DEPARTMENT OF THE INTERIOR

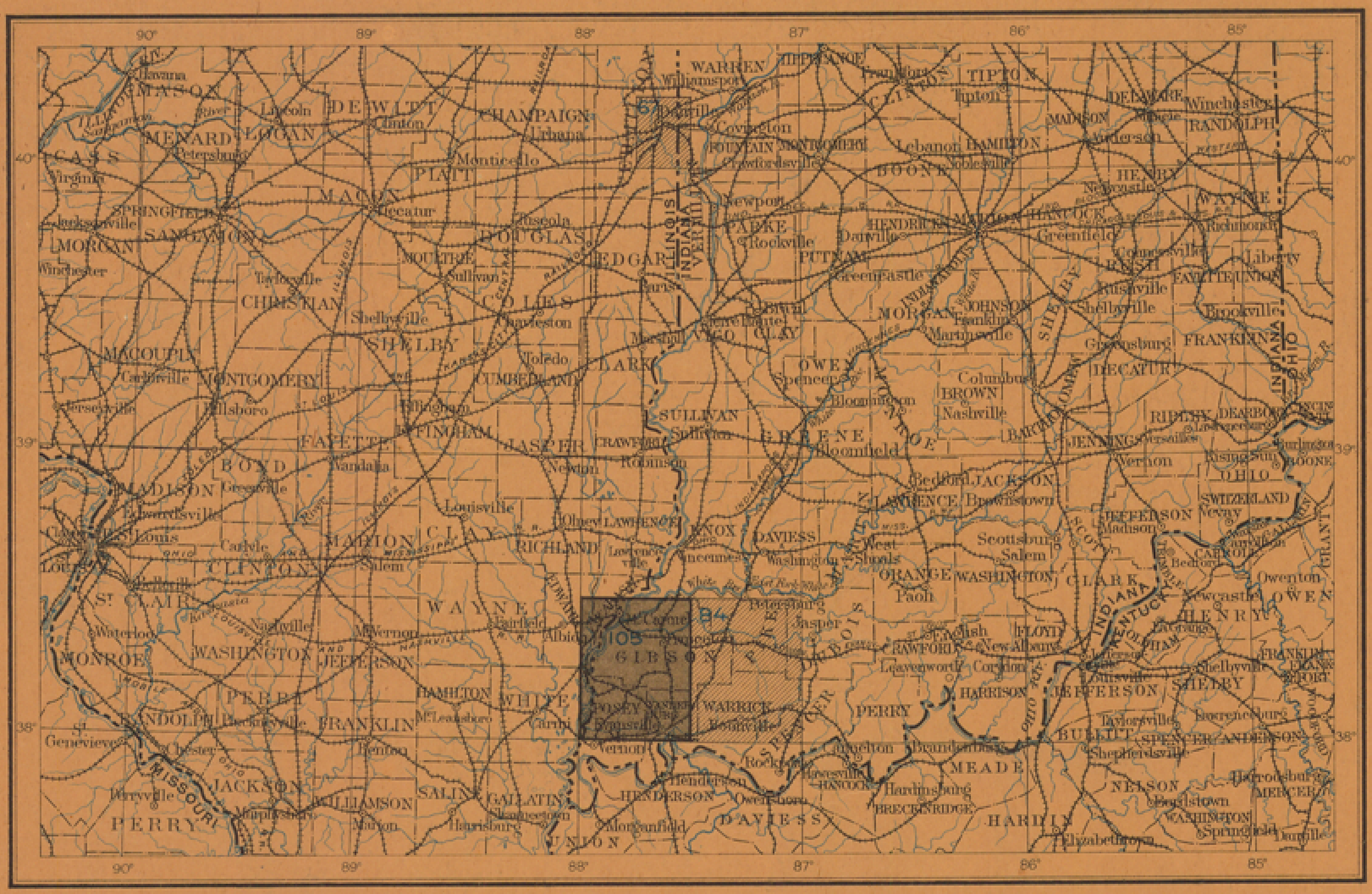
UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS
OF THE
UNITED STATES

PATOKA FOLIO
INDIANA – ILLINOIS

INDEX MAP



SCALE: 40 MILES = 1 INCH

AREA OF THE PATOKA FOLIO

AREA OF OTHER PUBLISHED FOLIOS

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LIBRARY EDITION

PATOKA FOLIO
NO. 105

WASHINGTON, D. C.

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GEORGE W. STOSE, EDITOR OF GEOLOGIC MAPS   S. J. KUBEL, CHIEF ENGRAVER

1904

GEOLOGIC AND TOPOGRAPHIC ATLAS OF UNITED STATES.

The Geological Survey is making a geologic map of the United States, which is being issued in parts, called folios. Each folio includes a topographic map and geologic maps of a small area of country, together with explanatory and descriptive texts.

THE TOPOGRAPHIC MAP.

The features represented on the topographic map are of three distinct kinds: (1) inequalities of surface, called *relief*, as plains, plateaus, valleys, hills, and mountains; (2) distribution of water, called *drainage*, as streams, lakes, and swamps; (3) the works of man, called *culture*, as roads, railroads, boundaries, villages, and cities.

Relief.—All elevations are measured from mean sea level. The heights of many points are accurately determined, and those which are most important are given on the map in figures. It is desirable, however, to give the elevation of all parts of the area mapped, to delineate the outline or form of all slopes, and to indicate their grade or steepness. This is done by lines each of which is drawn through points of equal elevation above mean sea level, the altitudinal interval represented by the space between lines being the same throughout each map. These lines are called *contours*, and the uniform altitudinal space between each two contours is called the *contour interval*. Contours and elevations are printed in brown.

The manner in which contours express elevation, form, and grade is shown in the following sketch and corresponding contour map (fig. 1).

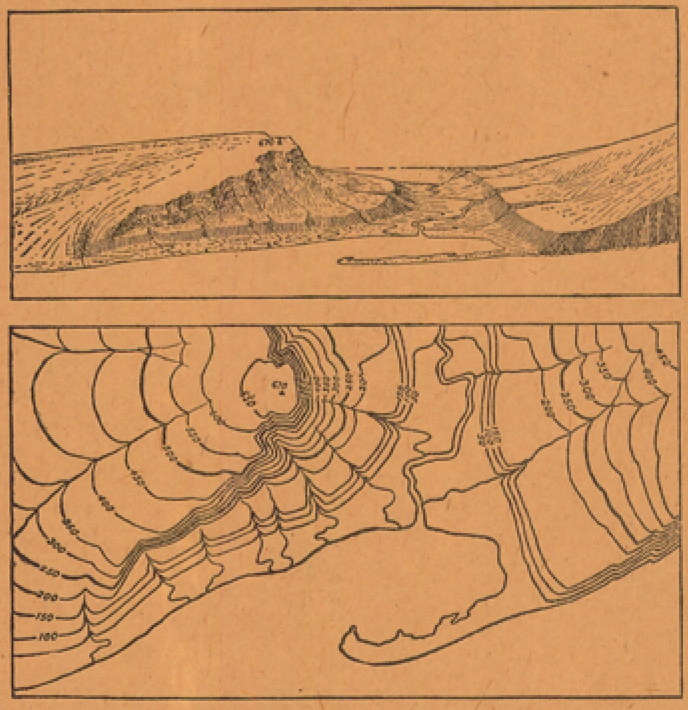


FIG. 1.—Ideal view and corresponding contour map.

The sketch represents a river valley between two hills. In the foreground is the sea, with a bay which is partly closed by a hooked sand bar. On each side of the valley is a terrace. From the terrace on the right a hill rises gradually, while from that on the left the ground ascends steeply, forming a precipice. Contrasted with this precipice is the gentle slope from its top toward the left. In the map each of these features is indicated, directly beneath its position in the sketch, by contours. The following explanation may make clearer the manner in which contours delineate elevation, form, and grade:

1. A contour indicates a certain height above sea level. In this illustration the contour interval is 50 feet; therefore the contours are drawn at 50, 100, 150, and 200 feet, and so on, above mean sea level. Along the contour at 250 feet lie all points of the surface that are 250 feet above sea; along the contour at 200 feet, all points that are 200 feet above sea; and so on. In the space between any two contours are found elevations above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, while that at 200 feet lies above the terrace; therefore all points on the terrace are shown to be more than 150 but less than 200 feet above sea. The summit of the higher hill is stated to be 670 feet above sea; accordingly the contour at 650 feet surrounds it. In this illustration all the contours are numbered, and those for 250 and 500 feet are accentuated by being made heavier. Usually it is not desirable to number all the contours, and then the accentuating and numbering of certain of them—say every fifth one—suffice, for the heights of others may be ascertained by counting up or down from a numbered contour.

2. Contours define the forms of slopes. Since contours are continuous horizontal lines, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing about prominences. These relations of contour curves and angles to forms of the landscape can be traced in the map and sketch.

3. Contours show the approximate grade of any slope. The altitudinal space between two contours is the same, whether they lie along a cliff or on a gentle slope; but to rise a given height on a gentle slope one must go farther than on a steep slope, and therefore contours are far apart on gentle slopes and near together on steep ones.

For a flat or gently undulating country a small contour interval is used; for a steep or mountainous country a large interval is necessary. The smallest interval used on the atlas sheets of the Geological Survey is 5 feet. This is serviceable for regions like the Mississippi delta and the Dismal Swamp. In mapping great mountain masses, like those in Colorado, the interval may be 250 feet. For intermediate relief contour intervals of 10, 20, 25, 50, and 100 feet are used.

Drainage.—Watercourses are indicated by blue lines. If a stream flows the entire year the line is drawn unbroken, but if the channel is dry a part of the year the line is broken or dotted. Where a stream sinks and reappears at the surface, the supposed underground course is shown by a broken blue line. Lakes, marshes, and other bodies of water are also shown in blue, by appropriate conventional signs.

Culture.—The works of man, such as roads, railroads, and towns, together with boundaries of townships, counties, and States, are printed in black.

Scales.—The area of the United States (excluding Alaska and island possessions) is about 3,025,000 square miles. A map representing this area, drawn to the scale of 1 mile to the inch, would cover 3,025,000 square inches of paper, and to accommodate the map the paper would need to measure about 240 by 180 feet. Each square mile of ground surface would be represented by a square inch of map surface, and one linear mile on the ground would be represented by a linear inch on the map. This relation between distance in nature and corresponding distance on the map is called the *scale* of the map. In this case it is "1 mile to an inch." The scale may be expressed also by a fraction, of which the numerator is a length on the map and the denominator the corresponding length in nature expressed in the same unit. Thus, as there are 63,360 inches in a mile, the scale "1 mile to an inch" is expressed by $\frac{1}{63,360}$.

Three scales are used on the atlas sheets of the Geological Survey; the smallest is $\frac{1}{250,000}$, the intermediate $\frac{1}{125,000}$, and the largest $\frac{1}{62,500}$. These correspond approximately to 4 miles, 2 miles, and 1 mile on the ground to an inch on the map. On the scale $\frac{1}{62,500}$ a square inch of map surface represents about 1 square mile of earth surface; on the scale $\frac{1}{125,000}$, about 4 square miles; and on the scale $\frac{1}{250,000}$, about 16 square miles. At the bottom of each atlas sheet the scale is expressed in three ways—by a graduated line representing miles and parts of miles in English inches, by a similar line indicating distance in the metric system, and by a fraction.

Atlas sheets and quadrangles.—The map is being published in atlas sheets of convenient size, which represent areas bounded by parallels and meridians. These areas are called *quadrangles*. Each sheet on the scale of $\frac{1}{250,000}$ contains one square degree—i. e., a degree of latitude by a degree of longitude; each sheet on the scale of $\frac{1}{125,000}$ contains one-fourth of a square degree; each sheet on the scale of $\frac{1}{62,500}$ contains one-sixteenth of a square degree. The areas of the corresponding quadrangles are about 4000, 1000, and 250 square miles.

The atlas sheets, being only parts of one map of the United States, disregard political boundary lines, such as those of States, counties, and townships. To each sheet, and to the quadrangle it represents, is given the name of some well-known town or natural feature within its limits, and at the sides and corners of each sheet the names of adjacent sheets, if published, are printed.

Uses of the topographic map.—On the topographic map are delineated the relief, drainage, and culture of the quadrangle represented. It should portray to the observer every characteristic feature of the landscape. It should guide the traveler; serve the investor or owner who desires to ascertain the position and surroundings of property; save the engineer preliminary surveys in locating roads, railways, and irrigation reservoirs and ditches; provide educational material for schools and homes; and be useful as a map for local reference.

THE GEOLOGIC MAPS.

The maps representing the geology show, by colors and conventional signs printed on the topographic base map, the distribution of rock masses on the surface of the land, and the structure sections show their underground relations, as far as known and in such detail as the scale permits.

KINDS OF ROCKS.

Rocks are of many kinds. On the geologic map they are distinguished as igneous, sedimentary, and metamorphic.

Igneous rocks.—These are rocks which have cooled and consolidated from a state of fusion. Through rocks of all ages molten material has from time to time been forced upward in fissures or channels of various shapes and sizes, to or nearly to the surface. Rocks formed by the consolidation of the molten mass within these channels—that is, below the surface—are called *intrusive*. When the rock occupies a fissure with approximately parallel walls the mass is called a *dike*; when it fills a large and irregular conduit the mass is termed a *stock*. When the conduits for molten magmas traverse stratified rocks they often send off branches parallel to the bedding planes; the rock masses filling such fissures are called *sills* or *sheets* when comparatively thin, and *laccoliths* when occupying larger chambers produced by the force propelling the magmas upward. Within rock inclosures molten material cools slowly, with the result that intrusive rocks are generally of crystalline texture. When the channels reach the surface the molten material poured out through them is called *lava*, and lavas often build up volcanic mountains. Igneous rocks thus formed upon the surface are called *extrusive*. Lavas cool rapidly in the air, and acquire a glassy or, more often, a partially crystalline condition in their outer parts, but are more fully crystalline in their inner portions. The outer parts of lava flows are usually more or less porous. Explosive action often accompanies volcanic eruptions, causing ejections of dust, ash, and larger fragments. These materials, when consolidated, constitute breccias, agglomerates, and tuffs. Volcanic ejecta may fall in bodies of water or may be carried into lakes or seas and form sedimentary rocks.

Sedimentary rocks.—These rocks are composed of the materials of older rocks which have been broken up and, the fragments of which have been carried to a different place and deposited.

The chief agent of transportation of rock débris is water in motion, including rain, streams, and the water of lakes and of the sea. The materials are in large part carried as solid particles, and the deposits are then said to be mechanical. Such are gravel, sand, and clay, which are later consolidated into conglomerate, sandstone, and shale. In smaller portion the materials are carried in solution, and the deposits are then called organic if formed with the aid of life, or chemical if formed without the aid of life. The more important rocks of chemical and organic origin are limestone, chert, gypsum, salt, iron ore, peat, lignite, and coal. Any one of the deposits may be separately formed, or the different materials may be intermingled in many ways, producing a great variety of rocks.

Another transporting agent is air in motion, or wind; and a third is ice in motion, or glaciers. The most characteristic of the wind-borne or eolian deposits is loess, a fine-grained earth; the most characteristic of glacial deposits is till, a heterogeneous mixture of bowlders and pebbles with clay or sand.

Sedimentary rocks are usually made up of layers or beds which can be easily separated. These layers are called *strata*. Rocks deposited in layers are said to be stratified.

The surface of the earth is not fixed, as it seems to be; it very slowly rises or sinks, with reference to the sea, over wide expanses; and as it rises or subsides the shore lines of the ocean are changed. As a result of the rising of the surface, marine sedimentary rocks may become part of the land, and extensive land areas are in fact occupied by such rocks.

Rocks exposed at the surface of the land are acted upon by air, water, ice, animals, and plants. They are gradually broken into fragments, and the more soluble parts are leached out, leaving the less soluble as a *residual* layer. Water washes residual material down the slopes, and it is eventually carried by rivers to the ocean or other bodies of standing water. Usually its journey is not continuous, but it is temporarily built into river bars and flood plains, where it is called *alluvium*. Alluvial deposits, glacial deposits (collectively known as *drift*), and eolian deposits belong to the *surficial* class, and the residual layer is commonly included with them. Their upper parts, occupied by the roots of plants, constitute soils and subsoils, the soils being usually distinguished by a notable admixture of organic matter.

Metamorphic rocks.—In the course of time, and by a variety of processes, rocks may become greatly changed in composition and in texture. When the newly acquired characteristics are more pronounced than the old ones such rocks are called *metamorphic*. In the process of metamorphism the substances of which a rock is composed may enter into new combinations, certain substances may be lost, or new substances may be added. There is often a complete gradation from the primary to the metamorphic form within a single rock mass. Such changes transform sandstone into quartzite, limestone into marble, and modify other rocks in various ways.

From time to time in geologic history igneous and sedimentary rocks have been deeply buried and later have been raised to the surface. In this process, through the agencies of pressure, movement, and chemical action, their original structure may be entirely lost and new structures appear. Often there is developed a system of division planes along which the rocks split easily, and these planes may cross the strata at any angle. This structure is called *cleavage*. Sometimes crystals of mica or other foliaceous minerals are developed with their laminæ approximately parallel; in such cases the structure is said to be schistose, or characterized by *schistosity*.

As a rule, the oldest rocks are most altered and the younger formations have escaped metamorphism, but to this rule there are important exceptions.

FORMATIONS.

For purposes of geologic mapping rocks of all the kinds above described are divided into *formations*. A sedimentary formation contains between its upper and lower limits either rocks of uniform character or rocks more or less uniformly varied in character, as, for example, a rapid alternation of shale and limestone. When the passage from one kind of rocks to another is gradual it is sometimes necessary to separate two contiguous formations by an arbitrary line, and in some cases the distinction depends almost entirely on the contained fossils. An igneous formation is constituted of one or more bodies either containing the same kind of igneous rock or having the same mode of occurrence. A metamorphic formation may consist of rock of uniform character or of several rocks having common characteristics.

When for scientific or economic reasons it is desirable to recognize and map one or more specially developed parts of a varied formation, such parts are called *members*, or by some other appropriate term, as *lentils*.

AGES OF ROCKS.

Geologic time.—The time during which the rocks were made is divided into several *periods*. Smaller time divisions are called *epochs*, and still smaller ones *stages*. The age of a rock is expressed by naming the time interval in which it was formed, when known.

The sedimentary formations deposited during a period are grouped together into a *system*. The principal divisions of a system are called *series*. Any aggregate of formations less than a series is called a *group*.

(Continued on third page of cover.)

DESCRIPTION OF THE PATOKA QUADRANGLE.

By Myron L. Fuller and Frederick G. Clapp.

GENERAL RELATIONS.

The Patoka quadrangle is located in southwestern Indiana and southeastern Illinois. Its southern boundary is only about 2 miles from the Ohio River at Evansville, and its northwest corner is about 17 miles west of the Wabash River, which marks the boundary between the States of Indiana and Illinois. It embraces the area between latitude 38° on the south and 38° 30′ on the north, and between longitude 87° 30′ on the east and 88° on the west, and includes one-fourth of a square degree of the earth's surface. Its north-south length is 34.5 miles, its breadth 27.2 miles, and its area about 938 square miles. It comprises four 15-minute quadrangles—the Mount Carmel, Princeton, New Harmony, and Haubstadt—and includes by far the larger portions of Vanderburg, Posey, and Gibson counties and part of Knox County, in Indiana, and nearly the whole of Wabash and parts of Edwards and White counties in Illinois. The principal cities and towns included in the area are Princeton, Mount Carmel, Grayville, New Harmony, Owensville, Hazleton, Patoka, Fort Branch, Haubstadt, Cynthiana, and Poseyville. The name of the quadrangle is taken from Patoka one of the larger of the towns whose names have not already been used for the smaller quadrangles.

TOPOGRAPHY.

DRAINAGE.

All of the drainage from the surface of the Patoka quadrangle finds its way to the Ohio River. A small area in the southeastern part of the quadrangle is drained directly into the Ohio by Pigeon Creek, but the remaining portions of the area are drained by streams that flow first into the Wabash, in the western portion of the quadrangle, and thence south to the Ohio. The Wabash River is a broad stream, in some places over a third of a mile wide, and next to the Ohio River is by far the most important drainageway in the region. It enters the quadrangle from the north at a point about 4 miles east of the center and flows in a general southwesterly direction to Grayville, near the middle of the western border, whence it runs in a very irregular course southward and southwestward, finally passing out of the quadrangle a little over 3 miles from its southwest corner. The next most important stream is the White River. This river enters the quadrangle near its extreme northeast corner, and flows with a course about S. 60° W. until it joins the Wabash near Mount Carmel. It receives no tributaries of importance within this area. The Patoka River, which in size comes next to the White River, enters the quadrangle about 5 miles south of the northeast corner, and flows in a general westerly direction, joining the Wabash about a mile south of the mouth of the White River, near Mount Carmel. Like the White River the Patoka receives few tributaries of importance in the quadrangle. Of the minor streams Black River, entering the Wabash from the east about 3 miles north of New Harmony, Bonpas Creek, entering the Wabash from the north at Grayville, Fox River, joining the Wabash from the west near New Harmony, and Big Creek, which drains the south-central portion of the quadrangle, are the most important.

Before the advent of the great ice sheet which, in relatively late geologic time, covered the northern portion of the quadrangle and the region to the north, the rivers showed in their broader relations a noticeable conformity with the geologic structure. The Wabash River flowed, in a general way, near the center of the broad, low, synclinal trough constituting the coal basin of Illinois and Indiana, while the Ohio and the tributaries of the Wabash in Indiana followed courses roughly parallel with the dips. The pronounced drainage features have survived to the present time, but many of the smaller streams underwent important modifications in consequence of the obstruction of their valleys by the ice sheet or of the deposition of glacial materials by the ice or by streams associated with its occupancy. In fact, the Wabash and White rivers and Bonpas, Flat, and Big creeks are the only large streams in the quadrangle that follow their pre-Glacial valleys, and the positions of all these except the latter have been more or less modified by glacial or other Quaternary deposits.

RELIEF.

The Patoka quadrangle exhibits four rather distinct types of topography: (1) Rugged uplands, (2) rolling uplands, (3) upland plains, and (4) river flats. The last two resulted from the accumulation of unconsolidated material in relatively recent geologic times, while the first two, which embrace by far the greater part of the area, have resulted from the action of stream erosion upon the hard rocks. The resistance of these rocks to erosion has been very nearly the same throughout the quadrangle, the consequent relief depending, therefore, upon the relations of the surface to the drainage lines.

The general rule that the larger the stream the more will the surface of the adjoining areas suffer reduction to low and rounded forms holds good within the quadrangle, except where alterations were effected in the drainage system through the influence of the Pleistocene ice invasion. Among exceptions of this nature is the narrow valley, with rock outcrops at short distances on either side, through which the Patoka River flows near Patoka, and the narrow valley south of the Illinois Central Railroad, through which flows Big Creek. On the other hand there are broad and deep rock valleys, now obstructed by drift or sand, in which streams are insignificant or wanting. Such valleys occur among the rock hills lying south of Hazleton and north of Patoka, southwest of Princeton and northeast of Owensville, and north and south of Cynthiana. Both phases of discrepancy are due to the closing of old valleys by drift during the ice invasion and the consequent deflection of the streams into new courses, where they have not yet materially widened their valleys.

Rugged uplands.—In the group designated rugged uplands are included the highest hills and ridges of the quadrangle. The type is developed on both the drift and the rock hills, the former being most conspicuous in the region north of Patoka and the latter in the region north, northeast, and east of Princeton and in the area between Big Creek and the eastern edge of the quadrangle. In the latter area ridges several miles long, with moderately uniform crests, are numerous. As a rule, they are sharp and narrow and are characterized by steep slopes, which are cultivable only with difficulty. The minor channels, which are exceedingly numerous, are usually more or less V-shaped and are separated from one another by equally sharp divides. In their upper courses they exhibit steep descents.

In the Ditney quadrangle, which is immediately east of the Patoka, the higher points of the uplands rise to nearly uniform elevations of from 600 to 640 feet, and are believed to be the remnants of an old surface, almost a plain in character, which once extended over the whole of this region. In the Patoka quadrangle, however, owing to the greater maturity of the drainage, the reduction is more complete, only an occasional peak rising to the 600-foot level. The hills on which the Princeton standpipe is built rise to 610 feet, those on the Petersburg road, 2 miles north of the same city, to 645 feet, those north of Maxams station, southeast of Princeton, to 625 feet, and that northeast of St. Joseph to 605 feet. The development of the plain of which these hills are supposed to be remnants is considered in detail under the heading "Geologic history," p. 6.

In addition to the high upland level just described there appear to be traces of old land surfaces at lower levels, for there are a number of rather extensive crests or flats shown by hills at elevations of 480 to 520 feet, especially at 500 feet. Many of these flats have been found to be composed of stratified marl-loess overlying a rugged topography, as in the regions south of New Harmony, while others have proved to consist of till or other drift deposits. There are apparently, however, many more or less flat rock surfaces at or near the same elevation, which may indicate a second and later plain that was formed at an elevation of from 100 to 150 feet below the first. If such a plain existed it was probably much less perfectly developed, and it seems likely that in this region it was generally confined to the areas bordering the main drainage lines.

Rolling uplands.—In this class are included the lower and less rugged upland surfaces. The hills are generally much smaller than in the previous group. Their altitude seldom exceeds 550 feet, and they usually exhibit smooth, gently rounded forms. The valleys are broad and relatively shallow, showing gentle curves in cross section, and are characterized by the low pitch of their streams, and by broad, flat divides. The rolling uplands are best developed in the vicinity of the older drainage lines, especially in the region west of the Wabash River. The Claypole, Gordon, Mumford, Foots Pond, and other hills projecting above the Wabash flats are to be classed in this type in part, although the flatter portions of their tops belong to the group next to be described. The sand hills along the eastern border of the Wabash flats, the rock hills southeast of Hazleton, around Owensville, and along Big Creek, and the morainal ridges between Princeton and Fort Branch, southeast of Owensville, and near Poseyville and Cynthiana belong in the main to the rolling uplands, though the steeper portions approach the previous class in ruggedness.

Upland plains.—The upland plains consist of broad, flat, or gently sloping surfaces standing at an elevation of 500 feet or less and composed of deposits that accumulated during the period of the ice invasion or of loess or marl-loess deposited at a later period. The drift deposits are limited to the sloping drift plains east of the Princeton–Fort Branch moraine, the similar drift plains southwest of Fort Branch, and a few flat hilltops of the Mount Carmel quadrangle, where the rock is at no place far from the surface.

The most conspicuous of the upland plains are the broad level or gently sloping marl-loess flats along the east side of the Wabash Valley south of the Black River and the smaller flats of the same material southwest of Mount Carmel, on Mumford, Foots Pond, and Claypole hills, and at points near Owensville and Hazleton. These marl-loess flats lie at a maximum elevation of 500 feet above sea level or about 120 feet above the Wabash bottoms. They frequently exhibit floor-like flats at this altitude, although sloping terraces, as in the Mumford Hills and along the north side of Big Creek, are more common.

River flats.—All of the rivers and large streams, and also many of the minor streams, flow through broad, flat plains of silt or of sand and gravel, which are generally overflowed, at least in part, each spring. Wells sunk for water show that the thickness of these silts and sands ranges from a few feet in the minor valleys to 150 feet or more in the valleys of the Patoka and Bonpas Creek. No deep wells are known in the portion of the Wabash or White River flats lying within the quadrangle, but the thickness of the deposits is probably 200 feet or more. In the process of the upbuilding of this considerable thickness of sediments the minor hills and valleys have been entirely obliterated, only the higher prominences rising as "islands" above the flats. The general level of these flats is very uniform, being a little over 400 feet above the sea in the higher portions of the Wabash flats at the northern edge of the quadrangle, and about the same in the White and Patoka river bottoms. There is, however, a gentle slope southward to a 370-foot level at the southwest corner of the quadrangle. The low rate of fall has led to the development of meanders, which, because of their resistance to the free flow, cooperate with it in giving rise to annual overflows that cover all but the higher portions of the adjacent flats to depths of several feet. This frequent overflow leads to many changes in the courses of streams, and bayous and abandoned channels are common.

GEOLOGY.

STRATIGRAPHY.

Derivation of the rocks.—The rocks exposed at the surface of the Patoka quadrangle are of two types. They include not only those firm, hard beds which every one at once recognizes as rock, but also the loose, unconsolidated deposits of silt, sand, glacial till, etc., likewise considered by geologists as rock, which occur as fillings in the valleys or as a mantle of greater or less thickness over the general surface of the quadrangle.

The materials of which the harder rocks are composed were in the main originally derived, in the form of gravel, sand, mud, etc., from the wearing away of some old land mass under the action of streams or waves, the resulting waste being carried to the margin of the seas then existing and there deposited as stratified, sedimentary, or fragmental rocks. As time has elapsed these beds have been gradually solidified by the chemical deposition of matter about the grains of which they are composed, the material thus deposited acting as a cement to bind the grains together into a solid mass. Besides the materials derived from older land masses, beds of shells and marls, sometimes many feet in thickness, were formed beneath the sea, and beds of peat accumulated in the swamps and basins along its borders. The former, like the fragmental rocks, were cemented largely by the chemical deposition of matter between the component grains, while the latter gradually became hardened to their present form through the loss of their volatile and unstable portions by oxidation, only the carbon and its more stable compounds remaining.

The materials of the unconsolidated or surficial rocks were derived from the underlying consolidated rocks or from other rocks lying north of this area, some from sources even as far distant as Canada. In part these materials were laid down by streams and rivers, and in part by the direct action of an ice sheet which was similar to that now covering the surface of Greenland, and which in the early part of the present geologic period started in the far north and spread out over nearly the whole of the northeastern portion of North America.

The Patoka quadrangle is located at the outer limit reached by the ice sheet in this region, the boundary entering it from the east near Pigeon Creek, and passing southwestward to a point about 1½ miles north of the southwest corner. The southernmost point reached is in Illinois some distance west of the quadrangle. The materials deposited by the ice or by the water flowing from it probably do not anywhere in the quadrangle reach a thickness of much more than 200 feet, while the deposits laid down since the disappearance of the ice are of slight importance, except the marl-loess deposits along the eastern borders of the Wabash Valley and the plains and dunes of the Wabash and White river valleys. Even these are supposed to have been connected with later invasions which, though furnishing material to the waters of the region, did not actually reach the Patoka quadrangle.

The older consolidated rocks reach a thickness in southwestern Indiana of several thousand feet, though probably not more than 400 feet are exposed in this quadrangle. These strata exhibit many alternations of sandstones, shales, limestones, and coals, but they may be grouped by their lithologic characters into five formations, which, in ascending order, are the Millersburg, Somerville, Ditney, Inglefield, and Wabash. Certain beds of the last named, though not warranting designation as formations, are nevertheless very persistent, especially in the southern portion of the quadrangle, and in the case of the coals, are mapped. All of the formations belong to the Pennsylvanian or "Coal-Measure" series of the Carboniferous system. Their general characters and relative thickness are described in some detail in the following paragraphs, and are shown graphically in the geologic column at the end of the folio.

General geologic relations.—While in a broad way it is possible to consider the geologic basin of the Mississippi region as coextensive with the physiographic basin, the former has less unity than the latter. During very early geologic time, however, and throughout many subsequent geologic periods, the larger part of the south-central portion of North America was covered by a sea which extended from the region of the Gulf of Mexico on the south to that of the Great Lakes on the north and from near the eastern limits of the Appalachian Mountain system on the east to the Rocky Mountain region on the west. Over the bottom of this broad basin there were deposited beds of sedimentary rocks, including limestones, shales, sandstones, and conglomerates, the limestones predominating among the lower beds and the sandstones among the upper, and the whole probably reaching a total thickness of from 4000 to 5000 feet. These rocks were originally deposited in a horizontal position, but were afterward subjected in places to broad, gentle warpings, giving rise to broad, low rock domes, from which the beds dip gently away into basins that are equally extensive and equally shallow. The Patoka quadrangle is situated a little to the east of the center of such a broad, shallow basin, which lies between a broad dome known as the Cincinnati anticline on the east and a similar low, flat dome in Missouri. This basin is known as the Illinois-Indiana coal basin (fig. 1), and into it the rocks dip gently from all

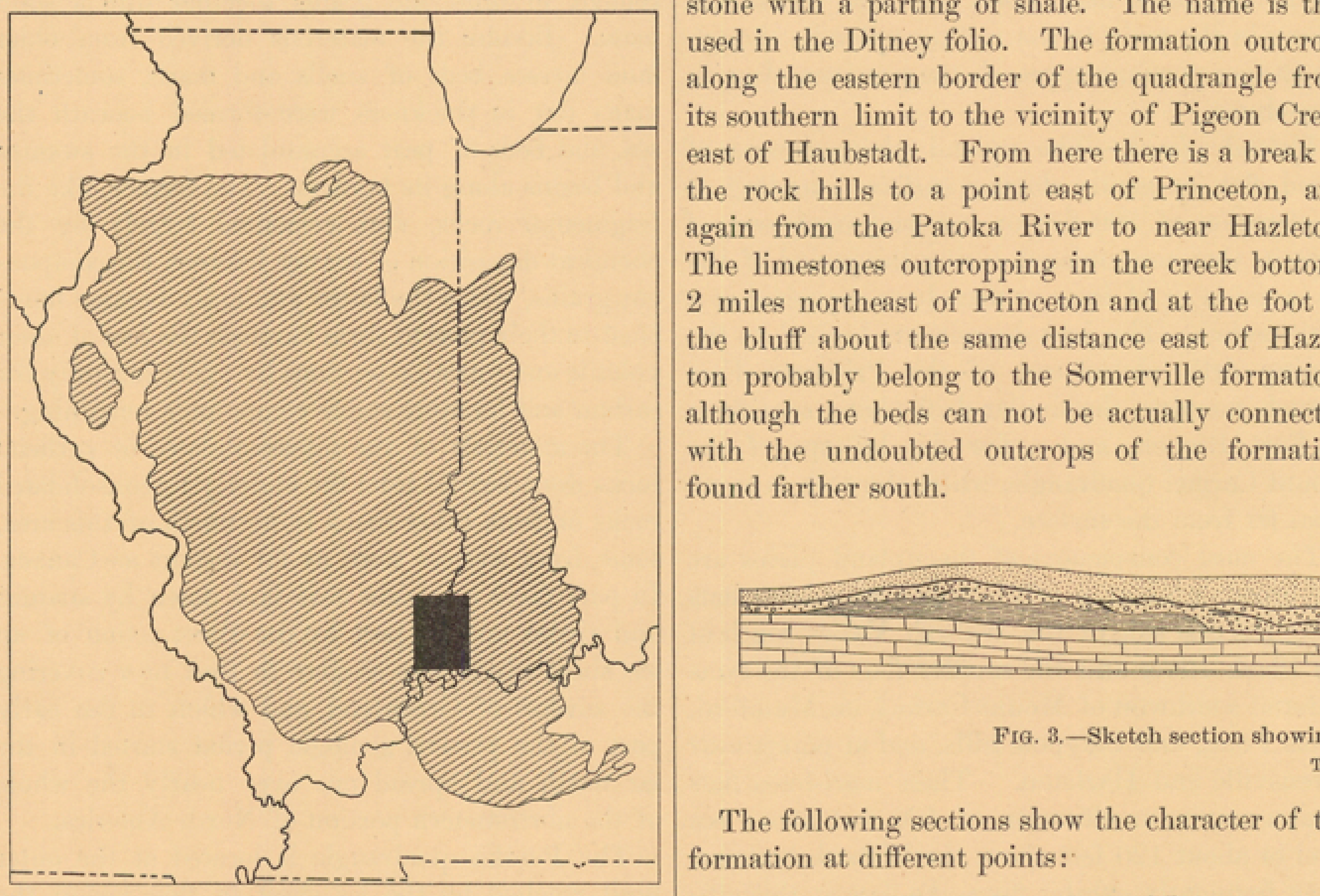


FIG. 1.—Outline map showing the relations of the Patoka quadrangle to the Illinois-Indiana coal field.
The coal field is represented by the obliquely ruled area.

directions. In the Patoka quadrangle the rocks belong to the upper (sandy) portion of the great series of sediments occupying the Mississippi Basin, and present a dip to the west averaging about 17 feet per mile.

Carboniferous System.

Millersburg formation.—The Millersburg formation includes the sandstones and shales between the bottom of the Millersburg coal and the base of the lower limestone of the Somerville formation. The coal outcrops in the Ditney quadrangle, lying immediately east, and is encountered in shafts and wells about Princeton and elsewhere, but is nowhere exposed in the Patoka quadrangle. Underlying the Somerville limestone in hills in the southeastern corner of the quadrangle, however, nearly 120 feet of the formation is exposed. The coal is here reported in wells at 50 feet below the flood plain, making the total thickness of the formation about 170 feet, or 20 feet greater than at Lynville, Warrick County, where one of the best exposures is found. The name is that used in the Ditney folio.

This appears to be one of the most variable of the formations of this region, the wells or borings, even where close together, often showing marked variations in character of materials penetrated. Complete sections of the formation are afforded by the borings and shaft at Princeton (see section sheet), but in the southern portion of the quadrangle, where the formation is at the surface, no detailed sections could be obtained. The following section, taken at the Ingleside mine, Evansville, about 2 miles south of the southern border of the quadrangle, gives all but the upper few feet of the formation, while the generalized section shows the character of the upper 86 feet.

Section in Ingleside shaft, Evansville.[1]

	Thickness. Feet.	Thickness. Inches.	Depth. Feet.	Depth. Inches.
Clay and alluvial sand	29	0	29	0
Clay and shale	61	0	90	0
Shaly coal and fire clay	3	0	93	0
Sandstone	4	6	97	6
Siliceous clay shale	12	9	110	3
Shale and ironstones	5	8	115	11
Fire clay		10	116	9
Ferriferous sandstone	7	9	124	6
Fire clay with sandstone iron	12	3	136	9
Sandstone (ferriferous)	12	1	148	10
Shale	1	0	149	10
Sandstone	7	5	157	3
Millersburg coal ("Coal VII" or "Little Newburg")	2	11	160	2

Generalized section of upper part of Millersburg formation.

	Thickness in feet.	Depth in feet.
Light clay shale	10	10
Fine brownish sandstone	7	17
Sandstone (reported in well)	5	22
Clay shale	5	27
Greenish clay shale	5	32
Clay shale (reported in well)	8	40
Soft, sandy, greenish to bluish shale with nodules of iron ore	10	50
Blue clay shale	8	58
Clay shale	5	63
Hard, gray sandstone	3	66
Sandstone (reported in well)	20	86
Blue shale	10	96

Somerville formation.—The Somerville formation in general is essentially a double bed of hard limestone with a parting of shale. The name is that used in the Ditney folio. The formation outcrops along the eastern border of the quadrangle from its southern limit to the vicinity of Pigeon Creek east of Haubstadt. From here there is a break in the rock hills to a point east of Princeton, and again from the Patoka River to near Hazleton. The limestones outcropping in the creek bottoms 2 miles northeast of Princeton and at the foot of the bluff about the same distance east of Hazleton probably belong to the Somerville formation, although the beds can not be actually connected with the undoubted outcrops of the formation found farther south.

The following sections show the character of the formation at different points:

Section in Kurtz well, northeast of Princeton (sec. 5, T. 2 S., R. 10 W.).

	Feet.
Limestone in bands	15
Clay shale	8
Gray limestone	2½

Section in Hoffman well, Fort Branch.

	Feet.
Limestone	8
Clay shale and fire clay	18
Limestone	8

Section along creek 3 miles east of Staser.

	Feet.
Limestone	10
Covered, sandstone fragments	2
Limestone	21

Section in quarry, 1 mile northwest of Zipp.

	Feet.
Limestone	3
Gray, purplish shale	5
Limestone	9+

In character the limestone is uniformly hard, but varies from light to dark gray in color, and from a compact to a fossiliferous fragmental texture. The bedding planes are frequently 3 or more feet apart, giving rise to large blocks on weathering. It has undergone some solution along joint planes, the widening being sufficient in cases to cause a settling of the overlying shales into the cavities, forming "dikes" of shale fragments (fig. 7).

Ditney formation. — The Ditney formation embraces all beds from the top of the Somerville formation to the base of the Inglefield sandstone. It appears to be composed of the ordinary succession of sandstones, shales, and coals, so characteristic of all Carboniferous formations, although in general the shale predominates. A typical section is shown by the following well record at St. James:

Section of Ditney formation in well at St. James.

	Feet.
Shale	30
Rotten coal	1
Good coal (Ditney coal)	2
Clay shale	12

In the northern portion of the quadrangle, east of Hazleton, sandstone begins within a short interval of the limestone, the Ditney formation, if present, being limited to a thickness of a few feet. At Townsend's quarry, north of Princeton, and in the wells in and near the town, a considerable thickness of the Ditney shales is found, together with an included coal, as at St. James and elsewhere. East of Haubstadt the formation is about 50 feet thick, but its thickness decreases rapidly southward, being 45 feet near St. James, 40 near Staser, and 20 at Inglefield. A mile and a half south of Inglefield the Inglefield sandstone rests directly on the limestone, and from here southward to the southern limit of the quadrangle it continues to hold this relation, except at a few points where 4 or 5 feet of the Ditney shales intervene. West of the Illinois Central Railroad, however, the shale is more persistent, though it is usually not over 5 to 10 feet in thickness.

The sudden replacement by the massive Inglefield sandstone of the thick shale bed that persists from north of the Patoka River to Inglefield—a replacement that takes place within a horizontal distance of not more than 75 to 100 feet in the railroad cut south of Inglefield (fig. 2) and the

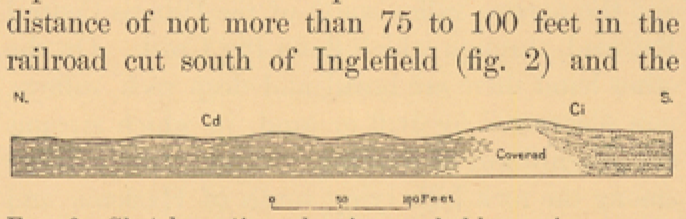


FIG. 2.—Sketch section showing probable erosion unconformity between the Ditney and Inglefield formations in railroad cut at Inglefield, Ind.
Cd, Ditney formation; Ci, Inglefield formation.

patchy character of the shales throughout the southeastern portion of the quadrangle (fig. 3) lead to the belief that there was probably an erosion interval between the deposition of the Ditney and the overlying Inglefield sandstone. This erosion interval has been correlated by the Indiana geological survey with the marked unconformity at the base of the Merom sandstone in Parke, Fountain, and Vermilion counties, Ill., but the correctness of the correlation can not be determined until the intermediate area has been mapped in detail.

Inglefield formation.—The Inglefield formation includes the prevailingly sandy beds lying between the top of the Somerville formation and the Parker coal, at the base of the Wabash formation. At the base there is always a massive sandstone, in some places having a thickness of at least 60 feet, as in the series of bluffs in the valley east of St. Joseph. This basal sandstone, however, is frequently replaced by a number of thinner beds separated by a few feet of shale. In most of the exposures the upper portion of the formation is of a shaly character, although, in some instances, as near St. Joseph, the formation is sandy throughout, though doubtless separated into several beds by shale partings of a few feet in thickness, and exhibiting rapid variations in thickness and character, frequently terminating abruptly. The total thickness of the formation varies from about 110 feet at the southern border of the quadrangle to about 150 feet near St. Joseph. The following section, measured along the railroad south of the deep cut northeast of this town, shows the character of the formation at this point very perfectly:

Section of Inglefield formation near St. Joseph.

	Feet.
Unexposed interval below Parker coal	40
Sandstone, soft and sometimes shaly	20
Clay shale, bluish	5
Sandstone, soft, buff	10
Sandstone, highly ferruginous and honeycombed with cavities left by solution of calcareous fossils	1½
Shale, light argillaceous to sandy	3
Shale, sandy	3
Sandstone, light, micaceous, and shaly	5
Shale, bluish gray	8
Sandstone, white	1
Shale, light, argillaceous	10
Sandstones, light, and friable, coarser near bottom	40+
	146+

Owing to the massive character of the sandstone beds in its lower portion, outcrops of the Inglefield formation are more common than those of most other formations. In the valley east of St. Joseph it outcrops as a series of cliffs showing an aggregate of 60 feet of sandstone. The faces of these cliffs are frequently vertical and are often marked by cavities and other sculptural effects resulting from disintegration due to the action of the weather. The sandstones are, in large part, of a buff color, though gray or even nearly white varieties were noted. Some of the beds are brownish, but the darker red, brown, or purplish tints are usually of local occurrence and are evidently the result of weathering. The name of the formation is taken from Inglefield, a station on the Evansville and Terre Haute Railroad about 7 miles north and 3½ miles west of the southeastern corner of the quadrangle, just south of which the sandstone, with probable basal unconformity, is well exposed in the railroad cut (see figs. 2 and 6). It has been correlated by the State survey with the Merom sandstone, formerly quarried near the village of Merom, Sullivan County, Ind., and this name has been used in the reports of the Indiana survey since 1870. Recent field work, however, has served to throw grave doubts upon the exactness of the correlation, and the name Inglefield has therefore been given to the formation. In the southwestern portion of the State it appears to have an average thickness of from 110 to 150 feet.

Wabash formation. — In this formation are included all of the shales and sandstones, with an occasional thin limestone or coal, lying above the top of the Inglefield formation within the limits of the Patoka quadrangle. The generalized section given below, measured from the top downward, indicates the character of the formation.

The Parker coal, with overlying black shale and limestone, though each is occasionally absent, constitutes a persistent horizon which has been chosen as that of demarcation between the Inglefield and Wabash formations. Its outcrop outside the drift area is shown on the geologic map, but inside the drift limits it is difficult to trace. The thin coal about 70 feet above the river at Patoka, the coal at or near the same level in the bluffs 2 miles northwest of that town, the thin coal near flood-plain

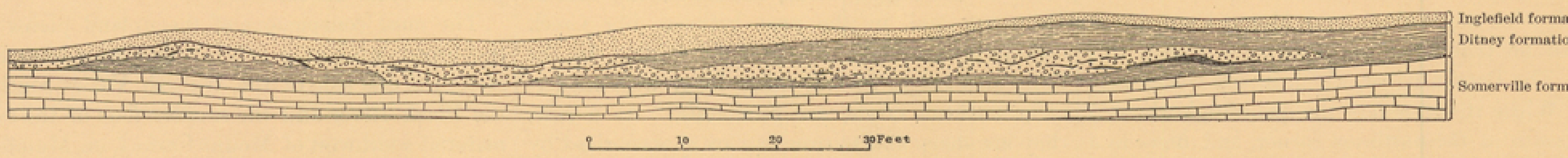


FIG. 3.—Sketch section showing relations of Somerville, Ditney, and Inglefield formations in exposure 1 mile northwest of Zipp, Ind.
The Ditney formation here has a sandstone parting with irregular or unconformable relations.

Generalized section of the Wabash formation.

		Feet.
Sandstone		15
Shale, etc. with 6-inch local coal		20
Sandstone, heavy bedded		15
Shale, part not seen		25
Shale, siliceous		8
Shale, blue and argillaceous		8
Limestone, soft and shaly to very hard		4
Aldrich coal		1
Coaly shale		2
Fire clay		1
Sandstone, soft and sometimes shaly	Sandstone of Mumford Hills, etc.	8
Sandstone, locally poikilitic		20
Limestone, hard, gray, and fossiliferous		3
Shale, black		3
Friendsville coal		2
Fire clay		1
Sandstone, massive or cross bedded	Sandstone of Gordon Hills, etc.	20
Sandstone, light gray and micaceous		15
Limestone, or calcareous and fossiliferous sandstone		3
Shale, black		5
Parker coal		1
		180

[1]Collett, Seventh Ann. Rept. Geol. Surv. of Indiana, p. 265.

level on the southwest side of Gordon Hills, and the coal in the hills northeast of Owensville, are believed to be the Parker coal. The coal is generally very impure, approaching in places a sheety shale—a shale composed of very thin, tough, sheet-like layers. The limestone runs from 2 to 4 feet in thickness in the southern half of the quadrangle and is frequently fossiliferous. In places it merges into a honeycombed sandstone, the cavities of which are due to the solution of fossils and other calcareous materials of the original sandy limestone. At Patoka and elsewhere in the northern half of the area the limestone is absent, the coal and the overlying sandstone bed marking the horizon. It derives its name from Parkers Settlement, just east of which it is well developed in the uplands.

The heavy sandstone just above the Parker coal and its associated limestone, next to the Inglefield formation, is the cliff-making sandstone of the quadrangle. It outcrops at the base of the bluffs in Gordon Hills, in Claypole Hills, and at Grand Rapids, Hanging Rocks, and Skelton Cliff. In the last two places it forms vertical or even overhanging cliffs of bare rock from 20 to 40 feet in height, which are the most striking natural outcrops of this portion of the Wabash Valley. In the southern half of the quadrangle what is probably the same sandstone outcrops at many points on both sides of the Posey-Vanderburg county line south of St. Wendells, but to the south and west it appears to be generally replaced by more shaly beds.

Overlying the sandstone just described is the Friendsville coal and fire clay, so called from their typical development about Friendsville. The coal is best developed in the region between the Wabash River and Bonpas Creek, where it has an average thickness of about 3 feet. It is in many places overlain by a limestone, which, however, in the region just mentioned, is by no means of general occurrence. In the southern half of the quadrangle the limestone and not the coal is most commonly present, the limestone there having a thickness of from 2 to 6 feet, while the coal rarely measures over a foot in thickness. West of the Wabash the depth of the coal below the surface is shown on the geologic map, but in the remaining portion of the quadrangle it is of no importance. The horizon of the Friendsville coal is about half way between the Aldrich and Parker coals.

Above the Friendsville coal is a thick sandstone of variable character, which is typically exposed at the base of the Mumford Hills and which also occurs at a number of points northeast of New Harmony. It is gray to buff in color, and in the last-mentioned region is marked locally by the occurrence of poikilitic crystals of calcite—that is, by areas of rectilinear outline in which a calcite cement has been deposited, inclosing instead of replacing sand grains and giving the rock a porphyritic aspect on fresh fractures. In the northern half of the quadrangle the sandstone is found in many of the wells, shafts, and borings that reach the Friendsville coal, but its occurrence is not so persistent as in the southern half of the area, and it is more frequently replaced by shale.

The Aldrich coal or the overlying limestone forms a rather persistent horizon, the outcrop of which in the region south of the drift border is shown on the geologic map. It may be recognized also along the Wabash bluff at New Harmony and southward, in the Mumford Hills, at the Illinois Central Railroad bridge south of Grayville, in the river bluffs at that town, in a bluff facing Bonpas Creek 3 miles to the northeast, at McClearys Bluff, in the bluff at Rochester, and probably at a number of other points. The limestone appears to be absent in the region north of Grayville.

The portion above the Aldrich coal and limestone is nowhere shown in its entirety, this portion of the generalized section being made up from exposures in the bluffs at Grayville and in the high hills northeast and north of that town.

Tertiary System.

The only beds intermediate in age between Carboniferous and Quaternary are the bright-colored sands and gravels capping the two high knobs about 2 miles north of the court-house at Princeton. The section here is given in the next column.

The coarser material of the gravel bed consists entirely of chert and quartz pebbles from 1 to 3 inches in diameter, coated with a bronze-colored enamel of iron oxide. The matrix is of finer gravel and sand, which in places is cemented into a firm

Section of Tertiary and other beds 2 miles north of Princeton.

	Feet.
Quaternary:	
Loess	3
Till (fragments from Tertiary beds predominating)	4
Tertiary:	
Gravel (iron-stained cherts, etc., partially cemented)	2
Sand and clay (red to orange in color)	4
Probably Carboniferous:	
Gray to white sand (probably decomposed sandstone)	6
Carboniferous:	
Gray sandy shale	13

bed by the iron oxide. Masses of this conglomerate are found in the overlying till. The stratification of the Tertiary beds is horizontal.

The altitude of the base of the deposits is about 610 feet above sea, a level which is but slightly lower than that postulated for the early Tertiary peneplain in this region. Taken in connection with deposits of similar character and altitude in the vicinity of other pronounced drainage lines—as in the south bluff of the East White River 2 miles southwest of Shoals, Ind.; in the bluff of the Ohio River back of Tell City and Cannelton, Ind.; near Brandenburg, Meade County, Ky.; and near Rosebud, Pope County, Ill.—the Tertiary beds appear to have accumulated as stream deposits along the rivers either of the peneplain or of the slightly uplifted surface. They are believed in a general way to be contemporaneous with the Irvine formation which caps the hills along the Kentucky River in the Richmond quadrangle (see folio 46) and elsewhere in Kentucky.

Quaternary System.

The deposits which in North America characterize the Quaternary period as a whole are of three classes, and embrace (1) those whose deposition was associated, either directly or indirectly, with the presence of the great ice sheets which at several stages during the period covered large portions of the northern half of the continent; (2) those which were deposited through the ordinary influences of wind and water in the intervals between the stages of glacial invasion; and (3) those which have been deposited by similar agencies since the disappearance of the ice of the latest advance. The first are known as *glacial*, the second as *interglacial*, the third as *postglacial* or *recent* deposits. The materials of these deposits can not always be referred to a single definite class, however, for in many instances the deposition has continued through more than a single stage.

GLACIAL AND INTERGLACIAL DEPOSITS.

Definitions.—The glacial deposits consist of materials that have been picked up by the ice sheet or dragged along its bottom during its southward movement, or transported by its associated streams. The material has all been moved from its original location, and is therefore known under the name of *drift*. This drift was frequently deposited directly by the ice, being either set free by the melting of the portion into which it had been frozen, or simply left behind as a sheet beneath the ice, as the friction between it and the overridden surfaces became so great as to cause lagging and lodgment. The drift liberated by either of these methods usually consists of a heterogeneous mixture of all grades of material, ranging from clay to large bowlders, and is known as *till*. Drift which was not deposited directly from the ice, but which was taken up and transported by glacial streams and finally deposited in more or less stratified masses, is known as *stratified* or *modified drift*.

Glacial stages.—While subdivisions of the drift are not usually apparent from superficial study, a detailed examination of its structure and its general distribution and associations shows that, instead of there being a single sheet formed by one ice advance, there are in reality several distinct drift sheets, each of which represents a separate ice advance. The intervals of deglaciation or disappearance of ice between the advances are made apparent by the presence of soils, by beds of peat and marl, and by the weathering of certain zones now buried in the midst of the drift deposits. The sheets themselves differ markedly in extent, and often in color, composition, and other physical properties, and these differences, together with the morainal ridges marking the various positions of the ice margins, form the basis for the subdivision of the Glacial epoch in North America into nine stages, as follows:

Table of glacial stages.

1. Pre-Kansan or sub-Aftonian glaciation.
2. Aftonian deglaciation.
3. Kansan glaciation.
4. Yarmouth deglaciation.
5. Illinoian glaciation.
6. Sangamon deglaciation.
7. Iowan glaciation.
8. Peorian deglaciation.
9. Wisconsin glaciation (latest stage).

Of the drift sheets of the various stages described, only one, the Illinoian, is known to occur within the Patoka quadrangle. Certain features of the deposits in the Ditney quadrangle, on the east, suggest the possibility of the occurrence of an earlier drift sheet, but further studies seem to show that no such sheet exists in this area. A pre-Illinoian soil zone, the soil and weathered zone of the Sangamon stage, the silt deposits (loess) of the Iowan and the early part of the Peorian and Wisconsin stages, and the terraces, dunes, and loess deposits of the Wisconsin and later stages are, however, well represented in the area.

DEPOSITS EARLIER THAN THE LATER ILLINOIAN DRIFT.

Lignites, soils, and other organic deposits.—Logs, more or less carbonized on the exterior, "coal streaks" (lignite), zones of black muck, and other organic deposits, have been reported in wells at considerable distances below the surface of both morainal and valley deposits at many points. Among such wells may be mentioned: (1) one occurring in morainal deposits in SE. ¼ sec. 21, T. 2 S., R. 11 W., 4 miles southwest of Princeton; (2) a well in the outwash gravels in NW. ¼ sec. 17, T. 3 S., R. 10 W., about a mile northeast of Fort Branch, and (3) a well starting near the level of the high stream flats 1½ miles west of Keensburg. The records are given below.

Record of well (1) in moraine southwest of Princeton.

	Feet.
Surface soil Blue clay, with pebbles and occasional geodes, etc.	50
Thin coal (lignite)	1
Gravel	1+

Section of well (2) in outwash gravels northeast of Fort Branch.

	Feet.
Blue mud with sand and sometimes with pebbles	96
Sand (semi-consolidated)	4
Blue mud (abundant water bringing up numerous "black oak" leaves)	1+

Section of well (3) on sandy flats west of Keensburg.

	Feet.
Sand and quicksand (dune sand)	18
Blue mud, mostly clayey	72
Unrecorded	36
Coal (lignite)	1
Gravel at top, remainder unrecorded	60
Limestone (first consolidated rock)	

In almost every instance the lignite, muck, and leaves are found just below the variable "blue mud" of the drillers and beneath the lignite there is generally a water-bearing gravel. Most of the wells stop in this bed and therefore afford no information as to the depth and character of the bed rock, but in a few records, as in that of the Keensburg well, a considerable thickness of unconsolidated material intervenes between the vegetable matter and the solid rock. No samples of this underlying material have been seen, but from descriptions it appears to be similar in character to the deposits near the surface. This suggests that the time of origin of the lower beds was not very much more remote than that of the upper beds, and would seem to indicate that the lower beds belong simply to an earlier portion of the Illinoian stage. This is borne out by the apparent absence of the lignitic zone separating the surficial deposits in the region south of the recognized limits of the ice invasion.

Absence of pre-Illinoian drift.—In the survey of the Ditney quadrangle, adjoining the Patoka quadrangle on the east, considerable quantities of reddish stratified and sometimes partially cemented sand and gravels, with slightly stained chert and quartz pebbles, and an occasional crystalline fragment, were found outside the limits of the till sheet proper. These were mapped as outwash gravels, though it was suggested, because of their oxidized and somewhat weathered characters, that they might possibly belong to an invasion preceding the Illinoian. The more extended studies made in connection with the survey of the Patoka quadrangle have shown that the stained condition is a characteristic possessed by many undoubted Illinoian deposits of the same composition. This feature is, in fact, well shown in nearly every exposure in the morainal hills. It is now believed that in this area there is no evidence of deposits earlier than those of the last Illinoian invasion other than that presented by the wells in which gravels and other loose materials occur below the lignitic layers, at considerable depths from the surface. It seems practically certain that in the upland exposures evidences of the existence of more than one drift sheet (exclusive of the loess) are wanting. The pre-Illinoian age of the loess in the canal bank 1 mile southwest of Francisco (2 miles east of Maxams), which was suggested in the Ditney folio, is likewise now believed to be improbable, as later work has shown that the materials are probably mainly Sangamon or Iowan.

ILLINOIAN DRIFT.

Till sheet.—The only deposits known to have been laid down by the direct action of the ice within the Patoka quadrangle during the Illinoian invasion are those belonging to the till sheet deposited beneath ice of that invasion by the melting of the basal débris-laden layer or by the lodgment of débris, as previously explained.

In the region under consideration the matrix or body of the till thus deposited consists of a more or less sandy clay, which was derived partly from old soils or earlier drift sheets and partly from the grinding and pulverizing of fragments of sandstones, shales, limestones, etc., which had been torn from the parent ledges by the action of the overriding ice. In this clayey matrix are embedded angular or moderately well-rounded fragments of rock varying from mere chips to large pebbles and even to bowlders several feet in diameter. Rock fragments showing surfaces that are smoothly polished or striated by friction with overridden rocks are much less common than in many glaciated areas, especially those of harder rocks, but a considerable number have been observed within the quadrangle. The fragments were generally less than an inch in diameter, and were mainly of hard rocks, such as outcrop at points far to the east, northeast, or north, many having been derived even from beyond the Great Lakes. Many varieties of rock are represented, the more common being granite, diorite, quartzite, quartz, flint, and jasper, the first three, and possibly the fourth, being derived from the Great Lakes region or beyond, and the remainder probably mainly from the Silurian and Carboniferous limestones to the northeast.

The soft sandstones and shales that underlie the till in this region and that probably furnished the larger part of the material of the finer portions of the till are not commonly represented by pebbles or bowlders, though a few fragments of somewhat massive sandstone and of limestone have been noted. The pebbles known to have been derived from the Great Lakes region or beyond are almost universally well rounded, but the flinty pebbles from the limestone areas, though they have lost their sharp edges, still present a rather angular appearance. The local bowlders, being of relatively soft and friable materials, generally exhibit considerable rounding. The weathering of the granite and diorite pebbles and bowlders varies greatly, some being hardly stained even on the exterior, while others are almost completely disintegrated. Most of them show a weathered zone that reaches an eighth or a quarter of an inch inward from the surface. It seems probable that the variation in the extent of weathering is due largely to differences in composition or to the stage to which incipient weathering had advanced at the time of the removal of the fragments from their parent ledges.

The texture of the finer portions of the till varies greatly, probably depending upon the nature of the rock from which it was principally derived. Where shale appears to have furnished the larger portion of the material the till is generally very clayey, and is of a gray or bluish-gray color in its unoxidized portion. Where sandstones have furnished much material the till is sandy, and varies in color from a rather deep buff in the moderately oxidized portions to a deep red in the upper and more strongly weathered parts. The limestones in the Patoka quadrangle appear to have been of too limited development to have had a marked influence upon either the color or the composition of the till. The till within the quadrangle is usually oxidized to a depth of 7 to 10 feet, or even more, the unoxidized portions being rarely seen, except in unusually deep cuts. In the oxidized portions the color is ordinarily deep buff to brown, but reddish tints are very common in the sandier varieties. The red type of till frequently gives evidence of incipient cementation by iron oxide, but the solidification is usually less marked than in the stratified sandy layer formed as an original deposit by the glacial streams or from the reworking, by water, of the red till.

Sections giving accurate measurements of the thickness of the till are uncommon, and are generally so located as to give only minimum thicknesses. Wells have afforded data of great value as to depth to the rock, but usually little information can be obtained as to the exact nature of the material penetrated. In general the thickness of the till, though showing great variation, may be said to be slight, and usually ranges from 2 to 15 feet, though occasional exposures show much greater amounts. A typical exposure is shown in fig. 8. The broad plateau-like plains that stand at considerable elevations above the valleys and that are so conspicuous in the Ditney quadrangle, to the east, are not represented in the area under discussion. In the moraines and other thick drift deposits, stratified sands and gravels predominate almost, if not entirely, to the exclusion of the till.

Drift plains.—At many points within the quadrangle, especially at the lower levels, there are more or less extensive drift flats that usually stand a few feet above the older and highest stream silts. Because of their low relief exposures are rare and usually indecisive, but the flats generally occur in positions unfavorable for lake deposition and appear to merge into the sloping till plains of the upland hillsides. They are, therefore, thought to belong to the unstratified rather than to the stratified type of drift. They are best developed near Poseyville and in the region northwest of the Wabash River.

Drift ridges (probably morainal).—These deposits consist of ridge-like accumulations of drift that broaden into wider hilly belts in some places, as in the region north of the Patoka River. The minor details of their topography exhibit in general almost none of the normal morainic features, the uneroded portions usually presenting smooth, gently undulating surfaces, free from kettles and conspicuous knobs, though a few rounded knobs and remnants of shallow depressions, now drained by the cutting back of the streams, appear to exist. The ridges, however, exhibit an alignment parallel with the ice margin, and in some places, as, for example, in the ridge from Princeton to Fort Branch, are associated with outwash plains. The ridge east of Owensville is almost esker-like in outline, a resemblance which is heightened by the sandy and stratified character of the deposits and the steepness of the slopes. The width, however, is probably too great to permit such assumption as to origin. Its parallelism with the ice margin is also against this supposition.

Practically no till has been identified with certainty in any of the ridges. Wherever the exposures are good the material is found to consist of deposits of oxidized sands and gravels containing rounded pebbles of quartz and fragments of flint and jasper, supposedly derived from the older limestones to the east and north. Crystalline rock fragments, of Canadian origin, though rare, are occasionally found. The materal is clearly stratified and is prevailingly sandy, the pebbles forming a relatively small proportion of the mass. The color of the upper beds is usually a deep red, but lower down in the sections the red colors give place to browns and buffs.

Notwithstanding the absence of till and the lack of a distinctly morainal topography, the ridges, because of their location at or near the ice limits and their alignment with the margin, are believed to be essentially morainal in their nature. The normal morainal topography, if it ever existed, was long ago obliterated by the marl-loess or loess mantles, or destroyed by erosion, which, because of the relative softness of the material and the steepness of the slopes, has gone on rapidly until the ridges are very generally deeply trenched by ravines in which the semi-consolidated sand frequently stands as vertical walls.

Deposits of this class occur in greatest development between Patoka and Hazleton and near Princeton, where they reach an elevation of 170 feet above the adjacent plains. In many places they lie from 100 to 130 feet above the lowlands. They are evidently the same as the kame moraine mentioned in the Ditney folio as occurring 2 miles southwest of Wheeling, and are probably the general equivalent of the patches of outwash gravel of that quadrangle.

Outwash gravel plains.—While the ice front rested along the moraine between Princeton and Fort Branch more or less water was continually set free by the melting of the ice, and on flowing away carried with it a considerable portion of the detritus previously held by the ice. In this manner the broad, sloping drift plains bordering this moraine on the east were built up, as were probably the similar plains at Haubstadt and vicinity.

There appear to have been two stages in the development of the plains bordering the moraine. In the earlier stage the ice front probably lay about 1½ miles east of and parallel to the present line of the Evansville and Terre Haute Railroad, its position being marked by isolated drift knobs of buried moraine that project above the outwash plain. In the second stage the ice rested along the main ridge between Fort Branch and Princeton, the area between the two ridges being then filled up by the later outwash materials and the two plains practically united into one.

The Henry Whitman well, 3 miles east of Fort Branch (NE. ¼ sec. 16, T. 3 S., R. 10 W.), gives a typical section of the deposits:

Section 3 miles east of Fort Branch.

	Feet.
Soil	2
Loess (possibly some sand in lower portion)	18
Sand, fine and of varying color ("quicksand"), probably stratified	65
Gravel	5
Coal (lignite)	1
White sand	1
Sandstone	

Exposures in this region are very rare and show very little of the character of the material. Several cuts, however, were noted in which reddish and buff sands were exposed, and in some a few pebbles were found. From a well in the NW. ¼ sec. 9, T. 3 S., R. 10 W., a sort of stiff, stratified sandy clay, probably mainly quartz-flour, characterized by marked contortions and numberless miniature faults, was thrown out. Some of the coarser sands are semi-consolidated and are to be correlated with parts of the lower "outwash" deposits described in the Ditney folio.

ILLINOIAN GLACIAL LAKE DEPOSITS.

The general drainage of the northern two-thirds of the quadrangle was originally to the west or northwest. When the ice advanced and lay across the lower portion of the valleys lakes were created in their upper portions in which large quantities of silts and smaller amounts of coarser sediments derived from the melting of the ice were laid down, generally accumulating nearly to the level of the standing water. Four stages of lake deposits are recognized in this region: (1) the deposits laid down at the maximum extension of the ice; (2) the deposits of the first halt in the ice retreat; (3) the deposits of the second halt; and (4) the deposits of the third halt. The materials are usually silts or very fine sands, but fine gravels are frequently encountered in wells, while geodes and other bowlders are reported at several points in the glacial lake deposits of the second halt.

Lake deposits of the maximum advance.—Previous to the ice advance the drainage in the valley now occupied by the West Fork Pigeon Creek was to the west and northwest, passing into the Wabash Valley between Owensville and Princeton. During the most southerly extension of the ice this outlet was obstructed and waters were ponded until they overflowed southward into a valley east of Elberfeld, about 3 miles east of the limit of the Patoka quadrangle. In this body of water, which in the Ditney folio was designated Lake Pigeon, silts accumulated, but these deposits lie mainly east of the limit of the Patoka quadrangle. Similar silts also accumulated in the valley at the headwaters of Flat Creek.

Lake deposits of the first halt.—At its maximum extension the ice margin probably lay several miles east of the limit of the quadrangle at the latitude of the Patoka River. At this time deposits that formed broad plains were laid down in a glacial lake, which has been called Lake Patoka, occupying the upper valley of the Patoka River, but it was not until the ice margin had fallen back to a point about 2 miles east of Patoka that the lake was extended downstream into the Patoka quadrangle. The deposits at the lower end of the extended lake were laid down during the first recorded halt in the ice retreat, and consist mainly of silts and fine sands. The accumulations do not rise much above the 420-foot level, indicating that the deposition failed to reach what must have been the water level if the overflow was over the 460-foot divide near Francisco, as it appears to have been.

Lake deposits of the second halt.—After the deposition of the above silts the ice fell back a few miles and halted along a second line, now marked by the ridge of morainal and similar deposits extending with a few breaks from near Hazleton southwest to a point beyond Cynthiana. In front of the new ice margin four small glacial lakes accumulated. The northernmost of these was a lakelet lying just south of Hazleton, now marked by alluvial flats composed of materials then deposited.

A second and much larger lakelet accumulated between the ice along the morainal ridge that extended from near Mounts to the highlands southwest of Princeton and the moraine that was formed during the first halt of the ice and extended from the vicinity of Princeton southward to beyond Fort Branch, probably damming the valley south of the latter village. In this lakelet was deposited a considerable thickness of silts, sands, and fine gravels, with an occasional bowlder or erratic geode. They reach an altitude of about 450 feet, the probable level of the ponded waters. The outlet was over the morainal barrier south of Fort Branch—which was thereby greatly reduced—and through the valley east of Elberfeld.

The two remaining lakelets of this stage occupied the valleys of Flat and Barr creeks. Before the ice invasion these streams had flowed northwest along the valley of the Black River to the Wabash, but at the second halt of the ice on its retreat the old valleys were permanently clogged by the morainal ridge extending from Mounts southward past Cynthiana toward Poseyville. In front of the combined barrier of ice and drift the two lakelets mentioned accumulated. In them were laid down deposits similar to those of the lakelets previously described. In the upper portions of the valleys and beyond the ice limits, these overlie the silts of the earlier lake stages. The waters escaped along the ice margin and over a col probably located about 2½ miles north of Blairsville, so reducing the latter that the drainage persisted in the channel then established after the retreat of the ice.

Lake deposits of the third halt.—This halt was shorter than the earlier ones. The lake in which these deposits were laid down occupied the upper portion of the valley of the Black River and the lowlands south of Poseyville, now drained in part by Caney Creek. The ice margin probably lay across the Black River just north of Poseyville. The deposits are represented by the thick beds of silts, sands, and fine gravels constituting the broad flats in the vicinity of Poseyville.

SANGAMON DEPOSITS AND WEATHERED ZONE.

Erosion and local deposition.—Studies of the erosion features of the Sangamon stage in other regions have shown that the streams were broad and sluggish, with only shallow and rather poorly defined channels, and that the deposition was very slight in amount. In southern Indiana, however, the erosion was locally of considerable importance, probably removing 80 to 100 feet of Illinoian till from the valley of the White River and possibly even greater amounts of material along the Ohio River. Deposition during the Sangamon stage was probably limited to a few unimportant secondary deposits, produced by the reworking of the Illinoian drift by the agency of the streams.

At many localities in Iowa and Illinois, and to less extent in Indiana, peaty beds of black muck which were deposited in this interglacial stage have been noted and described. Beds apparently of this character have been reported beneath the thick marl-loess deposits of the Patoka quadrangle at a number of places. The following well section (SW. ¼ sec. 10, T. 5 S., R. 13 W.) is typical of the occurrence:

Section 4 miles west of Wadesville.

		Feet.
Marly soil	Iowan	3
Clay (marl-loess)	Iowan	30
Rich soil, logs, etc., (Sangamon)		3
Blue mud and gravel (till)	Illinoian	10
Quicksand (stratified drift)	Illinoian	1+

Weathered zone.—Though important deposits of the Sangamon stage are lacking, the interval between ice advances is nevertheless well represented by the Sangamon weathered zone. This zone marks the top of the Illinoian drift, and is recognized by the leached and weathered character of that portion of the deposits. Where the overlying loess and especially the marl-loess is of considerable thickness its lower part is usually but little oxidized and its appearance is in somewhat marked contrast with that of the weathered zone upon which it rests.

IOWAN DEPOSITS.

Following the formation of the weathered-zone soils, and possibly silts, of the Sangamon stage, a considerable thickness of fine silt known as loess was deposited as a mantle over nearly the entire surface of Iowa, Illinois, and Indiana, and in portions of many other States to the east, south, and west. This loess has been traced as far back as the edge of the drift sheet of the Iowan ice invasion in northern Illinois, but stops at or near its border, apparently indicating that the deposition took place during the stage of glacial occupancy.

Previous to the present survey of the region no attempt had been made to differentiate the silts, but evidence is now at hand for separating them into two types: (1) thick, yellowish, calcareous, and frequently stratified silts along the immediate borders of the Wabash Valley, which are designated *marl-loess*, and (2) the more clayey, oxidized, and structureless silts designated as *common loess*, forming the general mantle over the surface more remote from the river. The first is believed to be of aqueous and the second of eolian derivation. The evidence on which this conclusion is based is given in full in Bulletin of the Geological Society of America, volume 14, pages 153–176.

Marl-loess.—The marl-loess is a white, gray, or more commonly a yellowish silt occurring in rather definite belts bordering the Wabash Valley on both sides. It occurs at all altitudes from the flood plain to the 500-foot level (120 feet above the river), at which altitude it frequently forms broad terraces and flats (figs 10 and 11), burying a rugged rock or till topography. The thickness of the marl-loess in these terraces and flats is sometimes 40 feet or more, but thicknesses of 10 to 20 feet are more common. True marl-loess appears never to occur above the 500-foot level in this region.

The marl-loess is characterized by a high calcareous content and frequently by a sandy texture. Calcareous concretions are exceedingly abundant. In many instances it is delicately stratified (fig. 9), and in some cases is interbedded with sands or fine gravels, or even carries scattering pebbles itself. Fossils were found in a large number of exposures, but with the exception of those from one locality, were all land forms. About thirty land species and six aquatic species were identified by W. H. Dall. The silts are conspicuous only along the immediate border of the Wabash Valley, and are rarely found at a distance of more than 10 miles from the river.

The perfection of their stratification, their interbedding with sand and gravel, the presence of pebbles in them, their terraced form, and their limitations to the borders of the Wabash point to water as the most probable agent in the accumulation of the marl-loess deposits, the deposition probably being in a fluvio-lacustrine body occupying the lower Wabash Valley, into which the silt was brought from the Iowan ice sheet by the Wabash River.

Common loess.—This is usually a fine, clayey, buff or brown, but sometimes gray, reddish, or mottled silt, which mantles the hills as a relatively uniform sheet having but little relation to the character of the topography. It is essentially non-calcareous in composition, differing markedly in this respect from the marl-loess, as the following analyses will attest. The first sample (No. 1) was from near Princeton and was analyzed by Prof. Robert Lyons for the Indiana geological survey and published in its twentieth and twenty-first annual reports. The second (No. 2) was from the land of B. C. Macy (said to be near New Harmony) and was given in D. D. Owens's report on "A Geological Reconnaissance of the State of Indiana," 1838, part 2, p. 66. The two are selected because they mark extremes in the range of the content of carbonate of lime ($CaCO_3$). The average sample of the common loess would probably show less than 1 per cent of the $CaCO_3$, while the average sample of the marl-loess would probably show more than 5 per cent.

Analyses of loess (No. 1) and marl-loess (No. 2).

	No. 1. Princeton.	No. 2. New Harmony.
SiO_2	71.20	
Al_2O_3	18.56	60.00
Fe_2O_3	1.34	
FeO	.15	.80
CaO	.14	20.27
CO_2	......	15.93
TiO_2	.88	
MgO	.52	1.00
Na_2O	1.26	
K_2O	.32	
H_2O	6.30	2.00
Total	100.67	100.00

Mechanical analyses of the loess are given in the discussion of the soils on page 10.

Calcareous concretions are relatively rare, and when they occur are generally of small size. On the other hand, small iron concretions, both of the tubular and the rounded or irregular type, are abundant in places. The common loess has not been found to carry fossils at any point in the region examined, nor does it contain pebbles except where the sheet is so attenuated that roots penetrate the till beneath and on the falling of the tree, drag the pebbles upward into the loess. The common loess of the region presents no definite evidences of stratification, though an indistinct banding in planes parallel with the surface, made visible because of differences in moisture absorption of the materials, has been here and there noted.

Along the borders of the east side of the Wabash Valley loess of the common type is often absent, marl-loess of typical composition, structure, and topography frequently forming the immediate face of the bluffs. Though differentiated only with some difficulty from the marl-loess where the latter is weathered, a thin coating of the common type of loess usually appears to begin within a quarter or half a mile of the edge of the marl-loess and increases gradually in thickness for several miles, probably reaching a maximum of 15 feet or more at a distance of 6 or 7 miles, beyond which it slowly decreases until, at a distance of 35 or 40 miles, it has a thickness of only 2 or 3 feet, or possibly even less. On the west side of the river the conditions of distribution are similar, though the strip of marl-loess is narrower and the maximum thickness of the common type occurs much nearer the borders of the valley. The same thinning of the deposit away from the river is noted, the common loess being generally absent, at least in recognizable amounts, at a distance of 15 miles from the Wabash.

The common loess is not confined to any one horizon, but occurs at all elevations, from the level of the river bottoms to the crests of the highest hills. Above a certain altitude, which detailed observation has shown to be approximately 500 feet (120 feet above the river), it constitutes the only silt noted. Below this level, especially near the river, the common loess, though generally occurring, is not, as has been seen, necessarily present, the marl-loess, which normally underlies it, forming the bulk of the silts. Eastward from the river there is a persistent though gradual decrease in the thickness of the marl-loess, the common type becoming at the same time of greater relative, if not real, importance.

The apparent presence of pebbles in some localities in the common loess, and the occurrence of flats and silted divides of loess of the same type overlying more or less irregular surfaces, points toward a modified aqueous origin of this class of silts in a few cases in the Ditney quadrangle, to the east, but no examples were recognized in the area now under discussion. The great mass of the common loess appears to be undoubtedly of eolian derivation, the source of the material being found in the marl-loess of the Wabash Valley.

Older stream silts.—In the class of older stream silts are included the silts occupying most of the smaller valleys. They consist largely of reworked loess and are therefore of a marked clayey texture. A few sandy layers and more rarely gravelly streaks occur. The deposits are characteristic of overloaded streams, the work of which is to build up rather than reduce their beds. While many of the bottoms mapped as older silts are no doubt receiving additions even at the present time, the presence of the earlier Wisconsin dunes upon their surface in the northwestern part of the quadrangle shows that they had in places practically reached their present development in early Wisconsin time. The bulk of the filling is probably Illinoian, though the surficial clays doubtless accumulated largely during the Iowan stage. For the reason that their principal period of development terminated in the Iowan stage they are grouped with the deposits of that age rather than with the recent deposits, classification with which might appear to be warranted by their recent surface silts. This classification was, in fact, made in the Ditney folio, in which is described the area lying immediately to the east. In the vicinity of the main drainage lines the older stream silts are invariably trenched, and are in some places superficially removed or represented only by a few small terraces.

WISCONSIN DEPOSITS.

The ice sheet of the Wisconsin stage did not reach the Patoka quadrangle, and there are therefore no deposits of this stage covering the general surface of the region. Every stream, however, which led either directly outward from the ice margin or was fed by tributaries heading at the ice front carried considerable amounts of glacially derived materials, which were deposited as broad, flat plains of sand or fine gravel. Of the streams in the vicinity of the Patoka quadrangle, only the Wabash and White rivers head in the region occupied by the ice, though the Ohio received the drainage of a number of other streams heading near the ice front and bringing down quantities of glacial sediments, which were deposited as broad flats on either side of the river. The Wabash River was also the outlet of a large glacial lake in the region of the Great Lakes.

Wisconsin terrace.—Although it is certain that the larger part of the sand and gravel filling of the Wabash and White river valleys was transported indirectly through the agency of the Wisconsin ice sheet, and was probably brought nearly to its present place during Wisconsin times, there is only one unaltered deposit in the quadrangle which has been referred to this stage. This is the deposit between Cowling and Keensburg, in the northwestern portion of the area. It consists of a thin layer of silts, fine sand, and gravel of fresh northern material spread over the upper stream silts. Toward the higher of the late Wisconsin or recent terraces on the east it presents a low bluff, perhaps 10 feet in height, but the bluff overlooking the abandoned channel near Cowling is about 40 feet high. The surface generally consists of fine sand, which is frequently drifted into low dunes. The flatter and poorly drained portions are characterized by black muck accumulations.

Wisconsin dunes.—Besides the low sand dunes of the Wisconsin terrace, the larger of which are represented on the map, there is a well-defined ridge of dunes extending from east of Keensburg nearly to Bonpas Creek. The sand of the dunes, both of the flat and ridge, is notably finer and whiter than that of the more recent dunes bordering the Wisconsin terrace on the south.

WISCONSIN-RECENT TRANSITIONAL DEPOSITS.

Upper flood-plain deposits.—These deposits consist of broad flat plains of sands or fine gravel, with occasional areas of muck in broad, shallow depressions in their surface that occur along the Wabash and other prominent streams. They constitute in fact a perfected flood plain, the topography of which is in marked contrast with that of the rolling to broken surface of the lower flood plain. They are overflowed in part at periods of exceptionally high water, but the higher portions along the edges of the valley always remain above water. There is no break between the lower and higher portions, the plain exhibiting a gentle, even slope from the edge of the valley to the banks of the streams or to the bluffs facing the lower flood plains. The upper flood plains are bordered by broad and originally forested dune belts, apparently composed of sands derived from the surface of the flats.

The muck and a part of the surface silts are undoubtedly of recent origin, but as important dunes are nowhere forming under the conditions now existing in this region it is thought that they represent an accumulation at a period of greater depositional activity, when broad, bare flats, possibly extending over the greater part of the present width of the valley, were exposed to the sweep of the winds, and when the rate of dune accumulation probably precluded the existence of a vegetable mantle. These conditions are believed to have characterized the latter part of the Wisconsin stage, and possibly extended into Recent time. It is thought, however, that the covering of the flood plain and dunes with vegetation probably took place immediately upon the subsidence of the floods that are supposed to have attended the Wisconsin ice retreat, but it is considered safer to class both the flood plain and dune deposits as transitional rather than with either the Wisconsin or Recent stages.

Later dune sands.—These sands, the origin of which has just been considered, occur principally as a broad but interrupted belt along the east side of the Wabash Valley, though a few small areas are found bordering the river flats on the Illinois side of the river. The material is usually a coarse quartz sand which in the better exposures shows stratification either of the steep advancing-face type or of the irregular type characteristic of accumulation after vegetation has begun to take hold. Fig. 12, from a photograph taken just west of Mount Carmel, shows the former type in the lower right hand portion of the view, while the latter type is shown on the left.

The coarse sand is in some places interbedded with fine or marly sand not much different in composition from the marl-loess, though it never exhibits the perfect stratification of the latter. It carries fine fragments of shells, but no perfect forms, such as universally characterize the marl-loess, were found.

The sand has in places a maximum thickness of about 100 feet. It is characterized by a typical dune topography, though somewhat subdued in some of the outlines through the reworking of the surficial portion by creep or through the influence of the original forest growth. Large undrained kettle-like depressions are common.

Late loess.—The sand of the dune belts in some places becomes finer away from the valley and merges into a sandy loess. This coating is usually so thin that the material has become commingled with the underlying Iowan loess through the action of penetrating roots, and can not be differentiated. In the railroad cut at Mount Carmel and in a few other localities, however, there appears to be a surficial loess mantle, a foot or two in thickness, resting upon the loess of the ordinary type, from which it is separated by a weathered zone. It is believed to be contemporaneous with the later dune sands.

RECENT (POST-GLACIAL) DEPOSITS.

Lower flood-plain deposits.—These deposits consist of silts, sands, and fine gravels, with occasional areas of muck occupying the shallow depressions as in the upper flood plains. The chief particulars in which the lower differs from the upper plain are: (1) the low level of its surface, which is generally subject to annual overflow and is frequently separated from the upper flood plain in the case of rivers (or from the older stream silts of the smaller streams) by an escarpment 5 to 15 feet in height, and (2) its undulating, rolling, or broken surface, characterized by numerous bayous and abandoned channels. Two distinctly different processes are involved in the production of the lower flood plains, namely, unequal degradation due to localization of the erosion of the flood plain on the one hand, and unequal upbuilding of previously reduced areas on the other. The two processes, however, have so cooperated that the resulting forms can seldom be differentiated.

Swamp deposits.—Under swamp deposits are included those deposits of muck, peat, and vegetable mold which occupy the broad, shallow depressions in both the upper and lower flood plains. They are characterized throughout by a heavy growth of timber. The thickness of the accumulation is usually 3 or 4 feet, but may reach 7 to 10 feet. The most notable of the swamps are those surrounding the Cypress Ponds, near the junction of the White and Wabash rivers. Some of these ponds, it is said, contain water throughout the year, and several retain it in all but the dryer seasons. Most of the cypress has been cut out, but enough remains to give a decidedly southern aspect to the swamps.

Abandoned channel deposits.—The abandoned channels are of all stages, from freshly-cut bayous to channels nearly filled and effaced as topographic features. The filling of the channels is at first very rapid because of their connection with, or proximity to the rivers. Fillings of silt amounting to 6 inches in a season have been recorded. In addition to this, large quantitities of driftwood are frequently washed in, and trees on falling not uncommonly add their remains to the deposit. As the filling approaches completion the deposition is less rapid and consists mainly of a mixture of silt and vegetable matter, differing but little from the swamp deposits except in the shape of the areas.

Natural levees.—The natural levees consist of overwash sands or fine gravels deposited when the current of the overflowing river waters is first checked. They are conspicuous in the quadrangle only along the Wabash and Fox rivers, and are confined to the banks or near vicinity of the streams. In age they are the most recent of the deposits of the quadrangle, unless it be some of the swamp and abandoned channel deposits. They are found on both the lower and the upper flood plain.

STRUCTURE.

Local dips, often of several degrees and of various directions, may be seen in some of the exposures of the Patoka quadrangle, and from a superficial examination might appear to indicate not only that there is a considerable dip to the rocks of this area, but that there is also considerable irregularity in its direction and amount. A closer study, however, reveals the fact that these irregularities usually extend but a few feet or rods, and that they have almost no effect on the broader structural features. By the tracing of coals or other persistent beds it is clearly shown that, although the dips are extremely variable and even easterly in places, the general dip is to the west, the amount varying from 5 to 40 feet to the mile, with an average of about 11 feet. This dip, slight as it is, is sufficient to make a difference of about 300 feet between the altitude of a given bed at the eastern border and that which it has at the western border of the quadrangle.

The Somerville formation, the Parker coal or associated limestone, the Friendsville coal, and the Aldrich coal and associated limestone are the best defined beds in the quadrangle and where they outcrop or are reached by ordinary water wells dips may be determined with some accuracy. By combining the observations based on each separate bed the structure can be worked out, especially in the southern half of the quadrangle. The general dip is northwestward and is greatest along the eastern border and least along a line extending from the vicinity of Little Rock to the southwest corner of the quadrangle. A low anticline runs from near Friendsville southeastward to the vicinity of Mount Carmel. Between this anticline and Gards Point, Bellmont, and Keensburg the dip is low, but steepens again in the vicinity of Bonpas Creek.

From the southeast corner of the quadrangle to the vicinity of Kasson the dip is about 15 feet to the mile, but farther north it is somewhat steeper, reaching about 30 feet to the mile between Inglefield and Little Pigeon Creek. Northeast of St. Joseph the dips are as high as 4° NW.

for some distance along the railroad, making a very material difference in the elevation of the outcrops of the Parker coal and associated limestone on opposite sides of the same hill. The dips are steeper here than elsewhere in this region so far as observed. From the ridge between St. Joseph and Kasson westward to the vicinity of Parkers Settlement the dips are about 15 feet to the mile. From Lippe to Springfield the dips average only about 6 feet, while westward from Springfield to the Wabash River they are as low as 3 feet to the mile.

North of the drift area the outcrops are less frequent and poorer and the dips are more difficult to determine. The Aldrich coal, however, can be traced from near Stewartsville to the Wabash River near Grayville, and shows in this interval an average dip of about 6 feet to the mile. At Princeton the deep wells and the coal shafts show that the dip is as high as 50 feet, but along the Patoka it is only about 20 feet to the mile. From Patoka to the Gordon Hills the dip is about 12 feet to the mile. From the latter hills to Crawfish Creek the dip is nearly flat, but from the creek westward it rises rapidly to a height of 450 feet in about 2 miles (see geologic map and fig. 4). From the crest of this low anticline the beds dip gently westward at a rate of from 18 feet to the mile between Friendsville and Gards Point to about half this rate west of Mount Carmel. In the region about Maud and Bellmont the beds, though showing several minor undulations, are, on the whole, nearly flat. To the south and southwest the dips are more pronounced, averaging 20 feet to the mile between Sugar Creek and Rochester and 15 feet to the mile from Bellmont to Cowling. Between Rochester and McClearys Bluff the rocks are nearly horizontal.

GEOLOGIC HISTORY.

PALEOZOIC EVENTS.

Deposition.—The deposition of the great series of sediments laid down in the interior sea occupying the broad Mississippi Basin began in Cambrian time with a thick bed of sand which was spread along the changing shores in waters that were generally shallow, ripple marks and other shallow-water or shore features being common in the or of shells, corals, etc., which on subsequent solidification became sandstones, shales, and limestones. At times the region was occupied by wide swamps or shallow lagoons, in which accumulated quantities of peaty matter, now changed to coal. Together these beds make up a series of coal-bearing rocks of which those of the Patoka quadrangle are a part. They are the highest and youngest of the solidified rocks of Indiana.

The thickness of the entire series, from the Cambrian to the close of the Carboniferous, is probably 4000 or 5000 feet, of which, in the Indiana region, considerable more than half is limestone, the conditions being in marked contrast to those existing near the borders of the sea to the east, where the deposits were composed largely of sandy and shaly materials.

The deposition of the sedimentary rocks did not take place uniformly over the whole of the basin. Even at the beginning of the Cambrian period islands existed, it is believed, in the southern portion of Missouri, and possibly elsewhere in the great continental sea, and local uplifts, possibly in some cases accompanied by slight folding, brought similar islands into existence from time to time at other points as deposition progressed. Of these the one most intimately related to the region of the Patoka folio was the Cincinnati island, produced by the broad, dome-like fold known as the Cincinnati anticline, the maximum development of which is in the vicinity of Lexington, Ky. From here this fold extends southwestward to Nashville, Tenn., and northward and northwestward through Cincinnati and into the north-central portion of Indiana. This broad dome (the uplift of which began long before the beginning of the deposition of the beds of the Patoka quadrangle) and the original island in southern Missouri, which had in the course of time become considerably enlarged, formed the opposite shores of a broad embayment or strait that extended from western Kentucky across southwestern Indiana, Illinois, northern Missouri, and southern Iowa, and connected with the northwestern extension of the interior sea in western Missouri and Iowa. It was in this embayment that the Carboniferous rocks of the Patoka region were laid down.

had the Carboniferous beds appeared above the surface of the sea by the further uplifting of the Cincinnati anticline than erosion set in and began its work of reducing the surface thus formed. It is probable that erosion did not at first keep pace with uplift, and an elevation of some prominence may have resulted. On the cessation of the upward movement, however, erosion continued with undiminished energy its work of reducing the land and carrying the materials to the sea, which now lay at some distance from the Indiana region. The surface of the land was thus gradually lowered and its prominences were reduced to broad, low, well-rounded hills separated by wide, flat, and shallow valleys. Such a featureless surface is called a peneplain, and there is but little doubt that a number of successive general or local peneplains were developed one after the other in the region under discussion, as appears to have been the case with the series beginning in pre-Triassic time and ending with the Tertiary plain along the Atlantic coast. The remnants of the latest of the pronounced plains in the region of the Patoka quadrangle are preserved even to the present time in the flat-topped crests and isolated hills rising, as described in the discussion of topography, to elevations of from 600 to 650 feet.

No remnants of a topography older than the peneplain under discussion are known in the Patoka region. The age of the peneplain can not be regarded as positively established, though it appears to form a part of a surface which stretched eastward to the base of the Allegheny Mountains and southward along their western margin to Alabama—a surface which is probably equivalent to the Lexington Plain of Kentucky, and is thought to have been formed in early Tertiary time.

Drainage of the peneplain.—On two of the knobs just north of Princeton and at a number of points in the hills bordering the Wabash, White, and the lower Ohio valleys, deeply stained, bronze-colored gravels, composed mainly of quartz and flint and supposed to be of Tertiary age, are found resting upon the peneplain remnants. Near Princeton the gravels have an elevation of 610 feet at their base (determined by level), and at the other localities of from 550 to 700 feet (barometric deter-

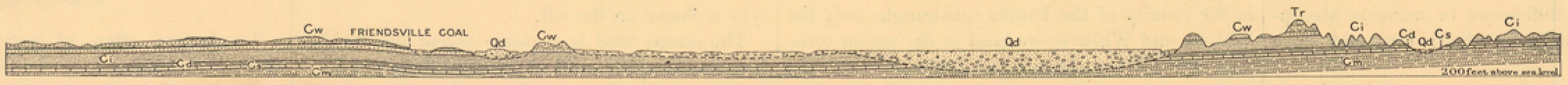
cutting, and there is some evidence, in the shape of divides and flat crests at an altitude not far from 500 feet, that a local peneplain was developed at that elevation, and it is possible that there are still other levels at which local plains developed. If so, these later peneplains, like the first, suffered uplift and erosion, until broad valleys were carved out to the level represented by the rock floors underlying the deep silts and glacial fillings of the present valleys.

Late Tertiary or early Pleistocene depositional stage.—Following the period of Tertiary erosion, during which the land was carved by the streams until it had essentially the form it would now show if the overlying silts and glacial deposits were removed, there appears to have been a subsidence or an overloading of the streams, which caused the deposition of bronze-colored gravels at Enterprise, on the Ohio, southeast of the Patoka quadrangle. Whether these gravels, which certainly look much older than the oldest glacial deposits, are to be regarded as the result of a reworking, in late Tertiary or early Pleistocene time, of older Tertiary sediments, as Mr. Leverett has suggested, or as undisturbed late Tertiary deposits, as Mr. A. C. Veatch has urged, is a question that has not been fully answered. It is certain, however, that they were deposited much later than the gravels on the peneplain remnants, and before ice-transported crystalline or other Canadian materials were brought within the reach of the old Ohio drainage system.

GLACIAL HISTORY.

Illinoian deposits and stream changes.—It has usually been believed that neither the pre-Kansan nor the Kansan ice sheet reached as far south as this quadrangle. Although some features in the Ditney quadrangle, immediately east, suggested the possibility of an early invasion, later studies fail to substantiate this view. In the Illinoian stage, however, the ice reached well into the quadrangle and remained there for a long time, during which the till sheet, the extensive morainal deposits, the marked outwash plains, and the glacial lake deposits were accumulated.

In consequence of the obstruction of the estab-



Horizontal scale, $\frac{1}{125000}$, or 1 inch=2 miles (approximately); vertical scale, 1 inch=1000 feet.

FIG. 4.—Structure section across the northern portion of the Patoka quadrangle along the line A—A on the Areal Geology map.

Shows the position and extent of the Friendsville coal. Cm, Millersburg formation; Cs, Somerville formation; Cd, Ditney formation; Ci, Inglefield formation; Cw, Wabash formation; Tr, Tertiary; Qd, glacial drift.

resulting sandstone. At the close of the Cambrian period, there was, in Indiana, a change from conditions favorable to the deposition of sandstone to those favoring the accumulation of limestone, and a 50-foot bed of the latter was deposited at the beginning of the Ordovician period. Although there was a partial return to the former conditions during the deposition of the succeeding formation, the St. Peter sandstone (portions of which are calcareous), the deposition of limestone continued, with a few relatively unimportant breaks, throughout the whole of the Ordovician, Silurian, and part of the Devonian periods. Beginning with Middle Devonian times, however, limestone gave place to black shale, which in the early part of the Carboniferous period was followed by sandstone, and later by limestone, the deposition of which continued until the close of the early Carboniferous (Mississippian). The series of deposits closed with an interval during which the recently deposited beds were lifted bodily, and without tilting, above the level of the sea, and were extensively eroded by the action of streams.

After the early Carboniferous interval of erosion the beds once more sank beneath the waters of the great interior sea, and deposition continued as before. The conditions, however, were no longer constant through long periods of time, but were continually changing, the waters of the sea being now shallow, now deeper, and at times, as following the deposition of the Mansfield sandstone and just before the deposition of the Inglefield formation, completely withdrawing and permitting the erosion by surface streams of the beds previously deposited. Each change was recorded by differences in the character or structural features of the rocks, beds of sand alternating with beds of mud,

Uplift and tilting.—The sedimentary beds were originally in an essentially horizontal position throughout the extent of the embayment in which they were deposited. At the close of the Carboniferous period there were further uplifts of both the Cincinnati and Missouri domes or anticlines. The intermediate area, constituting what is now known as the Illinois-Indiana coal basin, partook of the uplift, and its deposits were lifted above the level of the sea, but the amount of the elevation was much less than in the bordering region, the result being the development in the rocks of a slight but persistent dip toward the center of the basin in eastern Illinois. The coal-bearing rocks forming the surface were doubtless originally connected with similar rocks to the south and also to the northwest, but subsequent erosion destroyed these connections and left the coal rocks in the present isolated basin. The limits of this coal basin, together with the position of the Patoka quadrangle, are shown in fig. 1, p. 2.

MESOZOIC AND EARLY CENOZOIC EVENTS.

Subsequent to the uplift that followed the deposition of the Carboniferous rocks, and that raised them above the level of the waters in which they had been deposited, there appears to have been no further incursions of the sea into this region and there is, therefore, no recorded history in the form of rocks. It is only in the land forms, or the topography resulting from erosion, and in a few patches of old river gravels that evidence of the succeeding events is found. As each new set of the topographic features was developed at the expense of older ones, only later forms are left to tell of events that have taken place.

Formation of Tertiary peneplain.—No sooner

minations). A list of localities furnished by Mr. Frank Leverett includes the following: (1) South bluff of the East White River 2 miles southwest of Shoals, Ind.; (2) bluffs of the Ohio River back of Tell City and Cannelton, Ind.; (3) near Stephensport, Breckinridge County, Ky.; (4) near Brandenburg, Meade County, Ky.; and (5) near Rosebud, Pope County, Ill.

It will be noted that these deposits are in the vicinity of the present drainage lines, though from 100 to 200 feet or more above the stream levels, while on crests of equal heights in the intermediate areas gravel deposits are lacking. This is taken to indicate that the gravels were probably deposited in the broad, shallow valleys of the Tertiary peneplain, and that the main drainage lines of that period coincided in a general way with those of the present time.

Late Tertiary erosion.—After the reduction of this portion of the Mississippi Basin to the peneplain described, an elevation took place that lifted the region to an altitude considerably above that which it possesses at the present time. With the beginning of this elevation the streams, which during the later stages of development of the peneplain surface had been very sluggish, entered upon a period of active erosion that resulted in the carving out of broad valleys to a depth of 100 to 150 feet, or more, below the level of the surfaces of their present fillings and the reduction of the general surface to a lower level. Here and there, where the surface was more remote from the active streams or where the rocks were of a more resistant character, remnants of the peneplain were left in the form of the crests and outlying hills previously mentioned. It is not probable that erosion was uniformly active throughout the period of down-

lished drainage lines by the Illinoian ice, or by the till or various other deposits laid down during its occupancy of the region, many important changes in the arrangement of the streams were produced (see fig. 5).

The Patoka River, now a prominent stream reaching back eastward 80 miles or more from the Wabash, was not in existence as a single stream previous to this ice invasion, though parts of the valley through which it now flows were occupied by pre-Glacial streams that eventually flowed northwestward into the White or the East White River. The original lower Patoka River entered the quadrangle at the same point as the present stream, but instead of flowing westward past the site of Patoka turned northwestward and passed out into the Wabash Valley at a point about midway between Patoka and Hazleton. During the ice invasion this old valley was choked and obstructed and a glacial lake formed along the valley, the outlet of which was probably near Francisco, a few miles east of Maxams. Before the ice receded from the region the old valley was choked and practically obliterated by accumulations of thick morainal deposits that were laid down across its lower portion, with the result that the river was forced to seek a new outlet, which it found at Patoka.

It is believed that the Wabash River at this time flowed in the broader valley lying east of the Claypole and Gordon hills, and that it swerved southwestward near Lyles, passing north of Foots Pond Hills, west of Mumford Hills, and probably several miles west of its present position at New Harmony.

Previous to the ice invasion Pigeon Creek flowed in a direction opposite to its present course. It entered the quadrangle from the east, where it now leaves it, and flowed northwestward past the site of Fort Branch and into the Wabash Valley at a point a little east of Indian Camp Creek. The obstruction of this creek brought into existence a lake which overflowed a divide east of Elberfeld, several miles east of this quadrangle, having an elevation of about 410 feet. By the outflow from this lake the divide was reduced to a little less than 400 feet and so afforded an easy eastward outlet for the water that was ponded by the ice and the morainal deposits that accumulated across the old valley near Fort Branch.

As the ice retreated from the Fort Branch moraine two more glacial lakes came into existence. The first was situated between Owensville and Fort Branch. Its waters cut an outlet across the moraine at the latter point and passed off to the east and south through the Elberfeld pass. The upbuilding of the morainal barrier east of Owensville served to make the southward drainage a permanent feature. The second lake was situated in the valley of Flat Creek and was due to the obstruction caused by the ice near Cynthiana. This creek originally emptied into the Wabash River at a point 3 or 4 miles north of Stewartsville, but on its obstruction by the ice and the formation of the lake the waters ponded up the valley of an old tributary and passed over a divide at its head into Big Creek. This divide was probably about 2½ miles northeast of Blairville. Before the retreat of the ice the moraine at Cynthiana had been formed and the old valley so blocked that even after the retreat of the ice the drainage persisted in its new-found channel.

Barr Creek, like Flat Creek, which originally found outlet into the Wabash along the line of Black River, was deflected southward into Big Creek.

A still further retreat of the ice brought into existence a lake in the vicinity of Poseyville, in which deposits were built up to such a level that the original northern drainage lines were obliterated and a new drainage into Big Creek was inaugurated.

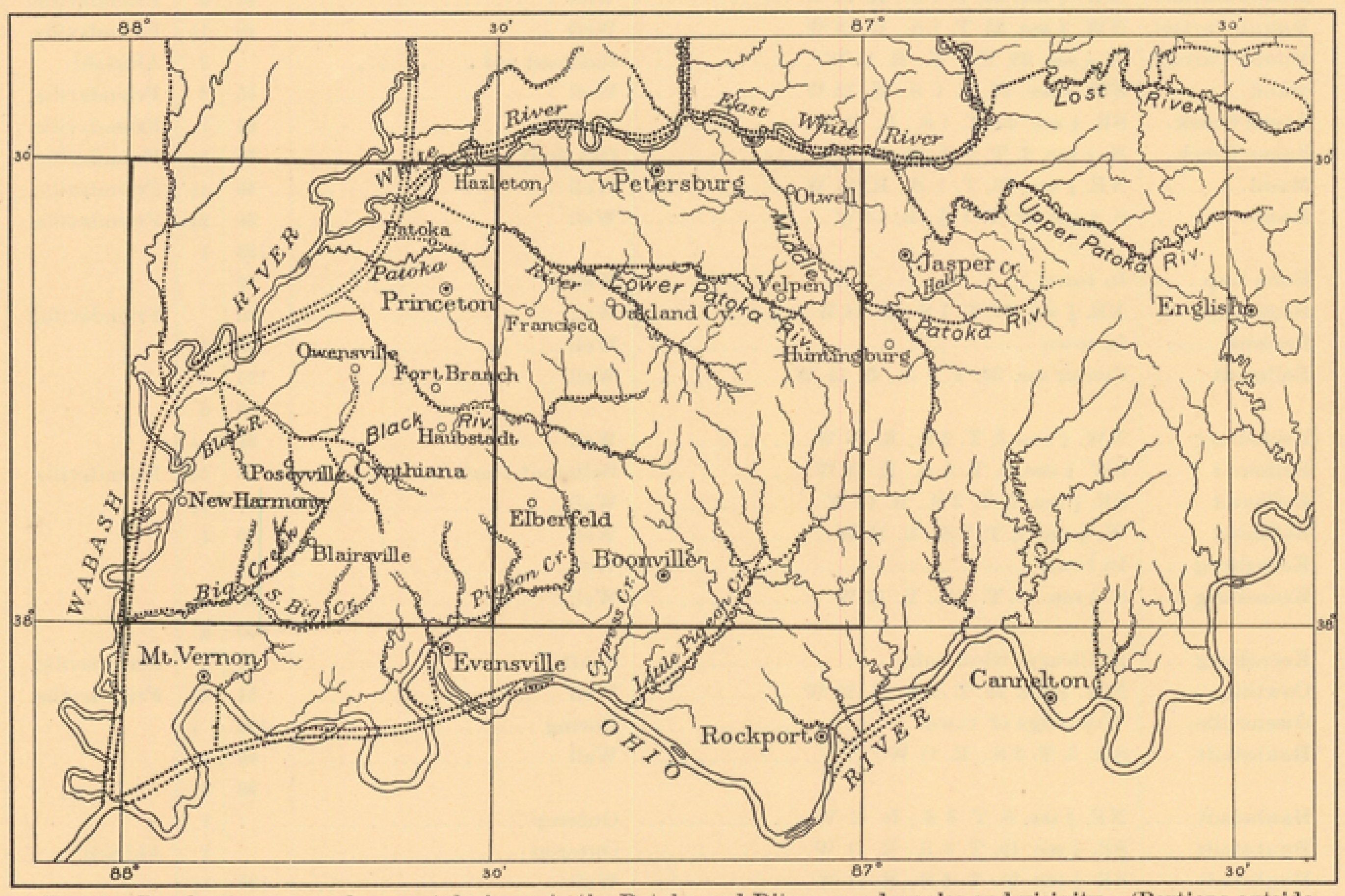


Fig. 5.—Pre-Quaternary and present drainage in the Patoka and Ditney quadrangles and vicinity. (Portions outside quadrangles after Leverett.)

Pre-Quaternary streams are shown by dotted lines.

Sangamon events.—After the disappearance of the Illinoian ice sheet there seems to have been a period of somewhat active erosion. In some other regions the Sangamon streams were broad and sluggish and eroded but little, but in the Ditney quadrangle, immediately east of the Patoka quadrangle, from 80 to 100 feet of the drift filling of the White River Valley over a breadth of 2 miles appears to have removed, while in the Patoka quadrangle the reduction of the drift deposits and the widening, deepening, and cutting back of valleys are conspicuous features. Large quantities of drift were also probably removed from the Lake Patoka deposits, 25 or more miles east of the area under discussion, and along the valley of the Ohio River. Whether there was a slight uplift of the land or whether the acceleration of erosion was due simply to the relatively steep constructional slopes of the drift deposits can not be definitely stated, but the latter is now thought to be the most probable.

Much of the material derived from erosion was doubtless deposited in the valleys, where it is now covered by more recent deposits. A considerable part of the lower portions of the older stream silts was doubtless accumulated at this stage. Other deposits of this age now remaining are the muck and lignitic deposits which were described (p. 4) as occurring under the marl-loess at various points.

That the stage was of considerable length is attested by the extent of the erosion, by the semi-rounded character of the resulting topography, and by the leaching and weathering of the drift as represented in many exposures.

Iowan deposition.—The next event of importance was the deposition of the mantle of silt, previously regarded as a unit and designated as loess. Reasons have been given (p. 4) for subdividing this silt into two groups, the marl-loess and the common loess. A study of the characters and relations of the two types leads to the belief that during the presence of the Iowan ice margin in northern Indiana, a fluvio-lacustrine body existed along the lower portions at least of the Wabash and White river valleys. This water body is thought to have been due to a general depression (amounting perhaps to 80 or 100 feet) of this region as compared with the land farther south, over which the waters had eventually to pass. Into this lake the two large rivers brought large quantities of fine silt, which was deposited in their valleys in the form of what is here known as marl-loess. While this material was accumulating and during the period immediately following the withdrawal of the water, before vegetation had covered the surface, broad flats were doubtless many times exposed to the sweep of winds, and by the action of these winds it is presumed the great sheet of common loess was accumulated. These winds were apparently prevailingly from the west, for the deposit is both thicker and more extensive on the east side of the Wabash Valley than on the west side.

It was probably in late Iowan times that the last important additions to the older stream silts were made.

Peorian interglacial stage.—The Peorian stage is not known to have been characterized by any notable events in the Patoka quadrangle. The land appears to have remained at practically the same elevation as during the deposition of the loess, which suffered little erosion during the interval, though doubtless there was a creeping and sliding of the material down the hillsides into the valleys.

Wisconsin deposition.—In the Wisconsin stage the ice, though failing by more than 75 miles to reach the Patoka quadrangle, by its melting furnished large quantities of water charged with sediments which flowed from the ice margin down the Wabash and White rivers and formed broad flat plains of sand and fine gravel along their valleys.

The only deposits of Wisconsin age that still remain in this area are the stratified beds of fine sand and gravel, with their associated dunes, that occur northwest of the Wabash River, near Keensburg. The upper flood-plain deposits and the great dune belts along the eastern edge of the Wabash Valley were probably formed in late Wisconsin time or in the early part of the post-Glacial epoch and are in a measure transitional. The older and higher Wisconsin deposits doubtless represent an upbuilding during a period when the waters were heavily loaded with sediment as compared with their condition during the formation of the later flood-plain deposits. As the upbuilding of the fluviatile beds of the valleys continued many of the low divides of the earlier topography were buried beneath the resulting accumulations, leaving a number of the higher points as "islands" projecting above the river flats. In the course of the meanderings and swings of the rivers these have been attacked first from one side and then from another until nearly all of them now present steep faces or even bluffs to the flats. Among these "islands" Claypole, Gordon, and Mumford hills are the most prominent, though a few smaller ones were noted. The depth of the rock valleys separating these hills from the general uplands is not known, but in some places the rock floors are only a few feet below the flood plains (see fig. 13), or at about the limit of erosion of the present streams. This would indicate that the broadening of the divides and the isolation of the "islands" was brought about after the stream had reached practically its present level. The steepness of the bluffs indicates that the completion of the broadening took place in very recent time.

During the final retreat of the ice the Wabash River was the outlet for Lake Maumee, a large glacial lake extending over the areas now covered in whole or in part by Lakes Michigan, Huron, and Erie, together with considerable areas about their borders. This lake formed between the retreating ice and the northward-sloping land in the region mentioned and emptied into the Wabash a little west of Fort Wayne, Ind.

RECENT EVENTS.

Subsequent to the deposition of the Wisconsin and transitional sediments, just noted, the region appears to have stood approximately at the same level as at present. The streams, with diminished volume and less sediment, cut into the deposits of the Wisconsin and transitional stages and excavated the lower flood plains, which were in places several miles in breadth and several feet below the upper plains. This work is still going on, new channels constantly being formed by local concentration of the overflowing waters in times of flood. At the same time, however, old channels are being closed up and the old level is being restored in places, the tendency on the whole being rather toward a simple shifting than toward either a general broadening or narrowing of the lower flood plains.

MINERAL RESOURCES.

COAL.

COALS IN INDIANA.

Petersburg coal.—With a few minor exceptions none of the coals outcropping in that portion of the Patoka quadrangle included in Indiana are now worked, even for local supply, the beds rarely being much over a foot in thickness, and often too impure to be of any value. In the Indiana portion of the quadrangle there are but two mines, the Oswald at Princeton, and the Diamond just inside the quadrangle near Evansville. These mines reach what is known as the Petersburg coal (Coal 5 of the Indiana geological survey), which outcrops 12 to 15 miles to the eastward, in the Ditney quadrangle.

At the Diamond mine, Evansville, the coal is 250 feet below the surface, or about 135 feet above sea level. The bed in this mine is 4 feet 6 inches in thickness, overlain by 2 feet of black shale, which forms a fairly good and strong roof. Below is 2 feet of firm fire clay, underlain by limestone. A band of sulphur occurs in the middle of the coal.

In the Oswald mine the coal is reached at about 450 feet, or 30 feet above sea level, and averages 6 feet 6 inches in thickness. It is a good, firm coal, without regular sulphur or clay bands, but thin bands of sulphur are abundant in places. The roof is a shale, which is sometimes overlain by limestone. The following analyses are taken from the Twenty-third Annual Report of the Indiana Geological Survey, pp. 1243–1244. The Sunnyside mine is just south of the limits of the quadrangle.

Analyses of Petersburg coal at Princeton and Evansville.

[Analyst, W. A. Noyes.]

Source of material.	Fixed carbon.	Volatile combustible matter.	Total combustible matter.	Ash.	Moisture.	Sulphur.	Total waste.
Boring at Princeton	59.70	23.90	83.60	7.80	8.00	......	16.40
Oswald mine, Princeton	51.18	22.71	83.90	11.02	5.09	1.38*	16.11
Sunnyside mine, Evansville	48.14	38.59	86.73	6.83	6.44	1.85	14.12

*Sulphur separately determined.

The general dip of this coal in the southern portion of the quadrangle is northwestward at an average of about 5 feet to the mile. From an elevation of 135 feet above sea level, near Evansville, it descends northward to 50 feet at Fort Branch and 30 feet at Princeton, westward to about sea level in the extreme southwest corner of the quadrangle, and northwestward to probably a little below sea level at New Harmony.

Millersburg coal.—This coal, which in the Ditney quadrangle, on the east, lies 70 to 90 feet above the Petersburg and is several feet thick, is not mined in the Patoka quadrangle, but three-fourths of a mile northwest of Stringtown a coal supposed to be the Millersburg is reached by a well at 150 feet below the bottom of the valley, or about 235 feet above sea level. In Evansville two wells situated near Pigeon Creek penetrated the Millersburg bed, here about 18 inches thick, at depths of 152 and 180 feet below the surface, or at 98 and 100 feet, respectively, above the Petersburg. At Fort Branch this coal is 3 feet 6 inches thick and is reached 254 feet from the surface; at Princeton the deep borings penetrated it at depths varying from 201 to 260 feet, the interval above the Petersburg bed varying from 120 to 145 feet.

Parker coal.—This is an unimportant coal, varying in thickness from 6 inches in its purer form to 18 inches when shaly, which occurs about 90 or 100 feet above the Somerville limestone. It has been stripped in a few places for use in threshing machine boilers, but is generally too thin and impure to be of value. The thickness reported in wells is somewhat greater than that observed in outcrops, which are nowhere such as would warrant development. The outcrop of this coal outside of the drift area and also within the drift area as far as it can be definitely traced is shown on the geologic map. The thin coal about 70 feet above the river at Patoka, the coal at or near the same level in the bluffs 2 miles northwest of town, the thin coal near the flood-plain level on the southwest side of Gordon Hills, and the coal in the hills northeast of Owensville are believed to be the equivalents of the same bed.

Friendsville coal.—This coal, which is of some importance west of the Wabash, occurs about midway between the Parker and Aldrich beds. It is usually associated with a limestone that is from 2 to 6 feet thick. The coal in Indiana rarely measures over a foot in thickness and is frequently absent. So far as known it has not been worked, even for local supplies.

Aldrich coal.—The Aldrich coal is another thin coal and lies from 50 to 70 or more feet above the Parker. Like the latter it is generally associated with an overlying limestone, though in some places the limestone occurs beneath it and at other times is wanting. At its outcrop it shows a thickness of 7 to 20 inches. It is of a somewhat better quality than the Parker, and has been worked at a considerable number of points in the past. The old drift in the bluff 1 mile southwest of New Harmony and the outcrops 6 miles southwest of the same town are probably on this coal, as are also the outcrops near Kilroy and along the base of the Mumford Hills. Its greatest development, however, is along McAdoo Creek 2½ miles west of Wadesville, where it has been stripped at a number of points.

The outcrop is shown on the geologic map. West of the outcrop it is encountered in many of the wells, the records showing the dip to be nearly flat.

Miscellaneous coals.—Because of the thickness of loess and of glacial till and gravel it is impossible to trace the coals continuously in the region north of the drift boundary, and correlation is, therefore, uncertain. A coal which underlies a limestone, probably the Somerville, outcrops with a thickness of 18 to 24 inches along the bottom of the tributary joining the Patoka from the southeast at a point about 3 miles northeast of Princeton. It has been worked occasionally. A coal about 6 inches thick, belonging to the same general horizon, occurs beneath a thin limestone at the level of the flood plain at Townsend's quarry. The black shale exposed near low-water level beneath the bridge one-half mile southwest of the quarry is probably to be correlated with that overlying the coal at the quarry section. About 50 feet above this horizon there is another coal, generally 6 or 8 inches thick, which has been seen in the ravine in the center of sec. 5, T. 1 S., R. 10 W., and in the bluff southwest of Patoka, about 13 feet above the river. The coal occurring in the bluff section at Patoka 50 feet above the coal just described, and again in the ravines 1½ miles northwest of that town is correlated, as has been indicated, with the Parker bed.

There is a general coal horizon along the bluffs on the south side of the White River near Hazleton. Three miles east of that town and just outside the quadrangle a coal several feet in thickness is stripped in one of the ravines, and an abandoned mine, in which the coal is said to have been 30 inches thick, is found farther north, on the face of the bluffs. The coal appears to be both overlain and underlain by sandstone. A mile and a half east and a little north of Hazleton a coal, apparently at or near the same horizon as the preceding, shows just beneath a 10-foot bed of massive limestone. At the town itself neither the coal nor the limestone have been reported, but a mile west of the town a thin coal is found resting on top of the limestone instead of beneath it, and 2 miles west of the town the coal outcrops in the bluff on the north side of the White River with a reported thickness of 3½ feet. The outcrop is on a level with the river, in the bed of which it outcrops with a thickness of 14 inches. It is extensively worked by stripping at the Wharf mine.

COALS IN ILLINOIS.

Friendsville coal.—The only coal of importance in the Illinois portion of the quadrangle is the Friendsville bed. This coal outcrops near the town of the same name and possibly at a few other points, but it has seldom been opened on its outcrop. It underlies the surface of Wabash County at a moderate depth from a point north of Friendsville southward to Bellmont and Keensburg and westward to the bottom lands of Bonpas Creek, but no coal that could be correlated with the Friendsville bed has been reached by the wells west of this creek in Edwards County, although it is reported in a well just east of the creek, 1½ miles southwest of Cowling. A deep drilling at Grayville, made expressly for information regarding coals, failed to find any over a few inches in thickness, indicating that the Friendsville vein has pinched out from 4 feet to nothing in the 3 miles stretch between the town and the well mentioned. The bed has not been recognized in the wells at Mount Carmel, and there is every evidence that it has likewise pinched out to the east.

The Friendsville coal, when at its best, maintains rather persistently an average thickness of about 3 feet and is often accompanied by an overlying limestone which in turn is in some places, especially in the northern portion of the quadrangle, overlain by a massive sandstone. It is mined by a 36-foot shaft at the Couch and Adams mine, a mile east of Friendsville, and by a 32-foot shaft at the Grigsby mine, 2 miles southeast of that town. One and one-half miles south of Bellmont the Bellmont Mining Company has sunk a shaft reaching the coal at a depth of 36 feet. In the McClearys Bluff shaft, 3 miles east of Cowling, the coal, here 4 feet thick, was reached at a depth of 35 feet, or about 10 feet below low-water level of the river. In the past this coal has been mined at Sugar Creek, at Maud, and at several points in the region just northwest of Mount Carmel. The coal burns moderately freely, but has a large ash constituent and does not coke.

The dips of the Friendsville are more irregular in character but less in amount than those exhibited by the coals in the eastern part of the quadrangle; the general dip, however, is still westward. The highest altitude at which the coal occurs is from 450 to 460 feet, these altitudes being reached at a number of points between Mount Carmel and Friendsville. East of Friendsville it declines to 400 feet or less near Crawfish Creek, while to the west, southwest, and south, a gentler but more persistent dip carries it to an altitude of about 350 feet in the vicinity of Gards Point, 385 feet at Maud, 395 feet at Bellmont, 360 feet at Keensburg, 370 feet at Rochester, and probably 335 feet 1½ miles southwest of Cowling.

The gap between the rock outcrops on the opposite sides of the Wabash Valley is of such width that any correlation of the beds on the two sides is subject to doubt, especially when the great variability and inconstancy of the smaller coal beds are considered. If, as appears somewhat probable, the 4-inch coal that occurs in the bluff at Grayville a few feet above the flood plain is to be correlated with the Aldrich coal of the Indiana side of the river it would seem probable that the Friendsville bed is to be correlated with the thin coal between the Parker and Aldrich beds of the Indiana side, as has been done.

Aldrich coal.—What is supposed to be the Aldrich coal outcrops just below the flood plain at the Illinois Central Railroad bridge south of Grayville, in the river bluffs at that point, in a bluff facing Bonpas Creek 3 miles to the northeast, at McClearys Bluff, in the bluff at Rochester, and probably at a number of other points. It is, however, too thin to be worked.

SUMMARY.

Thickness of coals in Patoka quadrangle and vicinity.

Nearest town.	Location.	Source of information.	Depth.	Thickness.	Coal.
			Feet.	*Feet.*	
Hazleton	Thorn place, Donation	Boring	44	1	
			105	1	Millersburg?
			221	4	Petersburg?
Hazleton	Top of bluff 2 miles east of town	Boring	116	½	
			172	1½	Millersburg?
Hazleton	Bank of river, 2 miles west of town	Wharf mine		4	
Patoka	Bluff south of river	Outcrop		1	Parker.
Princeton	Indian Creek, northeast of town	Outcrop		2	
Princeton	NE. ¼ sec. 5, T. 2 S., R. 10 W	Kurtz deep bore	146	1	
			258	2½	Millersburg.
Princeton	Sec. 5, T. 2 S., R. 10 W	Kurtz shallow bore	90	4½	
Princeton	Sec. 33,(?) T. 1 S., R. 10 W	Shannon well	76	1½	
Princeton	SE. ¼ sec. 12, T. 2 S., R. 11 W	Oswald shaft	430	6	Petersburg.
Princeton	North edge of town	Interstate Gas & Oil Co.'s well	380	7	Petersburg.
			460	4	
			615	5	
Princeton	NW. ¼ sec. 8, T. 2 S., R. 10 W	Evans well	62	1½	
			281	½	Millersburg.
			402	6	Petersburg.
			514	6	

Thickness of coals in Patoka quadrangle and vicinity —Continued.

Nearest town.	Location.	Source of information.	Depth.	Thickness.	Coal.
			Feet.	*Feet.*	
Princeton	Near preceding	Deep well	80	1½	
			283	3	Millersburg.
			422	7	Petersburg.
			471	7	
			593	4	
			628	3½	
			670	4	
Princeton	SW. ¼, sec. 7, T. 2 S., R. 10 W	Hall well	355	6	Petersburg.
			470	6	
			670	6	
			730	7	
			1020	3	
Princeton	SE. ¼ sec. 7, T. 2 S., R. 10 W	Thompson well	82	1	
			281	2	Millersburg.
			396	6	Petersburg.
			462	5	
			604	6	
			723	6	
Princeton	NE. ¼ sec. 18, T. 2 S., R. 10 W	Southern R. R. shops well	199	2	Millersburg.
			346	7	Petersburg.
			451	2	
Fort Branch	Peter Hoffman place	Well	56	1	
			178	5	
			250	3½	Millersburg?
			301	5	Millersburg.
Fort Branch	Grove Mill	Well	408	7	Petersburg.
Friendsville	SW. ¼ sec. 19, T. 1 N., R. 12 W	Couch & Adams shaft	36	3½	Friendsville.
Friendsville	W. ½ sec. 31, T. 1 N., R. 12 W	Grigsby shaft	32	4	Friendsville.
Friendsville	S. ½ sec. 36, T. 1 N., R. 13 W	Well	70	3	Friendsville.
Friendsville	SE. ¼ sec. 35, T. 1 N., R. 13 W	Well	20	½	
Gards Point	SE. ¼ sec. 30, T. 1 N., R. 13 W	Well	65	1½	Friendsville.
Mount Carmel	NE. ¼ sec. 8, T. 1 S., R. 12 W	Outcrop		1½	Friendsville.
Grand Rapids	Government quarry	Outcrop		1	
Mount Carmel	1 mile west of town	Boring	590	12	Petersburg.
Mount Carmel	NE. ¼ sec. 18, T. 1 S., R. 12 W	Well	70		Friendsville.
Friendsville	S. ½ sec. 1, T. 1 S., R. 13 W	Well	23	3½	Friendsville.
Friendsville	NE. ¼ sec. 2, T. 1 S., R. 13 W	Well	9	¼	Friendsville.
			11	1	Friendsville.
Friendsville	NW. ¼ sec. 3, T. 1 S, R. 13 W	Well	28	4½	Friendsville.
Mount Carmel	NE. ¼ sec. 12, T. 1 S., R. 13 W	Well	35	2	Friendsville.
Mount Carmel	W. ½ sec. 12, T. 1 S., R. 13 W	Well	65	3½	Friendsville.
Mount Carmel	SE. ¼ sec. 13, T. 1 S., R. 13 W	Abandoned shaft	36	3	Friendsville.
Mount Carmel	S. ½ sec. 14, T. 1 S., R. 13 W	Well	34	4	Friendsville.
Bellmont	S. ½ sec. 18, T. 1 S., R. 13 W	Well	70	½	
Maud	NW. ¼ sec. 22, T. 1 S., R. 13 W	Well	35	2½	Friendsville.
Mount Carmel	NW. ¼ sec. 24, T. 1 S., R. 13 W	Well	20	3	Friendsville.
Mount Carmel	NW. ¼ sec. 25, T. 1 S., R. 13 W	Well	40	1½	Friendsville.
Mount Carmel	N. ½ sec. 25, T. 1 S., R. 13 W	Railroad cut		2	Aldrich?
Maud	SW. ¼ sec. 27, T. 1 S., R. 13 W	Well	15	3	Friendsville.
Sugar Creek	SE. ¼ sec. 35, T. 1 S., R. 13 W	Well	34	1	Friendsville.
Sugar Creek	N. ½ sec. 2, T. 2 S., R. 13 W	Old shaft	50	3½	Friendsville.
Maud	NE. ¼ sec. 33, T. 1 S., R. 13 W	Well	40	4½	Friendsville.
Maud	S. ½ sec. 32, T. 1 S., R. 13 W	Well	50	2½	Friendsville.
			123	1	
Bone Gap	In town	Well	70		
Bone Gap	NE. ¼ sec. 17, T. 1 S, R. 14 W	Well	125		Friendsville?
Browns	In town	Well	240	1	
Bellmont	Center sec. 36, T. 1 S., R. 14 W	Well	125	4	
			175	6	
Keensburg	NW. ¼ sec. 3, T. 2 S., R. 13 W	Well	27	½	
Bellmont	SW. ¼ sec. 6, T. 2 S., R. 13 W	Bellmont shaft	36	3½	Friendsville.
Bellmont	SE. ¼ sec. 7, T. 2 S., R. 13 W	Well	130	1½	
Bellmont	W. ½ sec. 7, T. 2 S., R. 13 W	Well	70	4	
Keensburg	In town	Well	61		
Keensburg	S. ½ sec. 10, T. 2 S., R. 13 W	Well	90	1	
			200	4	
Keensburg	McClearys Bluff mine	Shaft	35	4	Friendsville.
Cowling	NW. ¼ sec. 35, T. 2 S., R. 14 W	Well	54	3½	Friendsville.
Owensville	West edge of town	Boring	186	½	
Haubstadt	Sec. 3, T. 3 S., R. 11 W	Well	60	2	
			90	4	
Haubstadt	NE. ¼ sec. 6, T. 3 S., R. 11 W	Outcrop		1	
Haubstadt	SE. ¼ sec. 19, T. 3 S., R. 11 W	Outcrop		1	Aldrich.
Haubstadt	SE. ¼ sec. 21, T. 3 S., R. 11 W	Well	140	1½	
Cynthiana	SE. ¼ sec. 7, T. 4 S., R. 13 W	Well	130	1½	
Cynthiana	W. ½ sec. 10, T. 4 S, R. 13 W	Well	70	4	
Cynthiana	SE. ¼ sec. 11, T. 4 S., R. 13 W	Well	70	2	
			105	3½	
Stewartsville	NE. ¼ sec. 2, T. 4 S., R. 13 W	Well	80	3	Parker.
St. James	S. ½ sec. 12, T. 4 S., R. 11 W	Well	25	1	Parker.
St. Wendells	SE. ¼ sec. 33, T. 4 S., R. 12 W	Well	60	2	Parker.
St. James	SW. ¼ sec. 18, T. 4 S., R. 10 W	Well	50	3	
Armstrong	SW. ¼ sec. 10, T. 5 S., R. 11 W	Well	60	3	
St. Wendells	NE. ¼ sec. 12, T. 5 S., R. 12 W	Well	80	1½	Parker.
Wadesville	NE. ¼ sec. 11, T. 5 S., R. 13 W	Outcrop		1½	Parker.
Lippe	SE. ¼ sec. 6, T. 6 S., R. 12 W	Well	65	1	Parker.
Evansville	Ingleside mine	Shaft	157	3	Millersburg.
			261	4	Petersburg.
			353	5	
Mount Vernon	In city	Boring	115	1	
			391	1½	

LIGNITES.

Coals up to 18 inches in thickness have been reported in connection with unconsolidated deposits in a large number of wells sunk in the glacial drift of the Patoka quadrangle, and especially in that portion of the quadrangle lying in the southern part of Gibson County, Ind. A number of instances occur in the vicinity of Fort Branch. No samples have been seen, but from descriptions some of the material would seem to be a fair grade of lignite. The lignites appear to occur in a dark-grayish clay, usually reported as "blue mud," but they are also in some places associated with water-bearing sands and gravels, often resting upon considerable thicknesses of these materials. Though apparently sometimes overlain by till, the beds associated with the lignites are probably water deposited. They are of no economic importance.

OIL, GAS, AND ASPHALT.

Five or more wells reaching a depth of 500 feet or more, one of them more than 1200 and one more than 1400 feet deep, have been drilled at Princeton in search of oil and gas, but have met with little success. Small quantities of gas were obtained in nearly all of the wells, and in one or two of them very slight indications of oil are said to have been obtained. Neither gas nor oil, however, was found in sufficient quantities to be of any commercial value.

During the drilling of a well by the Interstate Gas and Oil Company at Princeton, in 1902, a 5-foot bed of asphalt was reported at a depth of about 500 foot, or a little over 100 feet below the Petersburg coal. Small samples of the material brought out by the bailer showed the asphalt to be a jet black, nearly pure variety closely resembling Trinidad asphalt in its reactions to physical and chemical tests. A small bed of similar material is reported to have been encountered in the old Hall well, on the southwest outskirts of Princeton, about a mile south of the new well, while in the Oswald mine, three-fourths of a mile to the west, a black substance, known as liquid asphalt, seeps into the bottom of the mine at 430 feet to such an extent that some of the rooms have been abandoned and closed. It is said to enter through a nearly vertical "break" filled with clay.

The fact that wells reaching depths of over 1000 feet have been drilled at only one point shows that the territory has been by no means carefully tested. None of the wells have reached the Trenton limestone. While there is nothing to indicate the presence of oil or gas in the region, there is nothing to indicate its absence, and it is not impossible that drilling may develop pools of commercial value.

In general it may be said that the positions that are geologically most favorable for drilling are the low anticlinal swells and the flat areas of the rocks just east of the points where their westward dip changes from low to steep. The most pronounced anticlinal swell is between Friendsville and Mount Carmel in the northern portion of the quadrangle, while the most notable flat area extends from north of the Claypole Hills southwestward to the southwest corner of the quadrangle. Flat dips are also encountered to the west of the low anticlinal swell mentioned. Both of these areas of flat rocks are marked by many minor undulations of the rocks, some of which are brought out on the geologic map by figures, which show the depths to the Friendsville coal in the northwestern portion of the quadrangle. These minor irregularities are, perhaps, more likely to be important as regards the occurrence of oil or gas than some of the broader features, but they do not usually extend farther than a few hundred yards, and in most cases their location can not be predicted. In the eastern half of the quadrangle the dips are more pronounced, and are less favorable to the occurrence of the oil or gas in definite pools.

CLAYS.

The clays of the Patoka quadrangle fall into two general classes: (1) Fire clays or the refractory clays occurring beneath the coals and elsewhere in the Carboniferous formations of the area, and (2) brick clays, including the less refractory clays, argillaceous shales, till, loess, and alluvial clays. The clays of the coal-bearing rocks of Indiana have been investigated by W. S. Blatchley, State geologist, and the results are published in the Twentieth Annual Report of the Department of Geology and Natural Resources. The portion of the following discussions relating to this class of clays is based largely on that report, but the discussion of the other types of clays is based on the present field work.

Fire clays.—These clays occur in beds of rather widespread occurrence beneath most of the coal seams. East of the Wabash the thickest beds known are at Princeton, where they have been penetrated by several borings and by one shaft sunk through the coals. Below the higher thin coals is a bed 1 to 7 feet in thickness, the upper half of which is said to be of excellent quality for terra cotta and similar products. A second bed, a tough, plastic fire clay 1 to 3 feet in thickness, and appearing to possess high refractory properties, is sometimes found below the Millersburg coal. Three miles east of Princeton, along Indian Creek, an under clay, 4 feet in thickness, outcrops beneath a vein of coal, and 1½ miles north of town is an outcrop 4 feet in thickness. Both these clays are said to be of high refractory quality, and have been used locally in making fire brick for furnaces and kilns near Princeton.

At the southeastern edge of the quadrangle the Evansville mines show fire clays beneath both coal beds. That below the worked or Petersburg seam is said to be of quality similar to the clay associated with the same bed at Princeton. It contains some pyrites, which can be easily removed, but is not of so good quality as that below the Millersburg coal.

In Wabash County, Ill., fire clays have been reported in a number of deep wells.[1] At Mount Carmel several beds have been penetrated, one showing a thickness of 9 feet being found at 49 feet below the surface, one of 3 feet 10 inches at 62 feet, one of 4 feet 2 inches at 154 feet and above 7 inches of coal, and one of 3 feet directly below the same coal. The coal outcropping along Bonpas Creek, between Grayville and Cowling, is underlain by a light-gray fire clay, and in Crawfish Creek, sec. 5, T. 1 S., R. 12 W., a bed 4 feet thick and of good quality is reported.

Clays other than fire clays.—Clays useful in the manufacture of common building brick and drain tile are of wide distribution and are worked at a number of points. The most valuable deposits consist of loess and of argillaceous shale.

The shales, known locally as "soapstone," are abundant throughout the quadrangle. The colors vary from blue to buff. They are often almost free from grit and where weathered are soft and soapy, although in fresh exposures they may be firm and hard. The largest pit is operated by the Evansville Pressed Brick Company, and is situated just north of Pigeon Creek on the State road, where the following beds are exposed: Loess, 15 feet; soft, drab argillaceous shale, 10 feet; blue arenaceous shale, 10 feet; and sandstone (only top exposed). With the exception of three bands of kidney iron ore, each 2 inches in thickness, the entire argillaceous bed is excellent material. For making brick it is mixed with the overlying loess and enough argillaceous shale to form one-fifth of the whole, making a mixture with the composition given in Column I of the accompanying table of analyses. It forms a valuable vitrified brick, which is strong, tough, and non-absorbent.

An exposure along the roadbed of the Southern Railway southeast of Princeton gives the following section: Soil and loess, 12½ feet; sandstone 6 feet; gray argillaceous shale, 8 feet. The analysis of the shale given in the second column of the accompanying table shows it to be of good quality for paving brick. Aside from the two instances mentioned, shale is not known to have been used in the quadrangle.

A number of pits in the loess now furnish brick clay of good quality. Two of these are located at Princeton, two at Mount Carmel, and one each at Owensville, Haubstadt, Cynthiana, and Poseyville. At Evansville, just outside the limits of the quadrangle, a score or more pits are worked. All the companies make soft mud brick, and occasionally small outputs of tile are reported. The plants generally run only five or six months of the year, and the entire production is usually retailed within a few miles of the kilns. The red type of loess throughout the quadrangle is thought to be of fair quality for making ordinary brick.

At Princeton, in the southwestern part of town, there is a large yard where the following section has been opened: Loess, 10 to 15 feet; red pebbly till, 10 feet; buff stratified sand, 10 feet. The loess in this pit is a good brick clay, and the underlying bed furnishes sand for the molds. The annual output of bricks is said to average 700,000, of which about one-third is shipped out of town. No analysis of the clay from this locality has been made, but Column III of the table gives the composition of the loess at an opening in southeastern Princeton, indicating a very pure clay, with a remarkably low percentage of lime. The only other yard at Princeton is located near the junction of the railroads, 1 mile northwest of the center of the town.

A brick yard near the station at Owensville uses the loess and produces a fair output of brick of good grade. At Fort Branch are the works of William Pope, where tile has been manufactured for 15 years, but only since 1902 has the production of brick been attempted. The pit when visited was entirely in the loess. The works of George Wehler, one-half mile west of Haubstadt, have produced common brick for several years, the output being reported to average 500,000 a year. The clay bank is about 7 feet in depth, and as the lower portion is a little tough, it is necessary to mix material from the upper and lower portions of the bed to produce a brick that will not crack. At Cynthiana brick making has been carried on for many years, but the only plant now running is that of Redmond & Company, which produces about 700,000 bricks and 3000 to 4000 rods of tile in a year. The maximum depth of this pit is 8 feet. To obtain the best consistency the materials from all parts of the bed from top to bottom are mixed. Fairchild's tile and brick works, 1½ miles southeast of Poseyville, have been operated for over 30 years. The loess is here less than 5 feet thick and rather sandy. Three miles northeast of Inglefield is a loess pit which formerly produced good clay but which has not been worked for many years. At New Harmony there has been a small brick industry for many years, the clay coming from alluvium on the upper portion of the flood plain north of the town, at the works of George B. Beale. The pit is 8 feet deep; the top is a tender clay, which is mixed with one-fifth part of the underlying terrace sand to make it suitable for use.

The only one of the numerous plants at Evansville which comes within the limits of the Patoka quadrangle is that of Henry Alexander, on First avenue, north of Pigeon Creek. The pit is 4 feet in depth and the loess is toughest near the bottom. About 600,000 bricks are made annually.

Till is not known to have been used in the quadrangle for the manufacture of brick, and although the more clayey forms are often suitable for making a fair grade of brick, the superior quality of loess makes it unnecessary to use poorer material.

buff in color, though gray, or even nearly white types are noted. Brownish, reddish, and purplish tints are frequently present as the result of weathering. Outcrops are especially numerous east of St. Joseph and Armstrong. Fine exposures occur in the railroad cut near Inglefield, at a place 1 mile northeast of St. Joseph, and in many of the ravines between Inglefield and St. Joseph. The sandstone has been quarried on a small scale east of Inglefield and east of Wadesville. The rock is usually very soft on quarrying, but hardens somewhat on exposure. Long continued exposure to the weather, however, frequently causes it to scale or even completely disintegrate, making it undesirable for important structures.

The sandstone over the Parker coal is a cliff-making sandstone, and outcrops in the Gordon and Claypole hills, and at Grand Rapids, Hanging Rock, and Skelton Cliff. It is an even-grained buff to gray sandstone of rather pleasing appearance, but, like the Inglefield, scales or crumbles on exposure. Large quantities were quarried at the northern end of the Gordon Hills for the piers of the Southern Railway bridge at Mount Carmel, but the stone was found to scale badly and it became necessary to cover it with a protecting coating of cement. The same sandstone was also used in the construction of a dam at Grand Rapids.

The sandstone over the Friendsville coal is a thick bed outcropping in the Mumford Hills, at the lower end of the "cut off" near New Harmony, at points northeast of this town, and along McAdoo Creek. In the northern half of the quadrangle the sandstone is found just over the Friendsville coal. It is gray to buff in color, and in the southern half of the area frequently shows cementation by crystalline calcite. It has been quarried at several points, and has been used by the Illinois Central Railroad in some of its bridges and in the levee along the bayou.

Thick sandstones outcrop in the hills southeast of Hazleton, but in general are too soft to be of use, though certain layers are sometimes worked for local supplies. At Townsend's quarry, 3 miles northeast of Princeton, a gray stone of fair quality is taken out in some amounts. Both probably belong to the Inglefield formation. Sandstone was formerly taken from the river bed at Rochester and between Rochester and Mount Carmel. A higher sandstone, of the Wabash formation, is quarried 2 miles north of Gards Point, in the northern portion of the quadrangle.

Analyses of brick clays.

Constituent.	I Evansville (shale and loess).		II Princeton (shale).		III Princeton (loess).
Clay base and sand:					
Silica (SiO_2)	65.87	......	62.04	......	71.20
Insoluble silica	......	46.10	......	43.58	......
Titanium oxide (TiO_2)	1.10	......	1.30	......	.80
Alumina (Al_2O_3)	14.66	......	18.49	......	18.56
Insoluble alumina	......	2.63	......	3.70	......
Water (combined)	4.59	......	6.50	......	6.30
Fluxes:					
Ferric oxide (Fe_2O_3)	6.23	......	7.54	......	1.34
Ferrous oxide (Fe_2O)	1.37	......	.06	......	.15
Lime (CaO)	.39	......	.16	......	.14
Magnesia (MgO)	1.54	......	.91	......	.52
Potash (K_2O)	2.66	......	.93	......	.32
Insoluble potash	......	1.21	......	......	......
Soda (Na_2O)	1.30	......	2.04	......	1.26
Total	99.72	49.94	99.97	47.28	100.59
Total clay base, sand, etc	86.22		87.33		96.86
Total fluxes	13.50		12.64		3.73

Analyses I and III are by Robert Lyons; Analyses II is by W. A. Noyes.

BUILDING STONE.

Sandstone.—There are three general horizons of sandstone in the Patoka quadrangle. The first, which includes the sandstones of the Inglefield formation, is the most important, though the second and third, the sandstones over the Parker and Friendsville coals in the Wabash formation, are strongly developed in many places.

The sandstones of the Inglefield horizon occur mainly in the lower half of the formation, the beds, which include a few thin partings of shale, sometimes reaching, as in the bluffs in the valley east of St. Joseph, an aggregate thickness of more than 60 feet. The faces of the cliffs are frequently vertical and are marked by the presence of cavities due to weathering. The sandstones are mainly

Limestone.—There are three rather persistent limestones within the limits of the quadrangle: (1) in the Somerville formation, (2) over the Parker coal, and (3) over the Aldrich coal. Neither of these is everywhere uniform in lithologic character, each varying from light-gray shaly forms through darker gray fossiliferous varieties into compact and almost black types. The portions of the outcrops of the three beds that lie outside the boundary of the glacial drift are shown on the geologic map. Inside this boundary they are difficult to trace.

The limestone in the Somerville formation is the only one that has been quarried to any extent. Near the eastern edge of the quadrangle the limestone appears to lie in two benches, each generally less than 10 feet thick, and separated by a few feet of shale or sandstone. A few miles farther west the

[1] Worthen, Report on the Economical Geology of Illinois, vol. 3, pp. 383-398.

limestone appears to occur as a single bed, with a thickness of 10 or 12 feet, and still farther west and also farther north it is 5 or 6 feet thick. The limestone has been used mainly as road metal, though the more massive portions are sometimes quarried for use in rough masonry. A large number of quarries were formerly worked about Evansville, and small quarries have been worked farther north, especially near Kasson, Staser, Kratzville, and Inglefield.

The limestone over the Parker coal is from 2 to 4 feet thick and was formerly worked for road metal 2 miles southeast of St. Wendells. It has also been quarried 2 miles south of Armstrong. The Aldrich bed runs from 2 to 6 feet in thickness, and has been quarried in the past at several points south of Big Creek. Neither of the limestones are worked at present.

A limestone, possibly that of the Somerville formation, occurs near the level of the valley floors of the tributaries of the Patoka River northeast of Princeton, and is reported beneath the sandstone at Townsend's quarry. A limestone is frequently found with the Friendsville coal, but it outcrops only for short distances near Friendsville. There are also numerous thin limestones of local occurrence, but they are generally too thin to be of value, though beds have been opened near Rochester, north of Mount Carmel, and at a number of other points.

GRAVEL AND SAND.

Gravel is found at slight depths at many points on the Wabash and White river flood plains, and occasionally forms the surface layer. In a few instances it has been hauled for short distances and used as road metal, but in general no use is made of it.

Sands are found at many points on the Wabash and White river bottoms, and in the sand hills (old dunes) along the east side of the Wabash Valley, and to a less extent near Patton, Keensburg, McClearys Bluff, and Cowling on the west side. As a rule no use is made of this sand, though there are two large pits west of Princeton where considerable quantities have been taken out for use in mortar and for other purposes in that city. Small quantities are also occasionally used in sanding the molds, or mixed with the clay at the various brick yards.

SOILS.

The region in which the Patoka quadrangle is situated is primarily an agricultural one, and contains some of the best agricultural land of the two States. The staple products are corn, wheat, hay, and watermelons. Sorghum, broom corn, and tobacco are raised in limited amounts. Artificial fertilizers are seldom used. Fruit is grown to only a limited extent, though many varieties do well. Apples, peaches, pears, plums, and grapes are raised.

The soils of the Patoka quadrangle may be divided into nine very distinct classes, shown in the first column of the accompanying table, which gives the types recognized by the United States Geological Survey. By the refined methods of physical and chemical analyses some of these soils may be still further subdivided. These subdivisions, which are the results of detailed studies by Mr. H. W. Marean of the Bureau of Soils of the United States Department of Agriculture, are given in the second column. The third column states briefly their occurrence in relation to the geologic formations and surface deposits shown on the accompanying geologic map. The mechanical analyses and many of the details in the following description as to the productiveness are the results of the careful examination by the Bureau of Soils.

Residual soils.—Although the rock underlies the loess and drift at very moderate depths over the larger part of the uplands, it has been removed only on the steep bluffs and the sides of the sharper ravines. The soils of this type are usually stony, sandstone fragments predominating, though occasional shale soils were noted. The slopes on which they occur are generally too steep for cultivation and are covered with moderate growths of timber.

Drift soils.—As in the case of the residuary soils, it is only where the slope of the land is so steep that the coating of loess has been removed that the drift soils are found at the surface. The soils are generally sandy or even gravelly, but clayey types are not uncommon. Because of their limitation to steep bluffs and the sides of ravines they are never cultivated, but are generally timbered.

Common loess soils.—The common loess forms the immediate surface over the entire quadrangle, except on the river and stream flats and over the narrow belts of sand and marl-loess hills along the borders of the Wabash Valley. It is generally of a light-buff to reddish-brown color, though becoming pale at times. The upper 9 inches is usually fairly open, but below the limit it is more plastic, tenacious, and clayey. Under cultivation it becomes ashy gray in color. The materials of the loess were originally derived from diverse materials that were scattered over wide areas and it thus contains all the essential ingredients of an unusually fertile soil. It gives good yields of corn, wheat, clover, timothy, and would probably make good tobacco land. Fruit, especially apples, and some garden vegetables are raised. The average yield of wheat is said to be about 20 bushels and of corn from 35 to 40 bushels per acre. The accompanying mechanical analyses by the Bureau of Soils indicate the physical character of the soil.

Mechanical analyses of loess soils from a point 1 mile north of Mount Vernon, Posey County, Ind.

Diameter in millimeters.	Conventional name.	0-8 inches from surface.	8-36 inches from surface.
.0001- .005	Clay	13.68	9.10
.005 - .05	Silt	81.82	84.16
.05 - .1	Very fine sand	3.86	5.92
.1 - .25	Fine sand	.36	.50
.25 - .5	Medium sand	.08	.12
.5 -1.	Coarse sand	.14	.10
	Total mineral matter	99.94	99.90
	Organic matter, water	2.47	.34

Soils of Patoka quadrangle.

Descriptive Terms Used in This Folio.	Soil Names Used by H. W. Marean, Bureau of Soils (Ms. of report for 1902).	Geologic Equivalents.
Residual soils.		Steep slopes of Carboniferous deposits.
Drift soils.		Steep slopes of morainal deposits.
Common loess soils.	Miami silt loam.	Common loess.
Marl-loess soils.		Marl-loess.
Sand-hill soils.	Miami sand.	Earlier and later dune sands and Wisconsin terrace deposits (in part).
River sands and gravels.	Miami sandy loam. Yazoo sandy loam (in part).	Wisconsin terrace deposits (in part) and upper and lower flood-plain deposits (in part). Natural levees.
River silts.	Yazoo sandy loam (in part). Yazoo loam. Yazoo clay.	Upper and lower flood-plain deposits (in part).
Lake and subordinate stream silts.	Memphis silt loam (stream)	Older stream silts.
	Waverly silt loam (lake or swamp).	Glacial lake deposits (in part).
Swamp deposits.	Griffin clay.	Abandoned channel deposits. Swamp deposits.

Marl-loess soils.—The marl-loess soils lie in two belts, one on each side of the Wabash Valley. They do not occur over the entire area mapped as marl-loess, but only along the edges of the belts next the river, the remaining portions being covered with common loess. In color the marl-loess is a pale yellow or straw color. It is also in somewhat marked contrast with the loess of the common type in composition, frequently carrying 5 per cent or more of $CaCO_3$, while the latter generally contains less than 1 per cent. It weathers to a deep reddish brown and frequently shows abundant lime, even at the immediate surface, while in the common type the lime is rarely present at the surface. Its soil is superior to that of the common loess, with which it is sometimes mixed as a fertilizer, with some success. The following analysis, taken from the Thirteenth Annual Report of the Indiana Geological Survey (p. 46), gives a fair idea of its character:

Chemical analysis of loess, Posey County, Ind.

Constituent.	Amount.
Combined moisture	1.35
Soluble organic matter	.30
Insoluble silicates	73.30
Carbonic acid	10.00
Lime	6.80
Magnesia	3.78
Alumina and peroxide of iron	2.80
Chlorine	.12
Loess and alkalies	1.55
Total	100.00

Sand-hill soils.—The sand hills of the quadrangle are of two types, the first including the relatively fine white sands extending from Keensburg westward to Bonpas Creek, and the second embracing the wider interrupted belt of coarse sands extending along the eastern border of the Wabash flats from near Hazelton to the southwestern limits of the quadrangle. In general these sand hills are so porous and are so well drained that they are poorly adapted to general farm crops, but large quantities of watermelons are grown, 500 to 1000 car loads being shipped annually from Posey County. Stock peas are raised in small amounts, and wheat does well if it follows melons in rotation. Mr. H. W. Marean, of the Bureau of Soils, believes that alfalfa might profitably be introduced.

River sands and gravels.—In this class are included the areas of coarser materials of both the lower and upper levels of the Wabash and White River flats. These areas, being limited to original depositional elevations, are of slight extent as compared with the areas of fine silts filling the intermediate depressions. In general the soils consist of buff sandy or gravelly loams which nearly always contain considerable quantities of fine silts and in places are mixed with considerable quantities of vegetable matter, giving almost black colors. In general the sandy soils are most common near the immediate banks of the rivers, where additions are constantly being made by overflow or through the action of wind.

The higher portions of the sand and gravel flats will yield an average of 25 bushels of wheat per acre, and will afford good crops of clover or timothy. About 40 bushels of corn per acre may be obtained. The sandier upper portions in places yield good crops of melons.

River silts.—By the term river silts is meant those finer deposits which have been mentioned as occupying the original depressions of the Wabash and White river flats. The material is largely what may be termed a coarse silt. While much finer than the sand of the preceding class of soils, it is coarser than the clayey silts of the smaller streams. These silts appear to be composed of particles which, as compared with those of the clay soils, are only moderately weathered. They constitute, next to the loess, the most important soils of the quadrangle, comprising the larger portion of the Wabash and White river flood plains. Owing to the very recent drainage of much of the area of the flats, large tracts are still timbered. The cleared areas produce large crops of corn, averaging 45 bushels per acre. The lower portions next the river, are subject to annual overflow and are never troubled with drought. They include some of the best corn lands in Indiana and Illinois.

An analysis of the river silts near Mount Vernon shows 2.42 per cent of organic matter, 66.70 per cent of silt from .05 to .005 millimeters, and 28.42 per cent from .005 to .0001 millimeters in diameter. This soil is frequently underlain by a gravel layer which is of great assistance in draining.

Lake and subordinate stream silts.—This class embraces the silt deposits of all streams except the Wabash and White rivers and the broad drift flats marking the old lake beds. Most of the material is derived from the erosion and redeposition of the loess and is therefore exceedingly fine and clayey. The material is generally strongly weathered and leached of its lime. The stream silts are generally overflowed annually and are frequently wet throughout the year in places. Where artificial drainage has not been established the old lake flats are also very wet. Corn is the best crop, yielding 50 bushels per acre in places. Good crops of grass can also be grown.

In the class of subordinate stream silts may also be included the clayey soils of some of the low terraces bordering many of the streams of the quadrangle, especially in the southern half.

Swamp deposits.—In this class are included the black silts, mucks, and peaty deposits that occur in the various depressions of the flood plains and on the broad drift flats. The depressions of the flood plains are of two types, the broad, shallow depressions, representing incomplete upbuilding of the plains, and the relatively narrow bayous and other abandoned stream channels. The broader depressions are usually filled by the slow accumulation of ordinary river silts, which are washed in at times of flood, and which are mixed with accumulations of leaf mold, etc., giving a black color to the whole. Occasional cypress ponds and swamps, in which the accumulations are almost entirely of vegetable matter, are found on the Wabash flats, especially northeast of Mount Carmel, on the Indiana side of the Wabash. The bayous are generally filled with silts mixed with large quantities of leaves, logs, etc.

Many depressions in the surface of the drift flats marking the beds of the old glacial lakes have been occupied by shallow water bodies even up to within the memory of many of the present inhabitants. The soil of these portions consists of a black muck containing more or less silt washed in from the surrounding areas. The soil is very fertile and after drainage yields as high as 50 bushels of corn, 25 bushels of wheat, 1½ to 2 tons of clover, or 1½ tons of timothy to the acre. The higher portions of the flats are characterized by the redeposited loess soils of the previous class.

RECLAMATION OF BOTTOM LANDS.

Ditches.—One of the notable features of the surface of the quadrangle is the existence of numerous wide flats bordering the present rivers and larger creeks and also occupying areas that are supposed to have once contained the larger lakes, such as those north of the Patoka River, southwest of Princeton, east of Cynthiana, and about Poseyville. The flats of both types originally included extensive undrained areas, shallow lakes of considerable size remaining in the depressions throughout the year, even within the memory of many of the present inhabitants. Within the last forty years, however, and especially during the last decade, numerous ditches have been dug and the lake areas have been drained, and some of the finest crops of the region are raised where the waters formerly stood. Even now, however, though large areas, especially on the Wabash flats, have been drained by the McCarty, Blair, Stunkle, and other large ditches built by county aid, many square miles of bottom land within the quadrangle are yet to be reclaimed for agricultural purposes. These undrained areas support a heavy growth of timber, which is now being rapidly cut off both by lumbermen and farmers.

Dikes.—The lowlands along the Wabash and White rivers are protected in some places from the scour of the overflowing waters in times of flood by systems of dikes or levees. The most important of these are located near Grayville, one on each side of the river. The one on the south extends along the neck inclosed by the sharp loop of the river on which Grayville is located and has doubtless been of importance in delaying the formation of a cut-off at this point. The second dike extends along the west bank of the river from a point about a mile south of Cowling to the southern portion of the area in the southward loop east of Grayville.

FOREST RESOURCES.

Originally the forest lands of the Patoka quadrangle consisted of two well-defined types: (1) The heavily timbered bottoms of the rivers and larger streams, and (2) the more thinly forested areas interspersed with open prairies of the uplands. Since the settlement of the country, early in the century, great inroads have been made into the forested areas of the bottoms, especially since the opening of the drainage ditches of the last decade. On the uplands, however, there has in places been a rapid encroachment of young forests on uncultivated portions of the original prairie lands.

The most marked features of the forests are the absence of coniferous trees, the many species growing together, the great number of southern species, and the rank growths of portions of the bottoms. As many as forty or fifty species of trees may be found in a single 50-acre lot, and very seldom does a particular species predominate over all the others. This feature has done much toward the preservation of the forests, the lumbermen in many instances simply culling out the particular species having the greatest value at the time. Rankness of growth is especially marked in the abandoned channels and in partially filled bayous. Grape vines up to 32 inches, trumpet vines up to 38 inches in circumference, and immense cross vines are found pendant from or clinging to sycamore and other trees from 5 to 10 feet in diameter, while the smaller vines frequently form impenetrable networks. Although one of the rarest of the southern species, the bald cypress is probably the most noticeable of them all. It is limited in occurrence, so far as was seen, to the cypress swamp just northeast of the junction of the White and Wabash rivers. Large trees formerly grew here, some of them measuring 22 feet or more in diameter above the basal swelling and 90 feet high clear of branches, but most of the perfect trees have now been culled out. They are associated with sweet gums and ashes of even greater size.

Larger trees and shrubs of the Patoka quadrangle.

Common name.	Specific name.	Habitat.	Maximum height.	Maximum h't first branches.	Maximum circumference.	Authority.*
			Feet.	Feet.	Feet.	
Bald cypress	Taxodium distichum	Ponds of bottoms	146	74	19	J. S.
Red juniper	Juniperus virginiana	Uplands	75	....	5	R. R.
Butternut	Juglans cinerea	Upland hills	117	....	.....	R. R.
Black walnut	Juglans nigra	Upland hills	155	74	22	J. S.
Pecan	Hicoria pecan	Rich bottoms	175	90	16	J. S.
Butternut	Hicoria minima	Bottoms	113	....	.....	R. R.
Shagbark	Hicoria ovata	Uplands	129	....	.....	R. R.
Shellbark	Hicoria laciniosa	Rich bottoms	119	....	8	J. S.
Mocker nut	Hicoria alba	Uplands	112	55	10	J. S.
Pignut	Hicoria glabra	Bottoms and wet land	120	....	8½	J. S.
Small pignut	Hicoria odorata	Uplands	134	....	10	R. R.
Black willow	Salix nigra	Streams and wet places	......	....	.....	J. S.
Longleaf willow	Salix fluviatilis	Lowlands	70	....	1¾	R. R.
Large-tooth aspen	Populus grandidentata	Uplands	97	....	4¾	R. R.
Swamp cottonwood	Populus heterophylla	About ponds	......	....	.....	J. S.
Common cottonwood	Populus deltoides	Along streams	170	75	22	J. S.
River birch	Betula nigra	Uplands	105	....	10	J. S.
Beech	Fagus atropunicea	Bottoms and along streams	122	10	11	J. S.
Chestnut	Castanea dentata	Uplands	100+	....	.....	R. R.
White oak	Quercus alba	Uplands	150	60	18	J. S.
Post oak	Quercus minor	Uplands and prairies	103	....	10	J. S.
Bur oak	Quercus macrocarpa	Bottoms	165	72	22	J. S.
Overcup oak	Quercus lyrata	Bottoms along swamps	100+	....	.....	R. R.
Chinquapin oak	Quercus acuminata	Bottoms and stream banks	......	....	.....	J. S.
Swamp white oak	Quercus platanoides	Bottoms and about ponds	100+	....	.....	R. R.
Cow oak	Quercus michauxii	Bottoms and wet places	119	....	13	R. R.
Red oak	Quercus rubra	Along streams	150	....	.....	R. R.
Scarlet oak	Quercus coccinea	Drier bottoms and hills	181	94	20	J. S.
Yellow oak	Quercus velutina	Uplands and prairies	160	75	20	J. S.
Spanish oak	Quercus digitata	Uplands and barrens	100+	....	.....	R. R.
Pin oak	Quercus palustris	About swamps	135	23	12	J. S.
Black jack	Quercus marilandica	Sand barrens	......	....	.....	J. S.
Water oak	Quercus nigra	....	65	....	3½	R. R.
Shingle oak	Quercus imbricaria	Wet swamps	100	....	.....	R. R.
Slippery elm	Ulmus pubescens	Drier bottoms and uplands	......	....	.....	J. S.
White elm	Ulmus americana	Uplands and drier bottoms	119	....	.....	R. R.
Wing elm	Ulmus alata	Low rich lands	......	....	.....	J. S.
Hackberry	Celtis occidentalis	Bottoms and along streams	136	....	.....	J. S.
Sugarberry	Celtis mississippiensis	Bottoms and about ponds	100+	....	.....	R. R.
Mulberry	Morus rubra	Drier bottoms and uplands	62	20	10	J. S.
Cucumber-tree	Magnolia acuminata	Along Sugar Creek	100+	....	.....	R. R.
Tulip tree	Liriodendron tulipifera	Uplands	190	91	25	J. S.
Papaw	Asimina triloba	Uplands and bottom lands	48	....	2¾	R. R.
Sassafras	Sassafras sassafras	Drier bottoms and uplands	95	75	8	J. S.
Sweet gum	Liquidambar styraciflua	Bottoms	164	80	17	J. S.
Sycamore	Platanus occidentalis	Wet bottoms along streams	176	68	33	J. S.
Wild cherry	Prunus serotina	Upland hills	135	....	10½	J. S.
Honey locust	Gleditsia triacanthos	Upland hills	156	61	18	J. S.
Water locust	Gleditsia aquatica	....	90	....	4¾	R. R.
Coffee-tree	Gymnocladus dioicus	About swamps	129	....	.....	J. S.
Locust	Robinia pseudacacia	Uplands	95	....	11½	R. R.
Sugar maple	Acer saccharum	Uplands	118	60	12	J. S.
Black maple	Acer saccharum nigrum	Uplands	......	....	.....	J. S.
Silver maple	Acer saccharinum	Bottoms	118	....	.....	R. R.
Red maple	Acer rubrum	Bottoms	108	60	13	J. S.
Boxelder	Acer negundo	Uplands	60	60	9½	R. R.
Ohio buckeye	Aesculus glabra	Uplands	83	....	3	R. R.
Basswood	Tilia americana	Bottoms and along upland streams	135	50	9¾	J. S.
White basswood	Tilia heterophylla	Bottoms	100+	....	.....	R. R.
Black gum	Nyssa biflora	Drier bottoms and uplands	......	....	.....	J. S.
Persimmon	Diospyros virginiana	Drier bottoms and uplands	115	80	5½	J. S.
Blue ash	Fraxinus quadrangulata	Drier bottoms	124	....	.....	R. R.
White ash	Fraxinus americana	Uplands	144	90	17	J. S.
Red ash	Fraxinus pennsylvanica	Low grounds	138	...	16	J. S.
Green ash	Fraxinus lanceolata	Bottoms and about ponds	100+	....	.....	R. R.
Black ash	Fraxinus nigra	Wet, mucky land	100+	....	.....	R. R.
Hardy catalpa	Catalpa speciosa	Uplands	101	48	6	J. S.

*J. S., Dr. J. Schneck, Seventh Ann. Rept. Indiana Geol. Surv., p. 512; R. R., Robert Ridgway, Proc. U. S. Nat. Mus. vol. 5, pp. 55-57, 1882, and vol. 17, p. 419, 1894.

The accompanying table gives a list of the principal trees of the quadrangle. Nearly all are of more or less value for lumber. Originally the cottonwood, hickory, elm, gum, Spanish oak, and sycamore were the principal trees, but there were a number of pecan, walnut, water oak, white oak, bur oak, white ash, poplar, cypress, and a lesser number of the other species. With the exception of the water oak, sweet gum, black or yellow gum, and the various hickories, a large proportion of the timber of value has been cut. The trees just mentioned, however, are still being cut for timber along the Wabash, important mills being located at Mount Carmel and Grayville.

WATER SUPPLY.

The surface of the Patoka quadrangle may be subdivided into lands of two classes, the first including the broad, flat bottom lands bordering the Wabash, White, and Patoka rivers, characterized by a never-failing water supply at slight depths, and the second embracing the remaining portions of the quadrangle, including the uplands and the relatively narrow bottoms of the smaller streams, characterized as a whole by a deficiency of water during the summer months. The sources of supply are streams, artificial ponds, springs, and ordinary and artesian wells.

Streams.—The only streams maintaining any notable flow through the drier seasons are the Wabash, White, and Patoka rivers. Of these the Wabash is by far the largest—in fact, it is stated that its volume at its junction with the Ohio River is greater than that of the latter above the junction. During the summer the water is frequently nearly colorless and carries but little organic matter. It is used as a source of municipal supply at Grayville, at the western border of the Patoka quadrangle. The water is not so wholesome as could be wished, but it is probably superior to that of the Ohio River.

Next to the Wabash in volume is the White River. The water, though not generally so clear as that of the Wabash, is frequently nearly free from sediment during the drier seasons, and is probably equally wholesome. The Patoka River is the smallest of the three perennial streams; in fact, in seasons of unusual dryness it is hardly more than a series of mud holes, frequently filled with rotting logs, through which a weak flow is maintained. The water is always highly charged with sediment. It is, nevertheless the source of public supply for Princeton, the largest city within the quadrangle, and although disagreeable in aspect, does not appear to have any very marked effect on the health of the users.

In wet years the Fox and Black rivers, and Bonpas, Pigeon, Big, and Flat creeks maintain weak flows nearly if not quite through the summer, but in dry years dwindle to series of disconnected and stagnant pools. All of the smaller streams go dry each summer except a few that start from springs and flow short distances before being absorbed or evaporated.

Springs.—Springs are numerous in the sand hills bordering the Wabash Valley on the east, especially along the base next the flats, and give rise to a number of brooks, some of which flow for a mile or two before they are absorbed by the sands and gravels of the Wabash flats. It is probable that the loess, marl-loess, or till that in many places underlies the sand furnishes a relatively impervious stratum, which causes the water to appear at the surface, although the finer sand layers are known to be the determining factor in some instances. The water is usually fairly soft and pure.

The drift hills bordering the flats between the White and Patoka rivers on the east side of the Wabash Valley also give rise to numerous springs, but the streams from them are soon absorbed. The water is more likely to be hard than the water from the springs in the sand hills, but is a pure and safe drinking water.

The rock hills are also sometimes the source of springs. Perhaps the most notable of these is Dripping Spring, located on the face of the bluff bordering the Wabash flats about 4 miles northwest of Owensville (NE. ¼ sec. 33, T. 2 S., R. 12 W.). This spring, which is one of the largest within the quadrangle, emerges at an elevation of about 25 feet above the base of the bluff, over the face of which it has built an irregular coating of calcareous tufa several feet in thickness, crowded with impressions of leaves and mosses. The water at present flows downward in a definite channel several inches in width and bordered by an elevated calcareous rim or miniature levee about 2 inches broad.

Next to Dripping Spring the most notable feature of this type is the line of springs occurring along the bluff at an elevation of about 30 feet above its base for about 1½ miles west of Hazelton. The conditions are not clearly shown, but the water appears to issue directly from a tufa bed, which in turn is overlain by a sandstone, both apparently belonging to the Carboniferous rocks. The tufa, although very open and porous, and marked by small convolutions and other similar structures, does not appear to afford any traces of vegetable impressions. The mineral matter itself is of a harder consistency than that at the Dripping Spring. Tufa blocks of a similar character were found in a ravine cut in the drift 3 miles southwest of Hazelton, but their origin could not be determined.

Besides the springs mentioned there are numerous smaller ones in nearly all of the sharper rock ravines, both at the borders of the flats and in the Claypole, Gordon, Mumford, and other rock "islands" that project through the Wabash flats. The limestone outcrops, especially those of the Somerville formation, are frequently marked by springs of small size.

At a few places the springs are used for domestic purposes or for watering cattle, but this source of supply is in the main rarely available, mainly because it is generally found only in ravines and other similar situations, where the surface is too rugged for cultivation.

Wells of the river flats.—Under the term river flats are included the bottom lands of the Wabash, White, and Patoka rivers. The materials of these flats vary from fine clay-like silts, or even muck, upward to coarse gravel. In the Wabash flats sand and gravel predominate. They usually obtain an abundant water supply at a depth of 15 feet, and it is almost never necessary to go more than 25 feet for a supply. Practically all the wells are driven. The wells usually go through a few feet of clayey silt and then strike coarse sand or quicksand. The clay is usually gray or black at the surface because of the contained vegetable matter, but is gray, bluish, or greenish at a depth of a few feet. The gravels contain all types of fresh, unweathered pebbles, many of them being of Canadian materials. Quartz pebbles are, however, generally the most common. Large bowlders are reported in some wells.

The materials of the White River flats are of the same general character as those of the Wabash flats, but are, perhaps, a little finer on the average. Water is readily obtained. The Patoka flats are composed of more clayey materials. Gravels are not commonly reported in the wells, the water being derived generally from quicksands. Near the river the wells are usually not more than 15 or 20 feet deep, but farther back, and especially near the borders of the valley, an abundant supply is more difficult to obtain, some of the wells deriving water from depths of 75 to 100 feet.

The water from the Wabash and White river flats is generally soft and pure, but sometimes carries lime derived from calcareous clays which are occasionally present. Mount Carmel obtains its supply from wells sunk in the flats. The water of the Patoka flats is generally good, though it is frequently hard, and often tastes strongly of iron sulphate. The latter substance is especially likely to be present where buried wood or lignitic beds are encountered.

Wells of the tributary valleys.—The coarse sands and gravels of the Wabash and White river flats were derived from places at considerable distances to the north at a time when the northern portion of the State was covered with ice and the glacial torrents were discharging large quantities of sands and gravels into the headwaters of the streams mentioned. Their tributaries, however, had no such source to draw upon, the materials they transported being derived at first from the rather fine and clayey glacial drift and later from the loess coating. The result is that the deposits of the tributaries consist largely of clay or of interrupted beds of very fine sand, and these, as compared with the White and Wabash deposits, contain relatively little water. There is rarely a point, however, where wells do not obtain a fair supply near the center of the valleys, although nearer the sides and in the smaller tributaries, where clays predominate, the success of wells is less probable. The water level is not so near the surface as on the river flats. The quality of the water is generally good, though in some wells the supply is hard or even marked by the presence of iron sulphate. Logs of wood and coal beds (lignite) are frequently reported in the deeper wells. Some of the wells enter the rock.

Wells of the sand hills.—Nearly all of the water falling on the sand hills bordering the Wabash Valley sinks into the ground at once to the basal portion of the sand, where it meets the underlying impervious loess, which it follows until it reappears as springs along the base of the hills. Wells sometimes find water in this basal layer, but as the water tends to follow channels on the underlying surface the higher portions are practically dry and successful wells are not numerous in the sand hills. Many of the sand-hill wells obtain their supply from the underlying rocks.

Wells of the old lake flats.—What is here termed old lake flats are those broad, flat areas such as occur southwest of Princeton, east of Cynthiana, south of Poseyville, and at other places, where deposits are supposed to have accumulated in broad shallow lakes ponded in front of the ice margin when it occupied this region. As these materials were derived from a glacier that was near at hand they are frequently rather coarse, but at other points may consist mainly of clay. In the lake flats southwest of Princeton wells obtain water from sand or gravels at 15 or 20 feet, on top of which rests an impervious clay bed. When this is penetrated the water sometimes rises rapidly in the wells to within 10 feet of the surface. The wells of the lake flats west of Cynthiana and about Poseyville are not uniformly successful, the materials penetrated consisting largely of clay. Many of the wells enter and derive their supplies from the underlying rock. The water of the flats is usually good, but sometimes tastes strongly of sulphate or phosphate of iron. Samples of the latter mineral (vivianite) were found in the gravel from one well.

Wells in the loess.—By loess is meant the more or less clayey silts which everywhere cover the uplands, whether the latter are of rock or of gravelly drift. As the loess is rarely over 20 feet and usually 10 feet or less in thickness, only the shallower wells derive their supplies from it. Although it undoubtedly holds large quantities of moisture, its clayey texture and the absence of sandy layers prevent the easy passage of water through it, and only in relatively rare instances does it furnish a considerable supply, the majority of the wells failing in years of drought. The marl-loess, or the coarser and more calcareous type occurring along the east border of the Wabash Valley, is more porous, but does not usually hold water, except near its base. From this portion, however, water is frequently obtained. The water from the loess is generally hard, and sometimes contains sufficient magnesia to have a deleterious effect on health.

Wells in the drift.—Under this term is included those more or less sandy or gravelly materials supposed to have been deposited either directly by the ice or indirectly by streams leading away from its margin. The principal deposits of this type are those forming the moraines shown on the geologic map. The sloping plains leading eastward from the moraine between Princeton and Fort Branch to the vicinity of Port Gibson, near the eastern boundary of the quadrangle, are believed to have been deposited by streams flowing from the ice margin and are classed with the drift deposits. The composition of the deposits is far from uniform, and from this it follows that the water supply is very variable. While one well may yield an abundant supply another near-by well may be an utter failure. In general the higher and more rugged the drift hills the less will be the supply of water. Thus in the high drift hills between Patoka and Hazelton water is rarely present, while in the wash plains between Princeton and Fort Branch water is commonly obtained at a moderate depth except near the moraine, in the vicinity of which some of the wells enter the rock. Wood and coaly matter (lignite) are reported in many of the wells. Most of the water from the drift is hard, and water tasting of iron sulphate or iron phosphate is not uncommon.

Shallow rock wells.—Most of the upland wells, even when dug, enter the rock for short distances, water generally being obtained in some one of the numerous sandstone beds. In many instances, however, the water does not occur throughout the sandy stratum, but only in rather definite channels, neighboring wells often varying greatly in amount of supply. The rock water is extremely variable in quality, much of it being excellent; while some of it is hard or is charged with iron sulphate, which impregnates especially water derived from places where coal beds have been encountered. Wells in the rock on narrow ridges or on the edge of steep bluffs are usually dry throughout several months in the year, and many of the shallow wells in other situations are dry at times.

Deep rock wells.—The Carboniferous rocks of the region consist mainly of shale and sandstones in frequent alternation, the sandstones often being water bearing. Wells drilled to a depth of 200 feet usually obtain a satisfactory supply of water either from the sandstones or from beds associated with the coals or limestones. The water associated with the coal is likely to be charged with iron sulphate resulting from the decomposition of pyrite, while the water from the limestone and even some of that from the sandstone is hard. In many areas little but shale is encountered and no water is found even at considerable depths. This is especially true in the portion of the quadrangle lying within the State of Illinois.

Notwithstanding the regular westerly dip of the rocks, which affords the structural conditions for an artesian supply, very few of the wells flow. In fact, no definite water horizons have been recognized. This is probably due to the well known lenticular and disconnected character of the beds of the Carboniferous series, few if any of the beds continuing without interruption for any considerable distances.

Among the few flowing wells the following may be mentioned: (1) The Bixler well, about 5 miles southwest of Haubstadt, which delivers good water at a height of 3 feet above surface; (2) the Silas Redmond well, east of Cynthiana, 80 feet deep, mostly through "blue mud," which obtains from a quicksand water that rises 3½ feet above the surface; (3) a well 1¾ miles northeast of Poseyville, 126 feet deep, sunk through sand or gravel all the way, which finds water in gravel at 85 and 126 feet that flows out at the surface; (4) a well at the foot of the bluff south of the Wabash River, 2½ miles north of Savah, drilled for coal, in which water charged with iron sulphate rises 2½ feet above the surface.

Cisterns.—Because of the insufficiency of the supply derived from the shallow wells of the loess, drift, or rock, a supplementary supply consisting of rainwater is frequently collected in cisterns. Many of the inhabitants have been forced in late years to rely on cisterns as the only source of domestic water supply, as numerous wells, because of improper location, have become badly contaminated from outhouses, barns, drains, etc. The supply furnished by the cisterns is rarely sufficient, however, for other than domestic uses, and water for stock is often hauled from neighboring streams.

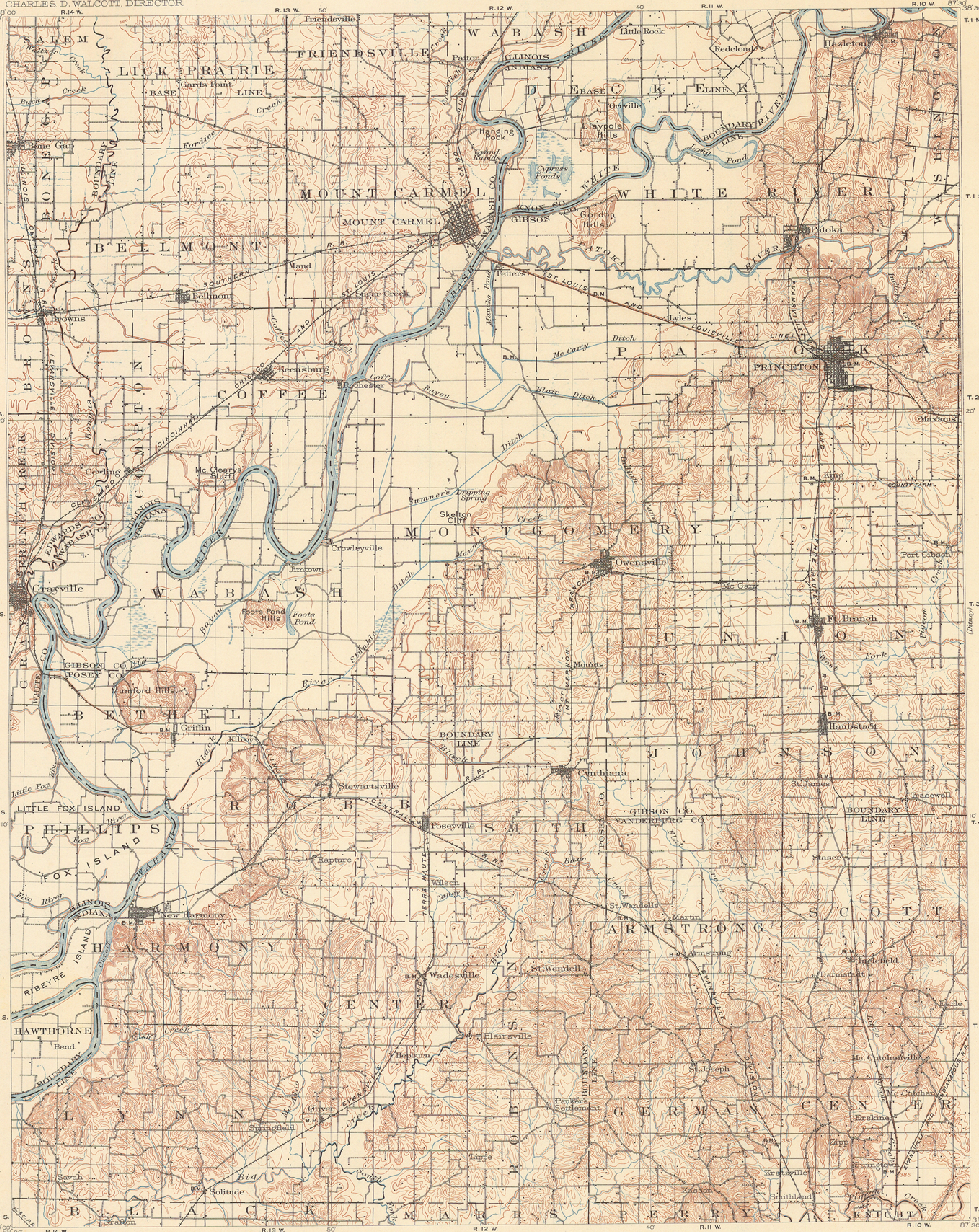
Artificial ponds.—Except the cypress ponds occupying depressions at one or two points on the Wabash flats and the occasional bayous, neither of which are of importance as sources of water, no natural ponds occur in the area. The loess soil with which the larger part of the uplands is covered is rather impervious, a fact that is taken advantage of at many points by the construction of small artificial ponds, which furnish watering places for stock. The water in these ponds is, however, very muddy and is generally of inferior quality.

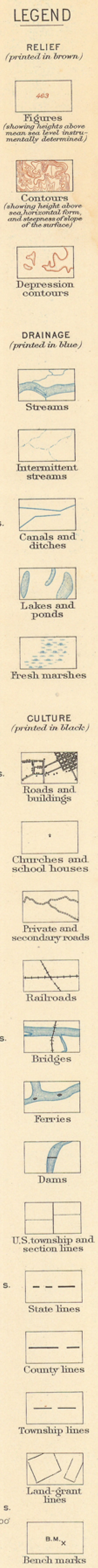
May, 1903.

U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

TOPOGRAPHY

INDIANA - ILLINOIS
PATOKA QUADRANGLE





Jno. H. Renshawe, Geographer in charge.
Control by Geo. T. Hawkins.
Topography by Chas. W. Goodlove.
Surveyed in 1901-1902.

APPROXIMATE MEAN DECLINATION 1903

Scale $\frac{1}{125000}$

Contour interval 20 feet.
Datum is mean sea level.

Edition of Jan. 1904.

AREAL GEOLOGY

LEGEND

SEDIMENTARY ROCKS
(continued)

UNCONFORMITY

Pennsylvanian series — CARBONIFEROUS

- Cw — Wabash formation *(sandstone and shale with thin limestones and coal beds)*
- Ci — Inglefield formation *(sandstone with some shale and a thin coal bed)*

UNCONFORMITY ?

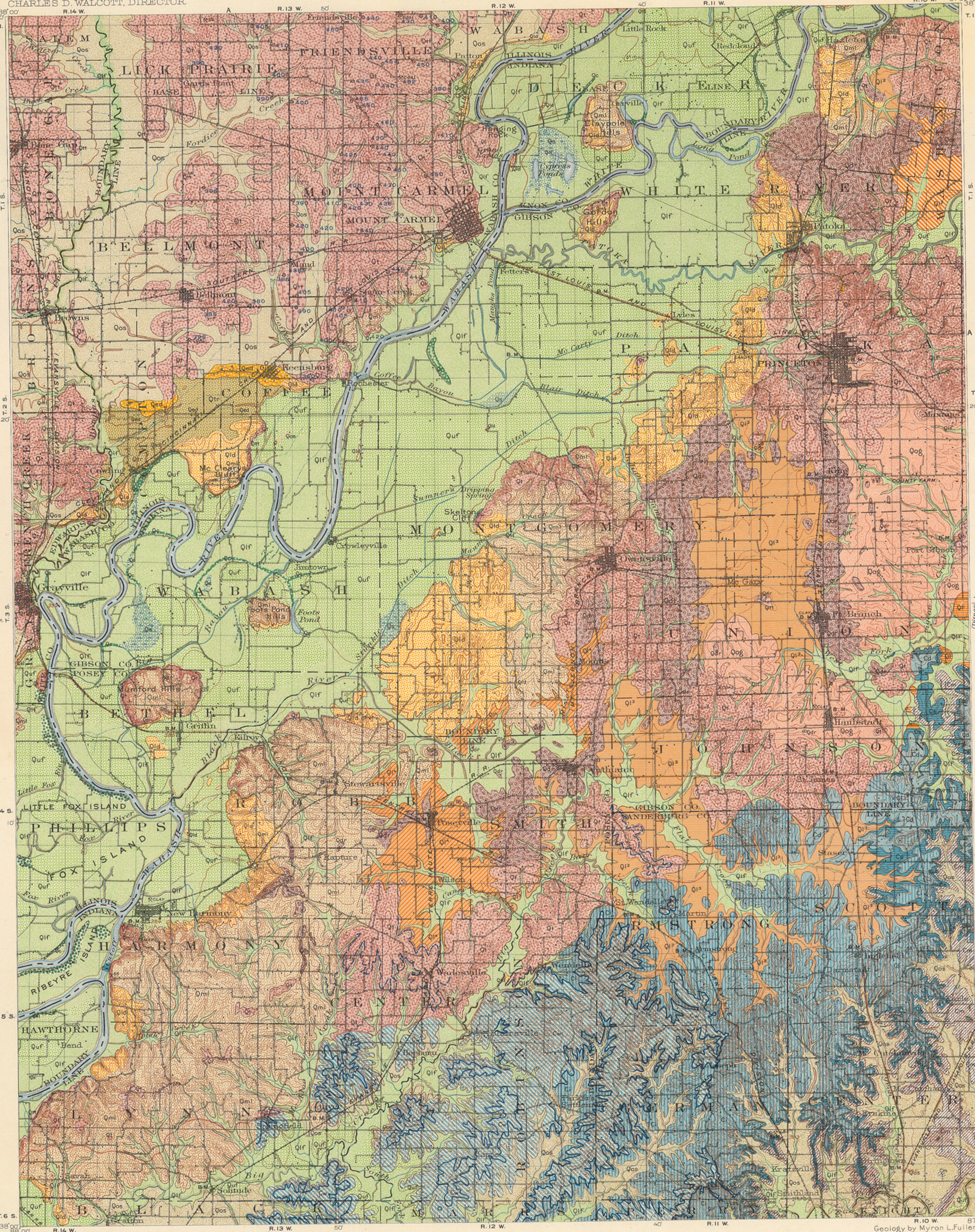
- Cd — Ditney formation *(shale, with a thin coal in places)*
- Cs — Somerville formation *(limestone with interbedded shale)*
- Cm — Millersburg formation *(sandstone, shale, and coal beds; Millersburg coal at the base)*

Coal beds *(continuous lines indicate known outcrop; dashed lines, outcrop beneath Quaternary deposits)*

Aldrich coal (Ca) *in Wabash formation*
Parker coal (Cpr) *at base of Wabash formation*

- ⚒ *Coal mines, stone quarries, and pits*
- X *Prospects, abandoned shafts, and coal outcrops*
- LS *Limestone*
- SS *Sandstone*
- ® *Wells in the area of workable Friendsville coal*
- 420 *Altitude of Friendsville coal determined in shafts, prospects, and wells*

Section



Jno. H. Renshawe, Geographer in charge.
Control by Geo. T. Hawkins.
Topography by Chas. W. Goodlove.
Surveyed in 1901-1902.

TRUE NORTH — MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1903.

DIAGRAM OF TOWNSHIP

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles
1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.
Datum is mean sea level.
Edition of Mar. 1904.

Fuller
Clapp

Geology by Myron L. Fuller
and Frederick G. Clapp.
Surveyed in 1902.

LEGEND

SEDIMENTARY ROCKS
(Areas of subaqueous deposits are shown by patterns of parallel lines, subaerial deposits by patterns of dots and circles.)

QUATERNARY

Recent epoch

- Qnl — Natural levees *(concentrated overwash of sand or fine gravel)*
- Qc — Abandoned channel deposits *(fine silts with logs and other vegetable material)*
- Qs — Swamp deposits *(muck, peat, and vegetable mould)*
- Qlf — Lower flood-plain deposits *(silts and sands with undulating to broken surface, subject to annual overflow)*

Pleistocene epoch

Transition stage

- Qld — Later dune sands *(coarse sands resting on or bordering the upper flood-plain deposits)*
- Quf — Upper flood-plain deposits *(silts and sands of the flat perfected flood plain, rarely overflowed)*

Wisconsin stage

- Qed — Earlier dune sands *(fine sands on Wisconsin or earlier material)*
- Qtr — Terrace deposits *(fine sands and gravels)*

Iowan stage

- Qos — Older stream silts *(fine silts, mainly of pre-Wisconsin age but including some of more recent age)*
- Loess *(fine silt, mainly wind deposited, covering all older glacial deposits and bed rock)*
- Qml — Marl-loess *(stratified silts and very fine sands, probably water deposited)*

Illinoian stage — *Glacial retreat*

- Ql⁴ — Lake deposits of third halt *(silts, sands, and fine gravels)*
- Ql³ — Lake deposits of second halt *(silts, sands, and fine gravels)*
- Ql² — Lake deposits of first halt *(silts, sands, and fine gravels)*

Glacial occupation

- Ql¹ — Lake deposits of maximum advance *(silts, sands, and fine gravels)*
- Qog — Outwash gravel plains *(apron plains of stratified drift)*
- Qdr — Drift ridges *(probably morainal; mainly stratified sands and gravels)*
- Qtt — Thick till and drift plains
- Qt — Thin till sheet *(covers Carboniferous rocks and includes small areas of rock exposure and talus; approximate margin of till sheet shown by continuous line)*

TERTIARY

Eocene?

- Tr — River deposits *(orange-colored sands and iron-stained gravels)*

Legend is continued on the left margin.

COLUMNAR SECTION

COLUMNAR SECTION FOR THE PATOKA QUADRANGLE.
SCALE: 1 INCH = 100 FEET.

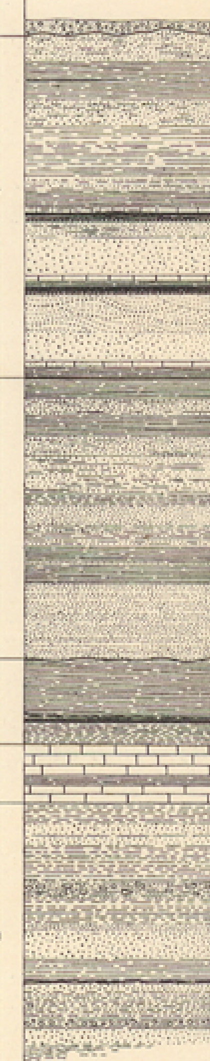
System.	Series.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.
TERTIARY	EOCENE?	River deposits. UNCONFORMITY ?	Tr		6	Oxidized gravels and sands.
CARBONIFEROUS	PENNSYLVANIAN	Wabash formation. (Aldrich coal.) (Friendville coal.) (Parker coal.)	Cw		180	Alternating sandstones and shales. Heavy sandstones, with thin shales, limestones, and coal beds.
		Inglefield formation. UNCONFORMITY ?	Ci		145	Shaly sandstone and shale. Massive sandstone.
		Ditney formation.	Cd		45	Shale and sandy shale with a thin coal bed.
		Somerville formation.	Cs		30	Limestone with interbedded shale.
		Millersburg formation.	Cm		120+	Sandstone, sandy shale, and shale, with thin beds of coal and fire clay.

TABLE OF FORMATION NAMES.

System.	Names and Symbols used in this Folio.		Fuller and Ashley: Ditney Folio, No. 84, U. S. Geological Survey, 1902.	Ashley: Indiana Geological Survey, Twenty-Third Annual Report, 1898.
Tertiary	River deposits (Eocene ?).	Tr		
Carboniferous (Pennsylvanian series)	Wabash formation.	Cw		Coal Measures, Division IX, including Merom sandstone.
	Inglefield formation.	Ci	Inglefield sandstone.	
	Ditney formation.	Cd	Ditney formation.	Coal Measures, Division VIII.
	Somerville formation.	Cs	Somerville formation.	
	Millersburg formation.	Cm	Millersburg formation.	Coal Measures, Division VII.

TABLE OF QUATERNARY DEPOSITS.

Age.			Formation Names and Symbols used in this Folio.		Formation Names used in Ditney Folio, Fuller and Ashley, 1902.	Age.		
Recent epoch			Natural levees.	Qnl	Recent alluvium.	Recent epoch		
			Abandoned channel deposits.	Qc				
			Swamp deposits.	Qs				
			Lower flood-plain deposits.	Qlf				
Pleistocene epoch	Transition		Later dune sands.	Qld	Dune sand.	Wisconsin stage	Glacial epoch	Pleistocene
			Upper flood-plain deposits.	Quf	Terrace sand and gravel.			
	Wisconsin stage		Earlier dune sands.	Qed	(Not represented in quadrangle.)			
			Terrace deposits.	Qtr	(Not represented in quadrangle.)			
	Iowan stage		Older stream silts.	Qos	(Mapped with overlying recent alluvium.)	Iowan stage		
			Loess.		Loess.			
			Marl-loess.	Qml	(Not mapped.)			
	Illinoian stage	Glacial retreat	Lake deposits of third halt.	Ql^4	(Not represented in quadrangle.)	Illinoian stage		
			Lake deposits of second halt.	Ql^3	(Not represented in quadrangle.)			
			Lake deposits of first halt.	Ql^2	Older terrace deposits.			
		Glacial occupation	Lake deposits of maximum advance.	Ql^1	Lake Pigeon deposits.			
			Outwash gravel plains.	Qog	Outwash gravel (in part).			
			Drift ridges.	Qdr	Outwash gravel (southwest of Wheeling only).			
			Thick till and drift plains.	Qtt	Till.			
			Thin till sheet.	Qt				

ILLUSTRATIONS

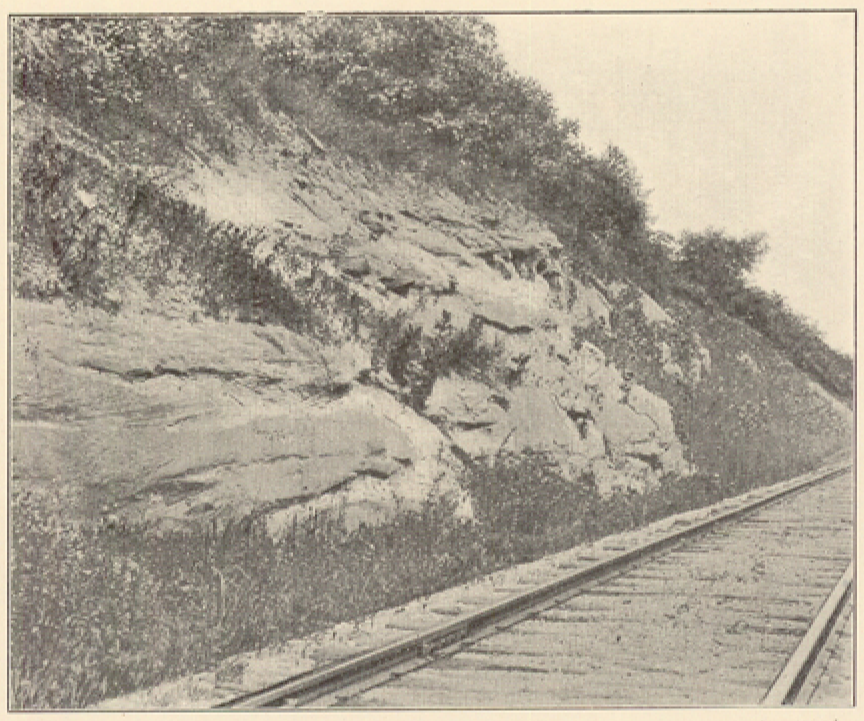


Fig. 6.—CHARACTERISTIC EXPOSURE OF THE INGLEFIELD SANDSTONE, NEAR INGLEFIELD STATION, IND.

Fig. 7.—SHALE "DIKE" IN LIMESTONE, NEAR EVANSVILLE, IND.

Formed by the creep of the decomposed shale into a solution crevice. The pre-Iowan soil is the dark band beneath the loess at the surface.

Fig. 8.—CHARACTERISTIC RECENT EROSION TOPOGRAPHY IN TILL.

The illustration also shows a horizontal contact of the light-colored loess with the underlying darker till

Fig. 9.—STRATIFICATION IN FOSSILIFEROUS MARL-LOESS, NEAR NEW HARMONY, IND.

Fig. 10.—MARL-LOESS TERRACE OF MUMFORD HILLS, IND., FROM THE SOUTH.

Fig. 11.—SURFACE OF A MARL-LOESS PLAIN SOUTH OF NEW HARMONY, IND.

Fig. 12.—STRATIFICATION IN THE LATER SAND DUNES NEAR MOUNT CARMEL, ILL.

Fig. 13.—VIEW OF THE WABASH RIVER BED AT THE NEW HARMONY, IND., CUT-OFF.

Sandstone bed of the Wabash formation in foreground.

As sedimentary deposits or strata accumulate the younger rest on those that are older, and the relative ages of the deposits may be determined by observing their positions. This relationship holds except in regions of intense disturbance; in such regions sometimes the beds have been reversed, and it is often difficult to determine their relative ages from their positions; then *fossils*, or the remains and imprints of plants and animals, indicate which of two or more formations is the oldest.

Stratified rocks often contain the remains or imprints of plants and animals which, at the time the strata were deposited, lived in the sea or were washed from the land into lakes or seas, or were buried in surficial deposits on the land. Such rocks are called fossiliferous. By studying fossils it has been found that the life of each period of the earth's history was to a great extent different from that of other periods. Only the simpler kinds of marine life existed when the oldest fossiliferous rocks were deposited. From time to time more complex kinds developed, and as the simpler ones lived on in modified forms life became more varied. But during each period there lived peculiar forms, which did not exist in earlier times and have not existed since; these are *characteristic types*, and they define the age of any bed of rock in which they are found. Other types passed on from period to period, and thus linked the systems together, forming a chain of life from the time of the oldest fossiliferous rocks to the present. When two sedimentary formations are remote from each other and it is impossible to observe their relative positions, the characteristic fossil types found in them may determine which was deposited first. Fossil remains found in the strata of different areas, provinces, and continents afford the most important means for combining local histories into a general earth history.

It is often difficult or impossible to determine the age of an igneous formation, but the relative age of such a formation can sometimes be ascertained by observing whether an associated sedimentary formation of known age is cut by the igneous mass or is deposited upon it.

Similarly, the time at which metamorphic rocks were formed from the original masses is sometimes shown by their relations to adjacent formations of known age; but the age recorded on the map is that of the original masses and not of their metamorphism.

Colors and patterns.—Each formation is shown on the map by a distinctive combination of color and pattern, and is labeled by a special letter symbol.

Symbols and colors assigned to the rock systems.

	System.	Series.	Symbol.	Color for sedimentary rocks.
Cenozoic	Quaternary...	Recent........ Pleistocene....	Q	Brownish-yellow.
	Tertiary......	Pliocene....... Miocene....... Oligocene...... Eocene........	T	Yellow ocher.
Mesozoic	Cretaceous....	....	K	Olive-green.
	Jurassic	....	J	Blue-green.
	Triassic......	....	Ꞧ	Peacock-blue.
Paleozoic	Carboniferous.	Permian....... Pennsylvanian Mississippian..	C	Blue.
	Devonian.....	....	D	Blue-gray.
	Silurian.......	....	S	Blue-purple.
	Ordovician....	....	O	Red-purple.
	Cambrian.....	Saratogan..... Acadian....... Georgian......	Ꞓ	Brick-red.
	Algonkian....	....	A	Brownish-red.
	Archean......	....	Æ	Gray-brown.

Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea or in lakes. Patterns of dots and circles represent alluvial, glacial, and eolian formations. Patterns of triangles and rhombs are used for igneous formations. Metamorphic rocks of unknown origin are represented by short dashes irregularly placed; if the rock is schist the dashes may be arranged in wavy lines parallel to the structure planes. Suitable combination patterns are used for metamorphic formations known to be of sedimentary or of igneous origin.

The patterns of each class are printed in various colors. With the patterns of parallel lines, colors are used to indicate age, a particular color being assigned to each system. The symbols by which formations are labeled consist each of two or more letters. If the age of a formation is known the symbol includes the system symbol, which is a capital letter or monogram; otherwise the symbols are composed of small letters. The names of the systems and recognized series, in proper order (from new to old), with the color and symbol assigned to each system, are given in the preceding table.

SURFACE FORMS.

Hills and valleys and all other surface forms have been produced by geologic processes. For example, most valleys are the result of erosion by the streams that flow through them (see fig. 1), and the alluvial plains bordering many streams were built up by the streams; sea cliffs are made by the eroding action of waves, and sand spits are built up by waves. Topographic forms thus constitute part of the record of the history of the earth.

Some forms are produced in the making of deposits and are inseparably connected with them. The hooked spit, shown in fig. 1, is an illustration. To this class belong beaches, alluvial plains, lava streams, drumlins (smooth oval hills composed of till), and moraines (ridges of drift made at the edges of glaciers). Other forms are produced by erosion, and these are, in origin, independent of the associated material. The sea cliff is an illustration; it may be carved from any rock. To this class belong abandoned river channels, glacial furrows, and peneplains. In the making of a stream terrace an alluvial plain is first built and afterwards partly eroded away. The shaping of a marine or lacustrine plain is usually a double process, hills being worn away (*degraded*) and valleys being filled up (*aggraded*).

All parts of the land surface are subject to the action of air, water, and ice, which slowly wear them down, and streams carry the waste material to the sea. As the process depends on the flow of water to the sea, it can not be carried below sea level, and the sea is therefore called the *base-level* of erosion. When a large tract is for a long time undisturbed by uplift or subsidence it is degraded nearly to base-level, and the even surface thus produced is called a *peneplain*. If the tract is afterwards uplifted the peneplain at the top is a record of the former relation of the tract to sea level.

THE VARIOUS GEOLOGIC SHEETS.

Areal geology map.—This map shows the areas occupied by the various formations. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any colored pattern and its letter symbol the reader should look for that color, pattern, and symbol in the legend, where he will find the name and description of the formation. If it is desired to find any given formation, its name should be sought in the legend and its color and pattern noted, when the areas on the map corresponding in color and pattern may be traced out.

The legend is also a partial statement of the geologic history. In it the formations are arranged in columnar form, grouped primarily according to origin—sedimentary, igneous, and crystalline of unknown origin—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology map.—This map represents the distribution of useful minerals and rocks, showing their relations to the topographic features and to the geologic formations. The formations which appear on the areal geology map are usually shown on this map by fainter color patterns. The areal geology, thus printed, affords a subdued background upon which the areas of productive formations may be emphasized by strong colors. A mine symbol is printed at each mine or quarry, accompanied by the name of the principal mineral mined or stone quarried. For regions where there are important mining industries or where artesian basins exist special maps are prepared, to show these additional economic features.

Structure-section sheet.—This sheet exhibits the relations of the formations beneath the surface. In cliffs, canyons, shafts, and other natural and artificial cuttings, the relations of different beds to one another may be seen. Any cutting which exhibits those relations is called a *section*, and the same term is applied to a diagram representing the relations. The arrangement of rocks in the earth is the earth's *structure*, and a section exhibiting this arrangement is called a *structure section*.

The geologist is not limited, however, to the natural and artificial cuttings for his information concerning the earth's structure. Knowing the manner of formation of rocks, and having traced out the relations among the beds on the surface, he can infer their relative positions after they pass beneath the surface, and can draw sections representing the structure of the earth to a considerable depth. Such a section exhibits what would be seen in the side of a cutting many miles long and several thousand feet deep. This is illustrated in the following figure:

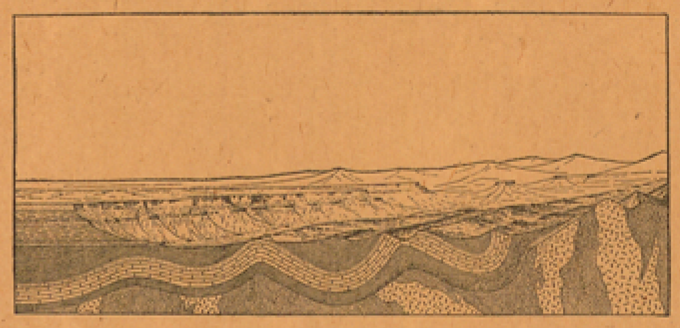


Fig. 2.—Sketch showing a vertical section at the front and a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground on a vertical plane, so as to show the underground relations of the rocks. The kinds of rock are indicated by appropriate symbols of lines, dots, and dashes. These symbols admit of much variation, but the following are generally used in sections to represent the commoner kinds of rock:

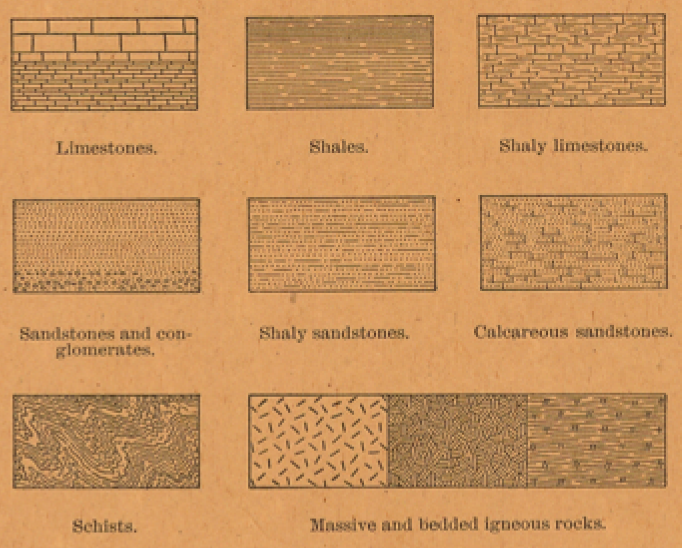


Fig. 3.—Symbols used in sections to represent different kinds of rocks.

The plateau in fig. 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and shales, constituting the slopes, as shown at the extreme left of the section. The broad belt of lower land is traversed by several ridges, which are seen in the section to correspond to the outcrops of a bed of sandstone that rises to the surface. The upturned edges of this bed form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shale.

Where the edges of the strata appear at the surface their thickness can be measured and the angles at which they dip below the surface can be observed. Thus their positions underground can be inferred. The direction that the intersection of a bed with a horizontal plane will take is called the *strike*. The inclination of the bed to the horizontal plane, measured at right angles to the strike, is called the *dip*.

Strata are frequently curved in troughs and arches, such as are seen in fig. 2. The arches are called *anticlines* and the troughs *synclines*. But the sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets; that they are now bent and folded is proof that forces have from time to time caused the earth's surface to wrinkle along certain zones. In places the strata are broken across and the parts have slipped past each other. Such breaks are termed *faults*. Two kinds of faults are shown in fig. 4.

On the right of the sketch, fig. 2, the section is composed of schists which are traversed by masses of igneous rock. The schists are much contorted and their arrangement underground can not be

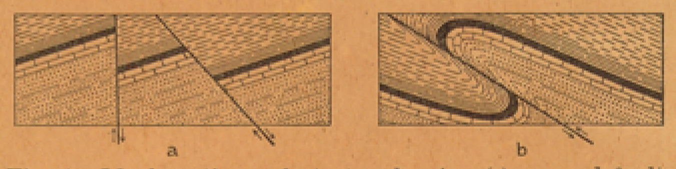


Fig. 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* fault.

inferred. Hence that portion of the section delineates what is probably true but is not known by observation or well-founded inference.

The section in fig. 2 shows three sets of formations, distinguished by their underground relations. The uppermost of these, seen at the left of the section, is a set of sandstones and shales, which lie in a horizontal position. These sedimentary strata are now high above the sea, forming a plateau, and their change of elevation shows that a portion of the earth's mass has been raised from a lower to a higher level. The strata of this set are parallel, a relation which is called *conformable*.

The second set of formations consists of strata which form arches and troughs. These strata were once continuous, but the crests of the arches have been removed by degradation. The beds, like those of the first set, are conformable.

The horizontal strata of the plateau rest upon the upturned, eroded edges of the beds of the second set at the left of the section. The overlying deposits are, from their positions, evidently younger than the underlying formations, and the bending and degradation of the older strata must have occurred between the deposition of the older beds and the accumulation of the younger. When younger rocks thus rest upon an eroded surface of older rocks the relation between the two is an *unconformable* one, and their surface of contact is an *unconformity*.

The third set of formations consists of crystalline schists and igneous rocks. At some period of their history the schists were plicated by pressure and traversed by eruptions of molten rock. But the pressure and intrusion of igneous rocks have not affected the overlying strata of the second set. Thus it is evident that a considerable interval elapsed between the formation of the schists and the beginning of deposition of the strata of the second set. During this interval the schists suffered metamorphism; they were the scene of eruptive activity; and they were deeply eroded. The contact between the second and third sets is another unconformity; it marks a time interval between two periods of rock formation.

The section and landscape in fig. 2 are ideal, but they illustrate relations which actually occur. The sections on the structure-section sheet are related to the maps as the section in the figure is related to the landscape. The profile of the surface in the section corresponds to the actual slopes of the ground along the section line, and the depth from the surface of any mineral-producing or water-bearing stratum which appears in the section may be measured by using the scale of the map.

Columnar section sheet.—This sheet contains a concise description of the sedimentary formations which occur in the quadrangle. It presents a summary of the facts relating to the character of the rocks, the thickness of the formations, and the order of accumulation of successive deposits.

The rocks are briefly described, and their characters are indicated in the columnar diagram. The thicknesses of formations are given in figures which state the least and greatest measurements, and the average thickness of each is shown in the column, which is drawn to a scale—usually 1000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement—the oldest formation at the bottom, the youngest at the top.

The intervals of time which correspond to events of uplift and degradation and constitute interruptions of deposition are indicated graphically and by the word "unconformity."

CHARLES D. WALCOTT,

Director.

Revised January, 1904.

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