THE GEOLOGY

OF

The Lower Carboniferous Area

OF

SOUTHERN INDIANA.

BY GEORGE HALL ASHLEY, PH. D.,
Assisted by
EDWARD M. KINDLE, PH. D.

LETTER OF TRANSMITTAL.

INDIANAPOLIS, IND., January 15, 1902.

Hon. W. S. Blatchley, State Geologist of Indiana:

Sir—I have the honor to hand you herewith my report on the geology of the area of the Lower Carboniferous rocks of southern Indiana. This work was planned, in accordance with your instructions, primarily as a continuation of the survey of the Bedford Oölitic Limestone made north of Orange County in 1896. Pursuant to your instructions, however, the other members of the Lower Carboniferous have been mapped, and examined, especially for any strata of economic value. The most valuable part of the report is believed to be given on the accompanying maps, which attempt to show the distribution of the different formations with as much or greater accuracy than has hitherto been attempted in this State. They also show graphically the character of the topography by profiles, and the structure of the strata as a whole. In addition a columnar section is added. In order to complete the work in the time allotted it was necessary to omit much work that would have been necessary for the mapping of the quaternary and the formation herein called the "Ohio River Formation," believed to be of Tertiary age. The field work occupied the season of 1900. The writer was assisted by Dr. Edward M. Kindle. The writer is entirely responsible for the maps and reports of Washington and Harrison counties. Dr. Kindle made a rapid survey of the area in Scott, Floyd and Clark counties, scrutinizing the map of the Knobstone recently made by the University of Indiana Geological Survey, and adding the outcrop of the Bedford stone and other matter of value. He then took up the work in Orange, Crawford and Perry counties, and traced the line of contact between the Mitchell and Huron formations. The upper line of the Huron was traced by him in this area in 1895 and 1898. He also made a study of the Mitchell and Huron in this area.

Very respectfully yours,

GEO. H. ASHLEY.

ABSTRACT OF REPORT.

GEOGRAPHY OF THE AREA.—The area under study lies in the central part of the south end of Indiana. Topographically it consists of a low rolling strip on the east, then rough broken country in the "Knobs," then a high central, rather level plateau, then a broad belt of hilly broken land on the west. The drainage is north into White River, west into Lost and Patoka rivers, and south into the Ohio River, by way of Blue and Little Blue rivers, Indian, Buck, Silver and smaller creeks.

STRATIGRAPHY.—Quaternary deposits of limited extent occur, as glacial drift in the northeast corner, and alluvial deposits along the rivers and streams. On the divides at the east exist remnants of a once extensive deposit of sand and gravel. Their age is not known, but it has been thought they are of the Tertiary age. They have been called the Ohio River formation. The practical necessities of mapping have made it necessary to draw the line between the main body of the Kaskaskia and what has been called the Mitchell, well up in the Kaskaskia. The Mitchell has been continued up to this line, and the strata above grouped as the Huron group. This group consists of alternating sandstones and limestones with much shale at the south, the whole having a thickness of from 100 to 150 feet. The Mitchell limestone next underlies the Huron. It is almost entirely limestone, with much chert, and has a thickness of from 350 to 400 feet. Under that is a massive stratum of limestone highly suitable for building purposes, known as the Bedford oölitic limestone. It ranges from a thickness of 90 feet at the north to a thickness of usually less than 15 feet as the Ohio River is approached. It would appear that the thin bed of oölitic stone on the south represented only part of what has been called the "Bedford" stone at the north, the rest of the bed having become so changed as to be classed with the Mitchell or Harrodsburg. Below the Bedford stone is the Harrodsburg limestone, with which is some shale. This has a thickness of about 60 feet. At the bottom of the Lower Carboniferous is the Knobstone, a series of shales and shaly sandstones, the latter predominating at the top.

GENERAL STRUCTURE OF THE AREA.—In structure this area is a westward dipping monocline, with a dip of from 30 to 40 feet to the mile, about west by south.

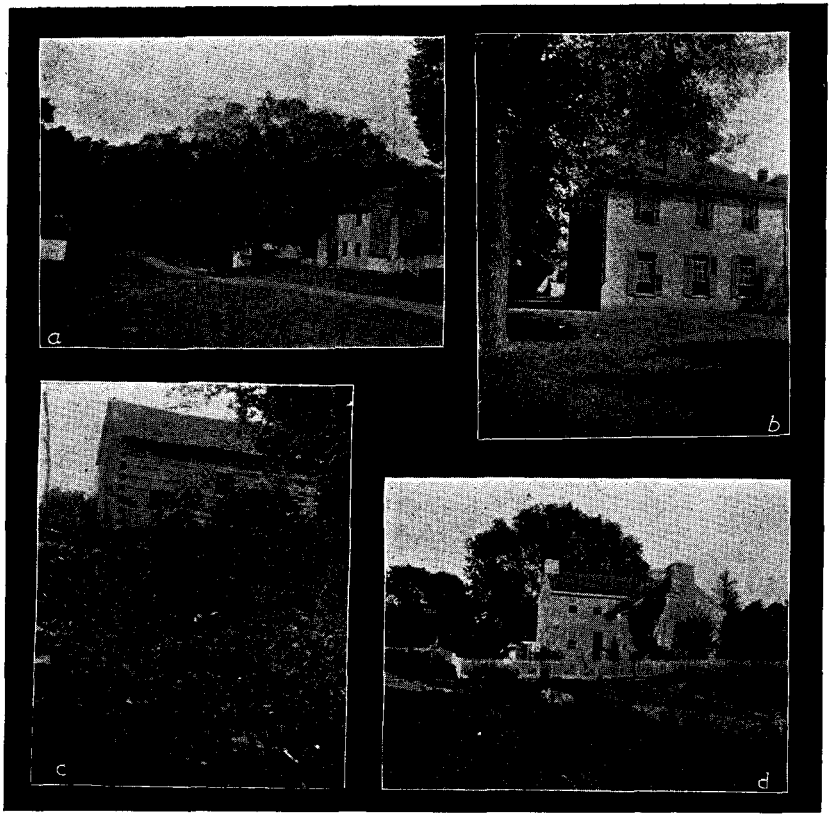
ECONOMIC GEOLOGY.—First the soils of the area are briefly discussed. The Ohio River formation has yielded glass sand of excel-

lent quality and contains an almost unlimited further amount. In the Huron are limestones that have proved suitable for glass manufacture, and for lime. In places the limestone has been used as marble with fair results. The lower sandstone has had extensive local use and has proved durable and especially suitable for bridge foundations and similar work. The Mitchell, in addition to the limestones that have proven suitable for rough masonry, or for road material, or for ballast, for which purposes much stone has been used and some exported, gives promise of yielding much stone of value for the manufacture of Portland and Roman cement. The stone best suited for the former is a very white, pure, coarsely oölitic limestone. It has a thickness of from five to 15 feet, and extends all through Orange and Crawford counties. The stone suitable for Roman cement is found nearer the bottom of the formation, and is an argillaceous limestone, that appears on analysis to be suitable for this purpose, and has been manufactured across the river in Kentucky, where it is claimed to make a high grade cement. Lithographic limestone occurs abundantly in this formation, but as yet has not been found sufficiently free from flaws to answer the purposes of engraving.

The Bedford Oölitic Limestone from the northwest corner of Washington County to Salem, has a thickness of about 65 feet and in general good quality, though tending to be a little more crystalline and a little harder than the stone further north. At Salem the stone appears to split up and in part to lose its oölitic character for one much more crystalline. A small thickness of truly oölitic rock continues, sometimes attaining a thickness of 25 or 35 feet, but in the main is from 5 to 15 feet thick. Most of this oölitic stone to the south is partly or largely crystalline, making it proportionally harder to work but correspondingly enduring and strong. Some of it, however, is of good oölitic grain. The use of the Bedford for the manufacture of lime and Portland cement calls for notice.

The Harrodsburg Limestone has some local use for road material, and locally for rough structural purposes. The Knobstone has furnished some sandstone for building, and some of the shales near the bottom have been successfully used for the manufacture of bricks.

Attention is also called to the possibilities of large water power, taking advantage of the large springs and the narrow, almost uninhabited, ravines. One hundred foot impounding dams could be used in places, giving large power all the year round.



SOME HISTORICAL POINTS IN HARRISON COUNTY.

a. The Constitution Elm, Corydon, Ind., under which much of the constitution of Indiana was written, the legislature having adjourned there on account of the heat.
b. The old State Capitol, at Corydon, Ind.
c. Goshen church, Boone Township, one of the few log churches in Indiana still used as a church.
d. "The Capitol Hotel," a stone house a mile east of Corydon, where many of the members of the Constitutional Legislature were guests.

GEOLOGY OF THE LOWER CARBONIFEROUS AREA OF SOUTHERN INDIANA.

By George Hall Ashley.

GEOGRAPHY OF THE AREA.

Location and Limits of Area Treated.—The present report covers an area in southern Indiana which includes all the area of outcrop of the rocks of Lower Carboniferous age between the Ohio River on the south and Lawrence County and the east fork of White River and Muscatatuck River on the north. As shown on the maps the eastern border runs through the center of Scott and Clark counties and the eastern edge of Floyd County to the Ohio at New Albany.

The western limit is very irregular and extends through eastern Dubois and Western Orange counties, reaching the Ohio in the vicinity of Rock Island, in Perry County. The area has an extreme width of about 65 miles from east to west and the same extent north and south.

Refer to maps for exact boundaries.

Political Subdivisions of Area.—The area includes all of Washington and Harrison counties, nearly all of Floyd County, the western part of Scott and Clark counties, nearly all of Orange County, the eastern part of Crawford and Perry counties, and parts of the western half of the two last named counties.

The boundaries of these counties as well as the boundaries and names of the townships into which they are divided are shown on the large maps.

Topography.—Elevations.—The region ranges in elevation from about 340 to over 1,000 feet above mean sea-level. The lowest point is on the Ohio River where it leaves the region south of Perry County, and the highest is one of the high points in eastern Washington County. Exact elevations are not at hand to show whether the highest point would come in the divide around the headwaters of Blue River or whether any such elevation is exceeded by one of the high hills near Harristown.

The following table contains the elevations that have been determined:

	Feet Above Tide.
Birdseye	711
Borden	553
Boston	710
Chestnut Ridge	552
Corydon Junction	616
Crandall	650
DePauw	642
Edwardsville	799
Edwardsville, Knob at	901
English	503
Fort Ritner	522
Fredonia, Low water	348
Georgetown	710
Harristown	874
Lawrenceville, Low water	425
Leavenworth, Low water	349
Livonia	787
Maukport, Low water	351
Marengo	574
Memphis	489
Milltown	552
New Albany, Low water	367
Orangeville	635
Pekin	609
Paoli	611
Ramsey	707
Salem	717
Scottsburg	569
Sellersville	477
Smedley	878
Taswell	770
Tell City, Low water	337
Vienna	565

TOPOGRAPHY.—An attempt has been made in the small map (Plate I), to give some general idea of the topography. A look at that map will show that there is a comparatively level strip of land extending from northeastern Orange County to the south end of Harrison County. This is from five to fifteen miles wide and will be found in the main to correspond to the area of outcrop of the Mitchell rocks. Extending around the north and east of this is a belt, known as the "Knobs," in which the streams cut down rapidly from the upland, then run off with a slight gradient through deep valleys with rather wide, flat bottoms and very steep almost precipitous sides. West of the broad flat belt mentioned rise a series of isolated knobs

of Mitchell Limestone capped by Kaskaskia Sandstone. These increase in size going westward at the expense of the intervening level stretches until the topography along the western part of the area becomes a succession of high irregular ridges and deep narrow ravines.

The topography presents a series of types which may be studied more in detail.

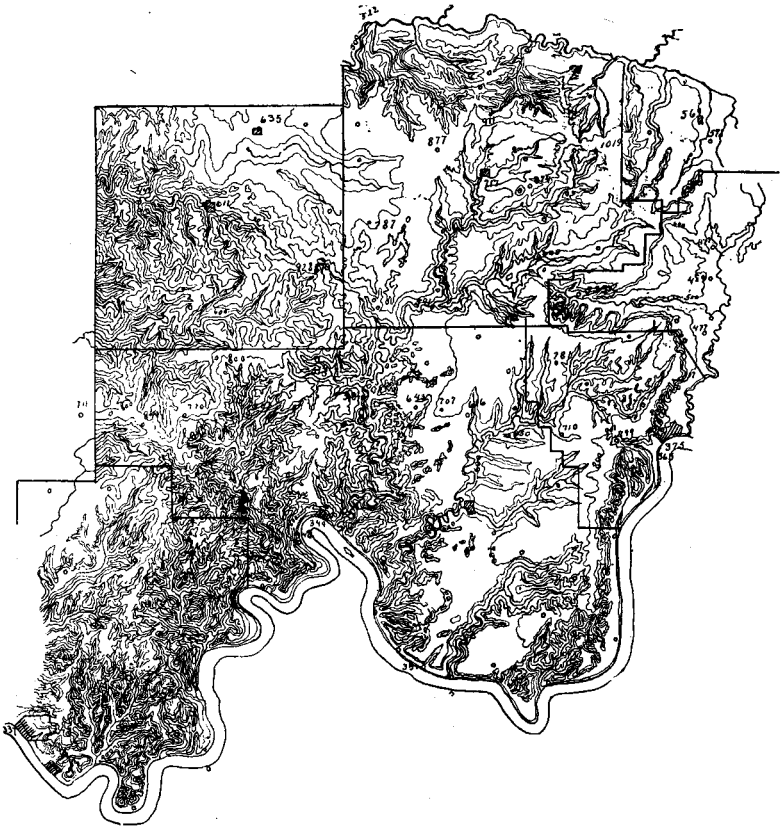


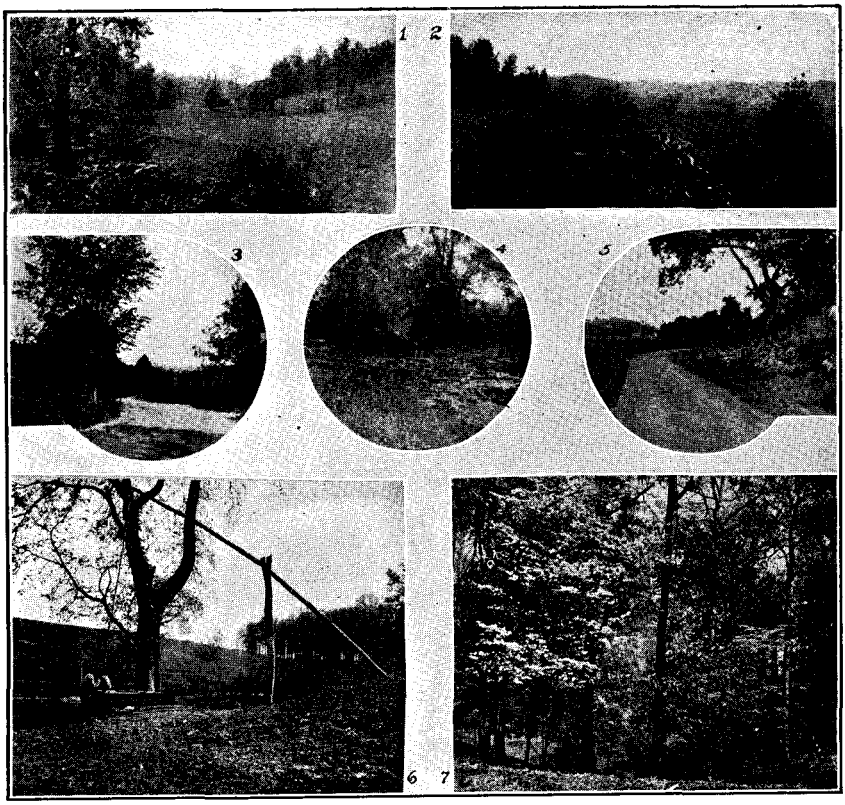
Plate I. Sketch map showing elevations, and the topography by 100-foot contours.

Lower Knobstone Type.—As will be shown further on the Knobstone with a thickness of about 400 feet is predominantly shaly in this region, especially toward the bottom. This characteristic dominates the topography in the area of its outcrop, and as a result the eastern edge of the area of the Lower Carboniferous rocks is a low, comparatively level, stretch of country, as is well displayed along the J., M. & I. Railroad. This area has a general descent to the

west of less than 50 feet to the mile. The elevations along the eastern edge range from about 450 to 600 feet.

Knob Type.—Going westward, or southward from Muscatatuck River, the upper part of the Knobstone is approached. This has a larger proportion of sandstone and is capped by the hard limestones of the Harrodsburg. These withstand erosion much better than the lower members of the Knobstone and give rise to a belt of country of extremely broken character. The hard overlying limestones tend to form a high plateau sloping to the west with the dip of the rocks. The eastward and northward flowing streams have eaten through this overlying crust where it is thinning out along its edge, and once through that and the hard sandstones in the upper part of the Knobstone formation, they have cut rapidly through the soft underlying shales nearly to the base level of the region to the east. This sharp descent at their heads has allowed the streams to eat their way some distance from what tends to be the face of the plateau. The result is a series of valleys from 250 to 300 feet deep and from one to five miles long, separated by narrow divides. The divides tend to be flat-topped, evidently being uneroded prolongations of the plateau. As they extend out from the plateau they tend to become narrower and to have low saddles cut in the crest; and finally the ridge ends abruptly, making a bold headland, to which the name "knob" has been given. The character of one of the intervening valleys is shown by the accompanying profiles and half tones. (Fig. 1 and Plate II.) In the profile it will be noted that Twin Creek, which is taken as a type, starts from the fairly level plateau at an elevation of about 900 feet. Half a mile from the head, as indicated by the dotted line, it has descended 200 feet and presents a narrow V-shaped valley. At a distance of a mile from its head it is 50 feet lower, the lower valley being U-shaped with nearly perpendicular walls to a height of 80 to 90 feet, then the banks slope rapidly up nearly to the 900-foot level. A part of the bluff at this point is shown in Plate II. The descent is still rapid, in the next mile amounting to about 60 feet. This brings the stream down into the soft knobstone rocks, and from this point the descent is slight and the valley rapidly widens out with a flat bottom, though with very steep banks still. At six miles from the head it will be seen that the valley has a level floor nearly a mile wide. The appearance of the valley at this point is shown in Fig. 2 of Plate II. In the case of Twin Creek it crosses a fault a couple of miles above its mouth, beyond which point its valley is cut almost entirely in the hard overlying limestones, and the result is shown in

PLATE II.



VIEWS ILLUSTRATING THE TOPOGRAPHY OF THE AREA.

Fig. 1. View in branch southwest of McKinley Postoffice. Characteristic Knobstone valley.

Fig. 2. In valley of Twin Creek below junction with Rush Creek, showing wide flat valley bottom. The headlands across the valley do not come out distinctly in the picture.

Figs. 3 and 4. Views in Orange County. The valleys are cut in Mitchell limestone; the hills are capped with Huron sandstone.

Fig. 5. View in upper valley of Little Indian Creek, in Harrison County. Shows broad, rather shallow valley. The lower valley of Indian Creek, like that of Blue River, becomes narrow, deep and largely unsuited to cultivation.

Figs. 6 and 7. Views characteristic of the sinkhole area of the Mitchell limestone.

the lowest profile, the valley changing from a width of a mile to a few rods. Fig. 1 of Plate II is looking down a small branch of Buffalo Creek just above where it passes out from between the enflanking ridges. In the case of such streams as Delanys Creek, that occupy a rather broad basin, the side branches have the same characters as that just given, but the sides of the main valley become reduced to a series of parallel headlands with nearly perpendicular

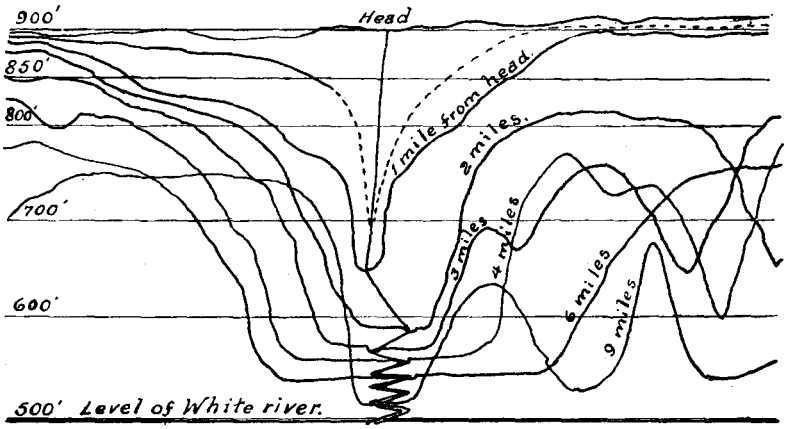


Fig. 1. Orthogram of Twin Creek.

Vertical scale: 1 inch = 200 feet.
Horizontal scale of valley profiles: 1 inch = ¼ mile.
Horizontal scale of stream profile: 1 inch = 4 miles.
The view shown in Fig. 2 of Plate II shows the character of the valley floor at the profile at six miles from the head, east of Mt. Carmel.*

faces 250 to 300 feet high, standing between the entering side valleys. Where the valley has a flat floor a mile wide, such a series of headlands make a striking appearance.

*A word of explanation may be needed in regard to the orthographic drawings presented with this report, as it is probable that this is a new use of the word orthogram, applied to a new method of representing topography. In a word, this method consists in projecting a series of equidistant profiles upon a vertical surface. This is strictly carried out only in the orthogram of Little Pigeon Creek. In that are represented a series of vertical profiles of one-half of the creek valley taken at points five miles apart. A modification of this may be necessary or desirable in some cases, where data is lacking for all the profiles, or where, on account of the length of the valley or topographic feature being studied, or for other reason, a limited number of profiles will best give the desired result. In such cases such profiles only may be given as are desired or as have been obtained. When this is done some means of indicating the relative distance apart of the profiles is necessary. In the cases presented, those of Twin Creek and Blue River, we have assumed a vertical profile of the stream bed to have been folded back and forth at equal horizontal distances, the horizontal scale in the cases given having been purposely taken very small as compared with the vertical. The zigzag line thus obtained is then projected on a vertical surface, and the vertical profiles are placed on this at the proper points. The vertical scale being stated or placed on the ortho-

Central Plateau Type.—Standing at the head of one of the streams just described a most striking contrast is presented. To the east or north the streams have cut down so sharply that a stone may be rolled down 100 to 150 feet in the head of a ravine, while on the other side in most places is a gently sloping plain into which the streams have cut only shallow channels as far as can be seen. We may first study the valleys of this region, of which the valley of Blue River has been selected as a type. As shown by the profiles, Fig. 2, this starts on the nearly level edge of the plateau at an elevation of about 900 feet. The first part of its course it occupies a broad valley with gentle slopes, almost entirely under cultivation, in striking contrast with the upper part of the streams, of which Twin Creek, was taken as a type. In the case of Blue River the creek cuts through into the soft Knobstone strata for a short distance,.giving a flat valley bottom a quarter of a mile wide and rather steep banks for 30 to 40 feet. By the time Salem is reached the dip of the rocks, which is greater than the gradient of the stream, has carried the Knobstone under and the stream is again flowing over limestone. The low gradient above this point where it is flowing through the Knobstone is shown by the figure. Figs. 2 to 4 of Plate III are views in this valley a little southwest of Canton where it has cut through into the Knobstone as described, and Fig. 1 of Plate III shows the character of the flow of water. From Salem to its mouth Blue River continues as a rapid stream with a nearly uniform de-

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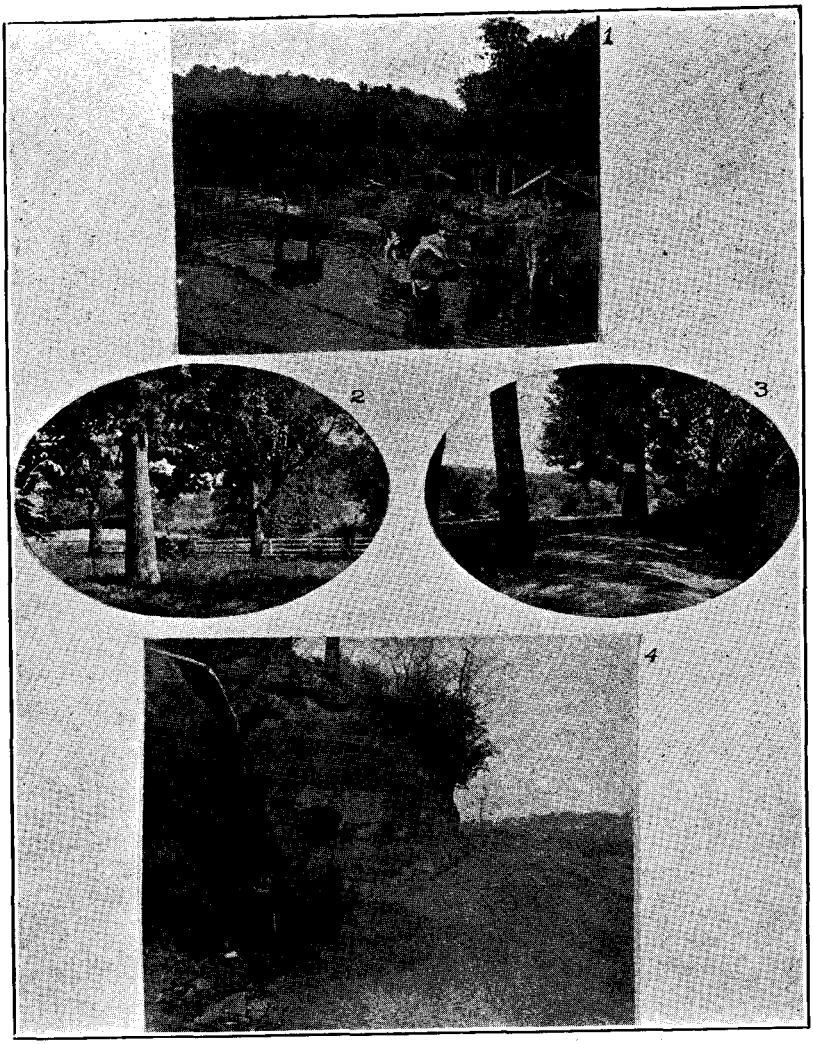
gram, as in the accompanying examples, may express not only the vertical value of the profiles, but the gradient of the river between the equidistant points chosen on the horizontal. Thus, in Fig. 1, the original profile of the bed of the stream (assumed, but of course not separately drawn) had a vertical scale of 200 feet to the inch, and a horizontal scale of four miles to the inch. This is supposed to have been folded at each mile, or at horizontal distances one-fourth inch apart.

Interpreting Fig. 1, it is seen that Twin Creek rises in a fairly level country, at an elevation of 900 feet. In its first mile, represented by the line running downward from the word "Head" and to the left, it descends to about 650 feet above sea level. The profile shows the shape of the valley at this point. The profile at one-half mile is shown by the dotted line. Successive shapes of the valley are shown at distances of 2, 3, 4, 6 and 9 miles from the head by the successive profiles, and at the same time is shown the change from a very high gradient in the first mile to a moderate and finally to a low gradient in the last miles.

In its unmodified form the orthogram, as thus described, is intended to give an outline view of the shape of a valley as viewed from the mouth, assuming the stream to have been straightened so as to give an uninterrupted view up its valley. While it is believed that there will be many to whom this method of practically vertical contours gives a clearer mental picture than the horizontal contours usually used, it is believed that its principal advantage will be where, as in this case, it is desired to make comparison of certain general features of two or more stream valleys and where the data is not at hand for making a contour map. It has the advantage over the hatchure method often used in such a case of giving definite and accurate information as far as it goes, and in a very condensed form. The relative or actual elevation of outcropping rocks can be readily shown on the profiles, thus serving in many cases to show the cause of minor topographic features. It seems possible to apply the same idea to hills or ridges of limited extent, associated with indicated structure.

PLATE III.



Views in the upper part of valley of Blue River, between Salem and Canton. The river here is flowing through a fine farming country, in a broad, shallow valley. The stream, as shown in Fig. 1, has a quiet flow, with few rapids and slight descent.

scent of about five feet to the mile, but its banks gradually increase in height and average steepness, as is indicated in the profiles. A few additional figures will help to make this character more real. Fig. 2 of Plate IV shows Blue River near Beck's Mill, at the point of the fifth profile. Figs. 3 and 4 of Plate IV give views at the succeeding profiles, near Sharp's Mill and just above Wyandotte. Fig. 1 of Plate IV shows the river at Fort Hill.

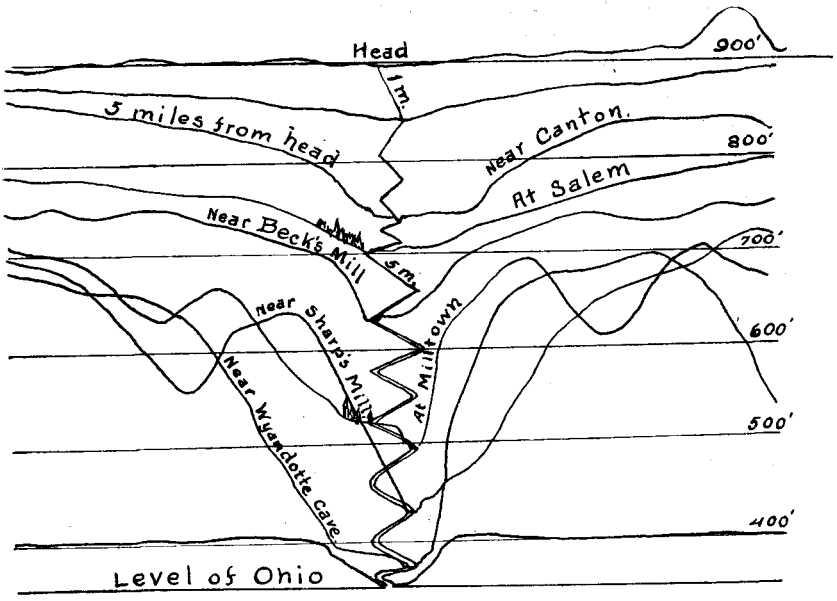


Fig. 2. Orthogram of Blue River.

Vertical scale: 1 inch = 200 feet
Horizontal scale of valley profiles: 1 inch = ¼ mile.
Horizontal scale of stream profile from head to Salem: 1 inch = 8 miles; from Salem to mouth: 1 inch = 20 miles.
Plates III and IV give views at points along the valley of Blue River.

Before attempting to interpret this type of valley topography it will be of interest to compare it with that found 50 miles further west. Fig. 3 gives a series of contours across the valley of Little Pigeon Creek taken five miles apart. In this case it will be noticed that almost the total descent of the stream is in the first five miles, amounting to about 100 feet in the first half mile, while the stream along its lower half has a fall of only a foot a mile or less. In this respect it would seem to resemble the streams of which Twin Creek was taken as a type, but examination shows some decided differences. Twin Creek has all along its course steep, precipitous banks. Pigeon

Creek has well rounded banks, nearly everywhere suitable for cultivation. Twin Creek has broad bottoms, but evidently carved out of the rock by erosion, the creek bed being everywhere in rock. Pigeon Creek's broad bottoms are evidently due to the filling of sunken valleys. The difference between the Pigeon Creek valley of erosion and the filled valley is well shown by comparing the valley just east of Ash Iron Springs, where the creek is at present running in a recently eroded channel, with the valley at other points. In brief, the area in which Pigeon Creek lies has evidently sunk below drainage level so that all the valleys have filled up until the streams have been raised so that they will run off again. At that point the sinking has been estimated at not less than 100 feet.

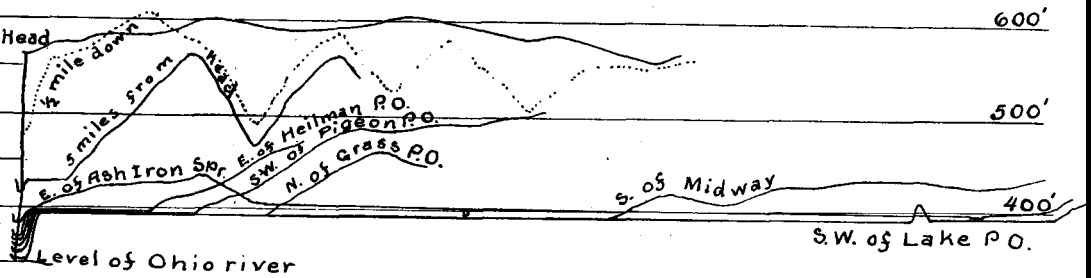
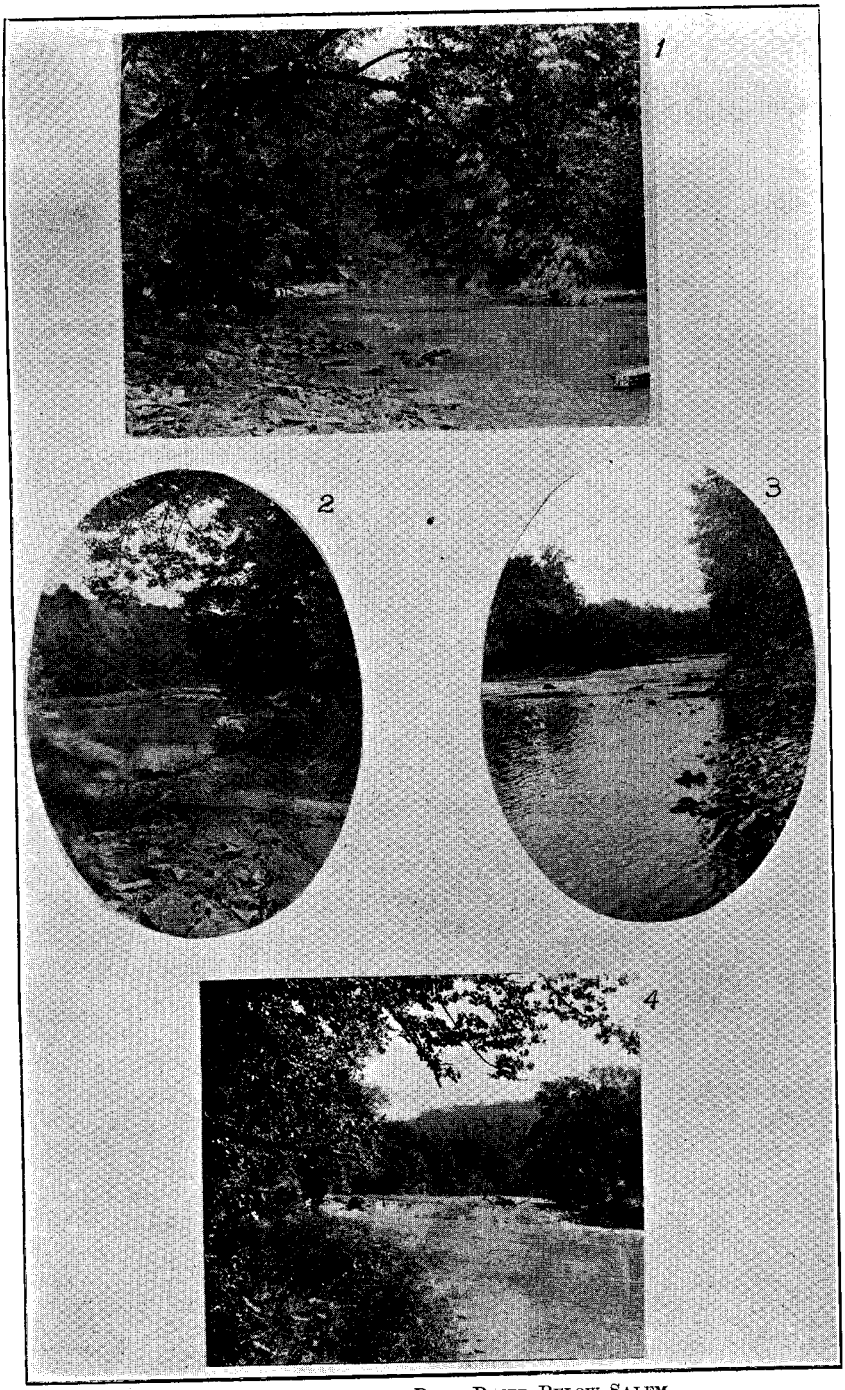


Fig. 3. Orthogram of valley of Little Pigeon Creek. Horizontal scale: 1 inch = ¼ mile.

Turning again to the region of Blue River, it is at once evident that that region has not suffered the same depression as has occurred to the west. On the contrary the evidence is quite strong that the Blue River region has recently been uplifted. For those not versed in geology a few words of explanation may help to make clearer the nature of the evidence. As is well known, if any region of land remains at one level for any length of time, erosion tends gradually to lower the valleys, then to widen them, reducing the height and steepness of the intervening hills, and if allowed to continue long enough, the land will become a flat base level, as it is called. If at any stage in the process, say when the area in question has been reduced to a gently rolling type of country, uplift takes place in part of it, it is evident that the streams that rise in the uplifted area will have their upper courses in shallow valleys with gently sloping banks just as before the uplift. When, however, the stream reaches the edge of the uplifted portion, where it slopes down to the portion not elevated, or where it runs into the channel of a large stream that has cut down below the general level of the plateau, it will become a rapid stream and one that will erode and deepen its channel rapidly.



VIEWS IN VALLEY OF BLUE RIVER BELOW SALEM.

Fig. 1. Blue River at Fort Hill.
Fig. 2. Blue River at ford near Beck's Mill.
Fig. 3. Blue River at Sharp's Mill Postoffice.
Fig. 4. Blue River at ford near Wyandotte Cave.

Below Salem, Blue River becomes more rapid, and the banks finally become toward the mouth from 300 to 400 feet high, and steep, leaving little or no bottom land, and making a narrow valley.

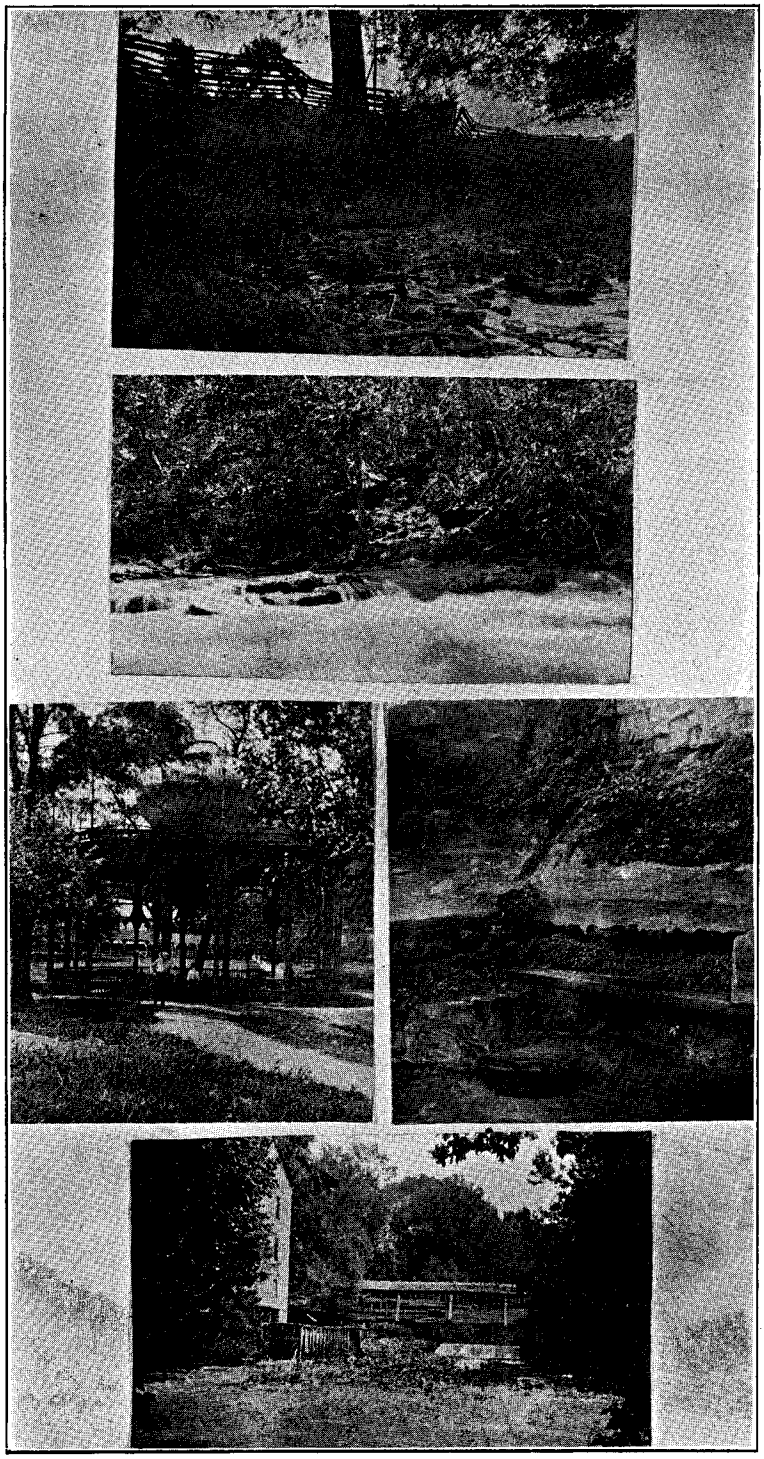
A gorge will thus be started at the edge of the plateau or at the mouth of the stream, which will rapidly tend to eat its way back into the plateau. With the process only partly completed we should have just such conditions as we find in the valley of Blue River, Indian Creek, Buck Creek and the other creeks of that region,—headwaters in shallow valleys with gently sloping banks, changing in their lower courses into rapid streams flowing through deep gorge like valleys. In the case of Twin Creek and the creeks flowing north and east, the soft and easily eroded nature of the Knobstone has allowed the erosion to proceed more rapidly so that the gorge has in many cases sunk its bottom down to drainage level, and the point of rapid descent has advanced from the mouth to the head waters on account of the shortness of the stream. Indeed in many cases it is evident that, due to their shortness, these northward and eastward flowing streams are cutting down the divides at the expense of the streams flowing the other way. A good illustration of this, "river stealing," as it is called, is seen about Borden. The valley in which Borden lies originally drained to the northwest, the divide being nearly as far east as Broom Hill. But the Muddy Fork of Silver Creek having cut down its side of the divide faster than the stream draining to the northwest, has captured all the drainage about Borden and it is only a question of time when it will extend up so as to tap the Mutton Fork of Blue River at Pekin and divert all the drainage above that point to Silver Creek.

Upland Types of Eastern Plateau.—In addition to the valley types already described, several features of the intervening divides remain to be noticed. First are the remnants of an old sea bottom or peneplane. It would appear that at some time not long ago, geologically speaking, the eastern part and possibly all of this area had been reduced to a nearly level plain and covered by the sea. Remnants of this old plain are still to be seen along the crest of the divide in eastern Harrison and Washington counties and western Floyd County. It is best preserved at the south, being over a mile wide east of Elizabeth. It may be doubted if any of the original flat surface still remains, but its influence is still evident in the nearly level divide, often from a half to a mile wide at points all the way from Buena Vista to Martinsburg. It is always accompanied by sands or gravelly deposits to be described later. North of Martinsburg the original level has disappeared, but a number of very high points, such as Spurgeon's Hill, must reach very nearly to the old surface, as remnants of the characteristic sandy deposits still cap them. These hills often rise as sharp conical knobs some miles from the divide and frequently

100 feet or more above the adjacent upland. At the south this plain appears to be between 800 and 900 feet above tide, while to the north some of the hills mentioned rise to 1,000 feet above tide. Whether the difference in elevation is due to unequal uplift or to the original slope of the sea bottom is not plain, probably both. The character of the deposits indicate that the original slope was from the north.

Descending to the west or southwest from the eastern edge of the plateau the country changes from a nearly flat to a gently rolling type in which the hills rise from 25 to 100 feet above the adjacent valleys, but with generally rather gentle slopes from hill to valley. A little further in the same direction finds the hills maintaining about their same height, while the valleys have steadily cut down, resulting in a much more broken type of topography. Still continuing westward the last type is replaced by large areas of sink-hole type. In these areas surface streams are wanting or as a rule are very short, and the surface presents the appearance of a nearly level plain, as viewed at a short distance; but at close range more or less completely dessicated by sink-holes. These may range from little round or oval depressions a rod or less wide and from a few feet to 40 or 50 feet deep up to a miniature drainage system, with little valleys often a mile or more long all converging at one point where the waters pass under ground. In places in this sink-hole area are to be found flat, often almost drainless tracts of prairie land. The level upland of this central region is believed to be the fairly well preserved remnant of gradation plains extending up the Big and Little Blue rivers, Indian Creek, etc. Similar gradation plains have been noted further east at slightly greater elevation. The plain rises from about 550 feet above tide, near the Ohio, to nearly or quite 900 feet above tide about the head waters of Big Blue River. The streams which are barely trenched in this gradation plain at their heads are 150 feet or more below it toward their mouths.

At the western edge of the sink-hole region it is everywhere encroached upon by hills and ridges capped with sandstone. These usually rise 100 to 150 feet above the general level to the east. They are sometimes found long distances east of the main body of rocks to which the sandstone belongs, and range from sharp conical sugar loaf hills, as Pilot Knob, near Corydon, to narrow-topped, steep-sided, ridges of extremely irregular shape. In Harrison County many of these knobs and ridges do not show any sandstone at present, or sometimes only a few scattered boulders can be found, but in either case they were capped with sandstone formerly, though it has now been removed by erosion.



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TYPES OF SPRINGS IN THIS AREA.

Fig. 1. Spring near Blue River on road east from Beck's Mill. A common type in this area.
Fig. 2. Clifty Creek, below spring. A type of large springs associated with caves.
Fig. 3. No. 3 Spring at West Baden. Type of mineral spring not rising quite to surface.
Fig. 4. Pluto Spring. Freely flowing mineral spring.
Fig. 5. Stream from Harrison Spring. Small river rising to surface and flowing away. The drainage of a large area rises to the surface in such a spring. Photo taken in August, in dry season.

Type of the Western Upland.—The isolated hills and ridges last described become more numerous to the west and occupy larger and larger areas until the flat intervening areas are reduced to narrow V-shaped valleys, often 200 to 300 feet deep and sometimes hardly wide enough to allow the building of a road beside the stream.

DRAINAGE.—There is not as yet sufficient data at hand to enable making anything like a thorough study of the drainage of the area and its interpretation. It has already been stated that the present drainage appears to date from the elevation that followed the laying down of the Ohio River beds. Where this uplift had its center has not as yet been discovered. The difficulty is to differentiate that movement from those that followed in the Pleistocene. As the writer hopes to be able to make further studies along this line he will here only call attention to some of the most salient features of the drainage.

In general the drainage is to the southwest. Along the northern edge of the area the drainage is north and northwest into Muscatatuck and the East Fork of White River. Most of the eastern edge drains east and southeast into Silver Creek. From the edge of the central plateau the drainage is to the west and south into Blue River, Indian, Buck, and Mosquito creeks. Orange County drains to the west by Lost and Patoka rivers; Crawford County drains south in the main by way of Little Blue River; Perry County drains southeast by Oil and Poison creeks and southwest by Anderson River.

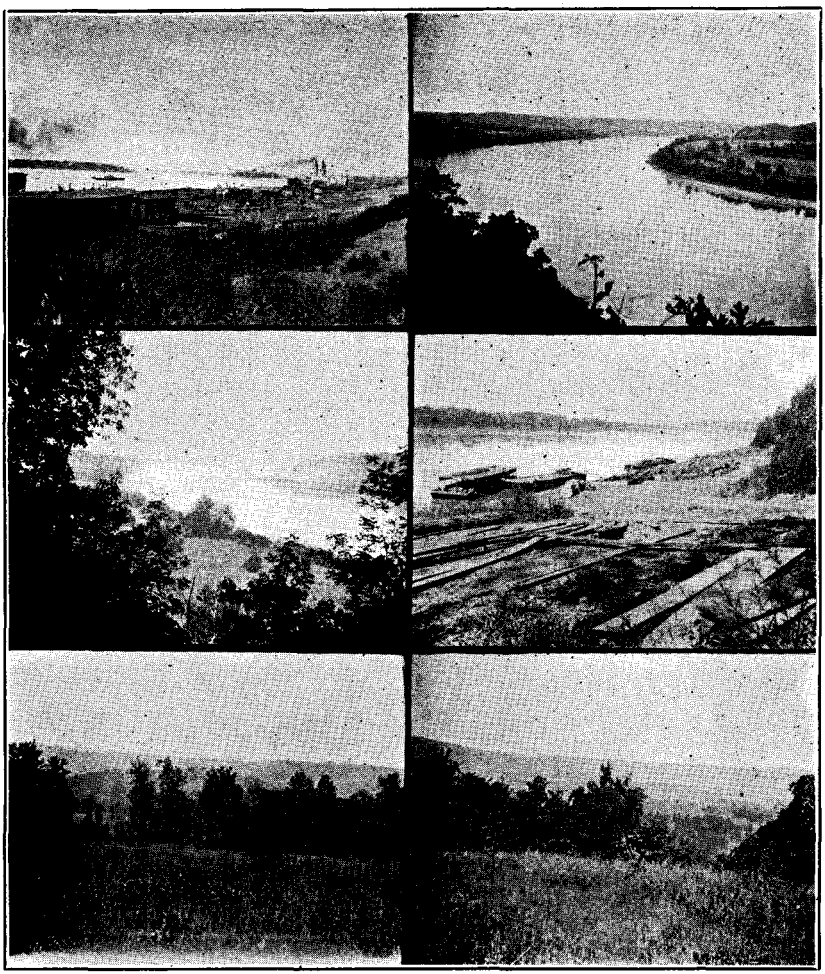
In the sink-hole region the drainage is almost entirely subterranean. The result is seen in the lack of surface streams, in the lack of stream valleys, and in the presence of caves and large springs. This region contains the well known Wyandotte and Marengo caves, besides a large number of other caves, mostly smaller, though many of them are of no small interest. (See the Twenty-first Annual Report of this Department.) This is a notable region for springs. The famous French Lick and West Baden springs occur in this region, also the well known sulphur springs at Sulphur Well Postoffice, in Crawford County, and at Corydon. Fig. 3 of Plate V, shows the No. 3 Spring at West Baden, and Fig. 4 shows the Pluto Spring at French Lick. Turning to non-mineral springs we find the region abounding with them of every size.

The top of the Knobstone is a notable spring horizon, especially where erosion has cut across this down the dip, in which case a succession of springs marks the horizon. The larger springs are mostly found further west, bordering the sink-hole region. A number of these are used to run mills or have been in the past. Of these may

be mentioned: Clifty Mill, two mills in Twin Creeks, Beck's Mill, Organ Springs, in Washington County, and Harrison and Boone's Mills in Harrison County. Fig. 1, of Plate V, gives a spring such as is common all over the western part of the two counties mentioned. The spring figured is from near Beck's Mill. Fig. 2 of the same plate shows Clifty Creek a short distance below the springs; while Fig. 5 shows Harrison Spring Creek a quarter of a mile below the spring. This subject will be referred to again under the head of "Water Power." An interesting feature of the underground drainage of this region is the passing under ground for a greater or less distance of surface streams. The most notable case of this kind is Lost River. This stream, after rising in Washington County, flows a third of the distance across Orange County, then passes underground, in the so-called "Sink of Lost River." The River appears again at Orangeville at the "Rise of Lost River." It would appear that a large stream from the north enters Lost River in the underground part of its course. Parts of this channel may be explored from a boat. At times of high water the river occupies a channel upon the surface indicated by dotted lines on the map. It is of interest that this channel becomes filled from the lower end rather than from the upper end. Thus, for a short time the peculiar condition exists of the river flowing down stream through its underground channel and upstream in its aboveground channel. Indian Creek has an underground channel several miles long, starting a few miles below Corydon, as indicated on the map. In this case, however, the stream occupies its surface channel except at extreme low water, when the surface channel is practically abandoned, the underground channel at such times serving to carry the full volume of the stream. In several cases the roofs of these underground streams have fallen in for short distances. In some cases there are only a few yards between the points of appearance and disappearance of the stream, while in others the stream may be exposed for a quarter of a mile.

Many interesting problems present themselves for solution in connection with the drainage of this region, which will require further study. Thus, a comparison of the valley of White River along the north side of Washington County, or further up stream, with its valley a short distance above the mouth of Lost River will show a marked contrast, the valley being only a quarter of a mile wide in the latter region, as against several miles in the former region. How much of this difference is due to difference in the rock through which it flows and how much to earth movements and possible changes in channel? The Ohio River presents somewhat similar problems.

PLATE VI.



VIEWS ALONG OHIO RIVER SOUTH OF THIS AREA.

Fig. 1. At Louisville.
Fig. 2. Bend at Brown's Landing.
Fig. 3. East from Brown's Landing.
Fig. 4. At Tobacco Landing, near Laconia.
Figs. 5 and 6. Ohio Valley, near mouths of Blue River and Indian Creek, taken from high upland.

Plate VI gives a series of views extending from Louisville to Leavenworth. At Leavenworth the river, ten feet above low water, is 1,920 feet wide and the valley from bluff to bluff 3,960 feet wide. The river continues in this narrow gorge-like channel to Cannelton or beyond, but 20 miles further west it is found flowing in a valley four or five miles wide. In this case the difference in the width of the valley would seem to be mainly due to recent uplift at the east. A study of the course of the Ohio, as well as of the courses of Blue River, Indian Creek and others of the region, suggests very strongly that their present courses are largely a survival of their courses when flowing at the level of the upland or gradation plain then nearly at base level. Thus, take the horseshoe curve at Leavenworth, the two arms of the curve are separated by a high divide with bluffs as marked and precipitous as on the outside of the curve, indicating that the river has sunk its channel *in situ*. The same thing is very noticeable in following down Blue River where horseshoe curves abound, and in most cases the arms of the curve are separated by high divides.

GENERAL GEOLOGY OF THE AREA.

STRATIGRAPHY.—*General.*—The area to be studied has been limited to the area of outcrop of the Lower Carboniferous rocks. On the west they are overlain by the coal measures, as described in the Twenty-third Annual Report of this Department. On the east they are underlain by the New Albany black shale of Devonian age. Quaternary deposits occur in the Area in the form of alluvial deposits in the valleys, and glacial drift in the northeastern part of the area. There are also found deposits of limited extent associated with an old peneplane that evidently are younger than the Carboniferous and older than the Quaternary. They are thought to be of Tertiary age.

The Lower Carboniferous strata consist at the top of alternating limestones and sandstones with some shale for a thickness of from 100 to 200 feet. Below that comes from 400 to 500 feet of limestone with a few very thin beds of shale. One layer of this limestone appears to be of different origin than the most of the stone and can be traced more or less continuously over the course of its outcrop. It is, moreover, of the highest economic value. It has therefore been mapped by itself and will be considered under the name "Bedford Oölitic Limestone." It occurs from 50 to 100 feet from the bottom of the great limestone bed. The limestone below the Bed-

TABLE OF FORMATIONS, ETC.

AGE.	FORMATIONS OR GROUPS.	CORRELATIONS.	CHARACTER OF ROCKS.	ECONOMIC MATERIALS.
Quaternary or Pleistocene.	Recent alluvial and lacustral deposits. Glacial drift.	Illinoian.	Gravel, sand. Till.	Road material.
Post Carboniferous (Tertiary?)	Ohio River.	Irvine formation of Campbell. ?	Sands, gravels.	Glass sand.
Coal Measures.	Mansfield.	Pottsdam.	Massive sandstone, shale, coal.	Building stone, coal.
Lower or Eocarboniferous. (Mississippi Series.)	Huron group.	Kaskaskia or Chester, of Illinois.	Archimedes limestone, upper sandstone, middle limestone, lower sandstones, shales.	Building (sand) stone. Marble. Lime.
	Mitchell limestone.		Lithographic limestone, Oölitic limestone (white). Hydraulic limestone, limestone and shale, cherty *limestones*.	Lithographic stone. ? Portland cement. Roman cement. Lime. Limestone for glass manufacturing. Limestone for rough masonry. Road material.
	Bedford oölitic limestone.	St. Louis, Warsaw.	Massive, even-grained, oölitic limestone.	Building stone. Portland cement. Lime. Road material.
	Harrodsburg limestone.	Burlington and Keokuk.	Hard limestone with chert and geodes, shale.	Road material. Limestone for rough masonry.
	Knobstone.	Waverly.	Sandstone, shaly sandstone, shale, thin limestone.	Building stone. Brick shale.
Devonian.	New Albany black shale.	Genesee.	Black shale (silicious).	Oil, tar, etc.

ford has received the name of "Harrodsburg." The limestone above the Bedford has been called the "Mitchell." Below the Harrodsburg limestone come about 400 feet of shales and shaly sandstones to which the name Knobstone has long been applied. The uppermost beds have been called the "Huron" group for reasons to be given below.

Quaternary Stratigraphy.—Deposits of Quaternary age divide themselves into upland deposits, river deposits from the country rock, from the Illinoian ice lobe, from the Wisconsin ice lobe, glacial drift of Illinoian age.

Mention has previously been made of the limited areas of prairie that occur in the central plateau. No detailed study of these was made but they had all the appearance of water deposits. It was judged that their origin was purely local in character, probably being due to the filling of some large sink-hole or area of former erosion with subterranean outlet, which had afterward become stopped up. In the eastern part of Harrison County are many stretches of flat country, some of which are undoubtedly due to recent deposition by water. Thus, Mr. Collett reports a well on the Conrad Bickell place in Section 1 (T. 4 S., R. 4 E.) as follows:

	Ft.	*In.*
Black soil	1	6
Yellow clay and gravel	15	0
Gravel and sand	8	0
Plastic blue clay	4	0
Sand to limestone	4	0
	32	6

This occurs in what are known as the "flat woods," which occupy a broad area in the eastern part of Harrison County. On the theory that this belt was formerly a gradation plain, these deposits may be described as flood plain deposits.

The deposits along the stream bottoms, except the Ohio, White and Muscatatuck rivers, consist of material derived from the country rock. The narrow valleys of the streams flowing south or west give little room for extensive river deposits, and the rapid character of the streams makes little tendency to form bottoms. The streams to the north and east have broad valleys, but they are in the main valleys of erosion and not of deposition.

Turning to the rivers on the north and south boundary of the area, we find that they take their rise in drift-covered areas, and as a result the alluvial deposits along them contain a large percentage

of granitoid and other rocks derived from Canada. Along the Ohio, and the Muscatatuck nearly to its mouth, the alluvial matter consists largely of valley Illinoian, while the alluvial of White River across the northern border of Washington County is a mixture of Illinoian and Wisconsin drift.

The unmodified drift of this area belongs to the Illinoian ice lobe. No attempt was made to trace the boundary of the drift with accuracy. The western limit of the deposit in a general way may be said to cross the Muscatatuck River near the mouth of Elk Creek, in Washington County, and extends southeast to the Ohio River. A large boulder composed principally of hornblende and augite was found beside the road just south of the center of Section 1 (T. 2 N., R. 5 E.). As this is high up on the central plateau, its position beside a road seemed to make the chances strong that it had reached its present position through human agencies. At the southeast corner of Section 32 (T. 3 N., R. 5 E.), a boulder of quartzite 15 inches long was found, but its association with some other quartz and chert pebbles indicated that it might belong to the Ohio River formation rather than the drift.

Ohio River Formation.—Along the divide between the streams flowing east into the Ohio or Silver Creek and the streams flowing west or south are found more or less extensive deposits of sand and gravel, or locally, conglomerate. These sands are the ones that have been extensively dug for the manufacture of glass at New Albany. At the south these deposits have a thickness of from 20 to 30 feet or a little over; to the north they thin out. The thickness given is not the original thickness, which it is more than possible was greater at the north than at the south. In the area being studied these deposits reach their greatest development along the divide east of Buena Vista and Elizabeth. At the old DePauw bank, formerly worked for glass sand, it appears as a deposit of coarse-grained, yellow sand, in large part consolidated into a soft sandstone. On the surface level south and west of the quarry are to be found many boulders of hard brown sandstone that appear to belong to the same deposit. Considering the length of time since active work was carried on here it would appear that the sandstone when freshly exposed must have been much more solid than at present, for as a rule exposure to the atmosphere tends to make it disintegrate rapidly into a sand. The sandstone shows a slight degree of bedding, with false bedding showing abundantly. At or near the bottom of these deposits, here and at other mines in the region, it is reported that considerable quantities of kaolin have been found, ranging from white

through yellow, red and blue to green. It was sometimes semi-crystalline. It is said that occasionally streaks of black magnetic sand carrying fine gold dust was found in the bottom layers.

The deposits of the Ohio River formation were formerly worked on the flat summit of the ridge east of Martinsburg on the border between Washington and Clark counties. Here the deposit shows seven or eight feet of brown sand, then from 12 to 16 feet of sand that varies from white to brown, much of it being white with bands of brown following the lines of cross-bedding. Under the glass this sand, as at all places examined, shows grains of clear transparent quartz, often stained with iron. In the southwest quarter of Section 11 (T. 1 N., R. 4 E.), similar deposits of sand cap the divide, but associated with the sand is a hard, ferruginous conglomerate. North of the middle fork of Blue River this formation is only found on the tops of the very highest points, and then usually in such a condition as to suggest that none of what remains is strictly in place, being merely fragments of the formation not as yet carried away. These deposits show less sand and unconsolidated material, but instead, are largely conglomerate. In the southwest corner of Section 19 (T. 2 N., R. 5 E.), on a high point east of the road, the deposit consists of scattered boulders of hard ferruginous sandstone. No gravel was seen here. The road between Sections 17 and 18 climbs over the top of a sugar-loaf-shaped hill, 100 feet higher than the surrounding land, which is capped with boulders, some of which are sandstone and some conglomerate. A somewhat similar high hill at the turn of the road at the center of Section 5 of same township, has on the top and slope many blocks of conglomerate up to 2½ feet across. As in all these cases, the conglomerate consists of a matrix of coarse-grained, brown, ferruginous sandstone, like the sand mined further south, in which are imbedded larger masses ranging from small pebbles of quartzite to pieces of limestone a foot square and several inches thick. Some of this conglomerate is fairly soft, breaking readily under the hammer, while other pieces are very hard, requiring many blows of a light hammer to produce fracturing.

Just north of Millport postoffice, in Washington County, the road cuts through a bed of water-worn gravel composed mostly of chocolate-colored chert, pieces of quartzite, and brown and yellow hard sandstone. The pebbles range in size from three inches down. This would seem to belong to the Ohio River formation, but it does not occupy the highest part of the ridge. As it is probably 300 feet or over above the river it would not seem to belong with any of the

river deposits. Similar deposits have been found on the highest hills of Martin and Perry counties.

In the bluffs of the Ohio, just north of Enterprise, in Spencer County, at an elevation of 400 feet above sea level occurs a deposit of gravel, of quartz, quartzite and chert, strikingly similar to that found near Millport postoffice, and in general to the beds of the Ohio River formation, as developed in Washington County. It is overlain by loess and thus evidently antedates that formation. It is about 100 feet above low water in the river. The composition of this gravel suggests that it likewise is a part of the Ohio River formation. But its position does not agree with that of the deposits farther east. However, recalling the abundant evidences of recent submergence in the Spencer County area and of elevation in the Harrison County region, it is evident that the possibility of their being the same must be admitted, if not the probability. Much field work must be done in the intermediate territory before satisfactory answers can be made to the questions that suggest themselves. In the meanwhile there seems to be a growing mass of evidence that the region occupied by the present valley of the Ohio River has been base-leveled in preglacial times, that sea deposits of limited thickness but of probably wide extent were deposited over the area, that differential elevation has since taken place and the present valleys of the Ohio and its tributaries in Indiana and Kentucky have since been carved out. The lack of any named geographical feature immediately associated with these deposits in the area under study, and the possible wide distribution of the formation in the Ohio River Valley led to the selection of the name used in this report.

Some conglomerates along Middle Creek, in Boone County, Kentucky, from descriptions given by Dr. Geo. Sutton, in 1876, and Mr. E. T. Cox, in 1878, were for a time thought to correspond with the deposits here named Ohio River. However, they have recently been examined by Mr. Frank Leverett, who reports finding about one per cent. of rocks of Canadian derivation, and other evidence, such as their freshness, etc., that has led him to classify them as glacial till, possibly modified by water.*

The suggestion has been made that these deposits correspond with the Irvine formation, described by Mr. M. R. Campbell.†

Upper Carboniferous Coal Measures.—These deposits have been described in the Twenty-third Annual Report of this Department, to which the reader is referred for further information.

* U. S. Geological Survey, Monograph XLI, p. 266.
† Geological Atlas of U. S. folio 46, Richmond, Ky., 1898.

LOWER CARBONIFEROUS.

THE HURON GROUP.—The strata at the top of the Lower Carboniferous in Indiana have hitherto been described under the names of Chester or Kaskaskia. The two terms were originally applied to practically the same group of rocks by Messrs. Hall and Worthen independently, one from a study of the series of rocks along the Kaskaskia River, and the other from the study of the same rocks at Chester, Illinois, at the mouth of the Kaskaskia River. The determination that certain strata in Indiana were of the same age as the Chester, or Kaskaskia, of Illinois was, as usual, done through a study of the fossils. The upper limit of the group was easily determined as the bottom of the Coal Measures. In the valley of the east fork of White River the top of this group of rocks seems to be a limestone showing an abundance of Archimedes, and other forms of the Chester group further west. North of Greene County this limestone runs out and finally the lower strata, as well, thin out. South of Orange County again great trouble has been experienced in determining the line between the Coal Measures and what has been called the Chester, mainly on account of the unconformity between the two apparently becoming more marked. In Perry County the worked coal is in places apparently only 10 or 15 feet above a limestone recognized as of Chester age, while only a short distance off it is 135 feet above any such limestone. So that while a limestone has been taken as the top strata of the Lower Carboniferous in that region, it is evident that, if there is any such unconformity as is indicated by the above figures, different limestones have been used in mapping. While the existence of an unconformity in that region is considered well proven, it has been thought possible that much of the difference between the worked coal and the limestone indicated above is due to faulting. Not enough work has yet been done to satisfactorily settle the question. It will from this be evident that the top of what has been called the Kaskaskia is not a single recognizable stratum, but, starting in the north with the lower sandstones or limestones of the group, becomes successively higher sandstones and limestones to the south, with much uncertainty as to the correlation of the upper members in the Ohio Valley. No effort has been made in recent years to trace or even determine the lower limit of the Kaskaskia in Indiana until the field work of the present study. Considerable work was done on that line some years ago by Mr. Collett and others. How far from satisfactory these results were may be judged when it is stated that sandstones that at one point

Mr. Collett places only 20 feet above the bottom of the Chester, at other points within a few miles he placed in the Coal Measures; in one of the latter cases the bottom of the Chester is given as 127 feet below the sandstone. (The sandstone can be easily traced continuously from the locality of one of his sections to the others.)

In his report on Harrison County,—Eighth, Ninth, and Tenth Annual Reports, Geological Survey of Indiana, p. 303,—Mr. Collett gives the following generalized section of the Chester group:

	Feet.
Kaskaskia limestone	5 to 20
Chester sandstone	35 to 70
Thin-bedded lithographic limestone	40 to 20
Carboniferous shale (bone coal)	1 to 0

In a general section of Crawford County, p. 425 of the same report, Mr. Collett gives the following section:

	Feet.
Kaskaskia limestone, upper bed	2 to 10
Black pyritous shale (marl?)	1 to 25
Kaskaskia limestone, lower bed	5 to 20
Massive sandstone, passing into shales and flagstone	20 to 98
Argillaceous limestone in bands	10 to 26
Coal bone	trace to 1
Siliceous limestone and argillite	2

Mr. Gorby gives the following generalized section of the Chester group in his report on Washington County, Fifteenth Report, p. 124:

	Ft.	*In.*
Chester sandstone	10 to 100	0
Coal, semicannel		6
Thinly bedded gray limestone	5 to 20	0
Heavy bedded lithographic limestone	10 to 40	0

In Orange County Messrs. Elrod and McIntire found the following general section, Seventh Annual Report, p. 207:

	Ft.	*In.*
Chester limestone	17	0
Chester sandstone	105	0
Chester limestone	25	0
Chester sandstones.		
Heavy bedded or shaly, red or blue	5	3
Coal		4
Sandstone or shale	30	0
Limestone, massive and heavy bedded	50	0
Chester chert	1	0
Limestone, locally lithographic	40	0

In the Washington and Harrison county sections only the bottom of the Chester is given, the top not occurring in those counties.

The above sections have had their limits determined by an examination of the contained fossils and a comparison with the fossils of the Chester in the original locality. In these sections a heavy bedded sandstone is recognized in each near the bottom, underlain by from 20 to nearly 100 feet of limestone. An examination of the same sections as originally published shows that in each case the top of the next division below, the St. Louis group, is a limestone, and limestone continues on down with more or less variation for 100 to 200 feet or even more. Thus, the bottom of the Chester, as determined from the life forms, has been found to occur in the center of several hundred feet of limestone with no constant lithologic features to mark the line. An examination of the local sections given by the above geologists shows a still greater lack of constant, lithologic features to mark the line between the two groups; in fact, in many or most of those sections little or no attempt was made to indicate exactly where the line came. If this line can not be drawn at the few places where the exposures warrant publishing sections, how useless to attempt to draw it over the hundreds of miles of its outcrop in the region involved.

In view of these facts it became evident that if any lines were to be shown on the maps between the bottom of the Coal Measures and the Bedford Oölitic limestone some other horizon would have to be chosen than the bottom of the Chester, as determined by the fossils. A study of the conditions in the field showed that the bottom of the lowest, heavy sandstone, could be followed with some approach to certainty. As this was the nearest horizon to the bottom of the Chester available it was chosen for the purpose of mapping. Having done that, it was necessary to refer to the group of rocks between this line and the bottom of the Coal Measures, and as this line in places appears to be half way up in the Chester group it was evident that the use of the words Chester or Kaskaskia would not be correct, and at Mr. Hopkins' suggestion the name "Huron" has been adopted, on account of the complete and fine exposure of the rocks of this group at that point in Lawrence County. It has been further agreed since the term "Mitchell" was applied to a lithologic group of rocks, that though the top of the Mitchell was originally defined as the bottom of the Kaskaskia, in view of the impossibility of mapping the bottom of the Kaskaskia, for the reasons given above, the rocks included in the term Mitchell should be continued up to this line at the bottom of the sandstone. This

rather full exposition of our reasons for adopting a new term has been given because of certain criticisms that have been made of the present survey on account of the introduction of new names in the past. It may be added further that in this matter we are confronted with a condition, not a theory, and that in meeting the condition we have tried to follow the methods now in use in all the better State and government surveys.

From what has preceded it is seen that the Huron is, in the main, an alternating series of thick-bedded sandstones and limestones, with smaller amounts of shale and one or two coal horizons, in which the coal seldom reaches a thickness of more than four inches. At the top is a noticeable unconformity with the overlying Coal Measures. See the Twenty-third Annual Report of this Department, for a discussion of this unconformity, with figures. As stated above, the Huron appears to have been laid down in a retreating sea. That is, when the lowest or earlier beds were being laid down the shore was in northern Indiana, and as the succeeding beds were laid down the shore gradually shifted south so that the upper beds were limited to the south part of the field. The group has a thickness of from 100 to 150 feet or more in the region being studied. The following sections, obtained by Mr. Kindle, give some idea of the stratigraphy:

Section at Foote's Spring, southwest quarter of the southwest quarter of Section 11 (T. 1 N., R. 2 W.):

	Ft.	*In.*
Slope with Mansfield fragments	18	0
Huron.		
Upper Kaskaskia limestone	15	0
Upper Kaskaskia sandstone	35	0
Middle Kaskaskia limestone	16	0
Lower Kaskaskia sandstone	30	0
Mitchell.		
Lower Kaskaskia limestone, etc	6	0+

In contrast with this simple section may be given two sections from Leavenworth. The first is from the wagon road leading up to the State road:

	Ft.	*In.*
Massive buff sandstone, rather soft	4	0
Covered, with sandstone debris	6	0
Light gray clay, nearly free of sand	1	0
Covered	2	0
Soft, shelly sandstone	1	4
Bluish drab, sandy clay shale	6	0
Dark blue clay shale	5	0
Green, slightly sandy clay shale, with limonite concretions	6	0

	Ft.	In.
Blue clay shale	6	0
Sandy blue shale	0	6
Coarse, brown, cross-bedded sandstone	3	6
Blue clay shale	5	0
Crystalline, gray to bluish, limestone	8	0
Bluish drab to green, clay shale with dark red patches, iron ore toward base	5	0
Shelly, gray sandstone and shale	3	0
Blue clay shale	6	0
Brownish crystalline limestone, splitting into thin layers	3 to 4	0
Brown calcareous, sandy shale and limestone	1	0
Blue clay shale (Level of cross roads)	4	10
Hard, fine-grained, crystalline, blue limestone	1	4
Blue clay shale, interbedded with coarsely crystalline limestone	3	10
Fine-grained, bluish gray, lithographic to sub-crystalline limestone	5	0
Bluish gray clay shale	2	8
Thin bedded and shelly sandstone	5	0
Sandy, blue shale with mica and traces of plants	5	0
Gray to brownish, coarsely crystalline limestone	3 to 4	0
Gray sub-crystalline limestone, in 2 to 4-foot strata	16	0
Blue clay shale	1	0
Very soft, buff sandstone, bedding irregular to Mitchell. (See page 81)	8	0

Another section made above the reservoir gave:

Blue and greenish clay shale	30	0
Hard, bluish to gray, crystalline limestone	10	0
Covered	5	0
Drab sandy shale	2	0
Covered (clay shale?)	8	0
Gray, coarsely crystalline. limestone	2	0
Covered	1	0
Sub-crystalline to oölitic, gray to brown limestone, with some sand	3	0
Covered	2	0
Hard, brownish buff sandstone	1	10
Shelly sandstone	1	8
Bluish, sandy shale	4	0
Covered (clay shale?)	5	0
Gray, crystalline to sub-crystalline limestone	18	0
Buffish, irregularly bedded sandstone	8	0

Mitchell.

The following section was obtained at Fredonia:

	Ft.	In.
Massive, thin-bedded sandstone	9	0
Covered	8	0
Gray crystalline limestone	4	0
Gray oölitic limestone	15	0
Massive buff sandstone	8	0
Drab colored, shelly sandstone, merging into massive sandstone	10	0
Dark blue clay shale	3	0
Shelly sandstone	7	0
Blue clay shale	1	0
Brownish crystalline limestone .....15 in. to	2	0
Bluish crystalline limestone	6	0
Blue clay shale	4	0
Shelly drab sandstone	1	0
Covered	3	0
Gray limestone	5	0
Covered	3	0
Buff sandstone	3	0
Covered	3	0
Blue clay shale	3	0
Mitchell limestone	10	0+

Near the head of the middle fork of Indian Hollow, Section 1 (4 S., 1 E.), the following section was obtained:

	Ft.	In.
Covered from level of wagon road	6	0
Shelly buff sandstone	5	0
Blue clay shale	3	0
Crystalline gray limestone	6	0
Covered	4	0
Bluish clay shale	0	6
Impure drab shelly limestone	1	2
Dark blue clay shale	7	0
Greenish clay shale	1	0
Covered	6	0
Sandy shale and shelly sandstone	5	0
Drab-colored clay shale	2	0
Thin-bedded to shelly sandstone	4	0
Brownish to buff, hard sandstone, in two to five foot strata	15	0
Gray sub-crystalline limestone	12	0
Covered	10	0
Shelly gray limestone	2	0
Buff earthy limestone	4	0
Covered	20	0
Gray limestone	3	0
Covered	4	0

	Ft.	In.
Sub-crystalline limestone	6	0
Covered	3	6
Hard, brownish sandstone, with sigillaria	1	6
Shelly buff sandstone	1	0
Mitchell, light gray sub-oölitic limestone	10	0

At the east the base of the Huron is represented by a considerable thickness of sandstone at the bottom. Thus in Section 5 (4 S., 3 E.), the section from the top of the hill shows:

	Ft.	In.
Sandy soil	20	0
Red ferruginous, coarse-grained sandstone	18	0
Gray and red limestone	12	0
Red and blue shales and sandstone	40	0

At the Rothrock Cliff in Section 34 (3 S., 2 E.), this shale and sandstone shows as follows:

	Ft.	In.
Laminated clay shale	14	0
Massive, gritty sandstone	8	0
Soft ferruginous sandstone	11	0

The limestone shows further up the hill but back from the cliff with no connected section between.

In tracing the line at the bottom of the Huron it was found that the lowest bed of sandstone, often only a foot and a half thick, was quite commonly filled with sigillaria, and was conveniently referred to as the sigillaria sandstone.

The distribution of the Huron is shown on the maps.

THE MITCHELL LIMESTONE.—A glance at the maps will show that the eastern and western limits of the Mitchell are generally 10 to 15 miles apart, and in no place less than about three miles apart in this area; therefore, at no point was it possible to obtain a single complete section. Furthermore, on account of the generally level character of the country where the Mitchell outcrops and the absence of valleys, due to the underground character of the drainage, extensive exposures of the Mitchell rocks are not common, in fact not common enough to permit saying whether certain somewhat similar beds were at the same horizon or not. And as no well records were found that were considered reliable in their determination of the variations in the limestone the result was that no complete section of the Mitchell was obtained. The best exposures of Mitchell rocks were found along the Ohio River. Perhaps the best estimate of the thickness of the Mitchell was made at Corydon. The top of the

Mitchell is found in Pilot Knob at 265 feet above the creek, according to the barometer. The bottom of the Mitchell is last seen at the quarry, four miles east of Pilot Knob. The average dip of the strata along the Air Line Railway, a few miles north, is found to be approximately 33 feet to the mile. If the same dip holds between the foot of Pilot Knob and the quarry, the bottom of the Mitchell should be 100 or 125 feet below the stream at the foot of the knob, allowing for the descent of the stream, or between 350 and 400 feet below the top of the Mitchell in the knob. In a well at Corydon the Bedford stone was not recognized. It was, however, 230 feet to the Knobstone. Allowing 100 feet for the thickness of the Harrodsburg and Bedford, it leaves 130 feet as the depth to the Bedford. It may, therefore, be assumed that in the region of Corydon at least, the thickness of the Mitchell is between 350 and 400 feet.

The following sections from this region and one section from Lawrence County will give some idea of the stratigraphy:

Mr. Siebenthal reports this section in Section 13 (7 N., 2 W.):

	Ft.	*In.*
Drab lithographic limestone	20	0
Chert breccia, rotten, lithographic groundmass	8	0
Bluish drab, fine-grained, fetid limestone	10	0
Lithographic limestone	4	0
Drab, calcareous, clay shale	9	0
Drab, rotten, magnesian limestone, with chert inclusions	29	0
Bluish, vermicular, shaly limestone	2	0
Drab calcareous shale	4	0
Rotten and shaly, lithographic limestone	5	0
Lithographic limestone	2	0
Rotten lithographic limestone	5	0
Drab calcareous shale	7	0
Fine-grained, bluish gray limestone, with conchoidal fracture	5	0
Calcareous clay shale	2	0
Gray limestone, in 8-inch beds	5	0
Fossiliferous, shaly limestone	14	0
Concealed	6	0
Fossiliferous, coarse-grained limestone	2	0
Bedford oölitic limestone	0	0

There is here presented a thickness of 139 feet. How near it reaches to the top of the Mitchell is not known. Apparently the Mitchell is much thinner to the north.

The following section, taken at the perpendicular bluff beside the railroad, a mile north of Corydon, shows the variable tendency of the Mitchell:

	Ft.	*In.*
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	1½
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 ft. above creek)	2	0

The following section was obtained at the Eichol Quarry on the northeast side of Blue River, opposite Milltown:

	Ft.	*In.*
Slope, mostly hidden, appears to be mostly brown sandstone (Huron)	24	0
Mitchell.		
Semi-crystalline, semi-oölitic, fossiliferous limestone (trilobite tails abundant)	4	0
Gray oölitic limestone, pentremite bed at top	1	3
Yellowish-brown, sub-crystalline limestone	3	0
Brownish-gray, crystalline limestone	1	0
Hidden (same as last?)	9	0
Light drab, lithographic limestone	3	0
Gray, crystalline limestone	20	0
Hidden to top of quarry face	25	0
Light drab and light brown, lithographic limestone	7	0
Light bluish-drab, calcareous shale	1	3
Light drab, lithographic limestone, slightly cross-bedded, with thin lines of coarse sand grains, especially toward the top	12	0
Light gray limestone	9	0
White to dark gray, oölitic limestone, oölitic structure not distinct	13	0
Hard blue, sub-crystalline, sub-oölitic limestone (crow-feet)	6	8
Bluish-green shale	0	2
Light gray, granular limestone, one notable crow-foot near the middle accompanied with some green matter	5	0

	Ft.	In.
Shale parting	0	1
Interlayered, gray crystalline and oölitic limestone	3	9
Lithographic limestone, in thin layers, with shale partings	2	0
Drab lithographic limestone with calcareous bands and nodules	3	6
Gray crystalline limestone	0	2-6
Lithographic limestone, with numerous flint bands and nodules	7	0
To river, about	10	0

Mr. Collett gives several sections covering about the same strata as the last section. Three of these from the southwest part of Harrison County are given below:

Section at Stockslager's Quarry, Section 21 (5 S., 3 E.). (Eighth Annual Report, p. 403):

	Ft.	In.
To top of hill	70	0
Huron.		
Massive sandstone	6	0
Mitchell.		
Sandy limestone	30	0
Cherty shale	10	0
Shaly limestone	40	0
Gray fossiliferous limestone	5	0
Snow white oölitic limestone	8	0
Banded limestone	8	0
Massive gray limestone	10	0
Cherty shale, with bands of limestone	80	0
Flint balls	10	0
Shaly limestone	30	0

Section at John Brown's Mill, Section 10 (4 S., 2 E.):

Huron.	Ft.	In.
Sandstone	100	0
Mitchell.		
Limestone, etc	22	0
Shaly clay (marl?)	18	0
Shaly limestone	15	0
Shaly clay	11	0
Shaly limestone	35	0
Flinty limestone	30	0
Gray limestone	40	0
Hard limestone	15	0
White oölitic limestone	4	0
Cherty limestone	12	0
Oölitic limestone, fractured	6	0

Section at Kendall's Landing, Section 16 (4 S., 2 E., p. 405):

	Ft.	In.
To top of hill	33	0
Huron.		
Shale and sandstone	17	0
Thin-bedded sandstone	40	0
Massive coarse grained sandstone	7	0
Soft coarse grained sandstone	5	0
Calcareous shale and soft sandstone	20	0
"Keil"	5	0
Mitchell.		
Massive crystalline limestone	30	0
Shale	15	0
Gray and red, laminated limestone	11	0
Fissile, shaly limestone	25	0
Massive gray limestone	25	0
Flinty, shaly limestone	26	0
White oölitic limestone	4	0
Shaly limestone with plates of chert	40	0
Cherty limestone, partly covered	75	0

A part of the section obtained at Leavenworth by Mr. Kindle was given in the discussion of the Huron group. The following section is a continuation of that into the Mitchell. It begins where the other leaves off:

	Ft.	In.
Sub-crystalline to oölitic, gray limestone	6	0
Shelly limestone and shale	1 to	6
Bluish-gray to buff, lithographic limestone	7	6
Buff calcareous shale	0	10
Gray lithographic limestone, in solid ledge	3	2
Clay band	0	0½
Gray lithographic limestone	1	8
Blue and buff clay shale, interbedded	0	8
Hard sub-crystalline limestone	2	0
Buffish to drab colored, granular, soft limestone, with much chert	2	0
Bluish-gray sub-lithographic to sub-oölitic limestone, some chert	4	0
Gray to buff lithographic limestone	7	0
White or light gray, sub-lithographic, sub-oölitic limestone	4	0
Shelly gray limestone	1 to	6
Bluish calcareous shale	0	1-6
Gray oölitic limestone	4	6
Very soft, weathered, buff, saccharoidal, magnesian limestone	6	0
Buff to drab, rather soft, saccharoidal, magnesian limestone	8	0

	Ft.	In.
Clay band and crow-foot seam	0	1-3
Light gray to drab, coarsely crystalline limestone	3-4	0
Bluish-gray, saccharoidal limestone	1 to	8
White oölitic limestone, very pure	4	5
Drab sandy limestone	0	10

For comparison with the bottom of Mr. Siebenthal's section, the following short section of the bottom of the Mitchell is given, taken from the most southern outcrop of the Mitchell in the State, in Section 23 (6 S., 4 E.):

	Ft.	In.
Shaly limestone (Hydraulic)	3	0+
Coarsely fossiliferous, crystalline limestone, some oölitic grain	10	0
Light drab clay shale	15	0
Bluish limestone, like crystalline part of Bedford	10	0
Bedford oölitic stone	7	0

Notwithstanding the thickness of the Mitchell, only one layer was recognized as doubtfully, but possibly persistent. Oölitic structure is fairly common in the formation, but at a large number of points there was found an oölitic bed of unusual purity and whiteness. It ranged from 13 feet in thickness down, generally being from four to 10 feet thick. In different sections it is found from 60 to 185 feet below the top of the Mitchell. It was not definitely determined whether this very white limestone was all at one horizon or not. The recurrence of oölitic limestones of much the same structure, if not the same degree of purity, threw much doubt over the persistence of the very white layer and suggests that such layers are only local facies of the oölitic limestone so common in the Mitchell.

Another facies of the Mitchell that occurs abundantly but is not apparently confined to any horizon, is a fine-grained limestone eminently suited to the purposes of lithographing, provided rock can be found sufficiently free of crevices filled with calcite. As yet no such commercial stone has been found. But in its structure this limestone is clearly a lithographic stone. It appears to be most abundant near or at the very top of the Mitchell, but seems to occur at all horizons down almost to the bottom of the formation.

A third facies of interest, especially from the economic side, is the presence in this series of a shaly limestone that from tests made appears to indicate a suitable stone for the manufacture of hydraulic

cement. This runs from 10 to 20 feet in thickness and is found not far from the bottom of the Mitchell. Different sections give its distance above the Bedford stone at from 15 to 70 feet. It is often spoken of as the "hydraulic limestone." It was stated above that many layers of the Mitchell tend to be oölitic. This oölitic limestone is quite distinct from the Bedford oölitic limestone. At first sight the grains are larger, more closely resembling fish roe than the Bedford stone. Closer examination reveals that this oölitic limestone is the result of chemical segregation of the calcite around centers resulting in building up the minute round grains, the grains usually being distinctly visible to the naked eye. The Bedford stone on the other hand has been found to consist of innumerable microscopic shells of the foraminifera, one of the single-celled protoza. This will be discussed more fully further on.

Having noted these three facies of the Mitchell the sections given are sufficient to show that the formation as a whole consists of a variable series of limestones and shales, the limestones greatly predominating.

The general geographic distribution of the Mitchell is shown on the maps.

THE BEDFORD OÖLITIC LIMESTONE.—This limestone has been so fully treated in the report of Messrs. Hopkins and Siebenthal, 21st Annual Report, that in this report we may concern ourselves mainly with its character and distribution in this area, referring the reader to the report just mentioned for fuller information as to the physical and chemical properties of the stone. In general the Bedford stone is a solid bed of limestone without bedding and usually without fossils of noticeable size. It is very uniform in grain, soft when first taken from the quarry, but rapidly hardening under the weather. It has been found under the microscope that the grains are composed of the microscopic shells of one-celled foraminifera. This grain is easily seen with a magnifying glass and frequently with the naked eye. The grain is much smaller than the white oölitic limestone of the Mitchell. In color the stone ranges from a creamy white to a dark drab, most commonly being between a buff and a light drab. The bed in this region is from 90 feet in thickness down. The thickest stone comes in the northwest corner of the area. A thickness of about 60 feet is maintained along the outcrop to Salem. Then the thickness decreases rapidly to 10 feet or less, sometimes running down to 3 or 4 feet, or even disappearing altogether, and on the other hand occasionally thickening up to 35 feet or more.

In some places the bed seems to have broken up into two or more strata. Thus at the Salem Lime and Stone Quarry is found the following:

	Ft.	*In.*
Grayish buff limestone	2	6
Grayish buff oölitic limestone	7	0
Grayish buff limestone	12	0
Grayish buff oölitic limestone	30	0

In this case, on microscopic examination, no difference was detected in the two layers of oölitic stone.

In the northwest quarter of Section 27 (2 S., 4 E.), occurs the following section:

	Ft.	*In.*
Soft shale	10	0
Oölitic limestone, grain medium fine, regular, close	5	0
Limestone, dark blue, oölitic in spots	8	0
Coarse-grained, slightly crystalline, oölitic limestone	5	0
Sub-crystalline limestone, slightly oölitic locally	3	0
Limestone, half oölitic and half crystalline	4	0

In this case, and the same thing is probably true at Salem, the apparent dividing into beds seems to be due to parts of the bed having lost the oölitic character.

The Bedford limestone in this region presents four marked facies. First, there is the characteristic oölitic facies. In this the stone appears as a granular limestone, the grains being almost microscopic shells of foraminifera, with sometimes bryozoa, and occasionally minute gasteropods, all being cemented together by calcite.

In the second facies, the stone is porous, due to the grains having all been dissolved out. Over most of the southeast quarter of Township 2 north, 4 east, all the rock seen on the surface is of this character. To what depth this weathering extends was not ascertained.

In a third facies the calcite is replaced by crystallized quartz, so that the rock which, when held at arm's-length, appears to have the characteristic structure, is seen, on close inspection, to be made up of minute quartz crystals. This facies was found most abundantly around New Philadelphia.

In the fourth facies the rock tends to grade over into a crystalline limestone, probably due to the solution and subsequent deposition of the calcite in the rock. This tendency becomes more and more pronounced in going southward, so that in many places in Harrison County it was not possible to recognize the horizon of the Bedford stone.

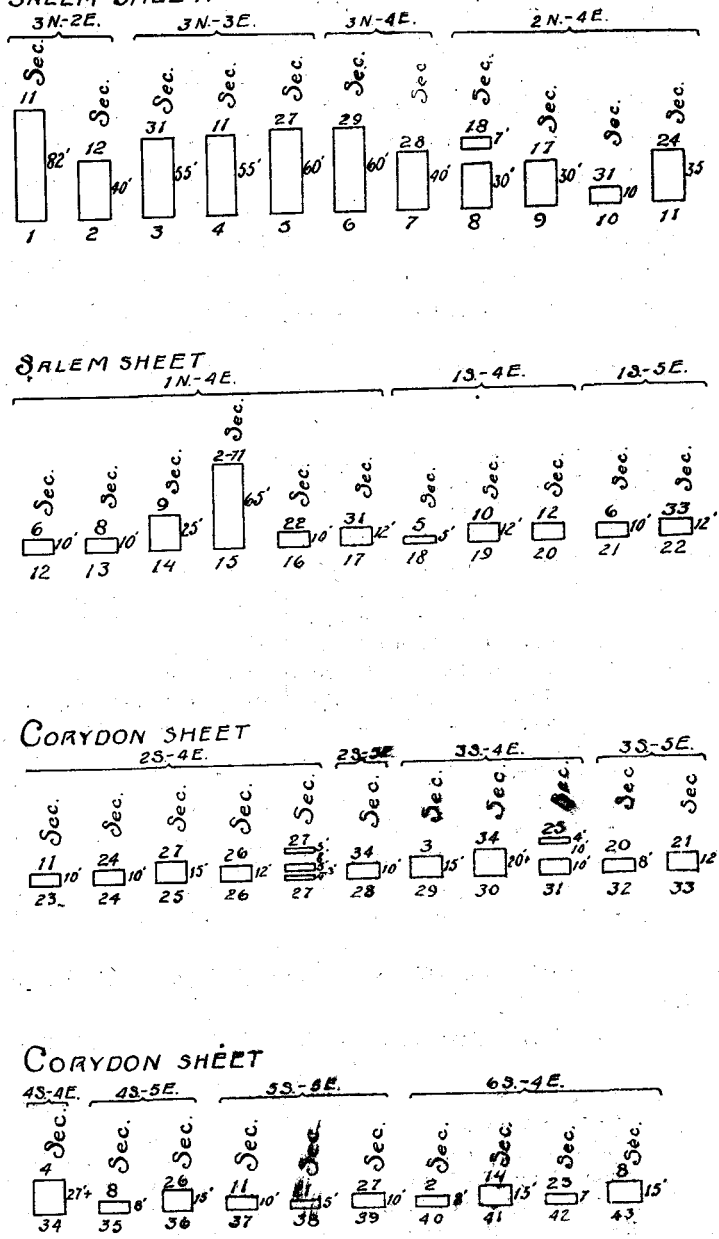


Plate VII. Sections of the Bedford oölitic limestone.

The distribution of the Bedford oölitic stone is shown on the map, and on account of its commercial value will be considered in some detail under the head of Economic Geology.

HARRODSBURG LIMESTONE.—The Harrodsburg limestones, named from the excellent exposure of these rocks at Harrodsburg, in Lawrence County, consists of a series of limestones with thin beds of shale, with sandy limestones in places just at the bottom, where it meets the Knobstone. The thickness of the series is from 35 to 100 feet or a little less, the average being about 65 feet in this area.

Fig. 4, from the face of the quarry just west of Salem, below the cemetery, gives an idea of the stratigraphy and of the variation to which the individual beds are subject. In the figure the numbers referring to the different strata correspond to the following section:

		Ft.	*In.*
1.	Soil, red ..... 2 ft. to	3	0
2.	Bedford oölitic limestone ..... Harrodsburg.	5	0
3.	Light drab limestone, with crow-feet.....	5	0
4.	Yellow to light drab limestone, with crow-feet....	6	0
5.	Light to dark blue limestone, crow-feet, fossiliferous, bryozoa common, top layer crinoidal, numerous cavities with calcite crystals.....	6	0
6.	Gray, fine-grained limestone, composed largely of finely comminuted crinoid stems and shell fragments. One persistent crow-foot, several smaller ones	6	0
7.	Soft, blue shale	0	0-6
8.	Gray to drab limestone, similar to No. 6.....	3	0
9.	Shale like No. 7, only more persistent.....	0	6
10.	Limestone, like Nos. 6 and 8.....	4	0
11.	Blue shale	1	to 6
12.	Blue, shaly limestone, fuel of geodes.....	2	0+

Two sections from Harrison County will show the character of the series in that region.

Section of Harrodsburg at Stoner's Hill, Section 11 (5 S., 5 E.):

	Ft.	*In.*
Cherty limestone	45	0
Shale, with geodes	11	0
Black, white and blue flint, in bands of one or two feet, with clay partings	14	0
Red, encrinital limestone	8	0

Section at Eversol Cliff, Section 13 (5 S., 5 E.):

	Ft.	*In.*
Crinoidal limestone	39	0
Clay shale and geodes	7	0
Blue, fossiliferous limestone	3	0
Sandy shale, with geodes	14	0
Flint in bands of six to twenty inches, with shale partings	12	0

The presence of geodes in these strata is quite characteristic of the Harrodsburg beds.

In places there appears to be a slight unconformity at the top of the Harrodsburg, as indicated in Fig. 2, of Plate VIII, showing the contact between the Harrodsburg and Bedford stone in the railroad cut at Spurgeon Hill, in Washington County. At other places the top of the Harrodsburg is a limestone full of bryozoa, resembling closely the Bedford stone at points where it is largely made up of bryozoan remains. The Harrodsburg limestones are often hard and well suited for road purposes.

The geodes of the Harrodsburg predominate in the lower strata, and range from two feet in diameter down to the size of peas. Fossils are abundant in these strata, many of them being of large size.

THE KNOBSTONE.—In the Knobstone the same difficulty is met with as in the case of the Mitchell, from the fact that the outcrop of the formation has a width of from two to fifteen miles, with no completely connected sections across it. The Knobstone has a thickness of about 400 feet, as shown by drillings, for, due to the character of the strata of which it is composed, it can be recognized with considerable certainty in deep drillings. In the well at Corydon the Knobstone has a thickness of 422 feet. In the Brandenburg Well, the Knobstone has a thickness of 380 feet. In a well at Mifflin, Crawford County, the Knobstone is reported to have a thickness of 490 feet. Some of the exposures in the bluffs along the eastern edge of the knobs show exposures of up to nearly 350 feet, with the bottom still some distance to the east.

In general the Knobstone consists of shale and shaly sandstones. At least two thin beds of limestone occur, one at the bottom, very persistent; the other, near the top, does not seem to be persistent. The shales predominate at the bottom of the formation and at the south; most of the sandstone being found toward the top of the formation, while to the north the proportion of sandstone greatly increases. At the bottom of the formation is the thin limestone mentioned, known as the Rockford Goniatite limestone. It runs

from 10 inches to two feet in thickness, with an average of about 18 inches. It tends to be a bluish-gray on a fresh surface and a dull brown where weathered. It usually contains large quantities of crinoid stems. Above this limestone comes from 100 to 250 feet of greenish-colored, marly shale. The lower 100 to 125 feet of this was called the New Providence shale by Mr. Borden. This lower shale contains many thin bands of carbonate of iron, averaging from four to six inches in thickness.

The upper 200 feet of the Knobstone is composed of a variable deposit of shales and sandstone, the latter usually quite shaly. At the south shales predominate, while to the north these upper beds become almost entirely sandstone, and even the lower shales are largely replaced with sandstone to the north of the area under study. From 30 to 120 feet below the top of the Knobstone there occurs at many horizons a thin limestone, as shown in the following sections:

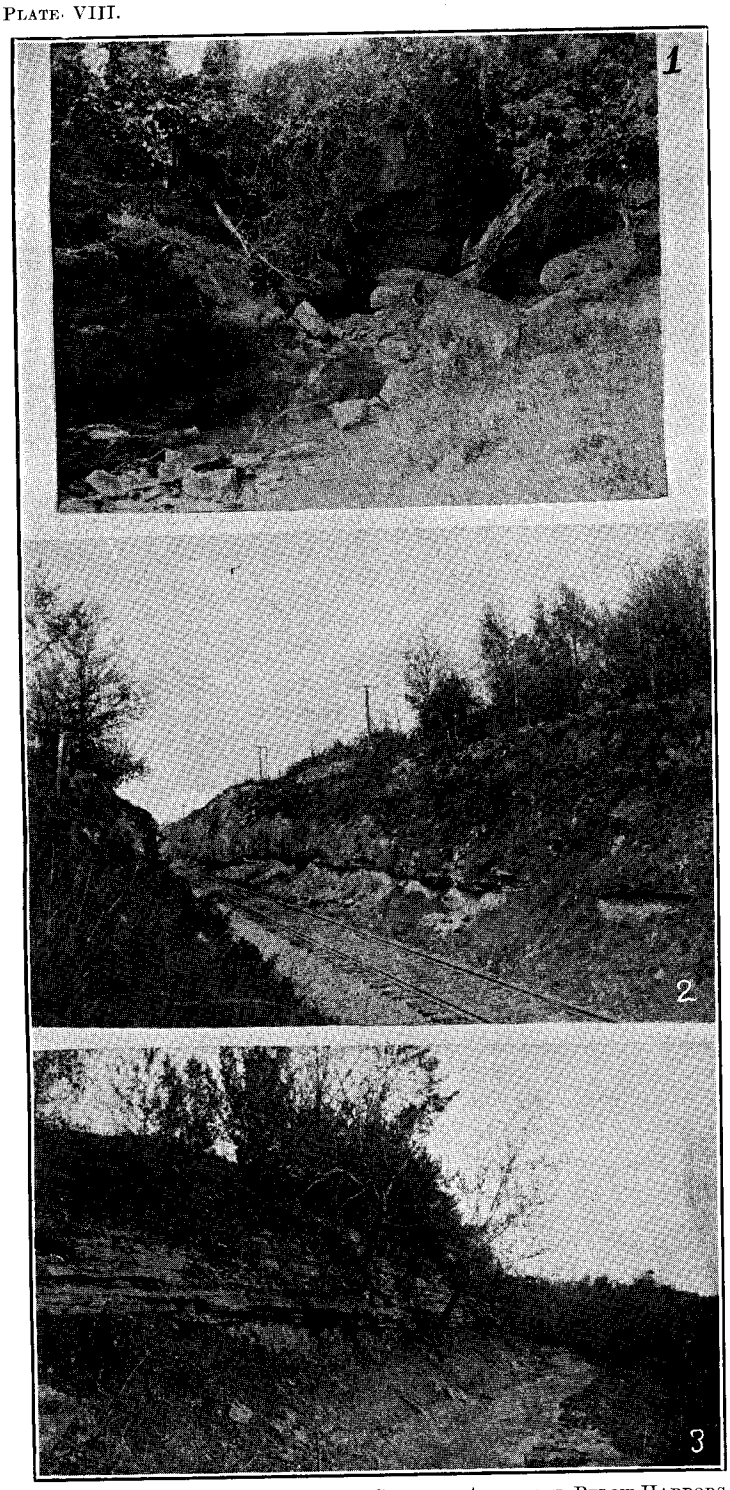
Section east of Mt. Carmel, Section 7 (3 N., 3 E.):

	Ft.	*In.*
Buff, shaly sandstone, soft	95	0
Hard, brown sandstone, with geodes	20	0
Light brown limestone	2	0
Yellow sandstone	20	0
Gray, fine-grained sandstone	30	0
Gray, shaly sandstone	30	0

At the center of Section 19 (3 N., 4 E.), the limestone is found 70 feet from the top of the Knobstone, the rock between being a gray, splintery, sandy shale. In the northeast corner of Section 27 (3 N., 3 E.), the limestone is four feet thick, ferruginous in character, and is 70 feet below the Harrodsburg limestone, the intermediate strata being shale and sandstone. In the northeast quarter of Section 27 (3 N., 4 E.), this limestone is a dark brown, crystalline limestone, three feet thick. It is here only 35 feet below the Harrodsburg limestone, with gray shale between. Below it comes massive light brown sandstone.

At the top, the Knobstone in places appears to grade over almost insensibly into the Harrodsburg limestone. Generally the line is quite distinct, as shown in Fig. 3 of Plate VII, but in other places the limestone becomes more and more sandy until it has become a true sandstone.

Mr. Kindle obtained the following section on the road up the knob from Locust Point Postoffice, Section 12 (4 S., 5 E.):



VIEWS SHOWING BEDFORD STONE AND CONTACTS ABOVE AND BELOW HARRODSBURG LIMESTONE.

1. Bluff of Bedford Stone at upper end of open stretch of underground stream, in southeast 40 of Section 10 (3 N., 2 E.).
2. Railroad cut at Spurgeon Hill, showing famous locality for fossils of Bedford stone, and contact between Bedford stone and Harrodsburg limestone.
3. Contact between Harrodsburg limestone and Knobstone shale.

	Ft.	In.
Gray crinoidal limestone (Harrodsburg)	15	0
Knobstone.		
Shelly sandstone	2	6
Limestone	2	0
Shelly sandstone, with one or two limestone bands	6	0
Sandstone and chert	0	11
Yellowish sandstone, with geodes	3	0
Gray chert, with small geodes	1	8
Buff, soft, shelly sandstone	3	0
Massive sandstone, rather shelly	10	0
Shelly, bluish sandstone	6	0
Light gray, heavy bedded sandstone (building stone)	35	0
Crinoidal limestone	0	to 18
Shelly sandstone	10	0
Massive, drab colored sandstone	5	6
Covered	6	0
Buff to blue sandstone, with crinoid stems	2	0
Shelly, buff to drab sandstone where exposed, with fossils	50	0
Blue sandstone, containing iron which slacks on exposure, causing rock to crumble	65	0

THE NEW ALBANY BLACK SHALE.—This shale, which is here the highest member of the Devonian, is a black, bituminous shale about 100 feet thick. At Scottsburg this shale has a thickness of 120 feet. The black shale is very persistent and has been recognized in deep drillings all over Indiana. The outcrop of the black shale forms the eastern limit of the area to be studied in this report.

GENERAL STRUCTURE OF THE AREA.

In its general structure this area shows a uniform westward dip, being on the eastern side of the Illinois basin. The lack of an accurate topographic base or of a large number of railroad levels gave little opportunity for determining the dip with accuracy. Between Harristown and Salem the Bedford stone descends from about 900 to 740 feet, giving a dip of about 40 feet to the mile. Between the Edwardsville Tunnel and Crandall the Bedford stone descends 300 feet, or 33 feet to the mile. Between New Albany and Corydon the New Albany black shale descends from about 450 feet above tide to about 200 feet below tide (in Corydon Well) or, again, about 40 feet to the mile. These dips are not accurate nor inclusive enough to fully decide the average dip, but suggest an average between 30 and 40 feet to the mile. In the minor details of structure this area shares with other parts of the State in having much variation. In many places

dips of one or two feet in the hundred can be seen in bluffs, and frequently in very small exposures the rocks have a very noticeable dip, often amounting to 50 or 100. Though the most of these had a dip to the west, the dip is variable.

The strike appears to be a little east of south. The top of the Knobstone is about 700 feet above tide at Salem, and reaches about the same elevation at Georgetown, about Section 15, east of Salem. But, as showing the variation to which it is subject, the top of the Knobstone in the Mutton Fork of Blue River on the line between Salem and Georgetown, instead of being about 700 feet above tide, is only about 600 feet above tide. Vienna, Henryville, Memphis and New Albany are all nearly in a north and south line, and all about on the edge of the bottom of the Knobstone, but the elevation along that line decreases from 570 feet at Vienna, to 478 and 489 feet approximately at Henryville and Memphis, and to about 450 feet at New Albany. Many evidences of local disturbances were found, including the finding of one large fault and probably of another.

The Mt. Carmel Fault.—North of the East Fork of White River there is a prominent strip of limestone, known as the "Heltonville Strip," that is found some distance east of the regular outcrops of the limestones of the Lower Carboniferous. This limestone strip is found in patches as far north as Section 10 (9 N., 1 E.), and from Limestone Hill, about eight miles southeast of Bloomington, it runs more or less continuously to White River at Fort Ritner. It has a width of from one-half to one and a half miles, and is bordered on each side by Knobstone. At Heltonville, the stone shows the facies of the Mitchell, Bedford and Harrodsburg limestones, the Bedford stone being extensively quarried here. Evidently this strip is a portion of the overlying limestone occupying a depression in the Knobstone. Mr. Siebenthal, who first studied this strip, concludes that "This depression may have resulted from a double fault or may be an old erosion channel. Some things seem to point to one as the origin and some to the other. The facts at hand incline us to the latter view."*

In the proceedings of the Indiana Academy of Science for 1897, Mr. J. A. Price gives the results of his study of this strip, including a study of the disturbance south of White River. Unfortunately he was not familiar with the slight differences characterizing the different horizons of the limestone. He concludes: "It is not possible

*21st Annual Report Department Geology and Natural Resources, of Indiana, p. 391.

from the data at hand, to say surely whether this limestone owes its existence to an unconformity or a fault."

Due to the change in the slope of the land after crossing White River, coming from the north, the outcrop of the Lower Carboniferous limestone turns and swings some distance to the east, south of White River. It is evident that if the limestone strip north of White River is due to a fault its effects should continue to the south rather than turn and follow the outcrop. A glance at the map in the region north of Campbellsburg is alone almost sufficient proof of the fault character of the disturbance. However, in the branches of Clifty Creek, south of Mt. Carmel, is even more conclusive evidence. In the first ravine just south of Mt. Carmel, as the fault is approached from below, the Bedford limestone is noted outcropping rather prominently and almost continuously on the north bank. This outcrop ends abruptly, then in the bed of the ravine a few rods farther up, the Harrodsburg is seen with a dip of about 40° to the west. Only a few yards above this the Knobstone is found in the bottom of the ravine and well up the bank. In the next ravine to the south the fault shows just east of the quarter section line. The Knobstone here is exposed for a thickness of 20 feet on the east of the fault; the top of the Bedford is just above creek level on the west of the fault. The fault can then be traced southward through a series of sink-holes that appear to follow its course.

At Mt. Carmel the down-throw appears to be 130 feet. Where last seen in Section 24, of the same township, it appears to have a down-throw of over 100 feet. The evidence in this region does not indicate a double fault, but simply a down-throw on the west side of the fault line. West of the fault line the down-throw strata rise rapidly as though to gain their normal elevation. Though no exposures showing this rise were found, it was shown in the greatly increased apparent thickness of the stone; for example, the Bedford stone when measured by barometer westward from the fault line, has an apparent thickness of 140 feet, though the bed was probably less than 90 feet thick. It shows again in the relative elevation of any bed near the fault and a mile or so to the west. Thus, in the center of Section 26 (4 N., 2 E.), the bottom of the Harrodsburg is only a few feet above Twin Creek, while a mile west the same horizon is 140 feet above White River.

A glance at the geology in Indian Creek north of Georgetown, in Floyd County, shows a peculiar condition, very suggestive of a fault, running northwest and southeast. In Section 19 (2 S., 5 E.), about

60 yards above where Indian Creek turns sharply to the east of south, the Harrodsburg outcrops in cliffs down to the level of the flood-plain of the creek, five or six feet above the creek level. Within a few feet of where this outcrop abruptly ends the Knobstone extends in outcrop for 60 feet up the bank. In this case the downthrow is to the east. Though less clear, there is evidence of a continuance of this probable fault in Section 11 (2 S., 4 E.). At the north side of this section the rocks seem to be Mitchell down to creek level, while near the center of the section the Bedford stone outcrops 40 to 50 feet above the creek bed. The evidence here is negative. While no Bedford stone could be found north of the north line of this section, the evidence that the few exposures were of Mitchell was not conclusive.

ECONOMIC GEOLOGY.

MATERIALS OF VALUE IN AREA.—Although the primary object of this study was to continue the work of tracing the outcrop of the Bedford stone, with a study of its thickness and character, in extending the plans to include the mapping of the other formations of the Lower Carboniferous, it was planned to also make a study of the economic materials included in those formations.

The economic materials, as far as observed, may be listed under the heading of the formation in which each is contained.

Quaternary.—Soils, surface clays for brick, etc.

Ohio River Formation.—Gravel for roads, sand for glass making.

Huron.—Whetstones, sandstone for structural purposes, limestones for building, marble.

Mitchell Limestone.—Oölitic limestone for Portland cement, hydraulic limestone for Roman cement, lithographic limestone, road building material, limestone for structural purposes.

Bedford Oölitic Limestone.—Building stone, limestone for Portland cement, road material.

Harrodsburg Limestone.—Road material.

Knobstone.—Brick shales, sandstone for structural purposes.

Quaternary Materials.—Until a detailed study of the soils of the State is taken up, little can be said about the soils of any locality. It is important to recognize that the soil at any point in Indiana is in most cases derived in one of a few ways. First, it may come from the decomposition of the indurated rock immediately underlying, as is the case with most of the soils of this region; second, it may consist of the surface of the deposits, often of considerable thick-

ness, laid down during the glacial period by overland glaciers; third, it may be material associated with stream bottoms, recently deposited by running or standing water, and depending for its character on the character of the rocks or deposits from which it was derived.

The first, or residual soils, partake of the character of the underlying rock. If that rock be sandy, the soil will be sandy. If the underlying rock is a limestone, the soil above will be limy or calcareous; if the limestone is very pure, as in the case of the Bedford stone, in weathering the waters that weather it may, by dissolving the limestone, carry it all away, leaving almost no soil except such as may wash in from the adjacent areas. This probably accounts for the fact that the outcrop of the Bedford stone, though that stone is softer than the surrounding limestones, tends to present bare exposures. In general, however, limestones tend to carry a large per centage of clay or shale, so that when weathered the clay is left behind, most of the calcite of the limestone being removed in solution. Such limestones are characterized by a calcareous clay soil. Thus the Harrodsburg limestone in places around Salem has yielded a rich clay soil, often 25 feet deep. Any other insoluble substances in the limestone, such as sand, flint or geodes, will, of course, be left in the soil. Thus soil derived from the Harrodsburg limestone often contains large numbers of geodes, and over a large part of its extreme eastern outcrop in Clark and Floyd counties is represented by fragments of chert, and geodes that originally were in the solid limestone. In the area of the Mitchell, especially, this is noticeable, in large areas the ground being so strewn with chert fragments as to interfere with agriculture. These, of course, are the residuum left after the removal of the calcite of the Mitchell limestone that formerly existed above the present surface. In the case of hillsides or long slopes there is always a tendency for formations outcropping high up on a hill to influence the character of the soil derived from some other formation outcropping further down the hill. Otherwise a knowledge of the character of the soil derived from any given formation will apply anywhere that that formation has been the source of a residual soil. So that a geological map, especially one prepared not only to show the outcrops of the underlying indurated rocks, but also the glacial and other alluvial deposits of recent time, becomes at once the basis of a soil map or may serve as such a map itself. After such maps have been prepared it is only necessary to determine the character of the soil derived from each formation or recent deposit, and the map will show at once where soil of that kind

may be found. Without such maps analyses and other tests of soils scattered over the State may be very misleading, for the next farm to the one examined may have soil derived from a different formation, and therefore of entirely different character and needing entirely different treatment.

From what has been said it will be seen how the maps accompanying this report may be made of value to those living in the region, or planning to settle in the region. In the first place, general repute will in every region assign unusual richness, or unusual adaptability to certain crops, to some farm, or part of a farm, or it may be to a group of farms, or it may even be to certain divisions of the township or county. Locate such rich or adapted area on the map and if it be found to overlie the outcrop of a given formation, it is highly probable that similar richness or adaptability will be found over much of the outcrop of that formation. In the same way in the experiments being tried with different types of fertilizers or correctives, a use of the map in connection with a study of actual results obtained by different people over a region may prove of great actual value. The line between, for example, the Harrodsburg limestone and the Knobstone is seldom one that can be detected in a farming area; and while a partial recognition of differences of soil either side of the line might have existed there is often a failure to recognize that the two soils are inherently different and require entirely different treatment, and are capable of yielding entirely different results in the way of success with differing crops. It is hoped later to make a complete study of all the types of soils in Indiana, as to their contents, their needs, their adaptability, etc. The State map and the series of maps upon which it is based, of which the last are published in this report, form the basis for an intelligent examination of the soils of the State and for a profitable application of the results of such an examination by the farmers all over the State.

Ohio River Formation.—From a commercial standpoint this formation is chiefly of interest as having proved a satisfactory source of sand for the making of glass. For many years these deposits supplied the glass factory at New Albany, of Mr. W. C. DePauw & Company. The discovery of natural gas in the northern part of the State led to the abandoning of these works and consequently of the quarrying of sand. Recently, I understand, a new company has been organized and has reopened the plant. When previously worked the sand was partly obtained from quarries near Martinsburg, whence it was hauled four miles to Borden (then New Providence) and shipped by rail to New Albany, a small amount going to Louisville

and Cincinnati. Part of the sand was obtained from quarries east of Elizabeth. In 1873 the quarries near Borden yielded 250 carloads, of 65 barrels to the car. Weight of sand per barrel, 330 pounds. Cost, washed and delivered at Borden, per barrel, $1.00; delivered in Louisville, per barrel, $1.40. The sand as seen in the quarry ranges from a white to a brown, the latter color due to iron. By washing this iron is readily removed, leaving it in a very pure and white condition. The elevation and position of these deposits has prevented the running of a railway switch to them. However, their elevation would seem to make it certain that the deposits along the bluffs above the Ohio, especially, could be shipped by means of a gravity tramway, loaded cars descending being used to draw up the empties.

The distribution of these deposits is not fully shown on the maps. In general they may be stated to be found, or rather confined, to the high divide between the streams draining direct to the Ohio River and those draining westward to Blue River, Indian and Little Indian creeks, Buck and Mosquito creeks. It is probable that the areas mapped are the most important, but it is probable that examination would reveal remnants of this formation along all the least eroded parts of that divide.

As stated under the head of general geology, this deposit is up to 20 feet thick and covers several square miles, so that the deposit may be considered sufficient to supply a large demand for an almost indefinite period.

The use of deposits of this age for road building may be considered as very limited, for the reason that they are gravelly to any extent only to the north, and in that region the deposits are very limited and often rather inaccessible.

HURON GROUP.—As at present developed the only commercial stones obtained from this group are the coarse whetstones and grindstones quarried in the valley of French Lick Creek. These have been described and their location shown by map in the Twenty-first Annual Report of this Department, pp. 329 to 368. For details the reader is referred to that volume of the report. Suffice to say here that the fine-grained whetstones manufactured around French Lick come from the Mansfield sandstone, the lowest division of the Coal Measures. Coarse whetstones are made from thin layers in the upper sandstone of the Huron. While this sandstone is well developed along the upper course of Lost and Patoka rivers, and to the south, the only stone yet found suitable for whetstones has been along French Lick Creek. Most of the stone is not apt to be sufficiently

white and free from iron to be used for whetstones. The stone that is used is a white, coarse-grained, friable stone resembling loaf sugar. It would seem quite probable that further search would reveal other areas of desirable rock. In 1901 and 1902 about 100,000 pounds of this coarse whetstone was put on the market from the Indiana quarries.

Grindstones are or have been made from the sandstone of this group for both local use and for shipment. Thirty years ago grindstones were made quite extensively in the northwest part of Orange County. They were made by hand and shipped to points in Indiana and adjacent States. The introduction of machinery in their manufacture elsewhere led to the decline of the industry here. The Indiana stone ranges in grit from medium coarseness to fine. The most of it is soft. It has been found well adapted to grinding carpenters', mechanics', and machinists' tools.

Grindstones have been cut from the sandstones of this group from many points, and from different horizons. A number of grindstones have been cut from the lower sandstone in the top of the cliff just east of Blue River at St. Cloud, Harrison County.

The use of Huron group rocks for building purposes is apt to be confined to a more or less strictly local use on account of the nearness of the Bedford Oölitic limestone, one of the best building stones in the United States. The sandstones have been extensively used for foundations of buildings and especially for bridge foundations for which latter use they are preferable to the Bedford stone. On account of the quality and quantity of the Bedford stone there is not likely to be any large commercial demand for these stones for some time. On the other hand, the comparative excellence of these stones and the ease with which they can be gotten out and worked into desired dimensions will probably exclude any other stone for local use. The two sandstone beds of the Huron appear to be very similar in character. They vary from a white to a dark brown in color, a light brown predominating. White or gray rock of quite uniform color is not uncommon. In most places the rock is soft when quarried, often being wedged up the natural thickness of the bed and trimmed to shape with a common axe. It hardens afterward. Some stones were seen near Central Postoffice, in Harrison County 16½ feet by three feet by one foot. These came from a quarry a mile southwest of Central. Others were obtained from this outcrop 26 feet long, by three by three feet. They were too large to be moved. A number of structures were examined in which these stones from various parts of the area had been used, and in every

case the results seemed to indicate stone of good durability. The old county jail at Dover Hill, in Martin County, was built from the upper sandstone of the Huron, over fifty years ago, and the stone appears in good preservation still. A number of bridge foundations were examined and in general showed fairly satisfactory wearing qualities. In many of the old houses built 70 and 80 years ago the stone still shows the tool marks sharply. In places the sandstone occurs in thin beds of more or less convenient thickness for use; in more cases the beds are quite massive, often showing almost no bedding in a thickness of 40 feet or more. Bold perpendicular outcrops of from five to 20 feet are not uncommon, and along the Ohio bluffs of 40 or 50 feet are found.

The position of the lower sandstone is well indicated on the map as it always comes just west or inside of the line marking the bottom of the Huron group. The upper sandstone will be found in general near the line marking the upper boundary of the Huron group.

While nearly every hill that contains these sandstones may, in general, be considered a possible quarry site, not all of the stone is suitable for building. In places it is found that instead of becoming harder the stone crumbles into sand. Such rock as a rule, however, will not make prominent bluff-like outcrops and thus is not likely to attract the quarrymen. Again in places this massive sandstone in a short distance is sometimes found to grade into shale, as near Indian Hollow near Leavenworth.

The limestones of the Huron group have been used for making lime to some extent and seemingly with success. As a rule they are pure, but they tend to be hard and in view of the large quantities of waste Bedford stone to be found lying around all of the quarries, it does not seem probable that this use will ever extend beyond local needs.

The limestones of the Huron tend to be coarsely crystalline and of close grain. In many cases they take a good polish and would seem to answer the requirements of marble. Many gravestones have been cut out from these limestones, but as far as seen most of this limestone does not hold its polish well when exposed to the atmosphere. In color these marbles range from gray to a handsome mottled red. In places the limestone is coarsely fossiliferous, which shows up well in a polished face. The position of the lower limestone is shown in places by the use of the dotted line, above or within the line of the bottom of the Huron. On the whole the proportion of these limestones that may prove suitable for the purposes to which marble is

put is probably very limited, and it has yet to be proven that it will satisfactorily meet the exacting demands of competition.

MITCHELL LIMESTONE.—*Oölitic Limestone for Portland Cement.*—Within the last few years an oölitic limestone at Milltown has attracted some attention as a possibly commercially valuable deposit. It is the same stone that has long been known from its exploitation at the Stockslager quarry in southwestern Harrison County. The latter has long been assumed to be the same as the Bedford oölitic limestone. The survey of this part of the State has shown that this limestone occupies a more or less constant horizon near the top of the Mitchell, that it is widely distributed through Orange, Crawford and Harrison counties, and, at its proper horizon, in Madison and Posey townships, in Washington County. In the first place, this limestone differs structurally from the Bedford stone. Instead of a grain composed of minute more or less globular shells, the grain of this limestone is composed of small spears, composed of concentric layers of calcite formed around a center. The resulting grains are somewhat larger than the grains in the Bedford stone, and by analysis this stone is somewhat purer than the Bedford stone. A recent analysis of this stone by Mr. Noyes of an average specimen, gave as follows:

Calcium carbonate ($CaCO_3$)	98.91
Magnesium carbonate ($MgCO_3$)	.63
Ferric oxide and alumina (Fe_2O_3 Al_2O_3)	.15
Insoluble in hydrochloric acid	.48
Total	100.17

An analysis of the Stockslager limestone, published in 1879 by this survey, gave as follows.

Water, dried at 212° F.	.50
Insoluble silicates	.31
Ferric oxide	.18
Alumina	.14
Lime	54.93
Magnesia	none.
Carbonic acid	43.17
Sulphuric acid	.25
Chloride of alkalies	.40
Combined waste and loss	.12
	100.00

Carbonate of lime, 98.10.

The strength of this stone, as determined by General Gilmore, gave crushing strength, 10,350 pounds; a cubic foot weighs 149.59 pounds; rate of absorption, 1 to 27.

As a rule this limestone is a very pure white wherever found. As a building stone it has not as yet proved a distinct success, as it is found to be too hard to work easily and seems to show a tendency to flake off from the edges of squared blocks. It can hardly be said that a fair test has been made of the stone, as all the quarrying yet done has been on a more or less weathered outcrop, and with the use of powder. However, its unusual purity has recently suggested its use for the manufacture of Portland cement. For this it seems eminently suited. No suitable clay was noted in close proximity to the deposits of this limestone. But it would seem quite probable that some of the beds of shale occurring in the Mitchell, though thin, might be found of suitable quality. Again, it is but a short distance west to the Coal Measure shales. The reader is referred to the Twenty-fifth Annual Report of this Department for fuller discussion of this subject. In its distribution, this stone will usually be found very close to the upper limit of the Mitchell. Considered from the standpoint of immediate availability the deposits along the railroad are the most valuable. These outcrops occur along the French Lick branch of the Monon Railway, especially a short distance west of Paoli. Also along the Southern Railway from Marengo to Milltown and in the hills east of Blue River to the tunnel east of DePauw. West of Paoli this stone is being used as ballast by the Monon Railway. A rock-crushing plant was being installed at the time this region was examined. Outcrops of this white stone are abundant over eastern Orange County, as far as to within a quarter of a mile of Millersburg. At Spring Mill the oölitic limestone shows an unusual thickness. The bluff at the spring above the mill shows the following section:

	Ft.	*In.*
White to light gray oölitic limestone	10	0
Gray oölitic to semi-oölitic limestone	6	0
Fine textured lithographic limestone, sub-oölitic or sub-crystalline in places	18	0
Drab colored calcareous shale	4	0
Massive, gray, oölitic, sub-lithographic in places	14	0
Drab colored magnesian limestone "cement rock" 3 ft. to	5	0
White to gray oölitic limestone	10	0

In Crawford County this white oölitic limestone outcrops at Milltown as described above. It is only from two to four feet thick

where it outcrops in the quarry at Marengo. A section of the face of the quarry at Marengo shows:

	Ft.	In.
Surface clay ..... 1 to	5	0
Hard, gray, sub-oölitic limestone.....	4	6
Hard, light bluish-gray, sub-oölitic limestone.....	5	0
Gray, sub-oölitic to sub-lithographic limestone, in six to 36 inch strata	6	0
Buff limestone, hard to rather soft.....	4	6
Coarse, crystalline, gray limestone, oölitic in places....	6	0
Dark gray, lithographic limestone..... 3 to	5	0
Pure white to light gray, oölitic limestone..... 2 to	4	0
Buff limestone, very hard to very soft.....	5	6
Dark, bluish-gray lithographic limestone, irregular in layers and texture	5	6

South of the railroad the white oölitic limestone outcrop is constantly noted near the top of the Mitchell, but it is seldom well enough exposed to reveal its thickness. Where the thickness can be determined it is found to run from about four to 10 feet. At Leavenworth it is only three feet thick. In the hills two or three miles west of Corydon this stone runs 10 feet thick. About Kellarsville it is six feet thick. At Frenchtown it is from four to eight feet thick. At the Stockslager Quarry in Section 21 (5 S., 3 E.), it is six feet thick. At Kendall's Landing it is four feet thick, and has a similar thickness in the valley of Potato Creek.

As shown by many of the sections semi-oölitic limestone or oölitic limestone of gray color is fairly abundant in the Mitchell, and much of it would undoubtedly fall but little behind the white oölitic limestone in purity. Thus, analysis of the different limestones from the face of the quarry at Milltown, gave an average of only a little over 2 per cent. of impurity, 1.19 per cent. being magnesium carbonate. In like manner the most of the lithographic limestone appears to be very pure. The Mitchell would therefore seem to have an abundance of pure limestone suited for the manufacture of Portland cement.

The position of the while oölitic limestone in Harrison County is in part indicated by a dotted line near, but within the upper boundary of the outcrop of the Mitchell.

Hydraulic Limestone in the Mitchell.—In the '70's and later, hydraulic cement was made from limestone quarried at Rock Haven, in Meade County, Kentucky, just across the Ohio River from the south point of Harrison County. No official reports of practical tests of this stone are at hand, but reports indicate that it was a

stone of good quality, holding its own in competition with the Louisville and other cements. Indeed the reasons usually assigned for the closing of the works are not unfavorable to the quality of the stone. However that may be, the fact remains that limestone suitable for hydraulic cement is found at Rock Haven and presumably should be found on the Indiana side.

The Rock Haven stone gave the following analysis:*

Water expelled at 212° F.	.75
Insoluble silicates	34.30
Soluble silicates	.20
Ferric oxide and alumina	1.90
Lime	30.80
Magnesia	.66
Carbonic acid	24.20
Sulphuric acid	1.80
Combined water, organic matter, traces of alkalies, etc.	5.39
Total	100.00

Analysis made of similar rock in Harrison County a few miles north gave about 7 per cent. less of the insoluble silicates, and from 10 to 12 per cent, more of calcium carbonate. Stone was seen at a number of places that was thought to be an hydraulic limestone. On the south slope of Spurgeon Hill some 25 or 30 feet above the Bedford stone, in the railway cut, is an outcrop of light drab, very fine grained limestone, that was judged to have hydraulic properties. The rock has a thickness of 10 feet or over. The upper part contains some calcite crystals, but the lower part is very even grained and free from impurities. As this is but a few rods from the railroad track, it is admirably situated as regards transportation facilities. The only other place where this rock will be found close to the Monon Railway is in Sections 11, 12 and 14 (2 N., 3 E.). Good looking stone was seen at many places in the heads of the streams north of Hitchcock, Smedley and Campbell stations. The stone in the head of Clifty Creek has been tested and is said to have shown an excellent quality of cement. No record of the tests could be found. At many of these points the large springs furnish abundant water power. The bed runs from 10 to 20 feet thick. A similar bed was noted at various points down Blue River and at Beck's Mill. These points are farther from the railway and so have not the immediate prospects of the places mentioned above. In general, this bed should be looked for between 25 and 50 feet above the top of the Bedford stone.

* Geological Survey of Indiana, 8-10th Annual Report, p. 73, 1878.

Lithographic Limestone.—Near the top of the Mitchell, but found at all horizons in it, are beds of massive gray, lithographic limestone. These have the fine texture and even grain peculiar to such rocks. These rocks are often well exposed, and have been examined at a great many points, but as yet no place has been found that seemed to promise stone of commercial value. Practically everywhere examined it is found to be cut up with minute seams of calcite in such a way as to prevent the obtaining of sizeable blocks free from such imperfection. Nevertheless we can not but hope that the future may disclose areas of this rock that will prove suitable for lithographic purposes.

"Glass Rock."—One of the uses to which this lithographic limestone has been successfully put has been in the manufacture of glass. At Glass Rock Station, on the French Lick branch of the Monon Railway this stone has been quarried and shipped. It has been quarried for the same purpose at other points along Lick Creek. This rock is apt to be found wherever there is an exposure of any thickness of the upper part of the Mitchell. Only the lighter colored beds are used.

Lime.—The many pure limestones of the Mitchell lend themselves admirably for the production of lime.

Lime is made on a commercial scale at Milltown. A section was given above of the quarry east of the river. As the section west of the river at the Speed Quarry differs somewhat from that, it may be given here. Section at Speed Quarry, Milltown:

		Ft.	*In.*
1.	Buff, weathered limestone	1	8
2.	Coarsely crystalline limestone, with numerous crinoid stems	2	0
3.	Pure white, oölitic limestone, with few fossils	4	0
4.	Light buff to drab lithographic limestone	5	0
5.	Greenish shale	0	4
6.	Gray, lithographic limestone	0	10
7.	Greenish-gray shale, intercalated with bands of lithographic limestone, two to eight inches thick	0 to 1	6
8.	Gray, lithographic limestone	7	0
9.	Soft, granular, buff, magnesian? limestone	3 to 4	0
10.	Lead gray, fine-grained, crystalline limestone,	3 to 4	0
11.	Pure white, oölitic limestone	5	0
12.	Calcareous shale	2 in. to 0	4
13.	Gray, oölitic to sub-oölitic limestone	4	6
14.	Limestone with black chert	1 in. to 0	8
15.	Drab colored, impure limestone	4	0

		Ft.	In.
16.	Bluish gray lithographic limestone..... 0 to	0	10
17.	Dark gray, sub-oölitic to sub-crystalline limestone.	8	0
18.	Very soft, drab colored, magnesium limestone....	6	0
19.	White oölitic limestone	6	0
20.	Gray limestone	16	0

The beds used for lime are Nos. 3, 11 and 17; Nos. 3 and 11 make a very pure, white lime; No. 17 makes a good lime, but of a darker color. The other beds of the quarry except Nos. 9 and 18, which are thrown out, are used for crushed stone. No. 18 is at present the floor of the quarry. It is intended to deepen the quarry so as to obtain Nos. 19 and 20. No. 11 is believed to correspond to the oölitic bed in the east bank of the river. The Speed plant has a capacity of 1,500 bushels a day. (See *a*, Plate IX.) Small kilns are to be found all over the area of outcrop of the Mitchell making lime for local purposes.

Crushed Rock.—At least four quarries are using limestone of the Mitchell for the purposes of ballast or for road building on a large scale. The Monon Railway has a large plant on the French Lick Branch west of Paoli, using the white oölitic limestone. At Milltown the Speed Quarry has a capacity of 200 cubic yards a day. The Eichol Quarry, on the east side of the river, ships from 14 to 20 cars of crushed stone a day, employing 66 hands. Another large quarry is situated at Marengo. The continued existence of these large quarries is the best of evidence of the suitability of this limestone for the purposes mentioned, at least as compared with competing materials in this general region. This part of the Mississippi Valley yields none of the traps and other igneous rocks that experiments seem to show have the highest resistance to abrasion, and the other qualities necessary in good road material.

ECONOMIC GEOLOGY OF BEDFORD OÖLITIC LIMESTONE.

As Building Stone.—In view of the complete exposition of the properties and adaptability of this stone for the purposes of building, as well as of the methods of quarrying, preparing and marketing the stone, given in the Twenty-first Annual Report of this Department, it seems best to refer the reader to that report for information on that line. Suffice to say here that due to the facts that the stone has a pleasing buff color, that it has in a high degree the requisite qualities of strength, endurance, resistance to weathering or heat, an even soft grain that facilitates its quarrying, preparation for the market, trimming or carving in place, its extensive exposure

near the surface facilitating quarrying, and other desirable qualities have led to its having a most extensive use in this country. It combines the qualities of ease of quarrying and consequently of cheap production with many of the most desirable qualities of a stone for building purposes. The report mentioned gives lists of buildings built of this stone in 26 States and one territory, and the list could undoubtedly be much swelled. It was said at that time that 80 per cent. of the buildings going up in New York City were of this stone.

In the area of this study there are only two commercial quarries, and on account of high freight rates due to lack of competition, neither of these is at present producing stone. Both quarries show a good grade of stone, equal to the best in strength and durability. The general tendency of the stone of this area is to be a little more crystalline, and therefore a little harder to work than the stone around Bedford.

For Lime.—At the present time the most extensive use made of the Bedford stone of this region is for lime. The quarries at Salem are actively engaged in quarrying and burning this rock for lime. For this use the rock is quarried by blasting. The lime is said to be very white and of excellent quality.

For Portland Cement.—Attention has recently been called to this stone as especially suited for the manufacture of Portland cement. Its uniformity of composition, purity, ease of working, and the fact that large quantities of it are immediately available in the waste heaps at the present quarries, are some of the advantages to be claimed for it. In the Twenty-fifth Annual Report of this Department are given some of the results of recent tests made with a view to determining the value of cement made of this stone. Sufficient to say at this point that the following results were obtained:

Cold pat test: 7 days, sound; 28 days, sound.

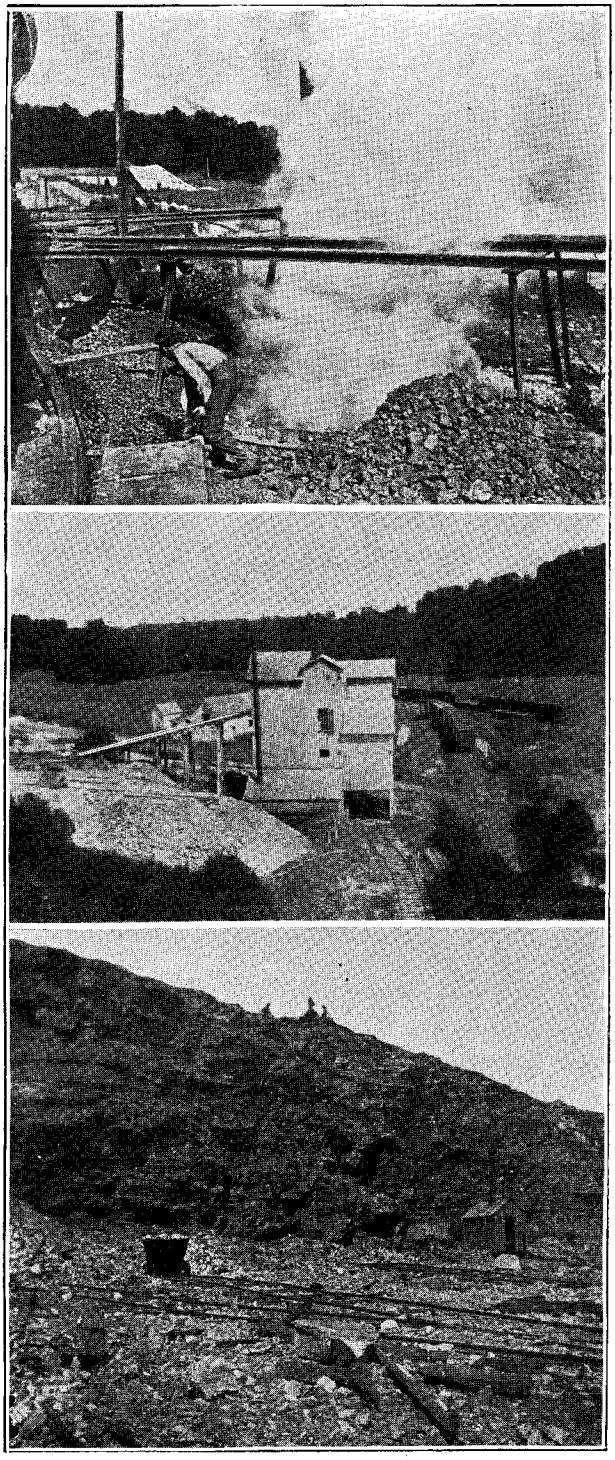
Hot test: 5 hours in steam, 19 hours in boiling water, sound.

Tensile strength, neat; 7 days, 713-740; 28 days, 870-935.

Tensile strength with three parts standard sand: 7 days, 415-490; 28 days, 536-585.

"These tests show the cement to be of the highest quality and at least equal to any Portland cement manufactured in this country or in Europe." The oölitic stone of this region undoubtedly will give as good results.

For Road Material.—This stone has been used locally for the building of roads. Such use was probably induced mainly because of prominent outcrops in the immediate neighborhood of the road being built. None of the roads of this stone in this region has been in use



a

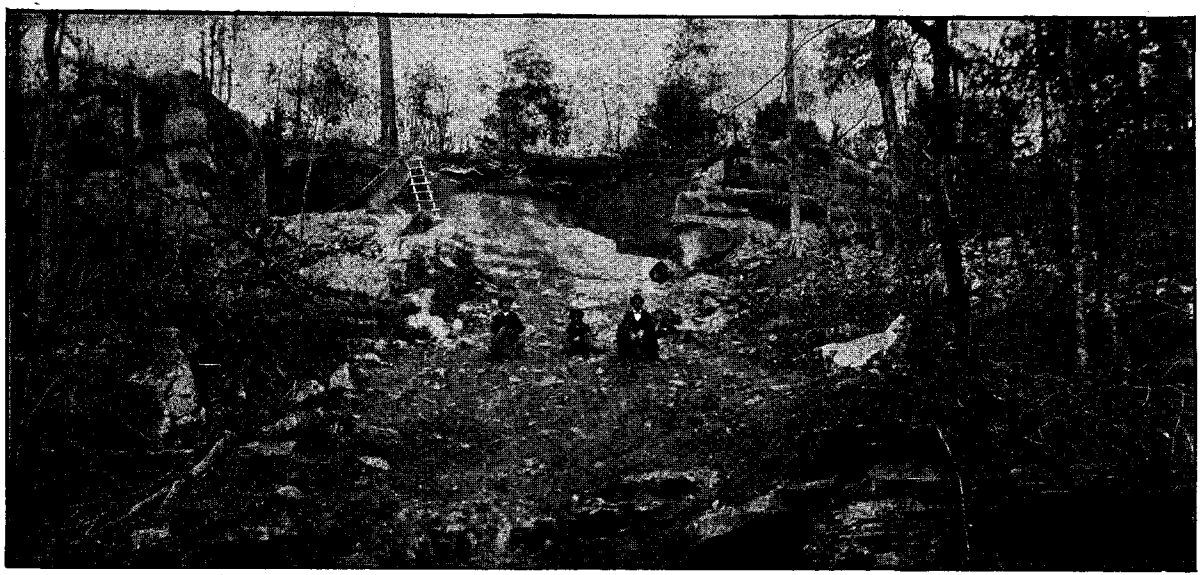
b

ILLUSTRATING QUARRYING INDUSTRY AT MILLTOWN, INDIANA.

(From photos by E. M. Kindle.)

(a) Top of lime burner at J. B. Speed & Co.'s quarry.
(b) Rock crushing plant.
(c) Quarry on east side of Blue River; output used for railway ballast.

PLATE X.



OUTCROP OF OOLITIC LIMESTONE ON BLUFF EAST OF TWIN CREEK, WASHINGTON COUNTY.

(Harrodsburg limestone in the foreground. Bedford white limestone at the top.)

long enough to fairly test its wearing qualities. Appearances would indicate, though, that it was inferior for this purpose to the harder stone of the Mitchell or Harrodsburg.

DISTRIBUTION AND CHARACTER OF BEDFORD OÖLITIC LIMESTONE.

IN TOWNSHIP 4 N., 2 E.—The Bedford stone occupies the top of the ridge in Sections 26, 27, 34 and 35. The fault cuts off the outcrop on the east. In the southeast quarter of Section 26, west of the fault, about 25 feet of Bedford stone tops the point of the ridge. It is about 120 feet above Twin Creek, the Harrodsburg here being 45 feet thick. In the region of No. 7 school, the Bedford gave an apparent thickness of 160 feet. This was due to the fact that the measurement was made where the stone had a very decided, though unseen, dip to the east, or toward the face of the fault. It is probable that the stone measures 90 feet or less. It is fairly fine grained.

IN TOWNSHIP 3 N., 2 E.—In this township the distribution of the different formations is much disturbed by the Mt. Carmel fault. Bedford stone is believed to cap the hill just north of Mt. Carmel. It makes the surface rock at the bend of the road southeast of Mt. Carmel. Small outcrops of Bedford stone occur on the east side of the fault in the line of sink-holes in Sections 12, 13 and 24. West of the fault the Bedford stone is found at elevations of from 100 to 130 feet below the same stone east of the fault. It outcrops up Clifty Creek to the mill, and makes up the surface over a broad area in the west part of Section 11. Measurements here gave the bed a thickness of 90 feet. There are several bold exposures in this area (see Fig. 1 of Plate VIII). The stone here is a buff, medium fine grain, and lies so that a large area could be worked to advantage. In the figure referred to just above, a stream comes from the mouth of a cave, runs in a narrow valley for about a quarter of a mile, then passes under ground again only to appear a quarter of a mile further down at the foot of a perpendicular face of Bedford stone 50 feet high. The stone of this bluff is a light brown, very coarse and irregularly grained. At a small quarry just west of Mt. Carmel the Bedford stone is coarse grained, buff, fossiliferous, with several crowfeet showing. Some weathered stone in this vicinity showed calcite geodes.

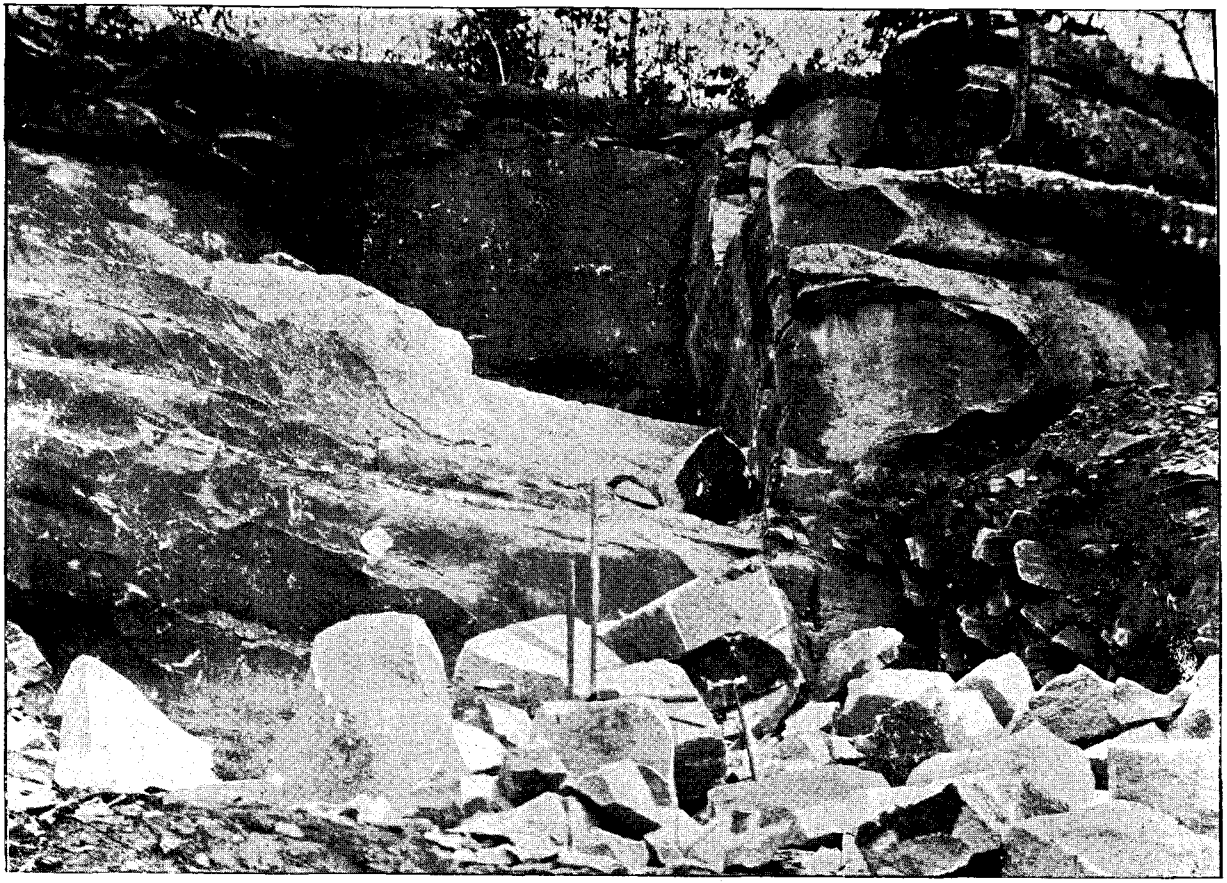
The Knobstone has an exposed thickness along the lower course of Clifty Creek of about 120 feet. The Harrodsburg is about 55 feet thick along Clifty Creek.

IN TOWNSHIP 4 N., 3 E.—In this township the Bedford stone is confined to a very small area in Section 34. It is found there capping the ridge, but of too slight a thickness to probably pay for working.

IN TOWNSHIP 3 N., 3 E.—Some of the best Bedford stone in the area occurs in this township. The stone occurs in the hills and valleys south of Rush Creek and capping the ridge north of Rush Creek. On the ridge last mentioned it caps all the highest parts of the ridge except in two small areas, where it is overlain by thin bodies of Mitchell. It is thus very easy of access for quarry purposes. In the northeast quarter of Section 11 the bed measured 55 feet by the barometer. At most points examined the stone appeared to be of a dark color. The grain tends to be good at the top, tending to become coarse and fossiliferous toward the bottom. The best grained stone was noted at the top of the bed near, but north of the center of Section 11, but the bottom of the stone a short distance west is coarse grained and full of gasteropods one-fourth inch or less in diameter. In places, as in the southeast quarter of Section 12, the stone lacks cement, tending to crumble easily.

In the valley of Twin Creek, the Bedford stone is in the bottom of the valley in Sections 31 and 32. A little stone has been taken out beside the road east of the center of Section 31. The stone is about 70 feet thick. The stone is of good color, medium grain as regards fineness and regularity. At the section line between Sections 31 and 32 the Bedford stone outcrops in a bold perpendicular bluff 25 feet high. The grain, though irregular, is of medium fineness. Just south of the section line between Sections 31 and 30, is an outcrop of Bedford stone that was examined by Mr. Hopkins after a study of the stone about Bedford and further north, so that for purposes of comparison with the stone being quarried in those regions his description of the stone at this point will be of interest and value. He says: "On Twin Creek, about two miles north of Smedley Station, on the Monon Railway, and seven or eight miles west from Salem is a promising outcrop of oölitic limestone. It is exposed on both sides of the creek in bold cliffs at or near the top of the bluff, in some places forming perpendicular or overhanging ledges. There are clean exposures of not less than 25 or 30 feet of oölitic stone, and the total thickness may be greater than that, as at no one place are both the top and bottom of the bed clearly exposed. (The writer made the total thickness 55 feet, and the bottom of the stone 40 feet above the creek.) A few small stylolite seams were observed, and there are a few joint seams, all of which appear to be regular.

PLATE XI.



A NEAR VIEW OF PORTION OF THE BLUFF SHOWN ON PLATE X.

The weathered surface is in most places comparatively even and smooth.

"The bluff at OL place shows 25 to 30 feet of massive oölitic limestone overlain by 10 to 20 feet of coarse, partly oölitic laminated stone, overlain by eight to 10 feet of earthy, sandy limestone, overlain by blue limestone. The massive ledge has a fairly uniform texture of medium fineness and buff color. It appears to be a little more crystalline and harder than the stone further north.

"The Twin Creek Stone Land Company, of Salem, who own the greater part of this bluff on the east side of the creek, sent in samples for testing, the results of which show for the crushing strength:

Tested on natural bed, No. 1....11,700 pounds per square inch.
Tested on natural bed, No. 2.... 6,900 pounds per square inch.
Aested on natural bed, No. 3....11,100 pounds per square inch.
Tested on edge, No. 4..... 8,900 pounds per square inch.

The average of all being 9,400; the average on the natural bed, 9,900; but as No. 2 was an imperfect sample, the side chipping off before breaking, the average for the good specimens on the natural bed would be 11,400, a result higher than that for any of the other specimens of oölitic limestone tested in the same lot, with one exception. The absorption shows about equal to the average oölitic limestone in this respect, one in 31. Its specific gravity is a little higher than any of the other limestones tested. The chemical analysis shows it to be a very pure carbonate of lime, closely resembling the oölitic stone from other localities in this respect."

The analysis given shows 98.16 per cent. carbonate of lime.*

Plates X and XI are taken from Mr. Hopkins' report, illustrating this exposure.

In Section 19 the stone where noted was of a brown color, uniform and rather fine grained. In Section 18 the grain as noted was a buff, and irregular. In Section 17 in places the stone has scattered all through it hollow oölitic grains. West of Rush Creek Postoffice the Bedford stone covers the top of a broad ridge in Sections 9 and 16. The stone is a buff, fine-grained stone, and appears to be of good thickness, probably over 50 feet in the higher part of the ridge. On the whole this was judged to be one of the best localities noted for quarrying the stone. In part of this area the grain was judged to be as fine as any noticed in the county and elsewhere; though coarser, it was quite regular.

*21st Annual Report Department Geology and Natural Resources, p. 395.

At a quarry for crushed stone in the northeast quarter of Section 27, the Bedford stone is blue in color, and coarse and irregular in grain. Several crow-feet showed in the quarry face. About the center of the section line between Sections 26 and 27, a little quarrying has been done for road use. The stone is here about 150 feet above the branch, and measured 60 to 70 feet thick. It is buff in color. The grain is large and slightly irregular. The stone here makes bold cliffs 20 feet high along the crest of the bluff. Going up this branch into Section 35, the grade of the stream gradually brings the Bedford stone to creek level. Most of the stone in this section is blue, with coarse and irregular grain. Some of the stone seen on the summit of the ridge a mile southeast of Rush Creek Postoffice was of fair grain and a light gray in color. In Section 24 the oölitic stone caps a large area of hill. It appears to be of good color but of irregular grain.

In Township 3 N., 4 E.—In this township the Bedford stone is confined almost entirely to the western half. South of Kossuth Postoffice, the Mitchell occupies the top of the ridge; north of that postoffice the Bedford limestone caps the ridge nearly to the township line. In Section 5 the oölitic stone is too thin to work. In Sections 8 and 9 it becomes thicker, its full thickness in places, the grain being irregular, buff at the top, blue at the bottom.

At Kossuth Postoffice the stone is a fairly fine-grained, buff stone. It outcrops prominently just southeast of the postoffice. In Sections 18 and 19 some fine-grained stone was noted, though it is inclined to be irregular. In Sections 21 and 29 the stone varies, some of it being of fine grain, while other stone near by is quite irregular in grain. The stone has a thickness of 60 feet. In general the finest stone is at the top in this neighborhood. In Section 28 the stone is from 40 to 60 feet or over thick, 40 feet being measured just southwest of the center of the section. At the latter point the stone is of good color and of fairly uniform and fine grain. Farther east, around No. 12 school, the grain tends to be coarse and irregular. The Bedford stone is well exposed in the northeast quarter of Section 32. The stone, which is mostly rather coarse-grained, is buff at the top and blue below. The stone here is some 30 feet below the top of the ridge.

In Township 2 N., 3 E.—Practically all of this township is underlain by Bedford stone, but it is only along the very eastern edge that it reaches outcrop in the valleys there. A little stone has been quarried at the Richardson Quarry in the southeast quarter of Section 13. About 10 feet of Bedford stone is exposed here. From nothing to

eight feet of the dark overlying Mitchell has been removed in stripping. The stone can best be discussed in connection with the next township east.

In Township 2 N., 4 E.—The drainage divides the outcrop of the Bedford stone into several distinct areas here. The first is the area west of Brock Creek and north of Blue River. The bottom of the stone is only about 10 feet above Blue River where the river turns south. Near Salem it is between 40 and 50 feet above the river. In Section 5 it is only about 15 feet above Brock Creek. The top of the bed reaches to the top of the ridge in places. The stone in this area is, as a rule, not very characteristic, so that considerable difficulty was found in drawing the lines of boundary. In places the grain is coarse and irregular. In others the grain is extremely fine, so much so as to leave much doubt as to its oölitic character. The best stone seen in this area was in the west half of Section 5. The stone here was blue but even grained. East of Brock Creek the country is gently rolling, and while the Bedford stone outcrops over a considerable area, it is weathered to such a depth as to leave almost no exposures and to make it doubtful if the stone could be profitably worked even if it should prove to be of desirable quality and of sufficient thickness.

West of Blue River this stone outcrops along a narrow band along the western edge of the township. It has been worked extensively just where the river turns south, by the Salem Lime and Stone Company. This quarry is south of the Monon Railway, with which it is connected with a switch. As shown under the general geology of the Bedford stone, the oölitic stone here occurs in two beds, the upper seven feet thick, the lower 26 feet thick at the north end of the quarry and 30 feet thick at the south. The two beds are 12 feet apart. The stone is mainly a buff, of medium fine and uniform grain. In places cross-bedding is noticed. At present (June, 1900) no dimension stone is being quarried, all the stone being used for lime and obtained by blasting. The stone has been quarried for about a quarter of a mile along its outcrop in the face of the hill. These quarries have supplied a large amount of stone, which has been used in many important buildings, especially in Louisville and the South. Thus in Louisville might be mentioned the City Hall, Galt House, City Hospital, Broadway M. E. Church, First Christian Church, German Methodist Church, German Evangelical Church, Temple Adas Israel, Hamilton Block, J. T. Thompson & Company Block, Falls City Bank, Pendennis Club House. The State Capitol Building of Georgia, at Atlanta, and the State Capitol Building of New

Jersey, at Trenton, are of this stone. Among other buildings of stone from these quarries may be mentioned the Cincinnati Courthouse, the New Orleans Cotton Exchange, and the fine courthouse at Salem. This stone was among those tested by Gen. Q. A. Gilmore and gave him 11,750, 10,000 and 12,000 pounds resistance to the square inch. Tests made for the State House Commissioners of Georgia, of fresh stone, gave 8,975 pounds to the square inch.

Chemical analysis of this stone showed 96.04 per cent. of carbonate of lime. The stone withstood a temperature of 1,200° F., without injury. Its rate of absorption was found to be one to 42.

Going south from the quarry the Bedford stone is exposed at points about 10 feet above Blue River through Section 19. Just south of the north section line of Section 30 is a bold cliff exposure of Bedford stone, 29 feet thick. The stone is blue or brown in color, of uniform and medium fine grain. South of this the stone appears to decrease in thickness, and west of the center of Section 30 it is very coarsely fossiliferous. In Section 31 the Bedford stone is only 10 feet thick as far as could be found, and varies from 15 or 20 feet to 40 feet above the river. The grain is fine, but the color dark.

South and east of Blue River the stone is variously developed. South of Salem the stone runs from a fairly typical oölitic stone to a semi-crystalline stone, in some places very little of the typical oölitic stone appearing, so that it was found difficult to draw the limiting lines. Just south of the center of Section 26 is a little fairly fine-grained stone, but grading up into a sub-crystalline, hard, blue stone. Ten feet above that is a bluish-gray stone, somewhat resembling the Bedford in appearance, but still more crystalline than the last. The same conditions are found just southeast of Salem, most of the stone being brown, and ranging from a fairly fine grain to a crystalline stone. At Poynter's Hill, at the intersection of two roads near the center of Section 26, the Bedford stone is a brown, porous stone, in some cases the cement is gone, in others the grains are gone. In the northeast quarter of the northeast quarter of Section 21 the Bedford appears to be only about 10 feet thick. A quarter of a mile east it is from 15 to 30 feet thick, of good color, fairly fine grain, but irregular. All the oölitic limestone seen in Section 23 was of the porous weathered type. This weathered porous limestone is often quite fossiliferous, notably at Poynter's Hill. Approaching Harristown, the Bedford stone is well exposed in Spurgeon's Hill where cut by the railway a quarter of a mile south of the station. See Fig. 2 of Plate VIII. It was from the rock thrown out of this cut that the fossils were found in such abundance and in

VIEWS AT SALEM QUARRY.

1. In part of old quarry.
2. In present quarry. a. Stripping. b. Seven-foot bed of oölitic limestone. c. Twelve-foot bed of buff limestone, not oölitic. d. Main bed (30 feet thick) oölitic limestone.
3. Lime-kilns.

such perfection as to make Spurgeon's Hill known to students of fossils all over. The rock thrown out is no longer accessible, so that only a limited number of specimens can now be picked up as they gradually weather out of the rock. At the bottom of the cut is six feet of gray, sandy, calcareous shale, containing lenticular masses of limestone up to 10 feet long. The contact of this shale with the limestone above is quite regular. Above the shale is 35 feet of oölitic limestone. It is buff to gray in color, with very coarse grain at the bottom, which becomes finer toward the top. Much of the oölitic grain is so coarse that it can readily be distinguished at a distance of several feet from the face of the bluff. The stone here contains many fossils, in places seeming to contain little else. Gasteropods and pentrimites predominate. An unusual thing found here are numerous masses of calcite crystals, some of the masses being up to a foot in diameter. In the northeast corner of Section 24 the oölitic stone is fairly fine in grain, a gray or buff. The rocks appear to be disturbed by faulting, or in some way, a half mile east of Harristown. Oölitic rock underlies the top of the hill in the center of Section 13 and forms a small outlier in Section 12.

In the south part of Section 29 the Bedford stone appears to be only 12 or 15 feet thick. In the northwest part of Section 33 the stone is about 25 feet thick, of dark to light gray color, very fine-grained rock, though somewhat irregular. The grain is not as good at the top as below. Under this bed is a 15-foot bed of crystalline limestone that is partly oölitic. It is dark in color. At the center of Section 33 the grain is coarse, but even, a light brown, with many dark brown grains scattered through it. Bedford stone occupies the crest of the ridge in the northeast corner of Section 33. At the bottom of the bed it is of good grain and fair color, but gets more crystalline above.

In Township 3 N., 5 E.—The Bedford stone in this township is confined to a small area in Sections 32 and 33. In places the weathered, porous facies are found, but in most cases the stone is not a characteristic oölitic grain. The Mitchell is exposed at one point, but lack of exposures made it impossible to determine the thickness of the oölitic rock, or its general character.

In Township 2 N., 5 E.—The Bedford stone in this township is confined to the ridge between the Middle Fork of Blue River and the headwaters of the North Fork. No outcrop of the oölitic stone was seen in Sections 4 and 5, though the surface is strewn in many places with the porous, weathered stone. Most of the stone seen in Sections 7 and 8 were weathered surface fragments. Some stone seen

in the south part of Sections 7 and 8 is a rather coarse-grained, fairly regular, blue stone. At other places the stone shows only a skeleton of minute quartz crystals. In Sections 17 and 18 the most of the stone seen was of large concretionary grain, gray in color, and in places quite uniform in structure. In places in these sections the stone outcrops as huge blocks over the surface. Near the top of the high knob over which the road runs between the two sections is more of the stone showing only a skeleton of minute quartz grains. In the center of Section 19 the oölitic stone shows an outcrop of 25 or 30 feet near the top of the hill. At the top of the bed the stone is very white, concretionary in structure. The grain is fairly fine, and quite uniform, but toward the bottom is dotted with dark crystals of calcite.

In Township 1 N., 3 E.—The Bedford stone underlies all of this township, but is exposed only in the valley of Mill Creek and Blue River, and there, as a rule, only at or very near the water level. Where Blue River enters the township the Bedford stone extends for 15 feet above the water. The stone here is very fine-grained. At all the outcrops seen in Sections 1 and 12 about the same conditions are found, the stone extending from water level to about 15 feet up the bank; fine-grained at the top, but becoming coarser below, and in places softer and more porous. The stone is buff in color.

There appears to be a disturbance of some kind in the northeast corner of Section 11. There appears to be a sharp southward dip and in a short distance, what was taken to be the hydraulic limestone in the Mitchell, is found at the water's edge. At Beck's Mill the Bedford stone shows an exposed thickness of 36 feet. Lack of outcrops prevented connecting this point structurally with the stone in the river bed in Section 12. On the south side of Mill Creek the bluff exposures seem to indicate that the oölitic stone at Beck's Mill is the upper of two beds, of which the lower bed becomes exposed at a six-foot fall in the creek near the mouth. Near the ford of the river below the mouth of Mill Creek, the lower bed, which seems to have the more typical oölitic structure is exposed only just at the water's edge and for two or three feet up. The upper bed here, believed to be the same bed as at Beck's Mill, has been reduced to a thickness of six or seven feet. Between the two is first 10 feet of light brown shaly limestone, then over that 10 feet of irregular grained limestone. Whether the two oölitic beds and their intermediate strata represent the single 60-foot bed in the north part of this county or not can not be definitely stated, but many things in-

dicate that such is the case. If so, it is evident that the thin bedded Bedford stone mapped from Salem south to the Ohio River is in most cases only part of the bed mapped north of Salem, the other parts not being absent, but so changed in character as not to be recognized.

Near the center of Section 14 the stone is found for about 10 feet above the water, with a coarse and irregular grain, and showing some crow-feet. At the center of Section 23 the stone outcrops for 20 feet above the river. The grain here is not very characteristic. At the center of Section 26 Bedford stone is exposed in a perpendicular bluff to a height of 40 feet. The grain is fairly good at the top but becomes coarse at the bottom. At Organ Springs Mill about 10 feet of Bedford stone of fine and uniform grain is exposed. A little further south fully 20 feet are exposed in nearly perpendicular bluffs.

In Township 1 N., 4 E.—The Bedford stone underlies most of this township. Starting in the northwest corner, the stone is well exposed on the south side of Blue River near the center of Section 6, in a perpendicular bluff 15 feet high, starting about 15 feet above the water. The stone ranges from buff to blue, and from medium fine to coarse in grain, with a tendency to show a large percentage of blue crystals. Along the Middle Fork of Blue River, between Sections 5 and 8, the stone must be about 75 feet above the water, and apparently only 10 to 15 feet thick. It is gray in color, fossiliferous, and generally irregular in grain, though some fine grain was seen. In Section 4 is found some stone that is sub-pisolitic in structure, resembling the white oölitic limestone found in the Mitchell. The color is gray. Some of the stone in this section is fine-grained and darker. The stone seen in Section 9 was of fair quality, blue in color, with a rather coarse, irregular grain.

In Sections 2 and 11 the Bedford stone presented the most promising outcrop seen in the south part of the county. The stone appeared to be 30 feet thick, blue, uniform, medium fine in grain, on the whole, excellent stone except for color. The stone seen in Section 14 was of buff color, and irregular grain, but with more or less quartz in it. Small outcrops in Section 15, northern half, indicated a soft blue stone of good grain. The stone seen in Section 16 was of fair grain. In Section 22 the stone seen was buff, coarse and irregular in grain. At the center of Section 33 the grain of the stone seen was coarse and irregular. Good exposures in Section 31 showed stone at least 12 feet thick, light brown in color, with a medium fine, uniform grain. Over most of this township the outcrop shows only

weathered fragments on the surface, these often showing the characteristic fossils.

In Township 1 S., 4 E.—Along the valley of Dutch Creek, the only outcrops of stone seen were small, giving little idea as to the thickness of the bed or the general character of the stone. The stone seen was all of fair grain. Appearances indicated that the bed here was quite thin. Up the Bear Creek Branch of Blue River extending south of Martinsburg, several exposures of the stone showed a thickness of uniformly 12 feet, at most points only a few feet above the water and having about the same rise to the east as the stream bed. At the center of Section 10 the stone is buff, coarse and uneven in grain. In the southeast corner of Section 10 the grain is more even and of medium fineness. South of Martinsburg the stone runs from buff to blue, and in the main is coarse and irregular in grain, and more or less crystalline.

In Township 1 S., 5 E.—(In Washington County.) The outcrop of Bedford stone in the county is confined to Section 6. The only stone seen there had a thickness of six to eight feet and a grain hardly recognizable as Bedford, crystalline and powdery.

Bedford Stone in Floyd County.

The outcrop is shown on the map. The Bedford stone has been quarried a little in the west edge of Greenville. The blocks seen show a good quality of buff to gray stone, though rather hard. The Bedford stone is believed to cap the ridge between Indian and Richland creeks, though little stone was seen that could be identified as such. Some typical Bedford stone was seen on the west side of Richland Creek, with a thickness of at least eight or nine feet and probably more. North of Georgetown the stone seen was irregular in character, earthy and with shelly bands, making it of little value. Just south of Edwardsville the Bedford stone is eight feet thick and a buff to gray close-grained stone. In Section 12, a mile south of Edwardsville, the Bedford stone is quite typical in appearance, uniform though rather coarse in grain. It runs from five to 10 feet thick. Three miles south of east of Lanesville, in the northwest quarter of Section 26, the Bedford stone attains a thickness of 15 or 20 feet. It is buff or gray in color.

Bedford Stone in Harrison County.

In Township 2 S., 4 E.—There is some evidence of a fault in the northeast part of Section 11. Above this, Bradford Creek appears to be flowing in the Mitchell, but near the middle of Section 11, the Bedford stone is found 40 or 50 feet above the creek bed. The stone here is a soft, sub-crystalline stone of medium grain and gray color except the crystalline part which is dark. The stone has a thickness of 15 or 20 feet. In the northeast quarter of Section 24 the stone is 10 feet thick, coarse but uniform in grain. At one point it has a dip to the west of 5°. In the northeast quarter of Section 27 the stone appears to show three oölitic strata, as given under the general geology of the Bedford stone. In the southeast quarter of Section 26 the stone is 20 feet thick and lies 40 to 50 feet above Indian Creek. The stone is gray, irregular and varies from fine to coarse grained. In the southeast quarter of Section 27 the stone is a buff with the grain generally coarse and irregular. The upper 15 feet is oölitic in the main, then come several feet of rock that are only partly oölitic. South of the center of Section 34, the stone is light gray, oölitic, uniform in places, in others quite irregular. In the southeast corner of this section is a small quarry. The quarry face shows about 18 feet of stone with from one to four feet of stripping, the latter mostly limestone. The Bedford stone here is coarse grained, fossiliferous, and irregular in grain. In the southwest quarter of Section 33 the stone is well exposed, coming just below the level of the railroad bridge over Indian Creek. Further west it shows as a perpendicular bluff 10 to 12 feet high gradually running down to creek level.

In Township 3 S., 4 E.—South of Crandall the Bedford stone is about 15 feet thick. At the bottom it is gray, fairly oölitic, grain coarse, irregular, open. In the center of the bed the stone is of medium fineness and uniform; at the top it is coarser though still uniform, not close textured.

In the valley of Little Indian Creek, there is some excellent stone around Kings Cave Postoffice in Section 34. At the "Cave" there is a bluff of 20 feet of stone extending down to the creek bottom. As a whole the grain appears as good or in some places better than at the quarry half a mile down stream. At the bridge at the east side of this section the stone is quite crystalline, hardly distinguishable from the rock above, which is similar in color, but finer in grain, and from the rock below, which is darker, more crystalline, and coarser grained. The rocks here have a dip of from 5° to 10° S., 35°

W. From this point up to Breckenridge the stone shows a similar lack of characteristic oölitic structure, and appears to have a thickness of about 15 feet. At Breckenridge are better exposures, the stone showing a thickness of 11 feet. It is coarse and irregular in grain, largely made up of small fossils, which in places weather out very much in the same way as at Spurgeon's and Poynter's hills in Washington County; the fossils are the same as at those points. The underlying stone here has some resemblance to Bedford but is darker and almost entirely crystalline. East of this in Section 25 there appear to be two beds of oölitic stone separated by about 10 feet of laminated crystalline limestone. The upper bed is only three or four feet thick. On the south side of the creek in this section no strictly oölitic stone could be found. A slightly oölitic tendency in the stone about 20 feet above the creek was taken to indicate the horizon of the Bedford stone.

In Township 3 S., 5 E.—At the north side of Section 30 a six-foot ledge of coarse grained blue Bedford stone outcrops from 20 to 25 feet above the creek. No characteristic Bedford stone could be found in Section 19, the line being drawn at the top of a bed believed to correspond to the bed just below the Bedford at Breckenridge. To the south and west of Lanesville, though good exposures exist, the horizon of the Bedford stone could not be certainly recognized. As in all such cases the apparent lack of the stone is probably due not to its absence but to its character becoming so changed as not to be distinguishable from the over and underlying stone. North and especially east of Lanesville, the stone sets in with a fairly characteristic grain and runs to the county line. At the schoolhouse just east of town it appears to be only eight feet thick, but in Section 21 thickens up to 12 or 15 feet, and makes a series of fairly bold outcrops on the hillside, from 10 to 15 feet above the creek. The grain is coarse and fossiliferous.

In Township 4 S., 4 E.—Outcrops in this township are confined to the point where Buck Creek enters the township and to a small area along Little Indian Creek in Sections 3 and 4. In Section 4, however, is located the only extensive quarry south of Salem. This is near the northeast corner of the section. The stone here has been quarried to a depth of 27 feet. It lies at creek level, the top of the stone being only about 15 feet above the creek, so that the stone in the bottom of the quarry is some 10 feet or more below creek level. The stripping at present amounts to 11 feet. Of this the lower eight feet is gray to black limestone in beds one to two feet thick. Above that is clay and decomposed limestone for a thickness of three feet.

The color is buff at the top as usual, and blue at the bottom. The grain is close and runs from medium fine to coarse. Much of the stone tends to show dark bands, like cross-bedded lines, that on examination prove to contain a large percentage of dark brown crystals of calcite. In places fossils make the grain open and very coarse. No stylolites were seen. There appears to be a noticeable non-conformity at the top of the Bedford stone. The quarry is equipped with single and double channelers, cranes, a single bladed saw for trimming, etc.

In Township 4 S., 5 E.—The outcrops of Bedford stone in this township are confined to the valley of Buck Creek, in the northwest part of the township, and to the bluffs of the Ohio along the eastern edge of the township. Along Buck Creek the stone seen ran from five to 10 feet thick. The grain is uniform, fine and in places characteristic, though in most places it tends to be nearly half crystalline. The Bedford stone at Bridgeford, Locust Point Postoffice, is dark, full of cavities, and partly silicified. At the center of Section 24 it is five feet thick, a hard, even textured, gray oölitic limestone. The section here shows:

	Ft.	*In.*
Hard blue, close-grained limestone	10	0
Buff, magnesian to gray limestone	15	0
Bedford limestone, as above	5	0
Thin-bedded, blue limestone	5	0
Massive blue to gray limestone	8	0
Hard gray limestone	15	0
Sandstone (Knobstone)	0	0

At the center of Section 26 the Bedford stone shows a thickness of 15 feet. It is light drab or gray, the grain is close, fairly fine, only slightly crystalline, and the crystals fine. In places the grain is almost entirely oölitic. No crow-feet were seen. It has been worked a little for road use. The overlying stone is a shaly limestone and shale. The underlying stone is a dark blue limestone.

In Township 5 S., 4 E.—The outcrop of Bedford stone in this township is confined to the valley of a branch of Mosquito Creek, in Sections 25, 26 and 35. The stone here, as far as seen, is less than 10 feet thick. The stone ranges from a true oölitic limestone to a crystalline limestone. Most of the grain seen was fine and regular.

In Township 5 S., 5 E.—In Section 11 the Bedford stone has a thickness of about 10 feet. The grain is coarse and irregular. In the center of Section 27 the Bedford stone is fairly well exposed, and shows a coarse, oölitic structure, mostly bryozoa. The thickness is over 10 feet.

Over the Bedford stone here is the following section:

	Ft.	In.
Shale and shaly limestone	7	0
Shale	5	0
Shaly limestone	6	0
Shale	8	0
Blue limestone and chert	4	0
Bedford limestone	10	0

A mile up the creek from Buena Vista (Convenience Postoffice) there is a five-foot bed of typical oölitic limestone five feet above the creek, with a three-foot, semi-oölitic bed four feet above; the two being separated by a shaly limestone and shale. At Buena Vista the Bedford stone shows a thickness of eight feet and is not very characteristically developed. The grain in most cases though uniform and fairly fine is almost entirely crystalline.

In Township 6 S., 5 E., no typical Bedford stone was found and the line in the main is drawn on the map from the shales and other rocks accompanying the Bedford. The following section, by Mr. Kindle, in the northwest quarter of Section 5 will give an idea of the stratigraphy in this region:

	Ft.	In.
Red clay	10	0
Hard, bluish-gray limestone	12	0
Soft, buff, magnesian limestone	10	0
Bluish, calcareous shale, with an abundance of bryozoa	8	0
Blue limestone	2	0
Covered	?	0
Bluish, shelly, magnesian limestone	2	0
Massive, even-grained, gray limestone	7	0
Covered, limestone fragments	14	0
Hard, blue limestone	12	0
Shelly, buff sandstone	4	6
Crinoidal limestone	0	10
Blue, sandy shale	5	0
Limestone	0	5
Shelly, sandstone, with small geodes	3	0
Cherty limestone	0	8
Shelly, blue to buff sandstone	6	0
Sandy, drab colored shale	10	0
Cherty, hard limestone	0 to 1	8
Sandy shale and sandstone	7	0
Crinoidal limestone	3	0

In Township 6 S., 4 E.—In Section 2 the Bedford stone is about eight feet thick and only slightly oölitic. It is 35 to 40 feet above drainage. Above it is 12 to 15 feet of gray shale, with one or two

thin, fossiliferous bands; over that is 20 feet or more of shaly limestone. On the road up from Brown's Landing in Section 14, at a height of 85 feet above low water in the river, is a massive outcrop of limestone 38 feet thick. The lower 15 feet of this is semi-oölitic and appears to correspond to the Bedford stone. There is a marked crow-foot at the top of this, above which is compact fine limestone with thin shale partings toward the top. In Section 23 the Bedford stone comes just at or above the bottom land of the river. It is six or eight feet thick, of medium fine, sub-crystalline grain. In the southwest quarter of Section 4 the stone appears to be only three or four feet thick, dark blue, only partly oölitic. A little typically oölitic stone was found on the surface. Just below Tobacco Landing the Bedford stone is about 15 feet thick, and occurs about 70 feet above low water in the river. It is about 45 feet above the narrow river bottoms. The stone here is a dark gray or bluish in color, fairly even in grain, but coarse. The stone is in part typically oölitic, but principally crystalline, the crystals in places being large—1-16 of an inch in diameter and down. Masses as large as small houses have fallen down from the face of the cliff. Over the bed is a perpendicular cliff from 50 to 100 feet high. In Section 6 the Bedford stone approaches the level of the bottom land. Only five feet showed oölitic structure here.

ECONOMIC MATERIALS OF THE HARRODSBURG LIMESTONE.

In the presence of the overlying limestones, which as a rule are rather purer and freer from chert, the limestones of the Harrodsburg have little to offer of economic value except in the way of road material or for ballast, or as a rock yielding a fine deep soil by its decomposition. It has been extensively quarried for use as ballast in the western part of the town of Salem, and on a small scale it has been used for building roads at many points over the area of its outcrop. The quarry at Salem has not been operated in several years, the stripping having become quite extensive at the last. There is apt to be a larger proportion of clay in this limestone, rendering it less suited to use for making lime. On the other hand, in places it weathers into a deep, rich soil. East of Salem in places this soil was found of depths up to 17 feet or more.

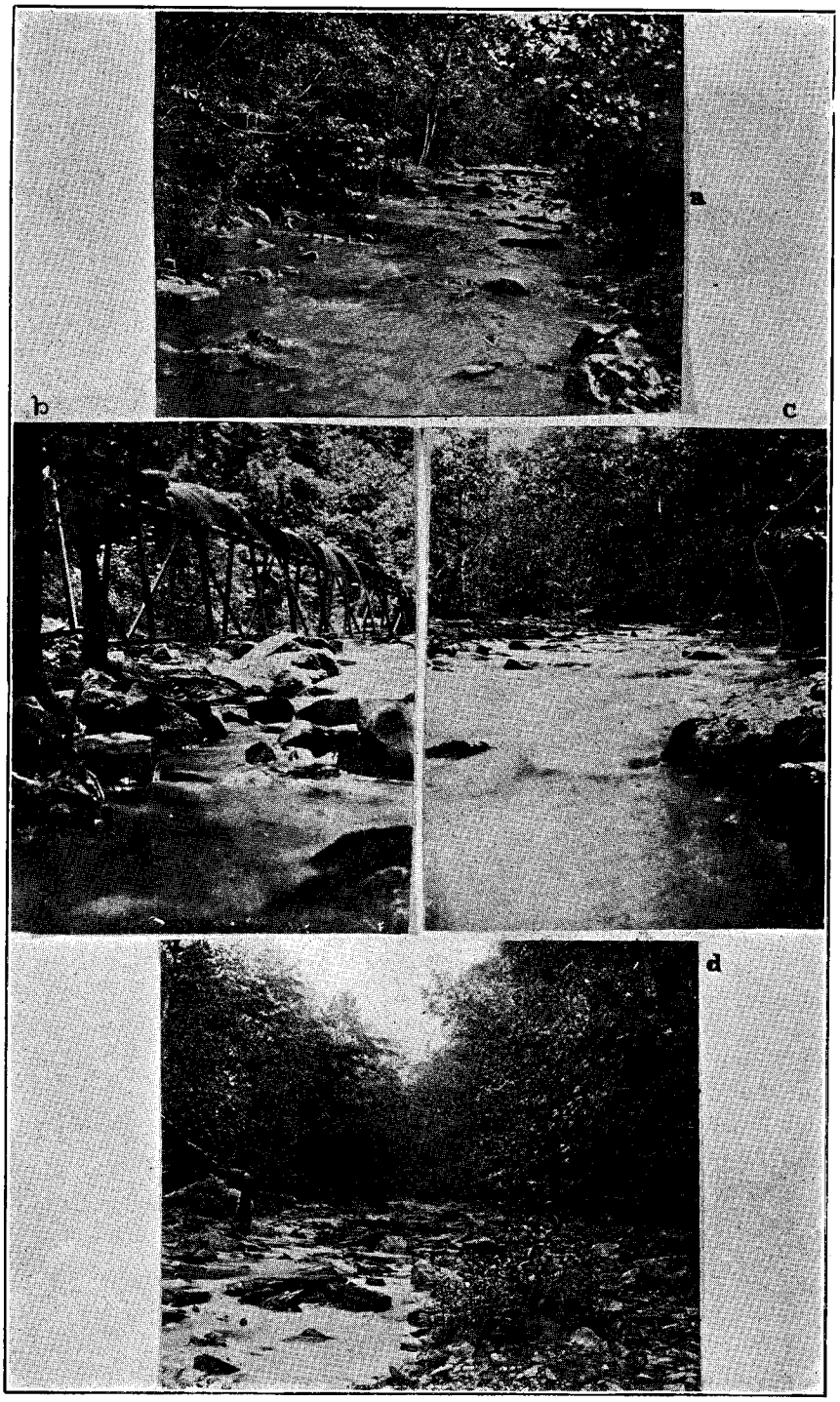
ECONOMIC GEOLOGY OF THE KNOBSTONE.

Considering the thickness of rocks involved the Knobstone presents a very limited amount of material of commercial value. The upper beds in this area consist of shaly sandstones and sandy shales that have little value for structural or other purposes. At present, development is confined to a very limited use of sandstone from a quarry just east of Mooresville, and to a slight use of the shales of the lower part of the section. The Mooresville sandstone has a thickness at the quarry of 12 feet; it is a massive, dove-colored stone, dark blue when first quarried. It is a soft stone when first obtained but hardens on exposure and makes a durable stone. It is used to some extent in New Albany. This stone has been prepared for market by the Acme Stone Company of New Albany. The Hoosier Brick Company is working the Knobstone shale two miles west of New Albany on the Southern Railway. The shale is a tough, blue shale, with an exposed thickness of 40 feet. It contains very little fine sand. The product is light red brick of good color and good quality. Some lenticular concretions of ironstone occur in the shale, but they are not numerous. The factory is well equipped, having a capacity of 25,000 brick a day. Shale from near this point is used by Bannon and Company, of Louisville, in their brick and tile plant.

The limestone sometimes found near the top of the Knobstone has been used some for local road work. Thus a quarry for this purpose has been opened in the southeast quarter of the southeast quarter of Section 29 (2 S., 6 E.). It is said to reach a thickness of 11 feet, though eight feet was the greatest thickness observed. The stone from this quarry has been used on the New Albany and Vincennes Turnpike.

WATER POWER.

With the perfecting of long distance transmission of power by electricity, the question of the utilization of the water power resources of this area becomes one of great importance. Over a large part of this region the underground drainage lends itself well to power production. Three methods of utilizing the water power of the interior of this region present themselves. First. The building of impounding dams at suitable points; second, the fluming of waters downstream a suitable distance; third, the sealing of the mouths of spring caves. To take an example: The position for an impounding dam on Twin Creek would seem to be at the north side of Section 31 (3 N., 3 E.). The valley here is very narrow, with almost perpen-



ILLUSTRATING SOME OF THE WATER POWER RESOURCES OF THIS AREA.

a, b and c. Views in valley of Clifty Creek, north of Campbellsburg, showing descent and volume of water in July.

d. Twin Creek, near north side of Section 31, 3 N., 3 E., showing volume of water in June. The narrow part of the valley is below this. See Plate X.

dicular banks to a height of nearly, if not quite, 100 feet. A dam at this point 100 feet high would impound a fairly good-sized body of water, reaching at least a mile up each of the three main forks. The value of the land inundated would be slight, as practically none of it is at present under cultivation, or in fact cultivatable, and is almost uninhabitable. Fig. d of Plate XIII shows the flow of water in June above the point suggested for the impounding dam. The power house placed at the foot of the dam could secure a maximum head of 100 feet. This head could be increased by carrying the water further down stream, but at considerable additional expense.

Clifty Creek rises in two large springs, while another large spring adds its waters in Section 11. As shown in Plate XIII the fall of Clifty Creek is quite rapid, for the first mile or two. To get the full benefit of the fall the dam should be in Section 2. However, there is no suitable place there.

Probably the best results could be obtained by a dam a short distance below the present mill, say, across from the Lover's Leap, and another in the side valley below the spring in Section 11. Plants could be established at each of these points. It is probable also that the fall is sufficient to warrant fluming the streams after leaving the power houses, and from the side ravines to some point in Section 2, where a third power plant could be established. It is possible that the mouths of the three caves could be successfully sealed, and at a much smaller expense than the building of impounding dams.

This condition of large springs with narrow valleys below is found in a number of places in the knobs, and in the valley of Blue River. In such cases it would seem as though high impounding dams could advantageously be placed at a number of points so as to secure large power. In most of these cases it would probably be best to build impounding dams near the spring where the valley is narrow and then flume the water down stream some distance to secure fall. Along Blue River, especially along the western bank, are a number of large springs, as at Beck's Mill, Organ Springs, and at many other points are springs that result from the drainage of large tracts of land. Many of these springs are at present used in a small way. In most cases it would seem as though they could be made to yield many times as much power as at present. This could be accomplished in many cases by leading the water a mile or two down stream. High impounding dams would usually accomplish the same result more easily and with the added advantage of securing a larger supply of water. Blue River itself is used at a number of places for water

power, but in most cases no attempt is made to secure a fall of more than a few feet, five to 10 at most. (See Plate IV.) Many places were seen where it was thought that impounding dams could be built from 20 to 40 feet high. The river has a fall of 89 feet between Milltown and its mouth, or about seven and one-half feet to the mile. Indian Creek likewise, along its lower course presents many places where high impounding dams could be built, storing up the spring waters for use during summer. The streams of western Orange County and at Spring Mill also suggest possibilities of greatly increased water power.

With the limited data at hand this paragraph can only hope to be suggestive of the possibilities of this subject. In almost every case suitable stone can be had on the spot where needed. This subject can hardly be passed over without reference to what must have occurred to many, the utilization of the fall of the Ohio River at New Albany. The Ohio has a fall here of some 22 feet. During a large part of the year boats use the canal rather than descend the falls, an impossible feat in the summer months. It would seem, then, as though all the water not needed by the canal in summer might be utilized for power, while in the spring there would be water enough for the boats and for water power purposes as well.