DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS

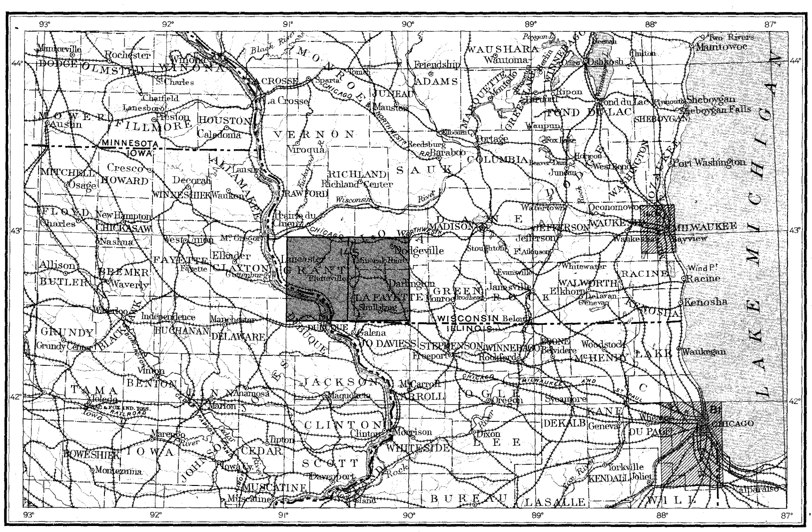
OF THE

UNITED STATES

LANCASTER-MINERAL POINT FOLIO

WISCONSIN-IOWA-ILLINOIS

INDEX MAP



SCALE: 40 MILES=1 INCH

LANCASTER-MINERAL POINT FOLIO

OTHER PUBLISHED FOLIOS

CONTENTS

DESCRIPTIVE TEXT

AREAL GEOLOGY MAPS

TOPOGRAPHIC MAPS

WASHINGTON, D. C.

ENGRAVED AND PRINTED BY THE U. S. GEOLOGICAL SURVEY

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

1907

GEOLOGIC AND TOPOGRAPHIC ATLAS OF UNITED STATES.

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

THE TOPOGRAPHIC MAP.

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

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

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

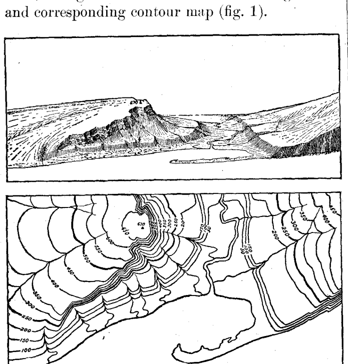


FIG. 1.—Ideal view and corresponding contour map.

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

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

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

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

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

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

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

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

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

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

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

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

THE GEOLOGIC MAPS.

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

KINDS OF ROCKS.

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

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

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

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

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

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

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

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

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

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

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

FORMATIONS.

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

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

AGES OF ROCKS.

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

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

(Continued on third page of cover.)

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

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

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

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

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

Symbols and colors assigned to the rock systems.

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

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

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

SURFACE FORMS.

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

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

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

THE VARIOUS GEOLOGIC SHEETS.

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

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

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

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

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

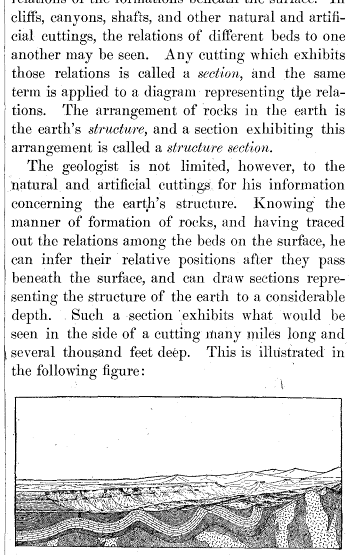


Fig. 2.—Sketch showing a vertical section at the front and a landscape beyond.

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

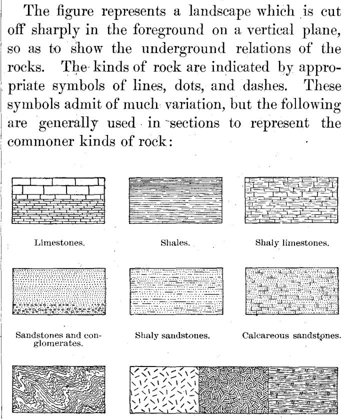


Fig. 3.—Symbols used in sections to represent different kinds of rocks.

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

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

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

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

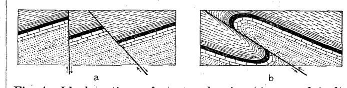


Fig. 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* fault.

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

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

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

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

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

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

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

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

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

CHARLES D. WALCOTT,

Director.

Revised January, 1904.

DESCRIPTION OF THE LANCASTER AND MINERAL POINT QUADRANGLES.

By Ulysses S. Grant and Ernest F. Burchard.

INTRODUCTION.

LOCATION AND AREA OF THE QUADRANGLES.

The Lancaster and Mineral Point quadrangles are located between longitude 90° and 91° west and latitude 42° 30′ and 43° north, and cover one-half of a square degree. Each quadrangle has an average width of about $25\frac{1}{2}$ miles and a length of nearly 35 miles, and together they have an area of approximately 1756 square miles. The quadrangles are in the southwest corner of Wisconsin and in northeastern Iowa, and part of the southern border of each extends less than half a mile into Illinois. They comprise parts of Lafayette, Iowa, and Grant counties, Wis.; parts of Dubuque and Clayton counties, Iowa; and a small part of Jo Daviess County, Ill.

GENERAL FEATURES.

The district was settled early in the history of the Mississippi Valley and is part of a rich agricultural region. Its chief farm products are hay, corn, oats, cattle, butter, and cheese. There are manufacturing establishments at a number of places, and at the town of Mineral Point large quantities of sulphuric acid and zinc oxide are produced.

The district is in the heart of the upper Mississippi Valley lead and zinc region and has long been known as a producer of lead and zinc ores. For a series of years its production of these ores decreased, but within the last four or five years its production of zinc ore has increased markedly. This increase is due to the mining of bodies of zinc sulphide which are found beneath the level of ground water, below which little of the early mining extended. The prospects are that this mining industry will be more extensively developed and that the district, which for nearly a century has been a producer of lead, and in later years a producer of zinc also, will continue for some time to be an important source of the ores of both metals, especially zinc.

Dubuque, Iowa, a city of about 40,000 inhabitants, situated on Mississippi River at the extreme southern edge of the Lancaster quadrangle, is the largest and most important city in the area. Other important towns, all in Wisconsin, are Dodgeville, Darlington, Fennimore, Lancaster, Mineral Point, Platteville, and Shullsburg. The district is reached by five railroads—the Illinois Central, the Chicago Great Western, the Chicago, Milwaukee and St. Paul, the Chicago, Burlington and Quincy, and the Chicago and Northwestern.

OUTLINE OF THE GEOGRAPHY AND GEOLOGY OF THE REGION.

The parts of southwestern Wisconsin and northeastern Iowa that are included between the latitude of the Illinois boundary on the south and Wisconsin River on the north, and that extend from the confluence of Mississippi and Wisconsin rivers eastward nearly to the longitude of Madison, comprise an elevated district from which streams flow out in all directions, although most of them run southward. Nearly all of this part of the Mississippi Valley is included in the "Driftless Area"—a district comprising about 10,000 square miles, mostly in southwestern Wisconsin, but embracing also adjacent portions of Minnesota, Iowa, and Illinois. This area was not covered by the great continental ice sheet but was entirely surrounded by it, and the surface features here therefore present a marked contrast to those of the surrounding drift-covered districts. Outside of this area—that is, in the region of the drift—the bed rock is covered to a varying thickness by glacial drift, composed in some places of a stratified and in others of an unstratified mixture of clay, rock flour, sand, gravel, and bowlders. The bed rock beneath this drift is commonly scratched, smoothed, or polished, and there is a sharp line of demarcation between the rock and the overlying unconsolidated material. The surface of the ground is here rough and hilly, there undulatory, elsewhere smooth; there is a lack of system in the arrangement of the topographic features, and the streams wander about, in places in an apparently aimless way. Moreover, none but the larger streams have well-defined valleys, and swamps and lakes are common. The surface is topographically young, at least in its minor features.

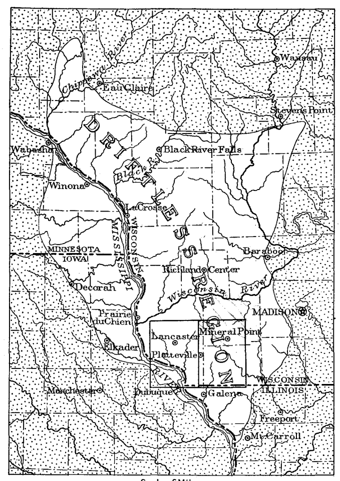


FIG. 1.—Diagram showing relation of Lancaster-Mineral Point area to Driftless Region.

Within the Driftless Area, on the other hand, the bed rock is overlain by unconsolidated material that is derived directly from this rock by decay. The underlying rock is not scratched or smoothed and is not sharply separated from the unconsolidated material above. The topographic features are systemized, and even the smaller streams have well-defined valleys and locally straight courses. There are no swamps and no lakes, except along river bottoms. The surface is topographically mature. The Mineral Point quadrangle lies wholly within the Driftless Area, and there is but a thin fringe of drift in the southwest corner of the Lancaster quadrangle, along its boundary, and only a few scattered and fragmentary outliers of drift between this fringe and Mississippi River.

The geologic structure of this district is simple. The area is underlain by early Paleozoic sedimentary rocks—sandstone, limestone, and shale—ranging in age from Cambrian to Silurian. The strata dip very gently south-southwest, descending a little more steeply than do the main southward-flowing streams, so that, in general, the younger rocks are found in the southern part of the area and the older rocks in the northern part. Locally the rocks have been thrown into slight folds, whose axes generally trend east and west, and whose southern limbs are long and gentle, while their northern limbs are shorter and steeper. The material to form these rocks was derived from the older highlands, composed of pre-Cambrian rocks, which lie farther north and northeast, in central and northern Wisconsin. In early Paleozoic time this highland district was a land area, while the sea lay over southwestern Wisconsin. During this time, however, there were some changes in the relation of sea and land, the shore at one period lying farther south and at another farther north. Still, the rocks deposited in this region may be considered broadly as the product of one period of sedimentation, which began in the Cambrian and extended at least into the Silurian period. There is no certain evidence that the district has been below sea level since the deposition of the Niagara (Silurian) limestone, and erosion has been marked only in comparatively recent geologic times—Tertiary and later. If the district was above sea level in later Paleozoic and Mesozoic times it was probably a low-lying area, in which erosion was relatively inactive.

EARLIER PUBLICATIONS ON THE DISTRICT.

As the Mineral Point and Lancaster quadrangles constitute an important part of the upper Mississippi Valley lead and zinc district, their general features, geology, and ore deposits have been described rather fully. The most complete account yet published is by T. C. Chamberlin (Geol. Wisconsin, vol. 4, 1882, pp. 365–571). Some other reports on this district are as follows:

Whitney, J. D., Report on the lead region of Wisconsin: Geol. Survey Wisconsin, vol. 1, 1862, pp. 73–420.

Whitney, J. D., Geology of lead region: Geol. Survey Illinois, vol. 1, 1866, pp. 153–207. Republished in Economical Geology of Illinois, vol. 1, 1882, pp. 118–162.

Shaw, James, Geology of northwestern Illinois: Geol. Survey Illinois, vol. 5, 1873, pp. 1–24. Republished in Economical Geology of Illinois, vol 3, 1882, pp. 1–20.

Shaw, James, Geology of Jo Daviess County: Geol. Survey Illinois, vol. 5, 1873, pp. 25–56. Republished in Economical Geology of Illinois, vol. 3, 1882, pp. 20–54.

Strong, Moses, Geology and topography of the lead region: Geol. Wisconsin, vol. 2, 1877, pp. 643–752.

Strong, Moses, Lead and zinc ores: Geol. Wisconsin, vol. 1, 1883, pp. 637–655.

Chamberlin, T. C., and Salisbury, R. D., Preliminary paper on the Driftless Area of the upper Mississippi Valley: Sixth Ann. Rept. U. S. Geol. Survey, 1885, pp. 199–322.

Jenney, W. P., Lead and zinc deposits of the Mississippi Valley: Trans. Am. Inst. Min. Eng., vol. 22, 1894, pp. 171–225, 642–646; especially pp. 208–212.

Hershey, O. H., Physiographic development of the Mississippi Valley: Am. Geologist, vol. 20, 1897, pp. 246–268.

Leonard, A. G., Lead and zinc deposits of Iowa: Iowa Geol. Survey, vol. 6, 1897, pp. 9–66.

Calvin, Samuel, and Bain, H. F., Geology of Dubuque County: Iowa Geol. Survey, vol. 10, 1900, pp. 379–622; especially pp. 480–597.

Bain, H. F., Preliminary report on the lead and zinc deposits of the Ozark region, with an introduction by C. R. Van Hise and chapters on the physiography and geology by G. I. Adams: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 2, 1902, pp. 23–227; especially the introduction, pp. 33–49.

Grant, U. S., Preliminary report on the lead and zinc deposits of southwestern Wisconsin: Bull. Wisconsin Geol. and Nat. Hist. Survey No. 9, 1903, 103 pp.

Bain, H. F., Zinc and lead deposits of northwestern Illinois: Bull. U. S. Geol. Survey No. 246, 1905, 56 pp.

Grant, U. S., Report on the lead and zinc deposits of Wisconsin, with an atlas of detailed maps: Bull. Wisconsin Geol. and Nat. Hist. Survey No. 14, 1906, 100 pp., 18 atlas sheets.

Grant, U. S., Structural relations of the Wisconsin lead and zinc deposits: Economic Geology, vol. 1, 1906, pp. 233–242.

Bain, H. F., Zinc and lead deposits of the upper Mississippi Valley: Bull. U. S. Geol Survey No. 294, 1906, 155 pp.

Bulletin No. 14 of the Wisconsin Survey, cited above, contains a nearly complete bibliography of the lead and zinc deposits of the Wisconsin district.

ACKNOWLEDGMENTS.

The senior author is, in the main, responsible for the matter in this folio that relates to the Mineral Point quadrangle and to the ore deposits. The junior author is responsible for those parts that deal especially with the Lancaster quadrangle. In the study of the area the authors were associated with Mr. H. Foster Bain. Mr. E. O. Ulrich has identified the fossils and has aided in solving questions of structure and correlation. In this investigation there was informal cooperation with the Wisconsin Geological and Natural History Survey, which mapped in detail certain important ore-bearing areas. Some of the results of this detailed work are incorporated in this folio. No attempt is made to give references to sources of information on definite points. The authors are indebted to several persons and publications, but especially to Prof. T. C. Chamberlin, whose thorough work on the general geology and ore deposits of the district is well known, and whose main conclusions the present investigation has abundantly confirmed.

TOPOGRAPHY OF THE QUADRANGLES.

RELIEF.

The surface of the eastern half of the area is notably flat. Viewed from almost any stream divide it appears to be a broad, upland plain (here called the Lancaster peneplain) of monotonously even sky line. On closer examination, however, the plain is seen to be trenched by numerous wide, open valleys. Toward the west the extremes of relief become greater and the declivities steeper. In the western part of the area the plain is represented by ridges and by flat interstream areas of limited extent. The broad, flat-bottomed gorge of Mississippi River, which is cut through the southwest portion of the area, constitutes, with its precipitous rock walls, the dominating topographic feature of the region. A few mounds rise above the plain on both sides of Mississippi River, while southwest of the river, in Iowa, a solid front of hills and ragged promontories—the Niagara escarpment—marks the outer boundary of a still higher table-land.

THE MOUNDS.

The most marked elevations in the quadrangles are ten hills, which stand singly or in groups in widely separated portions of the area. Three of these hills, which lie in an east-west line about 4 miles northeast of Platteville, are known as the Platte Mounds. The central one of these is the smallest and is conical in form. The others are flat-topped and rise about 300 feet above the surrounding plain. These mounds, as well as all the others mentioned below, are capped by layers of Niagara limestone, which are rendered especially resistant to erosion by the large amounts of chert which they contain. The upper slopes of the Platte Mounds are steep and in places are almost bare of vegetation, while their lower slopes, composed of the soft Maquoketa shale, are gentle and grade off insensibly into the level of the upland plain. The westernmost of the Platte Mounds rises 1430 feet above sea level, and the easternmost almost 1400 feet, but the central mound is 100 feet lower. The western mound is the highest point in the two quadrangles; and the lowest point, where Mississippi River leaves the Lancaster quadrangle at its southern border, is below 600 feet. Thus the range of elevation in the quadrangles is about 830 feet.

Sinsinawa Mound, about 5 miles west of Hazel Green, is a prominent, isolated, conical hill, 1160 feet above sea level at its summit. It stands nearly 300 feet above the immediately surrounding surface and its preservation is due to the same lithologic causes that have produced the Platte Mounds.

Sherrill Mound and an unnamed mound of similar extent, together with two smaller intermediate knobs, lie in a northwest-southeast line in Jefferson Township, 10 to 12 miles northwest of Dubuque. These mounds are outliers that have been but recently detached from the Niagara escarpment or from the ends of the digitate ridges that project like rocky headlands from the high table-land to the southwest. The tops and the steep upper slopes of most of these mounds and the escarpment are heavily wooded, while the gentler slopes below are cleared and cultivated.

Two other mounds, not so prominent, lie south of Shullsburg, and still farther south, in Illinois and Iowa (outside the quadrangles), there are many others. About 8 miles east-northeast of the northeast corner of the Mineral Point quadrangle is Blue

Mound, the top of which—the highest point in this part of Wisconsin—stands approximately 1700 feet above sea level.

All these mounds are, possibly, remnants of a structural plain that was developed on the Niagara limestone, and clearly illustrate the extent to which the limestone has been removed from the surface by erosion.

NIAGARA ESCARPMENT.

The Niagara escarpment, a northeastward-facing scarp of wide extent, is present only in that portion of the area that lies southwest of the Mississippi. Its outline is very irregular, for it has been deeply serrated by the erosive action of the Mississippi and the Little Maquoketa and its branches. It consists of steep slopes, most of them timbered, and occasional small dolomite cliffs and buttresses, or detached blocks, the whole aggregating from 60 to 150 feet in height.

The upper plateau or table-land, west of the Niagara escarpment, occupies a relatively small proportion of the area under discussion. Its extent practically coincides with the continuous area of Niagara limestone and may be readily ascertained by reference to the geologic map of the Lancaster quadrangle. The elevation of this portion of the plateau is approximately 1200 feet, but beyond this quadrangle it slopes perceptibly to the south-southwest. Toward the northeast the former plain apparently rose much higher, as is shown by the progressive increase in elevation, for instance, from Sherrill Mound through Platte Mounds to Blue Mound. This plain does not so completely bevel across underlying formations as does the one next lower. There is a greater difference between their respective elevations at the extreme northeast corner of this area than at the southwest corner, or, in other words, the plains are not parallel to each other. The facts observed within these two quadrangles are not sufficient to determine whether this upper plain—that is, the one lying above the Niagara escarpment—is a peneplain or a structural plain, and its general history outside of these two quadrangles has not yet been completely worked out, though its age is probably Cretaceous.

LANCASTER PENEPLAIN.

From Military Ridge, the divide on which the Chicago and Northwestern Railway runs between Dodgeville and Montfort, and also from points along that railway between Montfort and Cuba, or from the town of Lancaster, a comprehensive view can be had of the broad upland that is here called the Lancaster peneplain. The even horizon is broken only by the mounds and the Niagara escarpment, already mentioned, or by other similar elevations in adjoining portions of Illinois and Iowa. The highest portions of this plain in the area here described are near Dodgeville, in the northeastern portion of the Mineral Point quadrangle, where the general upland surface is over 1200 feet above sea level. From this area it slopes gently southward and, to a much less extent, westward. South of Gratiot the general elevation is somewhat more than 1000 feet above sea level; near Fennimore it is above 1200 feet; in the northwest corner of the area, near Patch Grove, it is over 1100 feet; at Lancaster, from which the name of the plain is derived, and where it is typically developed, it stands at an altitude of about 1100 feet; south of Hazel Green it is at about 950 feet; while the lowest surface of the plain, near Asbury, Iowa, is somewhat less than 900 feet.

The surface of the plain lies mainly in the thick dolomitic formation known as the Galena, but toward the southern border of the quadrangles it lies in the lower portion of the soft Maquoketa shale. In other words, the plain, sloping more gently to the south than do the underlying formations, cuts across the edges of these formations. In the region farther south, outside the quadrangles, near Galena, Ill., the plain lies well up in the Maquoketa shale. In the area north of the quadrangles, beyond Wisconsin River, the same plain lies in the Prairie du Chien formation, and still farther north it passes into the Cambrian sandstone. This upland plain, then, is not parallel with any particular geologic horizon, but cuts across different formations; it is of the nature of a *peneplain*—a plainlike surface produced by subaerial erosion. It dates probably from Tertiary time.

VALLEYS.

The Lancaster peneplain has been cleft by Mississippi River and extensively dissected by tributary streams which have, near their headwaters, rather wide, open valleys and in their lower portions canyonlike phases and well-developed but narrow flood plains. In fact, this dissection has gone so far that the original plain surface now commonly remains only along the stream divides. The main valley bottoms in the east half of the area lie 200 to 300 feet below the general level of the peneplain, but the Mississippi water level lies 300 to 600 feet below it, and consequently the streams joining the master stream within the area have excavated the lower reaches of their valleys to a corresponding depth. On the smaller streams the valley sides have rather gentle slopes, except where the streams are now, or recently have been, actively encroaching on the sides of the valleys; and well-developed flood plains are common, even along intermittent streams.

The district, aside from the Mississippi River trough and the territory immediately adjacent, where the erosion forms are relatively youthful, may be called topographically mature, or may even be regarded as passing from maturity toward old age. It has been calculated that the cubic contents of the valleys equal approximately the cubic contents of the ridges between the valleys. If the valleys lie approximately 300 feet below the general upland level, this will mean that material equal in bulk to a layer 150 feet thick over the whole district has been removed by stream erosion since the peneplain was formed.

The Mississippi flows in a steep-walled gorge bordered by rock faces 60 to 90 feet high, above which abrupt slopes rise to a height of 150 to 200 feet above the river. From the border of this inner gorge rise gentler slopes that ascend 100 to 150 feet higher, to the general level of the Lancaster peneplain. These gentler slopes constitute the sides of what has been termed the "Basin" valley. The width of the inner valley or gorge, averaging $1\frac{1}{2}$ miles, is slightly greater at Cassville, where it enters the area, than where it leaves it at Dubuque. Below Dubuque this valley maintains an even width of $1\frac{1}{4}$ miles for about 12 miles beyond the border of the area. Above Cassville it widens, except for a slight local constriction below the mouth of Wisconsin River, until it reaches a width of $3\frac{3}{4}$ miles at New Albin, Iowa, more than 60 miles distant. This somewhat anomalous widening of a river valley upstream

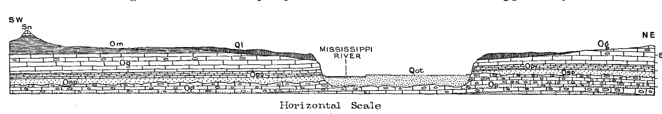


FIG. 2.—Sketch section northeast on ridge from Sherrill Mound to ridge a mile east of Potosi.

Shows deeply eroded Mississippi gorge and preglacial bed-rock surface of upland bordering the river, covered by the overlapping deposit of loess. Op, Prairie du Chien formation; Osp, St. Peter sandstone; Opv, Platteville limestone; Og, Galena limestone; Om, Maquoketa shale; Sn, Niagara limestone; Ql, loess; Qot, outwash terrace deposits and alluvium.

may be plainly seen by assembling the Waukon, Elkader, Lancaster, and Peosta topographic sheets, prepared by the United States Geological Survey. It suggests that in preglacial time the valley may have been occupied by a northward-flowing stream.

The Mississippi Valley has a flat bottom, lying but 8 or 10 feet above low-water level except where terraces occur, and it is commonly overflowed throughout its full width by spring floods. The river channel, one-fourth to one-half mile wide, swings back and forth across the bottom land, under the influence of the bends in the gorge, besides branching into many minor channels and sloughs. By the formation of "cut-offs," or by the silting up of portions of the minor channels, the countless little islands and lakes that dot the flood plain have been formed. At one time Grant River flowed along the east side of the Mississippi flood plain for 7 miles below the point where it now emerges into the valley and joined the Mississippi only after uniting with the Platte. Direct communication has now been established between the Grant and the Mississippi by means of a canal opposite Spechts Ferry.

That the river gorge has been excavated to a depth of 100 to 150 feet below its present bed is shown by borings. At Dubuque a well showed loose material to a depth of 132 feet below low-water mark in the Mississippi, and at Prairie du Chien the rock bottom was found 112 feet below low-water mark. Observations at La Crosse and Lake Pepin also indicate corresponding depths. Near the inner edge of Peru Bottoms a well penetrates 143 feet of sand containing a small pocket of gravel, reaching limestone at a depth of 80 feet below low-water mark.

The rock faces displayed along the walls of the gorge are the truncated ends of what were once graceful promontories that extended out to the main stream between its numerous tributaries and short-stream gullies. Normally the base of these bluffs is hidden by heavy talus, but the railroads on both sides of the gorge have cleared the lower part of this away at some places to such an extent as to afford continuous exposures of the strata from the bottom to the top of the bluffs.

The canyons of the streams in the southern portion of the area, near the Mississippi, are particularly striking, especially those of the Little Maquoketa and its tributaries, whose canyons are excavated practically their whole depth in the Galena limestone. Prominent crags and isolated towers and "chimneys" of this cliff-forming rock are conspicuous features of North Fork of Little Maquoketa River and of the small branch just west of Durango, although similar cliffs and crags are not rare along the bluffs of the Mississippi and other streams in the area.

Besides a terrace which is peculiar to the northern portion of the district, and which is discussed below under the heading "Prairie du Chien formation," there is in places along the Mississippi and in the adjacent valleys of its tributary streams a well-defined terrace composed of silt, sand, and gravel. On the Mississippi the Peru Bottoms, west of the Chicago, Milwaukee, and St. Paul Railway, comprise an extensive remnant of this terrace that lies more than 60 feet above the river. Another remnant, below the mouth of Sinnipee Creek, lies 40 feet above the river, and portions of the cities of Dubuque and Cassville are built on similar remnants of this terrace. This terrace has been observed above Burton, in the valley of Grant River. A remnant extends back three-fourths of a mile from the mouth of the hollow below Potosi. The small stream that occupies this hollow has cut its bed down through the unconsolidated deposit without much lateral corrasion, and the terrace is consequently a noticeable feature. Remnants of the terrace have been observed in the valleys of the Platte and Little Platte at distances exceeding 5 miles from the Mississippi. Beyond the southern border of the quadrangles, along Fever River, this terrace is present, and at Galena, Ill., its position is marked by Grant Park.

DRAINAGE.

As has been stated above, the upland district is thoroughly dissected and its drainge is complete. Lakes occur only on the Mississippi flood plain, and there are no swamps except locally along stream bottoms. Most of the streams of the district flow southward. North of Military Ridge, which runs east and west about 3 miles south of the north edges of the quadrangles, there are some short streams which descend rapidly northward to Wisconsin River. The streams south of this ridge have a much gentler slope and flow eventually into the Mississippi, the controlling stream. The other important streams are the Grant, the Platte, the Little Platte, the Fever, and the Little Maquoketa, which empty into the Mississippi, and the Pecatonica, a branch of Rock River. All these smaller streams except the Little Maquoketa rise within the quadrangles, and within the Driftless Area. The streams that flow northward into Wisconsin River are rapidly eating their way headward and thus tending to shift the divide between the northward-flowing and the southward-flowing streams farther to the south. In the area northeast of Dodgeville the divide has already been cut into by the encroachment of streams from each side, and this may eventually result in the capture, by a northward-flowing stream, of the headwaters of one of the less actively cutting southward-flowing streams.

A striking illustration of stream rearrangement is afforded by the deserted channel northwest of Dubuque known as the Couler Valley. Couler Valley is a clean cut, almost straight canyon with steep rock walls. It is less than one-half mile wide, and about 5 miles long, leading from the Little Maquoketa Valley at Sageville to the Mississippi at Dubuque. This valley has a flat bottom, and well records show that it is deeply filled with loose material similar to that in the Mississippi trough. Yet it is at present occupied by no stream commensurate with its size and depth. A small branch fed by a spring flows northward from near the fair grounds, while the southern portion of the valley is drained by the feeble flow of Couler Creek. There is no perceptible divide in this valley and as late as 1853, at a time of high water, floods from the Little Maquoketa passed through it to the Mississippi. That this valley was once the natural outlet of the Little Maquoketa is probable, for it was evidently cut by a stream of about the size of that river, and in the processes of stream capture a creek working backward from the Mississippi to Sageville, along the present route of the Little Maquoketa, would have had the advantage of shorter distance and greater fall, and so in time would have captured the stream that occupied Couler Valley. The Mississippi may have cut a deep embayment in its western bank at the place now occupied by the Peru Bottoms and thus aided in reducing the divide. Other unusual topographic features in the vicinity of Sageville, such as the isolated mounds and gaps near the mouth of Bloody Run and at the place where the Chicago Great Western Railway passes from the Little Maquoketa Valley to Couler Valley, suggest several shiftings of drainage prior to the present arrangement.

The courses of some other streams near the Mississippi exhibit a rough parallelism with the course of the main river; for example, the lower part of Grant River, McCartney Branch, Menominee Creek, Sinsinawa River, Bloody Run, and North Fork of Little Maquoketa River.

DESCRIPTIVE GEOLOGY.

STRATIGRAPHY.

The solid rocks exposed in the region consist extirely of sediments deposited in early Paleozoic time, comprising beds of sandstone, shale, limestone, and dolomite. These are underlain by metamorphic and igneous rocks of more ancient date. A detailed graphic section of the deposits is given on the columnar section sheet. The formations are comprised in the following list:

Quaternary	Alluvium.	
	Travertine.	
	Residual soil.	
	Terrace deposits.	
	Loess.	
	Kansan drift.	
Silurian	Niagara limestone.	
Ordovician	Maquoketa shale.	
	Galena limestone.	
	Platteville limestone.	
	St. Peter sandstone.	
	Prairie du Chien formation (dolomite, chert, sandstone).	
Cambrian	Sandstone, shale, dolomite.	Not exposed in Lancaster-Mineral Point area.
Pre-Cambrian	Metamorphosed sedimentary and igneous rocks.	

PRE-CAMBRIAN ROCKS.

Rocks of pre-Cambrian age do not outcrop within the quadrangles, but are known to underlie this district and have been struck in deep borings. Everywhere they are several hundred feet below the present surface. They consist of igneous and metamorphic rocks, chief among which are granites, gneisses, schists, and quartzites. The nearest outcrops of these pre-Cambrian rocks lie northeast of this area, about Baraboo and Devils Lake, Wis., where considerable areas of quartzite (the Baraboo quartzite) and smaller areas of igneous rock emerge from beneath the Cambrian sandstone. These pre-Cambrian rocks form the floor on which the Cambrian and later sediments were laid down. No igneous rocks whatsoever of as late date as the Cambrian sandstone are known in this area.

CAMBRIAN SYSTEM.

The Cambrian system is represented by a thick formation, consisting of sandstone, as a rule poorly consolidated, with minor amounts of shale and dolomite. In the Wisconsin reports the name "Potsdam" sandstone has been applied to this formation, although it is not the exact equivalent of the Potsdam sandstone of New York. It reaches a maximum thickness of about 1000 feet. A generalized section of the Cambrian rocks shows that more than their lower half is sandstone, above which lies 85 feet of shale, and above this 150 feet of sandstone, at some places calcareous, overlain by 35 feet of shale and limestone that is known in the vicinity of Madison as the "Mendota" limestone. The upper part of the Cambrian is sandstone, about 30 feet thick. This is exposed in the vicinity of Madison and elsewhere, and has been named in the Wisconsin reports the "Madison" sandstone.

The Cambrian rocks outcrop nowhere in either the Mineral Point or the Lancaster quadrangle, erosion having not yet cut down to them, but they do appear in the stream valleys just beyond the northern edge of the quadrangles.

ORDOVICIAN SYSTEM.

The chief strata exposed in the quadrangles belong to the Ordovician system, and especially to the Galena dolomite. The Ordovician rocks directly underlie both quadrangles, except on the mounds. The divisions of the Ordovician here represented are as follows, in ascending order: (1) a thick dolomite, chert, and shale formation—the Prairie du Chien; (2) a sandstone formation—the St. Peter; (3) a limestone, dolomite, and shale formation—the Platteville; (4) a thick dolomite formation—the Galena; (5) a shale formation—the Maquoketa.

PRAIRIE DU CHIEN FORMATION.

Thickness and subdivisions.—Above the Cambrian sandstone and below the next sandstone (St. Peter) there is a formation ranging in thickness from 150 to 250 feet, composed largely of dolomite. To this the name Prairie du Chien formation is applied, as it is well exposed in the vicinity of the town of that name, at the junction of Wisconsin and Mississippi rivers. This same formation is commonly known in the upper Mississippi Valley as the "Lower Magnesian" limestone. Locally it is separable into three divisions, as follows: (1) At the base a thick dolomite, the main body of the formation, which has been called "Oneota"; (2) a thinner division called the "New Richmond" sandstone; (3) at the top, a thin division to which the name "Shakopee" limestone has been applied. The separation of the Prairie du Chien formation into these three divisions can not everywhere be readily made, first, because of the thinness or local absence of the second division (sandstone), and, second, because the upper part of this formation was in places removed by erosion before the St. Peter sandstone was deposited.

Lithologic character.—The dolomite is gray to white in color and varies from a very compact, fine-grained rock to one that is porous and coarse grained, but on the average it is less porous and less coarse grained than the other thick dolomite of the district—the Galena limestone. It also commonly weathers less roughly than does the Galena, though at some localities the Prairie du Chien is a markedly rough-weathering rock, but at these places this feature is due largely to its semi-brecciated, brecciated, or possibly conglomeratic character. Beds of clay shale, 3 to 10 inches thick, are locally developed in the finer grained portions of the dolomite.

Many small masses of chert, more commonly termed flint, some of them a foot or more in diameter, also occur in the upper third of this formation, but the chert is, as a rule, aggregated in certain layers rather than scattered indiscriminately through the dolomite. In general the coarser parts of the formation carry the most chert; most of the finer compact portions are entirely free from it. Here and there in the dolomite, or in the chert masses, there are small cavities, which are lined with small crystals of quartz; in fact there are more quartz crystals in this formation than in the others of the district, which are noticeably deficient in silica in crystallized form.

Near or at the very top of the formation there is at many places a marked development of oolite, a rock consisting of small rounded bodies, about the size of a pin's head, embedded in a siliceous cement. These bodies have a concentric structure and are mainly siliceous, though some of them may be calcareous. This oolite may be seen in fragments in many places along the wagon roads of the district, as, for instance, in the eastern part of sec. 14, T. 5 N., R. 2 W., 2 miles west of Annaton; also just west of the bridge across Pecatonica River, in NE. $\frac{1}{4}$ sec. 36, T. 4 N., R. 2 E., 5 miles south of Mineral Point; also along the road near the south side of sec. 3, of the same township, about 3 miles west-southwest of Mineral Point. At the latter place some large masses of cellular chert are associated with the oolite.

In the extensive exposure of the formation along Mineral Point Branch in secs. 2, 3, and 10, T. 4 N., R. 2 E., about 30 feet of rock is seen in one cliff. The upper 10 feet consists of rough-weathering, hard, more or less broken beds of dolomite; while the lower part is more regular, less rough-weathering, and in heavy beds. Some chert occurs in both parts of the cliff.

The exposures of the Prairie du Chien in these quadrangles are mainly of dolomite, sandstone exposures of this age being rather uncommon, especially in the southern part of the area. Sandstone occurs, however, at several places in the northern part of the quadrangles. Near the northeast corner of sec. 24, T. 5 N., R. 2 E., on the east bank of the creek, $2\frac{1}{2}$ miles north of Mineral Point, the following section is exposed:

Section near top of Prairie du Chien formation north of Mineral Point.

	Ft.	In.
12. Sandstone, crumbling, not clearly in place.	5	0
11. Fine-grained dolomite	0	6
10. Sandstone	4	0
9. Fine-grained dolomite in undulating beds 1 to 3 inches thick	1	8
8. Sandstone	0	1
7. Fine-grained dolomite	0	1
6. Sandstone, commonly pure, but in places with blue clay cement.	2	0
5. Soft, calcareous shale or shaly limestone	0	2
4. Sandstone.	0	3
3. Soft, calcareous shale or shaly limestone	0	6
2. Sandstone	2	0
1. Coarse dolomite	0	6
	16	9

Along the road that runs through sec. 14 and into sec. 10, T. 6 N., R. 2 E., just north of the Mineral Point quadrangle, there are imperfect exposures showing both dolomite and sandstone in the upper part of the Prairie du Chien formation. Another road section in which the exposures are not continuous, but which shows the presence of sandstone in the formation, occurs in the E. $\frac{1}{2}$ sec. 14, T. 5 N., R. 2 W., on the Annaton-Stitzer wagon road. The rocks dip perceptibly eastward here, so that on the hill slope the apparent thickness of the beds is greater than the actual thickness. At the base of the hill are about 30 feet of massive, rough-weathering dolomite, overlain by 5 feet of interbedded, crystalline dolomite and sharp-grained, reddish sandstone, and for some 30 feet above this horizon there are scattered outcrops and débris of reddish sandstone and oolitic chert, with an exposure, at the top, of bluish-green sandy clay, succeeded above by St. Peter sandstone.

Near Dodgeville a drill record is reported as follows:

Section near Dodgeville.

	Feet.
5. Limestone (Galena)	70
4. Limestone (Platteville)	58
3. Sandstone (St. Peter)	52
2. Solid limestone, no openings (Prairie du Chien)	191
1. Sandstone, probably Cambrian	8
	379

A few other indefinite drill records have been reported, but in these no sandstone has been noted in the Prairie du Chien formation.

Far better exposures of the Prairie du Chien formation are found a few miles north of these quadrangles, toward Wisconsin River and farther west, near the Mississippi. The nature of the upper portion of the formation in the eastern part of the Elkader quadrangle is shown in the following section:

Section of upper part of Prairie du Chien formation north of Bagley, Wis.

	Ft.	In.
Sandstone (St. Peter)	30	0
Débris, concealing contact	30	0
PRAIRIE DU CHIEN:		
Limestone, hard, porous	1	0
Sandstone, white, very soft	2	0
Dolomite, hard, fine grained, thin bedded, grading into sandy beds	30	0
Siliceous dolomite, hard and quartzitic	0	4
Sandstone, thin-bedded, yellow	8	0
Shale, blue, with 1-inch band of white, siliceous oolite	1	2
Dolomite, very massive, hard, with large concretions	20	0
Shale, blue, with some sand	1	0
Limestone, white, fine grained, thin bedded	2	0
Chert in irregular, wavy beds	2	0
Shale, sandy	1	0
Limestone or dolomite, irregularly bedded, with small concretions. At base is a thin layer of calcareous sandstone	20	0
Shale, blue, with sandstone interbedded, and at bottom a fine-grained, white, conglomeratic limestone	2	0
Sandstone, pure white, coarse grained, friable	6	0
Siliceous dolomite, very irregularly bedded, weathering rough, and containing a large proportion of chert	20	0
Total exposure of Prairie du Chien	116	6
Base not exposed.		

The sandstone beds in the above section appear to have little horizontal extent, but rather seem to be sandstone lenses in the formation. In the Lancaster quadrangle evidence of the occurrence of such sandstone beds in the Prairie du Chien was seen about 2 miles southwest of Fennimore, along the north-south road in sec. 36, T. 6 N., R. 3 W., about 100 paces south of the schoolhouse.

In these quadrangles the upper 50 to 60 feet of the formation may contain considerable sandstone, interbedded with dolomite and chert. At some places, especially in the northwest portion of the area, the sandstone layers are few and very thin, and occasionally may be entirely absent. When present, the sandstone of the Prairie du Chien formation can usually be distinguished from the St. Peter sandstone by one or more of the following criteria: (1) the St. Peter is usually a thick-bedded, massive formation, while the lower sandstone is generally a thinner bedded, rougher weathering formation in which cross-bedding is common; (2) the St. Peter has little foreign matter, i. e., it is a pure, waterworn quartz sand, while the lower sandstone is commonly highly charged with iron oxide, at some localities has a clay or calcareous cement, and in many places is interbedded with dolomite; (3) at the junction of the St. Peter with the underlying rocks there is at many localities a layer of siliceous oolite, and at some places large masses of cellular flint, which are not known to occur in the St. Peter itself.

Distribution and physiographic expression.—Exposures of the Prairie du Chien formation in the Mineral Point quadrangle are, with one exception, confined to some of the valleys in its northern half, and commonly these exposures rise only a few feet above the water. The deeper valleys of the Lancaster quadrangle north of the Mississippi nearly all cut well into the formation, which at a few places extends completely across low divides. The formation is seen north of Lancaster in bluffs 30 to 40 feet high, but it tends to break up into small, flinty fragments, which completely cover the slopes and quickly give rise to soil. The presence of this formation can at some places be detected, even if outcrops are not at hand, by its effect on the form of valley bottoms. Most of the valleys in the St. Peter sandstone have wide, flat bottoms. Where the valley bottoms pass from this easily eroded sandstone into the harder dolomite of the Prairie du Chien they become much constricted and a terrace marks the location of the dolomite. This feature is made more prominent by the tendency of the immediately overlying sandstone to form a low escarpment. Such terraces occur at several places on Pecatonica River and its branches, south and west of Mineral Point, and one very noticeable terrace is in the southern part of sec. 2, T. 4 N., R. 2 E., 2 miles west-southwest of that town. Terraces of similar origin are also perceptible along the larger streams in the Lancaster quadrangle, even where the valley has been cut but a few feet below the top of the Prairie du Chien without producing any constriction in width of the valley, as, for example, along Platte River just above the mouth of the Little Platte. Other localities farther north are on Bull Branch, near its junction with Bacon Branch, and along Roger Branch, on the Lancaster-Mount Ida wagon road. From the small knob crossed by this road in sec. 17, T. 5 N., R. 3 W., may be viewed a broad plain developed on the Prairie du Chien formation, into which valleys have been grooved. Above the plain rise occasional knobs of sandstone, and the St. Peter escarpment encircles it 2 or 3 miles to the west and north.

Fossils and correlation.—The fossils contained in the Prairie du Chien formation in this region are somewhat rare. The only one at all common is a large globular mass, some specimens a foot or more in diameter, of concentric structure, roughly resembling a cabbage head, and known as *Cryptozoon*. The exact horizon of this fossil has not been fully determined, but it apparently occurs in the upper 50 feet of the formation. So far as known it has not been found in the lower main dolomite division. The other fossils consist almost entirely of gasteropods and cephalopods. These also occur only or chiefly in the cherty upper one-third of the formation. Among the collections made in these and in adjacent quadrangles the following described species have been identified:

Helicotoma pecatonica Sardeson.
Raphistoma multivolvatum Calvin.
Raphistoma minnesotensis (Owen) Sardeson.
Straparollus claytonensis Calvin.
Murchisonia argylensis Sardeson.
Murchisonia putilla Sardeson.
Subulites exactus Sardeson.
Cyrtoceras luthei Calvin.

These indicate that in general the Prairie du Chien is the equivalent of the "Calciferous," or Beekmantown limestone, as it is now known, of New York and Canada, and that it also corresponds to that part of the "Magnesian" series of Missouri immediately underlying the "First Saccharoidal" or St. Peter sandstone of that State. It is highly probable that it may all be included in the horizon of the Jefferson City limestone of Missouri.

Stratigraphic relations.—Wherever the base of the formation is exposed in the surrounding region the passage from the underlying Cambrian sandstone to the Prairie du Chien dolomite appears to be gradual. There is no sharp lithologic break, but rather an interbedding of sandstone and dolomite, the dolomite predominating above and the sandstone below the line of division. The following sections illustrate the character of the passage from the uppermost Cambrian to the Prairie du Chien formation of the Ordovician:

Section showing contact of Prairie du Chien formation (Ordovician) and Cambrian sandstone, near Boscobel, Wis.

	Feet.
ORDOVICIAN:	
Limestone, rather thin bedded, fine grained, and compact	10
Sandstone, soft, fine grained, yellow, and friable	10
Unexposed	5
Limestone, hard, compact, almost like "glass rock"; blue on fresh surface	4
Dolomite, hard, flinty, rough weathering, and irregularly bedded; grades into thin-bedded limestone	15
Débris	5
Sandstone, limy, hard, crystalline, and buff colored	1
CAMBRIAN:	
Sandstone, soft, yellow to white, with blue shaly streaks	6
Unexposed	4
Limestone, heavy bedded, hard, subcrystalline, with blue shale layer near top	3
Sandstone, iron stained, without bedding planes, resembling St. Peter sandstone	27

Section showing Ordovician-Cambrian contact, near Boscobel, Wis.

	Feet.
ORDOVICIAN:	
Slope covered with fragments of St. Peter sandstone.	
Limestone in subcrystalline beds 2 to 4 inches thick	20
Unexposed	4
Dolomite, heavy compact buff beds, effervescing, but not very vigorously, in acid	10
Limestone, yellow, very irregularly bedded, flinty, with some sandstone partings, and blue shale	30
Limestone, very hard, crystalline	1
Sandstone, composed of rounded quartz grains embedded in yellow calcareous cement. Has oolitic appearance	3
Sandstone, calcareous	2
Sandstone, containing little concretions or pockets of pure white material that looks like carbonate of lime, but does not effervesce with acid	1
CAMBRIAN:	
Sandstone, white to yellow, with blue shale partings, showing ripple marks and cross-bedding	12

The Prairie du Chien formation is overlain unconformably by the St. Peter sandstone. The upper surface of the Prairie du Chien appears to have suffered considerable erosion before the deposition of the St. Peter. Evidence of this was noted in an exposure, about 200 feet long, in the belt south of Grant River, at the side of the Lancaster-Cassville wagon road in sec. 22, T. 4 N., R. 4 W., where the basal clay shale and succeeding sandstone of the St. Peter lie on a very uneven surface of dolomite, oolitic chert, and sandstone.

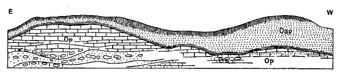


FIG. 3.—Sketch showing uncomformable relations between Prairie du Chien formation, Op, and St. Peter sandstone, Osp.

South side Grant River, 1½ miles below Flora, Wis. Horizontal length, 200 feet. Vertical scale exaggerated.

The fact that the St. Peter sandstone varies greatly in thickness within short distances, the irregularity being confined to its lower surface, is good evidence of erosional unconformity. Depressions or valleys in the Prairie du Chien dolomite, filled with St. Peter sandstone, have been observed in secs. 14 and 15, T. 5 N., R. 3 W., respectively, along Roger Branch and Borah Creek, and near the mouth of Crow Branch, 1 mile south of Annaton. The two formations have similar relations, still more marked, about Castle Rock and Highland, Wis., a few miles north of the area. In the vicinity of Highland, blocks of sandstone conglomerate containing pebbles of chert have been found. While these were not absolutely in place, they occur very close to the base of the St. Peter and seem to mark a basal conglomerate at this horizon. Indications of such a conglomerate have been found also at one or two other points outside of the quadrangles. In other parts of Wisconsin, noticeably toward the east, the irregularity of the junction line between the Prairie du Chien and the St. Peter has been explained, at least in part, by the irregular reeflike character of the upper surface of the Prairie du Chien. Features of this sort are not, however, conspicuously developed in these quadrangles.

ST. PETER SANDSTONE.

Thickness and relations.—Unconformably upon the Prairie du Chien formation lies a comparatively thin sandstone long known as the St. Peter from the fact that it occurs along the lower course of St. Peters (now known as Minnesota) River. The thickness of this sandstone varies considerably, averaging in this district perhaps 70 feet, but ranging from 35 to 175 feet. These extremes were observed, respectively, at points one-fourth mile northeast and 1 mile southwest of Annaton, Wis. The variation in the thickness of the St. Peter sandstone is due, at least in the main, to irregularities in the surface of the underlying formation—the Prairie du Chien—which suffered considerable erosion before the sandstone was deposited. The top of the sandstone likewise may have been somewhat eroded prior to the deposition of the succeeding Platteville limestone, although this is not evident from discordance of stratification.

Character and distribution.—Nearly everywhere at the base of the formation there is a foot or two of bluish-green, sandy, clay shale. Above this basal shale the St. Peter is practically pure quartz sandstone, the percentage of silica in its composition being very high and at some places exceeding 99 per cent. Analysis of a sample of this sandstone gave the following results:

Partial analysis of St. Peter sandstone near Flora, Wis.

[George Steiger, analyst.]

Silica (SiO_2)	99.17
Alumina (Al_2O_3)	.25
Ferric oxide (Fe_2O_3)	.22

The grains are well waterworn and of medium fineness, the greater part passing a sieve having 40 meshes to one inch. Commonly the sand is very poorly cemented, so that the rock crumbles readily and does not stand up in marked exposures. An exception to this last statement should be made for the district along the streams immediately west of Mineral Point and for mounds such as those near the mouth of Crow Branch, south of Annaton, where this sandstone is better cemented and forms prominent cliffs along the sides of some of the valleys. The cementing substances are quartz and iron oxides. In some parts of the sandstone the grains have been enlarged by the addition of silica and now present more or less perfect crystal faces, which glisten in the sunlight. Commonly, near the surface of an exposure the rock is stained yellow, brown, or red by iron oxides which have filtered down into the clean white sand; the colors are mainly superficial, however, and are not found at places where the sandstone has been protected from surface waters.

Throughout the northern part of the Lancaster quadrangle, especially in the headwater valleys of Grant and Platte rivers, there is exposed at many places a low escarpment of St. Peter sandstone rising above a floor of Prairie du Chien dolomite. The St. Peter sandstone is easily eroded and the valleys cut through it are therefore relatively wide. The scarps that border such valleys are due to the fact that the sandstone has been rapidly eroded back to a point where it is still overlain, or has been until lately overlain, by a thin cap of protecting limestone. Locally the sandstone may be indurated to the hardness of a quartzite and even systematically jointed.

The St. Peter presents a limited outcrop in the valleys of all the main streams northeast of the Mississippi. Owing to the ease with which it is eroded its areal extent is unimportant.

The transition from the St. Peter sandstone to the overlying Platteville limestone is marked by a bed of blue sandy shale which ranges in thickness from a few inches to 5 feet or more. This shale is not commonly sharply separated from the sandstone, but grades into it. On the other hand, the upper edge of the shale is sharply delimited by the overlying massive beds of the lower part of the limestone. The sand grains in the shale do not usually extend to its upper surface, and very rarely are these grains found in the lower beds of the Platteville. This shale may be regarded as the initial deposit of Platteville time—the product of the first wash of the Platteville sea in its advance on the St. Peter surface. Thus there was apparently, in this area, an interval of emergence between the St. Peter and the Platteville, and in the Ozark region this interval is represented by the Joachim limestone.

Fossils and correlation.—The St. Peter can be regarded as a practically nonfossiliferous formation, though a few casts, mainly of pelecypods or bivalve shells, have been reported from it. This scarcity of fossils seems to be due as much to the fact that in so porous a rock solution would destroy calcareous shells as to the fact that few animal remains were entombed in it originally. The St. Peter is a wide-reaching formation in the upper Mississippi Valley, and in the Ozark region it is represented by the sandstone which immediately underlies the Joachim limestone and which has frequently been termed the "First Saccharoidal" sandstone.

PLATTEVILLE LIMESTONE.

Thickness and distribution.—This formation is noticeably different from the other calcareous members of the Paleozoic section in these quadrangles in that it is largely a pure limestone, or a magnesian limestone, rather than a dolomite. In earlier reports on this district this formation was called the Trenton limestone, but the name Platteville has recently been applied to it, as it is possible that these beds do not represent the exact equivalent of the Trenton in its type locality. This formation is typically exposed in the vicinity of Platteville, and may be seen in its entire thickness along Little Platte River west of that town.

The Platteville averages 55 feet in thickness, and maintains this average over a considerable part of the area. Toward the eastern edge of the Mineral Point quadrangle its thickness increases to a maximum of about 65 feet. Its minimum thickness in the district, 40 feet, is found in the S. ½ sec. 30, T. 5 N., R. 2 E., about 3½ miles southwest of Linden.

Except where removed from the valleys of the present streams the Platteville underlies the whole of the area here described. Owing to the thinness of the formation its outcrop area is very small, being confined to sides of stream valleys and to a few places along interstream ridges.

Lithologic character.—A generalized section of the Platteville is given in the next column.

No. 1 of this section has been already noted in the description of the St. Peter sandstone.

No. 2 occurs in beds ranging in thickness from 6 inches to 2 feet. It is a coarse, earthy, magnesian limestone, or a true dolomite, which can be distinguished in the field from the more abundant, coarse, thick-bedded dolomite of the Galena by its more earthy nature, by its lack of chert, and by its thin, irregular, dark partings. This member of the Platteville is buff on weathered surfaces, but where perfectly fresh is blue-gray in color. In southern Wisconsin it has been called the "lower buff limestone" and also the "quarry beds."

Generalized section of Platteville limestone.

	Feet.
4. Limestone, principally in thin beds, and shale	10-15
3. Thin-bedded, brittle, fine-grained limestone	15-25
2. Thick-bedded magnesian limestone or dolomite	15-25
1. Blue shale, at some places sandy	1- 5

No. 3 of the section occurs commonly in thin beds, 1 to 3 inches thick. The beds are separated by very thin shale partings and have an undulating or wavy appearance. Most of these beds are of a dense, very fine-grained, gray to light-brown limestone, which breaks with a more or less marked conchoidal fracture. On weathered surfaces the rock is at most places white or very light gray. When this member has the peculiar lithologic characters just mentioned it is sometimes called the "glass rock," though the main "glass rock" beds of the district lie higher up in the Platteville. This peculiar thin-stratified, wavy-bedded character of this part of the formation is very persistent, and is noticeable as far east as Beloit, where this division becomes magnesian and is known as the "lower blue limestone."

No. 4 of the section consists of limestone and shale. These occur commonly in thin, alternating beds, many of which agree closely in lithologic features with the nondolomitic basal layers of the Galena. This resemblance is especially apparent in the basinlike areas (corresponding to the productive mineral areas) in which the thin limestone and shale beds at the top of the Platteville and at the base of the Galena have their fullest development. In these areas, therefore, it is at some places difficult to draw the boundary between the Platteville and the Galena on purely lithologic criteria. The contact, however, is probably unconformable, despite its obscurity and the fact that it apparently occurs in the midst of a shaly unit. A close study of the fossils rarely fails to locate the contact within very narrow bounds, and then the actual physical break between the two formations may in places be determined. At many places the first few inches of the Galena consist of a shale or clay containing more or less clear evidence that it is a deposit which has been reworked by water. At some places it contains fragments of fossils, more perfect forms of which occur in the bed just below. At some localities this lowest bed of the Galena consists of a yellow to white clay, called "pipe clay," underlain by an inch or two of dark carbonaceous clay.

In the anticlinal areas between the productive basins the contact of the two formations is accompanied by less shale, and at some places the two are separated by an apparently waterworn limestone surface. An occasional thin seam of highly carbonaceous shale, of the type locally termed "oil rock," occurs within the limits of the Platteville, but the true "oil rock" belongs with the overlying basal beds of the Galena. In some of the mines at Linden and elsewhere in the eastern part of the Mineral Point quadrangle there is a noticeable layer of this carbonaceous shale at the base of the main "glass rock" beds.

Massive deposits of travertine commonly occur at the horizon of the Platteville limestone in the valleys of the larger streams and branching ravines. As these deposits are of recent date they will be described in connection with the Quaternary rocks.

Glass rock.—The most characteristic part of the fourth member is composed of beds known to the miners of the lead and zinc region as "glass rock." They consist of dense, very fine-grained, hard, conchoidally breaking limestone, which rings when struck with a hammer. When fresh this rock is of a light-chocolate color, which on weathering changes rapidly to a very light gray or to white. This peculiar limestone occurs typically in strata that range from 3 to 8 inches in thickness and are separated by thin partings of chocolate-colored shale, or oil rock. The lower beds at some places have a peculiar mottled appearance.

The main glass rock ranges in thickness from 18 inches to 4 feet. It lies below the horizon of the upper shale or clay bed and forms the most readily recognized stratum in the middle portion of the district. This limestone strongly resists weathering, so that exposures and fragments of it are almost everywhere easily found. In the eastern part of the area it becomes coarser grained, somewhat magnesian and thicker, being in places 15 feet thick. It still retains, however, some of its usual characteristics. In the eastern portion of the area a few thin bands of oil rock at most places directly underlie the glass rock. A chemical analysis of this peculiar limestone gave the following results:

Analysis of glass rock.

[By E. T. Sweet, Geology of Wisconsin, vol. 2, 1877, p. 681.]

Silica (SiO_2)	6.160
Alumina (Al_2O_3)	2.260
Sesquioxide of iron (Fe_2O_3)	.950
Carbonate of lime ($CaCO_3$)	85.540
Carbonate of magnesia ($MgCO_3$)	3.980
Water (H_2O)	.930
Phosphoric anhydride (P_2O_5)	.055
	99.875

Blue shale.—The very top of No. 4 of the Platteville is commonly a blue calcareous shale or blue clay, in part highly fossiliferous. The chief fossil is the large longitudinal variety of *Orthis* (*Dalmanella*) *subæquata*, which is characteristic of this bed. The thickness of this highly fossiliferous bed varies from a few inches to 2 or 3 feet, but where the greatest thickness occurs, in the territory west of Platte River, there are usually developed within the shale several bands or lenses of limestone that range from an inch to a foot in thickness. This blue shale is present generally beneath the ore beds in most of the mines in the central and western part of the area, but it is frequently absent in the extreme eastern part.

Fossils and correlation.—The Platteville is commonly highly fossiliferous, more so than any other formation within the area except possibly the Maquoketa shale. Although practically all the beds of the formation except the basal shale contain fossils in greater or less abundance, certain beds are literally packed with organic remains. The dolomitic second member contains relatively few fossil remains, and at some places this bed may appear almost barren. A few species range through nearly all the beds, notably *Leperditia fabulites* Conrad, which is the most characteristic fossil of the formation. Many other species, however, being more restricted in range, may occur in only one or two of the beds. Of species in the Mississippi Valley confined to the Platteville, *Streptelasma profundum*, *Rafinesquina minnesotensis*, *Orthis deflecta*, *O. subæquata* (long-hinged variety), *Leperditia fabulites*, *Protowarthia rectangularis* and *Thaleops ovata* may be found in any of the limestone beds of the formation. All of these species are common in the thin-bedded, nearly pure limestone constituting division 3. Among the species which are apparently restricted to this member or which occur so much more abundantly here than elsewhere in the section that they may be considered as characteristic of it may be mentioned: *Maclurea bigsbyi*, *Zygospira* (*Hallina*) *nicolleti*, *Hindia inæqualis*, *Rhinidictya pediculata*, *Phylloporina sublaxa*, *Monotrypa magna*, *Rhynchotrema minnesotensis*, *Ambonychia planistriata*, *Clionychia lamellosa*, *Salpingostoma buelli*, *Conradella triangularis*, *Hyolithes baconi*, *Encrinurus vannulus*, and sponges of the genera *Anthaspidella* and *Zittelella*.

The characteristic fossils of the glass rock and interbedded chocolate shales are *Buthograptus laxus* and other delicate plumose marine algæ.

The top shale of the formation everywhere contains great numbers of a large and rather tranverse variety of *Orthis* (*Dalmanella*) *subæquata*, which is confined to this horizon. There are only a few other species, but one or both of the bryozoa *Stictoporella frondifera* and *S. angularis*, which occur only in this shale bed, may commonly be found wherever the bed is well developed. A few Platteville fossils, especially of the brachiopods, and notably *Orthis tricenaria*, *O. subæquata*, and *Strophomena incurvata*, pass upward into the lithologically similar basal division of the Galena.

The large variety of *Orthis* (*Dalmanella*) *subæquata*, which occurs abundantly in the top shale, is a very characteristic form and is confined, as far as abundance and its large size are concerned, to a thickness of 2 or 3 feet of rock between the main glass rock beds and the base of the Galena. It thus furnishes an easy criterion for separating the

Galena from the Platteville—a criterion which is of use in geologic mapping as well as in determining a horizon that is important in mining operations.

The Platteville is regarded as the equivalent of the Stones River group of Tennessee and Kentucky, a group that lies lower than the Black River and Lowville (Birdseye) limestones of New York.

Detailed sections.—The upper part of the Platteville limestone is exposed at several places, at some of which continuous sections from this formation up into the lower part of the Galena are observable. The eight sections given below are particularly well exposed, and each exhibits a greater thickness of rock than is commonly observed in one exposure. The section first given is from an old quarry on the west bank of Little Platte River, about 1½ miles west-northwest of Platteville; the exact location is in NE. ¼ sec. 8, T. 3 N., R. 1 W.

Section near Platteville, Wis.

	Ft.	In.
GALENA:		
13. Subcrystalline, magnesian limestone at base, but in 2 or 3 feet grading into coarse, thick-bedded dolomite	20	0
12. Blue to gray calcareous shale or shaly limestone	0	8
11. Thin-bedded, subcrystalline limestone. A few specimens of *Orthis tricenaria* Conrad and *O. subæquata* Conrad	5	0
10. Thin, wavy-bedded limestone, resembling glass rock, becoming subcrystalline above. Some beds are very fossiliferous. *Orthis tricenaria* Conrad, *O. subæquata*, *O. pectinella* Hall, and *O. testudinaria* Dalman	6	0
9. Dark-brown or chocolate-colored shale or oil rock	0	2
8. Thin, wavy-bedded limestone, resembling glass rock; commonly very fossiliferous; a few thin partings of oil rock. *Orthis tricenaria* Conrad, *O. subæquata* Conrad, *Strophomena incurvata* Shepard, *Rafinesquina alternata* Conrad, *Ctenodonta astartiformis* Salter, *Ceraurus pleurexanthemus* Green, *Asaphus* (*Isotelus*) *gigas* Dekay, *Rhinidictya mutabilis minor* Ulrich	8	0
PLATTEVILLE:		
7. Blue shale	0	8
6. Thin, undulating, hard limestone, at some places resembling glass rock, interbedded with blue shale. The limestone is very fossiliferous. This is the chief horizon for *Orthis subæquata* Conrad (var. *minneapolis* Winchell), which is here very abundant and of large size. *Stictoporella frondifera* Ulrich occurs at the top of this division	2	0
5 Gray to yellow-brown to almost black clay	0	7
4. Dark-gray shale and hard gray limestone interbedded	1	2
3. Main glass rock beds. Some oil rock bands occur in the lower part, and in these are *Isotelus gigas* and fernlike forms, probably of the fossil alga *Buthograptus laxus* Hall	2	6
2. Thin shaly layers of glass rock with oil-rock partings; weathers to clay	0	3
1. Blue, gray-weathering limestone with dark partings. The upper part is separated by blue shale into 2 beds, each 21 inches thick. The upper part of these beds has in places the appearance, of thin wavy-bedded glass rock. *Orthis deflecta* Conrad, *Rafinesquina minnesotensis* Winchell, *Thaleops ovata* Conrad, *Leperditia fabulites* Conrad, *Monotrypa magna* Ulrich	7	0
Total exposure	54	0
Galena limestone, exposed	39	10
Platteville limestone, exposed	14	2

In the above section No. 1 belongs to the thin-bedded member (No. 3 of generalized section) of the Platteville, Nos. 2 to 7 belong to the upper member of the Platteville, while Nos. 11 to 13 clearly belong to the Galena. Nos. 8 to 10 are regarded as the equivalents of the main oil-rock horizon that marks the base of the Galena. The division between the Galena and Platteville will then be drawn between Nos. 7 and 8.

Section at City Quarry, Mineral Point, Wis.

	Ft.	In.
GALENA:		
11. Residual soil	5	6
10. Decayed dolomite, called by the miners the "brown rock"	4	0
9. Oil rock, with some cubes of galena and some decayed limestone	1	6
8. Compact, brownish magnesian limestone	1	0
7. Unexposed	17	6
PLATTEVILLE:		
6. Thin, wavy-bedded limestone, much like glass rock	4	0
5. Compact, magnesian limestone; brown on weathered surface, but blue on fresh surfaces; in beds 3 inches to 1 foot in thickness	10	6
4. Thin, wavy bedded, hard, glass rocklike limestone	15	6
3. Coarse, thick-bedded dolomite	20	6
2. Traces of shale	0	6
ST. PETER:		
1. Sandstone	3	0
Total	83	6
Galena limestone, exposed	6	6
Platteville limestone, exposed	51	0
St. Peter sandstone. exposed	3	0

In this section No. 1 represents the St. Peter sandstone. The shale (No. 1 of the generalized section of the Platteville) just above this is here very thin and not well exposed. No 3 represents division 2 of the generalized section of the Platteville, while Nos. 4 and 5 represent the next higher member; and No. 6 and probably a part of No. 7 represent the upper member of the Platteville. Nos. 8, 9, 10, and part of No. 7 belong to the Galena.

Section at Mineral Point, near Mineral Point Zinc Works.

	Feet.
6. Débris of limestone, containing *Streptelasma corniculum* Hall and a few *Orthis subæquata* Conrad	3
PLATTEVILLE:	
5. Compact, fine-grained limestone	2
4. Thin, wavy-bedded limestone resembling glass rock; *Orthis tricenaria* Conrad, *O. deflecta* Conrad, *Rafinesquina alternata* Conrad, *R. minnesotensis* Winchell, *Zygospira* (*Hallina*) *nicolleti* Winchell and Schuchert, *Strophomena trentonensis* Winchell and Schuchert, *Rhynchotrema minnesotensis* Sardeson, *Leperditia fabulites* Conrad, *Isotelus gigas* Dekay, *Monotrypa magna* Ulrich, *Zittelella typicalis* Ulrich and Everett, and *Anthaspidella* sp	25
3. Coarser, thick-bedded dolomite	14
ST. PETER:	
2. Unexposed	6
1. Sandstone	10
Total	60
Platteville limestone, exposed	41
St. Peter sandstone, exposed	10

In this section No. 1 represents the St. Peter; No. 3 (and part of No. 2) is the second member of the Platteville, No. 4 is the third member of the Platteville, and No. 5 is part of the uppermost member of the Platteville.

Section in quarry at Darlington, Wis.

	Ft.	In.
GALENA:		
11. Coarse-grained, thick-bedded dolomite, with *Receptaculites oweni* Hall	4	0
10. Coarse-grained, thick-bedded dolomite.	3	0
9. Coarse-grained, thick-bedded dolomite with chert	5	0
8. Coarse-grained, thick-bedded dolomite..	2	0
7. No exposure	6	0
6. Coarse-grained, thick-bedded dolomite, with 3 shaly bands, one-half inch to 4 inches thick. Near base are a few *Orthis tricenaria* Conrad, *O. plicatella* Hall, *O. subæquata* Conrad	27	6
5. Thin-bedded dolomite	4	6
4. Thin-bedded limestone with oil-rock partings, which range from one-fourth inch to 2 inches in thickness. *Orthis tricenaria* Conrad, *O. subæquata* Conrad	4	0
PLATTEVILLE:		
3. Fine-grained, compact, magnesian limestone, with some chert, and containing *Buthograptus laxus* and a few oil-rock partings; represents the glass rock. The upper surface is smooth, apparently waterworn. *O. subæquata* Conrad (var. *minneapolis* Winchell) on top surface; *Streptelasma profundum* Owen, in body of bed	15	6
2. Blue magnesian limestone with dark wavy partings	19	6
1. Very blue magnesian limestone with prominent clay partings. *Clathrospira subconica* Hall, *Streptelasma profundum* Owen	10	0
Total	101	0
Galena limestone, exposed	56	0
Platteville limestone, exposed	45	0

In the above section No. 2, and probably No. 1, belong to No. 3 of the generalized Platteville section, while No. 3 belongs to the upper member of that section. Nos. 4 to 11 belong to the Galena.

In the western half of the area the thickening of the shale in division 4 of the Platteville becomes noticeable, as is shown in the following sections; and certain changes in lithology toward the north are illustrated in the last section given.

The section next following is exposed in a ravine entering the main Potosi hollow just above Potosi station, in SW. ¼ sec. 4, T. 2 N., R. 3 W.

Section of Platteville limestone near Potosi station, Wis.

	Ft.	In.
GALENA:		
14. Limestone, heavy, with shaly clay at base. *Orthis testudinaria* and small variety of *Orthis subæquata*.		
13. Limestone, hard, fine grained, in thin, wavy beds with chocolate-colored shale partings	12	0
12. Limestone, crystalline, fossiliferous	0	7
11. Shale, brown, carbonaceous (oil rock)	0	4
10. Limestone, crystalline, fossiliferous	0	7
PLATTEVILLE:		
9. Shale, drab and brown	1	4
Limestone, drab	0	1
Shale, bluish	0	4
Limestone, ferruginous	1	0
Shale, olive and brownish; somewhat fissile	1	1
Limestone	0	3
Shaly clay	0	2
Limestone, drab	0	4
Shale, bluish	1	8
Calcareous "mud rock;" fossiliferous in places	0	5
Shale, brown and carbonaceous at base..	0	6
Limestone, hard, fossiliferous, bluish where unweathered, parted by thin band of brown carbonaceous shale	1	0
8. Limestone, fine grained, compact; beds 2 to 3½ inches thick	2	6
7. Limestone, even grained, buff colored where weathered; beds 4 to 6 inches thick; grades into overlying thinner beds	3	0
6. Limestone, brownish, somewhat iron stained, in thin, hard, rather crystalline beds. More massive where unweathered. Contains *Leperditia fabulites*, *Bathyurus schucherti*, and *Pterygometopus intermedius*	12	0
5. Limestone, fine grained, compact, bluish white where fresh, in thin, wavy beds (2 to 4 inches), with thin leaves of brown shale in partings. Rather fossiliferous. Contains *Leperditia fabulites*, *Leperditella germana*, *Clathrospira subconica*, *Protowarthia rectangularis*	18	0
4. Débris	3	0
3. Magnesian limestone, buff, heavy bedded (only top exposed).		
2. Débris	8	0
1. Shale, below which is St. Peter sandstone	1	6
Total	69	8
Total thickness of Platteville	56	2

No. 1 belongs to general division 1 of the Platteville; Nos 2 and 3, and probably No. 4, belong to division 2; Nos. 5 and 6 represent an unusual development of division 3; Nos. 7, 8, and 9 belong to the topmost division.

Section of Platteville limestone at Spechts Ferry, Iowa.

	Ft.	In.
GALENA:		
15. Limestone, thin bedded and compact, grading upward into cherty magnesian beds.		
14. Limestone, in alternating thin beds and shaly beds, weathering to clay	3	6
13. Limestone, hard, compact, crystalline beds, weathering thin and light colored	4	0
12. Calcareous shaly material inclosing 6-inch limestone bed; *Orthis testudinaria* and *Plectambonites*	1	6
11. Limestone, fossiliferous, fine grained, compact, rather thin and wavy bedded, with chocolate-colored shale partings; less wavy bedded and more crystalline than No. 10; heavier bed underlain by a few inches of shale at base; *Plectambonites*	10	0
10. Limestone, fine grained, compact, thin and wavy bedded, with chocolate-colored shale partings. *Plectambonites*, *Rafinesquina alternata*, *Strophomena filitexta*, *Ctenodonta astartiformis*, *Bathyurus spiniger*	10	0
PLATTEVILLE:		
9. Shale, bluish green	0	6
Limestone, argillaceous	0	8
Shale, bluish, with two thin limestone bands. *Orthis subæquata*, *O. tricenaria*, and *bryozoans*	3	0
Limestone lenses	0	3
Shale	0	4
Limestone, argillaceous, with shale partings, 2½ inches	0	10
Shale, bluish green	1	8
Limestone	0	8
Shale, green and brown.	0	6
Limestone	0	5
Shale, dark and carbonaceous	0	2
8. Limestone, massive beds, 10 to 42 inches, thinner on weathered edges; bluish where fresh, buff where weathered	17	0
7. Limestone, bluish, rather massive, weathering to 4 to 8 inches in lower part. *Leperditia fabulites*	5	0
6. Limestone, chocolate brown to bluish, compact and fine grained, containing fine calcite streaks (exposed)	8	9
5. Débris	2	0
4. Limestone—brownish magnesian beds—only top exposed.		
3. Débris	5	0
2. Magnesian limestone, in beds of 12 to 15 inches	7	6
1. Débris, probably overlying shale horizon	2	6
ST. PETER:		
Sandstone, top only exposed in ditch.		
Total	85	9
Total thickness of Platteville	56	9

No. 1 of the above section represents division 1 of the Platteville; Nos. 2, 3, and 4 represent division 2; Nos. 6, 7, and 8 probably belong to division 3, and No. 9 to division 4.

The following section is derived from the most complete exposure of the whole thickness of the Platteville that has been obtained. It was measured in a steep gully on the east side of Grant River just above Burton, Wis.

Section of Platteville limestone near Burton, Wis.

	Ft.	In.
GALENA:		
10. Limestone, hard, fine grained, thin, and wavy bedded, with chocolate-colored shale partings; fossiliferous	10+	0
PLATTEVILLE:		
9. Shale, bluish, with limestone partings and lenses; very fissile toward top; fossiliferous at bottom	3	0
Limestone, light blue	0	2
Shale, blue	0	6
Limestone, blue	0	3
Clay shale, bluish, with hard, thin partings	1	3
Limestone, bluish	0	3
Clay shale, bluish	0	7
Calcareous beds, bluish, not very hard: thin and shaly at top, with fossils and worm trails	1	0
8. Limestone, in wavy beds, 2 to 4 inches thick	4	0
7. Magnesian limestone, in medium heavy beds	5	0
6. Limestone, in very thin, wavy beds	15	0
5. Limestone, in thin, hard beds	3	0
4. Magnesian limestone, in heavy beds, 8 to 14 inches thick, weathering thinner in places and becoming thinner at top	23	0
3. Magnesian limestone, thin bedded	1	0
2. Concealed by bowlders, with traces of shale at bottom	2	3
ST. PETER:		
1. Sandstone, brown, massive, cross-bedded	10	0
Total	80	3
Total thickness of Platteville	60	3

No. 2 represents general division 1 of the Platteville; Nos. 3 and 4 belong to division 2; Nos. 5, 6, and 7 to division 3, and Nos. 8 and 9 to the top division.

The following section is derived from exposures along the Boscobel-Fennimore wagon road at the place where it descends into the valley of Crooked Creek, about 3 miles north of the border of the Lancaster quadrangle.

Section of Platteville limestone in road about 5 miles north of Fennimore, Wis.

	Feet.
GALENA:	
9. Limestone, cherty.	
8. Limestone, fine grained, containing the hemispheric bryozoan of genus *Prasopora*	15
7. Limestone, somewhat crystalline; upper part full of *Orthis* (*Dalmanella*) *testudinaria* and ramose bryozoans	20
PLATTEVILLE:	
6. Shale and limestone bands, full of *Orthis subæquata; Stictoporella* bed prominent	2
5. Limestone, magnesian, in medium beds; *Columnaria halli* at base	12
4. Limestone, thin bedded; *Protowarthia rectangularis*	25
3. Limestone, magnesian	10
2. Shale, thin, sandy	1+
ST. PETER:	
1. Sandstone, massive.	
Total thickness of Platteville	50

At many of the mines in the district the upper member of the Platteville and the lower part of the Galena differ considerably from the sections given above. In general it may be said that the oil rock and the blue shale immediately underlying it are much better developed in the basinlike or productive mineral areas than elsewhere, and it appears that these shales may be entirely absent at some other places.

Stratigraphic relations.—The lithologic features of the Platteville-St. Peter contact and of the Galena-Platteville contact have been shown in foregoing sections. No discordance of bedding has been observed at the base of the Platteville and the contact follows a plane, more or less undulating according to the degree of folding. There is, however, a sharp southward-dipping fold in the southern part of sec. 34, T. 3 N., R. 2 W., or else erosion has there produced an uneven surface of the St. Peter. The field relations of the rocks point to the latter possibility. Other facts regarding the Platteville-St. Peter contact have been given in the description of the latter formation. The delimitation of the upper part of the Platteville has been discussed in the description of the upper member (No. 4) of the generalized Platteville section.

Physiographic expression.—Under favorable conditions a terrace may be developed on the top of the glass rock beds in the Platteville, and one such terrace is well displayed in the valley just below Beetown.

GALENA LIMESTONE.

Thickness and distribution.—This formation was named from the lead ore (galena) which it contains and from its typical exposures at Galena, Ill. It is the most important and the most extensively developed formation within the boundaries of these quadrangles. It forms the country rock of the district, immediately underlying the surface over the whole area except on the mounds and along some of the higher ground about the mounds and southwest of the Mississippi, where the Galena is covered by later strata, and in some of the stream valleys. Many of the streams have cut through the Galena into the Platteville limestone, and at some places even through the St. Peter to the top of the Prairie du Chien. The Galena is not only the thickest formation that is fully exposed in this area, but it also comprises by far the most important ore-bearing rocks in the district. In fact, nearly the whole of the lead ore that has been produced in this region and the main part of the zinc ore has come from the Galena limestone, especially from the lower part of it.

The thickness of the formation within this area averages about 235 feet. At some places, especially in the northern portion of the area, it seems to be thinner, but on account of the lack of continuous exposures and the dip of the rock, exact measurements are not there obtainable. At some places this formation would seem not to exceed 200 feet in thickness. In the vicinity of Hazel Green some drill holes extending to the bottom of the formation indicate a thickness of nearly 250 feet.

Lithologic character.—Lithologically the Galena is a dolomite—a granular, crystalline, coarse-grained, porous rock, which weathers into exceedingly rough, pitted, and irregular forms. As a result of this weathering it breaks down at some places into a coarse, yellow, dolomitic sand. The formation exhibits the same lithologic character everywhere except in its extreme upper and lower parts. As a whole it is massive in appearance; the average thickness of the beds is from 1 to 4 feet. Near the bottom and near the top, however, thinner beds occur. Chert nodules are common in the middle part. At many places very thin seams or partings of clayey material, a little darker in color than the main mass of the dolomite, separate the formation into irregular layers. When unweathered, the dolomite is commonly light bluish gray in color; but in some places, especially in its upper part, it loses the bluish tinge and becomes gray, while in the lower part this bluish shade is at some places intensified. On weathering the dolomite changes to a light yellowish gray, or buff, and in its more weathered parts has a somewhat brownish to reddish color, the exact shade depending on the proportion and the character of the iron oxide present in the residual material. Nearly all the dolomite beds are intersected by joints, which trend and dip at different angles. Many of the joint faces are coated with stalagmite.

The accompanying analyses of selected fresh samples of this rock from several Wisconsin localities will give a general idea of its composition. As these samples include no chert nodules and practically none of the clayey partings nor of the nondolomitic basal material, the average Galena rock would contain a larger proportion of alumina, silica, and lime than is here shown.

Analysis of Galena dolomite from Wisconsin.

[By W. W. Daniels, Bull. Wisconsin Geol. and Nat. Hist. Survey No. 9, 1903, p. 15.]

Calcium carbonate ($CaCO_3$)	54.33
Magnesium carbonate ($MgCO_3$)	41.56
Ferric oxide (Fe_2O_3)	.90
Alumina (Al_2O_3)	.99
Silica (SiO_2)	2.10
	99.88

An analysis of Galena dolomite from eastern Iowa is as follows:

Analysis of lime-burning Galena dolomite from Eagle Point quarry, Dubuque, Iowa.

[By J. B. Weems, Ann. Rept. Iowa Geol. Survey for 1899, vol. 10, 1900, p. 567.]

Water (H_2O)	.02
Insoluble	2.15
Calcium oxide (CaO)	30.72
Magnesium oxide (MgO)	19.90
Carbon dioxide (CO_2)	45.91
Ferric oxide (Fe_2O_3)	.82
Phosphorus pentoxide (P_2O_5)	.60
Organic	.13
	100.25
Dolomite	94.14
Limestone	2.47

Divisions.—The Galena can be separated into five divisions, shown in the generalized section given in the next column.

No. 1 of this section varies considerably in thickness and composition. In the vicinity of the mines this member of the Galena is everywhere present and is more markedly developed than at other places. As a rule this member is thicker in the western part of the district and thinner in the eastern part. A characteristic part of it is the oil rock, described beyond.

Generalized section of Galena formation.

	Feet.
5. Dolomite, earthy, thin bedded	30
4. Dolomite, coarse grained, thick bedded, with little chert	60
3. Dolomite, coarse grained, thick bedded, with much chert	90
2. Dolomite, thick to thin bedded, coarse to fine grained; the lower 15 feet locally a limestone	50
1. Thin, fine-grained limestone and bluish shale interbedded with one or more seams of chocolate-colored carbonaceous shale known as oil rock	2 to 10
Mean total	235

No 2 of the section consists of thin-bedded to thick-bedded dolomite and limestone. The thin-bedded portions (limestone) are at the base, but locally, especially in the eastern part of the district, they are lacking. In the region west of Mineral Point thin beds of highly fossiliferous limestone lie at the base in some places, instead of dolomite beds. Two localities within the eastern half of the area where this member of the Galena is not dolomitic are: (1) Along the road that extends northward from Etna in the E. ½ sec. 11, T. 1 N., R. 1 E.; (2) at an old quarry immediately east of Benton, where also the upper part of this member is only partially dolomitic. This variation in lithology of the basal part of this member may be due to the more extensive dolomitization of these lower beds at certain localities and also to the fact that in certain districts (especially in the anticlinal areas) the thinner limestone beds were not deposited. This member (No. 2) of the Galena marks the horizon at which most of the lead and zinc deposits of these quadrangles are found.

No. 3 of the section is a coarse-grained, porous, thick-bedded dolomite, which carries nodules and layers of chert. These masses of chert range in diameter from a few inches to a foot, and many of them are lens-shaped. They are commonly distributed in layers; in fact at some places the chert is so abundant that layers 1 inch to 3 inches thick can be traced for some distance through the dolomite.

No. 4 of the section is practically like No. 3 but contains no chert. These two members of the section can be best separated in areas along the Mississippi gorge and in adjacent valleys, where nearly the full thickness of the formation is exposed.

No. 5 of the section consists of thinner bedded, earthy dolomite. The beds range in thickness from 2 inches to 1 foot, the thinner beds being near the top. This member is not well exposed at many places in the Mineral Point quadrangle, but may be seen in a quarry near the southeast corner of sec. 23, T. 1 N., R. 2. E., 1½ miles southeast of Shullsburg. Several quarries in the southern portion of the Lancaster quadrangle are working these beds, affording exposures to the base of the Maquoketa shale; for instance, at Fair Play, Wis., in the western part of Dubuque, Iowa, in the valley of the Little Maquoketa above Twin Springs, and in the valley of Middle Fork south of Rickardsville.

Practically the whole thickness of the Galena is exposed at Dubuque, where the following sections have been measured:

Section of Galena formation at Dubuque (Eagle Point), Iowa.

	Ft.	In.
18. Loess-covered slope above the outcropping ledges of Galena dolomite	15	0
17. Ledges of well-dolomitized Galena, varying from 2 to 3 feet in thickness	10	0
16. Two or three rather heavy ledges containing large numbers of *Receptaculites oweni* Hall. This fossil is found sparingly in other members of the section, but at this horizon, the upper Receptaculites zone, it is very abundant	10	0
15. Heavy-bedded, typical Galena; hard, crystalline, and relatively free from chert; in ledges 3 to 6 feet in thickness	70	0
14. Bed containing pockets of calcite, the calcite in some places forming large crystals.	3	
13. Bed containing large quantities of chert	4	0
12. Ledges showing the character of the typical Galena; hard, compact, crystalline, completely dolomitized, with a small amount of chert	18	0
11. Thick, massive beds with a large amount of chert	12	0
10. Thick beds of crystalline dolomite, the ordinary kind	6	0
9. Ledge of varying texture, containing small pockets of calcite and some chert; a single specimen of *Receptaculites* was found in this ledge	4	0
8. Heavy ledge nearly on level with the top of lime kiln	3	0
7. Dolomite, varying in aspect according to degree of weathering; at Eagle Point showing bedding planes 10 to 18 inches apart, a few nodules of flint, and numerous specimens of *Receptaculites oweni*, marking the lower Receptaculites zone	15	0
6. Massive, crystalline dolomite; bedding planes almost completely obliterated	20	0
5. Incompletely dolomitized beds with shaly partings at intervals of 6, 8, or 10 inches	10	0
4. Limestone, earthy, incompletely dolomitized	2	0
3. Oil rock, carbonaceous shale, weathering to brown, earthy matter	0	3
2. Thin-bedded, brittle, nonmagnesian limestone in 2-inch or 3-inch layers with irregular clayey partings	3	0
1. Shales, green, argillaceous, many fossils, among them the characteristic lower Galena species *Dinorthis pectinella*; exposed	3	0

Above the beds represented in this section lies a considerable thickness of limestone, as shown in the following section:

Section of Galena formation at Dubuque (Hill street), Iowa.

	Feet.
2. Thin-bedded Galena limestone, earthy, noncrystalline; the layers ranging from 10 to 12 inches near the base to less than 3 inches in thickness near the top; upper part of this member very shaly; carries as fossils *Lingula iowensis*, *Liospira lenticularis*, and *Conularia trentonensis*.	30
1. Well-dolomitized Galena in layers ranging from 1 to 2½ feet in thickness; with softer beds near the middle, which at some places disintegrate so as to form caverns; only the basal part of this member is represented above the Receptaculites beds at Eagle Point	30

These beds, forming No. 2 of this last section, are fairly representative of the uppermost portion of the formation. They are thin bedded, earthy, soft and noncrystalline. Dolomitization is imperfect. The layers range from 3 to 10 or 12 inches in thickness, the thicker beds being near the base and the layers becoming progressively thinner toward the top. Shaly partings between the strata are more common in this division than elsewhere in the formation; indeed, the thickness of the bands of shale in the upper part becomes equal to the thickness of the alternating layers of limestone. In the very upper part, as a matter of fact, the limestone is at some places reduced to mere rows of disconnected nodules embedded in clay. This member of the Galena is overlain directly by the Maquoketa shale. Its thickness is somewhat variable, but averages about 30 feet. The division is not definitely separated by any well-marked line from the member below. It contains beds of fairly good quarry stone toward the base; the calcareous bands and nodules of the upper part are practically worthless.

Oil rock.—The material here called oil rock is a finely laminated brown to black shale. It is commonly of a dark-chocolate color. When burned it gives off an odor of petroleum, and it is from this that it is named. The shale contains fragments of slightly harder rock in a matrix of softer material. These fragments show fracture and are bent and broken, while the soft material has evidently been squeezed in between the fragments. Particularly striking examples of this structure were seen at the Hoskin mine, near Hazel Green. In the blue clay bed beneath the main oil rock there are numerous small, black, rounded, pebblelike bodies, which are made up of phosphate of lime. Since they include pieces of fossils it is supposed that they either represent fossils themselves or are concretionary masses derived from them.

The typical oil rock is one of the most interesting materials found in the region, and its significance in relation to the ore deposits warrants the following rather full description. Chemically it consists of impure limestone impregnated with organic matter. Partial analysis of this material showed contents of "carbonaceous" matter of 40.60 per cent, 18.31 per cent, and 15.76 per cent. Recent tests of material from the Dugdale prospect west of Platteville show a content of 20.85 per cent of volatile matter and 7.95 per cent of true carbonaceous material, in thoroughly air-dried shale. Leaching the shale with ether gave a thick, heavy oil, which is doubtless the most important element in the volatile matter and which contains an appreciable amount of sulphur.

This oil rock closely resembles the torbanite of Scotland, central France, and New South Wales. These foreign deposits are an important source of certain illuminating gases, particularly desirable for train service and other uses requiring compression, and of oil for enriching ordinary gas. In the Wisconsin districts some experiments looking toward the use of the oil rock as a source of gas have been undertaken but not yet concluded.

The significance of the oil rock in relation to the ore deposits of these quadrangles lies in its capacity to furnish a large amount of material that is especially well suited to precipitate metallic salts as sulphides. It is very porous and light, having a specific gravity of only 1.98 and yielding gas bubbles when placed in water. One volume of the rock gave 57.46 volumes of gas when heated to a red heat in a vacuum for two hours. A gas analysis of this material gave the following results:

Analysis of gases derived from carbonaceous shale (oil rock) of the Galena formation.

[By Rollin Chamberlin.]

Hydrocarbon vapors	11.11
Heavy hydrocarbons	4.00
CH_4	35.98
H_2S	6.79
CO_2	18.12
CO	8.40
O	0.26
H_2	13.18
N_2	2.21
	100.05

Under the term hydrocarbon vapors are grouped various hydrocarbons which are liquid at ordinary temperature and soluble in alcohol; benzine may be taken as a type. They contain more than 6 atoms of carbon per molecule. The heavy hydrocarbons are gases such as ethylene, acetylene, and their analogues.

A microscopic examination of thin slides of the oil rock shows that it is made up largely of minute, flattened, generally oval and discoid, translucent bodies of a brilliant lemon-yellow color, which are highly refractive, the refringence being 1.619. These yellow bodies vary from 8 to 62 microns in horizontal diameter and from 5 to 20 microns in vertical diameter. Many of them are lenticular and irregularly rounded at the edges, but most of them are nearly oval and, in vertical section, seen to be horizontally matted with other sediments and with crystals of later formation, precisely like forest leaves beneath the winter snow.

The larger of the yellow bodies include a number of horizontally oval forms that are characterized by a narrow and usually obscure marginal ring, and by a small, roundish, or slightly irregular, denser and often darker colored mass near the center. These forms, which average about 8 microns in length and 5 microns in width, are suspended in the translucent yellow bodies. In contour they resemble collapsed and flattened unicellular plants, the outer ring representing the cell boundary, the inner, denser portion, the residual contents of the cell, whose original envelope is preserved as the bright, lemon-colored, environing mass. The smallest yellow bodies appear to have contained a single oval, the larger ones, several. The yellow bodies are, therefore, regarded as the fossil remains of microscopic unicellular algæ, apparently comparable to the living *Protococcales.*

The oil rock owes its volatile hydrocarbons to these fossil algæ, which locally comprise over 90 per cent of the mass of the rock. It is thought that these algæ were originally floating forms which accumulated in large numbers on the bottoms of shallow basins in early Galena time. These deposits were originally thicker than now, their thinning being due to actual compression and to the loss of some of the volatile hydrocarbons. As these gases passed upward into the other beds of the Galena limestone they probably played an important part in the precipitation of the lead and zinc deposits of this district.

Fossils and correlation.—Some beds of the Galena contain abundant organic remains, but the main body of the dolomite carries few recognizable fossils. Locally, however, where the basal limestone and shale were deposited, as shown in the first two sections of the Platteville limestone given in the description of that formation, they are highly fossiliferous, and contain a number of brachiopods and pelecypods, viz, *Orthis tricenaria*, *O. pectinella*, *O. testudinaria*, *Plectambonites sericea*, *Leptæna charlottæ*, certain varieties of *Rafinesquina alternata*, and *Strophomena incurvata*. In such places certain fossils, viz, *Orthis tricenaria*, *Ctenodonta astartiformis*, and *Vanuxemia niota* are more or less common, and, except the first, which occurs also in the Platteville, are highly characteristic of this horizon.

Over a large part of the two quadrangles the basal 3 or 4 feet of the Galena comprise a thin bed of fine-grained limestone containing *Rafinesquina*, *Ctenodonta*, and most of the other fossils just mentioned, and, in addition, a very large variety of *Ceraurus pleurexanthemus*. Bryozoa are practically absent from this bed, but along the northern edge of the Lancaster quadrangle they are abundant in corresponding strata.

The remains of a peculiar organism known as *Receptaculites oweni* Hall, commonly called "the lead fossil" and "the sunflower coral," occur somewhat rarely throughout the Galena above the basal member. There are, however, two important strata in which these remains are especially abundant. These strata are from 1 to 4 feet thick and afford a ready means of determining the horizon in the Galena of outcrops in which they occur. The lower stratum occurs from 35 to 50 feet above the base of the formation. In other words, it marks rather closely the separation between Nos. 2 and 3 of the generalized section, the first chert in the formation being at this horizon, or just a few feet above or below it.

The lower Receptaculites horizon is exposed at a number of places in the east half of the district. It may be seen (1) at the small quarry on the west side of Roundtree Branch, just south of the Chicago and Northwestern Railway trestle at Platteville; (2) at places along the east side of the road north of Etna, in E. ½ sec. 11, T. 1 N., R. 1 E.; (3) at several places along the streams north of Dodgeville; (4) at a quarry on the south side of the road near the southeast corner of sec. 8, T. 1 N., R. 2 E., 2 miles west of Shullsburg; (5) at Darlington, near the top of the fourth section given in the description of the Platteville limestone.

The upper horizon of these fossils is about 60 feet below the top of the Galena, or 30 feet below the top of division 4, and it is even more distinct than the lower horizon. As exposures of this part of the formation are more common in the Lancaster than in the Mineral Point quadrangle, the bed marking this horizon may be seen at many places in the western part of the area. What is probably this bed occurs in a small quarry along the west side of the road in E. ½ sec. 3, T. 1 N., R. 2 E., southeast of Shullsburg. It is exposed near the top of the quarry at Eagle Point in Dubuque, at the Julien avenue quarry and other openings in West Dubuque, and at many places along the bluffs of the Mississippi and of the Little Maquoketa and its branches.

A few specimens of a brachiopod of the genus *Lingula* are found in the Galena at some places but more especially in the upper thin-bedded parts—that is, in No. 5 of the generalized section. The two horizons of *Receptaculites* just described, however, furnish the principal evidence derived from fossils found in the Mineral Point quadrangle for the separation of the main body of the Galena into different horizons.

The Galena and the Platteville form a thick dolomite-limestone series, which is of much importance in the upper Mississippi Valley. The lithologic features of the two formations here described are those which are common to the lead and zinc district. Outside of this district the characteristics vary somewhat, and toward the west the Galena becomes less dolomitized, especially in its lower part.

In the lead and zinc district the Platteville, commonly known as "Trenton" in the reports on this district, is essentially a nondolomitic formation, while the Galena is a dolomite. If this lithologic distinction should be used as a means of separating these formations in areas lying farther west the thickness of the Platteville would be there greatly increased. Recent work, however, has shown that the Platteville is a well-defined formation of comparatively uniform thickness, possessing distinctive faunal characteristics; that, at least locally, it is separated from the Galena by a period of nondeposition; and that in certain localities, especially at places west of the Mississippi, the Galena is in considerable part nondolomitic.

Physiographic expression.—The beds in divisions 3 and 4 of the generalized section constitute the characteristic part of the Galena. Although the Lancaster peneplain is largely developed within this part of the formation, the character of the rock has probably had only a moderate influence on this portion of the topography. In that part of the area that lies southwest of Potosi, however, the hard, heavy beds of dolomite stand at such an elevation with respect to the Mississippi base-level that erosion has produced in them the rugged walls, crags, and "towers" that are so prominent about the middle height of the bluffs. These features, which make the city of Dubuque and the surrounding region so picturesque, are well displayed to travelers on the river steamers and on the railroads that follow the Mississippi gorge or approach it through tributary valleys. The precipitous sides and sharp angles of these striking products of erosion are due to the breaking down of the rock along joint planes.

MAQUOKETA SHALE.

Thickness and distribution.—Upon the Galena dolomite lies a shale formation, which has been described in reports of the Iowa Geological Survey under the term Maquoketa, a name derived from Little Maquoketa River, on which it is typically exposed. The same formation is known in the Wisconsin State reports as the Cincinnati shale. This shale is confined to the higher land of the quadrangles, and occurs in its complete thickness only where it is overlain by later limestone. The most extensive tract underlain by the Maquoketa shale is southwest of Mississippi River, but it covers also a number of square miles of high land near the southern edge of the area, south and southeast of Shullsburg. Other scattered areas are at and near Hazel Green, at Sinsinawa Mound, at the Platte Mounds, and on a small hilltop 4 miles east-northeast of Mineral Point.

The shale ranges in thickness from 160 to 200 feet, and in the region south of this area is more than 200 feet thick. The minimum thickness appears to be less than 160 feet, especially at the Platte Mounds, but this may be due to the fact that the heavy limestone above has settled down and the shale has been lessened in thickness by squeezing out. Records of wells in Dubuque County, Iowa, which have passed completely through the formation give thicknesses of shale ranging from 175 to 225 feet, most of them showing from 195 to 200 feet. According to the testimony of experienced drillers, the transition from the overlying beds to the Maquoketa and from the Maquoketa to the underlying beds is everywhere sharp and easily recognized by the driller. The beds are practically flat, and the evidence furnished by drill records is therefore probably reliable. The base of the formation is generally very well exposed in this portion of the area, and, although the top is not everywhere so distinct, wherever barometric measurements were made of its full thickness the Maquoketa shale reaches 195 feet or more. This shale is nowhere exposed to any considerable thickness in the Mineral Point quadrangle.

The base of the Maquoketa is important to miners, since it marks the top of the Galena and indicates within a few feet the depth to which a drill must be sunk to reach the bottom of the ore-bearing horizon. Partial exposures of the base of the formation occur at a few places east of the Mississippi, and are mentioned below in the section devoted to fossils. Other but rather poor exposures occur (1) on the Chicago and Northwestern Railway about a quarter of a mile south of the crossing of this road and the Chicago, Milwaukee and St. Paul Railway between Platteville and Belmont; (2) on the road in the NE. ¼ sec. 22, T. 1 N., R. 2 E., 2 miles south of Shullsburg; (3) in several small valleys heading on the slopes of Sinsinawa Mound, especially at the point where the north-south road crosses the hollow about one-half mile west of the mound; also in prospect pits between Fair Play and Louisburg.

As a rule, where the Maquoketa is thin, it is so deeply covered by soil or loess that outcrops are difficult to find, and its presence must be determined by the character of material passed through in drill holes, wells, or prospect pits. On the ridges near Mississippi River and in the middle portion of the valley of Little Maquoketa River the shale is not present. Many of these ridges stand so high above the base of the Galena limestone that they should apparently be capped with shale, but careful search for outcrops and débris, together with a study of all obtainable well records and the testimony of the men by whom the wells were drilled, have shown that in place of shale above the top of the Galena there is a deposit of silt or loess, 40 to 60 feet thick. (See fig. 2.) The upper limit of the shale is likewise very obscure.

Lithologic character.—The Maquoketa shale in this area can be arranged roughly into the three characteristic divisions described below:

General divisions of Maquoketa shale.

	Feet.
3. Argillaceous and calcareous shale, in beds becoming thicker and possibly dolomitic toward the top, about	35
2. Plastic blue and green shale and clay, with some indurated fossiliferous bands near the top, about	100
1. Drab and blue, thin-fissile shale, interbedded with thin layers of fossiliferous argillaceous limestone; near base is a thin, hard conglomerate of fine chert and phosphatic pebbles in a ferruginous matrix	60

The shale disintegrates rapidly and is therefore largely concealed by products of decay and by vegetation. Continuous vertical sections of any considerable thickness are to be found only along some stream which is still vigorously scouring its bed, or in gullies that have cut deeply into the shale. A good section of division 1 of the Maquoketa, from its contact with the Galena to the plastic clay shale of the overlying member, is exposed along the road that follows the ravine westward from the Little Maquoketa in the southern part of sec. 20, T. 89 N., R. 1 E. (Center Township).

Section of lower part of Maquoketa shale in Center Township, Dubuque County, Iowa.

	Ft.	In.
MAQUOKETA:		
30. Clay shale, plastic, blue and green, concealed by slope above.		
29. Shale, yellowish, weathering to plastic clay	1	0
28. Hard yellow bed	0	3
27. Shale, laminated, fissile, yellow	2	0
26. Shale, dark drab, nonfissile; a few small specimens of *Orthoceras*	0	3
25. Shale, fissile, slaty, bluish, weathering yellow	0	6
24. Hard calcareous bed, yellow, nonlaminated; *Murchisonia gracilis* and numerous small specimens of *Lingula*	3	0
23. Shale, drab, slaty; minute *Coleolus iowensis; Orthoceras sociale;* fragments of *Calymene mamillatus;* small gasteropods	2	0
22. Shale	1	0
21. Bed similar to No. 12; many *Orthoceras sociale*	1	0
20. Shale, slaty, fissile, dark gray; *Spatiopora iowensis*	9	6
19. Bed lithologically similar to No. 12 and containing *Orthoceras sociale* in great abundance and well preserved	0	6
18. Shale, dark gray	0	2
17. Bed similar to No. 12; *Orthoceras sociale*	0	10
16. Shale, thin, irregular, dark and fissile	0	2
15. Bed similar to No. 12; *Orthoceras sociale*	0	10
14. Shale, drab and fissile	0	3
13. Shale, nonlaminated; *Murchisonia gracilis*	0	3
12. Hard layer, earthy, slightly calcareous, light brown and nonlaminated; crowded with imperfect *Orthoceras sociale*, some of which retain original nacreous luster	0	6
11. Shale, brown, fissile, fossiliferous	1	0
10. Shale, earthy, granular, nonlaminated; *Coleolus iowensis, Murchisonia gracilis, Liospira micula*	2	0
9. Shale, brown, fissile; species of *Lingula* three-eighths of an inch long by one-quarter of an inch wide	2	0
8. Shale, earthy, fossiliferous	0	2
7. Shale, blue, slaty; *Leptobolus occidentalis* and two species of *Lingula*	1	2
6. Shale, hard, yellowish	0	3
5. Shale, laminated; *Lingula* one-half of an inch long and three-eighths of an inch wide	13	0
4. Shale, bluish and drab, laminated; traces of graptolites and numerous *Leptobolus* and *Lingula* in lower part	8	0
3. Shale, bluish, laminated, nonfossiliferous	8	0
2. Shale of variable color and texture, generally nonlaminated and coarse; small species of *Orthoceras, Liospira micula, Pleurotomaria depauperata, Hyolithes parviusculus, Cleidophorus neglectus, Ctenodonta fecunda*	2	0
GALENA:		
1. Limestone, very thin at top, exposed in vertical bank of Little Maquoketa	15	0
Total exposure	76	7

Exposures of the middle division of the Maquoketa are rather rare, but occasionally the plastic clays are laid bare temporarily by heavy rains and may be seen in gullies that cut across the gently sloping hillsides. The upper shale beds and the Niagara-Maquoketa contact are exposed at the heads of several deep gorges in Concord and Iowa townships. In NW. ¼ sec. 9, T. 90 N., R. 1 W., about 2 miles northeast of Holy Cross, the following section occurs:

Section of upper part of Maquoketa shale near Holy Cross, Iowa.

	Feet.
NIAGARA:	
5. Dolomite, pitted, grayish buff, in overhanging ledge; very massive at bottom	10
MAQUOKETA:	
4. Argillaceous, calcareous, jointed beds, 2 to 6 inches thick, smooth, fine grained, weathering yellowish gray; possibly slightly magnesian at top	10
3. Shaly and slabby argillaceous beds	20
2. Argillaceous rock, blue, weathering to grayish yellow; massive and jointed, breaking into blocks which split into slabs 1 inch thick	5
1. Clay shale, soft, laminated, blue-green	6
Débris, mainly from overlying formation; some Kansan bowlders.	

No. 5 of the above section is clearly Niagara, and the upper surface of the Maquoketa is possibly represented by No. 4. It is only in such situations—that is, under waterfall escarpments, or in drill records—that the true top of the Maquoketa can be determined, since the slopes below the Niagara plateau are usually strewn with huge blocks and débris of the overlying dolomite.

Physiographic expression.—In the Iowa portion of the Lancaster quadrangle the area of the shale is characterized in the landscape by gracefully rounded swells and long gentle slopes. These slopes, gently rolling and cultivated, are bounded above by the forested declivities of the Niagara escarpment and below by the steep bluffs of Galena limestone, especially where the base of the latter is washed by the Mississippi and the Little Maquoketa and its forks. In Wisconsin the Maquoketa slopes are well exhibited on the flanks of Sinsinawa, Platte, and other mounds, but otherwise, in the southern part of the area, where forming the Lancaster peneplain, the formation is not distinguished by any topographic feature.

Fossils and correlation.—The Maquoketa shale in general throughout the upper Mississippi Valley forms a markedly fossiliferous horizon. There is at the very base of the formation a thickness of 2 to 5 feet of shale which contains rather abundant fossils. East of the Mississippi fossils are seen at this horizon at many places, especially along roadsides. These fossils remain after the rest of the rock has weathered away. They are found: (1) in a few of the gullies running down from the Platte Mounds; (2) along the east-west road through the center of sec. 18, T. 3 N., R. 1 E., about 3 miles east of Platteville; (3) along the road that marks the boundary line between Wisconsin and Illinois near the southeast corner of sec. 36, T. 1 N., R. 1 W., about 2 miles south of Hazel Green; (4) in débris from a shallow well in the northeast part of the town of Hazel Green; (5) in débris from a cistern at the first house on the north side of the road east of Little Platte Mound; and (6) in débris from a test pit in NW. ¼ sec. 6, T. 1 N., R. 1 W.

In this fossiliferous zone at the base of the Maquoketa the following forms occur, all small and generally preserved as casts of the interior: A cephalopod of the genus *Orthoceras;* a pteropod, *Hyolites parviusculus* Hall; two gasteropods, *Liospira micula* Hall and *Pleurotomaria depauperata* Hall; and two pelecypods, *Cleidophorus neglectus* Hall and *Ctenodonta fecunda* Hall. West of the Mississippi, except along the bluffs immediately bordering the river, there is seldom any difficulty in recognizing this horizon.

At the top of the formation there is another horizon, more frequently exposed, that affords fossils, at some places in great abundance. The thin plates of limestone and apparently the intercalated shale as well are in many places highly magnesian, and the fauna itself is altogether different from the one at the base of the formation. The following species collected near the tops of the mounds 2 to 4 miles south of Shullsburg are characteristic of these beds:

Monotrypella quadrata.	Dinorthis subquadrata.
Monotrypa rectimuralis.	Platystrophia acutilirata var.
Heterotrypa singularis.	Rhynchotrema capax.
Plectambonites saxea.	Rhynchotrema perlamellosa.
Leptæna unicostata.	Rhynchotrema neenali.
Plectorthis whitfieldi.	

This association of species indicates that the beds are of Richmond age.

Stratigraphic relations.—Definite evidences of stratigraphic unconformity or of an erosion interval at the base of the Maquoketa have not been observed during the survey of this area. The change from the dolomite beds of the Galena to the shale is fairly abrupt, and mention has been made of a small conglomerate that occurs locally in the basal shale, but the sedimentation planes on the two sides of the contact line are parallel, as far as seen. The evidence, so far as it goes, does not indicate any marked physical break between the formations, although the fossils would indicate a period of nondeposition.

Upon the Maquoketa lies a heavy magnesian limestone of the Niagara, whose basal layers apparently rest concordantly on the magnesian upper Maquoketa beds where these are present. Here the lithologic change is less abrupt than at the bottom of the formation; nevertheless, the evidence furnished by fossils indicates a hiatus. There is also some evidence that the topmost fossiliferous Maquoketa beds are not everywhere present, this fact suggesting that erosion has actually occurred.

SILURIAN SYSTEM.

NIAGARA LIMESTONE.

Distribution and thickness.—This is the only Silurian formation that occurs within these quadrangles. The total outcrop of this formation east of the Mississippi within the quadrangles does not exceed a square mile in area. It is exposed here at only three places: (1) On the top of the Platte Mounds, (2) on the top of three mounds south of Shullsburg, and (3) on the top of Sinsinawa Mound. That part of the Lancaster quadrangle which lies west of the Mississippi includes a small portion of the eastern edge of the area of Silurian rock that outcrops throughout seven or eight counties of eastern Iowa. The area underlain by Niagara limestone in the Lancaster quadrangle comprises more than 30 square miles of the upland, principally in Buena Vista, Concord, Iowa, and Center townships, although some of this is thinly covered by scattered patches of glacial drift. Undoubtedly at one time the Niagara extended over the whole of both quadrangles, but erosion has removed all but the remnants just mentioned.

The total original thickness of the formation is doubtless nowhere represented in these quadrangles. Good exposures occur on the west Platte Mound, where a thickness of over 100 feet of the lower part of the Niagara limestone is visible, and there may be a greater thickness than this, for the lower portion of the formation is not exposed. Between 100 and 150 feet of this rock remain near the eastern margin of the plateau, but on the outlying mounds its thickness is usually much less than this. Beyond the limits of the area its thickness is greater, aggregating 220 feet in the southwest corner of Dubuque County, Iowa.

On all the Maquoketa shale slopes between the Niagara escarpment and the top of the Galena, but particularly on the upper part of the slopes, lie large masses of the basal Niagara beds. They may occur in trains that are parallel to the ridges and may exhibit all stages of weathering and of progress down the slopes, clearly illustrating the great extent to which the dolomite may be displaced as a result of the disintegration of its insecure foundation. An extreme case has been noted in the valley of the Little Maquoketa, near Twin Springs, where a large mass of Niagara limestone became detached from its bed, crept down the entire Maquoketa slope and tumbled over a 60-foot cliff of Galena into the stream below. Masses of the dolomite 100 feet or more in height have settled down many feet below their normal level, and at Sinsinawa, Sherrill, and other places quarries have been opened in these settled blocks. Bodies of dolomite 50 feet or more in thickness and one-half mile long which cap ridges or mounds appear in certain places to have caused the underlying plastic beds of the Maquoketa to flow out under their great weight, allowing the dolomite to settle evenly without any apparent displacement.

The scarcity of exposures of the actual Niagara-Maquoketa contact and the frequency of displacement of the dolomite beds has made the determination of the true position of the base of the formation difficult, and has heretofore resulted in slight inaccuracies of mapping and the assignment of much too small a thickness to the Maquoketa shale. Another source of error has been the assumption that certain springs, which to outward appearance emerge at the top of the shale, represent its true top. As a rule such springs make their appearance below that horizon, many of them at the top of division 3 of the general section of the Maquoketa; although well back in the plateau country, where the formations occupy their normal relations, the base of the Niagara is a water-bearing horizon.

Lithologic character.—The Niagara is mainly a light-gray to light-buff, fine- to medium-grained dolomite. It comprises both thick and thin beds, and at certain horizons considerable chert, in the form of nodules and interrupted layers. The following analysis of this rock from Sherrill Mound represents fairly well its chemical composition:

Analysis of Niagara limestone from Sherrill Mound, Iowa.

[By J. B. Weems, Ann. Rept. Iowa Geol. Survey for 1899, vol. 10, 1900, p. 567.]

Water (H_2O)	0.05
Insoluble	3.24
Calcium oxide (CaO)	30.01
Magnesium oxide (MgO)	18.99
Carbon dioxide (CO_2)	44.91
Ferric oxide (Fe_2O_3)	0.74
Phosphorus pentoxide (P_2O_5)	0.52
Organic	1.34
	99.80

A generalized section of that portion of the Niagara which is exposed within the area under discussion may be expressed as follows:

Generalized section of Niagara limestone in Lancaster and Mineral Point quadrangles.

	Feet.
5. Dolomite, hard, massive, compact to coarse grained, containing some chert; characterized by casts of a large-sized brachiopod *Pentamerus oblongus;* "Pentamerus beds" of Iowa geologists. Top not exposed	25
4. Dolomite, light buff to dark gray, in beds of varying degrees of hardness; generally rough weathering; characterized by several silicified corals, chiefly *Syringopora tenella;* "Syringopora beds" of Iowa geologists	65
3. Dolomite, coarse grained, in uneven thin layers, interbedded with a large amount of chert; "chert beds" of Iowa geologists	25
2. Dolomite, light gray to cream color, fine grained, in beds from 8 to 24 inches thick; somewhat cherty in upper part; "lower quarry beds" of Iowa geologists	20
1. Dolomite, light gray to buff, in heavy, rough-weathering beds, which become slightly laminated in upper part; "basal beds" of Iowa geologists	15
Total exposed	150

The beds most conspicuous in this area are those of No. 1, which are commonly exposed at or below the base of the formation on the mounds and ridges. These basal beds tend to split along lamination planes into relatively thin slabs, but the cohesion of the layers is still so strong that thick masses that have been broken off, tilted, or, as at many places, greatly displaced by the undermining and weathering of the softer Moqueketa shale are not disintegrated.

Above the section of the upper Maquoketa near Holy Cross, Iowa, already given, there is exposed in the ravine in the NW. ¼ sec. 9, T. 90 N., R. 1 W., about 50 feet or more of weathered Niagara beds, which gave the following section:

Section of lower part of Niagara limestone near Holy Cross, Iowa.

	Ft.	In.
8. Dolomite, weathering to thin beds, 1 to 4 inches, rarely 5 to 6 inches, containing considerable chert	8	0
7. Dolomite, or "cotton rock," yellowish white, in beds 4 to 6 inches thick; upper part quarried and showing small band of chert	13	6
6. Dolomite, cherty, in irregular beds 3 to 4 inches thick	3	0
5. Dolomite, cream colored, fine grained, in thin, wavy beds 1 to 5 inches thick, weathering to clay on bedding planes; little or no chert	10	0
4. Dolomite, yellowish, coarse grained, in beds 4 to 6 inches thick; weathers to pitted surface	5	6
3. Dolomite, in beds 2 to 6 inches thick; carries a little chert	3	0
2. Dolomite, grayish, in beds 6 to 8 inches thick, with much chert on bedding planes	4	0
1. Dolomite, grayish buff, with rough, pitted surface, in 2 massive beds, the upper of which weathers slightly thinner in upper part; stromatoporoid corals	10	0

Exposures of the higher divisions of the Niagara section are rare in this area and their presence is mainly deduced from residual material on the tops of mounds and on the plateau. These divisions and others still higher have been defined by the Iowa geologists in surveys of Delaware and Dubuque counties. Dark reddish clay and abundant chert constitute the characteristic products of the disintegration of this formation.

In its general features the Niagara resembles the Galena, but may be distinguished from that formation not only by its stratigraphic position and its fossil contents but by the following criteria: (1) The lithologic character of the strata composing the Niagara is not so persistent or homogeneous as that of the strata forming the Galena, since beds of the Niagara that occupy the same stratigraphic level differ more or less at different localities; (2) the color of the Niagara inclines a trifle more to a straw shade than that of the Galena, which is prevailingly gray; (3) the Niagara strata are more thinly laminated and their weathered surfaces are not in general so carious or pitted as those of the Galena; and (4) chert occurs in the Niagara in greater abundance and in larger masses and is more highly fossiliferous than in the Galena; it is also harder, of a finer grain, and at most places of a lighter color than the older chert.

Physiographic expression.—In connection with the softer underlying shale the resistant dolomite and chert beds of the Niagara give to the region its crowning topographic features, viz, the mounds and the Niagara plateau and escarpment, described under the heading "Topography of the quadrangles." In fact, the distribution of this formation is so directly related to the topography that its presence may usually be recognized in a very casual survey of the landscape. The Niagara is not so much a cliff-forming rock as the Galena, owing to its position high in the section, but in the area under discussion it forms many small but picturesque towers and buttresses, and farther west, in Dubuque and Delaware counties, some cliffs of this rock reach a height of 80 feet. On the level surface of the plateau north and south of Holy Cross sink holes are of common occurrence. These sink holes are apparently in line with ravines that develop farther out toward the edge of the plateau, and were probably caused by solution of the dolomite. Some of these sinks have been utilized by farmers as water reservoirs.

Fossils and correlation.—The organic remains found in this formation in these quadrangles are not very abundant, but on the top of the west Platte Mound and on Sherrill Mound three compound corals—*Halysites catenulatus* Linnæus, *Favosites favosus* Goldfuss, and *Favosites niagarensis* Hall—occur rather commonly, as well as many casts of a brachiopod, *Pentamerus oblongus* Sowerby. These casts are found in the chert masses, which are loose and probably originally lay at a horizon higher than that of the corals mentioned, these being found also in place in the dolomite.

Samuel Calvin, State geologist of Iowa, applied, in 1896, the name Delaware limestone to the equivalent Silurian rocks in that State. Last year he proposed Hopkinton limestone instead of Delaware, as that name was found to be preoccupied. It has been thought advisable to continue in the reports of the U. S. Geological Survey the use of the well-known New York term Niagara until more exact information respecting the stratigraphic relations of the Silurian rocks in the upper Mississippi Valley to those in New York is available.

Stratigraphic relations.—The Niagara overlies the Maquoketa shale in apparent stratigraphic concordance, as has been stated, although certain suggestions of a hiatus in deposition and of pre-Niagara erosion have been observed. Long-continued preglacial erosion and decay removed some of the upper beds of the Niagara in this vicinity, and consequently the Quaternary deposits—glacial till and loess—rest unconformably on the Niagara.

QUATERNARY SYSTEM.

Within this area there are no deposits intermediate in age between the Silurian and the Quaternary, except, possibly, some gravels of probable Tertiary age, reported to occur at a few localities in adjacent areas but not observed within these quadrangles. Such gravels occur in small and thin deposits, dating from about the time of the completion of the peneplain of this district.

The deposits later than the gravels may be grouped under six heads: Residual soil, Kansan drift, loess, terrace deposits, travertine, and alluvium.

RESIDUAL SOIL.

The residual soil of this area is produced by the decay in place of the underlying rocks. The most widespread formation of the district—the Galena—consists principally of a mixture of calcium carbonate and magnesium carbonate, but with these are mingled certain impurities. These impurities are chiefly three substances: (1) Quartz, (2) oxide (and probably carbonate) of iron, (3) clay. The two carbonates in the limestone are dissolved and carried away by percolating waters during the process of weathering, while the impurities of the rock usually remain. The chemical composition and the relative percentages of the components of the rock and those of the soils thus differ materially. Chemically the soils contain a large percentage of silica, derived, first, from the chert, which is abundant in the limestone, and second, from the clay, which is a hydrous aluminous silicate.

The analysis of the Galena dolomite already given shows that it contains nearly 96 per cent of soluble material (calcium and magnesium carbonates), which is practically all carried away in the complete weathering of the rock to soil, and only 4 per cent of impurities, which mostly remain in the soil after the removal of the above carbonates. The samples analyzed contained no chert nodules, which are abundant in some parts of the dolomite, and no noticeable clayey laminæ, so the average rock of the formation would comprise considerably more silica and alumina than is shown by this analysis.

The accompanying analyses of residual clays from this district exhibit their general composition:

Analyses of residual clays.

[Analyses 1-4 by R. B. Riggs, Sixth Ann. Rept. U. S. Geol. Survey, p. 250, analyses 5-6 by S. V. Peppel, Bull. Wisconsin Geol. and Nat. Hist. Survey No. 7, pt. 1, 1901, p. 273.]

	1	2	3	4	5	6
SiO_2	71.13	49.59	53.09	49.13	70.48	70.79
Al_2O_3	12.50	18.64	21.43	20.08	13.26	12.87
Fe_2O_3	5.52	17.19	8.53	11.04	4.20	4.50
FeO	.45	.27	.86	.93		
TiO_2	.45	.28	.16	.13	.50	.50
P_2O_5	.02	.03	.03	.04		
MnO_2	.04	.01	.03	.06	Trace.	Trace.
CaO	.85	.93	.95	1.22	.81	.98
MgO	.38	.73	1.43	1.92	1.11	.88
Na_2O	2.19	.80	1.45	1.33	1.18	1.52
K_2O	1.61	.93	.83	1.60	1.84	2.26
H_2O	4.63	10.46	10.79	11.72	6.98	5.93
CO_2	.43	.30	.29	.39		
C	.19	.34	.22	1.09		
	100.39	100.50	100.09	100.68	100.36	100.23

Nos. 1 and 2 are analyses of samples from the same vertical section, the first being taken 4½ feet and the second 8½ feet from the surface, the latter in contact with the underlying dolomite; Nos. 3 and 4 are related in the same way, the sample for the former being taken 3 feet from the surface and that for the latter 4½ feet, in contact with the underlying rock; Nos. 5 and 6 are analyses of samples taken from a brickyard at Platteville.

The residual soil in the area varies considerably in thickness from place to place. It is thicker on the hilltops and in the bottoms of the valleys, and thinner on the slopes; and at some places it is entirely absent, as on the bare rocky ledges along some of the valley sides. Its maximum thickness noted is 70 feet. Its average thickness as determined by 1800 measurements, is 7.08 feet. About 1000 measurements on slopes gave an average of 4.61 feet, and 219 measurements on broad uplands gave an average of 13.55 feet.

When the chemical composition of the original rock is compared with that of the soil derived from it and the thickness of this soil is considered it is readily seen that the amount of soil now present at any locality represents a very great thickness of rock—just how great a thickness it is impossible to say without complete analyses, but the data at hand afford ground for a good general estimate. The analyses given show that the carbonates of lime and magnesia have practically disappeared from the soil. These carbonates make up probably 90 per cent of the original rock. From some residual soils that have been carefully studied, over 97 per cent of the original limestone has been removed by weathering; in other words, a present thickness of 3 feet of soil would represent an original thickness of 100 feet of rock. In this district, assuming that 90 per cent of the rock has been removed by weathering, a thickness of 10 feet of soil would represent an original thickness of 100 feet or more of rock. As the numerous measurements already quoted show that the soil has an average thickness of about 13½ feet on the broad uplands, it is clear that a vertical thickness of at least 100 feet of rock has slowly disappeared from this district by weathering.

KANSAN DRIFT.

Distribution and character.—Although most of the area of the Lancaster and Mineral Point quadrangles lies outside of the district covered by the North American ice sheet, a small portion of the former quadrangle falls within that district and contains glacial deposits (drift). These are commonly of unassorted material (till) deposited directly by the ice.

These deposits have already been so thoroughly studied as a whole that duplication of work on them was avoided in the present survey. Only about 20 square miles along the southwestern edge of the Lancaster quadrangle are covered by drift. The eastern margin of the drift in this area has heretofore been supposed to lie approximately along the divide between the present drainage of the Little Maquoketa and that of North Fork of Maquoketa River, making a sinuous line that lies from 1 to 3 miles within the quadrangle. During the present survey, however, scattered deposits of till were observed beyond the margin of the drift sheet, chiefly on the wagon road 1 mile south of Asbury along the southern edge of secs. 19 and 20, T. 89 N., R. 2 E., and sec. 24, T. 89 N., R. 1 E., where it is exposed on the slopes of several north-south ridges. Here about 10 feet of till lies on Maquoketa shale and is capped by loess. It is composed of yellow, reddish, and brown clay, much jointed and conspicuously oxidized along the joints. In the clay are embedded pebbles of quartz, quartzite, greenstone and other dark rocks, granite, jasper, and sandstone. This material is mostly subangular, but a small portion of it is waterworn and a few striated pebbles were noted. The larger fragments were 4 to 5 inches in diameter.

The approximate eastern margin of the Kansan drift and the relation of these quadrangles to the Driftless Area are indicated on the diagram forming fig. 1. The marginal line is not absolutely definite, but in general does not deviate by more than 1 or 2 miles from the extreme position occupied by the edge of the Kansan ice.

The following discussion of Kansan deposits is in greater part adapted from an account of the geology of Dubuque County, Iowa, published in the Annual Report of the Iowa Geological Survey for 1899 (vol. 10, pp. 463–470):

The Kansan drift is the oldest Pleistocene deposit positively recognized in Dubuque County, but in certain well records there are indications of a pre-Kansan drift.

This sheet of till is fairly well developed over the portion of Dubuque County that lies west and southwest of the margin of the Driftless Area. The Kansan drift is overlain by loess. Normally, beneath the loess, it shows (1) a weathered zone reaching in places 6 or 8 feet in thickness, much oxidized and sometimes very ferruginous, reddish or brownish near the upper surface, but becoming yellow beneath; and (2) blue, unaltered till, the thickness of which depends on the amount of drift present. The yellow zone may blend somewhat gradually into the blue; and narrow, yellow, weathered bands may descend along joints in the blue till to depths of 10, 15, or 20 feet. The unaltered, blue Kansan is at most places calcareous, but calcareous material is absent from the upper part of the oxidized zone, the normal lime constituent having been removed by long exposure. The surface of the Kansan drift in Dubuque County suffered the usual amount of erosion before the deposition of the loess. The present topography, essentially, was fully developed before the loess was laid down. This later deposit forms a relatively thin sheet, more or less evenly spread over an erosion-carved system of hills and trenches which, if the loess were stripped off, would differ but little from the present relief.

The Kansan till seems originally to have been a tenacious blue clay carrying a large amount of powdered limestone. The upper zone, however, has been altered in color; oxidation and weathering have developed the reds, and browns, and yellows which now distinguish it. The zone has also been altered in composition; by leaching it has lost its calcareous constituent. Limestone pebbles and nodules are common in both the altered and unaltered Kansan. Many northern bowlders are seen in the drift, but few of them exceed 2 or 3 feet in diameter. Some are of granite, and many of these have become softened and decayed; but striated greenstone bowlderets are among the most characteristic constituents of the Kansan till. Almost as characteristic are the battered, frayed, and splintered fragments of trees, which are distributed promiscuously throughout a thickness of many feet in the lower part of this drift sheet.

Along the eastern margin of the Kansan drift the topography undergoes an abrupt change. On one side is the eroded drift plain; on the other side are the deep trenches cut in indurated rocks, and all the other topographic forms and features of the Driftless Area. The Kansan drift is greatly thickened toward its margin, this thickening giving rise to a fairly well-defined ridge from which the surface slopes both ways. The descent to the Driftless Area is abrupt; that to the westward is more gentle, and the slope eventually blends imperceptibly into the general Kansan plain. By reference to the map it will be seen that the drainage of this part of the county is, on both sides, away from the marginal ridge, as is exhibited by streams heading north of Holy Cross and north of Tivoli, Iowa.

The thickness of the Kansan drift is variable. At many points west of the margin, in some places within less than a mile of the marginal ridge, the trenches and rain-washed gullies in fields and along waysides show no trace of drift, except probably a few pebbles of crystalline rocks mixed with local chert and residual clay. The loess rests directly on residual materials. On many slopes within the Kansan area, both till and loess, if they were ever present, have been removed by erosion, which has left only some small northern bowlders to indicate that an ice sheet had ever occupied the region.

Kansan outwash in the Driftless Area.—Within the Driftless Area, well out from the margin of the Kansan drift as this is traced in fig. 1, there are occasional Kansan bowlders from a few inches to a foot or more in diameter. Some of the bowlders and gravel deposits are found on comparatively high ground; but, most naturally the outwash from the Kansan ice margin followed the drainage courses. Trains of gravel and bowlders seem to have been strewn along the Little Maquoketa Valley from a point a short distance below North Farley to the mouth of the stream, but only a few remnants of these deposits have escaped subsequent erosion. [A Kansan bowlder, 26 inches in diameter, was noted lying on Niagara limestone in the hollow below the road in the eastern part of sec. 8, T. 90 N., R. 1 W.; and there is a body of gravelly material, with cobblestones of Kansan type, on the ridge followed by the road in sec. 18, T. 89 N., R. 1 E. About 1½ miles east of Rickardsville, in N. ½ of sec. 28, T. 90 N., R. 1 E., there are numerous pebbles of northern crystalline rocks mingled with residual materials from the Galena limestone underneath the loess.]

LOESS.

The uppermost unconsolidated material over a considerable part of the area is a light buff-colored fine-grained silt or clay, rather porous in texture. This is the loess, and in this vicinity it appears to be partly of fluviatile and partly of eolian origin—fluviatile along the Mississippi, where it is very thick, obscurely stratified, and carries quartz pebbles; and eolian over the upland, where it is thinly spread. This loess mantles the general surface, covering the broad upland areas and extending down the sides of the valleys. It thus seems to have been deposited since the present topographic features of the district were formed and it can be regarded in general as of the age of the more extensive loess mantle associated with the edge of the Iowan drift. At the same time, nothing yet seen in these quadrangles precludes the idea that some of this loess may be of later than Iowan date.

The loess is exposed at many places along roadsides and is usually sharply divided from the residual soil below, for where the soil has been produced by the disintegration of dolomite, it is of a reddish or much darker brown color, is more compact and claylike, and generally contains angular fragments of chert. In thickness the loess varies from 60 feet along the Mississippi bluffs to a few inches at a distance of 30 to 40 miles from the river. On the uplands the thickness is usually only a foot or less. Along the rim of the Mississippi gorge and north of the Little Maquoketa the loess occupies the horizon of the lower part of the Maquoketa shale, which in these localities was evidently removed by rapid erosion that occurred at some early stage of the Pleistocene epoch. (See fig. 2.)

TERRACE DEPOSITS.

The terraces in this area that are of late Pleistocene age are confined to the Mississippi gorge and to the lower parts of the valleys of tributary streams. They are mainly fragmentary, having been cut away completely in places by recent erosion. The terraces in the valleys of the tributary streams are, as a rule, at a height of about 60 feet above the Mississippi flood plain. The elevation of these terraces above the stream beds steadily decreases upstream to the upper limit of the deposits.

Along the Mississippi the terrace is built of stratified gravel and sand of glacial origin. It has been traced up the river and certain of its branches north of these quadrangles to connection with the Wisconsin drift sheet and consequently has been considered to be of Wisconsin age, but it is possible that older terraces, representing earlier stages of the ice, have been confused with it. The Wisconsin ice sheet did not occupy the river valley where it passes through this area, but when the ice was in existence and was melting farther north the valley was flooded and the waters were loaded with detritus. Much of this detritus was laid down as an outwash deposit in the valley, which it filled to a depth of 125 feet or more and to higher levels wherever lateral enlargement afforded opportunity for slack water.

The drainage of Wisconsin time seems to have been essentially the same as it is now. Flooding and filling of the Mississippi channel caused back water in the tributaries (to a degree greater, of course, than at present) and the lower courses of these tributaries were accordingly filled with closely laminated fine silt or clay of *local derivation* to the height that the main channel was filled with foreign gravel and sand. Recent erosion has removed much of this material, but remnants of it lie along the valley sides as terraces at some places—for instance, in the hollow below Potosi and along Grant River below Burton. At the mouth of an important tributary, such as the Little Maquoketa, large quantities of detritus were dropped by both streams, forming terraces that are particularly marked. Foreign gravel and much loess may of course be found in the material along and at the mouth of the Little Maquoketa, for this stream and its tributaries have their sources within the area of Kansan and Iowan drift. Gravels have been noted on the backwater terraces of a few streams in Wisconsin. From the west side of Grant River, in sec. 36, T. 3 N., R. 4 W., Waterloo Township, there were collected several pebbles of rock apparently representing the pre-Cambrian complex of northern Minnesota and Wisconsin. These pebbles included biotite granite, reddish hornblende diorite, quartz-feldspar porphyry, a probable mica-diorite porphyry, a red, fine-grained igneous flow rock, and two varieties of greenish impure quartzite. A possible explanation of such unusual deposits is that they were borne to their present position by floating ice.

TRAVERTINE.

Large masses of calcareous tufa, or spring deposits, occur at many places along the valleys of the Platte, Little Platte, Grant, and Mississippi rivers, covering the faces of Platteville limestone ledges and in some places extending downward into the horizon of the St. Peter sandstone. The tufa is grayish, finely crystalline, not very hard, and usually porous or cellular, although it may be built up of solid mammillary incrustations. The rocks at some small waterfalls are coated to a thickness of 10 feet with this chemical deposit, which also cements the loose talus fragments at the bases of some cliffs. This calcareous material has been derived from the solution of the Platteville limestone by water bearing carbon dioxide. Its deposition has been facilitated by conditions which tend to liberate the carbon dioxide. The presence of fresh-water algæ has been suggested as one of the conditions operating here, and it is also probable that increase in temperature and evaporation of the water have likewise played an important part. The travertine marks extinct springs, probably dating back to pre-Pleistocene time, and is also being formed at the present day.

ALLUVIUM.

Along all the permanent streams of the district, and even along many of the intermittent streams, there are well-developed flood plains made of alluvial deposits, which are even yet in times of flood receiving additions. The scale of the map does not permit the representation of this alluvium on any but the Mississippi flood plain, but a larger detailed map would show considerable areas underlain by flood-plain deposits along other rivers, such as the Grant, the Platte, the Little Platte, the Little Maquoketa, and the Pecatonica. The alluvium consists of fine clay, gravel, and in places of coarse rock fragments. Beds of gravel composed of angular to subangular fragments of chert, occur in some places at higher levels than those of the present flood plains, representing deposits made before the rivers reached their present levels. Such deposits do not constitute well-marked terraces, though at some places they have terracelike forms. Most, if not all, of the terracelike forms seen in the northern part of this area are either rock platforms that mark the top of the Prairie du Chien formation or alluvial fans formed at the mouths of side streams, the downstream sides of the fans being now cut into by the shifting of the main stream.

STRUCTURE.

FOLDS.

In these quadrangles the rock strata, in a broad way, dip very gently south-southwest, but this general dip is hardly noticeable in single exposures. Dips of 1° or 2° are not uncommon, but these are shown only on the limbs of minor folds. The dip averages about 20 feet to the mile. In general it may be said that the rocks underlying the district, which have heretofore been regarded as undisturbed strata that dip to the south-southwest at a very low angle, are really broken into a complex system of slight folds. This fact has been brought out by recent detailed maps in the atlas accompanying Bulletin XIV of the Wisconsin Geological and Natural History Survey. These maps cover selected areas in the lead and zinc district, most of which are included in the Mineral Point and Lancaster quadrangles. Figs. 4 and 5 are taken from these maps. These folds become important through their relation to mineral deposits.

The axes of the folds extend nearly east and west, or a little north of west and south of east. Two major uplifts of this sort run through the quadrangles. The axis of one of these passes south of Mineral Point and extends west-northwest, being particularly marked at the junction of Platte River and Crow Branch, south of Annaton. This broad uplift brings to the surface the lowest rocks of the quadrangles—the Prairie du Chien dolomite and the St. Peter sandstone—along a number of streams near Mineral Point and also on the headwaters of Platte and Grant rivers. The eastern end of a less broad, but equally long axis of uplift, parallel to the first, may be noted at Red Rock, in Darlington Township. It extends westward across the Platte and the Little Platte in Harrison Township, and crosses Grant River just southeast of Beetown.

Aside from these major uplifts there are many minor folds, or gentle rolls of the strata, whose axes are in general parallel to the major lines. Locally the axes of these minor folds pitch toward the east or toward the west, indicating slight folding in an east-west direction also. The axis of a minor fold close to the larger fold first mentioned passes north of Platteville, across the headwaters of the Little Platte. At Meekers Grove there is a fold whose axis probably extends westward to the Mississippi below Potosi. At Eagle Point (Dubuque) the top of the Platteville limestone is brought above river level by an anticline whose axis may be traced northwestward as far as Rickardsville, but this plunges and disappears to the southeast. Some of these anticlines are displayed in the walls of the Mississippi gorge and are sufficiently striking between Dubuque and Spechts Ferry to be noticeable from the decks of river steamers, but between Cassville and McCartney the river flows for the most part of its course along the strike of the beds, and folds are not conspicuous.

Most of the anticlinal folds have long, gently rising southern limbs and shorter northern limbs of much steeper dip. A marked example occurs along Fever River south of Meekers Grove. Here the St. Peter sandstone first appears at the southern edge of sec. 34, T. 2 N., R. 1 E., and rises gradually northward for about 2½ miles, its ascent in this distance being from 818 feet to 900 feet above sea level; then in the next quarter of a mile it descends abruptly toward the north, falling about 90 feet, and within one-half mile falling 130 feet. A synclinal fold of the same character, but not so strongly marked, occurs a short distance northwest of Mifflin, where the strata descend 50 feet in about one-eighth of a mile, and then rise to the north the same amount in the distance of nearly a mile. An illustration of this type of folding is shown in the accompanying sketch (fig. 4), in which the folding of the rocks is shown by contour lines drawn on the base of the Galena limestone.

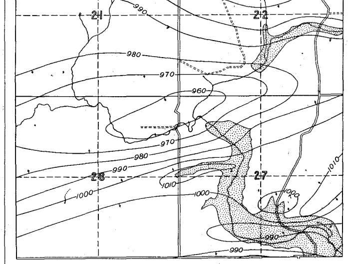


FIG. 4.—Geologic structure map of secs. 21, 22, 27, and 28, T. 5 N., R. 1 E., near Mifflin.

Contour lines, representing the altitude of the base of the Galena limestone, show the folding of this area, especially the steep dip on the south limb of the syncline and the more gentle dip on the north limb. Stippled areas represent Platteville limestone; unstippled, Galena limestone.

In addition to the kind of folds just mentioned, there is another, which is monoclinal in character. At a number of places the St. Peter sandstone or the Platteville limestone are brought to the surface in stream valleys by what would appear from a study of the map to be anticlines, but at several of these places, where the structure has been carefully worked out, the underlying rock comes to the surface because it rises abruptly toward the north for a short distance and then flattens out, thus giving a series of steplike elevations, or monoclinal folds, with no downward dips on the north. Two folds of this sort may be seen along the stream in the SE. ¼ sec. 30, T. 2 N., R. 1 E., north of Benton, where the Platteville limestone is exposed but disappears below the surface both higher up and lower down the stream. Another fold of the same kind occurs along the streams in secs. 4 and 5, T. 1 N., R. 2 E., about 2 miles northwest of Shullsburg. This kind of monoclinal fold is shown in fig. 5, in which structure contour lines are drawn on the base of the Galena limestone.

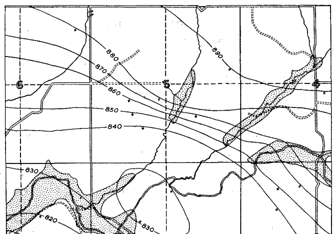


FIG. 5.—Geologic structure map of sec. 5 and parts of adjoining sections, T. 1 N., R. 2 E., west of Shullsburg.

Contour lines, representing the altitude of the base of the Galena limestone, show a small monoclinal fold. Stippled areas represent Platteville limestone; the unstippled, Galena limestone.

Many of the lead and zinc deposits of these quadrangles lie in small basins or synclines. Such basins may have originated in at least four different ways: (1) They may be due to original inequalities that existed on the sea bottom when the sediments were deposited, since such inequalities were present at the beginning of Galena time, as has been noted in the description of the basal layers of the Galena limestone; (2) they may be due to irregularities of deposition, a lack of sediment in some areas causing slight local depressions, although in this district such a cause is not probable, for the areas that exhibit lack of sediments are really anticlinal; (3) vertical compression and consequent slumping of the beds may have produced such basins, and as they occur in areas comprising thick deposits of oil rock—a carbonaceous deposit which, in the manner of coal beds, has undoubtedly decreased much in thickness—this means of producing such basins has certainly been important; (4) actual mechanical deformation of the rocks by lateral pressure may have and undoubtedly has taken place, especially in some of the more marked and steeper folds. It is probable that no one of these causes alone has produced all the basins, but that two or more have worked together, for while the lower beds of the Galena were being deposited small basins were already in existence, and in these basins the thicker deposits of oil rock were made. The shape of the basins themselves and the later compression or shrinking of the oil rock would produce initial dips which would very likely be accentuated by any lateral compression to which the beds were subjected.

JOINTS.

All the formations in the district except the St. Peter sandstone and the Maquoketa shale show systems of distinct joints, and the St. Peter sandstone exhibits joints in places where it has been firmly cemented. Jointing is especially well developed in the massive beds of the Galena limestone and plays an important part in the deposition of the ores. The joints extend in several directions, but the principal ones are practically vertical. The most pronounced system strikes a few degrees north of west. This is crossed by other less important systems, the one more commonly developed striking a few degrees east of north.

In addition to the vertical joints, there are at many places, most of them near the mines, series of dipping joints. These are confined to the smaller synclines, and most of them have the same strike as the main vertical joints. These joints, which are inclined at angles ranging from 20° to 60° to the horizontal, are especially important in some of the mines, for they contain the ore deposits known as "pitches." They occur in the minor synclines in which the mines are located and dip outward from the axes of the basins. These dipping joints are thought to be due either to the slumping of the beds, on account of the shrinking of the underlying oil rock, or to actual lateral compression. At some places both causes may have conjoined to produce them. They occur mainly in the lower 50 feet of the Galena limestone and may be seen along the west side of Bull Branch, near the Hoskin and Kennedy mines, at places east of Hazel Green, and at the east end of the lower bridge across the Mississippi at Dubuque.

FAULTS.

Some of the early writers on this district were of the opinion that notable faulting occurred here, but most of the later workers have not recognized faulting, and careful field work by the authors for three seasons has failed to discover clear evidence of important faulting. It is believed, therefore, that the area is practically without faults.

UNCONFORMITIES.

There is evidence that during certain periods deposition ceased within these quadrangles, and that the surface was at those times above sea level and therefore subjected to erosion. At intervals the surface sank below sea level and deposition was resumed. The relation between deposits that are separated in age by a period of nondeposition and erosion is termed unconformity. By a study of unconformities much may be learned concerning earth movements and structural geology.

Although the Cambrian sandstone is not exposed in these quadrangles it no doubt rests unconformably on pre-Cambrian rocks, for this is the relation between these two series wherever their contact is exposed in regions north of this area. Within the Cambrian sandstone itself there is possibly another unconformity, but this is not nearly so marked nor of as great magnitude as that at the base of the Cambrian. Between the time of deposition of the Prairie du Chien and that of the St. Peter there was evidently a considerable period of erosion, which is shown by the abrupt variations in the thickness of the upper formation (the St. Peter) as well as in that of the Prairie du Chien, by the irregularity of the upper surface of the latter, and by the presence of a conglomerate at the base of the St. Peter. At several horizons there are also other evidences of periods of nondeposition, but not of considerable erosion. Much of the evidence for these minor breaks in the sedimentary series is derived from a study of the fauna. These horizons are at the base of the Prairie du Chien formation, at the base of the upper division of the Prairie du Chien, at the base of the Platteville limestone, at the base of the Galena dolomite, and at the base of the Maquoketa shale. That at the base of the Galena is the most important of these, and the evidence for it has been cited in the description of that formation.

HISTORICAL GEOLOGY.

The pre-Cambrian record in the Lancaster and Mineral Point quadrangles is not known, but it was no doubt very like the history of that time in the central and northern part of Wisconsin, where rocks of this age are exposed. Before Cambrian time several great series of deposits were laid down in this region and these are separated by great unconformities. The rocks are now metamorphosed, highly folded and at many places intruded by eruptives. The outcrops of pre-Cambrian rocks nearest to the Mineral Point quadrangle are in the vicinity of Devils Lake and Baraboo, where the Baraboo quartzite emerges from beneath the Cambrian sandstone in two high ridges. That this quartzite itself extends under these quadrangles is not known, but it has been determined that earlier crystalline rocks here lie below the Cambrian sandstone and are separated from it by an unconformity representing a long period of erosion.

Toward the middle of Cambrian time the ocean spread over this general district, probably advancing from the south and southeast. In this ocean was deposited a thick formation, mainly sandstone, which is not exposed in these quadrangles but which undoubtedly underlies their entire area. During the time of deposition of this great formation, which reaches a maximum thickness of 1000 feet, there appears to have been at least one period of uplift and erosion, which was followed by another period of depression and deposition. Upon the Cambrian sandstone, after a period of nondeposition, there was deposited a considerable thickness of rock, mainly dolomite (Prairie du Chien), indicating quieter and deep water.

At this time the shore line had probably advanced farther to the north, where the Wisconsin highlands formed a land area all through Cambrian, Ordovician, and Silurian times, and furnished the mechanical sediments which make up in part the rocks of these ages in this district. Toward the latter part of Prairie du Chien time conditions of uplift with shallow water prevailed and sandstone was again deposited. This sandstone was apparently in considerable part reworked and redeposited Cambrian sandstone. After this uplift there was a general depression, or rather an oscillation of the sea bottom on which materials that formed thin beds of sandstone and dolomite were laid down in alternation. The final result was the uplift of at least a considerable part of this portion of Wisconsin above sea level and the subjection of the Prairie du Chien formation to erosion and possibly to gentle folding. The exact position of the shore line at this time is unknown, but it is probable that this district was wholly above sea level and that the Prairie du Chien formation suffered great loss of material. At some places the whole of its upper calcareous and associated siliceous part was removed by erosion, which also at some localities cut deep into the main dolomitic part of the formation.

After this period of uplift and erosion came another of depression and shallow-water conditions, when the St. Peter sandstone—a comparatively thin formation—was deposited over this quadrangle and over a large part of the upper Mississippi Valley. Much of this material was, no doubt, derived from the reworking of the upper part of the Prairie du Chien and of the Cambrian sandstone, both of which were exposed farther to the north.

After the St. Peter sandstone had been laid down there was a period of nondeposition in this area, during which the Joachim limestone of the Ozark region was probably deposited, and then a period of general depression, during which there was an influx of small quantities of argillaceous material; but this period was of short duration, as only a few feet of clay at the maximum was deposited. Next the waters of the ocean in this area became practically free from mechanical sediment, and the Platteville limestone, which in places consists largely of remains of various marine animals, and which owes its origin mainly to these organisms, was laid down. Toward the latter part of the Platteville there was in this area a gradual shoaling marked by alternating thin beds of limestone and shale, and there is evidence that at this time part, at least, of the district was for a while above sea level.

Galena time began with gradual depression and submergence. The earliest Galena deposit is known as the oil rock, which consists not only of clayey material but of a large proportion of carbonaceous matter. Conditions for shale formation were succeeded gradually by conditions indicating deeper water, and the great thickness of the Galena formation was then deposited. This whole formation, 235 feet or more thick, includes only a few shale beds, but during this time some clay was brought into the ocean and deposited with the calcareous material.

The next series of rocks, the Maquoketa shale, represents a period of shallow water, in which vast quantities of clay were brought into the sea from lands adjoining this district on the north. At the end of Galena time the district may have been for a brief period above sea level, this being indicated by the presence of waterworn pebbles in the basal shale. The Maquoketa shale may likewise have formed a land area for a short time, after which marine conditions returned and produced a great dolomite formation, the Niagara, even thicker, where it is totally developed, than the Galena.

In this district there is nothing to show how long the Paleozoic sea existed in the region after the Niagara dolomite had been deposited. Paleozoic rocks of later age may have been laid down and eroded, but probably not in Devonian time and almost certainly not in Carboniferous time, for there is no evidence that the Carboniferous shore line reached as far north as the southern border of Wisconsin. No sea deposits later than the Niagara are found in the district. During the latter part of Paleozoic time, and also during Mesozoic time, these quadrangles may have been above sea level, but their relief was probably not great, for, although the surface was subjected to erosion, this was neither very rapid nor very extensive.

During Cretaceous time the sea advanced from the west and in its waters sandstones, shales, and limestones were deposited in western Iowa and parts of Minnesota, reaching as far eastward as the longitude of Lake Superior, but there is no evidence that the Cretaceous ocean covered this part of Wisconsin.

The whole history of the district, both as to sedimentation and as to erosion, from Silurian to the beginning of Cenozoic time is almost unknown. One marked erosional epoch, however, stands out distinctly. In this epoch, which probably occurred late in Tertiary time, the whole district except a few erosional remnants, or monadnocks, now represented by the mounds, was reduced to a low-lying plain—the Lancaster peneplain. This peneplain was probably formed in late Tertiary time, during the period in which a similar peneplain was produced in various parts of the Mississippi Valley.

After the close of Tertiary time there was an uplift, which, as nearly as can be determined, only slightly antedated the advance of the great Pleistocene ice sheets. This region was then again actively subjected to erosion, which has continued uninterruptedly to the present day. Only a small corner of the area was encroached upon by the ice, and, so far as the evidence now shows, practically the present elevation has been maintained during this long erosional period. In areas immediately outside of the district erosion was interrupted by an ice invasion. In certain portions of the district, also, there have been interruptions due to floods in the streams, which built up terraces like those along the Mississippi and near the mouths of the Grant, the Platte, and the other main streams. The district in general forms an excellent illustration of the results of one practically continuous cycle of erosion, beginning shortly after Tertiary time and continuing to the present, during which the residual soil, loess, travertine, and alluvium were formed.

Aside from the residual soils, the travertine, and the alluvium in the river bottoms, no deposits have been made in this district above the bed rock except the thin fringe of Kansan till at the margin of the area, the loess, and the terrace deposits.

ECONOMIC GEOLOGY.

MINERAL RESOURCES.

LEAD AND ZINC DEPOSITS.

HISTORICAL STATEMENT.

The district included in the Lancaster and Mineral Point quadrangles has long been known as a producer of lead and zinc ores. It includes the most productive portion of what has been termed the upper Mississippi Valley lead and zinc district. Lead seems to have been discovered in the upper Mississippi Valley by Nicholas Perrot about 1692. It was later noted by Le Sueur in 1700 or 1701, and by John Carver in 1776. The first mining in the upper Mississippi Valley lead and zinc district was done on the site of the present city of Dubuque, in 1788, by Julien Dubuque, who obtained from the Indians land on which lead had been discovered a few years before. After Dubuque's death, in 1810, little was done until about 1820 or later, but before 1830 mining had become general in the vicinity of Dubuque, Iowa, and Galena, Ill., and also in southwestern Wisconsin. From that time down to the present day mining has been carried on continuously in the zinc and lead district of the upper Mississippi Valley, and at certain periods the district has figured prominently as a producer of lead and zinc.

The early work was for many years devoted entirely to the mining of lead, the zinc ores being unrecognized, or, when recognized, regarded as of little value. It was not until about 1865 that zinc ores began to be mined in this region, and the amount of these ores produced rapidly increased until the district became more important as a source of zinc than of lead. Subsequently, for a number of causes, mining activity in the district decreased, but since 1900 there has been a marked revival of interest, and the present high prices of both lead and zinc, together with the fact that the district is being exploited carefully, are combining to make mining within these quadrangles very active.

ORE MINERALS.

Galenite (PbS; lead 86.6 per cent, sulphur 13.4 per cent; specific gravity 7.4 to 7.6).—Galenite, known also as galena, as lead sulphide, and by the miners as "mineral," is the only important lead ore of the district. It usually occurs in the form of crystals, which are cubes or, less commonly, octahedrons. At some places combinations of these two forms are seen. Some of the large crystals of galenite are several inches or a foot across, and to these the miners have applied the term "cog mineral." When galenite occurs in small crystals, especially when it is disseminated through the rock, it is called "dice mineral." It also occurs in peculiar reticulated forms having treelike branches. Galenite was the original lead ore of the district and from it have been derived other minor ores, none of which are important. Unlike the galena of most mining districts, the galena of the upper Mississippi Valley lead and zinc district contains practically no silver.

Cerussite ($PbCO_3$; carbon dioxide 16.5 per cent, lead oxide 83.5 per cent, metallic lead 77.5 per cent; specific gravity 6.46 to 6.57).—Cerussite is known as lead carbonate and also as white-lead ore. It occurs in minute, colorless crystals on the surface of the larger crystals of galena at some places, as, for instance, at the Robarts mine, near Linden. More commonly, however, it occurs as a white to yellowish powderlike coating on altered galena crystals. Cerussite is a secondary mineral derived from the alteration of galena in the zone of weathering. It is not found in large amount and is not mined as a source of lead.

Anglesite ($PbSO_4$; sulphur trioxide 26.4 per cent, lead oxide 73.6 per cent, metallic lead 68.3 per cent; specific gravity 6.3).—This mineral has been mentioned in some of the earlier reports on this district, but it is of rare occurrence. The so-called anglesite from Mineral Point is not a lead mineral, but is really selenite or gypsum. In fact it may be questioned whether anglesite has been found in southwestern Wisconsin, although no reason is known why it may not occur there.

Sphalerite (ZnS; zinc 67.15 per cent, sulphur 32.85 per cent; specific gravity 3.9 to 4.1).—This mineral is known as zinc blende, zinc sulphide, and by the miners as "black jack," or simply as "jack." It is by far the most important ore of the district, and is the original zinc mineral. As it is usually found below the level of ground water, it was not discovered in the early explorations of the district and was not utilized until some years after its first discovery. It varies in color from a light straw-yellow through brown to jet black, the black color being due to impurities, especially iron. Sphalerite occurs most commonly in sheets that line the sides of veins. On free surfaces it occurs in small and rather poorly formed crystals. At some places small nodules of sphalerite, an inch or less in diameter, are embedded in the clays, especially in the clay bed that marks the base of the Galena dolomite. This form of sphalerite is frequently spoken of as "strawberry jack." It is seen at the Penitentiary mine near Mifflin and at the Capitola mine west of Platteville. By the alteration of sphalerite the other zinc minerals of the district have been formed.

Smithsonite ($ZnCO_3$; carbon dioxide 35.2 per cent, zinc oxide 64.8 per cent, metallic zinc 52.06 per cent; specific gravity 4.3 to 4.4).—Smithsonite is known by the miners as carbonate, or more commonly as "dry bone," a name given by reason of its light, porous structure, which roughly resembles the inside of a bone. This mineral generally occurs in the porous masses just spoken of, which are usually brownish or yellowish in color, and have a decidedly earthy appearance. It is also found, but less commonly, in more compact and irregular masses, most of which are white in color. Next to sphalerite smithsonite is the most important zinc mineral in the region. It generally occurs above the level of ground water, but at some places extends a short distance below this level. In the early lead mining in the district it was neglected, and in the early period of zinc mining it was about the only ore of zinc mined, sphalerite not being then used, but it is now produced in considerably less amounts than formerly and in decidedly lesser amounts than sphalerite. At the present time most of the smithsonite is burned into zinc white at Mineral Point, and none of it is used in the production of spelter.

Hydrozincite (a basic hydrous carbonate of zinc; specific gravity 3.58 to 3.8).—This is known as zinc bloom. When pure it contains 60 per cent of metallic zinc. Hydrozincite is frequently associated with smithsonite, and it is difficult to distinguish one from the other in the field. In fact this mineral is rarely recognized in this district and no definite statements can be made as to its occurrence.

Calamine (H_2ZnSiO_5; silica 25 per cent, zinc oxide 67.5 per cent, water 7.5 cent, metallic zinc 54.23 per cent; specific gravity 3.4 to 3.5).—This ore of zinc is common in some districts, but has not been certainly recognized in the upper Mississippi Valley, although, because of its close resemblance at times to the massive, nonporous variety of smithsonite, it may possibly have been overlooked.

MINERALS ASSOCIATED WITH THE ORES.

Marcasite and pyrite (FeS_2; iron 45.78 per cent, sulphur 54.22 per cent; specific gravity 4.67 to 5.2)—These two minerals are intimately associated with galena and the sphalerite, especially with the latter. Marcasite, sometimes known as white iron pyrite crystallizes in the orthorhombic system, while pyrite crystallizes in the isometric system and ordinarily takes the form of cubes and octahedrons. Marcasite is by far the most common form of the iron sulphide in this district, and in the descriptions that follow it is assumed that all of the iron sulphide is in the form of marcasite. Pyrite is very much less common, although it is found at some places, as, for instance, at the Hazel Patch mine, a short distance northwest of Mineral Point, where the two minerals occur side by side. Marcasite is associated with sphalerite, and is detrimental to the commercial use of the ore, because in milling it is separated with some difficulty from this zinc ore. Above the level of ground water marcasite is usually altered to limonite.

Psilomelane (a hydrous oxide of manganese; specific gravity 3 to 4.7).—This occurs as an amorphous black substance known as wad. It is widely distributed in small quantities, and generally takes the form of a fine black powder.

Calcite ($CaCO_3$; carbon dioxide 44 per cent, lime 56 per cent; specific gravity 2.7).—This is widely known as calc spar or simply as spar, and the miners usually call it "tiff." It is the most common mineral in the district. It is almost everywhere associated with the lead and zinc ores and at many places lines the interior of the veins, having been deposited after the metallic sulphides already mentioned. It also occurs in veins or in any kind of cavity throughout the dolomites and limestones of the district, especially in the Galena and Platteville formations.

Dolomite ($MgCaCO_3$; carbon dioxide 47.9 per cent, lime 30.4 per cent, magnesia 21.7 per cent; specific gravity 2.8 to 2.9).—Although this mineral is the important constituent of most of the Galena formation, it rarely occurs in crystals of large size and it does not seem to have been deposited in the veins.

Selenite ($CaSO_4\ 2\ H_2O$; sulphur trioxide 46.6 per cent, lime 32.5 per cent, water 20.9 per cent; specific gravity 2.3).—This occurs in small crystals, but is not very common. It undoubtedly owes its origin to certain chemical reactions that take place between the calcium carbonate of the rocks and the sulphuric acid produced by the breaking down of the marcasite.

Barite ($BaSO_4$; sulphur trioxide 34.3 per cent, baryta 65.7 per cent; specific gravity 4.3 to 4.6).—Barite is commonly known as heavy spar. It is found at some places near the oil rock, but also lines cavities in the veins, being the last mineral deposited. It is not common in the mines, although in certain of them it is abundant.

Sulphur (S; specific gravity 2).—Native sulphur, though not abundant, occasionally occurs in the lead region in a pulverulent or minutely crystalline form in crevices or small cavities in the mines. It is undoubtedly due to decomposition of the iron sulphides, marcasite and pyrite. It is nowhere found in sufficient abundance to be economically important.

Quartz (SiO_2; oxygen 53.3 per cent, silicon 46.7 per cent; specific gravity 2.6).—This occurs chiefly in the form of chert, which is abundant in certain parts of the Galena formation. Notwithstanding the large amount of silica in the ore-bearing rocks, it is rarely found in crystalline form except in cavities in the Prairie du Chien limestone, and here the crystals are commonly small.

FORMATIONS IN WHICH THE ORES OCCUR.

Small amounts of lead and zinc have been found in all the formations of the district, from the Niagara dolomite down to the Cambrian sandstone. In the Maquoketa shale south of Shullsburg a little work for zinc ore has recently been done, but apparently with no very encouraging results; and in the Prairie du Chien formation some lead ore has been mined, although none is being mined at the present time, and so far as could be ascertained, no ore has been mined in this formation within these quadrangles. The productive ore bodies, then, are confined to the Galena dolomite and to the uppermost division of the Platteville limestone. The deposits occur in all the divisions of the Galena, but the most important deposits—that is, the peculiar flats and pitches and the disseminated deposits—lie at or near the base of this formation. Some of the crevice deposits, rarely in the form of flats and pitches, reach as high as the upper half and even close to the top of the Galena. In the Platteville the ore is confined to the upper member of this formation, and occurs most commonly in the shales that immediately underlie the oil rock, in the main glass-rock beds (as for instance, at the Little Giant mine near Shullsburg), and at some places near the base of the glass rock, in association with some narrow bands of oil rock. Ore in this last location is found at several points in the eastern part of the district, especially at places near Linden, and particularly at the Mason mine.

Considerable prospecting for ore has been done in the Prairie du Chien formation, and some ore has been found in it, especially in areas north of these quadrangles. The known ore bodies in this formation, however, are nowhere so extensive as those in the Galena, and it is doubtful whether ore deposits of economic value exist in the Prairie du Chien. Moreover, prospecting for ore in the Prairie du Chien by deep drillings or by shafts is very expensive compared with prospecting in the Galena where it reaches the surface. It is therefore not advisable to expend time and money in drilling or in sinking deep shafts into the Prairie du Chien in this area with the hope of finding ore, except where the formation outcrops.

FORMS OF DEPOSITS.

Classification.—The lead and zinc ores are at many places associated, and both occur in the same kinds of formations and at the same horizons. The ores may be grouped into two divisions based upon their form: First, those which occur in cracks or crevices in the rocks and which are in the nature of vein deposits, including both vertical crevices and the flats and pitches described below; second, those which are disseminated in small particles throughout the rock.

Crevice deposits.—Deposits occur in cracks or fissures and along joint planes, many of which have been enlarged by solution before the ore was deposited. The ore deposits were formed in open cavities, and not by replacement.

Most of these crevices extend in an east-west direction, or a little north of west and south of east, and they are essentially vertical. These are crossed by many other crevices, the main series of which runs a little east of north and south of west, about at right angles to the major set. To the first series of crevices the miners apply the term "east and wests," and to the second, "north and souths." In addition to these, there are smaller fissures, called quartering crevices, that cross the main fissures at various angles, and to these the names "two o'clocks," "ten o'clocks," etc., have been applied by the miners, since their direction coincides with that of the shadow cast by the sun at two o'clock or ten o'clock, or at other times. Most of the ore mined has come from the east-west crevices, but particularly rich deposits may occur at the intersections of crevices.

The general term "range" is applied by the miners of the district to an ore-bearing crevice or to a series of such crevices that lie parallel and close together. Some of these ranges can be traced for several hundred feet, and some, apparently, for a few miles.

The ore deposits in these vertical crevices at some places impregnate adjacent beds laterally for short distances, where solution of the dolomite has occurred. Irregular cavities that are more or less filled with ore have been thus formed, and to these cavities the term "openings" has been applied. Most of these openings are in the upper half of the Galena limestone, while most of the flats and pitches are in the lower part of that formation. A crevice containing openings is shown in fig. 6.

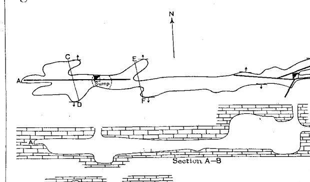


FIG. 6.—Plan and sections of the Hazel Green mine.

The upper figure is the ground plan; the middle, a longitudinal section; the lowest, two cross sections. In the plan the heavy lines represent vertical crevices; arrows indicate direction of dip of pitches. In the cross sections the ore is shown by heavy dashed lines.

In the lower part of the Galena limestone especially in No. 2 of the generalized section, many of the vertical joints are replaced by a series of joints that dip away on either side of a main vertical crevice. These dipping joints, which carry ore, are connected with horizontal openings or joints, running along the bedding, which also carry ore. To these peculiar forms of deposits the name "flats and pitches" has been given, the flats being the horizontal parts of the deposit, the pitches the inclined parts. This kind of deposit is shown in fig. 7, in which the black lines represent the joints or cracks that are now filled, or nearly filled with ore. Many of these flats and pitches are connected with vertical east-west crevices. The crevices as a rule do not extend below the horizon of the oil rock, although in some places, notably at the Little Giant mine near Shullsburg, the main glass-rock beds (Platteville) contain numerous fractures filled with ore. A series of flats and pitches may be 100 feet to 200 feet across, and where the flats run back from the pitches into the foot wall

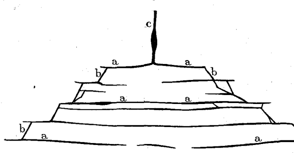


FIG. 7.—Diagrammatic cross section of a series of flats and pitches.

a, flats; b, pitches; c, vertical crevice.

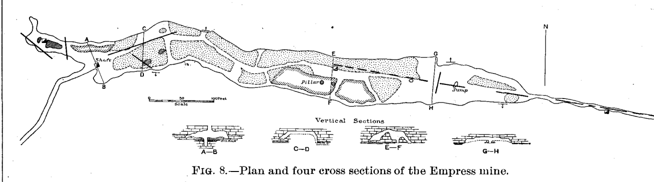


FIG. 8.—Plan and four cross sections of the Empress mine.

Stippled areas represent refuse-filled parts of the mine. Vertical crevices are shown by heavy black lines. Arrows indicate direction of dip of pitches.

there may be a considerable mass of rock, extending from one pitch to the other, which can be mined out, as in the Hoskin and Kennedy mines near Hazel Green. The same occurrence on a smaller scale is seen at the Empress mine east of Benton, a map of which, with section, is shown in fig. 8. Other examples of flats and pitches are

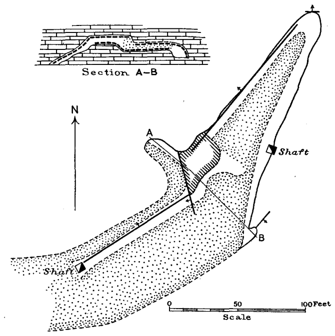


FIG. 9.—Plan and cross section of part of the Robarts mine.

Stippled area represents refuse-filled parts of the mine. Pitches are shown by heavy black lines, the arrows indicating the direction of their dip. In the section the ore is represented by heavy dashed lines.

seen in the Robarts mine, near Linden, (fig. 9) and in the Ellsworth mine, northwest of Mifflin (fig. 10). The Robarts is a lead mine, the others are zinc mines.

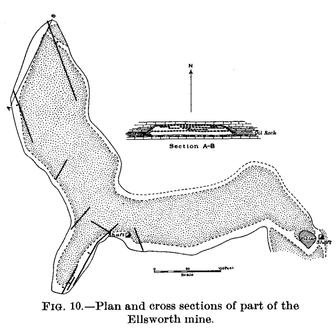


FIG. 10.—Plan and cross sections of part of the Ellsworth mine.

Stippled areas represent refuse-filled parts of the mine. Crevices and pitches are shown by heavy black lines, the arrows indicating the direction of dip of the pitches. In the section the ore is represented by heavy dashed lines.

In general the pitches in any one mine strike approximately parallel with one another and also parallel with a vertical crevice, but at some places there are secondary pitches which carry ore and which have a direction markedly different from the main system of pitches. In the earlier workings of the Enterprise mine at Platteville the main pitches dipped to the south, while a subordinate series of pitches, near the east end of the mine, dipped to the east-northeast. Similar occurrences have been seen in other mines.

Associated with the crevice deposits are others, to which the name "honeycomb" deposits has been applied, but these are not genetically different from the ordinary crevice deposits. The honeycomb deposits occur in connection with the crevices at places where the rock has been brecciated or semi-brecciated or strained, and where it has therefore been more subject to solution. In the solution cavities that have been made along the zones of brecciation ore has been deposited. Deposits of this kind, which grade directly into the crevice deposits, occur at many places. They are found in the Hazel Green mine near Hazel Green, at the Strawberry Blonde mine near Strawbridge, and at Dawson mine near Benton.

As before stated, many of the vertical crevices that are filled with ore are not connected with any flats or pitches. Flats also occur without pitches. Most of these are found at or just above the horizon of the oil rock. In some places, however, especially around Linden, flats occur just below the main glass-rock beds, where there is also another small band of oil rock. The ore in some of these flats has been deposited in open cavities made by solution, but that in others seems to be a replacement deposit, and thus to grade directly into the next class, called disseminated deposits.

Disseminated deposits.—At certain horizons the rock has been more or less permeated or impregnated by ore-bearing solutions and in these places crystals of sphalerite and of galena occur in abundance. These disseminated deposits can not be sharply separated from the flats that occur in connection with the oil rock, just mentioned. Most of the disseminated deposits are found (1) in thin beds of limestone or dolomite that immediately overlie the oil rock, (2) in the oil rock itself, (3) in the clay bed which, in some of the mines, immediately underlies the oil rock, and (4) at the base of the main glass-rock beds, associated with some thin layers of oil rock. Deposits of this character are especially well developed west and south of Platteville, as for instance, at the Graham and Stevens, the Klondike, the Tippecanoe, and the Capitola mines.

Most of the flats and pitches and the vertical crevices carry notable amounts of marcasite, and at some places this mineral occurs in great abundance. As a general rule less marcasite is found in the disseminated deposits than in the flats and pitches or the vertical crevices.

ORDER OF DEPOSITION OF THE ORES.

As has been already stated, the ore in the crevice deposits was laid down in the open fissures. The usual order of the minerals deposited, from the wall to the center of the vein, is as follows: (1) marcasite, (2) sphalerite, at some places containing galena, (3) galena, (4) calcite, (5) barite. This may be called the universal order of deposition of these ores and the associated minerals. All five of these bands are not observable in every deposit, however, but practically everywhere the wall rock is coated by a layer of marcasite, either thin or thick, and outside of this is sphalerite which may or may not carry a little galena, and which may or may not have galena outside of it. The richest ore of the district, an ore that is very important in some of the larger mines in the flats and pitches, is this second layer, which is made up essentially of sphalerite with occasionally a little galena. In places a layer of ore on either side of the open crevice is from 3 to 6 inches thick.

Although the order of deposition given above for the ores is that generally noted throughout the district, a second period of deposition of marcasite has occurred at some places, and at a few other places all of these metallic sulphides are mingled together.

DOWNWARD CHANGE OF ORES.

There is not only a general arrangement of ore minerals from the wall rock out to the center of the vein, but there is a more important arrangement in a vertical direction. Three distinct horizontal zones occur in this vertical succession. At the top, in many places near the surface of the ground, there is a zone containing galena in large crystals and masses. This, of course, is above the level of ground water, and it is being continually lowered by erosion. Below this zone is a second, in which smithsonite is the important ore. This extends down to the level of ground water and in some places a few feet lower. The third zone, which is below ground-water level, is essentially a zone of sphalerite.

In this quadrangle the level of ground water—that is, the level below which the rocks are saturated with water—varies markedly in depth. In the valleys, it ranges from the surface to a level 10 feet below, while on some of the broad interstream areas water lies 100 feet below the surface.

While each of these three zones is characterized by its own peculiar mineral, the galena of the first extends down into the second, which contains principally smithsonite, and galena is also found to some extent in the zone of sphalerite, especially near its top. In this lower zone, at many places, crystals of galena have been deposited on sphalerite in the open center of the veins, but a short distance below the top of this zone these crystals become very much less numerous, and in its deeper part most of the galena is intimately mingled with the sphalerite.

The smithsonite of the whole district is a product of the alteration of the original sphalerite, and this alteration has taken place everywhere in the zone above the level of ground water, and in some places extends a few feet below the top of the water level. The lower part of this second zone contains specimens showing all stages of alteration from sphalerite to smithsonite.

RELATION OF ORE DEPOSITS TO STRUCTURE.

The fact that the crevice deposits occur in joints, and more usually in joints that have been enlarged by solution, has already been mentioned. These joints bear a close relation to the folding that the district has undergone, the principal joints running approximately parallel to the main axes of folding.

Recent detailed work in the Wisconsin lead and zinc district has shown that very many of the lead and zinc deposits of the region lie at or near the bottoms of the synclinal basins. This is especially true of the disseminated deposits and of the flats associated with the main oil rock and with the thin seams of oil rock that lie just below the glass rock of the Platteville formation. Practically all of the mining near Dodgeville is confined to a wide, shallow, basin-shaped rock depression which slopes off toward the southwest. At the Graham mine and at the Capitola mine, both west of Platteville, the disseminated deposits worked lie in basinlike depressions in the rocks; and the mines in the Highland mining district, a few miles north of the northern edge of the Mineral Point quadrangle are working deposits that are in a similar position.

Not only are there disseminated deposits in the synclinal rock basins, but certain well-known and important flats and pitches occur near the axes of such basins, as in the Blende and the Ida mines, just southeast of Benton; the Rowley mine, north of Buncombe; and the Sally Waters mine near New Diggings. The important deposits of the Empire and Enterprise mines at Platteville also seem to lie in another basin of this kind. The Hoskin and the Kennedy mines, near Hazel Green, are in a synclinal basin, which apparently extends westward and includes a number of abandoned mines south and east of Hazel Green.

Sufficient data are not at hand to show that all of the deposits that occur in flats and pitches lie in synclinal basins, but there can be no question that many of them are in such basins.

A notable ore deposit in a synclinal basin is shown in fig. 11, a sketch map of the mines near Linden. The Mason mine, which has been one of the most important in the district, and which is still producing, lies very close to the axis of a syncline. The Milwaukee and the Glanville mines, just east of the Mason, are similarly situated, and the Robarts mine lies in a minor syncline that is included in the large synclinal basin about Linden. It is probable that the old workings west and northwest of the Robarts mine are also in a minor southward-plunging syncline which is not well brought out by the structure contours in fig. 11.

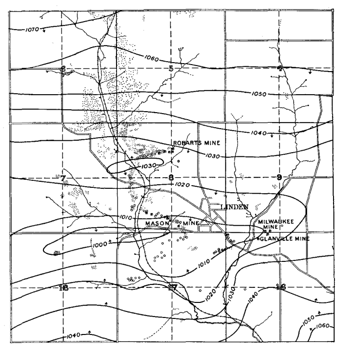


FIG. 11.—Geologic structure map of vicinity of Linden, T. 5 N., R. 2 E.

Contour lines represent the altitude of the base of the Galena limestone. The dots represent old workings; the circles, test pits and small shafts; the squares, shafts.

The general character and the origin of these synclinal basins have been discussed under the heading "Folds," in the description of the structural geology.

ORIGIN OF THE ORE DEPOSITS.

It is now commonly believed by geologists that the ore deposits of this district are derived entirely from the country rock, and in the main from the Galena limestone. There is no evidence that the ores have been brought up from deeper seated zones, as they have been in many metalliferous mining districts. The ore-forming substances were probably brought in solution from the crystalline rocks that lay farther north, and were precipitated by some means, possibly the agency of plants, in the Ordovician sea. The ore deposits as they exist today were laid down by waters that circulated in these Ordovician rocks. These waters have dissolved minute particles of the metallic substances that were scattered through the rocks, and have redeposited them in their present positions. The percentage of lead and zinc required in the country rock to form important ore deposits is very small indeed. An estimate has been made of the degree or amount of impregnation of the rock that would exist if the entire quantity of ore taken from the Potosi district, in the Lancaster quadrangle, were uniformly distributed through the adjacent rock. In determining the limits of the district, a margin outside the outermost crevices was allowed equal to half the average distance between the crevices—that is, the outside crevice was supposed to draw only as much from the territory outside as from that between it and the neighboring crevice. As the basin occupied by the district is large this is a very moderate assumption. Furthermore, it was assumed that the rock had been leached to a depth of only 100 feet in the deposition of the ores, although probably twice that amount of rock originally lay above the base of the deposit. The estimate showed that the ore content of the rock amounted to one fourteen-hundredth of 1 per cent of the mass of the rock.

As has already been stated, many of the ore deposits are intimately related to structural basins. These structural basins, or at least such of them as occur in the Galena dolomite, are floored by practically impervious layers—that is, by the oil rock and shales below it. It seems clear, then, that these basins have acted as channels for water that has descended to the impervious floors and has then flowed along in the direction of the pitch of the synclines forming the basins. The disseminated deposits and those in the lowest part of the flats and pitches indicate that the organic matter found in the oil rock has played an important part in precipitating the metallic substances held in solution by this circulating water, and the volatile materials given off from the oil rock may reasonably be supposed to have aided materially in precipitating the ore in crevices higher up in the formation.

There is evidence that the ore minerals are continually migrating downward along the crevices to become arranged in the horizontal zones already described. Sphalerite, which is readily altered to smithsonite, is dissolved and carried downward to be precipitated close to the water level as smithsonite, or carried still farther down and precipitated as sphalerite. Galena is not so easily dissolved and does not travel downward so rapidly. A large part of the galena remains close to the surface, and travels downward only a little faster than the surface is lowered by erosion. The lead ore that is dissolved and carried down is commonly precipitated near the level of ground water, and this precipitation gives rise to the large crystals of galena that line the veins in the upper part of the lower ore zone at many places.

DEVELOPMENT.

Mining in this region was at first carried on in a very primitive manner, and crude methods are still employed in some of the smaller diggings. The ores were formerly mined and brought to the surface by hand and were cleaned by cobbing and by hand jigging. The present development of the region is due in great part to the introduction of modern methods of mining and concentrating the ores. By reason of the nature of the deposits the plants are comparatively small but they are well adapted to the needs of the region. During the last few years a number of concentrating mills have been erected in the district. These mills, which are similar to those used in the Joplin region, successfully separate galena from sphalerite and marcasite. The latter two minerals, because of their nearly identical specific gravities, can not be completely separated by ordinary jigging, but the percentage of marcasite in much of the cleaned ore is so low that the ore is purchased for the zinc smelters, that portion in which the percentage of marcasite is too high for spelter making being sold to the Mineral Point Zinc Company for use in the manufacture of sulphuric acid and zinc oxide. A number of the mines have installed roasters and magnetic separators, by which the marcasite is successfully removed from zinc ores, and steps are now being taken to build more roasters and magnetic separators.

Experiments in separating the marcasite from the sphalerite by static electricity have been made in the district, and if this process should prove successful and economical the marcasite, which is rendered unsalable by roasting, can be sold. Concentrating tables have been introduced in a few mills, but their use has not yet become common.

The zinc ore that is cleaned by magnetic methods, and much that is not so cleaned, is suitable for the manufacture of spelter and is shipped to the zinc smelters at La Salle, Peru, and Wenona, Ill. Some is smelted at North Chicago, Ill., and most of the carbonate ore (smithsonite) and the lower grades of sphalerite are shipped to Mineral Point.

Throughout certain small areas in both quadrangles there are marked evidences that extensive mining operations have been carried on in past years. Many of these were shallow workings in search of lead. In places the ground, down to a distance of 20 feet from the surface, has been literally honeycombed by this early work, so that over tracts that are many acres in extent the surface is a tumultuous mingling of knolls and hollows. Small areas that have been rather thoroughly worked near the surface are shown in fig. 11.

PROSPECTING.

The ranges and the districts that in early days produced lead, or lead and zinc, in large quantities close to the surface of the ground are, other things being equal, the most favorable locations for prospecting. The chances are that a range that has borne considerable quantities of these minerals in its upper part will continue to bear large quantities in its lower part, the main difference being that below the level of ground water there will be less lead, practically no smithsonite, and probably much sphalerite. In selecting an area for prospecting, however, one should be taken in which there is below the level of ground water a considerable thickness of the Galena limestone—that is, a considerable thickness of rock which may carry ore—for the deposits are in most places limited by the base of the Galena limestone, and in practically all places are limited by the oil-rock bands at the base of the main glass-rock horizon of the Platteville formation. Besides the two points just mentioned, a third should be added, and that is, that a range or a series of ranges or a district which lies in a synclinal basin is a more favorable place for prospecting than one which is not so situated. Many of these synclinal basins and the relation that they bear to past and present development work are shown in the series of detailed maps already mentioned (Atlas, Bull. XIV, Wisconsin Geological and Natural History Survey, 1906). The areas mapped comprise those which have been centers of the most active surface mining and which are now receiving most attention from prospectors. These maps include areas in the Mineral Point and Lancaster quadrangles that range in extent from 6 to 42 square miles, and bear the following names: Dodgeville, Mineral Point, Mifflin, Platteville, Potosi, Meekers Grove, Hazel Green-Benton, and Schullsburg, while the Highland map comprises an area that lies just north of the Mineral Point quadrangle. The United States Geological Survey has mapped in a similar detailed manner the ore-bearing area at Dubuque, Iowa. (See Pl. VIII in Bull. 294.)

SULPHUR ORES.

The metallic sulphides—galenite, sphalerite, and marcasite—are sources of sulphur. The sulphur obtained by smelting sphalerite is used in the manufacture of sulphuric acid. Where the lower grade sphalerite ores are burned for zinc oxide they are first roasted and the resulting sulphur is used for making sulphuric acid. In a few of the mines marcasite is so abundant that it is possible to sell it to manufacturers of sulphuric acid; and a mine near Montfort is being worked entirely for marcasite. The separation of marcasite from sphalerite by static electricity, if practicable, would greatly increase the amount of available marcasite.

IRON ORES.

Marcasite and pyrite occur abundantly in connection with the lead and zinc ores, especially below the level of ground water. Above this level these ores have been altered to limonite. No deposits of limonite large enough to form workable iron-ore bodies are now known within these quadrangles, and it is very unlikely that such bodies will be found.

COPPER ORES.

The original copper ore of the district is chalcopyrite, a sulphide of copper and iron, but this is very much less common than the sulphides of lead, zinc, and iron. At a few localities copper ores have been mined to a slight extent, but no work is now done on these deposits. Chalcopyrite is at many places associated with marcasite and pyrite. In the zone of weathering chalcopyrite changes to green hydrous carbonate of copper, known as malachite, and less frequently to blue hydrous carbonate of copper, known as azurite. Green stains due to malachite are seen at many places in the rocks.

BUILDING STONE.

In the eastern part of the district the "lower buff" or quarry beds (No. 2 of the generalized section) of the lower part of the Platteville formation furnish good building stone. These beds are exposed at many places throughout the quadrangles and are commonly quarried for building stone. The main glass-rock beds of the Platteville are easily quarried and easily dressed, and have been used to some extent for building, especially at Platteville, where the Normal School and one of the high schools are built of this rock.

The thinner beds of the Galena, especially those found in the upper member of this formation, are equally important as a source of building stone. The high school at Shullsburg is built of rock from these beds. At Dubuque, Iowa, some of the massive beds lower down in the Galena have been used in the construction of important buildings and in bridge and railroad work. West of Dubuque the lower part of the Niagara dolomite includes about 20 feet of good building stone, which has been quarried at some places for local use, and to a considerable extent for export in the neighborhood of Farley, 4 miles south of the southwest corner of the Lancaster quadrangle.

A few buildings at Mineral Point are made of the St. Peter sandstone, which is much better cemented than usual at some places near this town. At Redrock, on Pecatonica River, a short distance north of Darlington, quarries have been opened in this formation, and from these quarries sandstone has been shipped to points outside the district. At Spechts Ferry, Iowa, a two-story building 80 by 30 feet, has been built of dressed sandstone quarried from the top of the St. Peter.

In a few places the dolomite of the Prairie du Chien formation has been used locally as a building stone.

The district contains plenty of building stone for all local uses, and even a good supply for export, but it probably will not be shipped in large amounts to outside points, for the surrounding district is almost equally well supplied.

CLAYS.

The clays of these quadrangles, although widespread and of excellent quality, have not yet been extensively used. A few brickyards in the district, most of them at Platteville and Dubuque, manufacture clay products. The clays used are derived from four sources: (1) Loess and alluvium, (2) residual clays, (3) clays in the Maquoketa formation, and (4) clays at or near the top of the Platteville. Alluvium and sandy loess taken at low levels are used at Dubuque for making building brick.

The Maquoketa formation, near its base, contains shale and clay that can probably be used for the manufacture of clay wares, and the middle portion of the formation comprises nearly 100 feet of fine-grained plastic clay, some parts of which are eminently suited to pottery making, and other parts to the manufacture of pressed brick or tile. None of this material is now used within this area. An analysis of shale from Kidder, Iowa, near Lattners, just south of the Lancaster quadrangle, is given.

Transportation for these plastic clays of the Maquoketa can be had only at points along the Chicago Great Western Railway, in the southern part of the Lancaster quadrangle, where, since the shale lies rather high above the railroad track, gravity methods of handling the material could be employed.

Analysis of Maquoketa shale from Kidder, Iowa.

[J. B. Weems, analyst, Ann. Rept. Iowa Geol. Survey for 1899, vol. 10, p. 606.]

Silica (SiO_2)	42.53
Ferric oxide (Fe_2O_3)	5.66
Alumina (Al_2O_3)	16.83
Calcium oxide (CaO)	5.66
Magnesium oxide (MgO)	4.82
Potassium oxide (K_2O)	3.70
Sodium oxide (Na_2O)	4.10
Combined water	15.76
Undetermined	.94
	100.00

Residual clays have been used for brickmaking at Platteville and a few other places.

Many of the clay and shale beds of the Platteville limestone that lie immediately below the main oil-rock horizon are of good quality, and it is reported that terra-cotta ware has been recently produced in an experimental way from this material. Wherever these shale beds reach a thickness of 4 to 5 feet they may afford material for this use. These shale beds are now exploited only along Little Platte River just west of Platteville.

CEMENT MATERIALS.

The Platteville limestone and shale throughout the district contain materials that are fairly suitable for the manufacture of Portland cement. Residual clays and loess, if they average rich in silica and poor in lime, might also be utilized for this purpose at places where the shale of the Platteville is not present in quantity sufficient for making Portland cement. The limestone, clay, and loess are favorably situated for cement manufacture at many places along the bluffs on both sides of Mississippi River. Five of the most favorable localities were examined during this survey, the rock being sectioned and sampled in detail. Below are analyses of materials obtained at two places.

related, having been taken respectively 3 and 4½ feet from the surface, the latter clay in contact with the rock. No. 5 is loess from Dubuque, Iowa; No. 6 is loess from Galena, Ill.

Analyses of samples of material taken near McCartney and Potosi, Wis., and Waupeton, Iowa, are still in progress, and kiln tests, or actual burning, on a small scale, of materials into cement will follow. The results of these analyses and tests will be published as soon as they are available.

LIME.

The ruins of kilns that once furnished local supplies of lime may be seen at many places throughout the district. The rock usually burned in the eastern part of the district was the comparatively pure limestone of the upper part of the Platteville formation, especially that of the main glass-rock beds. A kiln at Darlington, Wis., now produces lime from rock taken from these beds. At Dubuque, Iowa, two concerns crush and burn for lime large quantities of dolomite obtained from the lower half of the Galena, and in the valley of the Little Maquoketa above Durango there are remains of old kilns in which dolomite was burned. An analysis of this lime-burning rock is given in the description of the Galena dolomite.

SAND.

The St. Peter sandstone, some beds in the upper part of the Prairie du Chien formation, and the outwash terrace and recent river deposits furnish sufficient sand for mortar and other building material. Some of the St. Peter sandstone is as pure as that used in areas outside of this district in the manufacture of glass, and it might also be suitable for use as molding sand when mixed with a small proportion of clay. An analysis of the rock is given in the description of the St. Peter sandstone.

Analyses of Platteville limestone and shale.

[Analyst, L. G. Michael, Iowa College of Agriculture and Mechanic Arts, Ames, Iowa.]

No.	Location and character of bed.	Thickness.		Constituents.							
				SiO_2	Fe_2O_3-Al_2O_3	$CaCO_3$	$MgCO_3$	Alk. as K_2O	SO_3	Comb. H_2O	H_2O (Moisture)
	Spechts Ferry, Iowa; sec. 3, T. 90 N., R. 2 E.	*Ft.*	*In.*								
	Limestone, becoming magnesian above	10									
5	Limestone	10	0	5.74	6.69	83.56	.25	.....	1.77	1.50	.10
4a	Limestone, thin bands interbedded with shale, No. 4.	2	8	11.24	6.31	78.51	.24	.....	1.58	1.85	.10
4	Shale, exclusive of limestone bands, No. 4a	6	9	49.32	8.30 20.16	9.52	3.21	4.68	Tr.	4.82	.72
3	Limestone, massive beds	20	0	10.71	6.69	78.67	.28	.....	1.51	1.70	.15
2	Limestone, medium beds	5	0	7.94	12.05	73.38	3.52	.....	1.69	1.40	.10
1	Limestone, thin beds	9	0	7.50	6.17	79.50	3.97	.....	1.48	1.60	.15
	Limestone, heavy magnesian beds	7	6								
	Sandstone.										
	Near Zollicoffer Lake, Peru Tp., Iowa; sec. 23, T. 90 N., R. 2 E.										
	Limestone, becoming magnesian above										
7	Limestone, subcrystalline, medium beds	2	6	8.28	4.67	80.14	2.37	.....	2.60	2.17	.13
6	Limestone, thin beds	5	0	3.26	.83	90.20	2.65	.....	1.64	1.84	.06
5	Limestone, thin beds	5	10	4.54	2.54	86.33	3.54	.....	.22	2.62	.08
4	Limestone, in heavy bed	1	4	3.85	6.03	84.16	1.93	.....	.64	4.23	.03
3a	Limestone, thin bands interbedded with shale, No. 3.	2	3								
3	Shale, exclusive of limestone bands, No. 3a	5	10	50.22	9.08 12.45	13.83	2.96	5.23	1.16	3.81	1.71
2	Limestone, coarse grained	6	0	6.79	4.61	78.24	5.12	.....	1.74	3.28	.04
1	Limestone, fine grained, thin beds, unexposed below.	12	0	8.02	5.78	77.93	4.43	.....	.22	3.18	.16

Following are analyses of residual clays and loess from the Driftless Area:

Analyses of residual clays and loess.

[Analyses by R. B. Riggs, Sixth Ann. Rept. U. S. Geol. Survey, 1885, pp. 250 and 282.]

	1	2	3	4	5	6
SiO_2	71.13	49.59	53.09	49.13	72.68	64.61
Al_2O_3	12.50	18.64	21.43	20.08	12.03	10.64
Fe_2O_2	5.52	17.19	8.53	11.04	3.53	2.61
FeO	.45	.27	.86	.93	.96	.51
TiO_2	.45	.28	.16	.13	.72	.40
P_2O_5	.02	.03	.03	.04	.23	.06
MnO	.04	.01	.03	.06	.06	.05
CaO	.85	.93	.95	1.22	1.59	5.41
MgO	.38	.73	1.43	1.92	1.11	3.69
Na_2O	2.19	.80	1.45	1.33	1.68	1.35
K_2O	1.61	.93	.83	1.60	2.13	2.06
H_2O (+ H of organic matter)	4.63	10.46	10.79	11.72	2.50	2.05
CO_2	.43	.30	.29	.39	.39	6.31
C	.19	.34	.22	1.09	.09	.13
SO_3	......	......	......	......	.51	.11

Nos. 1 and 2 are samples of clay from the same vertical section, the former having been taken 4½ feet from the surface, and the latter 8½ feet from the surface, in contact with the underlying limestone. Nos. 3 and 4 are samples of clays that are similarly

ROAD MATERIALS.

The rough topography of the Driftless Area and the steep grades in the vicinity of the Mississippi and larger streams have necessitated the general improvement of the roads in these quadrangles. Fortunately the region is well supplied with material suitable for use as road metal. Dolomite, limestone, and chert are the rocks commonly so used. The rock is hand broken and spread over a graded and rolled surface, on which a top-dressing of gravel or finer crushed rock may be added. The flood plains of the larger streams become almost impassable at times of high water, especially those that lie along the lower courses of the tributaries of the Mississippi, and it has therefore been necessary to build substantial roads across the valleys to the height of 4 or 5 feet above the bottom land. A road of this kind has been built in the valley of Grant River, 1½ miles south of Flora.

WATER RESOURCES.

SPRINGS.

These quadrangles contain numerous springs, most of which have their sources at the bases of the St. Peter sandstone, the Platteville limestone, the Galena limestone, and the Niagara limestone.

Springs issue at other horizons, such as shaly layers in the Galena and Prairie du Chien formations, but these springs are not large or numerous.

The oil rock at the base of the Galena is generally underlain by one or more thin strata of bluish clay or shale. All these strata are practically impervious and turn much of the water that soaks down through the porous Galena limestone above. Springs at this horizon are less common in the eastern portion of the area than elsewhere, although they do occur here, but in the vicinity of Platteville and farther west they are found at many places where streams have cut down into the Platteville limestone.

Immediately above the St. Peter sandstone lies a bed of blue shale, at some places sandy, which is from 2 inches to 3 feet thick. This generally turns water and produces a marked line of springs above a porous sandstone formation—a rather unusual phenomenon. This spring horizon is very constant throughout the parts of the district that contain outcrops of the St. Peter sandstone.

The Prairie du Chien formation appears irregularly beneath the St. Peter sandstone in some of the deeper valleys. Close to the top of the Prairie du Chien formation at some places are beds of very compact limestone or of shale and clay. The springs at this horizon are not so numerous nor so constant in flow as those at either of the other horizons, but some of them are of large volume.

Many of the springs form the starting points of permanent streams and are of importance to farmers, as they furnish supplies of excellent water for domestic uses and for refrigeration and thus determine the location of farm houses.

WELLS TO GROUND WATER.

The level of ground water in this area ranges from the surface to 10 feet below the surface in the valleys and reaches a depth of 100 feet or more on some of the high interstream areas. No figures are available to show the average depth to ground water, but it lies far enough below the surface to make the sinking of open dug wells inexpedient at most places, so that wells sunk by the churn drill are common, especially in the broad upland parts of the district. The Galena limestone, which immediately underlies about three-fourths of the area of these quadrangles, is sufficiently porous to furnish adequate domestic supplies to wells sunk a few feet below the ground-water level. At some places the water is "let out" by a crevice, and it is there necessary to drill beyond the ordinary depth. The water of wells in the Galena is somewhat hard but of excellent quality for domestic use. Wells sunk to ground-water level in areas underlain by the St. Peter sandstone furnish good supplies of softer water than that derived from the limestone. The horizons at which the springs appear are the same that furnish the supplies of some of the wells.

DEEP WELLS.

Water-bearing horizons.—For deep wells there are two important water-bearing horizons, one or both of which can be found under the whole area. These are the Cambrian sandstone and the St. Peter sandstone. Little need be said concerning the water derived from the sandstone in the upper part of the Prairie du Chien formation, for this sandstone does not extend under the entire area, and in some places it is not separated from the St. Peter by marked limestone strata. At Dubuque, however, where it lies about 435 feet below the Mississippi level, it yields an artesian flow.

Wells to the St. Peter sandstone.—The St. Peter is a poorly cemented homogeneous sandstone of medium grain, composed at some places of 99 per cent of rounded quartz grains. It is an ideal water-bearing stratum. Near Fennimore, Wis., the upper surface of this sandstone stands about 1100 feet above sea level, and at Dubuque it has an elevation of about 450 feet. This stratum may be regarded as descending uniformly from the higher to the lower altitude, except in two areas where it is 50 to 150 feet above its normal height. These areas lie along gentle anticlinal folds whose axes run nearly east and west. The axis of one fold lies south of Mineral Point and north of Platteville; that of the other runs from Redrock on the east to Beetown on the west. From the general upland level (the Lancaster peneplain surface), where the Galena is the surface rock, the St. Peter can be reached in from 100 to 300 feet, but in areas immediately underlain by Maquoketa shale it is farther from the surface. Wells sunk into the upper part of this sandstone at some places furnish good supplies of water, and an abundant supply may be expected, except near some of the outcrops of the Prairie du Chien formation, in wells sunk to the base of the St. Peter. The water obtained from this sandstone is less liable to hold considerable quantities of mineral substances than that derived from lower horizons.

The surface and also the strata incline toward the south-southwest, the strata sloping at a greater angle than the surface. Thus favorable conditions for artesian flows from the St. Peter sandstone would exist in the southern part of the quadrangles were it not for the fact that at places farther south beyond this area (at La Salle and Oregon, Ill.) and within the area along the Mississippi north of Dubuque this sandstone outcrops at low levels. Artesian flows are therefore not usually to be expected from this water-bearing stratum, though in some wells the water will rise for a short distance above the top of the sandstone.

Wells to the Cambrian sandstone.—The Cambrian sandstone is in large part as sparsely cemented as the St. Peter and is therefore a good water-bearing formation. It includes, however, a greater amount of calcareous and argillaceous impurities, which at some places form distinct limestone and shale beds. It thus furnishes more than one water-bearing horizon. The Cambrian sandstone undoubtedly underlies the whole area at a depth of from 230 to 400 feet below the top of the St. Peter. It can be relied upon as a strong water-bearing formation, and is even more important than the St. Peter. Water from the Cambrian sandstone will rise above the top of the St. Peter and at Dubuque supplies many artesian wells that have a head 40 to 100 feet above the level of Mississippi River, but probably will not furnish flowing wells at altitudes higher than 650 feet above sea level, which would limit them in this district to the deeper valley bottoms.

Analyses of artesian water from Dubuque.

[Parts per million.]

[Analysts, Wahl and Henius, Iowa Geol. Survey, vol. 6, 1897, p. 209.]

	1.	2.
Calcium (Ca)	66	71
Magnesium (Mg)	22	22
Sodium (Na)	14	11
Carbonate radical (CO_3)	131	151
Sulphate radical (SO_4)	18	15
Chlorine (Cl)	21	17
	272	287

Analyses of water from beds at two horizons in the Cambrian sandstone, penetrated in an artesian well at Dubuque, are presented herewith.

STREAMS AND WATER POWER.

The rainfall in this district is approximately 35 inches a year, the streams are numerous, and irrigation is not necessary. The smaller streams descend rather rapidly, at some places as much as 60 feet per mile, while the large streams have in their lower parts an average descent not exceeding 10 feet per mile. There are no waterfalls that are large enough to be utilized for water power. All the main streams are capable of furnishing water power for local use, but they are not yet utilized for power except at Darlington on Pecatonica River and near Benton on Fever River, where small dams have been erected. At Benton there is also a power tunnel through the narrow neck of land between the loops of the stream at "Horseshoe Bend." Many of the streams of the district that have a fall of 10 to 40 feet per mile are of sufficient volume to furnish water power for small flour and grist mills. Abandoned mills and mill-races testify to the use of these water powers before the large mills in the northwest had been established. The Mississippi is the only navigable stream in the area, although at times of high water steamboats pass through the "cut-off" and up Grant River as far as Potosi station.

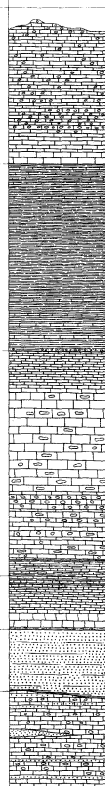
SOILS.

The soils of the district are essentially residual. On the uplands a thin layer of loess mantles the residual soil, while in some of the wider bottom lands the soil is distinctly alluvial. The soils are fertile, although, apart from the alluvium, the area contains little of the black loam that is so common in the drift soils of the surrounding glaciated region. The residual soils are of rather slight capacity and do not grow very diversified crops, yet corn, oats, and hay are raised in abundance throughout the quadrangles.

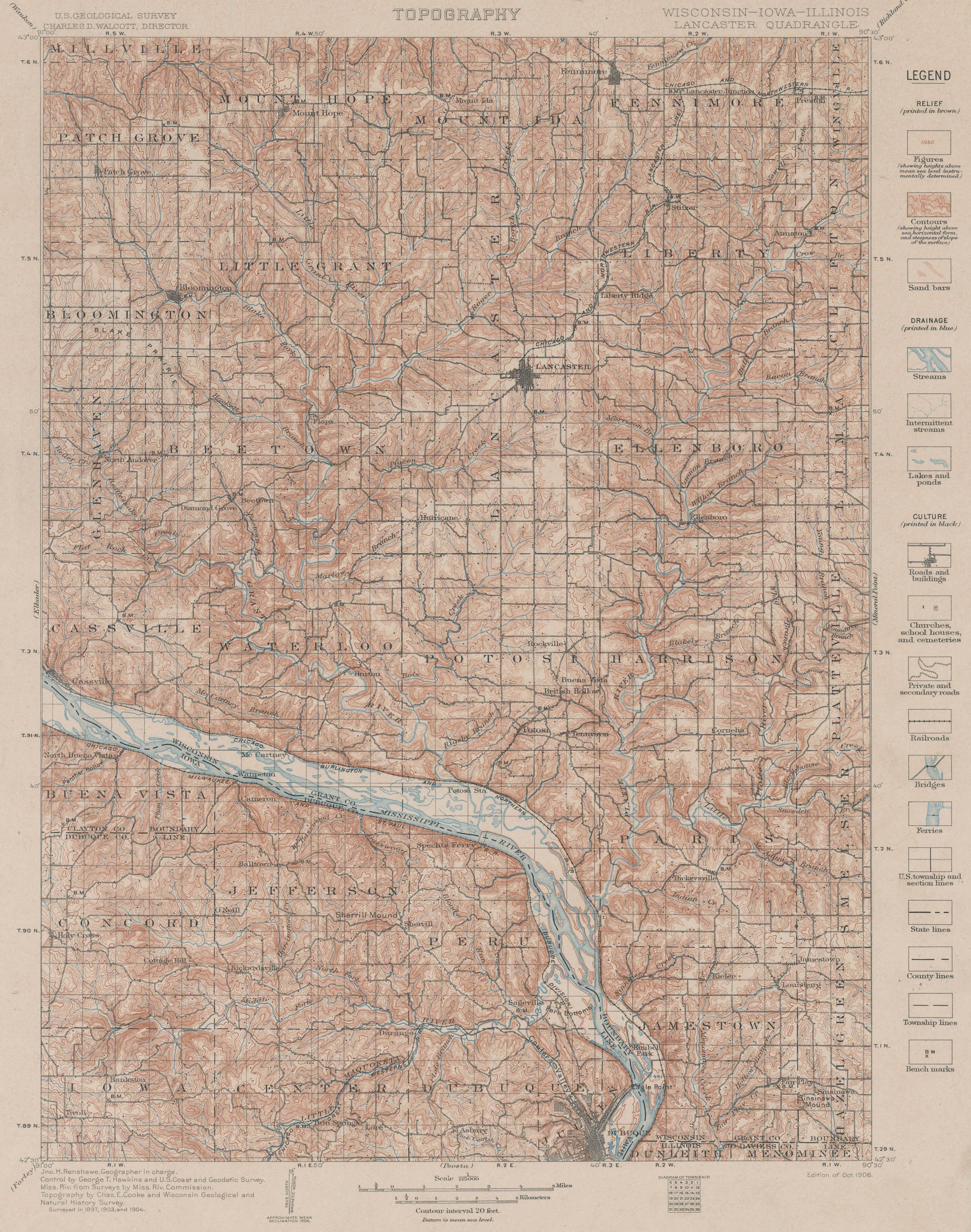
June, 1906.

GENERALIZED SECTION FOR THE LANCASTER AND MINERAL POINT QUADRANGLES.

SCALE: 1 INCH = 100 FEET.



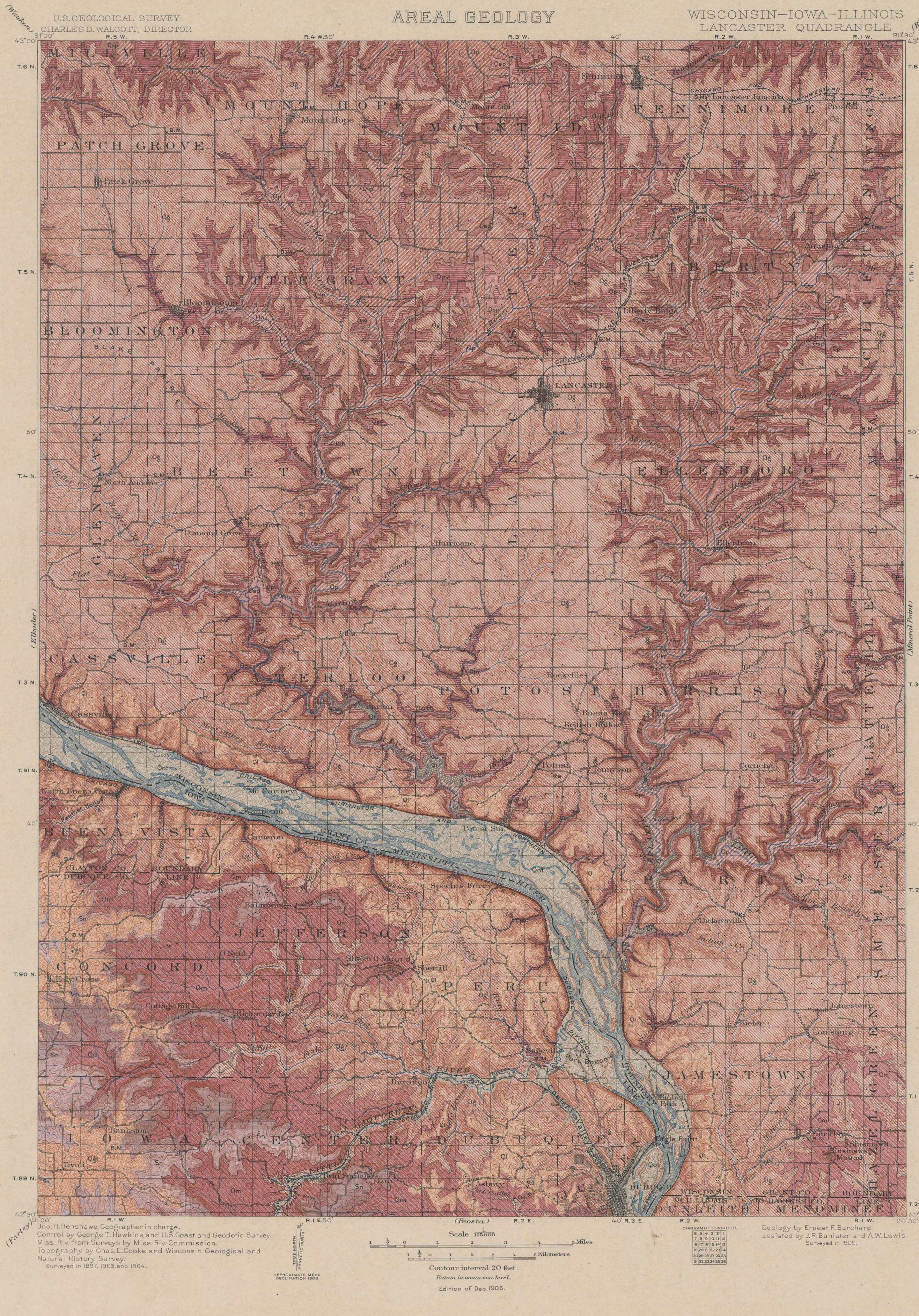
System.	Formation Name.	Symbol.	Columnar Section.	Thickness in Feet.	Character of Rocks.	Character of Topography and Soils.
SILURIAN	Niagara limestone.	Sn		150+	Light-buff to gray dolomite. Basal beds massive and rough weathering, succeeded by thinner beds, above which are layers containing more or less chert. Fossiliferous. Top of formation eroded.	Forms plateau with escarpment southwest of Mississippi River and caps the mounds scattered over the quadrangles. Dark-red clay soil containing residual chert.
ORDOVICIAN	Maquoketa shale.	Om		160–225	Gray argillaceous and calcareous shale, locally fossiliferous and magnesian at the top. Plastic blue and green shale and clay with indurated fossiliferous bands near the top. Drab and blue, thin, fissile shale and fossiliferous, thin, argillaceous limestone. Fine conglomerate locally near base.	Low, rounded swells and long, gentle slopes. Thick, fertile soil.
	Galena limestone.	Og		235	Coarse-grained gray dolomite, cherty and thick bedded in middle portion, thin bedded at top, with thin, shaly, fine-grained limestone and locally carbonaceous shale at base. Sparingly fossiliferous. Basal portion locally contains zinc and lead ores.	Flat uplands and precipitous, rocky gorges. Thick, dark-red clay soil containing residual chert.
	UNCONFORMITY?					
	Platteville limestone.	Opv		55	Fine-grained limestone and very fossiliferous, calcareous shale. Thin, wavy-bedded, fine-grained, fossiliferous limestone. Thick-bedded magnesian limestone with thin, sandy shale at base.	Valley slopes and a few narrow stream divides. Good limestone soil.
	St. Peter sandstone.	Osp		35–175	White or iron-stained quartz sandstone, massive and usually poorly cemented. Thin, sandy clay-shale at base.	Small cliffs, rounded knobs, and flat valley bottoms. Light, sandy soil.
	UNCONFORMITY					
	Prairie du Chien formation.	Op		100+	Irregularly bedded, rough-weathering dolomite, cherty in places and locally containing thin beds and lenses of sandstone. A few fossils. Base not exposed.	Valley slopes and stream bottoms. Good limestone-clay soil.


U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR
TOPOGRAPHY
WISCONSIN–IOWA–ILLINOIS
LANCASTER QUADRANGLE
LEGEND
RELIEF (printed in brown)
Figures (showing heights above mean sea level instrumentally determined)
Contours (showing height above sea, horizontal form, and steepness of slope of the surface)
Sand bars
DRAINAGE (printed in blue)
Streams
Intermittent streams
Lakes and ponds
CULTURE (printed in black)
Roads and buildings
Churches, school houses, and cemeteries
Private and secondary roads
Railroads
Bridges
Ferries
U.S. township and section lines
State lines
County lines
Township lines
Bench marks
MILLVILLE
MOUNT HOPE
MOUNT IDA
FENNIMORE
PATCH GROVE
LITTLE GRANT
LIBERTY
BLOOMINGTON
LANCASTER
BEETOWN
ELLENBORO
CASSVILLE
WATERLOO
POTOSI
HARRISON
BUENA VISTA
MISSISSIPPI RIVER
JEFFERSON
PARIS
CONCORD
PERU
JAMESTOWN
IOWA
CENTER
DUBUQUE
DUNLEITH
MENOMINEE
Jno. H. Renshawe, Geographer in charge.
Control by George T. Hawkins and U.S. Coast and Geodetic Survey.
Miss. Riv. from Surveys by Miss. Riv. Commission.
Topography by Chas. E. Cooke and Wisconsin Geological and Natural History Survey.
Surveyed in 1897, 1903, and 1904.
APPROXIMATE MEAN DECLINATION 1906.
Scale 1/125000
Miles
Kilometers
Contour interval 20 feet.
Datum is mean sea level.
DIAGRAM OF TOWNSHIP.
Edition of Oct. 1906.

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

AREAL GEOLOGY

WISCONSIN–IOWA–ILLINOIS
LANCASTER QUADRANGLE



LEGEND

SEDIMENTARY ROCKS

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

QUATERNARY — *Pleistocene*

- Qt — Terrace silts *(laminated fine clay and sand, of local derivation, deposited under backwater conditions during glacial flooding)*
- Ql — Loess *(light-buff, fine-grained silt, with small concretions and pebbles. Only the thicker deposits shown)*
- Qot — Outwash terrace deposits and alluvium *(glacial gravel and sand, largely covered by modern alluvium)*
- Qgt — Glacial till *(covered by loess; only the areas containing heavier deposits shown; boundaries approximate)*

SILURIAN

- Sn — Niagara formation *(light-buff to gray, thin- to thick-bedded dolomite with chert nodules)*

ORDOVICIAN

- Om — Maquoketa shale *(green to blue shale and clay, with thin beds of earthy limestone)*
- Og — Galena limestone *(coarse-grained, thick-bedded, gray dolomite; middle portion with chert nodules; lower part locally thin-bedded limestone)*

UNCONFORMITY ?

- Opv — Platteville limestone *(thin-bedded limestone, with thicker magnesian beds in lower part, and some shale in upper part)*
- Osp — St. Peter sandstone *(white, or iron-stained, massive sandstone, usually poorly cemented)*

UNCONFORMITY

- Op — Prairie du Chien formation *(thin- to thick-bedded dolomite with some sandstone and chert in upper part)*

⚒ *Zinc and lead mines*

Note: *Zinc and lead ores occur throughout the Galena dolomite but more commonly near the base.*

NAMES OF MINES.

Location indicated on the map by numbers.

1. Eberle.
2. Blackjack.
3. Fitzpatrick.
4. Durango.
5. Rake Pocket.
6. Level.
7. Stewart and Bartlett.
8. Cardiff No. 2.
9. Trego.
10. Krog and Webster.
11. Cardiff No. 1.
12. Red Dog.
13. Whig.
14. Edgerton.
15. Tippecanoe.
16. Capitola.
17. Graham and Stevens.
18. Big Jack.
19. Klar-Piquett.
20. Saint Rose.
21. Phoenix.

Index to location of mines.

Jno. H. Renshawe, Geographer in charge.
Control by George T. Hawkins and U.S. Coast and Geodetic Survey.
Miss. Riv. from Surveys by Miss. Riv. Commission.
Topography by Chas. E. Cooke and Wisconsin Geological and Natural History Survey.
Surveyed in 1897, 1903, and 1904.

APPROXIMATE MEAN DECLINATION 1906.

Scale $\frac{1}{125000}$

Contour interval 20 feet.
Datum is mean sea level.

Edition of Dec. 1906.

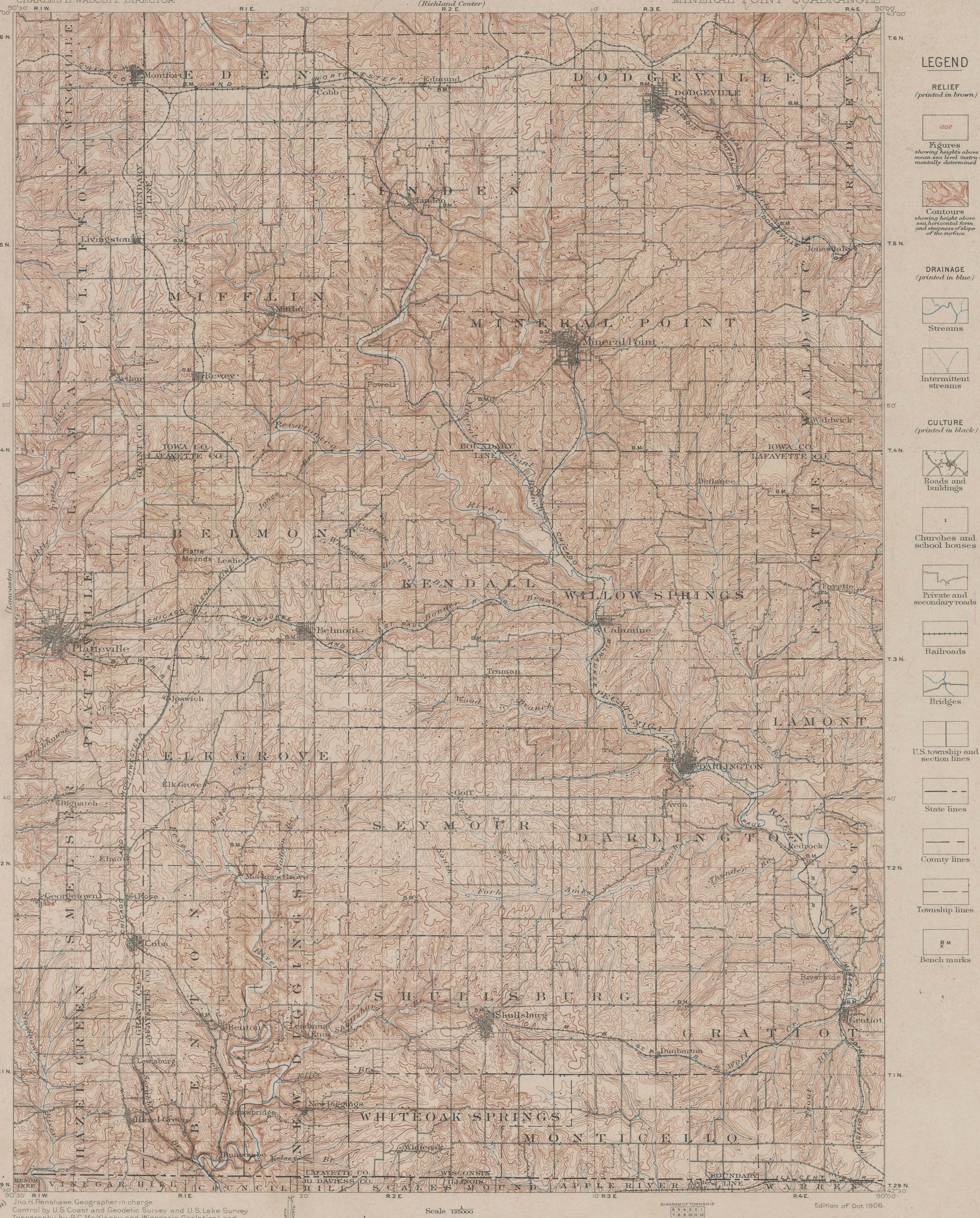
DIAGRAM OF TOWNSHIP.

Geology by Ernest F. Burchard.
assisted by J. R. Banister and A. W. Lewis.
Surveyed in 1905.

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

TOPOGRAPHY

WISCONSIN - ILLINOIS
MINERAL POINT QUADRANGLE



(Peosta)

Jno. H. Renshawe, Geographer in charge.
Control by U.S. Coast and Geodetic Survey and U.S. Lake Survey.
Topography by R.C. McKinney and Wisconsin Geological and Natural History Survey.
Surveyed in 1900, 1903, and 1904.

APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{125000}$

Contour interval 20 feet.
Datum is mean sea level.

DIAGRAM OF TOWNSHIP

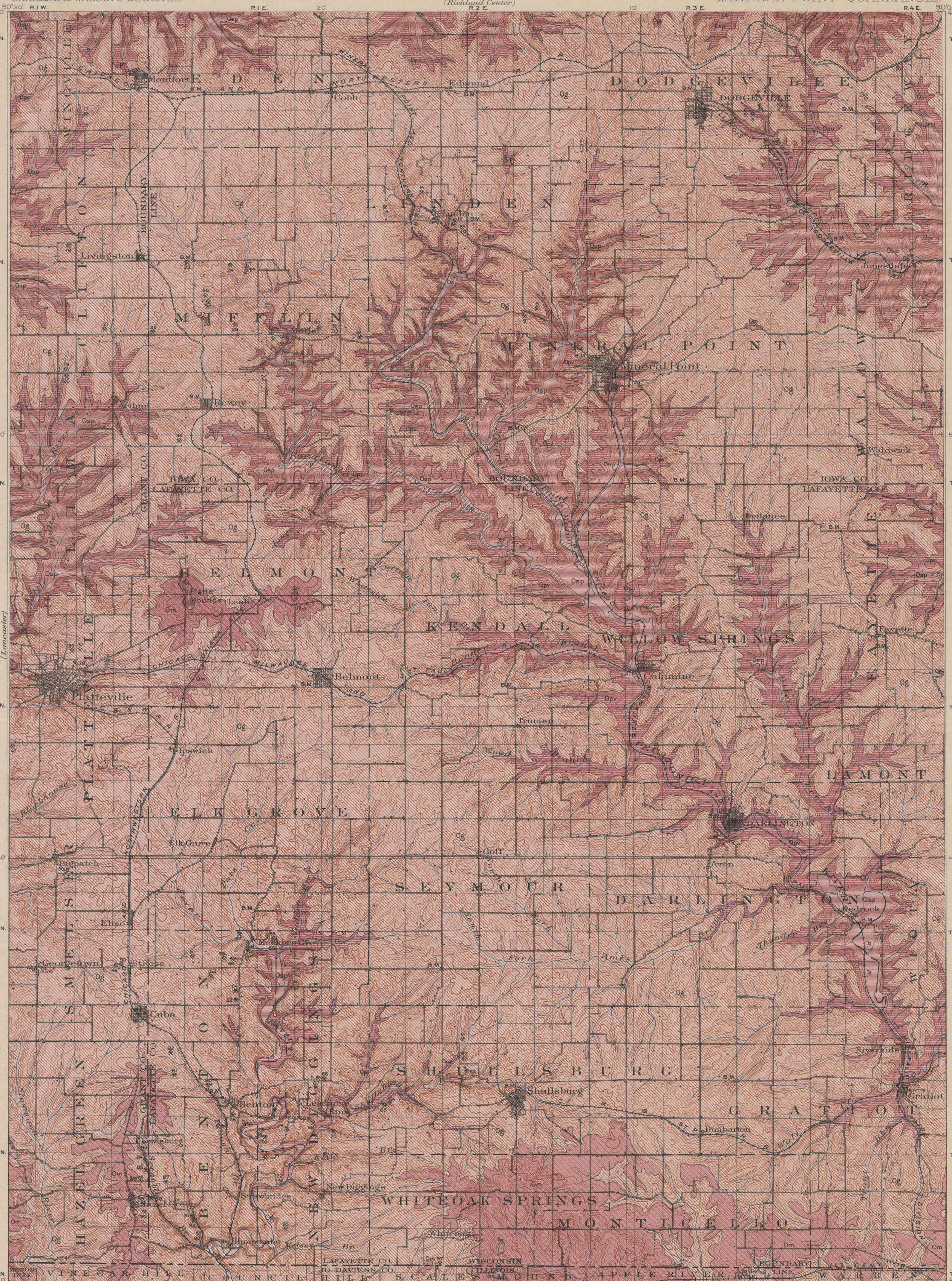
Edition of Oct. 1906.

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

AREAL GEOLOGY

(Richland Center)

WISCONSIN-ILLINOIS
MINERAL POINT QUADRANGLE



Jno. H. Renshawe, Geographer in charge.
Control by U.S. Coast and Geodetic Survey and U.S. Lake Survey.
Topography by R.C. McKinney and Wisconsin Geological and Natural History Survey.
Surveyed in 1900, 1903, and 1904.

APPROXIMATE MEAN DECLINATION 1902.

Scale $\frac{1}{125000}$

Contour interval 20 feet.
Datum is mean sea level.
Edition of Dec. 1906.

DIAGRAM OF TOWNSHIP

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

Index to location of mines.

Geology by U.S. Grant, A.F. Crider, and Wisconsin Geological and Natural History Survey.
Surveyed in 1903 and 1904.

LEGEND

SEDIMENTARY ROCKS

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

SILURIAN

Sn — **Niagara formation** *(light-buff to gray, thin- to thick-bedded dolomite with chert nodules)*

ORDOVICIAN

Om — **Maquoketa shale** *(green to blue shale and clay, with thin beds of earthy limestone)*

Og — **Galena limestone** *(coarse-grained, thick-bedded, gray dolomite; middle portion with chert nodules; lower part locally thin-bedded limestone)*

UNCONFORMITY ?

Opv — **Platteville limestone** *(thin-bedded limestone, with thicker magnesian beds in lower part, and some shale in upper part)*

Osp — **St. Peter sandstone** *(white, or iron-stained, massive sandstone, usually poorly cemented)*

UNCONFORMITY

Op — **Prairie du Chien formation** *(thin- to thick-bedded dolomite with some sandstone and chert in upper part)*

⚒ *Zinc and lead mines*

Note: *Zinc and lead ores occur throughout the Galena dolomite but more commonly near the base.*

NAMES OF MINES.

Location indicated on the map by numbers.

1. Hartford.
2. Williams.
3. Snowball.
4. Oxman.
5. Tyrer.
6. McKinley.
7. Pengelly.
8. Tripoli.
9. Hazel Patch.
10. Ross.
11. Glanville.
12. Milwaukee-Platteville.
13. Mason.
14. Robarts.
15. Platteville-Linden.
16. Montfort Mining Company.
17. Johns.
18. Famous.
19. Washburn.
20. LaFollette.
21. Bourette.
22. Ebenezer.
23. Ludd.
24. Dolphin.
25. Bickford.
26. Ellsworth.
27. Sunrise.
28. Sunset.
29. Bainbridge.
30. Gruno.
31. Penitentiary.
32. Slack.
33. Peacock.
34. Squirrel.
35. Crescent.
36. Trego.
37. Great Northern.
38. Hibernian.
39. Acme.
40. Grant County.
41. Empire.
42. Enterprise.
43. West Empire.
44. Hodge.
45. Morning Star.
46. Oudyn.
47. Kohinoor-Blende.
48. Black Hawk.
49. Wicklow.
50. Jarrett.
51. Cuba City.
52. Baxter.
53. Rico.
54. Roosevelt.
55. Gritty Six
56. Raisbeck.
57. Meekers Grove.
58. Trego.
59. Dall.
60. Cook.
61. Lucky Hit.
62. Hardy Brothers.
63. Murphy.
64. Expansion.
65. Helena.
66. Etna.
67. Benton Development Company.
68. Benton Star.
69. Jug Handle.
70. Empress.
71. Sallie Waters.
72. Jack of Diamonds.
73. Ollie Belle.
74. Ida.
75. Blende.
76. Swift and Rooney.
77. Coltman.
78. Century.
79. Dawson.
80. Temple.
81. Beacon Hill.
82. Only Wann.
83. Jefferson.
84. Hazel Green.
85. King Bee.
86. Sixteen.
87. Murphy.
88. Square Deal.
89. Honest Bob.
90. Madison.
91. Hoskin.
92. Kennedy.
93. Big Dad.
94. Tunnel Hill.
95. Rowley.
96. Occidental.
97. Vista Grande.

PUBLISHED GEOLOGIC FOLIOS

No.*	Name of folio.	State.	Price.†
			Cents.
1	Livingston	Montana	25
‡2	Ringgold	Georgia-Tennessee	25
‡3	Placerville	California	25
‡4	Kingston	Tennessee	25
5	Sacramento	California	25
‡6	Chattanooga	Tennessee	25
‡7	Pikes Peak	Colorado	25
8	Sewanee	Tennessee	25
‡9	Anthracite-Crested Butte	Colorado	50
‡10	Harpers Ferry	Va.-Md.-W.Va.	25
11	Jackson	California	25
12	Estillville	Ky.-Va.-Tenn.	25
13	Fredericksburg	Virginia-Maryland	25
14	Staunton	Virginia-West Virginia	25
15	Lassen Peak	California	25
16	Knoxville	Tennessee-North Carolina	25
17	Marysville	California	25
18	Smartsville	California	25
19	Stevenson	Ala.-Ga.-Tenn.	25
20	Cleveland	Tennessee	25
21	Pikeville	Tennessee	25
22	McMinnville	Tennessee	25
23	Nomini	Maryland-Virginia	25
24	Three Forks	Montana	25
25	Loudon	Tennessee	25
26	Pocahontas	Virginia-West Virginia	25
27	Morristown	Tennessee	25
28	Piedmont	West Virginia-Maryland	25
29	Nevada City Special	California	50
30	Yellowstone National Park	Wyoming	50
31	Pyramid Peak	California	25
32	Franklin	West Virginia-Virginia	25
33	Briceville	Tennessee	25
34	Buckhannon	West Virginia	25
35	Gadsden	Alabama	25
36	Pueblo	Colorado	25
37	Downieville	California	25
38	Butte Special	Montana	25
39	Truckee	California	25
40	Wartburg	Tennessee	25
41	Sonora	California	25
42	Nueces	Texas	25
43	Bidwell Bar	California	25
44	Tazewell	Virginia-West Virginia	25
45	Boise	Idaho	25
46	Richmond	Kentucky	25
47	London	Kentucky	25
48	Tenmile District Special	Colorado	25
49	Roseburg	Oregon	25
50	Holyoke	Massachusetts-Connecticut	25
51	Big Trees	California	25
52	Absaroka	Wyoming	25
53	Standingstone	Tennessee	25
54	Tacoma	Washington	25
55	Fort Benton	Montana	25
56	Little Belt Mountains	Montana	25
57	Telluride	Colorado	25
58	Elmoro	Colorado	25
59	Bristol	Virginia-Tennessee	25
60	La Plata	Colorado	25
61	Monterey	Virginia-West Virginia	25
62	Menominee Special	Michigan	25
63	Mother Lode District	California	50
64	Uvalde	Texas	25
65	Tintic Special	Utah	25
66	Colfax	California	25
67	Danville	Illinois-Indiana	25
68	Walsenburg	Colorado	25
69	Huntington	West Virginia-Ohio	25
70	Washington	D. C.-Va.-Md.	50
71	Spanish Peaks	Colorado	25
72	Charleston	West Virginia	25
73	Coos Bay	Oregon	25
74	Coalgate	Indian Territory	25
75	Maynardville	Tennessee	25
76	Austin	Texas	25
77	Raleigh	West Virginia	25
78	Rome	Georgia-Alabama	25
79	Atoka	Indian Territory	25
80	Norfolk	Virginia-North Carolina	25
81	Chicago	Illinois-Indiana	50
82	Masontown-Uniontown	Pennsylvania	25
83	New York City	New York-New Jersey	50
84	Ditney	Indiana	25
85	Oelrichs	South Dakota-Nebraska	25
86	Ellensburg	Washington	25
87	Camp Clarke	Nebraska	25
88	Scotts Bluff	Nebraska	25
89	Port Orford	Oregon	25
90	Cranberry	North Carolina-Tennessee	25
91	Hartville	Wyoming	25
92	Gaines	Pennsylvania-New York	25
93	Elkland-Tioga	Pennsylvania	25
94	Brownsville-Connellsville	Pennsylvania	25
95	Columbia	Tennessee	25
96	Olivet	South Dakota	25
97	Parker	South Dakota	25
98	Tishomingo	Indian Territory	25
99	Mitchell	South Dakota	25
100	Alexandria	South Dakota	25
101	San Luis	California	25
102	Indiana	Pennsylvania	25
103	Nampa	Idaho-Oregon	25
104	Silver City	Idaho	25
105	Patoka	Indiana-Illinois	25
106	Mount Stuart	Washington	25
107	Newcastle	Wyoming-South-Dakota	25
108	Edgemont	South Dakota-Nebraska	25
109	Cottonwood Falls	Kansas	25
110	Latrobe	Pennsylvania	25
111	Globe	Arizona	25
112	Bisbee	Arizona	25
113	Huron	South Dakota	25
114	De Smet	South Dakota	25
115	Kittanning	Pennsylvania	25
116	Asheville	North Carolina-Tennessee	25
117	Casselton-Fargo	North Dakota-Minnesota	25
118	Greeneville	Tennessee-North Carolina	25
119	Fayetteville	Arkansas-Missouri	25
120	Silverton	Colorado	25
121	Waynesburg	Pennsylvania	25
122	Tahlequah	Indian Territory-Arkansas	25
123	Elders Ridge	Pennsylvania	25
124	Mount Mitchell	North Carolina-Tennessee	25
125	Rural Valley	Pennsylvania	25
126	Bradshaw Mountains	Arizona	25
127	Sundance	Wyoming-South Dakota	25
128	Aladdin	Wyo.-S. Dak.-Mont.	25
129	Clifton	Arizona	25
130	Rico	Colorado	25
131	Needle Mountains	Colorado	25
132	Muscogee	Indian Territory	25
133	Ebensburg	Pennsylvania	25
134	Beaver	Pennsylvania	25
135	Nepesta	Colorado	25
136	St. Marys	Maryland-Virginia	25
137	Dover	Del.-Md.-N. J.	25
138	Redding	California	25
139	Snoqualmie	Washington	25
140	Milwaukee Special	Wisconsin	25
141	Bald Mountain-Dayton	Wyoming	25
142	Cloud Peak-Fort McKinney	Wyoming	25
143	Nantahala	North Carolina-Tennessee	25
144	Amity	Pennsylvania	25
145	Lancaster-Mineral Point	Wisconsin-Iowa-Illinois	25

* Order by number.
† Payment must be made by money order or in cash.
‡ These folios are out of stock.

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.