DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

GEOLOGIC ATLAS
OF THE
UNITED STATES

NEW ATHENS-OKAWVILLE FOLIO
ILLINOIS

BY

E. W. SHAW

SURVEYED IN COOPERATION WITH
THE GEOLOGICAL SURVEY OF ILLINOIS

WASHINGTON, D. C.
ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY
GEORGE W. STOSE, EDITOR OF GEOLOGIC MAPS S. J. KUBEL, CHIEF ENGRAVER
1921

GEOLOGIC ATLAS OF THE UNITED STATES.

UNITS OF SURVEY AND OF PUBLICATION.

The Geological Survey is making a topographic and a geologic atlas of the United States. The topographic atlas will consist of maps called *atlas sheets*, and the geologic atlas will consist of parts called *folios*. Each folio includes topographic and geologic maps of a certain four-sided area, called a *quadrangle*, or of more than one such area, and a text describing its topographic and geologic features. A quadrangle is limited by parallels and meridians, not by political boundary lines, such as those of States, counties, and townships. Each quadrangle is named from a town or a natural feature within it, and at the sides and corners of each map are printed the names of adjacent quadrangles.

SCALES OF THE MAPS.

On a map drawn to the scale of 1 inch to the mile a linear mile on the ground would be represented by a linear inch on the map, and each square mile of the ground would be represented by a square inch of the map. The scale may be expressed also by a fraction, of which the numerator represents a unit of linear measure on the map and the denominator the corresponding number of like units on the ground. Thus, as there are 63,360 inches in a mile, the scale 1 inch to the mile is expressed by the fraction $\frac{1}{63,360}$, or the ratio 1:63,360.

The three scales used on the standard maps of the Geological Survey are 1:62,500, 1:125,000, and 1:250,000, 1 inch on the map corresponding approximately to 1 mile, 2 miles, and 4 miles on the ground. On the scale of 1:62,500 a square inch of map surface represents about 1 square mile of earth surface; on the scale of 1:125,000, about 4 square miles; and on the scale of 1:250,000, about 16 square miles. In general a standard map on the scale of 1:250,000 represents a "square degree"—that is, an area measuring 1 degree of latitude by 1 degree of longitude; one on the scale of 1:125,000 represents one-fourth of a "square degree"; and one on the scale of 1:62,500 represents one-sixteenth of a "square degree." The areas of the corresponding quadrangles are about 4,000, 1,000, and 250 square miles, though they vary with the latitude, a "square degree" in the latitude of Boston, for example, being only 3,525 square miles and one in the latitude of Galveston being 4,150 square miles.

GENERAL FEATURES SHOWN ON THE MAPS.

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

Relief.—All altitudes are measured from mean sea level. The heights of many points have been accurately determined, and those of some are given on the map in figures. It is desirable, however, to show the altitude of all parts of the area mapped, the form of the surface, and the grade of all slopes. This is done by contour lines, printed in brown, each representing a certain height above sea level. A contour on the ground passes through points that have the same altitude. One who follows a contour will go neither uphill nor downhill but on a level. The manner in which contour lines express altitude, form, and slope is shown in figure 1.

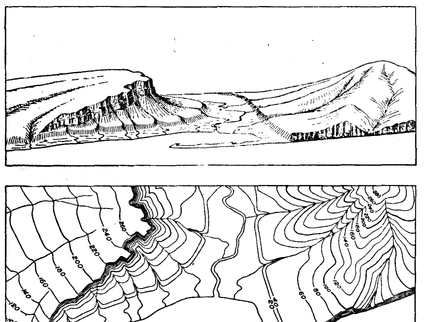


FIGURE 1.—Ideal view and corresponding contour map.

The view represents a river valley between two hills. In the foreground is the sea, with a bay that is partly inclosed by a hooked sand bar. On each side of the valley is a terrace. The terrace on the right merges into a gentle upward slope; that on the left merges into a steep slope that passes upward to a cliff, or scarp, which contrasts with the gradual slope back from its crest. In the map each of these features is indicated, directly beneath its position in the view, by contour lines. The map does not include the distant part of the view.

As contours are continuous horizontal lines they wind smoothly about smooth surfaces, recede into ravines, and project around spurs or prominences. The relations of contour curves and angles to the form of the land can be seen from the map and sketch. The contour lines show not only the shape of the hills and valleys but their altitude, as well as the steepness or grade of all slopes.

The vertical distance represented by the space between two successive contour lines—the contour interval—is the same, whether the contours lie along a cliff or on a gentle slope; but to reach 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 slopes.

The contour interval is generally uniform throughout a single map. The relief of a flat or gently undulating country can be adequately represented only by the use of a small contour interval; that of a steep or mountainous country can generally be adequately represented on the same scale by the use of a larger interval. The smallest interval commonly used on the atlas sheets of the Geological Survey is 5 feet, which is used for regions like the Mississippi Delta and the Dismal Swamp. An interval of 1 foot has been used on some large-scale maps of very flat areas. On maps of more rugged country contour intervals of 10, 20, 25, 50, and 100 feet are used, and on maps of great mountain masses like those in Colorado the interval may be 250 feet.

In figure 1 the contour interval is 20 feet, and the contour lines therefore represent contours at 20, 40, 60, and 80 feet, and so on, above mean sea level. Along the contour at 200 feet lie all points that are 200 feet above the sea—that is, this contour would be the shore line if the sea were to rise 200 feet; along the contour at 100 feet are all points that are 100 feet above the sea; and so on. In the space between any two contours are all points whose altitudes are above the lower and below the higher contour. Thus the contour at 40 feet falls just below the edge of the terrace, and that at 60 feet lies above the terrace; therefore all points on the terrace are shown to be more than 40 but less than 60 feet above the sea. In this illustration all the contour lines are numbered, but on most of the Geological Survey's maps all the contour lines are not numbered; only certain of them—say every fifth one, which is made slightly heavier—are numbered, for the heights shown by the others may be learned by counting up or down from these. More exact altitudes for many points are given in bulletins published by the Geological Survey.

Drainage.—Watercourses are indicated by blue lines. The line for a perennial stream is unbroken; that for an intermittent stream is dotted; and that for a stream which sinks and reappears is broken. Lakes and other bodies of water and the several types of marshy areas are also represented in blue.

Culture.—Symbols for the works of man, including public-land lines and other boundary lines, as well as all the lettering, are printed in black.

GEOLOGIC FEATURES SHOWN ON THE MAPS.

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

KINDS OF ROCKS.

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

Igneous rocks.—Rocks that have cooled and consolidated from a state of fusion are known as *igneous*. Molten material has from time to time been forced upward in fissures or channels of various shapes and sizes through rocks of all ages to or nearly to the surface. Rocks formed by the consolidation of molten material, or *magma*, within these channels—that is, below the surface—are called *intrusive*. An intrusive mass that occupies a nearly vertical fissure which has approximately parallel walls is called a *dike*; one that fills a large and irregular conduit is termed a *stock*. Molten material that traverses stratified rocks may be intruded along bedding planes, forming masses called *sills* or *sheets* if they are relatively thin and *laccoliths* if they are large lenticular bodies. Molten material that is inclosed by rock cools slowly, and its component minerals crystallize when they solidify, so that intrusive rocks are generally crystalline. Molten material that is poured out through channels that reach the surface is called *lava*, and lava may build up volcanic mountains. Igneous rocks that have solidified at the surface are called *extrusive* or *effusive*. Lavas generally cool more rapidly than intrusive rocks and contain, especially in their outer parts, more or less volcanic glass, produced by rapid chilling. The outer parts of lava flows are also usually made porous by the expansion of the gases in the magma. Explosions due to these gases may accompany volcanic eruptions, causing the ejection of dust, ash, lapilli, and larger fragments. These materials, when consolidated, constitute breccias, agglomerates, and tuffs.

Sedimentary rocks.—Rocks composed of the transported fragments or particles of older rocks that have undergone disintegration, of volcanic material deposited in lakes and seas, or of material deposited in such bodies of water by chemical precipitation or by organic action are termed *sedimentary*.

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

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

Most sedimentary rocks are made up of layers or beds that can be easily separated. These layers are called *strata*, and rocks deposited in such layers are said to be *stratified*.

The surface of the earth is not immovable; over wide regions it very slowly rises or sinks with reference to the sea, and shore lines are thus changed. As a result of upward movement marine sedimentary rocks may become part of the land, and most of our land surface is in fact composed of rocks that were originally deposited as sediments in the sea.

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

Metamorphic rocks.—In the course of time and by various processes rocks may become greatly changed in composition and texture. If the new characteristics are more pronounced than the old the rocks are called *metamorphic*. In the process of metamorphism the chemical constituents of a rock may enter into new combinations and certain substances may be lost or new ones added. A complete gradation from the primary to the metamorphic form may exist within a single rock mass. Such changes transform sandstone into quartzite and limestone into marble and modify other rocks in various ways.

From time to time during geologic ages rocks that have been deeply buried and have been subjected to enormous pressure, to slow movement, and to igneous intrusion have been afterward raised and later exposed by erosion. In such rocks the original structural features may have been lost entirely and new ones substituted. A system of parallel planes along which the rock can be split most readily may have been developed. This acquired quality gives rise to *cleavage*, and the cleavage planes may cross the original bedding planes at any angle. Rocks characterized by cleavage are called *slates*. Crystals of mica or other minerals may have grown in a rock in parallel arrangement, causing lamination or foliation and producing what is known as *schistosity*. Rocks characterized by schistosity are called *schists*.

As a rule, the older rocks are most altered and the younger are least altered, but to this rule there are many exceptions, especially in regions of igneous activity and complex structure.

GEOLOGIC FORMATIONS.

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

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

AGE OF THE FORMATIONS.

Geologic time.—The larger divisions of geologic time are called *periods.* Smaller divisions are called *epochs,* and still smaller ones are called *stages.* The age of a rock is expressed by the name of the time division in which it was formed.

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

As sedimentary deposits accumulate successively the younger rest on the older, and their relative ages may be determined by observing their positions. In many regions of intense disturbance, however, the beds have been overturned by folding or their relations to adjacent beds have been changed by faulting, so that it may be difficult to determine their relative ages from their present positions at the surface.

Many stratified rocks contain *fossils,* the remains or imprints of plants and animals which, at the time the strata were deposited, lived in bodies of water or were washed into them or were buried in surficial deposits on the land. Such rocks are said to be fossiliferous. A study of these fossils has shown that the forms of life at each period of the earth's history were to a great extent different from the forms at other periods. Only the simpler kinds of marine plants and animals lived 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 forms that 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. If two sedimentary formations are geographically so far apart that it is impossible to determine their relative positions the characteristic fossils found in them may determine which was deposited first. Fossils are also of value in determining the age of formations in the regions of intense disturbance mentioned above. The fossils found in the strata of different areas, provinces, and continents afford the most effective means of combining local histories into a general earth history.

It is in many places difficult or impossible to determine the age of an igneous formation, but the relative age of such a formation can in general be ascertained by observing whether an associated sedimentary formation of known age is cut by the igneous mass or lies upon it. Similarly, the time at which metamorphic rocks were formed from the original masses may be shown by their relations to adjacent formations of known age; but the age recorded on the map is that of the original masses and not that of their metamorphism.

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

Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea, in lakes, or in other bodies of standing water. Patterns of dots and circles represent alluvial, glacial, and eolian formations. Patterns of triangles and rhombs are used for igneous formations. Metamorphic rocks of unknown origin are represented by short dashes irregularly placed; if the rock is schist the dashes may be arranged in wavy lines parallel to the structure planes. Suitable combination patterns are used for metamorphic formations that are known to be of sedimentary or of igneous origin. The patterns of each class are printed in various colors. The colors in which the patterns of parallel lines are printed indicate age, a particular color being assigned to each system.

Each symbol consists of two or more letters. The symbol for a formation whose age is known includes the system symbol, which is a capital letter or monogram; the symbols for other formations are composed of small letters.

The names of the geologic time divisions, arranged in order from youngest to oldest, and the color and symbol assigned to each system are given in the subjoined table.

Geologic time divisions and symbols and colors assigned to the rock systems.

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

DEVELOPMENT AND SIGNIFICANCE OF SURFACE FORMS.

Hills, valleys, and all other surface forms have been produced by geologic processes. Most valleys are the result of erosion by the streams that flow through them (see fig. 1), and the alluvial plains that border many streams were built up by the streams; waves cut sea cliffs, and waves and currents build up sand spits and bars. Surface forms thus constitute part of the record of the history of the earth.

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

All parts of the land surface are subject to the action of air, water, and ice, which slowly wears them down, producing material that is carried by streams toward the sea. As this wearing down depends on the flow of water to the sea it can not be carried below sea level, which is therefore called the *base-level* of erosion. Lakes or large rivers may determine base-levels for certain regions. A large tract that is long undisturbed by uplift or subsidence is worn down nearly to base-level, and the fairly even surface thus produced is called a *peneplain.* If the tract is afterward uplifted it becomes a record of its former close relation to base-level.

THE GEOLOGIC MAPS AND SHEETS IN THE FOLIO.

Areal-geology map.—The map showing the surface areas occupied by the several formations is called an *areal-geology map.* On the margin is an explanation, which is the key to the map. To ascertain the meaning of any color or pattern and its letter symbol the reader should look for that color, pattern, and symbol in the explanation, where he will find the name and description of the formation. If he desires to find any particular formation he should examine the explanation and find its name, color, and pattern and then trace out the areas on the map corresponding in color and pattern. The explanation shows also parts of the geologic history. The names of formations are arranged in columnar form, grouped primarily according to origin—sedimentary, igneous, and crystalline of unknown origin—and those within each group are placed in the order of age, the youngest at the top.

Economic-geology map.—The map representing the distribution of useful minerals and rocks and showing their relations to the topographic features and to the geologic formations is termed the *economic-geology map.* Most of the formations indicated on the areal-geology map are shown on the economic-geology map by patterns in fainter colors, but the areas of productive formations are emphasized by strong colors. A mine symbol shows the location of each mine or quarry and is accompanied by the name of the principal mineral product mined or quarried. If there are important mining industries or artesian basins in the area the folio includes special maps showing these additional economic features.

Structure-section sheet.—The relations of different beds to one another may be seen in cliffs, canyons, shafts, and other natural and artificial cuttings. Any cutting that exhibits these relations is called a *section,* and the same term is applied to a diagram representing the relations. The arrangement of the beds or masses of rock in the earth is called *structure,* and a section showing this arrangement is called a *structure section.*

The geologist is not limited, however, to natural and artificial cuttings for his information concerning the earth's structure. Knowing the manner of formation of rocks, after tracing out the relations of the beds on the surface he can infer their relative positions beneath the surface and can draw sections representing the probable structure to a considerable depth. Such a section is illustrated in figure 2.

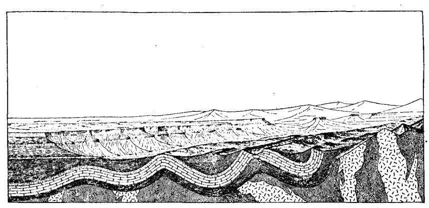


FIGURE 2.—Sketch showing a vertical section below the surface at the front and a view beyond.

The figure represents a landscape that is cut off sharply in the foreground on a vertical plane, so as to show the underground relations of the rocks. The kinds of rock are indicated by appropriate patterns of lines, dots, and dashes. These patterns admit of much variation, but those shown in figure 3 are used to represent the commoner kinds of rock.

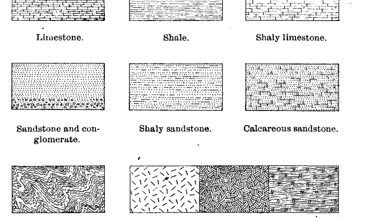


FIGURE 3.—Symbols used in sections to represent different kinds of rock.

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

Where the edges of the beds appear at the surface their thickness can be measured and the angles at which they dip below the surface can be observed, and by means of these observations their positions underground are inferred. The direction of the intersection of the surface of a dipping bed with a horizontal plane is called its *strike.* The inclination of the bed to the horizontal plane, measured at right angles to the strike, is called its *dip.*

In many regions the beds are bent into troughs and arches, such as are seen in figure 2. The arches are called *anticlines* and the troughs *synclines.* As the materials that formed the sandstone, shale, and limestone were deposited beneath the sea in nearly flat layers the fact that the beds are now bent and folded shows that forces have from time to time caused the earth's crust to wrinkle along certain zones. In places the beds are broken across and the parts have slipped past each other. Such breaks are termed *faults.* Two kinds of faults are shown in figure 4.

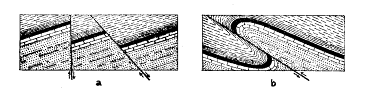


FIGURE 4.—Ideal sections of broken and bent strata, showing (a) *normal* faults and (b) a *thrust* or *reverse* fault.

At the right of figure 2 the section shows schists that are traversed by igneous rocks. The schists are much contorted, and the form or arrangement of their masses underground can not be inferred. Hence that part of the section shows only what is probable, not what is known by observation.

The section also shows three sets of formations, distinguished by their underground relations. The uppermost set, seen at the left, is made up of beds of sandstone and shale, which lie in a horizontal position. These beds were laid down under water but are now high above the sea, forming a plateau, and their change of altitude shows that this part of the earth's surface has been uplifted. The beds of this set are *conformable*—that is, they are parallel and show no break in sedimentation.

The next lower set of formations consists of beds that are folded into arches and troughs. The beds were once continuous, but the crests of the arches have been removed by erosion. These beds, like those of the upper set, are conformable.

The horizontal beds of the plateau rest upon the upturned, eroded edges of the beds of the middle set, as shown at the left of the section. The beds of the upper set are evidently younger than those of the middle set, which must have been folded and eroded between the time of their deposition and that of the deposition of the upper beds. The upper beds are *unconformable* to the middle beds, and the surface of contact is an *unconformity.*

The lowest set of formations consists of crystalline schists and igneous rocks. At some period of their history the schists were folded or plicated by pressure and intruded by masses of molten rock. The overlying beds of the middle set have not been traversed by these intrusive rocks nor have they been affected by the pressure of the intrusion. It is evident that considerable time elapsed between the formation of the schists and the beginning of the deposition of the beds of the middle set, and during this time the schists were metamorphosed, disturbed by the intrusion of igneous masses, and deeply eroded. The contact between the middle and lowest sets is another unconformity; it marks a period of erosion between two periods of deposition.

The section and landscape in figure 2 are ideal, but they illustrate actual relations. The sections on the structure-section sheet are related to the maps in much the same way that the section in the figure is related to the landscape. The profile of the surface in each structure section corresponds to the actual slopes of the ground along the section line, and the depth to any mineral-producing or water-bearing bed shown may be measured by using the scale given on the map.

Columnar section.—Many folios include a *columnar section,* which contains brief descriptions of the sedimentary formations in the quadrangle. It shows the character of the rocks as well as the thickness of the formations and the order of their accumulation, the oldest at the bottom, the youngest at the top. It also indicates intervals of time that correspond to events of uplift and degradation and constitute interruptions of deposition.

THE TEXT OF THE FOLIO.

The text of the folio states briefly the relation of the area mapped to the general region in which it is situated; points out the salient natural features of the geography of the area and indicates their significance and their history; considers the cities, towns, roads, railroads, and other human features; describes the geology and the geologic history; and shows the character and the location of the valuable mineral deposits.

GEORGE OTIS SMITH,
Director.

January, 1922.

DESCRIPTION OF THE NEW ATHENS AND OKAWVILLE QUADRANGLES.

By Eugene Wesley Shaw.

INTRODUCTION.

POSITION AND AREA.

The New Athens and Okawville quadrangles are in southwestern Illinois a short distance southeast of St. Louis and comprise a large part of St. Clair and Washington counties as well as small parts of Monroe and Clinton counties. (See fig. 1.) They lie entirely within the drainage basin of Kaskaskia River, which flows from northeast to southwest across the area. The quadrangles are bounded by parallels 38° 15′ and 38° 30′ and meridians 89° 30′ and 90° and include 468 square miles.

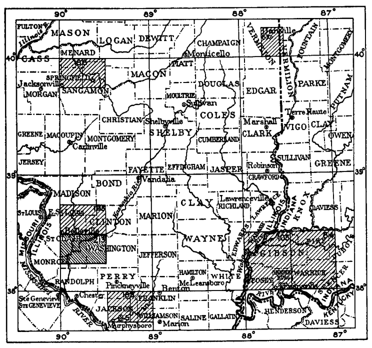


Figure 1.—Index map of southern Illinois and portions of adjacent States.

The location of the New Athens and Okawville quadrangles (No. 213) is shown by the darker ruling. Published folios describing other quadrangles, indicated by lighter ruling, are the following: Nos. 67, Danville; 84, Ditney; 105, Patoka; 185, Murphysboro-Herrin; 188, Tallula-Springfield; 195, Belleville-Breese.

This area lies in a great stretch of rolling plains that has been called the Glaciated Plains, all parts of which have a general geographic and geologic history in common, recorded in the rocks and in the topography.

OUTLINE OF GEOGRAPHY AND GEOLOGY OF THE GLACIATED PLAINS.

Definition.—The Glaciated Plains province (see fig. 2) extends from the Appalachian province on the southeast to the Great Plains on the west, and from the Gulf Coastal Plain on the south to the northern boundary of the United States and beyond it into Canada. It is coextensive with the glaciated area of the Central States except at its western border, which is placed at the 2,000-foot contour, and at its eastern, which is placed at the Pennsylvania-New York State line. The boundary between the Appalachian province and the Glaciated Plains province is not sharply defined, for parts of the typical Appalachian region were covered with ice and parts of the Glaciated Plains have surface features of Appalachian type and origin. Near the middle of the Glaciated Plains there is an area of about 10,000 square miles which was not covered by glacial ice and hence contains no drift. However, in other respects the history of this driftless region is like that of the surrounding territory, and on account of its relatively small size it is here considered as an exceptional part of the Glaciated Plains.

Relief.—The Glaciated Plains province consists in general of a broad rolling plain which is developed on low-lying, nearly horizontal beds of rock, though its surface in different places shows considerable diversity in form. Most of its surface lies 500 to 1,500 feet above sea level, but the low-water surface of the Mississippi at the south edge of the province is only about 300 feet above sea level, and a few places in the Upper Peninsula of Michigan and on the western border of the province in North Dakota rise to a height of about 2,000 feet.

In some parts of the province the range in elevation of the surface is less than 100 feet; in others it is 600 to 800 feet. One of the principal features of the province is the valley of the Mississippi, which is fairly regular in shape and direct in

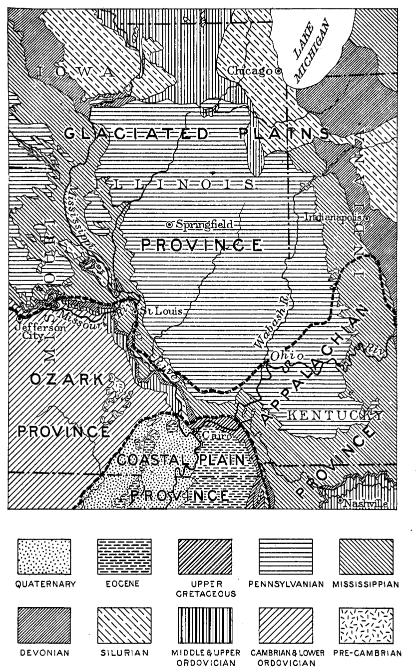


Figure 2.—Generalized geologic map of Illinois and surrounding regions, showing also physiographic provinces.

The indefinite boundary between the Ozark and Appalachian provinces coincides approximately with the southeast boundary of Illinois. Geologic maps copied from map of North America in U. S. Geol. Survey Prof. Paper 71, 1911.

course, flat-bottomed, steep-sided, and generally 3 to 6 miles wide and 200 to 400 feet deep. On the other hand, most of the tributaries of the Mississippi, being less powerful eroding agents, flow in valleys that are irregular in width and depth and have indirect courses. In general the drainage basin of the Great Lakes was originally forested and that of the Mississippi was not, so that about half of the province consisted of prairie land.

Drainage.—The Glaciated Plains include most of the upper Mississippi drainage basin and the southern part of the Great Lakes or St. Lawrence drainage basin, though the southern tributaries of the Ohio and the western tributaries of the Missouri drain parts of adjacent provinces. The run-off of the western, central, and southern parts of these plains flows to the Gulf of Mexico by way of Mississippi River. That of their northern and eastern parts flows into the Great Lakes and thence, after losing part of its volume by evaporation, it passes by way of the St. Lawrence to the Atlantic Ocean. The watershed between these drainage basins is very irregular and indefinite and is so low as to be scarcely perceptible.

Throughout most of the province poorly drained marshes and swamps are common. The streams have irregular courses, and lakes are numerous. The poor drainage was caused by the continental glaciation, during which ice blocked many drainage lines and on melting left a sheet of débris that reached in places a thickness of several hundred feet and filled many of the old valleys. Where the drift was thick its accumulation considerably modified the drainage systems, which are only slowly regaining a more normal condition. Several sheets of till were deposited in as many different stages of glaciation, but an irregular belt along the western and southern sides of the province was not covered by the later glaciers. In this belt the streams have become almost readjusted, so that this area is well drained. Throughout most of the province the streams have irregular courses and profiles and the drainage systems have little symmetry.

The average discharge of the Mississippi at Menard, Ill., about 70 miles below St. Louis, is about 187,000 cubic feet per second. Many careful measurements show that the river carries annually past Menard 142,402,000 tons of sediment and in addition about 52,650,000 tons of material in solution. The surface of the basin above Menard is thus being lowered at an average rate of about 1 inch in 700 years.

Climate and vegetation.—The annual precipitation over most of the Glaciated Plains is 30 to 40 inches, somewhat more than half of which falls in the six months between the end of March and the beginning of October. The rainfall is thus bountiful and fairly well distributed, though in many years droughts are troublesome in August. The mean temperature and the variations in temperature are similar to those of the North Central States.

A rather large part of the Glaciated Plains was once forested with deciduous trees, and the remainder was prairie. In general, the rougher parts—the valley sides and the morainic hills—were forested and the flatter areas were prairie. There are still many small tracts of woodland, and some areas are being reforested, but most of the land is under cultivation.

Stratigraphy and history.—The rocks that underlie the Glaciated Plains are igneous, sedimentary, and metamorphic and range in age from pre-Cambrian to Recent, or from the oldest known rocks to the youngest, but many epochs are unrepresented by beds of rock, and no epoch is represented by a formation that underlies the whole province, for there have been many shifts from deposition to erosion, some of which have involved the whole province.

In earlier geologic time the sea frequently covered a large part of the province and remained long enough to permit extensive marine deposits to be formed. The surface was rarely, if ever, depressed far below sea level or elevated much above it but was affected throughout by gentle and more or less continuous warping, which allowed the sea to advance and retreat irregularly and brought about, from time to time and place to place, not only deposition in the sea and erosion on the land but sometimes, especially in the Pennsylvanian epoch, deposition on the land. Since the end of the Paleozoic era the entire province seems to have remained above sea level and to have been subjected to continuous erosion except in Quaternary time, when it received extensive deposits of glacial drift.

The pre-Cambrian formations are made up of igneous and metamorphic rocks that have a complex structure. Upon their deeply eroded and planed surface rest all the later strata—the shales, sandstones, limestones, and unconsolidated rocks that crop out throughout the province except in that part where the pre-Cambrian rocks themselves lie at or near the surface.

Lower and Middle Cambrian time seems to be unrepresented by deposits in the Glaciated Plains province, but in Upper Cambrian time most of its middle and southern parts received deposits. In the upper Mississippi Valley the Cambrian strata are from 400 to more than 1,000 feet thick and consist principally of sandstone and shale, little limestone seeming to have been formed here or elsewhere in the province in Cambrian time. To the south and west, however, in southeastern Missouri, Oklahoma, and central Texas, the Upper Cambrian rocks include considerable limestone. The rocks of Ordovician age consist mainly of dolomite and limestone but include also two or more sandstone formations, of which the St. Peter is the most widespread. The seashore migrated widely during this period, and the deposits then laid down are now divisible into numerous formations.

The Silurian system is made up of dolomite and limestone and a little shale. Most of the numerous layers were formed in shallow seas, none of which covered the whole province, and all were surrounded by low-lying land. The Devonian system is best represented in the eastern, southern, and western parts of the province, where its thickness is several hundred feet but generally less than 1,000 feet. In the central part of the province the Devonian is thin, and toward the north it is

[1] The area mapped and described in this folio was surveyed under a cooperative agreement between the United States Geological Survey and the Geological Survey of Illinois. Some of the quadrangles in Illinois are being surveyed exclusively by the State Survey, others by the Federal Survey, and in the survey of others both organizations are contributing field or office work. The area here considered has been mapped and this folio has been prepared entirely by the United States Geological Survey, but the analyses of the coals and some additional analytical data have been furnished by the Geological Survey of Illinois.

absent. In western Illinois it consists chiefly of blue fossiliferous limestone overlain in places by black carbonaceous shale. The limestone was deposited in the open sea and the shale perhaps in a shallow part of the sea or perhaps on low-lying swampy land. The area covered by the sea in the early part of the period was small.

In the eastern part of the province the Mississippian series consists of clastic rocks having a thickness of 1,000 feet or more, but in the central and western parts it is made up largely of thick beds of limestone and interbedded lenses of shale and sandstone, having a total thickness of 300 to 800 feet. In the Mississippian as in the preceding epochs the extent and depth of the sea varied considerably and, especially near the close of the epoch, the earth's crust was extensively warped and large bodies of sand were deposited. The Pennsylvanian series is made up largely of rather sandy shale but includes much sandstone and some limestone and coal. The area in which it crops out is larger than that in which any other series of rocks crops out in the province. Many of the beds are lenticular, but some of the beds of coal and limestone can be traced continuously over hundreds of square miles. The conditions in Pennsylvanian time were markedly different from those that prevailed in the preceding epochs, for between periods of occupation by the sea extensive marsh deposits were formed, which have been more or less completely preserved in the form of carbonaceous shale and coal. Traces of the Permian series have been found near Danville, Ill., and large Permian deposits occur also to the southeast, in West Virginia and Ohio, and to the southwest, in Kansas. The Permian series resembles in lithologic character the underlying Pennsylvanian except that it contains less coal and in the western part of the United States is generally reddish. During this epoch most of the Glaciated Plains province seems to have stood above sea level, and much material was carried from it into other areas.

Rocks of post-Carboniferous age, except those of the Quaternary system, are rare in the Glaciated Plains. Throughout Mesozoic and Cenozoic time the region stood considerably above sea level, and the land had sufficient slope to permit practically all the earthy material in the area that was moved at all to be carried out into other areas. The surface of the province has apparently been brought to its present level by several minor uplifts, and there may have been also some subsidence. The record, however, is obscure, because the movements were not great and because the strata are nearly horizontal and of uniform hardness over wide areas, so that it is difficult to distinguish low plateaus due to hard rock from those due to interrupted elevation. Furthermore, the age of features that appear to mark stages of elevation and erosion is uncertain, owing to difficulties in correlating them with deposits of known age. At the times of principal uplift of the Appalachian and Ozark mountains, however, at least the borders of the Glaciated Plains were also uplifted.

The older rocks almost throughout the province are covered with Quaternary deposits, which consist principally of glacial drift—material very different from any previously deposited within the area—but which include also stream, lake, and wind deposits. At several times continental glaciers spread out from the north, bringing into the region great loads of gravel, clay, and sand and remodeling drainage systems.

In certain districts outcrops of the older rocks are numerous, but elsewhere, over whole counties and even groups of counties, the consolidated rocks are almost completely concealed and the mantle of unconsolidated material is several hundred feet thick. Even within the Driftless Area most of the surface is covered either with wind-deposited loess or stream deposits.

Structure.—The structure of most of the consolidated rocks that underlie the Glaciated Plains is comparatively simple. As a rule the strata of the province lie nearly flat, their regularity being broken only by small faults and low, broad folds. The principal exceptions to this rule are the pre-Cambrian rocks that crop out in Wisconsin, Minnesota, and northern Michigan, which are in some places so completely folded, contorted, and faulted that their structure can be discerned with difficulty. Aside from the complex structure of the pre-Cambrian rocks and the local more or less pronounced irregularities, the major structural features are the following:

1. A low, broad arch on the southeast, known as the Cincinnati anticline, which lies in part within the Appalachian Plateau. North of Cincinnati, where it is highest, this arch divides, one branch running toward Lake Erie and the other toward Lake Michigan.

2. A shallow basin that is practically coextensive with the Lower Peninsula of Michigan.

3. Another basin, which occupies most of Illinois and southwestern Indiana.

4. A still broader basin, which extends westward from the Mississippi across Iowa and Missouri into the Great Plains.

5. A broad arch that affects Wisconsin and Minnesota.

The basins contain great coal fields, which are known as the northern interior, eastern interior, and western interior coal fields, and east of the province lies another basin, which contains the Appalachian coal field. In each basin the strata crop out in concentric belts. The youngest beds lie in the middle of the basin and the oldest around the outer border. Thus, for example, beds that lie 1,000 feet above sea level in northern Illinois are more than 3,000 feet below sea level in the south-central part of the State, and if all the beds found in Illinois were extended northward the uppermost would be several thousand feet above the present surface in central Wisconsin. The formation of the domes, basins, and other structural features seems to have begun early in the Paleozoic era, if not before, but the greatest movement seems to have occurred near the end of the Carboniferous period.

TOPOGRAPHY.

RELIEF.

General features.—The New Athens-Okawville district is characterized by comparatively slight relief and gentle slopes. Its altitude is low considering its great distance from the sea, ranging from about 355 feet in the channel of Kaskaskia River, at the southern boundary of the area, to about 650 feet at the hilltops near Rentchler. The area as a whole is rather smooth, but some parts are somewhat rough and others are very flat. In general its central and northeastern parts are considerably lower and smoother than its southern and western parts. The surface features fall into four principal classes—upland prairies, morainic hills, valley sides, and flood plains.

Upland prairies.—Rather flat uplands occupy about one-third of the area and differ from the remainder in being largely prairie. They are remnants of a plain that was formed by the deposition of a nearly flat topped body of glacial till over which a mantle of loess of comparatively uniform thickness was afterward spread. They lie 40 to 80 feet above the streams and about 430 feet in average height above the sea.

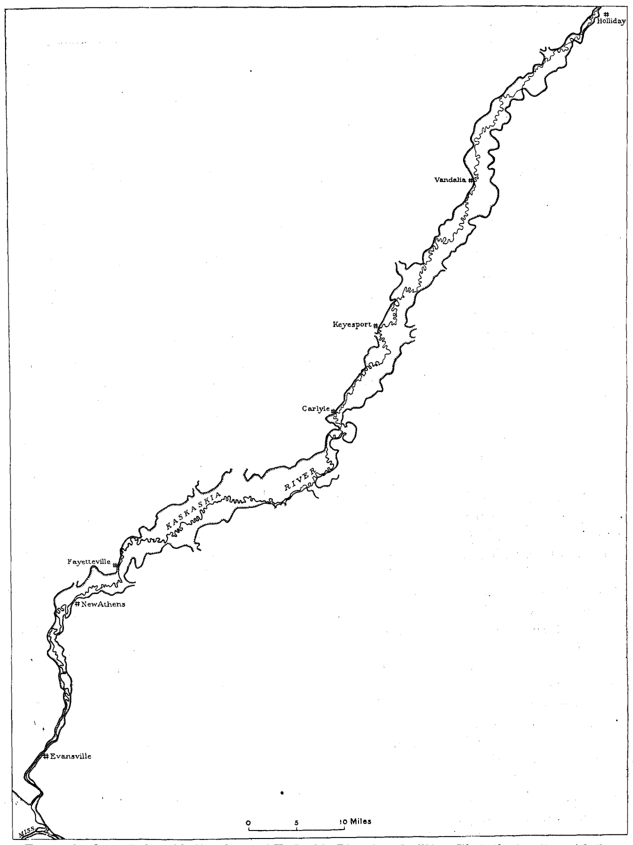


FIGURE 3.—Ground plan of bottom lands of Kaskaskia River from Holliday, Ill., to the junction with the Mississippi.

Shows irregular width of its valley and narrow section near its mouth; also the great length of the river compared with that of its flood plain.

Though the upland areas are almost featureless plains they include, almost throughout their extent, scattered more or less conspicuous low undulations. The borders of the uplands are extremely tortuous, winding back and forth among the valleys and around the ridges that rise above them. They are most extensive in the eastern part of the area, particularly near Okawville and between Venedy and Darmstadt, and they are also conspicuous around Mascoutah and 3 to 8 miles south-southwest of Freeburg.

Morainic hills.—The monotony of the upland plains is broken by hills which here and there rise somewhat abruptly above them. These hills are of many different sizes and shapes. Some of them, such as the two in the northwest corner of the Okawville quadrangle, are small and roundish but rather sharp and stand isolated on the upland. Others of similar size and shape are joined in groups. Some are elongate ridges with sinuate crests, such as Pleasant Ridge, near Freeburg, and Tamarawa Ridge, near New Athens. The trend of most of these ridges ranges from eastward to northeastward. Still others are joined into great irregular masses that cover several square miles, such as Turkey Hill, north of Freeburg, parts of which rise 200 feet above the general upland surface.

Valley sides.—Most of the valleys of the area are less than 100 feet deep, and the breadth of the widest is about 2 miles. In some places, as at a bluff 2 miles southwest of New Athens, the sides of the valley are very steep, and elsewhere, as at Fayetteville, they slope at angles so low that the top and the base are indistinctly defined. The largest valley is that of Kaskaskia River, which is for the most part broad and shallow, though it is here and there somewhat constricted and steep-sided. (See fig. 3.) The walls of this valley are irregular both in course and in slope, being in some places steep and in others very gently sloping. The other valleys of the district are considerably smaller but show similar irregularities.

Flood plains.—The streams of the district have flood plains that range in width from a few hundred feet to a mile or two. The broadest and also the most swampy flood plain is that of Kaskaskia River. It has a rather uneven surface and here and there, particularly near the south border of the area, shows traces of a low terrace. Throughout the flood plain there are scattered elongate depressions, many of which contain intermittent or permanent lakes. The flood plain of the Kaskaskia and the flood plains in the lower courses of many of its tributaries are often deeply covered with water, an occurrence that is perhaps related both to comparatively recent relative downwarp of the earth's crust in the area and to extensive aggradation by the Mississippi. The depressions that contain lakes were once parts of the bed of the stream, and the fact that many of them have not the curved form of typical oxbow lakes may indicate that at the time of their formation the stream was a braided one, with rapidly shifting channels.

DRAINAGE.

The greater part of the area is well drained, but somewhat extensive flood plains, particularly along Kaskaskia River, are subject to frequent overflow, and part of the upland is so flat that the water from heavy rains disappears slowly. The western part of the area is better drained than the eastern, not only because of its generally higher altitude, the greater slope of its surface, and the steeper gradient of the streams but because the loess, which lies immediately beneath the surface in both parts of the area, is more porous in the western part, so that water passes into the ground more readily there than in the eastern part. In the western part also the country is more rugged, because drift ridges are there more abundant.

The run-off of the area passes by way of many small streams to Kaskaskia River, which crosses the area from northeast to southwest. The Kaskaskia joins the Mississippi near Chester, Ill., about 75 miles south of New Athens as the stream flows, at a low-water altitude of 350 feet and a highwater altitude of about 390 feet. At New-Athens the Kaskaskia has a low-water altitude of only about 360 feet, and, the fall being slight, the water passes off slowly, particularly at times of high water. Some of the small streams, however, especially those in the northern and western parts of the area, have considerable fall, and by these the water from heavy rains passes off rapidly. The Kaskaskia, like many other streams in the central Mississippi basin, has very little fall in the lower part of its course, and the water therefore often backs up into tributary valleys at times of flood. Backwater from floods on the Mississippi also often reaches this area. Several plans for protecting areas in the Kaskaskia bottoms by levees have been formulated, and some of these areas that lie a short distance to the north have been reclaimed.

The water of Kaskaskia River comes from a long and rather narrow drainage basin whose upper end is near Champaign, Ill. The length of the basin is about 180 miles and its average width is about 33 miles, so that it covers about 5,880 square miles. The discharge of the river in the New Athens-Okawville district ranges from about 100 to 10,000 cubic feet per second and averages about 4,000. Within or near this area the Kaskaskia receives from the north the waters of Shoal, Sugar, Silver, and Richland creeks and from the south the waters of Plum, Elkhorn, Mud, and Doza creeks. The fall of these creeks is 2 to 5 feet to the mile. It receives also many smaller tributaries, most of which are dry for a part of the year.

In the upland part of the area erosion channels are not well developed and the surface drainage is imperfect. The little intermittent streamlets lie in ill-defined depressions, and here and there throughout their courses are fed by small springs that issue from the contact between the porous loess and the underlying boulder clay and from sandy lenses in the boulder clay.

CULTURE.

The principal towns of the area are Mascoutah, Freeburg, New Athens, Marissa, and Oakdale, which have 1,000 to 2,000 inhabitants each. There are also numerous villages, such as Smithton, Hecker, Lenzburg, Darmstadt, Elkton, St. Libory, Venedy, New Memphis, and Okawville, which have a few hundred inhabitants each.

The area is crossed by two railroads—the Louisville & Nashville, which passes through Mascoutah and Okawville, and the Illinois Central, which runs a little east of south through Freeburg, New Athens, and Marissa. Another railroad, which has been planned for some time and the grade of which has been partly constructed, is to run from Freeburg nearly eastward through St. Libory.

There are many coal mines in this area, particularly along the railroads, and next to farming the coal-mining industry is the largest in the area. The wagon roads average about a mile apart, and most of them run on section lines, but there are several conspicuous exceptions, such as the road which runs from the northwest to the southeast corner of the area, giving direct connection between several towns and villages. The houses along the roads are on an average about half a mile apart, and the farms have an average size of 100 or, say, 150 acres. The schoolhouses are 2 to 4 miles apart, and country churches are numerous.

VEGETATION AND CLIMATE.

More than half of the area, including all the flatter parts of the upland, was originally prairie; the remaining, rougher parts were forested with the hard, medium, and soft wood trees that are common in the northeastern United States. Evergreens are not abundant, however, and several of the trees, such as the gums and the pecan of the river bottoms, are more characteristic of southern forests. There are also several smaller plants, such as small cane, which are southern species. A considerable part of the land has been cleared of its original forest and put under cultivation, but much remains uncleared or uncultivated, and some small tracts are being reforested.

The climate of the New Athens-Okawville district differs from that of other parts of the northeastern United States only in showing somewhat larger and more rapid variations in temperature and a slightly higher average humidity. The annual rainfall is about 45 inches and is fairly evenly distributed throughout the year. The swampy bottom land is malarial, and few people live on it. Indeed, little of it has been cleared of its original forest.

DESCRIPTIVE GEOLOGY.

STRATIGRAPHY.

GENERAL CHARACTER OF THE ROCKS.

The rocks of the New Athens-Okawville district are wholly sedimentary and consist in part of nearly horizontal indurated strata, of Carboniferous age or older (see fig. 4), and in part of unconsolidated surficial deposits of Quaternary age, which nearly everywhere overlie the hard rocks. The hard rocks are known from scattered exposures at the surface and from records of borings for oil, coal, and water, many of which are more than 1,000 feet deep.

Strata of ages ranging from Cambrian to Ordovician, resting on a pre-Cambrian floor of metamorphic rocks such as crop out in the St. Francis Mountains in Missouri, probably underlie the New Athens-Okawville district, for such strata have been penetrated by deep borings at many places in Illinois and crop out in neighboring States. The deepest borings in this region are one at Monks Mound, just east of St. Louis, and one at Mascoutah. They pass through all the thick Pennsylvanian and Mississippian formations and appear to have passed through Devonian and Silurian strata also to the St. Peter sandstone, of the Ordovician system. Samples from many of the strata encountered in these wells have been preserved and have been carefully examined by the writer and others. Sections made up from logs of wells are given on the columnar-section sheet. A few others are described below.

System.	Series.	Formation and group.	Section.	Thickness (feet).	Character of rocks.
Carboniferous.	Pennsylvanian.	McLeansboro formation.		400+	Sandstone and shale, with thin beds of limestone, clay, and coal.
		Carbondale formation.		90-225	Shale and sandstone, with thin beds of limestone, clay, and coal, and thick Herrin coal at the top.
		Pottsville formation.		10-200	Chiefly sandstone, with some clay.
		UNCONFORMITY			
	Mississippian.	Chester group.		30-425	Greenish to reddish shale, compact fine-grained limestone, and sandstone.
		Ste. Genevieve limestone.[a]		75	Oolitic limestone, usually cross-bedded; in few places arenaceous.
		Meramec group. St. Louis and Spergen limestones.		400-500	Pure light-gray limestone, in part oolitic, and some dark limestone.
		Meramec group. Warsaw shale.		60	Chiefly bluish shale.
		Osage group. Keokuk and Burlington limestones.		235	Gray crinoidal limestone, in large part cherty.
		Kinderhook formation.		80	Limestone, in part pink, and red shale.
		UNCONFORMITY[b]			
Ordovician.		Richmond group and Kimmswick limestone.		220	Largely gray to white limestone; some dark shale at top.
		Plattin and Joachim limestones.		660	Dark and light limestone, in part crinoidal, and crystalline and greenish shale.
		St. Peter sandstone.		125	Pure sandstone with rounded grains.

FIGURE 4.—Generalized columnar section of rocks underlying the New Athens and Okawville quadrangles.

[a] Whether Ste. Genevieve limestone should be included in Chester group is undecided by the United States Geological Survey.

[b] Devonian and Silurian systems probably represented by deposits in some localities.

The well in Mascoutah was drilled by Julius Postel and reached a depth of about 3,050 feet. Only a few samples of the drillings have been preserved, but some were examined and described by J. H. Southwell, who has studied many drill cuttings and well records.

Log of Postel Mill well, Mascoutah, Ill.

[Altitude of surface, 425 feet.]

System, formation, and bed.	Thickness.	Depth.
Quaternary system:		
Loess and till (104 feet):	*Feet.*	*Feet.*
Clay	30	30
Quicksand	5	35
Sand, white, compact	5	40
Boulder clay, with gravel 7 feet above base	64	104
Carboniferous system:		
Pennsylvanian series (237 feet):		
McLeansboro formation (41 feet):		
Limestone	8	112
"Lime," hard, coaly	30	142
Limestone	3	145
Carbondale and Pottsville formations (196 feet):		
Coal, Herrin (Belleville, or No. 6)	6	151
Shale	15	166
"Soapstone"	10	176
Shale	25	201
Coal (probably equivalent to Springfield or No. 5)	5	206
Shale, light gray	50	256
Shale, blue	40	296
Shale, light gray	45	341
Mississippian series (1,739 feet):		
Chester group (399 feet):		
Shale, red, sandy ("red rock")	45	386
Shale (?)	154	540
Limestone	5	545
Sandstone	45	590
Shale	25	615
Limestone	20	635
Shale, red, sandy ("red rock")	55	690
Shale, light colored, calcareous, with some sandstone	50	740
St. Louis and Spergen limestones (460 feet):		
Limestone	460	1,200
Warsaw shale, Osage group, and Kinderhook formation (880 feet):		
Shale (?)	420	1,620
Limestone, shaly	390	2,010
Marl, red (Fern Glen limestone member of Kinderhook formation?)	70	2,080
Ordovician and possibly Silurian and Devonian systems (989 feet):		
Limestone	126	2,206
Shale (Maquoketa?)	127	2,333
Limestone	449	2,782
Shale	58	2,840
Limestone	10	2,850
Shale and limestone	48	2,898
Sandstone, clean frosted grains, well rounded, probably St. Peter	171	3,069

The following log is made up from a study of about 100 samples of the rocks penetrated:

Log of well near Monks Mound, Ill.

[Altitude of curb, about 480 feet.]

System, formation, and bed.	Thickness.	Depth.
Quaternary system:		
Alluvium (150 feet):	*Feet.*	*Feet.*
Soil, sand, and gravel	40	40
Sand, fine grained	20	60
Sand, coarse	10	70
Gravel; one worn *Unio* shell	80	150
Carboniferous system:		
Pennsylvanian series ("Coal Measures") (75 feet):		
Shale, gray, slightly calcareous	55	205
Shale, light blue, noncalcareous, in places laminated; a little limestone near top and base	20	225
Mississippian series (790 feet):		
Chester group (90 feet):		
Sandstone, calcareous	5	230
Sandstone, white, compact	5	235
Sandstone, moderately fine grained, friable	65	300
Limestone, shaly, light colored	5	305
Sandstone, gray, fine, light colored	10	315
St. Louis and Spergen limestones (403 feet):		
Limestone, fine grained, compact, white	45	360
Limestone, white, with a little sandstone and shale	20	380
Limestone, grayish white, with a little thinly laminated shale	30	410
Gravel and sand, cemented by laminated iron, with some dark chert in dolomitic limestone	30	440
Limestone, gray, with bluish coarse sand	50	490
Limestone, white, fossiliferous	15	505
Limestone, gray, crinoidal, somewhat bituminous	10	515
Limestone, gray, brecciated	10	525
Limestone, nearly pure, with some chert	65	590
Limestone, fossiliferous	35	625
Limestone, brecciated, fossiliferous, no chert	45	670
Limestone, cherty, fossiliferous	10	680
Limestone, gray, not cherty, fossiliferous, containing some clay. (This bed and probably several overlying beds are Spergen)	38	718
Warsaw shale (62 feet):		
Shale, calcareous, gray	62	780
Osage group (Keokuk and Burlington limestones) (235 feet):		
Limestone, gray, crinoidal, fossiliferous, cherty	10	790
Limestone, cherty, light colored	20	810
Chert, white, and limestone	140	950
Limestone and chert, some having a greenish tinge and some containing organic fragments	15	965
Limestone, dull greenish; one crinoid stem	30	995
Limestone, greenish gray, cherty; some of it dull purple and pinkish[a]	20	1,015
Kinderhook formation, with possibly some Devonian at base (80 feet):		
Marl, pink	30	1,045
Limestone, brecciated, crinoidal	5	1,050
Limestone, green	5	1,055
Limestone, grayish white	15	1,070
Limestone, gray, fossiliferous, with some gray and pink fragments	11	1,081
Limestone, gray	14	1,095
Ordovician system:		
Richmond group and Kimmswick limestone (220 feet):		
Marl, gray, with some marcasite	10	1,105
Shale, dark bluish gray, calcareous, very hard	20	1,125
Limestone, dark gray, shaly, with many grains of marcasite. (This and the two preceding beds probably constitute the Maquoketa shale of the Richmond group)	10	1,135
Limestone, gray, in thick flakes	35	1,170
Limestone, purplish and greenish pink, gritty, crinoidal	25	1,195
Limestone, pinkish, greenish gray, and white	18	1,213
Limestone, dull pink, with some chert	12	1,225
Limestone, magnesian, dull greenish, with pinkish blotches of indistinct outline and many imperfect crinoid stems and other fossils	5	1,230
Limestone, red and reddish and greenish gray, with some white limestone that has a resinous luster	20	1,250
	5	1,255
Limestone, dull pinkish gray		
Limestone, white, compact, with crinoid stems, in places coarsely crystalline	20	1,275
Limestone, slightly fossiliferous, marcasitic	5	1,280
Limestone, nearly white	5	1,285
Limestone, white, crystalline, granular	15	1,300
Limestone, white, with greenish and black specks and a little marcasite	15	1,315
Plattin and Joachim limestones (660 feet):		
Limestone, magnesian, faintly yellowish gray, slightly porous and siliceous	20	1,335
Shale, greenish gray, noncalcareous	55	1,390
Limestone, gray, bituminous, somewhat crinoidal and pyritic	100	1,490
Limestone, white, coarsely crystalline	90	1,580
Limestone, light gray, slightly bituminous	100	1,680
Limestone, dark gray	20	1,700
Limestone, light straw-colored	75	1,775
Limestone, gray, with some pyrite	5	1,780
Limestone, gray to brownish straw-colored	35	1,815
Limestone, brownish gray	160	1,975
St. Peter sandstone (125 feet):		
Sandstone, pure; some of the grains have facets of secondary crystallization, but most of them are rounded, uniform grained	125	2,100

[a] The basal part of this stratum should possibly be classed with the Kinderhook.

The well near Monks Mound was drilled for oil about the year 1903 on a small mound 1,000 feet southwest of the village, northwest of the New Athens quadrangle. Samples of the rocks penetrated were carefully collected by S. L. Shellenberger, of East St. Louis, and presented to the St. Louis Academy of Science. In the log on page 3, made up from a study of the samples, the identification of one or two formations and the exact boundaries of several others are in doubt.

PRE-CARBONIFEROUS ROCKS.

In the well near Monks Mound a sandstone that was entered at a depth of 1,975 feet and penetrated for 125 feet closely resembles the St. Peter sandstone. It has approximately the same stratigraphic position and is therefore correlated with that formation. There appears to be little doubt about the correctness of this correlation, for the St. Peter sandstone is peculiar in that it is composed of well-rounded, poorly cemented grains of clear quartz sand whose surfaces are like frosted glass.

The strata that lie between the St. Peter sandstone and the Mississippian series and the probable identity of the beds are indicated in the foregoing record. Although the Monks Mound well is several miles beyond the northwest corner of the New Athens quadrangle, its log is so complete and satisfactory, because samples of the drillings were carefully collected and preserved, that it is inserted here.

CARBONIFEROUS SYSTEM.

MISSISSIPPIAN SERIES.

LOWER FORMATIONS.

Not much more is known of the lower part of the Mississippian series in the New Athens-Okawville district than is known of the underlying formations, but these lower Mississippian rocks are extensively exposed in the Waterloo and other quadrangles to the west, where they have been carefully studied by Prof. Stuart Weller. The lowermost beds constitute the Kinderhook group, which consists of limestone, sandstone, and shale, the proportions ranging through wide limits.

The uppermost beds of the Kinderhook in this region are composed of a reddish stratum known as the Fern Glen limestone member. This stratum is of considerable value in correlating well records, for it is usually noted by drillers on account of its red color. It also contains an organic fragmental limestone of somewhat characteristic appearance.

Above the Fern Glen limestone lie the Burlington and Keokuk limestones of the Osage group, which are commonly identifiable in wells from their stratigraphic position and their cherty character. They are much more uniform than the Kinderhook beds and consist largely of crinoidal cherty limestone.

The Meramec group, which includes the Warsaw shale and the Spergen and St. Louis limestones, has a total thickness in this region of 460 to 560 feet. The Warsaw is composed chiefly of bluish shale and in most places is readily distinguished from the upper formation of the Osage group, the cherty Keokuk limestone. In the area northwest of the New Athens-Okawville district it is extensively developed, but in this district it is commonly absent and the Keokuk is shaly, so that in well records the strata are difficult to identify. The overlying Spergen limestone is a nearly pure light-gray limestone, which is in places oolitic and in places very fossiliferous, containing many bryozoans. Some of the beds are dolomitic. The St. Louis limestone is composed of light to dark gray, commonly fine-grained limestone, including local beds of shale and shaly limestone. It is better known than the underlying formations because of its extensive outcrop along the Mississippi bluffs and because it is usually noted in well drilling, owing to its thick, resistant, and cherty character. In fact, the well drillers use it extensively as an index stratum, and generally refer to it as the "Mississippi lime." It is about 300 feet thick and is not very fossiliferous. Some of its beds are very brittle and resemble lithographic stone. Very little dolomite has been found in the formation in this region.

The St. Louis limestone is overlain by an oolitic limestone, the Ste. Genevieve, which is generally very pure calcium carbonate. This limestone is comparatively persistent, though it is absent at some places. It crops out in the vicinity of Ste. Genevieve, Mo., about 20 miles south of these quadrangles, and is found in wells drilled at many places in southern Illinois. In the oil fields of the southeastern part of the State it is known as the McClosky sand. It is separated from the underlying St. Louis limestone by an unconformity, as is shown by the uneven surface of the lower formation and the solution channels in that formation, which are filled with oolite. At some places, particularly in its central part, the Ste. Genevieve includes sandstone. Its greatest thickness in the vicinity of these quadrangles is 75 feet. The oolite is commonly cross-bedded and in a few places is arenaceous. The cross-bedding is especially well developed near the base. Whether the formation should properly be inculded in the Chester group is undecided.

CHESTER GROUP.

The Chester group, which constitutes the uppermost part of the Mississippian series of the region, includes the rocks which in southern Illinois and western Kentucky were formerly classified by Ulrich as Cypress sandstone, Tribune limestone, and Birdsville formation. Whether it also includes, at the base, the Ste. Genevieve limestone is undecided. As a result of recent detailed stratigraphic and paleontologic work Prof. Stuart Weller has subdivided the Chester group of the Mississippi Valley region of southern Illinois into the following formations, from the top downward: Kinkaid limestone, Degonia sandstone, Clore limestone, Palestine sandstone, Menard limestone, Okaw formation, Cypress sandstone, Paint Creek formation, Yankeetown chert, Renault formation, and Aux Vases ("Brewerville") sandstone.

The only formation of the Chester group that crops out in the New Athens and Okawville quadrangles is the Okaw formation, which is exposed along the west border of these quadrangles near Smithton, along the stream flowing from Hirst School to Richland Creek, and along several of the streams in the southwest corner of the area.

The rocks of the Chester group consist of about equal amounts of shale, limestone, and sandstone. The shale is gray, greenish, bluish, and reddish. The limestone is compact, fine to coarse grained, and in places magnesian, as was noted in samples obtained from a well at the vinegar factory west of Belleville, near the northwest corner of the area. Some specimens of limestone are nearly white but contain scattered dark-green grains, others are dark, and some contain embedded fine sand. The sandstones of the Chester are not uniform in composition or in texture. In some places the grains are coarse and rounded; elsewhere they are fine and angular. The sandstones are also locally calcareous. Almost everywhere beneath these quadrangles the Chester includes conspicuously red shale and marl, easily noted and almost always reported by careful drillers.

From the type locality, which is about 25 miles south of New Athens, the Chester group dips northeastward and thins in that direction. The thinning is largely the result of the removal of the upper part of the group by erosion before the succeeding Pennsylvanian series was deposited. The top of the Chester is everywhere very uneven, and an unconformity at this position is well known from outcrops outside this area and from the records of many borings in the southwestern part of Illinois.

The stratigraphy of the Chester is, on the whole, somewhat irregular, as shale, limestone, and sandstone give place to one another within comparatively short horizontal distances.

The sandstones of the Chester group contain water almost everywhere, except where they are very compact, though generally the water is salty, particularly at a distance of several miles from the outcrop. At Smithton one of them contains a little oil, and near Carlyle and Sandoval, a few miles northeast of the New Athens-Okawville district, two of them contain valuable pools of oil and gas.

The lowermost sandstone of the Chester group was called the Cypress sandstone by Engelmann, but later work proved that the sandstone on Cypress Creek, in Johnson County, Ill., the type locality of this formation, is much higher in the stratigraphic column and is represented in southwestern Illinois in the "Ruma formation." The lowermost sandstone formation of the Chester group in the Mississippi Valley section is the Aux Vases sandstone, which consists of massive beds of fine-grained sandstone, generally cross-bedded and commonly about 80 feet thick. Where the sandstone is unweathered it is yellowish brown or whitish, but where it is weathered it is reddish brown. On account of this reddish-brown color it was known to some of the earlier writers as "the ferruginous sandstone." The Aux Vases rests unconformably upon the Ste. Genevieve limestone, except in places where that formation is absent, where it rests immediately upon the St. Louis limestone. No fossils have ever been found in the formation.

The Renault formation, named from Renault Township, a short distance west of the New Athens quadrangle, ranges in thickness from 40 to 100 feet. It is extremely variable in lithologic character and includes sandstone, shale, and limestone members. Some of the sandstone closely resembles that of the underlying Aux Vases, but it is commonly thinner bedded and is associated with shale and limestone. At some places impressions of tree trunks (lepidodendroids) are found, and other fossils are abundant in the limestone. The Renault formation commonly overlaps the Aux Vases sandstone to the west and rests directly on the Ste. Genevieve or St. Louis in unconformable contact.

The Renault formation is overlain by a thin but persistent cherty group of beds, which though unfossiliferous are yet widely usable as a key in correlation. These beds, which have been named the Yankeetown chert by Weller, have a thickness of 20 feet or less. This formation is commonly irregularly cross-bedded and knotty or banded. Where it is encountered in wells it is recorded as a very hard limestone, and in dug wells it usually puts an end to further excavation. This formation is so resistant that in considerable areas where the overlying beds were removed by erosion in pre-Pennsylvanian time it constitutes the floor on which the Pennsylvanian strata rest. The contact between the Yankeetown and Renault is believed to be unconformable.

The Paint Creek formation, which rests on the Yankeetown chert, is about 60 feet thick and consists chiefly of shale at the base, limestone in the middle, and variegated red and blue shales at the top. Its most conspicuous stratum is a deep-red clay, which lies at or near its base. This red clay is generally reported by well drillers and is a valuable index stratum. It shows little evidence of stratification and contains no fossils, but fossils are abundant in the limestone and shale in the middle and upper parts of the formation.

Above the Paint Creek is the Cypress sandstone, which consists of massive cliff-forming sandstone, from 70 to 110 feet in thickness.

The Okaw formation, which overlies the Cypress sandstone, consists of alternate beds of limestone and shale and is about 200 feet thick. The shale is generally blue or gray, but in some places it shows a reddish tinge. The limestone is very fossiliferous, *Archimedes* being especially abundant. About 60 feet above the base of the formation there is generally a bed of oolite, 10 feet thick, which contains many small pelecypods and gastropods. The upper part of the Okaw, which appears at the surface in the southwest corner of the New Athens quadrangle, is characterized by the large blastoid *Pentremites sulcatus*, and according to Prof. Weller this fossil is restricted to the upper part of the Okaw, as is also *Archimedes laxus*. This is the only formation of the Chester group that crops out in the New Athens-Okawville district. Near Hirst School, in T. 2 S., R. 8 W., it is extensively exposed and has been quarried. The rock is commonly translucent and yellowish, resembling onyx. It contains many varieties of fossils, including the trilobite *Phillipsia*. In the western part of sec. 28, 2 miles north of Hecker, there are extensive exposures of another part of the Okaw formation, in which *Camarophoria explanata* is abundant. The name Okaw is taken from that of the Okaw Valley, in the lower end of which the formation is well exposed. The Okaw is the equivalent of the Glen Dean limestone and the underlying Hardinsburg sandstone and Golconda limestone of western Kentucky.

The Menard limestone, which in the Mississippi Valley region rests on the Okaw formation, is made up of limestone and shale and is 60 to 100 feet thick. It is nearly everywhere absent in the district, as it was removed in most places by the pre-Pennsylvanian erosion.

The Palestine sandstone, which overlies the Menard along the Mississippi bluffs, is not known to occur anywhere in the district. It consists mainly of sandstone and has a thickness of about 40 to 80 feet.

The Clore limestone overlies the Palestine sandstone. It consists of limestone, shale, and shaly limestone and has a maximum thickness of about 40 feet, but, like the Palestine and a large part of the Menard, which crop out a short distance to the west, it was removed from the district by erosion at the end of the Mississippian epoch.

The Clore limestone is overlain by the Degonia sandstone, a massive bed 40 to 100 feet thick. The Degonia is in turn overlain by the Kinkaid limestone, the highest formation of the Chester group. The Kinkaid consists of regularly bedded limestones separated by thin shaly seams and has a maximum thickness of 140 feet. The Degonia and Kinkaid formations have heretofore been included in the Pennsylvanian, but the discovery of Chester fossils in both formations led Prof. Weller to include them in the Chester group. Both formations have been eroded away from the New Athens-Okawville district.

PENNSYLVANIAN SERIES.

CORRELATION.

The Pottsville, Allegheny, and Conemaugh formations of Pennsylvania and other Eastern States are represented in southern Illinois, but the exact correlation and limits of these formations have not yet been determined. The upper limit of the Pottsville, however, is known with fair accuracy and lies a short distance below the Murphysboro (No. 2) coal. For convenience the base of the underclay of that coal is used as the boundary of the formation. The division plane between the Allegheny and the Conemaugh is much more difficult to determine. It probably lies near the Herrin (No. 6) coal or coal No. 7, but as there is doubt local formation names (Carbondale and McLeansboro) have been applied to the strata of Allegheny and Conemaugh age, and the top of the Herrin coal has been used as the boundary of the formation.

POTTSVILLE FORMATION.

Character and thickness.—The Pottsville formation consists largely of sandstone but includes some shale, clay, and a few thin layers of irregularly bedded coal. No limestone is found in it in this region. It ranges in thickness from 10 feet, or perhaps even less, to about 200 feet. So far as known it is thinnest in the northwestern part of the area, where it consists of clay containing local lenses of sandstone and traces of coal. It thickens toward the east somewhat irregularly and is probably about 150 feet thick at the northeast corner of the New Athens-Okawville district. At the southeast corner of the district it appears to be 200 feet thick and to consist of water-bearing sandstone in several thick layers, separated by thinner layers of soft shale containing small lenses of argillaceous sandstone and coal. Here and there the sandstone contains a few quartz pebbles, but it is generally rather fine grained. All the strata are irregular. Beds of sandstone grade laterally into shale, and hardly any layer holds an invariable physical character throughout any considerable area. The sandstone is generally barren of fossils, but some of the shales bear impressions of land plants—most of them fernlike. The most persistent coal bed is approximately equivalent to the bed named coal No. 1 by Worthen and also to the Mercer coal of Pennsylvania.

Relations and identification.—The Pottsville formation rests unconformably on the very uneven upper surface of the Chester group and extends up to the base of the underclay of the Murphysboro (No. 2) coal. Commonly it may be identified in drill holes by the fact that it includes the rocks lying between the coal and the next limestone below. The coal, however, is not persistent, and the uppermost bed of the Chester in many places is not limestone. Hence it is often necessary to use other criteria, and in some wells it is not possible to determine the exact limits of the formation, even from carefully collected samples. However, the approximate position of the formation may be known in all wells by the fact that it is roughly coextensive with the great water-bearing sandstones that generally lie between 175 and 350 feet below the Herrin coal—the principal coal of the region. Its relation to the Chester group is one of unconformity and overlap, its thinner parts being its higher parts. The formation resembles the overlying Carbondale more than it does the Chester.

Areal distribution.—The outcrop of the Pottsville forms an irregular belt 1 to 5 miles wide west of the Illinois Central Railroad in the New Athens quadrangle. From this belt it dips eastward, passing beneath higher Pennsylvanian formations, and at the eastern side of the area it is 400 to 500 feet below the surface. It is actually exposed at only a few places, for it is generally covered by surficial formations. The best exposures are on Douglas Creek, where it was once quarried, half a mile east of Smithton, and along the road 3 miles east of Hecker. The rock in all these exposures is yellowish speckled with brown, micaceous, fine grained, and rather firmly cemented.

CARBONDALE FORMATION.

Definition, character, and thickness.—The Carbondale formation includes the Pennsylvanian strata between the base of the underclay of the Murphysboro (No. 2) coal and the top of the Herrin (No. 6) coal. The name was proposed by the writer in the Murphysboro-Herrin folio, the formation being well exposed in the vicinity of Carbondale, in Jackson County, south of the Murphysboro-Herrin district. The Carbondale formation, like the Pottsville, is known in the New Athens-Okawville district mainly from borings, though it crops out in the western part of the district. For the most part it is 160 to 225 feet thick, apparently thickening toward the east, but near its western border there is indication that its thickness decreases more abruptly and that it never extended far west of the district here considered. There appears to be an overlap to the west, as well as a general thinning of all beds. The formation consists chiefly of shale and sandstone but includes several thin layers of limestone and somewhat lenticular beds of coal. The shale is generally poorly laminated and claylike and ranges in color from dark bluish gray to light greenish gray. Some of it is hard and black and contains carbonaceous material, and some is a soft light-gray clay which is not at all shaly. The sandstone is generally loosely cemented and rather micaceous, though one or two of the beds in the central part of its area are commonly cemented by calcium carbonate. The limestone is fine grained, hard, gray or bluish gray, and more or less fossiliferous. Parts of it are peculiarly brecciated or conglomeratic.

Members.—The Murphysboro coal is absent throughout considerable areas, and where it is present it is of irregular thickness, ranging from a thin seam to a bed 4 feet thick. The next stratum is shale, 10 to 30 feet thick, containing traces of coal near the middle, and above the shale is a soft brownish sandstone or sandy shale, which has been called the Vergennes sandstone member. This bed is commonly water-bearing. Above this rock is shale containing traces of coal and local lenses of sandstone, which extends up to a coal that lies about midway between the Murphysboro and Herrin beds. This coal appears to be present beneath a considerable part of the area and is similar in some respects to the Springfield (No. 5) coal, which generally lies only about 50 feet below the Herrin coal. It resembles that bed in that it is associated with much clay and is cut by numerous veins of clay, but its position is incompatible with the general thinning of all beds to the west, which should bring the Springfield coal nearer the top of the formation instead of farther from the top than the average. Its stratigraphic relations indicate that it is a lower bed—perhaps coal No. 3 of Worthen.

Above this coal is about 75 feet of shale and shaly sandstone, which is overlain by calcareous beds that lie beneath the underclay of the Herrin coal. Generally this member includes one or more beds of pure limestone.

The underclay of the Herrin coal is light gray or greenish and is plastic when wet. It averages about 2 feet in thickness but is irregular and is in some places absent, the coal resting immediately upon the underlying limestone. In contrast with the underclays of other coal beds throughout the State that of the Herrin coal is thin and underlies more than three-fourths of the area in which the coal is present.

The Herrin coal is 5 to 12 feet thick. With the exception of the "blue band" it contains only a small amount of original sedimentary impurities. Its bedding is uniform, and the several parts of the bed are rather easily recognized. The "blue band" is a layer of bluish-gray clay, in places calcareous or ferruginous, lying 15 to 30 inches above the base. It is 1 to 3 inches thick. The Herrin coal has several other persistent partings which separate the bed into distinct divisions or benches. The partings consist generally of thin layers of clay, seams of marcasite, and layers of "mineral charcoal," but at many places they appear to be merely planes of sedimentation along which the coal splits easily. Above the "blue band" the coal is more or less distinctly divided into three divisions, to which, owing in part to irregularities in the coal, names are applied differently by different miners.

The western limit of this coal is not known exactly, but its approximate position is indicated by the boundary of the formation. West of this line the Carbondale formation crops out, and east of it the McLeansboro formation immediately underlies the surficial materials.

Correlation of coal beds.—In the early reports on the geology of Illinois an attempt was made to give the successive coal beds serial numbers beginning with No. 1 at the bottom. The correlation of beds in different parts of the State was in general correct, but most of the coal beds are lenticular, and furthermore it is now known that the same number was given to different beds and vice versa. Moreover the same beds extend continuously into Indiana and Kentucky and bear, in each of these States, different sets of numbers, the result being that great confusion has arisen in the significance of the numbers. For these reasons the use of numbers for the coal beds is not so desirable as the use of geographic names. The bed known in Illinois as No. 2 has been called the Murphysboro because of its development at that place. It is probably the same bed that is mined at Colchester, the "third vein" near La Salle, and coal No. 2 in the vicinity of Morris and Braidwood, in the northeastern part of the basin. The thick "blue band" coal (No. 6) is called the Herrin coal and is equivalent to the Belleville and the Duquoin coal. Coal No. 5, which lies 40 to 80 feet below the Herrin coal, has been called the Springfield coal. Other beds of coal occur in this area, but they are of minor importance and have not been designated by geographic names. Knowledge concerning them is rather scant, and there is doubt as to their proper correlation.

David White has shown by the fossil plants in the Murphysboro coal that it corresponds approximately to the Brookville or perhaps the Clarion coal bed of Pennsylvania and that the Herrin coal is of Freeport age, being possibly equivalent to the Upper Freeport coal, which is the uppermost layer of the Allegheny formation in the Appalachian coal basin.

McLEANSBORO FORMATION.

Definition, character, and thickness.—The McLeansboro formation, named from the town of McLeansboro, Ill., extends from the top of the Herrin coal to the uppermost Pennsylvanian strata that are preserved in Illinois. At McLeansboro, near the center of the coal basin, these rocks are about 1,000 feet thick, but, owing in part at least to uplift and erosion, their thickness decreases in all directions away from that place. At the east side of the Okawville quadrangle only the lowermost 400 feet or more is present, and toward the west the beds crop out successively from above down, the lowest bed of the formation appearing at the surface along the line of outcrop of the Herrin coal. The formation consists chiefly of shale, sandstone, and limestone but contains a subordinate amount of coal, the proportion of coal being considerably less than in the Carbondale formation.

Distribution.—The McLeansboro formation immediately underlies the surficial formations throughout more than three-fourths of the New Athens-Okawville district, including all the territory east and northeast of the outcrop of the Herrin coal, above described. Rocks belonging to it, particularly sandstones, are actually exposed at many places, as at a point a few miles southeast of Freeburg, at another just east of Marissa, and at places in Elkton and Plum Hill townships, Washington County.

Members.—The lowest stratum of the McLeansboro formation is the roof shale of the Herrin coal, which is generally black from its content of carbonaceous material, though its upper part is gray. At some places this bed includes lenses of coal, a few of which are as much as 6 inches thick. The shale contains some fossils, chiefly more or less distinct impressions of plants and shallow brackish water shells such as discinoids, and at a few places it contains concretions of iron and calcium carbonate.

Above the roof shale is a very persistent limestone having a maximum thickness of 20 feet, which in some places is separated into two beds by a layer of soft shale. Where the limestone is thin some of it is probably represented by shale. In many mines, particularly where the underlying shale is thin, the limestone is used as a roof. It is generally light gray, though locally it is dark from bituminous matter, is close grained, and is composed of layers 6 to 24 inches thick. The limestone and shale are both well exposed near the country banks southeast of Freeburg. The limestone contains a *Fusulina* which has been referred in different places to *F. secalica*, *F. cylindrica*, and *F. cylindrica* var. *ventricosa* but which according to G. H. Girty is probably *Girtyina ventricosa*. Specimens of this fossil may be found in almost every piece of this rock, and it is therefore a valuable index fossil. Other animal remains, such as crinoid stems, a brachiopod which has often been identified as *Productus longispinus* but which is now known to be a *Marginifera* (*M. splendens?*), and *Composita subtilita* (formerly called *Athyris subtilita*), are fairly common in it. The lower surface of the limestone is at some places smooth and at others rugose, the ridges extending downward as much as several inches and being known among the miners as "cat claws."

The strata that lie 20 to 40 feet above the Herrin coal are generally limestone, though in places they consist of sandstone. The limestone is commonly brecciated or conglomeratic. About 40 feet above the Herrin coal is a coal bed less than 2 feet thick, which appears to underlie more than half the New Athens-Okawville district. Upon this coal lie shale and another bed of limestone, above which the strata for about 40 feet consist predominantly of sandy shale and water-bearing sandstone. At a few places there is a bed of coal about 75 feet above the Herrin coal. From 90 to 125 feet above the Herrin coal the rock except at a few places consists of soft gray or bluish clay shale, with a lenticular limestone bed in the upper part.

Above the clay shale just mentioned is a massive porous brown or buff sandstone nearly 100 feet thick. This sandstone is exposed east of Marissa, where it has been quarried as rough building stone, and at several other places. It is fairly persistent but irregular in thickness, in some places being represented for the most part by shale that contains only a few thin layers of sandstone. The rock commonly shows cross-bedding, and it grades within short distances from soft and friable to tough and hard. In general it becomes more argillaceous toward the south. It is exposed at many places, as at a point a mile southeast of Marissa, where it has been quarried; on the road a mile northeast of Lenzburg; and in the bank of a small stream a mile and a half northeast of Lively Grove. At the place last named and at several other places it contains impressions of plants, in particular those of trunks of *Lepidodendron*. As it is a resistant rock it underlies the surficial formations throughout a large area and is as well or better exposed than any other bed. Its upper part is, however, less resistant than the lower. In places, particularly about 30 feet above its base and also 20 feet below its top, traces of coal are found.

Above this sandstone lie thin beds of shale, separated by clay, limestone, or thin coal, which have an aggregate thickness of 20 or 30 feet and are overlain by about 100 feet of strata consisting in the northern part of the area predominantly of shale containing small lenses of limestone and in the southeastern part of soft sandstone, extensively exposed near Oakdale. A limestone that lies about 240 feet above the Herrin coal is rather persistent and may be equivalent to the Carlinville limestone member. At the top of this group of beds there is generally a layer of hard black shale containing abundant impressions of *Productus cora*.

Shoal Creek limestone member and overlying strata.—One of the most persistent strata in southwestern Illinois is a limestone that lies about 360 feet above the Herrin coal. In the New Athens-Okawville district this limestone has been removed by erosion everywhere except in a small area along the eastern border. It was noted in the reports on the earlier geological surveys of Illinois and named the Shoal Creek limestone, from its extensive outcrops along Shoal Creek in the central part of Clinton County. For a time it was regarded as equivalent to the Carlinville limestone, but it is now known that these are two distinct beds. It crops out in hillsides about midway between Elkton and Oakdale, where the following fossils, identified by G. H. Girty, were collected: *Marginifera wabashensis*, *Dielasma bovidens*, *Cryptacanthia compacta*, *Squamularia perplexa*, and *Hustedia mormoni*. It is compact and hard and contains many organic fragments, which are embedded in a finely crystalline calcareous matrix. The layers average a foot or more in thickness, but where much weathered they are only 2 or 3 inches thick. Above the Shoal Creek limestone member lies a few feet of irregularly bedded sandy shale, which constitutes the uppermost Pennsylvanian strata in this area.

QUATERNARY SYSTEM.

CHARACTER AND THICKNESS OF THE DEPOSITS.

In this area the Quaternary system is made up of unconsolidated materials comprising old residuum, the product of the more or less deep decay of rocks of the district; a bed of glacial drift or till consisting of unassorted clay, pebbles, and boulders; an earlier valley filling—sand and clay deposited as a result of disturbance of drainage by glaciation; loess, probably of eolian origin; a later valley filling; and alluvium underlying the present flood plains. All this material has been derived from consolidated rocks, partly by the usual processes of weathering, partly by the grinding action of glaciers, and in small part by the wear effected by running water. It has been transported different distances and deposited by ice, wind, or water.

The average thickness of the Quaternary deposits in this area does not exceed 50 feet. The greatest thickness is north of Freeburg, where the bedrock lies more than 200 feet below the surface, at some places as much as 300 feet. In a belt along the river also the Quaternary deposits are thick, but throughout much of the district, particularly in its western and southern parts, the average thickness is scarcely 20 feet.

PLEISTOCENE SERIES.

PRE-ILLINOIAN DEPOSITS.

Beneath the glacial drift of the region there is generally a bed of clay or silt of very irregular thickness. Much of it appears to be part of a pre-Illinoian mantle of deeply decayed rock, such as might have occupied the surface of the region before the Illinoian glacial invasion. The upper part grades into the glacial drift or till, but the lower part contains no foreign pebbles. However, at some places the material appears to be bedded, although just what this bedding signifies is not yet clear.

The till nearly everywhere appears to be a single deposit, but at some places its middle and upper parts differ in appearance and composition from the lower part. The lower part contains a larger proportion of limestone pebbles, and at some places in the till a very distinct plane of separation is apparent, but these features may have resulted from local irregularities in the deposit and from weathering. It is reported that wood has been found in the till at several places. Limestone pebbles have been generally lost by solution from the upper part of the Illinoian till. If there is a pre-Illinoian till it is thin and has been largely reworked into the Illinoian.

ILLINOIAN TILL.

The Illinoian till covers the whole of the New Athens-Okawville district except comparatively small areas from which it has been removed by erosion. It consists on the whole of an intimate mixture of clay and more or less decayed pebbles and boulders of many kinds of rock, but its uppermost part generally contains few pebbles. Many of the pebbles are well rounded, but most of them are subangular and some have sharp corners. The proportion of gravel in the main body of the till appears to be large for a low, flat region where the bedrock was not deeply eroded and in places was scarcely touched by the glacier. It appears that either a part of the fine material had been sorted out and carried away by water or wind or that the till was derived from material, perhaps Tertiary, that was more gravelly than the deeply weathered Carboniferous rocks. A large proportion of the pebbles range in diameter from half an inch to $1\frac{1}{2}$ inches. Only a few have a diameter exceeding a foot. Another prominent feature of the till is its relatively large content of quartz and flint. These rocks are least easily broken down into sand or rock flour, and this fact no doubt accounts in part for their abundance, but remnants of Tertiary (?) gravels are found at several places north of this area, and perhaps there were extensive deposits of this sort in preglacial time which were largely worked up into the till.

The upper part of the till contains only a few pebbles, and those are small and most of them are of either angular chert or well-rounded quartz. This part of the till is generally leached and oxidized, is of yellow or rusty color, and seems to consist of two kinds of material, which are easily distinguished in dry weather. One kind is made up of relatively uniform fine grains and the other consists of clay, sand, and pebbles generally containing concretions of lime, iron, or manganese and forming patches a few rods across on the more or less flat surface of the till. The middle part of the till is generally oxidized to a yellowish color; the lower part is less oxidized and is dark gray, but in some places, especially where it is thin and lies above the ground-water table, the till is oxidized to a yellowish or red color throughout.

Most of the till is ground moraine, including both material deposited beneath the ice and material let down as a blanket from within the ice as it melted, but there are extensive drift ridges whose origin has not yet been determined.

EARLIER TERRACE DEPOSITS.

Deposits of clay, fine sand, and a little gravel reaching a thickness of more than 100 feet in places are found along the bottom of the valley of Kaskaskia River. These deposits really consist of two separate formations, the younger one, comprising the later terrace deposits, described below, partly filling a valley within the older terrace deposits in the same way that the older deposits partly fill the rock-walled valley. The evidence indicating the presence of an earlier and a later valley filling consists of a rather persistent old soil near the middle of the deposit and of two extensive and fairly distinct terraces or groups of terraces, the top of one (the earlier) being at 410 to 420 feet above sea level, and the top of the other, which is compound, being at 390, 400, and 410 feet. The materials that form these terraces differ somewhat, and the higher or earlier terrace is capped in places with loess, whereas the lower or later group has no such capping. The deposits are not very distinct in this area, but to anyone who studies the whole valley of the Kaskaskia their existence and relations become more clear.

The higher or earlier terrace deposits may be of either late Illinoian, Sangamon, Iowan, or possibly slightly later age; the lower or later terrace deposits are of either Wisconsin or Recent age.

LOESS (PEORIAN?).

Throughout most of its extent the till is overlain by loess, a buff-gray clayey silt. The exceptions are areas on the sides of the valleys, in little washes that have cut through the loess, and in numerous spots on the flat upland where gravelly clay appears at the surface. This gravelly clay differs somewhat from the average till; more of its pebbles are rounded and composed of quartz and flint, and it contains more concretionary masses of iron, lime, and manganese, but it differs even more markedly from the loess.

The loess is thickest in the western part of the New Athens-Okawville district, where its maximum thickness is about 20 feet and its average thickness on the upland is 6 or 8 feet. Toward the east it thins to 5 feet or less. The loess is more loose and porous in the western part of the district than in the eastern part, where it is hard and compact when dry and plastic when wet. Its color differs somewhat from place to place but averages grayish buff. In places it is distinctly reddish, particularly on the drift ridges, where it appears to be coarser and more porous than on the general upland.

The uppermost foot or two of the loess is generally much more porous than that at a depth of 3 to 5 feet and less porous than that at a depth of 10 feet. Mechanical analyses indicate that the particles near the surface are being broken up by vegetation, frost, and other agencies of weathering and that the finest particles are being carried down a few feet, forming a secondary, compact layer. In many exposures this layer is conspicuous.

At many places the loess seems to grade into the drift below. No definite evidence of the existence of a layer of wood fragments or old soil at the base of the loess has been found.

LATER TERRACE DEPOSITS.

The later valley filling is similar to the earlier except that it is on the whole somewhat more clayey and is not capped with loess. It is well exposed near the mouth of Little Mud Creek and at many other places along the valley of Kaskaskia River on terraces that range from 390 to 410 feet in altitude. The clay nearly everywhere contains much calcium carbonate, which is scattered through it in little irregular white masses, whose origin is not known. They may be secretions of algae or they may have been segregated from disseminated small particles in the clay since it was laid down. The deposit is prevailingly greenish gray but in places displays purple and other tints. Near Keyesport, about 25 miles northeast of Okawville, the later valley filling is unusually sandy but contains very little coarse sand.

The deposit contains shells of gastropods and lamellibranchs such as live in the region to-day. The evidence obtained indicates that the later terrace deposit is of either Wisconsin or Recent age. It occurs not only along the valley of the Kaskaskia but extends short distances up tributary valleys. On Richland Creek it is not certainly distinguishable from the alluvium, but on Silver Creek it is exposed 3 miles southwest of Mascoutah and at several other places. The best exposures along the Kaskaskia are in the southern part of sec. 8, Lenzburg Township, 4 miles southwest of New Athens; in sec. 17, Fayetteville Township, 2 miles south of Fayetteville; in sec. 22, Freeburg Township, 6 miles southwest of Mascoutah; in sec. 30, Venedy Township, 4 miles south of New Memphis; and in sec. 4, Okawville Township, 3 miles north of Okawville.

RECENT SERIES.

Present flood plains or "first bottoms" are found along almost all the streams of the New Athens-Okawville district. In the rougher parts of the district the alluvium is made up of gravel, some of which is scarcely rounded at all. In the smoother parts of the district, especially along the larger streams, it consists of sandy clay containing some gravel and overlain by silty clay.

STRUCTURE.

REPRESENTATION OF STRUCTURE.

Geologic structure is commonly represented in one of two ways—by cross sections or by structure contour lines. For representing a region in which the rocks are sharply folded and faulted cross sections are best, but for representing one where the folds are very low and there is little or no faulting they are of small value, for the structural details in them are almost imperceptible. For representing such a region structure contour lines show the minor details of structure more clearly.

STRUCTURE CONTOURS.

Delineation.—In delineating structure on a map by contours an easily recognizable reference stratum or "key rock" is chosen whose position can be determined at many points by means of outcrops, mines, or borings. The altitude and the dip of the surface of this stratum are determined at as many points as possible, and points of equal altitude on it are connected on the map by lines in the manner in which topographic contour lines are drawn. The direction of the dip of the strata is thus at a right angle to the direction of the structure contour line. At some places the altitude of the reference stratum may be observed directly in outcrops, mines, or wells; at others it must be calculated from observations of the altitude of some other recognizable stratum, for most layers of stratified rock are approximately parallel, and the average interval between any two distinctive layers may be determined. So, if the outcrop of a bed above the reference layer is found its altitude may be determined, and the altitude of the reference stratum may be calculated from it by subtracting the average distance (or the nearest measured distance) between the two. If the outcrop of a bed below the reference stratum is found the average interval is added, the result showing approximately the altitude at which the reference layer would lie if it were present. If it were not for the surficial deposits the intersection of a surface contour with a structure contour of the same altitude would mark a point of outcrop of the reference stratum.

Use of structure contours.—A structure contour map is not only useful for the study of broad structural problems and for conveying a general knowledge of the structure of a region but is of practical value in locating and recognizing valuable beds and in determining their "lay." As the strata are approximately parallel and as the average distance between valuable beds is known it is not difficult to calculate, from the altitude of the reference stratum, the approximate altitude of any bed at any point by adding or subtracting, as indicated above, the average distance between the two. A map made in this way may be used for locating beds containing coal, clay, limestone, oil, or gas.

A structure contour map also shows the direction and the amount of the dip of the beds, a knowledge of which is essential to successful and economical mining. It also gives information that is useful to anyone who is selecting locations for the shafts of coal mines, for the dip of a coal bed affects very greatly the cost of drainage and haulage.

Reliability of structure contours.—The reliability of structure contours thus drawn is determined by the accuracy of the altitudes obtained directly, by the variability of the calculated intervals between the reference strata or "key rocks," and by the number and distribution of the points whose altitudes are known.

The reference strata in the New Athens-Okawville district are coal beds which have been extensively worked and whose depth below the surface has been noted in numerous shafts, wells, and drill holes. The altitude of the surface at such points was obtained by hand level or barometer, and as bench marks are numerous the determinations involved only short horizontal distances and small possible errors.

The variability of the interval between beds is more likely to lead to mistake, because the beds are not absolutely parallel, but the difference in the interval between two particular beds in this district does not seem to exceed 20 feet, and, curiously enough, this difference does not seem to be much larger between strata that are far apart than between those that are close together.

As outcrops are scarce in this area artificial excavations, particularly borings, are the principal sources of information concerning the altitudes of the beds, and the determined altitudes of recognizable beds are not so numerous as might be desired, but they are fairly evenly distributed, so that the error arising from scant determinations of this kind is probably not great. The dip of the coal beds in the mines also afforded some information that has been useful in the task of working out the structure.

The assumption that a coal bed is of uniform dip between determined points is a source of slight error, for the beds show local irregularities in dip, and these irregularities are not generally shown on a structure contour map.

The probability of error on such a map is also greater for areas where the test holes whose records were obtained are far apart. The contour lines for such areas are broken.

In general, however, the errors due to the causes mentioned are probably not so great as to amount to one contour interval, or 25 feet, and it may be assumed that the general altitude of the coal beds, and thus the general structure of the Pennsylvanian strata in this area, is essentially that shown on the map.

STRUCTURE OF THE NEW ATHENS AND OKAWVILLE QUADRANGLES.

GENERAL FEATURES.

The strata in the New Athens and Okawville quadrangles have a general slope to the east of 15 to 25 feet to the mile, yet this slope is not at all regular but is at many places interrupted by irregular low anticlines, shallow synclines, and, in the western part of the area, by faults. The structure of the area is shown on the areal-geology maps by contour lines drawn on the base of the Murphysboro coal. The vertical interval between two adjacent contours is 25 feet. Where the contour lines are far apart the dip of the strata is gentle; where they are close together the dip is steep. The structure of the region in which the New Athens and Okawville quadrangles lie is shown on a small scale in figure 5.

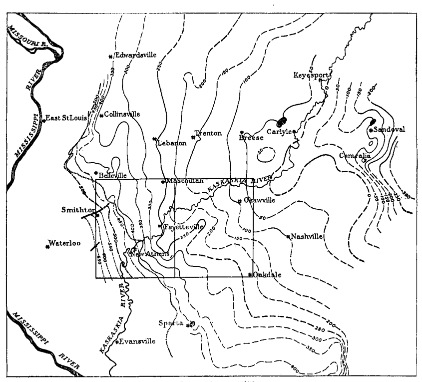


FIGURE 5.—Structure map of southwestern Illinois, showing by contours the lay of the Herrin (No. 6) coal.

The outcrop of the Herrin coal is shown by a fine dotted line. Structure contours are drawn solid where definitely located, are dashed where doubtful, and are represented by dash and dot line where the Herrin coal is eroded. Contour interval, 50 feet. Oil pools are indicated by diagonal ruling.

FAULTS.

The western part of the New Athens quadrangle lies on the eastern border of an area in which the rocks are much deformed and in places faulted. The fault planes appear to be even and nearly vertical, so that they make long, straight lines on the map, but their form and position can not be determined very precisely. Two faults and perhaps more extend eastward from Missouri into this area. One of these faults passes just north of Smithton, a town that stands on Mississippian strata, whereas 2 miles northwest of Smithton there is an outcrop of the Herrin coal, a bed that lies in the Pennsylvanian series. The rocks at Smithton thus appear to have been forced up several hundred feet higher than those a short distance to the north, or those that include the Herrin coal have been dropped that much. From Smithton the strata dip eastward and southward, and within a distance of less than a mile from that place there are outcrops of Pennsylvanian rocks. About 2 miles north of Hecker there is another fault, which brings Mississippian rocks to the surface. The fault plane is exposed on a stream half a mile north of Hirst School. There is some indication that still another fault extends southeastward from Hirst School, and there may be other displacements.

FOLDS.

Darmstadt anticline.—The most pronounced fold in the district is the Darmstadt anticline, which, though somewhat irregular, trends in general northeastward, probably extending as far as Venedy, where there is a low dome and beyond which the anticline appears to be lower and double-crested, one crest striking nearly northward to New Memphis and the other northeastward to Okawville. This anticline is highest near Darmstadt, where the Herrin coal reaches an altitude of 298 feet above sea level, whereas it is 50 to 75 feet lower toward the west, north, and east. It is possible that the coal is lower on all sides, so that the structural feature here would be a dome on an anticline. At least it is a well-marked uplift flanked on the northwest and southeast by synclines.

White Oak anticline.—The axis of a low anticline plunges gently southwestward through White Oak, which is 2 or 3 miles southeast of Marissa, in the Coulterville quadrangle. This anticline is unsymmetrical, its southeast limb being rather steep and about 40 feet high and its northwest limb being less than 10 feet high, so that it has somewhat the form of a terrace facing southeastward. It appears to extend northeastward nearly to Lively Grove, in the Okawville quadrangle. The highest known point on it is 6 or 7 miles northeast by east of Marissa, where the Herrin coal in a test hole is reported to lie 295 feet above sea level, higher than it lies either to the northwest, northeast, or southeast. But, unfortunately, the position of the strata in this district is not well known, and the form of the flexure is therefore somewhat doubtful. There may be a dome just northwest of the middle of Lively Grove Township, and the anticline may be high or low, steep-sided or gently sloping.

Mascoutah terrace.—Mascoutah seems to stand near the edge of a small structural terrace in which the dip of the strata to the east is considerably greater than the dip to the west. This terrace flattens out toward the south and also toward the north within a distance of 5 or 6 miles.

Nashville anticline.—The southeast corner of the Okawville quadrangle appears to be traversed by a long, well-formed anticline that extends from the vicinity of Sparta, in Randolph County, where it is narrow, northeastward through Coulterville to Nashville, in Washington County, where it is broad, and possibly on to Hoffman, in Clinton County, and to the Sandoval oil field, in Marion County. At Oakdale, the only place in the area here described that is affected by this anticline, the Herrin coal has an altitude of 185 feet and appears to dip 5 or 10 feet to the mile toward the northwest, northeast, and southeast.

GEOLOGIC HISTORY.

IMPERFECTION OF THE RECORD.

Only a small part of the geologic history of the New Athens-Okawville district can now be deciphered from rocks that are exposed at the surface or have been penetrated in borings. The record of many of the principal and some of the minor events of the Carboniferous and Quaternary periods is preserved and is legible, but the record of pre-Carboniferous time lies so far below the surface that only the rocks showing its later part have been reached by drill holes. The record of the periods between the Carboniferous and Quaternary has been erased, though there is an indistinct record of the progress of erosion. However, many facts in the history of the New Athens-Okawville district may be inferred from the results of studies in other areas in the general region, for the processes that operated in this district affected also an extensive province around them. Much of the history of the smaller area is therefore contained in the more complete record of the larger area.

During the Paleozoic era Illinois was intermittently submerged in an epicontinental sea, the shores of which shifted widely and almost continuously, though the rate at which they shifted varied greatly. Since Paleozoic time the surface of the State has, so far as known, been continuously above sea level and has been subjected to the wear of streams.

Most of the lower Paleozoic strata of this region were laid down in a basin or an arm of the sea that perhaps extended into this area from the region that now borders the Gulf of Mexico. The coast line of this basin shifted widely, sometimes moving farther north than the area here described and again moving southward beyond its limits. The arm of a sea from the north also occupied Illinois intermittently, but except possibly in the Maquoketa epoch and once or twice in the Silurian period it did not reach so far south as the New Athens-Okawville area. During periods of submergence beds of clay, sand, and more or less comminuted shells and other limy matter accumulated on the sea bottom and in time became limestone, shale, and sandstone through consolidation by the pressure of overlying beds and through cementation by calcium carbonate, iron oxide, or other mineral matter deposited from the sea water. During periods of emergence the deposits were eroded, and there are consequently many erosional unconformities in the region, though some of these may have been produced by submarine erosion. The basin lay immediately east of the Ozarkian land mass, which was no doubt the source of a large part of the sediment thus deposited, and earth movements, even minor oscillations, that affected both erosion and deposition are here registered clearly.

In Pennsylvanian time the sea was shallow and the land emerged frequently, but the many movements of the strand line that occurred in the early part of the Paleozoic era, particularly in late Ordovician and early Silurian time, show that oscillations were not peculiar to the Pennsylvanian epoch. The scarcity of recorded earth movements in the early part of the Paleozoic era is no doubt due in part to the fact that such movements are much less certainly and clearly recorded in an area when it is considerably above or considerably below sea level than when it is very near sea level, as Illinois was in Pennsylvanian time, for a slight movement may then shift the processes at work from erosion to deposition.

PALEOZOIC ERA.

EARLY PERIODS.

At the beginning of the Paleozoic era the surface of the region now included in the State of Illinois had probably been above the sea for a long time and had been eroded until it was nearly flat. Early in the era the region was gradually submerged and sandy deposits were laid down in the encroaching sea. The submergence probably took place late in Cambrian time and lasted at least until its end.

The sediments deposited during Ordovician time consisted mainly of calcium carbonate and perhaps of magnesium carbonate but included some argillaceous or muddy material. Many animals inhabited the sea, and their remains have been preserved in the beds. In Silurian time much of the area that is now included in the Mississippi basin was covered by a sea of clear water and received extensive calcareous deposits. During a part of the Devonian period also calcareous deposits were formed, but the water at times was shallow and muddy and occasionally it retreated from large parts if not all of the region.

CARBONIFEROUS PERIOD.

MISSISSIPPIAN EPOCH.

The general region was a land surface between the deposition of the Upper Devonian strata and that of the lowermost Mississippian. During the Mississippian epoch the Mississippi Valley was extensively submerged. In Kinderhook time a considerable quantity of fine sand and clay was carried to the sea by the streams. At the end of Kinderhook time and during Burlington time the sea expanded farther and became clearer, so that the deposits which accumulated then consist largely of limestone. In Keokuk and Warsaw time conditions varied, both sand and calcareous mud being deposited. At the end of Warsaw time the sea withdrew to the southern part of the region. When it next advanced it was bordered by lands so low that they yielded little sediment. The waters were therefore clear and the deposit consisted of pure limestone, now known as the Spergen limestone, which in some places is made up mainly of oolite. During the succeeding St. Louis time the sea grew deeper and extended at least to central Iowa. At the end of St. Louis time the water withdrew by a series of oscillations that furnished conditions for the accumulation of oolitic beds similar to the Spergen, which contain a sandy member in the middle part and form the Ste. Genevieve limestone. After a considerable interval in which the area of the New Athens-Okawville district was dry land further warping elevated much of the surrounding region but permitted the sea again to advance as far north as St. Louis. The thick beds of sandstone, limestone, and shale deposited during this period of submergence constitute the Chester group.[1]

PENNSYLVANIAN EPOCH.

Pottsville time.—Chester time was followed by Pottsville time, a long period during which most of the continent lay above sea, and although the general altitude of the land was not great it was sufficiently high for much material to be carried away by the processes of erosion. This period of erosion is marked by one of the most extensive and conspicuous unconformities known, and the relief of the old surface must have amounted to 100 feet or more. After erosion had progressed for a long period, including a large part of Pottsville time, warping of the beds of rock brought about conditions that led to the deposition of the somewhat gravelly sand and more or less carbonaceous mud that now make up that part of the Pottsville formation which is present in this region. At first sedimentation in the central Mississippi basin was confined to a rather small area in southwestern Illinois, but later it slowly spread northward until it covered the New Athens-Okawville district. Most if not all of the Pottsville sediments are terrigenous, and their distribution appears to be closely related to unusually extensive and rapid warping. The source of the material that now makes up the Pottsville in this district was doubtless in part the rocks of the Chester group that lay a short distance to the west, where erosion had not ceased. At times marshes were formed in which enough vegetal material accumulated to form beds of coal, and at other times well-rounded quartz pebbles were transported to the region and buried in the sand. These pebbles must have come from a great distance, for the formations near by do not contain such large particles of vein quartz. Around the edge of the area of deposition, as in the northwest corner of the New Athens quadrangle, layers of clay were formed, perhaps largely by the weathering of the Chester rocks in place.

Carbondale time. — Conditions in Carbondale time were generally much quieter than those in Pottsville time. The sea

[1] Whether the Ste. Genevieve limestone should properly be included in the Chester group is undecided.

alternately covered most or all of the district and retreated from it for longer or shorter periods. During the periods of submergence deposits of shale, limestone, and perhaps sandstone were laid down, and during the periods of emergence the surface was either so low and flat that fresh-water swamps covered extensive areas, or else the area lay in such relation to areas of higher land that sand and mud were deposited above sea level. The deposits along the western border of the district were not so thick as those in other parts of the district; indeed, the western border of the district appears to have been near the old shore.

The origin of coal has been the subject of much speculation. It is evidently, however, an accumulation of vegetal débris. Most coals are compressed, hardened, and more or less devolatilized peats. The question most debated is that regarding the conditions of the accumulation of this material. The generally accepted theory is that this accumulation took place in marshes, usually of wide extent and in most regions near sea level, and that the coal-forming vegetation grew in the areas where the coal beds now lie.

It appears that during many intervals in Pennsylvanian time great intermittent peat marshes or swamps were developed in Illinois and other States and persisted in the aggregate for a period estimated by some geologists to be about 100,000 years. The time may have been much longer or not so long. At successive times conditions so changed that mud or sand was washed in over the peat — sometimes in thin films and at other times in deposits many feet in thickness. Frequently the sea covered the region, and sometimes it was clear, so that nearly pure limestone was deposited over large areas. There were also times of both local and general emergence and erosion, accompanied by the formation of soils and the growth of forests. Most of the sediment was probably brought into the coal basins by streams and then re-sorted and spread out by waves and currents. The beds were more or less lenticular, and many of them had little lateral extent, but groups of them are so combined as to make a layer of fairly uniform thickness. The sediments were filling a basin, formed by downwarp, as fast as it subsided, and although in any single year or century the deposit differed considerably in thickness from place to place, still in a much longer period of time the differences would compensate for each other, for the deposition was controlled in the long run by the downwarp of the basin. As each successive layer was spread out, it increased the pressure on the buried peat beds that has aided in converting them into coal.

Throughout much of the shale of the Carbondale formation concretions of iron and lime carbonate are common. Such concretions are usually formed after the consolidation of the inclosing rock by the gathering of like material from scattered sources and its deposition in concentric layers upon some object that serves as a core.

McLeansboro time.—Conditions such as prevailed in Carbondale time continued into McLeansboro time without much change, except that those favorable to the formation of peat were less widespread and of shorter duration. The strata laid down during McLeansboro time consisted mainly of more or less sandy mud and interbedded sand, but they included a subordinate though considerable amount of limestone.

Peat forms to-day in quiet shallow water or swampy ground in regions that are not very dry or subject to prolonged dry seasons. Where the rainfall is very heavy and well distributed through the year peat is formed in tropical regions, the rate of plant growth outstripping the rate of decay under favorable conditions. In the large marshes of Carboniferous time the water was presumably kept quiet by the extremely rank-growing vegetation. Bars and barrier shoals also were present. At times the water became a little too deep for peat-yielding plants to grow, and at other times too shallow for them to grow and be preserved. Then carbonaceous muds or other sediments were laid down.

At the beginning of McLeansboro time the New Athens-Okawville district formed part of a great, almost unbroken peat swamp in which the material for the Herrin coal had just been formed. But as the rate of subsidence became too great for the maintenance of the peat level, the vegetal peat-producing cover was killed and the swamp was buried under mud. Deeper subsidence and quiescence favored the secretion of a bed of calcium carbonate by marine organisms. There is some indication of emergence and erosion after the deposition of the first muds and limestone, and no doubt there were later periods of at least local emergence in McLeansboro time. The kind of material deposited at any place in this area changed from time to time, the most widespread beds being a thick, predominantly sandy stratum and two relatively thin limy beds, now called the Carlinville and the Shoal Creek limestone members. How long sedimentation continued after the Shoal Creek deposition is not known, for all the records except that preserved in a few feet of immediately overlying strata has been destroyed. Events in this district in the later part of the Pennsylvanian epoch and in the Permian epoch are unknown. If any deposits were made they have since been entirely removed by erosion, for no trace of such deposits is found in the surrounding region. Very likely the area, though low, stood in such relations to the surrounding areas that little or no sediment was laid down.

Deformation at the end of the Carboniferous period.—The end of the Carboniferous period in this region was marked by widespread movements, which resulted in the uplift of the Appalachian Mountains on the east and the Ouachita Mountains and the Ozark dome on the southwest and in the permanent withdrawal of the sea from the region. Previously the region had lain most of the time so near sea level that slight movements were recorded by the deposition or erosion of sediments. From this time on the region lay well above sea level, and moderate vertical movements, although they affected stream erosion to some extent, left a comparatively obscure record.

The exact time of the deformation and the rate of movement are not known. Perhaps the deformation began in Pennsylvanian time or even before and continued into the Mesozoic era. The maximum movement took place at or near the end of the Carboniferous period, but the present structure may not be a fair indication of the amount of deformation at that time, for it is the product of all the deformation since the strata were deposited.

In parts of southern Illinois molten rock from far down in the earth was forced up into the overlying rocks so near to the surface that it has since been laid bare by erosion. No igneous rock has yet been found in these quadrangles, and possibly no such rock is present within several thousand feet of the surface.

MESOZOIC ERA.

EARLY MESOZOIC TIME.

The deformation at the end of Carboniferous time greatly increased the general altitude of the central and eastern parts of the United States, and the New Athens-Okawville district was raised considerably above sea level, though not nearly so high as other areas were raised. Because of this uplift new processes began to act, and areas which had almost continuously received rock material now began to lose it. Erosion has continued with few interruptions to the present time, though at several epochs it has probably been accelerated by uplifts of the region. At times parts of the region have undergone relative subsidence.

In areas where the uplifts were greater—especially where the strata are rather resistant—several stages of uplift are recorded between which considerable parts of the surface were reduced almost to a plain. Perhaps at each of the epochs of mountain uplift the area now included in southern Illinois was also uplifted but to a less degree. Furthermore, there may have been unrecorded periods of planation for each planed surface, as the record of one cycle of erosion may have been more or less completely destroyed by erosion during the next cycle. The process of reduction may be stopped at any stage, and the less complete the cycle the more easily is its record destroyed. In most of Illinois the uplifts were not great and most of the rocks are nonresistant, so that the records of uplift and erosion are poorly preserved. In the Appalachian and Ozark provinces the record is better preserved because of the presence of harder rocks, but it has not yet been completely deciphered.

In the Appalachian province the earliest known and apparently the most perfect peneplain seems to pass beneath the Cretaceous rocks of the Coastal Plain and hence must have been developed before they were laid down. Similar Cretaceous rocks extend northward into the southernmost counties of Illinois, and the surface beneath them, though not very flat, is a peneplain. In places this peneplain seems to end rather abruptly against the Shawneetown Hills, but this appearance may be due to deformation in the hills, and the peneplain probably would lie above their tops. Farther north it has been even more greatly deformed. With the possible exception of remnants in the high rough country in the southern end of the State, this peneplain where not buried has been completely destroyed by erosion.

CRETACEOUS PERIOD.

Near the beginning of the Cretaceous period a crustal movement probably again raised the Appalachians and the Ozarks, and if so, presumably at least, the borders of the Glaciated Plains were affected. After this uplift erosion of the surface proceeded with renewed vigor until a lower, more or less planed surface was formed. In places this surface seems to pass beneath the Tertiary sediments of the Coastal Plain without great deformation, though generally there appears to be a downward bend of the surface where it passes under the cover of these sediments. Some of the hilltops in the southern end of Illinois are of medium and concordant height and may be remnants of this surface. A positive statement can not be made, because the hills are scarcely extensive enough to form a good basis for generalization, and because detailed work has not been done either there or in the Ozark province. Both of the old surfaces that have been mentioned seem to be older than any part of the surface in the New Athens-Okawville district, and therefore a third cycle of uplift and erosion seems to have occurred before the surface in this area was formed.

CENOZOIC ERA.

TERTIARY PERIOD.

The third cycle of erosion just mentioned was brought about by an uplift, which seems to have occurred near the beginning of the Tertiary period. During this cycle the surface features of Illinois acquired almost their present form. No doubt there were other Tertiary movements, but if their record is preserved it has not yet been deciphered. Perhaps the uplift was continuous and slow and the climate was uniform. If so there were no substages of erosion, and the only record made was the surface at the end of the period—the product of erosion that progressed at a uniform rate.

By the end of the Tertiary period the lowland that now occupies most of southern Illinois had developed, and belts along Ohio and Mississippi rivers were left standing high, perhaps through differential erosion and perhaps by late Tertiary uplift of the Ozarks. The rocks of the lowland yield somewhat more readily to erosion than those along the Mississippi, though the lowland contains numerous somewhat resistant layers of limestone and here and there one of sandstone. The southern part of Illinois is somewhat basin-shaped, and the normal place for the master drainage line would seem to be in the lower part of the area, instead of up on the side of the basin. Furthermore, the valley of the Mississippi is narrow and steep-sided and apparently is in a youthful stage of development. Perhaps one cause of this youthful appearance is the fact that the basin now draining into the Gulf is much larger than the preglacial basin, for the glacier blocked many northward-flowing streams and held them until southward outlets were formed.

Near the end of Tertiary time there seems to have been a depression of the border of the continent at least, but no certain evidence of subsidence at this time has been found in Illinois. The gravel deposits commonly called "Lafayette," which are found here and there on high hills in Illinois and near-by States and which are thought to be of late Tertiary age, suggest some crustal warping during late Tertiary and early Quaternary time.

QUATERNARY PERIOD.

At the beginning of the Quaternary period the surface of southern Illinois had the same general form and position which it has at present, though certain details, particularly of the valleys, were different. The surface at that time had been formed solely by the erosion of the old Carboniferous coastal plain. The present surface has been modified by further erosion in the early part of the Quaternary period; by a deposit of unconsolidated material that averages nearly 100 feet in thickness, some of which has been brought to its present position by ice, some by wind, and some by water; and by stream erosion in later Quaternary time. Soon after the beginning of the Quaternary period the interior of the continent seems to have been relatively uplifted, so that the streams could deepen their valleys. Perhaps this uplift was earlier and was contemporaneous with a movement in the opposite direction that affected the continental border late in the Tertiary period. No doubt the great changes of climate which began early in the Quaternary period if not late in the Tertiary period also aided greatly in the development of the deposits and topographic features which originated at about that time.

PLEISTOCENE EPOCH.

So far as now known the first recorded event of Pleistocene time in this area was the advent of the Illinoian ice sheet. Older ice sheets—the Nebraskan and Kansan—covered much of the northern United States, but no certain evidence has yet been found that these ice sheets reached the New Athens-Okawville district. In many places the upper part of the till of this area has a somewhat different appearance from the lower, but it is quite possible that these differences are due to weathering or to incidental causes. It is also possible that the lower part of the Illinoian till was derived from a thin older till which was so generally mixed with other material that it has not yet been recognized. Old soils and pieces of wood are reported in some drill records, but apparently they come from several horizons. Scattered pieces of wood in till do not indicate more than one sheet of till, for in a single invasion of ice wood may be so incorporated in the till as to be preserved.

ILLINOIAN STAGE.

The great Illinoian glacier reached in southern Illinois the most southerly point attained by any Pleistocene ice sheet and covered more than 1,000 square miles south of the 38th parallel. It occupied all the area included in the New Athens-Okawville district, and when it melted it deposited its load of clay and fragments of rock which it had gathered on the journey from Canada. Stones that came from near-by areas are most numerous in the till, but it contains also coarse-grained igneous rocks from Canada, jaspilite and conglomerate from the Huronian formations, quartzite from the eastern end of Lake Superior, and chert and silicified limestone from northern Indiana and eastern and central Illinois. Fragments of the most resistant rocks are by far the most abundant, because the other rocks were more easily abraded and more rapidly weathered. Pebbles of quartz make up a surprisingly large part of the gravel, for most of the native rocks of Illinois do not contain quartz particles larger than sand grains. Perhaps at the time the ice sheet advanced there were in Illinois extensive remnants of the gravel which has commonly been called "Lafayette formation" and which was so disintegrated that little remained but loose pebbles.

Aside from some of the rounded pebbles and some sand and silt, the material carried by the ice was gathered from the weathered parts of older formations, including both the completely decayed rock and blocks which had been loosened by weathering. Not all the old residual material was removed. In places none of it was removed far. Elsewhere the whole thickness of residual material and here and there some of the underlying hard rock was displaced, for the ice was thousands of feet thick and the friction at its base was very great. As the ice melted at the margin this glacial débris, consisting of clay, sand, pebbles, and boulders, was spread somewhat evenly upon the surface. Some of the material was no doubt deposited under the moving ice; a small part was pushed along in front of it; some was dropped at the ice front, as it melted along the edge while still advancing; and a part was let down when the ice melted away bodily and formed a layer of rather uniform thickness covering the surface.

The Illinoian glacier seems to have been less vigorous than some of the others, for example the Wisconsin. It did not pick up all the surface materials and severely abrade bedrock and the stones which it carried; it did not develop large terminal and recessional moraines; it did not carry a very heavy load of débris or many blocks of rock larger than small pebbles; and on wasting it did not yield extensive outwash deposits.

EVENTS BETWEEN ILLINOIAN AND WISCONSIN STAGES.

When the glacier disappeared it left a layer of drift which covered the hills and buried some of the valleys previously developed, leaving the surface more nearly even than before. As the ice melted the streams took possession of the surface, some of them perhaps being developed first on the ice, but the general process consisted in the headward development of the drainage lines as the surface was uncovered, so that streams which flowed directly away from the ice front were extended headward and thus became longer than other streams. To-day the streams that flow southward or southwestward are noticeably longer than those that flow in any other direction. The valleys were deepened until at the beginning of Wisconsin time they seem to have been deeper than they are to-day.

Another notable feature was the development of soil through the reoccupation of the region by plants. In northern Illinois and elsewhere some of the soil formed at this time was buried and preserved, for a dark layer that contains plant débris is found at the top of the Illinoian till in many places. This soil has been called the Sangamon soil because it is extensively developed in Sangamon County, Ill. It was thickest on the more level parts of the upland, where in many places it was peaty. On the slopes in the vicinity of the streams, where erosion processes were more active, the soil was not so well developed.

At about this time Mississippi and Kaskaskia rivers began to receive more sediment than they could carry, and the sediment was so abundant and so generally delivered that they built up their channels above the rock floor almost throughout their lengths. Perhaps subsidence or the relative elevation of certain marginal areas or a climatic change also aided the deposition of sediment, but the uniformity and great length of these deposits and their seeming relation to the glacial deposits suggest that the cause was overloading of the streams, either directly by some glacier or indirectly by the rapid excavation of tributary valleys that immediately followed glaciation. At any rate the process of valley filling by the main streams went on so rapidly that the tributary streams were dammed and lakes were formed in the lower ends of at least some of them. The exact time when this took place is not known, but it was certainly after the deposition of the Illinoian till, for that till had been deeply dissected before the deposition of the valley filling, which in most places rests on bedrock. Apparently it was before the loess was deposited, for the valley filling is mantled in places by loess. This loess, however, is comparatively thin and discontinuous and may possibly be younger than the main deposit of loess on the hills.

The next conspicuous event in this region was the deposition of the loess. Exactly when this event occurred and the length of time that it occupied are not known, but the principal deposit was made at some time between the invasions of the region by the Illinoian and the Wisconsin ice sheets. Some investigators think that it occurred about the middle of this interval, and the United States Geological Survey classifies the loess as Peorian.

The method of accumulation of the loess presents a problem which is not yet fully solved, but apparently most of the material that is called loess is dust which was transported and deposited by the action of the wind. However, many have thought that it was laid down in water, for in places material that is believed by some to be loess is stratified and contains aquatic fossils. Besides, material could hardly be carried by the wind to extensive areas so much more rapidly than it could be removed by weathering that it would accumulate to a thickness of many feet. On the other hand, the fossils in the loess are mostly land animals, in most places stratification is absent, and the distribution of the material indicates that if it was deposited by water the highest hills must have been submerged—all of which favors the view that the loess was deposited by the wind. If the loess was laid down in water there must have been in southern Illinois a body of water at least 100 and probably several hundred feet deep and hundreds of miles broad. Most of the surface of southern Illinois lies below the altitude of the principal deposits of loess on the river bluffs of the Mississippi, and if the bluffs were submerged the lowland must have been under deep water, but throughout the southern part of the State the loess does not appear to be stratified or to show other evidence of aqueous origin. It is thinner in the interior than it is on the river bluffs, and its character and surface features throughout seem very different from those which would result from a general submergence. The difference, for example, between the loess and the valley filling is very marked. In the New Athens-Okawville district the loess covers hills and valleys alike, except that probably because of erosion it is now somewhat thinner on the sides of the valleys than on the hills. It contains no interbedded sand or gravel, and the surface does not have the form of a terrace. All the fossils found in it are shells of woodland snails (land animals), and it therefore seems probable that the loess of this district was deposited by the wind.

The derivation of the loess is an even more difficult problem. Those who have done the most work on it incline to the belief that it was carried as dust from the river flood plains. The facts in support of this view are that the loess is not only thickest on the river bluffs but thicker on the side opposite the direction from which the prevailing winds blow. In the semiarid Great Plains province dry river bars are to-day productive sources of dust. At the time when the loess accumulated the river bluffs may have been, as they are now, covered with forests, and the trees may have aided greatly in catching and holding the dust.

On the other hand, the view that all or nearly all the loess was derived from stream-deposited silt seems doubtful because of the great volume of the loess. It now covers most of the surface of several States to a depth of 5 to 10 feet, and the original thickness may have averaged 15 feet or even more. Such a mass could hardly in a small part of one period have been blown up by wind from the river channels. A part of the loess may have come from dry plains to the west and perhaps a part from glacial till that was not yet covered with vegetation.

The accumulation of some material that has been classed as loess, though in reality it is not true loess, has been attributed to the work of earthworms. In making their borings these animals are continually bringing fine material to the surface, and the result of many thousand years of their work may be a considerable layer of this material. This process is counteracted by erosion, which tends to carry away fine material from the surface, and it is limited by the depth to which worms penetrate. Most of the loess, however, is certainly not a product of the work of worms.

After the loess had been deposited and before Wisconsin time the main streams deepened their valleys 50 feet or more.

WISCONSIN STAGE.

In late Pleistocene time the Wisconsin ice sheet was formed in the northern part of the country and extended southward into Illinois, but it did not reach the area included in the New Athens-Okawville district. However, it furnished more material to Kaskaskia and Mississippi rivers than they could carry, and hence they built up their channels throughout their courses. This process of valley filling also went on so rapidly that the tributary streams were dammed and lakes were formed in their lower ends. This event occurred in either Wisconsin or early Recent time, after the melting of the ice and during the excavation of new valleys in areas where the old valleys were partly filled or obliterated. The main streams of southern Illinois show indications of both epochs of valley filling, and probably each of these was connected with a distinct epoch of glaciation.

When the later valley filling began, the rivers were flowing on beds probably somewhat below their present beds. The old channel on bedrock 100 feet or more below, which had probably been cut in a preglacial or a preceding interglacial stage, may have been due to a regional uplift, or to the deep scouring by the glacial floods, or possibly simply to the enlargement of the drainage basin. In the early part of Wisconsin time the tributaries entered the flood plains of the Mississippi and the Kaskaskia on beds perhaps 40 feet lower than those on which they flow to-day, and their flood plains lay near the position of their present beds, these positions being controlled by low-water and high-water stages on the master streams. At low-water stage the tributaries contained no standing water, but at high water the channels 30 to 50 feet deep were filled by back water from the rivers, thus intermittently forming long, narrow, winding lakes. When aggradation began on the Mississippi and the Kaskaskia, both low-water and high-water levels on them and on their tributaries rose. At low water small perennial lakes were formed in the channels of the tributaries at their mouths, and at high water the flood plains were covered more deeply than before. The area covered at both stages was gradually extended until the low-water stage may have reached the altitude of the former flood plain. From this time on each tributary held perennial bodies of quiet water of considerable size, and a lake deposit, which was nearly 100 feet thick at its lower ends and which thinned to feather edges upstream, accumulated on the old flood plain.

Nearly all the material deposited in the lakes was fine sediment, such as would be carried in suspension, and the lakes seem to have been filled with this material up to certain concordant positions, probably to the natural position of a flood plain or just below the high-water mark of the time.

When the Mississippi and the Kaskaskia finally became able to carry not only the load delivered to them but a little more they began to cut down their beds again. Perhaps even before this time the lakes had become intermittent and were drained except at times of high water, for they were almost filled with sediment. The great flat lake bottoms became swamps, and the channels began to be deepened again at the former outlets. The lakes may have existed in the early part of Recent time, for though it is customary to think that glacial outwash deposits, such as caused these lakes, were developed directly in front of the ice, it would seem quite possible that they might at least have continued to grow after the ice melted.

RECENT EPOCH.

Since Wisconsin time the streams have deepened their valleys, but the dissection of the valley filling was checked at times and perhaps at some of these times there was more or less aggradation. At any rate several low terraces were probably formed at this time in the Kaskaskia bottoms, as shown on the geologic map. Some of these terraces, however, may be normal stream terraces that do not mark stages of erosion.

There is some indication of uplift along the Mississippi since the formation of the terraces, for those along the lower Kaskaskia, particularly the higher and older ones, seem to rise upstream.

All the streams, whether building up or cutting down, have made deposits continuously, and these deposits are found along their banks to-day. Each stream, as it swings back and forth across its valley, deposits on one bank and cuts on the other. Most of this work is done at times of high water, when the streams spread over their flood plains and drop the finer material where the land surface is high and the water is shallow and the coarser material where the water is deeper. In consequence, an average section of a flood-plain deposit is progressively finer from base to top, and there seems to be a fairly sharp change from coarse to fine material a little above the middle of the deposit.

Besides the work of streams that has been described, several other processes of gradation have been in operation in this district throughout Recent time. Among the most effective of these processes is the work of surface water from the time when it falls as rain until it is gathered into streams that have comparatively fixed courses. Some of the fine material that is carried in this way from slopes is soon dropped, especially if it reaches the flat surface of one of the lake deposits, and forms lenticular masses of small extent and characteristic appearance. During this process the rounded pellets known as "buckshot" seem to be formed, but that the whole process is not essential is shown by the fact that the "buckshot" are found almost at the source of the fine material.

Throughout the district fine particles from the surface are probably being carried down a few feet by percolating water, and this process, in part at least, has caused the formation of the very compact subsoil that is commonly known as hardpan. In places where the hardpan is best developed the vegetation consists almost entirely of *Quercus obtusiloba*, and these districts are known as "post-oak flats." In the rougher areas the soil is more porous, perhaps because the transportation of material is more active.

MINERAL RESOURCES.

Aside from the soil and water the most valuable mineral resource of the New Athens-Okawville district is coal. Most of the area is underlain by at least one bed of workable coal, and the eastern part by two or three beds. Next in value are the clay and shale, of which there is an abundant supply. Sandstone suitable for rough building stone crops out here and there throughout the area.

COAL.

The New Athens-Okawville district lies in the southwestern part of the eastern interior coal field. (See fig. 6.) In the year 1918 St. Clair County produced 7,810,186 tons of coal, all of which was mined from the Herrin bed. Other coals, however, are present in many places, most of them in the Carbondale formation. The Pottsville formation includes a few thin lenses of coal, but so far as known not any of them are of commercial value.

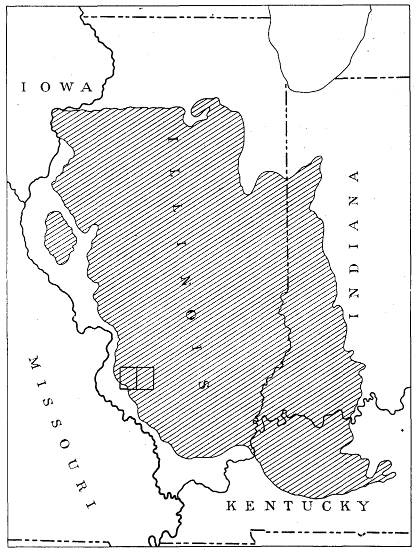


FIGURE 6.—Outline map showing the location of the New Athens and Okawville quadrangles (the small rectangles) in the eastern interior coal basin of Illinois, Indiana, and Kentucky, represented by the ruled area.

Murphysboro (No. 2) coal.—Probably the lowest coal workable anywhere within the New Athens-Okawville district is the Murphysboro (No. 2) coal at the base of the Carbondale formation, 175 to 250 feet below the Herrin coal, which is extensively worked. It is probably equivalent to the coal bed that is mined at Colchester, to the "third vein" near LaSalle, and to coal No. 2 in the vicinity of Morris and Braidwood, in the northeastern part of the basin.

The Murphysboro coal is of excellent quality as compared with the other coals of the State, all of which are of a medium bituminous rank, but its thickness is irregular and is probably less than 3 feet throughout three-fourths of the New Athens-Okawville district. However, data concerning its character and thickness in this district are scarce. Most of the test borings for coal extend down only to the Herrin coal, and the test borings for oil, which are made with a churn drill, do not afford accurate information concerning coal beds. The Murphysboro coal does not crop out, partly because the beds are concealed by surficial material and partly because in many places the beds in the upper part of the Carbondale formation, immediately above the coal, extend farther west than the coal. In adjacent territory to the north and east the Murphysboro coal has been penetrated in several borings, and in Jackson County, about 30 miles to the southeast, it is extensively mined. Samples collected in Jackson County were found on analysis to consist "as received" of 9 to 14 per cent of moisture, 50 to 52 per cent of fixed carbon, 31 to 36 per cent of volatile matter, 4 to 6 per cent of ash, and about 1 per cent of sulphur. The heating value of the coal as received ranged from 12,102 to 12,558 British thermal units, and the fuel ratio ranged from 1.39 to 1.65. The amounts of ash and sulphur are considerably below the average for coals of the eastern interior coal field. The roof of the coal is generally a tough black shale that is overlain by sandstone or sandy shale, and the floor is a hard clay.

Coals between the Murphysboro and Herrin coals.—A coal that is commonly reported in drill holes in this and adjoining areas lies 125 to 160 feet above the Murphysboro coal. This bed may be equivalent to the Springfield (No. 5) coal, which it resembles in some respects, particularly in that it is associated with much clay, both in the roof and floor and forming veins in the coal. This coal is probably not very persistent, but it may be workable in some places. Several years ago a mine on this coal was opened at Carlyle, about 20 miles northeast of Okawville, and in that mine the bed is separated into two benches by a layer of clay several feet thick. Traces of coal are present at other horizons between the Murphysboro and Herrin coals, but little is known of these other coals, and as they are only rarely reported in drill records and where reported are very thin they are probably not workable under present commercial conditions anywhere within the New Athens-Okawville district.

Herrin (No. 6) coal.—The Herrin coal is by far the most valuable coal in the New Athens-Okawville district and is the bed worked in all the mines now in operation. It underlies the eastern three-quarters of the district, and its western limit is indicated in figure 5 and described under the heading "Stratigraphy" (p. 5). So far as known, it is present throughout the area east of its outcrop, and its average thickness is about 6½ feet. It is mined extensively along the Illinois Central Railroad and also at Rentchler, Mascoutah, Okawville, St. Libory, and Darmstadt. A list of the mines is given in the table below:

Coal mines in or near the New Athens-Okawville district.

[Arranged in order of tonnage produced in 1911.]

Name of operator and mine.	Post-office address of mine.	Location.				Depth of coal below surface.	Thickness of coal.	
		Quarter.	Section.	Township.	Range.	*Feet.*	*Ft.*	*in.*
Mulberry Hill Coal Co., Mulberry Hill mine	Freeburg	SW.	18	1 S.	1 W.	150	7	
Kolb Coal Co., Mascoutah mine	Mascoutah	SE.	32	1 N.	6 W.	180	7	
Borders Coal Co., No. 1 mine	Marissa	SW.	27	3 S.	6 W.	80	7	
Johnson Coal Co., O. K. mine	do	NW.	35	3 S.	6 W.	120	7	
Kolb Coal Co., Fairbanks mine	New Athens	NE.	2	3 S.	7 W.	180	7	
Missouri & Illinois Coal Co., Rentchler mine	Rentchler	NE.	33	1 N.	7 W.	130	6	6
Bessemer Washed Coal Co., Lenzburg mine	Lenzburg	SW.	7	3 S.	6 W.	191	7	
Star Coal Co., Star mine	Freeburg	NW.	18	1 S.	7 W.	130	6	
Borders Coal Co., No. 2 mine	Marissa	SW.	21	3 S.	6 W.	90	7	
Avery Coal & Mining Co., Rundle mine	Freeburg	NE.	19	1 S.	7 W.	150	7	
Missouri & Illinois Coal Co., Wilderman mine	Wilderman	SW.	1	1 S.	8 W.	90	6	6
T. M. Meek Coal Co., Meek mine	Marissa	SW.	36	3 S.	6 W.	170	6	6
Bessemer Washed Coal Co., Advance mine	do	NE.	28	3 S.	6 W.	87	6	
Sunlight Coal Co., Freeburg mine	Freeburg	NE.	30	1 S.	8 W	120	7	
Kolb Coal Co., Vinegar Hill mine	New Athens	NW.	2	3 S.	7 W.	180	7	
Gauch Coal Co., Enterprise mine	Rentchler	NW.	34	1 N.	7 W.	120	6	6
Silver Creek Valley Coal Co., Beaty mine	Mascoutah	SW.	35	1 N.	7 W.	100	6	
Cooperative Coal Co.	New Athens	SW.	26	2 S.	7 W.	80	6	
John T. Beaty	Mascoutah	NW.	32	1 N.	6 W.	100	6	
O. W. Schumacher & Son	Marissa	SE.	28	3 S.	6 W.	60	6	
Henry Hoffman	Freeburg	NE.	5	2 S.	7 W.	([a])	5	6
St. Libori Coal Co.	Belleville	NW.	14	2 S.	6 W.	200	6	6

[a] Open cut.

The coal from the Herrin bed has a cubical cleavage and in general is shining black but laminated with alternate bright and dull lines. A persistent layer of dirt 2 inches thick—the "blue band"—lies about 20 inches above the base. Higher in the bed, especially near its top, there are several partings along which "mother of coal," or "mineral charcoal," is conspicuous. "Sulphur balls" are numerous in some places and do not seem to be more abundant in one part of the bed than in another. The coal is noncoking. So far little if any of it has been washed.

The roof of the coal consists of black and gray shale, generally only a few feet thick and overlain by limestone. It can be supported by an ordinary amount of timbering, but generally some coal is left for additional support. Blocks of both shale ("roof slate") and coal, however, frequently fall, and more miners have been killed or seriously injured in this way than in any other. The floor under the coal is a hard clay, generally less than 2 feet thick and underlain by limestone. Squeezes are rare. The coal has a distinct cleat, which, however, is not so strong as to prevent cutting the coal in any direction desired. It is shipped to St. Louis and other points in Missouri and to many points in Illinois, including Chicago.

Methods of working.—Most of the coal produced in the New Athens-Okawville district is mined from shafts, but a part of it is mined from slopes and drifts. The room and pillar method is used in all mines.

In the larger mines the coal is either undercut with electric chain machines and shot down or it is cut with compressed-air punchers. The coal is hauled by mule or electric power to the bottom of the shaft, and from there it is hoisted 40 to 60 feet above the surface by steam power and dumped on inclined stationary or shaker screens, so that it is sized as it slides down over the screens into the railroad cars. The sizes produced are generally run of mine (unscreened), lump, egg, nut, pea, and slack. The capacity of the mines ranges from 20 to 700 tons a day, but as the coal gradually deteriorates on being exposed to the air it is mined according to the demand, and some of the mines shut down for a few months every summer. Others run two or three days a week. Grain threshing late in the summer makes a perceptible increase in the demand for coal. Of the total output about 25 per cent is shipped as run of mine, 45 per cent lump, 5 per cent egg, 3 per cent nut, 20 per cent pea, and 2 per cent slack or waste. The relative amount of run of mine coal appears not to vary greatly; that of lump coal is gradually decreasing; that of egg rapidly increasing, being nearly four times as much as ten years ago; that of nut about the same; that of pea increasing; and that of slack decreasing, being about half as much as it was ten years ago.

The deeper mines are dry, but the shallower ones are troubled with water. Generally, however, neither the necessary pumping nor sprinkling involves great expense. From one-third to one-half of the coal is left in the ground, mostly in pillars, but in some mines, where the overlying shale is not strong, coal is left in the roof, and in a few it is left in the floor.

Analyses.—Several samples of the Herrin coal were collected, the method of sampling being that used by the United States Geological Survey as well as by the Illinois Geological Survey. By this method the average composition of the coal at a certain point can be determined.

Analyses of coal from mines in or near the New Athens-Okawville district.

[Made in laboratory of State University by J. M. Lindgren and others under supervision of S. W. Parr, unless otherwise specified.]

Laboratory No.	Kind of sample.	Form of analysis.	Proximate.				Ultimate.					Heating value (British thermal units).
			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxgen.	
2628	Face	A	10.04	37.61	41.04	11.31	4.36					11,219
		B	5.92	39.38	42.92	11.83	4.56					11,733
		C		41.81	45.62	12.57	4.85					12,471
		D		47.82	52.17							
2631	Face	A	10.80	38.08	40.01	11.11	4.49					11,072
		B	6.73	39.82	41.83	11.62	4.69					11,577
		C		42.69	44.85	12.46	5.04					12,412
		D		48.76	51.23							
2632	Face	A	10.43	37.62	40.35	11.60	4.21					11,060
		B	6.10	39.44	42.30	12.16	4.41					11,595
		C		42.00	45.05	12.95	4.70					12,348
		D		48.23	51.75							
991	Face	A	9.76	37.26	38.72	14.26	4.29					11,011
		B	3.19	39.97	41.54	15.30	4.61					11,813
		C		41.29	42.91	15.80	4.76					12,202
		D		49.08	50.90							
992	Face	A	10.18	34.37	40.89	14.56	4.50					10,596
		B	3.75	36.83	43.82	15.60	4.82					11,354
		C		38.26	45.53	16.21	5.01					11,797
		D		45.65	54.33							
995	Face	A	10.05	39.00	39.73	11.22	3.77					11,311
		B	5.27	41.07	41.84	11.82	3.97					11,913
		C		43.36	44.17	12.47	4.19					12,587
		D		49.52	50.46							
3910 (U. S.) [a]	Face	A	10.73	39.60	40.41	9.26	4.12					
		D		49.49	50.50							
3 12 (U. S.) [a]	Face	A	9.88	42.26	37.05	10.81	3.83					11,439
		D		53.28	46.71							
4364 (U. S.) [a]	Car	A	11.69	35.70	39.42	13.19	4.38	5.46	57.15	0.94	18.88	10,699
		D		47.50	52.81							
Coop. 79A	Face	A	10.69	40.16	37.84	11.28	4.55					11,063
		B	4.08	43.18	40.64	12.12	4.89					11,882
		C		44.94	42.39	12.64	5.10					12,387
		D		51.45	48.54							
Coop. 79B	Face	A	11.12	40.54	38.27	10.07	4.18					11,145
		B	4.30	43.65	41.21	10.84	4.50					12,001
		C		45.61	43.06	11.33	4.70					12,540
		D		51.43	48.53							
Coop. 79C	Face	A	12.12	38.61	40.61	8.66	3.10					11,217
		B	4.39	42.01	44.18	9.42	3.37					12,204
		C		43.93	46.22	9.85	3.52					12,764
		D		48.72	50.16							
Coop. 80A	Face	A	10.19	38.44	40.41	10.96	3.95					11,127
		B	5.18	40.58	42.67	11.57	4.17					11,747
		C		42.79	45.00	12.21	4.49					12,388
		D		48.63	52.27							
Coop. 80B	Face	A	9.83	39.84	37.97	12.36	4.02					10,958
		B	4.79	42.07	40.09	13.05	4.24					11,570
		C		44.19	42.11	13.70	4.45					12,152
		D		51.19	48.79							
Coop. 80C	Face	A	10.11	39.42	38.84	11.30	3.69					11,051
		B	5.16	41.91	41.01	11.92	3.89					11,660
		C		44.19	43.24	12.57	4.10					12,294
		D		51.20	48.79							
1600	Face	C		42.64	42.22	15.14	5.69					11,908
		D		50.25	49.77							

[a] Analyses made in laboratory of the United States fuel-testing plant at St. Louis, Mo. See U. S. Geol. Survey Bull. 332, p. 115, 1908.

A, Sample as received; B, air dried; C, moisture free; D, moisture and ash free. C and D are calculated from A and B.

2628. Fairbanks mine of Kolb Coal Co., near Lenzburg.
2631. Mine No. 1 of Kolb Coal Co., Mascoutah.
2632. Mine No. 2 of Kolb Coal Co., Mascoutah.
991, 992. Fullerton mine of Fullerton Coal Co., Belleville.
995. Pittsburgh mine of Pittsburgh Mining Co., Belleville.
3910, 3912, 4364, Coop. 79A, Coop. 79B, Coop. 79C. Mine No. 8 of Southern Coal & Mining Co., Shiloh Township.
Coop. 80A, Coop. 80B, Coop. 80C. Mine No. 1 of Borders Coal Co., Marissa.
1600. Mine No. 2 of Mulberry Hill Coal Co., Freeburg.

OIL AND GAS.

Several deep borings have been made in the New Athens-Okawville district in the search for oil and gas. A showing of oil was found near Smithton, where a sandstone of the Chester group—probably the Carlyle sand—yielded traces of oil in several shallow wells. One well was sunk at this place to a depth of 1,375 feet, but oil in paying quantities was not found. Other dry wells have been sunk at Marissa, Mascoutah, Okawville, and Oakdale, and one near Addieville, just east of the district. One well at Mascoutah produced about a gallon of oil a day for some time.

Although these tests have all been failures, it appears quite possible that one or more pools of oil may underlie the area, because some places where the geologic conditions, so far as known, are good have not yet been tested. The writer has described these areas elsewhere.[1]

CLAY.

Clay suitable for the manufacture of common brick and tile is abundant in the New Athens-Okawville district but has been very little worked. The loess, which lies at the surface throughout the district and which is the most abundant source of clay, ranges in character from loose and porous to compact and plastic or "fat" and, except the surface soil, is everywhere free from stones or other impurities which need be excluded.

The till includes much good clay and generally lies near enough to the surface to be worked in connection with the loess. However, it contains so many stones that it is of comparatively little use.

The shale of the Carboniferous system is abundant in this district, but it lies so far below the surface that it may not be worth working. The Chester group contains much good clay shale, and a few years ago a good-sized plant was erected near Columbia, a short distance west of this district, to mine this shale underground and make clay products, including semi-refractory brick.

The valuable clay mined at St. Louis and known by the trade name Cheltenham belongs near the top of the Pottsville formation, and pockets of this clay may possibly be found in this district.

WATER RESOURCES.

Water supplies.—The water in the New Athens-Okawville district is chiefly of meteoric origin—that is, it has fallen upon the surface from time to time in the form of rain or snow. The average precipitation is about 40 inches a year. About one-fourth of the water that falls as rain or snow leaves the area by way of Kaskaskia River; a large part if not most of the other three-fourths is evaporated before it reaches the streams or percolates far underground, but a small part sinks below the surface and accumulates in the porous strata. However, some of the water in the deep wells, particularly the salt water, was probably inclosed in the sediments when they were deposited and was sealed in by impervious beds of clay. It is thus, so to speak, fossil sea water.

The major part of the district has an adequate supply of fairly good water for drinking and ordinary industrial uses, but it is commonly difficult to obtain a sufficient quantity of good water for municipal and other uses for which relatively large supplies are required.

The water supplies are obtained from streams, wells, cisterns, and reservoirs. The streams are supplied by water which has flowed to them directly over the surface and by water which has seeped to them through the ground.

The rain or snow as it falls contains practically no dissolved material except small quantities of gases. Even these gases are not of much significance except the carbon dioxide, which enables the water to dissolve certain constituents of the rocks, particularly limestone, in much larger quantities than would otherwise be possible.

On reaching the ground the water begins to dissolve the rock materials, and in general everything dissolved makes the water less valuable for nearly all uses. In most waters the main constituents dissolved and the ones which most affect the value of water are compounds of calcium and magnesium, which are obtained from limestone, dolomite, and gypsum and in greater or less proportions from nearly all rocks. Limestone and dolomite, which are carbonates, do not dissolve readily without the aid of carbon dioxide, but when it is present they go into solution, forming bicarbonates. Removal of the carbon dioxide by boiling or by the use of chemicals causes most of the calcium and some of the magnesium present as bicarbonates to separate out as a precipitate. Most of the scale in tea kettles and boilers using certain waters is formed of calcium carbonate, which has been precipitated in this way.

Calcium and magnesium are the active ingredients in the formation of scale in steam boilers. If the water has dissolved gypsum, which contains calcium and sulphate, or if it has obtained much sulphate from some other source, the scale formed in boilers will be harder than that formed from a water that carries little sulphate. Some plants prevent the scale from adhering to their steam boilers by the use of boiler compounds, and some plants remove the calcium and magnesium from the water before it is fed to the boiler.

Calcium and magnesium cause the hardness of water. Hardness is usually recognized by the formation of a curdlike precipitate when soap is used with the water. This precipitate wastes soap and makes difficult the cleansing of articles washed in the water. Hard water can be softened to some extent by the addition of chemicals. Soda is mostly used for this purpose, though borax, ammonia, and sodium phosphate can also be used. In large commercial plants lime and soda are used. These plants require chemical supervision to insure addition of the correct quantities of chemicals.

In recent years water-softening systems have been introduced that depend upon the use of sodium-aluminum silicates, which are known as "exchange silicates" and which are made from different natural or manufactured raw materials. When hard water flows through a bed of grains of one of these exchange silicates, the calcium and magnesium in the water are replaced by sodium, leaving the water practically free from hardness. When the silicate no longer softens water completely it is regenerated by the use of a strong salt solution, which causes a reversal of the softening reaction and gives sodium back to the silicate in exchange for the calcium and magnesium removed from the water. After the material is washed it is ready for use again.

Water softening by exchange silicates is particularly suitable for laundry work. Some waters are not greatly improved for boiler use by this means, because the excessive quantity of sodium salts that results from the removal of the scale-forming calcium and magnesium leads to foaming in the boilers.

Ground waters commonly contain excessive quantities of iron, which may give them an unpleasant taste. The iron also causes stains on porcelain or enameled ware or plumbing fixtures and may stain articles washed in the water. Iron can sometimes be removed easily by allowing the water to spray or trickle through the air and then settle or pass through a filter.

The best and most generally used method of procuring soft water in the New Athens-Okawville district is by the use of cisterns. Care is necessary in the construction and use of cisterns, and even when care has been exercised the water may not be suitable for drinking or cooking, but with proper precautions cisterns furnish the best possible water for use in washing.

By far the most important feature of the problems of water supply is the question of the sanitary quality. Though details relating to this subject belong in the field of work of national and State health organizations, geologic conditions are frequently determining factors.

Mineral constituents present in waters in the quantities found in the waters of this district that are regularly used for drinking have comparatively little effect on health. The real danger is the contamination of drinking water with bacteria which produce diseases, notably typhoid fever. Water may be badly polluted with human and other excreta, but if germs of typhoid fever or other infectious disease are not present in the polluting matter those drinking the water may not be harmed. Therefore the fact that water from a given source has not caused disease is no guaranty that it will not do so as soon as excreta containing the germs of certain diseases are contributed to the pollution.

Deep wells are the safest as a general rule. Shallow wells are always open to suspicion, but by proper location and construction they can nearly always be made safe. Stream waters in most parts of the United States are so exposed to pollution that water from them is not considered safe for drinking until it has been filtered or sterilized by bleaching powder or by chlorine or has received both treatments. Some stream waters that are collected from carefully guarded drainage basins and subjected to long storage are considered safe, but sterilization is at present very widely practiced as an added precaution.

Chemical analyses at best furnish little basis for judging the sanitary quality of waters. The analyses in this folio and the statements made in regard to different waters do not take into account possible pollution.

Surface water.—Streams furnish the cheapest and most abundant source of water in the district. The United States Geological Survey, in cooperation with the State of Illinois, has obtained records of stream flow within or near the New Athens-Okawville district at the following points:

Kaskaskia River at Carlyle: The gaging station is located at the Baltimore & Ohio Southwestern Railroad bridge about one-fourth of a mile east of the railroad station. The record extends from March 2, 1908, to December 31, 1912, with the exception of October, 1912.

Kaskaskia River at New Athens: The gaging station is located at the Illinois Central Railroad bridge about 600 feet north of the Illinois Central Railroad station. The record extends from November 1, 1909, to December 31, 1912, with the exception of October, 1912. A record of river height at this point from January, 1907, to October, 1909, was obtained by the New Athens Journal. The river height was read twice a week, and monthly mean discharges based on these observations have been computed and published by the Survey in Water-Supply Paper 265. These results, however, are not included in the following tabulation for the Carlyle station.

Shoal Creek near Breese: The gaging station is located at the Baltimore & Ohio Southwestern Railroad bridge about 1½ miles east of Breese. The record extends from November 5, 1909, to December 31, 1912, with the exception of October, 1912.

Silver Creek near Lebanon: The gaging station is located at the highway bridge at Wright's Crossing, about 2 miles west of Lebanon. The record extends from March 21 to August 15, 1908, and January 21, 1909, to December 31, 1912, with the exception of October, 1912.

The following tables, which have been compiled from the records obtained at these stations, show in a general way the flow that can be expected for a given month of an average year. The tables show, for each month, in the first column the maximum flow for 24 hours which has been observed during the period covered by the table; in the second column the minimum flow for 24 hours which has been observed during the same period; in the third column, the mean flow for that month, calculated from the observations made during the same period. The fourth and fifth columns are computed from the third column. The fourth column gives the mean flow for the entire period in cubic feet per second per square mile on the assumption of a uniform rate of discharge from each square mile of the drainage area. The fifth column gives the depth in inches to which the entire drainage area would be covered in each of 12 average months if all the water flowing from it during that month were conserved and uniformly spread over the surface. This amount is used in comparing run-off with rainfall, which is usually expressed in depth in inches.

Monthly discharge of Kaskaskia River at New Athens, Ill., for the period from Nov. 1, 1909, to Dec. 31, 1912.

[Drainage area, 5,220 square miles.]

Month.	Discharge in second-feet.				Run-off (depth in inches on drainage area).
	Maximum.	Minimum.	Mean.	Per square mile.	
January	18,000	1,130	4,760	0.912	1.05
February	12,400	802	3,600	.690	.72
March	34,100	1,010	11,500	2.20	2.54
April	37,200	738	9,440	1.81	2.02
May	25,500	802	8,400	1.61	1.86
June	13,700	296	2,890	.554	.62
July	7,680	174	2,430	.466	.54
August	9,280	162	1,420	.272	.31
September	22,200	174	3,460	.663	.74
October[a]	19,600	571	8,670	1.66	1.91
November	7,220	236	2,340	.448	.50
December	7,600	198	2,020	.387	.45
The period	37,200	162	4,830	.925	13.26

Monthly discharge of Shoal Creek near Breese, Ill., for the period from Nov. 1, 1909, to Dec. 31, 1912.

[Drainage area, 760 square miles.]

Month.	Discharge in second-feet.				Run-off (depth in inches on drainage area).
	Maximum.	Minimum.	Mean.	Per square mile.	
January	4,670	60	605	0.796	0.92
February	3,810		554	.729	.76
March	6,100	94	1,420	1.87	2.16
April	5,580	87	1,160	1.53	1.71
May	5,580	66	1,010	1.33	1.53
June	2,450	48	290	.382	.43
July	2,960	29	300	.395	.46
August	3,450	26	230	.303	.35
September	3,510	29	565	.743	.83
October[a]	5,900	87	1,110	1.46	1.68
November	3,050	41	446	.587	.65
December	2,450	38	284	.374	.43
The period	6,100	26	638	.839	11.91

Monthly discharge of Silver Creek near Lebanon, Ill., for the periods from Mar. 21 to Aug. 15, 1908, and Jan. 21, 1909, to Dec. 31, 1912.

[Drainage area, 335 square miles.]

Month.	Discharge in second-feet.				Run-off (depth in inches on drainage area).
	Maximum.	Minimum.	Mean.	Per square mile.	
January	3,500		286	0.854	0.98
February	3,080		343	1.02	1.06
March	3,820	29	497	1.48	1.71
April	3,190	26	519	1.55	1.73
May	5,240	16	522	1.56	1.80
June	1,880	2.8	209	.624	.70
July	3,190	.4	204	.609	.70
August	2,880	.1	111	.328	.38
September	2,580	.1	243	.725	.81
October[a]	3,610	.0	284	.848	.98
November	2,080	7.0	178	.531	.59
December	860	6.0	108	.322	.37
The period	5,240	.0	297	.887	11.81

[a] No record for October, 1912.

[1] Shaw, E. W., The Carlyle oil field and surrounding territory: Illinois Geol. Survey Bull. 20, pp. 45-80, 1915.

The stream water of the district contains less dissolved mineral matter than most of the ground water, but for many purposes the stream water is less desirable on account of the suspended material which it carries. Much of this suspended matter is so finely divided that it settles exceedingly slowly and can not be removed on a practical scale without the use of a coagulant such as alum or aluminum sulphate. Some water is not sufficiently alkaline to make a satisfactory precipitate with the aluminum salt, and soda or lime must be added to effect clarification.

From August, 1906, to July 31, 1907, samples of water were collected daily from a number of sources in Illinois, and analyses were made of composites consisting of ten consecutive samples from a station. No samples were taken in the New Athens-Okawville district, but samples of the water of Kaskaskia River were taken at Carlyle, and samples were taken from a reservoir of the Chicago & Eastern Illinois Railroad at Cartter, in Marion County. The following table gives the average results for the year of analyses of water from these two points:

Analyses of surface waters of southern Illinois.[a]

[Parts per million. W. D. Collins and C. K. Calvert, analysts.]

	1	2
Turbidity	184	72
Suspended matter	126	88
Silica (SiO_2)	17	16
Iron (Fe)	.89	1.9
Calcium (Ca)	47	9.0
Magnesium (Mg)	20	3.6
Sodium and potassium (Na+K)	14	8.6
Carbonate radicle (CO_3)	.0	.0
Bicarbonate radicle (HCO_3)	218	34
Sulphate radicle (SO_4)	34	16
Nitrate radicle (NO_3)	4.8	2.1
Chloride radicle (Cl)	6.9	5.2
Total dissolved solids at 180° C	248	92
Total hardness as $CaCO_3$[b]	200	37

[a] U. S. Geol. Survey Water-Supply Paper 239, pp. 62, 79, 1910.
[b] Computed.
1. Kaskaskia River at Carlyle, Clinton County.
2. Reservoir at Cartter, Marion County,

The quantities of the different constituents of the river water shown in these analyses are very near the average of these quantities for all the rivers of the State. Kaskaskia River rises far to the north, and its water in the New Athens-Okawville district is a mixture of waters from the northern and southern parts of the State. The water of the smaller streams in the district contains less dissolved mineral matter and resembles more the water from the reservoir at Cartter, for which an analysis is given above.

Few open reservoirs, if any, are in use in the district, although there are several in the adjoining region. They furnish water similar to the river water in every respect except the hardness and quantity of dissolved constituents.

Well and spring water.—Most of the well and spring water of this area is usable for human consumption and has no deleterious effects due to dissolved mineral matter, but some of it is so heavily mineralized that it has a somewhat objectionable taste, and it is nearly always hard. For this reason some families use cistern water only. Most of the well and spring water comes from surficial material. Water is commonly present at the base of the loess, just above the less permeable till. It is also present in the till, especially in sandy lenses and at the top of the bedrock in places where the bedrock is compact shale. A few wells obtain water from sandstones that belong to the Chester, Pottsville, Carbondale, or McLeansboro formations. Fresh water is found in most of the sandstone beds that lie within about 500 feet of the surface, but below 500 feet the water is generally salt or otherwise so heavily mineralized as to be unfit for use. The water of the St. Peter sandstone, which in the region on the north is abundant and satisfactory, in this district contains too much mineral matter for use. Owing perhaps to the fact that the pores of the Carboniferous sandstones are commonly more or less clogged with clay, they yield in many places but little water, and all of it carries dissolved mineral matter which though small in amount is somewhat objectionable. One of the best water-bearing sandstones is in the McLeansboro formation. This rock lies not far below the surface in the eastern two-thirds of the New Athens-Okawville district, and generally some part of it yields a good supply of water. The water supply of Mascoutah is taken from wells about 50 feet deep and appears to come from the lower part of this sandstone. The water system was installed by the city in 1906 at a cost of $15,000. An analysis of this water is given below.

Analysis of sample of water collected from public supply of Mascoutah July 11, 1906.[1]

	Parts per million.
Silica (SiO_2)	27
Iron (Fe)	9.4
Aluminum (Al)	2.9
Calcium (Ca)	216
Magnesium (Mg)	63
Sodium and potassium (Na+K)	50
Ammonium (NH_4)	.7
Bicarbonate radicle[2] (HCO_3)	572
Sulphate radicle (SO_4)	322
Chloride radicle (Cl)	85
Nitrate radicle (NO_3)	.7
Total dissolved solids[2]	1058
Total hardness[2] as $CaCO_3$	798

At Okawville there is a spring and a well that yield water which has been widely advertised, and every summer hundreds of persons, most of them from St. Louis, visit the large hotels which have been built there. The largest spring was known early in the nineteenth century, but it did not receive much attention until 1864, when a private investigation led to the development of the spring as a health resort and the building of a hotel, which from time to time has been enlarged. The spring is said to yield about 50,000 gallons daily. A well sunk a short distance from the spring obtained water somewhat similar to that of the spring, though according to Prof. Edward H. Keiser the well water contains only 1,369 parts per million of dissolved solids (80 grains per U. S. gallon), whereas according to Dr. Enno Lander the spring water contains 5,736 parts per million (335 grains per U. S. gallon). A large hotel has been built at the well also. Prof. Keiser gives the following analysis of water from the well:

[1] Illinois Univ. Bull., vol. 5, No. 7 (Water Survey Series No. 5), p. 72, 1908.
[2] Computed.

Analysis of sample of water collected from well of Washington Hotel, Okawville, September 20, 1901.

[Edward H. Keiser, analyst.]

	Parts per million.[1]
Silica (SiO_2)	68
Iron oxide and alumina ($Fe_2O_3+Al_2O_3$)	2.4
Calcium (Ca)	139
Magnesium (Mg)	89
Sodium (Na)	184
Potassium (K)	10
Carbonate radicle (CO_3)	305
Sulphate radicle (SO_4)	508
Chloride radicle (Cl)	63
Total dissolved solids	1369
Total hardness[2] as $CaCO_3$	712

The analysis indicates that the composition of the water is similar to that of the public supply at Mascoutah. It is slightly less hard and contains appreciably more sodium and sulphate, which in proper proportions form Glauber's salt. Similar water is likely to occur at many places in the district. Variations in composition will be largely in the quantities of sodium and sulphate, except that water from the deeper wells may contain more sodium and chloride, the constituents of common salt.

SOILS.

The soil of the New Athens-Okawville district has been derived in part from the loess and in part from the till, but in a few small tracts it is made up largely of detritus of the underlying bedrock. The streams of the district are bordered by alluvium that has been transported from the interstream areas, and as those areas are mantled almost continuously by loess the alluvial soil is largely derived from the loess, but it contains considerable gravel and sand derived from the till.

The fertility of a soil depends on many factors, all of which are controlled rather closely by geologic processes, for the texture and the physical and chemical composition of a soil at any place are determined by the character of the rock or rocks from which it has been derived and the conditions and forces that have affected it.

The soil of the district consists of a great variety of more or less decomposed minerals. In its formation there seems to have been a general leaching of calcium carbonate, which has been compensated in places by the addition of this material by plants and animals. The loess soil has the consistency which would be expected of a soil made up of particles of dust somewhat modified by weathering. It is comparatively open and porous and consists of extremely fine sand and more or less clay. In general the proportion of clay seems to increase with the distance from the Mississippi, so that the soil in the eastern part of the district is rather heavier and less porous than that in the western part. The porous soil is yellowish gray, and the more compact soil is light gray. In some places, especially on the alluvial bottoms, the soil is dark gray or black.

The organic content of the soil differs from place to place both in kind and amount. The general light color of the loess soil is due to the character and amount of the organic material that it contains, which is controlled in large part by the warm climate and good drainage of the region, though there are no doubt other important factors, such as the original content of calcium carbonate.

March, 1921.

[1] Recalculated from hypothetical combinations in grains per U. S. gallon.
[2] Computed.

TOPOGRAPHY

DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION
FRANCIS W. SHEPARDSON, DIRECTOR
GEOLOGICAL SURVEY DIVISION, FRANK W. DE WOLF, CHIEF

ILLINOIS
NEW ATHENS QUADRANGLE

R. B. Marshall, Chief Geographer.
W. H. Herron, Geographer in charge.
Topography by J. F. McBeth and E. W. McCrary.
Control by J. R. Ellis, W. A. Gelbach, and Coast and Geodetic Survey.
Surveyed in 1908-1909.

SURVEYED IN COOPERATION WITH THE STATE OF ILLINOIS.

TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1920

Scale $\frac{1}{62500}$

Miles

Kilometers

Contour interval 20 feet.

Datum is mean sea level.

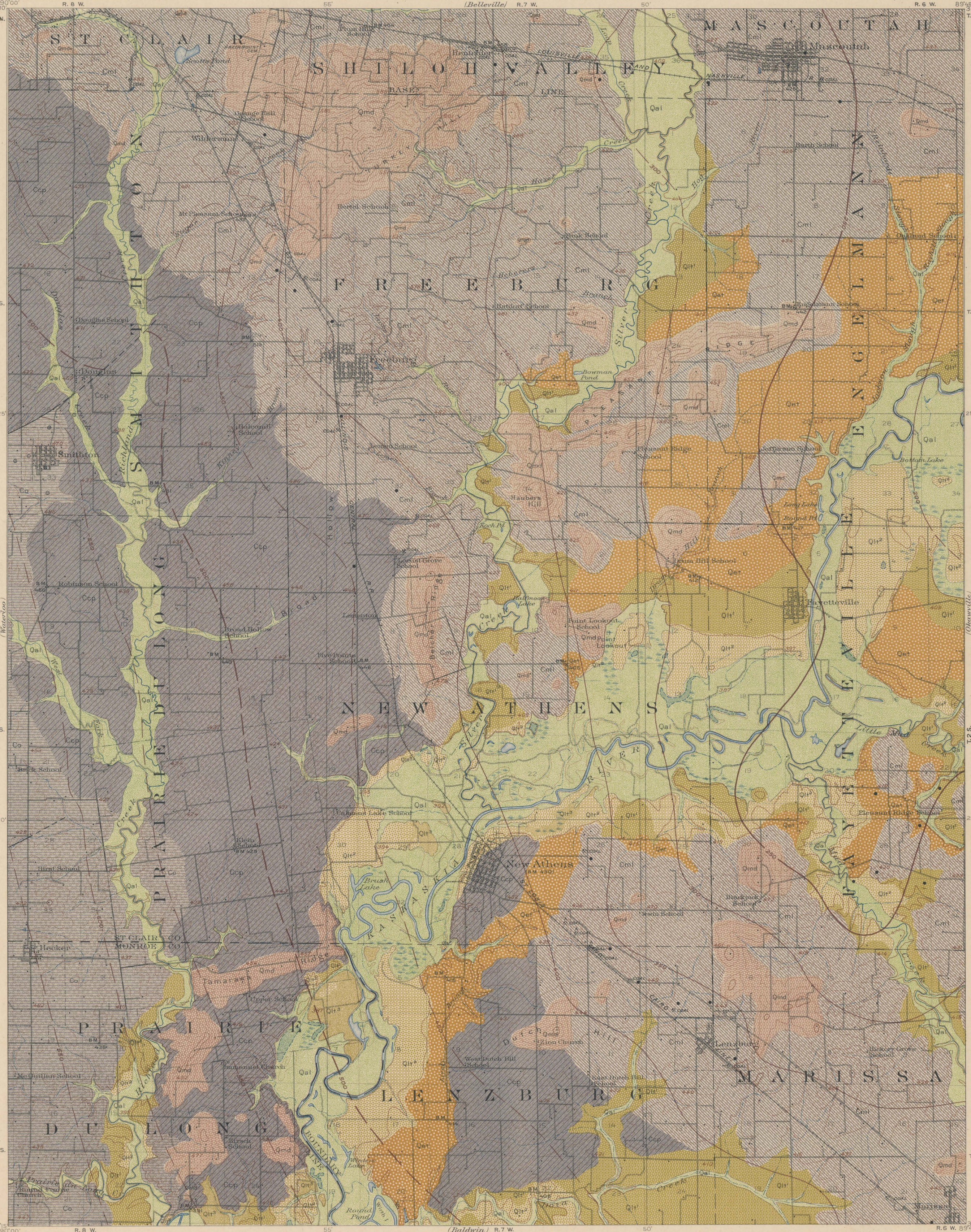
Edition of Mar. 1912, reprinted 1921.

AREAL GEOLOGY

DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION
FRANCIS W. SHEPARDSON, DIRECTOR
GEOLOGICAL SURVEY DIVISION, FRANK W. DE WOLF, CHIEF

ILLINOIS
NEW ATHENS QUADRANGLE



EXPLANATION

SEDIMENTARY ROCKS

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

QUATERNARY

Recent

Qal — Alluvium *(in flood plains of present streams, upper part generally fine silt, lower part sandy or gravelly; in Kaskaskia River bottom includes lake and sluggish-stream deposits which are from 380 to 405 feet above sea level)*

Pleistocene

Qlt¹, Qlt², Qlt³ — Later terrace deposits *(mainly clay and silt; Qlt¹, higher terrace, altitude about 410 feet; Qlt², middle terrace, about 400 feet; Qlt³, lowest terrace about 390 feet)*

Qet — Earlier terrace deposits *(mainly clay and silt; altitude about 420 feet)*

Illinoian stage

Glacial till overlain by post-Illinoian loess; bedrock formations described below *(gravelly and sandy clay generally overlain by buff to gray loess; near the larger streams the material is partly sorted by water and in places entirely removed by erosion)*

Qmd — Morainal drift *(hills of gravelly and sandy clay with some lenses of clean sand and gravel, mantled with loess)*

UNCONFORMITY

CARBONIFEROUS

Pennsylvanian

Deeply covered by drift and loess in most places

Cml — McLeansboro formation *(generally soft shale and sandstone with some limestone and thin beds of coal)*

Ccp — Carbondale and Pottsville formations *(sandstone, shale, and clay; some limestone in Carbondale formation; lenticular coal beds and one persistent coal bed [Herrin (No 6)] at top, which is present and workable throughout quadrangle except in southwestern part)*

Mississippian (Chester group)

Co — Okaw formation *(gray to whitish limestone, shale, and sandstone)*

Faults

ECONOMIC AND STRUCTURE DATA

Structure contours on the base of Herrin (No 6) coal *(doubtful position of coal indicated by dashed lines; contour interval, 50 feet; datum, mean sea level)*

Local coal mines
Abandoned coal mines
Coal test borings
Wells drilled for oil

Note: *The most valuable coal [Herrin (No. 6) and known in the region about New Athens and Okawville as the Belleville bed] lies 50 to 400 feet below the surface throughout the area except in the southwestern part of the New Athens quadrangle; other coals occur in the Pottsville, Carbondale, and McLeansboro formations; shale for brick and tile, and limestone for cement materials and building stone occur in the Okaw, Carbondale, and McLeansboro formations; loess and glacial till yield clay for brick and tile; alluvium, valley filling, and morainal drift locally carry sand and gravel.*

R. B. Marshall, Chief Geographer.
W. H. Herron, Geographer in charge.
Topography by J. F. McBeth and E. W. McCrary.
Control by J. R. Ellis, W. A. Gelbach, and Coast and Geodetic Survey.
Surveyed in 1908-1909.
SURVEYED IN COOPERATION WITH THE STATE OF ILLINOIS.

APPROXIMATE MEAN DECLINATION 1920.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.
Datum is mean sea level.
Edition of Mar. 1921.

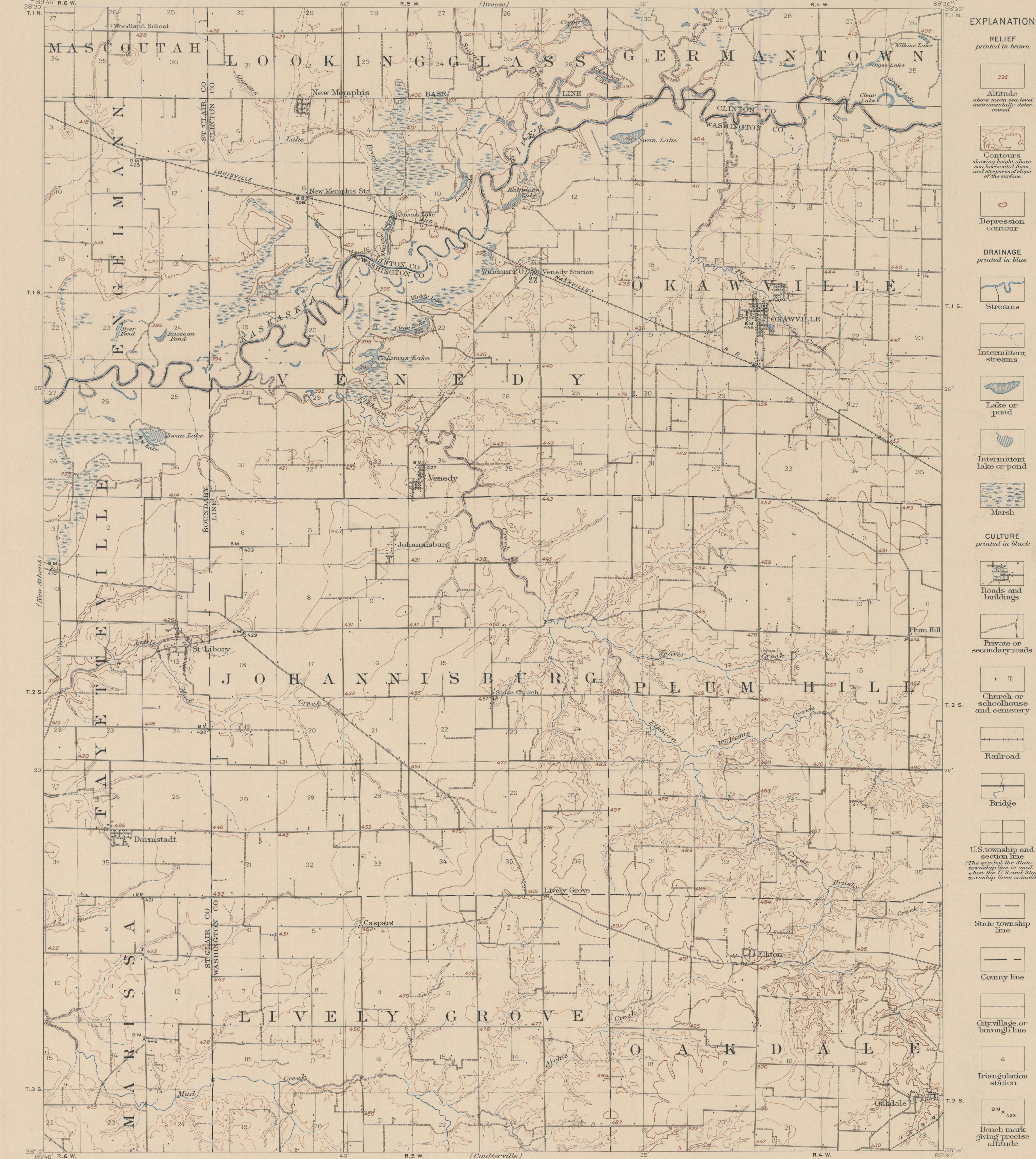
Geology by E. W. Shaw.
Surveyed in 1911.
SURVEYED IN COOPERATION WITH THE STATE OF ILLINOIS.

TOPOGRAPHY

DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION
FRANCIS W. SHEPARDSON, DIRECTOR
GEOLOGICAL SURVEY DIVISION, FRANK W. DE WOLF, CHIEF

ILLINOIS
OKAWVILLE QUADRANGLE



R.B. Marshall, Chief Geographer.
W.H. Herron, Geographer in charge.
Topography by W.J. Lloyd and E.W. McCrary.
Control by J.R. Ellis and W.A. Gelbach.
Surveyed in 1908.

SURVEYED IN COOPERATION WITH THE STATE OF ILLINOIS.

TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1920.

Scale $\frac{1}{62500}$

Contour interval 20 feet.
Datum is mean sea level.

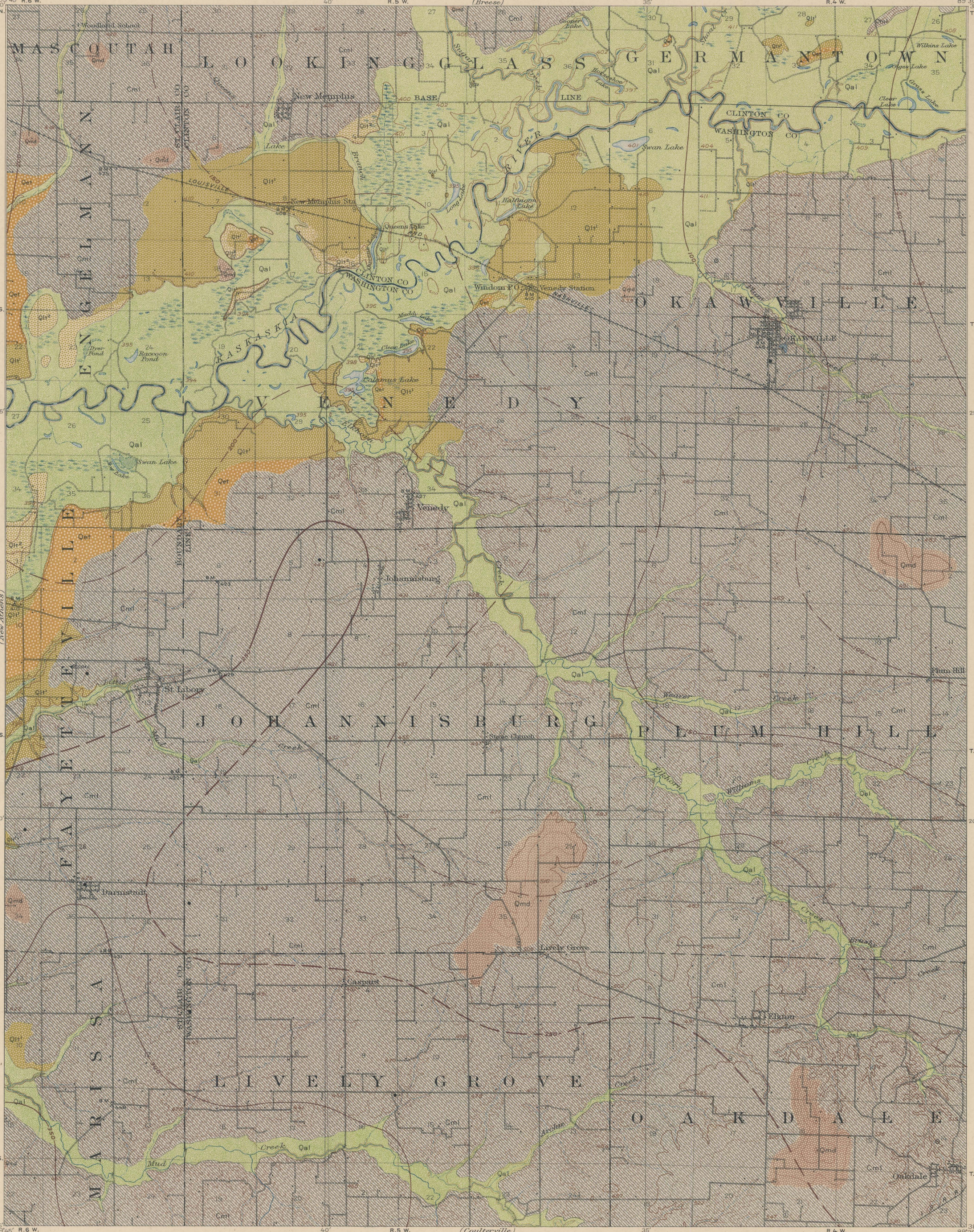
Edition of Oct. 1910, reprinted 1921.

AREAL GEOLOGY

DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, SECRETARY
U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION
FRANCIS W. SHEPARDSON, DIRECTOR
GEOLOGICAL SURVEY DIVISION. FRANK W. DE WOLF, CHIEF

ILLINOIS
OKAWVILLE QUADRANGLE



EXPLANATION

SEDIMENTARY ROCKS

(Areas of subaqueous deposits are shown by patterns of parallel lines; subaerial deposits by patterns of dots and circles)

QUATERNARY

Recent

Qal — **Alluvium** *(in flood plains of present streams, upper part generally fine silt, lower part sandy or gravelly; in Kaskaskia River bottom includes lake and sluggish-stream deposits which are from 380 to 405 feet above sea level)*

Pleistocene

Qlt¹ / Qlt² — **Later terrace deposits** *(mainly clay and silt; Qlt¹, higher terrace, altitude about 410 feet; Qlt², middle terrace, about 400 feet)*

Qet — **Earlier terrace deposits** *(mainly clay and silt; altitude about 420 feet)*

Illinoian stage

Glacial till overlain by post-Illinoian loess; bedrock formation described below *(gravelly and sandy clay generally overlain by buff to gray loess; near the larger streams the material is partly sorted by water and in places entirely removed by erosion)*

Qmd — **Morainal drift** *(hills of gravelly and sandy clay with some lenses of clean sand and gravel, mantled with loess)*

UNCONFORMITY

CARBONIFEROUS

Pennsylvanian — *Deeply covered by drift and loess in most places*

Cml — **McLeansboro formation** *(generally soft shale and sandstone with some limestone and thin beds of coal; underlies all Quarternary deposits in the quadrangle)*

ECONOMIC AND STRUCTURE DATA

250 — *Structure contours on the base of Herrin (No 6) coal* *(doubtful position of coal indicated by dashed lines; contour interval, 50 feet; datum, mean sea level)*

⚒ *Local coal mines*
⚒A *Abandoned coal mines*
● *Coal test borings*
⊙ *Wells drilled for oil*

Note: *The most valuable coal [Herrin (No. 6) and known in the region about New Athens and Okawville as the Belleville bed] lies 50 to 400 feet below the surface throughout the area except in the southwestern part of the New Athens quadrangle; other coals occur in the Pottsville, Carbondale, and McLeansboro formations; shale for brick and tile, and limestone for cement materials and building stone occur in the Okaw, Carbondale, and McLeansboro formations; loess and glacial till yield clay for brick and tile; alluvium, valley filling, and morainal drift locally carry sand and gravel.*

R.B. Marshall, Chief Geographer.
W.H. Herron, Geographer in charge.
Topography by W.J. Lloyd and E.W. McCrary.
Control by J.R. Ellis and W.A. Gelbach.
Surveyed in 1908.

SURVEYED IN COOPERATION WITH THE STATE OF ILLINOIS.

TRUE NORTH / MAGNETIC NORTH 5°
APPROXIMATE MEAN DECLINATION 1920.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 20 feet.
Datum is mean sea level.
Edition of Mar. 1921.

Geology by E.W. Shaw.
Surveyed in 1911.

SURVEYED IN COOPERATION WITH THE STATE OF ILLINOIS.

PUBLISHED GEOLOGIC FOLIOS

No.*	Name of folio.	State.	Price.†
			Cents.
1	Livingston	Montana	Out of stock.
2	Ringgold	Georgia-Tennessee	do.
●3	Placerville	California	100
4	Kingston	Tennessee	Out of stock.
●5	Sacramento	California	100
6	Chattanooga	Tennessee	Out of stock.
7	Pikes Peak	Colorado	do.
8	Sewanee	Tennessee	do.
9	Anthracite-Crested Butte	Colorado	do.
10	Harpers Ferry	Va.-Md.-W. Va	do.
●11	Jackson	California	100
12	Estillville	Ky.-Va.-Tenn	Out of stock.
13	Fredericksburg	Virginia-Maryland	do.
14	Staunton	Virginia-West Virginia	do.
15	Lassen Peak	California	do.
16	Knoxville	Tennessee-North Carolina	do.
17	Marysville	California	do.
18	Smartsville	California	do.
19	Stevenson	Ala.-Ga.-Tenn	do.
20	Cleveland	Tennessee	do.
21	Pikeville	Tennessee	do.
22	McMinnville	Tennessee	do.
23	Nomini	Maryland-Virginia	do.
24	Three Forks	Montana	do.
25	Loudon	Tennessee	do.
26	Pocahontas	Virginia-West Virginia	do.
27	Morristown	Tennessee	do.
28	Piedmont	West Virginia-Maryland	do.
29	Nevada City Special	California	do.
30	Yellowstone National Park	Wyoming	do.
31	Pyramid Peak	California	do.
32	Franklin	West Virginia-Virginia	do.
33	Briceville	Tennessee	do.
34	Buckhannon	West Virginia	do.
35	Gadsden	Alabama	do.
36	Pueblo	Colorado	do.
37	Downieville	California	do.
38	Butte Special	Montana	do.
39	Truckee	California	do.
40	Wartburg	Tennessee	do.
41	Sonora	California	do.
42	Nueces	Texas	do.
43	Bidwell Bar	California	do.
44	Tazewell	Virginia-West Virginia	do.
45	Boise	Idaho	do.
46	Richmond	Kentucky	do.
47	London	Kentucky	do.
48	Tenmile District Special	Colorado	do.
49	Roseburg	Oregon	do.
50	Holyoke	Massachusetts-Connecticut	do.
51	Big Trees	California	do.
52	Absaroka	Wyoming	do.
53	Standingstone	Tennessee	do.
54	Tacoma	Washington	do.
55	Fort Benton	Montana	do.
56	Little Belt Mountains	Montana	do.
57	Telluride	Colorado	do.
58	Elmoro	Colorado	do.
59	Bristol	Virginia-Tennessee	do.
60	La Plata	Colorado	do.
61	Monterey	Virginia-West Virginia	do.
62	Menominee Special	Michigan	do.
63	Mother Lode District	California	do.
64	Uvalde	Texas	do.
65	Tintic Special	Utah	do.
66	Colfax	California	do.
67	Danville	Illinois-Indiana	do.
68	Walsenburg	Colorado	do.
69	Huntington	West Virginia-Ohio	do.
70	Washington	D. C.-Va.-Md	do
71	Spanish Peaks	Colorado	do.
72	Charleston	West Virginia	do.
73	Coos Bay	Oregon	do.
74	Coalgate	Oklahoma (Ind. T.)	do.
75	Maynardville	Tennessee	do.
76	Austin	Texas	do.
77	Raleigh	West Virginia	do.
78	Rome	Georgia-Alabama	do.
79	Atoka	Oklahoma (Ind. T.)	do.
80	Norfolk	Virginia-North Carolina	do.
81	Chicago	Illinois-Indiana	do.
82	Masontown-Uniontown	Pennsylvania	do.
83	New York City	New York-New Jersey	do.
84	Ditney	Indiana	5
85	Oelrichs	South Dakota-Nebraska	5
86	Ellensburg	Washington	5
87	Camp Clarke	Nebraska	5
88	Scotts Bluff	Nebraska	5
89	Port Orford	Oregon	Out of stock.
90	Cranberry	North Carolina-Tennessee	do.
91	Hartvllie	Wyoming	5
92	Gaines	Pennsylvania-New York	5
93	Elkland-Tioga	Pennsylvania	5
94	Brownsville-Connellsville	Pennsylvania	Out of stock.
95	Columbia	Tennessee	5
96	Olivet	South Dakota	5
97	Parker	South Dakota	5
98	Tishomingo	Oklahoma (Ind. T.)	Out of stock.
99	Mitchell	South Dakota	5
100	Alexandria	South Dakota	5
101	San Luis	California	Out of stock.
102	Indiana	Pennsylvania	do.
103	Nampa	Idaho-Oregon	do.
104	Silver City	Idaho	5
105	Patoka	Indiana-Illinois	5
106	Mount Stuart	Washington	Out of stock.
107	Newcastle	Wyoming-South Dakota	do.
108	Edgemont	South Dakota-Nebraska	5
109	Cottonwood Falls	Kansas	5
110	Latrobe	Pennsylvania	Out of stock.
111	Globe	Arizona	do.
112	Bisbee (reprint)	Arizona	25
113	Huron	South Dakota	5
114	De Smet	South Dakota	5
115	Kittanning	Pennsylvania	Out of stock.
116	Asheville	North Carolina-Tennessee	do.
117	Casselton-Fargo	North Dakota-Minnesota	5
118	Greeneville	Tennessee-North Carolina	5
119	Fayetteville	Arkansas-Missouri	Out of stock.
120	Silverton	Colorado	do.
121	Waynesburg	Pennsylvania	do.
122	Tahlequah	Oklahoma (Ind. T.)	do.
123	Elders Ridge	Pennsylvania	do.
124	Mount Mitchell	North Carolina-Tennessee	do.
125	Rural Valley	Pennsylvania	do.
126	Bradshaw Mountains	Arizona	do.
127	Sundance	Wyoming-South Dakota	do.
128	Aladdin	Wyo.-S. Dak.-Mont	do.
129	Clifton	Arizona	do.
130	Rico	Colorado	do.
131	Needle Mountains	Colorado	do.
132	Muscogee	Oklahoma (Ind. T.)	do.
133	Ebensburg	Pennsylvania	do.
134	Beaver	Pennsylvania	do.
135	Nepesta	Colorado	do.
136	St. Marys	Maryland-Virginia	do.
137	Dover	Del.-Md.-N. J	do.
138	Redding	California	do.
139	Snoqualmie	Washington	do.
140	Milwaukee Special	Wisconsin	do.
141	Bald Mountain-Dayton	Wyoming	do.
142	Cloud Peak-Fort McKinney	Wyoming	do.
143	Nantahala	North Carolina-Tennessee	do.
144	Amity	Pennsylvania	do.
145	Lancaster-Mineral Point	Wisconsin-Iowa-Illinois	do.
146	Rogersville	Pennsylvania	do.
147	Pisgah	N. Carolina-S. Carolina	do.
148	Joplin District (reprint)	Missouri-Kansas	50
149	Penobscot Bay	Maine	Out of stock.
150	Devils Tower	Wyoming	do.
151	Roan Mountain	Tennessee-North Carolina	do.
152	Patuxent	Md.-D. C	do.
153	Ouray	Colorado	do.
154	Winslow	Ark.-Okla. (Ind. T.)	do.
155	Ann Arbor (reprint)	Michigan	25
156	Elk Point	S. Dak.-Nebr.-Iowa	5
157	Passaic	New Jersey-New York	Out of stock.
158	Rockland	Maine	do.
159	Independence	Kansas	do.
160	Accident-Grantsville	Md.-Pa.-W. Va	do.
161	Franklin Furnace	New Jersey	do.
162	Philadelphia	Pa.-N. J.-Del	do.
163	Santa Cruz	California	do.
‡164	Belle Fourche	South Dakota	5
‡165	Aberdeen-Redfield	South Dakota	5
166	El Paso	Texas	Out of stock.
167	Trenton	New Jersey-Pennsylvania	do.
‡168	Jamestown-Tower	North Dakota	5
169	Watkins Glen-Catatonk	New York	Out of stock.
170	Mercersburg-Chambersburg	Pennsylvania	do.
‡171	Engineer Mountain	Colorado	5
‡172	Warren	Pennsylvania-New York	5
173	Laramie-Sherman	Wyoming	Out of stock.
174	Johnstown	Pennsylvania	do.
175	Birmingham	Alabama	do.
176	Sewickley	Pennsylvania	do.
177	Burgettstown-Carnegie	Pennsylvania	do.
178	Foxburg-Clarion	Pennsylvania	do.
179	Pawpaw-Hancock	Md.-W. Va.-Pa	do.
‡180	Claysville	Pennsylvania	5
‡181	Bismarck	North Dakota	5
‡182	Choptank	Maryland	5
183	Llano-Burnet	Texas	Out of stock.
184	Kenova	Ky.-W. Va.-Ohio	do.
‖185	Murphysboro-Herrin	Illinois	25
‖186	Apishapa	Colorado	5
‖187	Ellijay	Ga.-N. C.-Tenn	25
‖188	Tallula-Springfield	Illinois	25
189	Barnesboro-Patton	Pennsylvania	25
‖190	Niagara	New York	50
‖191	Raritan	New Jersey	25
192	Eastport	Maine	25
‖193	San Francisco	California	75
194	Van Horn	Texas	25
195	Belleville-Breese	Illinois	25
196	Phillipsburg	Montana	25
‖197	Columbus	Ohio	25
198	Castle Rock	Colorado	25
199	Silver City	New Mexico	25
200	Galena-Elizabeth	Illinois-Iowa	25
‖201	Minneapolis-St. Paul	Minnesota	25
202	Eureka Springs-Harrison	Arkansas-Missouri	25
203	Colorado Springs	Colorado	25
204	Tolchester	Maryland	25
‖205	Detroit	Michigan	50
206	Leavenworth-Smithville	Missouri-Kansas	25
207	Deming	New Mexico	25
208	Colchester-Macomb	Illinois	25
209	Newell	South Dakota	25
210	Herman-Morris	Minnesota	25
211	Elkton-Wilmington	Md.-Del.-N. J.-Pa	25
212	Syracuse-Lakin	Kansas	25
213	New Athens-Okawville	Illinois	25

* Order by number.

† Payment must be made by money order or in cash.

● The texts and economic-geology maps of the Placerville, Sacramento, and Jackson folios, which are out of stock, have been reprinted and published as a single folio (Folio reprint Nos. 3, 5, and 11), the price of which is $1.

‡ Octavo editions of these folios may be had at same price.

‖ These folios are also published in octavo form at 50 cents each, except No. 193, which is 75 cents.

The stock of folios from Nos. 1 to 184 and No. 186 was damaged by a fire in the Geological Survey building, but those folios that were only slightly damaged and are usable will be sold at 5 cents each. They are priced accordingly in the list above. Circulars showing the location of the area covered by any of the above folios, as well as information concerning topographic maps and other publications of the Geological Survey, may be had on application to the Director, United States Geological Survey, Washington, D. C.