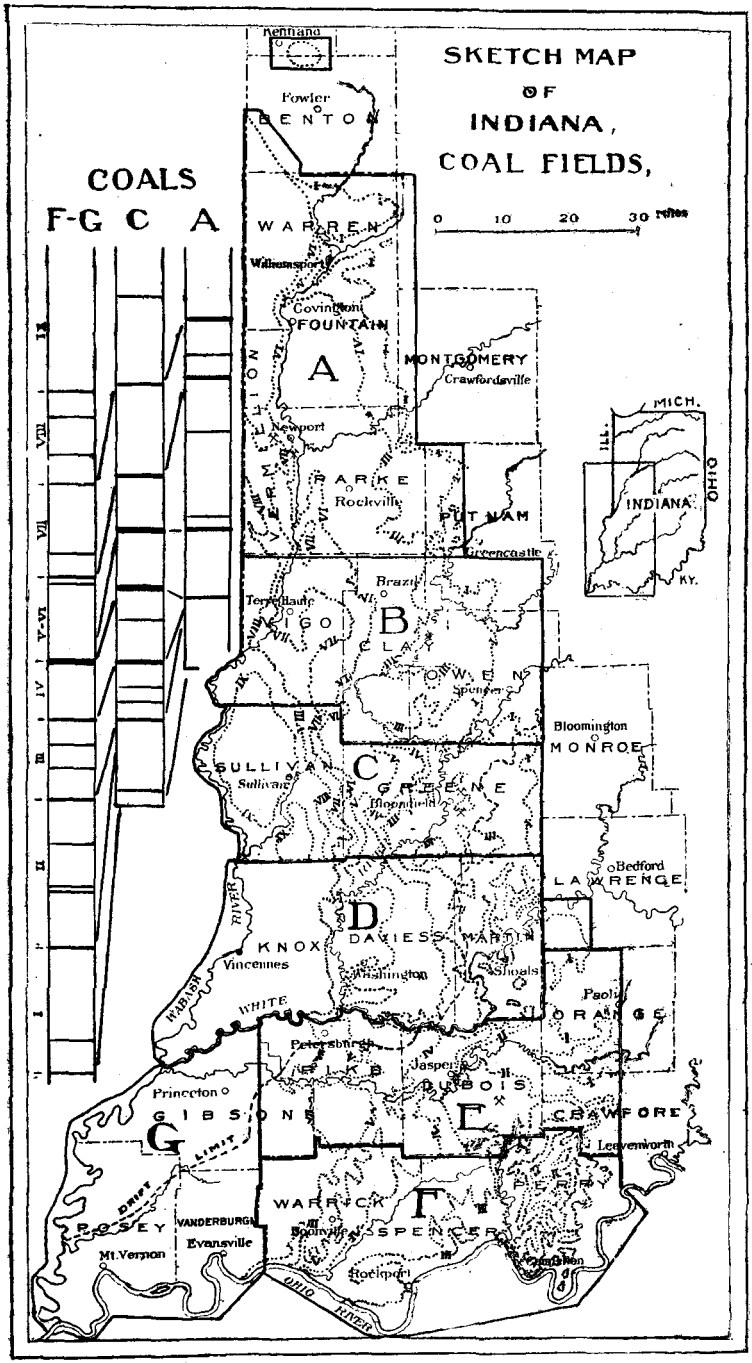


PLATE V. Sketch map of Indiana coal field to show general relation to State and relations of sheets of colored geological map, etc.

PART II.—GENERAL GEOLOGY OF THE COAL MEASURES IN INDIANA.

VI. GEOGRAPHIC POSITION OF COAL MEASURES IN INDIANA.

73. GEOGRAPHIC POSITION.—If on a map of Indiana the position of every point at which a bed of true coal has been found be marked, it will be evident that coal is confined to the southwestern part of the State. More careful examination shows that the following counties are practically entirely underlain by the coal or coal measures:

County.	*Area in Square Miles.*
Vermillion	249
Parke	480
Vigo	415
Clay	360
Sullivan	443
Knox	540
Daviess	424
Gibson	450
Pike	338
Dubois	426
Posey	420
Vanderburgh	240
Warrick	388
Spencer	389

The coal measures also underlie the principal part of the following counties:

County.	*Coal Area in Square Miles.*
Warren	300
Fountain	315
Owen	150
Greene	360
Martin	280
Perry	216

The edge of the coal measures lap over the bounds of the following additional counties:

County.	*Coal Area in Square Miles.*
Benton	30
Montgomery	9
Putnam	125
Lawrence	20
Orange	42
Crawford	60

Total coal area of State, 7,560 square miles, of which probably less than 7,000 square miles are underlain by coal, if, indeed, that area does not run down close to 6,000 square miles.

There are thus fourteen counties entirely underlain by coal, six counties mostly underlain by coal, six counties containing small quantities of coal, or a total of twenty-six counties containing coal, with a total area of 7,500 square miles. The coal area of the State has a maximum length north and south of about 200 miles and a maximum width from east to west of about 100 miles, being narrow to the north and broad to the south.

The accompanying sketch map of the State, Plate V, will show a little more in detail the relative position of the coal field to the rest of the State.

VII. PHYSICAL FEATURES OF INDIANA COAL AREA.

74. ALTITUDE.—In altitude the area of the coal measures range from below 400 to 800 ft. above tide, most of the area coming between the 400 and 700 ft. contours.

In the north part of the region in Warren county all but the valleys are above 700 ft. Through Fountain, Vermillion and Parke counties the average is over 600 ft., running under 500 in Wabash valley and over 700 in highest ground. Clay county will average a little lower, nearer 600 ft., while Owen will average nearer 700 ft. Vigo and Sullivan will not average much over 500 ft.; Greene county, while but little over 500 ft. west of White river, will approach 700 ft. on an average east of the river. Knox and Daviess counties will average below 500 ft., while Martin county will range from a little over 400 ft. to over 800 ft. Gibson, Pike, Posey, Vanderburgh, Warrick and Spencer will average between 400 and 500 ft., getting lower to the southwest. Dubois will average about 600 ft., while the coal measure area in Orange, Crawford and Perry counties will run over 700 ft. The lowest point in the area is at the junction of the Ohio and

Wabash, 311 ft. above tide. Elevations of over 800 ft. are reached all along the eastern and northern rim of the coal area.

75. RELIEF TYPES.—The southwestern part of Indiana shows great diversity in its surface features, some areas being so flat as to be drained only at great expense, while other regions are so broken and hilly as to be in large part unsuitable for cultivation. Of the more level types of surface, very common are the bottoms found along the rivers and streams. Considered from the standpoint of source, these are of three types:

76. (1) RIVER BOTTOMS produced by the lateral swinging of streams which have nearly or quite reached their base level. Though in general this is the commonest kind of a river bottom, in this area it is not common, and when it exists is usually of limited width. From the standpoint of our subject it is characterized by the thinness of the superficial deposits, the coal measure rocks being found at but a few feet below the surface, and often outcropping in the banks of the immediate channel of the stream or river. Such bottoms usually occur along the upper courses of streams in the unglaciated regions.

77. (2) River bottoms formed by unstratified drift filling a preglacial valley. These are perhaps the most common of the stream bottoms. They are usually characterized by a considerable depth of superficial material, by a lack of outcrops of coal measure rocks, and by their large size as compared to the size of the streams flowing through them. With the larger streams, the old valley filling, the surface of which makes the present bottom, is often 100 ft. deep. In other words, a shaft sunk in one of these bottoms to an underlying coal bed must pass through from 50 to 100 ft. of soft material, which will require to be curbed and which may render the sinking a matter of some difficulty and embarrassment. These are often of considerable extent, and not uncommon are bottoms of a stream which are from one to five miles broad. Of course, over such areas no coal outcrops are found, and they often render it difficult to trace the relations of the coal on either side. They are usually prairie lands, and in an early day were wet and marshy much of the time, though extensive ditching has now drained most of these areas.

78. (3) River bottoms made by the filling of preglacial valleys by glacial deposits brought in by water. This type is common in the unglaciated area, and has a notable example in the drift area in the Wabash valley. These fillings appear to have been made by the

washing in of glacial material during a depression of the land. The present surface is probably in most cases not the original surface of the filling. In many cases the original filling appears to have been from 25 to 100 ft. deeper than the present filling, the land at the time the filling was made having been at least that much lower than at present. Later, an elevation of the land started the streams to clearing out their old channels. This proceeded until base level was reached, when lateral swinging by the streams produced the level surfaces now existing. Where the present stream is small compared to the size of the ancient valley, the first stage of the clearing-out process may not yet be complete, and the old deposits still flank the margins of the valley as terraces. (See description of terraces along Wabash river in report on Vigo county.)

79. An interesting variation of this type of topography is found all around the glacial boundary. As the ice sheet moved southward or southeastward, it pushed across the lower courses of many of the streams, damming them up. The ice stayed at, or near, its extreme limits long enough to have the bodies of water thus made silt up full. In many cases the streams thus dammed up were of considerable size, as for example, the Patoka river above Jasper, and the body of water thus created was also of large size—up to several scores of square miles. Oftentimes the higher points of the pre-existing topography project, island-like, above level deposits surrounding them. These are typically found in northwestern Dubois county. In some cases these level fillings are still preserved, and then resemble closely the river bottoms of Class 3. In such cases the drainage has usually formed a new channel, having flowed out at the lowest point of the rim of the basin in which the water accumulated. In Greene county are found some interesting cases, where the water appears to have escaped by channels under the ice, and the surface water to-day runs into sinkholes in the level fillings and escapes by channels at the bottom of the deposits. In many cases where such fillings have existed, the streams resume their old courses after the retreat of the glacier, and while in some cases they have removed all of their old filling, in other cases traces of it still show in the form of terraces on the banks.

An examination of the deposits forming the bottoms of the streams in the drift area show that quite commonly these bottoms belong to both Classes 2 and 3.

80. Upland Levels.—In the glacial area away from the larger streams it is usual to find wide areas of the divides practically level. Examination shows that these level lands are drift deposits, usually

of considerable depth. They appear to be remnants of the old level surface left by the glacier in its retreat. As yet they have not been reached by surface drainage, the water sinking into the soil and escaping by numerous underground channels. In some places the drainage lines are rapidly encroaching on these areas. Mr. Scovell cites cases in Vigo county where six to ten little streams head up into one 20-acre tract. These level stretches commonly are prairie land, and as in the case of Grand Prairie, in Vermillion county, are often of considerable extent. No outcrops of coal or rock occur in them, and as wells for water seldom go to the underlying coal measures, information about the coal in such areas is generally very scattering, or more commonly entirely lacking. This topographic type is common on the divides all over the glaciated part of the coal field, but is increasingly found from the south northward, until in Warren county it covers a large part of the county.

81. Glacial Sub-Level Topography.—Probably the larger part of the glaciated area would be a modification of the preceding type produced by the encroachment of surface drainage. In this type the surface, while nearly level, has had drainage lines developed in it and so consists of gentle slopes to the streams and smaller drains, with often sharp bluffs along the lower courses of the larger streams. The upper courses of the streams are not marked. In some cases there is a gentle slope to the stream which has hardly any appreciable banks. In other cases the slope to the stream is not perceptible and the stream has cut a narrow V-shaped channel. As a rule the streams are still cutting in the glacial deposits and so seldom disclose outcrops of coal or coal-measure rocks. Here and there, especially where the drainage is following new lines, the coal-measure rocks have been reached. In many cases such exposures seem to be due to the stream in its downward cutting having encountered some high point in the preglacial surface.

82. Bluff Topography in Glacial Area.—In the region adjacent to the Wabash and its principal tributaries the preceding type has been considerably modified. A study of the topography of the country adjoining this river as compared with that found along White river, Eel river and other streams suggests that conditions existed somewhat similar to those found in the Colorado canon region of Arizona. That is, the erosion in the stream bed has been proportionally greater than the erosion of the banks. As a result, the adjacent country, instead of sloping gently to the river, approaches the river with a fair slope and then reaches the immediate valley at an elevation of

from 100 to 200 ft. above the river, necessitating a rapid descent by means of bluffs. In the same way the tributary streams have taken advantage of the low points of discharge to cut their channels some distance below the normally lowest point of their valley slope. Where such tributary streams are large and are flowing in channels of post-glacial age, their banks are sometimes very precipitous or perpendicular. This U-shaped type of valley is not uncommon in the glaciated part of North America, but is usually the result of the backward cutting of streams flowing in new channels. This can hardly be the case with the Wabash, and we are led to suspect that at some previous time the area drained by the Wabash was much larger than at present. Whether the Wabash was formerly an outlet of Lake Michigan or Lake Erie, as some have thought, can not be determined with the present facts at hand. It certainly appears that the Wabash was the outlet of Lake Erie during the last part of the Ice Age, the northeastern outlet being still closed by the retreating ice, yet that the channel should have received its extra depth during that time hardly seems credible. It is possible that a closer study may show that other factors not yet generally considered have been largely influential.

83. Sandstone Topography in Glacial Area.—At the base of the coal measures all along its eastern margin occurs a massive bed of sandstone 40 to over 100 ft. thick. Over most of the area of its outcrop it has greatly influenced the topography. In Warren and Fountain counties it is buried too deeply to make its presence felt at the surface. Through Parke county and southward it would seem to have formed prominent ridges or high land, as it does now in the unglaciated area. In Parke county these were completely overridden by the ice and planed down so that they do not now show as distinct ridges above the old level left by the glacier. But the glacial deposit left over the area, while thin, was deep enough to turn many of the streams out of their old courses and start them cutting new ones across the top of these old ridges. The result has been to produce a number of narrow, rock-bound gorges, cut almost perpendicularly down from the level upland. In extreme cases the depth of the gorge may be much more than its width at the top, and as they follow all the windings of the original superimposed stream, the resulting topography is about the wildest and most picturesque to be found in the State. To the southward, in Clay, Putnam, Owen and Greene, the topography along the outcrop of this sandstone is a combination of the glacial topography to the westward, with its flat ridges, and the sandstone topography outside the glacial areas, the latter type becoming more

and more dominant to the southward, or as the glacial boundary is approached. In this mixed type the divides are still level and high, but they have been deeply cut into by the erosion, which has formed between them ravines from 100 to 250 or more feet deep. Going southward the ravines occupy a larger share of the region, the flat divides become narrower, then begin to break down in places, and finally become irregular, sharp crests as the glacial boundary is reached, showing little or none of the influence of the ice.

84. SANDSTONE TYPE OUTSIDE OF THE GLACIAL BOUNDARY.—This type of topography exists all along the eastern edge of the coal measures from southeastern Owen county southward to Perry county. It is characterized by having but little flat land, and that mostly river bottoms of the third class, as enumerated above. The drainage lines are completely developed, the divides being sharp crests and irregular, the streams running in deep ravines from 100 to 300 ft. deep, the banks generally too steep for cultivation, except near the top and bottom, where they round up to the summit of the ridge or round outward to meet the bottom land. As far as possible the roads follow the top of the ridges or keep in the valleys, and, as shown on the maps, serve as a good index of the broken character of the country. As might be imagined, such a type of country is very favorable for rock exposure, and it is possible there to trace the horizon of any chosen rock or coal bed with a considerable degree of accuracy. On the other hand, in view of the fact that from the nature of the country, with its labyrinth of deep ravines, it requires much effort and time to trace the lines of outcrop, and as the area possesses but little workable coal, it has proved more of a detriment than an advantage. It has been a common experience with all the members of the survey that, after working in the flat country to the west, where the mapping of the outcrop lines has had such a large element of conjecture in it, upon entering this area, where outcrops could be traced with much certainty, to devote much more time to it proportionally than the value of the coal found would warrant.

85. TOPOGRAPHY OF PRODUCTIVE COAL MEASURES OUTSIDE OF GLACIAL BOUNDARY.—Most of the column of rocks above this basal sandstone is a very variable mixture of shales, sandstones, clays, coals and limestone. Of these the shales generally predominate, and the result is that within the eastern sandstone rim, but outside the glacial boundary, the topography, while resembling the last type in general plan, is more of a rolling character, the ridges having been reduced by erosion until they are fairly low, with gentle slopes running to the

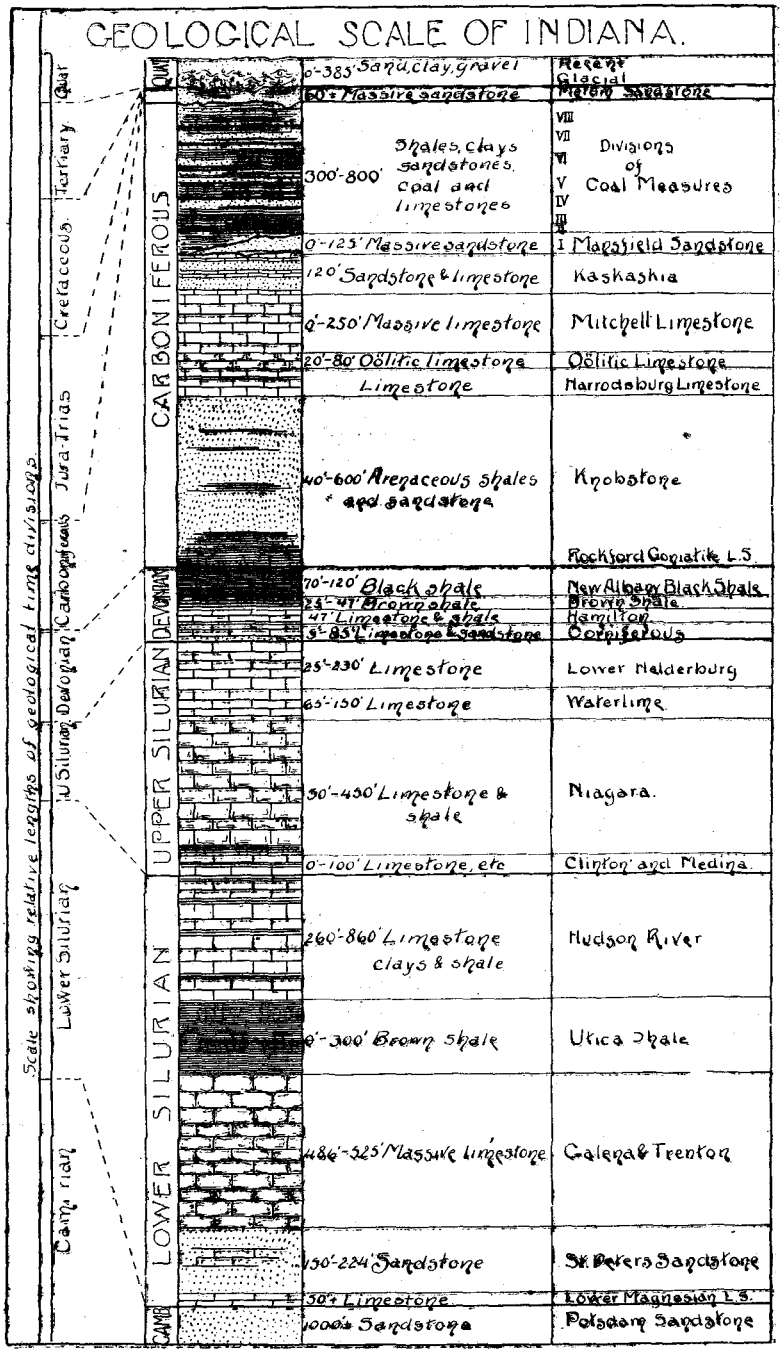


PLATE VI. Table showing relations of coal measures to the stratigraphy of the State.

streams and generally suitable for farming. The ridges will generally vary between 50 and 100 ft. above the stream channels, so that the drainage is good. The depth of surface material formed by the disintegration of the underlying rocks is greater than in the sandstone area, rock exposures are generally small, and often as much scattered as in many parts of the glaciated area. On the whole, however, this type of country yields the information desired by a survey like the present with a degree of fullness that renders it possible to obtain the stratigraphy and to trace the outcrops of the coals in a fairly satisfactory manner.

In a general way, an examination of the roads as given on the maps will serve as an index to the character of the topography of any area. This is not always true, as in many of the hilliest sections it is the practice to make the roads conform strictly to the section or fractional section lines without any reference to topographic features. In a multitude of cases a better method of rendering a road valueless could hardly be devised. On the other hand, in some districts where the roads as shown on the maps would suggest a broken, uncultivated country, a visit reveals a rich farming region with gentle topographic features, in which the residents appreciate the use and purpose of roads, and have employed engineering skill in their laying out and construction, with the result of good roads of great permanence and carrying capacity.

In a still greater measure the topography is indicated by the lines of outcrop on the maps. Where those lines are dendritic in form, it may safely be assumed that the topography is marked and probably quite rugged. Where two outcrop lines occur close together, a steep slope is indicated, unless the coals are very close together. In parts of the area the outcrop lines serve very well to indicate the topography to those who are accustomed to contour maps.

VIII. STRATIGRAPHIC POSITION OF COAL MEASURES IN INDIANA.

Thousands of dollars have been wasted in this State in the past in the fruitless attempt to find coal where coal not only did not exist, but where a knowledge of the geology of coal would have conclusively shown beforehand that no coal could have been found. Unlike gas or oil, fairly definite statements can be made as to the distribution of coal. Thus, it can be stated that all workable coal will be found

within such and such limits; that outside of those limits no coal exists except a few scattered very thin seams found just beyond the limits given. The coal of the State is all confined to rocks of a particular geological age, characterized by certain forms of animal and vegetable life, and, to a slight extent, by the rocks. The geological formations that overlie or underlie may also be distinguished, either by the character of the rocks forming them, or more accurately by the animal and vegetable remains contained.

To prevent, if possible, the waste of many more thousands of dollars in the fruitless search for coal, it may be well to make a brief comprehensive study of the rocks above and below the coal measures, as well as of the coal measures themselves, the fossils by which they may be recognized, and their structural position and distribution.

86. The accompanying table,* Plate VI, shows a columnar section of all the rocks of the State, the time period during which each group was laid down, a statement of the character of the dominating rocks of each group, and in the last column the names given to the more important subdivisions. In the first column is placed a time scale, of the time from the laying down of the earliest rocks known to underlie Indiana to the present, showing the relative estimated length of each of the major time divisions, and connection with the rest of the table shows, in a measure, during what part of geological history Indiana was under water and receiving deposits, and the time it was, as far as we know, above water and undergoing erosion. The rocks preceding the Carboniferous Age will be treated very briefly.

87. POTSDAM SANDSTONE.—It has been customary to label a sandstone which has been met with in several drillings that passed through the Trenton limestone as Potsdam sandstone. It is probable that Potsdam sandstone has only been reached in the well at Laporte, and at a depth of probably 600 ft. below the bottom of the Trenton. The drill there entered it some 323 ft. without reaching bottom. It does not crop out in this State.

88. The LOWER MAGNESIUM LIMESTONE is thought to be represented by the last 50 ft. of limestone penetrated by the boring at

*In this table and the accompanying description I have drawn largely on the valuable paper on The Natural Gas Field of Indiana, by Dr. A. J. Phinney, in the 11th Annual Report of the U. S. Geol. Surv., for that part of the table preceding the Carboniferous. The averages used in drawing the columnar section were personally obtained by a study of all the deep well records obtainable. For the lower or Sub-carboniferous I am especially indebted to the recent reports of Messrs. Hopkins, Siebenthal and Kindle contained in the 20th and 21st annual reports of the Geological Survey of Indiana. The present survey is alone responsible for the coal measures and overlying beds.

Bloomington, and possibly was reached in the boring at Greenwood, Johnson county. It appears as a gray sandy limestone. Does not outcrop in this State.

89. The St. Peters Sandstone has been penetrated by a number of drillings that have passed through the Trenton limestone. It varies from a pure sandstone to a sandy limestone, usually of a light color. Does not outcrop in this State. Outcrops in Illinois and Wisconsin. It is the source of the "Blue Lick water" of several of the deep wells. Thickness, 150 to 224 ft., with doubt.

90. The Galena and Trenton Limestone has become popularly known as the reservoir of the natural gas and oil. It is a massive thickness of limestone, with a little shale in places. It probably underlies the whole State, with an average thickness of close to 500 ft. It does not outcrop in this State, but is well known from outcrops in nearly every direction beyond our borders. The upper part of the Trenton, which contains the oil and gas, is thought to correspond to the Galena limestone of Illinois.

91. The Utica Shale is a persistent dark brown or black shale, though tending in some places to grade over into the lighter colored Hudson river shale. It varies up to a reported thickness of nearly 400 ft., but grows thinner to the northwest, and seems to entirely disappear before reaching outcrop in Illinois and Wisconsin.

92. The Hudson River or Cincinnati rocks are the lowest rocks outcropping in Indiana. They outcrop only in the southeast corner of the State. They consist of bluish-green shale, bluish limestone, and clays. The limestone is most prominent in the upper part of the series, with a much greater thickness of shales below. The whole formation thins to the northwest, the limestone being more persistent than the shales. The formation varies from 260 to 860 ft. in thickness, with an average of over 400 ft. The upper part of the series is very fossiliferous and has been long and extensively studied.

93. The Clinton and Medina periods, which are represented by such thick deposits further east, are, in this State, hardly recognizable, and some doubt still exists as to the correctness of assigning certain beds to the Medina. The Clinton is usually represented by a light colored limestone, often not over 10 ft. thick, and often wanting altogether.

94. The Niagara rocks consist of a characteristic bed of bluish-green shale, very persistent at the base of the formation, with a thick-

ness of from 2 to 40 ft., though disappearing to the northwest, and a great thickness of limestone overlying. The overlying limestone varies from a subcrystalline buff to bluish crypto-crystalline, or bluish-green shaly limestone, or even passing into calcareous shale. From a thickness of 100 ft. along the Ohio, these limestones range up to 440 ft. in the northern and northwestern part of the State. The upper part of this limestone has been correlated with the Guelph of Canada.

95. The LOWER HELDERBERG AND WATERLIME are closely related limestones, varying from 25 to 230 ft. and 65 to 150 ft., respectively. Traces of Gypsum are found in the formation in places. Exposures of the Lower Helderberg show a buff to gray cherty limestone. The formations are confined principally to the northern part of the State.

96. The CORNIFEROUS period is represented in Indiana by sandstones 15 to 20 ft. thick, thought to correlate with the Schoharie group of New York, and limestones 5 to 65 ft. thick, correlated with the Upper Helderberg. The formation increases in thickness to the northward.

97. THE HAMILTON group is taken by Mr. Phinny to be represented by a 20-ft. bed of brown, calcareous shale and an overlying 27-ft. bed of dark-gray limestone.

98. The NEW ALBANY BLACK SHALE and a persistent underlying brown shale form the top of the Devonian in this State, and have been recognized in all the deep wells drilled in the State west of its eastern outcrop. This is the formation furnishing the gas and oil found in the coal field up to the present. This black shale contains a great deal of bitumen, enough so that when set fire to on the outcrop, it has been known to burn for weeks.

99. The LIFE during the Ordovician (Lower Silurian), Silurian and Devonian ages has largely been confined to the lower animals; at first to the invertebrates exclusively, then in the Lower Silurian traces of fish appear. In the Upper Silurian they become more plentiful. Among plants, seaweeds predominate. In the Devonian, fishes become a marked feature of the life, while the coming of reptiles is foreshadowed. The great mass of the fossil remains, however, still continues to be largely shells and other low forms of sea life.

100. The history of these periods probably starts with Indiana all under water, this water probably having a small average depth, so that slight oscillation will produce widespread changes in the character of

the deposits. Toward the close of the Lower Silurian a movement of some importance began. It consisted of a gentle uplifting of the rocks laid down along the eastern border of the State and a slow subsidence of the western part of the State. The movement of uplift continued until a broad arch of land had appeared, known now as the Cincinnati-Nashville arch, and extending from northwest to southeast across Indiana, passing by Cincinnati, Nashville, and extending southwest through Arkansas into the Indian Territory. The movement of sinking, which centered in Illinois, was to continue by irregular but almost imperceptible degrees all through the Upper Silurian, Devonian and Carboniferous, until the old sea bottom had sunk several thousand feet, the deposits laid down in the basin so formed at times about keeping pace with the sinking. Several times the movement seems to have been stopped or reversed temporarily. In Carboniferous times they more than kept pace, so that the basin became filled to sea level, and slight oscillations would either lift a great area just above the water level or sink it just below. The last part of this history will be given beyond; but it is of interest to see that the initial steps for the formation of the coal were taken several ages before the coal appeared.

101. The LOWER CARBONIFEROUS OR EO-CARBONIFEROUS was ushered in in Indiana by the laying down of the thin bed of limestone and shale known as "Rockford goniatite limestone." Above this lies the great thickness of alternating sandy shales and sandstones known as the "Knobstone." This formation reaches a thickness of 600 ft. Above the Knobstone lies a great thickness of limestones. These are divided from the bottom upward into:

102. The HARRODSBURG LIMESTONE of Keokuk age, consisting of limestones and shale, with a thickness of from 60 to 90 ft. It is characterized by the presence of great numbers of geodes.

103. The BEDFORD OOLITIC LIMESTONE, well known as a building stone, is a formation of calcareous sand, having a thickness of from 25 to nearly 100 ft. It usually appears as a massive bed of a buff or blue color, with an even and rather fine grain. The grains have been shown to consist largely of fossils, foraminifera and bryozoa of almost microscopic size.

104. The MITCHELL LIMESTONE OR ST. LOUIS LIMESTONE is a series of impure limestones, calcareous shales and fossiliferous limestones, with a total thickness of from 150 to 250 ft. This is the limestone in which most of the well-known caves of Indiana occur.

105. The CHESTER OR KASKASKIA GROUP, which immediately underlies the coal measures, varies somewhat along its outcrop. In Orange and Martin counties, Mr. Kindle found three limestones separated from each other by sandstones. The lower limestone he describes as a light ash color, a close, fine texture stone, breaking with subconchoidal fracture. In places it contains nodules of chert. The thickness is given as 18 ft. The two sandstones, separated by the middle limestone, are of medium coarseness, buff to light gray or white in color, and in places contain coal seams 6 in. thick. One of these coal seams has been mined in the southwest quarter of the southwest quarter of section 24 (2 N. 2 W.). The middle limestone is usually a close textured, semi-crystalline, gray limestone, usually fossiliferous. In places it is oolitic in structure. It varies in thickness from 30 ft. down to 5 or 6 ft. The upper limestone is a dark to light gray crystalline limestone, composed largely of crinoid stems. Chert bands are common in it in places.

106. The COAL MEASURES consist principally of shale, but with an intermingling of sandstone, clay, coal and limestone. As the stratigraphy of the coal measures is considered at some length just beyond, it will be unnecessary to discuss that at this point.

107. The MEROM SANDSTONE.—Division IX. Just as the main body of the coal measures is underlain with unconformability by a massive sandstone, so it is also overlain with unconformability by a massive sandstone. In the earlier reports this sandstone was designated the "Merom sandstone" from its excellent exposure at that point. It there, as in the counties to the south, lies on an eroded surface of the coal measures, its lowest member consisting of a calcareous conglomerate containing shale, coal, pebbles of sandstone, etc. To the north, in Parke and Fountain counties and Vermilion county, Illinois, occur a number of extensive channels cut down into the coal measures, to depths ranging up to 200 ft., and filled with a sandstone very similar in many respects to the sandstone at Merom, Sullivan county. Though no such readily distinguishable channels were found in the southern part of the coal field, the position of the sandstone there relative to the coal below it indicates extensive erosion. If we are correct in correlating the massive sandstone of the channel fillings in the north part of the coal area with the overlying massive sandstone of the southern part of the area, it would appear that this sandstone was laid down at no inconsiderable time after the laying down of the coal measures proper. The great depth and width of the stream channels cut out of the coal measures prior to its deposition suggest a long time

interval. So far as known, no fossils have been found associated with this sandstone in Indiana. In Illinois, however, some fossils were some time ago found in some shale thought to be of the same age as the Merom sandstone. The possible Triassic age of the fossils led Mr. Collett to suggest that the Merom sandstone might be of a Triassic age. Concerning these fossils he says:* "Adjoining this locality, Section 25, Township 19, Range 13, Vermilion county, Illinois., Dr. J. C. Winslow, of Danville, Ill., discovered a bed of fossils which is named in his honor 'Winslow Bluff.' They occur in a bed of black, brown, gray, red and pink shales, backed with sandstone, filling a depression denuded by forces acting at the close of the coal age, which has carried away the regular deposits, including probably three seams of coal. They consisted of separate vertebræ, teeth and other elements of several skeletons, amounting to about 93 bones and fragments, and were submitted by the writer to that distinguished comparative anatomist, Prof. E. D. Cope. After a careful study, Prof. Cope found that they comprised two new genera and species of Reptilia and two of fishes. In a paper read by him and published in proceedings of Academy of Natural Sciences of Philadelphia, September 28, 1875, page 404, the professor says that 'a remarkable peculiarity of the vertebræ of the series is the longitudinal axial perforation of the centrum. They present the character observed in *Archegosaurus* and other *Stegecephalus* Batrachia; but which also exists, according to Gunther, in the living Rhynchocephalous lizard—the *Sphenodon* of New Zealand. The bones of the limbs and scapular arches are so decidedly reptilian, and so unlike those of any Batrachia with which we are yet acquainted, that I am disposed to refer them to the former class. And as there are several points in which the fossils resemble the order *Rhynchocephalia,* I refer them provisionally to that neighborhood. They constitute the first definite indication of the existence of animals of that type in the Western hemisphere. Associated with these Saurians we found teeth of two species of fishes, which are important in evidence of the position of the beds in which they occur. One of these is a new species of *Ceratodus,* Agass., and the other a *Diplodus.* The former genus is characteristic of the Triassic period in Europe, one species having been found in the Oolite. It still lives in North Australia. In both these respects the *Rhynchocephalian* lizards present a remarkable coincidence. *They also belong to the horizon of the Trias in Europe,* and the only living species is found in New Zealand. Thus it would seem that a fragment of this fauna, so

*7th Ann. Rep., Geol Surv. of Ind , p. 256.

ancient in the Northern hemisphere, and so remarkably preserved in the Southern, has been brought to light in (the Wabash valley) Illinois.' He names the new Reptilia, *Cricodus heterolitus*, and *Clepsydrops collettii*, the fishes *Ceratodus basilatus* and *Diplodus vinsolvii*, and adds that while the first are so distinctly of Triassic type, that the last has not before been found above the Carboniferous, and waits further material before venturing a decision whether they belong to *Triassic* or *Permian* time."

We can only say at this time, the question is still an open one. If the correlation of the channel sandstones of Parke county which fill channels that cut down to and through Coal III, correlate with the similar sandstones of adjacent Illinois and southwestern Indiana, then it will be seen that previous to their laying down, the coal measures of the State have been tilted at an angle that would place nearly their whole thickness above sea level in Parke county, while a score or a little over of miles to the southwest, nearly the whole of the coal measure column, as preserved in this State, seems to have been under water. This exposed condition of the eastern part of the measures seems to have resulted in the strata, from Division VI up, having been carried away, with valleys extending down into the measures to Division III.*

108. Glacial Deposits.—The fact is a familiar one to nearly every one in Indiana, that, except over a small triangular area in the southern part of the State, the hard or consolidated rocks of the State are overlain by a considerable thickness of soft sands, clay and gravels. These make up the general surface soil, and are the only materials penetrated by the majority of the wells of the State. This soil differs, however, from the soil of the States farther south, first, in its unusual thickness, and second, in that much of its material is entirely different from the rocks immediately underlying it, or even exposed in the same drainage basin. In thickness these unconsolidated deposits vary from nothing up to nearly 400 ft. In material they consist of boulders, angular, rounded, or with both flat and rounded surfaces, scattered irregularly in a bed of sandy clay known as "boulder clay," till, or commonly in Indiana as "hard pan," together with usually smaller deposits of sand and gravel. A plate in XL, showing coal at Crawford No. 1 mine, illustrates a fairly typical exposure of boulder clay. A study of the drillings in the body of the text will show the way these materials vary in thickness and in proportional amount.

*Note.—These sandstone filled valleys were thought, at the time Mr. Collett wrote the above, to be ridges of Mansfield sandstone projecting up through the coal measures. Their true character was first noted by Mr. Hopkins in 1895.

The boulders in this boulder clay may vary in size from pebbles an inch in diameter and down up to many feet in diameter. An examination quickly reveals a large proportion of boulders of granite and similar igneous and metamorphic rocks, none of which are found as regular deposits in Indiana. An examination of some of the larger ones will often show one or more flat sides that seem to have been planed off and to have been much scratched in the process. Further, there are often found in Indiana exposures of the harder of the underlying rocks whose upper surface appears to have been planed and scratched in a manner very similar to the smooth faces of the boulders. Again, examination of a considerable bluff of this boulder clay shows that as a rule the materials have not been laid down with any regularity or apparent bedding. These deposits have been very extensively studied during the past 20 years, and it is now generally recognized that they were laid down by great glaciers or moving fields of ice, which, starting from different points in the Dominion of Canada, and at different times, pushed their way southward like enormous planes, gathering and grinding up great quantities of rock and dirt and carrying it forward to be dropped at a greater or less distance to the south of their original position. In this way granite boulders from Canada are found scattered over most of Indiana.

In the coal area these glacial deposits cover all except the eastern edge of Greene county, most of Martin county, the southwest corner of Daviess county, from whence the limiting line extends from northeast to southwest across northwestern Dubois, northern Pike, central Gibson and northwestern Posey counties, the area to the east and south of this line never having been covered by the ice.

The thickness of the glacial deposits increases from south to north. At the southern edge they thin out very gradually, so that it is often difficult to determine the exact former extension of the ice sheet. Careful study by many geologists has shown that the greater thickness to the north is in part due to that part of the State having been invaded more than once by ice. In some of these later invasions the ice sheet seems, after reaching a certain extent, to have melted as fast as it moved forward, so that its front line for a time stood still, and the rock and dirt carried forward to that line was heaped up, forming more or less of an irregular ridge. Such a ridge is called a "moraine." Such a moraine crosses northern Vigo county and southwestern and central Parke county. To the south of that the drift will average about 30 ft. deep; to the north it increases until in Benton county it averages 200 ft. The white clay covering the glacial area south of the moraine in Vigo county is thought by Mr. Frank Leverett, of the

U. S. Survey, who has studied the area extensively, to have possibly resulted from the advance of a glacier of which no trace now exists in Indiana, on account of its not having advanced far enough to escape being covered up by the later glacier that reached Vigo county.

The relation of these glacial or drift deposits to the older rocks is one of marked unconformability. The general land surface of southwestern Indiana would appear to have stood at least 100 ft. higher above sea level before the ice age than at present. The evidence of this is seen in the fact that the present drainage level is about that height above the preglacial drainage. Thus, the Wabash river in southwestern Indiana flows on the top of about 100 ft. of glacial deposits that filled its old channel, and the same of the other streams. But between the ice age and the present time the southwestern part of the State has evidently stood at a much lower level than at present. One result of this was to allow the streams laden with dirt from the glacier or from the fresh glacial deposits, to fill up the stream valleys that, starting in the glacial area, run southward through an unglacial area. In some cases these valleys, as with the east fork of White river, appear to have been filled up probably 100 ft. or more above their present level. Traces of these old deposits can be seen along the banks of such streams many score of feet above the channel of to-day. In these cases, as far as observed, the streams flowed to the west, so as to have been dammed up by the ice sheet, and these deposits may have been made while the water was thus backed up. As a secondary result of this filling, when the streams began to cut down their channels again after an elevation of the land, it is frequently found that they did not cut directly down into their old channels, but often started a new channel, especially if by so doing they could cut off a loop and so shorten their courses. Good examples of this are found in Martin county, as described under that county.

IX. SUBDIVISIONS OF THE COAL MEASURES IN INDIANA.

109. The COAL MEASURES.—It has been customary in the past, as shown by the geological maps of Indiana issued by the State Survey, to divide the coal measures of the State into three divisions as follows:

3. Upper or barren coal measures.
2. Middle or productive coal measures.
1. Lower coal measures or millstone grit.

In making such a division it was usually stated that the divisions were purely artificial and made for convenience only. These divisions have never been very strongly insisted on, except perhaps between 1 and 2, and as an unconformability exists at that horizon, the division was well made. Recent studies have shown, however, that certain workable coals usually placed in Division 2 belong well up in 3, as that has usually been defined. As the separation of Division 2 and 3 was purely on the lack of workable coals in 3, it would seem better to put the two divisions together. A massive sandstone, the Merom, which we usually put in Division 3, may well be considered by itself, as it lies unconformably on the coal measures wherever found, and further, some question has been raised as to whether it is really of carboniferous age.

Furthermore, deep drillings in the coal area have seemed to show that the massive sandstone known as the millstone grit occupies in Indiana only a limited area along the border of the coal field, and to the west is largely replaced by shales containing coal beds. While in some cases there is little doubt that these shales and coal beds lie in eroded depressions in the millstone grit, in others there is a question as to whether the massive sandstone, being a shore deposit, was not represented by shales and coal beds at a short distance, which were laid down at the same time, and so horizontally equivalent. Again, over much of the coal field unconformability between 1 and 2 is not noticeable, the sandstone of 1 is not so distinct in its structure and character from massive sandstones of much later date as we had been led to suppose, as may be judged by the fact that it was frequently confused with higher coal measure sandstones by the first survey, and finally, there are other unconformabilities at higher levels that are but little less marked. Hence it has been thought best to treat the coal measures of the State as a unit, to be divided up into as many divisions as the facts will warrant. In the economic discussion of the coal

measures it is of considerable importance that some satisfactory method be adopted whereby it will be possible to indicate the vertical position in the coal measures of any particular coal or rock bed.

110. PREVIOUS SYSTEM.—In his first geological report on the coals of Indiana, Mr. Cox adopted, as a temporary expedient, the use of letters to designate the different coal beds. He says:* "In advance of a more thorough study of the coal measures of this State, it is a matter of some importance to be able to decide upon a system of numbering that will not prove objectionable before the completion of the survey, and yet enable us to show at a glance, in each section, the equivalent beds of coal. For the present, therefore, I have thought best to omit the system of numbers, and adopt instead thereof, corresponding letters for equivalent coal beds. By this means we may construct, after completing the detailed survey of the coal measures, a general vertical section that will be harmonious in all its parts." He accordingly called the lower bed A and the successively higher beds B, F, G, H, I, J, K, L, M and N; A, F, I, K, L and M or N being the principal beds. B was sometimes applied below the millstone grit, sometimes above; M of many of the counties is equivalent to N in the other counties. A 4-ft. coal bed lying above N was not recognized as higher than L or M. It was called O in 1896 by Mr. Scovell, who first recognized its true position.†

111. INADEQUACY OF OLD SYSTEM.—The system as started has been retained up to the present, though, probably due to the below indicated causes, it has largely fallen into disuse. In starting the present survey it was our own purpose to retain that system, and for a considerable length of time this was done and the attempt made to make all local sections fit the section given by Mr. Cox for the State in his second report. Several difficulties were, however, encountered: First—We found about twice as many coal beds as the system, as applied, gave room for. Second—The application of the system to the coal beds found contained so many errors as to make the past application at great variance to our own. To illustrate: Let us take the four northeast townships of Sullivan county as given on the map accompanying the report for 1870. Prof. Collett starts with the section at Sullivan. Of 37 points which came within our notice, at which he had referred the coal to the upper coal at Sullivan, the present survey seemed to show that 14 were correctly correlated, 5 should have been the first coal above, 15 the first coal below, and 3

*1st Ann. Rep. Geol. Surv. of Ind., pp. 18-19.
†21st Ann. Rep. Dept. of Geol., etc, 1897, p. 517.

the second coal below. Of coal at 17 points correlated with the coal at Sullivan at 265 ft., we found 3 to be correct, 4 should have been the coal above and 10 should have been the next coal below. These errors were found to be so abundant through most of the field that their correction would almost amount to the application of a new system. Third, and most important—The exact equivalency of the coal beds has yet to be proven in a large proportion of cases, especially with the lower coals. Many only slightly familiar with the coal fields imagine the problem of determining the exact correlation or equivalency of the coal beds a simple matter. It would be so were the popular idea of the regularity of the coal beds a true one. But as one becomes more and more familiar with the lack of regularity in the coal measures, he will have less and less confidence in exact correlations. He finds a coal which appears to underlie all of one county with an average thickness of from 4 to 6 ft., in an adjacent county averaging from 4 to 6 in., and only developed in certain localities. In places two beds are two or three score of feet apart, while not many miles distant they are mined as a single bed of coal. In many cases coal beds which have long been considered as distinct beds, one 40-50 ft. above the other, have been shown by mining to be the same bed. It is often the case that a section of the coal and roof taken at one part of a mine will be entirely dissimilar to that taken at another part of the mine. Thus, it is quite common to find a shale roof in one part of a mine and a sandstone roof in another part, or a limestone roof. As a result of this constant variability it has been found very difficult or often impossible to prepare type columnar sections of the lower coals, and frequently when prepared, their unreliability has been clearly demonstrated by the first test made of them. As before stated, the coals and strata of the upper part of the coal measures are more regular, but even with the information at present obtainable there are large areas where the correlation of the coal is extremely uncertain, and there is hardly a township in the whole area in which the vertical position of all the coals found at different points is beyond question.

In view of these facts it became evident before the survey was half completed that the old system would have to be entirely remodeled or a distinctly new system adopted. The latter course was thought to be the better. In arriving at a decision it was found of advantage to examine the systems in use elsewhere, and the extent to which they met or failed to meet the conditions existing here.

112. METHODS OF NAMING COAL BEDS.—Three methods of naming coal beds are in common use: First—That of naming them from some locality, as geological formations are named, or from some pecu-

liarity of the coal bed itself; as, Pittsburg bed, Red Ash bed, etc. Second—By the use of numbers, as in Illinois and Kentucky. Third —By the use of letters, as in this State since the first survey. In some places the first of these methods is combined with one of the others.

The principal advantages of the first method over the others are two: First—The discovery of new beds does not introduce confusion into the system; and, second, where the correlation of a bed is in doubt, it can simply be given a new name. There are also two principal objections, and these apply as well to the present method of nomenclature all through stratigraphical geology. First—The names in themselves give no hint of the relations of the beds of coals; and, second, there is likely to follow a multiplication of names which may become very confusing.

113. Requirements of a Good System.—The last two methods are simple, the first is elastic. An ideal method should be both simple and elastic. It is doubtful if any method can be found at once perfectly simple and perfectly elastic. The proportion of simplicity to elasticity must be determined by the state of our knowledge of the field. In an unexplored field the system must be very elastic to allow each new discovery to be put in its proper place in the system, while in a field that has been thoroughly and completely explored, the system may well be wholly inelastic for the sake of simplicity. Our state of knowledge of the Indiana coal field would seem to warrant our selecting a system in which simplicity should take precedence over elasticity; in other words, which shall be, first, simple; second, elastic. To obtain both means a double system. That it may be first simple, some simple system must be applied to those principal features about which our knowledge would seem to be complete enough to warrant the application of a perfectly inelastic system. The elastic portion of the system must then take care of the rest as best it can.

114. Basis of Simple System in Indiana.—In this connection the work of the present survey has brought out the following points:

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

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

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

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

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

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

115. System Adopted.—For the simple part of our system it is proposed to divide the coal measures vertically into eight spaces or divisions to be designated by the Roman numerals I, II, III, etc., these divisions to be based on the position of some principal coal beds or horizons. In order to give definiteness to the system, it will be based on the vertical position of the worked coals as found in northern Clay and Vigo counties, that region being chosen principally because of the abundant developments in that area having rendered the relative position of the principal beds quite certain, in many cases two or three of the beds chosen being found in the same shaft.

Along the eastern edge of Clay county, and in general along the eastern edge of the Indiana coal field, occurs a very persistent massive sandstone. This is sometimes a fine conglomerate or grit and was called the Millstone grit or conglomerate by the first survey, or more recently the Mansfield sandstone. This sandstone is frequently underlain by one or two coal beds of minor importance. The sandstone and accompanying underlying coals are separated from the rocks both above and below by slight unconformabilities. It thus becomes a distinguishable division of the coal measures and the vertical space which it is supposed to occupy will be called Division I.

The main worked coals all occur above Division I; of these there are four in northern Clay county and two additional beds in Vigo county, while in southern Indiana coals occur between the lower block coal in Clay county and the Mansfield sandstone. The minor beds occurring in the same space, some of which are very locally of good, workable thickness, will not be now considered.

We have here, then, the basis for seven space divisions. Of these the uppermost coals can be traced with considerable certainty. The coal at West Terre Haute being persistent and traceable the whole length of its outcrop. The next coal below it, locally known as the "big vein," while not so persistent as the coal above, has, we believe, been traced as a horizon from the Ohio river to northern Warren county. The "rider" at Brazil, while not very important or readily recognized in the northern part of the field, to the south appears as a continuous

coal bed for 100 miles and can be traced readily and with great certainty. Descending from this the coals appear in smaller and smaller basins and correlation is attended with more and more uncertainty, so that the conviction has grown upon the members of the survey that the lower coals do not occur at widespread horizons, and therefore any attempts at exact correllation between distant points will be fruitless. However, as workable beds are found in this space, and as some of these beds are of great importance, it becomes desirable to extend our system to them. As it is found that workable coals occur at such distances below the "rider," as traced, as to divide the rocks into from one to three divisions, according to the aggregate thickness, it will be convenient to divide the time space represented by these rocks into three divisions to be known as Divisions II, III and IV. The upper and lower block coals will be known as Coals IV and III, respectively. The rider, most typically developed at Petersburg, Pike county, where it is 8 to 10 ft. thick, will be called Coal V. The "big vein," worked at Turner, Stanton, Seeleyville, Coal Bluff, Coxville, etc., will be known as Coal VI.

The space from any one of these coals to the next will be known as a division. Thus, Division VI will comprise all of the rocks from Coal VI to Coal VII, including Coal VI.

Above the "big vein" at Seeleyville is a coal bed of frequently or generally workable thickness. It is the bed worked above drainage at Clinton and Lyford, and believed to be the bed extensively worked at Terre Haute. A workable bed at a similar height is commonly found, though on account of the presence of the thicker "big vein" it is but little worked commercially. The space from the big vein to it will constitute Division VI. Still above the bed last mentioned is a coal bed which locally along Coal creek, Vigo county, and Brouilett's creek, Vermillion county, is of workable thickness. Division VII will extend to this coal bed from the bed last mentioned.

At Merom, Sullivan county, the coal worked by shafts is believed to be at this horizon. Near the top of the bluff at the same place is a massive sandstone, called in the old reports the Merom sandstone. It lies unconformably upon the rocks below, and as no coal has ever been reported as found in it or above it, it is taken as marking the top of the coal-bearing rocks of the State. The space from it down to the coal mined by shafts at about river level at Merom will be taken as Division VIII.

The age of the Merom sandstone is in doubt, but temporarily it, with any overlying rocks, exclusive of the drift, will be considered as in Division IX. It will be noted that with the exception of Divi-

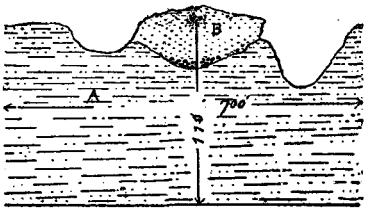
sions II and IX, a major coal is taken as the bottom of each division, so that in representing the outcrop of any division on the map, the bounding lines will practically represent the lines of outcrop of the coals at the top and bottom of the division. The coal at the botttom of the division in each case will be considered to be in that division, and in general will be designated by the number of the division in which it is included. Thus, the "big vein" at Seeleyville, etc., will be called Coal VI, the rider at Brazil, Coal V; the top block at Brazil, Coal IV, etc.

In the majority of cases one or more minor coal beds occur between the major beds. In all cases where more than one coal is assigned to a division, the coals will be distinguished by the addition of a, b, c to the Roman numeral. Thus, three coals in Division V would be called Coals V, Va, Vb. In cases where it is known that a coal bed or group of beds are above a certain division, as say Division II, and below another division, as say Division VI, but data is lacking for any closer adjustment to the time scale, it may be named by the combination of two or more divisions; as, in the case above, it might be called Coal III—V.

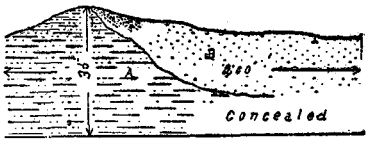
In order to make a reference to a minor coal definite, there could be added the name of the basin in which it occurs, or of some locality at which a typical section containing it is found. Thus, a comparative study could be made between Coals VIb of the Turner-Coxville basin and Coal VIa of the Petersburg-Evansville basin, the basins in this case being named from the towns at their extreme limits. Or they could be designated VIa (Stanton) and VIb (Petersburg), referring to typical sections at those places.

X. EPITOME OF STRATIGRAPHY.

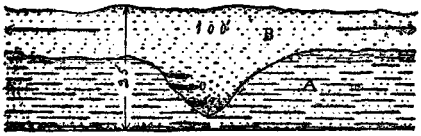
116. Relation of Coal Measures to Lower Carboniferous.—The relation of the coal measures to the Lower Carboniferous is everywhere one of unconformity, evidently quite a time period intervening between the laying down of the Kaskaskia and the lowest beds of the coal measures. This is best shown by the accompanying figures, Plates VII and VIII.



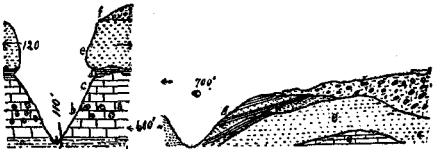
1. Black rock.



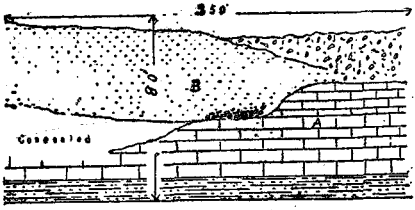
2. Little Pine creek.



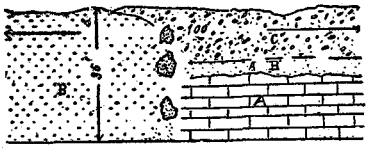
3. Turkey run.



4. Sugar creek.



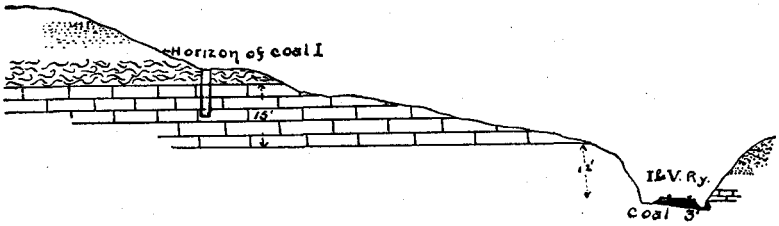
5. Ramp creek.



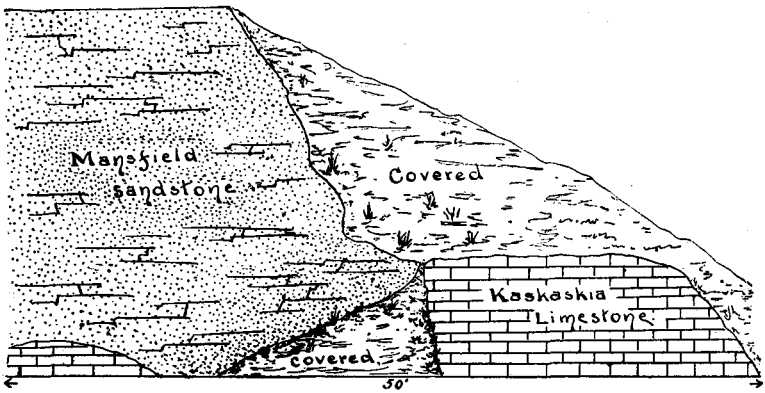
6. Byrd branch.

Plate VII. Sections illustrating the unconformity by erosion between the lower carboniferous and the coal measures, by T. C. Hopkins. (Area of Sheet A.)

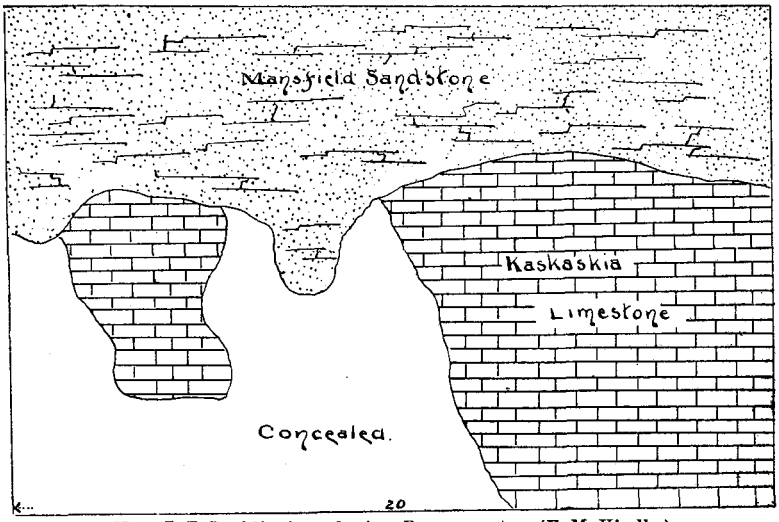
The evidence of this nonconformity is shown in four different ways: (1) The observed relations as shown in the figures; (2) the materials of the lowest members of the coal measures are largely derived from the underlying rocks, Keokuk material especially being recognized; (3) the irregular thickness and entire disappearance over large areas of the uppermost division of the Lower Carboniferous; (4) irregularities in thickness of Division I of coal measures.



At Nelson's cut, near Freedom, Owen county. (C. E. Siebenthal.)



Near Pleasant Valley, Martin county. (E. M. Kindle.)



Near J. E. Poehline's coal mine, Perry county. (E. M. Kindle.)

PLATE VIII. Same, area of sheets B to F. (From sketches by C. E. Siebenthal and E. M. Kindle.)

As the Lower Carboniferous rocks underlying the coal measures are quite commonly limestones, with their characteristic fossils, this nonconformity is often readily observed by noting the relative level of the limestone and coal measure sandstone. In many cases there may be room for doubt as to whether this is due to unconformity, high dip or fault, yet in some cases the contact of the two is clearly visible, the upper surface of the lower showing the effects of the erosion, while the lowest part of the upper member, as shown in the figures, is not unfrequently a conglomerate. Thus, in Fig. 4 of Plate VII, the top of the Lower Carboniferous in the figure to the left is 65 ft. above drainage, while a short distance up stream the limestone is below drainage.

The Kaskaskia was the last member of the Lower Carboniferous to be laid down. In the south part of the area it shows a section of limestones and sandstones of nearly or fully 150 ft. Going northward this becomes thinner and seems to disappear in Putnam county, from which point northward the coal measures rest on the lower members of the Lower Carboniferous, the Knobstone underlying a large part of the north end of the coal field. How much of this thinning to the north is due to pre-coal measure erosion and how much to an original thinning out of the deposits in that direction can not be told with the information at hand. It seems probable that the latter factor is much the most important. Thus, in Orange and Martin counties, the upper bed of the Kaskaskia is a limestone 10 to 20 ft. thick and lying but a few feet below the horizon of Coal I. In Greene county this limestone bed gradually thins down to an irregular bed wanting in many places and showing a thickness of very few feet in other places, and, as before, just below Coal I. Going north into Putnam county this upper limestone appears to have entirely run out and the coal measures rest on the upper Kaskaskia sandstone. As this sandstone has no small resemblance to the sandstone of Division I, it appears to have been taken to be a part of what is now called Division I. As this tendency to thin to the north is also observed in the other formations of the Lower Carboniferous, it seems safe to assume shore conditions to the north during the Lower Carboniferous period, and that this shore line gradually shifted to the south. It would seem, therefore, as though the land period following the laying down of the Lower Carboniferous was but the culmination of a tendency long active. How far to the south and west the shore line advanced cannot be told, but evidently beyond the present borders of the coal measures.

From a third standpoint the evidence lies in the materials composing the massive sandstone of Division I. In places this sandstone is quite gritty and examination shows that at least some of this coarse-grained material is composed of more or less comminuted pieces (?) of geodes, or of the geodes themselves, presumably from the top of the Knobstone or bottom of the Keokuk or Harrodsburg rocks. See further under Martin county.

One of the strongest points of evidence is found in the varying thickness of Division I, due to the uneven bed upon which it was deposited. As an illustration of this may be taken the varying thickness of Division I about Cannelton in Perry county. Near Rock Island, Coal II, or the main Cannelton coal, is at least 125 ft. above the Lower Carboniferous rocks. To the north and west this distance is found to vary greatly, so that at places the Lower Carboniferous limestone is found within 20 to 30 ft. vertically of the entries on Coal II, and at one point the limestone was observed only about 10 ft. below Coal II. It is said that on the south side of the Ohio at one of the mines the coal ran out squarely against the limestone; however, this may have been due to a fault.

Section 1. Division I.

117. This division corresponds with what was in the early days called the "Millstone Grit." In the earlier State reports it is commonly referred to as the "conglomerate sandstone," or conglomerate." In 1896 Mr. T. C. Hopkins, who studied it as a source of building stone, called it the Mansfield sandstone, as it was there typically exposed and extensively quarried. As a matter of fact, neither the gritty facies nor the exposure at Mansfield are typical of the larger part of the sandstone of this division. Fossils collected in this division by Mr. E. M. Kindle and determined by Mr. I. C. White indicate that in stratigraphic position it corresponds with the Pottsville conglomerate of the Pennsylvania rocks, so that the use of the term "millstone grit" in a stratigraphic sense appears to have been correct. Considering, however, that in Indiana this formation is a grit at only a few spots, the use of the lithological term in a stratigraphic sense is misleading and undesirable. Furthermore, we are interested here principally in the coal associated with this sandstone, and neither "millstone grit," "conglomerate" or "Mansfield sandstone" properly include the accompanying coal and shale. While, therefore, "Mans-

field sandstone" will often be used to designate the massive bed or beds of sandstone in this formation, the term "Division I" will be used for the formation as a whole.

The bounds of this division are determined by two unconformities. The lower one was mentioned above, the upper one, which is not so marked, will be spoken of below. As a matter of practice, however, it is only here and there that these unconformities can be detected and other means must be employed. For the lower border the presence of the thick beds of Lower Carboniferous limestone with their characteristic fossils makes a certain downward limit. In using the limestone an error is liable to arise through the fact that the limestone is often overlain by unfossiliferous shales or sandstones of Lower Carboniferous age. At its upper limit no such reliable criterion exists, and often an arbitrary bound must be made, based principally upon the presence of a workable bed of coal and an abundance of shales overlying the sandstone.

118. Principal Features of Division I.—Plate IX, Figs. 111 to 131. As suggested by the names previously used, this formation is principally sandstone. This sandstone, which generally appears as a single bed, is commonly coarse-grained, cross-bedded, yellow or brown. Locally the grain becomes fine enough to serve as a whetstone, while not far away it becomes a coarse grit or fine conglomerate. Sometimes a somewhat coarser conglomerate occurs at its base, but is then only a foot or two thick and of a very limited lateral extent. The crossbedding, commonly one of its most characteristic features, is often absent, making it possible to use the stone for building and structural purposes. The yellow color is the most common, but it is frequently found approaching a white and more often it becomes a dark brown, resembling the well-known Portland building stone.* In thickness this sandstone varies from 0 up to over 140 ft. It is commonly without marked bedding planes, and often presents vertical or overhanging cliffs nearly or quite its full thickness.

In some places this single bed of sandstone comprises all of Division I, but generally there are shales, coal and iron ore found at or near its base and to the south at a horizon above its base. The shales are usually only a few feet thick, but in places thicken up to 10 or 20 ft. They are generally of a dark blue color or black. The iron ore found at the base of this division is somewhat abundant in Greene county, and elsewhere, but is lacking in quality, containing too great an ad-

* Of this stone as a building stone, see the report of Mr. T. C. Hopkins, in the 20th report of this Department, and of its use as a whetstone, the report of Mr. E. M. Kindle in the same volume.

mixture of sand for profitable working. In many localities the bed is more nearly a ferruginous sandstone than an iron ore. It has been worked to same extent and at one time or another 14 blast furnaces have been erected to work this and other iron ores of the State. This ore was not able to compete with richer and purer ores, and as a result most of these furnaces have gone to ruin, while the last one went out of blast in 1893.

The coal in this division is confined to one horizon near the bottom of the division, and in the south to two horizons not far apart. While in a few places the coal at this main horizon runs up to a thickness of 3 or 4 ft. and is of an excellent quality, as a rule the coal is both too thin and too poor to work commercially. It is inclined to be very pockety in its distribution, especially to the north and south, its best development being reached in Martin county. In many places it consists in part of bone coal, which may locally become a cannel coal.

119. Division I in the Area of Sheet A.—A reference to the map and legend of Sheet A will show at once its distribution in Warren, Fountain, Parke, Montgomery and Putnam counties. In general, the area of outcrop will be seen to have an east of south direction, through eastern Warren, Fountain and Parke counties, and overlapping slightly into southwestern Montgomery and western Putnam counties. In width the outcrop varies from a quarter of a mile in the face of the hills west of Walnut creek in Putnam county to 12 to 15 miles in northern Putnam and Parke and in Warren counties. The heavy mantle of drift renders it impossible, over most of the area, to draw the limiting lines accurately and in detail. Where Division I extends down the valleys of streams flowing to the west or south, its outcrop can be more accurately mapped. Its influence on the general topography in this area is minor, and is principally seen in making more abrupt banks along the streams, with often vertical bluffs. This is most noticeable in Parke county, where it results in much picturesque scenery. Where fairly complete sections are obtained in this area, Division I shows principally as a massive sandstone 75 to 100 ft. thick, resting on the Lower Carboniferous.

Coal I is found at a few places, generally only a few inches or a foot thick, in Warren and Fountain counties. It would appear to occur there only in very limited lenticular pockets laid down in hollows of the underlying surface. There is hardly a place in these two counties where the coal has been worked with any regularity even for local trade, most of the openings going no further than to determine the thickness and character of the bed.

In Parke and Putnam counties Coal I becomes somewhat more regular, and in some pockets thickens up to 2 or even 3 ft., or, including bone coal, to 4 ft. in one or two places. As a rule these thicker beds are very limited and often in a few feet or yards will run down to a thickness of less than a foot. Many of these pockets will serve the local trade near them, but hardly any will meet a large local demand, and at no place was this coal seen of sufficient thickness or extent to be mined commercially.

120. DIVISION I, SHEET B.—The area of outcrop on this sheet runs in a nearly north and south line with an extreme width of up to 20 miles. The thickness of the drift is, in this area, much reduced, so that the sandstone has become the main factor in determining the topography. The result is that the outcropping belt presents almost everywhere, but more especially toward its eastern limit, a rugged type of surface with narrow ridges and ravines and the intervening slopes generally steep. It thus becomes possible here to show the area of outcrop of this division with much more accuracy and detail than could be done on Sheet A. Division I in this area appears to have a larger pencentage of shale than to the north. Perpendicular bluffs of more than 10 or 12 ft. are not common, and none were found yielding complete sections of the division.

An interesting feature of the coal in this area is the presence in a few localities of two beds, separated by up to 10 ft. or more of shale and sandstone. The two beds appear to be parts of the same bed at most places. Coal I in this area, while reaching a thickness at points of 2 or 3 ft., is seldom of a thickness and quality to indicate even a fair local trade. It is too often the case that where the quality is desirable it is too thin to work, while where of workable thickness it is not of marketable quality. In some townships no coal over a foot thick was seen or reported. In southwestern Owen county Coal I is often partly bone or cannel, and at some points will answer well for local trade. Practically no workable coal is found in this area, except it be in connection with the fire-clay or shale or other accompanying material.

West of its outcrop this division appears to have an irregular and limited existence, as wells or drillings at many places a little to the west find its sandstone replaced by shale.

121. DIVISION I, SHEET C.—The outcrop of Division I as shown on Sheet C, spreads over about the eastern two-thirds of Greene county. Near the east county line it appears crowning the highest ridges. Going westward it gradually descends, but still keeps above

drainage until White river is reached. Its exposure west of White river is due to the higher formations having been cut out by preglacial erosion, so that it is there largely below drainage and covered by a thick mantle of recent sediments or drift. As on the sheet just north, while small bluffs of the sandstone are common, and hillsides show half exposed ledges of sandstone, but few if any vertical cliffs are found exposing nearly the whole of the division. The eastern edge of the county is not in the limits of the drift, and the rugged topography there makes possible the mapping of the lower limit of the division with considerable accuracy. As White river is approached the glaciated area is reached, but only slight evidences of its existence are seen in the here and there more rounded contours.

Coal I becomes more regular in this county except near its eastern limit, where it is generally wanting or only a few inches thick. At a few places it reaches a thickness and extent which may permit a small amount of commercial working under more favorable conditions than now exist. It was formerly worked and shipped by rail near Owensburg, where 18 or 20 in. thick, and in a few neighborhoods is extensively worked for local trade. Its thickness is generally under 2 ft., and very frequently under 1 ft.; and while at a few places it attains a thickness of 3 ft., under existing trade conditions it may safely be said that no commercially workable coal exists there except it be worked with the underlying clay or overlying shale or sandstone. In quality the coal is usually a semi-block, occasionally being mined without powder, but generally requiring shooting, and while often of good quality is generally reported as rather poor and not suited for blacksmithing.

122. Division I, Sheet D.—The outcrop of Division I on this sheet is almost entirely confined to Martin county. As regards the exposures of sandstone the conditions here are similar to those on Sheet C, except on White river and especially around Shoals. Along White river are found not only excellent exposures of the sandstone, but at numerous points are abundantly exposed the gritty or conglomeritic facies. At the Pinnacle a little north of West Shoals the sandstone shows a solid perpendicular face, variously estimated at from 110 to 170 ft. thick. At points west of Shoals the ground is literally paved with geodes, usually quite small but sometimes as large as the fist or larger, which appear to have weathered out of the sandstone. In places these can be seen in the sandstone.

Coal I, while generally not workable, is of workable thickness, extent and quality south of White river a few miles west of Shoals, and at a few other places. The roof, while sometimes of sandstone, is more

often of shale a few feet thick and then sandstone. At a few points Coal Ia appears above Coal I, but was nowhere seen of workable thickness. Coal I here reaches a thickness of over 3 ft. of good, workable coal, though at most openings it will run under 2 ft. in thickness. Over large areas the coal is wanting and at the same horizon appears a bed of kaolin. This is certain to be utilized in the future, and it is quite probable that when that time comes some of Coal I will be used in its development.

123. DIVISION I, SHEETS E AND F.—The sandstone of Division I is here still a very important factor in making the topography, which is in this area extremely rugged. The coal here, however, becomes thinner and more pockety and appears at two horizons, of which the upper is the most important. Yet workable coal can hardly be said to have been found at either horizon. The sandstone is somewhat broken up, as the upper coal as we go to the south, appears to be getting farther and farther from the lower, and the sandstone that comes between is often more important than the sandstone above Ia. There are many stratigraphic questions still unanswered in this area and the area of Sheet F. The principal one is as to whether this lower sandstone thins to the north, and possibly also the underlying coals and shales, while the upper one persists, or is it the lower sandstone that persists, or as a third alternative does Coal Ia and its accompanying shales thin out, allowing the two sandstone members to come together and form what appears as a single body of sandstone to the north? Near the Ohio river Coal I is only found at a few places and appears to be generally absent, and, what is of especial interest, when found it appears to be above the conglomeritic facies of the sandstone. Coal Ia here is quite persistent, but lies much nearer the top than the bottom of what is thought to correspond with Division I to the north. If the workable coal at Shoals represents either or both of these coals as is generally assumed, it becomes evident that the conglomerates in Martin county and in Perry county are not at the same horizon. If they are at the same horizon, then what have been assumed to be coals I and Ia really belong above the Mansfield sandstone, and the Mansfield sandstone near the Ohio river occurs only here and there in some depression eroded out of the Lower Carboniferous. While this view has many things in its favor, I am inclined to take the former view and to consider the gritty or conglomeritic facies as the result of local conditions purely, and liable to be found at very different horizons. Thus the abundance of geodes in Martin county in the conglomeritic sandstone suggests the neighborhood of the mouth of a river from the east.

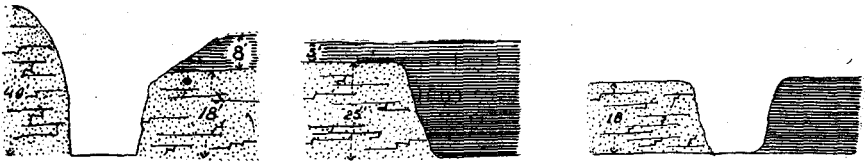
One of the main factors rendering the solution of these questions difficult is the unconformity existing between the Lower Carboniferous and Division I. In Perry county, near Cannelton, where extensive operations on Coal II make it possible to use that coal as a base line, the fact that Division I varies from 10 ft. to 125 ft. or more in a short distance is clearly recognized and no confusion results. But to the north where Coal II is not generally worked or workable and rock exposures are seldom extensive, and generally small and scattering, these irregularities cannot all be allowed for, and among the four or five sandstone horizons with which the geologist starts from the Ohio, he readily loses his way stratigraphically, and when he reaches Clay or Parke county where he has but one sandstone and the stratigraphy is simple, he finds it impossible to decide which of the sandstones of the Ohio river region has persisted. Practically no workable coal exists at either the horizon of Coal I or of Coal Ia in the area of these sheets. The division in this area contains some sandstone of value, as indicated in the reports of Mr. Hopkins and Mr. Kindle in 1896.

Section 2. Divisions II, III, IV and V (In Part) from Brazil Northward.

124. General Features.—An examination of Figs. 92 to 110 of Plate IX shows quite clearly a marked change in Divisions II to IV from north to south, assuming our correlation of Coal V to be correct. The correlation of Coal V from Clay county southward is given with much confidence. From Clay county northward it was impossible to trace it with the desired accuracy, and correlation was based principally upon the presence just above it of a limestone and other rocks, telling of marine conditions which followed the laying down of the coal, and upon its relation to what was thought to be there Coal VI. For this reason Division V from Clay county northward will be discussed with Divisions II to IV. Another reason for that treatment lies in the fact that from Clay county northward, what has been taken for Coal V is principally found closely associated with Coal IV; the two coals being commonly found at the same mines and in the same drillings, and it shares with Coal IV many of the block or non-caking features.

As shown by the figures, there appears to have been a very marked increase in the thickness and number of coals contained in the coal measures between Coal V and Division I from north to south. In Warren county Coal V appears to lie unconformably directly on Division I, while to the south they become separated by several hundred

feet. In arriving at an explanation of this, two facts should be kept in mind. The first is that an unconformity exists between Division I and the overlying divisions, and that this unconformity becomes most marked to the north. It was thought to have been observed by Mr. Kindle in Perry county, where shales of Division II appear to lie against the sandstone of Division I. In the mines of Clay county it is the irregularities in the upper surface of Division I that produce the pockety or basin nature of the block coals about Brazil, the lower block coal there resting in places directly upon ridges of the sandstone of Division I, and partly on the half-filled hollows between. Further north, especially in Warren county, this unconformity is better marked and more readily recognized. The accompanying figures from Pine



Figs. 18-20. Showing nonconformity between Mansfield sandstone and coal measures along Pine creek and its branches.

creek or its tributaries will illustrate the appearance there. In the second place it was assumed by the first survey and at first by this survey, that the worked coals in this part of the coal measure section were at the same horizon all over the field. As the work has progressed, however, there has been more and more impressed upon the members of the survey the feeling that the atttempt to correlate the worked coals of these lower horizons of one district with those of another must be done with the utmost caution, and that such correlations must never be assumed to have more than a homotaxic value. That is, that in calling coals in different districts each Coal III, it is not assumed that they were being laid down at exactly the same time, but only at about the same time relative to other coals, just as we might say of two events that they both occurred in the third century, though possibly coming nearly 100 years apart. Then, as the work was carried toward the Ohio river with a constantly increasing number of coals, it began to be questioned whether the correlations assumed were even homotaxial, or if it were not more probable that the lower coals there were laid down during a land period to the north and had no representatives in the northern countries.

With all the evidence in it must be admitted that there are many facts favoring the theory that deposits were being laid down simul-

taneously to the north and south, but that sedimentation was much the more rapid to the south, and that the coal immediately underlying the lower block coal at Brazil is at least the homotaxic representative of the first coal above Division I all through the southern countries. On the other hand, the evidence is just as strong or stronger in favor of the theory that uplift followed or occurred during the laying down of the Mansfield sandstone, this uplift being greatest to the north. That this was followed by coal forming conditions to the south and west, land erosion meanwhile taking place to the north. Gradually the coal forming conditions spread northward and eastward and probably culminated during the time of Division V, at which time the overlap reached nearly or quite to the original northeastern bound of Division I. In view of the doubt existing we have compromised by naming the coals as though the first theory were correct, but accompanying that by the caution that this is done purely for convenience, and must not be taken to imply intended correlation.

The number of coal horizons in Divisions II to IV at different localities varies from 0 to 14 or 15. While some of these horizons have been traced over one or more hundred square miles with great certainty, and over much larger areas with some doubt, it would seem probable that the majority of the horizons are only local and that were it possible to exactly correlate the different sections obtained there would probably be found to be many more horizons than the number given above. The intervening rocks are so variable that no constant characters were recognizable. It has been thought best to take the area around Brazil as the type locality for these divisions, on account of the value and extensive working of the coal, and describe the coals first to the north, including Division V, then to the south.

125. Divisions II-V, Brazil Basin.—East of the meridian of Brazil are found three coals, the lower two of which are commonly workable, and in a few cases, all three coals. These coals have been designated Coals V, IV and III, and are locally known as the "rider," "upper block" and "lower block." Of these the middle coal, or Coal IV, is the most persistent. For illustration of the stratigraphy of this district, see Figs. 336-341, 361-366, 406-413, and Plate XXXI.

These show Coal V to have a thickness of from 0 to 4 ft., with an average of probably less than 2 ft. Overlying the coal are two different covers which have led to a little question in regard to the correlation of the coal. One of these is the characteristic roof of Coal V to the south. Immediately over the coal is a bed of black bituminous shale, splitting into large sheets and characterized by the presence of fish scales and other fish remains, aviculopectens and other marine forms,

often pyritized, the whole indicating that that coal period was immediately followed by subsidence and marine conditions. Over that black shale is a limestone which here seems to be quite pockety, often reaching a thickness of 12 or 15 ft. and as often thinning out entirely. Sometimes these changes take place quite rapidly. Above the limestone comes either sandstone or shale, no regularity being apparent. In the other case the cover is a thickness of 20 or 30 ft. or more of clay shale, very suitable for clay work and largely used by the clay factories around Brazil. As a rule, in this case no limestone or black shale appears, but in the record of the old Brazil shaft the limestone appears about 30 ft. above the coal with the clay shale between.

In a drilling at the Gladstone mine at Lodi, Clay county, and exposed near by in the bank of Otter creek, are found two coals about 20 ft. apart and the lower one about 75 ft. above Coal IV. These seldom run over 2 ft. in thickness, are each overlain by a few feet of black sheety shale, resembling that over Coal V, and generally by a thin bed of ferruginous or clayey limestone, commonly only a few inches thick. They are separated principally by shale and appear to lie about 25 ft. below Coal VI. These coals resemble Coal V so closely that care should be taken to distinguish them. At Seeleyville a drill record reports still another coal above what is considered to be Coal V, making four coals in Division V at that point.

Coal V has been worked at only a few points in this area, the principal reasons being: Too thin; so near the surface as to be of limited distribution, and often without roof; too poor quality, the lower one-fourth or one-third being generally bone coal; the unusual excellence of the underlying coals.

Division IV in this area contains one coal horizon, though at one point a second horizon was reported. The space between Coals IV and V varies from 2 to 36 ft., with an average of about 20 ft. Where the two beds are closest together they are separated only by a clay, locally known as "white top." At these points Coal V appears to dip down sharply, and the clay would appear to be its under-clay. A possible illustration of this is seen at the Chicago Sewer Pipe Works, south of Brazil, as shown in Fig. 479. The strata between are the fire-clay of Coal V, two sandstones, unconformable with each other, and shale. In many of the sections no sandstone appears. However, there appears to be a regular sandstone horizon at which the sandstone lies unconformably on a lower sandstone or the shale or, these having been cut out, it lies directly on the coal, making the roof. This unconformity is well shown at quarries on either side of Otter creek, just east of the C. & I. C. R. R. bridge. In nearly every mine the roof is in part

shale and in part sandstone. Of the two roofs the shale is the weaker, often making a very poor roof, but, on the other hand, the coal under it is more regular and the more easily worked. Where the thickness of the shale is small it tends to come down, as is usual in such a case.

Coal IV, in this area, varies from 5 ft. down, and averages in the worked parts of the mine a little over 3 ft., being a little thicker than Coal III, with which it averages 3 ft. 1 in. It will therefore average about 3 ft. 2 or 3 in. The early reports gave an average of 4 ft. 4 in. The average for the whole field, not including areas where coal is cut out, will probably not be much, if any, over 2 ft., as in parts of the field not one 40 acres in 4 is workable. This coal almost invariably shows, usually a little below the middle, a band locally known as the "bench mining," composed sometimes of a 2-in. band of bony coal, sometimes of a band of hard, brittle coal that chips out readily, and at one place the writer noted a little clay at the height of the bench mining. The block nature of this coal was noticed in Part I. A feature existing in most cases is that in this bed the slips are most open at the top, and tend to offset at the bench mining, and often to become obscure below, while in Coal III the slips are more open at the bottom. The coal is non-caking, very free from sulphur and ash, and with the coal just below it, is more widely and favorably known than any other Indiana coal. Notwithstanding the thinness of these two beds about Brazil, they are and long have been extensively worked. In 1895 the yield of the Brazil block coal field, not including southern Clay county, but including the Center Point and Caseyville mines, was 1,340,321 tons out of 4,202,084 tons for the State, or nearly one-third. The question so often asked of how long this coal will last is a difficult one to answer. That the supply is limited, and that those portions of the field where mining is and has been carried on most extensively, are slowly but surely nearing exhaustion, must be admitted. But there are several factors which will tend to lengthen the life of the field very much. In the first place most of the companies at present operating in this field hold coal lands in this or adjacent fields that may prove more profitable than is commonly thought. In the second place, there are large areas in this field now considered to contain no workable coal. Considering the basin character of the coal in this district, with the consequent liability of drilling to strike the thin coal on the ridges, also the presence of preglacial cut-outs, so liable to render the testimony of drillings deceptive, it seems more than probable that some and possibly much of this barren territory may yet be found to contain workable coal. Next, the introduction of washing plants in the caking field is producing a coal which will serve some purposes as well as the

block coal and at less cost, and this withdrawal of demand will lengthen the life of the field. In the fourth place, while most of the basins now being worked are small, with much coal considered unworkable, there is a tendency, and with improved methods and machinery this will be accelerated, to constantly work thinner and thinner coals, so that much coal now considered unworkable will be worked later. Fifth, as the supply in this field approaches exhaustion, there will be a tendency to shift mining operations from this to other fields where similar or somewhat similar coals can be more easily won. On the whole it seems safe to say that the Brazil block coal field will last another 25 years, and possibly 50 years, with a diminished output. Closer than that it hardly seems wise to go. It should be remembered that those figures apply only to the Brazil field, and not to the block field as a whole, nor is it intended to imply that the Brazil field will be utterly exhausted in that time. There will probably be mines operating in this field for the next hundred years or more, but as an important source of coal it is estimated that this field will be exhausted in between 25 and 50 years.

Division III in this field contains only one coal, known as the "lower block coal." The space between Coals III and IV varies from about 10 ft. to 50 ft., but usually is between 25 and 35 ft., with an average of about 30 ft. The intermediate rocks are usually the fire-clay under Coal IV and shale, or the peculiar alternation of shale and sandstone in thin leaves, known as "fake." The clay under Coal IV is usually very sandy and is much used around Brazil in the manufacture of certain clay products. It tends to grade down into a sandstone, which, however, appears to have but slight downward extent. In places the "fake" makes the roof, tending to stand in the rooms but to flake down in the entries, while elsewhere the shale is the roof. Less trouble is had with the roof of Coal III than with that of Coal IV.

Coal III, or the lower block coal, varies from 4 ft. 6 in. in thickness down. It averages in working places about 3 ft. or possibly a little less. Its thickness is quite variable, as it tends to lie in rather smaller basins than Coal IV. It is nearly everywhere characterized by a smooth or knife-edge parting, less than half a foot from the top. The coal above this is usually a semi-caking coal, and in mining this coal tends to stick to the roof, breaking into small blocks when it falls or is wedged down. The lower or main bench is much like Coal IV, but, if anything, of a little better quality. One of the characters by which this bed may be most readily recognized is the presence immediately under it of a rash or bone coal and underlying good coal.

Coal II, as it will be convenient to term the underlying coal and bone, appears to be a distinct bed from Coal III, though in places they are so intimately associated that several inches of the bone coal adheres to Coal III and is taken up in mining. In most cases there is a little clay between Coals III and II, which may be a fraction of an inch thick, or thicken up to 8 or 10 ft. or even more. In thickness this coal varies from 0 to 3 ft. 6 in., being generally about half bone coal and half good coal, the latter having been found by experience to be too soft to ship. In some cases the good coal is absent, in others the bone coal. This coal seems to be confined to the hollows in the top of Division I, as it and its underlying clay always tend to run out as the ridge or edge of a basin is approached.

The block coals around Brazil lie in basins of from a few acres up to several square miles, as was the old basin north of Harmony. The coal is thickest in the center of the basin or swamp and thins to the rise, but is thought to nearly always extend over the ridges in a thin bed to the next basin. This fact and the remarkable persistence of the details of the coals indicate that the basins of the Brazil field are but parts of a large basin, their form being due to the irregularities of the surface upon which they were deposited. This major basin (which is taken as defining the Brazil block coal field) appears to lie between Raccoon creek in Parke county on the north and Eel river on the south, within the limits of outcrop of Divisions II to V, as given on the map.

126. Divisions II to V, on Sheet A.—As soon as Raccoon creek is crossed, going north, all certainty in the correlation in these divisions ceases and the application of the numbers to the coals is for convenience rather than to indicate exact correlation with the coal of the type locality just described. No constant character in the coals themselves was found. In the Minshall mining district there appear to be three coals, as in the Brazil coal field, but with a limestone between the upper and middle coals. It has been thought that this limestone is the same as the limestone found at points up Williams creek, on Sand creek, on Sugar creek near West Union, on Sugar Mill creek near the Fountain county line, at Yeddo, on Wabash Mill creek at the Falls, around Silverwood, Coal Creek P. O. (Snoddy's Mills), and elsewhere, so that the determination of the division to which it belongs involves the stratigraphy of most of Parke and Fountain counties. The principal coal of this area lies a little below this limestone. It is the coal worked at Minshall, Williams creek, Sand creek, Sugar Mill creek, Yeddo and Silverwood. Above the limestone is a coal

which reaches a thickness of 2 ft. 6 in. or 3 ft., and has been worked at some places. Below the coal under the limestone is a coal which is worked for local trade at a few places, but in parts of Fountain county becomes 5 or 6 ft. thick in places. Do these three coals correspond to the three block coals around Brazil, or is the limestone at the same horizon as the limestone over the rider at Brazil? That is a question that we are not able to answer satisfactorily. As stated, the peculiar characteristics of the block coals about Brazil were not observed in this area. On that basis we were led to assume that the coals of this area belonged in an entirely different basin, wholly disconnected from the Brazil basin, and that being so, it is possible there is no exact correspondence, and we are free to assign the coals to divisions without regard to the coals at Brazil. Practically, that has been done. In calling the coal under the limestone Coal V, it has been done upon the theory that the limestone, from its tendency to be persistent, is more likely to correspond with the limestone overlying Coal V in Clay county and all the counties to the south than to occur in Division IV, where no limestone appears in sections anywhere to the south. In view of the many facts suggesting that the two coals below the limestone are Coals IV and III, it must be acknowledged that our action is simply a compromise.

Assuming that the limestone belongs in Division V, it becomes necessary to suppose that Division III has been overlapped in most of this area, though pockets of it may still be expected, especially to the west, and it does seem to be found at Coxville, Mecca, Hillsdale, and probably elsewhere.

Division V, in Parke county, may then be said to show three coals, the lowest one a coal of excellent quality, at Minshall and Sand creek, with a thickness of from 3 to 5 or even 6 ft., overlain by shale and then by limestone. At times the limestone lies directly on the coal, making the roof; again it is found up to 20 ft. above the coal, with shale between, often but not always black. This coal is not persistently workable coal, as at Coxville, Mecca, West Union and at other places where seen, it was too thin to work, and sometimes runs out altogether, but on the whole it is the most valuable coal in these divisions in Parke county. A short distance above the limestone occurs Coal Va, a coal which has been worked commercially north of West Union, on Sugar creek. As a rule, it has a thickness of less than 2 ft. and is not workable. Coal Vb is not of a workable thickness at any point, as far as recognized, though dug a little for neighborhood use at a few points. Coals Va and Vb, near Mecca, where their stratigraphic relations are most certain, resemble the same coals in the

northwest corner of Clay county and northeast corner of Vigo county, being usually overlain by black sheety shale, and that in turn by a few inches or a foot of ferruginous limestone. They lie usually 10 to 20 ft. apart, separated principally by shale, and about 30 ft. below Coal VI. At several points in southwestern Parke reports indicate the presence of from one to three coals between Coal Vb and VI. These are minor coals of no practical value.

Division IV appears to underlie all of the area in Parke county shaded for these divisions on the colored map. The division usually has a thickness of about 20 ft., varying from 6 to 30 ft. or over. It contains one coal which, while usually subordinate to Coal V, is locally of good thickness and quality. Thus at Mecca it has a thickness of 4 ft. Up Sugar Mill creek it reaches a thickness of 5 or 6 ft., and at a few other places it has locally a workable thickness. At Mecca, on Sugar Mill creek, and at Sand creek, it appears to occur in considerable bodies. At many places it was observed to be thin or almost entirely lacking. It frequently exhibits a sandstone roof, but has a shale roof at most of the points where mined.

Coal III is found along the western part of Parke county, where it is developed from 3 ft. to 6 ft. thick. It is the lower bed worked at Mecca where it is in part overlain by limestone. It lies from 2 ft. to 30 ft. below Coal IV, and its presence here has rendered doubtful the assumption of its absence further east and north. The presence of the limestone over it here and at Hillsdale adds strength to this feeling of doubt. In this same line may be mentioned the occurrence of a limestone on Coal creek at the Fountain county line below Coal V and its limestone, and presumably in Division IV. These are some of the facts that would make it appear that the limestone we have placed in Division V really belongs in Division IV or even below. In the latter case it might be the equivalent of a limestone found in the southern counties just below Coal IV. These suggestions are thrown out for future students of this field. We have preferred to assume lack of persistence rather than the opposite.

Passing into Fountain county we find the same conditions continuing. Coal V is the important coal in the southern part of the county, ranging from 5 to 7 ft. near Silverwood, Yeddo and east of Kingman, accompanied by its limestone. Going northward, both coal and limestone appear to lose in importance, and at Coal Creek P. O. and Veedersburg, Coal IV is the worked coal, attaining a thickness of 6 or 7 ft. at the former place, and apparently over a large area. The coal east of Coal Creek, on Prairie creek, shows a 3 or 4 in. parting of clay, with 1 ft. 6 in. to 2 ft. of poor coal above and 3 ft. 8 in. to 4 ft. 10 in.

of good coal below. Mr. Cox reports the two benches at one point here as reaching a thickness of 10 ft. This coal is also of workable thickness around Silverwood and north of Veedersburg. The shale overlying it around Veedersburg is highly suitable for paving brick, and much of this coal will doubtless be mined in connection with the shale.

Division III was not certainly recognized in Fountain county, though it is possible it occurs in borings near Silverwood. Crossing the Wabash into Warren county, the lowest coal of the three occurring there underlies a limestone which has been assumed with some doubt to be at the same horizon as that met in Parke and Fountain counties. It is commonly a black limestone, associated with black shales. A similar black limestone was found in Parke county, on Sugar creek, and was there thought to be at the same horizon as the more common lighter colored limestone. This lowest coal, therefore, is called Coal V. It reaches a workable thickness on Fall creek, west of the Indiana mineral springs, and barely a workable thickness northwest of Covington and at one or two other points. As the result of a preceding erosion, and the consequent inequalities of the surface immediately preceding its laying down, it appears to be very irregular in distribution, and often lacking. It averages over 3 ft. on Fall creek. In places it appears to lie almost immediately on the sandstone of Division I. At other places 20 or 30 ft. of black shale lie under it, apparently filling up the hollow worn in the Mansfield sandstone. A short distance from the north county line of Warren county this coal seems to have run out, and what is called Coal VI lies on the sandstone of Division I.

As far as known, no coals in these divisions occur further north. A small basin of coal seems to exist in the southern edge of Newton county, but as no developments have yet been made there, and the coal is deeply buried under drift, its stratigraphical position can not be given.

Section 3. Divisions II, III and IV South of Brazil Basin.

127. LANCASTER—CLAY CITY BASIN.—This coal basin lies east of Eel river, in the southern part of Clay and western part of Owen counties. Over most of the area two coals are found in Divisions III and IV, which are thought to correspond to Coals III and IV of the Brazil field. Nothing corresponding to Coal II was found associated with Coal III, nor did it have the smooth parting near the top, as far as could be ascertained. In like manner the bench mining of Coal

IV, around Brazil, though reported at a few places in this area, was not found persistently. Drillings around Clay City, and also southeast of Clay City, report one or two small coals above Coal IV; whether either or both of them belonged in Division IV or in Division V could not be decided. Coal IV is usually of a workable thickness in this area, in the center of basins ranging from 3 to 4 ft. Coal III ranges up to over 6 ft., but is generally thinner than Coal IV. Both are solid coals, approaching the Brazil block coal in block quality and purity, though not reaching as high a standard in either respect. The roof in most cases, with both beds, is shale, very poor in some places, but good in others. Some sandy shale roof is met with. The two beds vary from 10 to 30 ft. apart, averaging less than 20 ft., the material between being shale, as a rule. Coal IV is worked, especially around Clay City. Coal III is thickest in Owen county about Patricksburg or Lancaster and at other points. Where these coals reach the unusual thickness of 5 ft. or 6 ft. they are apt to lose somewhat in quality. They tend to occur in smaller basins here than around Brazil. While in places the lower of these two coals is seen to lie directly on the Mansfield sandstone, at other places drillings indicate the removal of the sandstone and its replacement with shale; so that in some cases drillings 90 or 100 ft. below Coal III strike only shale.

128. LINTON BASIN.—Sufficient data was not obtained to show with any degree of certainty the lateral extent of the coal so extensively mined at Linton, but there seems to be a slight resemblance between the Linton coal and what has been correlated as Coal IV over practically all the outcrop of that division in Greene county and extending north into Clay county in the southwestern townships. Taking the section at Linton as a type we find that there Division IV contains two coals—Coal IV, with an average thickness of over 5 ft.; an excellent semi-caking coal, very free from sulphur and other impurities, though hardly equal to the best of the block coal in that respect. The roof is shale, and good. Some 50 ft. above it occurs Coal IVa, 1 to 2 ft. thick. The space between, while in many cases mostly shale, often contains a massive sandstone. Above Coal IVa is shale with a considerable thickness of sandstone, which is quarried some where it outcrops. Coal IVa lies about 50 ft. below Coal V. Coal IV in this area is split in the middle, and, though in most of this area the bed appears to be solid, a couple of miles west or southwest of Linton the two benches begin to separate, and a mile or two further west drillings show the separation to have become from 13 to 17 ft. While sometimes underlain with a little fire-clay, at most of the mines here the

coal lies on a micaceous sandstone 20 or 30 ft. thick. Below that, in Division III, are two beds from 1 to 2 ft. thick, and then 70 or 80 ft. below Coal IV is a bed showing about 3 ft. of coal in two benches, separated by a foot or 18 in. of shale or limestone. A little northwest of Linton drillings show Coal IV to have a thickness of almost 6 ft., but going northward it runs down to about 4 ft. Crossing into Clay county it is traced north to Splunge creek, with a thickness of 3 to 4 ft., overlain by sandstone. At one point it was seen in two benches, each 3 ft. thick, separated by 1 ft. of fire-clay, and a drilling to the west in Sullivan county reported Coal IV as 5 ft. 4 in. thick. At the drilling mentioned Coal III was reported as 4 ft. 8 in. thick, 75 ft. below Coal IV. At the other point mentioned Coal III was reported as 5 ft. thick at a depth of 25 ft. below Coal IV. South of Linton, near Marco, some drillings report a 4 ft. 6 in. to 5 ft. 6 in. coal, which, it is thought, may be Coal IV.

The correllation of the coals around Linton with those around Switz City and west of Worthington, and especially east of White river in Greene county, is done with some uncertainty. Toward Worthington Coals III and IV appear to come nearer together, often being less than 20 ft. apart, resembling in that respect Coals III and IV across Eel river in Clay county. East of Linton, Coal IV appears to get thinner, and though here and there reported of good thickness, at most points it is not of sufficient thickness to promise well for future developments. Its nearness to the surface will also serve to prevent extensive developments in that quarter. East of the river the coal found above the Mansfield sandstone, called Coal III, though its correlation with Coal III at Brazil, or even Linton, is uncertain, is a coal which, though locally reaching a thickness of 3 or 4 ft., is, for the most part, too thin and too pockety to work or attract attention. It is possible some small basins will prove extensive enough to pay for development.

Passing south into the area of Sheet D, Coal IV loses somewhat in importance, though workable over large areas, while Coal III gains, giving two workable coals in these divisions in this area. Coal IV at most of the openings at which it was seen will average a little over 3 ft. and up to 4 ft. It usually shows a clay band ¼ of an inch to 4 in. thick near the center. It is often a semi-block coal, though not usually, and generally tends to be rather sulphury. The roof is usually shale overlain by sandstone. In a few places Division IV appears to contain an additional coal lying either not far above Coal IV or not far below Coal V. We were not entirely satisfied that the coals found in these positions were not really Coal V. If it prove to be so, then in

places the space between Coal IV and Coal V runs down to 2 ft., though normally from 60 to 80 ft. apart. In general, Division IV and Coal IV have considerable resemblance to the corresponding strata in western Greene county. The heavy sanstone, so pronounced in Wright township of Greene county is even more prominent in southern Daviess county, culminating at High Rock in a thickness of massive coarse-grained sandstone, of 65 ft. So massive is this sandstone in places in this county and Pike and Dubois county that it was thought by the earlier members of the State survey to be the millstone grit or Mansfield sandstone, and the stratigraphy was made to fit, with the result of assuming the absence of any coals between Coal V and Coal I in southern Daviess and Pike and Dubois counties. The presence of two other beds of massive sandstones between this one and the Mansfield helped to confirm the error. The High Rock sandstone, then, is at present correlated with sandstone at this horizon as far north as the quarries on South Otter creek below the C. & E. I. R. R. bridge near Brazil and on into Parke and Fountain counties.

Coal III in this area becomes of some importance, reaching a thickness of 6 ft. at Cannelburg. At this point it is of special interest, as it there appears to be a double bed, the upper half or more being a good cannel coal. Whether this cannel coal is a separate bed which is here locally associated with the lower bed could not be definitely decided. The evidence suggests that it may be, as east of Cannelburg the two parts of the worked bed separate so as to become a dozen feet or more apart. Generally the coal called Coal III here contains no cannel, though not infrequently it is accompanied by more or less bone coal which may represent the cannel coal of Cannelton. As a rule this coal is solid, but shows a parting near the middle at a number of places. It appears to be freer of sulphur than Coal IV. The rest of the division in the nothern and central part of the area of this map is largely shale, with at least one thin coal above Coal III, and probably two or more. As the south part of Daviess county is approached there appear to be three coals between Coals III and IV. The uppermost of these is characterized by resembling Coal V in being overlain by black sheety shale and limestone. As it reaches a workable thickness in places it was without question considered by the earlier survey to be at the horizon of Coal V. The same error was at first made by the present survey. South of White river, however, Coal V is everywhere a thick coal, while this coal occurring about 75 ft. below is usually thin, and after being once distinguished is not likely to be confused. Between this coal and the next one below is generally a sandstone. Between the second and third coals is usually shale.

Drillings at Vincennes, Washington and east of Washington show a large increase in the number of coals in these divisions with an increase in the thickness of the coal-bearing measures. This increase in the number of coals is more apparent to the south, where most of them seem to reach daylight.

After crossing White river, the number of outcropping coals seems to increase somewhat, so that the first coal above the Mansfield sandstone is conveniently called Coal II. Whether Coal II of the area south of White river is the same as Coal III at Cannelburg has not been satisfactorily determined. Division IV here contains usually one coal which will average well under 3 ft. It is 3 ft. thick at some points and running up to 4 ft., but on the whole appears to be thinner and more pockety than north of White river. It is from 50 to 75 ft. below Coal V, the strata between being shale and sandstone. Division III has three coals, III, IIIa, IIIb. Coal IIIb, as in Daviess county, is usually overlain by black sheety shale and limestone. As a rule, it is thin, but of a good quality. Coal IIIa resembles Coal IV in its stratigraphic relations. It is usually a thin coal, but reaches a workable thickness in a number of areas. It is usually overlain by shale or sandstone, the sandstone between it and the next coal above often being massive and of a thickness that often led to its being correlated as Mansfield sandstone. Coal III in this area resembles Coal IIIb somewhat, though averaging somewhat thicker. It is usually overlain by black shale and limestone, with principally shale above to the next coal. Division II appears to increase in importance as the Ohio river is approached, finding its greatest development in southern Perry county. At this point Coal II is the well known Cannelton bed. It is of good workable thickness, up to 5 ft., but lies in basins of limited extent.

In northern Dubois, as in southern Daviess county, only one limestone is found in Division III, while in southern Dubois and Spencer county limestones are found over both Coals III and IIIb. This has led to much uncertainty as to the correctness of the correlation of the coals at many points. In western Pike and Gibson counties deep borings indicate a thickness of the coal measures in that division similar to that observed in Daviess and Knox counties, except that the coals reported are often quite thick. As these are all from churn drillings made for gas, the thicknesses given can hardly be considered strictly reliable.

Section 4. Division V, South of Clay County.

129. Division V, from Clay county northward, has appeared to be a division of some thickness, containing from one to three or possibly six coals, none of which are persistently workable. Its limits and the coals belonging to it have had to be arbitrarily assigned from point to point, often with much uncertainty, based principally upon the theory that limestones found all through from Clay county northward were at the same horizon. Much the same difficulty exists in correlating the rider in the Brazil field, which has been called Coal V, as developed near Clay City and at Alum Cave in Sullivan county. However, from those points southward, the problem is comparatively simple, as the division contains but one coal, which was laid down in a more or less nearly continuous basin to the Ohio river and beyond, and was followed by a uniform set of conditions, resulting in the overlying rocks showing a remarkable uniformity over that whole distance. The time during which the coal bed was forming must have been considerable, as this bed at a number of points reaches a reported thickness of 11 ft. and measures 7, 8 or 9 ft. over considerable areas, while over still larger areas it is uniformly found to be over 5 ft. thick. The coal forming period seems to have been followed by a comparatively rapid sinking of the whole basin. This was accompanied by an overflowing of the area by the sea and for a time sediments accumulated slowly in the form of very fine mud with a large mixture of fish remains and a limited variety of shells, orthocera, nautili and aviculopecten being the most common. It would seem as though at first the life was limited to those forms, like the fishes and the shells mentioned, that possessed more or less freedom of motion and hence were the first to take possession of the new feeding ground. A little later the more slowly moving forms, especially brachiopods, arrived in great numbers, and their remains ere long accumulated to form beds of limestone. Then further movements of the surface change the conditions, so that abundant deposits of mud or sand are spread over this submerged area. In some cases this fauna remains for some time and these shales are full of shells; more generally the changed conditions drive, the bulk of the life to new feeding grounds, probably farther west. As a result of these conditions, we find the coal first overlain with a black bituminous shale, usually breaking up into thin sheets often many feet square, with a somewhat meager fauna as described. This shale accumulated to a depth of from a few inches to several feet, sometimes, though not often, being over 6 ft. thick. It

is apt to contain a large number of pyrite concretions, "niggerheads," often 6 or 8 ft. in diameter, and often the shells in it are replaced by pyrite. Lying above it is usually a limestone from a few inches to 10 or 15 ft. thick, full of brachiopods. Overlying this is shale or sandstone, in some cases the lower part of the shale being full of fossils.

As stated, from southern Clay county to the Ohio river and beyond appears to have been a continuous basin during the laying down of this coal.

The distance from Coal V to Coal VI varies greatly, as shown by the sections on Plate IX. At Middlebury, in Clay county, the two coals are only 20 or 30 ft. apart. In southwestern Clay and northeastern Sullivan counties they average about 50 ft. or more apart. In northwestern Greene they again approach to within 30 ft. of each other, then going southward at Dugger we find them again over 50 ft. apart; two or three miles further they are over 70 ft. apart. At Edwardsport they run from 65 ft. north of town, to 25 ft. south of town. At Washington the variation is from 8 to 9 ft. to 80 or 90 ft., the larger space occurring east of Washington, the smaller south; 40 to 50 ft. is not an uncommon space in this region. Going south into Pike county, Coal VI has nearly run out, and the space between it and Coal V becomes smaller, running from 20 ft. to a more common space of 6 to 10 ft., and apparently at some of the mines the two coals are separated only by a thin parting, the double coals at such a point having the characteristic roof of Coal VI. Coal VI is last seen in northern Warrick county, so that from that point southward the exact proportion of the strata between Coals V and VII that belongs in Division V is somewhat conjectural, but probably lies within 20 ft.

As to the makeup of Division V in this basin, the following section will be typical of a majority of the sections:

	Ft. Aver.	*Ft.*
1. Shale with some admixture of sandstone	20	10 to 80
2. Limestone, often with clay parting	4	0 to 15
3. Black bituminous sheety shale	2	1 to 8
4. COAL V	5+	1 to 11

Coal V has a thickness of 3 or 4 ft. in the outlier at Middlebury, in Clay county. Starting at Splunge creek, in Clay county, where the thickness is but a little over a foot, it gradually increases in thickness until about Alum Cave and to the eastward it runs from 6 to 9 ft., with a reported thickness of 11 ft. See frontispiece for an illustration

showing a typical outcrop of this coal in this area. The overlying black sheety shale and limestone are perhaps even better shown in Part IV. Only about 6 ft. of the coal is taken in mining. Along the edge of Greene and Sullivan it shows a thickness of from 5 to 7 ft., though the quality does not appear to be very good at most places. Along White river and east in Daviess county its thickness is irregular, reaching 7 ft. just southwest and west of Washington, where it is of excellent quality; also several miles farther down the river, where the quality is poor, but over most of the area ranging from 1 to 4 ft. with an average over much of the eastern part of its outcrop of less than 2 ft. Around Washington its roof, while generally black, is not so sheety as at many points, nor so full of concretions, so that it has been generally mistaken for Coal VI. Entering Pike county, it reaches its greatest development around Petersburg, the coal being mined for a thickness of 8 and 9 ft. and here and there reaching a thickness of 10 and 11 ft. The coal appears to be generally without partings, but at the Woolley mine has a parting of several inches. As this parting is developed in one or two other areas, becoming sometimes over 3 ft. thick, it has suggested an interpretation of some drillings made in Petersburg, which show two beds at about the horizon of Coal V, separated by up to 6 or 8 ft. If these are the two benches of Coal V, then Coal V, in at least two of these drillings, shows a thickness of 12 ft. At the Woolley mine there is 6 ft. of coal below the parting and 3 ft. above. Over most of Pike county Coal V is found with a thickness of seldom less than 4 ft. 6 in., and averaging over 5 ft., apparently having originally been in a continuous or nearly continuous sheet. The limestone is not as persistent as further north, and in some places the roof is a clay shale, which in some cases appears to be the roof of Coal VI, in others it occurs under the black shale. Its relation to the black shale is well shown in the Blackburn mine, near Petersburg, where it can be seen to be a lenticular mass of some extent, 3 or 4 ft. thick in the center, but thinning out at the edges and everywhere overlain by the black shale. In some cases the black shale over this clay shale nearly or quite thins out. One of the best exposures, showing Coal VI but a few feet above Coal V, is seen at the Hartwell mine, near Augusta.

Passing south into Warrick county, the conditions continue much as in Pike county. In the northeastern part of its outcrop in this county Coal V usually shows a parting, usually less than 6 in., but northwest of Folsomville increasing to 3 ft. 6 in. or more. A good thickness is maintained as far as Boonville, where the coal on its eastern crop runs up to 7 or 9 ft., but west and south of there the thickness averages nearer 4 ft.

In general the quality of Coal V is fair. In many areas it appears to contain numerous irregular streaks of dirt or shale, making the coal yield a large percentage of ash. Such coal could be largely improved by washing, and the introduction of washing plants would render available many acres where the coal is above the average in thickness and other workable features, but not acceptable to the market for the reason mentioned. At other places the coal is of a much better grade and sells readily with the other coals of the State, while locally it is above the average of the caking coals.

The roof of this coal is usually above the average. Rooms 40 ft. wide in places were seen that had stood 7 and 8 years without a prop, and did not show the first signs of flaking down. The same thing is shown in another way, and that is that openings made to this coal or exposures made by creeks tend to stay open or exposed longer than most of the coals of the State, rather than to fall in and fill up.

With the facts just presented it will be better understood why the survey, working north from White river, where they had grown accustomed to consider this coal the thickest and one of the most important in the State, felt that it ought to be found in northern Clay county and to the north, and finding there a coal overlain by a limestone and sometimes with black shale in the same relative position as Coal V, hastened to call it Coal V. Upon this the assumption has been based that Coal V is co-extensive with the area of the coal measures in this State within the limits of its eastern line of outcrop. It may therefore be well to express the caution that, while this may be so, it is also possible that Coal V as last described is limited to the basin just defined and that what is called Coal V around Brazil and to the northward is an entirely different coal, though occupying about the same relative position and having many of the same characters as the one called Coal V to the south.

Section 5. Division VI.

130. This division, from the standpoint of supplying coal, is one of the most important in the State, if indeed it does not at present supply more coal than any other division, there being in 1897 more large mines working Coal VI than any other seam except Coal IV. The group of strata which have been arbitrarily designated as Division VI can be readily traced from the north part of Vermillion county and with less certainty from the northernmost coal mined in Indiana to the Ohio river. The division is everywhere limited at the top by

Coal VII, the most persistent bed in the State, and at the bottom by Coal VI over most of its area, though as the Ohio river is approached Coal VI runs out and the division contains no coal. Further north the division contains from one to five coals, the lowest of which is generaly workable, while of the others one reaches a thickness of 6 ft. in places, while another reaches a workable thickness at a few places. In thickness the division varies from about 20 ft. (?) to 175 ft. or over. As a rule it is over 40 ft. thick. The data is suggestive that west of its outcrop Coal VI lies in a more or less continuous basin. Along its outcrop it is easy to divide it into four areas, within which it presents somewhat similar conditions, though these do not appear to be sharply marked basins, as it is generally possible to trace the coal more or less continuously from one to another. The first of these areas extends from the north limit of the coal field to Clinton in Vermillion county and Coxville in Parke county. In this area the coal, while readily traceable by the stratigraphy, is seldom workable. It may be called the Vermillion river area.

The second area extends from Clinton and Coxville to south of the T. H. & I. Ry. in Vigo and Clay counties, a small outlier at Middlebury, Clay county, belonging to this area. Within these limits the coal is known as the "Big Vein," and averages between 6 and 7 ft. thick. We may call this the "Big Vein" area.

The third area starts from northern Sullivan county and runs to Edwardsport, in Knox county. It might be called the Sullivan county area. Here the coal runs from 5 to 7 ft. in thickness.

The fourth area runs from Edwardsport to northern Warrick county, and may be called the Washington area, as the coal has been most extensively worked at Washington, in Daviess county.

131. Stratigraphy of First or Vermillion River Area.—This region is included entirely in the area of Sheet A. Though supposed to include all of western Warren county, only the lower part of the division is found there, and it is necessary to go south into the regions of the Big and Little Vermillion rivers to get complete sections. The division here shows a thickness of about 100 ft. or a little over, with three regular coal horizons, and coal appearing at one or two points at a fourth horizon, above the others. The strata show (see Plates XX and XXI, first, the fire-clay below Coal VII, then sometimes a band of limestone, then black shale with coal less than 1 ft. thick at one or two points. Then comes 30 or 40 ft. of shale, with sometimes a little sandstone to Coal VIb. This coal appears to start in between the two rivers, being very thin, but to the south be-

comes more prominent, finally becoming workable, and, though not persistent, is thought to have been traced almost to the Ohio river, if not quite. It is overlain by a foot or two of black sheety shale, and that in turn by a thin bed of limestone. The limestone is probably a little more persistent than the coal. On the Big Vermillion the coal is only a few inches thick, as a rule, or is not present at all, its horizon being indicated by the black shale and limestone. It appears to have been laid down under somewhat similar conditions to Coal V in the southern counties, and was often mistaken for Coal V in the old reports. This coal horizon was never recognized by the older surveyors, it either being overlooked or assigned to some other horizon.

Below Coal VIb occurs some 40 ft. of very variable strata, being shale at points and sandstone at other points. In places it is a compact sandstone, extensively quarried for building purposes, and at others a sandy clay shale, extensively quarried for the manufacture of clay products. That these are not two distinct beds lying unconformably together is readily shown by the two facies grading into each other at numerous places and sometimes within very narrow limits; so quickly, indeed, does the change take place at points that a fault would be suspected were not the exposure too clear to admit of such a proposition. The two facies are well exposed at the Portland sandstone quarry, near Worthy, and at the clay factories at West Montezuma and Highland.*

Below this sandstone is usually 10 to 20 ft. of shale to Coal VIa. This coal here lies but a few feet above Coal VI, and in at least one place they are reported to be separated by only a thin clay band. Coal VIa resembles Coal VIb in being overlain by a black bituminous sheety shale and generally by a little limestone. This limestone is seldom more than 1 ft. thick and more often is less than 6 in. thick, or wanting altogether. It is apt to be very shaly and ferruginous, being often spoken of as an iron ore. This coal and its accompanying strata persist over this area and most of the second area. It is a very persistent bed, with a general average of about 1 ft. 6 in., and to the south always showing a clay band in the middle. It is the coal called "Coal M" by Mr. Cox in his report on Clay county. In northern Vermillion county it has a thickness of 2 ft. 6 in. to 3 ft., usually showing its parting, and has been somewhat extensively mined near Eugene. In Warren county it is usually thin, though running up to 2 ft. 8 in. and at one point to 3 ft. 7 in. In general its quality is excellent, and it is mined at a large number of places, especially as a

*See Plate X. Note the outcrop of Coal VIb in the upper right hand corner of the plate.

PLATE X. Massive coal measure sandstone in Division VI at Worthy, Vermillion county. (From Hopkins' report on sandstones.)

blacksmith coal. The space between Coals VI and VIa varies from a few inches to 20 ft., but in this area is usually under 10 ft. and frequently under 6 ft. Where thin the space is all fire-clay, otherwise some sandstone and shale occur in addition. At points on the Big Vermillion and again in Clay county a thin, irregular bed of coal is found in this space. It is usually only a few inches and nowhere over 1 ft. thick, lying in lenticular pockets of limited extent.

Coal VI in this area is an irregular, pockety coal, only here and there workable, though at such times ranging from 3 to 6 ft. In Warren county it varies from 4 ft. 2 in. down to nothing. In northern Vermillion county it ranges from 4 ft. 6 in. down. In Parke county in this area from 6 ft. down. For this area as a whole it will probably average between 1 and 2 ft. Due to its liability to be found of good thickness at points in this area, caution should be exercised to ascertain the extent of the coal of workable thickness there before preparing for extensive mining. For the same reasons it is not possible to predict with any degree of certainty the thickness of this coal in unexplored areas.

The correlation of the two coals in Warren county, designated Coals VI and VIa, with the coals correspondingly named in Vermillion county is far from certain. Stratigraphically, there is much similarity, and, assuming the coal below them to be Coal V, the two coals would normally be Coals VI and a higher coal.

132. THE TRANSITION from the first area to the second is well exhibited in the numerous ravines along the west side of Raccoon creek, in Parke county, from Mecca to Coxville. Plate XI shows the gradual thinning of the coal from Coxville northward, until finally the lower bench disappears; then the upper bench continues to decrease in thickness until, before Mecca is reached, it has become pockety or absent, a set of conditions that continue to the north end of the coal field. Coal VIa assists greatly in tracing this change.

133. THE SECOND AREA differs from the first, principally, in the thickness and workability of Coal VI. The measures in this division acquire a thickness of over 175 ft. along the Wabash, from Clinton to Terre Haute. To the eastward they are usually not so thick.

Coal VIb thickens up to 4 ft., though usually not over 2 or 3 ft. thick. At the Buckeye shaft, near Clinton, three thin beds of coal are reported to have been found at about the horizon of Coal VIb. As these are found nowhere else, their presence here is problematical.

Coal VIa is found all over the eastern part of the area, but is lacking in the western part. Where found, it is very uniformly from 1 ft. to 1 ft. 6 in. thick, with a clay parting about the middle and the black

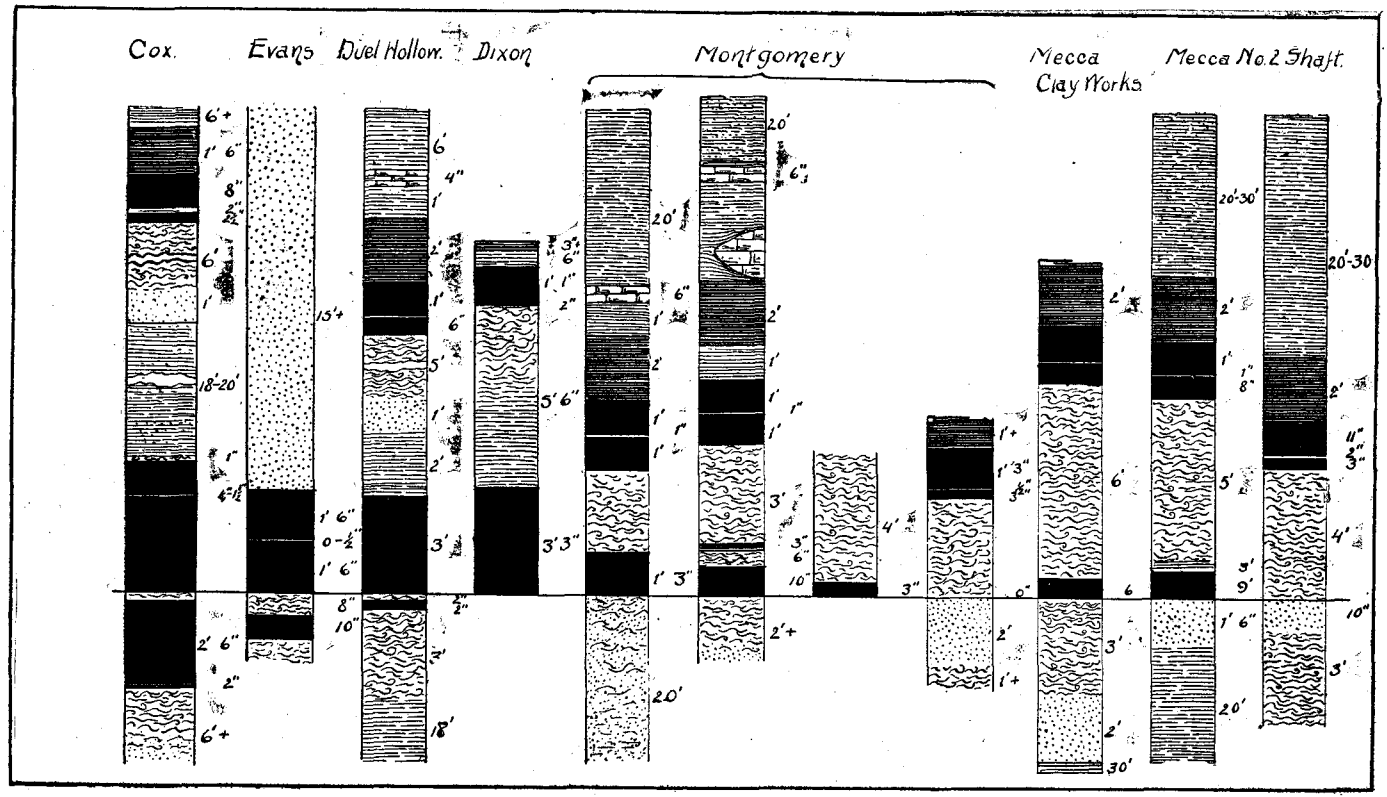


PLATE XI. Figures showing gradual thinning out of Coal VI between Coxville and Mecca, Parke county.

sheety shale roof with the thin overlying ferruginous limestone. It is generally reported an excellent blacksmith coal. It lies usually not many feet above Coal VI, but varies up to 20 ft. above, with traces of a thin coal between at a few points.

Coal VI in this area appears to have originally been a continuous sheet, though now much cut out along the edges by the present and pre-glacial erosion. The coal runs from 5 to 9 ft. in thickness, averaging between 6 and 7 ft. It is commonly divided by a band which, where thickest, is seen to be about one-half shale and one-half clay. In places this clay or "dirt band" runs out, but as a rule it is a conspicuous feature of the coal, being found at or below the center of the coal; about 4 ft. of coal above and 3 ft. below would be a fair average, though there is much variation from this. The next most constant feature is a thin band of pyrite 1 ft. to 1 ft. 6 in. from the top. Another pyrite band often occurs near the bottom of the coal, and in places a band termed the "blue band," of bony, dirty coal, with some pyrite, is found between the main band and the lower sulphur band. At many places in northeastern Vigo county and Clay county there is a tendency for the single main dirt band to split into two, with several inches of coal coming between them.

This band of coal, from 2 to 6 in. thick, was seen to come in and pinch out at several places. At the Bell mine, east of Coal Bluff, in Vigo county, it is reported that the dirt band increased until it had a thickness of 2 ft. At the Ray mine, east of Seeleyville, the coal has two bands, dividing it into three nearly equal parts, while at the Parke County Coal Co.'s No. 10 mine there is reported to be no band at all. So that it will be seen that while this coal has a tendency to show a definitely banded cross-section, there is much variation from the type.

This coal is a strong steam coal, not as free from dirt and sulphur as some of the coals discussed. Much care is required to secure the removal of the dirt and sulphur, but where that is well done it makes one of the best steam coals of the State.

The roof of this coal is usually a blue shale overlain by sandstone. Usually the roof is from fair to good. In places much trouble is had with the lack of any roof but drift. The floor is fire-clay, with often a little bone coal or black shale lying between the coal and clay. This clay has a strong tendency to creep, making it necessary at many of the mines to lay out the mine so as to overcome the difficulty.

134. South of the T. H. & I. Railway, over most of Vigo and Clay counties, within the limits of outcrop of Division VI, the country is not favorable to outcrops, and little is known of this di-

vision. It appears to grow thinner, however, so as to average under 4 ft. However, at the outlier at Middlebury it shows no signs of thinning, ranging up to a reported thickness of 11 ft. Drillings at Lockport, or Riley, and at Pimento, or Hartford, give Coal VI a thickness of from 6 to 7 ft. At Middletown, Vigo county, drilling shows only 3 ft. 6 in. of coal, and in the northeast corner of Sullivan County Coal VI is from 2 ft. to 4 ft. 6 in., as reported in drillings. The exact status of this coal in this area is therefore very uncertain.

Coal VIb in Riley and Pierson townships of Vigo county attains its greatest development, ranging there from 3 to 6 ft. in thickness, overlain as usual with black sheety shale and up to 10 ft. of limestone.

At the south side of Vigo county Division VI very rapidly changes from a thickness of 130 ft. or over at Pimento to 40 ft. at Farmersburg. The space between Coal VII and VIb has decreased greatly at points east of Pimento, so that at one point there only a few inches of fire-clay came between Coal VII and the limestone over Coal VIb.

135. THE THIRD AREA from Farmersburg to Edwardsport presents a basin of coal of remarkable uniformity. Division VI is in this area only from 30 to 40 ft. thick; and except in the north edge of Sullivan county, where Coal VI has really not acquired the thickness and details characteristic of the area, it is the only coal in the division. Coal VIb disappears in the north edge of Sullivan county, being there close to Coal VII, from which it is only separated by the fire-clay, limestone and a little shale, or, in one case, by only 1 ft. 6 in. of limestone. In places the limestone acquires a considerable thickness, and it is fairly persistent near the top of Division VI all through this area. Below it comes a massive sandstone lying unconformably on the roof shales of Coal VI. Stratigraphically this is the same sandstone as is quarried at Worthy, Vermillion county. It would appear that at the end of the coal-forming period, the area involved settled enough to put an end to the formation of coal deposits and allow fairly clean clay mud to be deposited over the area. After these had reached a depth of from 10 to 20 ft., elevation took place and the freshly laid down mud or shale was soon carved into erosion channels, often of some width and frequently deep enough to cut into the recently deposited coal. Subsidence followed with the influx of sand which filled up these hollows, and as sinking progressed gradually accumulated as a bed of sandstone. Some question has arisen as to whether the channels found in Parke, Fountain and Vermillion counties were not formed at this time rather than later, and that the sandstone filling the channels is really the same as this sandstone lying above Coal VI, in Division VI.

Coal VI in this area ranges from 5 to 8 ft. in thickness, with an average of about 6 ft. Three clay bands appear in the coal with great persistency, dividing the seam into four benches that maintain great uniformity of thickness and, in a less degree, in quality. The lowest parting comes about 1 ft. from the bottom, and the bottom coal is apt to be shaly, so that in most of the mines it is not taken up. The other two partings are from 4 to 10 in. apart and lie about midway of the rest of the coal. The thin bench in the middle of the coal is often used to mine in as in many cases it is of poor quality, and where removed the bench above will often sag down of its own weight, until it can be easily broken up and removed, after which the bottom bench can be wedged up. As indicating how persistent these benches are in this field, it may not be out of place to give in tabular form the thickness at a number of the mines and openings in this area.

NAME AND LOCATION.	Total.		Upper.		Mining.		Lower.		Bottom.	
	Feet.	Inches.	Feet.	Inches.	Feet.	Inches.	Feet.	Inches.	Feet.	Inches.
T. 9 N., R. 9 W.—										
Berlin, Sec. 1	5	4	2	0	0	6	2	2	0	8
Farmersburg, Sec. 2	5	2	1	8	0	8	2	0	0	10
Currysville, Sec. 35	5	6	2	0	0	10	2	0	1	0
Shelburn, Sec. 34	7	0	2	8	0	8	2	6	1	2
Lofton, Sec. 25	5	9	1	6	1	6	2	9	1	0
T. 8 N., R. 9 W.—										
Sullivan, Sec. 27	5	2	1	10	0	6	1	10	1	0
T. 6 N., R. 9 W.—										
Carlisle, Sec. 10	5	3	2	0	0	7	1	6	1	2
T. 6 N., R. 8 W.—										
Ward, Sec. 12	4	9	1	0	0	5	2	2	1	0
Padgett, Sec. 13	5	0	1	0	0	6	2	4	1	0
T. 5 and 4 N., R. 8 W.—										
Roots and Bensing, Sec. 14-5-8.	4	10	0	10	0	5	2	0	0	10
Edwardsport C. & M. Co., Sec. 36-5-8	6	3	2	6	0	9	2	0	0	10
Harrington Coal Co., Sec. 2-4-8	6	6	2	4	0	9	2	1	1	2
Thurston, Sec. 2-4-8	5	6	1	6	0	6	2	4	1	2
T. 9 N., R. 8 W.—										
Hymera, Sec. 35	6	10	2	6	0	6	2	10	1	0
Stark, Sec. 35	5	6	2	0	0	6	2	0	1	0
Dick, Sec. 30	5	7	2	1	0	6	2	0	1	0
T. 8 N., R. 8 W.—										
Shepherd, Sec. 3	6	0	2	3	0	6	2	6	1	0
Star City, Sec. 6	6	0	2	2	0	8	2	2	1	0
Jackson Hill, Sec. 10	6	0	2	0	0	6	2	2	1	2
Bush Creek, Sec. 31	5	2	2	0?	0	8	2	0	0	0?
Farnsworth, Sec. 32	5	10	2	0	0	6	2	0	1	2
Buell, Sec. 35	5	4	2	2	0	6	1	10	0	8
Ring, Sec. 3	5	4	2	0	0	6	2	0	0	3
Wilson, Sec. 15	6	4	2	9	0	4	2	0	1	0
Pigg, Sec. 36	5	2	2	0	0	6	2	6	0	0
Zaeyer & Allman, Sec. 31	5	10	2	0	0	10	2	0	1	0
T. 7 N., R. 8 W.—										
Dugger, Sec. 12	6	0+	2	6	0	4	2	2	1	0
Co-operative, Sec. 2	6	3	2	4	0	4	2	4	1	3
Superior, Sec. 10	6	0+	2	4	0	6	2	2	1	0
Carbon Hill, Sec. 24	6	0	2	3	0	6	2	3	1	0

The partings run from ¼ in. to 2 in. or a little over, and will average about 1 in. thick. In the entries of many of the mines these are very distinct, often resembling parallel chalk marks on the black coal walls. In some of the mines the bottom bench is little more than a bone coal, while in others it is regularly mined with the other benches.

In quality this coal is much the same as in the "Big Vein" area. It tends to carry much sulphur, but usually in a form that allows of its easy removal with a little trouble, when the coal will be found to be a strong steam coal. Most of this coal would be greatly improved by washing.

The roof is from fair to good, being usually good for a time, but tending to come down badly in entries long used. The floor is quite commonly a black shale, occasionally containing thin bands of good coal.

136. THE SOUTHERN AREA from Washington south to the Ohio river appears to continue the stratigraphy of the area just considered, except that Coal VI runs out, Coal VIb comes in again, and the limestone over Coal VIb becomes very persistent. Coal VIb, while found at points all the way from White river to, or almost to the Ohio, is nowhere workable, nor is it quite persistent. The limestone over it here very frequently lies directly on the coal and varies from a foot or less to 10 or 12 ft. in thickness. One of the best exposures of the limestone is just east of Newbury, in Warrick county. The space from Coal VII to Coal VIb runs from 20 ft. down, but will generally be only a few feet, in many cases only a foot or two of limestone, with or without a little clay intervening. Coal VIb attains its greatest thickness near Petersburg and Millersburg, reaching at those points 2 ft. 10 in. and 3 ft., respectively.

Coal VI, which was found to be thin in the south part of Edwardsport, appears to acquire a workable thickness only east of Washington, in Daviess county, and there it has practically been worked out, all of the coal now coming from that locality coming from Coal V. It there reaches a thickness of 4 ft. or over, and is of excellent quality. Southwest of Washington it appears as a rider over the seam being worked, being only a foot or two thick. In Pike county it is, in most cases, absent, and where seen was, in a majority of instances, less than a foot thick, though occasionally, as at Hartwell, thickening up to 2 or 3 or even 3 ft. 6 in. This coal was last seen in going south, near Scalesville, in northern Warrick county.

Section 6. Division VII.

137. This division, with but few local exceptions, shows only one workable coal, and that the most persistent in the State. The division ranges from 60 ft. to over 140 ft. in thickness. In the northern part shales predominate, in the southern part sandstones. This fact, taken in connection with differences in the roof rocks of Coal VII and other features of the stratigraphy, seem to imply that the assumption that what is called Coal VII is all at the same horizon, may not be quite correct. In the north part of the area Coal VII can be traced with little question from the "Horseshoe," on the Little Vermillion river, to West Terre Haute. The strata here are mostly shales, with often sandstone above, and near the top are two beds of limestone. Coal VII in this area runs from 4 ft. to 5 ft. in thickness, without regular partings, though locally sulphur bands are often persistent, and overlain with a dark or light shale in the north, but from Clinton to Terre Haute with black bituminous sheety shale, like that over Coal V, but which is frequently a true bone coal; this will run from 1 to 2 ft. in addition to the 5 ft. of good coal. The fire-clay under this coal is apt to be soft when wet, and then exhibits a decided tendency to creep. Drillings around Clinton indicate that there is a coal horizon there about 20 ft. above Coal VII, and at places there also appears in the black shale or bone coal over the coal a band of bone that in places becomes a fair grade of coal. Neither of these coals are of workable thickness or commercial importance. At the "Horseshoe" there appears a 3 ft. 3 in. bed of coal only 12 ft. above Coal VII, which we have drawn in this division, but with the expectation that further study, especially in Illinois, will show that the upper bed is Coal VIII.

From Terre Haute eastward and southward the conditions are found to have changed, yet it is believed that the strata are correctly tied up. Thus, it is thought that Coal VI has been traced from Clinton, in Parke county, then down into eastern Vigo county and elsewhere without question. It is also believed, though with less certainty, that the correlation of Coal VIb at Seeleyville with VIb of Vermillion county is correct. Coal VII in Vermillion county lies 40 or 50 ft. above Coal VIb, while the upper workable coal at Seeleyville lies about 30 ft. above Coal VIb. In this case Division VI is used to bridge over the uncertain ground. From Seeleyville to Farmersburg, across which much uncertainty exists concerning Coal VI, Division VII serves as a bridge. Furthermore, the double limestones in the top of this di-

vision in Vermillion and western Vigo counties appear in their proper place in the sections in Sullivan county. Thus it appears well settled that whether Coal VII from Terre Haute south to the Ohio river was laid down in exactly a continuous basin with Coal VII north of Terre Haute, they occur at, at least, approximately the same horizon.

From Seeleyville south Coal VII continues nearly everywhere workable, seldom under 3 ft. thick, or over 4 ft., though around Seeleyville and in northern Sullivan county running up to 5 or 6 ft. in thickness. This coal was called "N" in Mr. Cox's reports on Clay and Daviess counties and Mr. Collett's report on Pike county, but in Mr. Collett's reports on Sullivan, Knox and other places, was called "M." Locally it was called by other letters. From Seeleyville southward its roof is irregularly shale and sandstone, with standstone predominating in the division. The conditions following the laying down of the coal seem to have been subsidence, with the deposition of mud or shale, then uplift and extensive erosion, then sinking, with influx of sandy deposits. The roof is often or even characteristically very irregular and full of rolls, so much as to seriously interfere with the mining of the coal at most points where it has been mined, and in some cases the lowest part of these rolls consists of a conglomerate. These rolls not only render the roof uneven, but greatly reduce the average thickness of the coal, so that coal which it would appear would normally have been 4 or 5 ft. thick will average less than 3 ft.

The quality of the coal usually appears to be excellent in the area from Seeleyville southward, being unusually rich and free from sulphur, but not a good coal to stand transportation. Partly for the reason given, but principally because of the proximity of Coal VI of much greater and more regular thickness, and of a better quality to ship to market, Coal VII is not very extensively mined in Indiana. In northern Warrick county the roof is again a black shale and not of a good quality.

Section 7. Division VIII.

138. The old survey recognized but one workable horizon above Coal VI. In 1896 Mr. Scovell correctly determined that a workable coal in Brouillet's creek and Coal creek valleys was above Coal VII or Coal "N," and he applied to it the name of Coal "O." This coal horizon now becomes the basis of Division VIII and will be called Coal VIII.

Division VIII has a thickness of from 50 to over 100 ft. It contains from one to four coals, only the lowest of which is ever workable and only over limited areas in the northern part of the field. Shales predominate, though with a goodly mixture of sandstone and more than the average of limestone. Coal VIII has a thickness of 4 ft. or over up Brouillet's creek in Vermillion county. The roof is much like the roof of Coal VII in the same area, being black bony shale one or two feet thick. The coal continues workable southward into Vigo county along Coal creek, but before reaching the center of the county it becomes too thin to work. It continues so over all the area to the south except in western Sullivan county, where it reaches a total thickness of 3 or 4 ft., but so broken up by partings and the benches so poor as not to furnish more than a small amount of coal of workable character. The coals above seem to be of very uncertain character, seldom more than one of them being present at any one point. They are usually overlain by black sheety shale with limestone above, and are frequently of too bony a character to recommend themselves. However, in many places they are of good quality and where readily gotten at are often dug in a small way. The limestones near the top of this division are very persistent and can be traced from southwestern Vigo county to the Ohio river west of Evansville, where they are quarried at many points for road material.

Section 8. Division IX.

139. This is the division containing the Merom sandstone and any overlying Carboniferous or Permo-Carboniferous strata, assuming at present that no younger rocks occur there. This division contains no coal, except it be in the basal conglomerate, obtained by erosion from the underlying strata. It generally shows only sandstone in a massive bed up to 75 ft. thick. Shale appears in places.

XI. PALEONTOLOGY OF THE INDIANA COAL FIELDS.

M. M. AND G. H. ASHLEY.

140. At the time of the early geological work upon the Indiana coal fields it was a commonly accepted belief that certain life forms accompanied certain coal beds, and the finding of certain fossils at two distant places was considered proof of the identity of the accompanying coals. On this basis some of the coal beds of Pennsylvania were by some believed to have originally extended not only all along the Alleghany mountains, but to have covered a vast area stretching to the west of the Mississippi. In this State the services of Mr. Leo Lesquereux, the highest authority on Paleobotany living at that time, were secured, and he accompanied Mr. Richard Owen on his trip through the coal field in 1860. He not only traced the Mahoning sandstone of Pennsylvania through the coal field, but determined the stratigraphical position of all the coals met on their reconnaissance.

When, under Mr. Cox in 1869 and 1870, the coal counties began to be examined with more care, it became evident at once that not only were the former determinations unreliable, but to a large degree incorrect. This Mr. Cox points out at some length in a paper read by him before the American Association for the Advancement of Science in 1871. Nevertheless in the following years considerable attention was given to the collecting and identifying of the coal measure fossils, and to a slight degree they appear to have been considered of value in unraveling the stratigraphy, especially by Mr. Collett. The lists of fossils so collected were usually placed in the columnar sections.

At the time of beginning the present survey it was the writer's feeling that while the off-hand determination of species might prove of litttle stratigraphic value, by a detailed study of all the minute features of all the fossils found, combined with a study of distribution at different times and of the probable migrations which had taken place, it might be possible to trace the changing or modifying of some of the forms which continued, the dropping out of other forms from time to time, and the gradual appearance of new forms, so that the fossils would become of the highest stratigraphic value. For several reasons it soon became evident that it would be impossible to make such a study. The fossils in the coal measures are not overabundant and when found are usually very difficult to get out or to preserve. Those in the limestone are usually very fragmentary, requiring not alone considerable labor but much time to chisel them out, with but

few, if any, perfect specimens obtainable. In the shale the plant remains are often abundant and well preserved, but in such friable material that in most cases special measures would have to be adopted to secure their safe transportation to the laboratory. In view of these facts it was soon evident that the fossils must largely be studied in place, and it became further evident that to do the work with the thoroughness necessary to secure results of value, this part of the survey alone would require many times the amount of time allotted for the whole work.

Therefore no systematic attempt was made to either collect or study the fossils, nor was any direct use made of them in working out the stratigraphy. A possible exception to this general statement was the use constantly made of them to determine the conditions surrounding the laying down of the different rocks. In this way groups of fossils have been of much indirect help in distinguishing a given coal bed from the bed next above or below. But with every recurrence of the conditions surrounding that given bed there is found a return of the old fauna. To distinguish the different returns would be the desideratum sought. To save space it has been the plan to omit all names of fossils from the columnar sections, but in response to many requests the fossils reported in former State reports are here tabulated. In doing this an effort has been made to so arrange the matter that there should be shown, first, the vertical distribution as far as known (of course, it will be understood that when a fossil is reported to have been found in Division I and Division VIII, it is assumed to have existed all the time between); second, the horizontal distributions; third, the habitat or environment of each species as expressed by the character of the rock in which it is found.

The following tables in the main have been prepared by Mrs. Ashley. There is given under each county, first, a list of localities at which fossils have been found, then a list of the fossils arranged to show the distribution among the several localities, the divisions in which they occur and the character of the rock in which they occur. In these lists all mention of fossils in which specific names are not given are omitted; and all cases where doubt existed, as to the horizon at which a fossil occurs, or some other factor, have been omitted. Following the county tables is given a summary table which practically gives all the facts of interest to the general reader. In this table the X is used in all cases where the given species has been reported less than five times at any horizon or in any rock; if reported more than four times, the number is given.

The tables are given for what they are worth. The attempt to ascertain to what general conclusions they led was abandoned after a brief study, as it was evident from our knowledge of the field that the data were not of a character or of a quality to secure safe results. To give a single illustration: From the table it might appear that what we have called the marine black shale fauna was as much or more characteristic of Division VI than of Division V, whereas our field notes would suggest that this fauna is found many times in Division V for every once it is found in Division VI. Such discrepancies, which are abundant all through the table, are due principally to two causes: first, lack of balance in the character of the work done in different parts of the field, some areas or divisions having had their life worked out with some completeness, while others have barely been touched or entirely neglected; second, even in the areas best worked out, it would seem that at only a few of the places where fossils were found were specific determinations made, or at least published, the majority of the places being passed with a notice of "fossiliferous" shale or limestone or whatever the rock might be, or by such statements as, "The black shale contains the fossils usually found accompanying this coal," with a mention often of generic names, which, as stated, are omitted from this table.

The broad vertical and horizontal distribution of the more commonly reported species is readily noted from the table, also the existence of two faunas, the first characterized by the presence of fish remains, cephalopods, and such pelagic forms as aviculopectens. This I have interpreted as an "advance guard" fauna, or a fauna which, from a greater ability to move rapidly into new territory, would be the first to appear after an incursion of the sea. They in turn would be followed by the more abundant but slower-moving brachiopod fauna which ushers in a period of limestone forming. It will often happen that the former fauna will persist after the encroachment of the brachiopod fauna, the limestone showing a certain mingling of the two faunas. It is probable that closer study would result in dividing the fauna into still finer subdivisions. No division has yet been made of the flora. The predominance of Lepidodendrons in the sandstones and many similar possible facts are matters of note in the field work, but there are as yet too few data at hand to allow the formulating of definite or general laws in regard to the matter.

150. Abbreviations: S. S.—sandstone; L. S.—limestone; sh.—shale; Bl.—black; Bl. sh. L.—black shale with land flora; Bl. sh. M.—marine black shale fauna; calc. sh. or cl.—calcareous shale or clay, in

the latter case usually the decomposition product of a limestone; Fe.—iron or ferruginous, Fe. L. S.—ferruginous limestone; sandy shale is marked shale, and shaly sandstone is called sandstone; Cl. sh.—clay shale.

151. Clay County.

List of localities—

1. Elkins' place, Bowling Green, shales above Coal I.
2. John Andrews, Sec. 30, T. 13 N., R. 6 W., limestone over Coal V.
3. South of Staunton, black sheety shale over Coal VIa.
4. Peter Barrick's, southeast of Clay City, in ironstones in shales over Coal IV.
5. A. Harstein, north of Coal City, limestone over Coal V.
6. A. Phipp's bank, S. W. of S. W. of Sec. 30-10-6, black sheety shale over Coal V.
7. Mr. Gray, Sec. 3-9-6, limestone over Coal V.
8. Markland shaft, Clay City, shale over worked coal, Coal III.

Localities	1	2	3	4	5	6	7	8
Divisions	I	V	VI	IV?	V	V	V	III?
PLANTÆ.								
Asterophyllites equisetiformis, Cl. sh				×				×
Cordaites borassifolius, Cl. sh				×				×
Cordaites diversifolius, Cl. sh								×
Neuropteris hirsuta, Cl. sh				×				×
Neuropteris hirsuta, Bl. sh. L	×							
Neuropteris loshi, Bl. sh. L	×							
Neuropteris rarinervis, sh				×				×
Pecopteris arborescens, Bl. sh. L	×							
Sphenophyllum schlotheimi, Cl. sh				×				×
Sphenophyllum schlotheimi, Bl sh. L	×							
MOLLUSCOIDEA.								
Brachiopoda.								
Chonetes mesolobus, L. S		×	×		×		×	
Chonetes granulifer, L. S							×	
Derbya crassa, L. S							×	
Productus cora, L. S		×			×		×	
Productus costatus, L. S							×	
Productus longispina, L. S		×	×		×		×	
Productus punctatus, L. S					×		×	
Productus semireticulatus, L. S		×						
Rhipidomella pecosi, L. S		×	×		×			
Reticularia perplexa, L. S					×			
Seminula argentea, L. S					×			
Spirifer cameratus, L. S					×		×	
Spirifer cameratus, Bl. sh. M			×					

CLAY COUNTY—Continued.

Localities	1	2	3	4	5	6	7	8
Divisions	I	V	VI	IV?	V	V	V	III?
MOLLUSCA.								
LAMELLIBRANCHIATA.								
Aviculopecten rectilaterarius, Bl. sh. M	....	....	×	.....	....	×	....	.....
Aviculopecten fragilis, Bl. sh. M	....	....	×	.....	....	....	....	.....
Myalina perniformis, Bl. sh. M	....	....	×	.....	....	....	....	.....
Nuculana bellistriata, L. S	....	....	....	.....	....	....	×	.....
GASTROPODA.								
Bellerophon carbonarius, Bl. sh M	....	....	×	.....	....	....	....	.....
Pleurotomaria grayvillensis, Bl. sh. M	....	....	×	.....	....	....	....	.....
CEPHALOPODA.								
Nantilus decoratus, Bl. sh. M	....	....	×	.....	....	×	....	.....
Orthoceras rushense, Bl. sh. M	...	...	×	.....	....	×	....	.....
PALEOSTRACA.								
Phillipsia sangamonensis, L. S	....	....	....	.....	....	....	×?	.....
PISCES.								
Petrodus occidentalis, Bl. sh. M	....	....	....	.....	....	×	....	.....

152. DAVIESS COUNTY.

List of Localities—

1. Near Murry's, on White river, limestone and calcareous shale over Coal V.
2. Scale's mill, on Sugar creek, below Alfordsville, limestone above Coal IIIb.
3. Critchlow bank, east of Epsom, calcareous shale over Coal V.
4. High Rock on White river, cherty limestone above Coal V.
5. Wilson's mine, near Washington, limestone above Coal VI.
6. Washington, roof shales of Coal VI.

Localities	1	2	3	4	5	6
Divisions	V	III	V	V	VI	VI
PLANTÆ.						
Alethopteris lonchitica (?), Cl. sh	....	....	....	....	....	×
Asterophylites sublaevis (?), Cl. sh	....	....	....	....	....	×
Neuropteris hirsuta, Cl. sh	....	....	....	....	....	×
Neuropteris loshi, Cl. sh	....	....	....	....	....	×
Pecopteris arborescens, Cl. sh	....	....	....	....	....	×
Sigillaria reniformis Cl, sh	....	....	....	....	....	×
Sphenophyllum scholotheimi, Cl. sh	....	....	....	....	....	×

DAVIESS COUNTY—Continued.

Localities	1	2	3	4	5	6
Divisions	V	III	V	V	VI	VI
CŒLENTERATA.						
Lophophyllum proliferum, Calc. sh	×	....	....	....	....	....
MOLLUSCOIDEA.						
Brachiopoda.						
Chonetes mesolobus, L. S	×	×	....	×	×	....
Chonetes mesolobus, Calc. sh	×	....	×	....	....	....
Productus cora, L. S	×	×	....	×	....	....
Productus cora, Calc. sh	×	....	....	....	....	....
Productus longispina, L. S	×	....	....	....	×	....
Productus longispina, Calc. sh	×	....	....	....	....	....
Productus punctatus, L. S	×	×	....	×	....	....
Productus punctatus, Calc. sh	×	....	....	....	....	....
Productus semireticulatus, L. S	×	×	....	×	×	....
Productus semireticulatus, Calc. sh	×	....	×	....	....	....
Reticularia perplexa, L. S	....	×	....	....	....	....
Rhipidomella pecosi, L. S	....	....	....	....	×	....
Seminula argentea, L. S	....	....	....	....	×	....
Spirifer cameratus, L. S	....	×	....	×	×	....
MOLLUSCA.						
Lamellabranchiata.						
Aviculopecten providencensis, L. S	×	....	....	....	....	....
Aviculopecten providencensis, Calc. sh	×	....	....	....	....	....
Gastropoda.						
Bellerophon carbonarius, L. S	×	....	....	....	×	....
Bellerophon carbonarius, Calc. sh	×	....	....	....	....	....
Bellerophon montfortanus, L. S	....	....	....	....	×	....
Bellerophon percarinatus, L. S	....	....	....	....	×	....
Cephalopoda.						
Orthoceras rushense, Calc. sh	×	....	×	....	....	....
Orthoceras rushense, L. S	×	....	×	....	×	....
PALEOSTRACA.						
Entomostraca.						
Euproops danae (?), Cl. sh	....	....	....	....	....	×

153. Dubois County.

List of localities—

1. Keshner's mill, Sec. 18-2-5, limestone over Coal IIIb.
2. S. Dillon's, Secs. 5 and 8-2-5, limestone over Coal IIIb.
3. Near Kellersville, limestone over Coal IIIb.
4. Knoxville, east end of mill dam, shale Div. I.
5. Same, bituminous limestone, Div. I.
6. Mrs. Conley's, Sec. 16-2-3, limestone over Coal III.
7. N. E. ¼ of Sec. 21-2-3, bituminous limestone over Coal III.
8. Anderson Valley, Sec. 34-3-4.
9. Kemp, Secs. 31 and 32-3-5, limestone over Coal (?).

Localities	1	2	3	4	5	6	7	8	9
Divisions	III	III	III	I	I	III	III	I	?
PLANTÆ.									
Alethopteris serlii, Cl. sh	....	....	....	×	....	....	....	....	....
Cordaites borassifolia, Cl. sh	....	....	....	×	....	....	....	....	....
PROTOZOA.									
Fusilina cylindrica, L. S.	....	....	....	....	....	....	....	×	....
MOLLUSCOIDEA.									
Brachiopoda.									
Derbya crassa, L. S.	....	....	....	....	....	....	....	×	....
Dielasma bovidens, L. S.	....	....	....	....	....	....	....	×	....
Productus cora, L. S.	....	....	....	....	....	....	....	×	....
Productus costatus, L. S.	....	×	....	....	×	×	×	....	....
Productus longispina, L. S.	....	....	....	....	....	....	....	×	....
Productus punctatus, L. S.	×	×	....	....	....	....	....	×	×
Productus semireticulatus, L. S.	×	×	×	....	....	....	....	....	×
Reticularia perplexa, L. S.	....	×	....	....	....	....	....	×	....
Seminula argentea, L. S.	×	×	....	×	×	....	×	×	....
Spirifer cameratus, L. S.	×	×	×	....	×	×	×	×	×
Spiriferina cristata, L. S.	....	....	....	....	....	....	....	×	....
MOLLUSCA.									
Lamellabranchiata.									
Aviculopecten indianensis, L. S.	....	×	....	....	....	....	....	....	....
Aviculopecten providencensis, L. S.	....	....	....	....	....	....	....	×	....
PISCES.									
Edestus vorax, L. S.	....	....	....	....	....	....	....	....	....

154. Fountain County.

List of localities—

1. Thomas mine, Silver Island, limestone over Coal V.
2. Coal Creek P. O., shale over Coal IV.
3. Silver island, limestone over Coal V.
4. Yeddo, limestone over Coal V.

Localities	1	2	3	4
Divisions	V	IV	V	V
PLANTÆ.				
Alethopteris lonchitica, Sh	....	×	....	....
Neuropteris hirsuta, Sh	....	×	....	....
Sphenopteris crenata, Sh	....	×	....	....
MOLLUSCOIDEA.				
Brachiopoda.				
Chonetes mesolobus, L. S.	×	....	....	....
Productus longispina, L. S.	×	....	×	×
Productus nebraskaensis, L. S.	....	....	....	×
Productus punctatus, L. S.	×	....	....	....
Productus semireticulatus, L. S.	....	....	×	....
Seminula argentea, L. S.	×	....	....	×
Spirifer cameratus, L. S.	×	....	....	×
MOLLUSCA.				
Gastropoda.				
Bellerophon carbonarius, L. S.	×	....	....	....

155. Gibson County.

List of localities—

1. Hazelton.
2. "Dripping Spring," W. A. Walter's land, Sec. 33-2-12, shaly limestone VIIIa.
3. Northeast of Tafftown, Secs. 4 and 5-2-10, bituminous limestone, Div. VIII.
4. Kurtz bank, Sec. 5-2-10, Div. VIII.
5. Patoka, Sec. 25-1-11, bituminous limestone.

Localities	1	2	3	4	5
Divisions	VIII	VIII	VIII	VIII	VIII
COELENTERATA.					
Lophophyllum proliferum, L. S.		×			×
Lophophyllum proliferum, L. S. cl.	×				
MOLLUSCOIDEA.					
Brachiopoda.					
Chonetes verneuilianus, Bl. sh.				×	
Orbiculoidea discus, Bl. sh.					
Productus costatus, L. S.					×
Productus longispina, L. S.			×		×
Productus longispina, L. S. cl.	×				
Productus semireticulatus, L. S.		×	×		
Productus semireticulatus, L. S. cl.	×				
Reticularia perplexa, L. S.		×			
Seminula argentea, L. S.			×		
Seminula argentea, L. S. cl.	×				
Seminula argentea, Bl. sh.				×	
Spirifer cameratus, L. S.					×
Spirifer cameratus, L. S. cl.	×				
Spiriferina cristata, L. S.			×		×
MOLLUSCA.					
Lamellibranchiata.					
Nucula inflata, L. S.					×
Nucula inflata, Bl. sh.				×	
Nuculana bellistriata, Bl. sh.				×	
Gastropoda.					
Bellerophon carbonarius, L. S.					×
Bellerophon carbonarius, L. S. cl.	×				
Bellerophon carbonarius, Bl. sh.				×	
Bellerophon montfortanus, L. S.					×
Bellerophon montfortanus, Bl. sh.				×	
Bellerophon montfortanus, L. S. cl.	×				
Bellerphon percarinatus, L. S. cl.	×				
Macrochilina primigenia, Bl. sh.				×	
Macrochilina primigenia, L. S.					×
Pleurotomaria gravillensis, Bl. sh.				×	
Pleurotomaria sphærulata, L. S. cl.	×				
Pleurotomaria sphærulata, Bl. sh.				×	
Pleurotomaria sphærulata, L. S.					×
Pleurotomaria tabulata, L. S. cl.	×				
Pleurotomaria tabulata, Bl. sh.				×	
Cephalopoda.					
Orthoceras rushense, Bl. sh.				×	
PISCES.					
Petrodus occidentalis, Bl. sh.					

156. Greene County.

List of localities (Cox, '69)—

1. Phillips' mine, Sec. 20-6-4, shales associated with Coal I.
2. Limestone accompanying Coal V, in T. 8 N., R. 7 W.

Localities	1	2
Divisions	I	V
PLANTÆ.		
Calamites canniformis, Cl. sh	×	....
MOLLUSCOIDEA.		
Brachiopoda.		
Chonetes mesolobus, L. S.	....	×
Derbya robustus, L. S.	....	×
Productus carbonarius, L. S.	....	×
Productus cora, L. S.	....	×
Productus semireticulatus, L. S.	....	×
Seminula argentea, L. S.	....	...
Spirifer cameratus, L. S.	....	×
MOLLUSCA.		
Lamellibranchiata.		
Nucula inflata, L. S.	....	×
Gasiropoda.		
Bellerophon carbonarius, L. S.	....	×

157. Knox County.

List of localities—

1. Allen & Foulk's bank, Sec. 9-1-8, clay shale, Div. VII.
2. Edwardsport, Sec. 1-9-4, limestone and calcareous shale, Div. V.
3. Cox hill, Sec. 8-4-8, limestone, Div. V.
4. Edwardsport, Sec. 1-4-9, limestone, Div. V.

Localities	1	2	3	4
Divisions	VII	V	VIII	V
PLANTÆ.				
Alethopteris serlii, Cl. sh	×	.....	.....	.....
Cordaites borassifolia, Cl. sh	×	.....	.....	.....
Neuropteris hirsuta, Cl. sh	×	.....	.....	.....
Pecopteris arborescens, Cl. sh	×	.....	.....	.....
Sphenophyllum schlotheimi, Cl. sh	×	.....	.....	.....
CŒLENTERATA.				
Lophophyllum proliferum, L. S., Calc. sh	.....	×	.....	.....

KNOX COUNTY—Continued.

Localities	1	2	3	4
Divisions	VII	V	VIII	V
MOLLUSCOIDEA.				
BRACHIOPODA.				
Chonetes mesolobus, L. S.		×	×	×
Chonetes granulifer, L S				×
Derbya crassa, L S and Calc. sh		×		
Productus cora, L. S				×
Productus costatus, L. S. and Calc. sh		×		
Productus longispina, L. S			×	×
Productus longispina, L. S and Calc. sh		×		
Productus punctatus, L. S.			×	×
Productus punctatus, L. S. and Calc. sh		×		
Productus semireticulatus, L S			×	×
Productus semireticulatus, L. S. and Calc. sh		×		
Pugnax utah, L. S			×	
Pugnax utah, L. S. and Calc. sh		×		
Reticularia perplexa, L S			×	
Seminula argentea, L. S			×	
Spirifer cameratus, L. S. and Calc. sh		×		
Spiriferina cristata, L. S. and Calc. sh		×		
GASTROPODA.				
Bellerophon carbonarius, L. S. and Calc. sh		×		
Bellerophon carbonarius, L S				×
CEPHALOPODA.				
Orthoceras rushense, L. S. and Calc. sh		×		
Orthoceras rushense, L. S				×

158. MARTIN COUNTY.

List of localities (Cox, '70 and '69)—

1. Crim's coal bank, Sec. 7-2-3, roof shales of Coal I (?).
2. Rollin's coal bank, Sec. 9-5-3, bluish clay shale with Coal I (?).

Localities	1	2
Divisions	I?	I?
PLANTÆ.		
Asterophyllites sublevis, Cl. sh		×
Calamites canniformis, Cl. sh		×
Cordaites borassifolius, Cl. sh	×	
Lepidodendron elegans, Cl. sh	×	
Neuropteris loschi, Cl. sh		×
Neuropteris hirsuta, Cl. sh		×
Pecopteris arborescens, Cl. sh		×
Sigillaria menardi, Cl. sh	×	
Sphenophyllum schlotheimi, Cl. sh		×

159. Orange County.

List of localities—

1. Thos. N. Bronxton quarry, Sec. 5-1-2, in Mansfield sandstone.
2. Osborn quarry, at French Lick, Mansfield sandstone.
3. Bedster quarry, Mansfield sandstone.
4. Dishman quarry, Sec. 23-3-2, Mansfield sandstone.
5. Mansfield sandstone in county in general (Cox, '75, p. 7).

Localities	1	2	3	4	5
Divisions	I	I	I	I	I
PLANTÆ.					
Lepidodendron clypeatum, c. f., S. S	....	....	×	....	....
Lepidodendron dichotomum, S. S	....	....	....	....	×
Lepidodendron rushvillense, S. S	....	....	....	....	×
Lepidodendron veltheimianum, S. S	....	....	....	×	....
Lepidodendron vestitum, S. S	×	....	....	....	....
Lepidophloris crassicaulis, S. S	....	....	....	....	×
Neuropteris biformis, S. S	....	×	....	×	....
Neuropteris elrodi, S. S	....	....	....	....	×
Pseudopecopteris latifolia, S. S	....	....	....	....	×
Pseudopecopteris muricata, S. S	....	×?	....	×	....
Sphenopteris hoeninghausii, S. S	....	....	....	×	....
Sphenopteris tridactylites, S. S	×	....	....	....	×
Ulodendron minus, S. S	....	....	....	....	×
INSECTA.					
Paoli vestusta, S. S	×	....	....	....	....

160. Owen County.

List of localities—

1. Outcrops of Coal V, with black sheety shale and argillaceous and bituminous limestone over; near Clay City.

Locality	1
Division	V
CŒLENTERATA.	
Lophophyllum proliferum, L. S	×
MOLLUSCOIDEA.	
Brachiopoda.	
Productus cora, L. S	×
Productus costatus, L. S	×
Productus longispina, L. S	×
Productus semireticulatus, L. S	×
Reticularia perplexa, L. S	×
Seminula argentea, L. S	×
Spirifer cameratus, L. S	×
PISCES.	
Petrodus occidentalis, Bl. sh. M	×

161. Parke County.

List of localities (1-5, E. T. Cox)—

1. Sand and Sugar creeks, limestone over Coal V.
2. Jose Butler, Sec. 7-15-8, concretionary limestone over Coal VIa.
3. Same, black sheety shale over Coal VIa.
4. Same, black sheety shale over Coal Va.
5. Same, black shale passing into limestone, over Coal V.
6. Jackman, Sec. 7-14-7, limestone over Coal V.

Localities	1	2	3	4	5	6
Divisions	V	VI	VI	V	V	V
CŒLENTERATA.						
Lophophyllum proliferum, L. S.	×	....	....	....	×	....
ECHINODERMATA.						
Eupachycrinus tuberculatus, L. S.	×	....	....	....	....	....
MOLLUSCOIDEA.						
Brachiopoda.						
Chonetes mesolobus, L. S.	×	....	....	....	×	×
Productus cora, L. S.	×	....	....	....	×	....
Productus costatus, L S.	....	×	....	....	×	....
Productus longispina, L. S.	×	....	....	....	×	....
Productus muricatus, L. S.	....	×	....	....	....	....
Productus nebraskaensis, L. S.	....	....	....	....	....	....
Productus semireticulatus, L. S.	×	....	....	....	....	....
Reticularia perplexa, L. S.	....	....	....	....	....	....
Seminula argentea, L. S.	×	×	....	....	....	....
Spirifer cameratus, L. S.	×	×	....	....	×	....
MOLLUSCA.						
Lamellibranchiata.						
Aviculopecten rectilaterarius, Bl. sh. M.	....	....	×	....	....	....
Cardinia fragilis (?), Bl. sh. M.	....	....	×	×	....	....
Gastropoda.						
Bellerophon carbonarius, L. S.	×	....	....	....	×	×
Bellerophon montfortanus, L. S.	....	....	....	....	×	....
Bellerophon percarinatus, L. S.	×	....	....	....	....	....
Cephalopoda.						
Orthoceras rushense, L. S.	×	....	....	....	×	....
Orthoceras rushense, Bl. sh. M.	....	....	....	×	....	....
PISCES.						
Petrodus occidentalis, Bl. sh. M.	....	....	×	....	....	....

162. Perry County.

List of localities—

1. Godfried Everard's, Secs. 10 and 11-5-2, bituminous brown shales over Coal I.
2. Cannelton, clay shales overlying Coal II.

Localities	1	2
Divisions	I	II
PLANTÆ.		
Neuropteris hirsuta, Dk. sh. L.	×	....
Neuropteris loshi, Dk. sh. L.	×	....
MOLLUSCOIDEA.		
Brachiopoda.		
Lingula umbonata, Cl. sh.	....	×

163. Pike County.

List of localities—

1. Hosea Alexander's, Sec. 4-15-8, gray clay shale overlying Coal VII.
2. Sand hill, Sec. 22-1 N., 8, clay shale overlying Coal VII.
3. Same, ferruginous limestone over Coal VIa.
4. Dr. Posey's, Sec. 12-1 N., 8, magnesian limestone over Coal V.
5. River bank, Sec. 13-1 N., 8, ferruginous limestone over Coal VIa.
6. G. W. Thomas, Sec. 31-1 S., 6, dark shale and black sheety shale overlying Coal IIIb.
7. T. C. Milburn, Sec. 35-1 S., 7, shales (?) over Coal IIIb.
8. Wells & Whitman's mine, clay shale overlying Coal V.
9. Powers and Tevault farms, Secs. 16 and 17-3 S., 7, magnesian limestone over Coal V.

LOCALITIES	1	2	3	4	5	6	7	8	9
DIVISIONS	VII	VI	VI	V	VI	III	V	V	V
PLANTÆ.									
Alethopteris serlii, Cl. sh.							×		
Asterophyllites longifolius, Cl. sh.	×								
Cordaites borassifolia, Cl. sh.	×								
Cordaites borassifolia, Bl. sh					×				
Cordaites diversifolius, Cl. sh	×								
Neuropteris collinsi, Cl. sh.							×		
Neuropteris hirsuta, Cl. sh.	×						×		
Neuropteris rarinervis, Cl. sh.	×						×		
Pecopteris arborescens, Cl. sh.	×						×		
Sphenophyllum schlotheimi, Cl. sh.	×								
Trigonocarpum oliviforme, S. S.						×			
COELENTERATA.									
Chetetes milleporaceus, L. S.			×		×				
Lophophyllum proliferum, L. S.			×						
MOLLUSCOIDEA.									
BRACHIOPODA.									
Chonetes mesolobus, L. S.									×
Lingula umbonata, Bl. sh.					×				
Orbiculoidea missouriensis, Bl. sh. M.					×				
Productus costatus, L. S.				×					
Productus punctatus, L. S.			×	×				×	×
Productus semireticulatus, L. S.				×				×	×
Reticularia perplexa, L. S.			×	×					
Seminula argentea, L. S.			×						
Spirifer cameratus, L. S.				×					
MOLLUSCA.									
LAMELLIBRANCHIATA.									
Aviculopecten providencensis, L. S.				×					
Pseudomonotis hawni (?), L. S.									×
CEPHALOPODA.									
Nautilus decoratus, L. S., Bl. sh. M.				×				×	×
PISCES.									
Petrodus occidentalis, Bl. sh. M.					×				

164. POSEY COUNTY.

List of localities—

1. New Harmony cut-off, Div. VIII (Sampson collection).
2. Gluck's, S. W. ¼ Sec. 32-6-11, calcareous shale, Div. VIII.
3. Helfert's, St. Wendell, black sheety shale, Div. VIII.
4. New Harmony, Div. VIII.
5. Macadoo creek, Div. VIII.
6. Blairville, on Big creek, Div. VIII.

LOCALITIES	1	2	3	4	5	6
DIVISIONS	VIII	VIII	VIII	VIII	VIII	VIII
PLANTÆ.						
Asterophycus coxi, S. S				×		
Didymophyllum oweni, S. S.				×		
Didymophyllum oweni, Sh.						×
Paleophycus milleri, L. S.				×		
PROTOZOA.						
Lophophyllum proliferum	×					
MOLLUSCOIDEA.						
BRACHIOPODA.						
Productus costatus	×					
Productus longispina	×					
Productus punctatus	×					
Reticularia perplexa, Calc. sh.	×	×				
Rhipidomella pecosi, Calc. sh	×	×				
Seminula argentea	×					
Spirifer cameratus	×					
MOLLUSCA.						
LAMELLIBRANCHIATA.						
Cardiomorpha missouriensis, Bl. sh. M.			×			
Monopteria longispina, Sh.					×	
Nucula inflata, Bl. sh. M.			×			
Pernopecten aviculatus	×					
GASTEROPODA.						
Bellerophon carbonarius	×					
Bellerophon montfortanus	×					
Bellerophon percarinatus	×					
Pleurotomaria carbonarius	×					
Pleurotomaria grayvillensis	×					
Pleurotomaria sphærula	×					
Pleurotomaria tabulata	×					
CEPHALOPODA.						
Orthoceras rushense	×					
PISCES.						
Petrodus occidentalis, Bl. sh. M.			×			

165. SULLIVAN COUNTY.

List of localities—

1. Ferree's, Sec. 4-7-9, shelly limestone, Div. VIII.
2. Merom hill, Sec. 18-7-10, limestone.
3. Merom hill, Sec. 18-7-10, clay shale.
4. Turman's creek and branches, T. 8-10, productal limestone, Div. VIII.
5. Eli Dix's, Sec. 35-9-10, black clod.

6. Badger's mill, Sec. 25-9-11, productal limestone, and plant in rock not designated, Div. VIII.
7. On Parker creek, Sec. (?)-9-10, limestone (?), Div. VIII.
8. On Parker creek, Sec. (?)-9-10, clay shale, Div. VIII.
9. Mr. G. G. Taylor, Sec. 19-6-9, bluish-gray limestone, Div. VIII.
10. Pioneer shaft, Sec. 27-9-9, clay shale, Div. VII.
11. Shelburn shaft, Sec. 34-9-9, calcareous roof shales, Div. VIII.
12. Standard shaft, Sec. 27-9-9, limestone clay, Div. VIII.
13. Standard shaft, Sec. 27-9-9, clay shale, Div. VII.
14. Banholzer's shaft, Sec. 30-9-8, limestone clay, Div. VI.
15. Barnes' bank, Sec. 13-8-8, limestone, Div. V.
16. D. Ring and Jno. Everhart, Secs. 3 and 4-8-8, dark calcareous clay, Div. VI.
17. D. Ring and Jno. Everhart, Secs. 3 and 4-8-8, limestone, Div. V.
18. Berlin's shaft, Sec. 1-8-9, clay shale, Div. VII.

SULLIVAN COUNTY—Continued.

Localities	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Divisions	VIII	VIII	VIII	VIII	VIII	VIII	VIII	VIII	VIII	VII	VIII	VIII	VII	VI	V	VI	V	VII
PLANTÆ.																		
Annularia longifolia, Cl. sh										×								
Annularia sphenophylloides, Cl sh										×								
Asterophyllites equisetiformis, Cl. sh										×								
Asterophyllites longifolius, Cl. sh													×					
Calamites canniformis, Cl. sh																		
Cordaites **borassifolius**, Cl. sh						×		×		×								
Cordaites diversifolius, Cl. sh										×			×					
Lepidodendron **elegans**, Cl. sh													×					
Neuropteris hirsuta, Cl. sh								×		×			×					
Neuropteris loshi, Cl. sh													×					
Neuropteris rarinervis, Cl. sh								×		×								
Pecopteris arborescens, Cl. sh										×								×
Sigillaria reniformis, Cl. sh										×								×
Sphenophyllum schlotheimi, Cl sh										×			×					×
Stigmaria ficoides, Cl. sh										×								
Syringodendron **pachyderma**, Cl. sh																		×
PROTOZOA.																		
Fusilina cylindrica, L. S.	×																	
CŒLENTERATA.																		
Lophophyllum proliferum, L S	×																	
Lophophyllum proliferum, Calc. sh											×							
MOLLUSCOIDEA.																		
Brachiopoda.																		
Chonetes mesolobus, L. S		×				×	×					×						
Dielasma bovidens, L. S		×							×									
Lingula spatulata, L. S							×											
Orbiculoidea discus, L. S						×												

SULLIVAN COUNTY—Continued.

Localities	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Divisions	VIII	VIII	VIII	VIII	VIII	VIII	VIII	VIII	VIII	VII	VIII	VIII	VII	VI	V	VI	V	VII
Orbiculoidea missouriensis, L. S.							×											
Productus cora, L. S.		×				×(?)												
Productus cora, Calc. sh.											×							
Productus longispina, L. S.		×		×											×			
Productus longispina, L. S. cl.												×						
Productus longispina, Calc. sh.											×							
Productus punctatus, L. S.		×		×		×												
Productus semireticulatus, L. S.				×		×									×			
Reticularia perplexa, L. S.	×	×				×								×	×			
Reticularia perplexa, Calc. sh											×?							
Seminula argentea, L. S.	×			×		×												
Seminula argentea, Calc. sh.											×							
Seminula argentea, L. S. cl.																×		
Spirifer cameratus, L. S.		×		×		×			×						×		×	
Spirifer cameratus, L. S. cl.												×						
Spiriferina cristata, L. S.		×																
MOLLUSCA.																		
Lamellibranchiata.																		
Aviculopecten rectilaterarius, Calc. sh.											×							
Cardinia fragilis, L. S					×	×												
Cardinia fragilis, L. S. cl.												×						
Nucula inflata, L. S. cl.					×							×						
Nuculana bellistriata, cl.					×													
Nuculana bellistriata, L. S. cl.												×						
Scaphoda.																		
Dentalium sublæve, L. S.		×	×															
Gasteropoda.																		
Bellerophon carbonarius, L. S.						×	×		×									
Bellerophon carbonarius, L. S. cl.												×					×	
Bellerophon carbonarius, Calc. sh.											×							
Bellerophon montfortanus, L. S.						×	×											

Bellerophon montfortanus, L. S. cl												×						
Bellerophon percarinatus, Calc. sh											×							
Euomphalus subrugosus, L. S.																		
Macrochilina gracilis, L. S.			×			×												
Pleurotomaria carbonarius, L. S.						×												
Pleurotomaria tabulata, L. S						×												
CEPHALOPODA.																		
Nautilus decoratus, L. S							×		×		×							
Nautilus decoratus, Calc. sh											×							
Nautilus decoratus, L. S. cl												×						
Orthoceras rushense, Calc. sh											×							
PALEOSTRACA.																		
Phillipsia (Griffithides) scitula, Calc. sh											×							
PISCES.																		
Petrodus occidentalis, L. S.						×												

166. Vanderburgh County.

List of localities—

1. Phillip Koch Sons' and others, Sec. 14-6-1, in limestone, Div. VIII.
2. Stimson's spring, Sec. 28-6-11, limestone, Div. VIII.
3. Michael Gluck's lime kiln, Sec. 32-6-11, in calcareous shale, Div. VIII.
4. Geo. Helfert's, Sec. 7-5-11, in black shale covering Coal VIIIa.

Localities	1	2	3	4
Divisions	VIII	VIII	VIII	VIIIa
CŒLENTERATA.				
Campophyllum torquinum, L. S.	×	.....	.....	.....
Lophophyllum proliferum, L. S.	×	.....	.....	.....
MOLLUSCOIDEA.				
Brachiopoda.				
Derbya crassa, L. S.	×	.....	.....	.....
Dielasma bovidens, L. S.	×	.....	.....	.....
Productus longispinus, L. S.	×	.....	.....	.....
Pugnax utah, L. S.	×	.....	.....	.....
Reticularia perplexa, L. S.	×	×	.....	.....
Reticularia perplexa, Calc. sh.	.....	.....	×	.....
Seminula argentea, L. S.	×	.....	.....	.....
Spiriferina cristata, L. S.	×	.....	.....	.....
Spiriferina cristata, Calc. sh.	.....	.....	×	.....
MOLLUSCA.				
Lamellibranchiata.				
Cardiamorpha missouriensis, Bl. sh. M.	.....	.....	.....	×
Nucula inflata, Bl. sh. M.	.....	.....	.....	×
PISCES.				
Petrodus occidentalis, Bl. sh. M.	.....	.....	.....	×

167. Vermillion County.

List of localities—

1. Horseshoe, black sheety shale over Coal VIII (?).
2. Horseshoe, limestone over Coal VII.
3. Above Horseshoe, pyritous ironstone in roof of Coal VII.
4. A mile below Horseshoe, shales above Coal VIb.
5. Mouth of Jonathan's creek, black roof shales of Coal VIb.
6. Same, clay shale below Coal VIb.

7. Same, ironstone bands in clay shales below Coal VIb.
8. Bluffs south of Newport, ferruginous limestones with Coal VIa.
9. Hawley & Helt's mine, head of Helt's prairie, clay shale between Coal VIa and its usual black shale roof.
10. Nebecker & White's coal banks on Norton's creek, ironstones in shale overlying Coal VII.
11. Near Newport, in sandstone of old channel filling, Div. IX (?).
12. Between Perrysville and Covington, shales in Div. IV (?).
13. Perrysville, limestone over Coal V.
14. Same, black shales with Coal V.
15. Same, calcareous shales with Coal V.

VERMILLION COUNTY—Continued.

Localities	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Divisions	VIII	VII	VII	VI	VI	VI	VI	VI	VI	VII	IX?	IV	V	V	V
PLANTÆ.															
Alethopteris serlii, Cl. sh												×			
Cordaites borassifolia, Cl. sh												×			
Neuropteris hirsuta, Cl. sh						×						×			
Syringodendron porteri, S. S											×				
PROTOZOA.															
Fusilina cylindrica, L. S													×		
CŒLENTERATA.															
Lothophyllum proliferum, Calc. sh															×
MOLLUSCOIDEA.															
Brachiopoda.															
Ambocoelia planiconvexa, Bl. sh. M														×	
Chonetes mesolobus, Fe. L. S								×							
Chonetes mesolobus, Calc. sh															×
Chonetes mesolobus, L. S								×					×		
Chonetes mesolobus, Bl. sh. M														×	
Cleiothyris roissyi, Sh				×											
Derbya crassa, Sh				×											
Derbya crassa, Fe. L. S								×							
Derbya crassa, L. S													×		
Dielasma bovidens, Sh				×											
Orbiculoidea missouriensis, Bl. sh. M	×														
Orbiculoidea missouriensis, Fe. L. S										×					
Orbiculoidea missouriensis, L. S													×		
Productus longispina, L. S		×													
Productus longispina, Fe. L. S										×					
Productus longispina, Sh				×											
Productus punctatus, Sh				×											
Productus semireticulatus, L. S													×		
Productus scabriculus, Sh				×											
Pugnax utah, L. S													×		
Seminula argentea, sh				×											

Seminula argentea, L. S.													×		
Seminula argentea, Calc. sh.															×
Spirifer cameratus, Cl. sh.				×											
Spirifer cameratus, Fe. L. S.							×	×							
Spirifer cameratus, L. S.													×		
Spirifer cameratus, Calc. sh.															×
Spiriferina cristata, sh.				×											
Spiriferina cristata, L. S.													×		
MOLLUSCA.															
LAMELLIBRANCHIATA.															
Aviculopecten coxanus, Calc. sh.															×
Aviculopecten rectilaterarius, Fe. L. S.								×		×					
Aviculopecten rectilaterarius, Bl. sh. M.														×	
Aviculopecten rectilaterarius, Cl. sh.									×						
Cardiamorphia missouriensis, Fe. L. S.					×										
Cardinia fragilis, Fe. L. S.										×					
Cardinia fragilis, Bl. sh. M.								×							
Pernopecten aviculatus, Fe. L. S.								×							
Solenomya radiata, Calc. sh.															×
GASTEROPODA.															
Bellerophon montfortanus, Fe. L. S.							×								
Bellerophon percarinatus, sh.				×											
Euomphalus subrugosus, L. S.													×		
Pleurotomaria carbonarius, Calc. sh.															×
Trachydomia nodosa, L. S.													×		
CEPHALOPODA.															
Orthoceras rushense, Bl. sh. M.								×						×	
Orthoceras rushense, Fe. L. S.					×		×								
PALEOSTRACA.															
ARTHROPODA.															
Phillipsia sangamonensis (?), L. S.													×		
Phillipsia scitula, L. S.													×		
ENTOMOSTRACA.															
Leaia tricarinata, Bl. sh. M.															
PISCES.															
Petrodus occidentalis, Bl. sh.					×			×						×	
Petrodus occidentalis, Fe. L. S.										×					
Petrodus occidentalis, Fe			×												

168. Vigo County.

List of localities—

1. Barrick & Son's mine, Sec. 30-12-9, limestone above Coal VII.
2. Bigelow & Co.'s mine, Sec. 24-12-10, gray clay shale above Coal VII.
3. Coal creek, general section, Sec. 19-13-9, in limestone below Coal VIII.
4. Durkey's Ferry, Sec. 21-13-9, in clay shale over Coal VII.
5. Mr. J. S. Wyeth, at Hartford, Sec. 14-10-9, clay shale over Coal VII.
6. South Fork Otter creek, near Grant Station, in limestone concretions in roof shale of Coal VIa.

Localities	1	2	3	4	5	6
Divisions	VII	VII	VII	VII	VII	VI
PLANTÆ.						
Alethopteris grandifolia, Cl. sh				×		
Alethopteris niagarensis, Cl. sh				×		
Annularia longifolia, Cl. sh					×	
Annularia sphenophylloides, Cl. sh				×		
Calamites canniformis, Cl. sh				×	×	
Cordaites borassifolius, Cl. sh				×		
Cordaites diversifolius, Cl. sh				×		
Cyclopteris elegans, Cl. sh					×	
Hymenophyllites pinnatifidus, Cl. sh					×	
Lepidodendron elegans, Cl. sh				×		
Neuropteris collinsi, Cl. sh				×		
Neuropteris hirsuta, Cl. sh				×	×	
Neuropteris loshi, Cl. sh					×	
Neuropteris rarinervis, Cl. sh				×	×	
Pecopteris arborescens, Cl. sh				×	×	
Pseudopecopteris callosa, Cl. sh				×		
Sigillaria menardi, Cl. sh					×(?)	
Sigillaria obovata, Cl. sh					×	
Sigillaria oculata, Cl. sh					×	
Sphenopteris alata, Cl. sh					×	
Sphenophyllum schlotheimi, Cl. sh				×	×	
Spirangium corrugatum, Cl. sh				×		
Spirangium prendeli, Cl. sh				×		
Trigonocarpum oliviforme, Cl. sh				×		
Trigonocarpum ornatum, Cl. sh				×		
Trigonocarpum triloculare, Cl. sh				×		
Ulodendron punctatum, Cl. sh				×		
MOLLUSCOIDEA.						
Brachiopoda.						
Productus cora, L. S			×			
Productus punctatus, L. S	×		×			×
MOLLUSCA.						
Lamellibranchiata.						
Aviculopecten rectilaterarius, L. S		×				×
Gastropoda.						
Bellerophon carbonarius, Sh		×				
Euomphalus subrugosus, Sh		×				
PALEOSTRACA.						
Leaia tricarinata, Cl. sh				×		
PISCES.						
Petrodus occidentalis, L. S						×

169. Warren County.

List of localities—

1. Rock creek, Sec. 18-21-8, black bituminous limestone, Div. V.
2. Rock creek, Sec. 18-21-8, calcareous iron ore, Div. IV.
3. Main's mill, Redwood creek, Sec. 35-21-9, black limestone, Div. V.
4. Main's mill, Redwood creek, Sec. 35-21-9, carbonate of iron, Div. V.
5. Marshfield Coal Co.'s shaft, Sec. 9-20-9, clay shale, Div. VI.
6. Hooper & Barringer's shaft, Sec. 8-20-9, clay shale, Div. VI.
7. West Lebanon shaft, Sec. 13-21-9, clay shale, Div. VI.
8. Briscoe's Coal Bank, Sec. 29-23-8, clay shale, Div. VII.
9. Pine creek, Sec. 22-22-8, limestone, Div. V.

Localities	1	2	3	4	5	6	7	8	9
Divisions	V	IV	V	V	VI	VI	VI	VII	V
PLANTÆ.									
Alethopteris lonchitica, Cl. sh								×	
Alethopteris serlii, Cl. sh								×	
Annularia longifolia, Cl. sh					×	×			
Asterophyllites equisetiformis, Cl. sh						×		×	
Cardiocarpum ingens, Cl. sh								×	
Cordaites borassifolia, Cl. sh						×	×	×	
Sphenopteris spinosa, Cl. sh							×		
Lepidodendron clypeatum, Cl. sh							×		
Neuropteris collinsi, Cl. sh					×				
Neuropteris hirsuta, Cl. sh					×			×	
Neuropteris rarinervis, Cl. sh					×			×	
Pecopteris arborescens, Cl. sh								×	
Sigillaria reniformis, Cl. sh						×	×		
Sphenophyllum schlotheimi, Cl. sh					×	×	×	×	
Ulodendron punctatum, Cl. sh							×		
CŒLENTERATA.									
Lophophyllum proliferum, L. S.			×						
MOLLUSCOIDEA.									
Brachiopoda.									
Chonetes mesolobus, L. S.	×		×						
Productus cora, L. S.			×						
Productus costatus, L. S.		×	×						
Productus costatus, Fe		×							
Productus longispina, L. S.			×	×					
Productus semireticulatus, L. S.	×								
Reticularia perplexa, L. S.	×		×						
Reticularia perplexa, Fe		×							
Seminula argentea, L. S.			×						
Spirifer cameratus, L. S.	×		×						
MOLLUSCA.									
Gastropoda.									
Soleniscus fusiformis, L. S.			×						
Nautilus decoratus, L. S.									×
PALEOSTRACA.									
Phillipsia scitula, L. S.			×						
PISCES.									
Helodus carbonarius, L. S.			×						

170. Warrick County.

List of localities—

1. Beardsley's mine, Sec. 29-3-6, Div. III, black shale overlying Coal IIIb.
2. Miller's mine, Sec. 28-3-7, Div. V, ferruginous limestone over Coal V.
3. Chandler shaft, Chandler, Div. VI, limestone below Coal VII.

Localities	1	2	3
Divisions	III	V	VI
PROTOZOA.			
Lophophyllum proliferum, Bl, sh. M	×	.....	.....
MOLLOSCOIDEA.			
Brachiopoda.			
Chonetes mesolobus, Bl. sh. M	×	.....	.....
Productus costatus, L. S	.....	×	.....
Productus punctatus, L. S	.....	×	.....
Productus semireticulatus, Bl. sh. M	×	.....	.....
Reticularia perplexa, Bl. sh. M	×	.....	.....
Reticularia perplexa, L. S	.....	×	×
Spirifer cameratus, Bl. sh. M	×	.....	.....
Spirifer cameratus, L. S	.....	×	×
MOLLUSCA.			
Lamellibranchiata			
Aviculopecten rectilaterarius, Bl. sh. M	×	.....	.....
Gasteropoda.			
Bellerophon carbonarius, Bl. sh. M	×	.....	.....
Bellerophon percarinatus, Bl. sh. M	×	.....	.....
Macrochilina primogenia, Bl. sh. M	×	.....	.....
Pleurotomaria carbonarius, Bl. sh. M	×	.....	.....
Soleniscus fusiformis, Bl. sh M	×	.....	.....
Soleniscus paludinalformis, Bl. sh. M	×	.....	.....
Cephalopoda.			
Nautilus decoratus, Bl. sh. M	×	.....	.....
Orthoceras rushense, Bl. sh. M	×	.....	.....
PISCES.			
Edestus vorax, Bl. sh. M	×	.....	.....
Petrodus occidentalis, Bl. sh. M	×	.....	.....

171. Summary Table.

		Division I (and II).	Division III.	Division IV.	Division V.	Division VI.	Division VII.	Division VIII.	Division IX.	Sandstone.	Black Shale, Land.	Clay Shale.	Black Shale, Marine.	Calc. Clay or Shale.	Limestone.	Sheet A.	Sheet B.	Sheet C.	Sheet D.	Sheet E.	Sheet F.	Sheet G.
	PLANTÆ.																					
1	Alethopteris grandifolia Newberry						×					×					×					
2	Alethopteris lonchitica Schlotheim			×		×	×					×				×			×			
3	Alethopteris niagarensis						×					×					×					
4	Alethopteris serlii Brongniart			×	×		×					5				×			×	×		
5	Annularia longifolia Brongniart					×	×					×				×	×	×				
6	Annularia sphenophylloides Zenker						×					×					×	×				
7	Asterophycus coxi Lesq							×		×										×		×
8	Asterophyllites equisetiformis Schlotheim					×	×					5				×	×	×				
9	Asterophyllites longifolius Sternberg						×					×						×		×		
10	Asterophyllites sublævis Lesq					×						×							×			
11	Calamites canniformis Schlotheim					×	×					×					×	×	×			
12	Cardiocarpon ingens Lesq						×					×				×						
	Cordaites angustifolius (see 14).																					
13	Cordaites borassifolius Sternberg	×	×	×		×	5	×				12				×	×	×	×	×		
14	Cordaites diversifolius Lesq						×					5					×	×		×		
15	Cyclopteris elegans Lesq						×					×					×					
16	Didymophyllum oweni Lesq							×		×		×										×
	Hymenophyllites alata (see 41).																					
17	Hymenophyllites pinnatifidus Lesq						×					×					×					
	Hymenophyllites spinosus (see 44).																					
18	Lepidodendron clypeatum Lesq	×				×				×		×				×				×		
19	Lepidodendron dichotomum Sternberg	×								×										×		
20	Lepidodendron elegans Sternberg						×	×				×					×	×	×			
21	Lepidodendron rushvillense Andrews	×								×										×		
22	Lepidodendron veltheimanum Sternberg	×								×										×		
23	Lepidodendron vestitum Lesq	×								×										×		
24	Lepidophloros crassicaulis Corda	×								×										×		
25	Neuropteris biformis Lesq	×								×										×		
26	Neuropteris cellinsi Lesq				×	×	×					×				×	×			×		
27	Neuropteris elrodi Lesq	×																		×		
28	Neuropteris hirsuta Lesq	×		×	×	×	7	×			5	17				×	×	×	×	×	×	

SUMMARY TABLE—Continued.

		Division I (and II).	Division III.	Division IV.	Division V.	Division VI.	Division VII.	Division VIII.	Division IX.	Sandstone.	Black Shale, Land.	Clay Shale.	Black Shale, Marine.	Calc. Clay or Shale.	Limestone.	Sheet A.	Sheet B.	Sheet C.	Sheet D.	Sheet E.	Sheet F.	Sheet G.
29	Neuropteris loshi Brongniart					×	×				×	×					×	×	×		×	
30	Neuropteris rarinervis Bunbury				×	×	5	×				10				×	×	×		×		
31	Palæophycus milleri Lesq							×							×							×
	Paleoxyris (see 46, 47).																					
32	Pecopteris arborescens Schlotheim				×	×	7					10	×			×	×	×	×	×		
	Pecopteris callosa (see 33).																					
33	Pseudopecopteris callosa Lesq						×					×					×					
34	Pseudopecopteris latifolia Brongniart	×								×										×		
35	Pseudopecopteris muricata Brongn	×								×										×		
36	Sigillaria menardi Brongn						×					×					×		×			
37	Sigillaria obovata Lesq						×					×					×					
38	Sigillaria oculata Schlotheim						×					×					×					
39	Sigillaria reniformis Brongn					×	×					5				×		×	×			
40	Sphenophyllum schlotheimi Brongn	×				×	8				×	15				×	×	×	×	×		
41	Sphenopteris alata Brongn						×					×					×					
42	Sphenopteris crenata Lindley and Hutton			×								×				×						
43	Sphenopteris hoeninghausi Brongn	×								×										×		
	Sphenopteris latifolia (see 34).																					
44	Sphenopteris spinosa Goeppert					×						×				×						
45	Sphenopteris tridactylites Brongn	×								×										×		
46	Spiranginum corrugatum Lesq						×					×					×					
47	Spiranginum prendeli Lesq						×					×					×					
48	Stigmaria ficoides Brongn						×					×						×				
49	Syringodendron pachyderma Brongn						×					×						×				
50	Syringodendron porteri Lesq								×	×						×						
51	Trigonocarpum oliviforme Lindley and Hutton		×				×			×		×					×			×		
52	Trigonocarpum ornatum Newberry						×					×					×					
53	Trigonocarpum triloculare Hildreth						×					×					×					
54	Ulodendron punctatum Lindley and Hutton					×	×					×				×	×					
55	Ulodendron minus Lindley and Hutton	×								×										×		
	PROTOZOA.																					
56	Fusilina cylindrica Fischer				×			×							×	×		×				

	CŒLENTERATA.																					
57	Campophyllum torquium Owen	....	....	....	....	....	....	×	....	....	....	....	....	....	×	....	....	....	....	....	....	×
58	Chetetes milleporaceus Edwards and Haime	....	....	....	....	×	....	....	....	....	....	....	....	....	×	....	....	....	....	×	....	....
	Cyathaxonta prolifera (see 59).																					
59	Lophophyllum proliferum McChesney	....	×	....	7	×	....	5	....	....	....	....	×	5	10	×	×	×	×	×	×	×
	ECHINODERMATA.																					
60	Eupacycrinus tuberculatus Meek and Worthen	....	....	....	×	....	....	....	....	....	....	....	....	....	×	×	....	....	....	....	....	....
	MOLLUSCOIDEA.																					
	BRACHIOPODA.																					
61	Amboccœlia planoconvexus Shumard	....	....	....	×	....	....	....	....	....	....	....	×	....	....	×	....	....	....	....	....	....
	Athyris roissyi (see 65).																					
	Athyris subtilita (see 85).																					
62	Chonetes granulifer Owen	....	....	....	×	....	....	....	....	....	....	....	....	....	×	....	×	....	×	....	....	....
63	Chonetes mesolobus Nor. and Prat	....	×	....	18	×	....	5	....	....	....	....	×	×	24	×	×	×	×	....	×	....
	Chonetes smithi (see 62).																					
64	Chonetes verneuilianus Nor. and Prat	....	....	....	....	....	....	×	....	....	....	....	×	....	....	....	....	....	....	....	....	×
65	Cleiothyris roissyi L'Eveillé	....	....	....	....	×	....	....	....	....	....	×	....	....	....	×	....	....	....	....	....	....
66	Derbya crassa Meek and Hayden	....	....	....	×	×	....	×	....	....	....	×	....	×	5	×	×	....	×	....	....	×
67	Derbya robusta Hall	....	....	....	×	....	....	....	....	....	....	....	....	....	×	....	....	×	....	....	....	....
68	Dielasma bovidens Morton	....	....	....	....	×	....	×	....	....	....	×	....	....	×	×	....	×	....	....	....	×
	Discina convexa (see 71).																					
	Discina nitida (see 72).																					
	Hemipronites crassus (see 70).																					
	Hemipronites crenistria (see 70).																					
69	Lingula spatulata Vanuxem	....	....	....	....	....	....	×	....	....	....	....	....	....	×	....	....	×	....	....	....	....
70	Lingula umbonata Cox	×	....	....	....	×	....	....	....	....	....	×	×	....	....	....	....	....	....	×	×	....
71	Orbiculoidea convexa Hall	....	....	....	....	....	....	×	....	....	....	....	....	....	×	....	....	×	....	....	....	....
72	Orbiculoidea missouriensis Shumard	....	....	....	×	×	×	×	....	....	....	....	×	....	×	×	....	×	....	×	....	....
	Orthis carbonaria (see 84).																					
	Orthis pecosi (see 84).																					
	Orthis umbraculum (see 67).																					
73	Productus carbonarius de Konnick	....	....	....	×	....	....	....	....	....	....	....	....	....	×	....	....	×	....	....	....	....
74	Productus cora d'Orb	....	×	....	11	....	×	×	....	....	....	....	....	×	14	×	×	×	×	....	....	....
75	Productus costatus Sowerby (?)	....	....	×	7	×	....	×	....	....	....	....	....	×	11	×	×	×	×	×	×	×
76	Productus longispina Sowerby (?)	....	....	....	16	×	×	9	....	....	....	×	....	6	21	×	×	×	×	....	....	×
77	Productus muricatus Norwood and Prat	....	....	....	....	×	....	....	....	....	....	....	....	....	×	×	....	....	....	....	....	....
78	Productus nebraskaensis Owen	....	....	....	×	....	....	....	....	....	....	....	....	....	×	×	....	....	....	....	....	....
79	Productus punctatus Martin	....	×	....	9	×	×	5	....	....	....	×	....	×	18	×	×	×	×	×	×	×
	Productus rogersi (see 78).																					
80	Productus scabriculus Martin	....	....	....	....	×	....	....	....	....	....	×	....	....	....	×	....	....	....	....	....	....
81	Productus semireticulatus Martin	....	×	....	15	×	....	5	....	....	....	....	×	×	21	×	×	×	×	×	×	×
	Productus wabashensis (see 76).																					
82	Pugnax utah Marcou	....	....	....	×	....	....	×	....	....	....	....	....	×	×	×	....	....	×	....	....	×
83	Reticularia perplexa McChesney	....	×	×	6	×	....	10	....	....	....	....	×	×	20	×	×	×	×	×	×	×

SUMMARY TABLE—Continued.

		Division I (and II).	Division III.	Division IV.	Division V.	Division VI.	Division VII.	Division VIII.	Division IX.	Sandstone.	Black Shale, Land.	Clay Shale.	Black Shale, Marine.	Calc. Clay or Shale.	Limestone.	Sheet A.	Sheet B.	Sheet C.	Sheet D.	Sheet E.	Sheet F.	Sheet G.
84	Rhipidomella pecosi Marcou	....	....	....	×	×	....	×	....	....	....	....	....	×	×	....	×	×	×	....	×	....
	Rhynchonella osagensis (see 82).																					
85	Seminula argentea Shephard	....	....	....	7	×	....	9	....	....	....	×	×	×	16	×	×	×	×	×	....	×
86	Spirifer cameratus Morton	....	×	....	17	6	×	6	....	....	....	×	×	×	28	×	×	×	×	×	×	×
	Spirifer lineatus (see 83).																					
	Spirifer planoconvexus (see 61).																					
87	Spiriferina cristata Schlotheim	....	....	....	×	×	....	5	....	....	....	×	....	×	7	×	....	×	×	....	....	×
	Spiriferina kentuckyensis (see 87).																					
	Terebratula bovidens (see 68).																					
	MOLLUSCA.																					
	LAMELLIBRANCHIATA.																					
88	Aviculopecten coxanus Meek and Worthen	....	....	....	×	....	....	....	....	....	....	....	....	×	....	×	....	....	....	....	....	....
89	Aviculopecten providensensis Cox	....	....	....	×	....	....	....	....	....	....	....	....	×	×	....	....	×	×	....	....	....
90	Aviculopecten rectilaterarius Cox	....	×	....	×	5	×	×	....	....	....	×	5	×	×	×	×	×	....	....	×	....
91	Cardiomorpha missouriensis Shumard	....	....	....	....	×	....	×	....	....	....	....	×	....	×	×	....	....	....	....	....	×
92	Cardinia fragilis Cox	....	....	....	×	×	×	×	....	....	....	....	×	×	×	×	×	×	....	....	....	....
	Entolium aviculatum (see 98).																					
	Leda bellistriata (see 97).																					
93	Macrodon carbonarius Cox	....	....	....	....	×	....	....	....	....	....	×	....	....	....	×	....	....	....	....	....	....
94	Monopteria longispina Cox	....	....	....	....	....	....	×	....	....	....	×	....	....	....	×	....	....	....	....	....	....
95	Myalina perniformis Cox	....	....	....	....	×	....	....	....	....	....	....	×	....	....	×	....	....	....	....	....	....
96	Nucula inflata	....	....	....	×	....	....	5	....	....	....	....	×	×	×	....	....	×	×	....	....	×
97	Nuculana bellistriata Stevens	....	....	....	×	....	....	×	....	....	....	....	×	×	×	....	×	×	....	....	....	×
98	Pernopecten aviculatus Swallow	....	....	....	....	×	....	×	....	....	....	....	×	....	×	×	....	....	....	....	....	×
99	Solenomya radiata M. and W	....	....	....	×	....	....	....	....	....	....	....	....	×	....	×	....	....	....	....	....	....
	SCAPHOPODA.																					
100	Dentalium sublæve Hall	....	....	....	....	....	....	×	....	....	....	....	....	....	×	....	....	×	....	....	....	....

	GASTEROPODA.																					
101	Bellerophon carbonarius Cox	....	×	....	10	×	....	7	....	....	....	....	×	5	13	×	×	×	×	3	×	×
102	Bellerophon montfortanus Nor. and Prat	....	....	....	×	×	....	5	....	....	....	....	×	×	6	×	....	×	×	....	....	×
103	Bellerophon percarinatus Conrad	....	×	....	×	×	....	×	....	....	....	×	×	×	×	×	....	×	×	....	×	×
104	Euomphalus subrugosus M. and W	....	....	....	×	....	×	....	....	....	....	×	....	....	×	×	×	....	....	....	....	....
	Euomphalus rugosus (see 104).																					
	Macrocheilus fusiforme (see 111).																					
	Macrocheilus gracile (see 105).																					
	Macrocheilus paludinæformis (see 112).																					
	Macrocheilus primigenium (see 106).																					
105	Macrochilina gracilis Cox	....	....	....	....	....	....	×	....	....	....	....	....	....	×	....	....	×	....	....	....	....
106	Macrochilina primogenia Conrad	....	×	....	....	....	....	×	....	....	....	....	×	....	×	....	....	....	....	....	×	×
	Naticopsis nodosa (see 113).																					
107	Pleurotomaria carbonaria Nor. and Prat	....	×	....	×	....	....	×	....	....	....	....	×	....	×	×	....	×	....	....	×	×
108	Pleurotomaria grayvillensis Nor. and Prat	....	....	....	....	×	....	×	....	....	....	....	×	....	....	....	×	....	....	....	....	×
109	Pleurotomaria sphærulata Conrad	....	....	....	....	....	....	×	....	....	....	....	×	×	×	....	....	....	....	....	....	×
110	Pleurotomaria tabulata Conrad	....	....	....	....	....	....	×	....	....	....	....	×	×	×	....	....	×	....	....	....	×
111	Soleniscus fusiformis Hall	....	×	....	×	....	....	....	....	....	....	....	×	....	×	×	....	....	....	....	×	....
112	Soleniscus paludinæformis Hall	....	×	....	....	....	....	....	....	....	....	....	×	....	....	....	....	....	....	....	×	....
113	Trachydomia nodosum M. and W	....	....	....	....	×	....	....	....	....	....	....	....	....	×	×	....	....	....	....	....	....
	CEPHALOPODA.																					
114	Nautilus decoratus Cox	....	×	....	×	×	....	5	....	....	....	....	×	×	6	×	×	×	....	×	×	....
115	Orthoceras rushense McChesney	....	×	....	10	5	....	×	....	....	....	....	7	×	8	×	×	×	×	×	×	....
	ARTHOPODA.																					
	CLASS CRUSTACEA.																					
	PALEOSTRACA.																					
116	Euproops danæ M. and W	....	....	....	....	×	....	....	....	....	....	×	....	....	....	....	....	....	×	....	....	....
117	Phillipsia bufo M. and W	....	....	×	....	....	....	....	....	....	....	....	....	×	×	×	....	....	....	....	....	....
118	Phillipsia sangamonensis, M. and W	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
119	Phillipsia scitula M. and W	....	....	×	×	....	....	×	....	....	....	....	....	×	×	×	×	....	×	....	....	....
	ENTOMOSTRACA.																					
120	Leaia tricarinata M. and W	....	....	....	....	....	×	....	....	....	....	×	....	....	....	....	×	....	....	....	....	....
	INSECTA.																					
121	Paoli vetusta S. I. Smith	×	....	....	....	....	....	....	....	×	....	....	....	....	....	....	....	....	....	×	....	....
	PISCES.																					
122	Edestus vorax Leidy	....	×	....	....	....	....	....	....	....	....	....	×	....	....	....	....	....	....	....	×	....
123	Helodus carbonarius Newberry and Worthen	....	....	....	×	....	....	....	....	....	....	....	....	....	×	×	....	....	....	....	....	....
124	Petrodus occidentalis N. and W	....	×	....	×	5	×	×	....	....	....	....	10	....	×	×	×	×	....	×	×	×

XII. GENERAL STRUCTURE OF THE INDIANA COAL FIELD.

172. MINOR STRUCTURE.—Visiting any point in the coal field where the bedded rocks are exposed it would appear at first sight that the rocks lie perfectly horizontal. Of course, a few places might be visited where very limited exposures will reveal a marked inclination or dip of the strata, but this is not usual. However, if the exposure visited is of considerable extent, or if an extensive exposure be visited and examined for several hundred yards or a larger part of a mile, it will become evident that perfect horizontality is the exception rather than the rule, and that while the inclinations can hardly be compared with the surface slopes, yet at almost every point there is sufficient inclination for water to run down readily. Extensive examinations of that kind show that while there is a preponderance of southwestern dips, yet locally the dips are liable to be in any direction. This is illustrated in Fig. 21, where the outcrop of an 8-ft. coal bed is shown in

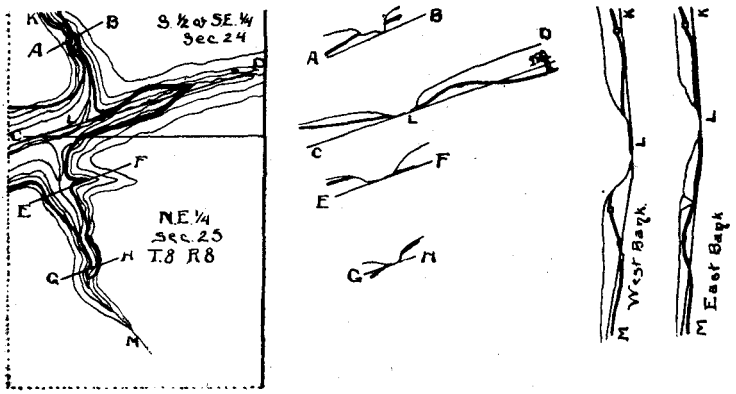


Fig. 21. Sketch map and sections showing local flextures of coal bed at Alum cave, Sullivan county.

its relation to 5 (?) ft. contours and its foldings in the different directions shown by the cross sections. Much the same thing would be seen if contour maps were made of any of the coal beds in any of the large mines. In the block coal field, of course, the original basin structure of the coal beds largely remains and renders a cross section of one of the beds, taken for any distance, to appear like a succession of waves. In the higher coals these irregularities are due to the latter movements, largely due, it is supposed, to irregular settling.

It is interesting to note that the larger folds have in many cases had a decided effect in determining the surface topography. This will be first observed by noting that in such cases a particular coal bed or rock stratum is observed to maintain approximately a given position relative to a stream, and that this will often be found to be true of streams flowing down the opposite sides of a hill, indicated anticlinal structure in the hill. While it would hardly be a safe rule to say that in this area the subdrift topography is governed by the structure, yet it seems safe to say that a large number of the principal divides and many of the minor ones are slightly anticlinal in structure. It is to be regretted that time and opportunity did not permit the determining instrumentally of the level of a sufficient number of points to have worked out somewhat in detail the system of folds of the second order, counting the little local folds figured above as of the third order. While the barometer was used to some extent in the work, it was found that with the method of work followed it could not be relied on sufficiently to be of any value in this connection. The few railroad levels obtainable are given on the maps and serve as a basis for determining the folding of the second order. In addition many suggestions as to the structure are obtained by assuming a uniform rate of fall for the larger streams and noting the relative position of given strata to the stream level at different points.

173. Major Structure.—A glance at the cross sections accompanying the colored maps will suffice to show that the structure of the first order is monoclinal. That is, the strata here are part of the western limb of what is known as the Cincinnati arch, or they may just as well be considered as part of the eastern slope of the Illinois basin or syncline. A generalized section of the strata from east to west along the fortieth parallel will show the position of the Indiana coal fields relative to the main structural features of the Eastern United States. See Fig. 22.

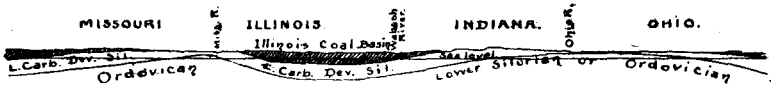


Fig. 22. Sketch of section along 39° N. lat., showing relative position of Illinois coal basin

174. General Strike.—As it is easiest to determine the direction of dip by determining the strike, we will first determine that. If southwestern Indiana were a level plain it would be easy to find the direction of strike by noting the direction of outcrop. As a matter of fact that part of the State is far from a level, so that coals that out-

crop at levels but a little over 300 ft. on the Ohio river have to reach over 600 ft. before they can be exposed in northern Warren county. Nevertheless there is one case in which that method can be used. If the eastern outcrop of the coal measures (Division I) be traced on a topograph map of Indiana, such as that compiled by Mr. Frank Leverett* it will be noted that it overlaps at a number of points the 800 ft. contour. It was suggested in a former chapter that these levels reached by the highest points of the Mansfield sandstone are parts of a tertiary (?) base level. It will be noted that Division I reaches 800 ft. or a little over east of Taswell in Crawford county; on the divide between Lost river and Patoka river in Orange county; on the divide between White river and Lost river in southeastern Lawrence county; at several places on the divide between the east and west forks of White river in northern Martin county, northeastern Greene county and southeastern Owen county. It again reaches 800 ft. on the divide between Eel river and Raccoon creek in northwestern Putnam county and between Raccoon and Sugar creeks in northeastern Parke and southwestern Montgomery counties. From there northwest to where the coal leaves the State the elevation is reduced by the erosion of the Wabash valley, which there enters from the northeast. Next, if a line be drawn connecting the points where the line of outcrop reaches 800 ft. it will be found to have a general direction of about N. 12½ degrees W. Of course this direction will not be maintained across the valleys of the Wabash or the Ohio at either end, where the general level has been greatly reduced, and the principal becomes inoperative. Another method of determining the strike consists in connecting points where certain selected strata reach the same altitude regardless of whether they outcrop or not. This method can be used also, regardless of the topography. To secure the result sought by this method the approximate elevations of the different coals were placed on a large State map, much as they are given on the colored sheets, and wherever the same bed was found to have approximately the same elevation at two points lines were drawn connecting these points. While, as might be expected, the lines so drawn are found to vary by as much as 20 degrees, or even more for the shortest lines, yet there is found to be an unexpected agreement between the longer lines. Without going into details, it may be said that this method gave the following results: From the northern outcrops to the Terre Haute and Indianapolis railway the strike is a little over 10 degrees west of north; from there to the Baltimore and Ohio Southwestern railway the strike is a little under

* 18th Ann. Rep. U. S. Geol. Surv., Part IV, Pl. XXXIII.

10 degrees west of north, making about an average of N. 10 degrees W. to this point. From this point to the Air Line railroad the strike is nearly north and south, while from the Air Line railroad to the Ohio river the strike appears to be a few degrees to the west of south. In further studying the results an interesting fact is brought out, that is the difference due to the thickening of the measures to the south. Thus, it will be observed that Division I continues an east-of-south strike as far south as Crawford county, beyond which the valley of the Ohio and lack of ascertained levels prevent the determining of its strike. But on going to the west it is quickly observed that the lines representing the higher coals have a more nearly north and south strike, with a west-of-south strike appearing as far north as Daviess county, so that for the upper coals, lines drawn from Vigo and Clay counties to Warrick and Vanderburgh counties average about due north and south. From Daviess and Knox counties to the Ohio river there is a decided west-of-south strike.

175. THE DIRECTION OF DIP.—If these figures be converted into direction of dip, the results may be summarized as follows:

Division I. Along whole outcrop, average of dip	S. 77½° W.
Divisions I-IV. Sheet A	S. 78° W.
Divisions I-IV. Sheets B, C and D	S. 82° W.
Divisions I-IV. Sheets D and E	W.
Divisions I-IV. Sheets E and F	N. 88° W.
Divisions V-VIII. Sheets A and B	S. 80° W.
Divisions V-VIII. Sheets B to F	W.
Divisions V-VIII. Sheets D to F	N. 80° W.+

These figures give evidence of the basin-like character of the slope.

176. THE AMOUNT OF DIP.—By referring to the figures given in the rectangles, it becomes possible to estimate the dip at various points. In the following table are grouped the figures indicating the dip at a number of places. It will be understood that the farther apart are the points considered the more nearly does the dip so obtained represent the general or average dip, but on the other hand there is much greater liability of error arising from mistakes in correlation. As the lower coals are seldom sought by deep shafts or recognizable with certainty where passed through in deep boring, the figures obtained are more characteristic of the area underlain by the upper or more workable coals than of the whole area, and probably give a little too high an average.

Points Compared.	*Coal.*	*Elevations.*				*Total Dip.*		*Mi.*		*Dip in Ft. Per Mi.*
Williamstown to West Lebanon	V	625	—	575	=	50	÷	5	=	10
Stone Bluff to Covington	IV	625	—	530	=	95	÷	8	=	11
Yeddo to Silver Island	V	650	—	500	=	150	÷	9	=	15+
W. Montezuma to Illiana	VII	600	—	485	=	115	÷	7½	=	16+
Coxville to S. W. of Clinton	VI	530	—	300	=	230	÷	6	=	38+
Wicksville to Lodi	IV	620	—	440	=	180	÷	5	=	36
Coal Bluff to Grant	VI	550	—	435	=	115	÷	5	=	23
Grant to W. Terre Haute	VII	515	—	450	=	65	÷	10	=	6+
Harmony to Terre Haute	IV	625	—	200	=	425	÷	20	=	21
Stanton to Terre Haute	VI	600	—	300	=	300	÷	12	=	25
Stanton to Seeleyville	VI	600	—	485	=	115	÷	4½	=	23+
Brazil to Seeleyville	IV	570	—	370	=	200	÷	8½	=	24
Cory to Riley	VIa	600	—	525	=	75	÷	5	=	15
Middlebury to Farmersburg	VI	640	—	375	=	265	÷	14	=	18—
Three-quarter miles east to Farmersburg	VI	450	—	375	=	75	÷	¾	=	100
Five miles east to Farmersburg	VII	573	—	413	=	160	÷	5	=	32
Hymera to Currysville	VI	525±	—	280	=	245	÷	5	=	49
Shoals to Mt. Pleasant	I	460	—	475	=	—15	÷	5	=	—3
Washington to Vincennes	VI	484	—	34	=	450	÷	20	=	22+
Edwardsport to Vincennes	V	460	—	(—30)	=	490	÷	18	=	27
Petersburg to Princeton	V	375	—	100	=	275	÷	20	=	18
Oakland to Princeton	V	350	—	400	=	250	÷	12	=	20
Francisco to Princeton	VII	415	—	258	=	157	÷	7	=	28—
Ayrshire to Oakland	V	450	—	350	=	100	÷	5	=	20
Taswell to Huntingburg	II	800	—	456	=	344	÷	24	=	14+
Boonville to Evansville	V	440	—	125	=	315	÷	20	=	16—
Chandler to Evansville	V	367	—	125	=	242	÷	11	=	22
Tennyson to Evansville	IV	464	—	24	=	440	÷	27	=	16

The dips will be seen to run from 100 ft. to the mile down, averaging per mile about 24 ft. A study of the sections shows that the dips in the western part of the field appear to be higher than those in the eastern part, but the suggestion also comes that this may be largely due to what appears to be a sharp monoclinal fold to the west along a line just east, in a general way, of the E. & T. H. and C. & E. I. R. R. It shows itself most clearly in southern Vermillion and Parke counties and northern Sullivan county. It is probable that fuller data would show an average dip of less than 20 ft.

Examining the data for evidence of folds transverse to the strike, it is of interest to note the elevations of Coal VI in a north-and-south line from Newport to Sullivan: Newport, 500 ft., Alta 500, Geneva 400, S. W. of Clinton 300, Terre Haute 300, Hartford 380, Farmersburg 373, Currysville 280, Shelburn 275, Sullivan 275. These figures give evidence of a syncline in northern Vigo county and an anticline in southern Vigo. The anticline in southern Vigo county would appear to correspond with an obscure anticline in eastern Clay county south of Bowling Green, but in western Clay county a syncline seems to come between. This is best seen by comparing Coal VI along the E. & T. H. R. R. and Coal V 10 miles to the east. At Currysville Coal VI is 280 ft. above tide; going north to Farmersburg and Hart-

ford, it rises to 373 and 380 ft., respectively. Ten miles east of Currysville Coal V is not far from 600 ft. above tide, being nearly up to the top of the divide between Eel river and the Wabash. Going north to the mouth of Splunge creek, about opposite Hartford, it is found to have descended almost to the level of Eel river, or to a level of about 530 ft. above tide. Evidence of this rapid north dip is not wanting in the northeastern corner of Sullivan county. Many other apparent anticlines were found, mostly small, but indicated by the relation to the drainage; but no attempts to trace out such folds were successful. Not that the folds are not there, or, being there, can not be traced; for I am confident that when an accurate topographic map of the coal area shall have been made, but little difficulty will be experienced in finding and establishing probably a very interesting series of folds. Much could be done with a proper equipment of barometers, aided by a system of lines run with the transit.

Attention was called, in Part I, to the abundance of micro-structural features, faults, etc. The attempt to reduce these to a system was not successful. As stated there, while a majority of the faults noticed generally approach the strike in direction, the number of exceptions is too large to admit of making any rule in regard to the direction of the fault line. In the same way the direction of downfall is so variable that no rule can be given, though it is thought that the majority downthrow in the direction of the dip. It may be possible, in places of unusual change of level, generally assigned to dip, that faulting is responsible for much of it. This is known to be true in one or two cases.

The theory has already been expressed elsewhere that the basin structure of the lower coal is due largely to the irregular surface upon which the coal measures were laid down, this being an erosion surface, but that as deposits gradually filled up these inequalities, a given earth movement would produce a given result with greater and greater uniformity and over increasing areas, until in the time of Divisions VI, VII and VIII similar conditions would exist simultaneously along most or all of a belt of surface entirely crossing the southwestern part of the State, so that coals and limestones especially can be traced continuously for 150 miles.

In connection with the basin character of the lower coals, one suggestion that came as a possible explanation of the block structure of those coals was that it was due to the increased length the top of the bed has, when compressed into the form of an arc or basin, over its length before compression as the chord of the same arc. While the theorum was not proven, it neither appeared to be disproven.

XIII. DISTRIBUTION OF WORKABLE COALS.

177. SHEET A.—Turning to Sheet A of the geological map, the area shaded to represent the outcrop of Division I contains no commercially workable coal. Toward the southern end of this area some coal occurs that may be worked for local trade.

In Warren county workable coal is found on Fall creek, northwest of Williamsport. The data indicates an area of several square miles, and possibly much more; Coal V is the main coal. Considerable coal has been dug on the east side of Kent township, northwest of Covington, but the coals are thin, as a rule. Coals V, VI and VIa underlie most of western Warren county and doubtless are workable in places. As, however, they are 100-200 ft. deep, and overlain by a very heavy mantle of drift, and as the drillings so far made have failed to find them of workable thickness, it is difficult to predict how much, if any, of them are workable. Developments here will be apt to be slow.

In Fountain county workable coal is found along the C. & I. C. Railroad, from Stone Bluff to Veedersburg (Coal IV). This basin may have considerable extent, but the coal is apt to run under a workable thickness over much of it unless the shale overlying it is taken at the same time. As this shale is an excellent brick shale, its presence may render much of this coal workable that would otherwise be considered too thin. Little or nothing is known of the coal west and northwest of Veedersburg, but there is probably no small amount of workable coal there. East of the C. & I. C. R. R. (C. & E. I. R. R.) there appears to be no workable coal known as far south as Stean Corner P. O. Around Yeddo there appears to be a basin of 5-ft. coal (Coal V), amounting to several thousand acres, extending especially to the south. Four miles east of Kingman the same coal is also workable. Whether this is part of the basin at Yeddo is not known. If it is, there is a large body of coal there. Probably the best basin in the county lies in the southern part of Wabash and northern part of Fulton of the civic townships. Coal IV, there, for several square miles runs from 5 to 7 ft. thick. A few hundred acres have been worked out around Coal Creek P. O. (Snoddy's Mills). Exposures along Prairie creek show up to 7 ft. and over of coal, though not all workable. Considering the quality, thickness and geographical position of the coal, this is one of the best undeveloped fields in the State.

East, west and northwest of Silverwood appears to be a considerable body of Coal V, running up to 7 ft. thick. This appears to underlie a

large part of what is called Silver island. Quite a little of the south end has been or is being worked out. A large sandstone-filled channel cuts off this area from the area to the north. It would appear as though considerable workable coal might yet be found within 2 or 3 miles of Cate's Station. Probably little or no workable coal will be found in this county below the level of the Wabash river, and, as a general rule, if a drilling does not strike coal within 100 or 150 ft., it will be useless to go farther. Something should be added if a drilling is started on high ground.

Montgomery and Putnam counties appear to contain no workable coal.

Parke county shows a square mile or more of good block or semi-block coal on Sugar Mill creek, west of Grange Corners (Coal IV). Along Sugar creek the coal is very pockety, reaching 5 ft. in places, but liable to be of very limited extent. It may be that drilling will show some of these pockets to be well worth developing. Meager reports indicate little of value in Liberty township. Many workable pockets and probably some extensive basins will no doubt be found here. A small basin of excellent semi-block coal is being worked on Sand creek, in the southern part of Washington township. The rest of the township has not yet shown much coal. Penn and Reserve townships probably contain some basins of workable coal, though as yet not well located or defined. Adams township has some workable coal basins on Williams creek, and south (Coal V), and pockets of coal up to 5 ft. in thickness in the south and southeast part. Wabash county has, about Mecca, and possibly over a large area, Coals IV and III workable. These are 50 to 75 ft. below Raccoon creek. Some small pockets of Coal VI, up to 6 ft. thick, exist here, but are probably of too limited extent.

Coals III and IV, of true block character, are being worked extensively in the southwestern part of Jackson and southeastern part of Raccoon townships. Sec. 35 of T. 14 N., R. 7 W., is at present furnishing more coal than any other square mile in the State. A small basin of coal around Minshall (Coal V ?) appears to have been worked out. Some of the same coal bed is workable north of Raccoon creek. Some coal in the northeastern part of Raccoon township may be worked, but it is thin. Workable coal should be found in the southwestern part of the township. Coals III and IV are deep in Florida township. They may prove workable over part of this area, but have hardly been found so as yet. Coals VI and VII may be considered workable over most of the area shaded for their outcrop.

Only a very small amount of drilling has been done in this county, but the stream exposures and mines indicate that over the area shaded for the outcrops of Divisions V to III the coals are pockety, lying in small basins of workable thickness, and these basins separated by areas of unworkable coal, the latter areas exceeding in extent the basins of workable coal. Future drilling will probably reveal much more workable coal than is now known, perhaps many times as much. Workable areas of Coals V, IV and III occur under the area of outcrop of Coal VI. Coal VI can hardly be counted workable in Ts. 15 and 16 N. The lowest workable coals will not be over 250 ft. below the level of the Wabash, in the southwestern corner, none below the level of the Wabash, in the northwestern corner, and little, if any, below the main drainage, in the eastern part of the county.

Going south, in Vermillion county, the first workable coal known is in the neighborhood of the Big Vermillion river, northwest of Eugene (Coals VI and VIa). From there south Coal VI is pockety and not usually workable until Norton's creek is reached. Coal VII is workable around the horseshoe, on the Little Vermillion river, west of Newport. It appears to be more or less continuously workable from there south under the area of its outcrop when not removed by preglacial erosion or overlain by too thin a roof. North of Highland several factors interfere somewhat with its workability. There seems some probability of the lower coals proving workable about Highlands, Coal III (?) having a thickness of 4 ft. there. Clinton township appears to have Coals VIII, VII and VI, all workable within their limits of outcrop.

No coal should be found in this county below sea level, and in the northern part no workable coal need be looked for much below 500 ft. above sea level.

178. Sheet B.—No commercially workable coal has been found in the southern part of Putnam county nor in Owen county, except in the southwestern corner, in Marion and Jefferson townships. Here Coals III and IV are generally workable, attaining a thickness of 6 ft. in places. In the east of these townships they occur in the tops of the hills, but are at or below the general drainage before the county line is reached. The stream valleys cut out the coal over a large share of the area, yet there is left one of the largest unmined basins of block coal in the State. The coal here lies in smaller pockets or basins than about Brazil, thus yielding a larger area of unworkable coal for a given area underlain by the coal bed.

Clay county has had a fine basin of block coal northeast of Brazil, but the known bodies of this coal here are rapidly being worked out. There is probably quite a little coal in the northern part of Van Buren township unworked. West and northwest of Brazil there appears to be a good body of semi-block coal undeveloped. Coals III and IV are being extensively worked along the Big Four, in the northwestern corner of the county, and this area will probably be the most active mining region in Clay county for some time. Coal IV is 130 ft. deep at Lodi.

Cass township has no workable coal. Coal III, and to a less extent Coal IV, have been much worked in Jackson township. There appear to be still some considerable bodies of coal here, but shallow, and not always workable on that account. Posey township has contained a large body of Coal VI along the T. H. & I. Ry.; this is nearly worked out between Staunton and Turner, but is still unworked west and southwest of Staunton. Coals III and IV were workable along part of the east side of this township, but are now nearly worked out.

Washington township contains little or no workable coal. Considerable block coal is found in Sugar Ridge township (Coals III and IV), but much of it will have too poor a roof to work, as the beds are usually quite shallow. They are cut out along the bottoms of Eel river and Birch creek. Perry township doubtless contains considerable workable coal, though present data indicates a thickness inferior to that of coals north or east.

Harrison township contains a large body of unworked block coal. This is a continuation of the Owen county block coal field, though the coals here are thinner, as a rule. A belt of land from 1 to 4 mi. wide following Eel river seems to contain no coal. A small basin of Coal VI exists in the hill at Middlebury. It is thick, but of poor quality.

Coal IV seems to be workable under much of Lewis township, running up to 6 ft. in places, but generally barely workable. Toward the southwestern part of the township Coal V is of good thickness, and is extensively worked from just across the Sullivan county line.

In Vigo county Coal VI is the principal coal. It is above drainage and outcrops along the eastern edge of Nevins township, but west of that line, except where preglacial erosion has removed it or its roof, it appears to be workable under all of Nevins, Otter Creek, Lost Creek and Harrison townships, having a thickness of from 5 to 7 ft. Coal IV is workable along the eastern edge of Nevins township, but it is probable that the coals below Coal VI in the area mentioned are not workable. Coal VII is workable over a large part of Lost Creek town-

ship, with a thickness of from 3 to 5 ft. In Riley and Pierson townships Coal VII is workable in places, running up to 6 ft. Coal VIb is workable at Riley's, 3 miles south, and possibly over a considerable area over which Coal VI is little known, appearing to be thin over part of the area at least, though probably workable over part or possibly much of the area. In Honey Creek and Linton townships Coals VII and VI are workable—VII only under the upland. The data are too meager to indicate whether the coals are workable wherever they are to be found, but probably there is here a large area of workable coal.

In Fayette and Sugar Creek townships Coal VII is the principal coal yet developed. The little evidence obtained indicates that Coal VI, lying 150 ft. below the river, is workable over most, if not all, of this area. Coal VII is workable under nearly all of it, and Coal VIII is workable under a large part of the northern half of this area.

In Prairieton and Prairie Creek township all the workable coals are below drainage, and little is known concerning them. Coal VI is probably below 300 ft. above sea level in this area, and the bottom of the coal measures at or below sea level.

179. SHEET C.—In Greene county there is very little, if any, commercially workable coal east of White river. The coals there occasionally reach a workable thickness, but at such times the area is so limited that, while they will serve well for local trade or for local industries, they can not compete with outside coals. In times past some extensive mining has been done near Owensburg on 20-in. beds. Good coal is also found a few miles east of Bloomfield. All the coal in this part of the area is above drainage, to the east rising so as to be from 100 to 250 ft. above adjacent valleys.

West of White river no coal should be looked for in the extensive prairies or former marshes that are so extensively found there. Coal of a workable thickness underlies most of the upland of Jefferson, Smith, Fairplay, Grant and Washington townships, but other conditions, as poor roof, etc., will prevent the working of much of it. Coals III and IV occur here. In Wright township Coal V appears to underlie all of the western two-thirds except the stream channels, being generally above drainage. It is of excellent thickness, good roof, etc., but appears to be of such poor quality as to require special treatment before marketing. Coal IV is found workable in the eastern side of the township, and it is thought will be found to be workable under most of the township. It is an excellent coal. In Stockton township Coals VII and VI just lap the western edge. Coal V occupies a con-

siderable area northwest of Linton, as shown on map, and a strip along the western side of the township. It is thick, but appears to be of variable quality. Coal IV underlies most of the township. It is cut out by the marsh-like prairies at the east, with much roofless coal adjacent, and west of a line passing just west of the Buckeye and Summit mines, it splits so as to lose much of its workability. Between these east and west limits it is from 5 to 6 ft. thick, of excellent quality, and altogether one of the best coals to mine in the State. That it is being extensively worked may be judged when it is stated that for several years the small area three miles long by a mile wide has been furnishing nearly 500,000 tons yearly, and in 1897 employed more men than any other whole county, except Clay. It is probable that this area shipped over one-eighth of all the coal shipped by rail from the Indiana mines. The undeveloped coal in this bed lies north and northwest of Linton. In Stafford township Coals VII, VI, V and IV are found in the southwest half, with probably considerable workable coal. It will require further prospecting here to settle which of the coals are workable and to what extent.

Sullivan county appears to contain workable coal under every foot of it, and over much of it two or three workable beds. Coal VIII reaches a workable thickness over parts of the western half of the county, especially at Merom and along Turman's creek, but in general should be counted as not workable. Coal VII is above drainage and outcrops in the eastern edge of the county, but west of that appears to be continuous from 3 to 6 ft. thick. Forty feet below it is Coal VI, from 5 to 8 ft. thick, except in the northeastern corner of the county, where it runs thin. This coal appears to be continuous within its outcrop over the eastern two-thirds of the county. Whether it continues workable over the western part of the county is not known, but it is thought that it does to a large extent. Coal V is from 6 to 9 ft. thick along much of the eastern edge of the county. It appears to thin to the west. One or two workable coals are reported at still lower levels. In vertical position Coal VI is about at drainage along the eastern edge of the county, about 250 to 275 ft. deep in the center of the county and 200 to 300 ft. below the Wabash river along the western edge of the county. The bottom of the coal measures is probably not less than 300 ft. lower still.

180. SHEET D.—In Martin county the workable coal is very limited. There is a strip along the divide between Boggs creek and Indian creek, where Coals I and III are workable in many places, but with usually a very limited extent. South of White river and west

of Shoals appears to be a body of Coal I of excellent quality, provided enough of it prove to be of workable thickness.

South of Shoals, in Sampson Hill, is a limited body of Coal III, of excellent quality. Still smaller areas of the same coal are found in the hilltops in the southeastern corner of the county. Small areas of Coal III of workable thickness occur a few miles north of Loogootee, and in the southwestern part of the county, and others may be found around Burn City.

In Daviess county there appears to be almost no workable coal in the northern tier of townships. A body of Coal III of good quality is found around Ragglesville. Enough is known to indicate at least two or three square miles of workable coal, and there may be much more. Around Epsom and to the southeast Coal IV is generally of workable thickness, and it is probable that 3 ft. of coal underlies a large percentage of Bogard township and doubtless underlies parts of Steele township.

Barr township, containing both the cannel coal (Coal III) around Cannelburg and Coal IV to the west of Montgomery, is probably more than half underlain by workable coal, and in many parts both the coals mentioned will be workable.

Much the same conditions prevail in Harrison and Reeves townships, except that Coal III contains no cannel there and both the coals are somewhat reduced in thickness.

In Washington township an excellent, though limited, body of Coal VI, lying east, south and northeast of the city of Washington, has been practically exhausted. Present workings are on a body of Coal V of good thickness, lying northwest and southwest of Washington.

In Veale township, though Coal V is over 7 ft. thick at Murry switch, the township as a whole appears to contain but little if any workable coal.

In Knox county Coal VII, though thin, might be classed as workable under the larger part of the county. It is worked at Vincennes at depths of from 350 to 400 ft. and is worked a little at numerous points along its eastern outcrop in the eastern part of the county. Coal VI is a thick workable coal around Edwardsport and Bicknell, and while it appears to thin out in the southeastern part of the county, it would seem probable that it is workable under much of the northern and western parts of the county. Coal V is workable west of Sanford, and near Edwardsport, also near Wheatland, but in general little is known of it, and it is likely it will be found to thin to the west. The known workable coal is nearly all above the level of White river along the eastern edge of the county, but is over 350 ft. deep along the

western edge. From the data obtained at Vincennes, it is probable that some trouble will be met in working Coal VI on account of its roof.

181. SHEET E.—Orange and Crawford counties may each be considered as without commercially workable coal. Some workable coal may be found in the ridge about Boston, Crawford county.

In Dubois county the coals are pockety, so that no coal can be regularly relied upon as workable. On the other hand, almost all the coals are workable in places. Coal II (?) is workable over a small area in the north part of Columbia township in the northeastern corner of the county, at Huntingburg and some other points. Coal III (?) or IIIb and Coal IV have been worked at points south of White river in Boone and Harbison townships. Several of the coals are workable around Jasper. In general, while the county is well supplied with coals for local trade, no extensive bodies of workable coal have yet been found.

In Pike county the area underlain by Coal VII, as shown on the map, is underlain by at least two workable coals, while Coal V, with a thickness of from 4 to 9 ft., is workable under nearly all of the area within its outcrop as shown on the map. Coal IV will be workable in places under the whole county, and workable area of the still lower coals will probably be found.

182. SHEET F.—Coal II is the only workable coal in Perry county, and it is confined to the hills in the western part of the county. It has been long and extensively mined in the hills about Cannelton and in Troy, where the dip has carried it down to river level. Coal II continues workable in basins part way up Anderson township. Small areas of workable coal are found in the western part of Clark township.

Spencer county resembles Dubois in its coal producing capacity. Practically all of the coals found in the county are of a workable thickness at points, but as a rule the workable areas are evry limited. The knob coal occurring in the "Knobs" northwest of Rockport is nearly worked out. Coal IV there ran from 2 ft. to 5 ft. 10 in. in thickness and of excellent quality. Other areas in which workable coals are found are, south of St. Meinrad, Coal II from 3 to 5 ft. thick; near New Boston and on Crooked creek, west of Maxville, Coal IIa (?) 2 ft. 6 in. to 4 ft. thick; in the southwestern quarter of township 4 S., 4 W., Coal III, 2 ft. 6 in. thick to 3 ft. 6 in.; near Buffaloville and Lincoln City, and near Newtonville.

As far as our information goes Warrick county is limited in the main to Coal V for a supply of workable coal. This appears to be workable under practically all of the area within its outcrop, barring, as usual, areas near the outcrop where the roof is poor. Being outside the drift, there are not so many hidden areas where the coal is lacking as farther north. The coal runs from 4 to 9 ft. in thickness.

Coal VII is workable in places in the northwestern part of the county, but gets thin toward the Ohio. In some cases Coal VIa, a few feet or less below, may be worked at the same time.

Small areas of the coals below Coal V may be found of workable thickness, but on the whole the evidence did not suggest much workable coal from these lower coals.

183. SHEET G.—Recent developments in Gibson county indicate an abundance of coal. The evidence suggests that Coal V is workable under all or at least the eastern two-thirds of the county. This coal is only 4 ft. to 4 ft. 6 in. around Oakland and Francisco, but what is thought to be the same coal at Princeton averages over 6 ft. Coal VII may be workable in places, but on the whole is a little too thin. Coal V runs from a depth of 130 ft. at Oakland to from 375 to 450 ft. at Princeton. Numerous drillings around Princeton indicate up to four thick coal beds below Coal V. A gas well at Oakland also reported thick coals below Coal V. The presence of so many thick coals at Princeton is not only unexpected, but is not corroborated by the most reliable deep sections obtained to the north and south. That coal beds occur at these lower horizons cannot be questioned, but that so many of them show thicknesses of from 5 to 7 ft., while not unreasonable, is unusual, and we accept it with much question. Whether or not these lower coals prove as good as the drillings indicate, there is enough coal in Coal V to supply the demand for a long time.

Coal V underlies Vanderburg county much as it underlies Gibson, though with a reduced thickness. It is about 250 ft. deep at Evansville, where it is extensively mined. Explorations at Evansville and elsewhere have as yet failed to show any other workable coals in the county. Coal VII is probably workable locally in the northern part of the county, and future explorations are apt to find workable basins of the lower coals.

In Posey county the workable coals are deeply buried, and as yet have not been discovered. But few if any borings have gone deep enough to reach Coal V, and if that horizon has been reached no workable coal has been reported. That the county appears to be without workable coal is doubtless due to lack of sufficient exploration.