Intermingled with the limestone layers are thin layers of shale and small quantities of chert. In the limestone, and less commonly in the shaly layers, quartz geodes occur often in great numbers. These appear to be more abundant in the lower than in the upper layers, and occasionally occur in the underlying Knobstone layers.

There are many stylolite seams at various levels, and nearly always a prominent seam of this kind occurs at the top of the group separating it from the oölitic limestone.

The limestone is in places coarsely crystalline, especially the crinoidal layers. The crinoid stems are always coarsely crystalline calcite, and the ground mass in which they are imbedded is crystalline in part, but consists largely of mud deposits. In the Heltonville locality the upper layers consist almost entirely of fragmental bryozoa, the delicate, lace-like appearance of which is very pretty on a broken or polished surface. It has been used in a limited way for an ornamental stone.

EXTENT.—The Harrodsburg limestone outcrops along a belt extending from the Wabash River in Warren and Tippecanoe counties in an east of south direction to the Ohio River and beyond into Kentucky. The outcrop varies in width from a few feet to several miles. It extends further north than the succeeding stratum, the Bedford oölite, but not as far as the underlying Knobstone. There appears to have been an elevation of the land and consequent recession of the sea during this part of the Mississippian or Lower Carboniferous period. The area covered by the outcrop of the Harrodsburg limestone is shown in detail on the State map.

In the central area the Harrodsburg limestone and shales vary from 60 to 90 feet in thickness. It thins out somewhat to the north and near the northern limits it appears only in isolated patches. A detailed section of the different layers near Harrodsburg indicates the general character of the stone for the central area.

SECTION OF THE NORTH BLUFF OF JUDAH'S CREEK, ONE MILE SOUTH OF
HARRODSBURG.

| | <i>Feet.</i> | <i>Inches.</i> |
|--|--------------|----------------|
| Massive fossiliferous limestone..... | 6 | 0 |
| Gray heavy-bedded limestone..... | 16 | 0 |
| Blue argillaceous shale | 2 | 0 |
| Limestone | 0 | 4 |
| Chert | 0 | 3 |
| Heavy-bedded blue to gray crystalline limestone..... | 6 | 0 |
| Yellow calcareous shale with geodes..... | 1 | 3 |
| Fine, heavy-bedded blue crystalline limestone..... | 11 | 0 |
| Flaggy limestone | 1 | 0 |
| Gray argillaceous limestone | 0 | 10 |
| Calcareo-argillaceous shale with bands of limestone and some geodes | 18 | 0 |
| Heavy limestone, weathering shaly..... | 3 | 0 |
| Calcareous shale in bed of creek..... | ? | ? |

The thickness over the southern portion of the area is stated to be 35 to 100 feet, averaging about 65 feet. The general character of the rock in the southern area resembles closely that in the central area, consisting of interstratified limestone and shale with many geodes and chert concretions.*

*See 27th Ann. Rep., Lower Carboniferous of southern Indiana, by G. H. Ashley.

The geodes of the Harrodsburg limestone vary in size from a fraction of an inch to several feet in diameter. They consist of an outer crust of crystalline quartz or quartz and chalcedony, which is lined or entirely filled with crystals. These crystals are most commonly quartz or calcite, or the two together; frequently quartz lining the shell and the central space filled with calcite. Several other minerals occur in smaller quantities, the most common ones being the metallic sulphides, pyrites and marcasite, the iron sulphides; galena, the lead sulphide; sphalerite, the zinc sulphide; and millerite, the nickel sulphide. In certain localities the geodes are very abundant; as many as 100 may be seen at one time on some of the cliffs bordering the creeks, and hundreds of others occur among the boulders and gravels of the creek bed. So abundant are they in places that the gravel bars on the creeks are composed almost entirely of geodes and geode fragments.

ECONOMIC.—The Harrodsburg limestone has a limited local use for building stone and for road metal. Its use is more limited than it would be otherwise by its proximity to the Bedford oölite, a much better building stone which is used in preference, and the Mitchell limestone proves to be a much better road metal and is used, or should be used, in preference where it can be obtained at reasonable cost.

BEDFORD OÖLITIC LIMESTONE.

(Synonyms: Oölitic stone; Bedford rock; Bedford stone; Indiana oölitic stone; Spergen Hill limestone; White River stone; St. Louis limestone; Warsaw limestone.)

Counties in which the oölitic limestone outcrops: Harrison, Floyd, Washington, Lawrence, Monroe, Owen, Putnam, Montgomery.

References—

The Bedford Oölitic Limestone of Indiana, by T. C. Hopkins and C. E. Siebenthal—Twenty-first Ann. Rept. Dept. Geol. and Nat. Resources. See p. 411 for other references.

The Lower Carboniferous Area in Southern Indiana, by Geo. H. Ashley, in Twenty-seventh Ann. Rept., 1902.

The Mineral Industry, New York, Vol. IV, 1894, p. 505. Nearly all the Annual Reports of the Department of Geology and Natural Resources of Indiana have short articles on the Bedford oölitic limestone.

The next stratum overlying the Harrodsburg limestone is a massive whitish oölitic limestone that has been described in the recent geological survey reports as the Bedford oölitic limestone. It has been referred to in earlier reports as Indiana oölitic stone, Spergen Hill limestone, White River stone, St. Louis limestone, Warsaw limestone, etc. Of all the many names which have been given to it, the Bedford oölitic limestone is thought by the present survey to be the best because it is a limestone, it is oölitic, it is typically developed in the vicinity of the city of Bedford and is known commercially throughout the State and the Union as the Bedford oölitic limestone.

The rock is a granular limestone or calcareous sandrock in which both the grains and the cement are carbonate of lime. It differs from sandstones, which it resembles in appearance, by having rounded grains instead of angular, grains composed of soft shells or fragments of shells instead of quartz, and hence is more easily cut and carved. It differs from nearly all other varieties of limestone in being more granular and more easily cut and carved into any desired shape. There is considerable variation in the size and regularity of the grains at different places. A fine grain of uniform size is the kind most sought after for building purposes. The coarse crystalline texture is not adapted to carved work or fine tool dressing. The grains are shells and shell fragments, consisting chiefly of minute forms of foraminifera, small bryozoa, brachiopods and gasteropods.

The fossils are imbedded in a cement of calcite and the hardness and compactness of the stone is governed by the relative amount and purity of this cementing substance. The firm crystalline cement gives the stone strength and the soft, partly hollow shells prevent it from being too hard to work easily under the tools of the stonecutter.

The stone occurs in a massive bed varying from a few feet up to 100 feet in thickness, and for the most part nearly free from bedding planes. The lamination appears in many places on a weathered surface and in a few places even cross-bedding is brought out by the weathering. In a number of places the bedding planes are marked by the black jagged points of the stylolites, the so-called "crow foot" or "toe nail" of the quarrymen. These black streaks are all too frequent in many localities

and cause large quantities of the stone to be thrown out on the waste, as they injure the strength of the stone as well as disfigure it.

The prevailing colors of the Bedford stone are blue and buff. The upper portion, extending down to a variable depth, is buff, and the deeper portions are blue. The parting between the two colors is commonly an irregular one and frequently causes the waste of considerable stone. In many places the stone has a light gray nearly white color on the weathered surface.

The blue appears to be the original color and the color that prevails in the deeper parts of the quarry. The buff is the secondary product, derived from the blue by the surface waters carrying down more or less oxygen which changes the lower oxides of iron to the higher, with corresponding change in color, or oxidizes the diffused carbonaceous matter. The depth to which the oxidation extends is sometimes only a few inches and in some places it extends to the bottom of the oölitic stone.

The Bedford stone has an average specific gravity of 2.47. Chemically it is a nearly pure carbonate of lime, varying from 95 to 98.25 per cent. of that substance. Probably no other limestone shows such a uniformly high percentage of lime.*

The oölitic limestone has no very marked effect on the general topography, as it lies in the midst of the limestones of almost equal durability. Where the outcrop has any considerable width, the surface is gently undulating. Quite frequently the outcrop is in the hillside, where it forms most commonly a steep cliff, and if along the stream channel, frequently an overhanging ledge, owing to the more rapid weathering at the base of the cliff, near the water. It is less subject to sink holes, depressions and caves than many of the other limestones.

ECONOMIC FEATURES.—The Bedford oölitic limestone ranks among the finest building stones in the United States, and from a commercial standpoint stands first among the rocks quarried in Indiana in both the quantity and quality of the stone quarried. This stone has been shipped to nearly every state and city in the United States and some foreign countries for use in public and private buildings; especially is it used extensively in the two largest

*For list of chemical analyses of the oölitic limestone see 21st Ann. Rept., 1896, p. 320.

cities, New York and Chicago, where it continues to grow in favor. It is also used extensively for monumental purposes.

The properties which make this stone valuable for building purposes are: (1) Its easy *workability*. It occurs in large masses, from which blocks of any required dimension may be obtained. It can be cut from the quarry with greater ease than almost any other rock, and after removal from the quarry it lends itself kindly to further cutting and carving. Probably no other building stone quarried in this country is better adapted to carved work than this. Its freestone nature, comparative softness, and freedom from lamination fit it for work of this character. Like nearly all building stones, it is softer and more easily cut and carved when first quarried, and becomes much harder and less tractable after seasoning.

(2) Uniformity of color and texture is another desirable quality in building stone in which the Bedford stone excels. Except along the generally somewhat irregular line of contact of the blue and the buff stone, the rock has either a uniform blue or uniform buff color, and rare indeed is the instance of patches, streaks or stains of other colors to mar the uniformity. The buff color is the one most in demand although a number of years ago the blue colored stone was most sought.

(3) Durability is one of the most important properties of a good building stone and one in which the Bedford stone excels. While its rather soft, granular structure might indicate otherwise, it has proven itself to be one of the most durable building stones on the market. Its ability to withstand disintegration is shown (a) by the bold cliffs and the smooth faces on many outcrops; (b) by the sharp corners, square blocks and even faces of the old quarries where the stone has been exposed for many years, and (c) by the good state of preservation of the stone in many old buildings where it has been exposed to the elements for many decades.*

(4) Transportation facilities. It will be noticed on the map that the entire area of the Bedford stone is fairly accessible to railways. The Monon Railway traverses the area lengthwise from Salem northward and several east and west lines cross the belt at different points.

*Specific instances and figures in corroboration of the above statements may be found in the Annual Report State Geologist, 1896.

DISTRIBUTION.—The areal distribution of the Bedford oölitic stone is shown on the accompanying State map,* where it will be seen to extend from Montgomery County south across the Ohio River, a distance of 142 miles in the State of Indiana. The rock loses its massive structure just north of Romona, on the White River, and in its northern extension becomes thin bedded or even shaly on some of its exposures. While it thus loses its massive structure and hence its value as a building stone, it retains its characteristic granular texture and fossils.

It outcrops on the hill a quarter of a mile north of Parkersburg in the southern border of Montgomery County, which is the most northern outcrop of it observed by the writer in the State.†

It is exposed at many points through Putnam County. It outcrops along the Monon Railway northeast of Greencastle in sections 22, 23, 34, and 35, T. 13 N. R. 4 W. It has been quarried for road metal in Greencastle in the quarry a few hundred yards northeast of the Monon depot, where a thickness of many feet is exposed on the quarry face. There is another outcrop in the gully crossing the Indianapolis & St. Louis Railway about a mile east of the depot. At many other points in the southern and southeastern parts of Putnam County the rock is exposed and at several places has been quarried for local use as road metal. There are a number of similar exposures in northeastern Owen and northwestern Morgan counties in T. 11, 12, and 13 N. and R. 2 and 3 W.

Outcrops of similar stone becoming a little more massive in structure occur over the area south of Quincy and between that point and Romona, where it first appears in a massive bed, and where the first large building stone quarry is met as one goes south.

Quarries of oölitic limestone have been operated at the following points going southward: Romona, Big Creek, Stinesville, Ellettsville, Bloomington (Hunter Valley), Sanders, Clear Creek, Peerless, Buff Ridge, Smithville, Harrodsburg, Spider Creek, Bed-

*More detailed and larger scale maps of the productive area between Salem and Quincy may be found in the 21st Ann. Rep. of this Survey for 1896, and larger scale maps of the area south from Salem may be found in the 27th Ann. Rep. accompanying the paper by Dr. Ashley.

†There is an oölitic limestone exposed near Darlington, ten miles northeast of Crawfordsville, but it is the concretionary oölite, quite different from the Bedford stone and which resembles the oölite found at several different places in the Huron group in Lawrence and Orange counties.

ford, Oölitic, Reed's Station, Heltonville, Fishing Creek, Rock Lick and Salem.

The quarries at Romona show a greater thickness of stone than at any of the other localities, but it is a little more crystalline and coarser grained than farther south, and is therefore better adapted to heavy masonry than to fine carved work. The Big Creek quarries have been abandoned for many years. At Stinesville and Ellettsville the quarries have been in operation for many years and are still productive, furnishing stone of fine quality. The Hunter Valley district near Bloomington is newer than the above, yet has had a number of large quarries and mills in operation for a number of years (since 1891). Between Bloomington and Bedford a good many quarries have been opened in the oölitic stone, some of which are still in operation and some have been abandoned.

Bedford is the center of the largest development along the oölitic belt. The Blue Hole quarry near the city, and the Dark Hollow, Reed's Station, and Oölitic Station quarries northwest of the city, are the more important quarries in the vicinity. All of these quarries are connected with Bedford by one or more lines of railway, and several large stone mills are located in the city.

The developments south of Bedford have not been so extensive as those at and north of that city. During the year 1901 a large quarry was opened in the Fishing Creek district, but has since been abandoned. South from Salem the stone has been quarried to some extent for local use but not for shipment. (See paper in the Twenty-seventh Annual Report by Dr. Ashley.)

MITCHELL LIMESTONE.

(Synonyms: Cavernous limestone, Barren limestone; St. Louis limestone.)

Counties in which the Mitchell limestone outcrops: Harrison, Floyd, Crawford, Washington, Orange, Martin, Lawrence, Monroe, Greene, Owen, Morgan, Putnam, Parke and Montgomery.

NAME.—Overlying the Bedford oölitic limestone is a heavy bed of compact limestone and chert, with small quantities of intercalary calcareous shales, which has been called the Mitchell lime-

stone by the Blatchley survey. It was first so called in the Twenty-first Annual Report in 1896. In the reports previous to that time it was called the St. Louis limestone, but there is good reason to think that it corresponds only in part with the St. Louis limestone of the Mississippi Valley, and since it forms a fairly well marked stratigraphical unit it was thought best to give it a local name that definitely fixes its position. It is named from Mitchell, a village in the southern part of Lawrence County.

The lower limit of the Mitchell group is the Bedford oölitic stone, the upper limit is the Huron sandstone, shale or limestone, or in the absence of the Huron, the Mansfield sandstone. In the middle portion of the area it ranges from 150 to 250 feet thick, thinning out toward the north and thickening to the south, as at Corydon, in the southern part of the State, it is 350 to 400 feet thick.

DESCRIPTION.—The Mitchell group in Lawrence County consists of limestones, shales and chert. The lower portion consists of yellow, drab or gray limestone; the upper portion consists of compact blue and gray limestone with some intercalary shales and considerable gray chert. Following is a detailed section of the Mitchell in one locality:

SECTION OF THE MITCHELL LIMESTONE IN T. 7 N., R. 2 W., SEC. 13.

| | <i>Feet.</i> |
|---|--------------|
| Drab lithographic limestone, <i>L. proliferum</i> , in top layer..... | 20 |
| Chert breccia, rotten lithographic groundmass..... | 8 |
| Bluish drab, fine-grained, fetid limestone..... | 10 |
| Lithographic limestone | 4 |
| Drab calcareous clay shale..... | 9 |
| Drab rotten, magnesian limestone with chert inclusions..... | 29 |
| Bluish, vermicular, shaly limestone..... | 2 |
| Drab calcareous shale | 4 |
| Rotten and shaly lithographic limestone..... | 5 |
| Lithographic limestone | 2 |
| Rotten lithographic limestone | 5 |
| Drab calcareous shale | 7 |
| Fine-grained, bluish-gray limestone with conchoidal fracture. | 5 |
| Calcareous clay shale | 2 |
| Gray limestone in eight-inch beds | 5 |
| Fossiliferous shaly limestone | 14 |
| Concealed | 6 |
| Fossiliferous coarse-grained limestone..... | 2 |
| Oölitic limestone | — |

The following section shows the character of the beds in the southern part of the area :

SECTION OF PART OF THE MITCHELL GROUP NEAR CORYDON HARRISON COUNTY.

| | <i>Feet.</i> | <i>Inches.</i> |
|--|--------------|------------------|
| Buff to drab and pink, shaly limestone..... | 8 | 0 |
| Outcrop of same rock, showing only clay to which the limestone has weathered, buff, yellow and red.... | 3 | 0 |
| Hard light drab limestone..... | 0 | 1- $\frac{1}{2}$ |
| Light brown to nearly black, fissile shale..... | 0 | 6-8 |
| Solid, dark blue limestone..... | 3 | 0 |
| Light brown shale and limestone..... | 1 | 0 |
| Light brown to blue shaly, hard limestone..... | 2 | 6 |
| Light brown fissile shale | 0 | 6 |
| Light drab limestone, with plates of chert..... | 4 | 6 |
| Soft, dark drab shale | 0 | 6 |
| Drab limestone | 5 | 0 |
| Drab limestone, softer than last, to railroad track (12-15 feet above creek) | 2 | 0 |

In a number of places a portion of the rock has the texture of a lithographic stone, but as yet no one has found it in sufficiently large blocks free from defects to have any commercial value for lithographic purposes. It contains minute veins and scattered crystals of calcite. The lithographic stone is practically free from fossils.

In a great many places throughout the area a good quality of flagstone and heavy building stone could be obtained from the bold outcropping ledges of the limestone. The chert occurs in varying quantities at different horizons, sometimes a few scattered nodules which may increase in size and number until they replace a greater part of the limestone. On the weathered exposures the lime carbonate is leached out and the chert fragments left in large numbers through the residual limestone clay. Over a large part of the area south of the glacial limit the surface is characterized by this deep red to reddish brown clay with its many angular chert fragments.

CAVES.—The greater part of the area of the Mitchell limestone is characterized by many caverns, large and small, which find expression on the surface in many sink-holes, all of which lead into caverns. The question arises, why should there be more caverns in this limestone than in any of the others? It is not easy to give

a decisive answer, yet the following suggestions may partially account for it: (1) The stone has a great many open joints, in and along which the meteoric waters are active. (2) The abundance of chert fragments on the weathered surface makes a porous soil mantle which absorbs a large per cent. of the rainfall and conveys it to the limestone. (3) The soil is quite fertile, hence there is a heavy growth of vegetation, the decaying portion of which furnishes the acids to the percolating waters, thus making them more active agents of dissolution. These caves are most abundant in the central and southern portion of the belt, but occur all over the area. Marengo and Wyandotte are two of the best known caves in Indiana, but there are scores of smaller and less noted ones throughout the area covered by the Mitchell limestone. The Mammoth cave and other large caves in Kentucky are in the southern extension of this same belt of limestone. The University cave at Greencastle is one of the most northern caves on the belt.*

TOPOGRAPHY.—The Mitchell limestone is characterized topographically by the numerous sink-holes over the area where it occurs, and by the scarcity of surface streams. Nearly all the drainage is subterranean, through the numerous caves. A few valleys have cut down through the limestone or down into it as far as the permanent water plane, and they receive the subterranean drainage in large springs that are the openings where the cave streams come to the surface. One of the most interesting of these underground streams is Lost River, in Orange County, which flows over the surface for a few miles near the head and then drops through one of the many sink-holes and flows as an underground stream for about eight miles, when it emerges as a large spring, the head of Lost River. During wet seasons all the water can not get into the sink-hole and the surplus flows over the surface through what, for the remainder of the year, is the "dry channel of Lost River." Part of this subterranean channel is said by Mr. Kindle to be in the overlying Huron limestone.

As may be seen on the map, the Mitchell limestone has a wider outcrop than any of the other groups in the Lower Carboniferous except the Knobstone. This greater width is due partly to its greater thickness and partly to the more level surface of the out-

*See paper on Indiana caves and their fauna, by W. S. Blatchley, 21st Ann. Rep., p. 121, which also contains bibliography of other papers.

crop. It forms a broad, rolling sink-hole area between the higher hilly region of the Huron and Mansfield groups on the west and the generally lower hills and valleys in the Bedford oölitic limestone on the east.

ECONOMIC FEATURES.—The stone is quarried in large quantities and used for road metal, wagon roads or railways; for flagstone, for paving and curbing, for burning to quick-lime and for building stone. It is one of the best road metal stones in the State of Indiana. It wears and packs better than the more granular oölitic stone or the more crystalline Harrodsburg. It compares favorably with the Niagara limestone of Silurian age in this respect, and is generally superior because the Niagara in many places has thin layers of intercalary shale which, if not separated in the quarrying, will quickly form mud on the roads.

The Mitchell limestone has been used quite extensively, especially during the last few years, in macadamizing the roads in the area where it occurs. Many small quarries have been opened in which the stone has been quarried for local use. Some of the largest railway quarries where the stone is quarried primarily for railway ballast are those at Williams' Station on the Indiana Southern Railway; at Spencer, Indiana, on the Indianapolis & Vincennes Railway; at Greencastle, Indiana, on the Vandalia Railway; at Greencastle, on the Big Four Railway; at Okalla, Putnam County, and on the Vandalia Railway near Waveland. Each of these quarries is capable of turning out from 10 to 25 or 30 carloads of crushed limestone per day.

The largest and best flagstone quarries in the Mitchell limestone are those at Putnamville, Putnam County, which have been in operation for many years, and have furnished large quantities of flagstone to neighboring towns. The flagstone is a superior quality, being very strong and durable. It is not used as extensively now as formerly on account of the expense of producing it as there is a heavy overburden to be removed before it can be obtained. The Putnamville stone has also been used extensively for building stone.

Much of the Mitchell limestone is a comparatively pure carbonate of lime and, when burned, makes a strong, fat quicklime. It has been burned for local use at many points throughout the area in small intermittent kilns. Lime has been burned in large

quantities at the following points: North of Mitchell on the Monon Railway, near Williams Station, Spencer, Cataract, Cloverdale, Putnamville, Okalla and Waveland. While lime has been burned at the above points, at only a few of them is it being burned at present.

As mentioned above, at many places the stone has a fine lithographic texture and considerable money and energy have been spent in trying to open up a good workable deposit of lithographic stone, but so far it has been in vain, the rock all having minute scattered crystals and veins of calcite. There remains a possibility of yet discovering a limited area of this rock suitable for lithographic stone, although experience in this line has not been encouraging.

Where it occurs free from the nodular chert, the Mitchell limestone in most places forms a very good building stone. It lacks many of the valuable qualities of the oölitic stone, and because of its proximity to that valuable stone, it probably will never be used extensively for building purposes. It lacks the massiveness of the oölitic stone and can not be obtained in such large blocks. It lacks the freestone character of the oölitic stone, hence it is not so easily carved and dressed. It occurs in thin beds and with numerous joint seams which facilitates its removal in rough blocks, thus adapting it to local use for foundations, bridge abutments, well-curbs, steps and similar uses. It is occasionally used for superstructures. The quarry at Putnamville is the only one that ships dimension stone to any distance.

DISTRIBUTION.—The most northern limit of the Mitchell limestone, so far as definitely recognized by the writer, is in the southwest corner of Montgomery County. However, the heavy bed of chert on Flint Creek, in the Wabash Valley above Attica, probably belongs to the Mitchell horizon. There is no limestone associated with this deposit of flint and it contains no fossils so far as observed. It resembles the chert which occurs abundantly in the Mitchell further south, and does not occur in the strata immediately below, or above, so it seems quite probable that the Mitchell group is represented at least as far north as the Wabash River in the eastern border of Fountain County. It occurs in heavy beds of limestone, locally including much chert, in Putnam, Owen, Monroe, Greene, Lawrence and Orange counties and on south to the Ohio River and beyond. In Putnam County it outcrops in large

quantities through the central and western part of the county. The large quarries in Greencastle are all in this rock, except the one a short distance north of the Monon depot, which is in the oölitic. The quarries at Limesdale, at Okalla, Putnamville and Cloverdale are in the Mitchell limestone. It also outcrops in large quantities along Little Walnut Creek, most prominently at Clinton Falls.

In Owen County the Mitchell limestone outcrops abundantly in a broad belt stretching through the county from north to south. The famous falls at Cataract are on this rock, which is pretty well exposed in the cliffs at and near the falls. The large quarry just west of Spencer is in this limestone. It turns out 20 to 25 car-loads per day and employs about 70 men. The quarry face shows a thickness of 75 feet of compact blue limestone with a little nodular chert near the top of the quarry. Some of the layers have the fine, lithographic grain, but, as in other localities, there is too much crystalline calcite.

South from Spencer through western Owen and Monroe counties, the Mitchell limestone outcrops in large quantities, showing in the lower part of the steep hillsides, which are capped by the Huron sandstone and limestone and which stretch out eastward over a low area covered with residual clay containing great quantities of chert fragments. It is likewise an area of many sink-holes and caverns.

Going southward through Lawrence County the Mitchell limestone apparently increases in thickness and the width of the outcrop. Many cliffs and rocky hillsides of this limestone appear along Richland, Popcorn, Spring and Indian creeks. Small quarries are numerous from which stone is taken for local use, as road metal, well curbing, for foundations, bridges, etc. Near Williams' Station, on the Southern Indiana Railroad in the western part of the county, in the White River Valley, is the largest Mitchell limestone quarry in the county. The face of the quarry shows a thickness of 100 feet of limestone with almost no overburden and the entire thickness is quarried and put through the crusher. The rock is mostly gray limestone, shading into blue in places and showing thin but irregular seams of blue clay between the layers in places. The upper portion of the quarry exposure shows

a rather thick-bedded limestone, the bottom portion is thin-bedded. Chert nodules occur, scattered through the basal portion.

South of White River the Mitchell limestone outcrops over a broad area from Huron Station on the west to several miles east of the village of Mitchell. In the western part of the area between Georgia and Huron stations the Mitchell limestone lies at the base of the hills that are capped with the Huron limestone and sandstone and in the extreme western part of this area the Mansfield sandstone occurs on the hilltops. In the eastern portion of the area, from near Georgia to beyond Fishing Creek, the Mitchell limestone forms the top and upper portion of the hills overlying the Bedford limestone which outcrops at the base of the hills. Near the eastern border of the area the caves and sink-holes are more prominent. In the upland area surrounding the village of Mitchell there are large quantities of chert fragments scattered through the reddish brown clay soil. (For details concerning the distribution of the Mitchell limestone in the southern part of the State, see *The Lower Carboniferous in Southern Indiana*, by Geo. H. Ashley in the Twenty-seventh Annual Report, Geological Survey of Indiana.)

THE HURON GROUP.

(Synonyms: Chester, Kaskaskia, Archimedes, Pentremital.)

Counties in which the Huron group outcrops: Perry, Harrison, Crawford, Washington, Orange, Dubois, Martin, Lawrence, Monroe, Greene, Owen, Clay and Putnam.

NAME.—The Huron group was first so called by Dr. Geo. H. Ashley in his report on the Lower Carboniferous area of Southern Indiana in 1902. Previous to that time it was known as the Chester or Kaskaskia from the localities in Illinois. The reasons for the introduction of the new term Huron in place of Chester are given in detail by Dr. Ashley, in the Twenty-seventh Annual Report, the principal reason being that the Illinois terms as originally used were more comprehensive and did not correspond with this remaining division of the Lower Carboniferous rocks in Indiana.

DESCRIPTION.—The Huron group name applies to the upper division of the Lower Carboniferous rocks comprising the limestones and sandstone and in some places the shale layers included

between the top of the Mitchell limestone and the bottom of the Mansfield sandstone and conglomerate. It consists generally of several alternating beds of coarse yellow sandstone and crystalline limestone.

It contains oölitic limestone in several places. The oölitic stone is local in occurrence, present in a few localities and not of very great thickness and extent. It is the true concentric oölite, consisting of concentric layers of calcite around a small grain of sand and hence structurally different from the Bedford oölitic limestone. It occurs in many localities in Orange and Lawrence counties. Intermingled with the sandstones and limestones there are beds of blue, gray, brown and black shales and clays with small deposits of coal. The coal varies from the merest trace up to three inches in thickness.

The exposure at the type locality in the rock cut on the railway a half mile east of Huron Station in Lawrence County, shows the following layers:

| | <i>Feet.</i> |
|--|--------------|
| Mansfield sandstone at top of hill. | |
| Huron limestone and shale group. | |
| Crystalline crinoidal limestone, 8"-10"..... | } 30 |
| Blue, compact, fossiliferous limestone..... | |
| Gray shale, 10'..... | } 35 |
| Compact limestone, 6"..... | |
| Blue gray shale, weathering to yellow and red clay, 24'... | |
| Buff oölitic limestone, 8"..... | 8 |
| Blue-gray shale, weathering to yellow brown clay, 15'-20'... | 15 |
| Compact evenly-bedded buff and blue oölitic limestone..... | 14 |
| Black carbonaceous shale with fossil plant remains..... | 3 |
| Yellow ferruginous sandstone and shale..... | 20 |
| Mitchell limestone at base of hill below the railway. | |

In Orange County Kindle divides the Huron ("Kaskaskia") into a lower limestone, a lower sandstone, a middle limestone, an upper sandstone and an upper limestone. Some of the sandstones are used for whetstones. The lower limestone is a compact, smooth-grained blue limestone. The middle limestone is a semicrystalline, gray fossiliferous rock. The upper limestone is gray colored with occasionally a pink tint. It is usually crystalline and in places it is composed largely of crinoid stems and Archimedes bryozoa. Locally there are thin bands of chert. The sandstones are described as buff to light gray or white, medium coarse grain, con-

taining limonite concretions and locally beds of shale, clay, and coal. The coal seams are from two to six inches thick.

Detailed sections of the Huron group in the vicinity of Leavenworth and other points in southern Indiana are given by Ashley in the Twenty-seventh Annual Report, pp. 74-77. These sections show a somewhat complex series of shales, limestones and sandstones.

The local variations in thickness of the different layers, and the rather rapid change along the outcrop, of sandstones to shales and vice versa, would throw considerable doubt on any correlation of the beds in the Huron group in different parts of the State that is based on the comparison of the sandstone and shale beds. The limestone beds in the series may be correlated over larger areas because they are much more persistent and widespread rocks and they carry more distinguishing features. For example, the limestones are more distinctly characterized by uniformity of color and texture and stratification, as well as having more and better preserved fossil remains than the sandstone.

In many places the top of the Huron group is marked by an erosion interval and the overlying group, the Mansfield, lies unconformably upon it.

TOPOGRAPHY.—The area covered by the outcropping Huron group is characteristically hilly and broken. It forms a belt of rather conspicuous hills bordering on the west the broad rolling, rather flat area of the outcropping Mitchell limestone. In places the hills are low and rounded, but are generally quite steep with rock cliffs and talus slopes. Through western Lawrence, Monroe and Owen counties and in parts of Putnam these hills composed of the Huron sandstones, shales and limestones form a quite prominent feature of the landscape as one approaches them from the east over the rolling plain surface of the Mitchell limestone. The higher hills and the higher upland areas a little further west are capped by a bed of the durable Mansfield sandstone. Probably many of the Huron hills have had a protecting cap of the Mansfield until comparatively recently.

DISTRIBUTION.—The Huron group has about the same northern limit as the Bedford limestone, but as it thins out gradually under the heavy mantle of glacial drift its exact northern limits are difficult to determine. In the Oldshoe limestone quarry, in the

southwest corner of Montgomery County, the upper portion of the rock quarried is thought to be the Huron group, and that is the most northern outcrop observed by the writer.

At Okalla Station, in Putnam County, there is an exposure of from two to five feet of Huron sandstone overlying the blue Mitchell limestone. Through the southwestern portion of Putnam the Huron sandstones and shales appear in large quantities and in continuous strata and become thicker and more prominent further south through Owen, Monroe, Lawrence and Orange counties, and thence on south to the Ohio River, as shown on the map.

ECONOMIC FEATURES.—The sandstones and sandy shales of the Huron group are used extensively in Orange County for whetstones and grindstones. The center of this industry is in French Lick and West Baden, in the vicinity of which there are numerous quarries, and a few rude mills. Much of the stone is shipped in the rough to factories in other states.*

In several places the sandstone has been quarried for local use as a building stone. It is easily quarried and dressed and, if carefully selected, is very durable, so that it might have a more extended usage in this line.

The limestone makes good road metal and has had a limited use for that purpose. The character of the roads over much of the region is such as to cause one to wish that much more of the stone might be used for this purpose. For road-making the more compact layers are more desirable than the more highly crystallized ones.

Some of the limestone is suitable for building stone, but will probably never have an extended use for this purpose because of its proximity to the Bedford oölitic, which is a much better stone. The limestone has been used to a limited extent for making quicklime and might be used in much larger quantity for this purpose if the demand would justify it.

MANSFIELD SANDSTONE.

(Synonyms: Conglomerate, Millstone Grit, Pottsville Conglomerate).

*Part of the whetstones and grindstones are obtained from the Mansfield sandstones. For particulars of the whetstone industry see the paper by E. M. Kindle in the 20th Ann Rep., 1895.

References—

- Hopkins, 20th Ann. Rep., 1895, pp. 188-323.
Kindle, 20th Ann. Rep., 1895, pp. 329-368.
Ashley, 23d Ann. Rep., 1898.
Thompson, 17th Ann. Rep., pp. 30-40.

Mentioned in many of the other Annual Reports: See Index.

Counties in which it occurs: Benton, Jasper, Warren, Fountain, Montgomery, Parke, Clay, Putnam, Owen, Monroe, Greene, Lawrence, Martin, Daviess, Orange, Dubois, Crawford, Perry and Spencer.

NAME.—The Mansfield sandstone is the bed of coarse-grained sandstone and conglomerate that lies at the base of the Coal Measures. The name was first used in 1895 in the first report of the Blatchley survey and in the annual reports since that date. It is named from the typical exposure at Mansfield, in Parke County, Indiana. In the earlier reports it is called the "Conglomerate" in some places, the "Millstone Grit" in places, and farther east, in the northern Appalachian region, the Pottsville conglomerate. Owing to the uncertainties involved in correlating this formation with the Pottsville Conglomerate in Pennsylvania, and the still greater doubt in correlating with the Millstone grit of England, and the lack of definiteness in the term "conglomerate," it was thought best to use the local name.

The group is limited below (1) by an unconformity and (2) by the underlying Subcarboniferous limestones and shales. Its upper limit is the coal, shales, and clay beds of the productive Coal Measures, from which it is also separated by an unconformity.

The rock varies greatly in texture, color and thickness. In places it is a coarse conglomerate, brecciated at times, from which it grades into coarse sandstone by the decrease in the number and size of the pebbles and the corresponding increase in the relative amount of sand. It is in places a massive sandstone, but elsewhere more or less laminated, and in many places shows cross-bedding. Locally it contains many nodular iron masses which are generally hollow. It is not rich in fossils but in places it contains fossil coal plants and locally it contains small coal seams and beds of fireclay.

The color varies from light gray through buff, yellow, yellow-

brown to red. The yellow to yellow-brown color is due to the hydrous ferric oxide or limonite, and the red and red-brown color is due to the anhydrous ferric oxide or hematite.

TOPOGRAPHIC FEATURES.—The Mansfield sandstone is more durable than the underlying and overlying rocks, and hence it forms cliffs and rock terraces in many places. The map shows the position of many small outliers where the sandstone forms the cap rock of the limestone, or the limestone and shale, hills. It forms many bold cliffs along the water courses. It yields readily to the corradating action of the stream, but resists the action of the weather so that it remains in almost vertical walls, and thus impresses itself very strongly on the topography of the area where it occurs. The bold cliffs at the Shades of Death, at Turkey Run and at the Devil's Basin and many other places along Sugar Creek and its tributaries are formed by the Mansfield sandstone.

GEOGRAPHY.—The Mansfield sandstone appears to correspond in part at least with that widespread bed of sandstone and conglomerate that almost everywhere underlies the productive Coal Measures, forming a bed of coarse-grained siliceous material on which rests the clays, shales and coals of the Coal Measures. It marks a period of subsidence and inflow of the sea. Previous to this period there had been an elevation of the land and erosion had cut numerous valleys to varying depths. The incoming sea gathered up the fragments of rock waste and formed deposits over the newly formed or forming seabottom, filling all the depressions of the former land area, thus forming a mantle of sand, gravel, clay and coal, which rests unconformably upon the underlying uneven surface. Different kinds of deposits would be forming in different parts of the area at the same time, thus the advancing shore lines would, in many places, have quite violent waves in which the characteristic beach or straticulate structure would show itself in mixed deposits of sand and gravel more or less inclined to the horizontal, while out from the beach in the deeper water, deposits of fine sand and mud would be formed on which as they reached the surface would form swamps and bogs that later became coal beds. As yet such vegetable deposits were quite limited in both vertical and areal extent, in comparison with those formed in the succeeding period.

In the bottom portion of the deposit, as might be expected, the coarse basal conglomerate is more pronounced than higher in the stratum.

DISTRIBUTION.—The Mansfield sandstone outcrops over a broad belt extending from the northern part of Warren County east of south to the Ohio River. It has an almost continuous outcrop over part of the area. Because of its massiveness and relatively greater durability, it outcrops at the surface more than many of the other strata. It forms a dividing belt between the Lower Carboniferous limestones on the east and the coal producing beds on the west.

DISTRIBUTION IN OTHER STATES.—The coarse-grained basal conglomerate and sandstone underlying the Coal Measures occur quite widely distributed in this country and Europe. In eastern Pennsylvania it is known as the Pottsville conglomerate and consists of a very coarse conglomerate with white quartz pebbles an inch or more in diameter. In central and western Pennsylvania and in Ohio and West Virginia the rock consists largely of coarse sandstone, grading into quartz conglomerate in many places. In some places there are pebbles scattered through the sandstone.

This sandstone is probably one of the most widespread rock groups in the central and eastern United States, forming great siliceous basins underneath all the coal beds, one extending over a wide area along the Appalachians from New York into Alabama; another in Indiana and Illinois; another underlying the west-central basin of Iowa, Missouri, Kansas, Oklahoma and Arkansas, and another in central Michigan.

ECONOMIC FEATURES.—Coal occurs in the Mansfield group in several places, but in only a very few is it in sufficient quantity and quality to justify mining operations. The fireclay and shales have some local value, but, like the coal, not much, because of the superior quality and greater quantity in the Coal Measure rocks overlying.

The most important economic product in the Mansfield group is the sandstone suitable for building stone. It has been quarried and used for building purposes, as brown sandstone, at the following points: Hillsboro, Judson, Mansfield, Bloomfield and St. Anthony, and as buff or gray sandstone at Williamsport, Kickapoo, Attica and in small quantities for purely local use at many other points.

In many places the stone contains too many impurities or lacks homogeneity of texture to fit it for good building stone, but locally, where it occurs free from the imperfections in composition and texture, it furnishes a stone of superior quality for building purposes. The stone is quite soft when first quarried but hardens on exposure, thus adding greatly to the ease with which it can be quarried and dressed. The most serious defect in it is the segregation of the iron oxide into nodules which both discolor and weaken it. That the Mansfield sandstone is a very durable stone is shown by the prominence of the outcrop, the numerous steep cliffs and rock terraces, and the many hills that are capped by it.*

Another important use of the Mansfield sandstone is for whetstones and grindstones. The center of this industry is French Lick Springs, in Orange County. In the hills surrounding French Lick the stone has been quarried and manufactured into whetstones and grindstones for many years.†

PRODUCTIVE COAL MEASURES.

Coal Deposits of Indiana. By George Hall Ashley. 23d Ann. Rept. Dept. of Geol. and Nat. Res., 1898, pp. 1-1574.

See the above report for maps, illustrations, detailed description and bibliography of previous publications on the coal deposits of Indiana.

Counties in which the productive Coal Measures outcrop: Newton (?), Benton (?), Warren, Fountain, Vermillion, Parke, Vigo, Clay, Putnam, Owen, Greene, Sullivan, Knox, Daviess, Martin, Dubois, Pike, Gibson, Crawford, Perry, Spencer, Warwick, Vanderburgh and Posey.

Only a brief outline of the geology of the Coal Measures will be given here, since such a complete and detailed report was published so recently (1898). (See referenc above.)

NOMENCLATURE.—In the older reports the coal beds are designated by letters of the alphabet, the lowest and oldest seam called A, the next one overlying, B, and so on up through the series. The more detailed survey, ending in 1898, attempted at first to

*For its use as a building stone see *Sandstones of Western Indiana*, by T. C. Hopkins, in 20th Ann. Rep., 1895, p. 188.

†For its use as an abrasive, see *Whetstones of Indiana*, by E. M. Kindle, in 20th Ann. Rep., 1895, p. 329.

continue this system, but they found such serious objections to it that it was thought best to abandon it. Mr. Ashley says: "1. We found about twice as many coal beds as the system, as applied, gave room for. 2. The application of the system to the coal beds found contained so many errors as to make the past application at great variance to our own."

In view of the difficulties involved in the old system of naming the coal seams, Mr. Ashley adopted a new system, which consists in dividing the strata of the Coal Measures into eight spaces and designating them by the Roman numerals, beginning with I at the bottom. Except the bottom division I., which is the Mansfield sandstone, and is separated by unconformity from both the lower carboniferous below and Division II. above, the divisions are based on the position of the principal coal beds, as found in northern Clay and Vigo counties. Divisions II. to VIII. each begins with a prominent coal seam and extends up to the bottom of the next prominent coal seam, and hence each division includes at least one coal seam, and also the other rocks, as sandstone, shale, limestone and clay, up to the next prominent seam, and likewise includes all the minor, secondary or local seams that occur in this space.

The classification of the coal seams and associated rocks is not so simple as that of the limestone strata of the preceding period, owing to the great many geographic changes that took place during the coal period. The work on the present survey brought out the following points in support of the above statement:

1. No single stratum of rock or coal in the Coal Measures, with possibly the exception of the basal sandstones, is persistent over the whole coal field, or even between the extreme points of its extent.

2. That, as a rule, the coal beds are a little more persistent than any of their accompanying rock strata.

3. That a thick coal bed is usually more persistent than a thin bed.

4. That the upper beds of the Coal Measures are usually more persistent than the lower, their accompanying strata also being more persistent than the strata accompanying the lower beds.

5. That often when a coal is lacking, the position of its horizon is shown by the accompanying strata.

6. That the horizon of certain coals can be traced persistently, if time and detailed study be given to it.

These points illustrate the fact that was not and is not appreciated by many, namely, that most coal seams, as well as the strata associated with them, are necessarily more local in their occurrence than are the thicker strata of purely marine origin. Conditions are more uniform over the sea bottom than over a land area, especially a swamp area, such as the Carboniferous coal fields. As these areas were subject to many periods of elevation and depression during the accumulation of the carbonaceous deposits that form the coal beds, there would from necessity be many swamp, lake, sea and land areas. While it is possible that a vegetable swamp might have extended over the entire Indiana-Illinois coal field, it is much more probable that over such a large area so near sea level, there would be portions of the area under water too deep for vegetation to grow, and other portions above the water where no vegetation would accumulate. Hence, the coal would form either in separated basins or in one large basin, with many barren spots, where the land areas and the deeper water areas were at the time. It should be kept in mind that many coal seams cover only a few acres, or a few hundred acres, while others may extend over hundreds, or even thousands, of square miles.

Division I. of the Coal Measures has already been described under the heading of the Mansfield sandstone. The coal that occurs in this division is in small seams and of quite limited extent. Over a large part of the area covered by the sandstones and shales of Division I. there is no coal at all.

The correlation of the other divisions, II. to VIII., over the coal area is attended with difficulty and often with uncertainty, as one gets away from the type locality where it was named. The correlation of a coal seam in the northern part of the field with one in the southern part is from necessity attended with uncertainty where it can not be traced across the intervening area or associated with some stratum above or below it that can be traced over the entire area. As the twenty-third annual report gives a detailed description of the entire area, any one by consulting the maps and text of that report may determine the stratigraphical position of any coal seam almost anywhere in the area.

VARIETIES.—Of the two great classes of coal, anthracite and bituminous, only the latter occurs in Indiana. Anthracite coal is harder than bituminous and contains less volatile material and a higher percentage of carbon than bituminous, and is commonly supposed to be derived from bituminous by the loss of most of the volatile material. Bituminous coal is commonly divided into two classes, *coking* and *non-coking*, both of which occur in Indiana. The coking coal, when heated, melts and runs into a coke, while the volatile material passes off as gas. It is the kind commonly used for the manufacture of artificial gas, and the coke is then a by-product. Where it is used for the manufacture of coke, the gases may or may not be saved. *Cannel* coal is a variety of bituminous that is hard, very compact, and has a dull lustre, resembling black shale. It generally has a higher percentage of volatile matter and kindles easily, and burns with a bright yellow flame. It is a good gas coal when mixed with a coking coal, and it is also a very desirable grate coal, because of its bright yellow flame.

Block coal is a variety of bituminous that splits readily in thin sheets parallel to the bedding, but breaks across the bedding with great difficulty. It burns freely without coking. It makes a good grate coal and is the only bituminous coal that can be used successfully in the blast furnace without coking. The block coal occurs abundantly at Brazil and vicinity in Clay County. It occurs in basins from a few acres to several miles in extent, and is found mainly between Raccoon Creek, on the north, and Eel River, on the south. It is found mainly in Divisions III. and IV. of Ashley's classification.

MEROM SANDSTONE.—*Division IX.*—The productive Coal Measures in Indiana occur between two great beds of sandstone. The Mansfield sandstone, at the base, is included in Division I., and overlying all the other strata is the heavy sandstone of Division IX., classed as the Merom sandstone, from the village of that name in western Indiana. It appears to rest unconformably on the underlying Coal Measures, and contains a basal conglomerate in many places. In the northern portion of the area it fills deep erosion channels in the Coal Measures. There is some doubt as to the stratigraphic position of this sandstone. No fossils have been reported from it in Indiana, but it is thought that it probably

corresponds stratigraphically to the Triassic period, as indicated by fossil forms from Illinois.

OCCURRENCE AND DISTRIBUTION.—The boundaries of the Coal Measures on the large State map are the same as on the larger scale sheets accompanying the coal report, but the subdivisions are different. Because of the necessarily smaller scale where the whole State is represented, the Coal Measures are divided above the Mansfield sandstone into three parts. The lowest division which lies immediately west of the Mansfield sandstone outcrop includes the block and semi-block coals. The next division, which overlies this and outcrops west of it, includes the coking coals and the upper division includes the Merom sandstone. These areas are separated on the map by light dotted lines similar to those separating the other groups, but the different divisions are not distinguished by separate colors.

As may be seen on the map, the Coal Measures cover nearly a third of the State. Coal occurs and has been mined in the following twenty-three counties: Warren, Fountain, Montgomery, Vermillion, Parke, Putnam, Clay, Vigo, Owen, Greene, Sullivan, Knox, Daviess, Martin, Orange, Crawford, Dubois, Pike, Gibson, Perry, Spencer, Warrick, Vanderburgh and Posey. Of the above the following six counties, Montgomery, Putnam, Orange, Crawford, Vanderburgh and Posey, produce such a limited quantity of coal that they could hardly be classed in the commercially productive area.

In 1898 there were 852 mines in operation, of which 731 employed less than 10 men, and 123 employed ten or more men in each. In 1881 there were 4,567 employes producing 1,771,536 tons. In 1891 there were 6,975 men producing 3,819,600 tons, and at the end of the next decade in 1901 there were 12,096 men producing 7,019,203 tons.

PLEISTOCENE. (Quaternary.)

About the close of the Carboniferous era the Indiana area was elevated above sea level, and has remained so since that time. It was subject to the action of the eroding agencies during all the long Mesozoic and Cenozoic times, since there is no evidence of any subsidence below sea level during that very long interval.

Early in the Quaternary or Pleistocene period there was a change in climate from a condition warmer than the present to one colder than the present. As the climate grew colder over North America the snow began to accumulate in the Canadian Highlands. More snow would fall than would be melted during the year, so that there was an accumulation on the upland. Probably just as at present this snow would become granular ice, and then compact blue ice, and as it accumulated it would flow away in sluggish streams from the center. This Pleistocene glacier was so large that it flowed out from the Canadian uplands as a great sheet of ice, hundreds, in places thousands, of feet in thickness, that spread over all the northern United States. It covered a large part of Indiana, extending nearly to the Ohio River in the southeastern and southwestern parts of the State, and in the central portions as far as the southern part of Owen County.

This vast sheet of ice had a very marked effect on the area over which it passed. It eroded the rocky surface, grinding it off in great quantities, but more in some places than in others. It also carried in from northern regions a great supply of boulders, and mineral and rock material and moved forward varying distances vast quantities of local material. When the glacier finally disappeared the rock material that was in and on the ice would be deposited and often in quite irregular masses.

One of the direct effects of the glacier was the formation of a great number of lakes. Some were formed in depressions in the rock which were gouged out by the eroding ice; others were formed by the deposition of earth across a valley, forming an earth dam; still others were formed by water accumulating in the depressions formed by the irregularities in the mantle of glacial debris. There are tens of thousands of these lakes over the Northern United States, and several scores of them in northern Indiana.

Another marked effect is the heterogeneous character of the soil-covering, which for the most part is more productive and valuable than the original soil.

Another effect is the general leveling of the area. In a few places the moraines or the deep erosion by glacial streams may tend to roughen the surface, but for the most part the opposite effect has been produced, as the grinding action of the glacier tends to wear off the sharper ridges and the deposit of the material carried

by the ice tends to fill up the deeper valleys. Northern and central Indiana probably has a much more regular and even topography and a much more fertile soil than it had before the glacial period.

The great masses of gravel deposited by the glacial waters furnish an excellent road metal. These gravels have been widely distributed and widely used over the glacial region of the State, and so far as they have been utilized judiciously better roads have been the result.

Besides earth, clay and gravel, the glacier carried many large boulders, and in some places these large boulders have been left in lines, known as boulder trains, which extend for many miles across the State. Along the line of these boulder trains the rocks are so numerous and so large in many places that it is not possible to till the soil.

The Pleistocene glacial period has been referred to in the singular number, but it should be noted that the studies of recent years seem to indicate that there were several recessions and advances of the glacier and the periods between the recession and the next advance may have been quite long; long enough, it is thought, in some instances, to permit extensive forest growth. It has been a question of dispute for some years as to whether these different advances of the ice should be considered separate epochs or only stages of the same epoch. In the Mississippi basin area the deposits have been subdivided into nine parts, named in order beginning with the bottom or oldest bed as follows: 1. Albertan Drift. Sheet. 2. Aftonian beds, interglacial. 3. Kansan Till Sheet. 4. Buchanan interglacial deposit. 5. Illinois Till sheet. 6. Interglacial deposit (not named). 7. Iowan Till sheet. 8. Toronto (?) interglacial deposit. 9. Wisconsin Till sheet.*

*See Journal of Geology Vol. IV, 1896, and Vol. II, 1893.

