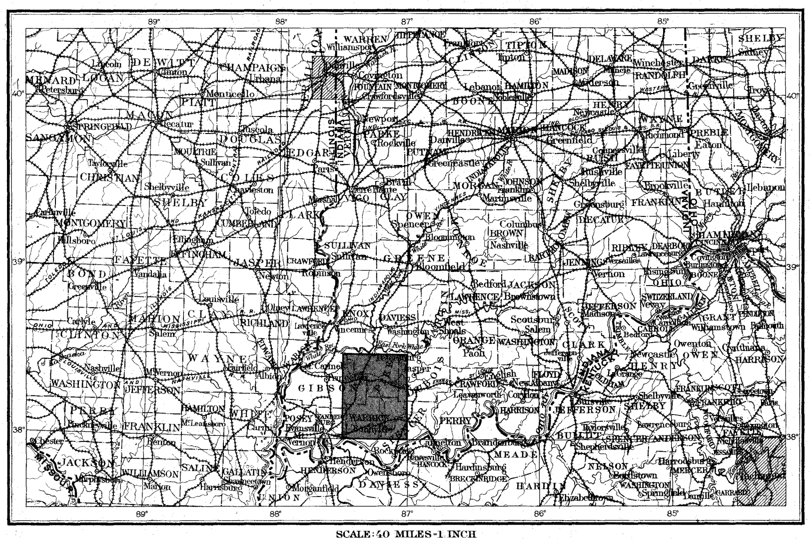
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS
OF THE
UNITED STATES

DITNEY FOLIO
INDIANA

INDEX MAP



SCALE: 40 MILES = 1 INCH

▩ AREA OF THE DITNEY FOLIO

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LIBRARY EDITION

DITNEY FOLIO
NO. 84

WASHINGTON, D. C.
ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY
GEORGE W. STOSE, EDITOR OF GEOLOGIC MAPS S. J. KUBEL, CHIEF ENGRAVER
1902

EXPLANATION.

The Geological Survey is making a geologic map of the United States, which necessitates the preparation of a topographic base map. The two are being issued together in the form of an atlas, the parts of which are called folios. Each folio consists of a topographic base 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 horizontal outline, or contour, of all slopes, and to indicate their grade or degree of steepness. This is done by lines connecting points of equal elevation above mean sea level, the lines being drawn at regular vertical intervals. These lines are called *contours*, and the uniform vertical 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:

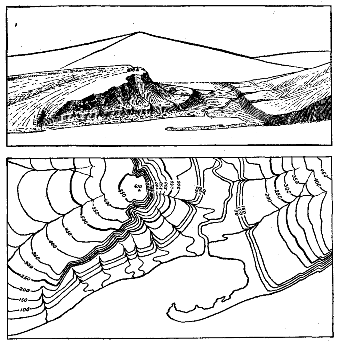

Fig. 1.—Ideal sketch and corresponding contour map.

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 in a precipice. Contrasted with this precipice is the gentle descent of the slope at 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 approximately a certain height above sea level. In this illustration the contour interval is 50 feet; therefore the contours are drawn at 50, 100, 150, 200 feet, and so on, above sea level. Along the contour at 250 feet lie all points of the surface 250 feet above sea; and similarly with any other contour. In the space between any two contours are found all 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 nearly all the contours are numbered. Where this is not possible, certain contours — say every fifth one — are accentuated and numbered; the heights of others may then be ascertained by counting up or down from a numbered contour.

2. Contours define the forms of slopes. Since contours are continuous horizontal lines conforming to the surface of the ground, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing about prominences. The 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 vertical 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 used 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.—Water courses are indicated by blue lines. If the streams flow the year round 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, and artificial details, are printed in black.

Scales.—The area of the United States (excluding Alaska) is about 3,025,000 square miles. On a map with the scale of 1 mile to the inch this would cover 3,025,000 square inches, and to accommodate it the paper dimensions would need to be 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 of "1 mile to an inch" is expressed by $\frac{1}{63,360}$. Both of these methods are used on the maps of the Geological Survey.

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 and corresponds nearly to 1 square mile; on the scale $\frac{1}{125,500}$, to about 4 square miles; and on the scale $\frac{1}{250,000}$, to about 16 square miles. At the bottom of each atlas sheet the scale is expressed in three different ways, one being a graduated line representing miles and parts of miles in English inches, another indicating distance in the metric system, and a third giving the fractional scale.

Atlas sheets and quadrangles.— The map is being published in atlas sheets of convenient size, which are bounded by parallels and meridians. The corresponding four-cornered portions of territory 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-quarter of a square degree; each sheet on a 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, respectively.

The atlas sheets, being only parts of one map of the United States, are laid out without regard to the boundary lines of the States, counties, or 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 sheet.—Within the limits of scale the topographic sheet is an accurate and characteristic delineation of the relief, drainage, and culture of the district represented. Viewing the landscape, map in hand, every characteristic feature of sufficient magnitude should be recognizable. It should guide the traveler; serve the investor or owner who desires to ascertain the position and surroundings of property to be bought or sold; save the engineer preliminary surveys in locating roads, railways, and irrigation ditches; provide educational material for schools and homes; and serve many of the purposes of a map for local reference.

THE GEOLOGIC MAP.

The maps representing areal geology show by colors and conventional signs, on the topographic base map, the distribution of rock formations on the surface of the earth, and the structure-section map shows their underground relations, as far as known and in such detail as the scale permits.

KINDS OF ROCKS.

Rocks are of many kinds. The original crust of the earth was probably composed of *igneous rocks*, and all other rocks have been derived from them in one way or another.

Atmospheric agencies gradually break up igneous rocks, forming superficial, or *surficial*, deposits of clay, sand, and gravel. Deposits of this class have been formed on land surfaces since the earliest geologic time. Through the transporting agencies of streams the surficial materials of all ages and origins are carried to the sea, where, along with material derived from the land by the action of the waves on the coast, they form *sedimentary rocks*. These are usually hardened into conglomerate, sandstone, shale, and limestone, but they may remain unconsolidated and still be called "rocks" by the geologist, though popularly known as gravel, sand, and clay.

From time to time in geologic history igneous and sedimentary rocks have been deeply buried, consolidated, and raised again above the surface of the water. In these processes, through the agencies of pressure, movement, and chemical action, they are often greatly altered, and in this condition they are called *metamorphic rocks*.

Igneous rocks.—These are rocks which have cooled and consolidated from a liquid state. As has been explained, sedimentary rocks were deposited on the original igneous rocks. Through the igneous and sedimentary rocks of all ages molten material has from time to time been forced upward to or near the surface, and there consolidated. When the channels or vents into which this molten material is forced do not reach the surface, it may consolidate in cracks or fissures crossing the bedding planes, thus forming dikes, or spread out between the strata in large bodies, called sheets or laccoliths, or form large irregular cross-cutting masses, called stocks. Such rocks are called *intrusive*. Within their rock inclosures they cool slowly, and hence are generally of crystalline texture. When the channels reach the surface the lavas often flow out and build up volcanoes. These lavas cool rapidly in the air, acquiring a glassy or, more often, a partially crystalline condition. They are usually more or less porous. The igneous rocks thus formed upon the surface are called *extrusive*. Explosive action often accompanies volcanic eruptions, causing ejections of dust or ash and larger fragments. These materials when consolidated constitute breccias, agglomerates, and tuffs. The ash when carried into lakes or seas may become stratified, so as to have the structure of sedimentary rocks.

The age of an igneous rock is often difficult or impossible to determine. When it cuts across a sedimentary rock it is younger than that rock, and when a sedimentary rock is deposited over it the igneous rock is the older.

Under the influence of dynamic and chemical forces an igneous rock may be metamorphosed. The alteration may involve only a rearrangement of its minute particles or it may be accompanied by a change in chemical and mineralogic composition. Further, the structure of the rock may be changed by the development of planes of division, so that it splits in one direction more easily than in others. Thus a granite may pass into a gneiss, and from that into a mica-schist.

Sedimentary rocks.—These comprise all rocks which have been deposited under water, whether in sea, lake, or stream. They form a very large part of the dry land.

When the materials of which sedimentary rocks are composed are carried as solid particles by water and deposited as gravel, sand, or mud, the deposit is called a mechanical sediment. These may become hardened into conglomerate, sandstone, or shale. When the material is carried in solution by the water and is deposited without the aid of life, it is called a chemical sediment; if deposited with the aid of life, it is called an organic sediment. The more important rocks formed from chemical and organic deposits are limestone, chert, gypsum, salt, iron ore, peat, lignite, and coal. Any one of the above sedimentary deposits may be separately formed, or the different materials may be intermingled in many ways, producing a great variety of rocks.

Sedimentary rocks are usually made up of layers or beds which can be easily separated. These layers are called *strata*. Rocks deposited in successive 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 over wide expanses, and as it rises or subsides the shore lines of the ocean are changed: areas of deposition may rise above the water and become land areas, and land areas may sink below the water and become areas of deposition. If North America were gradually to sink a thousand feet the sea would flow over the Atlantic coast and the Mississippi and Ohio valleys from the Gulf of Mexico to the Great Lakes; the Appalachian Mountains would become an archipelago, and the ocean's shore would traverse Wisconsin, Iowa, and Kansas, and extend thence to Texas. More extensive changes than this have repeatedly occurred in the past.

The character of the original sediments may be changed by chemical and dynamic action so as to produce metamorphic rocks. In the metamorphism of a sedimentary rock, just as in the metamorphism of an igneous rock, the substances of which it is composed may enter into new combinations, or new substances may be added. When these processes are complete the sedimentary rock becomes crystalline. Such changes transform sandstone to quartzite, limestone to marble, and modify other rocks according to their composition. A system of parallel division planes is often produced, which may cross the original beds or strata at any angle. Rocks divided by such planes are called slates or schists.

Rocks of any period of the earth's history may be more or less altered, but the younger formations have generally escaped marked metamorphism, and the oldest sediments known, though generally the most altered, in some localities remain essentially unchanged.

Surficial rocks.—These embrace the soils, clays, sands, gravels, and bowlders that cover the surface, whether derived from the breaking up or disintegration of the underlying rocks by atmospheric agencies or from glacial action. Surficial rocks that are due to disintegration are produced chiefly by the action of air, water, frost, animals, and plants. They consist mainly of the least soluble parts of the rocks, which remain after the more soluble parts have been leached out, and hence are known as residual products. Soils and subsoils are the most important. Residual accumulations are often washed or blown into valleys or other depressions, where they lodge and form deposits that grade into the sedimentary class. Surficial rocks that are due to glacial action are formed of the products of disintegration, together with bowlders and fragments of rock rubbed from the surface and ground together. These are spread irregularly over the territory occupied by the ice, and form a mixture of clay, pebbles, and bowlders which is known as till. It may occur as a sheet or be bunched into hills and ridges, forming moraines, drumlins, and other special forms. Much of this mixed material was washed away from the ice, assorted by water, and redeposited as beds or trains of sand and clay, thus forming another gradation into sedimentary deposits. Some of this glacial wash was deposited in tunnels and channels in the ice, and forms characteristic ridges and mounds of sand and gravel, known as osars, or eskers, and kames. The material deposited by the ice is called glacial drift; that washed from the ice onto the adjacent land is called modified drift. It is usual also to class as surficial rocks the deposits of the sea and of lakes and rivers that were made at the same time as the ice deposit.

AGES OF ROCKS.

Rocks are further distinguished according to their relative ages, for they were not formed all at one time, but from age to age in the earth's history. Classification by age is independent of origin; igneous, sedimentary, and surficial rocks may be of the same age.

When the predominant material of a rock mass is essentially the same, and it is bounded by rocks of different materials, it is convenient to call the mass throughout its extent a *formation*, and such a formation is the unit of geologic mapping.

Several formations considered together are designated a *system*. The time taken for the deposition of a formation is called an *epoch*, and the time taken for that of a system, or some larger fraction of a system, a *period*. The rocks are mapped by formations, and the formations are classified into systems. The rocks composing a system and the time taken for its deposition are given the same name, as, for instance, Cambrian system, Cambrian period.

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

Strata often contain the remains of plants and animals which lived in the sea or were washed from the land into lakes or seas or were buried in surficial deposits on the land. Rocks that contain the remains of life are called fossiliferous. By studying these remains, or fossils, it has been found that the species of each period of the earth's history have to a great extent differed from those 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 formations are remote one from the 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 rocks of different areas, provinces, and continents afford the most important means for combining local histories into a general earth history.

Colors and patterns.—To show the relative ages of strata, the history of the sedimentary rocks is divided into periods. The names of the periods in proper order (from new to old), with the colors and symbol assigned to each, are given in the table in the next column. The names of certain subdivisions and groups of the periods, frequently used in geologic writings, are bracketed against the appropriate period names.

To distinguish the sedimentary formations of any one period from those of another the patterns for the formations of each period are printed in the appropriate period-color, with the exception of the one at the top of the column (Pleistocene) and the one at the bottom (Archean). The sedimentary formations of any one period, excepting the Pleistocene and the Archean, are distinguished from one another by different patterns, made of parallel straight lines. Two tints of the period-color are used: a pale tint is printed evenly over the whole surface representing the period; a dark tint brings out the different patterns representing formations. Each formation is furthermore given a letter-symbol composed of the period letter combined with small letters standing for the formation name. In the case of a sedimentary formation of uncertain age the pattern is printed on white ground in the color of the period to which the formation is supposed to belong, the letter-symbol of the period being omitted.

Period.		Symbol.	Color.
Cenozoic	Pleistocene	P	Any colors.
	Neocene { Pliocene Miocene }	N	Buffs.
	Eocene, including Oligocene	E	Olive-browns.
Mesozoic	Cretaceous	K	Olive-greens.
	Juratrias { Jurassic Triassic }	J	Blue-greens.
Paleozoic	Carboniferous, including Permian	C	Blues.
	Devonian	D	Blue-purples.
	Silurian, including Ordovician	S	Red-purples.
	Cambrian	€	Pinks.
	Algonkian	A	Orange-browns.
	Archean	AR	Any colors.

The number and extent of surficial formations, chiefly Pleistocene, render them so important that, to distinguish them from those of other periods and from the igneous rocks, patterns of dots and circles, printed in any colors, are used.

The origin of the Archean rocks is not fully settled. Many of them are certainly igneous. Whether sedimentary rocks are also included is not determined The Archean rocks, and all metamorphic rocks of unknown origin, of whatever age, are represented on the maps by patterns consisting of short dashes irregularly placed. These are printed in any color, and may be darker or lighter than the background. If the rock is a schist the dashes or hachures may be arranged in wavy parallel lines. If the metamorphic rock is known to be of sedimentary origin the hachure patterns may be combined with the parallel-line patterns of sedimentary formations. If the rock is recognized as having been originally igneous, the hachures may be combined with the igneous pattern.

Known igneous formations are represented by patterns of triangles or rhombs printed in any brilliant color. If the formation is of known age the letter-symbol of the formation is preceded by the capital letter-symbol of the proper period. If the age of the formation is unknown the letter-symbol consists of small letters which suggest the name of the rocks.

THE VARIOUS GEOLOGIC SHEETS.

Areal geology sheet.—This sheet 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 particular colored pattern and its letter-symbol on the map 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 symbols and names are arranged, in columnar form, according to the origin of the formations—surficial, sedimentary, and igneous—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology sheet.—This sheet represents the distribution of useful minerals, the occurrence of artesian water, or other facts of economic interest, showing their relations to the features of topography and to the geologic formations. All the formations which appear on the historical geology sheet are shown on this sheet 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 symbol for mines is introduced at each occurrence, accompanied by the name of the principal mineral mined or of the stone quarried.

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 name 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 the formation of rocks, and having traced out the relations among beds on the surface, he can infer their relative positions after they pass beneath the surface, draw sections which represent the structure of the earth to a considerable depth, and construct a diagram exhibiting 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:

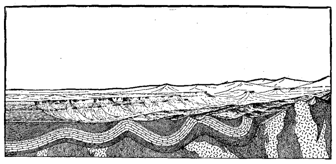

Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground by a vertical plane, so as to show the underground relations of the rocks.

The kinds of rock are indicated in the section 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:

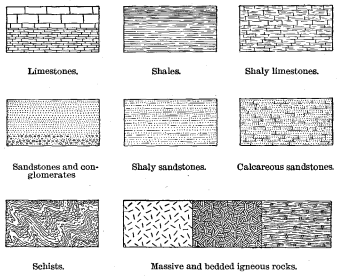

Fig. 3.—Symbols used to represent different kinds of rock.

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 beds of sandstone that rise to the surface. The upturned edges of these beds form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shales.

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*.

When strata which are thus inclined are traced underground in mining, or by inference, it is frequently observed that they form troughs or arches, such as the section shows. 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 regarded as proof that forces exist which 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 slipped past one another. Such breaks are termed *faults*.

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

In fig. 2 there are three sets of formations, distinguished by their underground relations. The first of these, seen at the left of the section, is the 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 swelled upward 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 horizonal 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 strata thus rest upon an eroded surface of older strata 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 this pressure and intrusion of igneous rocks have not affected the overlying strata of the second set. Thus it is evident that an interval of considerable duration 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, marking a time interval between two periods of rock formation, is another unconformity.

The section and landscape in fig. 2 are ideal, but they illustrate relations which actually occur. The sections in the structure-section sheet are related to the maps as the section in the figure is related to the landscape. The profiles of the surface in the section correspond 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 rock formations which occur in the quadrangle. It presents a summary of the facts relating to the character of the rocks, the thicknesses of the formations, and the order of accumulation of successive deposits.

The rocks are described under the corresponding heading, and their characters are indicated in the columnar diagrams by appropriate symbols. The thicknesses of formations are given in figures which state the least and greatest measurements. The average thickness of each formation 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 is placed at the bottom of the column, the youngest at the top, and igneous rocks or surficial deposits, when present, are indicated in their proper relations.

The formations are combined into systems which correspond with the periods of geologic history. Thus the ages of the rocks are shown, and also the total thickness of each system.

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

CHARLES D. WALCOTT,
Director.

Revised January, 1902.

DESCRIPTION OF THE DITNEY QUADRANGLE.

General and Pleistocene[1] Geology by Myron L. Fuller; Economic Geology by George H. Ashley.

TOPOGRAPHY.

LOCATION.

The Ditney quadrangle is located in southwestern Indiana, its southern boundary being only 5 miles from the Ohio River at its nearest point, and its northwestern corner about 9 miles from 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° on the east and 87° 30′ on the west, and includes one-fourth of a square degree of the earth's surface. Its north and south length is about 34.4 miles, its breadth about 27.3 miles, and its area 937.9 square miles. It comprises four 15-minute quadrangles — the Petersburg, Velpen, Boonville, and Degonia Springs — and includes nearly the whole of Pike County and considerable portions of Gibson, Vanderburg, Warrick, Spencer, and Dubois counties. Its name is taken from the Ditney Hills, which are a prominent topographic feature in the southwestern part of the area.

DRAINAGE.

All of the drainage from the surface of the Ditney quadrangle finds its way to the Ohio River, the streams of the southern half flowing south and emptying directly into that river itself, while those of the northern half flow first into the Wabash, a few miles west of the quadrangle, and thence south to the Ohio. The largest stream within the limits of the quadrangle is the Patoka River. This stream enters the area from the east, about 10 miles south of the northeast corner, and flows across it in a general westerly direction, passing out 5 or 6 miles south of the northwest corner and joining the Wabash at a point 13 miles west of the limits of the quadrangle.

With respect to area drained, Little Pigeon Creek stands next to the Patoka River. Its drainage area includes the southeast quarter of the quadrangle, and has an extent of over 225 square miles. Pigeon Creek proper drains about two-thirds of the western half of the quadrangle. Other streams of importance are Cypress Creek, draining a considerable area between Pigeon and Little Pigeon creeks in the southern portion of the quadrangle, and a number of small streams draining the northern edge of the quadrangle and flowing northward to the White River, just north of the area under consideration.

The minor streams show a somewhat radial arrangement about a point a little southeast of the center of the quadrangle, a region which in general is the highest within its limits. The southward-flowing streams as a whole are somewhat longer and have greater volume than those flowing northward, the difference probably being due to the shorter distances to the Ohio in the case of the former, and their consequent increased grade, by reason of which they have cut back farther into the upland.

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 the streams issuing from its margin. In fact, Little Pigeon and Cypress creeks are the only important streams in the Ditney quadrangle which persist in the main in their original courses.

RELIEF.

The Ditney 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 resulting 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 broad, open valley near Otwell, evidently formed by a large stream, but now occupied only by a small creek. The Patoka River from east of Velpen to beyond Winslow, on the other hand, occupies a narrow, steep-sided valley altogether disproportionate to the large size of the stream. The explanation of both lies in the deflection, through the indirect agency of the ice, of the large stream formerly occupying the Otwell Valley into the bed of a smaller steam heading not far from Velpen. Similar disproportions between the sizes of the streams and their valleys, likewise due to the influence of the ice invasion, exist in Pigeon and Bluegrass creeks in Greer and Campbell townships, the former, and larger, flowing in a narrow valley, while the latter flows in one which is broad and open.

Rugged uplands.—In the group designated rugged uplands are included the highest hills and ridges of the quadrangle. The type is best developed in the eastern half of the area, especially in the region between Flat Creek on the north and the valley of Pigeon Creek on the south, but is represented in the western half of the area by a number of more or less isolated peaks rising a hundred feet or so above the level of the surrounding regions. The hills are characterized by relatively sharp summits and the ridges by long, even crests sometimes extending for distances of 2 to 7 miles with change of elevation of only 20 to 40 feet, a feature that is the more noticeable because of the fact that the ridges, as a rule, 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. They exhibit steep descents in their upper courses.

The elevation to which the higher points of the uplands rise is nearly uniform throughout the area of the quadrangle, and appears to indicate that they are but the remnants of an old surface, almost a plain in character, which once extended over the whole of the Ditney area. Within the limits of this area the highest portion of the upland level is in the region a little to the east and northeast of the center, near the point from which the drainage diverges, and where a considerable number of the crests stand at elevations of from 600 to 640 feet above sea level. Isolated hills of similar elevation, however, are found at various points throughout the quadrangle. Among these may be mentioned McGregor and other hills about 3 miles west and 1 mile north of Somerville (elevation, 600 feet); Kennedy Knob, 1 mile northwest of Somerville (600 feet); the hill 1½ miles southeast of Somerville (620 feet); Snake Knob and several other hills to the northeast, north, and northwest of Lynnville (620 to 640 feet); Big Ditney Hill, 3 miles north and 1½ miles east of Millersburg (660 feet); and Little Ditney Hill, about 3 miles northwest of the same village (600 feet).

The level now represented by the upland crests appears, as stated, to have been a part of a broad, flat, or gently undulating plain of the kind known to geologists as a peneplain, which was developed over a large portion of the Mississippi Basin at a period when the land stood much nearer sea level than at present, and which was subsequently raised to its present level and eroded by streams until only the scattered remnants mentioned are left. Its development is considered in greater detail under the heading "Physiographic development," p. 6.

In addition to the high upland level just described there appear to be other remnants in the shape of long, even crests or of land surfaces at lower levels, for there are a number of rather extensive crests or flats shown by rock hills at an elevation of about 500 feet, while ridges and hills of intermediate elevations are common. Though the evidence is not conclusive, it seems probable that subsequent to the formation of the first a second peneplain was developed at an elevation of from 100 to 150 feet below the former. It was probably much less perfectly developed, however, 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, relatively shallow, and are characterized by gently curving cross sections, 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 southern and western portions of the quadrangle, the time since the ice invasion being far too short for the development of a rounded topography by erosion in the regions bordering streams that were forced into new channels at that time.

A rolling upland surface appears to exist between the White and Patoka rivers, in the northwestern portion of the quadrangle, but it is largely buried by deposits laid down during the ice invasion, and is now represented mainly by low, rounded hills projecting here and there through the deposits mentioned.

Upland plains.—The upland plains consist of broad, flat, or gently undulating surfaces standing at an elevation of about 500 feet and composed of deposits which accumulated during the period of the ice invasion. These deposits are of two distinct types. Those of the first type, including those forming the broad, flat uplands in the vicinity of Flat Creek, in the northeast portion of the quadrangle, were laid down as stratified clays, sands, and gravels by streams issuing from the ice sheet into a broad lake, known as glacial Lake Patoka, which then existed in this region. The deposits thus laid down constitute in places an almost featureless plain, above which the bordering uplands or occasional hills rise like bluffs or islands from a sea. Deposits of the second type, known as till, are composed of a heterogeneous mass of clay and sand with some pebbles, which was formed beneath the ice sheet during its occupancy of the region. These are best developed along the south side of the White River flats, in the northwestern portion of the area. The plain extends southward for several miles, but is more or less broken by rock hills which project above its surface and by streams which have eroded deep channels in its mass.

River flats.—All of the rivers and large streams, and also many of the minor streams, flow through broad, flat plains of silt or very fine sand, which are generally overflowed each spring. Wells sunk for water show that the silts are often of considerable thickness, varying from a few feet in the minor valleys up to 100 feet or more in some of the larger ones. The river flats are widest in those streams which still occupy their original valleys, and are narrowest in those which were forced into new channels during the ice invasion. The flats bordering the principal streams vary but little in elevation throughout the quadrangle, being in general between 380 and 400 feet above sea level. Between the elevation of the flats of Pigeon Creek at the southern border of the quadrangle (390 feet), distant 10 miles or less from the Ohio, and the elevation of the Patoka flats (400 feet) north of Oakland City and 75 miles or more from the Ohio, there is a difference of only 10 feet. The meanders of the stream are exceedingly pronounced, and by their resistance to the free flow of the water give rise to annual overflows which cover the adjacent flats to depths of several feet. These conditions are very favorable to changes in the courses of streams, and bayous and abandoned channels are common.

DESCRIPTIVE GEOLOGY.

Derivation of the rocks.—The rocks exposed at the surface of the Ditney 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. These beds, as time has elapsed, 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, there were frequently beds of shells and marls, sometimes many feet in thickness, which were formed beneath the sea, and beds of peat, which were 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 similar to that now covering the surface of Greenland, which in the early part of the present geologic period started in the far north and spread out over nearly the whole of the northeast portion of North America. The ice in the Ditney quadrangle appears to have reached as far south as the west-central portion of the area, though in the region lying farther west it reached a number of miles farther southward. The materials deposited by the ice or its associated drainage probably do not anywhere in the quadrangle reach a thickness of much more than 100 feet, while the deposits laid down since

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[1] Credit is due to Mr. Frank Leverett for many valuable suggestions and facts relating to the Pleistocene deposits and for final corroboration of results in a portion of the area.

the disappearance of the ice are of still less importance.

The older consolidated rocks, on the other hand, reach a thickness in southwestern Indiana of several thousand feet, though probably a thickness of not more than 600 feet is exposed at the surface of the quadrangle. These exhibit many alternations of sandstones, shales, limestones, coals, etc., but they may be grouped by their lithologic characters into five formations, which, in ascending order, are the Brazil, Petersburg, Millersburg, Somerville, Ditney, and Inglefield. All of them belong to the Pennsylvanian or "Coal-Measure" series of the Carboniferous period. The 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 broad sea, which extended from the area of the Gulf of Mexico northward to the region of the Great Lakes, and stretched 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 Ditney 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 directions. In the Ditney 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 amounting to about 25 feet per mile.

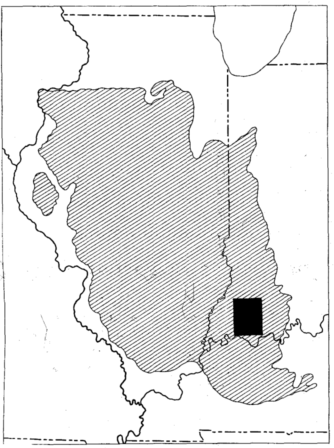

FIG. 1.—Outline map showing the relations of the Ditney quadrangle to the Illinois–Indiana coal field.

The coal field is represented by the obliquely ruled area.

CARBONIFEROUS ROCKS.

Brazil formation.—The Brazil formation includes the series of somewhat closely alternating sandstones, with occasional shales, limestones, coals, etc., extending from the top of the "Mansfield sandstone" (Pottsville) of the Indiana geological survey to the bottom of the Petersburg coal of the Petersburg formation. Five or six coals, some of them several feet thick, are included within its limits, making it an important coal-producing formation in certain parts of Indiana. The name of the formation is taken from the city of Brazil, 75 miles north of the Ditney area, in the vicinity of which the coals of the formation are of considerable economic importance.

Shaly sandstones constitute by far the larger part of the formation, though beds of shale and occasionally beds of limestone or of chert occur at a number of horizons. Of coals there are five or six beds, ranging in thickness from a few inches to 3 feet or more. The sandstones are extremely variable in thickness, giving rise to important differences in the intervals between the coals at different points. They are also subject to somewhat abrupt changes in physical character, and, like the almost equally changeable shales, can seldom be traced for any great distance. One or two limestones, however, could be followed over considerable areas, but the Petersburg coal, which immediately overlies the Brazil formation, is the only bed that could be satisfactorily followed throughout the area, though other coals were frequently recognized by their position relative to the Petersburg bed.

The absence of exposures more than a few feet thick and of carefully taken drill records makes it difficult to compile a satisfactory section of the formation, but the following, made up from all available information, will give an idea of the character, sequence, and thickness of the component beds:

Generalized section of Brazil formation.

Character of beds.	Limits of thickness.	Average thickness.
	Feet.	*Feet.*
Fire clay of the Petersburg coal	60–100	70
Massive sandstone		
Shale and shaly sandstone		
Black, carbonaceous, sheety shale		
Houchin Creek coal, not persistent	0–1½	1
Fire clay	30–60	45
Shale and shaly sandstone		
Clay shale, with rhombohedral jointing, sometimes replaced by massive sandstone		
Survant coal	0–5	3
Shale	25–55	40
Limestone	0–2	1
Black, carbonaceous, sheety shale	1–3	2
Velpen coal		1½
Sandstone and shale	40–50	45
Rock Creek coal, often double	0–3	1½
Shale	70–80	75
Chert or limestone	0–12	5
Holland coal, irregular, thin, or wanting	0–3	1
Massive sandstone, sometimes replaced by shale	60–80	70
Coal	0–3½	2
Average thickness of formation		363

No complete section was obtained between the Petersburg and the Houchin Creek coals, though the two are found so frequently in the same hill as to leave no doubt of their relative positions. The interval between them ranges from 60 to 100 feet, 70 feet being a fair average. In many places a massive sandstone 30 or 40 feet thick shows a short distance below the Petersburg coal, while in other places it appears to be almost entirely replaced by shale.

The following section, taken at the county line east of Pikeville, gives the thicknesses and characters of the Rock Creek and Holland coals, together with the intermediate beds, in somewhat more detail than the general section.

Section of a portion of the Brazil formation east of Pikeville.

	Feet.	Inches.
Shaly sandstone	2	..
Rock Creek coal:		
Coal	..	10
Drab shale	1	2
Coal	1	3
Fire clay	3	..
Shaly sandstone	6	..
Hard, massive sandstone	15	..
Soft, massive sandstone	10	..
Hard, massive sandstone	15	..
Hard sandstone and shale	5	..
Hard, massive sandstone	5	..
Shaly sandstone	3	6
Chert and impure limestone	1	8
Holland coal	..	1
Shale	3	..
Total	72	6

The cherty limestone of this section is probably its most noticeable bed. It varies from a pure limestone to a nearly pure chert, at least in the weathered outcrops. North of Duff it attains a thickness of 8 or 10 feet, and the hillsides below its outcrop are strewn with its fragments. It is believed to be the same bed that outcrops at High Rock, in Daviess County, and at the standpipe at Huntingburg.

The beds below the cherty limestone are seldom well exposed, but a good section is afforded at High Rock, on the north side of White River, just north of the northeast corner of this quadrangle. It is as follows:

Section in the lower portion of the Brazil formation near High Rock, Daviess County.

	Feet.	Inches.
Slope, with chert fragments	15	..
Massive, coarse-grained sandstone	65	..
Traces of coal in streamers and pockets	..	..
Gray, sandy shale	12	..
Coal	3	6
Blue, sandy shale	12	..
Coal	1	6
Light-drab shale	6	..
Coal reported in river bed	2	6

The detailed account of the characters and occurrence of the coals is reserved for discussion under the head of "Economic resources," p. 7.

Petersburg formation.—The Petersburg formation includes the sandstones, shales, limestones, coals, etc., from the bottom of the Petersburg to the bottom of the Millersburg coal, or in the absence of the latter to the top of the limestone which normally occurs just beneath it. The name is taken from the town of Petersburg, about which the coal of the same name is extensively mined. The character of the formation is brought out by the following selected sections, one each from the northern, central, and southern portions of the area.

Section of the Petersburg formation at Hosmer, Glezen post-office, Pike County.[1]

	Feet.	Inches.
Fire clay and shale of the Millersburg coal	3	..
Limestone	5	..
Sandstone and shale, the former sometimes massive	45	..
Soft shale	..	2
Coal	1	1
White clay	..	2
Soft white sandstone	2	4
Soft shale	..	7
Sandstone	..	4
Sandy shale	..	10
White shale	5	3
Clay	..	1
Soft shale	3	10
Black shale	8	6
Soft shale	..	10
Petersburg coal:		
Coal and slate	3	6
Shale with traces of coal	..	6
Coal	3	..

Section of Petersburg formation east of Scalesville.

	Feet.	Inches.
Limestone	?	
Covered	5	..
Limestone	1	6
Mainly covered, but with black "bloom," probably coal	8	..
Shale with lines of iron nodules	8	..
Light-brown, shaly sandstone	15	..
Light-drab clay shale	4	..
Dark-blue shale	6	..
Coal	..	10
Dark, shaly fire clay	3	..
Drab, sandy shale	3	..
Shaly sandstone	15	..
Sandy shale and clay shale	9	..
Limestone	1	..
Brown, sandy shale	2	..
Black, bituminous, sheety shale	1	..
Petersburg coal	4	8

Section of Petersburg formation at Chandler.[2]

	Feet.	Inches.
Fire clay of the Millersburg coal	2	6
Dark-blue limestone, with crinoid stems	9	5
Indurated clay shale	4	..
Hard sandstone	3	..
Light clay shale	..	8
Sandy shale	11	10
Sandstone	5	3
Gray shale	10	5
Dark clay shale	2	1
Gray shale with plates of sandstone	34	..
Black shale	1	..
Shale with large concretions	..	8
Coal, fair	1	4
Pyrite parting	..	2
Coal, good	1	4
Coal, laminated	1	4

The Petersburg formation outcrops as a belt several miles in width extending across the quadrangle from north to south, just west of the Brazil formation. Of its component beds the Petersburg coal constitutes the only one of economic value. It is mined at many points and varies in thickness from 4 to 9 feet, 5 feet being a common measurement. Further details are given under the head of "Economic resources," p. 7.

Millersburg formation.—In the Millersburg formation are included the sandstones and shales lying between the bottom of the Millersburg coal and the limestone of the Somerville formation. It constitutes the greater part of the surface in the western third of the quadrangle, receiving its name from the town of Millersburg, a village on the line of the old Wabash and Erie Canal about 8 miles northwest of Boonville, in the vicinity of which its main coal has been mined at a number of places. Outcrops are much rarer than to the east, and, the coal being seldom workable, few openings have been made. The following section, afforded by the high hill 1 mile north of Lynnville, in sec. 34, T. 3 S., R. 8 W., gives a good idea of the character of the formation in that vicinity. Though there is doubtless considerable variation in the individual beds, the general character probably remains essentially the same throughout the quadrangle.

Section of the Millersburg formation north of Lynnville.[1]

	Feet.	Inches
Somerville formation:		
Limestone, shaly and flinty	3	6
Covered, possibly containing thin coal	15	..
Limestone, compact and flinty	4	..
Millersburg formation:		
Clay shale and nodules	2	..
Buff fire clay	2	6
Coarse red sandstone	15	..
Sandy shale, with carbonaceous partings	8	..
Clay shale, with pyrite partings	12	..
Black "clod," rotten slate	1	3
Coal	1	1
Fire clay	3	2
Sandy shale and thin-bedded sandstone	18	..
Covered, mainly the same as preceding	60	..
Millersburg coal	3	6

Somerville formation.—The Somerville formation in general is essentially a double bed of limestone with a parting of shale. It outcrops on the hilltops about Somerville and Lynnville, on Big and Little Ditney hills, in the higher hills all along the western portion of the quadrangle, and possibly in the uplands south of Union. Its name is derived from the village of Somerville, in the vicinity of which it outcrops, as stated, on the hilltops. A limestone of this formation, some 15 feet in thickness, is reported to cap the hill 1 mile northwest of the town, and a similar thickness probably occurs on the hill 1 mile to the southeast. One and one-half miles north and 3 miles west of Somerville the lower bench of the limestone is 15 feet thick, the upper bench 5 feet thick, and the intervening gray shale 10 feet thick. North of Lynnville the limestone outcrops on several of the hills, but is absent on others of equal altitude, possibly being cut out by an unconformity at the base of the Inglefield sandstone. The character of the formation is shown in the section given in the discussion of the Millersburg formation. On Ditney Hill the limestone appears in two benches, each about 10 feet in thickness, separated by a 15-foot interval, probably of shale. West of Bluegrass Creek the limestone outcrops at numerous points, but the thickness is nowhere well exposed.

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, coals, etc., so characteristic of all Carboniferous formations, but in the area under consideration only a few feet are present as cappings above the limestone on the higher hills. A roadside section on the line between secs. 32 and 33, T. 2 S., R. 9 W., about 3 miles northwest of Somerville, shows the following succession:

Section of a portion of the Inglefield sandstone and of the Ditney and Somerville formations northwest of Somerville.

	Feet.
Inglefield sandstone:	
Heavy sandstone	25
Ditney formation:	
Covered	5
Coal	1
Sandy shale	10
Somerville formation:	
Limestone	5
Gray shale	10
Limestone	15

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[1] Compiled from surface outcrops and from diamond-drill records furnished by the J. Woolley Coal Co., Evansville, Ind.

[2] John Collet: Seventh Ann. Rept. Indiana Geol. Surv., p. 287.

[1] Authority, John Collet: Third and Fourth Ann. Rept. Indiana Geol. Surv., p. 279.

Evidence obtained outside the limits of the quadrangle to the southwest shows that there was probably an erosion interval between the deposition of the Ditney formation and the overlying Inglefield sandstone, and that a portion, or even the whole, of the Ditney, and possibly even the Somerville formation, may have been cut out in places before the deposition of the Inglefield sandstone.

Inglefield sandstone.—The name of this sandstone is taken from the station of Inglefield on the Evansville and Terre Haute Railroad, about 6 miles southwest of Elberfeld. In the railroad cut at this place the sandstone is well exposed and shows a probable unconformity at the base. This sandstone has been correlated by the geological survey of Indiana with the Merom sandstone, formerly quarried near the village of Merom, Sullivan County, Ind., and this name has been used in the various reports of the Indiana survey since 1870. Recent field work has served, however, to throw grave doubts upon the exactness of the correlation, and the formation has, therefore, been given the name Inglefield. In the southwestern portion of the State it appears to have an average thickness of from 80 to 100 feet. A sandstone caps the hills about 3 miles northwest of Somerville and probably occurs in the higher portions of the uplands northwest of Francisco. A similar heavy sandstone, of which John Collet[1] gives the following section, occurs along the Pike-Gibson county line (sec. 7, T. 1 S., R. 9 W).

Section of massive sandstone south of Union.

	Feet.
Soft white and yellow sandstone	30
Soft laminated sandstone	22
Quarry sandstone	18
Total	70

This sandstone was regarded by Mr. Collet as the Merom, with which it agrees in physical characteristics. The interval between its base and the Millersburg coal, however, is only about 100 feet, as compared with about 200 feet southeast of Francisco and elsewhere. This may be explained in part by the absence, presumably through erosion immediately antedating the deposition of the sandstone, of the Ditney formation and of all but a few feet, probably the lower portion, of the Somerville limestone. The remainder of the discrepancy may possibly be explained by the supposition of a thinning of the Millersburg formation to the northward.

Outcrops north of the glacial boundary are very rare because of the thickness of the drift covering, and it has been impossible to trace the sandstone in such areas. Its upper limit has not been recognized in the Ditney quadrangle, though its horizon probably touches the hilltops in the extreme northwest portion. A short distance to the west it is marked by a thin coal bed, overlain in turn by sheety black shale and a thin limestone. The character of the plant remains in the overlying shales shows the formation to belong to the Pennsylvanian series of the Carboniferous.

PLEISTOCENE DEPOSITS.

The deposits which in North America characterize the Pleistocene 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 *inter-Glacial*, and the third as *post-Glacial* 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 which have been picked up or dragged along on the bottom of the ice sheet 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 not usually apparent from a superficial study of the drift, 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 period in North America into nine divisions, as follows:

Outline 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, has been proved to occur within the area of the Ditney quadrangle, though the existence of an earlier one is suspected. A soil zone older than the Illinoian till, the weathered zone of the Sangamon stage, the silt deposits (loess) of the Iowan and the early part of the immediately following stages, and the terraces and dunes of stratified materials of the Wisconsin stage are, however, well represented in the area.

PRE-ILLINOIAN DEPOSITS.

Pre-Illinoian soils.—Logs, more or less carbonized on the exterior, coal streaks, (lignite ?), zones of black muck, etc., have been reported in wells, at considerable distances below the surface, at a number of points. Among these wells may be mentioned (1) one occurring just north of the east-west road at the point where it crosses the line separating sections 31 and 32, T. 1 N, R. 8 W. (3 miles west and 1½ miles south of Petersburg); (2) wells along the main road leading north from Oakland City to Dongola, and about 1 mile north of the former; and (3) a deep well near the center of the western border of sec. 31, T. 1 S., R. 9 W. (3½ miles north and 1 mile west of Francisco). The records are given below.

Record of well (1), southwest of Petersburg.

	Feet.
Blue mud	0-61
Logs of wood, lumps of coal (lignite), etc	61-62
Gravel (giving abundant but muddy water)	62-63
Soft clay (no pebbles reported)	63-98
Sandstone (water abundant on top, but tastes of ferrous sulphate)	98

Record of wells of group (2), north of Oakland City.

Wells are from 23 to 45 feet deep, and strike "black muck" at about the level of the Patoka flats. They do not go into this, however, and none have encountered rock.

Record of well (3), northwest of Francisco.

	Feet.
Dirt and sand	0- 12
"Ash loam"	12- 16
Blue clay	16- 76
Quicksand	76-106
Coal (lignite), 4 inches	......
Gravel (with water)	......

The coaly or more probably lignitic material of the last well, occurring as it does over 100 feet below the present flood plain of the Patoka River, points to an origin at a time when the land stood at a higher level than at present, presumably not long before the first of the Pleistocene ice invasions. The logs and lignites of the first well clearly occur under a thick filling of till, and their occurrence at the level of the present White River flats, and about 35 feet above the rock bottom, suggests that the till may have been deposited over a river flat standing at an elevation not far from the level of the present flood plain. The conditions north of Oakland City appear to be similar. After penetrating 20 to 45 feet of probable drift the wells enter black muck at about the level of the Patoka flats. It is recognized, however, that in either case it is also possible to suppose that the lignite and muck zones simply mark time intervals in a compound drift sheet.

Possibly pre-Illinoian drift.—At a number of points south of the known limits of the Illinoian till, there are shown on the Areal Geology map deposits of highly 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 material 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. The materials are partially cemented. Some of the pebbles are coated with a bronze-colored film of iron oxide, but the coating is generally lacking on a considerable number of the pebbles, being in this respect in contrast with the universal staining exhibited by the pebbles of the supposed Tertiary gravels which cap some of the hilltops near Shoals, to the northeast of the quadrangle, near Tell City and Cannelton to its southeast, near Princeton to the west of the quadrangle, and at points in Illinois and Kentucky.

The gravels generally appear to be only a few feet thick, and are exposed only on the tops or sides of the hills. They reach a considerable thickness on the south slope of the hill southeast of Littles, between it and the Patoka River, however, and appear to constitute nearly the entire mass of the high hill on the south side of the Patoka Valley 2 miles southwest of Wheeling, the hill, in fact, exhibiting many of the features of a kame moraine. A section in a small ravine just east of the road at the crest of the hill showed nearly 30 feet of partially cemented stratified sands and gravels under a 10-foot coating of loess, while minor exposures are to be seen on each of the roads leading to the crest. The gravel and sand is red at the top, but downward grades through brown to a yellowish-buff color. The stratification at the exposures in the ravine is nearly horizontal, but along the road on the northeast side of the hill the sands show a delta structure, with pitch to the south.

Though the gravels are nowhere exposed, it seems likely that they constitute a portion of the filling, shown by the wells to be at least 50 feet deep, and possibly nearly 100 feet in places, which separates the valleys of the South Fork of the Patoka River from Hurricane Creek just north of Oakland City. Single weathered pebbles and small bowlders of northern derivation have been found at a number of points along the roadsides nearly as far south as Boonville, but though suggestive of glacial origin their significance is not established.

The gravels occur at all levels, from near that of the stream beds, or perhaps even below, up to the crests of hills having elevations of 500 feet or more, and they are found over considerable areas in the quadrangle. Their arrangement and distribution are such that it seems impossible to explain them through the ordinary processes of stream deposition, and there appears to be no conclusive evidence of the existence of ponded waters during their deposition. On the other hand, the occurrence is in harmony with the conditions of deposition along the margin of an ice sheet, and at least a portion of the deposits, which in character seem to be a unit throughout the area, appears to be of the nature of a kame moraine.

Accepting the view that the gravels are glacial in origin, their age remains to be determined. Their color and general weathered aspect give them an appearance much older than the ordinary Illinoian drift, but this may be due to the fact that their material is mainly sandy, a composition which in this region seems to be associated with high oxidation. Careful search was made for exposures that would show the relations to the Illinoian till, but no case was noted where a highly colored till or gravel rested below one of less advanced oxidation. Drift exposures showing deep-red colors at the top are common, but the color is present only in the sandier varieties, and grades off, both downward and laterally, into the unoxidized portions. An examination of the pebbles seemed to show that there was no great difference in the degree of weathering of the two types of drift. The general absence of the gravels on the top of the Illinoian till would seem to have more weight than their absence from beneath it, as gravels in the latter position would naturally suffer extensive erosion if not complete removal, becoming incorporated in the mass of the later till sheet laid down by the overriding ice. On the other hand, tills often thin out, and in places practically disappear as the outer limits reached by the ice sheets are approached, the deposits at the outer margin sometimes consisting mainly, if not wholly, of stratified materials. The evidence, therefore, must be regarded as indecisive, but it seems probable on the whole that the date of origin of the gravels is earlier than that of the till, though both may belong to the same general invasion. The limits of the supposed glacial gravels are shown on the Areal Geology map, and their southern border is regarded provisionally as marking the limits of the farthest ice advance, though the possibility of a transient advance nearly as far as Boonville is suggested by the finding of the isolated northern fragments previously mentioned.

Possibly pre-Illinoian loess. — In a section afforded by the banks of the old Wabash and Erie Canal at the divide 1 mile southwest of Francisco some of the features are suggestive of a loess of a period earlier than at least a portion of the Illinoian stage. The section is as follows:

Section of bank of Wabash and Erie Canal southwest of Francisco.

	Feet.
Light-colored, loess-like clay	4
Yellow sand, very fine and distinctly though irregularly stratified	1
Black clay (gumbo)	1
Dark clay (stained by vegetable matter)	3
Light clay (like loess)	6
Disintegrated shaly sandstone	7

The question whether the yellow sand may not represent the pumpings of a hydraulic dredge has presented itself, but the present condition of the exposure is such that this question could not be decided with certainty, and the long period which has elapsed since the cutting of the canal makes it impossible to obtain trustworthy information in regard to its construction. The irregularities in the stratification are suggestive of dredgings, but the general occurrence and apparent relations to the other beds make it probable that the sand is a natural deposit, laid down by the outflow of glacial waters during a late stage of the Illinoian invasion. If so, the loess beneath it is distinctly older than that particular stage of the invasion, and if the gumbo is an indication of a long time interval it is much older; but whether it is to be regarded as belonging to an earlier stage of the same invasion or to an earlier invasion is not clear.

At a point some 5 miles west of Wheeling, and outside the limits of the quadrangle, a clay with abundant pebbles of the type characterizing the Illinoian drift was found overlying a true loess carrying the common loess fossils, which in turn rested on an oxidized drift sheet. It could not be determined, however, whether both of the supposed drifts, together with the included loess, are to be regarded as Illinoian, or whether the lower belongs to an earlier stage of glacial occupation.

ILLINOIAN DRIFT.

Till sheet.—The only deposits known to have been laid down by the direct action of the ice within the area of the Ditney quadrangle during the Illinoian invasion are those belonging to

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[1] Third and Fourth Ann. Repts. Indiana Geol. Surv., p. 251.

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.

The matrix or body of the till thus deposited consists, in the region under consideration, 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 limits of 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 underlying the till in this region and probably furnishing the larger part of the materials 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 hardly being stained even on the exterior, while others are almost completely disintegrated. A weathered zone reaching an eighth or a quarter of an inch inward from the surface is perhaps a fair average. 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 Ditney area 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 oxidized 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 gave evidence of incipient cementation by iron oxide, but the solidification was 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 materials penetrated. In general the thickness, though showing great variation, may be said to be considerable. Broad, plateau-like plains standing from 60 to 70 feet or more above the river flats occur along the south side of the White River Valley, in the northern portion of the quadrangle. The surface is in places almost absolutely flat over considerable areas, but is in general broken from place to place by rock hills and knolls which rise like islands above it, or by sharp ravines that have been cut into its mass by the streams since its completion. A somewhat broken plain of nearly the same elevation is found on the north side of the White River, indicating in all probability that the great drift plain was originally continuous across the present valley of the White River and continued for several miles northward. Its thickness along the White River probably reached 150 feet or more, for records of wells dug several miles back from the river on the south show in cases no rock down to a depth of 100 feet. In general, however, the thickness of the till of the drift plains is less than 50 feet, though it shows marked and somewhat sudden variations, due to the existence of a rather rugged rock topography beneath the accumulation of till (see fig. 3, p. 7). The material composing the plain is usually till, but deep sections reveal the presence of considerable quantities of stratified materials in places, especially along the bluffs bordering the White River Valley in the extreme northwestern portion of the quadrangle.

As the boundary marking the limits of the Illinoian till is approached the till plain is seen to be less perfectly developed. Rock begins to show through it with greater frequency, and it finally diminishes to a relatively thin mantle, which conforms to the contour of the rock surfaces. In general the till appears to continue with a thickness of several feet almost if not quite to the outer limits of its occurrence, though occasional areas of rather small size are found some distance back from the margin where no till appears to have been deposited. No prominent hills of till, such as are known to occur a few miles to the west of the quadrangle, have been noted within its area, though occasional low swells, apparently of till, have been observed at several points.

Outwash gravels, sands, and silts.—Since more or less water was continually being set free by the melting of the ice sheet, and on flowing from its margin carried with it a considerable portion of the detritus previously held by the ice, the sands and gravels deposited by these waters are commonly found in more or less intimate association with the tills along the ice margin and for considerable distances down the valleys leading away from it. It is possible that some of the lower deposits and gravels described as occurring outside the limits of the Illinoian till sheet may have been deposited when the ice stood in the position indicated by the boundary of the till sheet, but those deposits which occur as cappings to hills that themselves constitute pronounced elevations were apparently deposited in connection with an ice advance extending well beyond the limits of the till sheet. The principal overwash deposits are doubtless usually confined to the lower portions of the valleys, where they are now frequently hidden beneath later silts. They are known to reach a considerable thickness in the lower portion of the valley of Little Pigeon Creek, where they have completely buried a rock topography of considerable irregularity. The deposits here, as in other places removed from the influence of strong currents, appear to be largely composed of bluish silt, but near the ice margin, as along the Patoka Valley, they are often, according to well records, sandy and even pebbly.

Deposits of glacial Lake Patoka.—During the maximum development of the Illinoian ice sheet its margin lay across the Patoka River, in the central part of the Ditney quadrangle, probably in the region between Dongola and Winslow. From here the margin extended, with a number of irregularities, northeastward to the vicinity of Otwell, crossing East White River not far from the northeast corner of the quadrangle. The waters draining into the pre-Glacial Lower Patoka Valley (fig. 2, p. 6), being deprived of their outlet, accumulated as a glacial lake in this valley and its tributaries. To this the name Lake Patoka has been applied. Into it flowed the silt-laden streams issuing from the ice front, and in it were deposited many feet of fine glacial sediments. Their thickness at the lowlands bordering Flat Creek is 75 to 120 feet or more. At Otwell a boring sunk by Dr. W. M. De Motte to a depth of 119 feet failed, it is said, to reach rock. Another boring, made by William Bell, between Flat Creek and the headwaters of Mud Creek, 6 miles west of Otwell, is stated to have reached rock at a depth of 78 feet, while several others at short distances to the north and east are reported to have reached it at depths of 75 to 80 feet. The surface deposits of the Lake Patoka area, like those of the surrounding regions, consist of from 5 to 10 feet of loess. Below this in most sections in this portion of the lake is a considerable thickness of sand, while below the sand and continuing to the hard rock is what is commonly called a blue mud. In the portion of the Patoka Valley in the western third of the quadrangle, which became covered by the waters of the lake as the ice retreated, few deep wells have been sunk. A well 70 feet deep in the eastern half of sec. 33, T. 1 S., R. 9 W. (1½ miles south of Oatsville), however, gave the following section:

Section shown by record of well near Oatsville.

	Feet.
Surface	6
Soft yellow sand	3
Easy drilling (probably sandy clay)	47
Very tough clay	10
Easy drilling (probably sandy clay)	4
(Rock was not reached.)	
Total	70

The record already given in the discussion of the pre-Illinoian soils of the well northwest of Francisco shows an even greater depth of sediment. In the enlargement of Lake Patoka which occurs in the northeastern portion of the quadrangle the deposits seem to have been built up to an elevation of about 500 feet.

The deposits of the lake stand, as has been stated, at an altitude of about 500 feet above sea, and the outlets should, therefore, be found at that height. Divides of approximately that elevation do, in fact, occur at a number of points south and southwest of Oakland City, the lowest (apparently about 495 feet) being 1 mile north of Somerville, along the railroad. Like the Francisco divide, they have few features suggestive of outflowing streams. Whether the supply, and therefore the outflow, of the Patoka waters was slight, whether the outflow occurred at a number of points of the same elevation and therefore had little effect at any single one of them, whether there was a general submergence of the region to about the 500-foot level, or whether the waters, as Mr. Leverett has suggested, escaped beneath the ice is not established.

Lower than any of these divides, however, is that on the line of the abandoned Wabash and Erie Canal 1 mile southwest of Francisco. This divide is at an altitude of 460 feet, or about 40 feet lower than the waters of Lake Patoka are known to have stood. The presence of yellow sand in the section at this point, previously described, would seem to indicate a temporary outlet of glacial waters across the col at that point. As there is, however, no indication of any marked westward slope of the surface of the Patoka deposits, and no evidence in the shape of deposition or erosion features, either in the lake or at the divide, or of any strong currents, such as a difference of level of 40 feet in the width of a quadrangle would demand, it seems clear that the Francisco divide was not the site of an outlet, except, perhaps, in the closing stages, when the ice had retreated westward from the point at which it had previously rested, supposedly between Dongola and Winslow.

Deposits of glacial Lake Pigeon.—From the point at which the ice margin crossed the Patoka it continued southwestward to the limits of the quadrangle, and then southward, parallel with but just outside of the border. A little west of the center of the western boundary it crossed the valley then occupied by waters flowing from the region now drained by Big Creek, Smith Fork, and the eastern headwaters of Pigeon Creek in the west-central portion of the area. The result was the formation of a lake similar to but smaller than Lake Patoka, in which deposits of a similar nature were laid down.

In the case of Lake Pigeon the water rose until it formed an outlet over a divide 2 miles east of Elberfeld. This divide was probably at first somewhat reduced, through the agency of the overflowing waters, but to what extent has not been determined. Its original level must, however, have been less than 435 feet, which is the elevation of the present rock divide between Pigeon and Bluegrass creeks, otherwise the overflow would have been in the valley of Bluegrass Creek. The col east of Elberfeld is now buried beneath an unknown thickness of the silts which gradually accumulated and filled up the glacial lake nearly or quite to the level of its waters, and which extended down its outlet as far as the Ohio. The silt of the lake, taken in connection with a somewhat marked drift barrier formed along the ice margin to the westward, had the effect of permanently diverting the waters of Big Creek, Smith Fork, and Pigeon Creek from their old western outlet into the channel beginning east of Elberfeld and leading southward to the Ohio.

Stream deposits.—In this region deposits of the Illinoian streams are mostly covered by recent alluvium. Near the western border of the quadrangle, however, there are remnants of a low terrace, consisting of silt, 10 to 15 feet or more above the recent alluvium of the Patoka River bottom. These become more prominent to the westward and are there believed to be of late Illinoian age. Deposits of a similar nature, and probably belonging to the same category, occur at a few feet elevation above the alluvial bottoms at other points in the quadrangle, but they are too indefinite to admit of mapping.

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 the Ditney region, 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. It is thought that possibly some of the gravel deposits on the borders of the valleys may be of this type, but the evidence is not conclusive. In 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, but with the exception of the gumbo, of doubtful significance, at the Francisco divide, nothing of the sort was seen in the quadrangle. However, a black soil, possibly belonging to the Sangamon stage, occurs, it is reported, in sec. 15, T. 1 S., R. 5 W., 3 miles south of Jasper and just east of the limits of the quadrangle.

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 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 LOESS.

Following the formation of the weathered-zone soils, and possibly silts, of the Sangamon stage, a considerable thickness of fine, almost structureless 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.

Its composition varies considerably at different points, but the loess is generally characterized by about 70 per cent of silica, largely quartz, and a considerable amount of feldspathic material, in addition to the calcareous portion. Two analyses of loess from near Terre Haute, some distance north of the Ditney area, and a third of loess from near Princeton, just west of the quadrangle, are given below.

The first sample (No. 1) is from a point 10 inches, the second (No. 2) from a point 22 inches, and the third (No. 3 from Princeton) from a point at least 30 inches below the surface. The analyses were made for the Indiana geological survey and first appeared in its Twentieth and Twenty-first Annual Reports.

Analyses of Iowan silt from near Terre Haute and Princeton, Ind.

[Nos. 1 and 2 by Prof. W. A. Noyes; No. 3 by Prof. Robert Lyons.]

Constituent.	No. 1.	No. 2.	No. 3.
	Per cent.	*Per cent.*	*Per cent.*
SiO_2	79.77	72.87	71.20
Al_2O_3	9.95	11.25	18.56
Fe_2O_3	3.39	6.75	1.34
FeO	....	....	.15
TiO_2	.70	.95	.88
CaO	.67	.69	.14
MgO	.26	1.06	.52
Na_2O	1.08	.39	1.26
K_2O	2.05	2.26	.32
H_2O	2.55	4.24	6.30
Total	100.42	100.46	100.67

The amount of calcium carbonate ($CaCO_3$) present depends largely upon the amount of weathering to which the loess has been subjected, and consequently the calcium carbonate is present in minimum amounts near the surface. In the determinations of the CO_2 of the $CaCO_3$ at New Harmony, a few miles west of the limits of the quadrangle, a sample taken 2 feet below the surface is reported to have given but 0.229 per cent CO_2, while one taken 10 feet below the surface gave 6.032 per cent. The Terre Haute and Princeton samples are of the leached type.

In texture the loess is clayey, but the presence of fine grit is easily detected. The following mechanical analyses, made by Prof. Milton Whitney, of the Department of Agriculture, give some idea of the size of the grains of the surface loess in eastern Illinois, and probably present fairly well the composition of the loess of the Ditney area. Where the grains exceed 0.1 mm. they are usually concretions of iron oxide or of lime. These concretions frequently reach a diameter of an inch or more, and are of all shapes, tubular types, however, being especially common among the iron-oxide variety.

Mechanical analyses of the Iowan silt in eastern Illinois.

Diameter, in millimeters.	Conventional name.	Galatia; 1–18 inches from surface.	Near Greenup; 2–15 inches from surface.	Moweaqua; 2–18 inches from surface.
		Per cent.	*Per cent.*	*Per cent.*
2–1	Fine gravel	0.00	0.30	0.00
1–.5	Coarse sand	0.00	1.05	0.08
.5–.25	Medium sand	0.02	3.42	0.77
.25–.1	Fine sand	0.30	3.30	0.11
.1–.05	Very fine sand	5.21	6.47	4.88
.05–.01	Silt	57.75	55.48	52.50
.01–.005	Fine silt	12.78	11.70	12.15
.005–.0001	Clay	20.36	14.90	22.10
	Total mineral matter	96.42	96.62	92.59
	Organic matter, water, loss	3.58	3.38	6.61
	Loss by direct ignition	6.01	3.11	5.73

In color the loess is ordinarily buff or brown, but gray, yellow, and red are common colors. Mottling is very common. The gray colors are usually found some distance below the surface, but are sometimes within a foot or two of the top of the ground. In the Ditney area loess fossils have been discovered only in this type of loess. In one case, just outside the limits of the area to the west, fossils were found in gray loess within 3 feet of the surface, showing the clay to be very impervious to water and extremely resistant to both leaching and oxidation.

In the Ditney region the loess of a bright-red type occurs, as a rule, only outside the limits of the Illinoian drift sheet. The color is most markedly red at the bottom, but gradually becomes lighter upward, frequently in the thicker exposures being the ordinary brown or buff of the top. The red color is most common where the loess rests on sandstone, but red loess has also been noted, upon both shale and limestone. In some localities there appears to be a gradual transition from sandstone through disintegrated sandstone into the red loess, and also from till into loess, but in such instances it is probable that the loess, or more properly loess-like silt, is either a secondary deposit or has been partly reworked or modified through the action of the roots of trees and shrubs penetrating to the partly decomposed rocks or till beneath.

An indistinct banding frequently occurs in the loess because of the greater amount of moisture held by certain portions, but no sandy or pebbly layers, or in fact any reliable evidences of stratification, were seen in the area.

The large pebbles of northern material found outside the recognized drift border may possibly have been derived from the loess itself, being dropped, it may be supposed, by floating ice during a period of submergence, when the waters would have reached an elevation of at least 500 feet. There is other evidence, in the shape of divides silted with loess-like material and of elevated flats of similar silts, that there may have been standing water up to this elevation during the deposition of the loess, but sufficient evidence has not yet been obtained to establish this fact.

The thickness of the loess is extremely variable, but the amounts appear on the whole to be greater in the vicinity of prominent streams, in which places the loess sheet sometimes reaches a thickness of 10 or 12 feet or more. The mantle on the upland plains is generally 5 to 8 feet thick. On the slopes and on some hilltops it is much thinner, and in some places is wanting.

WISCONSIN DEPOSITS.

The ice sheet of the Wisconsin stage did not reach the Ditney area, 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 Ditney 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.

In the Ditney area the Wisconsin sediments seem to be confined to the flats deposited by the White River along the northern edge of the quadrangle just west of Petersburg, and to a narrow strip belonging to the Ohio flats west of Midway, in the southeastern portion of the area. They are entirely free from loess. The deposits west of Petersburg consist mainly of fine sand, and are in the form of a terrace standing about 10 feet above the flood plain which has been cut out by the river since Wisconsin times. The top and more especially the inner margins of the terrace are marked by sand dunes formed by the action of winds before vegetation had covered the surface (see fig. 3, p. 7). With the exception of this area, the flats along the White River are composed of recent alluvium. The deposits west and south of Midway include both sands and gravels and appear to reach considerable thickness. As in the case of the deposits along White River, they are in the form of a wide, ill-drained plain or terrace, which stretches to the Ohio, about 10 miles to the south, and which also stands a number of feet above the adjacent flood plain. The plain is several feet lower than the earlier and high alluvial deposits of the valley of Little Pigeon Creek, from which it is separated by an escarpment about 15 feet high.

RECENT DEPOSITS.

Under Recent deposits are included those which have accumulated since the disappearance of the last, or Wisconsin, ice sheet. The time since this ice retreat has been relatively short, and but little work has been accomplished in the Ditney region. In the smaller valleys there have probably been more or less additions to the glacial fillings through the downward creeping or wash of the loess from the hillsides. In the larger valleys the streams have been busy in cutting out flood plains a few feet below the level of the glacial stream fillings, but these are still too small to accommodate the waters at the time of excessive floods, and the second bottoms are still overflowed at times and doubtless receive more or less silt from the overflowing waters (see fig. 3, p. 7).

The flats along the White River, on the northern border of the quadrangle, are composed chiefly of recent alluvium. The low terrace just west of Petersburg is an exception, and is a remnant of the gravels of the Wisconsin stage. There has probably been no change in the altitude of the land since Wisconsin time, and the process of deposition appears to have been essentially continuous, though occasional deposits at a slightly higher level than those now forming have been noted.

GEOLOGIC STRUCTURE.

Local dips, often of several degrees, may be seen in many of the exposures of the Ditney quadrangle, and sometimes complicated series of minor warpings with dips as high as 20° to 30° have been observed. From a superficial examination, therefore, it might appear not only that there is a considerable dip to the rocks of the Ditney area, but that there is also great 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 10 to 40 feet, with an average of about 20 feet, to the mile. This dip, slight as it is, is sufficient to make a difference of more than 500 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 Millersburg and Petersburg coals are the only beds sufficiently well defined to admit of their recognition throughout the quadrangle, and only the latter is of much value in determining structures. In the vicinity of its outcrop the details of dip are readily determined, but to the west, where the coal lies at some distance below the surface, the information is very meager, being largely confined to a few shafts and wells, though approximate information is sometimes afforded by the elevation of the Millersburg coal, which occurs at intervals of from 80 to 120 feet above the Petersburg bed. On the basis of this information, underground or structural contours showing approximately the elevation and structure of the Petersburg coal have been made. All points on any one of these lines are of the same elevation, and points between two lines are of intermediate elevation. Where the contours are near together there is a steeper dip than where they are farther apart. From the contours, therefore, it will be seen that the dips in the region along the outcrop of the Petersburg coal and west of Francisco are relatively steep, while in the intermediate region, including the area about Oakland City, they are much more gentle.

An examination of the contours indicates that the general strike of the rocks is nearly north and south, but that there is a general though slight tendency to northwesterly dips in the northwestern portion of the quadrangle and to southwesterly dips in the southwestern portion, in addition to the many minor irregularities shown in the central portion of the quadrangle. It is probable that similar irregularities occur in the western portion, but data are lacking for all except the broader features.

For some distance west of Whiteoak the dip as measured on the Petersburg coal was 30 feet to the mile. South of Cabel the coal rises sharply to the north. At Hartwell it stands at an altitude of 510 feet, while 1¼ miles a little to the east of south of that place it stands at 610 feet. West of the same point the dip is 50 feet a mile for some 3 miles, after which it decreases to 20 feet or less. West of Stendal the dip is 20 feet a mile for 5 miles, and similar dips continue south to Scalesville. Around Folsomville and Crowville the dip amounts to only 10 feet a mile.

The dips along the eastern border of the quadrangle, where the coals are thinner, more variable, and less persistent, are much more difficult to determine and are less reliable. Measurements based on a thin, cherty bed in the hills between Ireland and Duff indicate a dip of 20 feet to the mile, but sections around Pikeville gave dips as high as 40 feet to the mile. Around Holland the dip is about 25 feet to the mile.

Faults of some magnitude have been noted at several points in adjacent regions, and some having a few feet throw have been seen within the quadrangle. It is possible that the sharp changes in the altitudes of the beds along the line from west of Whiteoak to near Cabel, in the region just east of Littles and Oakland City, and also immediately west of Chandler may be due to faulting, though monoclinal folding is regarded as more probable.

Among the more noticeable of the irregularities are the shallow synclinal troughs near Littles, Ayrshire, Winslow, and near the county line north of Scalesville, and the low anticlinal swells northwest of Glezen, from Oakland City to the Patoka River south of Winslow, near Arcadia, northwest of De Forest, and southeast of Boonville.

In addition to the structure contours of the Economic Geology sheet, sections showing the structure as brought out by the Petersburg and other coals are given on the Structure Section sheet.

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 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 Silurian 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 Silurian and part of the Devonian period. 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 or "Lower" Carboniferous. 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, where they 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 sandstone, 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, 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 quantities of peaty matter, now changed to coal, accumulated. Together these beds make up the series of coal-bearing rocks of which those of the Ditney 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, considerably 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 Ditney 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 Ditney quadrangle, together with 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 extending from western Kentucky across southwestern Indiana, Illinois, northern Missouri, southern Iowa, etc., and connecting with the northwestern extension of the interior sea in western Missouri and Iowa. It was in this embayment that the Carboniferous rocks of the Ditney region were laid down.

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 Ditney quadrangle, are shown in fig. 1, p. 2.

MESOZOIC AND EARLY CENOZOIC EVENTS.

PHYSIOGRAPHIC DEVELOPMENT.

Subsequent to the uplift which followed the deposition of the Carboniferous rocks, and which raised them above the level of the waters in which they had been deposited, there appears to have been no further incursion of the sea into the region under consideration, 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, that evidence of the succeeding events is to be looked for, and as each new set of topographic features was developed only at the expense of older ones, it is only the later ones that are left to tell of the events that have taken place.

Formation of Tertiary peneplain.—No sooner 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 at first erosion did not 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 was now well to the south of 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 of the series beginning with the pre-Triassic and ending with the Tertiary plain along the Atlantic coast. The remnants of the latest of the pronounced plains in the region of the Ditney 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 Ditney 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 times.

Drainage of the peneplain.—Though no deposits other than the loess and till have been found on the crests in the Ditney area, there are a number of points in the surrounding region where 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 at elevations of 550 to over 700 feet. A list of localities furnished by Mr. Frank Leverett includes the following: (1) South bluff of East White River 2 miles southwest of Shoals, Ind.; (2) bluffs of 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 in each case the occurrences are in the vicinity of 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 surface described, an elevation took place that lifted the surface of 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 the development of the peneplain surface had been very sluggish, entered upon an active period of erosion, resulting in the carving out of broad valleys and the general reduction of the 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 the erosion was uniformly active throughout the period of downcutting, and there is some evidence, in the shape of somewhat broad flats and divides at an altitude of about 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 along the Ohio south of the Ditney area. The question whether these gravels, which certainly have the aspect of being 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, can not be said to be fully answered. No deposits of the nature of those described have been found within the limits of the quadrangle.

GLACIAL HISTORY.

Pre-Illinoian events.—It has usually been considered that neither the pre-Kansan nor the Kansan ice sheet reached as far south as the Ditney region, but, although there is no reliable evidence in the quadrangle of glacial occupation at a period earlier than the Illinoian stage, there are two features that are strongly suggestive of earlier drift and loess deposits. These are the presence of a loess with a gumbo surface beneath apparent Illinoian sands at the divide 1 mile southwest of Francisco, and the occurrence of oxidized sands and gravels outside the known limits of the Illinoian till sheet. The real significance of these features is at least doubtful, and they may simply represent different stages of the same general invasion.

Illinoian deposition and drainage deflections.—In the Illinoian stage the ice reached well into the quadrangle and remained there through a long period of time, during which the great till plain of the northwestern portion of the quadrangle accumulated beneath its lower surface and the extensive sediments of Lake Patoka were built up by the streams flowing from its margin.

In consequence of the obstruction of the established drainage lines by the Illinoian ice, or by deposits of till or glacial sediments during its occupancy of the region, many important changes in the arrangement of the streams resulted (see fig. 2). In fact, as previously stated, Little Pigeon, Cypress, and Bluegrass creeks are the only streams of importance in the quadrangle which persisted in their original courses. The Patoka River, now a prominent stream reaching back to the 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 of some size, flowing eventually to the northwest into the White or the East White River. One of these northwestward-flowing streams crossed the northeast corner of the quadrangle in the vicinity of Otwell, the valley which it formerly occupied being easily recognized. Another took its rise south of Velpen, and followed the course of the present Patoka River nearly to the western edge of the quadrangle, when it also turned northwest and flowed into the White River (see fig. 2).

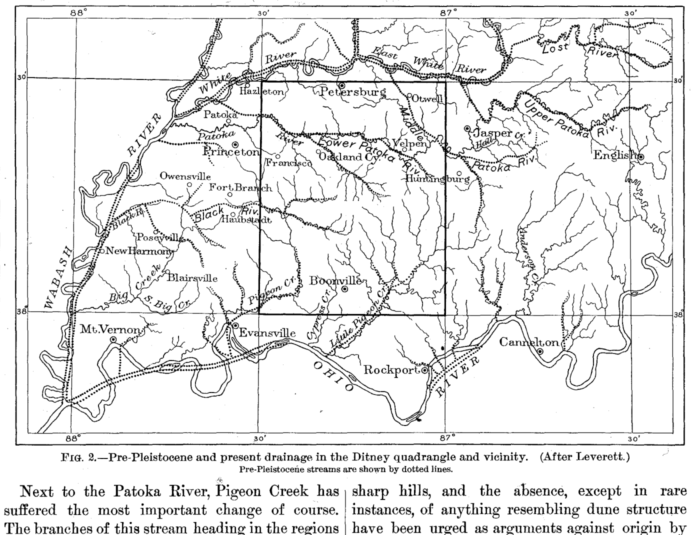


FIG. 2.—Pre-Pleistocene and present drainage in the Ditney quadrangle and vicinity. (After Leverett.)
Pre-Pleistocene streams are shown by dotted lines.

Next to the Patoka River, Pigeon Creek has suffered the most important change of course. The branches of this stream heading in the regions now drained by Snake Run, Sand Creek, Smith Fork, Big Creek, etc., originally united a short distance west of the quadrangle and flowed westward to the Wabash, but during the Illinoian invasion they were deflected by the ice and the drift ridges built up near its margin, and were forced to seek a southward outlet to the Ohio. This outlet was found just east of Elberfeld, the divide over which the waters flowed having an elevation of less than 435 feet, the elevation of the rock rim at the head of the valley of Bluegrass Creek, which otherwise would have served as the outlet. Minor changes in drainage, due to the deposition of silt, etc., in the sluggish streams or slack water which formerly existed in the region, have been observed near Tennyson, in the southeastern portion of the area, and northeast of Oakland City. In the former region Coles Creek and Barren Fork turn and flow for several miles parallel with but in the direction opposite that of Little Pigeon Creek, into which they eventually flow. In the latter region South Fork of Patoka River has been deflected from its old channel, which formerly entered the main river in the vicinity of Hurricane Creek north of Oakland City, into a much narrower channel roughly parallel with the first, leading into the Patoka just east of Dongola.

Sangamon erosion.—Following the disappearance of the Illinoian ice sheet there seems to have been a slight uplift of the land, which accelerated erosion during the Sangamon stage. In some other regions the Sangamon streams were broad and sluggish and eroded little, but in the Ditney area the erosion appears to have been considerable and removed at least 80 to 100 feet of the till filling the White River Valley over a breadth of 2 or more miles, and possibly even greater amounts of stratified materials along the Ohio River. The absence of till on many of the steeper slopes along the more important drainage lines is also probably due to erosion during this stage.

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 the Sangamon soils.

Deposition of the Iowan loess.—The next event of importance was the deposition of a mantle of loess over the general surface of the region from the lowest to the highest points, its thickness averaging 10 feet or more on level surfaces and from 5 to 8 feet on hilltops. The origin of the loess has been a puzzling problem, and has been attributed to the action of both wind and water. The presence of land fossils, the lack of evidence of water structure, and the range in elevation of the loess from the lowest valleys to the highest hilltops are the most common arguments for wind origin; while the greater abundance of the loess along the streams, its accumulation in many cases at especially exposed points, as at the crests of sharp hills, and the absence, except in rare instances, of anything resembling dune structure have been urged as arguments against origin by wind action. The most natural explanation that has been proposed is that the material of the loess was originally derived from glacial grindings and carried outward from the ice sheets by streams and spread over broad flats along the drainage lines, from which it was picked up, transported, and redeposited by the wind as a mantle over the general surface of the uplands.

The loess along the Wabash River up to a certain level is stratified, occurs in definite terraces, and appears to be unmistakably the result of aqueous deposition, while above this level the loess deposits appear with equal certainty to be the result of wind action. The level to which the water-deposited loess rises varies considerably. With the possible exception of the loess which covers portions of the lowlands in the western portion of the quadrangle, the deposits of the Ditney area appear to have originated mainly through the action of the wind.

Peorian interglacial stage.—The Peorian stage is not known to have been characterized by any notable events in the Ditney area. The land appears to have remained at essentially the same elevation as during the deposition of the loess, and the latter 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 Ditney area, 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, portions of which were subsequently taken up by the wind, before the introduction of vegetation, and redeposited as dunes along the valley borders. The Ohio River, though nowhere touching the ice front, received the drainage of a number of streams heading at the margin of the ice sheet and bringing down quantities of glacial sediments, which were deposited along its course. The deposits west of Midway are probably of this origin, though the upper portion may have been deposited in an extensive lake which appears to have occupied the area in relatively recent times, there still being undrained areas of considerable size at the time of the settlement of the region.

During the final retreat of the ice the Wabash River was the outlet of 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 which had accumulated between the retreating ice and the northward-sloping land in the region mentioned and which emptied into the Wabash a little west of Fort Wayne, Ind.

RECENT EVENTS.

Subsequent to the deposition of the Wisconsin sediments, just noted, the region appears to have stood approximately at the same level as at present. The streams, being narrower and less charged with sediment than during the Wisconsin stage, have cut into the deposits of that stage and excavated flood plains of more or less breadth a few feet below their surface. The work appears to be going on at the present time, the flood plains still being too small to accommodate the waters in time of excessive floods, which occasionally rise and overflow the Wisconsin flats, both along the White River and the Ohio.

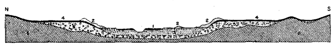


FIG. 3.—Diagrammatic section across White River Valley west of Petersburg.

1, Recent alluvium. 2, Late Wisconsin dunes. 3, Wisconsin sand and gravel. 4, Iowan loess. 5, Illinoian till. 6, Red rock.

The succession of Pleistocene events is well brought out by the cross section of the White Rivey Valley given above.

ECONOMIC RESOURCES.

COAL.

Coal constitutes by far the most important mineral resource of the quadrangle, there being five or more beds which are of sufficient thickness to warrant development, at least for local supplies. Only one of the beds, however — the Petersburg coal — is worked for purposes of shipment. The other veins, especially the Millersburg coal, are extensively mined in the fall and winter months, to supply local demands. The outcrops of the Millersburg, Petersburg, Survant, Rock Creek, and Holland coals are shown on the Economic Geology sheet, together with the location of the mines and the more important local workings. The approximate elevation of the Petersburg coal with reference to sea level is given by means of underground contours, the determinations being based on outcrops of the coal and overlying formations, and upon shaft and well sections where such could be obtained. The depth of the coal below the surface can be determined by subtracting its elevation as shown by the coal contours from that of the surface contours at the same point.

The thicknesses of the various coals at different points are shown on the Coal Section sheets following the maps. It will be noted that all of the coals show marked and sudden variations in thickness, due, it is believed, to their accumulation in basins of variable depth, or in series of basins that were only partially connected or even completely separated. The coals above the Millersburg are not shown, as they are few in number, are usually under a foot in thickness, and are not workable, even for local purposes, except in rare instances.

Millersburg coal.—At an interval varying from 70 to 90 feet above the Petersburg bed there is nearly always a second bed, several feet in thickness, immediately overlying 5 to 10 feet of limestone. Such a coal, some 3 feet or more in thickness, has been worked for the local supply at several points about Millersburg, and has received the name of Millersburg coal. Coals of similar thickness, likewise associated with limestones, have been seen at a considerable number of points to the south, east, northeast, and north of Millersburg. A recent boring and shaft at Buckskin shows the coal to be over 6 feet in thickness in that vicinity. To the south, east, and northeast the interval above the Petersburg bed appears to remain fairly constant at about 80 or 90 feet, and it seems probable that the coal is in reality the Millersburg bed; but in the vicinity of Oakland City the interval from the Petersburg bed to the lowest overlying limestone and coal is about 120 feet. At Ingleton, northeast of Oakland City, and in the region to the north of the Patoka River, however, a coal (and usually also a limestone), generally regarded as of the Millersburg bed, is to be seen at many points at an interval of about 100 feet above the Petersburg; but toward Petersburg the conditions become confusing, there being two and perhaps three coals within an interval of about 50 feet of one another, making it impossible to determine with certainty which, if any, of them is the equivalent of the Millersburg bed. The various outcrops are plotted on the Economic Geology sheet as belonging to the Millersburg coal, but their identity with the coal at Millersburg is not fully established in the areas mentioned.

The Millersburg coal, or a coal belonging to the same general horizon, is worked somewhat extensively for local supply southwest of Petersburg, on Robinson Creek, on both sides of the Patoka River at Dongola, north of Ingleton, south of Lynnville, and at Millersburg.

Petersburg coal.—The outcrop of the Petersburg coal is largely hidden by glacial deposits in the northern portion of the quadrangle, but over an area beginning near Cato and continuing to the southern border, south of Boonville, it has been opened at many points and is worked at short intervals. The dip being very gentle, averaging only about 20 feet to the mile, to the westward, and the coal lying at or near drainage level over considerable areas, the outcrop partakes of all the sinuosities of the drainage lines, its length being several times that of the quadrangle.

The coal is of variable thickness, but probably averages about 5 feet in this quadrangle. East and northeast of Boonville, however, its average thickness is somewhat greater, being not far from 6 feet, and thicknesses of 7 feet are common in many of the mines, while in pockets a thickness as high as 9½ feet is reported. In this region it is solid and uniform throughout, except that the upper 3 to 6 inches is dry, resembling cannel coal in places. Thicknesses of 8 feet occur in many of the mines about Petersburg. At other points thicknesses of 4 to 6 feet are most common (see Coal Section sheets).

It is believed locally that the coal worked at or near the surface at Ayrshire and between Winslow and Littles is a "floating vein" lying about 60 feet above the Petersburg bed, and it is claimed that an 8-foot bed has been found by drilling about 60 to 80 feet below the one now worked. A careful study of the available data, however, leads to the belief that the coal at Ayrshire, Winslow, Oakland City, and Littles all comes from the Petersburg bed, and that the 8-foot bed below is either a newly discovered bed or the continuation of one of the thin beds of the Brazil formation which outcrops farther east.

The coal frequently carries partings of bony coal, shale, etc., which sometimes reach considerable thicknesses. Such a parting occurs at Scalesville, and continues to thicken southeastward, until at a mine northwest of Folsomville it forms a parting 3½ feet thick between the two benches, but south of Folsomville it soon runs out. At several points the coal is associated with a small overlying vein known as a "rider." In the region between Winslow and Selvin the rider is a 6-inch vein occurring from 5 to 15 feet above the main bed. At Cabel a rather thick rider occurred just above the main coal, and the two were worked together at one time, but the working did not prove profitable. The thickness of the coal, with its partings, and the characters of its floor and roof at various points are shown on the Coal Section sheet.

The following analyses, made by the State geological and natural history survey, give some indication of the chemical character of the bed in this quadrangle. While they do not indicate a coal of very high grade, the ease and cheapness with which it may be worked makes it a valuable vein. The roof as a rule is excellent, being of the tough, black, sheety variety which maintains itself without props for years, even in large rooms.

Analysis of Petersburg coal.

Mine.	Total combustible matter.	Volatile combustible matter.	Fixed carbon.	Moisture.	Ash.	Sulphur.	Evaporative effect.[1]
De Forest ..	84.16	39.09	45.07	6.08	9.76	2.14	12.5
Ayrshire....	82.47	41.32	41.15	10.75	6.78	0.81	12.36
Blackburn..	87.33	43.38	43.95	7.47	5.20	5.21	12.9
Woolley, Petersburg..	85.31	43.51	41.80	6.87	7.82	3.56	12.6

[1] Pounds of water evaporated per pound of coal.

Mines of small size are operated at a large number of points, and in the aggregate have a large output. The larger mines, however, are of necessity located near the railroads. There are perhaps twenty points at which the coal is mined for shipment, among which are Petersburg, Ayrshire, Littles, Oakland City, Cabel, Boonville, De Forest, and Chandler. The small mines, frequently only strippings, are especially numerous north and northeast of Winslow, south of Augusta, west of Stendal, north and northeast of Scalesville, between Scalesville and Folsomville, and between Folsomville and Boonville.

Lower coals.—The coals below the Petersburg bed in the Ditney quadrangle are of relatively little importance. Several of them, however, reach a thickness of 3 feet in places, are usually of a semi-block character, and on the whole are of much better quality than the Petersburg bed. On account of the cheapness of the coal from the latter, however, little attempt has been made to develop the lower beds; and as natural outcrops are very rare, their tracing is attended with much difficulty and uncertainty, and it is only in exceptional cases that their thickness and quality can be determined. While some of the coals may locally thicken to workable beds, it does not seem probable that they will be developed for at least a considerable length of lime. The outcrops of three of the coals, the Survant, Rock Creek, and Holland beds, are shown on the Economic Geology sheet, while on Coal Section sheet 2 are given their thickness and associations at characteristic outcrops.

The Houchin Creek coal, lying between the Petersburg and Survant beds, is exposed in the vicinity of Houchin Creek, Selvin, and Hemingway, as well as at other places. Its thickness is variable, reaching in places 18 inches, and it is almost invariably overlain by black, sheety, bituminous shale like that overlying the Petersburg coal. The Survant coal is more important, having a thickness of 5 feet in the knobs near Gentryville, at the southeastern portion of the area, but is usually not over 3 feet thick. It is a semi-coking coal, and is characteristically overlain by a massive sandstone or by a light-colored shale that breaks into rhombs. At one point near Survant the interval is only 6 feet between this coal and the coal above, but as a rule the space is at least 30 feet. The Survant coal is probably the same as the Garrison coal north of Tennyson, the Taylor coal at Selvin, the Corn coal north of Stendal, the Miller coal west of Pikeville, the coal under the bridge at Survant, and the Hollenburg coal southwest of Velpen.

A short distance below the Survant coal is the Velpen coal, one of the most persistent beds in the region. It is frequently spoken of as "the 18-inch vein," as it maintains that thickness with great persistency. It is characteristically covered with a black, bituminous, sheety shale, above which there is often a foot or two of limestone. The interval between it and the Survant coal runs from 25 to 60 feet, the space being, as far as seen, all shale, with the exception of the black shale and the limestone over the lower coal and the clay under the coal above. The Velpen coal is abundantly exposed around Velpen, at Pikeville, northeast and south of Selvin, and southwest of Heilman, and is probably the coal occurring just east of Grass. Around Selvin it is reported in a number of places to be underlain at a distance of only a few feet by 3 feet of coal of poor quality. At no place was this underlying coal seen. One or two thin bands of impure coal are reported to come between the two in places. The lower coal may be the Rock Creek coal of the general section, but where that coal was seen it was usually at least 30 or 40 feet below the Velpen coal. The Rock Creek coal is of better thickness than the Velpen, often running up to 3 feet. It sometimes, however, splits into two benches, usually not more than a foot apart and often separated by a mere film, though it is supposed to be in places split into benches 5 or 6 feet apart. There appears to be considerable sandstone above the coal, sometimes coming down onto its roof. It outcrops as a double coal southeast of Velpen and northeast of Pikeville. Southeast of Pikeville and northwest of Zoar the parting is not so thick. It is double west of Holland, and usually appears to be broken up in Warrick and Spencer counties.

The Holland coal is often thin or wanting, but in places it acquires workable thickness. A mile south of Duff it is reported in a well to be 3 feet 4 inches thick, and to be overlain by 3 feet of blue, flinty limestone and underlain by 60 feet of sandstone. The cherty limestone which occurs with the coal can be traced along the eastern limits of the quadrangle and as far east as Dale, where it is underlain by 3 feet of coal. The limestone outcrops abundantly southeast of Holland, but the coal, if there, frequently fails to show in outcrop.

The coal underlying the Holland coal at an interval of about 100 feet does not appear to outcrop anywhere in the quadrangle. The coal above it has been opened along Birch Creek, and is probably one of the coals found along the Patoka River northeast of Duff. In the locality of the section given in the description of the Petersburg formation, a 2-inch parting occurs 1 foot from the top. At one point on Birch Creek this coal has a thickness of 3 feet, with an inch parting 14 inches from the top. The upper part of the coal is a sulphurous, caking coal, but the lower bench is reported to be of a good semi-block character. At this point the coal has 14 feet of hard, sheety shale over it, and it is thought to correspond to a coal found abundantly a little farther east, with limestone over it.

ECONOMIC PRODUCTS OTHER THAN COAL.

Natural gas.—A considerable pool of natural gas was struck in the "Jumbo" gas well near the Woolley coal mine at Petersburg, but, although considerable drilling was done about Petersburg and at other points within the quadrangle, no other commercial pools were developed. The "Jumbo" well, after flowing for a time, ceased to produce. It has since been cleaned out and supplies several hundred stoves in the town, and shows a rock pressure of 585 pounds. A new well in the same vicinity is now being drilled. It is possible that similar if not greater pools may occur elsewhere in the quadrangle, but their position can not be predicted in advance of drilling. The positions which are geologically the most favorable for wells are the low anticlinal swells, and the areas along strike lines just east of the points at which the westward dip changes from flat to steep. These localities can be roughly determined from the structure contours of the Economic Geology sheet.

Deep wells at Princeton, a few miles west of the quadrangle, and also in the vicinity of Birdseye, east of the quadrangle, have struck small quantities of both gas and oil, the latter sometimes carrying large amounts of asphaltic material.

Fire clay.—The clays of the coal-bearing rocks of Indiana have been investigated by W. S. Blatchley, State geologist, and the results were published in the Twentieth Report of the department of geology and natural resources. The following discussion is based mainly on that report.

Fire clays 3 to 8 inches in thickness are associated with the coals at numerous points about Petersburg, but are best developed north of the town and a short distance outside the limits of the quadrangle. On the land of Hosea Alexander, however, in the NE. $\frac{1}{4}$ sec. 4, T. 1 S., R. 8 W., a shaft showed 3 feet 4 inches of fire clay with numerous *Stigmaria.* Tests made at the brick yards at Petersburg showed it to make refractory brick of good grade.

No fire clay of importance has been reported from the portion of Dubois County lying within the limits of the quadrangle, but in the ravines running back from the Patoka River and its larger tributaries in the southeastern portion of Pike County there is a fire clay from 4 to 6 feet in thickness associated with the coal. It is light gray, siliceous, and suitable for making fire brick. Used with a soft gray shale overlying the coal, it makes a vitrified brick of superior grade.

Near Oakland City fire clay is reported as present below both coals. In the J. D. Johnson shaft, southwest of the town, the Petersburg coal is reported to be underlain by 8 feet of dark-gray fire clay, which is said to have furnished good fire brick for use at the mines. At the quarry 1 mile west of the town at least 4 feet of fire clay occurs just below a 2-foot bed of coal.

The clay beneath the Petersburg coal in the vicinity of Boonville contains a rather high percentage of alkalies, which act as fluxes, causing it to fuse to a black, porous mass. At the brick yards north of the town there is a soft shale which if ground and mixed with the siliceous surface clay (loess) would probably prove suitable for vitrified products and hollow brick.

In the portion of Vandenburg County lying within the quadrangle there are no important outcrops of coal, the Petersburg and Millersburg veins, with their associated clays, being some distance below the surface. Spencer County affords no important outcrops of fire clay within the area under discussion, but fire clays are associated with the coal at Lincoln City, 4 miles east and 1 mile north of Gentryville, and just outside the limits of the quadrangle.

Brick clay.—Clays used for making drain tiles and common building brick are obtained from the loess, from the tills, and from disintegrated shales. Two yards using the loess are located at Francisco, considerable quantities of drain tiling and some bricks being turned out annually. The clay is used just as it comes from the pit, no material, either sand, pebbles, or crushed brick, being added. Brick yards, also using the loess without the addition of any material, are operated at Oakland City and at Boonville. The works are run only a few months of the year, the output of the yards probably averaging from 500,000 to 1,000,000 bricks each, most of which are used in the adjacent towns or in the immediate vicinity.

In the southern part of the town of Petersburg is a brick yard which obtains its supply from the embankments of the abandoned canal. The material is apparently a mixture of loess, sand, and till, the sand being present in considerable amounts. Pebbles are not common. The output of the yards is said to average 800,000 bricks annually, most of which are used in and about Petersburg.

One or two brick kilns using the disintegrated shales are occasionally run at points in the eastern half of the quadrangle to supply local demands. In a few places shales were seen that seemed to give promise of being suitable for the manufacture of paving brick, tiles, etc. The shales occur most commonly above the second coal, below the Petersburg vein, and have been noted at several points west of Cup Creek (west of Pikeville), and at the Taylor mine at Selvin. So far as known no tests of the clay have been made.

Sandstone.—The sandstones of the region are usually shaly or thin bedded, but a few thick beds of massive character were noted. They are very soft and work easily, but harden somewhat upon exposure to the weather. They are used only locally. Considerable amounts have been quarried at a point about a mile west of Oakland City, where the sandstone occurs as a massive bed about 30 feet in thickness. A quarry about a mile south of Union has also furnished considerable quantities, while smaller amounts have been quarried at a number of other points in the quadrangle.

Limestone.—Thin limestones, usually not more than 5 or 10 feet in thickness, are common in the Ditney quadrangle. As a rule they are not persistent, but the one associated with the Millersburg coal is found to occur over a large area in the central portion of the quadrangle. Rather thick limestones are found on the knobs near Somerville, Lynnville, and on the Ditney Hills, but they underlie only very limited areas.

The colors on fresh surfaces are usually gray to dark bluish gray or almost black. The limestones are frequently fossiliferous, and are rather pure. They weather gray or yellowish. They do not work readily, and on weathering give a very undesirable color, and are consequently little used for building. Neither are they burned for fertilizer, as the soil is ordinarily sufficiently calcareous without the addition of lime. Their character is such that they could be used for road metal, but they are too thin to be worked profitably on a small scale, it being cheaper to ship crushed limestone from the large quarries located on the thick limestones of the Lower Carboniferous rocks farther east in the State.

Iron ores.—Several of the shale beds carry carbonate of iron in the shape of concretions or "blak banded ore," and beds of limonite of the bog-ore type, a foot or more in thickness, were noted at a few points. Bog ore covering a considerable area and still in process of formation was noted in the vicinity of a spring on the land of James Barker, near the north-south line between secs. 31 and 32, T. 1 N., R. 8 W. ($3\frac{1}{2}$ miles southwest of Petersburg), and probably similar ores occur at other points. There is no likelihood that any of the ores will become of economic value in the near future.

Glass sand.—In a few places, as southwest of Whiteoak and northeast of Velpen, white sandstones, possibly suitable for glass making, were noted.

Mineral waters.—A considerable number of the deeper wells penetrating the rock get water that is charged with ferrous sulphate ($FeSO_4$), known as "copperas water," but this type of water is not confined to the consolidated rocks. Springs issuing from the till plain on the property of James Barker, southwest of Petersburg, the exact location of which was given under the heading "Iron ores" above, not only taste strongly of $FeSO_4$ but are surrounded by a surface deposit of bog iron ore. A well nearby did not strike rock until a depth of nearly 100 feet was reached.

Strong mineral springs also occur at Degonia and Ash Iron Springs, in the southeastern portion of the quadrangle. An analyses of the water of the former showed the presence of the sulphates of potash, soda, alumina, and magnesia, phosphate of lime, chloride and carbonate of iron, carbonic acid, silicic acid, and free carbonic acid. The water is supposed to possess valuable medicinal properties, and a large hotel has been built at the springs for the accommodation of visitors. Another hotel is at Ash Iron Springs, a little over a mile south of the former.

SOILS.

The soils of the Ditney quadrangle may be divided into five groups: (1) Soils of the river bottoms; (2) soils of the terraces or second bottoms; (3) loess; (4) till or bowlder drift; and (5) residual soils. Each will be considered in turn.

Soils of the river bottoms.—In this group is included the soils of the lowest portion of the bottom lands, or those subject to at least annual overflow. In the quadrangle they are best developed along the Patoka River, where they reach a breadth of several miles in places. Similar flats also border Pigeon, Little Pigeon, Bluegrass, and Cypress creeks and other streams. The soils generally consist of clay or almost impalpably fine sands, are whitish in color and "cold," being saturated with water in the winter and spring months and parched by drought in summer. Although portions of the bottom lands have long been under cultivation, large areas still remain forested, the most common timber being elm, red maple, and gum; but where a considerable portion of sand is present beech, sugar maple, overcup oak, and tulip trees also occur. Within the last few years somewhat extensive areas have been reclaimed for agricultural purposes by drainage ditches.

Soils of the terraces or second bottoms.—The soils of this group are limited principally to a narrow belt along the south side of White River west of Petersburg. They are composed of a medium-grained sand deposited by the river during the Wisconsin stage of the glacial invasions. They are much coarser in texture than the soils of the river bottoms, and not being subject to overflow are not so wet and cold as the former. The dune sands southwest of Petersburg may be placed in this group. Wheat seems to be the principal crop.

Loess soils.—Where undisturbed the loess soils are buff in color, but under cultivation rapidly assume an ash-gray color and become more compact in texture. South of the Patoka River they frequently exhibit a strong red tinge in their lower portions. They occur over practically the entire surface of the uplands, and afford some of the best soils of the area. The broad loess-covered flats marking the top of the till plain in the northwestern portion of the quadrangle and the deposits of glacial Lake Patoka in the northeastern portion afford large crops of wheat. The moderately rolling portions are devoted to wheat, corn, and tobacco, five-eighths of the total product of tobacco in Indiana coming from the rolling or bottom lands of Spencer and Warrick counties. The tree growth includes walnut, sugar maple, wild cherry, pawpaw, and many other kinds.

Till or bowlder-drift soils.—Though underlying the loess over broad areas in the northern part of the quadrangle, it is only on the steep hillsides or the sides of ravines that the loess has been removed. The slopes composed of soils of this type are usually too steep for cultivation, and are covered with a growth of wood similar to that on the loess soils.

Residual soils.—As in the case of the till, it is only where the slope of the land is so steep that the coating of loess has been removed that soils of the residual type occur at the surface, though they are everywhere present beneath the loess outside the limits of the till sheet. They are composed of a heterogeneous mixture of sand, clay, and fragments of rock, and have resulted from the disintegration and decay of the underlying rock at a period before the loess was deposited. Like the till soils, they are generally covered with a growth of wood.

WATER SUPPLY.

Taken as a whole, there is in the Ditney area a shortage in the water supply during the summer months. All but the main streams are dry throughout a considerable portion of the year, and springs are far too few to supply the needed water. Dependence is therefore placed on wells and cisterns, with varying results. On the river bottoms, though the surface is frequently parched, water can usually be obtained within 15 feet of the surface, and large supplies can frequently be had by driving 75 to 100 feet in the soft silts and sands. Except possibly in rare instances, no irrigation is attempted, however. The water is generally of good quality.

Although the loess undoubtedly holds large quantities of moisture, its compact, clayey texture and the complete absence of sandy layers prevents the easy passage of water through it, and it is only in relatively rare instances that water in any amount can be obtained from it. The glacial till is more gravelly, and frequently good flows are obtained, but the water is usually hard.

Much of the surface rock throughout the quadrangle is sandstone, and this frequently affords good supplies of water of satisfactory quality. In many instances, however, the water does not occur throughout the sandy stratum in which it is found, but only in rather definite channels, one well often obtaining a good supply, while another but a short distance away fails entirely. The quality of the rock water is very variable. Some of it, as has been noted, is of excellent quality, but much of it is hard, and "copperas water" (water containing $FeSO_4$) is very common.

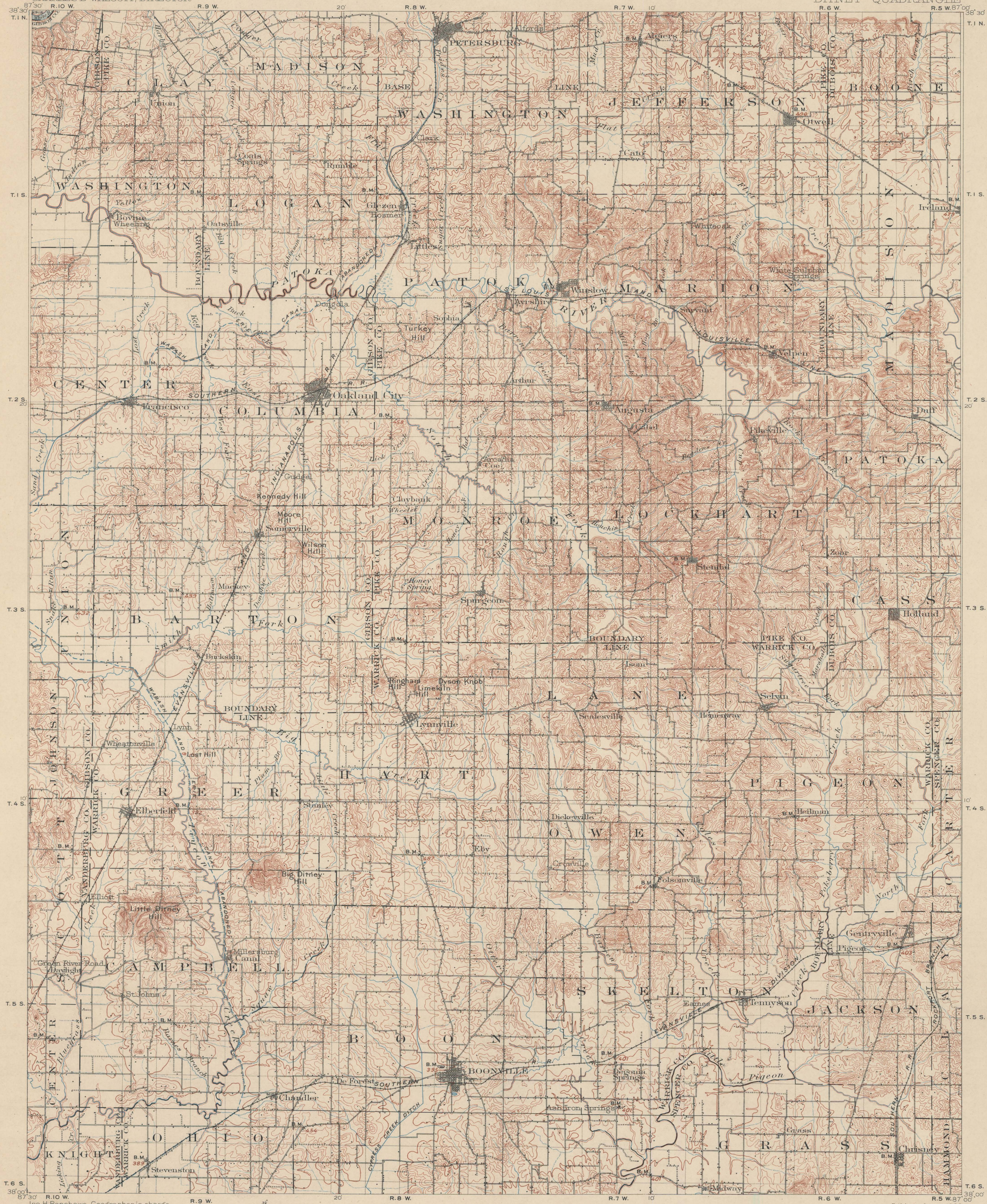
Wells in the rock on narrow ridges or on the edges of steep bluffs are usually dry throughout several months each year, and many of the shallower wells in other situations, in both rock and till, are dry at times. Cisterns are used in many instances, but the supply is small and is insufficient for any but domestic purposes, and hauling is not uncommon.

September, 1902.

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

TOPOGRAPHY

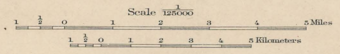
INDIANA
DITNEY QUADRANGLE



Jno. H. Renshawe, Geographer in charge.
Control by Geo. T. Hawkins.
Topography by H. B. Blair, R. C. Mc. Kinney,
and Chas. W. Goodlove.
Surveyed in 1899-1900 and 1902.

APPROXIMATE MEAN
DECLINATION 1902

Scale $\frac{1}{125000}$



Contour interval 20 feet.
Datum is mean sea level.

Edition of Nov. 1902.

LEGEND

RELIEF
(printed in brown)

- 487 Figures *(showing heights above mean sea level instrumentally determined)*
- Contours *(showing height above sea, horizontal form, and steepness of slope of the surface)*
- Depression contours

DRAINAGE
(printed in blue)

- Streams
- Intermittent streams
- Canals and ditches
- Lakes and ponds
- Marshes

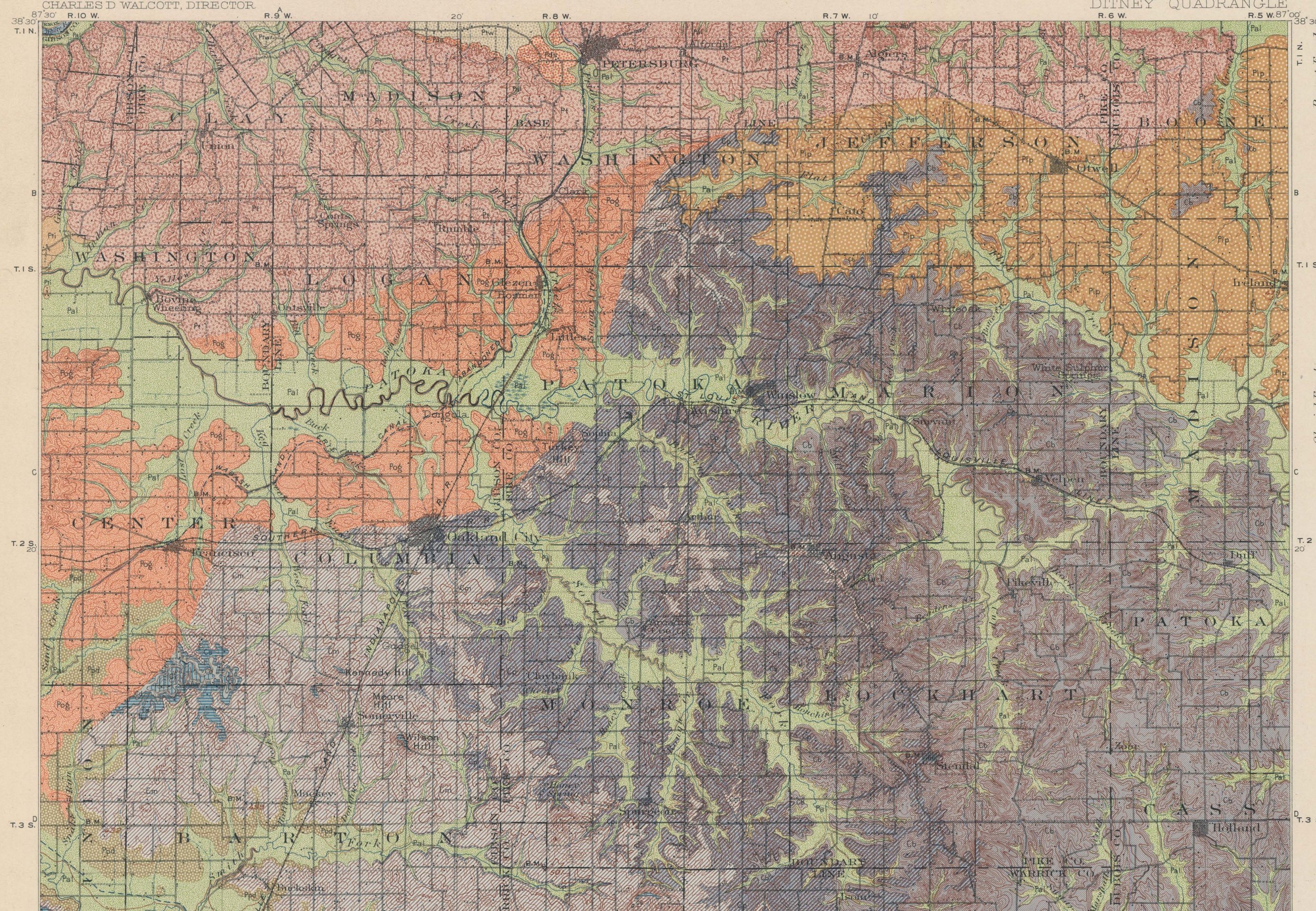
CULTURE
(printed in black)

- Roads and buildings
- Churches and school houses
- Private and secondary roads
- Railroads
- U.S. township and section lines
- County lines
- Township lines
- Land grant lines
- B.M.x Bench marks

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

AREAL GEOLOGY

INDIANA
DITNEY QUADRANGLE



LEGEND

SURFICIAL ROCKS

(Areas of Surficial rocks are shown by patterns of dots and circles)

PLEISTOCENE

Recent Epoch

Pal
Recent alluvium
(reworked loess and fine sand, generally underlain by alluvium of glacial age)

Glacial Epoch

Wisconsin Stage

Pds
Dune sand
(wind blown sand)

Ptw
Terrace sand and gravel
(remnants of fluviatile deposits of Wisconsin age)

Iowan Stage

Loess
(fine silt, mainly wind deposited, covering all bed rock and all older glacial deposits)

Illinoian Stage

Pti
Older terrace deposits
(remnants of fluviatile silts and sand of late Illinoian age)

Plp
Lake Patoka deposits
(silt, sand, and rarely fine gravel, covered with about ten feet of loess)

Ppd
Lake Pigeon deposits
(mainly silts, deeply covered by loess and alluvium)

Pog
Outwash gravel
(stratified drift in local patches)

Pt
Till
(yellow and red clay till, with pebbles generally small and moderately weathered)

SEDIMENTARY ROCKS

(Areas of Sedimentary rocks are shown by patterns of parallel lines)

CARBONIFEROUS

Pennsylvanian Epoch

Ci
Inglefield sandstone
(massive sandstone)

Unconformity

Cd
Ditney formation
(sandy shale)

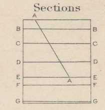
Cs
Somerville formation
(limestone with interbedded shale)

Cm
Millersburg formation
(sandstone, shale, and coal beds; Millersburg coal at the base)

Cp
Petersburg formation
(sandstone, shale, limestone, and coal beds; Petersburg coal, the main workable bed in the area, at the base)

Cb
Brazil formation
(sandstone, shale, limestone, and thin coal beds)

Sections



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Control by Geo. T. Hawkins.
Topography by H. B. Blair, R. C. Mc Kinney, and Chas. W. Goodlove.
Surveyed in 1899-1900 and 1902.

APPROXIMATE MEAN DECLINATION 1902

Scale $\frac{1}{125000}$

Contour interval 20 feet.
Datum is mean sea level.
Edition of Nov. 1902.

M. R. Campbell, Geologist in charge.
Geology by George H. Ashley, Myron L. Fuller, and John D. Irving.
Surveyed in 1900, 1901, and 1902.

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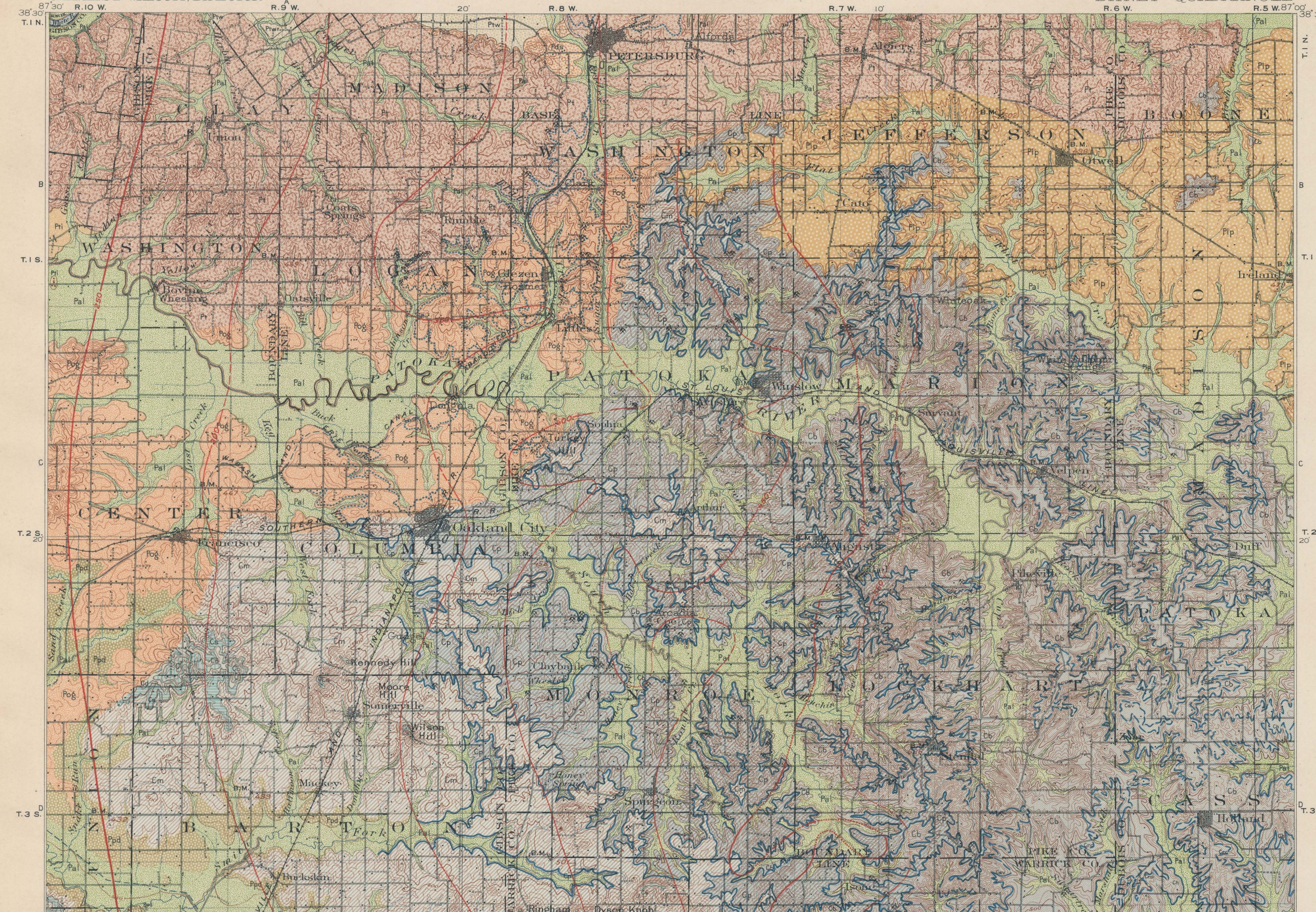
ECONOMIC GEOLOGY

INDIANA
DITNEY QUADRANGLE



Jno. H. Renshawe, Geographer in charge.
Control by Geo. T. Hawkins.
Topography by H.B. Blair, R.C. Mc Kinney,
and Chas. W. Goodlove.
Surveyed in 1899-1900 and 1902.

TRUE NORTH
MAGNETIC NORTH
3½°
APPROXIMATE MEAN DECLINATION 1902

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 Nov. 1902.

Fuller and Irving	Ashley

M.R. Campbell, Geologist in charge.
Geology by George H. Ashley,
Myron L. Fuller, and John D. Irving.
Surveyed in 1900, 1901, and 1902.

LEGEND

SURFICIAL ROCKS

(Areas of Surficial rocks are shown by patterns of dots and circles)

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Recent Epoch

Pal
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(reworked loess and fine sand, generally underlain by alluvium of glacial age)

Glacial Epoch

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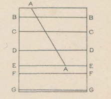
Cb
Brazil formation
(sandstone, shale, limestone, and thin coal beds)

⚒ Coal mines and surface strippings

Sections



Coal beds
(continuous lines indicate known outcrop; dashed lines, calculated outcrop; dotted lines, outcrop beneath glacial drift)

Millersburg coal, base of Millersburg formation
Petersburg coal, base of Petersburg formation
Survant coal (Csv), *in Brazil formation*
Rock Creek coal (Crc), *in Brazil formation*
Holland coal (Ch), *in Brazil formation*

Coal contours
(showing elevation above sea and configuration of Petersburg coal. Contour interval 50 feet. Continuous lines indicate present occurrence of coal; dashed lines indicate that coal horizon, though beneath the surface, may be eroded and replaced by alluvium; dotted lines indicate original position of the coal before removal by erosion)

U. S. GEOLOGICAL SURVEY
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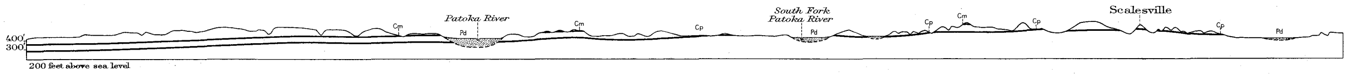
STRUCTURE SECTIONS

INDIANA
DITNEY QUADRANGLE

Section A - A.



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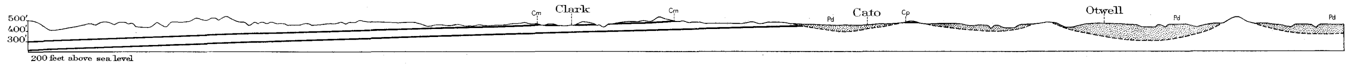

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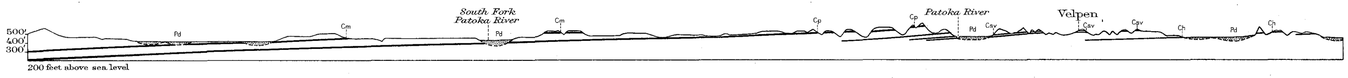

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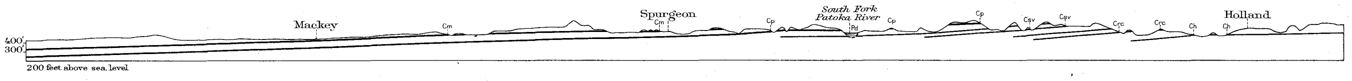
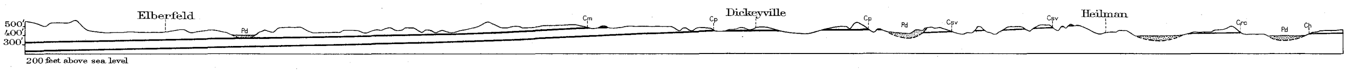
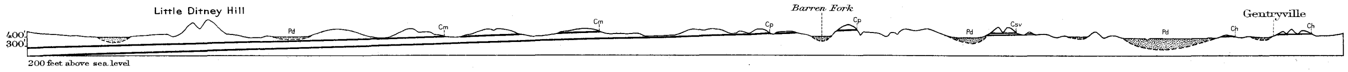


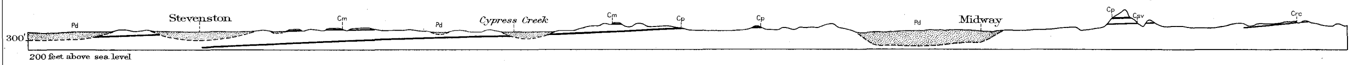
Section E - E.

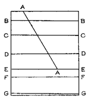


Section F - F.



Section G - G.





Position of sections on geologic maps

Horizontal scale: 1 inch = approximately 2 miles.
Vertical scale: 1 inch = 1000 feet, or approximately 10 times the horizontal.

Pd = *Pleistocene deposits.* Cm = *Millersburg coal, at base of Millersburg formation.* Cp = *Petersburg coal, at base of Petersburg formation.*
Csv = *Survant coal, in Brazil formation.* Crc = *Rock Creek coal, in Brazil formation.* Ch = *Holland coal, in Brazil formation.*

Edition of Dec. 1902.

M.R. Campbell, Geologist in charge.
Geology by George H. Ashley,
Myron L. Fuller, and John D. Irving.
Surveyed in 1900, 1901, and 1902.

COLUMNAR SECTIONS

COLUMNAR SECTION FOR THE DITNEY QUADRANGLE.

SCALE: 1 INCH = 100 FEET.

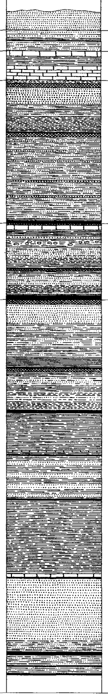
PERIOD.	FORMATION NAME.	SYMBOL.	COLUMNAR SECTION.	THICKNESS IN FEET.	CHARACTER OF ROCKS.
CARBONIFEROUS	Inglefield sandstone.	Ci		20+	Massive sandstone with thin shale partings.
	Ditney formation.	Cd		20	Sandstone and sandy shale with a thin coal bed.
	Somerville formation.	Cs		30	Limestone with interbedded shale.
	Millersburg formation. (Millersburg coal.)	Cm		150	Upper portion, sandstone, sandy shale, and shale with thin beds of coal and fire clay. Lower portion, alternating thin sandstones and sandy shales with the Millersburg coal at the base.
	Petersburg formation. (Petersburg coal.)	Cp		80	Alternating sandstones and shales with a persistent bed of limestone at the top, the Petersburg coal at the base, and an occasional intermediate thin coal.
	(Houchin Creek coal.) (Survant coal.) (Velpen coal.) Brazil formation. (Rock Creek coal.) (Holland coal.) (Coals of Daviess County.)	Cb		300	Alternating shales and thin sandstones with an occasional thin limestone and several coal beds. Massive sandstone at the top of the formation and below the Holland coal.

TABLE OF FORMATION NAMES.

AGE.	NAMES AND SYMBOLS USED IN THIS FOLIO.		ASHLEY: INDIANA GEOLOGICAL SURVEY, TWENTY-THIRD ANNUAL REPORT, 1898.
CARBONIFEROUS	Inglefield sandstone.	Ci	Merom sandstone, Coal Measures, Division IX.
	Ditney formation.	Cd	Coal Measures, Division VIII.
	Somerville formation.	Cs	
	Millersburg formation.	Cm	Coal Measures, Division VII.
	Petersburg formation.	Cp	Coal Measures, Divisions V and VI.
	Brazil formation.	Cb	Coal Measures, Divisions II (in part), III, and IV.

TABLE OF COAL NAMES.

NAMES USED IN THIS FOLIO.	ASHLEY: INDIANA GEOLOGICAL SURVEY, TWENTY-THIRD ANNUAL REPORT, 1898.	COX, COLLETT, ETC.: INDIANA GEOLOGICAL SURVEY, REPORTS 1-14, 1869-1884.
Millersburg coal.	Coal VII.	Coal N (sometimes M).
Petersburg coal.	Coal V.	Coal M (sometimes L).
Houchin Creek coal.	Coal IIIb, and others.	Letters A to K were given to the coals below the principal bed (M), but the usage varied at each locality.
Survant coal.	Coal IV.	
Velpen coal.	Coal IIIb.	
Rock Creek coal.	Coal IIIa, IIIb, and others.	
Holland coal.	Coal III in part.	

SECTION IN JUMBO GAS WELL, PETERSBURG.

SCALE: 1 INCH=100 FEET.

PERIOD.	FORMATION NAME.	SECTION.	THICKNESS IN FEET.	WELL RECORD.
PLEISTOCENE	Loess, stratified drift, and till.		37	Clay and sand.
CARBONIFEROUS	Petersburg formation.		11	Blue and yellow limestone.
			13	Coal (Petersburg) and shale.
	Brazil formation.		49	Shale.
			1	Hard rock.
			4	Coal.
			30	Shale.
			2	Coal.
			23	Shale.
			3	Hard sandstone.
			7	Sandy shale.
			35	Shale.
			10	Cannel coal or shale with streaks of fire clay.
			40	Shale.
			3	Limestone.
			32	Hard sandy shale.
			15	Streaks of limestone and shale.
			60	Shale.
			5	Rock and coal.
	Mansfield sandstone ?		44	Dark and light shale.
	Kaskaskia formation. Mitchell limestone. Oolitic limestone. Harrodsburg limestone.		202	Streaks of limestone and shale.
	Knobstone sandstones and shales.		51	Sandy limestone.
			31	White sandstone.
			8	Shale.
			45	White sandstone.
DEVONIAN	New Albany shales.		24	Black shale.
			20	White shale.
			17	Black shale.
	Hamilton formation.		4	Hard limestone.
			14	Blue limestone.
			18	Dark shale.
			8	Light shale.
			24	Limestone and shale.
	Corniferous formation.		30	Limestone.
			7	Shale.
			7	Hard sandstone (strong flow "Blue Lick" water).
			2	Shale.
			9	Hard sandstone.
SILURIAN	Lower Helderberg formation ?		35	Limestone.
	Waterlime formation ?		5	Shale.
			7	Limestone.
	Niagara formation.		23	Red marl and shale.
			18	Streaks of limestone and shale.
			19	Limestone.
	Clinton and Medina formations ?		13	Drab shale.
			6	Red marl.
			20	Shale.
	Cincinnati formation.		21	Streaks of limestone and shale.
			24	Limestone.
	Utica shale.		7	Black shale.
			1	Hard sandy rock.
			17	Black shale.

NOTE.—The names below the Brazil formation in this section are those used by the Indiana survey, and exact correlation with the New York section is not intended.

MYRON L. FULLER,
Geologist.

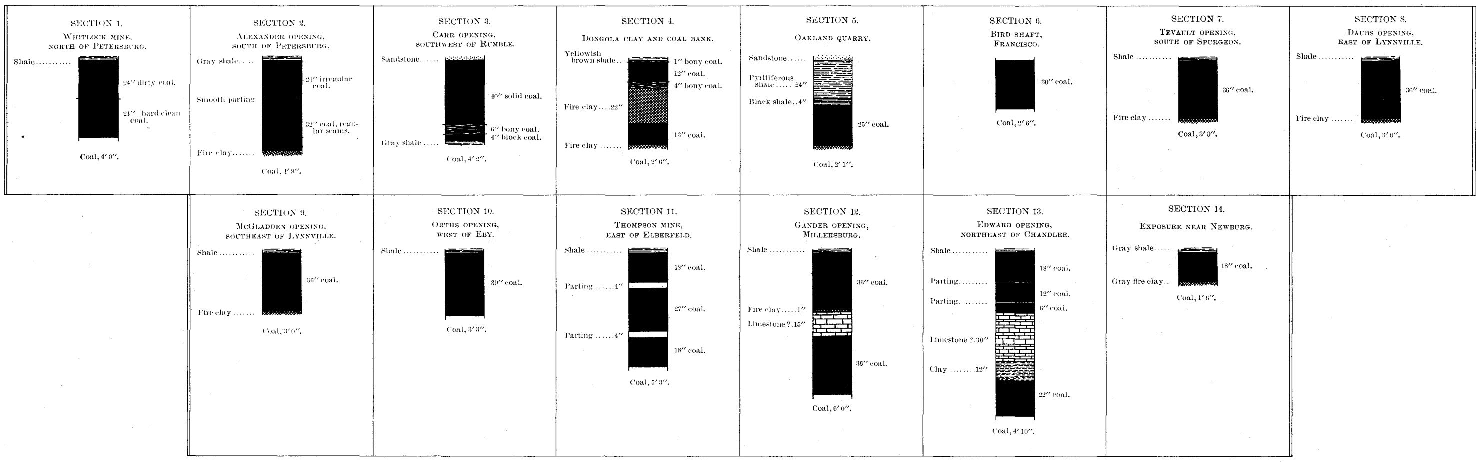
COAL-SECTION SHEET 1

SECTIONS OF COAL BEDS IN THE DITNEY QUADRANGLE AND VICINITY.

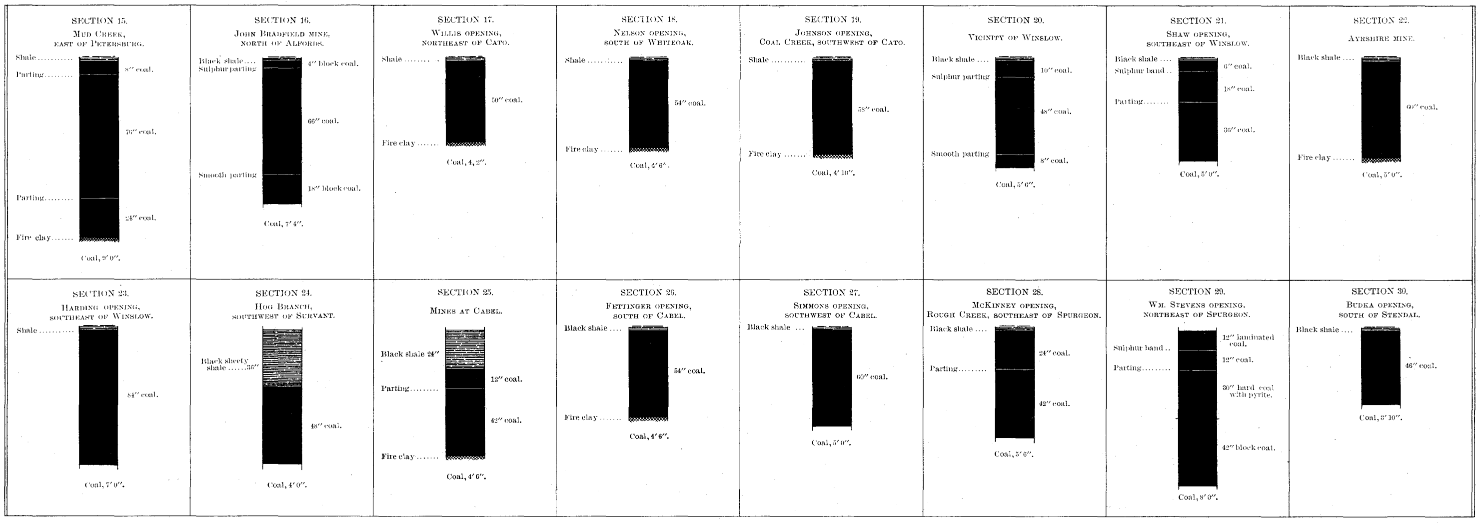
(THE ARRANGEMENT OF SECTIONS IN EACH GROUP SHOWS THE THICKNESS AND VARIATIONS OF THE COAL BED
FROM NORTH, ON THE LEFT, TO SOUTH, ON THE RIGHT.)

SCALE: 1 INCH = 5 FEET.

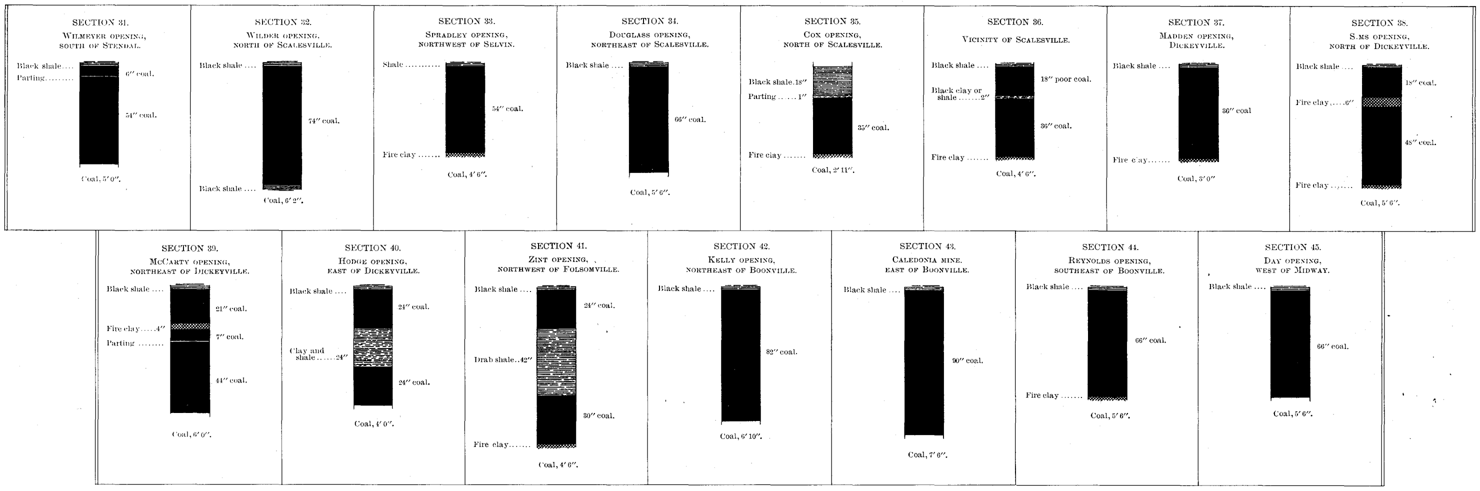
MILLERSBURG COAL.



PETERSBURG COAL, NORTHEAST QUARTER OF THE QUADRANGLE.



PETERSBURG COAL, SOUTHEAST QUARTER OF THE QUADRANGLE.



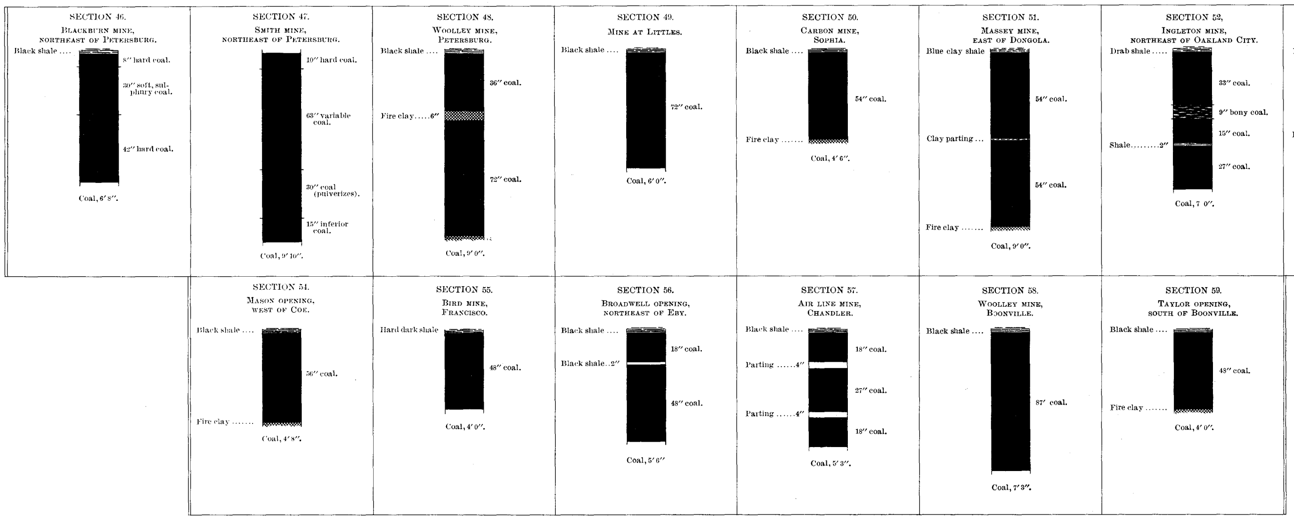
COAL-SECTION SHEET 2

SECTIONS OF COAL BEDS IN THE DITNEY QUADRANGLE AND VICINITY.

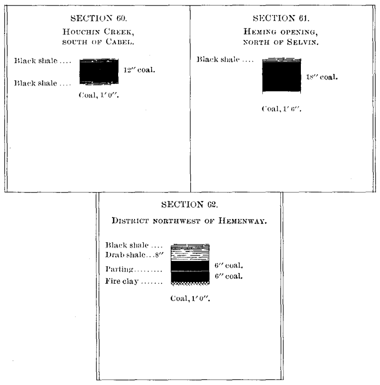
(THE ARRANGEMENT OF SECTIONS IN EACH GROUP SHOWS THE THICKNESS AND VARIATIONS OF THE COAL BED FROM NORTH, ON THE LEFT, TO SOUTH, ON THE RIGHT.)

SCALE: 1 INCH = 5 FEET.

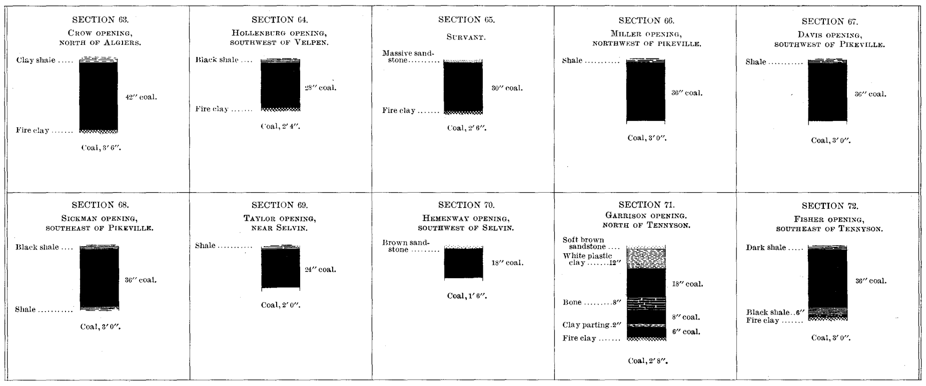
PETERSBURG COAL, WEST HALF OF THE QUADRANGLE.



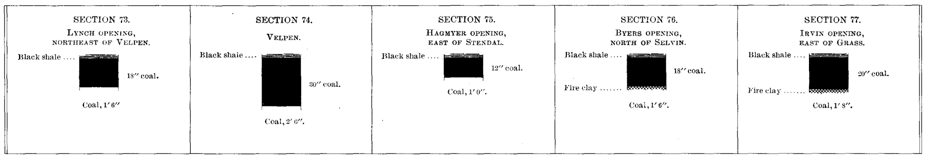
HOUCHIN CREEK COAL.



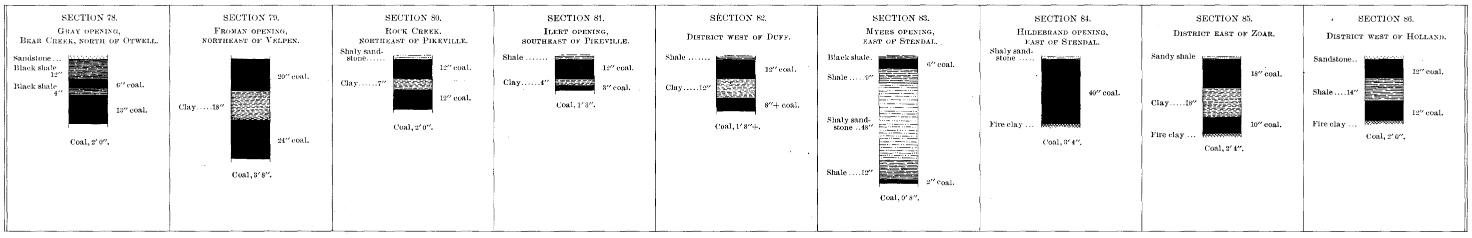
SURVANT COAL.



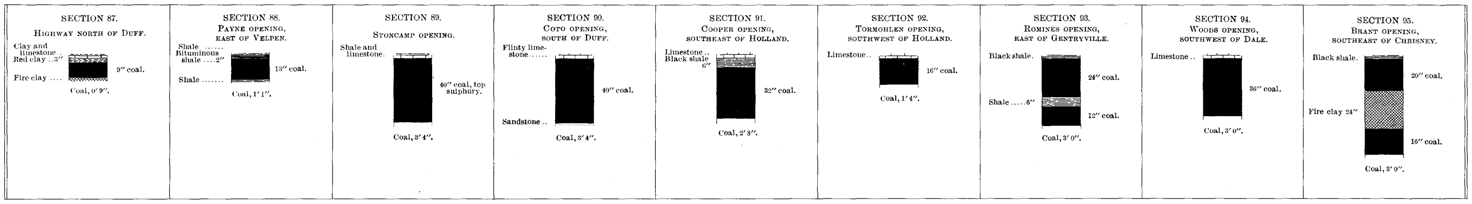
VELPEN COAL.



ROCK CREEK COAL.



HOLLAND COAL.



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