DEPARTMENT OF THE INTERIOR
ALBERT B. FALL, SECRETARY
UNITED STATES GEOLOGICAL SURVEY
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# GEOLOGIC ATLAS
## OF THE
# UNITED STATES

# CARLYLE-CENTRALIA FOLIO

## ILLINOIS

BY

E. W. SHAW

SURVEYED IN COOPERATION WITH
THE GEOLOGICAL SURVEY OF ILLINOIS



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# 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.

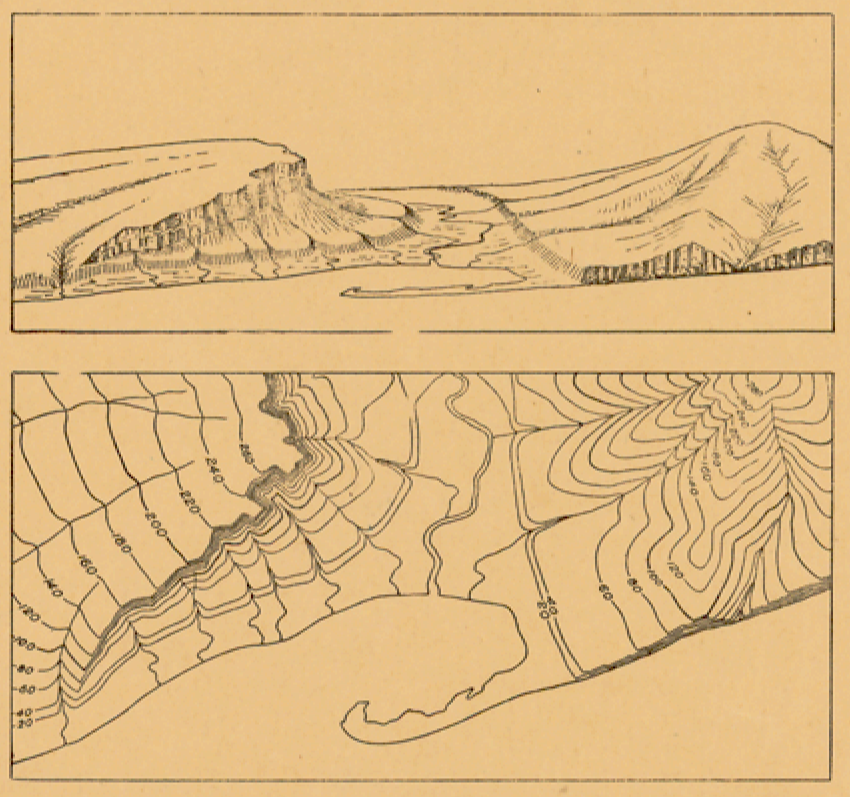

Figure 1.—Ideal view and corresponding contour map.

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*.

# DESCRIPTION OF THE CARLYLE AND CENTRALIA QUADRANGLES.

By Eugene Wesley Shaw.

## INTRODUCTION.

### POSITION AND GENERAL RELATIONS.

The Carlyle and Centralia quadrangles, which comprise the area described in this folio as the Carlyle-Centralia district, are bounded by parallels 38° 30′ and 38° 45′ and meridians 89° and 89° 30′. They cover an area of 466.56 square miles in southwestern Illinois (see Fig. 1), most of which lies in Clinton and Marion counties, though it includes small parts of Bond, Fayette, and Washington counties. The principal towns in the area are Centralia, Carlyle, Sandoval, Odin, and Beckemeyer.

The quadrangles were surveyed under an agreement for cooperation between the United States Geological Survey and the Geological Survey of Illinois. Certain quadrangles in Illinois are being surveyed exclusively by the State Survey, others by the Federal Survey, and still others by both surveys in cooperation. Both the field and the office work for this folio were done entirely by the United States Geological Survey, but the coals were analyzed and the results of the analysis and some additional analytical data were furnished by the State Survey.

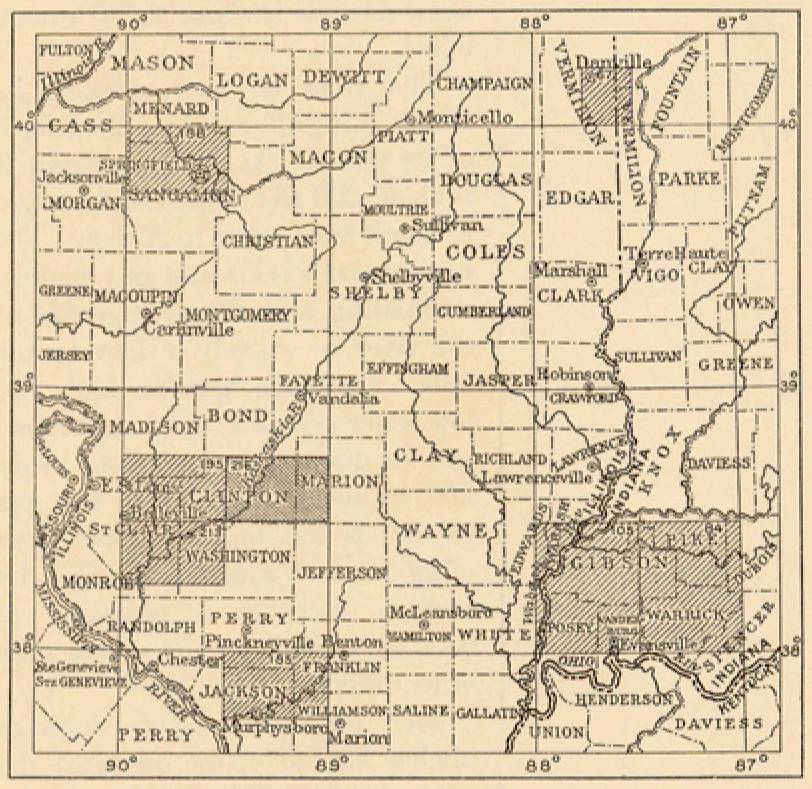


FIGURE 1.—Index map of southern Illinois and parts of adjacent States.
The location of the Carlyle and Centralia quadrangles (Folio 216) is shown by the darker ruling. Published folios, describing other quadrangles, which are shown by lighter ruling, include Folios 67, Danville; 84, Ditney; 105, Patoka; 185, Murphysboro-Herrin; 188, Tallula-Springfield; 195, Belleville-Breese; and 213, New Athens-Okawville.

In its physiographic and geologic relations this area forms a part of a great region of rolling plains, the surface features of which are to a large extent a product of glaciation. In the New Athens-Okawville folio (No. 213) these plains are called the "Glaciated Plains province," but the region has recently been reclassified, and the Carlyle and Centralia district is included in what is now called the Till Plains section of the Central Lowland province—a belt of comparatively low land that occupies the central part of the continent.

### CENTRAL LOWLAND PROVINCE.

#### GEOGRAPHY.

*General relations.*—The Central Lowland province, which consists chiefly of glaciated plains, is bordered on the east and southeast by the Appalachian Highlands, on the south by the Ozark Plateaus and the Interior Low Plateaus, and on the west by the Great Plains province. It extends northward into Canada, where it lies west of the Superior Highlands.

*Physiographic features.*—The province is not very sharply separated in its physiographic features from the adjoining physiographic units, for it differs from most of them chiefly in the degree of the dissection of its surface. The altitude of the surface has a considerable range. The water level of the Mississippi, in the southern part of the province, is only about 300 feet above sea level, but in its western part the province rises to an altitude of 1,500 feet. The province presents a distinct contrast to the surrounding provinces, however, in that it consists of a more or less rolling plain having a lower average altitude, ranging generally from 500 to 1,200 feet above sea level.

One of the principal features of the province is the valley of the Mississippi, which is flat bottomed, steep sided, and generally 3 to 6 miles wide and 200 to 400 feet deep. Most of the tributaries of the Mississippi, which are less powerful eroding agents, flow in valleys that are irregular in width and depth and have indirect courses. In general the basin of the Great Lakes was originally forested and the Mississippi Basin was not, so that about half of the province was prairie.

The Central Lowland lies within and includes most of the upper Mississippi basin and the southern part of the Great Lakes or St. Lawrence 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 the province flows to the Gulf of Mexico by way of the Mississippi. That of the 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 ill defined and is so low as to be scarcely perceptible.

Throughout most of the province there are many poorly drained marshes and swamps, the streams have irregular courses, and lakes are numerous. The poor drainage is due to continental glaciation. The ice blocked many drainage lines and on melting left a sheet of débris, in places several hundred feet thick, which filled many of the old valleys. Where the drift is thick the drainage systems were considerably modified, and they are now only slowly regaining their former condition. Several sheets of till were deposited at different stages of the glaciation. An irregular belt along the west and south sides of the province was not covered by the later glaciers, and in this belt the streams have had time to deepen their channels, so that it is well drained. Throughout most of the province, however, the streams flow in irregular courses and have uneven profiles and the drainage systems have little symmetry.

The average discharge of Mississippi River at Menard, Ill., about 70 miles below St. Louis, is about 187,230 cubic feet per second. The drainage basin above that point covers 711,900 square miles, and the run-off per square mile is thus 0.263 second-foot. Careful measurements show that the river carries annually past Menard about 142,400,000 tons of sediment and about 52,650,000 tons of material in solution. The surface of the basin above Menard is thus being worn off at an average rate of about 1 inch in 700 years.

*Climate and vegetation.*—Throughout most of the Central Lowland the annual precipitation 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 supply is thus bountiful and fairly well distributed, though in many years crops suffer from droughts in August.

A considerable part of the Central Lowland was once forested with deciduous trees, and the remainder was prairie. In general the rougher areas—the valley sides and the morainic hills—were forested and the flatter areas were prairie. Many small tracts of woodland still remain, and some areas are being reforested, but most of the land is under cultivation.

#### GEOLOGY.

The rocks underlying the Central Lowland include igneous, sedimentary, and metamorphic varieties that range in age from pre-Cambrian to Recent, or from the oldest known rocks to the youngest, though many epochs are not represented by beds of rock, and no one formation underlies the whole province, for the shifts from deposition to erosion have been numerous, and some of them have involved the whole province.

In earlier geologic time the sea at several times 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 modified 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 the deposition of marine sediments and the erosion of the surface of the land but sometimes, especially in the Pennsylvanian epoch, the deposition of material upon the land. Since the close of the Paleozoic era the entire province seems to have stood 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 consist of igneous and metamorphic rocks of complex structure. Upon their deeply eroded and planed surface rest all the later strata—the shales, sandstones, limestones, and unconsolidated rocks that outcrop throughout the province except where the pre-Cambrian rocks themselves lie at or near the surface.

The Central Lowland seems to contain no deposits of Lower and Middle Cambrian age, but deposits of Upper Cambrian age occur in most of its middle and southern parts. 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. Limestone seems to have been but slightly developed here or elsewhere in this province in Cambrian time, but to the south and west, 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 extensive. The seashore migrated widely during this period, and the deposits laid down are now divisible into many formations.

The Silurian system is made up of dolomite and limestone and some shale. The numerous layers, or most of them, were laid down in shallow seas, which were surrounded by low-lying land. None of these seas covered the whole province.

The Devonian system is best represented in the eastern, southern, and western parts of the province, where its greatest thickness is several hundred feet, in most places less than 1,000 feet, though in a few places it is somewhat thicker. In the central part of the province the Devonian series is thin, and toward the north it thins out entirely. In western Illinois it consists chiefly of blue fossiliferous limestone overlain in places by black carbonaceous and commonly fossiliferous shale. The limestone was deposited in open sea water and the shale perhaps in shallow sea water and perhaps on low-lying swampy land. The area occupied by the sea was comparatively small in the early part of the period.

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 consists largely of thick beds of limestone containing lenses of shale and sandstone and having a total thickness of 300 to 800 feet. In the Mississippian epoch, as in preceding epochs, the extent and depth of the sea varied considerably and the earth's crust was extensively warped, especially near the end of the epoch, when 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 of its outcrop is greater than that of any other series of rocks in the province. Many of the beds are lenticular bodies of small extent, 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 submergence 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 extensive Permian deposits occur also to the southeast, in West Virginia and Ohio, and to the southwest, in Kansas. The Permian deposits resemble in lithologic character those of the underlying Pennsylvanian series except that they contain less coal and that in the western part of the United States they are generally reddish. During this epoch most of the province seems to have stood above sea level, and much material was carried from it into other provinces.

Rocks of post-Carboniferous age, except those of the Quaternary system, are rare in the Central Lowland. Throughout Mesozoic and Cenozoic time all of this region except its northwestern part stood considerably above sea level, and the land had sufficient slope to permit practically all the loose material in it to be carried into lower areas. The surface of the province has apparently been brought to its present level by several minor uplifts and possibly also by 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 hard to distinguish low plateaus due to hard rock from those due to interruptions of elevation. Furthermore, it is hard to determine the age of features that appear to mark stages of elevation and erosion, owing to difficulties in correlating them with deposits of known age, but it is evident that at the time of the principal uplift of the Appalachian and Ozark mountains the borders at least of the Central Lowland 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 they include also stream, lake, and wind deposits. At several times continental glaciers entered the province from the north, bringing great loads of gravel, clay, and sand and remodeling drainage systems.

In certain areas in the province the older rocks crop out at many places, but in others, some of which cover whole counties and even groups of counties, they are completely concealed by a mantle of unconsolidated glacial drift, which in places reaches a thickness of several hundred feet. Even in the Driftless Area most of the surface is covered either with wind-deposited loess or stream deposits.

The structure of most of the hard rocks that underlie the surficial deposits in the Central Lowland is comparatively simple. In the greater part of the province the beds lie nearly flat, their regularity being broken only by small faults and low, broad folds. The pre-Cambrian rocks that outcrop in Wisconsin, Minnesota, and northern Michigan, however, are in some places so much folded, contorted, and faulted that their structure can be worked out only with difficulty. The structure of the Paleozoic rocks includes local more or less pronounced irregularities, but the larger structural features of the province are a low, broad arch on the southeast, known as the Cincinnati anticline, which lies in part within the Appalachian Plateau and which is divided north of Cincinnati, where it is highest, one branch running toward Lake Erie and the other toward Lake Michigan; a shallow basin that is practically coextensive with the Lower Peninsula of Michigan; another basin that occupies most of Illinois and southwestern Indiana; a still broader basin that extends westward from the Mississippi across Iowa and Missouri into the Great Plains; and a broad arch that lies in Wisconsin and Minnesota.

The basins contain the great coal fields known as the northern interior, eastern interior, and western interior coal fields. East of the province lies another basin which contains the Appalachian coal field. Around each basin the strata crop out in concentric belts, the youngest in the middle and the oldest around the outer border. Thus, for example, beds that are 1,000 feet above sea level in northern Illinois are more than 2,000 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 stand several thousand feet above the present surface in central Wisconsin. The movement that formed the domes, basins, and other structural features of the province seems to have begun early in the Paleozoic era, but the greatest movement seems to have occurred near the end of the Carboniferous period.

## GEOGRAPHY.

### SURFACE FEATURES.

The surface in the Carlyle-Centralia district is one of comparatively slight relief and gentle slopes. In view of the great distance of the district from the sea its altitude is low. Its highest point, which stands more than 580 feet above sea-level, is the summit of Pelican Pouch Hill, about 4 miles southwest of Carlyle, and its lowest point, about 400 feet, is a point in the valley of Kaskaskia River where that stream crosses the southern border of the Carlyle quadrangle. The surface features are due in part to the character of the original surface left by the ice and in part to stream erosion. Much of the area forms a comparatively flat upland that stands 450 to 550 feet above sea level. Above the level of this generally smooth surface rise morainic hills, particularly in the northern and southern parts of the Carlyle quadrangle and along the eastern border of the Centralia quadrangle, and below it the streams have carved valleys that are at some places 1 to 2 miles wide and 50 to 100 feet deep.

The area contains four rather distinct varieties of topographic forms—morainic hills and drift ridges, upland prairies, erosion slopes, and flood plains.

*Upland prairies.*—The upland that comprises more than half the area of the district is generally flat and differs from other parts of the area in being largely unforested. In the Carlyle quadrangle the flat upland stands about 470 feet above sea level. In the Centralia quadrangle the altitude rises eastward to about 550 feet along its eastern margin. The area of flat upland is being slowly but continuously reduced by the widening of the valleys and the headward extension of small tributaries. In the Centralia quadrangle, perhaps because of the greater slope of the surface, the upland is more irregular in outline and more diverse in topographic form. In the central and western parts of this quadrangle the upland is still extensive, though it is cut by half a dozen or more long, shallow valleys. In the northeastern and southeastern parts the upland is more intricately dissected, but most of the prairies that occupy the divides are from a mile to several miles broad.

The remarkable smoothness of the upland prairies is due in part to the fact that a mantle of glacial drift was so spread over the preglacial surface as to form a plain and in part to the fact that the preglacial surface was itself a plain of slight relief.

*Morainic hills and drift ridges.*—The general flatness of the upland is relieved at many places, especially in the Carlyle quadrangle, by hills that rise abruptly from the plains and form impressive features of the landscape. The hills are of three rather distinct forms—nearly round, elongate, and irregular. A typical round hill stands in the northwest part of Wheatfield Township. It has an altitude of more than 40 feet and a width of nearly half a mile. Other round hills are in the northeast corner of this township, 2 to 4 miles northwest of Beckemeyer, 2 miles south of Huey, and 4 miles southeast of Odin.

The most striking elongated drift ridge is Pelican Pouch and its continuation in the ridge that extends westward north of Bartelso. This ridge, like most of the others, has a rather uneven crest. Its highest point is not far from the river and stands more than 580 feet above sea level. From this point the crest slopes westward somewhat irregularly, and in about 2 miles it reaches an altitude a hundred feet lower, almost as low as the surface of the upland prairie. Thence westward for 4 miles its altitude ranges from 470 to 530 feet. Another conspicuous elongate ridge stands 2 miles northeast of Posey. It is one-fourth to one-half mile wide and 15 to 50 feet high. Other elongate ridges are prominent features southwest of Keyesport.

Most of the hills of irregular outline are somewhat oval. Two striking examples stand just east of Carlyle and another stands 4 miles to the southeast. Hills of this type are especially numerous near Keyesport.

All these hills form parts of an extensive system of drift ridges that occupies a belt 20 to 30 miles wide, which in general trends parallel to the Kaskaskia and extends from Shelbyville, Ill., to the Mississippi.

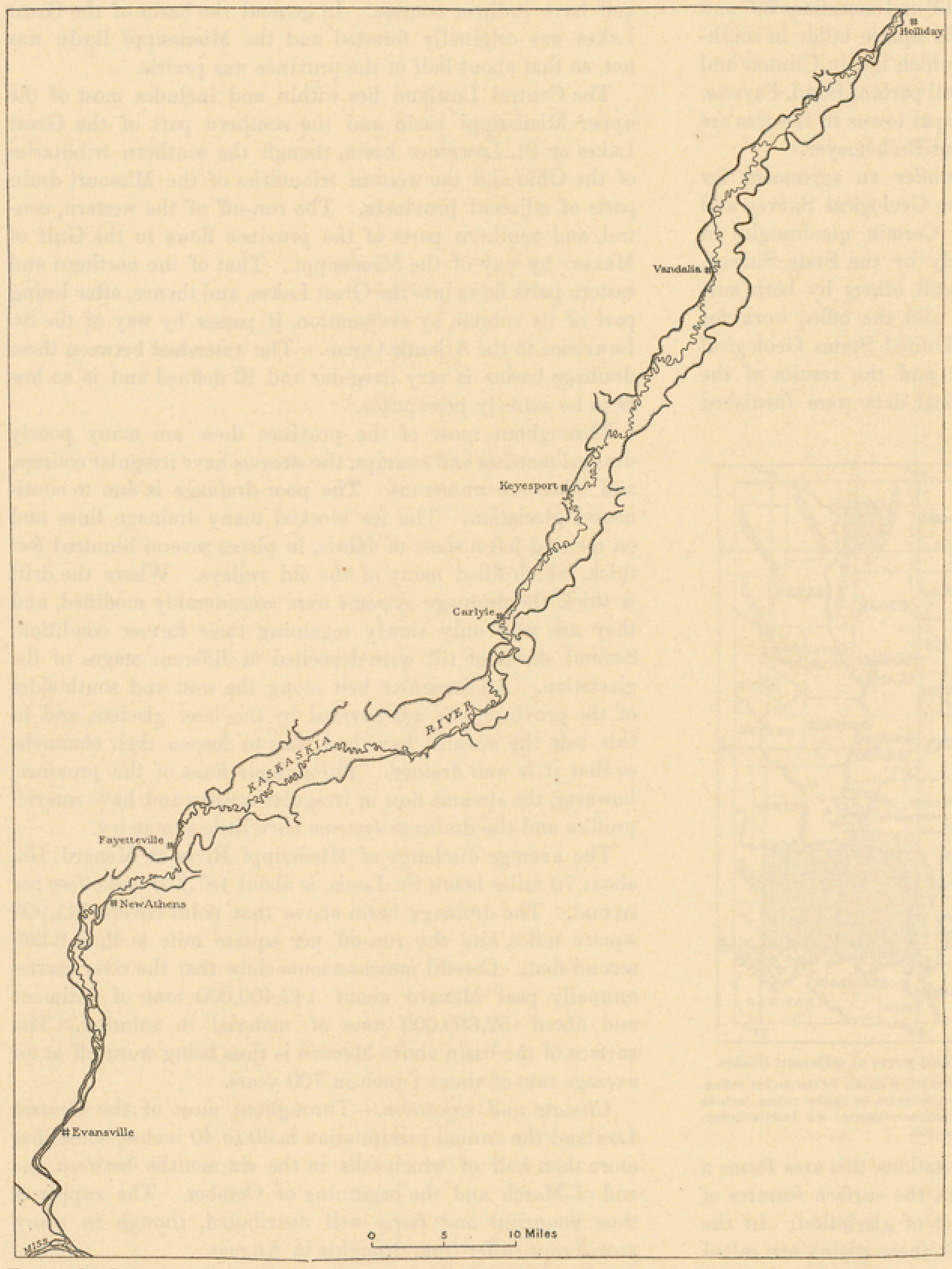


Figure 2.—Bottom lands in Kaskaskia River valley from Holliday, Ill., to the junction of Kaskaskia River with the Mississippi.
Shows irregular width of the valley and narrow section near the mouth of the river; also numerous meanders of the river over its flood plain.

*Erosion slopes.*—Forested bluffs, most of them 50 or 60 feet high, form the sides of the valley of Kaskaskia River. Nearly all these bluffs were formed in the unconsolidated material of the drift, and therefore none of them except some low ones that were formed in loess are very steep. In some of the tributary valleys, however, layers of hard rock have formed benches. Along the east part of Kaskaskia River southeast of Patoka the sides of the valley are especially rocky, and at a few places they are precipitous. The valley of Crooked Creek north of Centralia has also been formed in hard rock, and the surface there is correspondingly rough. Most of the other tributary valleys have steep sides along their lower courses and low, gently sloping sides near their heads.

*Flood plains.*—The flood plain of Kaskaskia River is an even surface that stands about 15 feet above low water. Its width is extremely irregular, ranging from scarcely half a mile to nearly 3 miles. (See Fig. 2.) It includes some depressions that mark abandoned parts of the river channel, many of which contain water. The flood plains of Crooked Creek and East Fork of Kaskaskia River are similar depressions, though they are not so broad nor so irregular in width. Most of the flood plains of the smaller streams are less than a quarter of a mile wide and extend headward to or beyond the places where the streams become intermittent.

### DRAINAGE.

The Carlyle-Centralia district is drained into Kaskaskia River, which flows in general southward to southwestward across the Carlyle quadrangle. The drainage basin of the Kaskaskia as a whole is long, narrow, and shallow. Its width ranges from 30 to 60 miles, and its area above Carlyle is about 2,720 square miles.

The river is very crooked, its length being almost twice the length of its valley. At ordinary stages it is about 200 feet wide, and it ranges in depth from 1 foot to 20 feet. The surface near it is low and only slightly undulating, and the average fall of the river is scarcely a foot to the mile. Its range between high and low water amounts to 25 or 30 feet, and its discharge ranges from about 250 to about 2,500 cubic feet per second, but at times in some parts of its course it runs nearly dry. Its average discharge is estimated at 0.74 second-foot to the square mile of its drainage basin.

The construction of drainage ditches has no doubt increased the range between high and low water, and the draining of the bottom land of the river will probably increase still further the height of floods. Most of the bottom land is flooded so frequently as to render it practically useless for agriculture, and therefore certain areas, such, for example, as one including 2 or 3 square miles southeast of Bartelso, have been protected by levees.

The river is generally muddy, decidedly so at times of high water, when it carries large quantities of sediment to the Mississippi. It carries an even larger amount of mineral matter in solution than in suspension, and by the loss of material that supplies matter thus carried the surface of the region is being continually lowered.

The gradients of the streams range from that of the Kaskaskia, which is less than a foot to the mile, to that of its intermittent tributaries, which is commonly 15 and at a few places 20 feet to the mile. The fall of Crooked Creek and East Fork is almost as low as that of the Kaskaskia.

A considerable area is without definite stream channels, though it has been in process of reduction ever since Illinoian time, when many of the valleys of southern Illinois were obliterated by glacial deposits. The principal tracts of flat upland with ill-defined drainage lines lie between the Kaskaskia and Beaver Creek and in the central part of the Centralia quadrangle. In deep indentations in the border of these areas small streams rise in ill-defined depressions in the prairie, and as they are fed here and there by springs, which commonly rise at the contact of the porous surface loess and the underlying boulder clay, they are perennial in parts of their courses and intermittent in other parts where there are no springs near by.

### SETTLEMENTS AND INDUSTRIES.

The area included in the Carlyle and Centralia quadrangles is rather thickly though not densely populated. The largest town, Centralia, had a population in 1920 of 12,491, and the area within a few miles of its center is one of the most thickly settled in southern Illinois. Other towns, including Carlyle, Beckemeyer, Sandoval, and Junction City, have a population of about 2,000 or less each. The area outside the towns is well settled, the houses being on the average not more than half a mile apart.

Most of the surface is under cultivation, and agriculture is probably the industry of first rank in the district, though several thousand men are employed and hundreds of thousands of dollars are invested in coal mining. The industry of third rank is probably that of exploiting petroleum. There are two well-defined producing pools in the district and another that is ill defined, and several prospect wells are sunk outside of them every year. There are plants for refining zinc just east of Beckemeyer and Sandoval, and there are many small factories, principally at Carlyle and Centralia.

Several railroads—the Illinois Central, the Chicago, Burlington & Quincy, the Southern, and the Illinois Southern—enter Centralia, and the Baltimore & Ohio Southwestern crosses the central part of the district from east to west. Most of the wagon roads follow land survey lines, and hardly any point in the district is more than half a mile distant from a public road. Few of the roads are macadamized.

### VEGETATION AND CLIMATE.

More than half the Carlyle-Centralia district, including all the flatter parts of the upland, was originally prairie, but the rougher parts were forested with the kinds of trees that are common in the northeastern part of the United States. Evergreens, however, are not abundant, and several of the trees, such as the gums and the pecans of the river bottoms, are more characteristic of southern forests. Several of the smaller plants, such as the small cane, are also southern species. Much of the land has been cleared of its original forest and put under cultivation, though some of the forest remains and small tracts are being reforested.

The climate of the district is subject to somewhat larger and more rapid variations in temperature and a slightly higher average humidity than that of other parts of the northeastern United States. The annual rainfall is about 45 inches and is almost evenly distributed through the year. The swampy bottom land, little of which has been cleared of its original forest, is malarial, and few people live in it, although some of of it has been protected from floods by levees.

## GENERAL GEOLOGY.

### STRATIGRAPHY.

#### CHARACTER AND AGE OF THE ROCKS.

All the consolidated rocks that lie near the surface in the Carlyle-Centralia district are sedimentary and consist in part of shale, sandstone, limestone, and coal belonging to the McLeansboro formation, of the Carboniferous system. These rocks are actually exposed in comparatively few places, being almost everywhere buried under beds of loess, glacial till, and alluvium that are from 1 to 100 feet thick.

Information concerning the rocks of older Carboniferous formations and those of the Devonian system is afforded not only by the rocks that lie near the surface but by records of borings made for oil and coal. All these rocks are doubtless underlain by still older ones, such as those which outcrop in Alexander County, Ill., and in the St. Francis Mountains, Mo., and they were penetrated in a deep well at Mascoutah, St. Clair County, Ill., a short distance southwest of the Carlyle-Centralia district.

The strata known from drill records are shown in the columnar section (Fig. 3).

#### ORDOVICIAN SYSTEM.

The Ordovician system is probably made up of four principal divisions. The lowermost division, a magnesian limestone, is several hundred feet thick and has not been reached in any of the deep wells in or near the district. The second division is the St. Peter sandstone, which has been reached in deep wells at Mascoutah and Monks Mound, in St. Clair County, west of the district. This rock is a porous sandstone, 100 feet thick or more, and is made up of well-rounded grains of sand.

Above the St. Peter sandstone there is several hundred feet of rock which is predominantly dolomite, though it includes some limestone and a little shale, particularly in its lowermost part. This rock is frequently called the "Galena-Trenton limestone" because it has been supposed to be, in part at least, of the same age as the Trenton limestone of New York and other States and the Galena dolomite of northwestern Illinois, but the beds in this part of the State are regarded by some geologists as older than the Trenton. They are here called the Plattin and Joachim limestones.



The uppermost division of the Ordovician system in or near the quadrangles is of Cincinnatian age and embraces the Richmond group and the Kimmswick limestone, which are more or less shaly.

| System. | Series. | Formation and group. | Section. | Thickness (feet). | Character of rocks. |
|---|---|---|---|---|---|
| Carboniferous. | Pennsylvanian. | McLeansboro formation. | | 650+ | 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. |

[a] Whether the Ste. Genevieve limestone should be included in the Chester group is undecided by the United States Geological Survey.
[b] Devonian and Silurian systems probably represented by deposits in some localities.

FIGURE 3.—Generalized columnar section of rocks underlying the Carlyle and Centralia quadrangles.

#### SILURIAN SYSTEM.

The Silurian system, which includes the Niagara group (the basal formation of which in New York and other eastern States is the Clinton), is probably thin, if it is present at all, in the Carlyle-Centralia district. Records of the wells so far drilled are not sufficiently detailed to make identification of its units possible.

#### DEVONIAN SYSTEM.

The Devonian system is for the most part also difficult to identify from ordinary well records, but a hard black shale that lies in the uppermost part of this system has been recognized in samples of borings from two wells, the records of which are given below. Some of the limestone and sandstone found beneath this black shale also belongs to the Devonian system.

These logs do not show great detail, and some of the measurements are probably inexact, but they are no doubt sufficiently accurate to give a general idea of the succession of rocks.

*Record of well on Petermeyer farm, in sec. 17, T. 3 N., R. 3 W., 7 miles northwest of Carlyle.*

[Altitude of surface, 460 feet above sea level.]

| Character of material. | Thickness. | Depth. |
|---|---|---|
| | Feet. | Feet. |
| Clay | 20 | 20 |
| Gravel, fine, well washed | 38 | 58 |
| "Limestone shells" | 6 | 64 |
| Various rocks, mostly shale | 561 | 625 |
| Sandstone | 20 | 645 |
| Various rocks, mostly shale | 83 | 728 |
| Sandstone | 37 | 765 |
| Various rocks, mostly shale | 55 | 820 |
| Sandstone | 56 | 876 |
| Various rocks, mostly shale | 14 | 890 |
| "Slate," broken | 80 | 970 |
| "Limestone shells" | 2 | 972 |
| Sandstone | 48 | 1,020 |
| Various rocks, mostly shale | 36 | 1,056 |
| Sandstone | 144 | 1,200 |
| Various rocks, mostly shale | 10 | 1,210 |
| Limestone | 565 | 1,775 |
| Various rocks, mostly shale | 10 | 1,785 |
| Limestone | 75 | 1,860 |
| Shale and limestone | 100 | 1,960 |
| Limestone | 220 | 2,180 |
| Various rocks, mostly shale | 90 | 2,270 |
| Limestone | 30 | 2,300 |
| Shale ("pencil cave") | 30 | 2,330 |
| Shale, black (top of Devonian?) | 28 | 2 358 |
| Limestone; salt water | 72 | 2,430 |

*Well on Herzog farm, in sec. 23, T. 2 N., R. 3 W.*

[Altitude of surface, 467 feet above sea level.]

| Character of material. | Thickness. | Depth. |
|---|---|---|
| | Feet. | Feet. |
| Clay and gravel | 46 | 46 |
| Shale | 395 | 441 |
| Limestone | 5 | 446 |
| Shale | 4 | 450 |
| Coal | 7 | 457 |
| Shale, locally sandy | 343 | 800 |
| Sandstone; salt water | 50 | 850 |
| Shale | 185 | 1,035 |
| Limestone | 45 | 1,080 |
| Red rock | 18 | 1,098 |
| Sandstone; salt water | 30 | 1,128 |
| Shale | 20 | 1,148 |
| Sandstone; salt water | 91 | 1,239 |
| Shale | 14 | 1,253 |
| Sandstone | 122 | 1,375 |
| Limestone | 610 | 1,985 |
| Shale | 8 | 1,993 |
| Limestone | 212 | 2,205 |
| Shale | 155 | 2,360 |
| Shale, black (Devonian?) | 30 | 2,390 |
| Shale | 145 | 2,535 |
| Limestone (Niagara?) | 25 | 2,560 |
| Shale | 40 | 2,600 |
| Limestone | 133 | 2,733 |

#### CARBONIFEROUS SYSTEM.

##### SUBDIVISIONS.

The Carboniferous, the thickest and economically the most important system of rocks in southern Illinois, falls naturally into two markedly different series. The lower series, the Mississippian, is composed of limestone that includes interbedded shale and sandstone in the upper part, and the upper series, the Pennsylvanian, is composed of soft shale and sandstone together with numerous thin beds of limestone and several more or less lenticular beds of coal. The Permian, which in some regions forms the uppermost series of the Carboniferous, is not found in southern Illinois. The individual beds differ somewhat in character from place to place, but the Carboniferous system as a whole is uniform throughout thousands of square miles in the central part of the Mississippi basin. It differs, however, from the same system in the Appalachian basin. In the Pennsylvanian series of the Mississippi basin much of the shale is greenish gray, very soft, and poorly laminated, whereas in the Appalachian basin it is darker and harder and contains many beds of whitish clay. In the western area also the Mississippian series contains chiefly limestone, whereas in the eastern area it is composed largely of sandstone.

##### MISSISSIPPIAN SERIES.

###### LOWER FORMATIONS.

The rocks of the lower part of the Mississippian series in the Carlyle-Centralia district are not much better known than the underlying formations. They are extensively exposed, however, in the Waterloo and other areas to the west, where they have been studied in detail by Weller.[1] The lowermost beds constitute the Kinderhook group, which consists of limestone, sandstone, and shale, the proportions ranging through wide limits. At the top of the Kinderhook in this region is a reddish stratum known as the Fern Glen limestone member, which affords a means of 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 member lie in ascending order 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 and consist largely of crinoidal cherty limestone.

Above the Keokuk limestone lies the Meramec group, consisting, in ascending order, of the Warsaw shale, the Spergen limestone, and the St. Louis limestone, the three formations having a combined thickness in the region of 400 to 500 feet. The Warsaw is usually composed chiefly of bluish shale, and in most places is readily separable from the upper formation of the Osage group, the cherty Keokuk limestone. Northwest of the district it is extensively developed, but within the district it is commonly wanting and the Keokuk is shaly, so that in well records the strata are difficult to identify. The succeeding Spergen limestone is a nearly pure light-gray limestone which is at some places oolitic or very fossiliferous, containing many brachiopods and fenestelloid Bryozoa. Some of the beds are dolomitic. The St. Louis limestone is composed of light to dark gray generally fine-grained limestone, including local beds of shale and shaly limestone. It is better known than the underlying formations, for it crops out extensively in the bluffs along the Mississippi, and it is usually noted in drilling

[1] Weller, Stuart, Mississippian Brachiopoda of Mississippi Valley basin: Illinois Geol. Survey Mon. 1, pp. 12-20, 1914.

wells because it is thick, resistant, and cherty. In fact, well drillers generally use it as an index stratum and refer to it as the "Mississippi lime." It is about 300 feet thick and is not very fossiliferous. Some of its beds are 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 generally consists of very pure calcium carbonate. In southern Illinois this limestone is comparatively persistent, though absent in places. It outcrops in the vicinity of Ste. Genevieve, Mo., about 45 miles southwest of the Carlyle-Centralia district, and is found in drilling wells at places eastward to Indiana. In the oil fields of southeastern Illinois it is known as the McClosky sand. It is separated from the underlying St. Louis limestone by an unconformity, as shown by the uneven surface of the lower formation and the solution channels in that formation which are filled with oolite. In many places the Ste. Genevieve includes sandstone and in some places shale and chert. Its greatest thickness in the vicinity of the Carlyle-Centralia district is 75 feet. The oolite is commonly cross-bedded and in a few places arenaceous. The cross-bedding is especially well developed near its base. Whether the Ste. Genevieve limestone properly belongs to the Chester group or to the Meramec group is undecided.

#### CHESTER GROUP.

The rocks of the Chester group above the Ste. Genevieve limestone consist of about equal proportions of shale, limestone, and sandstone. The shale is gray, greenish, bluish, and reddish. Almost everywhere beneath the district the Chester includes conspicuously red shale and marl, easily noted and almost always reported by careful drillers. The limestone is compact, fine to coarse grained, at some places magnesian and at others containing beds of fine sand. The sandstone is generally clean, but some of it contains argillaceous matter and some is calcareous. Some grains are large and rounded, but others are fine and angular.

From the type locality, which is about 45 miles south of Carlyle, the Chester group dips and becomes thinner to the northeast. The decrease in thickness is largely the result of the removal of the upper part of the group by erosion before the deposition of the succeeding Pennsylvanian series. The top of the Chester is everywhere very uneven, and this unconformity is well shown by outcrops outside the district and by the records of many borings throughout southwestern Illinois.

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

The sandstones of the Chester group, except where they are very compact, generally contain water, though the water is commonly salty, especially at a distance of several miles from the outcrop. Near Carlyle and Sandoval these sandstones contain valuable pools of oil and gas.

Above the Ste. Genevieve limestone, in the Mississippi Valley region of southern Illinois, lies the Aux Vases sandstone, which consists of massive beds of fine-grained sandstone, generally cross-bedded and about 80 feet thick. Where the sandstone is unweathered it is yellowish brown or whitish, but where it is weathered it is reddish brown. This reddish-brown color caused some of the earlier writers to call it "the ferruginous sandstone." The Aux Vases rests unconformably upon the Ste. Genevieve limestone, but where that formation is absent it rests immediately upon the St. Louis limestone. No fossils have ever been found in the formation.

The Renault formation, which lies next above the Aux Vases, was named from Renault Township in Monroe County, a little southwest of the Carlyle-Centralia district. It ranges from 40 to 100 feet in thickness and is extremely variable in composition, as it includes beds of sandstone, shale, and limestone. Some of the sandstone closely resembles that of the Aux Vases, but it is commonly thinner bedded and is associated with shale and limestone. At some places impressions of lepidodendroid tree trunks are found, and in the limestones other fossils are abundant. The Renault commonly overlaps the Aux Vases to the southwest and rests directly upon the Ste. Genevieve or the St. Louis in unconformable contact.

The Renault formation is overlain by a thin but persistent group of cherty beds, which, though unfossiliferous, are yet widely usable as a key rock. These beds, which have been named the Yankeetown chert, have a thickness of 20 feet or less. This formation is in most places irregularly cross-bedded and knotty or banded. In well records it is reported as a very hard limestone, and in dug wells it usually puts an end to excavation. It is so resistant that over considerable areas where the overlying beds were removed by erosion in pre-Pennsylvanian time it constitutes the floor upon which the Pennsylvanian series rests. The contact between the Yankeetown and Renault is believed to be unconformable.

The Paint Creek formation, which overlies the Yankeetown, has a thickness of about 60 feet and consists of shale at the base overlain by limestone. Its most conspicuous bed is a deep-red clay, generally regarded by well drillers and surveyors as a valuable index stratum, which lies at or near its base. It shows little evidence of stratification and contains no fossils. The limestone and shale in the upper part of the formation contain abundant fossils.

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

The Okaw formation, which overlies the Cypress sandstone, consists of alternating 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 at most places a 10-foot bed of oolite which contains many small pelecypods and gastropods. The Okaw formation contains numerous fossils. Its upper part is characterized by the large blastoid *Pentremites sulcatus*, which, according to Weller, is restricted to these beds, as is also *Archimedes laxus*. The Okaw is probably the highest formation of the Chester group that underlies the Carlyle-Centralia district, the overlying Chester formations having been removed by erosion at the close of the Mississippian epoch. The rock is commonly translucent and yellowish, resembling onyx. The formation is named from the Okaw or Kaskaskia Valley, in the lower part of which it is well exposed.

In the Mississippi Valley region of southern Illinois the formations which overlie the Okaw formation in ascending order and constitute the uppermost part of the Chester group include the Menard limestone, made up of limestone interstratified with shale and having a thickness of 60 to 100 feet; the Palestine sandstone, mainly sandstone and 40 to 80 feet thick; the Clore limestone, consisting of about 40 feet of limestone with some shale and shaly limestone; the Degonia sandstone, a massive sandstone 40 to 100 feet thick; and the Kinkaid limestone, consisting of 140 feet of regularly bedded limestones separated by thin shaly seams. The Degonia and Kinkaid formations were formerly included in the Pennsylvanian, but the discovery of Chester fossils in both formations led Weller to include them in the Chester group.

#### PENNSYLVANIAN SERIES.

The Pottsville, Allegheny, and Conemaugh formations of Pennsylvania and other Eastern States are represented in southern Illinois, but their exact correlation and limits have not yet been determined. The upper limit of the Pottsville, however, which is known rather accurately, lies at the base of the underclay of the Murphysboro coal (No. 2). For convenience the base of that coal is used as the formation boundary. The division plane between Allegheny and Conemaugh is much more difficult to determine. It probably lies near the Herrin coal (No. 6) or coal No. 7, but owing to the doubt local formation names have been applied, and the top of the Herrin coal is used as the formation boundary.

#### POTTSVILLE FORMATION.

*Character and thickness.*—The Pottsville formation consists largely of sandstone but includes some shale, clay, and a little thin, irregularly bedded coal. No limestone occurs 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 Carlyle-Centralia district, where it consists of clay that contains local lenses of sandstone and traces of coal. To the east it thickens somewhat irregularly, and at the southeast corner it appears to be about 200 feet thick. It consists of water-bearing sandstone in several thick layers that are separated by thinner layers of soft shale and small lenses of argillaceous sandstone and coal. Here and there the sandstone cotains a few quartz pebbles, but it is generally rather fine grained. All the beds are irregular. Beds of sandstone grade laterally into shale, and hardly any layer holds its physical character throughout any considerable area. The sandstone in most places contains no fossils, but some of the shales bear impressions of land plants—mostly fernlike. The most persistent coal bed is approximately equivalent to the bed named by Worthen coal No. 1 and also to the Mercer coal of Pennsylvania.

*Stratigraphic position and relations.*—The Pottsville formation rests unconformably upon the very uneven upper surface of the Chester group and extends up to the base of the underclay of the Murphysboro coal. It may be identified in many drill holes by the fact that it includes the rocks that lie between the coal and the next limestone below. The coal, however, is not persistent, and in many places the uppermost bed of the Chester is not limestone. Hence it is often necessary to use other criteria, and in some wells the exact limits can not be determined, even from carefully collected samples. However, the approximate position of the formation may be determined in all wells by the fact that it is roughly coextensive with the great water-bearing sandstones which lie as a rule 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, the thinner portions representing the higher parts of the formation. The formation resembles the overlying Carbondale more than it does the Chester.

#### CARBONDALE FORMATION.

*General features.*—The Carbondale formation includes all the Pennsylvanian beds between the base of the underclay of the Murphysboro coal (No. 2) and the top of the Herrin coal (No. 6). The formation is named from the town of Carbondale, near which it is well exposed. It is not exposed at the surface anywhere in the Carlyle-Centralia district, but it has been encountered in many drill holes and mine shafts. Its thickness, which seems to increase toward the east, is at most places from 160 to 225 feet. It consists chiefly of shale and sandstone but includes several thin layers of limestone and more or less lenticular beds of coal. The shale at many places forms 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 are commonly cemented by calcium carbonate. The limestone is hard, gray or bluish gray, and more or less fossiliferous. At some places it has a peculiar brecciated or conglomeratic character. The uppermost part is associated with the Herrin coal, which is the only coal now mined in the area.

*Character of the beds.*—The Murphysboro coal is absent over large areas, and where present it is of irregular thickness, ranging from a thin seam to a bed 3 or 4 feet thick. It is overlain by shale, 10 to 30 feet thick, which shows traces of coal near the middle, and above the shale lies a soft brownish sandstone or sandy shale, commonly water-bearing, which has been called the Vergennes sandstone member. Above this sandstone lies 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 throughout a considerable part of the district and is similar in some respects to the Springfield coal (No. 5), 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. The stratigraphic relations of this coal indicate that it is a lower bed—perhaps coal No. 3 of Worthen.

Above this coal lies about 75 feet of shale and shaly sandstone, which is overlain by calcareous beds beneath the underclay of the Herrin coal. Generally there are 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 in some places, where it is absent, the coal rests immediately upon the underlying limestone. The underclay of the Herrin coal underlies more than three-fourths of the area occupied by that coal and is thin as compared with the underclays of the other coal beds of Illinois.

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 fairly easily recognized. The "blue band" is a layer of bluish-gray clay, 1 to 3 inches thick, in places calcareous or ferruginous, which lies 15 to 30 inches above the base.

The Herrin coal is separated into distinct divisions or benches by three rather persistent partings and by others that are less persistent. The partings consist generally of thin layers of clay, seams of marcasite, and "mineral charcoal," but in many places they appear to be merely planes of sedimentation along which the coal easily splits. Above the "blue band" the coal is more or less distinctly separated into three divisions, which, owing in part to irregularities in the coal, are named differently by different miners.

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

*Correlation of the coal beds.*—The early reports on the geology of Illinois attempt to give the coal beds serial numbers, beginning at the bottom with No. 1. Though the correlation of beds in different parts of the State was in general correct, it has been found difficult to apply the serial numbers consistently, particularly because correlation is in many places difficult and uncertain owing to the fact that most of the coal beds are lenticular. It was also found that the same beds, which extend continuously into Indiana and Kentucky, bear different numbers in each of these States. The result is that great confusion has arisen in the significance of the numbers. For these reasons the use of numbers for the coal beds has been found less desirable than the use of geographic names. The bed known as No. 2 has been named the Murphysboro because of its extensive development at that place. It is probably the same bed as that mined at Colchester, as the "third vein" near La Salle, and as 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 designated the Herrin coal and is equivalent to the Belleville coal and to the Duquoin coal. A coal that lies 40 to 80 feet below the Herrin coal resembles the Springfield coal but is believed to be a lower coal, perhaps No. 3 of Worthen. Other beds of coal are present in this district, but they are of little value and have not been given geographic names. Little is known concerning them, and there is doubt as to their proper correlation.

The work of David White on fossil plants shows that the Murphysboro coal corresponds approximately to the Brookville or perhaps to 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.

*General features.*—The McLeansboro formation, named from the town of McLeansboro, Ill., extends from the top of the Herrin coal to the uppermost Pennsylvanian rocks that are present in Illinois. At McLeansboro, near the center of the coal basin, these rocks have a thickness of about 1,000 feet, but owing in part at least to erosion this thickness decreases in all directions from that place. At the eastern side of the Centralia quadrangle only about 800 feet of the lower part of the formation is present, and to the west the beds outcrop successively from above downward, so that beds nearly 500 feet lower, or a little more than 300 feet above the base of the formation, appear at the surface or lie beneath the drift along the western border of the Carlyle quadrangle.

The formation consists of shale, sandstone, limestone, and a subordinate amount of coal, but the proportionate amount of coal is considerably smaller than that in the Carbondale formation below. Shale that is generally soft and claylike constitutes the major part of the formation.

*Beds between the Herrin coal and the Shoal Creek limestone member.*—The Herrin coal, at the top of the Carbondale formation, is generally overlain by shale 10 to 30 feet thick, but locally this shale is absent and the overlying limestone rests directly upon the coal. Most of the shale is gray and more or less sandy, but at the base it is generally black and hard.

The limestone that overlies the shale is very persistent, even more so than the coal itself, and may be used to determine the horizon of the coal where the coal bed is absent or questionably present. So far as known this limestone contains throughout its extent a fusulinoid shell about the size of a grain of wheat, which has been identified as *Fusulina cylindrica*, as *F. secalica*, and also as *F. cylindrica* var. *ventricosa*, but which according to G. H. Girty is probably *Girtyana ventricosa* Meek and Hayden. This fossil is a valuable key to the stratigraphy and is hence of much significance in drilling, particularly in the search for coal. Other animal remains, such as crinoid stems, a *Productus* that has been often identified as *Productus longispinus*, though it is now known to be a *Marginifera* (*M. splendens?*), and *Composita subtilita* (formerly called *Athyris subtilita*), are fairly common. The lower surface of the limestone is in some places smooth and in some places rugose, the ridges, which are known among the miners as "cat claws," extending downward as much as several inches.

The beds 20 to 40 feet above the Herrin coal are generally calcareous, though locally they consist of sandstone. The limestone is locally brecciated or conglomeratic. From 35 to 50 feet above the Herrin coal lies a coal bed (No. 7) that ranges in thickness from 2 or 3 inches to 3 feet and appears to be present throughout more than half of the area. This coal is overlain by shale and by another bed of limestone, above which the strata for about 40 feet consist predominantly of sandy shale and water-bearing sandstone. In a few places a bed of coal lies about 75 feet above the Herrin coal.

From 90 to 125 feet above the Herrin coal the rock with few exceptions consists of soft gray or bluish clay shale, which has a lenticular limestone bed in its upper part. Above this shale lies a massive porous brown or buff sandstone nearly 100 feet thick. It is fairly persistent but irregular in thickness and in some places is represented chiefly by shale, only a few thin layers of sandstone being present. The rock commonly shows cross-bedding, and it varies in short distances from soft and friable to tough and hard. In places, particularly about 30 feet above the base, traces of coal are present.

Above this sandstone there are thin beds of shale, separated by clay, limestone, or thin coal, which have an aggregate thickness of 20 or 30 feet, and above these beds lies about 100 feet of beds that consist in the northern part of the area predominantly of shale and small lenses of limestone and in the southeastern part of soft sandstone. One of the limestones, about 240 feet above the Herrin coal, is rather persistent and may represent the Carlinville limestone member. A coal that lies 180 to 200 feet above the Herrin coal is perhaps equivalent to coal No. 8. The top of this group of beds is generally marked by a layer of hard black shale that contains abundant impressions of *Productus cora*. This shale is well exposed in the bank of Kaskaskia River above the mouth of Quarry Creek south of Carlyle.



*Shoal Creek limestone member and overlying beds.*—One of the most persistent beds of southwestern Illinois is a limestone that lies 275 to 375 feet above the Herrin coal. In general the distance above the coal increases eastward from Shoal Creek, in Clinton County. In the Carlyle-Centralia district the position of the Shoal Creek limestone ranges from 350 feet above the coal in the western part of the Carlyle quadrangle to 375 feet in the eastern part of the Centralia quadrangle. In the Carlyle oil field the distance is about 360 feet, and as the limestone immediately underlies the surficial materials it is used as a seat for the drivepipe. The strata between the Shoal Creek limestone and the Herrin coal, however, thicken somewhat irregularly.

The Shoal Creek limestone attracted the attention of the first Geological Survey of Illinois and was named from its extensive outcrop along Shoal Creek. It is extensively exposed along Shoal Creek, on the western border of the Carlyle quadrangle, where it has been quarried. In Timmermann's quarry, north of Breese, some of its ledges include a considerable admixture of fine sand. It differs from most other limestones of the Pennsylvanian series in that it exhibits on fractures, especially those that follow the bedding planes of the rocks, faint bluish-gray irregular blotches and that after much weathering it separates into flags from 2 to 3 inches thick. Even the more massive ledges exhibit faint partings 2 to 3 inches apart.

The limestone is generally compact and hard and contains many organic fragments in a finely crystalline calcareous matrix.

The Shoal Creek limestone is overlain by a few feet of irregular bedded sandy shale, above which lies a thick bed of clay shale that extends about 70 feet above the Shoal Creek. This horizon is commonly marked by a few feet of clay and limestone, which is underlain in places by a few inches of coal. Above this coal lies 60 to 70 feet of shale, sandy shale, and sandstone, which extends to another coal, in places about 2 feet in thickness. This coal is commonly overlain by a black roof shale, which is succeeded by a bluish-gray shale 15 to 20 feet thick. Above this shale lies another coal, which is immediately underlain by plastic clay together with some limestone and which is succeeded by about 50 feet of gray to black shale and lenses of limestone. Above this calcareous shale there are commonly streaks of coal and one or two beds of limestone. This limestone appears to be the highest bed that is present in this district, though in some places where it is buried beneath Quaternary deposits it may be overlain by the succeeding shale member, which has a thickness of about 40 feet in the area to the east.

## QUATERNARY SYSTEM.

### CHARACTER AND THICKNESS OF THE DEPOSITS.

The surficial deposits of the area, which are generally 40 to 60 feet thick, belong to the Quaternary system. They consist of till, loess, and terrace deposits of Pleistocene age and alluvium and lake deposits of Recent age. All this material has been derived from consolidated rocks, chiefly by normal weathering and by the grinding and plucking action of glaciers, though in small part by the wearing of the rocks by streams. It has been transported and deposited by ice, wind, and water.

This surficial material is thickest in the drift ridges and the wide preglacial valleys and thinnest on the preglacial uplands, except where they are traversed by postglacial valleys. The thickest Quaternary deposits are found in the drift ridge 4 miles south of Carlyle, where bedrock probably lies 200 feet below the surface, and there are also high drift ridges in the northeast corner of the Carlyle quadrangle.

### PLEISTOCENE SERIES.

#### UNCONSOLIDATED MATERIALS OLDER THAN ILLINOIAN TILL.

At some places the Illinoian till seems to rest immediately on the consolidated rock, though at others it overlies a dark blue-gray clay, some of which is sticky and has been called by well drillers blue gumbo and some of which is silty. This clay is 5 to 30 feet thick and at some places contains numerous blocks of stone, most of them apparently of local origin. The small amount of manifestly transported material in the clay is mainly in its upper part, where it grades into the overlying glacial till. Some of the more silty material that is free from stones is probably pre-Illinoian loess, such as occurs at other places in southern Illinois, and was probably laid down in Yarmouth time. At some places, however, the material beneath the till appears to be washed and stratified, and this material is no doubt pre-Illinoian alluvium.

No good natural exposures of the clay beneath the till have been found, and its origin remains in some doubt, but it is tentatively regarded as in part derived from the rock in place and in part as old loess. Similar material that is exposed near Waterloo, Ill., 50 miles southwest of Carlyle, seems to be certainly loess.

In other areas not far distant, particularly in States immediately west of Illinois, there are several Quaternary formations older than Illinoian. These formations consist in the main of glacial and interglacial deposits, known from below upward as sub-Aftonian or Nebraskan till; Aftonian soil, peat, and gravel; Kansan till; and Yarmouth soil. None of these formations are definitely recognized in the Carlyle-Centralia district, and doubtless none will be found there, except possibly the Yarmouth. If they were ever deposited in the district they were either removed by erosion or so reworked by the Illinoian glacier or so buried as to be now unrecognizable.

#### ILLINOIAN TILL.

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

The glacial till is exposed in all but the smallest stream valleys of the region and in places on the uplands, the most extensive upland exposure being in the southeast corner of the Centralia quadrangle. Its thickness ranges from 20 to 100 feet and averages about 40 feet. Its lower surface is somewhat uneven, but its upper surface is smooth, except in the numerous drift ridges. Where weathered it varies in color from light grayish yellow to dull orange, the darkest shades of red appearing at the base of the weathered part, particularly where the till is thin. Where it is thick the larger part of it is unweathered and is bluish gray. In some places the line of demarkation between the weathered part and the fresher bluish part below is so sharp that it seems to be two separate bodies of till.

At many places in the district there are high drift ridges. (See "Surface features," p. 2.) Leverett[1] has suggested that the belt of ridges of which these form a part may be glacial moraines. Those in the Carlyle-Centralia district, however, differ from the common terminal and recessional moraines of the Wisconsin till in the northern part of the State in that they consist of a series of more or less disconnected roundish hills that stand on a flat plain. The nearest approach to the Wisconsin type of moraine is the long ridge in the southwestern part of the Carlyle quadrangle. The drift ridges consist of a central core of drift like the ordinary Illinoian till, although some are more like kames or eskers, being composed of sand and gravel and an outside layer of loess.

The upper part of the till is generally leached and oxidized and is yellow or rusty. The middle part is generally yellowish, and the lower part, which is less oxidized, is dark gray. At some places, however, especially where the till is thin and lies above the ground-water table, it is yellowish or reddish throughout.

Most of the till is ground moraine and includes both material deposited beneath the ice and that let down as a blanket from within the ice as it melted. However, the origin of extensive drift ridges has not yet been positively determined.

#### SANGAMON SOIL.

The interglacial stage that followed the Illinoian is called the Sangamon because of the widespread development of a bed of forest litter and of a more or less deeply weathered zone at the top of the Illinoian drift in Sangamon County, Ill. The Sangamon soil is present throughout much of the Carlyle-Centralia district but differs from that in Sangamon County in carbonaceous material being less abundant and in a brownish stain of iron oxide or a light-colored leached appearance being commonly developed in place of the heavy dark or black soil of the country to the north. Where best developed it is sometimes recorded in well logs, and in a few wells pieces of wood have been reported from its horizon. The soil seems to have been best developed in poorly drained places at some distance from the valleys, where erosion was more or less inactive. The valleys of Sangamon time, though probably considerably shallower, were in the same locations as those of to-day, and

[1] Leverett, Frank, The Illinois glacial lobe: U. S. Geol. Survey Mon. 38, pp. 71-74, 1899.

probably it is partly due to this fact that the soil is rarely seen along the present slopes where its horizon reaches the surface. It is found at depths ranging from 1 to 10 feet and is directly overlain by the loess. It is well exposed just south of the depot at Shattuc and along the railroad 2 miles south of Centralia. At these places it lies about 2 feet below the surface.

At many places the Sangamon soil is obscurely developed, and generally it seems to consist of two divisions of very different appearance and constitution—a light clayey lower member and a darker soil above. Above the Illinoian till there is commonly a gray or whitish clay containing few stones, the origin and correct classification of which are somewhat uncertain. Its thickness is generally 3 to 7 feet, but it ranges from 1 foot to 10 feet. This clay differs from both the underlying main body of till and the overlying loess. It differs from the till not only in color and in including few stones but in being generally more sticky or gummy. Fresh exposures are dark to light gray; weathered surfaces are whitish. The few stones it contains are well-rounded pebbles of quartz and subangular pebbles of chert. It differs from the loess in its content of pebbles and in its clayey nature. It may be part of the Sangamon soil, but if so that soil apparently consists of two distinct members. Above this clay but beneath the loess there is commonly a well-developed darker soil from a few inches to a foot or more thick.

#### EARLIER VALLEY FILLING (PRE-IOWAN ?).

Along Kaskaskia River and its larger tributaries there are at some places two low terraces, both of which are sometimes called second bottoms. Both are above the reach of ordinary high water, and in places, particularly downstream or southwest of the Carlyle-Centralia district, both are considerably above the reach of extreme high water. The material composing these terraces is better stratified than the alluvium and consists more generally of rather even layers of sand, silt, and clay, whereas the alluvium generally consists of silt containing few layers of sand or clay.

The upper terrace deposit seems to antedate the loess, or at least a considerable part of it, for it generally bears on its upper surface a foot or two or in places more of that material. It differs from the lower terrace deposit in rising gradually upstream, though its grade is less than that of the river, so that the early filling and the alluvium gradually draw near to each other, and in the Carlyle quadrangle they nearly merge and in places are buried by the alluvium.

#### LOESS (PEORIAN).

Throughout a large part of its extent the Illinoian glacial till is overlain by loess, a buff-gray clayey silt. The loess is not found in the stream valleys, in an upland area 5 to 10 miles east of Centralia, and in numerous small upland areas, from a few yards to several hundred yards across, where the till comes to the surface. No doubt loess was deposited over the entire district, but some was removed almost as fast as it was laid down and some has been carried away.

Except in places where it has been removed by the streams and in the southeastern part of the Centralia quadrangle, the loess, which is 5 to 30 feet thick, overlies the Illinoian drift and the Sangamon soil and immediately underlies the surface of the entire district.

The loess is composed of friable, uniformly fine-grained, unstratified or very imperfectly stratified, dustlike material that contains a small amount of calcium carbonate. Though very easily crushed it is sufficiently coherent to stand for a long time with almost or quite vertical walls where it has been cut by streams or excavations. When wet it is somewhat plastic but less so than average clay. So far as seen in the Carlyle-Centralia district it contains no fossils, but a short distance to the west, where it is considerably thicker and more uniform in size of grain, it contains in places many shells of air-breathing gastropods.

In the northern part of the State the main body of loess passes beneath Wisconsin glacial till, and it is therefore older than that formation and younger than the Illinoian till, from each of which it is separated by a well-developed zone of soil. A small amount of loess overlies the Wisconsin drift in some places to the north, and indeed deposits of dust which are indistinguishable from the older loess are in places now accumulating, so that possibly a part of the original main deposit of loess has been shifted and other dust has been accumulated since the Peorian stage, but the total amount of such material is comparatively small, and the main body of loess is believed to be older than Wisconsin and probably of Peorian age.

#### LATER VALLEY FILLING (WISCONSIN).

Along the lower course of Kaskaskia River deposits of sand and silt are common in the form of terrace remnants whose tops are only 15 to 20 feet above the flat plain and 10 to 20 feet below the top of the earlier or pre-Iowan (?) valley filling. The material in these remnants resembles the Recent alluvium, except that on the whole it is coarser. This resemblance and the fact that the terraces are low and have been extensively eroded make it difficult in some places to distinguish terrace deposits from alluvium. Upstream the top of the terrace, which is nearly horizontal, approaches the flood plain, which rises upstream, and the two nearly merge southwest of the Carlyle quadrangle. The terrace deposit, however, extends across the quadrangle. The well at Carlyle penetrated 35 feet of sand and clay below the surface soil, and other wells sunk in the flood plain seem to penetrate stream deposits thicker than the Recent alluvium.

Along Muddy River also and in other parts of southern Illinois there seem to be two distinct deposits of the valley filling, the oldest apparently having been deposited before the loess. The deposits on the two low terraces thus seem to cover a large area and were no doubt due to aggradation by the Mississippi.

That the valley filling is a double deposit is shown by the following facts: A rather persistent old soil lies near the middle of the deposit; two extensive and fairly distinct terraces are present, the top of one being about 440 to 450 feet above sea level and the top of the other about 420 to 430 feet; the materials forming these terraces differ somewhat; and the upper terrace is capped with loess, whereas the lower has none. The deposits are more distinct to the south of the district and in its northern part are not separately mappable.

### RECENT SERIES.

#### ALLUVIUM.

Deposits of alluvium are present along all but the smallest streams, the largest being in the valley of Kaskaskia River. Less extensive areas stretch along East Fork of Kaskaskia River and Crooked Creek.

Along Kaskaskia River the alluvium is about 25 feet thick. Below a few feet of somewhat sandy surface clay the alluvium consists largely of more or less washed sand, in some places containing lenses of clay and scattered pebbles. Some of the lenses of clay are practically free from grit and were probably deposited in meanders of the river. The deposit is apparently though not very conspicuously stratified, the uppermost beds, such as those exposed at the bridge 2½ miles south of Carlyle, being even and horizontal and those below being more or less irregular and highly inclined.

#### LAKE DEPOSITS.

Several lake beds in the bottom land of the Kaskaskia have been recently drained. The deposits in these lake beds, which consist partly of decomposed plant remains mingled with fine silt, are brownish black and in places 10 to 15 feet thick.

## STRUCTURE.

### GENERAL FEATURES.

In south-central Illinois the layers of rock lie nearly horizontal but slope downward to the east at the rate of a few feet to the mile. This slope, however, is not regular but is interrupted by low anticlines, synclines, terraces, faults, and minor irregularities.

### REPRESENTATION OF STRUCTURE.

*Methods employed.*—Structure is commonly represented in two ways—by cross sections and by contour lines. Cross sections are best for showing structure in a region in which the rocks are sharply folded and faulted, but for one where the folds are low and there are few if any faults they are of small value, for the structural features are there almost imperceptible. In such a region contour lines show the structure more clearly. The structure contours for the Carlyle-Centralia district are shown on the areal-geology maps.

*Delineation of structure by contours.*—To delineate structure by means of contours an easily recognizable reference stratum is chosen, whose position can be determined at many places by means of outcrops or borings. The altitude and dip of its surface are determined at as many places as possible, and points of equal altitude are connected by lines on the map like those which represent topographic contours. At some places the altitude of the reference stratum is observed directly in outcrops, mines, or wells; at other places it is calculated from observations made on some other recognizable stratum, for generally the layers of stratified rock are approximately parallel, and the average interval between any two layers may be determined. Thus, if the altitude above sea level of a stratum that lies stratigraphically above the reference layer is determined at a certain point where it crops out, the altitude of the reference stratum or key rock at that point may be calculated by subtracting from the altitude of the outcropping stratum the average interval between the two. If the altitude of a bed that lies stratigraphically below the reference stratum is determined the average interval is added, thus giving approximately the altitude at which the reference layer would lie if it were present.

*Use of structure contours.*—The structure map is useful not only for studying broad structural problems and for conveying an abstract knowledge of the structure of the region, but it is also of practical value for the aid it gives in locating and recognizing valuable beds and in determining their "lay." As the strata are approximately parallel and the average spacing of valuable beds is known, it is not difficult to calculate from the altitude of the reference stratum the approximate position of any bed at any point by adding or subtracting, according as the bed is above or below the key rock, the average distance between the two. The map may be used in this way for locating beds containing coal, limestone, or oil.

The structure map also serves to show the direction and amount of dip of the beds, a knowledge of which is most essential in all mining operations.

*Accuracy of structure contours.*—The accuracy of the structure contours depends upon three factors—first, the accuracy of the altitudes obtained directly; second, the difference between the actual and the assumed distance to the key rock, as calculated; third, the number and distribution of the points whose altitudes have been determined.

In the Carlyle-Centralia district the Herrin coal, the only one now mined in the area, is used as a reference stratum. This stratum is not exposed at the surface but has been penetrated in many borings and several mine shafts, in which the altitude of its base was calculated by subtracting its depth below the surface from the altitude of the surface as determined by hand or spirit level or barometer. As bench marks are numerous the hand level and barometer determinations involved only short horizontal distances, and the errors were therefore probably small.

Variation in the average interval between the reference stratum and other beds is more likely to lead to error in the structure contours, because the beds are not absolutely parallel. However, the distance between the Herrin coal and other known beds does not generally vary more than 15 feet from the average, and this variation does not seem to increase with the distance of the beds from the Herrin coal.

Owing to the scarcity of outcrops artificial excavations are almost the only source of information, and the determined altitudes of recognizable beds are therefore not so numerous as might be desired, but they are comparatively evenly distributed, so that the errors are probably not great. The dip of the coal bed in mines also affords information for working out the structure. After allowance for possible errors, the structure shown on the map is probably correct within 50 feet, the vertical interval between the contour lines.

### STRUCTURE OF THE CARLYLE-CENTRALIA DISTRICT.

In general the beds in the Carlyle-Centralia district dip a little north of east at the rate of about 15 feet to the mile but this general dip is modified by low folds and minor irregularities, most of which are too poorly defined to be described separately. The structure of the district is shown on the geologic maps by contour lines drawn at intervals of 50 feet on the base of the Herrin coal. The irregularities shown by these contour lines are the product of irregularities in the surface on which each layer was deposited and of differential settling and warping since the deposition. The general eastward dip is in part at least the result of deformation. It carries the top of the Carbondale formation from a position about 400 feet below the surface at the western side of the area to one about 800 feet below the surface on the eastern side. This general dip is modified by a low dome at Bartelso, a short, plunging anticline in the oil field northwest of Carlyle, a long, shallow syncline just east of Kaskaskia River, a short anticline or dome at Hoffman, two domes at Sandoval and Junction City, an uplifted block near Centralia and Sandoval, a rather steep monocline southeast of Sandoval, and a syncline near the east side of the district. In parts of the area, particularly in Wheatfield Township, northwest of Carlyle, the dip seems to be only 3 or 4 feet to the mile. In some places the Herrin coal is almost level throughout several square miles, whereas in others it dips more than 20 feet to the mile. Commonly the coal dips in a direction different from that of the general dip and here and there in a direction opposite to it.

In many parts of the area, although borings are numerous enough to determine the approximate position of the coal, they are not sufficiently abundant to determine the direction of the dip; hence many structural features may not yet have been discovered. Throughout much of the area no borings have reached recognizable beds, and the structure shown on the map therefore lacks many details which can be shown when the coal has been worked more extensively. The mine shafts and borings sunk, however, are rather uniformly distributed, so that the major structural features as shown are believed to be approximately correct.

In the Marion Coal Co.'s mine at Junction City there is a fault, west of which the beds have dropped down 30 feet. For several years oil has seeped into the mine in places 200 to 300 feet east of the fault as well as along the fault plane. Indeed, the oil seep in this mine attracted attention to the region and thus led to the discovery of the Sandoval oil field. In mines 3 and 4 of the Centralia Coal Co., in Centralia, a fault lies 1,500 to 1,800 feet east of the shafts, and the exposures in the mine and some drill records seem to indicate that the beds west of the fault have dropped down more than 100 feet. A fault zone probably extends from the area near Sandoval southward beyond the southern border of the Centralia quadrangle. It follows the crest of a structural terrace which may be continuous with one at Duquoin, 35 miles to the south. The Sandoval and Junction City oil fields are on the edge of this terrace. These faults and some irregularities in the attitude of the beds east and southeast of Centralia are interpreted as indicating that an uplifted wedge-shaped block here lies between two faults that converge toward the north and meet near Central City.

## GEOLOGIC HISTORY.

### CONDITION OF THE RECORD.

Only a small part of the geologic history of the Carlyle-Centralia district can now be read in the rocks that are exposed at the surface or encountered 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 the drill. That of the periods between the Carboniferous and Quaternary has been in large part erased, though there is an indistinct record of the progress of erosion. However, many facts in the history of the district may be inferred from the results of studies made in other areas in the general region, for the processes that affected the district affected also an extensive province around it. Evidence concerning many occurrences in pre-Carboniferous time is found in rocks that crop out in southern Illinois and just west of the Mississippi in Missouri. Much of the history of the smaller area is therefore contained in the more complete record of the larger area.

During the Paleozoic era the general region 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 region, so far as known, has been continuously above sea level and subject to erosion.

### PALEOZOIC ERA.

#### EARLY PERIODS.

At the beginning of the Paleozoic era the surface of the district and the adjacent region 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 advancing sea. The submergence probably took place in Middle Cambrian time and lasted at least until the end of Cambrian time.

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

#### CARBONIFEROUS PERIOD.

##### MISSISSIPPIAN EPOCH.

Between the time of the deposition of the Upper Devonian beds and the time of the deposition of lowermost Mississippian beds the region was a land surface. During the Mississippian epoch it was again extensively submerged. In Kinderhook time much fine sand and clay was carried to the sea by the streams. At the end of the Kinderhook epoch and during the succeeding Burlington epoch the sea expanded farther and became clearer, so that the deposits which accumulated during that epoch consist largely of limestone. In the Keokuk and Warsaw epochs conditions varied, both sand and calcareous mud being deposited. At the close of the Warsaw epoch 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 water was therefore clear, and pure limestone, which in some places consists mainly of oolite, was laid down. The beds formed at this time are now known as the Spergen limestone. During the succeeding St. Louis epoch the sea deepened and extended at least to central Iowa. At the close of the St. Louis epoch the water withdrew by a series of oscillations which permitted the accumulation of beds of oolite similar to the Spergen, containing a sandy member in the middle part and forming the Ste. Genevieve limestone. After a considerable interval in which the area was land further warping elevated much of the bordering 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 formations of the Chester group.



##### PENNSYLVANIAN EPOCH.

###### POTTSVILLE EROSION AND DEPOSITION.

For a long period after the Chester submergence the region was a land area, and during this time its surface became much dissected. This old surface is now exposed at many places in Illinois and has been reached by numerous borings. It is nowhere smooth, and in places it has considerable relief. Slight warping seems to have preceded the resumption of extensive deposition. At first sedimentation was restricted to a rather narrow area in the eastern interior coal field of Illinois and western Kentucky, and this area slowly enlarged toward the north and east. Further warping elevated the surrounding country, so that the area of sedimentation gradually advanced northward and spread eastward and westward. Most of the sediments laid down at this time consisted of continental sand and mud, which now make up the Pottsville formation. The sand was doubtless in part derived from the rocks of the Chester group, which formed the western border of this portion of the Pottsville area of deposition, though as much of the sand of the Pottsville is coarser and more micaceous than any in the Chester, a large part must have come from elsewhere. The coarseness and the great volume of the material show that the land from which it was derived must have stood considerably above sea level.

Early in the Pennsylvanian epoch great peat marshes began to form in Illinois and parts of adjacent States, and some of them persisted for a long time. Now and then conditions changed, so that mud or sand was washed in upon the peat, sometimes in thin films and at others in deposits reaching a thickness of many feet. Most of these bodies of sediment were of lenticular form, but groups of them are so fitted together as to make a stratum of fairly uniform thickness. In the Pottsville epoch the accumulations of peat were not so extensive as in later epochs, but local marshes were developed in which layers of vegetal material were accumulated in quantities large enough to form seams of coal.

###### CARBONDALE DEPOSITION.

While the Carbondale sediments were being laid down the region was at times covered by the sea and received deposits of mud, both argillaceous and calcareous, and of sand, and at other times the sea was practically banished for longer or shorter periods, though the surface commonly remained so low and so level that brackish or fresh-water marshes covered large areas, in which were accumulated beds of vegetal matter that were afterward transformed into coal. Much of the sand may have been deposited on land, but the limestone and some of the shale formed during that time contain well-preserved remains of marine animals, showing conclusively that the rocks in which they are found were deposited in the sea.

At times both local and general emergence and erosion seem to have occurred, though the erosion was not nearly so extensive as that at the beginning of the preceding Pottsville epoch. Conditions generally were more quiet than in that epoch. Beds of sand, in some places thick though not extensive, were formed, but more of the material laid down was clay. More peat was formed in this epoch than in any other.

The time of the greatest development of peat occurred at the end of Carbondale time, when the Herrin coal was formed. The accumulation of this peat was interrupted from time to time by the spreading out of films of sediment and by the development temporarily of conditions favorable to decomposition, so that the deposit is divided into several layers.

###### McLEANSBORO DEPOSITION.

The conditions that prevailed in Carbondale time continued in McLeansboro time without much change, but the formation of peat was less widespread and was of shorter duration. The strata laid down consisted mainly of more or less sandy mud and interbedded sand, though a subordinate but considerable amount of limestone was also deposited.

Presumably in the large Carboniferous marshes the water was kept quiet by the extremely rank vegetation. Bars and barrier shoals also were formed. At times the water became a little too deep for the growth of peat-forming plants, and at other times it was too shallow to permit them to grow and be preserved. In the shallow waters carbonaceous muds or other sediments were laid down.

At the beginning of McLeansboro time the district was part of a great, almost unbroken peat swamp in which the material for the Herrin coal had just been formed. The rate of subsidence, however, became too great for the maintenance of the growth of peat, the peat-producing cover was killed, and the swamp was buried under mud. Deeper subsidence and quiescence favored the deposition of a bed of lime by marine organisms. There is some indication of emergence and erosion after the deposition of the first muds and limestone, and no doubt later in the McLeansboro epoch there came times of at least local emergence. The kind of material deposited in this area changed from time to time, the most widespread beds being a thick predominantly sandy bed and two relatively thin beds of lime, which now form the Shoal Creek and Carlinville (?) limestone members. How long sedimentation continued after the deposition of these limestones is not known, for all the record except that preserved in a few feet of immediately overlying strata has been destroyed. The later events of Pennsylvanian and those of Permian time in this area are unknown. Any deposits that may have been laid down have since been entirely removed by erosion, for no trace of them is found in surrounding areas. Very likely the Carlyle-Centralia district, though low, stood in such relations to surrounding areas that little or no sediment was laid down.

###### DEFORMATION AT CLOSE OF CARBONIFEROUS TIME.

Carboniferous deposition was ended by widespread movements which resulted in the uplift of the Appalachian Mountains on the east and the Ouachita and Ozark mountains on the southwest and the further uplift of the La Salle anticline in Illinois. These movements permanently excluded the sea from the region.

The attitude of the rocks of the Carlyle-Centralia district was not greatly modified by the widespread deformation that took place nearly at the close of Carboniferous time. The folds then produced are so broad and low that they are almost indistinguishable from original irregularities of deposition, and no large faults have been found, but the general altitude of the surface was probably considerably increased, for the district seems to have been raised from approximately sea level to a position a few hundred feet above it. Whether the general eastward dip of the strata was produced altogether at this time or is in part a result of subsequent movements is not known. The faulting near Centralia and Sandoval probably took place at this time.

In some parts of southern Illinois and elsewhere molten rock was forced from places far down in the earth up to levels so near the surface that it has since been laid bare by erosion, but no igneous rock has been found in this district and probably no such rock lies within several thousand feet of its surface.

### MESOZOIC ERA.

After the uplift and deformation near the close of the Carboniferous period new processes began to act in the region, and areas which before had almost continuously received deposits of sediment began to undergo erosion. Erosion has continued practically without interruption to the present time, though at several epochs it has probably been accelerated by uplifts. There is no definite evidence of any general subsidence.

Several great uplifts have affected the Appalachian Mountains and the Ozarks, and between and during these uplifts extensive erosion reduced the surface by many hundreds of feet. Perhaps each of the periods of mountain uplift produced some deformation in southern Illinois, though presumably the amount was slight. In each cycle of uplift and long-continued erosion valleys were carved and the intervening hills were afterward reduced nearly to a plain, and this process has been repeated several times, for each planed surface—the record of one cycle—was more or less completely destroyed by erosion during the next. Moreover, all possible stages occur in the process of reduction, and the less complete the cycle the more easily is its record destroyed. In southern Illinois, as the uplifts were slight and the rocks are almost uniformly soft, the records of uplift and erosion are not well preserved. In the southernmost and northernmost parts of the State the tops of certain hills of resistant rock apparently constitute remnants of two peneplains older than any recorded in the Carlyle-Centralia district; hence another cycle of uplift and erosion seems to have taken place before the oldest surface in the quadrangles was formed.

### CENOZOIC ERA.

#### TERTIARY PERIOD.

*Development of relief.*—Early in the Tertiary period an uplift may have marked the beginning of another cycle of erosion. In any event, some time before the end of the Tertiary the surface of most of Illinois and of the general region had been reduced to a nearly level plain, for the surface beneath the Quaternary deposits is very even except where narrow valleys were cut, in late Tertiary or early Quaternary time.

The surface of consolidated rock underlying the drift, which is similar in form to the surface at the end of the Tertiary period, is trenched by wide, shallow valleys, which seem to mark areas of softer beds of rock, and these valleys are bordered by wide, low table-lands of irregular outline, which are underlain by harder layers. Thus, the Shoal Creek limestone seems to have immediately underlain a few feet of residual material throughout many square miles in the western part of the Carlyle quadrangle. Some of the higher areas, however, did not have the form of a table-land but were irregular, like the hilly area in the northwestern part of the quadrangle.

The bedrock surface in general slopes southward, and this slope continues south of the Carlyle-Centralia district. Hence it appears that at the close of the Tertiary the general slope of the surface was southward, as it is to-day.

Near the end of the Tertiary period the region was apparently subjected to a general uplift, which accelerated erosion and caused the streams to deepen their valleys. Well borings show that several such valleys, 75 feet or more in depth and now filled with drift, crossed the Carlyle-Centralia district. The general form of the present bedrock surface is probably much the same as the preglacial surface and may be discussed as such.

The maximum known relief of the preglacial surface was 150 feet, but if the deepest valleys are not considered it did not exceed 50 or 60 feet. The valleys were generally broad and their slopes somewhat gentle and the divides were about as high above the valley as those of to-day. In these respects the preglacial surface somewhat resembles the present surface. The valleys had a different arrangement, however, and the courses of the present streams have little relation to the ancient lowlands. Kaskaskia River is the most striking exception, for its course within the district seems to lie almost entirely within the preglacial lowland. At only a few places, in an area 2 miles south of Carlyle, is bedrock in the Kaskaskia Valley as high as the present stream bed.

## QUATERNARY PERIOD.

### PLEISTOCENE EPOCH.

At the beginning of the Quaternary period the surface of the Carlyle-Centralia district, though in general much like the present surface, differed from it in one striking particular. The configuration of the surface at that time was produced solely by erosion, whereas that of the present surface has been in part produced by the deposition of drift and in part by the erosion of the drift by streams.

#### PRE-ILLINOIAN TIME.

In the earlier part of the Pleistocene epoch ice sheets formed in Canada at different times and spread broadly over the northern interior region of the United States, probably covering part of Illinois. These ice sheets are known as the Nebraskan and Kansan, and after each sheet had melted there were interglacial stages (Aftonian and Yarmouth, respectively) during which soils and in places lake and stream deposits were formed. These pre-Illinoian stages appear not to be represented by deposits in the Carlyle and Centralia quadrangles, except possibly the Yarmouth. In many wells layers of gravel and sand have been reported, and in some wells pieces of wood and materials that have somewhat the appearance of buried soils have been found, but in most of the borings the glacial till appears to be one continuous deposit, extending down to the preglacial residual material, which immediately overlies the bedrock surface.

At several places in southern Illinois a thin deposit of loess underlies the Illinoian till, and in the Carlyle-Centralia district material that appears to be loess is brought from beneath the till in well-drilling, though it is generally so much washed and mixed with the overlying and underlying deposits that its identification is difficult. A rather extensive deposit of loess, however, was probably laid down in southern Illinois, perhaps in Yarmouth time, and this loess, like the later and more extensive deposit, seems to thicken toward Mississippi and Ohio rivers.

#### ILLINOIAN TIME.

The events of the Illinoian glacial stage were of great significance in the history of the Carlyle-Centralia district. The Illinoian ice spread out from a center in Labrador and finally reached almost to the southern end of Illinois—the southernmost point reached by any Pleistocene ice sheet. As it advanced it gathered up material and carried it southward. However, this ice sheet seems at some places to have picked up only a part of the unconsolidated material available, though at others it wore off fragments of hard bedrock. In the Carlyle-Centralia district in particular the amount of erosion by this glacier was not great, as is shown by a few feet of unconsolidated material and other pre-Illinoian deposits generally left upon the bedrock, upon which no glacial striae have been found. The soil, clay, sand, and fragments of stone gathered all along the route from Canada southward were intermixed and the stones were further broken up by the glacier, and when the ice melted in the district it left a mantle of drift composed of this material spread over hill and valley alike, except that the deposits on the lower parts of the surface were at most places somewhat thicker than those on the higher parts and hence the resulting surface was somewhat more even. However, some irregularities were developed in the form of more or less isolated mounds and ridges.

The conditions and events that led to the formation of the drift ridges which cross the Carlyle-Centralia district are not definitely known. This system of ridges forms the middle one of three approximately parallel systems. The ridges may consist of interlobate morainic material deposited between two ice fields or they may be terminal or recessional moraines that mark the west border of an ice lobe which persisted in southern Illinois after the ice had retreated from the western part of the State. They may represent accumulations of material under the ice or they may consist of material collected in or upon it. There is no other evidence, however, of ice lobes on either side of the belt of drift ridges, and no immediate cause is known for such accumulations beneath the ice, which seems to militate against the first three possibilities, and as the bedding planes of the water-laid parts of the drift in the ridges have been disturbed and as the proportion of rocks from Canada seems larger than in the drift elsewhere the bodies of till that form the ridges would seem to have been in or near the top of the ice.

#### SANGAMON TO PEORIAN TIME.

Upon the surface of the Illinoian till, which with the exception of the drift ridges was somewhat more smooth than the preglacial surface, new lines of drainage were developed, and in the flattest parts of the interstream areas organic material from successive generations of plants accumulated in the form of a carbonaceous soil (the Sangamon soil), which was in places peaty, particularly in central Illinois, where it is dark, though elsewhere it is reddish or whitish. In the Carlyle-Centralia district this soil is represented in many places at the top of the till, where it appears as a grayish or reddish layer a foot or less thick. On slopes where erosion was more active vegetal material did not accumulate in the Sangamon soil or was not preserved, and hence in many exposures the upper limit of the till is not sharply defined. Indeed the till, probably as the result of creeping in places and of original scarcity and later solution and decomposition of pebbles near the top, has generally the appearance of grading upward into the loess.

After these conditions had continued undisturbed for some time, until the present valleys were fairly well developed and partly filled with stream deposits, favorable conditions arose for the accumulation of extensive deposits of silty material, probably dust. This dust, or loess, was spread over the Sangamon soil and over the leached and eroded Illinoian till in places where the Sangamon soil was absent. Later this deposition of dust diminished and became overbalanced by erosion, and the carving of valleys continued to Wisconsin time, when they had reached almost their present form.

The origin and mode of accumulation of loess has for many years been a problem for which no complete and universally satisfactory solution has ever been reached. Two general theories have been advanced—one that it was deposited by water and the other that it represents accumulations of wind-borne dust. Each of these theories seems to have many adherents, though the balance of opinion seems to favor the view that it was deposited by wind.

Some loesslike material is stratified and contains pebbles and aquatic fossils, which favors the opinion that it was deposited by water, but on the other hand nearly all the fossils are the remains of land animals, and the distribution of the material indicates transportation by wind rather than water. It is thicker on the high hills that border the large rivers than it is on the lowland 20 to 100 miles distant, and it is thickest on the east and north sides of the river valleys—that is, on the sides opposite the direction of prevailing winds. If the upland loess was deposited by water the highest hills must have been submerged and the streams several hundred feet deep. Though most of southern Illinois lies below the altitude of the thickest deposits of loess on the bluffs of the Mississippi, and though this region on this hypothesis must also have been under water, yet throughout the southwestern part of the State the loess does not appear to be stratified or to show other evidence of aqueous origin.

In the Carlyle-Centralia district the loess does not seem to show any stratification or other characters that would indicate that it was deposited by water. So far as known it is not interbedded with any sand or gravel and does not have a terrace form. Its character and surface features throughout southern Illinois 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.

The source of the loess is an even more difficult problem. Those who have studied it most thoroughly incline toward the belief that it was carried up as dust from the river flood plains. The facts that support this view are that the loess is not only thickest on the river bluffs but thicker on the side opposite the direction in which the prevailing winds blow and that in this region the dry river bars furnish large quantities of dust. While the loess was being accumulated the river bluffs were probably forest-covered, as they are now, for the fossils of the loess are largely the shells of woodland snails. Trees may have largely assisted in catching and holding the dust.

The loess that borders large rivers is coarser or at least freer from fine particles than that which lies some distance from them, perhaps either from differences in the conditions under which the two were deposited and to which they have since been subjected (such as the presence or absence of forests and other vegetation and the amount of moisture) or perhaps from wind sorting. If most or all of the loess was derived from large valley bottoms the coarser dust would no doubt have been dropped first. Incidentally, if there was some chemical difference between the coarse particles as a whole and the fine particles as a whole, the resulting deposits would differ not only physically but chemically. In fact, as already indicated, such differences, both chemical and physical, do exist, but that they are due to wind sorting has not been demonstrated.

On the other hand, that nearly all the loess was derived from stream deposits seems doubtful on account of its great volume. It now covers parts of a number of States to a depth of several feet and may have covered these areas to an average depth of 15 feet or more. It seems hardly believable that such a quantity of material could in a small part of one geologic period have been blown up by the wind from the river channels. It therefore appears probable that a part of the loess has come from the dry plains of the west, and possibly a part was derived from the glacial till before it was covered with vegetation.

#### WISCONSIN TIME.

After a long interval ice of the Wisconsin stage invaded northern and eastern Illinois, reaching into the upper end of the basin of Kaskaskia River. Water overloaded with glacial débris discharged southwestward from the ice and deposited in the valley large quantities of sand and gravel. This deposition may have continued after the ice front receded, while new valleys were being established on the deposited till. Final adjustment was again reached, and the river once more began to cut down into the material which it had recently deposited and to develop a flood plain at a lower level. This adjustment was reached first near the mouth of the river, and the new flood plain, which is being developed upstream, has scarcely yet reached the Carlyle-Centralia district.

The outwash of the Wisconsin glacier in the valley of the Kaskaskia forms a low terrace that extends out from the Shelbyville morainic system and merges into the flood plain in the northern part of this area. This terrace is recognizable east and southeast of Keyesport, in the Carlyle quadrangle, in the form of low elevations of very fine sand which lie above the area that is submerged in ordinary flood and which are composed of material rather markedly different from the main body of the alluvium of the Kaskaskia Valley. It seems to terminate rather abruptly here, as if it were an old delta and this were its front.

### RECENT EPOCH.

The altitude of the district, so far as known, has not materially changed in the Recent epoch. The principal event has been the removal of part of the material deposited during the Pleistocene epoch. The streams have been widening their valleys and forming flood plains.

The effectiveness of postglacial erosion in dissecting the drift plain differs greatly from place to place. As the general slope of the drift plain is very slight, the headward cutting of the valleys has in most places been exceedingly slow, no doubt because rain and snow water soaks slowly into the ground instead of being at once drained away.

All the streams, whether building up or cutting down, have been continually making deposits, and some of these deposits lie along their banks to-day. Each stream swings back and forth across its valley, depositing on one bank and cutting on the other. Most of this work is done at times of high water, when the streams spread over their flood plains, dropping the finer material where the water is shallower and the coarser where it is deeper. The average section of flood-plain deposit is therefore progressively finer from base to top.

# ECONOMIC GEOLOGY.

The mineral resources of the Carlyle-Centralia district, named in approximate order of commercial value, are coal, oil and gas, soils, water, clay, and building stone.

## COAL.

The Carlyle-Centralia district is in the southwestern part of the eastern interior coal basin. (See Fig. 4.) Coal occurs at several horizons in the Carbondale and McLeansboro formations, but the Herrin coal is of much greater value than any other and is the only bed now worked. The coal production of Clinton and Marion counties, in which the district is situated, in 1918 was more than 2,650,000 short tons.

### BEDS BELOW THE HERRIN COAL.

A few lenses of coal seem to be present in the Pottsville formation, but in no borings are they reported to be as much as 2 feet thick. The Murphysboro coal, at the base of the Carbondale formation, is reported in several wells, principally in the vicinity of Hoffman, where it is of good quality and about 5 feet thick. Other coal beds are present in certain areas but so far as known are less than 2 feet thick and are not sufficiently uniform or extensive to warrant exploitation under present conditions. One of these beds is rather persistent, though generally thin and irregular. Near Carlyle, however, this coal is 3 to 5 feet thick and has been worked to a small extent.

However, it is overlain and underlain by soft clay and cut by numerous clay veins, which make mining difficult.

### HERRIN COAL (NO. 6.)

*General features.*—The Herrin coal is by far the most valuable and best-known coal in the district. It is worked extensively near Centralia and Sandoval and so far as known is persistent. It ranges in thickness from 5 feet 6 inches to 6 feet 10 inches and averages about 6 feet. It is overlain generally by hard black shale, which forms a good roof, and is underlain by a hard sandy clay, which does not creep rapidly. In a few places the bed appears to fall below the general minimum of 5 feet 6 inches, and in a small area just west of Carlyle the coal seems to be absent. Throughout extensive areas, however, little is known concerning the coal, and hence it is somewhat unsafe to assume that the coal is present in all but this one small area. No drill records are available for T. 4 N., R. 3 E.; T. 3 N., Rs. 2 and 3 E.; and T. 1 N., Rs. 2, 3, and 4 E.

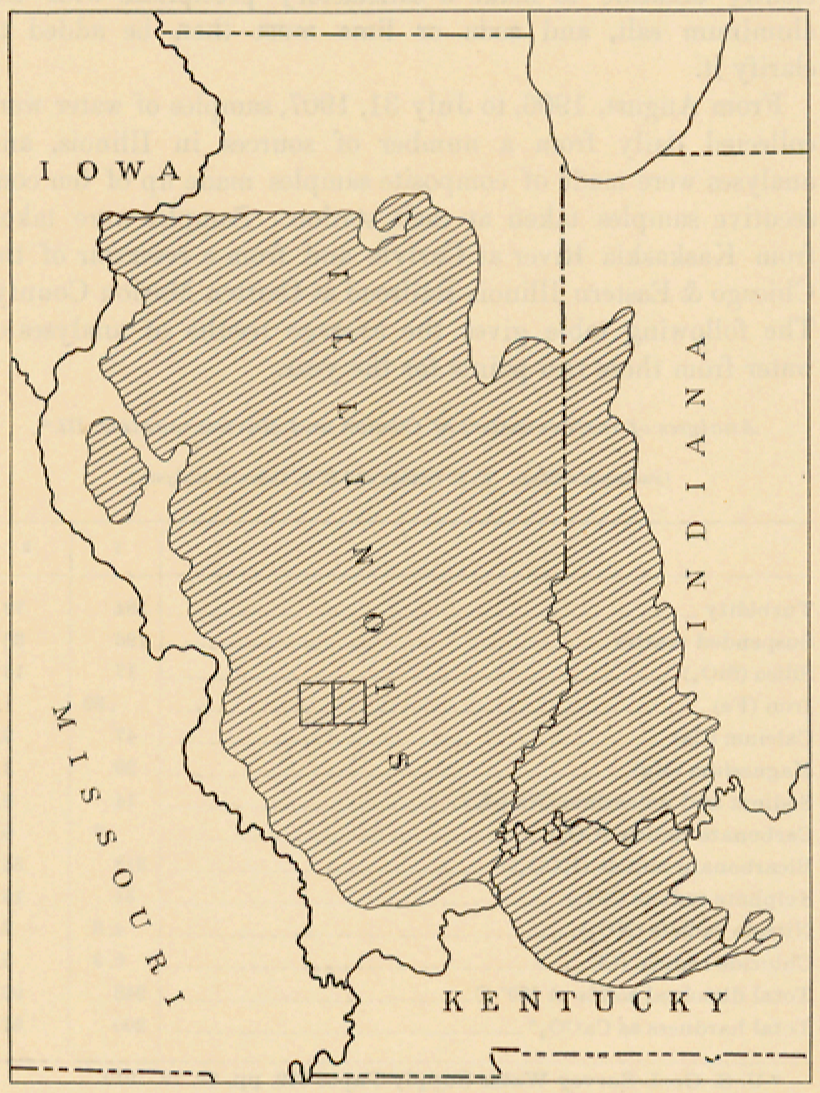


FIGURE 4.—Outline map of the eastern interior coal basin of Illinois, Indiana, and Kentucky.

The position of the Carlyle and Centralia quadrangles is shown by the small rectangles.

*Physical character.*—As stated under "Stratigraphy," the Herrin coal is made up of several benches, in most places three, and the most persistent parting is the blue band, which lies 3 to 12 inches above the base and separates the middle from the bottom coal. The coal of the middle and bottom benches breaks into more or less cubical blocks, and the upper bench contains considerable "mother of coal" or mineral charcoal. Five typical sections of the coal and associated beds in this area are shown in Figure 5.

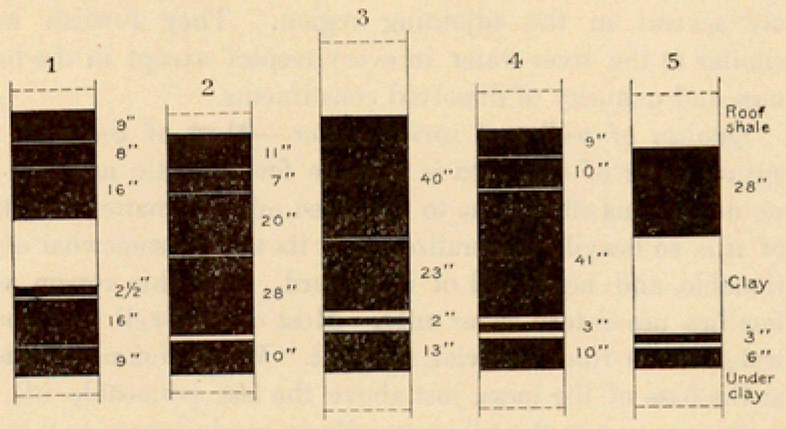


FIGURE 5.—Detailed sections of the Herrin (Belleville or No. 6) coal bed.

1, Breese-Trenton Mining Co., at Beckemeyer; 2, Odin Coal Co., at Odin; 3, Centralia Coal Co., mine No. 2, at Centralia; 4, Centralia Coal Co., mine No. 4; 5, Chicago-Sandoval Coal Co., mine No. 2, at Sandoval

The coal fractures along planes that are commonly marked by gypsum and calcite, and on the exposed coal in the mines fibrous ferrous sulphate, produced by the oxidation of marcasite or possibly pyrite, is abundant. In some places, particularly in the Odin mine, the coal is cut by calcareous clay veins, which are rarely more than an inch or two thick and extend from the top of the bed toward the floor. Such clay veins are very unusual in coal No. 6 but are characteristic of the Springfield coal (No. 5).

*Chemical character.*—The chemical character of the coal, like the physical character, differs greatly from place to place. In the following statements of analyses the figures showing the coal "as received" represent approximately the actual commercial product of the area, though there is doubtless some difference as regards moisture and ash.

The volatile matter in the coal averages about 38 per cent, the fixed carbon about 39 per cent, the moisture 12½ per cent, the sulphur 4 per cent, and the ash 10½ per cent. The heating value averages about 11,000 British thermal units, nearly the average or a little below the average for the coals of Illinois. The heating value of the coal of Jackson, Williamson, Franklin, and Saline counties is 12,000 or more British thermal units, and almost no coal in the State falls below 10,000. The sulphur content of the coal of the Carlyle-Centralia district is considerably greater than that of the coal in the southern end of the field. The analyses were made under the direction of Prof. S. W. Parr in the laboratories of the University of Illinois.

*Proximate analyses of samples of Herrin coal (Belleville or No. 6) from Clinton and Marion counties, Ill.*

| Locality. | Laboratory No.[a] | Form of analysis.[b] | Moisture. | Volatile matter. | Fixed carbon. | Ash. | Sulphur. | Carbon as $CO_2$. | Heating value (British thermal units). |
|---|---|---|---|---|---|---|---|---|---|
| **Clinton County.** | | | | | | | | | |
| Central Clinton County[c] | *5054 | A | 12.43 | 37.23 | 39.93 | 10.41 | 4.19 | 0.38 | 10,730 |
| | | B | 8.09 | 37.94 | 43.05 | 10.92 | 4.40 | .40 | 11,262 |
| | | C | ........ | 41.28 | 46.84 | 11.88 | 4.79 | .44 | 12,253 |
| Do.[c] | *5062 | A | 12.60 | 36.78 | 40.48 | 10.14 | 2.88 | .77 | 10,827 |
| | | B | 8.14 | 38.65 | 42.55 | 10.66 | 3.03 | .81 | 11,380 |
| | | C | ........ | 42.07 | 46.32 | 11.61 | 3.29 | .88 | 12,388 |
| Do.[c] | *5063 | A | 12.15 | 37.74 | 40.52 | 9.59 | 3.51 | .29 | 10,949 |
| | | B | 8.08 | 39.49 | 42.40 | 10.03 | 3.67 | .30 | 11,457 |
| | | C | ........ | 42.96 | 46.13 | 10.91 | 3.99 | .33 | 12,464 |
| Do. | 2636 | A | 12.06 | 35.62 | 40.89 | 11.43 | 3.38 | ........ | 10,825 |
| | | B | 8.33 | 37.13 | 42.62 | 11.92 | 3.52 | ........ | 11,284 |
| | | C | ........ | 40.50 | 46.51 | 12.99 | 3.84 | ........ | 12,309 |
| Breese | 1176 | A | 12.86 | 35.68 | 39.62 | 11.84 | 3.93 | ........ | 10,672 |
| | | B | 3.98 | 39.32 | 43.65 | 13.05 | 4.33 | ........ | 11,759 |
| | | C | ........ | 40.95 | 45.46 | 13.59 | 4.52 | ........ | 12,246 |
| Do. | 1175 | A | 11.83 | 34.42 | 44.25 | 9.50 | 3.49 | ........ | 11,162 |
| | | B | 4.08 | 37.44 | 48.14 | 10.34 | 3.80 | ........ | 12,143 |
| | | C | ........ | 39.03 | 50.19 | 10.78 | 3.96 | ........ | 12,659 |
| Southwestern Clinton County[d] | 996 | A | 10.97 | 38.08 | 41.62 | 9.33 | 4.27 | ........ | 11,409 |
| | | B | 5.91 | 40.25 | 43.99 | 9.85 | 4.52 | ........ | 12,058 |
| | | C | ........ | 42.78 | 46.75 | 10.47 | 4.80 | ........ | 12,815 |
| **Marion County.** | | | | | | | | | |
| Centralia | *5033 | A | 10.24 | 39.06 | 39.79 | 10.91 | 4.18 | 0.30 | 11,180 |
| | | B | 5.43 | 41.14 | 41.93 | 11.50 | 4.40 | .32 | 11,780 |
| | | C | ........ | 43.51 | 44.33 | 12.16 | 4.65 | .34 | 12,456 |
| Do. | *5035 | A | 10.69 | 38.76 | 39.01 | 11.54 | 3.98 | .51 | 10,963 |
| | | B | 5.51 | 41.01 | 41.27 | 12.21 | 4.22 | .54 | 11,599 |
| | | C | ........ | 43.41 | 43.66 | 12.93 | 4.47 | .57 | 12,275 |
| Do.[c] | *5030 | A | 12.45 | 37.22 | 39.81 | 11.52 | 3.62 | .67 | 10,874 |
| | | B | 5.43 | 39.75 | 42.52 | 12.30 | 3.87 | .72 | 11,614 |
| | | C | ........ | 42.03 | 44.96 | 13.01 | 4.09 | .76 | 12,281 |
| T. 2 N., R. 1 E.[c] | *5041 | A | 10.35 | 36.04 | 42.81 | 10.80 | 4.10 | .25 | 11,227 |
| | | B | 6.33 | 37.66 | 44.73 | 11.28 | 4.28 | .26 | 11,730 |
| | | C | ........ | 40.20 | 47.75 | 12.05 | 4.57 | .28 | 12,522 |
| Do.[c] | *5039 | A | 10.06 | 37.96 | 41.09 | 10.89 | 3.92 | .59 | 11,289 |
| | | B | 6.06 | 39.65 | 42.92 | 11.37 | 4.09 | .62 | 11,791 |
| | | C | ........ | 42.21 | 45.69 | 12.10 | 4.35 | .66 | 12,555 |
| Do. | *5044 | A | 10.96 | 36.54 | 40.68 | 11.82 | 4.00 | .43 | 11,002 |
| | | B | 6.81 | 38.24 | 42.58 | 12.37 | 4.21 | .45 | 11,515 |
| | | C | ........ | 41.04 | 45.69 | 13.27 | 4.52 | .48 | 12,364 |
| Western part of T. 2 N., R. 1 E. | 2614 | A | 10.77 | 37.99 | 41.52 | 9.72 | 3.91 | ........ | 11,413 |
| | | B | 6.76 | 39.70 | 43.38 | 10.16 | 4.09 | ........ | 11,926 |
| | | C | ........ | 42.58 | 46.53 | 10.89 | 4.38 | ........ | 12,789 |
| Do. | 1866 | A | 10.31 | 34.86 | 41.40 | 13.43 | 5.03 | ........ | 10,913 |
| | | B | 2.18 | 38.02 | 45.16 | 14.64 | 5.49 | ........ | 11,902 |
| | | C | ........ | 38.87 | 46.17 | 14.96 | 5.61 | ........ | 12,167 |
| Do. | 171 | A | 8.98 | 36.80 | 43.45 | 10.77 | 3.91 | ........ | 11,065 |
| | | B | 6.09 | 37.98 | 44.82 | 11.11 | 4.04 | ........ | 11,417 |
| | | C | ........ | ........ | ........ | 11.83 | 4.30 | ........ | 12,157 |

[a] Analyses marked with an asterisk (*) are furnished by Illinois Coal Mining Investigations, Cooperative Agreement.
[b] A, Sample as received; B, air-dried sample; C, moisture-free sample.
[c] Top coal not included.
[d] Abandoned mine.

*Mining practice.*—As the coal in this area lies rather deep below the surface it is everywhere mined by shafts, generally by double entry room and pillar, though some mines use the panel system or a modification of it. In general, the younger the mine the more highly developed is the practice of mining.

Nearly half the coal mined in the area is undercut, and less powder is accordingly used in blasting coal than in areas where the methods of mining are less modern.

The width of the entries and rooms depends a great deal on the character of the roof. Where the roof shale is thin or absent and the limestone is used as a roof, the rooms and entries are very wide; in places so wide that sometimes squeezes occur. Few of the mines are surveyed, and hence accurate knowledge of the width of the rooms and pillars is wanting. However, where the roof is good some of the entries are 30 feet or more in width, and some of the rooms more than 50 feet. In a few places the underclay is soft and thick, and flows somewhat readily, but in general it is comparatively resistant. The quantity of coal left as pillars in the mines, according to S. O. Andros, is 45 per cent and the coal recovered 55 per cent. A much larger percentage of the coal might be recovered by robbing the pillars and using a different mining system, as no doubt would be done if the coal in the ground had a greater value. A coal bed a foot thick contains about 1,770 tons to the acre. The Herrin coal therefore averages nearly 11,000 tons to the acre, but under present methods only about 6,000 tons is actually hoisted to the surface.

Where the roof shale is thick some of the top coal is commonly left to support the roof. The coal is less affected by exposure to the air than is the shale and hence makes a safer roof. Where the shale is 4 inches to 2 feet thick it is generally removed. The mines are ventilated by powerful fans at the surface, but the quantity of air required is not so great as in some regions, because explosive gases are not often encountered. Few of the mines are sprinkled for the prevention of explosions of coal dust.

### OTHER COALS.

As described under "Stratigraphy" (p. 5) coal occurs at several horizons above the Herrin or No. 6, but all these coals appear to be too thin for profitable mining. Most of them are also not persistent. Coal No. 7, where present, lies 35 to 50 feet above No. 6 and has been observed in several of the coal shafts. It ranges in thickness from 2 or 3 inches up to 3 feet or more. It appears to be divided into two beds separated by 10 feet of clay. Another coal, perhaps equivalent to No. 8, lies 180 to 200 feet above No. 6, and in the shaft of mine No. 2 at Centralia this coal is reported to be 7 feet thick. The bed was mined for a time before the shaft was sunk to No. 6.

### USES.

Most of the coal from the Carlyle-Centralia district is used for miscellaneous heating and for making steam. For such use this coal is not inherently so valuable as the best coals of the Appalachian field, owing to its relatively high content of oxygen, sulphur, ash, and moisture, but nevertheless it has a high average value, being as good as most of the coal in the eastern interior and western interior basins. It is essentially a noncoking coal, for attempts to produce a good blast-furnace coke from it have not been successful. The fuel-testing plant of the United States Geological Survey at St. Louis made steaming, coking, briquetting, and gas-producer tests of this coal, and the results of these tests have been published.[1] The briquetting and gas-producer tests show that the coal is also well adapted to use in gas producers and for briquetting, and that, with the development of these industries, the demand for the coal should increase.

## OIL AND GAS.[2]

Oil was discovered in paying quantities on the L. Stein farm, 2 miles northeast of Sandoval, in the spring of 1909. Oil had been known in a seep along a fault in the coal mine at Junction City for several years before this and had been used about the mine. Three shallow wells had been drilled not far from the mine in the search for oil, and a showing was found. After they had been shot two of the wells produced about 18 barrels a day each, but within a year the production dwindled to 3 barrels a day, and they were abandoned. Soon after the Stein well was drilled, another well, the Benoist No. 1, about 1,200 feet to the southeast, was sunk through the Stein sand to the Benoist, 140 feet lower. In July, 1909, soon after this well had been drilled, it was blowing off a large quantity of gas and a spray of oil, which covered the ground over a radius of an eighth of a mile from the well.

The Carlyle oil pool was discovered early in April, 1911, when two wells, the Smith No. 1 and Murphy No. 1, reached the pay sand. Two wildcat wells, about 1,000 feet deep, had previously been drilled just south of Carlyle, and one of them found a showing of gas but hardly enough to stimulate prospecting.

Since these pools were found many other wells have been sunk elsewhere in the area and in the surrounding region, in the search for other oil pools, but so far, although the structure in several places is favorable, none have been discovered. Showings of oil have been found, however, particularly at Barcelso and east and northwest of Centralia.

Each of the two productive oil pools yielded a maximum of about 5,000 barrels of oil a day. The individual wells produced at first from 10 to 1,000 or more barrels a day, the average being probably less than 100 barrels. A year after each of the pools had been fairly completely drilled its production had decreased to about 2,000 barrels a day, and since then the production has gradually dwindled.

The three producing sands, the Carlyle, the Stein, and the Benoist, lie respectively about 635, 785, and 930 feet below the Herrin coal. The Carlyle sand probably corresponds to the Cypress sandstone, the Stein sand belongs in the Renault formation, and the Benoist in the lower part of the Renault or perhaps the upper part of the Aux Vases sandstone. In both the producing pools showings of oil and considerable gas have been found in other sands, particularly in the Pottsville. At Carlyle showings of oil have been found 330, 440, and 580 feet below the coal, and in the western part of the pool a strong flow of gas and salt water was encountered in the second of these sands, which belongs in the Pottsville. In the Sandoval pool and near-by territory showings of oil were found in a sand less than 10 feet below coal No. 6, and here and there in other sands in the Pottsville formation. On the whole, gas has been found more frequently than oil in sands other than those that yielded the heavy production.

[1] U. S. Geol. Survey Bulls. 290, 332, 447, and Prof. Paper 48; Bureau of Mines Bulls. 13, 23, 24, and 58.
[2] The Sandoval oil pool has been described by the Geological Survey of Illinois in Bull. 16, 1910; the Carlyle oil pool in Bull. 20, 1915.

Although considerable gas flows from all the wells, almost none of it has been used, except in the work of developing the pools. Experiments to determine the amount of natural-gas gasoline that can be made from the gas show that it evidently carries several gallons to the thousand cubic feet, but no gasoline plants have been erected.

Salt water is found in all the wells, the main body lying just beneath the oil in the same sand, and great care is required in drilling to avoid a large flow of salt water.

The thickness of the productive part of the oil sands averages 10 or 12 feet. As the pore space is 10 or 15 per cent, it has been estimated that the total amount of oil originally in each pool was between 5,000,000 and 20,000,000 barrels. The amount recoverable, however, is considerably less, depending largely upon the movements of the water.

The gravity of the oil is generally a little above 33° Baumé (specific gravity, 0.860); some of it is as high as 37° or 38° (specific gravity, 0.835). The oil is similar to that obtained in the southeastern part of the State and contains much gasoline and illuminating oil.

### CLAY.

The clay resources of the Carlyle-Centralia district are extensive but have been little exploited. The principal sources of clay are the loess and the alluvium, though in some places shale in the Carboniferous system could possibly be worked to advantage in connection with surficial clays. By far the most abundant source of clay is the loess, which immediately underlies the surface almost throughout the district and is everywhere useful for making ordinary clay products. It is especially useful for making pressed brick.

### LIMESTONE.

The only limestones that outcrop in the district are those of the McLeansboro formation, and the purest and most valuable is the Shoal Creek limestone, which outcrops along the west side of the district. This limestone has been quarried at several places along Shoal Creek near the western boundary of the Carlyle quadrangle for making lime and rough building stone. Generally the limestones in the district are either too thin or too impure or the overburden is too great for extensive operation.

### SAND AND GRAVEL.

Sand suitable for plaster and cement occurs in the form of loess in the river alluvium, but not in large commercial quantities. Most abundant supplies of well-washed sand and gravel are contained in the drift ridges in the vicinity of Keyesport.

### SOIL.

Most of the soil of the Carlyle-Centralia district has been derived from the loess. In places it has been derived chiefly from the glacial till, and 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 transported from the inter-stream areas, and as those areas are mantled almost continuously by loess the alluvial soil is largely derived from the loess, but it contains much gravel and sand derived from the till.

The soil of the district consists of a great variety of more or less decomposed minerals. In its formation there seems in most places to have been a leaching of lime, compensated in some places by the addition of lime by lime-secreting plants and animals. The loess soil has the consistency that would be expected of a soil composed of dust particles that have been 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 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 in it, which is controlled in large part by the warm climate and good drainage of the region, though there are no doubt other factors, such as the original content of lime.

### WATER RESOURCES.

*Origin of the water.*—The water in the Carlyle-Centralia district is chiefly that which 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 is drained from the area by Kaskaskia River; a large part if not most of the other three-fourths evaporates before it reaches the streams or percolates far underground, though a small part sinks below the surface and accumulates in the beds of porous rock. 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 may thus be called fossil sea water. The following analysis of a sample collected a few months after the discovery of the Carlyle oil pool shows the character of this water:

*Analysis of water from oil sand in Schlaffly oil well No. 1, Carlyle oil field.*[a]

[Collected by E. W. Shaw, August, 1911; analyzed by R. F. Gardiner.]

Radicles.

| | Grams per liter. | Percentage of anhydrous residue. |
|---|---|---|
| Potassium (K) | Trace. | 0.00 |
| Sodium (Na) | 16.5 | 32.82 |
| Calcium (Ca) | .8 | 1.58 |
| Magnesium (Mg) | 1.6 | 3.16 |
| Chloride (Cl) | 31.2 | 62.05 |
| Sulphate ($SO_4$) | .2 | .39 |
| Bromide (Br) | Trace. | .00 |
| | 50.3 | 100.00 |

Conventional combinations.

| | Grams per liter. | Percentage of anhydrous residue. |
|---|---|---|
| Potassium chloride (KCl) | Trace. | 0.00 |
| Sodium chloride (NaCl) | 41.8 | 83.15 |
| Calcium chloride ($CaCl_2$) | 1.9 | 3.74 |
| Magnesium chloride ($MgCl_2$) | 6.3 | 12.52 |
| Calcium sulphate ($CaSO_4$) | .3 | .59 |
| Magnesium bromide ($MgBr_2$) | Trace. | .00 |
| | 50.03 | 100.00 |

[a] Well in southwest corner of SE. ¼ SE. ¼ sec. 3, T. 2 N., R. 3 W., Clinton County; depth, 1,052 feet; yield, 75 barrels of oil a day.

*Character of the supplies.*—The district has an adequate supply of fairly good water, which is obtained from streams, wells, cisterns, and reservoirs and which is adequate for drinking and for ordinary industrial uses, yet it is commonly difficult to obtain a sufficient quantity of good water for municipal and other uses that require large quantities.

Soft water is most generally obtained in the Carlyle-Centralia district by means of cisterns. Care is necessary in the construction and use of cisterns, however, and the water furnished by them may not be suitable for drinking or cooking, but if proper precautions are taken they furnish the best possible water for use in washing. Methods of treating water to improve its quality have been described elsewhere.[1]

*Records of stream flow.*—Streams furnish the cheapest and most abundant source of water in the Carlyle-Centralia district. The United States Geological Survey, in cooperation with the State of Illinois, has obtained records of stream flow of Kaskaskia River at Carlyle. The gaging station is at the Baltimore & Ohio Southwestern Railroad bridge, about a quarter of a mile east of the railroad station. The record given in the following table extends from March 2, 1908, to December 31, 1912, with the exception of October, 1912.

*Monthly discharge of Kaskaskia River at Carlyle, Ill., from Mar. 2, 1908, to Dec. 31, 1912.*

[Drainage area, 2,680 square miles.]

| Month. | Discharge in second-feet. | | | | Run-off (depth in inches on drainage area). |
|---|---|---|---|---|---|
| | Maximum. | Minimum. | Mean. | Per square mile. | |
| January | 6,720 | 47 | 1,890 | 0.705 | 0.81 |
| February | 6,420 | 280 | 2,100 | .784 | .82 |
| March | 12,500 | 615 | 4,540 | 1.69 | 1.95 |
| April | 12,200 | 394 | 4,330 | 1.62 | 1.81 |
| May | 19,900 | 478 | 4,460 | 1.66 | 1.91 |
| June | 6,270 | 100 | 1,410 | .526 | .59 |
| July | 6,570 | 25 | 1,430 | .534 | .62 |
| August | 2,150 | 25 | 450 | .168 | .19 |
| September | 3,890 | 47 | 659 | .246 | .27 |
| October[a] | 14,500 | 23 | 2,160 | .806 | .93 |
| November | 4,610 | 47 | 969 | .362 | .40 |
| December | 4,330 | 40 | 912 | .340 | .39 |
| The period | 19,900 | 25 | 2,120 | .791 | 10.68 |

[a] No record for October, 1912.

*Sanitary considerations.*—By far the most serious question in regard to the water of any supply is its sanitary quality. Details relating to this subject belong in the field of work ot national and State health organizations, but geologic conditions may have far-reaching effects.

The minerals 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 that produce diseases, notably typhoid fever. Even though water may be badly polluted with human and other excreta, the absence of the germs of typhoid fever or other infectious disease may enable those who drink it to escape ill effects. The fact that water from a given source has not caused disease, however, is no guaranty that it will not do so as soon as polluting matter containing the germs of certain diseases is contributed to it.

Deep wells are generally the safest. Shallow wells are generally open to suspicion, but by proper location and construction they can ordinarily be made safe. Many streams 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 collected from carefully guarded drainage basins and subjected to long storage may be safe, but sterilization is nevertheless widely practiced as an added precaution.

[1] U. S. Geol. Survey Geol. Atlas, New Athens-Okawville folio (No. 218), p. 11, 1921.

Chemical analyses at best furnish little ground for judging the sanitary quality of water. The analyses given below and the statements made in regard to different water supplies do not take into account possible pollution.

*Quality of surface water.*—Stream water in general contains less dissolved mineral matter than most ground water, but for many purposes surface water is less desirable on account of the suspended matter it carries. Much of this suspended matter is so finely divided that it settles very slowly and can not be removed in practice without the use of a coagulant, such as alum or aluminum sulphate. Some surface water is not sufficiently alkaline to make a satisfactory precipitate with the aluminum salt, and soda or lime must then be added to clarify it.

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 composite samples made up of ten consecutive samples taken at each station. Samples were taken from Kaskaskia River at Carlyle and from a reservoir of the Chicago & Eastern Illinois Railroad at Cartter, Marion County. The following table gives the average results of analyses of water from these two points for the year.

*Analyses of surface waters of Clinton and Marion counties, Ill.*[a]

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

| | 1 | 2 |
|---|---|---|
| Turbidity | 184 | 72 |
| Suspended matter | 126 | 33 |
| Silica ($SiO_2$) | 17 | 16 |
| Iron (Fe) | .39 | 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 | 0.0 |
| Bicarbonate radicle ($HCO_3$) | 213 | 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 by author.
1. Kaskaskia River at Carlyle, Ill.
2. Railroad reservoir at Cartter, Ill.

The quantities of the different constituents of the river water indicated in the table above are very near the average of these quantities for all rivers in the State. The river rises far to the north, and its water in this district is therefore a mixture of waters from the northern and southern parts of the State. Smaller streams in the district carry less dissolved mineral matter, and their water resembles rather that from the reservoir at Cartter.

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

*Quality of well and spring water.*—Most of the well and spring water of this area is suitable for domestic use and has no deleterious effects due to dissolved mineral matter, but some of it is so heavily mineralized that its taste is somewhat objectionable, and nearly all of it is hard. For this reason some families use cistern water only. Most of the well and spring water comes from surficial material. Water commonly stands 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 bedrock in places where compact shale forms the uppermost layer of bedrock. A few wells obtain water from sandstones that belong to the Chester, Pottsville, Carbondale, or McLeansboro formations. Fresh water occurs 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 is abundant and satisfactory in the region to the north, contains in this district too much mineral matter for use. The pores of the Carboniferous sandstones are commonly more or less clogged with clay, and perhaps for this reason they yield in many places but little water, all of which carries dissolved mineral matter of somewhat objectionable character. One of the best water-bearing sandstones is in the McLeansboro formation, which lies not far below the surface in the eastern two-thirds of the Carlyle-Centralia district. Some part of this formation generally yields a good supply of water.

November, 1922.

DEPARTMENT OF THE INTERIOR
ALBERT B. FALL, SECRETARY
U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

# TOPOGRAPHY

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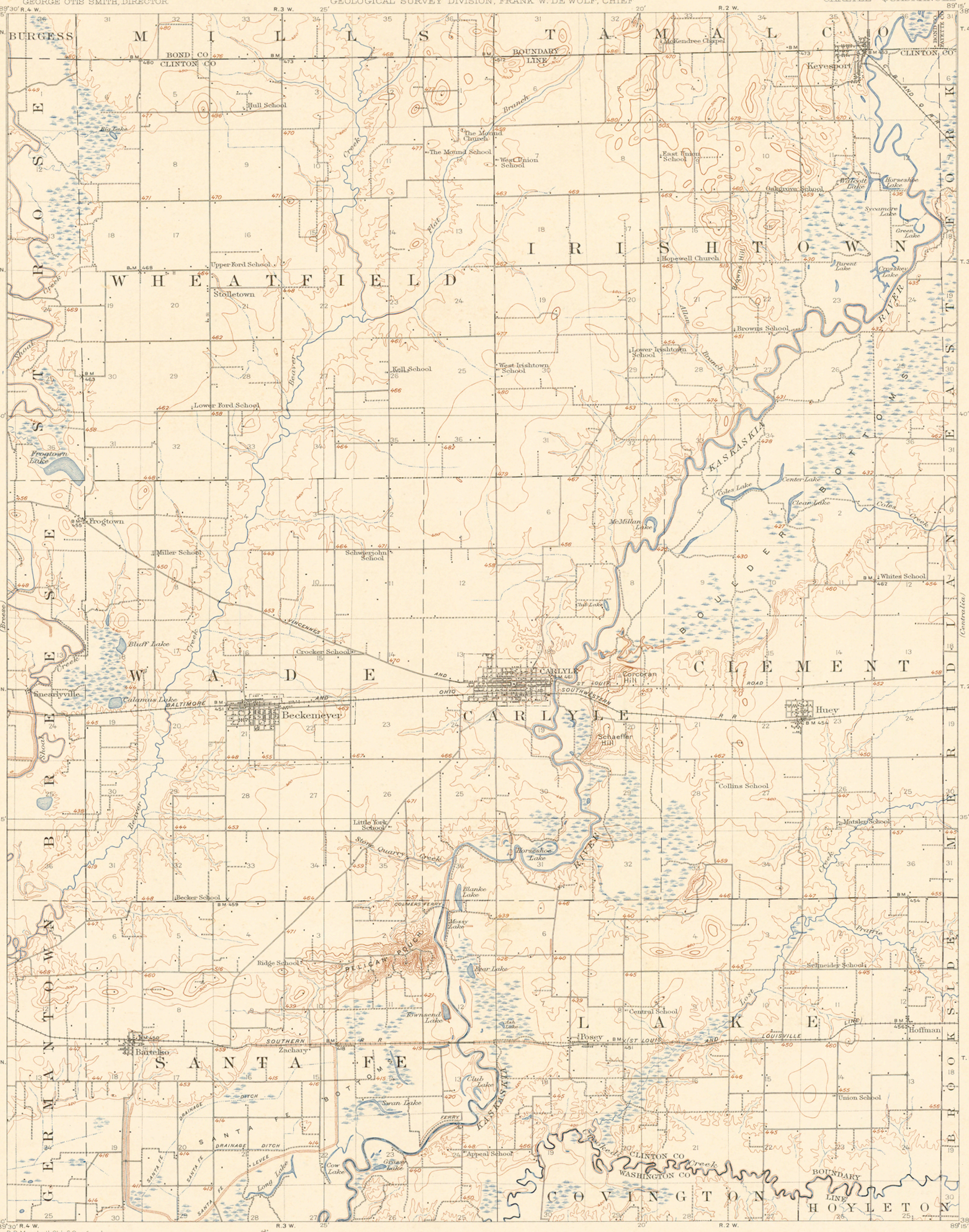
ILLINOIS
CARLYLE QUADRANGLE




## EXPLANATION

**RELIEF**
*printed in brown*

Altitude
*above mean sea level instrumentally determined*

Contours
*showing height above sea, horizontal form, and steepness of slope of the surface*

Depression contour

Levee or railroad fill

**DRAINAGE**
*printed in blue*

Streams

Intermittent streams

Drainage ditch

Lake or pond

Marsh

**CULTURE**
*printed in black*

Roads and buildings

Private or poor roads

Church or schoolhouse and cemetery

Railroad

Bridges

Ferry

U.S. township and section line
*(The symbol for State township line is used where the U.S. and State township lines coincide)*

State township line

County line

City, village, or borough line

Triangulation or primary traverse monument

Bench mark giving precise altitude

R.B. Marshall, Chief Geographer.
W.H. Herron, Geographer in charge.
Topography by A.T. Fowler and E.W. McCrary.
Control by Coast and Geodetic Survey, J.R. Ellis, and W.A. Geibach.
Surveyed in 1908.

SURVEYED IN COOPERATION WITH THE STATE OF ILLINOIS.

APPROXIMATE MEAN DECLINATION 1921.

Scale $\frac{1}{62500}$

Contour interval 20 feet.
*Datum is mean sea level.*

Edition of Sept. 1910, reprinted 1922.

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GEOLOGICAL SURVEY DIVISION, FRANK W. DE WOLF, CHIEF

ILLINOIS
CENTRALIA QUADRANGLE


## EXPLANATION

**RELIEF**
*printed in brown*

Altitude
*above mean sea level instrumentally determined*

Contours
*showing height above sea, horizontal form, and steepness of slope of the surface*

Depression contour

**DRAINAGE**
*printed in blue*

Streams

Intermittent streams

Reservoir, dam, and pond

Springs

Marsh

**CULTURE**
*printed in black*

Roads and buildings

Private or poor road

Church, schoolhouse, and cemetery

Railroad

Bridge

U.S. township and section line
*(The symbol for State township line is used where the U.S. and State township lines coincide)*

State township line

County line

City, village, or borough line

Triangulation or primary traverse monument

Bench mark
*giving precise altitude, brown cross, temporary bench mark*

R. B. Marshall, Chief Geographer.
W. H. Herron, Geographer in charge.
Topography by C. W. Goodlove, E. W. McCrary, and R. M. Herrington.
Control by Coast and Geodetic Survey, J. R. Ellis, P. W. McMillen, and R. G. Clinite.
Surveyed in 1908 and 1912.
SURVEYED IN COOPERATION WITH THE STATE OF ILLINOIS.

APPROXIMATE MEAN DECLINATION 1912

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 0 1 2 3 4 5 Kilometers

Contour interval 10 feet.
*Datum is mean sea level.*

Edition of April 1914, reprinted 1922.

# AREAL GEOLOGY

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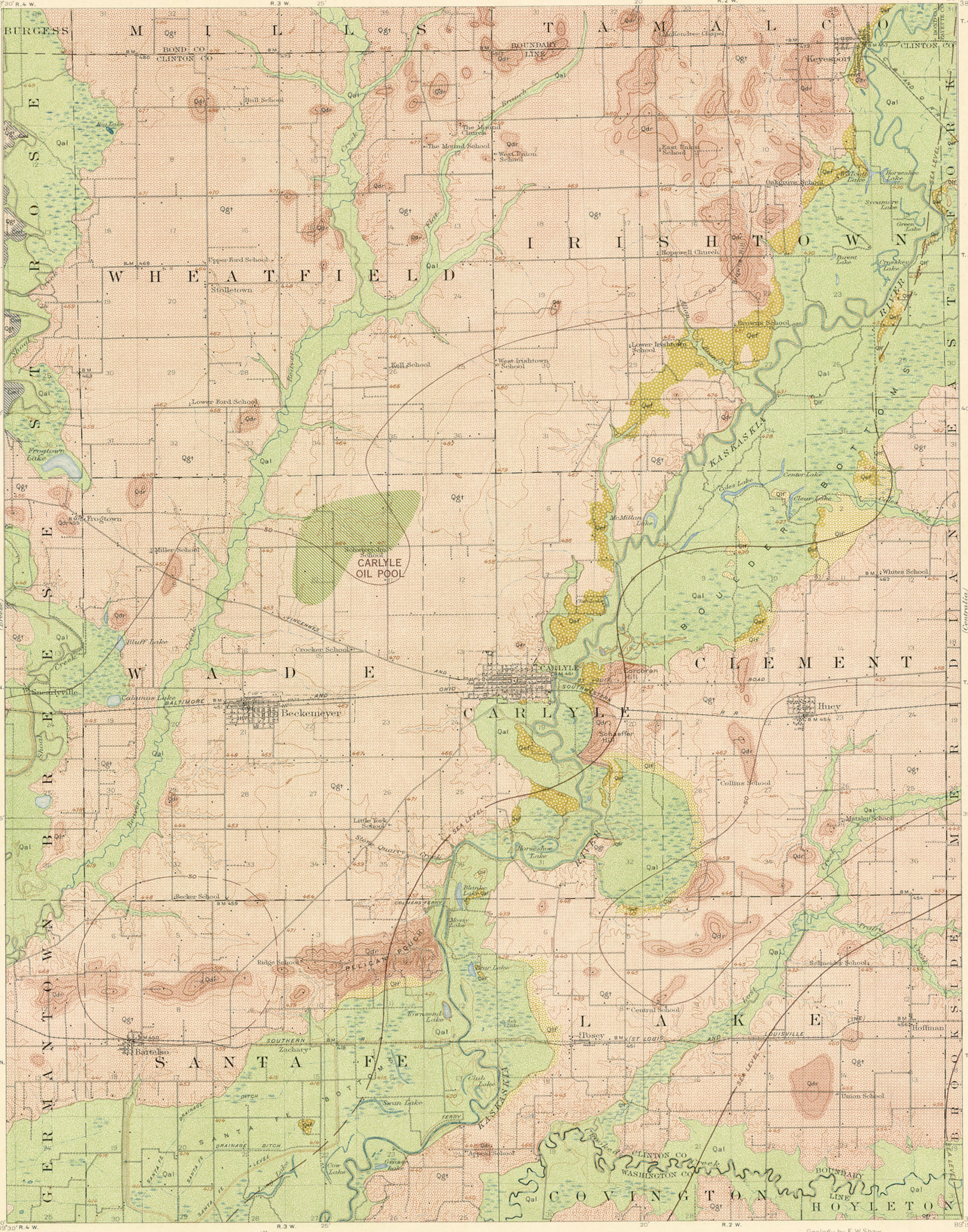
ILLINOIS
CARLYLE QUADRANGLE




## 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; mainly silt and sand, including marsh deposits on broader valley bottoms)*

Pleistocene — Wisconsin stage

- Qlf — **Later valley filling** *(valley filling mainly of clay and silt; altitude of terrace surface 420 to 430 feet)*

Pleistocene — Pre-Iowan?

- Qef — **Earlier valley filling** *(valley filling mainly of clay and silt; altitude of terrace surface 440 to 450 feet)*

Pleistocene — Illinoian stage

- Qgt — **Glacial till** *(mantled by loess of probable Peorian age; underlain by McLeansboro formation)*
- Qdr — **Drift ridges, possibly morainal** *(pebbly clay, sand, and gravel, in places mantled by loess of probable Peorian age)*

UNCONFORMITY

CARBONIFEROUS

Pennsylvanian

- Cml — **McLeansboro formation** *(soft shale and sandstone with some limestone and thin beds of coal; underlies the whole area but is concealed in most places by glacial drift)*

### ECONOMIC AND STRUCTURE DATA

- 50 — SEA LEVEL — *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)*
- *Oil pool*
- ⚒ *Coal mines*

R. B. Marshall, Chief Geographer.
W. H. Herron, Geographer in charge.
Topography by A. T. Fowler and E. W. McCrary.
Control by Coast and Geodetic Survey, 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, 1921

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 Sept. 1922.

Geology by E. W. Shaw.
Surveyed in 1911.
Structure by E. W. Shaw and Stuart St. Clair.

SURVEYED IN COOPERATION WITH THE STATE OF ILLINOIS.

# AREAL GEOLOGY

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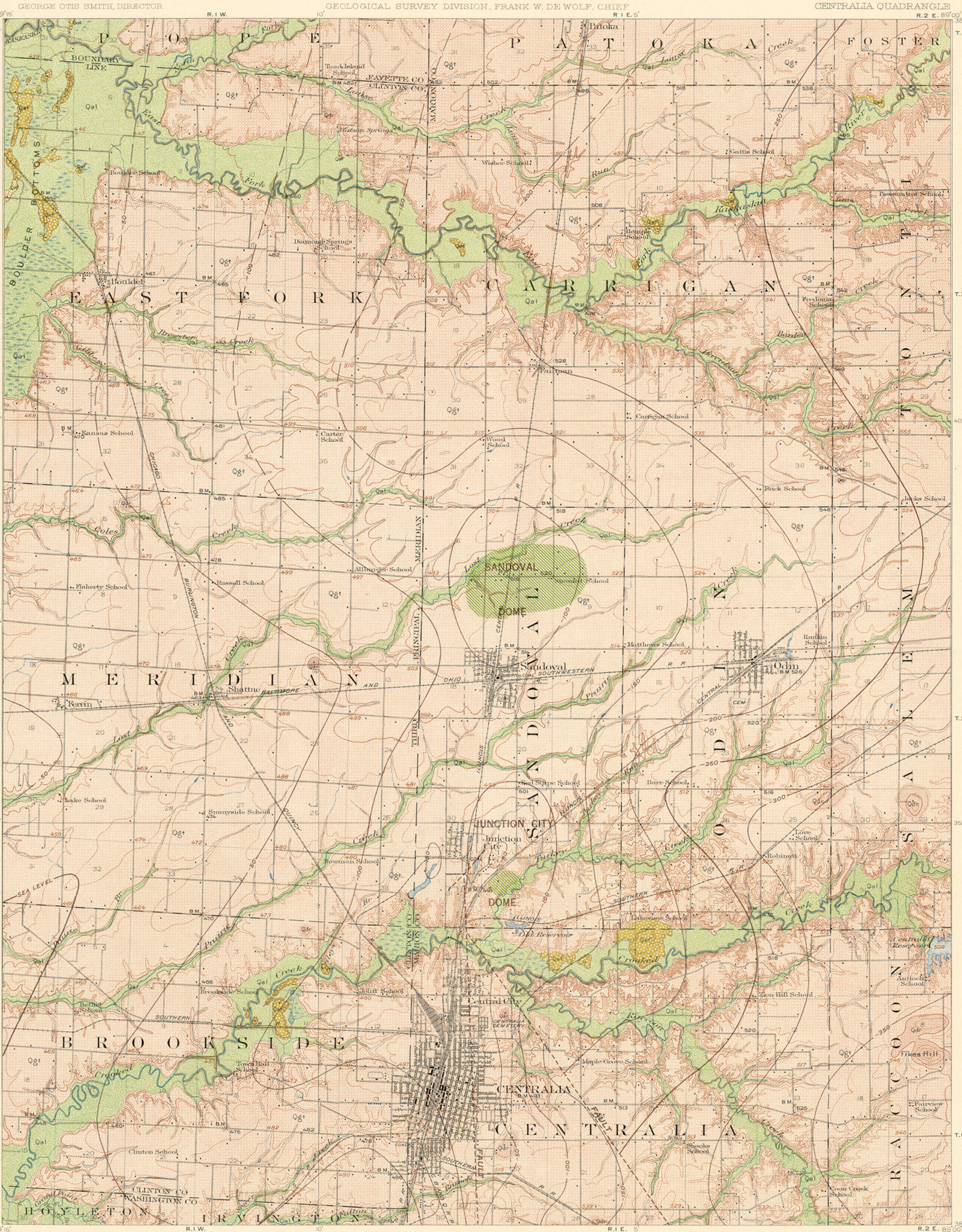
ILLINOIS
CENTRALIA QUADRANGLE




## 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; mainly silt and sand, including marsh deposits on broader valley bottoms)*

Pleistocene — Wisconsin stage
- Qlf — Later valley filling *(valley filling mainly of clay and silt; altitude of terrace surface 420 to 430 feet)*

Pleistocene — Pre-Iowan?
- Qef — Earlier valley filling *(valley filling mainly of clay and silt; altitude of terrace surface 440 to 450 feet)*

Pleistocene — Illinoian stage
- Qgt — Glacial till *(mantled by loess of probable Peorian age; underlain by McLeansboro formation)*
- Qdr — Drift ridges, possibly morainal *(pebbly clay, sand, and gravel, in places mantled by loess of probable Peorian age)*

UNCONFORMITY

CARBONIFEROUS

Pennsylvanian
- Concealed by glacial drift — McLeansboro formation *(soft shale and sandstone with some limestone and thin beds of coal; underlies the whole area but is concealed everywhere by glacial drift)*

### 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)*
- Oil pools
- ✕ Coal mines

R.B. Marshall, Chief Geographer.
W.H. Herron, Geographer in charge.
Topography by C.W. Goodlove, E.W. McCrary, and R.M. Herrington.
Control by Coast and Geodetic Survey, J.R. Ellis, P.W. McMillen, and R.G. Clinite.
Surveyed in 1908 and 1912.
SURVEYED IN COOPERATION WITH THE STATE OF ILLINOIS.

TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1921.

Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 10 feet.
*Datum is mean sea level.*
Edition of Sept. 1922.

Geology by E.W. Shaw.
Surveyed in 1912.
Structure by E.W. Shaw and Stuart St. Clair.
SURVEYED IN COOPERATION WITH THE STATE OF ILLINOIS.

## 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 | | Ћ | Peacock-blue. |
| Paleozoic | Carboniferous | Permian; Pennsylvanian; Mississippian | C | Blue. |
| | Devonian | | D | Blue-gray. |
| | Silurian | | S | Blue-purple. |
| | Ordovician | | O | Red-purple. |
| | Cambrian | | Є | 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.

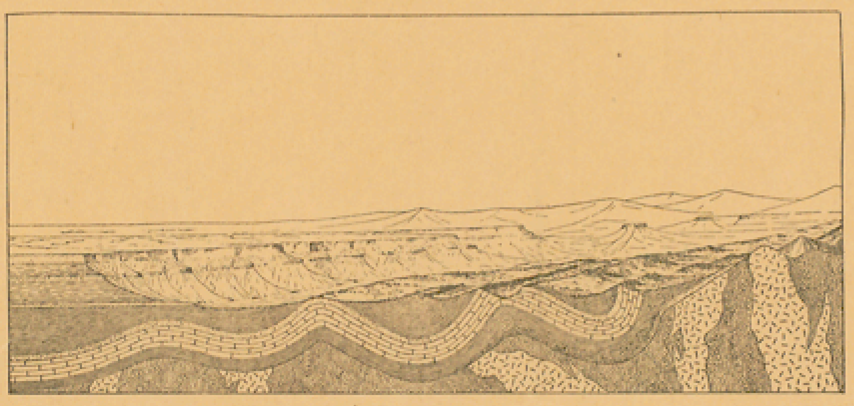


FIGURE 2.—Sketch showing a vertical section below the surface at the front and a view beyond.

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.

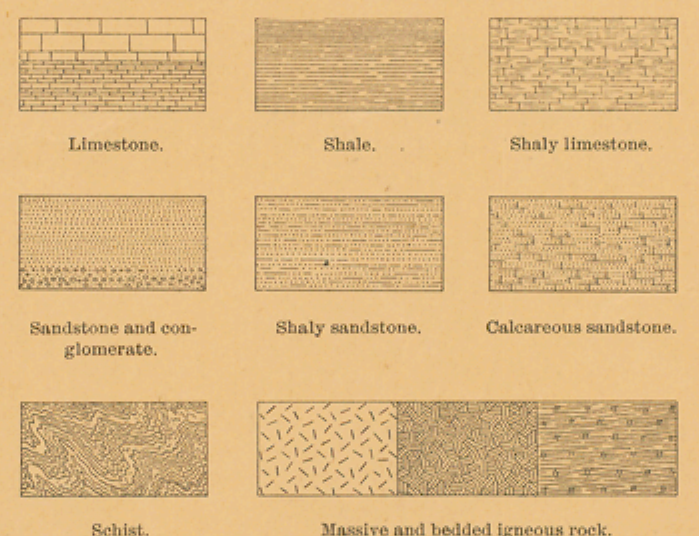



FIGURE 3.—Symbols used in sections to represent different kinds of rock.

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.

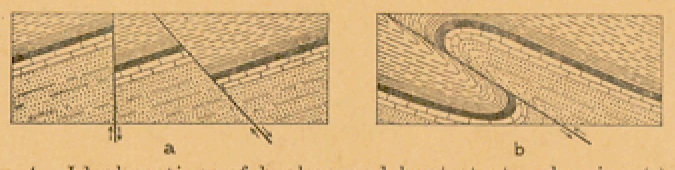



FIGURE 4.—Ideal sections of broken and bent strata, showing (a) *normal* faults and (b) a *thrust* or *reverse* fault.

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.

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● 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.